MedCLIVAR 2018

"Bridging the Mediterranean Climates"

18-21 September 2018
University of Belgrade
Belgrade, Serbia

Sessions & Conveners

The Mediterranean Regional Climate System
Francois Dulac, Margarida L. R. Liberato, Uwe Ulbrich

Past climate evolution of the Mediterranean region
Isabel Cacho, Maria Triantaphyllou, Polychronis Constantinos Tzedaki

Assessment of climate change in the Mediterranean region and climate projections
Paola Mercogliano, Samuel Somot

Climate extremes and hazards in the Mediterranean region under a changing climate
Maria Carmen Llasat, Shlomit Paz

Past, Present and Future change of Mediterranean-type climates
Richard Seager, Isla Simpson

Societal impacts of climate change in the Mediterranean region
Ana Iglesias, Athanasios T. Vafeidis

Climate Services in the Mediterranean regions
Silvio Gualdi, Vladimir Đurđević

Invited Speakers

Carlo Buontempo (ECMWF)
Lucas Lourens (Utrecht University)
Douglas Maraun (University of Graz)
Pierre Nabat (CNRM)
Eleonora Regattieri (University of Pisa)
Alexandre Ramos (University of Lisbon)
Steven Van Passel (University of Antwerp)
Giuseppe Zappa (University of Reading)

www.medclivar2018conf.eu

PREFACE

This MedCLIVAR 2018 conference "Bridging the Mediterranean climate" has been the fifth of a series of events that were previously held in Lecce (2011), Ma-drid (2012), Ankara (2014) and Athens (2016). It is part of the activities of the MedCLIVAR network (www.medclivar.eu), which, since 2003, when proposed at European Geophysical Society assembly in Nice, has been an independent forum for scientific discussion, involving scientists working on multiple and diver-sified aspects of the Mediterranean climate.

An important goal of the MedCLIVAR 2018 Conference in Belgrade (www.medclivar2018conf.eu) has been to connect scientists, research groups and scholars dealing with typical Mediterranean climates, which cover, apart from the proper Mediterranean region, also areas of Cali-fornia, central Chile, the Western Cape of South Africa, and Southwestern Aus-tralia. In order to achieve this, a special session has been devoted to past, present and future change of Mediterranean-type climates. The MedCLIVAR 2018 has also included traditional MedCLIVAR topics given in 7 sessions, with presentations reflecting the multidisciplinary characteristics of the network and studies that describe atmospheric, marine, and terrestrial climate compo-nents at multiple time scales:

1. *The Mediterranean Regional Climate System*, with contributions on model-ling and observing the Mediterranean regional climate. The focus is on understanding climate processes, feedbacks and interactions between the atmosphere, ocean, hydrosphere, biosphere, cryosphere and geosphere.
2. *Past climate evolution of the Mediterranean region*, including contribu-tions on trends, rhythms, and extreme events on Milanković, millenni-al/centennial and interannual timescales, based on paleo-reconstructions, simulations and long instrumental time series.
3. *Assessment of climate change in the Mediterranean region and climate projections*, focusing on i) observation, detection and attribution of past trends ii) future evolution characterization using recent multi-model initiatives iii) presentation of novel dynamical and statistical modelling approaches
4. *Climate extremes and hazards in the Mediterranean region under a chang-ing climate*, with contributions on extreme events and hazards in the Mediterranean, how they are linked to the changing climate and what are the predictions for the next decades.
5. *Past, Present and Future change of Mediterranean-type climates*, this session will compare and contrast across the five Mediterranean-type climates (occurring also in the Western United States, South Africa, central Chile and South Australia) the character and mechanisms of vari-ability and change on interannual to centennial timescales.
6. *Societal impacts of climate change in the Mediterranean region*, consid-ering multidisciplinary climate-environment-human societal systems, feedbacks and interactions, environmental pressures and responses, les-sons for the future.
7. *Climate Services in the Mediterranean regions, presenting and discussing activities related to the development of sustainable climate services*, based on continuous dialog and partnership between scientists, climate data and related product providers, stakeholders and end-users.

The Conference MedCLIVAR 2018 was organized by the University of Belgrade-Faculty of Geography and Faculty of Civil Engineering between 17th and 22nd September 2018. It gathered 130 participants from all over the world, includ-ing participants coming from the USA universities such as University of Cali-fornia Berkeley and Columbia University. The opening ceremony was dedicated to Milutin Milanković, who spent four decades teaching at the University of Bel-grade. We acknowledge the University of Belgrade for its support and hospitality for the opening ceremony in the historical building (REKTORAT), the Faculty of Ge-ography for overall organization and logistics, the Faculty of Civil Engineer-ing for the Conference Venue. Further, we thank the co-organizers Serbian Min-istry of Education, Science and Technical Development, University of Salento, and ScientAct S.A. for their support. Finally, we thank the organizing commit-tee; the support staff and the conference secretariat for their work; the con-veners for the conference organization, and the scientific committee for ad-vices and suggestions.

Jelena Lukovic and Piero Lionello

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SESSION 1

The Mediterranean Regional Climate System

AEROSOLS AND WEATHER REGIMES OVER THE MEDITERRANEAN: A COUPLED REGIONAL MODELING APPROACH

P Nabat (Invited) (1), M Mallet (1), S Somot (1)

1) CNRM, Toulouse, France

pierre.nabat@meteo.fr

The Mediterranean region is affected by numerous and various aerosols which have a strong spatio-temporal variability. These aerosols directly interact with solar and thermal radiation, and indirectly with clouds and atmospheric dynamics, with ensuing impacts on regional climate. The variations in aerosol loads are related with atmospheric conditions, as the latter influence their emission, transport and deposition. The objective of this work is to better understand these relationships between aerosols and atmospheric circulation, in order to improve the representation of aerosol forcing in regional climate models. In the present work we use the CNRM Regional Climate System Model including an interactive aerosol scheme (TACTIC). This scheme enables us to have an explicit representation of the main aerosol types (sulfate, organic matter, black carbon, sea-salt and dust) and their spatio-temporal variability, contrary to climate models using aerosol climatologies. Simulations driven by the ERA-Interim reanalysis have been carried out over the 1979-2016 period: a first one with the aerosols and their coupling with radiation and clouds, and a second one without in order to estimate the effects of aerosols on climate. The evaluation of the simulation with aerosols against satellite and ground-based observations highlights the ability of the model to represent the variability of aerosols. Moreover, the analysis of these simulations, using the NAO index and weather regimes, shows the strong relationship between atmospheric circulation and aerosol loads.

DECADAL AND CLIMATIC VARIABILITY OF THE IONIAN CIRCULATION

M Gacic (1), G Civitarese (1), M Menna (Invited) (1), G Notarstefano (1), C Reyez (1), V Cardin (1)

1) Ist. Naz. Oceanogr. Geof. Sperimentale, Trieste, Italy

mgacic@inogs.it

Ionian Sea flow field shows decadal inversions of the sub-basin circulation pattern. These inversions have been explained in terms of the feedback mechanism between the Adriatic or only in one occasion Aegean Sea, and the Ionian. Long-term variations of the dense water formed in the Adriatic are generated by the varying circulation patterns in the Ionian, which then bring into the Adriatic saltier or fresher water. The deep water density changes mainly determined by the salinity, on its turn cause the inversion of the Ionian circulation. Therefore, we sustain that the Ionian circulation inversions are only due to internal mechanism. Associated with the Ionian circulation inversions, we noticed long-term variations in the mesoscale activity in the same area. Pelops Gyre one of the most persistent, bottom trapped mesoscale anticyclone in the area, is very prominent during the last three decades except during the Eastern Mediterranean Transient (EMT) when the bottom water in the Ionian was mainly of the Aegean origin. In that period (1992-1997) as seen from altimetric data, the Ionian sub-basin scale circulation pattern was anticyclonic and instead of the Pelops anticyclone, the area along the eastern Ionian coast was characterized by a cyclonic mesoscale activity. After the year 2000, Adriatic became again the main bottom water source for the Ionian and the Eastern Mediterranean, and during the anticyclonic Ionian circulation mode (2007-2011) the cyclonic mesoscale activity is mainly present along the western Ionian coast, while the Pelops Gyre was very prominent. Thus, the mesoscale cyclonic activities occurs downstream of the dense water outflow (Aegean – eastern Ionian flank or Adriatic – western Ionian flank) as shown also in the laboratory experiment by Etling et al. (2000). We present also numerical simulation results performed using a multilayer frontal model to elucidate aspects of the dynamics mentioned above in the Adriatic as well as in the Ionian basin.

INTEGRATION OF AN AMMONIUM-NITRATE AEROSOL MODULE INTO THE CNRM REGIONAL CLIMATE SYSTEM MODEL AND ESTIMATION OF THEIR IMPACTS OVER THE MEDITERRANEAN REGIONAL CLIMATE.

T Druge (1), P Nabat (1), M Mallet (1), S Somot (1)

1) Meteo-France - CNRM, Toulouse, France

thomas.druge@meteo.fr

The Mediterranean region is subject to high aerosol loads, from both anthropogenic and natural sources. Because of their optical and microphysical properties, aerosols play an important role in the Mediterranean climate system. Indeed, they interact with radiation and clouds and they provoke a negative radiative forcing at the surface with ensuing cooling and decrease in the activity of the hydrological cycle. The main aerosols in this region are desert dust, sea salt, organic, black carbon, sulphate and ammonium-nitrate particles, whose contribution to aerosol radiative forcing is expected to increase up to the end of the 21st century. In order to estimate the role of aerosols on the future climate we will use the CNRM-RCSM6 model, which is a coupled regional aerosol-atmosphere-ocean model. Its atmospheric model, namely ALADIN-Climate, incorporates a prognostic aerosol scheme (TACTIC), including already desert dust, sea salt, organic, black carbon and sulphate particles, but not the ammonium and nitrate aerosols. Because of their future contribution to aerosol radiative forcing, we have recently added a new module in TACTIC, adapted from the LMDz-INCA module (Hauglustaine et al., 2014) to represent these types of aerosols. The aim of this study is to evaluate (Aerosol optical Depth, surface concentration) this new ammonium-nitrate scheme, as well as the aerosol impacts on the radiation and temperature over the Mediterranean. The methodology is based on two parallel simulations of 38 years (1979-2016), driven by the ERA-Interim reanalysis, which have been realized using the atmospheric model of CNRM-RCSM, including or not the ammonium-nitrate aerosol module.

MINIMUM TEMPERATURES IN SLOVENIAN ISTRIA AS THE RESULT OF LOCAL CLIMATE IMPACT

D Ogrin (1), M Ogrin (1)

1) Dept. of Geogrpahy, University of Ljubljana, Ljubljana, Slovenia

matej.ogrin@ff.uni-lj.si

Although Slovenian Istria is considered to be the warmest region in Slovenia – winters in particular are significantly warmer there than in other Slovenian regions, as also confirmed by the data of official meteorological network – minimum temperatures on the local level can drop very low. Local landform features allow the occurrence of frost hollows in concave shapes of land, where explicit night cooling occurs during the radiation weather type. This affects the local areas where natural vegetation grows and also causes less favourable conditions for growing cultural plants, also some Mediterranean ones, such as olive trees. The threat of frost and hoarfrost is bigger, temperature losses in residential buildings are greater, and stronger is the possibility of local air pollution if pollution sources are located within the areas of frequent temperature inversion. At the same time, the occurrence of frost hollows is a local particularity. The results of measurements in frost hollows over several years have confirmed the anticipations that thermometer drops lower than the values hitherto obtained by stations in the official meteorological network. Even more, the measurements have shown that the so-far measured extreme values that were believed to be exceptional events were registered at least at one measuring post in almost each observed winter. Outstanding as real frost hollows are the hollows with an uninterrupted rim in the Slavnik range and Čičarija, at the Podgorski Kras (the valleys of Petrinjska Vala and Črnotijska Vala), in the valleys at the transition from karst to flysch areas of Slovenian Istria (the valleys of Movraška Vala and Gračiščka Vala) and in the blind valley of Malinska. At least in one of these frost hollows temperature dropped under –15 0C each winter, and in very favourable conditions for air cooling, when the surface is covered with snow, even under –20 0C.

THE SENSITIVITY OF MEDITERRANEAN WINTER TO SIBERIAN SNOW COVER VARIABILITY

P Ruggieri (1), S Materia (1), M Benassi (1), S Gualdi (1,2)

1) Fondazione CMCC, Bologna, Italy
2) Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy

paolo.ruggieri@cmcc.it

Snow cover extent over Siberia in Autumn was found to be a potential driver of winter midlatitude circulation, thus providing a potential source of predictability for the state of the atmosphere on a seasonal and multi-annual range. The large scale adjustment of the atmosphere to snow-related surface forcing implies modifications of the flow that in principle can be relevant to the Mediterranean region. Hence, a better understanding of the aforementioned processes can help us exploit this predictability and quantify climate responses and impacts on human activities. However, the complex chain of mechanisms that leads to such impacts has not been robustly established yet and it is affected by uncertainty linked also to disagreement between state-of-the-art models. A crucial step to advance our knowledge on this field is to pin down relevant regional and global processes that can remotely propagate the signal through tropospheric and stratospheric pathways. In this work, we present a set of ensemble experiments with a state of the art atmospheric general circulation model, targeted at recognising and describing the constructive interference between snow and Arctic sea ice forcing, that has been hypothesised in previous studies. Results from four simulations are discussed, each with different combinations of snow cover in Siberia and sea ice cover in the Barents and Kara seas. The winter circulation response to these forcing patterns is analysed looking firstly at the local atmospheric adjustment, then at the hemispheric scale, with emphasis on the associated interaction between troposphere and stratosphere, and finally at impacts on the Mediterranean region.

ENSO TELECONNECTIONS OVER THE EURO-MEDITERRANEAN REGION: THE ROLE OF PDO MODULATION

M Benassi (1), S Materia (1), P Ruggieri (1), S Gualdi (1,2)

1) Fondazione CMCC, Bologna, Italy
2) Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy

marianna.benassi@cmcc.it

At the interannual timescale, El Nino Southern Oscillation (ENSO) is known to be one of the major driver of climate variability on the global domain. However, the detection of the ENSO influences over the Euro-Mediterranean region is made difficult by the large variability of the atmospheric circulation in the North Atlantic-European sector. In the literature, observational and model-based studies have fostered a long-standing debate on the shape and the mechanisms ruling the ENSO teleconnection over the Euro-Mediterranean sector. The proposed mechanisms driving the spread of the ENSO signal remotely involve the propagation of atmospheric planetary waves, and changes in the zonal and meridional atmospheric circulation. The background sea surface temperature (SST) state may indeed influence these mechanisms, and for this reason a deeper understanding on the role of the low frequency SST variability in enhancing the ENSO teleconnection is needed. In this research, we focus on the effects of the low frequency SST variability in shaping the influence of ENSO over the Euro-Mediterranean region, with particular emphasis on the role of the Pacific Decadal Oscillation (PDO). We present a set of idealized numerical experiments accounting for a standard ENSO and PDO SST forcing in an AMIP-like model setup. Moreover, in order to increase the signal to noise ratio and to evaluate the internal variability associated with these processes, an ensemble approach has been adopted. The comparison across simulations, including different combinations of ENSO and PDO SST forcing, permits to reveal the ENSO fingerprint over the Euro-Mediterranean region, and to evaluate the role of the PDO modulation. This process-oriented approach allows to advance the understanding on the connection between mid-latitude climate variability and tropical forcing, and to enhance a deeper insight on the key mechanisms driving the atmospheric circulation over the Mediterranean sector on a number of different time-scale. Furthermore, it will contribute to improve our understanding of possible sources of predictability for the Euro-Mediterranean region.

A NUMERICAL SIMULATION OF THE ERA-INTERIM PERIOD ON THE MEDITERRANEAN REGION WITH THE REGIONAL CLIMATE SYSTEM MODEL CNRM-RCSM6.

F Sevault (1), S Somot (1), P Nabat (1), R Waldman (1), S Darmaraki (1), M Mallet (1), A Alias (1)

1) CNRM, Université de Toulouse, Météo-France, CNRS, Toulouse, France

florence.sevault@meteo.fr

Regional Climate System Models (RCSM) belong to the same family as the global earth system models (ESM) used in the CMIP experiments, but generally have a higher resolution. They allow to reproduce medium scale atmospheric and oceanic phenomena on periods going from present time hindcast to scenarios for the 21st century. To compose this CNRM-RCSM6 model we chose the most recent versions of atmosphere and ocean models available at the CNRM, which are also used for CMIP experiments. The atmosphere model (ALADIN-Climate v6, with new atmospheric physics, 12 km resolution and 91 levels), the multi-surface model (SURFEX v8, new physics, 6-8 km resolution), the river routine model (CTRIP, with deep drainage and flood plains, but still a 50 km resolution), the inland model (FLAKE) are described in Voldoire et al. (2017). The ocean model is NEMOMED12 v3.6 (Beuvier et al. (2012), Hamon et al (2016) for the v3.2). OASIS3-MCT (Valcke et al. (2015)) is used at the coupler, at a 1h-frequency. Besides we use new lateral boundary conditions compared to the previous CNRM-RCSM4 model0: a new climatology for the aerosols (Nabat et al. (2013)), ORAS4 ocean reanalysis (Balmaseda et al. (2013)) for the Atlantic part of the model, monthly fields in temperature and salinity, a new Sea Surface Height climatology for relaxation in the Atlantic part, composed by the ORAS4 monthly fields, with a corrected seasonal cycle which follows the one of CCI-ECV (Adloff et al. (2017)), a monthly climatology of the surface Chlorophyll concentration (2003-2011 ESA-CCI, T. Arsouze personal communication). Finally ERA-Interim reanalysis (Berrisford et al. (2009)) is used for the spectral nudging in the atmosphere, and for the Sea Surface Temperature outside the Mediterranean region. After the description of the model, results for the 1980-2012 period will be presented and compared to observational datasets (oceanic and atmospheric data, river discharges). This first hindcast with CNRM-RCSM6 shows positive aspects like a realistic Aerosol Optical Depth trend on the period, and thus shortwave, latent heat and Sea Surface Temperature (SST) trends, a good simulation of SST and SSH, and realistic representation of the diurnal cycle of SST. Nevertheless one particular aspect to improve is the representation of the rivers runoffs, largely overestimated on the Black Sea drainage area, with consequences on the salinity, thermohaline circulation, and deep water convection.

STRUCTURE OF THE RAINY SEASON IN ISRAEL: EXISTENCE OF MODES AND A MID-WINTER MINIMUM

A Etkin (1), H Saaroni (2), B Ziv (3), A Gasith (1)

1) Porter School of the Environment and Earth Sciences, Tel Aviv University, Tel Aviv, Israel
2) Department of Geography and the Human Environment, Porter School of the Environment and Earth Sciences, Tel Aviv University, Tel Aviv, Israel
3) Department of Natural Sciences, The Open University of Israel, Ra'anana, Israel

adietkin13@gmail.com

The rainfall in the Mediterranean-climate region of Israel is confined almost to the period between October and April, 2/3 in the mid-winter months. The analysis is based on daily rainfall in 126 stations of the Israel Meteorological Service (representing the Mediterranean-climate region of Israel) for the period 1951-2014. A 'daily rainfall' average is calculated over the entire set of stations and the seasonal time-series is smoothed using a 27-days window, which is found optimal. In order to expose the modality of the individual seasons, each season is approximated by a series of Gaussians. Each Gaussian corresponds to one mode, characterized by its timing, amplitude and duration. The compatibility of the modeled season with the observed (smoothed) one is assessed by the correlation between them, the standard error and the variance, attempting to keep the number of Gaussians to minimum. The correlation between the modeled and the observed rainfall is above 0.9. Up to five modes are usually found, not confined to the mid-winter months. Significant modes were found for example in October (2000) and in April (1971). Moreover, a minimum in the middle of the winter was found in several seasons. An average course of 30 seasons, chosen randomly, as well as the average course performed for the entire set (62 seasons) indicate a minimum in the mid-season, with one peak in late December and another in the beginning of February. We hypothesize three factors that may explain this minimum: (1) the high contrast between the warm water of the Eastern Mediterranean and the overlying cold air masses responsible for the rains in Israel, reaching the maximum around December; (2) the maximum in the intensity of the Cyprus lows, which is expected to be in January-February, corresponding to the maximum of the polar-subtropical temperature gradient. The combination of the two factors above leaves the center of January with a secondary minimum. Another hypothesis (3) is that the Cyprus Lows' activity does not have a distinct peak, but their peak activity is spread over the entire mid-winter (DJF), so that occasional minima in the high season in various winters causes a secondary minimum to appear in the long-term mean. To examine the hypotheses, especially #2 and #3, the daily occurrence and intensity of the Cyprus lows will be analyzed.

IDENTIFYING REMOTE DRIVERS OF MEDITERRANEAN RAINFALL USING MACHINE LEARNING AND CAUSAL DISCOVERY TOOLS

E Rousi (1), M Kretschmer (1), J Lehmann (1), S Totz (1), D Coumou (1)

1) Potsdam Institute for Climate Impact Research, Potsdam, Germany

rousi@pik-potsdam.de

The Mediterranean region has been identified as one of the hotspots of climate change due to extensive drying and a warming trend, especially in summer. Winter rainfall is particularly important as it provides the main source of soil moisture for the following warm season, which is typically hot and dry. Over the last decades, winter precipitation has decreased and this trend is projected to continue in a warming climate. A better understanding of the drivers of Mediterranean climate variability is thus crucial to improve (sub) seasonal to decadal forecasting. Skillful forecasts are essential for actionable climate services and for policy-makers to mitigate climate impacts on agriculture, economy, infrastructure and societies in general. A lot of research has been done to study remote drivers of rainfall variability in the Mediterranean, such as North Atlantic sea-surface temperatures and large-scale atmospheric circulation. However, little attention has been given so far to the use of innovative techniques, such as machine learning tools and causal discovery algorithms, that are not simply based on correlation but rather try to tackle causality. Based on such methods, this work aims to better understand the causal drivers of precipitation variability in the Mediterranean. We will analyze large-scale atmospheric patterns, including the North Atlantic Oscillation (NAO), a well-known mode of variability over the Northern Hemisphere. NAO is established to be important for the Mediterranean climate variability, but usually its different spatial characteristics are not being considered. Here, specific "flavors" of the NAO, i.e. recurring spatial patterns identified by Self-Organizing Maps (Rousi et al., 2017), will be examined including their effects on Mediterranean precipitation. Moreover, we present studies on predicting winter precipitation anomalies in the Mediterranean using a cluster-based empirical forecast method, that considers the strength but also the spatial pattern of precursors. This method provides skillful empirical forecasts outperforming operational forecasting systems (Totz et al., 2017). Furthermore, causal effect networks have been used to identify Arctic-related drivers of the mid-latitude winter circulation and have given promising results (Kretschmer et al., 2017). A similar analysis is proposed here to study the causal drivers of Mediterranean precipitation.

THE ADRIATIC–IONIAN BIMODAL OSCILLATING SYSTEM (BIOS) AND THE ADRIATIC OCEANOGRAPHY

I Vilibic (1), N Dunic (1), H Mihanovic (1), J Sepic (1)

1) Institute of Oceanography and Fisheries, Split, Croatia

vilibic@izor.hr

Substantial year-to-year changes in the Adriatic salinity have been reported in literature since the early 1950s, with a number of researchers documenting their relevance to the biogeochemical cycle in the Adriatic Sea. Yet, no physical model was given to provide an explanation of these changes till 2010, when Gačić and co-authors pointed to an internal vorticity-driven process that can sustain circulation regime shifts in the northern Ionian Sea. The dual regimes can favour advection in the Adriatic of either ultraoligotrophic intermediate waters from the Levantine Basin characterized by higher salinity and temperature or nutrient-richer waters from the Western Mediterranean that might be traced by lower salinity and temperature. To tribute early Adriatic researchers, the mechanism was named Adriatic–Ionian Bimodal Oscillating System (BiOS). Since 2010, a great number of investigations revealed the dominance of the BiOS over local processes that drive changes in the Adriatic thermohaline properties. That also applies to coastal areas and the northern Adriatic, influencing chemical (nutrients, ocean carbon content) and biological (primary production, bivalve growth, allochthonous species) properties, and presumably fisheries. This presentation summarizes the knowledge on the BiOS and related processes relevant for the Adriatic-Ionian circulation, while discussing its aspect and perspective in interdisciplinary investigations and in the future climate.

DETECTION OF ENSO AND NAO IMPACTS ON EUROPEAN REGION IN A LARGE ENSEMBLE OF NUMERICAL SIMULATIONS

S Ivasic (1), I Muic (1), I Herceg Bulic (1)

1) Geophysical Department, University of Zagreb, Zagreb, Croatia

ihercegb@gfz.hr

El Niño Southern Oscillation (ENSO) is one of the strongest sources of climate variability all over the world. Although it has been examined extensively and its impact on climate variability of certain regions is clear and well explained, there are still a lot of questions regarding its effect on European and Mediterranean region. The ENSO-related signal is detectable there, but is generally weak as well as spatially and seasonally dependent. On the other hand, Europe is dominantly influenced by North Atlantic Oscillation (NAO), a mode of natural variability which impact is well established. Since both phenomena may exert a certain influence on European climate at the same time, it is not simple to distinguish this two effects. Firstly, ENSO impact may be masked with a stronger effect of NAO. Secondly, there is also possibility that NAO signal is modulated by ENSO, particularly during strong ENSO events. Therefore, we may pose a question whether is possible to separate ENSO and NAO signals. One way to answer this question is examination of climate anomalies considering the values of NAO and ENSO indices and categorizing years (seasons) into corresponding categories. This approach enables detection of years with different combinations of ENSO and NAO impacts which may be strong, weak and neutral. Due to periodicity of ENSO which is 2-7 years and the fact that there is no particular periodicity of NAO, it may be hard to obtain categories with a large enough sample size to achieve analysis with sufficient statistical power. Therefore, here we examine relative ENSO and NAO impact on European climate using a large ensemble of long numerical simulations. We analyze 35-member ensemble of numerical simulations for 1855-2010 period performed with ICTP AGCM, an atmospheric general circulation model (AGCM) of intermediate complexity developed at International Centre for Theoretical Physics (ICTP). Positive, negative and neutral ENSO years are determined according to the strength of wintertime (JFM) Nino3.4 index, while PC-based NAO index is used for classification of NAO years. Composite analysis is applied to the anomalies of different meteorological parameters (geopotential height, tempertaure etc.) with the aim to analyze atmospheric patterns associated with specific ENSO-NAO combinations. Additionally, signal-to-noise analysis is also performed.

THE EFFECT OF WIND-STRESS OVER THE EASTERN MEDITERRANEAN ON DEEP-WATER FORMATION IN THE ADRIATIC SEA

Y Amitai (1,2), Y Ashkenazy (2), H Gildor (1)

1) The Hebrew University of Jerusalem, Jerusalem, Israel
2) Ben-Gurion University of the Negev., Sede Boqer , Israel

yael.amitai@mail.huji.ac.il

Interannual variability of Adriatic Deep Water (ADW) formation is studied using an oceanic general circulation model of the Mediterranean Sea driven by realistic (Era-Interim) wind-stress of 1979–2014. Specifically, the effect of interannual variability of the wind-stress on ADW is isolated by using climatological sea surface temperature and freshwater flux but interannually varying wind-stress. A connection between the wind-stress magnitude over the Rhodes Gyre region and ADW outflow is found in association with the formation of Levantine Intermediate Water (LIW). Twenty sets of 36 years artificially generated wind-stress anomaly fields were constructed based on the first 50 EOFs of the wind-stress monthly anomalies. These simulations strengthen the connection that was found and reveal a centennial internal variability of both the LIW and the ADW outflow. Our results suggests that freshwater from the North and West Mediterranean compete with the saline LIW coming from the east due to the prominent southward-eastward wind-stress pattern.

SUB-HOURLY PRECIPITATION OVER A WESTERN MEDITERRANEAN CATCHMENT IN A CONVECTION-PERMITTING MODEL

E Meredith (1), KA Kpogo-Nuwoklo (1), HW Rust (1), U Ulbrich (1)

1) Institut für Meteorologie, Freie Universität, Berlin, Germany

ulbrich@met.fu-berlin.de

Convection-permitting atmospheric models have been shown to add value to coarser models with parametrized convection for the simulation of extreme precipitation, in particular for short-duration (i.e. sub-daily) extremes of a convective nature. Such events are the main cause of flash flooding, an acute risk in many coastal Mediterranean regions. The accurate simulation of short-duration rainfall events is thus key for the forecasting of flash-flooding and for predicting how the flash-flooding risk may change in the future. As such, evaluation of the realism of short-duration (extreme) precipitation in convection-permitting models is an important endeavour. Owing to a lack of observational datasets at both high spatial and temporal resolution, however, most evaluations of convection-permitting models have to date been at the hourly (or longer) temporal scale. The validation of precipitation in convection-permitting models at the sub-hourly scale has thus been identified as an important challenge for both weather forecasting and climate science (e.g. Chan et al., 2016). Using a unique regional micro-gauge network from the Mediterranean city of Barcelona, with 5-minute precipitation observations spanning on average 20 years, we analyse the performance of the COSMO-CLM model at 0.02° (~2.2 km) resolution in simulating the characteristics – both mean and extreme – of observed precipitation during this period. Results indicate that the model simulates 5-minute and sub-hourly precipitation with comparable realism to that found at the hourly scale, suggesting that convection-permitting models can be a useful tool for the study of sub-hourly precipitation extremes in the Mediterranean region. References: Chan, SC, EJ Kendon, NM Roberts, HJ Fowler and S Blenkinsop (2016). The characteristics of summer sub-hourly rainfall over the southern UK in a high-resolution convective permitting model. Environmental Research Letters, 11(9), 094024.

IMPACT OF THE INTERNAL VARIABILITY ON THE CYCLONE TRACKS SIMULATED BY A REGIONAL CLIMATE MODEL OVER THE MED-CORDEX DOMAIN

E Sanchez-Gomez (1), S Somot (2)

1) CERFACS/CECI, Toulouse, France
2) CNRM/CNRS, Toulouse, France

sanchez@cerfacs.fr

Regional climate models (RCMs) constitute a powerful tool to study and understand climate variability and change at local scales. Nevertheless, to correctly inter- pret regional climate simulations, a number of uncertain- ties need to be considered. In this study, we investigate the so-called Internal Variability (IV) of an RCM. The IV can be defined as the degree of irreproducibility in an RCM solution observed when it is conducted by the same lateral boundary conditions (LBCs) but initialised from different initial states. The main goal of this work is to investigate how the IV affects the cyclone tracks simulated by an RCM over a Mediterranean domain. For standard variables such as sea level pressure, 2 m temperature and precipitation, our results over the Mediterranean region are consistent with studies conducted over other geographical domains: the IV is stronger at the easternmost part of the domain, where the control exerted by the LBCs is weaker; the IV shows a strong seasonal dependence, reaching larger values in summer than in winter. We show here that the IV values associated with the density of cyclone tracks are much stronger than for the other documented variables, reaching more than 50 % of the estimated total variability. Concerning the cyclone characteristics, long travelling tracks are associated to a greatest IV. Within the latter cyclone category, the fast moving cyclones seems to exhibit also larger IV values. A secondary IV maximum is observed for static cyclones with short travelling distances (thermal lows) during the warm season.

THE MEDITERRANEAN SEA OVERTURNING CIRCULATION

N Pinardi (1), P Cessi (2), F Borile (1)

1) University of Bologna, Bologna, Italy
2) Scripps Insitution of Oceanography, LaJolla, USA

nadia.pinardi@unibo.it

The Mediterranean Sea overturning circulation is composed of both zonal and meridional cells, interacting among themselves and creating an active vertical circulation. A new 27 years eddy resolving reanalysis from the Copernicus Marine Environment Service is used to diagnose the eulerian and residual overturning circulations of the Mediterranean Sea. The zonal overturning cell of the Mediterranean Sea is known from Wust (1961) and connects the Gibraltar Strait inflow/outflow system to the intermediate and deep water formation regions of the Eastern Mediterranean Sea. Here, we map for the first time the eulerian and residual zonal streamfunction and show that the upper zonal anticyclonic cell is affected by both the mean and eddy dcirculation originating in the Aegean Sea. The basin-wide meridional overturning circulation is structured around two cells: the first is a multi-centered anticyclonic cell, dominating the intermediate water column and located in the top 1000 m. The second is cyclonic, located in the deep and abyssal regions. The intermediate water column, multi-centered anticyclonic circulation is connected to the different deep ocean formation areas in the basin. In the Eastern Mediterranean there are two anticyclonic cells: a weaker overturning cell connected to the Adriatic Sea and a stronger one connected to the northern Levantine regions and the Aegean Sea. The dynamical nature of the anticyclonic and cyclonic meridional cells differs between the Western and Eastern Mediterranean basins with important contributions from the eddy transport components of the residual circulation. The horizontal and vertical structure of the basin circulation is synthesized in a new scheme of the Mediterranean Sea overturning circulation.

SPACE-TIME INTERPOLATION OF DAILY PRECIPITATION OVER MEDITERRANEAN AREA USING RANDOM FOREST

A Sekulić (1), M Kilibarda (1), J Lukovic (2)

1) Faculty of Civil Engineering, Belgrade, Serbia
2) Faculty of Geography, Belgrade, Serbia

asekulic@grf.bg.ac.rs

High resolution gridded daily precipitation datasets are valuable for agriculture, hydrology, ecology, climate research, etc. Observational datasets, however, do not necessarily reflect real picture of precipitation change over particular area. For that purpose, gridded datasets are more preferable. In order to predict precipitation at locations with no measurements, spatial interpolation methods are mostly used. Previous studies report lack of accurate models for producing gridded daily precipitation data. High resolution gridded precipitation datasets have not been available for Mediterranean basin so far. In this study we use random forest model for gridded daily precipitation to produce gridded dataset for 2017 in the Mediterranean area at 1 km spatial resolution. The model uses EUMETSAT images as covariates, allowing possibility to extend dataset over longer period of time, and not only for one year. Distances in space and time are also used as covariates in order to examine, not only spatial, but spatio-temporal dependence of precipitation. Observational precipitation datasets (GHCN, GSOD, ECA&A) are used for development and testing of the model. Training and test data are selected in such a way that both present a representative sample in space-time domain and respective to altitude. The model we propose might be used for production of high resolution daily precipitation grids in Mediterranean basin for longer period of time.

ANALYSIS OF COSMO-CLM SENSITIVITY OVER TURKEY

A Ilhan (1), C Yuruk (1), Y Unal (1)

1) Istanbul Technical University, Department of Meteorology, Istanbul Turkey

sunal@itu.edu.tr

To assess the robustness of the COSMO-CLM regional climate model to simulate the precipitation and temperature distribution over Turkey, series of sensitivity experiments are conducted, and the comparisons of the sensitivity tests with the observations are presented. The climate mode of COSMO (COSMO-CLM) is used with spatial resolution of 0.11° (~10-12 km) and the model is integrated over 200x100 grid points domain over almost 5.5 year period between August 1st, 2007 and December 31th, 2012. The model is started end of summer when the soil moisture is near minimum over the most part of the domain. Therefore, only the first five months of model runs are considered as spin-up time and not included the analysis. The total of 212 observation stations common for both temperature and precipitation variables distributed approximately all over Turkey are used to investigate the model performance. The model simulation period includes two extreme years of 2008 and 2009 which represent dry and wet years, respectively. Although the temperature averages of dry and wet years are similar, the annual total precipitation averages of all 212 stations over Turkey are 430 mm for dry and 715 mm for wet years. In total, seven COSMO-CLM runs were performed with different options in terms of albedo, aerosol, vertical variation of critical humidity. Moreover, the performance of COSMO-CLM with two different spectral nudging is investigated. The effect of each sensitivity experiment on the precipitation and temperature simulations are evaluated over seven climatic zones of Turkey.

DECADAL AND CLIMATIC VARIABILITY OF THE IONIAN SEA

M Menna (1), M Gačić (1), G Civitarese (1), NC Reyes Suarez (1), PM Poulain (1,2)

1) OGS, Trieste, Italy
2) CMRE, La Spezia, Italy

mmenna@inogs.it

The upper layer circulation of the Ionian Sea is strongly influenced by quasi-decadal reversals of the Northern Ionian Gyre (NIG), due to the mechanism called BiOS (Bimodal Oscillating System) powered by the difference in salinity between the salty and warmer waters originating from the eastern Mediterranean, and the less saline water of Atlantic origin entering from the Sicily Channel. Altimetry data, drifter data and model surface salinity products were used to define the temporal phases and peculiar features of the circulation related to the anticyclonic and cyclonic NIG modes. Results not only highlight different shapes and intensities of the Mid-Ionian Jet and northern Ionian meander between the two circulation modes, but they emphasize also distinctive behaviour within the same mode, imputable to the variability of the mesoscale quasi-permanent features. The Messina Rise Vortex and the Pelops Gyre, on the western and eastern sides of the northern Ionian, respectively, showed different behaviours during the first (1993-1996) and the second (2006-2010) anticyclonic periods, related to the strong cyclonic activity along the dense water pathway. When the dense water was of Aegean origin (1993-1996; "Aegean" anticyclone), the strong cyclonic mesoscale activity on the eastern flank of the Ionian overwhelmed the anticyclonic wind forcing, and led to the disappearance of the Pelops Gyre. When the dense water was of Adriatic origin (2006-2010; "Adriatic" anticyclone), the strong cyclonic mesoscale activity on the western flank of the Ionian increased the longitudinal extension of the Messina Rise Vortex. The zonally-elongated Messina Rise Vortex reduced the inflow of Atlantic Water in the northern Ionian, and induced a cyclonic-like event in the southern Ionian and Cretan Passage. From these results, the interannual variability of the wind driven quasi-permanent mesoscale structures appear further influenced by internal forcings (i.e. deep water formation site). The interplay among decadal, interannual and climatic variability affects the characteristics of the basin-wide circulation and the water masses advection in the Ionian Sea.

MODELING APPROACHES TO IONIAN UPPER LAYER DYNAMICS

M Reale (1,2), S Salon (2), A Crise (2), R Farneti (1), R Mosetti (2), G Sannino (3)

1) ICTP, Trieste, Italy
2) OGS, Trieste, Italy
3) ENEA, Roma, Italy

reale.marco82@gmail.com

The observed decadal reversal of the upper layer circulation of the northern Ionian has been suggested to be driven either by variation in wind stress curl over the basin or by baroclinic mechanisms acting within or outside the Adriatic-Ionian System. To discriminate among these hypotheses we use a two-phase approach in analyzing different numerical simulation outputs . We firstly assess the relative role of the forcing and the dominant processes in the reversal of the northern Ionian circulation by running a set of numerical experiments (AISexp experiments) simulating the dynamics of Adriatic-Ionian System and characterized by an increasing complexity in the forcing and domain. The second step is based on a multi-model experiment considering advanced hindcast/reanalysis (MedMIT12, NemoMed8 and Copernicus reanalysis) and on the definition of a simplified sea surface height index. In this first case the major outcomes of the numerical experiments are that the wind stress role appears to be marginal in the vorticity/energy budget of the Ionian Sea: it is able to reinforce/weaken the circulation but not to induce changes in sign in the circulation. On the other hand changes in the upper layer circulation of the Ionian Sea take place only in presence of an active boundary in the Ionian Sea, on the Aegean Sea side so that Adriatic, Ionian and Aegean Sea behave like a coupled system. This is confirmed by the second phase analysis where we found in all the simulations considered the existence of a covariant behavior between Ionian Sea and Aegean Sea associated with a mutual zonal exchange of water masses with different salinity characteristics. These two different approaches support the idea that a complete characterization of observed variability in the northern Ionian needs to take into account a fully coupled Adriatic-Ionian-Aegean System and that BiOS-like observations during the period 1987–2008 reflect the switching between the two possible deep water sources of the Eastern Mediterranean , Adriatic and Aegean Sea.

ASSESSMENT OF REGCM-ES PERFORMANCES OVER THE MED-CORDEX DOMAIN

M Reale (1,2), F Giorgi (1), C Solidoro (2), V Di Biagio (2), L Mariotti (2), F Di Sante (1,2), R Farneti (1)

1) ICTP, Trieste, Italy
2) OGS, Trieste, Italy

reale.marco82@gmail.com

In this work we assess the preliminary results of the RegCM-ES (Earth System Regional Climate Model) model, developed and used at ICTP , which has been recently coupled with an active biogeochemical model (BFM, Biogeochemical Flux Model). The newly RegCM-ES has been implemented and tested over an area corresponding approximately to the Med-CORDEX domain (Mediterranean region).The physical model has an atmospheric component (RegCM 4.6.1) with a spatial resolution of 30 km , an ocean component (MITgcm) with a resolution of 1/12 degree and a component to simulate river discharge (HD). Preliminary comparisons with climatological data and recent available reanalyses (MyOcean,Copernicus) show that the new coupled model is able to reproduce the spatial pattern and the seasonal variability of atmosphere and ocean over the area. Moreover , the model effectively captures phytoplankton/zooplankton interactions , as well as nutrients (phosphate and nitrate) dynamics in the domain of study.

IS THERE ANY INFLUENCE OF THE EA/WR PATTERN ON PRECIPITATION OVER MEDITERRANEAN AND SERBIA?

I Tosic (1), S Putnikovic (1)

1) University of Belgrade, Institute for Meteorology, Belgrade, Serbia

itosic@ff.bg.ac.rs

Some of the most important modes of atmospheric variability characterizing the Northern Hemisphere are the North Atlantic Oscillation (NAO), the East Atlantic (EA) pattern, the East Atlantic/West Russia pattern (EA/WR), and the Pacific/North American pattern. The EA/WR pattern consists of four main anomaly centers and affects Eurasia throughout year. In this study, the influence of the EA/WR pattern on precipitation over Mediterranean and Serbia is examined. The monthly precipitation dataset for the period 1950 to 2013 with a 2.5×2.5° spatial resolution are obtained from the Global Precipitation Climatology Centre (GPCC). We used precipitation data from 1961 to 2016 for 15 stations, that are operated by the Republic Hydrometeorological Service of Serbia (http://www.hidmet.gov.rs/). Precipitation anomalies have been explored in relation to strong positive and negative phases of the EA/WR pattern. For the negative EA/WR phase, positive precipitation anomalies prevail over Mediterranean in January, March, June and July. Negative precipitation anomalies are distributed over Central and Eastern Mediterranean in February, April, May, August, September and December. A more complicated spatial distribution exists October. Strong positive anomalies are found over Western Mediterranean in February, April and December. For the strong positive EA/WR phase, positive precipitation anomalies are pronounced over Western Mediterranean in January. Positive precipitation anomalies prevail over Mediterranean in March, June and August, over central Mediterranean in April, September and November. Negative precipitation anomalies are pronounced in February, over central Mediterranean in October and over Eastern Mediterranean in November and December. The precipitation anomalies associated with the strong negative (positive) phase of the EA/WR pattern reflect above (below) average precipitation over Serbia. In addition, a spatial distribution of precipitation anomalies is examined for all combinations of positive and negative phases of the EA/WR pattern and NAO or EA pattern. We find that the effect of the EA/WR pattern on precipitation changes is not dependent of the NAO or EA phase over Serbia.

AUTOMATIC IDENTIFICATION AND CLASSIFICATION OF THE RED SEA TROUGH

B Ziv (1), H Saaroni (2), T Harpaz (1,2)

1) The Open University of Israel , Raanana, Israel
2) Tel Aviv University , Tel Aviv, Israel

saaroni@post.tau.ac.il

The Red Sea Trough (RST) is a low-pressure system extending from south toward the Eastern Mediterranean (EM) and further to the Levant. The semi-objective synoptic classification of Alpert et al. (2004) for the Levant identified 19% of the days of the year as 'RST days'. They are most frequent in the fall and the winter, fading out by mid-spring. This system is the most frequent among all easterly troughs, which extend from the east African Monsoon toward the EM, and is attributed to the lee effect of mountain ridges east of the Red Sea. The identification according to the above approach compares each day to one of 19 predefined synoptic types. Unfortunately, this identification does not differentiate successfully the RST from other synoptic systems, such as 'high pressure to the west' and 'shallow low east of Israel'. Our approach aims to explicitly identify RST days and classify them as one of three types, according to the location of the trough axis. For that end, we use the sea level pressure (SLP) and the sea level relative geostrophic vorticity. These two fields are interpolated (cubic) to a 0.5°x0.5° resolution. The following conditions has to be met in order for a day to be regarded as an RST day: (i) a north to south SLP drop across the Levant area, (ii) average positive relative vorticity over that domain, (iii) the existence of a distinct trough axis from the low pressure toward the domain along a continuous line where the curvature of the isobars is maximum and (iv) the absence of a pronounced closed cyclone in the region of interest (which is not a meso-cyclone within the RST). The classification of the RSTs is done according to the location of the trough axis; to the west of Israel, to the east or within Israel. It is found that the trough axis has a diurnal oscillation, whereas it tends to be located near the eastern coast of the Mediterranean at nighttime (00UTC) and shifts eastward (inland) toward noontime (12UTC). An evaluation of the automatic classification, done for randomly selected 200 days, showed that in 96% of them the subjective classification is similar. However, for the location of the trough axis, the agreement is 89%. For 100 days, identified subjectively as RSTs, the automatic classification agreed on 85% (72% agreement on the trough axis location). The fully automated algorithm is not tailored to a predetermined spatial resolution, so it is applicable to a variety of reanalysis datasets, operational forecast model results and climate model outputs.

THE EFFECTS OF MEDITERRANEAN OSCILLATION AND WESTERN MEDITERRANEAN OSCILLATION ON SURFACE CLIMATE VARIABLES IN THE MEDITERRANEAN

R Beranová (1), R Huth (1,2)

1) Institute of Atmospheric Physics, CAS, Prague, the Czech Republic
2) Faculty of Science, Charles University, Prague, the Czech Republic

rber@ufa.cas.cz

Temporal and spatial variability of both temperature and precipitation in the Mediterranean is related to atmospheric circulation patterns such as the Mediterranean Oscillation (MO) and the Western Mediterranean Oscillation (WeMO). Atmospheric circulation is characterized in terms of circulation indices traditionally defined either based on normalized SLP differences between two distant locations close to centres of action or based on the Principal Components Analysis (PCA). However, in the majority of previous studies the MO and WeMO indices are defined only based on SLP differences between two stations. The MO is described as a teleconnection pattern with opposite pressure and rainfall anomalies between the central–western and eastern Mediterranean areas. When the pressure increases in the western basin, a decrease is found in the east and vice versa. The MO index is defined by the Gibraltar – Lod dipole. The WeMO index is characterized by the San Fernando – Padua dipole. The positive phase corresponds to anticyclone over the Azores enclosing the southwest Iberian quadrant and low pressures in the Liguria Gulf, while its negative phase coincides with the Central European anticyclone located north of the Italian peninsula and a low pressure centre in the framework of the Iberian southwest. Both MO and WeMO PCA indices are computed as leading modes of SLP anomalies over the extended Mediterranean region (30°W–40°E, 30–60°N). In this contribution we analyse relationships between the circulation indices and climate elements in the Mediterranean region. Climatic elements analysed are monthly means of the daily maximum and minimum, monthly precipitation amounts and monthly number of wet days (i.e., days with precipitation amount ≥0.1 mm). We compare impacts of different defined circulation indices (station vs. PCA) on surface variables. We also find out if the relationships are stable in time.

WIND-DRIVEN SENSITIVITY ANALYSIS OF AEGEAN SEA COASTAL UPWELLING SYSTEM USING REGIONAL EARTH SYSTEM MODEL (REGESM)

C Ozcan (1), B Onol (1), UU Turuncoglu (1)

1) Istanbul Technical University, ISTANBUL, TURKEY

ozcan.ceyhunn@gmail.com

The two-way complex interaction between coastal wind-driven upwelling systems and atmospheric boundary layer might have big impact in hydrodynamics and ecosystem of the seas and the climate system of the surrounding region. The previous studies reveal that the costal upwelling systems can modify local and remote weather pattern and affect the stability of the atmospheric boundary layer by changing heat flux components over the sea. For better understanding coastal wind-driven upwelling systems that occur in a very short time scales (i.e. days and week) and their influence on the atmospheric condition, the fully-coupled multi-component and multi-scale non-hydrostatic modelling systems need to be utilized. Due to the complex feedback mechanism in the air-sea interface, the analysis of the direct and indirect effects of the upwelling event requires detailed analysis of the model results in a very high temporal and spatial resolution. This study aims to investigate complex relationship between Etesian wind and Aegean Sea coastal upwelling system using regional earth system model (RegESM). For this purpose, we designed a set of fully coupled atmosphere-ocean sensitivity simulations for selected strong upwelling events (July, 2004 and 2006) and analyze the results of model components in a very high temporal and spatial resolution by utilizing in-situ visualization component. In this case, the vast amount of data produced by the high-resolution atmosphere and ocean model components are transferred to the in-situ visualization component through the driver component developed by Earth System Modeling Framework (ESMF). The standardized and generic integration of the driver component and the in-situ visualization tool basically provides easy to use fully integrated modeling environment to analyze fast-moving processes such as coastal upwelling systems, extreme events, turbulence and air-sea interaction. The preliminary results indicate that the newly designed modeling system reveals very important information about wind-driven coastal upwelling system over Aegean Sea and regional atmospheric conditions. Acknowledgement: This study has been supported by a research grant (116Y136) provided by The Scientific and Technological Research Council of Turkey (TUBITAK). The computing resources used in this work were provided by the National Center for High Performance Computing of Turkey (UHeM) under grant number 5003082013 and 5004782017.

THE INFLUENCE OF MEDITERRANEAN CYCLONES ON PRECIPITATION DISTRIBUTION IN SERBIA

G Stanojevic (1), D Doljak (1), NB Curcic (1)

1) Geographical institute , Belgrade, Serbia

g.stanojevic@gi.sanu.ac.rs

There are several cyclone genesis regions in the Mediterranean basin with climate impacts on the Balkan Peninsula including territory of Serbia. In this study, we used sea level pressure and geopotential high of 500 hPa and principal component analysis to identify atmospheric circulation types for Southeast Europe domain, especially those with cyclonic activity on the ground and in the middle of the troposphere. The precipitation distribution was studied depending of cyclone position and air flow using daily values for 30 stations in Serbia. For this purpose, we used geostatistical interpolation method, regression kriging with additional predictors such as digital elevation model, latitude, and longitude. The high resolution spatial model showed regional differences in daily precipitation depending on whether cyclone genesis is in the Ligurian and Adriatic basins or eastern Mediterranean, but is some cases deep cyclone over Balkan can cause extremely high precipitation sums. The extreme precipitation events (over 90th, 95th, and 99th percentile of the empirical distribution of daily precipitation intensity) were analyzed separately.

HIGH-IMPACT STORMS IN PORTUGAL: CONSISTENT CATALOGUES OF COMPOUND EVENTS

MLR Liberato (1,2)

1) Instituto Dom Luiz (IDL), Universidade de Lisboa, Lisboa, Portugal
2) Universidade de Trás-os-Montes e Alto Douro (UTAD), Vila Real, Portugal

mlr@utad.pt

Extra-tropical cyclones dominate autumn and winter weather over western Europe and particularly over the Iberian Peninsula. Intense, high-impact storms are one of the major weather risks in the mid-latitudes. High winds and extreme precipitation from extratropical cyclones can result in windstorm damage, flooding and coastal storm surges, having large socioeconomic impacts. In Portugal, due to the extensive human use of coastal areas, the natural and built coastal environments have been amongst the most affected. In this paper a consistent catalogue of compound hydrometeorological extreme events over the Euro-Atlantic region is presented. Additionally reanalysis allow the assessment of the synoptic evolution, dynamical characteristics and the main impacts of the top-20 storms that provoked extreme impacts and considerable economical losses over Portugal. Acknowledgements: This work is supported by the Portuguese Science and Technology Foundation (Fundação para a Ciência e Tecnologia – FCT), under the projects UID/GEO/50019/2013 – Instituto Dom Luiz and AAC 02/SAICT/2017 029233 "Weather Extremes in the Euro Atlantic Region: Assessment and Impacts".

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G Stanojevic (1), D Doljak (1), NB Curcic (1)

1) Geographical institute , Belgrade, Serbia

g.stanojevic@gi.sanu.ac.rs

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THE LINK BETWEEN MEDITERRANEAN STORM TRACK AND SEA LEVEL ANOMALIES ALONG THE MEDITERRANEAN COASTLINE

P Lionello (1,2), D Conte (2), M Reale (3)

1) Università del Salento, Di.S.Te.B.A., via per Monteroni 164, Lecce
2) CMCC , Centro Euro-Mediterraneo per i Cambiamenti Climatici
3) OGS, Trieste, Italy

piero.lionello@unisalento.it

This contribution aims to show how both positive and negative sea level anomalies are related to intensity and position of cyclones moving along the Mediterranean storm track. This is not meant to suggest that sea level pressure minima produce a sea level decrease, but that the superposition of wind and sea level pressure gradient across the basin produce both positive and negative anomalies at several coastal locations as cyclones move over the surface of the Mediterranean basin. The analysis is based on sea level hindcasts complemented with a set of observed coastal sea level time series. It shows the presence of a sort of "teleconnection" (acting at a time scale from hours todays), which implies that a link between cyclone position and sea level is present for both positive and negative sea level anomalies. Anyway, it is confirmed that the dependence of the magnitude of the anomalies on the value of the low pressure minima is much stronger for positive than for negative sea level anomalies. Infact, sea level anomalies are produced by the inverse barometer effect, the action of the wind and a residual water mass redistribution within the basin, which, particularly, for negative sea level anomalies, play an important role and determines a link with cyclone position and intensity.

CLIMATIC IMPACT OF AN EXTREME LAND COVER CHANGE SCENARIO ON THE MEDITERRANEAN BASIN

IOA Sofiadis (1), E Katragkou (1)

1) Aristotle University of Thessaloniki, Thessaloniki, Greece

sofiadis@geo.auth.gr

Land cover changes play a crucial role in the land-atmosphere interactions and thus in climate, through their ability to modulate the exchange of energy and water fluxes between the land-surface and the atmosphere. In this study we use a coupled atmosphere-land model, WRF-CLM, to investigate the biogeophysical impact of an idealized land cover change on the Mediterranean climate. More specifically, we compare the climate of a maximally forested landscape with the climate of a fully covered by grass landscape, isolating the net impact of this type of conversion on regional climate. The replacement of forests with grass induces a cooling throughout the year in areas with high altitude (Alps, Pyrenees etc) due to an increase in the surface albedo. The decrease of surface temperature is largest in winter and spring, when these regions are snow-covered, since the deforestation exposes, the very reflective to solar radiation, snow underneath, thus reducing the net radiation at the surface and consequently lowering the upper air temperature. On the other hand, the deforestation in lowland and coastal areas results in a warming, due to a reduction in turbulent fluxes and surface roughness, which tend to dry and warm the boundary layer. Our results are in line with the existing bibliography and highlight the important climatic role that each type of forest vegetation have in Mediterranean region.

SESSION 2

Past climate evolution of the Mediterranean region

EXPRESSION, FREQUENCIES AND DYNAMICS OF SUB-ORBITAL SCALE VARIABILITY DURING MARINE ISOTOPE STAGES 19: INSIGHTS FROM THE SULMONA BASIN (CENTRAL ITALY)

E Regattieri (Invited) (1,2), B Giaccio (3), G Zanchetta (4), G Mannella (1), S Nomade (5), H Vogel (6), A Tognarelli (1), C Boschi (2), N Perchiazzi (1)

1) Earth Sciences Department, Pisa, Italy
2) IGG-CNR, Pisa, Italy
3) IGAG-CNR, Rome, Italy
4) LSCE-CNRS, Gif sur Yvette, France
5) University of Bern, Bern, Switzeland

eleonora.regattieri@unipi.it

The recovery of high-resolution records of climate variability from ice, marine and terrestrial archives has fundamentallychanged our perspective on global climate change by revealing the existence of very rapid and intense climate changes inthe past. As we are currently living in an interglacial period, the recognition of short term (i.e. multidecadal to millennial),global-scale climate variability within past interglacial is fundamental to better frame the background of natural variabilityin which human induced changes operate. (Tzedakis et al., 2009). The Marine Isotope Stage (MIS19), spanning the ca. 790-760 ka period is considered the best orbital analogue of the present interglacial over the last 1 Ma. Exploring patterns,causes and expression of its variability is important for framing Holocene climate into a historical-natural context and forprojecting its future in the light of both anthropogenic and natural forcing.Here we present an high resolution, multiproxy biogeochemical record (oxygen stable isotope composition, elemental andmineralogical composition, biogenic silica) from carbonatic endogenic lacustrine sediments hosted in the Sulmona Basin(central Italy) and covering the interglacial portion of MIS19. The record shows significant variability at the centennial tomillennial time scale. Sediments from the Sulmona Basin faithfully record regional hydrological and environmentalconditions, which can be linked to Mediterranean and North Atlantic conditions thanks to well-known climateteleconnections (e.g. Giaccio et al., 2015, Regattieri et al., 2016). The robust 40*Ar/39*Ar chronology developed onvolcanic ash layers (tephra) interbedded in the sediment allows to firmly place this variability onto an independent timescale. We investigate expression, pacing and periodicities of the short-term climate change and then compare it to theclimatic framework apparent from several North Atlantic marine records, to unravel potential forcing and mechanisms forintra-interglacial climate variability.Tzedakis, P. C., Raynaud, D., McManus, J. F., Berger, A., Brovkin, V., & Kiefer, T. (2009). Interglacial diversity. NatureGeoscience, 2(11), 751-755.Giaccio, B., Regattieri, E., Zanchetta, G., Nomade, S., Renne, P. R., Sprain, C. J., ... & Sposato, A. (2015). Duration anddynamics of the best orbital analogue to the present interglacial. Geology, 43(7), 603-606.Regattieri, E., Giaccio, B., Galli, P., Nomade, S., Peronace, E., Messina, P., ... & Gemelli, M. (2016). A multi-proxy record ofMIS 11–12 deglaciation and glacial MIS 12 instability from the Sulmona Basin (central Italy). Quaternary Science Reviews,132, 129-145.

THE MEDITERRANEAN PLIO-PLEISTOCENE: A REFERENCE FRAME FOR ASTRONOMICALLY PACED LOW AND HIGH LATITUDE CLIMATE CHANGES

LJ Lourens (Invited) (1)

1) Department of Earth Sciences, Faculty of Geosciences, Utrecht University, Utrecht, Netherlands

L.J.Lourens@uu.nl

The astronomical theory of climate has revolutionized our understanding of past climate change and the development of highly accurate geologic time scales throughout the Cenozoic. Most of this understanding has started with the construction of high-resolution stable oxygen isotope (d18O) records from planktonic and benthic foraminifera of open ocean deep marine sediments explored by international drilling operations, such as DSDP, ODP and IODP. This work has culminated into global ocean isotopic stacked records that encompassed the past 5 million years for the precession and obliquity tuned time series, towards the entire Cenozoic for tuning on an eccentricity scale. In the meantime, astronomers increased the accuracy of their orbital calculations, which enabled tuning the geological archives further back in time. In this talk I will highlight the astronomically calibrated time scale for the Pliocene and Pleistocene of the Mediterranean, which has become the standard reference of the Geologic Time Scales 2004 and 2012. I will present the first benthic d18O record of this reference scale and its comparison with the open ocean stacked records and discuss its potential to constrain phase relations in the climate system and global sea level changes over the past 5.3 million years.

MODELLING CLIMATE AND SOCIETAL RESILIENCE IN THE EASTERN MEDITERRANEAN DURING THE LAST MILLENNIUM

E Xoplaki (1), J Luterbacher (1,2), S Wagner (3), E Zorita (3), D Fleitmann (4), J Preiser-Kapeller (5), AM Sargent (6), S White (7), A Toreti (8), JF Haldon (6), L Mordechai (6), D Bozkurt (9), S Akçer-Ön (10), A Izdebski (11)

1) Climatology, Climate Dynamics and Climate Change, Department of Geography, Justus-Liebig-University Giessen, Giessen, Germany
2) Centre of International Development and Environmental Research, Justus-Liebig-University Giessen, Giessen, Germany
3) Institute for Coastal Research, Helmholtz-Zentrum Geesthacht, Geesthacht, Germany
4) Department of Archaeology and Centre for Past Climate Change, School of Human and Environmental Sciences, University of Reading, Reading, UK
5) Institute for Medieval Research/Division of Byzantine Research, Austrian Academy of Sciences, Vienna, Austria
6) History Department, Princeton University, Princeton, USA
7) History Department, Ohio State University, USA
8) European Commission, Joint Research Centre, Ispra, Italy
9) Center for Climate and Resilience Research, Department of Geophysics, University of Chile, Santiago, Chile
10) Geological Engineering Department, Mugla Sitki Kocman University, Mugla, Turkey
11) Byzantine History Department, Institute of History, Jagiellonian University in Krakow, Krakow, Poland

elena.xoplaki@geogr.uni-giessen.de

We analyse high-quality hydroclimate proxy records and spatial reconstructions from the Central and Eastern Mediterranean and compares them with two Earth System Model simulations (CCSM4, MPI-ESM-P) for the Crusader period in the Levant (1095-1290 CE), the Mamluk regime in Transjordan (1260-1516 CE) and the Ottoman crisis and Celâlî Rebellion (1580-1610 CE). During the three time intervals, environmental and climatic stress tested the resilience of complex societies. We find that the multidecadal precipitation and drought variations in the Central and Eastern Mediterranean cannot be explained by external forcings (solar variations, tropical volcanism); rather they were driven by internal climate dynamics. Our research emphasises the challenges, opportunities and limitations of linking proxy records, palaeoreconstructions and model simulations to better understand how climate can affect human history.

THE INFLUENCE OF MEDITERRANEAN CLIMATE ON SOUTHEASTERN EUROPE DURING THE LAST FIVE GLACIAL-INTERGACIAL CYCLES

SB Marković (1), I Obreht (2), RJ Schaetzl (3), U Hambach (4), C Zeeden (5), F Lehmkuhl (6), QZ Hao (7), D Veres (8), MB Gavrilov (1)

1) University of Novi Sad, Novi Sad, Serbai
2) MARUM, Bremen, Germany
3) Michigan State University, East Lansing, USA
4) BayCEER & University of Bayreuth, Bayreuth, Germany
5) Observatoire de Paris, Paris, France
6) RWTH Aachen University, Aachen, Germany
7) Chinese Academy of Sciences, Beijing, China
8) Romanian Academy, Institute of Speleology, Cluj, Romania

slobodan.markovic@dgt.uns.ac.rs

Loess and loess-like deposits cover about 10% of the Earth's surface. These deposits represent one of the world's best terrestrial archives of paleoclimate change. Because of their great thickness and rapid accumulation rates, they preserve paleoclimate signals that can be discerned at high resolution, including millennial-scale climate changes. Recently, loess–palaeosol sequences in the Southeastern Europe have been intensively investigated. Through multi-proxy analyses in combination with luminescence dating as a chronological tool, we have demonstrated that these loess–palaeosol sequences provide one of the most complete and most detailed terrestrial records of climatic and environmental changes for Europe, during the Middle and Late Pleistocene. Results presented in these studies emphasize the importance of understanding the mechanisms of Pleistocene climate change, as an important contribution towards a more detailed spatial and temporal reconstruction of environmental dynamics across the European continent.To understand the significance of the presented data, it is important to realize that besides several available lacustrine records from the southern Balkan Peninsula (Tenaghi Philippon, Ioannina, Kopais, Ohrid, Prespa and Dorjan), other high resolution records for the Balkan region are still lacking. Southeastern Europe is a climatically sensitive region, influenced by both Mediterranean and continental climates. Here, we present high-resolution grain-size, environmental magnetic, spectrophotometric and geochemical data from the loess sections in the Middle and Lower Danube Basin, and in the Central Balkans. These sections span the past ~650,000 years. The goal of this study is to determine the relative influence of the Mediterranean climate during this period, for the study area. Data show that Southeastern European was under different atmospheric circulation regimes, especially during Marine Isotope Stages (MIS) 9 and 7, while continental climates prevailed in areas further north. We observe a general weakening of the Mediterranean climate influence with time. Our data suggest that MIS 5 was the first interglacial in the Central Balkans with continental climate characteristics, contrary to fossils in a Cambisol (S4: MIS 11), which represents the oldest paleosol formed under predominant climatic conditions in the Middle and Lower Danube Basin.

A BAYESIAN TEST ON THE 4.2 KA BP ABRUPT CLIMATIC CHANGE EVENT FOR THE EASTERN MEDITERRANEAN AND ARABIAN PENINSULA PALEOCLIMATE DATA

ZB On (1,2), MS Ozeren (2), AM Greaves (3), S Akçer-Ön (1)

1) Mugla SK University, Geology, Mugla, Turkey
2) ITU Avrasya YBE, Istanbul, Turkey
3) University of Liverpool, Department of Archaeology, Liverpool, UK

bora.on@gmail.com

It has been proposed that an abrupt climatic change around 4.2 ka BP caused the collapse of the Akkadian Empire. Since then, many geological studies have arisen that support the theory. While there are also many studies which contradict the idea of an abrupt climate change, the time point has nevertheless even been suggested as a potential stratigraphic boundary within the Holocene. Time series plots of paleoclimate studies, which claim to support the abrupt climate change theory, show different temporal and geometrical patterns. In this study, we use Bayesian structural time series method to test time series data from the Eastern Mediterranean and Arabian Peninsula, which are claimed to have a climatic anomaly around 4.2 ka BP. While doing this, time series are reconstructed using "unaffected" time series in a fully Bayesian framework and consequently, a Bayesian hypothesis test is applied on the results. According to our study, the effect of any putative abrupt climatic change does not appear to be statistically significant in a number of studies that have previously been cited to support the 4.2 ka BP event.

THE LATEGLACIAL AND HOLOCENE GLACIAL HISTORY OF THE NORTHEAST MEDITERRANEAN MOUNTAINS INFERRED FROM IN-SITU PRODUCED COSMIC RAY EXPOSURE DATINGS OF PALEO-GLACIERS DEPOSITS. IMPLICATIONS FOR THE RELATIVE ROLES OF EXTERNAL AND INTERNAL CLIMATE FORCING.

MN Styllas (1), I Schimmelpfennig (2), L Benedetti (2), M Ghilardi (2), G Aumaître (2,3), D Bourles (2,3), K Keddadouche (2,3)

1) GEOSERVICE LTD, Athens, Greece
2) Aix Marseille Univ, CNRS, IRD, INRA, CoF, CEREGE, Aix-en-Provence, France
3) ASTER Team, Aix-en-Provence, France

mstyllas@gmail.com

A new glacial chronology from Mount Olympus in Greece, based on 20 36Cl in situ produced cosmic ray exposure (CRE) datings is used to complement existing CRE chronologies from the northeast Mediterranean (NEM) region. The new 36Cl ages of the glacial landforms range from 15.6 ± 2.0 to 0.6 ± 0.08 ka, spanning the Lateglacial and the Holocene. Based on the Probability Density Functions of all existing CRE ages, the Lateglacial is partitioned in three distinct phases (LG1-3): an initial phase of glacial moraine stabilization at 15.06 ± 0.53 ka with subsequent deglaciation starting at ~14 ka (LG1) evident in Mount Pelister, Sâra Range, Galicica Mountains, Mount Olympus, Rila Mountains and Mount Uludag. LG1 was followed by a transition to conditions marginal for glaciation at 13.3 ± 1.21 ka (LG2), recorded only on Mount Olympus that was characterized by enhanced aeolian activity (westerlies) and large amounts of windblown snow. Glacial conditions characterized by low temperatures and low precipitation, returned to the NEM mountains at 11.9 ± 0.56 ka (LG3), but they were not widespread as they are found on Sâra Range, Mount Uludag, Mount Chelmos and Mount Olympus. NEM glacial phases LG1-3 occurred during a period of increasing obliquity and peak eccentricity and exhibit an out-of-phase behaviour with the local solar insolation record from Duhlata Cave. Phases LG1 and LG3 occurred during solar insolation maxima and also coincided with a shutdown of the Atlantic Meridional Overturning Circulation (AMOC), whereas LG2 occurred during insolation minima with concurrent establishment of the AMOC. The Holocene glacial phases (HOL1-3) are recorded only in Mount Olympus. An early Holocene glacier stillstand (HOL1) at 9.6 ± 1.1 ka, occurred during peak obliquity, increasing solar insolation close to the record's peak values and is locally associated with a lagged recovery of north Aegean Sea Surface Temperatures (SST's). No glacier activity is observed during the mid-Holocene (~9.0 – 3.0 ka). The Late Holocene glacier expansions, include a moraine stabilization phase (HOL2) at 2.5 ± 0.3 ka, a period that coincides with solar insolation minima (Homeric Low), combined with a negative North Atlantic Oscillation (NAO) phase, which resulted in locally wet conditions, as recorded in Skala Marion Cave speleothem record. The last phase of glacial activity (HOL3) corresponds to the early part of the Little Ice Age (0.6 ± 0.08 ka). A link between the Holocene glaciations with the north Atlantic climatic regime is evident, as HOL1, 2 and 3 glacial phases, broadly correspond to Bond 6, 2 and 0 events. The new Lateglacial and Holocene glacial chronology emphasizes the relative controls of internal and external forcing along the headwaters of the major Northeast Mediterranean fluvial systems, is in pace with numerous regional and local terrestrial and marine proxies and establishes the basis for a source-to-sink approach to paleoenvironmental reconstrunctions.

LAST 2700 YEARS PALEOCLIMATE HISTORY IN THE SOUTHERN ADRIATIC SEA: COCCOLITHOPHORE EVIDENCES

A Cascella (1), S Bonomo (2,3), MA Sicré (4), D Insinga (2), P Petrosino (5), N Pelosi (2), S Schmidt (6), B Jalali (7), F Lirer (2)

1) Istituto Nazionale di Geofisica e Vulcanologia, Pisa, Italy
2) Istituto per l'Ambiente Marino Costiero, Napoli, Italy
3) IBM Alberto Monroy, CNR, , Palermo, Italy
4) Sorbonne Universités /UPMC/ CNRS-IRD-MNHN, Paris, France
5) Dipartimento di Scienze della Terra, Università degli Studi Federico II. Napoli, Italy
6) UMR5805 EPOC, Université de Bordeaux, Pessac, France
7) GEOGLOB, Université de Sfax, Faculté des Sciences, Sfax, Tunisia

antonio.cascella@ingv.it

The high-resolution study of calcareous nannofossils from the sediment core SW104-ND14Q, recovered at 1013m water depth, furnished new information on paleoenvironmental conditions over past 2700 years in the Southern Adriatic Sea. Changes in the abundance of the main surface eutrophic species Emiliania huxleyi and the deep dweller taxa Florishaera profunda were used to reconstruct the phases of stratification/vertical mixing of the upper water column and the associated changes in productivity (Bown et al., 2009). We evaluated the relation of these changes with the climatic and atmospheric conditions acting at local and regional scale (i.e. North Atlantic Oscillation, NAO), and the possible role played by the Bimodal Oscillating System (BiOS) mechanism of Ionian circulation (Civitarese et al., 2010). Reworked coccolith abundance trend were used to reconstruct runoff/precipitation oscillations. The higher productivity values occurred during periods of negative NAO likely coupled with cyclonic phase of BiOS. The inflow of salty and nutrient- rich Levantine Intermediate Water, coupled with the growth of the strength of the South Adriatic Gyre and a stronger positive vorticity wind patterns (Shabrang et al., 2015), favour the deep vertical convection, sustaining a more well defined upper mixed layer that facilitated the flourishing of E. huxleyi. The relative drops in productivity occurred in periods of positive NAO and possible anticyclonic phase of BiOS. This may be related to the advection of less salty and nutrient- rich Modified Atlantic Water which together with the lower positive or slightly negative wind vorticity, weakens deep winter convection and shifts the primary productivity in the deep layers of photic zone favouring the increase of F. profunda relative to other Coccolithophores. The correspondence of reworked coccolith abundance trend with the flood frequency of Southern Alps would confirm that they may be used to reconstruct large scale runoff/precipitation oscillations. This research was carried out in the ambit of Italian Project of Strategic Interest NEXTDATA (http://www.nextdataproject.it) "A national system for recovery, storage, accessibility and dissemination of environmental and climatic data from mountain and marine areas" and of ERC Consolidator Grant (Project ID: 68323) "TIMED" Testing the role of Mediterranean thermohaline circulation as a sensor of transient climate events and shaker of North Atlantic Circulation. Bown, P. R., Dunkley Jones, T., Young_ J. R., and Randell, R., 2009. Palaeontology, Vol. 52, Part 2, 2009, pp. 457–469. Civitarese, G., Gačić, M., Lipizer, M. and Eusebi Borzelli, G. L., 2010. Biogeosciences, 7, 3987–3997. Shabrang, L., Menna, M., Pizzi, C. , Lavigne,H., Civitarese,G. and Gačić, M., 2015. Ocean Sci., 12, 233–241.

Δ18O PROFILE MEASURED IN THE CENTRAL MEDITERRANEAN CORE CT85-5 AND THE LAST DEGLACIATION

C Taricco (1,2), S Mancuso (2), I Hajdas (3), S Rubinetti (1,2)

1) Dipartimento di Fisica, Università di Torino, Torino, Italy
2) Osservatorio Astrofisico di Torino (OATo, INAF), Pino Torinese, Italy
3) Laboratory of Ion Beam Physics, ETH, Zuerich, Switzerland

carla.taricco@unito.it

We measured δ18O in the upper 450 cm of the deep-sea core CT85-5 taken from the Tyrrhenian sea. The age model of this core is based on 15 Accelerator Mass Spectrometry (AMS)-14C measurements performed at ETH in Zürich (Hajdas et al., 2011). Two dates corresponding to the historically dated tephra layers of Pollena (472 AD) and Pompeii (79 AD) eruptions (Cini Castagnoli et al., 1992) were also used. The δ18O record at our site reflects several patterns typical of the last deglaciation and Late Holocene period, with some features which probably reflect local changes in temperature and salinity. We discuss the δ18O record in comparison with other marine records from the same area over the last 40 kyr. The good agreement in both general trend and timing of the major oscillations shows the consistency of the different core chronologies and a similar progression towards maximum values during the early Holocene around 9 cal kr BP.Hajdas, I., Taricco, C., Bonani, G., Beer, J., Bernasconi, S. M., & Wacker, L. Anomalous radiocarbon ages found in Campanian Ignimbrite deposit of the Mediterranean deep-sea core CT85-5, Radiocarbon, 53(4), 575, 2011.Cini Castagnoli, G., Bonino, G., Provenzale, A., Serio, M. & Callegari, E., The CaCO3 profiles of deep and shallow Mediterranean sea cores as indicators of past solar-terrestrial relationships, Il Nuovo Cimento C, 15, 547-563, 1992.

PALEONVIRONMENT CONDITIONS AT THE ONSET OF THE MESSINIAN SALINITY CRISIS TRIGGERED CALCAREOUS PLANKTON SIZE DECREASE.

F Lozar (1,2), D Violanti (1), F Dela Pierre (1,2), M Natalicchio (1,2), R Gennari (1,2), E Nallino (1)

1) Dep. of Earth Sciences - University of Torino, Torino, Italy
2) ALP Alpine Laboratory of Paleomagnetism, Peveragno (CN), Italy

francesca.lozar@unito.it

The Messinian salinity crisis (MSC) is a short lived (5.97-5.33 Ma) dramatic paleo-oceanographic event occurred in the Mediterranean area as result of the reduced hydrological connection with the Atlantic ocean. The beginning of the MSC, marked by the deposition of gypsum in the marginal basins, triggered an immediate response of the biota, and particularly of the calcareous microfossils. In detail, the first 21 kyr of the crisis were characterized by very peculiar calcareous nannofossil and foraminiferal assemblages preserved in the first Primary Lower Gypsum (PLG) cycle (Sphenolithus abies, Umbilicosphaera rotula, and Rhabdosphaera procera peaks, Globorotalia scitula and G. suterae peaks; Lozar et al. in press). Also, in the lower PLG cycles some foraminiferal taxa exhibit a sharp size decrease (e.g. Turborotalita quinqueloba), the significance of which is still unclear. In addition, no information regarding the size of the calcareous nannofossils is available so far. Samples from the Piedmont Basin (northern Italy) and straddling the MSC onset yielded the Sphenolithus abies and Helicosphara carteri specimens measured for this work. Total length and basal width for S. abies and major and minor axes for H. carteri specimens were measured. The measures sharply decrease at the onset of the MSC but show a slow recovery to average values in the following cycles, despite their group abundance decrease. As for other calcareous microfossils, among the foraminiferal assemblages from the same cycles, the >125 micron fraction is devoid of foraminifers, whereas the 45-63 micron and 63-125 micron fractions contain abundant Turborotalita quinqueloba and minor Bulimina spp., thus showing a sudden size decrease in the cycle where most foraminiferal taxa abruptly disappear. The disappearance of foraminifers and nannofossils at the beginning of the crisis was traditionally related to a fast salinity increase, in turn responsible for the deposition of the evaporites recorded in the marginal basins of the Mediterranean Sea. Conversely, the size decrease among calcareous nannofossils and foraminifers described in this study suggest that the surface water was characterized by high nutrient supply and possibly fresh water input. The eutrophication is also supported by the presence of Umbilicosphaera spp. blooms, a calcareous nannofossil genus considered to better flourish when nutrient supply is high, by the presence of diatom frustules, and by other independent geochemical data (e.g. high Ba concentration). The assemblage composition and the microfossil size decrease recorded in this study thus suggest that the MSC could have been triggered by high nutrient input to the basin, possibly derived by increased runoff from the continent.

EMILIANIA HUXLEYI CALCITE MASS VARIABILITY DURING PERIODS OF RISING ATMOSPHERIC CO2 IN THE MEDITERRANEAN SEA

M Grelaud (1), B D'Amario (1), P Ziveri (1,2)

1) Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona (UAB), Bellatera (Barcelona), Spain
2) Catalan Institution for Research and Advanced Studies (ICREA), Pg. Lluís Companys 23, 08010 Barcelona, Spain

michael.grelaud@uab.cat

Coccolithophores are marine phytoplanktonic organisms that play a significant role in both the marine food web and the carbon cycle. They are responsible for the photosynthetic fixation of inorganic carbon, regulating the particulate inorganic-organic carbon (PIC : POC) ratio and a large portion of the calcium carbonate ($CaCO_3$) production. It is challenging to understand how the current rising of atmospheric CO_2 concentration and the subsequent change in carbonate chemistry (i.e. ocean acidification) and temperature will impact the marine calcifying organisms. Most of the experiments conducted in vitro on the cosmopolitan species Emiliania huxleyi show in general a decrease of PIC production and PIC : POC ratio when grown in high pCO_2 conditions, pointing to the adverse effect of ocean acidification on these organisms. However, a recent study shed a new light on the factors controlling the average mass of E. huxleyi coccoliths in natural assemblages of the Mediterranean Sea (D'Amario et al., subm.). In this semi-enclosed sea, E. huxleyi is mainly represented by the morphotype A, which can be categorized into four calcification varieties going from low- to high-calcified coccoliths. As a result, the average mass of E. huxleyi is modulated by the relative abundances of the Type A calcification varieties, which in turn see their geographical distribution related to the sea water carbonate system. Here we present data of E. huxleyi calcite mass from Mediterranean surface sediments and sedimentary cores that cover the industrial era, the Holocene, the last glacial-interglacial transition and the marine isotopic stage (MIS) 5e. The relative abundances of the four calcification varieties and the average E. huxleyi calcite mass are investigated during periods of low and high atmospheric CO_2 concentrations. The calcite mass of E. huxleyi is anticorrelated with the atmospheric CO_2 concentrations both during the warm MIS 5e and the last deglaciation, Remarkably, the calcite mass variation of E. huxleyi observed over the last five centuries and in the surface sediment is of the same magnitude as for the last glacial-interglacial transition or the MIS 5e. This highlights the vulnerability and complexity of coccolithophore responses to the rapid rise of atmospheric CO_2 and environmental changes since the beginning of the industrial age.

EARLY-MIDDLE MIOCENE PALEOCLIMATIC RECONSTRUCTION IN THE EASTERN MEDITERRANEAN: KOTTAPHI HILL SECTION, CYPRUS ISLAND

M Athanasiou (1), MV Triantaphyllou (1), M Dimiza (1), A Arabas (2), IP Panagiotopoulos (1), K Kouli (1), A Gogou (3), I Bouloubassi (4), C Panagiotaropoulos (1), E Tsiolakis (5), G Theodorou (1)

1) National and Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Panepistimioupolis 15784, Athens, Greece
2) Institute of Geological Sciences, Polish Academy of Sciences, Research Centre in Kraków, ul. Senacka 1, Kraków 31-002, Poland
3) Hellenic Centre for Marine Research, Institute of Oceanography, 19013 Anavyssos, Attica, Greece
4) Laboratoire d'Océanographie et du Climat: Expérimentation et Approches Numériques (LOCEAN/IPSL), Université Pierre et Marie Curie-CNRS-IRD-MNHN, 4 Place Jussieu, Case 100, 75252 Paris, Cedex 05, France
5) Geological Survey Department of Cyprus, 1 Lefkonos Street, 2064 Strovolos Lefkosia, Cyprus

mtriant@geol.uoa.gr

The Kottaphi Hill Section (KHS) on Cyprus Island represents a well-exposed complete sequence of the hemipelagic Pakhna Formation with rhythmically bedded chalks and marls, most probably correlated to all three Earth's orbital parameters and reflecting the Miocene relative sea-level change (e.g., Davies, 2001). The current work aims to provide solid evidence for monsoon-type climatic variability during the Early-Middle Miocene in the Eastern Mediterranean. Seventeen laminated siltstone layers (3–10 cm thick), matching with the precession-scale cyclicity, were found exposed in-between 20.4–42.0 m of KHS and interbedded within 114 chalk / marly chalk / chalky marl alternations. These siltstones may be interpreted as transgressive basin-plain deposits, while the carbonate facies can be considered as hemipelagic sediments of the regressive stages of the relative sea-level change. High-resolution quantitative calcareous nannofossil analysis, performed for this interval, provides correlation with the NN4–NN7 biozones, while additional planktonic foraminiferal bioevents support the identified time framework. The studied sediment sequence is dated between 15.1 Ma (FO Orbulina suturalis at 16.4 m) and 11.6 Ma (LO Discoaster kugleri at 36.7 m). The organic carbon (OC) contents of the thin siltstone units appear quite higher, up to 0.36%, compared to the OC values in the chalk /chalky marl layers (0.17% on average). Carbon and oxygen composition analyses carried out on the planktonic foraminifera Orbulina universa indicate heavier values of δ18O (0.06‰ on average) within the low OC chalk / marly chalk / chalky marl layers. In contrast, for the thin laminated siltstones lighter δ18O signatures (up to -0.95‰) are exhibited, suggesting warmer temperatures and enhanced precipitation. Superimposed oxygen isotope excursions are associated with the Miocene Mi3a-Mi5 events, commonly interpreted as a record of brief glaciations. The positive excursions of the calcareous nannofossil species Discoaster spp., Sphenolithus spp. and Rhabdosphaera spp. within the OC-enriched siltstone layers provide evidence for warm oligotrophic surface waters and stratified conditions coupled with a salinity decrease (increment of Helicospahera spp.), whereas plant remains and palynological evidence suggest fluxes (strong enough to reach the basin-plain realm) of terrestrial organic matter triggered by vigorous river discharges during the monsoon seasons. The foraminiferal content comprising > 90% of the planktonic specimens refers to the lower epibathyal zone, however, the extremely rare benthic forms represented by the oxic-preference taxa Gyroidinoides, Uvigerina, Nodosaria and Hoeglundina indicate a well-oxygenated seafloor. All available evidence propose a shift to monsoonal activity between 15.1-11.6 Ma without, however, the regional depositional and hydrographic regime being appropriate for this signal to be preserved as sapropelic facies in the KHS sediment record.

VEGETATION HISTORY OF LAKES OHRID AND PRESPA AND RECONSTRUCTED CLIMATE VARIABILITY OVER THE LAST 17000 YEARS.

S Kyrikou (1), K Panagiotopoulos (1), O Peyron (2), K Kouli (3), A Francke (4), N Leicher (1), B Wagner (1)

1) Institute of Geology and Mineralogy, University of Cologne, Germany
2) Institut des Sciences de l'Evolution de Montpellie, University of Montpellier, France
3) Department of Geology and Geoenvironment, University of Athens, Greece
4) School of Earth and Environmental Sciences, University of Wollongong, Australia

s.kyrikou@uni-koeln.de

In this study we present two new pollen records with centennial resolution from lakes Ohrid and Prespa that provide new insights into the flora composition, vegetation changes and climate variability over the last 17000 years. The Lake Ohrid (DEEP core) pollen record is the first continuous Late Glacial-Holocene sequence from Lake Ohrid that together with the new high-resolution pollen archive of the adjacent Lake Prespa allows examining the evolution of local and regional vegetation patterns. Moreover, we employ the modern analogue technique (MAT) on the new pollen data to reconstruct climate variability in the area over the study interval. A new surface sample calibration set was established by including a total of 30 modern surface samples collected across an altitudinal transect within the catchments of Ohrid and Prespa. From 17000 years onwards, pollen spectra from both lakes suggest a rather open landscape dominated by steppe elements (mainly Artemisia and Chenopodiaceae) along with grasslands. Pines appear to be the dominant trees at Ohrid and Prespa during the Late Glacial. During the Bølling/Allerød, deciduous oaks dominate tree percentages at Ohrid, while at Prespa pines remain dominant over this period. Throughout the Younger Dryas, the resurgence of steppe elements accompanied by Betula, Ephedra and Hippophae in both pollen records suggest that cold and arid conditions prevailed. Mean annual precipitation values reconstructed applying the MAT method are above 400 mm/year during the last 17000 years. These findings imply that moisture availability was most likely not a limiting factor for tree growth and support the refugial character of the region. The Holocene is characterized by an estimated twofold increase of mean annual precipitation compared to the Younger Dryas. The onset of the Holocene is characterized by the gradual expansion of mixed deciduous oak woodlands in the surroundings of Ohrid and Prespa, while during the Mid- and Late-Holocene, the closed forests diversify and percentages of other deciduous taxa such as Acer, Alnus, Carpinus, Fagus, Ostrya increase, especially at Prespa. Although Lake Ohrid is situated a 150 m lower than Lake Prespa at 693 m asl, the presence of Mediterranean elements such as Pistacia and Phillyrea in Ohrid pollen spectra is rather limited compared to Prespa. Intensifying anthropogenic activities during the last two millennia can be inferred in both records from the decline of tree percentages and the coeval increase in pollen of cultivated plants such as walnuts and cereals.

CHANGES IN PRECIPITATION REGIMES SINCE 850 A.D.: THE ROLE OF THE INTEGRATED WATER VAPOR TRANSPORT AND GLOBAL WARMING

PM Sousa (1), AM Ramos (1), RM Trigo (1), CC Raible (2,3), M Messmer (2,3), JG Pinto (4)

1) Instituto Dom Luiz (IDL), FCUL, Lisboa, Portugal
2) Oeschger Centre for Climate Change Research, Bern, Switzerland
3) Climate and Environmental Physics, Bern, Switzerland
4) Institute of Meteorology and Climate Research, Karlsruhe, Germany

ppsousa@fc.ul.pt

Changes in Atlantic moisture transport corridors control a large fraction of the precipitation regimes in Western Europe, particularly though the long corridors that transport large amounts of water vapor, in the form of an Atmospheric River. The vertically integrated water vapor transport (IVT) has been computed using a long-term climatic simulation spanning between 850-2100 A.D. to examine long-term variability in precipitation regimes in this region. The simulation was performed with the Community Earth System Model (CESM 1.0.1), using a modified reconstruction of total solar irradiance, volcanic forcing and the RCP8.5 forcing scenario for the 21st century. We analyzed the variability of IVT fluxes along the Iberian Peninsula and UK, and compared them against: i) precipitation series (large scale, convective and total) in those regions; ii) mean surface temperature in oceanic boxes west of those coastlines. After the Industrial Period a steady increase in moisture transport towards Western Europe (superimposed to the inter-annual and inter-decadal variabilities) occurred, in line with the concurrent rise in surface temperatures. Nevertheless, while recent and projected rainfall regime changes follow this positive trend in the UK, a negative precipitation trend is foreseen through the 21st century for Iberia. In fact, the steady correlation between the IVT and precipitation (0.75) in the Pre-Industrial period is lost afterwards, especially towards the end of the simulation (21st century). As a consequence, further precipitation decreases in Southern Europe are projected, being this reduction substantial during autumn and spring transition months. Our results show that dynamical features are driving precipitation regime changes towards drier conditions in Southern Europe, despite the observed and expected rises in evaporative processes and moisture availability in a warming climate. To illustrate this, a Weather Type Classification (WTs) approach was performed, showing a significant increase (decrease) in the frequency of anticyclonic (cyclonic and/or westerly flow) days over Iberia, and an opposite response in the UK. Results also suggest a shortening of the rainy season in Iberia, as typical summer-like WTs extend towards November by the end of the 21st century. All these dynamical changes are occurring at a magnitude unprecedented for the time-scales of this long-simulation period, stressing the long-term drying trends in Mediterranean-like climates. This work was supported by project IMDROFLOOD – Improving Drought and Flood Early Warning, Forecasting and Mitigation using real-time hydroclimatic indicators (WaterJPI/0004/2014) funded by FCT. Alexandre M. Ramos was also supported by a FCT postdoctoral grant (FCT/DFRH/ SFRH/BPD/84328/2012).

THE PAST 23-KYR EASTERN MEDITERRANEAN SEA CIRCULATION INFERRED FROM AUTHIGENIC ND ISOTOPES, FORAMINIFERAL STABLE ISOTOPES AND BULK ELEMENTAL COMPOSITION

K Tachikawa (1), L Vidal (1), M Cornuault (1)

1) CEREGE-CNRS-AMU, Aix-en-Provence, France

kazuyo@cerege.fr

The Eastern Mediterranean Sea (EMS) circulation is sensitive to climate changes as documented by the recent Eastern Mediterranean Transient and repeated occurrence of organic-rich layers (sapropels) in precession cycle. It is well known that excess fresh water inputs to the EMS in relation to African monsoon variability and consequent stagnant circulation are a key to sapropel formation. Increased Nile discharge has been considered to be a main source of fresh water. However, recent studies on the sapropel S1 (ca 11-6 kyr cal.B.P.) revealed the importance of glacial termination conditions as well as the influence of the Atlantic inflow and water exchange between western and eastern basins as factors modulating freshwater budget in the EMS. In this presentation, we combine multi-proxy results obtained for two cores collected in the Levantine Sea and the Strait of Sicily at 1,780 m and 771 m water depth to further examine the circulation variability for the last 23 kyr. Authigenic Nd isotopic composition, benthic foraminiferal stable isotopes and redox sensitive elements are used as tracers of bottom water mass and oxygenation whereas planktonic foraminiferal stable isotopes and detrital elements are treated as indicators of hydroclimate changes (Tachikawa et al., 2015; Cornuault et al., 2016, 2018). Our main findings are a reduced ventilation and strong stratification in the Levantine Sea that started during the last deglaciation and modification of water masses and/or circulation pattern in the Levantine Sea and the Strait of Sicily from the last glacial maximum to mid-Holocene relative to the present-state. Comparison with available Nd isotopic data suggests that water mass exchange was markedly reduced and limited to surface layer between the western and eastern basins during S1 formation.

CLIMATIC EVOLUTION OF THE LAST 2700 YEARS IN THE BALEARIC SECTOR: INTEGRATED STUDY OF CAVE AND MARINE RECORDS

M Cisneros (1), I Cacho (1), J Frigola (1), M Canals (1), A Moreno (5), H Stoll (3), A Sanchez-Vidal (1), H Cheng (4), RL Edwards (4), JJ Fornós (2)

1) Universitat de Barcelona, Barcelona, Spain
2) Universitat de les Illes Balears, Mallorca, Spain
3) Universidad de Oviedo, Oviedo, Spain
4) University of MInnesota, MInneapolis, USA
5) Dept. de Processos Geoambientals i Cambio Global, Saragozza, Spagna

mercecisnerosb@gmail.com

Taking the advantage of the high sensibility of the centrl-western Mediterranean region to climate variability, here we present atmospheric and surface-deep ocean reconstruction for the last 2.7 kyr. Atmospheric conditions are evaluated in base to five speleothem records from two Mallorca-Caves. Ocean-conditions are recosntructed from sediment multicores recovered in the North Minorca drift. In addition, instrumental measurements of deep-sea currents from two moorings lines are also used to validate our proxy of past deep water current intensity related to the Western Mediterranean Deep Water (WMDW) formation. Stable isotopes and trace elements records in U-Th dated spelothems are used to interpret hydrological fluctuations on land. Sea surface temperatures are derived from Mg/Ca-ratios analysed on planktonic foraminifera Globigerina bulloides (Cisneros et al., 2016) and deep-current intensity-changes are evaluated by means of grain-size analysis (UP10-fraction). Both surface and deep marine reconstructions are based on stacked curves from several individual records. The strongest WMDW flow occurred during periods rather warm as Roman Period (RP) and the early Little Ice Age (LIA). The speleothem records indicate a change from wetter to drier conditions during the RP and a similar pattern for the Dark Middle Ages (DMA). In addition, a hiatus during most of the Medieval Climate Anomaly (MCA) and early LIA suggests these as the driest periods in the region. During the second half of the LIA it is observed a return to wetter conditions. The results indicate an intense WMDW foramtion occurred mostly related to drier periods in Balears but with some exceptions in the early RP and late DMA. Overall, these data suggest a complexity in the WMDW-convection triggers. When our data is compared with other oceanographical ana climatic reconstructions, a general change in the pattern relationships before and after the DMA appears. In particular, overturning cells in the eastern and western Mediterranean sea seem to be decoupled after the DMA, supporting the western-eastern Mediterranean seesaw previously proposede for hydrological conditions for this period (Roberts et al., 2012). This change in the oceanographic-climatic behaviour during the DMA is proposed to respond to a distinct combination of different climate modes such as the East Atlantic/West Russian patterns and the North Atlantic Oscillation.

HIGH RESOLUTION STUDY IN ALBORAN SEA (ODP 977) DURING THE MIS 11: A MID- BRUNHES EVENT INTERPRETATION PERSPECTIVE BASED ON COCCOLITHOPHORES.

A González-Lanchas (1), JA Flores (1), FJ Sierro (1), JO Grimalt (2)

1) Departament of Geology, Salamanca, Spain
2) I. of Environmental Assessment and Water Research, Barcelona, Spain

lanchas@usal.es

A submillennial study based on variability in the coccolithophore assemblage is carried out in order to improve the understanding dynamics in the surface waters as well as changes in paleoproductivity in the Alboran Sea during Marine Isotope Stage (MIS) 11, along the Mid-Brunhes event interval in the Atlantic – Mediterranean exchange area. The age-model is based on calcareous nannofossil biostratigraphy and planktonic foraminifera δ18O records, showing an orbital with a suborbital cyclicity overimposed. During the MIS 11, coccolithophore assemblage was widely dominated by the Gephyrocapsa group, with a high representation of "Gephyrocapsa caribbeanica" and small Gephyrocapsa (<3□m). Primary productivity proxies, such as total number of coccoliths and nannofossil accumulation rates (NAR), reveals a constant and intense high productivity conditions. Abrupt events (interstadial-type oscillations) reveals interesting changes in surface water conditions in the area. Characterization of this short-lived climatic events from a multiproxy approach and its relations with oceanographic dynamics variability arises as one of the main scopes of future work. Another outstanding issue of this preliminary study is the identification of several morphotypes of Gephyrocapsa ("G. caribbeanica", G. oceanica and G. muellerae) with variable calcification features, analyzed by the use of image analysis techniques (C-Calcita). We hypothesized about the relationship of these changes and oceanic processes occurred during the Mid-Brunhes at local and global level.

WESTERN-EASTERN MEDITERRANEAN FRESHENING DURING TERMINATION V

LA Azibeiro (1), FJ Sierro (1), L Capotondi (2), F Lirer (3), A Cortina (4), JO Grimalt (4), B Martrat (4), I Cacho (5), JA Flores (1), M Canals (5)

1) Department of Geology, University of Salamanca, Salamanca, Spain
2) CNR, Instituto Scienze Marine (ISMAR), Bologna, Italy
3) CNR, Instituto per l'Ambiente Marino Castiero, Napoli, Italy
4) Department of Environmental Chemistry, Barcelona, Spain
5) Geociències Marines, Universitat de Barcelona, Barcelona, Spain

luciaaa@usal.es

Termination V marks the transition from MIS 12, characterized by wide continental ice sheets in the northern Hemisphere and a prominent global sea level minimum, to MIS 11 a long interglacial stage with a sea-level highstand. In order to understand how that climate shift affected the surface Mediterranean waters, this study has compared two sites from western, ODP site 977, and eastern Mediterranean, KC01(B), through quantitative planktonic foraminifera analyses and stable isotopes. Planktonic oxygen isotopic composition measured in Globigerina bulloides and Neogloboquadrina pachyderma were corrected according to the average annual sea surface temperature (SST) obtained by Artificial Neural Networks (ANN) and the ice volume changes to obtain the sea water oxygen isotopic composition (d18Osw) relative to current values. Lower values than expected were found in d18Osw for MIS 12 at both sites, with a decreasing trend in the whole stage, but was especially significant during four episodes related with polar species increases – N. pachyderma (sinistral) and Turborotalita quinqueloba – and low temperatures. This evidences a high freshwater influence in the Mediterranean during TV and the straight coupling of both isotopic curves suggest a common freshwater source probably originated in the north Atlantic. However, the offsets observed between the western and eastern basins at certain times, point to possible different sources for this freshwater. The d18Osw decrease is reversed during the sharp warming at the onset of MIS 11 to reach values similar to current ones Surface temperatures and d18Osw millennial variability in western and eastern Mediterranean can clarify the timing, origins and dynamics of the fresh water entrance during glacial Termination.

COMPARING THE SIMULATED MEDITERRANEAN CLIMATE IN DIFFERENT CONDITIONS: LAST GLACIAL MAXIMUM, MID-HOLOCENE AND THE RCP8.5 PROJECTION AT THE END OF THE 21ST CENTURY

P Lionello (1,2), R D'Agostino (3)

1) Univ.of Salento, Lecce, Italy
2) CMCC, Lecce, Italy
3) Max Planck Institute for Meteorology, Hamburg, Germany

piero.lionello@unisalento.it

CMIP5 and PMIP3 global climate simulations allow to analyze a large set of climate conditions reproducing the last glacial maximum (LGM), the Mid-Holocene (MidH), the pre-industrial period (PIC, Control) , the historical (HIST) and a high emission Representative Concentration Pathway(RCP8.5). The comparison between the two most distant climate conditions (LGM and RCP8.5) shows contrasting changes of precipitation with respect to temperature. Temperature increases from LGM to PIC and from PIC to RCP8.5 (in both cases changes are about 4K), while precipitation during PIC is larger than during both LGM and RCP8.5 (about 30 and 90 mm more annual totals, respectively). Evaporation behaves differently with respect to precipitation: it is lower during LGM than during PIC, and larger during RCP8.5 than PIC. As a result, the decreased evaporation in the LGM overcompensates for the decreased precipitation, so that LGM is appreciably wetter then PIC. On the contrary, both increased evaporation and reduced precipitation lead to much drier conditions in RCP8.5 and larger water deficit of the Mediterranean basin with respect to PIC. These changes are supported by an increased atmospheric stability during RCP8.5 and a geopotential height trough extending over the Mediterranean during LGM. Model simulations in the MidH show small changes with respect to PIC for mean annual temperature and total precipitation. This is because contrasting changes along the annual cycle of MidH compensate each other: the MidH summer is warmer than PIC, while the rest of the year is mildly colder; the MidH spring is wetter, while the rest of the year is slightly drier than PIC.

CALCAREOUS NANNOFOSSILS STUDY REVEALS NEW PALEOENVIRONMENTAL AND BIOSTRATIGRAPHIC INSIGHTS AT AND PRIOR THE ONSET OF THE MESSINIAN SALINITY CRISIS IN THE SORBAS BASIN

AM Mancini (1), F Lozar (1), R Gennari (1), DJ Stolwijk (1)

1) UNITO, Turin, Italy

almancin@unito.it

Since the evaporites were discovered on the Mediterranean floor, an intense debate has arisen about the most appropriate scenario for the onset of their deposition, occurred at about 5.97 Ma. The Sorbas basin (SE Spain) records a continuous and complete succession of events characterizing the Messinian salinity crisis (MSC). We focus on the astronomically tuned pre-evaporitic Upper Abad Mb. (UA) and the lowermost Primary lower gypsum deposits (PLG). The UA deposits are characterized by a well-defined precession-driven lithological cyclicity, commonly made up of quadripartite cycles (sapropel - marl - diatomite - marl). The PLG unit represents the evaporitic phase and is composed of shales - gypsum cycles. Samples were collected in the Perales section (cycles UA23 to UA34) and in the shales of the lowermost 4 PLG cycles. Calcareous nannofossils (CN) relative abundance is calculated in order to obtain information about the environmental condition leading to the gypsum deposition, usually interpreted as change (increase) in salinity. These data could also help clarifying the disappearance of calcifying plankton reported in many sections across the basin. Preliminary results shows that the CN are present throughout the studied interval, except in PLG1 and PLG2 shales. A peak in abundance of Sphenolithus abies, followed or accompanied by a peak of Helicosphaera carteri, Umbilicosphaera rotula and Rhabdosphaera procera has been identified in an interval approximating the MSC onset. The identification in the western Mediterranean of this peculiar succession of CN paleobioevents, previously reported in Italy (Sicily, Emilia Romagna and Piedmont) and Greece (Cyprus) (Lozar et al., 2018 and references therein), strongly suggests that at approximately the time of the MSC onset, a strong increase in fresh water input and stratification of the water column affected the Mediterranean at basin-wide scale. This, at least in the Sorbas basin, culminates in the alternate deposition of shale – gypsum cycles. By contrast, in the shales of PLG3 and PLG4 cycles the CN assemblage reflects almost normal marine condition with high productivity in the water column, testified by the quasi monospecific assemblage made by Reticulofenestra spp and Coccolithus pelagicus. Summarizing, we report the first continuous CN record at the time and before the MSC in the Sorbas basin. The finding of the CN paleobioevent in the West Mediterranean strongly suggests that the evaporitic stage was triggered by the same changes in all the Mediterranean basin, that points to an high fresh water input and stratification of the water column events. Lozar, F., Violanti, D., Bernardi, E., Dela Pierre, F. & Natalicchio, M., 2002. Identifying the onset of the Messinian salinity crisis: a reassessment of the biochronostratigraphic tools (Piedmont Basin, NW Italy). Newsletters on Stratigraphy 51/1, 11-3

COUPLING PLANKTON-SEDIMENT TRAP-SURFACE SEDIMENT AND THE FOSSIL RECORD FOR THE DETECTION OF EMT-LIKE EVENTS: A CASE STUDY FROM THE NORTH AEGEAN SEA (NE MEDITERRANEAN)

E Skampa (1), MV Triantaphyllou (1), M Dimiza (1), A Gogou (2), E Xoplaki (3), J Luterbacher (3), E Malinverno (4), M Fatourou (1), C Parinos (2), S Stavrakakis (2), K-H Baumann (5)

1) National and Kapodistrian University of Athens, Athens, Greece
2) Hellenic Centre for Marine Research, Anavyssos, Greece
3) Justus-Liebig-University Giessen, Giessen, Germany
4) University of Milano-Bicocca, Milano, Italy
5) University of Bremen, Bremen, Germany

skampaelisavet@gmail.com

Quantitative coccolithophore analyses were performed on data from plankton samples (0–100 m water depth), the sinking particulate matter collected by a sediment trap time series (2011–2015) and the surface sediment of the North Aegean Sea (Athos basin, NE Mediterranean) M2 sampling site, in order to achieve a better understanding of potential modifications between the plankton vs. the exported through the water column coccolithophore assemblage and the one accumulated in the underlying sediment. Sediment trap coccolithophore multiannual mean fluxes (20 x108 coccoliths m2 day-1) documented similar values to the accumulation rates recorded in the surface sediment (23.6 x108 coccoliths m-2day-1). The dominant species in all three sampling types was Emiliania huxleyi reaching in some cases striking abundances (85–90%). Notably, F. profunda was not included in the plankton assemblage but in those of the sediment traps and the surface sediments, yet is presumed to flourish in nutrient-enriched layers below the sampled 100 m water column depth. Several fragile Syracosphaeraceae and holococcolithophore species and the delicate Algirosphaera robusta were found to have been gone while sinking through the water column down to the sea floor; however the main features of the living assemblages were generally preserved. Morphometric analyses on E. huxleyi coccoliths document the presence of a lightly calcified morphotype in plankton (increased frequency of low relative tube width values) and sediment trap samples (bimodal relative tube width pattern), indicating enhanced Black Sea Water inflows during May 2011, February 2015 and October 2015. However, such signal is not preserved in the surface sediment assemblage, presumable due to processes of secondary calcite overgrowth. The recorded high abundances of E. huxleyi were in accordance with positive North Atlantic Oscillation (NAO) shifts during recent production of dense waters in the North Aegean. The recent past (last 500 years) coccolithophore assemblage revealed a periodic change in the dominance of E. huxleyi (>60%), indicating strong water column convection at 1980–present, 1900–1950, 1760–1840 and 1620–1680 years AD, coupled with NAO positive shifts, Dalton solar minimum and volcanic activity. Stratified water column was detected when flourishing of F. profunda, possibly related to enhanced BSW influx. Climatic model data provided from the Coupled Model Intercomparison Project (CMIP5) simulations on annual and seasonal resolution were coupled with the E. huxleyi abundance changes in relation to the δ 18OG.ruber isotopic signal and the alkenone Sea Surface Temperature record in order to sufficiently evaluate past EMT-like events in the North Aegean Sea.

HISTORICAL AND PALEO-HYDROLOGICAL CHANGES RECORDED FROM MOROCCAN MIDDLE ATLAS LAKES INFERRED FROM SEDIMENTOLOGICAL AND GEOCHEMICAL APPROACHES

L Vidal (1), G Jouve (1), H Idabdellah (1,2), R Adallal (1,2), K Tachikawa (1), C Sonzogni (1), A Benkaddour (2), A Rhoujjati (2)

1) Aix Marseille University/CEREGE, Aix en Provence, France
2) Univ Cadi Ayyad/Géoressources, Marrakech, Morocco

vidal@cerege.fr

The Moroccan Middle-Atlas is considered as the "Moroccan water tower" and contains several natural lake systems of tectono-karstic origin functioning as "pluviometer". This region suffers from scarcity of observational hydrological data required for a coherent management of water resources. In this context, the precise study of the lacustrine sedimentary infill can provide some key information about past hydrological changes. The first study was conducted on well-dated sedimentary deposits of Lake Azigza (32°58'N, 5°26'W, 1550 m a.s.l.) by combining geochemical and mineralogical measurements coupled with microfacies characterization. The detrital component derived from XRF scanning and the microstructures observations of the lake sediments provided proxies of runoff activity and lake-level changes, respectively. These proxies were calibrated with regional hydro-climatic and instrumental measurements available over the last 50 years and used to reconstruct past hydrological changes on inter-annual to decadal time-scales between 1879 and 2013. During this period, lake level and runoff proxies responded to hydro-climate conditions. Following periods of drastic lake-level drop, the runoff proxy is more sensitive to variable precipitation regime. We also present a study on a 3 m sequence cored at Flower Lake (32° 59' 04''N, 5° 27' 13'' W, 1554 m asl) a small pond close to lake Azigza. High-resolution geochemistry (XRF) records and sedimentological and isotope analysis of this sequence are supported by five coherent and calibrated radiocarbon dates covering the last ~6 cal kyrs BP. Before 2500 yrs BP, low Ca contents coincided with an important detrital input characterized by high Si, K, Ti and Fe values. This could be related to more humid conditions with higher erosion of the surrounding landscape. The relative high Ca and Sr contents during the last 2500 yrs BP can be connected to drier conditions when carbonate precipitation occurs in shallow waters due to higher evaporation and photosynthetic activity of charophytes algae and other aquatic plants. These results emphasize the potential of these hydro-climate-sensitive systems and their sedimentary archives to assess the impact of climate change on the southern Mediterranean water cycle.

FLOOD EVENTS IN TRANSYLVANIA DURING THE MEDIEVAL WARM PERIOD AND THE LITTLE ICE AGE

I Persoiu (1), A Persoiu (1)

1) Emil Racovita Institute of Speleology, Cluj Napoca, Romania

aurel.persoiu@gmail.com

Over the past decade, Central and SE Europe experienced an increase in the frequency and magnitude of floods. In order to better understand the flood generating climatic conditions, we present here an 1100 years record of flood events in Transylvania (Romania) and their relationship with past climatic conditions. The study is based on documentary evidence and sedimentary records along one of the main rivers draining this area (Someșul Mic river). Two periods of increased flooding activity occurred in Transylvania, one at beginning of the 10th century, most likely as a result of generally wet conditions, and a second one, at the end of the 16th and beginning of 17th century, when a southward displacement of the westerlies storm-track lead to enhanced zonal moisture transport from the Atlantic Ocean. Between 1500 and 1899, the documentary evidence indicate a maximum incidence of floods during the 17th and 19th centuries, likely as flash-floods during heavy summer thunderstorms.

A 300 YEARS OLD HIGH RESOLUTION PALAEOENVIRONMENTAL RECORD FROM THE GULF OF ELEFSIS, ATTICA, SOUTH GREECE

A Papaioannou (1,2), K Kouli (1), C Parinos (2), M Dimiza (1), M Triantaphyllou (1), M Dasenakis (1), K Miaritis (1), A Gogou (2)

1) National and Kapodistrian University of Athens, Athens, GREECE
2) HCMR, Institute of Oceanography, Anavyssos, GREECE

agogou@hcmr.gr

In this study we present the first high resolution palaeoenvironmental record of the last 300 years from the area of Attica,South Greece. Despite the increasing number of marine palaeoenvironmental archives from Greece during the last decades, the veryrecent environmental changes and the imprint of human activity in such records are still poorly understood. Located in the northernSaronikos Gulf but with restricted communication -through two shallow straits-, the Elefsis bay is an extremely sensitive archive forthe study of both marine and terrestrial environmental variability. The multicore WFS2 was retrieved by the R/V AEGAEO (HCMR)from the deepest part of the Elefsis Bay. The 52-cm long core was sampled continuously at a sampling step of 0.5 cm. Age control isbased in combining 210Pb and accelerator mass spectrometry (AMS) 14 C dates. The sequence is a continuous, high resolutionpalaeoenvironmental archive of the last 300 years with its base dating back to 1660 AD (± 90).Based on the study of alkenone paleothermometry and a plethora of geochemical, micropaleontological and pollen proxy-indices obtained from the marine multi-core WFS2, we provide insights into the prevailing environmental and climatic dynamics inthis region (i.e. variability of temperature, salinity, humidity vs aridity patterns) as also as the development of the human-inducedanthropogenic signal (i.e. fossil fuel hydrocarbons and their combustion-derived compounds) throughout the Industrial RevolutionEra. Alkenone-derived SSTs at Elefsis Bay drop by more than 1 o C from the end of the 17 th to the beginning of the 18 th century. Thiscooling is probably synchronous to one of the coldest intervals (AD 1645–1715) of the 'Little Ice Age' (LIA), characterized by aprolonged episode of high volcanic and low solar activity known as 'Maunder minimum' (MM). After that and throughout the 18thcentury, SSTs stabilize at a mean of 23.8 o C until the first decades of the 19 th century when they drop again (1-2 o C). The latter SSTdrop pinpoints to a marked event (or a combination of events) which occurred at the first half of the 19th century and have thereafteraffected T and probably other physicochemical characteristics of the study area. During the 20 th century SST averages 22.4 o C andexhibits fluctuations which could be related to the prevailing atmospheric and oceanographic variability patterns.During the 2 nd half of the 19 th century, a significant population rise and the related urban activities in the Athens metropolitanarea, resulted to enhanced terrestrial inputs - as witnessed by rise in the abundance of all terrestrial markers - marking the entranceto the Industrial Era. During the same interval, the increasing trend in the abundance of all marine markers reflects higher productivityfrom algal species linked to enhanced continental inputs and thus increased nutrient supply to this coastal environment.Pollen assemblages record the existence of a diverse Mediterranean plant landscape with prominent signs of the humanactivities. Evergreen Quercus, accompanied by Pistacia and Phillyrea, are the most conspicuous taxa featuring the occurrence ofMediterranean macchia. Thermophilous deciduous oaks woodlands compose a noteworthy part of the vegetation, especially at thelower part of our record, while they start to retreat since the 19 th century. Olea is a major component of the vegetation throughout theentire record, demonstrating the landscape exploitation choices. Olive cultivation is intensified after the first quarter of the 18 th centuryand seems to be one of the major human activities in the area. Since the last quarter of the 19 th century and until the mid- 20 th centurya gradual retreat of Pinus is recorded, probably associated with the start of the Industrial Period in Greece and the increasedrequirement for fuel like firewood.

PAST MILLENNIUM MEDITERRANEAN CLIMATE FROM VERMETID SST PROXIES AND CMIP5 MODELS

Y Amitai (1), R Yam (1), P Montagna (2), A Shemesh (1)

1) Weizmann Institute of Science, Rehovot, Israel
2) Marine science institute (ISMAR), Bologna, Italy

yael.amitai@mail.huji.ac.il

Reef builders vermetid skeletons provide a high resolution reconstruction of the last millennium Mediterranean climate. Vermetid cores obtained from the west, central and east Mediterranean reveals that the different parts of the Sea surface have different thermal behaviors throughout the last millennium. The Sea Surface Temperature (SST), extracted from oxygen isotope measurements, show a signal of the Little Ice Age and of the Medieval Warm Period that is more apparent in the west and central Mediterranean while almost absent in the eastern Mediterranean. The rate of warming in the recent Industrial Period (1800 until present day) is also different according to the SST proxies. In the eastern Mediterranean the rate of warming is 0.54°C/100y, and it is more moderate in the western (0.46°C/100y) and central (0.35°C/100y) Mediterranean. By analyzing atmosphere-ocean coupled models from the CMIP5 project, that simulate the global climate of the past 1000 years, we aim to reconcile these behaviors with the variability of the North Atlantic Oscillation (NAO) and of the South Asia Monsoon (SAM) climate systems. We show a favorable impact of the NAO on the western and central Mediterranean and a favorable impact of the SAM on the eastern Mediterranean. This might explain the different in the observed SST signals during the last millennium.

SESSION 3

Assessment of climate change in the Mediterranean region and climate projections

INFERRING INFORMATION ON FUTURE CHANGES IN REGIONAL PRECIPITATION EXTREMES BY MEANS OF DYNAMICAL AND STATISTICAL MODELING

D Maraun (Invited) (1)

1) University of Graz Wegener Center for Climate and Global Change Graz Austria

douglas.maraun@uni-graz.at

Climate projections of with a very high spatial and temporal resolution are often demanded for assessing the impacts of extreme precipitation in a potential future climate. Yet classical scenario-based approaches of providing such information are still suffering from severe limitations: standard global general circulation models (GCMs) do not realistically simulate the dynamical large-scale fields controlling local-scale precipitation extremes, and operational dynamical regional climate models (RCMs) do neither resolve small-scale convective events nor local complex topography. Often bias correction is applied as a statistical post-processing step to close the gap between model output and user needs. Here we show that bias correction is not capable of mitigating the fundamental GCM and RCM errors mentioned above. Recently, storyline approaches of single events have been suggested as an alternative to provide user-relevant information. The idea is to simulate individual events that occurred in reality under potential future thermodynamic conditions. The focus on single real world events helps to avoid circulation errors, and enables one to conduct very high resolution simulations. Bias correction can be used as add-on to remove residual intensity biases. Dedicated sensitivity studies can also be used to isolate driving processes and to assess added value. Overall, such simulations have the potential to substantially increase the credibility of regional climate change information about extreme precipitation events.

COLLECTIVE STATISTICAL SIGNIFICANCE AND ITS RELEVANCE FOR CLIMATE CHANGE DETECTION IN THE MEDITERRANEAN

R Huth (1,2,3), M Dubrovsky (2,3)

1) Charles University, Faculty of Science, Praha, Czechia
2) Institute of Atmospheric Physics, Praha, Czechia
3) Global Change Research Institute, Brno, Czechia

huth@ufa.cas.cz

Detection of trends in climate elements and assessment of whether they are statistically significant are among the most important tasks in current climatology. The vast majority of studies only assesses the significance of trends at individual stations or grid points, that is, on a local level, providing no information on whether the occurrence of significant local trends is significant as a whole, that is, on a regional scale. To fill this gap and provide a guidance on how to evaluate the regional-scale significance of trends, we compare five methods of assessing the collective (global, field) significance of local trends: (i) counts of trends of one sign regardless of their local (in)significance; (ii) counts of locally significant trends; (iii) multi-site Kendall test extended to compensate for spatial autocorrelation; (iv) Walker test, based on the smallest p-value (highest significance) of all local tests; (v) false detection rate, which can be considered a generalization of Walker test. The evaluation is based on synthetic data, consisting of 10,000 realizations of time series on a regular rectangular grid with a given spatial and temporal autocorrelation and magnitude of trend, assuming first-order autoregressive process both in time and space. The data are generated by software tool SPAGETTA (SPAtial GEneraTor for Trend Analysis). Time series with no trend are used to create null distributions of test statistics and determine the critical values of the tests. Type II errors, that is, the probability of accepting the null hypothesis of no trend when it is false, are assessed using time series with non-zero trends. We set the type II error of 5% as the limit of detectability of trends, and calculate the magnitude of a trend that can be detected with such an error for a wide range of spatial and temporal autocorrelations, grid sizes, and lengths of the series. The performance of tests is better (that is, trends of smaller magnitude are detected with type II error of 5%) for longer time series, larger grids, and lower autocorrelations. The multi-site Kendall and sign-counting trends perform best; the gap in the performance between them and the Walker and fdr tests gets narrower with increasing autocorrelations. The sign-counting test is, however, not applicable to cases with very high spatial autocorrelations because of its discrete nature. The tests are applied to the detection of annual and seasonal temperature trends over the Meditarranean and adjacent parts of Europe, Africa, and North Atlantic, for various reanalyses and gridded datasets. The different performance of the tests is explained by different aspects of trends that they look at and by a different sensitivity to breaking their assumptions.

REGIONAL ASSESSMENTS OF HEAVY RAINFALL EVENTS IN THE MEDITERRANEAN AREA FOR THE 21ST CENTURY

C Merkenschlager (1), E Hertig (1), J Jacobeit (1)

1) University of Augsburg, Augsburg, Germany

christian.merkenschlager@geo.uni-augsburg.de

Since the Mediterranean area is a highly vulnerable region with respect to droughts and heavy precipitation, reliable assessments of the future development of precipitation behavior are of utmost importance. A novel statistical downscaling approach was developed to assess future regional precipitation extremes. The approach allows for non-stationarities in the predictors-precipitation relationships for assessing future precipitation extremes. It is based on 31 year contiguous calibration periods each shifted by one year. Consequently, a statistical model ensemble becomes available, with the number of established regression models corresponding to the number of years within the entire time series. By means of the regression model ensemble, first, the range of estimations for a stationary model setup was assessed. Subsequently, a selection process was performed in order to find the most suitable model for assessing future precipitation extremes under non-stationary conditions. Results show that the estimated quantiles of heavy precipitation (90th, 95th, 99th quantiles) of the non-stationary approach are within the range of estimations of the stationary regression model ensemble but sometimes, with respect to the historical GCM runs, absolute and relative changes outperform or undercut the estimations of the stationary approach. Although the direction of both approaches do not differ, differences appear with respect to the amount of change. For example under the RCP8.5 scenario the direction of change of the 90th quantile in autumn at Safed weather station (Israel) is rather the same but decreases are over 10% lower for the non-stationary approach than under consideration of a stationary model setup. Overall, the progression of the analyzed quantiles during the course of the 21st century strongly depends on season and region within the Mediterranean area. In autumn, with the exception of the eastern coast of the Iberian Peninsula, all regions show partly significant decreases of heavy precipitation until the end of the 21st century. In winter, especially the northern parts of the central Mediterranean area exhibit significant increases and smaller increases could be observed for northern Spain. Strongest decreases could be observed for the Levante region in spring, a region where decreases are projected throughout the year.

RAINFALL ESTIMATION OVER NORTHERN TUNISIA BY COMBINING MSG CLOUD TOP TEMPERATURE AND TRMM-TMI RAIN RATES

S Dhib (1), CM Mannaerts (2), Z Bargaoui (1), BHP Maathuis (2), P Budde (2)

1) Université de Tunis El Manar, ENIT, Tunis, Tunisia
2) University of Twente, ITC, Enschede, Netherlands

dhib_saoussen@hotmail.fr

In this study, a new method to delineate rain areas in northern Tunisia is presented. The proposed approach is based on blending geostationary Meteosat Second Generation (MSG) infrared channel (IR) with the passive Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI). The correlation coefficient of these two variables has a negative tendency, meaning that with decreasing temperature there is an increase in rainfall intensity. To blend this two products, we adopt two main steps. Firstly, we identify the rainy pixels based on a classification using MSG channel IR 10.8 and the water vapor WV 0.62. A threshold on the temperature difference of 11 K is adapted to identify the clouds that have a high likelihood of precipitation. The second step consists of fitting a statistical relation between IR cloud top temperatures with the TMI rain rates. The fitted equation is then applied to the MSG 15 minutes interval images of the whole day. To evaluate this combined product, we analyze a sample of daily extreme rainfall occurred during the period 2007-2009 in Northern Tunisia. A threshold is assumed for large rainfall depths (50 mm/day). The date is selected if at least one rainfall station of the studied network has a rainfall greater than the threshold. Inverse distance interpolation method is applied to draw rainfall maps for the drier summer season (from May to October) and the wet winter season (from November to April). The results were found very encouraging where all the events are detected rainy and the correlation coefficients between observed and calculated maps are much better than those obtained for MSGMPE and PERSIANN products. Moreover, during the wet season.

RECENT UPDATES OF LMDZ/NEMO-MED8 AND ITS APPLICATION IN AN ENSEMBLE OF CLIMATE CHANGE SIMULATIONS FOR THE MEDITERRANEAN REGION

L Li (1)

1) LMD, CNRS, Sorbonne Université, Paris, France

laurent.li@lmd.jussieu.fr

LMDZ/NEMO-med8 is a regional ocean-atmosphere coupled model for climate simulations in the Mediterranean basin. Its atmospheric component is a variable-grid global atmospheric general circulation model, with zoom over the Mediterranean to reach a regional resolution about 40 km. NEMO-med8 is the NEMO oceanic modelling platform configured for the Mediterranean Sea with a spatial resolution of 1/8 degree. Two operational modes are available for LMDZ to be used in regionally-oriented studies. The first one is to nest LMDZ into a global climate model by relaxing its physical variables toward the driving fields outside the zoom domain. This operational mode makes the coupled model similar to a traditional limited-area model. It is however a heavy procedure since it is not always easy to assemble high-frequency 3-dimentional driving fields. The second operational mode of LMDZ is to run it in an autonomous way, with monthly global SST and sea ice fields as the only inputs to use from a global climate model. This flexibility of LMDZ allows us to easily perform a large-size ensemble of simulations, which provides a convenient way to make estimation on dispersion of results and associated uncertainties. The present work will firstly compare the two operational modes for simulations realized with IPSL-CM5A, CNRM-CM5 and MPI-ESM. Secondly results obtained with 8 global models with the second operational mode will be detailed. There are 150 years of simulation for each of them covering 1951/2005 for the historical period and 2006/2100 following the RCP8.5 scenario. Prior to the presentation of results, recent updates of the regional ocean-atmosphere coupled system LMDZ/NEMO-med8 will be mentioned with an introduction of interactive rivers runoffs in the model. It is shown that the Mediterranean Sea general circulation is quite sensitive to the fresh water amount discharged into the sea.

THE INFLUENCE OF UNCERTAINTY IN THE NORTHERN HEMISPHERE STRATOSPHERIC POLAR VORTEX RESPONSE TO CLIMATE CHANGE ON FUTURE PROJECTIONS OF MEDITERRANEAN HYDROCLIMATE.

IR Simpson (1), P Hitchcock (2), R Seager (3), Y Wu (3), P Callaghan (1)

1) National Center for Atmospheric Research, Boulder, USA
2) Laboratoire de Meteorologie Dynamique, Palaiseau, France
3) Lamont-Doherty Earth Observatory, New York, USA

islas@ucar.edu

General circulation models display a wide range of future predicted changes in the Northern Hemisphere winter stratospheric polar vortex. Here analysis of the Coupled Model Intercomparison Project phase 5 (CMIP5) models will be combined with idealized experiments with the Community Earth System Model (CESM) to investigate the impact of this uncertainty in the stratospheric polar vortex response on future projected Mediterranean climate change. A regression analysis across the CMIP5 models reveals that with a relative weakening of the stratospheric polar vortex comes a relative drying over Northern Europe and wetting over the Mediterranean. Idealized CESM experiments in which stratospheric polar vortex responses on opposite ends of the CMIP5 range are artificially imposed through a nudging methodology confirm that the stratospheric influence inferred from the CMIP5 regression does indeed represent a true downward influence of the stratosphere on the troposphere below. While the stratospheric polar vortex influence represents a relatively small contribution to intermodel spread in future wintertime Mediterranean precipitation changes, the difference between models on opposite ends of the CMIP5 range in polar vortex responses can be substantial. The difference in wintertime Mediterranean precipitation changes between models with an extreme strengthening and those with an extreme weakening of the stratospheric vortex is of the order 0.25mm/day which is around 10% of the present day precipitation climatology in that region. Therefore, an improved understanding and narrowing of the uncertainty in the future of the stratospheric polar vortex may considerably improve projections of future wintertime hydroclimate in the Mediterranean.

PROJECTIONS OF MEDITERRANEAN HEAT AND SALT CONTENT EVOLUTION DURING THE XXI CENTURY BASED ON MEDCORDEX AORCMS AND A SIMPLE BOX-MODEL

D Gomis (1), J Soto-Navarro (1), G Jordà (1)

1) IMEDEA (Universitat de les Illes Balears - CSIC), Mallorca, Spain

damia.gomis@uib.cat

The evolution of the heat and salt contents of the Mediterranean Sea can differ significantly among different ocean regional climate models. A key source of discrepancies is the differences in the forcing, either through the air-sea interface or through the lateral boundaries (Strait of Gibraltar, Dardanelles Strait and rivers). However, an additional source of discrepancies is how each model redistributes the heat and salt that is introduced in the system through the boundaries. This determines both the regional differences in heat and salt content and the long term evolution of the Mediterranean, especially if the heat and salt are transferred to depths where the residence time is very long (i.e. below the sills of the Strait of Gibraltar or the Sicily Channel). In this presentation we will use outputs from the last generation of coupled atmosphere-ocean regional climate models (AORCMs) from the MedCORDEX initiative to characterize the main features of the heat and salt fluxes in the Mediterranean Sea and to project their evolution until 2100. The similarities and discrepancies in the heat and salt redistribution patterns of the different models will be described and tentative explanations based on differences in the forcings and/or model configurations will be developed. We also use the AORCMs results to set up and validate a simple box-model that accounts for the major features of the thermohaline circulation of the basin. The simplicity of the box model allows to easily check the major features of the long-term evolution of the basin under different forcings and different configurations for the heat and salt redistribution, as well as to assess the largest potential sources of uncertainty.

INCREASING IMPACTS OF EURO-ATLANTIC BLOCKINGS AND SUB-TROPICAL RIDGES IN THE MEDITERRANEAN AREA

PM Sousa (1), RM Trigo (1), D Barriopedro (2), AM Ramos (1)

1) Instituto Dom Luiz (IDL), FCUL, Lisboa, Portugal
2) Dept. Física de la Tierra II, U.Complutense, Madrid, Spain

ppsousa@fc.ul.pt

Atmospheric blocking episodes are an important component of the intra-seasonal and inter-annual variability at mid-latitudes. Their impacts in the European continent, and in particular, in the Mediterranean basin, depend on: i) blocking location; ii) spatial characteristics; iii) temporal length. A characterization of Euro-Atlantic blocking occurrence within different sectors (Atlantic, European and Russian) was performed, focusing on the impacts in temperature and precipitation regimes. High-latitude blocks were distinguished from sub-tropical ridges using a novel ridge detection scheme. Ridges do not require wave-breaking occurrence as blockings do, although they are frequent precursors of wave-breaking and subsequent high-latitude blocking episodes. The distinct seasonal and regional impacts associated with different blocking/ridge locations were analyzed, as well as the dynamical mechanisms driving the temperature and precipitation responses associated to each pattern, namely: the role of cyclonic activity; moisture transport; large-scale atmospheric instability; balances between horizontal advection, subsidence and radiation budgets. Our analysis clarifies that increasing extreme heat episodes in southern Europe and Mediterranean areas should not be attributed to blockings, but rather to sub-tropical ridges. In northern Europe, both regimes are responsible for warm conditions in summer, due to enhanced radiative heating and increased subsidence. Opposite temperature responses are found for winter blocking/ridges. While blockings reinforce cold northerly advection and foster cold spells, ridge patterns are related with mild Atlantic flows associated. An opposite north-south dipole is also found regarding precipitation anomalies. While blocks force a split of the Jetstream and storm-track, ridges are characterized by a stronger zonal flow at higher latitudes. Accordingly, negative (positive) precipitation anomalies during blocks occur at higher (lower) latitudes. We also demonstrate how enhanced atmospheric instability and cyclonic activity occurs south of blocking centers, highlighting the importance of torrential regimes in Mediterranean areas. On the other hand, the presence of sub-tropical ridge enhances a northward deflection of moisture corridors, leading to very dry conditions in southern Europe, and significantly increasing the chances of drought occurrence in Mediterranean areas. Finally, we discuss how sub-tropical ridge frequency has been increasing, in the context of a warming atmosphere and an expanding Hadley Cell, and how the expected further expansion of the tropics poses a severe threat for water availability in the Mediterranean area. This work was supported by project IMDROFLOOD – Improving Drought and Flood Early Warning, Forecasting and Mitigation using real-time hydroclimatic indicators (WaterJPI/0004/2014) funded by FCT. Alexandre M. Ramos was also supported by a FCT postdoctoral grant (FCT/DFRH/ SFRH/BPD/84328/2012).

EVALUATION OF MULTI-MODEL AND MULTI-DOMAIN ENSEMBLE SIMULATIONS BASED ON CORDEX INITIATIVE OVER TURKEY

S Kahraman (1), B Onol (1)

1) İstanbul Technical Uni., Meteorology Dept., İstanbul, Turkey

onolba@itu.edu.tr

The aim of this study is to define the future change of the mean temperature and precipitation over Turkey for period of 2025-2099 by using the ensemble of various regional climate simulations forced by RCP8.5 scenario. We have aggregated 64 temperature and 53 precipitation simulations from the project called the Coordinated Regional Climate Downscaling Experiment (CORDEX), since the overlapping area of five CORDEX domains (AFR, EUR, WAS, MED, MNA) covers the most of Turkey. We have calculated the precipitation and the temperature changes for the future by taking the advantage of the multi-model/multi-domain ensemble simulations. The period of 2025-2099 has been divided into 25-year periods to define the future change with respect to 1981-2005. The ensemble spread of annual mean temperature of Turkey is risen up to in the range of 13 to 17 °C by the end of the 21st century. The ensemble means of the temperature simulations indicate that the increase is more evident over the Eastern Turkey and temperature change varies between 0.8 and 7.2 °C. Seasonal temperature change signals in all 25-year periods are very strong in summer season. In terms of precipitation change, the water scarcity will escalate in 2075-2099 and the precipitation decrease over the Aegean and the Mediterranean region varies in the range of 20% to 30%. At the end of the century, the decrease of the ensemble precipitation mean reaches 20% for the entire Turkey which may cause inevitable impacts on every dimensions of social, economic and environmental life. Despite we managed the large amount of ensemble simulations, inequity for the ensemble size of each domain is still the main compelling factor to determine the uncertainty of the climate change scenario simulations.

COMBINED EFFECTS OF TEMPERATURE AND PRECIPITATION EXTREMES BASED ON CLIMATE EXTREMES INDEX OVER EUROPE

MB Kelebek (1), F Batıbeniz (1,2), B Onol (1)

1) ITU, Meteorological Engineering Department, Istanbul, Turkey
2) ORNL, Climate Change Science Institute, Oak Ridge, United States

kelebek15@itu.edu.tr

The Climate Extremes Index (CEI) is an implementation of five indicators those measure extremes in monthly maximum/minimum temperatures, drought or moisture surplus (Palmer Drought Severity Index), extremes in 1-day precipitation, and days with/without precipitation based on the thresholds. In this study, we have defined the extremes as the percentage of each indicator that existed above/below 90th/10th percentile of reference value which was calculated on the period of 1981-2010 and studied the CEI over the European countries for the years between 1979 and 2015 using gridded observational data sets. We applied calculations with E-OBS dataset for daily maximum and minimum temperature, Multi-Source Weighted-Ensemble Precipitation (MSWEP) dataset for daily precipitation and Climate Research Unit (CRU) data set for monthly self-calibrating Palmer Drought Severity Index (scPDSI). Results indicate that Northern Europe, Western Europe, and Central Europe have experienced extreme events in the range of 30%-35% for the long-term average. The climatological mean of CEI reaches up to 38% for Italy, Eastern Europe and Balkan countries and the maximum values calculated over southern parts of Europe, and the Mediterranean coasts exceeding 40%. Additionally, anomalies have been calculated to define the decadal variability. The decadal anomaly of 1979-1989 has negative biases over most of the countries of Europe. The recent decades (2000-2015) indicate that increased the CEI signal is detected and the extremes became more evident over the Mediterranean countries. During this period, the CEI exceeds 42% for these countries. Trend analyses reveal that the decadal increase reaches up to 4% over Turkey, Italy, the Balkan countries, some part of North Africa. The results of this study strengthen previous researches related to the recent shifts of the temperature and precipitation extremes caused by the human-induced climate change over the EURO-MED domain which is already determined as a major climate hot-spot region.

FUTURE EVOLUTION OF THE WESTERN MEDITERRANEAN DEEP WATER FORMATION UNDER CLIMATE CHANGE: A COUPLED HIGH-RESOLUTION MULTI-MODEL APPROACH

S Somot (1), F Sevault (1)

1) CNRM, Université de Toulouse, Météo-France, CNRS, Toulouse, France

samuel.somot@gmail.com

The North-Western Mediterranean Sea is known as one of the place in the world where open-sea deep convection occurs with the formation of the Western Mediterranean Deep Water (WMDW). At the Winter scale, it is characterized by different phases (preconditioning, strong mixing, restratification and spreading), intense buoyancy loss and strong ocean meso-scale activity. On a longer time scale, it shows a large interannual variability and may be strongly affected by climate change with impacts on the regional ocean circulation, coastal climate and biogeochemistry. Therefore anticipating the future evolution of the WMDW formation remains today a first-class challenge. We try here to tackle this issue for the first time in a multi-model framework. We use the recently-available Med-CORDEX ensemble of coupled and high-resolution Regional Climate System Models (RCSM, Ruti et al. 2016, www.medcordex.eu). The RCSMs are run in a scenario mode driven by ocean and atmosphere lateral boundary conditions coming from CMIP5 GCMs over the period 1950-2100 and under various socio-economic scenario forcings (RCP8.5, RCP4.5, RCP2.6). Using this model ensemble, we characterize the future evolution of the WMDW formation (mixed layer depth, surface of the convective area, dense water volume, deep water hydrology), we assess the multi-model robustness of the signal and we try to disentangle the main drivers of this evolution.

"OBSERVED AND PROJECTED CHANGES IN THE DRY SPELLS" STATISTICS OVER CROATIA

I Marinovic (1), K Cindric (1), I Güttler (1), Z Pasaric (2)

1) Meteorological and Hydrological Service, Zagreb, Croatia
2) Geophysical Department, Faculty of Science, Zagreb, Croatia

ivana.marinovic@cirus.dhz.hr

Drought in Croatia causes the highest economic losses inflicting serious damages, especially in agricultural sector. Present study performs a systematic analysis of dry spells (DS) in Croatia. DS are defined as consecutive sequences of days having daily precipitation less than a given precipitation-per-day threshold. Here, a commonly used threshold in climate and agriculture practice, that of 5 mm is used. Daily precipitation data from a dense national rain-gauge network (forming seven climatological regions) and spanning the time period 1961–2015 are employed. The spatial and temporal characteristics of mean and maximum seasonal and annual DS are analyzed as well as recent changes in DS using the trend estimations by means of Kendall' tau method. Additional period 1971–2000 is defined. For this period both observation based DS and regional climate models' based DS analysis is performed. Regional climate model RegCM in the present study covers the EURO-CORDEX domain, and is forced at its boundaries by the four CMIP5 global climate models. RegCM applies 12.5-km horizontal resolution, resulting in a realistic orography and land-sea structures over Croatia. For the 1971–2000, RegCMs systematic errors in terms of the DS statistics will be examined. Finally, projections and future changes in the DS statistics will be based on the RegCM simulations under the high and medium greenhouse gases concentration scenarios (i.e., RCP8.5 and RCP4.5) with the focus on the climate change signal between 1971–2000 and two future periods, 2011–2040 and 2041–2070.

A MULTI-MODEL, MULTI-SCENARIO AND MULTI-DOMAIN ANALYSIS OF REGIONAL CLIMATE PROJECTIONS FOR THE MEDITERRANEAN

G Zittis (1), P Hadjinicolaou (1), J Lelieveld (1,2)

1) The Cyprus Institute, Nicosia, Cyprus
2) Max Planck Institute for Chemistry, Mainz, Germany

g.zittis@cyi.ac.cy

Several observation and model-based studies have already identified the Mediterranean region as one of the most prominent climate change hot-spots. However, in order to better assess and tackle the impacts of climate change on a regional or national level it is essential to employ updated, high resolution and quality climate projections. These should preferably cover a wide range of possible futures and consider several sources of uncertainty. The most significant effort in addressing these issues and coordinating regional climate projections throughout the globe is the CORDEX initiative (Coordinated Regional Downscaling Experiment) supported by the World Climate Research Programme (WCRP). Fortunately, the Mediterranean region is included in several CORDEX domains such as the European (EURO-CORDEX), African (CORDEX-AFRICA), Mediterranean (MED-CORDEX) and Middle East/North Africa (MENA-CORDEX). In this study, we aim in compiling monthly temperature and precipitation information derived from regional simulations performed over different CORDEX domains. This multi-model, multi-scenario and multi-domain "Super-Ensemble" is used in order to create updated maps of projected changes for the Mediterranean region and for key hydro-meteorological variables. The statistical robustness and significance of the climate change signal is assessed. We also explore how critical is the domain location in the simulation of temperature and precipitation, particularly over regions that are located near the domain boundaries and are covered by more than one domains.

DIFFERENTIAL 20TH AND 21ST CENTURY WARMING AROUND THE MEDITERRANEAN AND THE GREATER MIDDLE EAST

P Hadjinicolaou (1), G Zittis (1), J Lelieveld (1,2)

1) The Cyprus Institute, Nicosia, Cyprus
2) Max Planck Institute for Chemistry, Mainz, Germanry

p.hadjinicolaou@cyi.ac.cy

We apply the WRF model as a regional climate model (RCM) over the MENA-CORDEX domain to downscale, at a horizontal resolution of 50 km, from 1951 to 2100, meteorological fields from the NCAR's CESM1 global climate model (GCM) and under two Representative Concentration Pathway (RCP) future scenarios (RCP4.5 and RCP8.5). The RCM and GCM simulated temperature climatology and temporal evolution are first analysed for the recent past using the ERA-Interim re-analyses (and other) data. Fourteen sub-regions within the MENA domain (including the Mediterranean) are analysed. The derived observed trends from 1979 up to 2016 indicate geographically differential warming rates, with parts of the Middle East exhibiting more than 0.5 degrees per decade (partly captured by the model scenario runs). A distinctly large winter/spring warming trend is revealed over Iran. The projected temperature change from the two downscaling experiments (the RCP 4.5 and RCP8.5) is also analysed for future periods by deriving annual and seasonal averages for the defined areas around Mediterranean, the Middle Rast and North Africa, in order to explore future sub-regional hot-spots of warming within the basin. Several sub-regions at the northern and eastern parts of the MENA domain (from the Balkans to the Gulf) are exhibiting faster warming trends for 2001 to 2100 compared to the global mean from the CIMP5 ensembles. The 21st century warming rates projected by the RCM over the sub-regions are analysed, in comparison to the global average warming from the driving GCM, and the timing and magnitude of the regional and sub-regional temperature change for 1.5 and 2 degrees global warming are deduced.

PRESENT AND FUTURE CLIMATE AND VARIABILITY OF THE ADRIATIC DENSE WATER FORMATION AND THE BIOS: ASSESSMENT OF CLIMATE MODELS

N Dunic (1), I Vilibic (1), J Sepic (1), H Mihanovic (1), F Sevault (2), S Somot (2), R Waldman (2), T Arsouze (3,4), R Pennel (4), P Nabat (2)

1) Institute of Oceanography and Fisheries, Split, Hrvatska
2) CNRM-GAME (CNRS/Meteo-France), Toulouse, France
3) ENSTA-ParisTech, Palaiseau, France
4) IPSL/Laboratorie de Meteorogie Dynamique, Palaiseau, France

dunic@izor.hr

Dense water formation (DWF) occurring in the Adriatic Sea, the northernmost Mediterranean basin, represents an important driver for the Eastern Mediterranean thermohaline circulation. There are two DWF locations in the Adriatic: the deep convection site in the Southern Adriatic Pit and the shelf convection site in the northern Adriatic. DWF at both locations influences decadal Adriatic thermohaline regimes and the Adriatic-Ionian Bimodal Oscillating System (BiOS). Recent long-term analyses, based on observations, suggest a weakening of the Adriatic thermohaline circulation, which is likely to affect the Adriatic biogeochemical cycle and fisheries. Here, we describe the climate and variability of DWF and BiOS, using available regional climate models developed for the Mediterranean area. Present-day DWF and BiOS climatology was analyzed using outputs of seven NEMOMED models covering the period of 1980-2012, and differing in spatial resolution (horizontal and vertical), atmospheric and river forcing, and in coupling strategies. It is shown that fully coupled models have a better capacity to reproduce the thermohaline properties and processes. For that reason, future behavior of the Adriatic thermohaline circulation, the DWF and the BiOS was analyzed using outputs of fully coupled future runs covering three common scenarios (RCP2.6, RCP4.5 and RCP8.5). Preliminary results of these analysis are shown.

MULTIDECADAL VARIABILITY OF THE MEDITERRANEAN SEA LEVEL

M Orlic (1), M Pasaric (1), Z Pasaric (1)

1) University of Zagreb, Zagreb, Croatia

orlic@irb.hr

Sea level data collected from 1930 to 2015 in the Atlantic off Gibraltar and in the West Mediterranean and Adriatic Seas are analyzed. Time series of regional sea level are constructed and are subjected to several methods that aim to separate trends from multidecadal variability. The results point to a steady sea level rise in the Atlantic but also to a deceleration of the rise in the late 1950s and early 1960s and to an acceleration of the rise in the late 1980s and early 1990s in the Mediterranean Sea. This strongly suggests that the Mediterranean sea level was considerably influenced by multidecadal variability, which was characterized by a period of ca 60 years. The finding also suggests that not only the Atlantic sea levels but also the Mediterranean sea levels could be reasonably well approximated by linear trends over the 1960-1990 interval. It is shown that the trends thus obtained could mostly be ascribed to (1) the regional trends of the air pressure and wind forcing, (2) the regional trends of thermosteric and halosteric sea levels, and (3) the increase of mass of seawater that was similar in the whole area considered. In the Atlantic the three contributions resulted in a sea level rise similar to the global one between 1960 and 1990, whereas in the Mediterranean Sea the increase of mass of seawater was nearly compensated by the atmospheric loading and steric effects during the thirty-year interval. Finally, it is tested whether a variant of semi-empirical method, which allows for both inertial and equilibrium response of sea level to temperature forcing and which has been previously successfully applied to global data, could be used to analyze and project the Mediterranean sea levels. The underlying theory suggests that the method is applicable to regional sea levels if regional temperatures are linearly related to global temperatures and if regional response times are similar to global response times. The test shows that the method is successful at reproducing past sea levels and sea level trends in the Mediterranean Sea but not in the Atlantic off Gibraltar. Consequently, semi-empirical projections of sea levels and related trends are prepared for the former basin.

ASSESSMENT OF CLIMATE VARIABILITY AND TRENDS OVER SLOVENIA IN THE PERIOD 1961–2011

M Dolinar (1), G Vertačnik (2)

1) Slovenian Environment Agency, Ljubljana, Slovenija
2) Slovenian Environmen, Ljubljana, Slovenija

m.dolinar@gov.si

Assessment of existing climate variability and trends is essential for various environmental and climate impact studies and a basis for climate change scenarios preparation. Slovenian Environment Agency has an extensive archive of meteorological measurements which dates back to 1852, when the first instrumental measurements on the territory of Slovenia had been carried out. However, only meteorological data from 1961 onwards were systematically digitised. For a robust assessment of climate change high-quality climate data is needed. To obtain such data, several important steps should be taken from measurements to data analysis, including quality control and homogenisation. Until 2013 only incomplete attempts, missing intensive homogenisation and quality control procedures, have been made to get a high-quality climate series for Slovenia. To fill the gap, the Slovenian Environment Agency (ARSO) launched the Climate Variability in Slovenia (CVS) project in November of 2008. The aim of the project was to deliver a comprehensive analysis of climate change and variability in Slovenia since 1961. In the first step time series of daily temperature, precipitation, sunshine duration and air humidity data from Slovenian stations spanning 1961 to 2011 have been rechecked via an intensive quality control procedure. Suspicious values were flagged by computer software and then manually inspected by comparison with the data from the paper archive, data visualisation and automatic spatial comparison. In the same time station metadata was systematically collected from many different sources and digitised. Quality control and metadata revealed the general quality of measurements at each station. Stations with low quality time series were discarded from further procedure. In the second step high quality time series were subject to a homogenisation procedure which was performed by recently developed software package, HOMER (Mestre et al., 2013). Based on quality controlled and homogenized time series the variability and trends of 7 climate variables were analysed; Air temperature, precipitation, fresh snow depth, accumulated snow depth, sunshine duration, reference evapotranspiration and air pressure. The results are consistent with detected regional trends of climate variables (EEA, 2015). Temperature trend between 0.35 and 0.45 °C/ decade is significant all over the country. On the other hand, precipitation-wise, statisticaly significant decreasing trend is limited to the western part of Slovenia. A significant decrease both in fresh and accumulated snow depth however is detected across the whole country, the highest occuring in mid altitudes. There is an increasing trend in solar radiation, allocated mainly to spring and summer.

PROJECT OPS21: THE ASSESSMENT OF THE AVERAGE AND EXTREME METEOROLOGICAL AND HYDROLOGICAL CONDITIONS IN SLOVENIA OVER THE 21ST CENTURY

R Bertalanic (1)

1) Slovenian Environment Agency, Ljubljana, Slovenia

renato.bertalanic@gov.si

In April 2016 the Slovenian Environment Agency (ARSO) initiated a project for estimating average and extreme meteorological conditions over the 21st century. Successful climate change mitigation and adaptation require the knowledge of the change in climate in the future. Beside the average changes of meteorological conditions due to climate change, it is also very important to estimate the frequency, intensity and duration of extreme weather events due to their impact on environment and society. Additionally, the objective of the project was the estimation of the impact of climate change on agricultural and hydrological conditions. The assessment of the future climate and hydrological conditions is focused on three 30-year periods: near future 2011–40, mid-century 2041–2070 and end of the century 2071–2100. It is based on the error-corrected 0,11° regional models simulations of the EURO-CORDEX initiative. Three different greenhouse gas emissions scenarios were taken into account. From all simulations, 6 were chosen on the basis of a good agreement between historical runs and observed data and with different combination of global/regional climate models with a main objective to take into consideration as much future variability as possible. Temperature, precipitation and calculated reference evapotranspiration data were error corrected with a modified method of quantile mapping, which preserves consistency between temperature and precipitation and does not change original model trends of individual variable. Reference data were 1981–2010 observations, interpolated into a regional model grid with kriging. The assessment of the future change of different meteorological conditions and in change of frequency and duration of extremes was done for every model and every model cell independently. Statistical significance of changes in the future with regard to present time was done with t-test and Wilcoxon-Mann-Whitney test, while trends in intensity of extremes were estimated with nonstationary methods of extreme values analysis, the GEV method and with point process method. At the end, the results of 6-member ensemble were combined and uncertainty of projections was estimated in two ways, as a hypothesis testing for a change to happen and as a calculation of confidence intervals. By now, we've already analyzed changes in temperature and temperature related extremes, precipitation and precipitation related extremes, potential evapotranspiration and water deficit. Error corrected simulations of temperature, precipitation and potential evapotranspiration were used in hydrological model to assess impacts of climate change on surface water discharges and in water balance model to assess ground water recharge. They were also used in assessment of soil moisture changes, soil temperature changes and future frost risk.

1-KM CLIMATE PROJECTIONS FOR CATALONIA BASED ON STATISTICAL DOWNSCALING FROM CMIP5 MODELS

A Barrera-Escoda (1), V Altava-Ortiz (1,2), J Amaro (1), J Cunillera (1), M Prohom (1), A Sairouni (1)

1) Meteorological Service of Catalonia, Barcelona, Catalonia (Spain)
2) Forest Fire Prevention Service, Santa Perpètua de la Mogoda, Barcelona, Catalonia (Spain)

tbarrera@meteo.cat

To assess future climate change impacts in Catalonia, a climatic diverse territory located at the North-western Mediterranean basin, high-resolution (1 km) temperature and precipitation climate projections for the period 2006-2100 have been developed. Future projections have been obtained using a statistical downscaling technique applied to three CMIP5 models (MPI-ESM, GFDL-ESM2G and CanESM2), and forced by three RCP emission scenarios (RCP2.6, RCP4.5 and RCP8.5). These models have shown a good skill on reproducing past synoptic variability in the North Atlantic area and Western Europe. The downscaling method is based on the meteorological analogues concept which takes advantage of a daily high-resolution (1 km) temperature and precipitation database developed from a high-densely weather station network for the period 1971-2015, which has been subjected to a primary quality control (removal of outliers). This method shows an outstanding improvement of the inter-annual cycle and variability range of precipitation and temperature in comparison of those obtained from dynamical downscaling simulations in the study area. The technique also tries to solve the issue on projecting extreme temperature values, usually a weakness in the statistical downscaling methods based on the analogy concept. The obtained projected changes in temperature and based climate indices are almost linearly dependent with increasing CO2 concentration. In detail, temperature projections show a clear increase of its annual-mean values (2-6ºC respect to 1971-2000, during this century). However, this increase is not homogeneously distributed within the year. The highest warming is found in autumn and spring, supporting the idea of an extension of summer-like conditions. Magnitude of projected change principally depends on the distance from the sea and altitude. On the other hand, extreme maximum and minimum temperature indices changes are heavily triggered with the CO2 concentration at the end of the century. An increase up to 60 and 30 days on average during this century are expected in the number of warm days (TX>30ºC) and tropical nights (TN>20ºC), respectively. As regards precipitation projection, it is pointed out a general decrease on annual-mean values but with a great range of variability. Seasonally, it is found a significant decrease during summer and a lesser one for spring, while winter and autumn do not present any staidly significant trend. It is also obtained a significant increase of high-precipitation events (>50 mm/day) and a decrease of low-precipitation days (<5 mm/day).

ASSESSING THE CLIMATE IMPACTS OF THE ATLANTIC MULTIDECADAL VARIABILITY ON THE MEDITERRANEAN BASIN

S Qasmi (1), E Sanchez-Gomez (1), C Cassou (1), J Boe (1)

1) CERFACS/CECI, Toulouse, France

sanchez@cerfacs.fr

During the last decades, the evolution North Atlantic sea surface temperature (SST) has been affected by both, low frequency intrinsic climate variability and external forcing, both anthropogenic and natural. The low frequency internal climate variability, also known as Atlantic Multidecadal Variability (AMV), has received particular attention in the last years. The SST pattern associated with the AMV exhibits homogeneous basin-wide SST anomalies of the same sign, leading to the warm AMV (AMV+) and cold AMV (AMV-) phases. Observational studies have shown the existence of decadal climate variability in the Mediterranean basin in the period 1850-2009, moreover a great part of this decadal variability can be explained by the AMV. All these studies highlight the importance of better understanding and predicting the AMV and its climate impacts to address the near term future changes in the Mediterranean-European climate. However, the shortness of the historical observational record compared to the AMV period makes it difficult to rigorously isolate the drivers and the impacts of the AMV. In this context, numerical coupled climate models offer a valuable alternative to investigate the AMV climate impacts and associated mechanisms. In this study we investigate the AMV impacts over the Mediterranean basin by using a set of idealized coupled experiments in which the coupled model CNRM-CM5 coupled model is used to carried out two ensembles of 40 members each, with SST restored to both, the warm and cold phases of the AMV. The difference of these two ensembles gives an estimate of the climate response to the AMV forcing. We focus on the AMV impacts and associated mechanism over the Mediterranean basin for two particular seasons: summer and autumn. Preliminary analysis shows that the response of surface temperature (2m) to the AMV SST anomalies is quite consistent with previous studies, with a prominent warming (cooling) over the Mediterranean area for the AMV+ (AMV-). The temperature impact over the Mediterranean area is more prominent in the western part of the basin. The AMV impact on precipitation during summer displays a general drying over the Mediterranean countries. Much less clear is the response of the atmospheric dynamics to AMV anomalies. An assessment of how AMV affect the temperature extremes in summer and cyclogenetic activity in late summer-autumn will be also investigated. Finally, the mechanisms explaining the AMV impacts over the Mediterranean basin are addressed by isolating the role of the atmospheric dynamics from the thermodynamically driven processes.

IMPROVING SPATIO-TEMPORAL INTERPOLATION OF DAILY PRECIPITATION USING PARALLELIZED MACHINE LEARNING AND PRECIPITATION DERIVED FROM MSG

M Perčec Tadić (1), T Hengl (2)

1) Meteorological and Hydrological Service, Zagreb, Croatia
2) Envirometrix Ltd, Wegeningen, Netherlands

melita.percec.tadic@cirus.dhz.hr

Preliminary analysis of 1 008 812 daily precipitation records measured on the 572 ground stations during 2005-2010 period in Croatia revealed that the 73% of data are zeros or the precipitation is less than 1 mm, hence data are zero inflated. Most non-zero data belong to [0,1] mm and [1,10] mm class, and just 5% of precipitation amounts are larger. That strongly affects the predictions that underestimate the observations, especially for large precipitation amounts. Spatio-temporal prediction using machine learning algorithm on the daily precipitation data accounts for 55% of the spatio-temporal variability. The machine learning algorithm of random forest RF is implemented through R ranger package. Even though the RF in general does not account for spatial location and auto-correlation which are important in spatio-temporal analysis of precipitation, the attempt is made to include it through covariates and distance fields. The preliminary set of covariates detected that the most influential predictors are time variables cdate representing cumulative time and doy representing seasonality effect. Than follow annual precipitation CHELSA_precip, altitude, distance to the sea and different buffer distances. Further attempt in improving the results is by taking into account larger data set for the 1981-2016 period, than monthly precipitation grids for Croatia instead of CHELSA precipitation and satellite precipitation data from MSG missions as additional time dependent predictors.

TEMPERATURE TREND ANALYSIS DURING THE GROWING SEASON AND DORMANCY IN SERBIA (1961–2010)

M Ruml (1), E Gregoric (1), G Matovic (1), M Vujadinovic (1), A Vukovic (1)

1) Faculty of Agriculture, University of Belgrade, Belgrade, Serbia

mruml@agrif.bg.ac.rs

Agriculture sector is very sensitive to climate variability, especially during growing season. However, climate conditions during dormancy are also very important for some agricultural crops. Since the climate variabilty is usually not uniform throughout the year, we evaluated recent temperature trends in Serbia for the growing season and dormancy, separately. The analysis was based on temperature observations from 26 uniformly distributed meteorological stations. The observation period (1961–2010) was split into two parts (1961–1980 and 1981–2010) according to the results of the sequential Mann–Kendall test for detecting change points in time series. The temperature metrics included: maximum temperature (Tx), minimum temperature (Tn), mean temperature, warm days (number of days when Tx> 90th percentile), warm nights (number of days when Tn > 90th percentile), cool days (number of days when Tx < 10th percentile), cool nights (number of days when Tn < 10th percentile) the hottest day (the highest Tx), the hottest night (the highest Tn), the coldest day (the lowest Tx) and the coldest night (the lowest Tn). Temporal trends were evaluated by a least-squares linear regression method for each station and for the entire Serbian territory using the average series. The statistical significance of the trends was detected using a t-test. Results revealed uneven changes of temperature within the observational period. Dormant temperature changes were uniform during the whole period (1961–2010), while pattern of growing season temperature changes was rather complex. In the sub-period 1961–1980, all examined temperature indices exhibited a cooling tendency during the growing season, with growing season mean temperature decreasing at a rate of –0.73 °C decade on average for all stations. A larger decreasing trend was detected in growing season Tx (a nationally averaged rate –1.10 °C per decade) and indices related to Tx than in growing season Tn (a nationally averaged rate –0.37 °C per decade) and indices related to Tn. In the same sub-period, temperature indices displayed a warming tendency during dormancy, with growing season mean temperature, Tx and Tn increasing at same rate of 0.49 °C per decade on average for all stations. In the sub-period 1981–2010, warming tendency of all examined indices was detected in the growing season, as well as in dormant period. Mean temperature increased at same rate in both periods (0.52 °C per decade on average for all stations). Similarly, growing season and dormant Tx and Tn and related indices showed a warming tendency with similar magnitudes of the trends. A nationally averaged rate of 0.55 and 0.49 °C per decade was detected for growing season Tx and Tn, respectively, while dormant Tx and Tn increased at almost exactly the same rate, 0.56 and 0.49 °C per decade, respectively.

SIMULATION OF PRESENT AND FUTURE SPATIAL COMPOUND EVENTS IN MEDITERRANEAN – WEATHER GENERATOR VS. REGIONAL CLIMATE MODELS

M Dubrovsky (1,2), O Lhotka (1,2), P Stepanek (1), J Miksovsky (1,3)

1) Global Change Research Institute, CAS, Brno, Czechia
2) Institute of Atmospheric Physics, CAS, Prague, Czechia
3) Department of Atmospheric Physics, Charles Univ., Prague, Czechia

madu1110@gmail.com

Weather generators (WGs) are often used to produce input weather data for climate change impact studies. To justify their use, WGs are validated for their ability to represent various features of statistical structure of the real-world weather regime, especially the features which may significantly affect outputs from the impact models. The validation indices may include characteristics of (a) probability distribution functions of individual weather variables (mean, variability, quantiles, extremes), (b) temporal structure (persistence, occurrence of spells of specific weather type), (c) spatial structure (only for the spatial WGs), and (d) relationships between variables. Having been validated, the WG may be used to produce arbitrarily long weather series representing the baseline climate for use in the impact studies. To produce weather series representing the future climate, the generators parameters are typically modified by climate change scenarios derived from GCM or RCM simulations. This contribution focuses on the results obtained by the parametric spatial weather generator SPAGETTA and compares its performance for selected Mediterranean regions with the results based on the ensemble of RCM simulations available from the CORDEX database. In the first part, the WG and RCMs are validated for their ability to reproduce spatial temperature and precipitation patterns focusing on compound temperature-precipitation event spells: spells of spatially extensive hot-dry, hot-wet, cold-dry and cold-wet weather; the use of the spatial compound event spells was motivated by the fact, that they are affected by multiple aspects of the statistical structure of weather series: spatial and temporal structure of weather data, and correlation between individual weather variables. In the second part, the future-climate spells are analysed from both WG-produced synthetic series (when using WG for a future climate, its parameters are modified by RCM-based climate change scenarios, which include changes in means, variability and spatial correlations) and RCM future climate simulations. In comparing the WG-based and RCMs-based results, a special attention is given to inter-model variability of results in the RCM ensemble. The experiment is made within the frame of SustES project (funded by European Structural and Investment Funds and Czech Ministry of Education, Youth and Sports; project no. CZ.02.1.01/0.0/0.0/16_019/0000797), and GRIMASA project (funded by Czech Science Foundation; project no. 18-15958S).

PROJECTED CHANGES OF PRECIPITATION AND EXTREME PRECIPITATION EVENTS FOR SLOVENIA OVER THE 21TH CENTURY

R Bertalanic (1), A Medved (1)

1) Slovenian Environment Agency, Ljubljana, Slovenia

renato.bertalanic@gov.si

As a part of project OPS21, The estimation of the average and extreme meteorological and hydrological conditions in Slovenia over the 21st century, we have analysed error-corrected regional climate model simulations ensemble from the project EURO-CORDEX, based on different RCP (Representative Concentration Pathways) scenarios: RCP2.6, RCP4.5 and RCP8.5. From daily data, we calculated average annual and seasonal amount of precipitation in three 30-years peri-ods (2011–2041, 2041–2070 and 2071–2100). Then we calculated relative change according to the reference period (1981–2010). These were made for each of the selected model simulations. In the end, we merged the results of all models for selected scenario, and calculated median, maximal in minimal values of these changes to represent the uncertainty of the results. On annual basis, the amount of precipitation would increase, especially in NE part of Slovenia. The biggest change would be in winter, while in summer signal is mixed and thus unreliable. For example, in scenario RCP4.5 amount of precipitation would decrease in the second projection period and then it would increase in the last projection period, in scenario RCP8.5 the course of events would be the exact opposite In the last projection period for both scenarios models results are inconsistent. Some are dry others are wet, leading to the high uncertainty of the results. For this purpose, a test was preformed to assess whether the simulated changes are reliable, unreliable or show no change with respect to the reference period. Changes in extreme precipitation events were calculated for one-, three- and five-day extreme precipitation and analysed with non-stationary generalized extreme value (GEV) theory. The results were estimated linear trends in extremes for the period from 1981 to 2100 and their uncertainty. We used the same reliability test as we did for the amount of precipitation. Extreme precipitation events would change the most in winter and on annual basis when these changes are most reliable. The biggest changes are expected in case of RCP8.5, a bit smaller in RCP4.5, while in case of RCP2.6 there would be no significant changes in extreme precipitation.

SIMULATION OF PAST CLIMATE VARIABILITY OF HIGH PRECIPITATION EVENTS IN FRENCH MEDITERRANEAN USING CONVECTION-PERMITTING MODEL AT CLIMATE SCALE

C Caillaud (1), S Somot (1), A Alias (1), A Ribes (1), Q Fumières (1)

1) CNRM, Météo-France/CNRS, Toulouse, FRANCE

cecile.caillaud@meteo.fr

The observed intensification of extreme precipitation events occurring over the French Mediterranean area is significant over the 1961-2015 period (Ribes et al, 2018). Up to now, climate models with too coarse resolution and deep convection parametrization failed to represent accurately the meteorological key processes highly linked with topography and various small-scale phenomena, especially meso-scale convective systems which are responsible for the heaviest extremes in the Mediterranean area. With the recent computer power increase, we start implementing convection-permitting models at climate scale. The Meteo-France one, called Arome-Climat with a horizontal resolution of 2.5km, inherits from most of the advances of the Numerical Weather Prediction model. We run past climate simulation over the last 15 years driven by ERAInterim (80km) using an Aladin-Climat-12.5km-simulation as an intermediate step. The domain (common CORDEX-FPS-Convection domain, 1300km□1500km, centred on the Alps) includes the north-western part of the Mediterranean basin. In a first step, we study the ability of the model to reproduce the high precipitation events and try to quantify the internannual variability and the added value compared to the driving model. In a second step, we try to recover the last 15 years observed trends in terms of intensity (and discuss the Clausius-Clapeyron relationship), frequency and properties (spatial coverage and severity index).

PROJECTED CHANGES OF TEMPERATURE AND TEMPERATURE RELATED EXTREMES FOR SLOVENIA OVER THE 21TH CENTURY

N Ključevšek (1), M Dolinar (1)

1) Slovenian Environment Agency, Ljubljana , Slovenia

m.dolinar@gov.si

The assessment of temperature changes and changes of temperature related extremes is based on bias corrected regional climate model simulations ensemble from the EURO-CORDEX initiative. The changes were assessed for three different periods: near future (2011–2040), mid-century (2041–2070) and end of the century (2071–2100) and three different GHG emissions scenarios: RCP2.6, RCP 4.5 and RCP8.5. The projected increase of annual and seasonal mean temperature is consistent with large scale warming over the Europe. It is amplified in summer and winter, and moderate in spring and autumn. While during the first period (2011–2040) there are no significant differences between temperature increase for different GHG emissions scenarios, at the end of the century the temperature increase strongly depends on the GHG emission scenarios. To assess changes of extreme temperature conditions several ETCCD temperature indices were calculated. For both, extreme minimum and maximum temperature indices, there are significant regional differences in changes, mostly dependant on elevation and distance to the sea. In comparison to mean temperature changes, the changes in extreme temperature are significantly different for different GHG emission scenarios already in the second time period (2041–2070). While one of the biggest climate change threats to society are summer heat waves, also the change of their intensity, frequency and duration was assessed, based on two methodologies: EFH and HWMId. Heat wave based on EHF methodology is defined as every three or more consecutive days long period when average daily temperatures are higher than climatological 95th percentile and in the same time higher than average temperature of 30 preceding days. This index is based on two excess heat indices (EHIsig and EHIaccl) and is used for operational heat wave forecast in Australia. Heat wave defined with HWMId methodology is defined as every three or more consecutive days with maximum temperature above the daily threshold for the reference period 1981–2010 (90th percentile daily maximum temperature centred on a 31 day window). There are significant changes between the results of two methodologies regarding the changes in number and duration of heat waves. While the EFH method predicts only a minor change in number of heat waves but strong increase of their duration, it is the other way around for HWMId index. However, both methods give the consistent results regarding the GHG emission scenarios. There would be no significant changes of heat waves in case of RCP2.6 scenario in the future. For both other two scenarios, we can expect moderate changes in magnitude of heat waves in the second period (2041–2070). At the end of the century, the heat waves would strongly intensify only in case of RCP8.5 scenario.

DIFFERENT IMPACTS OF GLOBAL WARMING BETWEEN NORTH AND SOUTH MEDITERRANEAN AREAS

P Lionello (1,2), L Scarascia (2)

1) Univ. Of Salento, Lecce, Italy
2) CMCC, Lecce, Italy

piero.lionello@unisalento.it

This contribution analyzes a large ensemble of CMIP5 global climate projections in order to link future regional climate change in the Mediterranean region and differences between north and south area to the global mean annual surface temperature change. Warming will be particularly large in summer (approximately 50% larger than global mean annual warming) and for the land areas located north of the basin (locally up to 100% larger than global warming). Reduction of precipitation will affect all seasons in the southern Mediterranean areas, with maximum reduction for winter precipitation (-7 mm/k or -7%/k), but mostly summer in the northern Mediterranean areas (-7mm/K or -9%/K). Areas located at the northern border of the Mediterranean region will not experience a reduction of precipitation in winter. Contrast between north and south areas will be even stronger than this for indices associated with extremes of precipitation and hydrological cycle. On this respect, it appears that climate change will significantly amplify differences between North and south regions. As global mean annual temperature increases, in the North Mediterranean the Simple Daily precipitation Intensity Index (SDII) and the total precipitation during very wet days (R95P) increase at a rate of approximately 0.1mm/K and 5mm/K, respectively, while the same indices show no relevant change in the southern Mediterranean. The maximum number of consecutive dry days (CDD) is already larger in the Southern than in the Northern Mediterranean and it is increasing faster in the former than in the latter as global warming increases (rates are about 8days/K and 5days/K) respectively. The maximum number of consecutive wet days (CWD) is larger in the northern than in the southern Mediterranean and decreasing at a similar rate (about 0.5 days/K) in both (actually the rate of decrease is slightly smaller in the south). At difference with the response of the regional hydrological cycle extremes to global warming, changes of warm nights (TN90p) and cold days (TX10p) are similar in the North and South Mediterranean. In both areas, the increase of warm nights is dramatic, to the extent that with a 4K global warming almost all nights would classified as warm nights and there will be no cold days (definitions of cold days and warm nights are based on the 1961-1990 reference period)

SPATIAL PATTERN OF RECENT RAINFALL TRENDS IN MONTENEGRO 1951-2010

J Lukovic (1), B Bajat (1), M Pejovic (1), D Buric (2)

1) University of Belgrade, Belgrade, Serbia
2) University of Montenegro, Niksic, Montenegro

jelenalu@yahoo.com

This study examines a spatial pattern of annual, seasonal and monthly rainfall trends in Montenegro. Montenegro has been poorly studied in terms of rainfall trends. So far, several studies assessed only precipitation extremes in Montenegro over last several decades. In this study we use observational data from 23 stations between 1951 and 2010. The rainfall series were examined by applying the nonparametric method of the Mann–Kendall test and Sen's method to determine the significance and magnitude of the trends. Particular attention was given to seasonal shifts in the Montenegro hydroclimate. Therefore the changes in the onset and termination of the rainy season were examined too. In the last section of the study global and local spatial autocorrelation indices were calculated in order to examine spatial pattern of rainfall trends on annual, seasonal and monthly timescales in Montenegro in the period 1951–2010.

NEAR AND FAR FUTURE CHANGES IN EXTREME TEMPERATURES OVER THE IBERIAN PENINSULA

M García-Valdecasas Ojeda (1), P Yeste Donaire (1), E Romero Jiménez (1), SR Gámiz-Fortis (1), Y Castro-Díez (1), MJ Esteban-Parra (1)

1) Universidad de Granada, Granada, Spain

mgvaldecasas@ugr.es

The Mediterranean region is considered as a hotspot due to its vulnerability to changes in the climate system. In this framework and under a climate change perspective, it is expected that the Iberian Peninsula (IP), as part of the Mediterranean region, will undergo important impacts on ecosystems and ultimately on humans due to the rising temperature. This study is focused on examining changes in extreme temperatures (maximum and minimum temperature) by using high-resolution climate projections. To do this, current (1980-2014) and future (2021-2050 and 2071-2100) climate simulations were carried out using the Weather Research and Forecasting (WRF) model over a domain centered in the IP with 0.088 degrees of spatial resolution (c.10 km) and nested in the 0.44 EURO-CORDEX region. The WRF model was driven by the bias-corrected outputs of two different global climate models, the version 1 of NCAR's Community Earth System Model (CESM1) and the Max Planck Institute's Earth System Model (MPI-ESM-LR). Additionally, in order to take into account the effects of the greenhouse gas (GHG) concentrations, two different representative concentration pathway (RCP) scenarios were used: the moderate emission scenario (RCP4.5) and the most severe emission scenario (RCP8.5). Future changes in temperature were examined by directly comparing grid-points between future and present through the Delta-change approach, and at different time scales. That is, the annual and seasonal scales were used to evaluate changes in long-term mean values and daily values were analyzed to elucidate changes in term of extreme temperatures. Our results suggested a substantial rise in both the long-term mean and extreme temperatures over the IP. The results also showed that changes are especially noteworthy in warm seasons and over the southern half of the IP. Key Words: WRF, Regional Climate Models, Climate change, Iberian Peninsula, high-resolution projections. ACKNOWLEDGEMENTS: This work has been financed by the projects, CGL2013-48539-R (MINECO-Spain, FEDER) and CGL2017-89836-R (MINECO-Spain, FEDER).

ASSESSING LAND-SURFACE VARIABLES USING THE WRF-NOAH OVER THE IBERIAN PENINSULA

M García-Valdecasas Ojeda (1), P Yeste Donaire (1), E Romero Jiménez (1), SR Gámiz-Fortis (1), Y Castro-Díez (1), MJ Esteban-Parra (1)

1) Universidad de Granada, Granada, Spain

mgvaldecasas@ugr.es

Land-surface variables play an essential role in predicting the potential effect of climate change, particularly in the Mediterranean region where a strong coupling land-atmosphere occurs at least during warm seasons. In this framework, Regional Climate Model (RCMs) are able to resolve land-surface processes with more detail than Global Climate Models (GCMs), which is needed to adequately represent variables such as the surface evapotranspiration or the soil moisture content. This work aims to evaluate the skill of the Weather Research and Forecasting (WRF) model coupled with the Noah land surface model (LSM) to represent land-surface variables over the Iberian Peninsula (IP). Thus, three 35-year (1980-2014) runs were completed using WRF over a domain centered in the IP with a 0.088 degrees of spatial resolution (c.10 km) and nested in a coarser domain that corresponds to the 0.44 EURO-CORDEX domain (c. 50 km). The simulations were conducted by the bias-corrected outputs from two CMIP5 GCMs: the version 1 of NCAR's Community Earth System Model (CESM1) and the Max Planck Institute's Earth System Model at Low Resolution (MPI-ESM-LR). Additionally, a simulation driven by the ECMWF ERA-Interim Reanalysis dataset was also carried out in order to examine uncertainties associated with the RCM. The evaluation consisted of the direct comparison of surface evapotranspiration and soil moisture content from WRF and those from the Global Evaporation Amsterdam Model (GLEAM) at annual and seasonal scale. In general, results revealed that the WRF model, although with a certain difficulty, represented quite well the spatiotemporal variability of land-surface variables. This suggests that WRF is a valuable tool to study the potential effects of climate change in regions with important land-surface-atmosphere feedbacks such as the IP. Key Words: Regional Climate Models, WRF, land-surface variables, Iberian Peninsula. ACKNOWLEDGEMENTS: This work has been financed by the projects CGL2013-48539-R (MINECO-Spain, FEDER) and CGL2017-89836-R (MINECO-Spain, FEDER).

THE RELATION BETWEEN THE GLOBAL HADLEY CIRCULATION AND THE CLIMATE IN THE MEDITERRANEAN REGION

AL Scambiati (1), P Lionello (1,2), R D'Agostino (3)

1) Disteba, University of Salento, Lecce, Italy
2) Euro Mediterranean Center on Climat Change, Lecce , Italy
3) Max Planck Institute for Meteorology, Hamburg, Germany

ascanioluigi.scambiati@unisalento.it

This study investigate the relation between the global Hadley Circulation (HC) and the climate in the Mediterranean region. The analysis is performed using the ensemble mean of the AMIP-like experiment ERA-20CM, the deterministic analysis ERA-20C and ERA-INTERIM. The analysis is restricted to the winter when the HC is stronger. Firstly, we have calculated the mean position of the northern edge (NE) of the HC considering the zonal mean distribution of the following variables: the Outgoing Longwave Radiation (OLR), Precipitation, Precipitation minus Evaporation (P-E), the Mean Sea Level Pressure (MSLP) and the Stream function. Then the NE has been correlated with the distribution of the vertical velocity in the Mediterranean basin. The correlation distribution shows a strong and extended positive values over the eastern part of the basin and a negative values in the central part of the Mediterranean for the majority of the metrics and for both ERA-20CM ad ERA-20C. Therefore, the poleward movement of the winter HC provokes on the one hand, an increase of the downward motion in the eastern Mediterranean, on the other hand an intensification of the upward motion in the central part. After removing the ENSO signal (Nino3.4) the correlation distribution is substantially the same even if by far weaker. We can affirm that the correlations are partially consequence of an ENSO common driving. Finally, we have adopted the same procedure correlating the position of the NE, estimated with the different metrics, with the precipitation distribution overt the Mediterranean. What emerges is a poleward movement of the NE provokes a reduction of precipitation, but there is a clear disagreement in positioning the area of precipitation decreasing over the basin.

LOCAL MEASUREMENTS AND MODEL WAVE DATA: COMPLEMENTARY ELEMENTS FOR LARGE-SCALE CLIMATE ASSESSMENT

A Pomaro (1), L Bertotti (1), L Cavaleri (1)

1) Institute of Marine Sciences CNR-ISMAR, VENEZIA, Italia

angela.pomaro@ve.ismar.cnr.it

Multi-decadal time series of wave data needed for climate studies are generally provided by long term model simulations (hindcasts). Valuable as they are, these estimates are necessarily affected by the approximations involved within the modelling process. On the contrary, multi-decadal observed time series are rare, but of course not exempt of problems. Local effects may prevent the identification of trends that are indeed present at large scale. Of course, where available for several decades, measured data are of great value for a number of reasons and can be valuable clues to delve further into the physics of the processes of interest, especially if considering that waves, as an integrated product of the local climate, can provide related compact and meaningful information. The present study refers to the analysis of the 39-year long directional wave time-series recorded between 1979 and 2017 at the CNR-ISMAR (Institute of Marine Sciences of the Italian National Research Council) "Acqua Alta" oceanographic research tower, located in the Northern Adriatic Sea, 15 km offshore the Venice lagoon, on 16 m depth. The dataset is explored both to characterize the local average climate and its variability, and to detect the possible long-term trends that might be suggestive of, or emphasize, large scale circulation patterns and trends. In addition, we take advantage of the availability for the area of interest of a 26-year long dataset of directional spectra (in frequency and direction), from the 3rd generation WAve Model (WAM) driven by the wind fields produced at the European Centre for Medium-Range Weather Forecasts (ECMWF), which offers an independent, but theoretically corresponding and significantly long, dataset at high resolution, allowing to penetrate the wave problem through different perspectives. In particular, we investigate the contribution of the individual wave systems that modulate the variability of waves in the whole Adriatic Sea basin, by analyzing the spectra partitions. A characterization of wave conditions and storminess based on wave spectra in fact brings out a more detailed description of the different wave regimes, their associated meteorological conditions and their variation in time and geographical space (crossed sea conditions, distribution of energy on direction, etc.), allowing to explore large-scale atmospheric circulation patterns or weather regimes. The same approach has been applied also to the Red Sea data, confirming at a larger geographical extent the possible links of the wave activity in the Mediterranean Region with large-scale north hemisphere teleconnection patterns or weather regimes. Hence we explore long-term trends of the relevant wave parameters in order to assess the correlation with the general climate and use the measured data as long-term indicators of the its evolution, thus helping the overall understanding of models capability to reproduce the physical processes in a climate change perspective.

SESSION 4

Climate extremes and hazards in the Mediterranean region under a chang-ing climate

THE ROLE OF ARS IN TWO CONTRASTING MEDITERRANEAN CLIMATE REGIONS: IBERIAN PENINSULA AND CAPE TOWN PROVINCE IN SOUTH AFRICA

AM Ramos (Invited) (1), RC Blamey (2), R Tomé (1), PM Sousa (1), MLR Liberato (1,3), CJC Reason (2), RM Trigo (1)

1) Instituto Dom Luiz, Faculdade Ciências, U. Lisbon, Lisbon, Portugal
2) Department Oceanography, University of Cape Town, Rondebosch, South Africa
3) Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal

amramos@fc.ul.pt

The Mediterranean climate is usually characterized by warm and hot summers intermingled with mild and rainy winters. Besides being coined for the Mediterranean basin area, it also characterizes the climate of other important areas of the planet, including California, southwestern South Africa, Central Chile or southwestern Australia. Recently, it has been suggested that another common feature shared by all Mediterranean climate regions is the occurrence of Atmospheric Rivers (ARs) and their related weather-driven extremes. ARs are relatively narrow and elongated filaments of high water vapour transport, which are associated with tropical moisture exports and often occur in combination with the passage of strong extratropical cyclones. Such structures transport more than 90% of the total mid-latitude vertically integrated water vapour and can lead to intense precipitation episodes due to its interaction with topography or ascent in the Warm Conveyor Belt. A detection algorithm allowed the identification and a comprehensive characterization of the major North Atlantic AR events that affected the Iberian Peninsula since 1948 (Ramos et al., 2015). The relationship between ARs and extreme precipitation events in western Iberian river basins (Minho, Tagus, and Duero) is noteworthy, while for eastern and southern basins (Ebro, Guadiana, and Guadalquivir) the impact of ARs is reduced. A similar climatology for Southern Atlantic was developed recently evaluating the role played by ARs bound for the western coast of South Africa since 1979, during the austral winter months (April–September) (Blamey et al., 2018). Meteorological stations positioned in areas of high topography present the highest percentage of persistent ARs contribution to rainfall, whereas stations downwind of the major topographic barriers show the lowest contributions. We show that around 70% of the top 50 daily winter rainfall extremes in South Africa were linked to ARs. Finally, we show that several recent major drought episodes in both settings are related to the dislocation of ARs impacting Iberia (e.g. 2004-2005) and South Africa (e.g. 2015-2017). References ' Blamey, R.C.; Ramos, A.M.; Trigo, R.M.; Tomé, R.; Reason, C.J. (2018) The influence of Atmospheric Rivers over the South Atlantic on Winter Rainfall in South Africa. Journal of Hydrometeorology, 19, 127–142. ' Ramos, A.M; Trigo, R.M.; Liberato, M.L.R.; Tomé, R. (2015) Daily Precipitation Extreme Events in the Iberian Peninsula and Its Association with Atmospheric Rivers, Journal Hydrometeorology, 16:579–597. Acknowledgments This work was supported by the project IMDROFLOOD funded by Fundação para a Ciência e a Tecnologia, Portugal (FCT, WaterJPI/0004/2014). Alexandre M. Ramos was also supported by an FCT postdoctoral grant (FCT/DFRH/SFRH/BPD/84328/2012).

SPATIAL VARIATIONS OF SEA LEVEL ALONG THE EGYPTIAN MEDITERRANEAN COAST

M Said (1), T El-Geziry (1)

1) National Institute of Oceanography and Fisheries, Alexandria, Egypt

mamsaid2@hotmail.com

The present work is based on hourly sea level data taken from six tide-gauges distributed over the Egyptian Mediterranean coast. The periods of data are different for each location with the longest records (30 years) at Alexandria and the shortest records (4 years) at Mersa Matruh. These data are used to calculate the tidal characteristics, spatial variations of the mean sea level, annual rates and its seasonal variations. The astronomical tidal constituents are calculated using t_tide package which works under the Matlab Environment. The present study focused only on the 12 major tidal components. Despite the weakness of the observed astronomical tides along the coast, the M2 constituent is still the key player in the observed variations in the astronomical tides. Tides are of semidiurnal type with a maximum M2 amplitude value of 13 cm at Port Said and a minimum one of 6 cm at Sidi Abdel-Rahman west of Alexandria. The results of the present study revealed that, the highest HHWL occurred at Port Said (87 cm) and the lowest LLWL occurred at Mersa Matruh (23 cm). The mean sea level along the coast increases from west to east with a difference of 35 cm between its western and eastern extremities. The sea level rate is varied between a minimum of 1.0 mm/yr in the west and a maximum of 6.4 mm/yr in the east with an average rate of 3.4 mm/yr. This rate is higher than the rates of the global and whole Mediterranean basins and is less than the rate of the eastern Mediterranean. Moreover, the rate of sea level rise is higher eastern region than the western region. The sea level examines a seasonal trend with usual low values in spring season and high ones in summer. The seasonal variations tend to be mostly affected by the air pressure scheme and wind regime over the study area. Land subsidence is another factor, which must be considered upon investigation of sea level variability along the Egyptian Mediterranean coast. However, this needs to be verified and concluded through more robust actual geological observations and analyses

METEOROLOGICAL DROUGHT CHARACTERIZATION FOR ADAPTION AND MITIGATION OF GLOBAL IMPACTS IN NORTHERN TUNISIA

M Mathlouthi (1), F Lebdi (2)

1) LRSTE at INAT, Tunis, Tunisia
2) INAT, Tunis, Tunisia

majid_mathlouthi@yahoo.fr

Climate variability and climate change in the longer term consequences of economic, social and environmental. It is likely that climate change increases the frequency and duration of droughts. This contribution focuses on an analysis by event of dry event, according to a predetermined threshold, from series of observations of the daily rainfall. The approach has been illustrated on a case study catchment localized in Northern Tunisia where the average rainfall is about 680 mm. The dry events are constituted of a series of dry days framed by the rainfall event. Rainfall events are defined themselves in the form a uninterrupted series of rainfall days understanding at least a day having received a precipitation superior or equal to a threshold of 4 mm. The rainfall events are defined by depth and duration, which are found to be correlated. An analysis of the depth per event conditioned on the event duration has been undertaken. The negative binomial distribution appears the best overall fit for the depth per event. The duration of the rainfall event follows a geometric distribution while that the dry event follows the negative binomial distribution. The length of the climatically cycle adjusts to the Incomplete Gamma. Event based analysis was used to study of the effects of climate change on water resources and crops and to calibrate precipitation models with little rainfall records.

COMPARISON OF FIVE SATELLITE RAINFALL ESTIMATES ALGORITHMS WITH RAIN GAUGE DATA OVER NORTHERN TUNISIA

S Dhib (1), CM Mannaerts (2), Z Bargaoui (3)

1) Université de Tunis El Manar, ENIT, Tunis, Tunisia
2) University of Twente, ITC, Enschede, Netherlands
3) Université de Tunis El Manar, ENIT, Tunis, Tunisia

dhib_saoussen@hotmail.fr

Five satellite rainfall estimation algorithms are evaluated against rainfall extreme events over Northern Tunisia. Evaluations are implemented for 77 daily heavy rainfall events observed during the study period from 2007 to 2009. We mean by heavy event the rain exceeding 50 mm/day for at least one station of the study area. Daily rainfall observations are derived from an average of 318 rain gauges interpolated using inverse distance method. Three statistical indices (correlation coefficient (R), amounts ratio bias (RB), normalized root mean square error (NRMSE)), as well as a contingency table (probability of detection (POD) and false alarm ratio (FAR)), are quantified to evaluate the satellite rainfall estimates quality. In general, the product that is most close to observed rainfall according to POD, RB, and R is raw Climate Prediction Center (CPC) Morphing Technique (CMORPH), followed by adjusted CMORPH, Tropical Rainfall Measuring Mission (TRMM 3B42), Precipitation Estimation from RemotelySensedInformationusingArtificial Neural Networks (PERSIANN), and Multisensor Precipitation Estimate (MPE). In terms of FAR, TRMM 3B42 product shows most potential followed by raw CMORPH, adjusted CMORPH, MPE, and PERSIANN. Additionally, TRMM 3B42 product shows the best skills in term of NRMSE followed by PERSIANN, raw CMORPH, MPE, and adjusted CMORPH. In terms of the POD, all the products perform better during the wet season (from November to April). An overestimation is noticed according to the RB coefficient for TRMM 3B42, PERSIANN, and MPE for both dry and wet seasons. However raw CMORPH and adjusted CMORPH showed an overestimation foremost during the dry season (from May to October). In term of R, all the products perform better during the wet season except MPE. For the NRMSE the two CMORPH products get a bit higher NRMSE coefficients in comparison with the other products for both seasons. We conclude that differences between the products are large. Thus, the evaluation of any satellite data before any application is recommended. In this case study, based on the average of all the evaluation metrics, the adjusted CMORPH is the product the most adequate.

THE COMBINED USE OF NDVI AND SPEI TO ASSES DROUGHT IMPACTS ON VEGETATION ACTIVITY IN THE MEDITERRANEAN

RM Trigo (1), C Gouveia (1,2), P Páscoa (1), A Russo (1), SM Vicente-Serrano (3)

1) IDL, University Lisbon, Lisbon, Portugal
2) IPMA, Lisbon, Portugal
3) IPE, CSIC, Zaragoza, Spain

rmtrigo@fc.ul.pt

This work analyzes the drought impacts on vegetation over the entire Mediterranean basin, with the purpose of determining the vegetation communities, regions and seasons at which vegetation is driven by drought. Our main approach is based on the NDVI time series with an 8 km spatial resolution from the GIMMS dataset and (8 km resolution). Correlation maps between fields of monthly NDVI and the Standardized Precipitation-Evapotranspiration Index (SPEI) at different time scales (1-24 months) were computed for representative months of winter (Feb), spring (May), summer (Aug) and fall (Nov). Results for the period from 1982-2006 show large areas highly controlled by drought, although presenting high spatial and seasonal differences, with a maximum influence in August and a minimum in February (Gouveia et al., 2017). The highest correlation values are observed in February for 3 months' time scale and in May for 6 and 12 months. The higher control of drought on vegetation in February and May is obtained mainly over the drier vegetation communities (Mediterranean Dry and Desertic) at shorter time scales (3 to 9 months). Additionally, in February the impact of drought on vegetation is lower for Temperate Oceanic and Continental vegetation types and takes place at longer time scales (18-24). The dependence of drought time-scale response with water balance, as obtained through a simple difference between precipitation and reference evapotranspiration, varies with vegetation communities. A similar analysis is performed with the NDVI obtained by the SPOT VEGETATION instrument at a higher resolution (1 km) for the Balkan area for the period 1998-2014, including a detailed analysis of the 2000-2001 major drought event (Páscoa et al., 2018). Although the vulnerability to drought depended on the land cover type, this drought event provoked a decrease in vegetation activity on the entire study area. References Gouveia, C.M., Trigo, R.M., Beguería, S., Vicente-Serrano, S.M., 2017. Drought impacts on vegetation activity in the Mediterranean region: An assessment using remote sensing data and multi-scale drought indicators. Global and Planetary Change, 151:15-27. Páscoa P., Gouveia C., Russo A., Bojariu R., Vicente-Serrano S.M., Trigo R.M., 2018. Vegetation vulnerability to drought on southeastern Europe, Hydrology and Earth System Sciences (submitted). Acknowledgments This work was partially supported by the project IMDROFLOOD funded by Fundação para a Ciência e a Tecnologia, Portugal (FCT, WaterJPI/0004/2014). This work was also supported by FCT through UID/GEO/50019/2013 - Instituto Dom Luiz.

WATER AND SEDIMENT DISCHARGE VARIABILITY FOR THE PERIOD 1961-2010 – CASE STUDY: NIŠAVA RIVER, EASTERN SERBIA

S Manojlovic (1), S Dragicevic (1), M Langovic (1), R Tosic (1), P Manojlovic (1), I Novkovic (1)

1) Faculty of Geography University of Belgrade, Belgrade, Serbia

sanjamanojlovicgeo@gmail.com

This study is concerned with identifying changes in the time series of precipitation, suspended sediment concentration, water and sediment discharge in the Nišava river basin for the period 1961-2010. Using the cumulative double mass-plot diagram, three time series are detected for precipitation, suspended sediment concentration, water and sediment discharge. Non parametric Mann–Kendall test is used to detect trends. Also, sediment discharge was analyzed for correlation analysis between extreme precipitation events and hydrological conditions. The results show significant decresase for the period 1961-1981 and 1981-1994 and no-significant increase in period 1995-2010 for all datasets. Also, we identified type and changes in the hysteresis loop and determined the relationship between the suspended sediment concentration and discharge for the different time series. The results show a clear shift in the phase timing for the maximum daily and monthly suspended sediment concentration from summer to spring months as a result of changes in the trend of precipitation and water discharge. We further investigate in a correlation manner how climate changes or extreme precipitation and hydrological events may affect a shift in the phase timing for maximum sediment discharge events. This work has potential significance for sediment management, stream engineering and restoration.

ROLE OF THE STRENGTH OF THE EAST ASIAN TROUGH ON THE TEMPERATURE VARIABILITY OVER THE EASTERN MEDITERRANEAN

Y Ezber (1), D Bozkurt (2), OL Sen (1)

1) Istanbul Technical University, Istanbul, Turkey
2) University of Chile, Santiago, Chile

yaseminezber@gmail.com

The East Asian trough (EAT) is the strongest stationary wave in the Northern Hemisphere mid-latitudes. In this study, we investigate how its strength affects the amplitude and location of the eastern Mediterranean trough that causes temperature variability over the eastern Mediterranean. We used daily ERA-Interim dataset whose time span is from 1979 to 2018 and whose horizontal resolution is 0.75 degrees. We employed two indices to reveal the strength of the connection between the East Asian and eastern Mediterranean troughs. For the EAT, a Trough Intensity Index (TII) is calculated by averaging the 500 hPa geopotential heights over the region between 30 -45oN and 125-145oE. For the eastern Mediterranean trough, an index (called Trough Displacement Index, TDI) to show zonal displacement of the trough is calculated by taking difference of 500 hPa geopotential heights between two points, 39°N-10°E and 39°N-50°E. We found statistically significant correlation (~0.5) between TII and TDI at the 13th pentad which represents the beginning of March. We applied EOF analysis to the 500 hPa geopotential heights over the East Asian region for the 13th pentad to separate the intensity mode of the EAT from the others. The principal component time series of EOF2, which is found to represent the intensity of the trough, have a strong negative signal for the year 2004. The observations show that the eastern Mediterranean region was anomalously warm in early March 2004. Our study indicates that a strong EAT displaces the eastern Mediterranean trough westward and increases its amplitude. The latter results in the advection of warm air of tropical region towards higher latitudes, which causes anomalous rises in temperatures over the eastern Mediterranean region, especially over the eastern Anatolia. Such an event in early March 2004 melted snowpack over the eastern Anatolian highlands, which produced unprecedented amounts of discharge in the snow-fed rivers of Euphrates and Tigris at this time of the year.

ELEVATION DEPENDENT CHANGE OF CLIMATE EXTREMES IN XXI CENTURY MODEL PROJECTIONS: A MEDITERRANEAN PERSPECTIVE

E Arnone (1), E Palazzi (1), J Von Hardenberg (1)

1) ISAC-CNR, Torino, Italy

e.arnone@isac.cnr.it

Elevation dependent warming has been observed in several regions of the globe, with higher rates of warming having occurred at increasingly higher altitude over the past decades. Similarly, greater trends of warming have been found to occur in mountain regions in XXI century climate model projections as compared to sea level trends. We used an ensemble of XXI century multi model projections to investigate whether a similar elevation dependency can be found in the projected change of climate extremes. Climate extremes were studied adopting a selection of indices from the ETCCDI project, including temperature and precipitation extremes and spells. Our results show an elevation dependent change in several adopted indices, pointing towards an amplification of the change in temperature extremes and of a shift from low intensity to heavy precipitation in mountain regions. Results are discussed with a particular attention to Mediterranean mountain regions.

ESTIMATION OF THE MID AND LATE CENTURY EXTREME SUMMER WINDS OVER THE EASTERN MEDITERRANEAN FROM EURO-CORDEX MODELS

S Dafka (1), A Toreti (2), J Luterbacher (3), P Zanis (4), E Tyrlis (5), E Xoplaki (6)

1) Justus-Liebig-University Giessen, Giessen, Germany
2) Joint Research Centre, Ispra, Italy
3) Justus-Liebig-University Giessen, Giessen, Germany
4) Aristotle University of Thessaloniki, Thessaloniki, Geece
5) Max Planck Institute for Meteorology, Hamburg, Germany
6) Justus-Liebig-University Giessen, Giessen, Germany

Styliani.Dafka@geogr.uni-giessen.de

Episodes of extremely strong northerly winds (known as Etesians) during boreal summer can cause hazardous conditions over the eastern Mediterranean and represent a major threat for the spread of wildfires, as well as the safe design, construction, and operation of wind energy turbines. Here, projections of changes in two 30-year future periods (2021-2050 and 2071-2100) relative to 1971-2000 under two Representative Concentration Pathways (RCPs) scenarios: RCP4.5 and RCP8.5, have been produced for Etesians. We analyze a Multi-Model Ensemble (MME) of the most recent EURO-CORDEX regional climate simulations, at the 12 km grid resolution, regarding changes, on a monthly/subperiod scale, of wind speed, mean sea level pressure (SLP) and 500 hPa geopotential height anomalies as well as the zonal wind at 200 hPa. Both scenarios for the mid and late century, indicate a strengthening of the Etesians (0.5 to 1 m/s, robust and significant in the period June to September), mainly associated with the strengthening of the subtropical and polar jet stream. The SLP is projected to increase over the eastern Atlantic, while there is a clear tendency of deepening of the low-pressure system over the eastern Mediterranean. Results suggest that the current estimate of wind power potential for the Aegean Sea can be significantly changed in the coming decades. In terms of fire weather threats in the future, this study suggests that there may be Etesians increases during critical dry periods, especially late in the summer season, leading to more extensive wildfires.

THE KEY ROLE OF BLOCKING IN DRIVING THE COLD SPELLS OVER SOUTHEASTERN EUROPE IN WINTER 2016 - 2017

E Tyrlis (1), D Matei (1), J Bader (1,2), E Manzini (1), K Lohmann (1)

1) Max Planck Institute for Meteorology, Hamburg, Germany
2) Uni Climate, Uni Research & Bjerknes Centre for Climate Research, Bergen, Norway

evangelos.tyrlis@mpimet.mpg.de

Winter cold extremes over the Mediterranean can have a significant financial and societal impact. In this work we investigate the dynamical environment that led to the extremely cold conditions that affected southeastern Europe in winter 2016-2017. We study the hemispheric scale circulation that was associated with this regional climate anomaly and we conclude that the latter was not an isolated event but rather it pertained to a series of cold spells that affected large parts of Eurasia during autumn and winter 2016-2017. The possibility of a link between the recently observed increasing trend of mid-latitude cold extremes, which can also affect the Mediterranean, and Arctic Amplification has become a topic of heated debate. Specifically, the role of sea ice loss over the Barents-Kara Seas (BKS) into driving cold episodes over Eurasia has been highlighted in the relevant literature. Here, we use ERA-Interim reanalysis data to investigate the daily evolution of the atmospheric state with view to trace the pathways that led to these extreme conditions. Abundant blocking over most of the Northern Hemisphere was the key circulation pattern in autumn 2016 when a nearly four-fold increase in blocking activity was observed over Eurasia. We identify distinct and successive blocking episodes over central Asia; each of them induced a pair of cold air advection to its south and warm advection over the Arctic. The resulting warm and cold anomalies over the BKS and central Asia, respectively, featured large concurrent variability on synoptic timescales whose pace was set by blocking. Subsequently, blocking activity spread towards Europe in early winter 2017. This favored the development of successive equatorward surges of cold air masses towards the Mediterranean that severely affected the Balkans. This work has been undertaken in the framework of the InterDec project funded under the 2015 joint JPI Climate-Belmont Forum call.

PERFORMANCE OF WRF IN SIMULATING THE HAIL EVENT OVER ISTANBUL ON 27 JULY 2017

E Toker (1), OL Sen (1), Y Ezber (1)

1) Eurasia Institute of Earth Sciences, Istanbul, Turkey

tokerem@itu.edu.tr

Several extreme weather events took place in Istanbul in July 2017. The heavy hail event on July 27 damaged hundreds of buildings and thousands of vehicles. The cost of this hazardous event was estimated to be around 300 Million US Dollars. As a result of these weather events, the total precipitation was recorded as of 30-40 kg. This study investigates this hail event using the state-of-the-art Weather Research and Forecasting (WRF) model. The model domain is set up with 4 nested domains (27, 9, 3 and 1 km resolutions from outer to inner) and Istanbul, located in northwestern Turkey, was used as the central point (41.96°N 20.06°E). Model simulations are performed for 30 hours starting from 18:00 UTC on 26 July 2017, and this time range includes 12-hour spin-up time. ERA-Interim Reanalysis dataset with 0.75°x0.75° spatial and 6-hour temporal resolution is used as the initial and lateral boundary conditions. Sensitivity tests were performed with different combinations of the parameterization. The performance of the model in simulating the hail event was assessed by comparing the model outputs with radar, satellite and meteorological station data which are obtained from Turkish State Meteorological Service. It is found that the hail event is best simulated when the model is run with Milbrandt 2-moment microphysics scheme, Kain-Fritsch cumulus scheme, MYNN2 planetary boundary layer scheme, RRTMG radiation scheme. As a result of the best model outputs, accumulated precipitation is 40 mm from 27 July to 28 July, hail event started at 14:15 UTC and the cloud top temperature on Istanbul is about -50°C in the same time. Deep convective clouds reached about 12 km height. Maximum hail concentration is about 400/kg at 14:15 UTC and occurred about 500mb pressure level. Reflectivity is about 50 dBZ when hail event occurred.

TRAJECTORIES OF CYCLONES AFFECTING TURKEY AND SOURCE OF PRECIPITATION

M Bozbura (1), OL Sen (1), Y Ezber (1)

1) Eurasia Institute of Earth Sciences, Istanbul, Turkey

bozbura@itu.edu.tr

Mid-latitude cyclones are the low-pressure systems that control the climate of mid-latitudes. Cyclones influence the precipitation patterns, so examining the cyclones is very important to understand the climate in a certain region. The source of precipitation in Turkey is characterised by cyclones that occur in the Mediterranean Basin. The way to understand the source of precipitation in Turkey is to examine climatology of the Mediterranean cyclones. Therefore, identifying cyclones affecting Turkey and finding their trajectories and revealing the source of precipitation are the main purpose of this study. The cyclone identification and tracking procedures are conducted by using the University of Melbourne automatic cyclone tracking scheme and 6-hourly mean sea level pressure (MSLP) fields. These MSLP datasets are ERA-Interim having 1.0° x 1.0° and NCEP Reanalysis 2 having 2.5° x 2.5° spatial resolution. The major sources of precipitation and the cyclones are obtained which are the Gulf of Genoa, northern Italy, the Aegean Sea, the Black Sea, Cyprus, and North Africa regions. The most of the cyclones affecting Turkey are generally westerly and they follow a southerly trajectory in winter, however, their trajectories become northerly towards summer. This study is continued to examine the changes in the cyclone sources. To achieve this CCSM4 MSLP fields are being used for the time intervals 1871-1900, 1961-1990, and 2071-2100.

TREND ON CONVECTIVE PRECIPITATION AND FLOODS IN THE SPANISH MEDITERRANEAN REGION

MC Llasat (1), M Cortés (1), A Del Moral (1), T Rigo (2), M Aznarez (1), B Aznar (3)

1) Dep. of Applied Physics, Univ. Barcelona, Barcelona, Spain
2) Meteorological Service of Catalonia, Barcelona, Spain
3) Barcelona Cicle de l'Aigua, SA, Barcelona, Spain

carmell@meteo.ub.edu

One of the major impacts of climate change seems to be the increase of heavy precipitation, as is pointed out by the Clasius Clapeyron equation (Alexander et al, 2006). There are some works that analyses the mechanisms that could justify the increase in the precipitation intensity associated to a warmer atmosphere. Some of them justify the increase in convective precipitation as a consequence of an increase of the CAPE due to warming and moistening of the atmospheric boundary layer. Other ones say that the increasing extremes and intensity in convective precipitation may be linked to the invigoration of clouds via feedback with more water vapor that intensifies the convective process. The aim of this presentation is to analyse the evolution of convective precipitation in the Mediterranean Spain, with a specific focus in the Metropolitan Area of Barcelona. To do this, 5-min precipitation series from 1996 to 2015 coming from more than 100 stations have been used. The intensity threshold of an average intensity of 35 mm/h in 5 min has been applied to characterize convective precipitation. Previously a regionalization has been done taking into account the precipitation characteristics. The β parameter, defined as the ratio between convective precipitation versus total precipitation in any period, has been analysed. Convective events have been related with floods (usually flash floods or surface water floods) in order to obtain any specific characteristic that could help to improve the early warning. The evolution of floods and precipitation has been analysed. Results do not show a common pattern but an increase of convective events has been detected in a wide region. Non climate factors that can affect the flood trend evolution have been also considered.

DENSIFYING THE RAINFALL DATA FOR THE LANDSLIDE HAZARD ASSESSMENT

M Samardzić-Petrović (1), M Marjanović (2), J Krušić (2), A Sekulić (1), B Abolmasov (2)

1) Fac. of Civil Engineering, University of Belgrade, Belgrade, Serbia
2) Fac. of Mining and Geology, University of Belgrade, Belgrade, Serbia

jelka.krusic@rgf.bg.ac.rs

Intensive and durable rainfall is one of the most common landslide triggers. The relationship between rainfall intensity and duration is what usually defines the landsliding threshold, for certain type of landslides (e.g. shallow slides). On the other hand, this relation is difficult to establish since the data sources require both, an impeccable landslide inventory with accurately dated events, as well as an hourly or sub-hourly rainfall repository. In this research, we will be focusing on the latter, and attempt to densify the rainfall data by using TRMM (Tropical Rainfall Measuring Mission) products. Its relatively coarse grid opens an opportunity to apply advanced spatial statistics interpolation techniques. The original grid centroids were used as interpolation points, whereas, ground truth for validating was used from the official Hydro-Meteorological Service of Serbia. The test area involves western Serbia as a pilot site affected by massive landsliding in 2010 and 2014. Namely, in 2014 many landslides occurred as a result of cyclone Tamara effect. In this extreme event, maximum, 72h precipitation was recorded in this region, exceeding 200 mm. Results are indicating that the rainfall-landslide thresholding can benefit from the spatial interpolation based densifying of the rainfall data, and can provide the basis for landsliding threshold definition, as well as for landslide hazard assessment map production.

CHANGES IN EXTREME PRECIPITATION REGIME IN THE BLACK SEA REGION (THE SOUTH OF RUSSIA)

E Vyshkvarkova (1)

1) Institute of natural and technical systems, Sevastopol, Russia

aveiro_7@mail.ru

According to the IPCC reports (Hartmann et al., 2013) since about 1950 the number of heavy precipitation events over land has increased in many regions and in the future extreme precipitation events will very likely become more intense and more frequent as global mean surface temperature increases. Such changes also apply to the Black Sea region. Daily precipitation data from 42 meteorological stations were used to calculated climate extreme indices in the Black Sea region (the south of Russia) for the 1970–2015 period. Data were taken from the website of the ECA&D. Data quality control and calculation of indices was performed by means of RClimDex software. Ten indices from the list of climate extreme indices recommended by the joint World Meteorological Organization (CCL/CLIVAR/JCOMM) Expert Team on Climate Change Detection and Indices (ETCCDI) were calculated. The resulting series of climate extreme indices were analyzed through trends. The results show statistically significant increasing trends in indices CDD (Consecutive Dry Days) over the Crimean peninsula and Sea of Azov coast. Decreasing trends of CDD are typical for the territory of the Caspian Depression. Increasing significant trends for CWD (Consecutive Wet Days) index were observed over the Crimean peninsula. Tendency to increase was found for PRCPTOT index, which describes the total annual amount of precipitation on wet days, on the Caspian Sea coast and in the territory of the Caspian Depression. The indices R10 and R20 are based on absolute thresholds (the number of very wet days). The indices show significant decrease in Crimea and significant increase in the territory of the Caspian Depression. Similar results were obtained for indices R95p and R99p (the 95th and 99th percentile of daily total precipitation).The analysis of station trend maps didn't show clear signal over study region for indices RX1day and RX5day (max 1-day and 5-day precipitation amount). Negative slope are dominate over the Crimean peninsula and positive ones in the territory of the Caspian Depression, but most of them is not significant. SDII (a simple measure of precipitation intensity) show significant decreasing over Crimean peninsula and a pattern of increase for the stations located in the territory of Caspian Depression. Analysis of climate extreme indices showed significant decrease over Crimean peninsula and significant increase in the territory of the Caspian Depression for intensity indices. In other territory mixed spatial patterns of nonsignificant negative and positive trends were found. The reported study was partly funded by RFBR according to the research project N° 18-35-00325.

VARIATIONS IN THE MOISTURE TRANSPORT FROM THE MEDITERRANEAN SEA DURING THE METEOROLOGICAL DROUGHT EPISODES OVER CENTRAL EUROPE

M Stojanovic (1), A Drumond (1), R Nieto (1), L Gimeno (1)

1) University of Vigo, Vigo, Spain

mstojanovic@uvigo.es

Central Europe is likely to experience a diverse range of impacts in response to climate change, with temperature increases and the variability of extreme events. Several authors have shown that precipitation deficit in combination with high evapotranspiration typically leads to a drought. The aim of this work is to analyze variations in the moisture transport from Mediterranean Sea (MDS) during the meteorological drought episodes occurred over the Central Europe (CEU) in the period 1980-2015. To identify the episodes occurred over CEU we calculated the Standardised Precipitation Evapotranspiration Index (SPEI) at 1-month time scale using monthly CRU (TS3.24.01) precipitation and potential evapotranspiration data set. The episodes were organized in two groups according to the month in which the respective onset was verified: summer (APR – SEP) and winter (Oct – Mar). From the 51 episodes identified for all the period, 22 episodes had their onset during the Summer, and 29 events in the Winter. A Lagrangian forward in time analysis was made to explore the major changes in the anomalous contribution from MDS to CEU during these episodes. Results revealed that for almost all drought episodes, negative anomalies of MDS prevailed. We applied T student test to the regression coefficient at 95% to see linear relationship and significance between MDS anomaly and severity, duration, intensity and peak value of the drought episodes. According to the regression analysis, there are significant linear relationship between severity, duration, peak value (winter season) and MDS anomaly. Nevertheless, we have not found a linear relationship between the intensity and peak value (summer season) of the drought episodes with the anomalies in the moisture contribution from MDS.

CLIMATE CHANGE, "NEW MERIDIAN ATMOSPHERIC CIRCULATION" AND EXTREME PRECIPITATION CAUSING FLOODS IN WESTERN MEDITERRANEAN

MS Karrouk (1)

1) University Hassan II, FLSH Ben M'Sick, LCEAT, Casablanca, Morocco

climdev.morocco@gmail.com

Thanks to satellite observation and daily monitoring of meteorological conditions for more than ten years, we have observed that the positive balance has shifted more towards the poles, mainly in the northern hemisphere. Subtropical anticyclones are strengthened and have extended to high latitudes, especially over the Atlantic and Pacific oceans. This situation creates global peaks strengthened in winter periods, and imposes on cosmic cold the deep advection toward the south under the form of planetary valleys "Polar Vortex".This situation imposes on the jet stream a pronounced ripple and installs a Meridian Atmospheric Circulation (MAC) in winter, which brings the warm tropical air masses to reach the Arctic Circle, and cold polar air masses to reach Western Mediterranean and Florida.This situation creates unusual atmospheric events, characterized by hydrothermal "extreme" conditions: excessive heat at high latitudes, accompanied by heavy rains and floods, as well as cold at low latitudes and the appearance of snow in the Sahara!The populations are profoundly influenced by the new phenomena. The socioeconomic infrastructures can no longer assume their basic functions and man when unprotected is weak and hence the advanced vulnerability of all the regions especially those belonging to poor and developing countries.The recent example of autumn 2014 and autumn-winter 2015-2016 reveals these conditions which left a deep psychological, economic and social impact on Moroccans in particular, and the Western Mediterranean in general.In autumn 2014, atmospheric conditions were marked by a stronger meridian atmospheric circulation, characterized by the persistence of high temperatures during this autumn period in Morocco, mainly south of the Atlas, combined with the intrusion of a drop cold at the beginning of the event on 17/11/2014, and the frank installation of a very deep planetary valley off the Moroccan coasts on 24/11/2014, which evolved in storm (Xandra) where the depression reached the surprising value of 975 hPa on 28/11/2014.These events, and other similar in Western Mediterranean area: floods of El Attaf, Ain Defla and M'sila in October 2007, Ghardaïa in October 2008, Algiers in October 2015 (Algeria), Tunis in October 2007, Sfax 2009 (Tunisia), Andaloucia (Spain) in December 2010, the Var (France) in June 2010, Genoa (Italy) in November 2011, ... etc., as well as many cases of floods, should be considered as reference laboratory case for the simulation of future situations, and integration into development plans in the future.

THE CONTRIBUTION OF THE MEDITERRANEAN SEA TO EXTREME PRECIPITATION EVENTS OVER THE DANUBE RIVER BASIN

D Ciric (1), R Nieto (1), AM Ramos (2), A Drumond (1), L Gimeno (1)

1) EPhysLab,Universidade de Vigo, Ourense, Spain
2) Instituto Dom Luiz, Universidade de Lisboa, Lisboa, Portugal

cdanica@uvigo.es

The Danube River Basin is the second longest river basin in Europe and the only river in the world receiving water from 18 countries and flowing through 10 countries. In recent few decades, the frequency and intensity of extreme daily rainfall have increased, and significant floods events occurred more frequently. These extreme precipitation events resulted in human causalities, economic losses, soil water availability, high water flows and other accompanying disasters. The periods of consecutive rainy days accompanied with huge amount of precipitation are in many cases the cause of the floods. The purpose of this work is to analyze the contribution of the Mediterranean Sea to extreme precipitation events registered over the Danube River basin during 1980-2015. Following a ranking method developed by Ramos et al. (2014; 2017) and using the daily high resolution (0.05º) Climate Hazards Group Infra-Red Precipitation with Station data dataset (CHIRPS, Funk (2015)) , we have made a ranking of the extreme events of precipitation (wet-spells) with different durations (1, 3, 5, 7 and 10 days) over the Danube River Basin, that was used in Ciric et al (2017) to analyzed the sources of moisture and synoptic situation for the most intense event. The aim of the present study is to analyzed the contribution from the Mediterranean Sea to the most intense wet-spells over the basin. So, we selected the 100 first cases in the ranking for all durations. From the outputs of the Lagrangian dispersion model FLEXPART V9.0 global running (and ERA-Interim dataset to run it) we followed forward all the particles that reside over the Mediterranean Sea and reach the Danube River basin. In this way we compute the moisture that generates precipitation over the basin coming from the Mediterranean Sea as (E-P) < 0 (herein, Pflex) for each event at different duration. Comparing these Pflex with CHIRPS precipitation data for each event, the percentage of total precipitation due to the moisture coming from the Mediterranean were calculated. The same analysis was done for the anomalies of Pflex and CHIRP precipitation.

WRF FORECASTING CAPABILITY OF A TROPICAL-LIKE CYCLONE IN THE IONIAN SEA

KC Douvis (1), N Politi (2), MP Mylonas (1), ID Polychroni (1), PT Nastos (1)

1) Lab Climatology and Atmospheric Environment, NKUA, Athens, Greece
2) Environmental Research Lab, NSCR Demokritos, Athens, Greece

nadiapol@ipta.demokritos.gr

The development and propagation of "medicanes", the tropical-like cyclones (TLCs) of the Mediterranean, have been studied by many researchers in recent decades due to their heavy impacts on infrastructure and even human lives in coastal areas. The Laboratory of Climatology and Atmospheric Environment, of National and Kapodistrian University of Athens, maintains an extreme weather database, including medicanes. In this context, the forecasting capability of WRF with respect to the TLC event "Zenon", that affected the Ionian Sea and parts of western Greece on November 18-19, 2017, is investigated. The study aims towards a better understanding of the thermodynamic structure of TLCs, as well as better simulating trajectories.Medicane "Zenon" developed in the northern part of the Ionian Sea, on Thursday November 16, 2017. Satellite imagery revealed the characteristic "eye" of clear sky when it approached the area south of Salento peninsula and west of Corfu. Then the TLC moved towards the western coast of Greece, causing winds gusts of 70 km/h and heavy rainfall and small floods in the region of Achaia, northwestern Peloponnese. The 31 km grid resolution data of ERA5 Reanalysis was dynamically downscaled to 9 km using the Weather Research and Forecasting (WRF) model. In order to select the optimum configuration a number of different physics configurations were applied and validated against observations from ground stations, soundings and remote sensing products. The aforementioned simulation will be compared with the 27 km grid resolution data of GFS forecast products. Also, the simulated trajectories were examined to those derived by EUMETSAT SEVIRI satellite. The findings of the performed analysis shed light on the shortcomings of the operational weather forecasts when a medicane develops. Acknowledgement: This study is under the project "Modelling the Vertical Structure of Tropical-like Mediterranean Cyclones using WRF Ensemble Forecasting and the impact of Climate Change (MEDICANE)" which is implemented through the Operational Program Human Resources Development, Education and Lifelong Learning" and is co-financed by the European Union (European Social Fund) and Greek national funds.

CLIMATIC FACTORS CONTROLLING THE GROWTH OF DECIDUOUS FRUIT TREES IN ISRAEL AND THE ASSESSMENT OF POTENTIAL CHANGES IN THE FUTURE, USING THE COSMO MODELS

M Kupermintz (1), H Saaroni (1), B Ziv (2)

1) Tel Aviv University, Tel Aviv, Israel
2) The Open University of Israel, Raanana, Israel

mkupermintz@gmail.com

Temperate fruit and nut trees (such as apple, peach, cherry and others) develop survival mechanisms to overcome winter cold stress, creating a yearly cycle of growth and dormancy. They require cultivar-specific chilling and heat requirements during the dormant period to produce economically viable yields. Timing and accumulation rate of chill and heat enable to predict the spring flowering timing. Hence, long-term phenological observations are useful to downscale atmospheric conditions to the local agriculture. The location of Israel on the border between Mediterranean climate and semi-arid climate limits the potential areas for deciduous growth. The risk of not fulfilling the chill requirements is high since the winter chill level is already close to its lower limit for successful yield. For that reason deciduous fruit trees are grown in Israel above heights of 600m (preferably closer to 1000m) in the Judean, the Galilean and the Golan mountains.No studies using trees phenology have been carried out in Israel to evaluate the response to variations in chill and heat accumulation rates. This study identifies the temperature variables, including accumulated chill portions and heat hours in the winter and spring and their temporal distribution that explain the flowering timing and yield of sweet cherry (Prunus avium) in Israel. First, the flowering dates of cherries of two cultivars, grown at the Golan Heights at 730m, are correlated with seasonal chill and heat accumulation between 1998 and 2017, using the Dynamic Model and a simple Growing Degree Hour (GDH) Model. No significant trend was found in the GDH, the minimum, the maximum and daily average temperatures for the winter season at the orchard location in the Golan Heights, for this period. In order to assess possible effects of climate change, we estimate winter chill and heat accumulation for the future (2050-2070), using two COSMO-CLM models with different resolutions (0.44° and 0.0715°), taken from the CORDEX-MENA domain, for the RCP4.5 scenario. The results will be presented. An increase of winter temperatures, i.e., a decline in winter chill, may become critical and may overcome the positive influence of an increase in heat accumulation even for the high mountains of Israel. Inadequate chilling may cause delays in flowering and leaf emergence and finally in fruit quality and yields. Identifying of such delays may serve as an early-warning indicator that the future productivity may be threatened by climate change. Assessments of this type may be used by growers, producers and policy-makers to develop adaptation strategies such as selecting adopted cultivars or changing the type of agricultural crop.

DROUGHTS FEEDBACK ON SUMMER HOT DAYS AND NIGHTS OVER THE MEDITERRANEAN

A Russo (1), C Gouveia (1,2), E Dutra (1), PMM Soares (1), RM Trigo (1)

1) Instituto Dom Luiz (IDL), FCUL, Lisbon, Portugal
2) Instituto Português do Mar e da Atmosfera, Lisbon, Portugal

acrusso@fc.ul.pt

The Mediterranean is often affected by extreme weather (EW) events [1], such as droughts and heatwaves, which are two of the most frequent EW events in the Mediterranean [1], having negative impacts on different economic and social activities [1]. Several studies have stressed the role played by recent climate change in the increase likelihood of occurrence of some of these extremes [1,2], with emphasis on the fact that temperature extremes are expected to occur more frequently [3]. A number of studies have put into evidence the existence of several positive feedback mechanisms between droughts and heatwaves, particularly in semiarid environments such as the Mediterranean [4,5]. Here, we propose to analyze if the occurrence of summer extremely hot days and nights in the Mediterranean is preceded by the occurrence of drought events in spring and early summer. This is assessed initially by computing the correlation coefficients between the number of hot days and nights in the regions' hottest months with a drought indicator in the prior months. The evolution and characterization of drought in the Mediterranean was performed using the Standardized Precipitation Evaporation Index (SPEI) and the Standardized Precipitation Index (SPI) for three different time scales (3-, 6- and 9-months), as obtained from CRU TS4.01 database for the period 1980-2014 with a spatial resolution of 0.5o. The number of hot days and nights per month (respectively NHD and NHN) is determined using the ECAD-EOBS daily dataset for the same period and spatial resolution (dataset v14). The most frequent hottest months in the Mediterranean are July and August and the magnitude of correlations obtained between detrended NHD/NHN and the preceding 3-months SPEI/SPI are usually higher than those attained for longer timescales. Most regions exhibit significantly negative correlations, i.e. high (low) NHD/NHN following negative (positive) SPEI/SPI values, and thus a potential for NHD/NHN early warning. Finally, spatial patterns of correlation values between the NHD/NHN with SPI and SPEI differ, with SPEI characterized by slightly higher values observed mainly for the 3-months timescale. References [1] Hov Ø et al., 2013. ISBN (electronic) 978-82-7144-101-2. [2] Sillmann J et al., 2013. J Geophys Res, 118, 2473–2493. [3] Fischer EM and Schär C, 2010. Nature Geoscience, 3, 398. [4] Seneviratne SI et al., 2010. Earth Sci. Rev. 99, 125–161. [5] Miralles DG et al., 2014. Nature Geoscience, 7, 345 Acknowledgements This work was partially supported by Fundação para a Ciência e a Tecnologia (Portugal) by the projects IMDROFLOOD (FCT, WaterJPI/0004/2014) and UID/GEO/50019/2013 - Instituto Dom Luiz. A.Russo thank FCT for the grant SFRH/BPD/99757/2014.

VARIABILITY OF THE UTCI INDEX IN SERBIA

MZ Lukic (1), DJ Filipovic (1), MM Pecelj (2), BM Protic (1)

1) University of Belgrade - Faculty of Geography, Belgrade, Serbia
2) University of E. Sarajevo,Department of Geography, Pale, East Sarajevo, Republic of Srpska

micalukic92@yahoo.com

Abstract: The main task of this paper is the assessment of bioclimatic conditions in Sebia. A special emphasis have been given to the heat budget bioclimatic Universal Thermal Climate Index (UTCI) whose purpose is to evaluate degree of thermal stress that human body is exposed to. In addition, the summer daily maximum temperatures are analysed in order to detect increase and frequency of heat waves during twenty years. For this research, daily and hourly (07h and 14h) meteorological data from 3 weather station (Mt. Zlatibor, Novi Sad, Nis) are collected for the period 1998-2017. Key words: Bioclimatic conditions, Universal Thermal Climate Index (UTCI),variability, heat waves

TORNADIC WATERSPOUT EVENT IN TIVAT (MONTENEGRO), JUNE 9, 2018-CASE STUDY

J Mihajlovic (1), D Buric (2), V Ducic (3), M Milenkovic (4)

1) Faculty of Geography, Belgrade, Serbia
2) Faculty of Philosophy, Niksic, Montenegro
3) Faculty of Geography, Belgrade, Serbia
4) GI , Belgrade, Serbia

millennijum@hotmail.com

Abstract: This paper presents the research results of synoptic and mesoscale weather conditions which created a favourable meteorological environment for a waterspout development in Tivat (on June 9, 2018, in the early morning hours (around 01 UTC, that is, 03 CET). Also, an analysis of atmospheric sounding measurements, radar and satellite images, has been carried out. Based on field survey analysis, damage estimates were undertaken to assess the tornado category by the Fujita scale (F-scale). Based on synoptic material analysis, there was too warm surface air which suddenly lifted up and cooled, with the atmospheric instability in the upper layers, that is, sufficient moisture and latent heat. Therefore, forecasting material indicated an abrupt development of thunderstorm clouds-cumulonimbus cloud (Cb) and a possible severe weather event. The forecast was almost completely accurate, which was proved by the analysis of SYNOP reports, satellite images and by the field damage estimates. Synoptic type for this situation was CLOSED-SW and was determined by a detailed examination of circulation on the AT 500 mb map, as well as by the position and characteristics of isobaric features in the upper levels and those at the surface. Further investigations of meteorological environment which leads to the development of waterspouts in the Adriatic Sea are needed in order to find more precise correlation between presented thermodynamic parameters and mesoscale synoptic situation. Key words: tornadic waterspout, synoptic types, instability indices, Tivat, Adriatic Sea

CLIMATE CHANGE IMPACTS ON SUMMER FIRES IN MEDITERRANEAN EUROPE

M Turco (1), J Bedia (2), S Jérez (3), MC Llasat (1), JP Montávez (3), A Provenzale (4), JJ Rosa Cánovas (3)

1) University of Barcelona, Barcelona, Spain
2) Predictia Intelligent data solution, Santander, Spain
3) University of Murcia, Murcia, Spain
4) National14 Research Council, Pisa, Italy

carmell@meteo.ub.edu

We present an assessment of future burned areas (BA) under different climate scenarios (1.5, 2 and 3°C warming) over the euro-Mediterranean area. We first built regional-scale regressions between summer BA and the Standardized Precipitation Evaporation Index (following and extending the study of Turco et al. 2017) and then we projected these relationships for different climate scenarios with and without taking into potential non-stationarities in the fire-climate relationships to a changing climate. BA projections are associated with large uncertainties, especially those related to climate drivers (here estimated using an ensemble of regional climate models). Despite these uncertainties, we find a robust increase in BA due to climate change and our results demonstrate that greater benefits would be achieved if warming is constrained well below 2°C, as expressed in the Paris Agreement (Turco et al. 2018). Turco, M., von Hardenberg, J., AghaKouchak, A., Llasat, M. C., Provenzale, A., & Trigo, R. M. (2017). On the key role of droughts in the dynamics of summer fires in Mediterranean Europe. Scientific reports, 7(1), 81. DOI:10.1038/s41598-017-00116-9 Turco, M., Rosa Cánovas, J. J., Bedia J., Jerez, S., Montávez, J. P., Llasat, M. C., Provenzale, A. Impact of climate change on summer fires in Mediterranean Europe at 1.5, 2 and 3°C warming. Nature Communications, in press.

THE EUROPEAN MEGA-HEATWAVE OF JUNE 2017

A Sánchez-Benítez (1,2), D Barriopedro (2), R García-Herrera (1,2), PM Sousa (3), RM Trigo (3)

1) Universidad Complutense de Madrid (UCM), Madrid, Spain
2) Instituto de Geociencias (CSIC-UCM), Madrid, Spain
3) Instituto Dom Luiz, Universidade de Lisboa, Lisboa, Portugal

dbarriop@fis.ucm.es

This work describes the exceptional mega-heatwave that affected western and central Europe in June 2017 as an example of summers with an earlier occurrence of record-breaking mega-heatwaves. To do so, we designed a novel algorithm that monitors mega-heatwaves by tracking the spatio-temporal evolution of extreme temperature patterns. The results indicate that the spatial extension, persistence and intensity of the June 2017 event were similar to those of top European mega-heatwaves of the reanalysis period. However, it occurred earlier than other well-known mega-heatwaves, such as that of 2003. The most affected area was southwestern Europe, where the event was the longest heatwave on record, causing the warmest temperatures from daily to seasonal scales, forest fires and human casualties. The mega-heatwave was associated with a record-breaking subtropical ridge in mid-June with signatures more typical of July and August, which caused an unprecedented subtropical warm air intrusion. Using the analogue method, we found that the recorded temperature anomalies were higher than those expected from past flow analogues. This was partially due to changes in circulation. However, thermodynamical changes of the last decades made a much larger contribution to the exceptionality of the event.

SESSION 5

Past, Present and Future change of Mediterranean-type climates

SUBTROPICAL JETS AND RAINFALL OVER CHILE AND WESTERN US IN RESPONSE TO PALEOCLIMATE FORCINGS

JCH Chiang (Invited) (1), SY Lee (2), F Lamy (3), JHC Bosmans (4)

1) University of California, Berkeley, USA
2) Academia Sinica, Taipei, Taiwan
3) Alfred Wegener Institute, Bremerhaven, Germany
4) Utrecht University, Utrecht, The Netherlands

jch_chiang@berkeley.edu

One of the pervasive ideas from paleoclimate studies is the meridional shift in the tropical rainband in response to interhemispheric contrasts. The question we ask is if there are subsequent changes to the atmopsheric circulation from the rainband shift: we audition the subtropical jet and its impact on Mediterranean rainfall climates as a direct consequence. A simulation imposing cooling in the North Atlantic - simulating a North Atlantic stadial - leads to a southward ITCZ displacement in the tropical Pacific and a weakening of the South Pacific subtropical jet and strengthening of the North Pacific subtropical jet; they in turn lead to reduced winter rainfall over subtropical Chile and increased rainfall over the western US. The changes to the South Pacific westerlies takes the form of a weakening of the South Pacific Split Jet, seen in today's interannual variability of the Southern Hemisphere wintertime westerlies. Changes to the North and South Pacific subtropical jets, and commensurate impacts on the winter rainfall over the subtropical western US and Chile, also occurs in coupled model simulation altering the phase of precession. However, the phasing of the response is somewhat counterintuitive, with the maximum subtropical jet over the South Pacific occurring when perihelion occurs during the Southern Hemisphere summer solstice, rather than during the Northern Hemisphere summer solstice. We attribute this behavior in part to the alteration of the phase of the Eastern Equatorial Pacific cold tongue with precession, and consequent impact on the South Pacific westerlies.

STORYLINES AND TIMESCALES OF FUTURE PRECIPITATION CHANGE IN MEDITERRANEAN REGIONS

G Zappa (Invited) (1)

1) University of Reading, Reading, UK

g.zappa@reading.ac.uk

Future changes in the atmospheric circulation can cause substantial socio-economic impacts, particularly by shifting the midlatitude storm-tracks poleward and by affecting precipitation patterns. However, the confidence in the atmospheric circulation response remains low, and multi-model ensemble projections of precipitation change cannot be interpreted in a probabilistic way. The presentation will highlight how different remote drivers of mid-latitude atmospheric circulation are important in shaping the precipitation response to climate change, and how understanding these processes is central to increase confidence in the Mediterranean regional climate projections. This will be explored by examining both the uncertainty in the transient response to climate change in the CMIP5 models future projections, and the equilibration of the circulation and precipitation responses once CO2 concentrations are stabilised. In particular, storylines will be developed where the Mediterranean precipitation response per degree of global warming is conditioned on the response in different remote aspects of climate. This will enable to identify worst case scenarios and evaluate the impact of different global warming targets. However, the dependence of the mid-latitude circulation response on global warming changes dramatically once CO2 concentrations are stabilised, a behaviour that is linked to the presence of different fast and slow components in the oceanic surface temperature response to greenhouse forcing. The implications of these different timescales for the hydro-climate response across the different Mediterranean type climates will be discussed.

SEASONAL SHIFTS IN THE MEDITERRANEAN TYPE CLIMATES

J Lukovic (1), JCH Chiang (2)

1) University of Belgrade, Belgrade, Serbia
2) UC Berkeley, Berkeley, USA

jlukovic@gef.bg.ac.rs

The Mediterranean hydroclimate is strongly seasonal and recent changes in climate trends have had considerable economic and environmental impacts. Shifts in seasonal cycles, exhibited by the early occurrence of spring, have been mainly studied from the temperature-driven perspective. However, questions regarding precipitation-driven seasonal changes remain open despite the fact that some of the regions experiencing Mediterranean type climate will face persistent megadrought in the future. In this study we explore and compare precipitation seasonality shifts of two regions: Western US and Mediterranean basin, by analyzing trends from past decades. Are there shifts in precipitation seasonality? What are the climate dynamics underpinning these changes? Are there changes in the onset and termination of rainy season? This study focuses on developing a fundamental understanding of hydroclimate dynamics behind precipitation seasonality shifts over the two regions with respect to the recent past. Knowing these shifts in advance can help water managers optimize reservoir operations and efficiently address competing demands, such as irrigation, environmental needs, and power generation. Due to analogies in climate between California and Mediterranean basin, a key study goal is to bridge the US and EU hydroclimate research and synergize with the European Horizon 2020 flagship initiative in Climate Action, Environment, Resource Efficiency and Raw Materials.

CLIMATE VARIABILITY AND CHANGE IN MEDITERRANEAN-TYPE CLIMATES

R Seager (1), TJ Osborn (2), Y Kushnir (1), H Liu (1), J Nakamura (1)

1) Lamont Doherty Earth Observatory of Columbia U., Palisades, USA
2) Climatic Research Unit, UEA, Norwich , UK

seager@ldeo.columbia.edu

Mediterranean-type climates are defined by temperate wet winter and hot or warm dry summers and exist at the western edges of five continents in locations determined by the geography of winter storm tracks and summer subtropical anticyclones. Here the climatology, variability and long term changes in winter precipitation in Mediterranean-type climates are analyzed as well as the mechanisms for model-projected change in the near-term future. Despite their commonalities in terms of location in the context of planetary scale dynamics, the causes of variability are distinct across the regions. Only in California and Chile is ocean-forcing of variability a notable influence. Instead in all Mediterranean-type climate regions, internal atmosphere variability is the dominant source of winter precipitation variability but only the the Mediterranean is this clearly related to annular mode variability. As a consequence potential predictability of winter precipitation variability in the the regions is low. In all regions, the trend in winter precipitation since 1901 is markedly similar to that which arises as a response to changes in external forcing in the models participating in Coupled Model Intercomparison Project Five. All Mediterranean-type climate regions except California are drying and the models project further drying over coming decades. In the northern hemisphere dynamical processes are responsible: development of a winter ridge over the Mediterranean that suppresses precipitation and of a trough west of the North American west coast that shifts the Pacific stormtrack equatorward. In the southern hemisphere thermodynamic changes are important that enhance zonal dry advection into Mediterranean-type climate regions due to a minimum in vertically integrated water vapor change at the coast of the MCRs.

CAN FUTURE SEA ICE COVER CHANGES AFFECT PRECIPITATION OVER CALIFORNIA?

I Cvijanovic (1), BD Santer (1), DD Lucas (1), C Bonfils (1), JCH Chiang (2), S Zimermann (1)

1) Lawrence Livermore National Laboratory , Livermore, USA
2) University California Berkeley, Berkeley, USA

ivanacbegg@gmail.com

Dramatic loss of Arctic sea ice cover since the beginning of the satellite era has intensified the interest into whether these high latitude changes can significantly influence the weather and climate far from the Arctic. Many attempts to demonstrate statistically significant remote responses to sea ice changes have been hindered by factors such as large high latitude variability, relatively short observational datasets, and model limitations in adequately representing current sea ice changes. We sample uncertainty in sea ice physics parameters and variability in atmospheric initial conditions to obtain an ensemble of simulations with substantially different states of Arctic cover. This large ensemble isolates a robust, statistically significant climate response arising from changes in sea ice cover only. The key novelty of our setup is that unlike previous studies that impose artificial energy fluxes to achieve sea-ice loss, our sea-ice parameter perturbations allow for energy budget conservation. In this manner we are able to ensure that the observed atmospheric response really originates from the sea-ice changes and that it is not altered by spurious energy flux perturbations. Our results show link between Arctic sea-ice loss and the North Pacific geopotential ridge development. In a two-step teleconnection, sea-ice changes lead to reorganization of tropical convection that in turn triggers an anticyclonic response over the North Pacific, resulting in significant drying over California. These findings suggest that the ability of climate models to accurately estimate future precipitation changes over California is also linked to the fidelity with which future sea-ice changes are simulated. We conclude that sea-ice loss of the magnitude expected in the next decades could substantially impact California's precipitation, thus highlighting another mechanism by which human-caused climate change could exacerbate future California droughts.
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CHANGES IN RECENT SYNOPTIC METEOROLOGICAL PATTERNS IN NORTH-WESTERN MEDITERRANEAN IN COMPARISON WITH 1871-1980 CLIMATE VARIABILITY

V Altava-Ortiz (1,2), A Barrera-Escoda (1), A Sairouni (1)

1) Meteorological Service of Catalonia, Barcelona, Spain
2) Forest Fire Prevention Service, Santa Perpètua de la Mogoda, Barcelona, Spain

vicent.altava@gencat.cat

The study of last few decades climate variability is of special relevance, not only to match recent precipitation and temperature anomalies with climate patterns anomalies, but also to find possible attribution of those changes according to the synoptic patterns changes suggested by Earth System Models. So that, the main objective of our study is to compare and contextualise recent climatic variability (1981-2017) in Western Mediterranean region, with that took place in a previous long reference period (1871-198). The NOAA twentieth Century Reanalysis Project v2(1871-2017) and NCEP-NCAR reanalyses (1948-2017) have been considered for this goal. In order to characterize climatic variability in the region, daily meteorological patterns of sea level pressure and geopotential height at 700 hPa has been classified for the 1948-2009 period using an Objective Classification Procedure based on a Self Organising Map(SOM) in a 4-D neural network. SOM has been used as the principal technique to reduce the climate variability complexity, thus this methodology allows getting a compromise between keeping low frequency patterns while reducing the degrees of freedom of the system. This process has been carried out each month separately, so as to obtain the inter-annual evolution of each synoptic pattern. As a result of the classification process, 33 weather types has been obtained, which in turn, can be grouped into anticyclonic, cyclogenic, westerly, easterly and blocking patterns. The frequency and temporal evolution of those patterns has been evaluated along the 1871-2017 period. The results obtained revealed that some weather patterns anomalies during the 1981-2017 period have no comparison in terms of duration and/or intensity in the preceding 1871-1980 records. Concretely it is observed an increase in almost all Anticyclonic related patterns during winter(NDGF) and late spring(MJ) and a diminution in the number of cyclonic types during winter and spring(AMJ), especially those related to Atlantic Cyclogenesis. Also strong decadal variability is well identified in the Mediterranean Cyclogesis types and cold advection types from Northern and Eastern Europe.

SESSION 6

Societal impacts of climate change in the Mediterranean region

WHAT IF POLICY DOES NOT LEVERAGE CLIMATE CHANGE ADAPTIVE CAPACITY? A CROSS-SECTIONAL ANALYSIS ON EUROPEAN FARMERS

SV Passel (Invited) (1)

1) University of Antwerp, Faculty of Applied Economics, Department of Engineering Management

steven.vanpassel@uantwerp.be

Agriculture suffers significantly from changes in weather and climate conditions, which increases risks in farm survival and food security. Adaptability of farming systems to a variety of changes is therefore very important as it determines the residual impact of climate change. Cross-sectional studies are the only type of studies that take into account full adaptation when examining the effects of climate change on agriculture. These studies assume that adaptation occurs autonomously, giving policy makers the impression that adaptation is the solution to tackle climate change effects. However, the degree of autonomous adaptation is dependent on the level of a farm's adaptive capacity. This adaptive capacity differs greatly between European member states, and policy incentives to increase climate change adaptive capacity are necessary. This paper therefore quantitatively shows the importance of adaptive capacity by accounting for it in a cross-sectional regression. Southern and Eastern European regions show significantly larger effects of climate change, and investments in climate change adaptive capacity are clearly needed. However, the relationship is nonlinear, implying that generic adaptive capacity will not continue increasing climate responsiveness and that investments in specific adaptive capacity are necessary.

ADAPTING AGRICULTURE TO CLIMATE CHANGE: MORE REALISTIC EVALUATIONS NEED TO TAKE ACCOUNT SPATIAL DIFFERENCES IN THE PEOPLE-CLIMATE INTERACTIONS

A Iglesias (1), L Garrote (1), D Santillan (1)

1) UPM, Madrid, Spain

ana.iglesias@upm.es

Effective adaptation to climate change require impact and response scenarios. Although climate and agricultural impact scenarios are based on the evaluation of spatially heterogeneous system, conventional response scenarios do not account for variation in the people-climate interactions. These interactions are often extremely heterogeneous and unevenly distributed in space, leading to errors in the adaptation needs and plans, especially in large areas. Here we develop a novel framework for adaptation that accounts for the heterogeneity of people response to climate, and apply the concept to adaptation of agriculture to climate change in the Mediterranean region. By incorporating spatially explicit information on farming systems, management practices, and agricultural ecosystem services, this approach may contribute to adaptation policy. The approach is composed of three modules: (a) An impact module that characterises the potential consequences of climate change for major agricultural ecosystem services (production, greenhouse gas emissions, and water savings). (b) A response module that statistically evaluates the people-climate interactions (in terms of farming systems and management practices), upscaling local or aggregated information. (c) An adaptation module that combines the results of the impact and response modules across space, and defines adaptation needs. This new approach is applied in the Mediterranean region, that is characterised by large heterogeneity of terrain, farming systems, and socio-economic characteristics. It considers that people response to climate change is spatially heterogeneous, facilitating a more insights into adaptation planning.

VULNERABILITY TO CLIMATE VARIABILITY AND CHANGE: CASE STUDIES FROM TUNISIA AND CROATIA

A Markandya (1), N Halouani (2), S Petit (3)

1) Basque centre of climate change, Leioa, Spain
2) Faculté Sciences de Tunis, Tunis, Tunisia
3) PAP-RAC, Split, Croatia

anil.markandya@bc3research.org

The paper reports two studies one climate variability and climate change: one for the coastal zones of Tunisia and one for the county of Sibenik-Knin in Croatia. Each case study looks at the data on past and projected vulnerability of the economy and society to climate variability and change. It assesses what actions are feasible to address the identified impacts and how well supported these actions are from the data and knowledge at our disposal. The comparison draws some lessons on the differences between the two countries in terms of knowledge base, institutions and actions that can be justified at the present time. Data gaps are identified in each case, so that more effective planning can be made in the future.

RESPONDING TO CLIMATE VARIABILITY AND CLIMATE CHANGE: TWO CASE STUDIES FROM THE MEDITERRANEAN

A Markandya (1), N Halouani (2), S Petit (3)

1) Basque centre of climate change, Leioa, Spain
2) Faculté Sciences de Tunis, Tunis, Tunisia
3) PAP-RAC, Split, Croatia

anil.markandya@bc3research.org

The paper reports on two case studies carried out to assess the social and economic impacts of climate variability and change in the Mediterranean: The coastal zones of Tunis and the county of Sibenik-Knin in Croatia. In each case state of the knowledge on impacts of climate variability and change was reviewed and used to see how far adaptation actions could be supported by that knowledge. A comparison of the two case studies reveals the differences in terms of knowledge base, institutions and capacity for effective action. Based on that recommendations for further support and action and identified to make climate adaptation more effective.

EVALUATION OF VARIOUS BIAS CORRECTION METHODS FOR MEDITERRANEAN AGRO-CLIMATE PROJECTIONS: FIRST RESULTS FROM THE MED-GOLD PROJECT

C Giannakopoulos (1), KV Varotsos (1), A Karali (1), M Gratsea (1)

1) National Observatory of Athens, Athens, Greece

cgiannak@noa.gr

Horizon 2020 Med-Gold is an EU funded project which aims to make European agriculture and food systems more competitive, resilient, sustainable and efficient in the face of climate change, by using climate services to minimize climate-driven risks/costs and seize opportunities for added-value. The ongoing project aims to demonstrate the proof-of-concept for climate services in the agriculture sector by developing case studies for three staples of the Mediterranean food system: grape, olive and durum. One of the early tasks of the project is the quantification of the uncertainty and the skill of climate data. In this study we focus on the climate change impacts on the olive sector using a set of four RCM simulations carried out in the framework of EURO-CORDEX (Coordinated Regional Climate Downscaling Experiment) under the RCP4.5 and RCP8.5 future emissions scenarios were used. However, the initial evaluation analysis revealed high deviations between the simulations and the available gridded reference data set (ERA-40, UERRA reanalysis and/or AgMERRA) for temperature (both daily maximum and daily minimum) and precipitation. Therefore, a set of different bias correction techniques were analysed for the aforementioned variables. The evaluation analysis between the bias corrected timeseries and the reference data set revealed that not all techniques can adequately capture the annual cycle and interannual variability of temperature and precipitation. Moreover, a number of climate threshold indices specifically tailored, within the LIFE Adapt2clima project, for the different phenological stages of the olives, olive production and crop quality as well as olive‘s survival were examined. For instance, for temperature (both daily maximum and daily minimum) only two out of the four examined bias corrected techniques were capable to capture the mean number of days with daily maximum temperature higher than 30oC which is related to the olive's flowering and the number of days with daily maximum temperature lower than -3 which is related to the late frost especially during spring. In addition, the higher the interannual variability of the observed variables the lesser the raw model output seems to be corrected.

WHAT EMERGED BEACH ANALYSIS CAN TELL ABOUT THE VULNERABILITY OF THE WHOLE SYSTEM: INFORMING ADAPTATION TO CLIMATIC CHANGE ON BEACHES OF CATALONIA, SPAIN.

J Lascurain (1)

1) SGM sl, Barcelona, España

lascurain@sgm.es

Mediterranean beaches are characterized by lack of sand, microtidal regime, and a very intensive social and economic use; therefore they are very vulnerable to climate change driven impacts like sea level rise and increase of storm intensity. So there is an urgent need of instruments to measure vulnerability; assess existing management practices, and inform a more efficient daily management practice. We propose a LIDAR-based instrument to identify dysfunctional beach stretches, its vulnerability to climatic change, and inform evidence-based management systems in order to adapt Mediterranean beaches to climatic change. Currently, the most widely-used information sources are numerical models that simulate the hydrodynamic and morphodynamic processes that govern sediment availability and predict the impacts produced by storms. Regarding beach management, these models have three main flaws. (1) Some relevant factors are undetectable to numerical models; the most relevant being aeolian sand transport and its interactions with human activity. (2) There are wide information gaps along the Mediterranean coast, because of the need of long-term data (preferably more than 20 years) provided by expensive sensors, like directional wave buoys. Lastly, (3) as numerical models are optimized to explain what happens in the course of extreme events, it is difficult to inform daily beach management, urban planning, and give clues to adapt to climatic change. The vertical accuracy of LIDAR data can be re-calibrated by comparing elevation values obtained by other sources, so reducing mean error and giving RMS values as low as 8 cm. The differentiation of the LIDAR data in a set of equal length cells (usually 100 m) leads to the transformation of the beach in a sequence of points containing three-dimensional information. To assess the efficiency of this instrument, we studied two different beach cells (with different sand grain diameters and morphodynamic beach states) at Catalonia, NE Spain. Some of the most relevant outcomes were the following: • The scatterplots of beach width and volume and also when comparing beach volume and average slope, showed characteristic patterns that change with sand grain diameter. • The analysis of outliers led to rapid identification of dysfunctional hot-spots and its causal processes. • Volume of emerged sand and average beach slope provide reliable spatial-explicit information of vulnerability. • Analysis and comparison between different LIDAR flights, and its correlates with well-known formulations for wave run-up and horizontal maximum wave reach for different return periods, can lead to reliable short-term scenarios. As a final conclusion, LIDAR data constitute a cheaper, faster and with increasing accuracy source of information that can help to fill the information gap along the Mediterranean coast, and provide much of the needed information to adapt to climate change.

USING A COASTAL URBAN CHANGE MODEL TO DEVELOP SPATIALLY EXPLICIT URBANIZATION SCENARIOS FOR THE MEDITERRANEAN

C Wolff (1), AT Vafeidis (1), G Vafeidis (1)

1) Kiel University, Kiel, Germany

wolff@geographie.uni-kiel.de

The rate and pattern of urban expansion will be one of the key determinants of future coastal flood risk in the Mediterranean. This study explores how exposure to coastal flooding could change in the future due to varying urbanization patterns. For this purpose, we develop a new set of spatially explicit coastal urbanization projections that are consistent with the global urbanization projections for the Shared Socioeconomic Pathways (SSPs). To forecast plausible future urbanization changes spatially, we develop an Urban Change Model which uses a machine learning approach, namely Artificial Neural Networks (ANN), for modelling urban development. The model employs simple parameters as proxies for processes that drive urban coastal development (e.g. distance to coast, elevation, slope, roads, or population density) and estimates the likelihood of urban transformation for every grid cell. We then classify the outputs of the ANN model according to the global urbanization projections for the SSPs (from Jiang and O'Neill (2017)) to develop spatially explicit coastal urbanization projections. These projections are then employed for calculating future exposure to coastal flooding for a range of sea-level rise scenarios. Preliminary results indicate that considering the spatial patterns of coastal development can lead to significant differences in the assessment of future exposure and should be considered in long-term adaptation planning.

UNESCO WORLD HERITAGE AT RISK FROM COASTAL FLOODING IN THE NORTHERN ADRIATIC SEA – COMPARISON OF INUNDATION MODELLING APPROACHES

L Reimann (1), AT Vafeidis (1)

1) Department of Geography, Kiel, Germany

reimann@geographie.uni-kiel.de

UNESCO World Heritage sites (WHS) located in coastal areas are increasingly at risk from coastal flooding due to accelerated sea-level rise (SLR). So far, limited work has been conducted on assessing the impacts of SLR on WHS, leaving stakeholders and policymakers with little information on adaptation needs. A recent regional assessment for the entire Mediterranean region found up to 85 % of cultural UNESCO WHS located in low-lying coastal areas to be at risk from a 100-year storm surge until 2100, depending on the SLR scenario considered. Further, flooded area and flood depth at WHS increased with SLR (Reimann et al. in review). This regional scale study employed a simple approach for modelling coastal inundation ('bathtub method', BT). In the present study, we compare different approaches for assessing inundation characteristics for selected WHS along the northern Adriatic Sea, which are among the WHS most at risk from coastal flooding, and assess exposure to the same surge heights using a hydrodynamic modelling approach (HD). Preliminary results confirm previous findings, suggesting that the flood extent of a HD approach is smaller than that of the BT approach, with a particularly high difference in mildly sloping terrains. Differences in flood extent seem to be less pronounced in steep terrains. The results of this study provide insights into how regional assessments relate to results produced using more detailed data and modelling approaches at local scale and to what extent the former can inform policy or management decisions regarding adaptation strategies at WHS. Reimann, L, Vafeidis, AT, Brown, S, Hinkel, J, Tol, RSJ (in review): Mediterranean UNESCO World Heritage at risk from coastal flooding and erosion due to sea-level rise. In Nature communications.

CLIMATOLOGY OF EXTREME RAINFALL EVENTS AND THE WATER HARVESTING POTENTIAL IN EGYPT

M Baldi (1), DM Amin (2), IS Al Zayed (2), G Dalu (1,3)

1) CNR-IBIMET, Rome, Italy
2) WRRI, El Qanater El Khayreya, Egypt
3) Accademia dei Georgofili, Florence, Italy

m.baldi@ibimet.cnr.it

The whole Mediterranean is suffering today from the impacts of climate change, and impacts are projected to be even more dramatic in the next decades. Egypt, on the southern border of the Mediterranean, is one of the Countries which already suffer due from water, food, and health problems, and the effects are even more exacerbated due to the arid climate conditions that characterize the Country. The largest water resources for the Country are from the river Nile (about 97%), and the rest is from (winter) rain and non-renewable ground water aquifers. In more recent years another important source is represented by non-conventional water, such as treated wastewater reuse and desalination, which are increasingly becoming an additional contributor to water availability. Although Egypt has limited rainfall, some studies have shown that a significant amount of water from rainfall and flash floods is available. Heavy rainfall and flash floods are responsible for huge losses of lives and infrastructure specially in parts of the Country, despite the semi-arid/arid/hyper-arid climate, and, on the other side, contribute to the discharge of river Nile, and, if opportunely conveyed and treated, can also represent a source of fresh water. In order to evaluate the water harvesting potential in semi-arid, water scarce and flashflood prone, areas of Egypt, a climatology of rainfall events and flash floods is presented and, in order to provide indications useful for improving the forecast of the phenomenon, results are presented of the dynamics of some selected episodes: their generation and evolution relatively to larger scale patterns. If the climatological study will provide useful information needed to identify and implement appropriate conservation measures for archaeological sites, better forecast will, in turn, help to evaluate the flash flood water volumes at the outlets of the effective watershed(s), and this information will help policy makers and local governments to define strategies and measures for water harvesting and/or protection works.

JOINT PROBABILITY OF DROUGHTS AND WHEAT YIELD ANOMALIES IN IBERIA

AFS Ribeiro (1), A Russo (1), C Gouveia (2), P Páscoa (1), CA Pires (1), RM Trigo (1)

1) Instituto Dom Luiz (IDL), Lisbon, Portugal
2) Instituto Português do Mar e da Atmosfera (IPMA), Lisbon, Portugal

ribeiroandreia@outlook.com

Extreme weather events, such as droughts, are major sources of risk to agricultural systems, often entailing substantial crop failures. An enhanced assessment of drought-related damages in croplands is crucial, particularly in the Mediterranean regions recurrently affected by dry episodes. This work aims to develop a multivariate probabilistic model using copulas to contribute to agricultural drought risk management and consequently attempt to prevent crop losses. The main target is to estimate the likelihood of drought risk in rainfed cropping systems. Drought impacts are assessed by wheat yield anomalies during 1986-2012 in the Iberian Peninsula (IP). Drought hazard is evaluated using the hydro-meteorological drought index SPEI (Standardized Precipitation Evapotranspiration Index) and the satellite-based indices VCI (Vegetation Condition Index), TCI (Temperature Condition Index) and VHI (Vegetation Health Index). This study adopts a bivariate modelling approach using Elliptical (t-copula) and Archimedean (Clayton, Frank and Gumbel) copulas, and the selection of the most suitable copula function is performed based the Akaike's Information Criteria (AIC). The copula-based approach is carried out in two steps: first the copula fits are estimated using the whole time-series and afterwards during different climatic conditions, differentiating drought and non-drought years. A good agreement is found between the bivariate copula simulations and the observations, pointing to an overall good performance of the selected copula functions and their ability in estimating the joint behaviour between yield and droughts. The results suggest that the Archimedean copulas provide the best statistical fits of the joint probability distributions in most of the cases. These findings support that, in general, the relationship between wheat yields and drought conditions is described by an asymmetric dependence in the tails of the joint distributions. The generated probability distributions of yield using the established copula models suggest relevant risk levels of wheat under drought conditions in the major agricultural areas of the IP. From an operational point of view, the results aim to contribute to the decision-making process in agricultural practices in the IP, particularly to assist farmers in deciding whether to purchase crop insurance and managing the adequate number of employees. Acknowledgements: This work was partially supported by Fundação para a Ciência e a Tecnologia, Portugal by the projects IMDROFLOOD funded (FCT, WaterJPI/0004/2014) and by UID/GEO/50019/2013 - Instituto Dom Luiz. Ana Russo and Andreia Ribeiro also thank FCT for grants SFRH/BPD/99757/2014 and PD/BD/114481/2016, respectively.

BIOMETEOROLOGICAL CONDITIONS RELATED TO RESPIRATORY ADMISSIONS IN CRETE ISLAND, GREECE

AG Bleta (1), PT Nastos (1)

1) National and Kapodistrian University of Athens, Athens, Greece

ableta@geol.uoa.gr

The objective of this study is to assess and analyze the human bioclimatic conditions in Heraklion city, Crete Island, Greece and quantify the association between these conditions with daily counts of admissions for respiratory problems, during the study period January 1, 2008 to May 31, 2013. Crete Island is located in a climatic sensitive area affected by frequent Saharan dust episodes, specifically during late winter and spring, when favorable synoptic meteorological conditions appear. Furthermore, the geomorphology of the island and Föhn winds cause adverse bioclimatic conditions. The latter combined with the ambient air pollution in the urban environment cause a high risk in public health. The thermal environment is analyzed by means of the Physiologically Equivalent Temperature (PET) and Universal Thermal Climate Index (UTCI), which are two of the most popular human thermal indices based on the human energy balance. Throughout the study period, 34350 emergency respiratory admissions have been recorded, and classified by gender. Asthma, chronic obstructive pulmonary disease (COPD), chronic bronchitis, emphysema, allergic rhinitis and decrease of lung function have been identified as respiratory disorders based on ICD-9 codes. Generalized Additive Models (GAM) have been applied to investigate the association of weekly counts of outpatients with cardiovascular admissions against bioclimatic conditions, after controlling for possible confounders and nonlinear variations. Air temperature, cloudiness and PET Index found to be statistically significant with all types of respiratory admissions. Our findings have given evidence that a negative correlation between hospital admission for respiratory diseases and cold weather exists and this association seems to be stronger in females ($p<0.01$). Also, both males and females are vulnerable to mean daily air temperature drop; namely, 1oC decrease in mean daily air temperature is associated with 2.8% increase in hospital admissions for respiratory problems and this impact appears up to 3 days later.

ASSESSING GROUNDWATER QUALITY OF CR(VI) IMPACTED WATER BODIES ALONG CLIMATE GRADIENT FROM CENTRAL- EAST MEDITERRANEAN TO OMAN.

K Pyrgaki (1), A Argyraki (1), M Hatzaki (1), E Kelepertzis (1), F Botsou (1), I Megremi (1), L Di Palma (2), M Paternoster (3), A Zissimos (4), A Christou (5), Z Hatipoglu Bagci (6), D Moraetis (7), D Dermatas (8)

1) National and Kapodistrian University of Athens, Athens, Greece
2) University of Rome 1, Rome, Italy
3) University of Basilicata, Bacilicata, Italy
4) Geological Survey Department, Nicosia, Cyprus
5) Agricultural Research Institute, Nicosia, Cyprus
6) University of Mersin, Mersin, Turkey
7) Sultan Qaboos University, Muscat, Oman
8) National Technical University of Athens, Athens, Greece

konstantinapyrgaki@gmail.com

Freshwater resources are directly linked to both ecological services and human development, while water quality has been recognized as a water management problem with great sensitivity to climatic variability and change as early as the 1980's. Specifically, groundwater quantity and quality can be directly affected through changes in precipitation, evapotranspiration, recharge rates, and indirectly through changes in land use, irrigation and other human activities. In the present collaborative research within the frame of the ERANETMED CrITERIA project, we assess real situation data from case study areas following a gradient from relatively wet to dry conditions. A common feature of the studied groundwater bodies is the presence of geogenic Cr(VI) which is linked to ophiolithic rock occurrences. Water samples were collected from central and eastern Mediterranean countries including Italy, Greece, Cyprus and Turkey. The effect of dry climate conditions on groundwater quality was also examined by using Oman as the arid end member. The quality characteristics of the studied water bodies have been assessed using a standardized sampling protocol within the same time frame. From a climate change perspective an overview of the present conditions and possible future changes has been assessed based on CORDEX experiment simulations under RCPs 4.5 and 8.5 after further downscaling over the case study areas providing high spatial resolution information. From the inter-comparison of the results among the case studies, the contrast of the diverse needs on water management in the Mediterranean can be drawn, while possible common messages related to the projected future changes on water resources can be identified.

COMBINING COASTAL MORPHOLOGY, EXPOSURE AND HAZARD FOR DISCUSSING FUTURE RISKS POSED BY MARINE STORMINESS ALONG THE MEDITERRANEAN COASTLINE

P Lionello (1,2), D Conte (2), L Marzo (1)

1) DISTEBA, Univ. of Lecce, Italy
2) CMCC, Lecce, Italy

piero.lionello@unisalento.it

The assessment of risk results from the combination of hazard, exposure and vulnerability. Here we try to use a new dataset containing information on exposure and vulnerability and to combine this information with projection of future changes of sea level extremes, wave height and direction, sea level. A former set of multi-decadal regional projections is available for the description of the likely future changes of regional marine storminess and their uncertainty depending on emission scenario, climate model and inter-decadal variability as made available by past projects (CIRCE, RISES-AM). Results show a widespread and progressive future reduction of marine storminess in the Mediterranean Sea, with a clear climate change signal in spite of uncertainties associated with interdecadal variability and differences among the regional sea level and wind fields provided by climate models. Sub-regional projections of mean sea level evolution are still uncertain and the level at which the different parts of the Mediterranean will deviate from the global mean sea level rise is a scientific topic that is presently debated. However, a tentative superposition of hazard level changes, morphology and exposure is here presented and it shows the key role of coastal morphology and exposure in determining the risk, to a large extent increasing it in present critical areas (North Adriatic, Gulf of Gabes, Nile Delta …).

PARTICIPATORY APPROACH FOR INNOVATION IN SPATIAL PLANNING PROCESS IN THE CONTEXT OF CLIMATE CHANGE IN SERBIA

M Pantić (1), M Nenković-Riznić (1), S Milijić (1)

1) Institute of Architecture and Urban Planning, Belgrade, Serbia

marijanap33@yahoo.com

Starting from the global concern organisations, such as the UN, the climate change represents one of the main contemporary challenges and focuses. The UN General Assembly adopted the 2030 Agenda for Sustainable Development, defining, among others, the goal that calls for taking prompt actions in order to deal with climate change and its consequences. Even sooner, the Territorial Agenda (2011) rises up as one of the European documents showing concerns about climate change risks and its potential development opportunities. However, the topic of alteration of climate has become increasingly important already in 1990s, when it was determined that climate change is not result of only natural causes, but it is additionally accelerated by human activity. In this course of events, the topic of climate change was introduced into the spatial planning of Serbia in 2010, by a modest pursuit under the "Climate Change Impacts" title in the Spatial Plan 2010-2020. Although the introduction of the topic into Serbian spatial planning could have been more elaborate, this was relevant innovation and announcement that climate change might be reflected in further decision-making and planning processes. Since that adoption of the next spatial plan of Serbia is expected in 2021, the main aim of this article will be to draw out lessons for the future, by examining existing role of spatial planning in addressing environmental and social impacts, responses and spatial planning instruments regarding the climate change. It will highlight recommendations on relativization of socio-economic and environmental conflicts that should contribute to preparation of upcoming and reconsideration of existing spatial plans at national and regional level, as well as to model decision-making quality – not only in Serbia, but to the Balkan-Mediterranean region that shares climate and challenges. The aimed results are to be obtained by revision of leading national and regional spatial documents in Serbia (national and regional spatial plans in Serbia, with their Implementation Programs, and instructions for Serbian Climate Change Strategy with its Action Plan, and Strategic Impact Assessment that are currently in preparation process), also addressing other EU regions. The main results are expected from communication with representatives of chosen local communities affected by direct climate change impacts (land-slides, hail, flood, drought, precipitation and water flow extremes, etc.) and the representatives of the ministries responsible for spatial planning, environment, etc. The participatory approach in this research will bring more profound results, as well as inspire decision-makers and planners to integrate societal perspective and impacts of climate change the way it corresponds to characteristics and vulnerabilities of the final users. A particular focus will be on rural/mountain areas and river basins having in mind that these areas are directly threatened by climate change.

VULNERABILITY ASSESSMENT IN URBAN AREAS IN FRONT OF CLIMATE CHANGE USING LOCAL CLIMATE ZONES

J Gilabert (1,2), MC Llasat (1), J Corbera (2)

1) University of Barcelona, Barcelona, Spain
2) Institute Cartographic and Geological of Catal, Barcelona, Spain

carmell@meteo.ub.edu

We present a proposal to map vulnerability to extreme temperatures in the Metropolitan Area of Barcelona, departing from Local Climate Zones (LCZs). This classification allows working with a high spatial resolution (GSD<30 m). We derive the LCZs (Stewart and Oke, 2012), defined according to morphological, radiative and thermal parameters, from different maps representing land cover and land uses, 3D models of the city and remote sensors. Two new indexes are then proposed: the Urban Climate Vulnerability Index (UCVI) and Climate Vulnerable People (CVP). These two indexes, when combined, allow us to determine integrated vulnerability scenarios when considering situations of extreme temperature and heat waves in urban areas in order to have a detailed cartography of the risk. As an example of this, the proposed scenarios of vulnerability are coupled to a specific situation of the urban heat island registered by the high-resolution hyperspectral thermal sensor TASI carried out by the Institute Cartographic and Geological of Catalonia. Through comparing the different geospatial parameters, we are able to evaluate the potential risk due to the combination of vulnerability, hazard and exposure. This risk will increase in the future due to climate change and the rise of vulnerability.

SESSION 7

Climate Services in the Mediterranean regions

RECENT DEVELOPMENT AT THE COPERNICUS CLIMATE CHANGE SERVICE

C Buontempo (Invited) (1)

1) European Centre for Medium-Range Weather Forecasts, Shinfield Park, Reading, RG2 9AX, UK

carlo.buontempo@ecmwf.int

This year marks the transition into the operational phase of the Copernicus Climate Change Service (C3S). This service, run and managed by ECMWF on behalf of the European Commission, is making a very vast amount of climate data easily accessible to the users. At the core of the C3S is the Climate Data Store, an entry point to a distributed archive of quality controlled climate data. Among many other datasets CDS provides access to global and regional reanalysis (e.g. ERA5), multi-model seasonal predictions (ECMWF, Met Office, Meteo France, CMCC, DWD, ..), gridded observation, climate records for the majority of GCOS Essential Climate Variables (ECVs) as well as regional and global climate projections (Euro-Cordex and CMIP5). The CDS offers also a cloud-based computational layer that allows users to manipulate and post-process data using a python-based environment without the need to first downloading the data on their machines. Here we present the basic architecture of the CDS describe some of the most iconic datasets available on the catalogue, and present the compute layer through a series of examples which show how the infrastructure could be use to address the needs of users operating in specific sectoral contexts.

PANNEX: THE PANNONIAN BASIN EXPERIMENT

A Ceglar (1), AE Croitoru (2), J Cuxart (3), V Djurdjevic (4), I Güttler (5), B Ivančan-Picek (5), D Jug (6), M Lakatos (7), T Weidinger (8)

1) European Commission, Joint Research Centre, Ispra, Italy
2) Faculty of Geography, Babeş-Bolyai University, Cluj-Napoca, Romania
3) University of the Balearic Islands, Palma, Spain
4) Institute of Meteorology, Faculty of Physics, Belgrade, Serbia
5) Meteorological and Hydrological Service (DHMZ), Zagreb, Croatia
6) Faculty of Agriculture, University of J.J.S., Osijek, Croatia
7) Hungarian Meteorological Service, Budapest, Hungary
8) Eotvos Lorand University, Budapest, Hungary

andrej.ceglar@ec.europa.eu

The Pannonian Basin Experiment (PannEx), under the umbrella of the Global Energy and Water Exchanges project of the World Climate Research Programme, aims to achieve a better understanding of the Earth System components and their interactions in the Pannonian Basin. The scientific basis of the PannEx supports research that can better translate and deliver relevant climate data, information and knowledge for societal decision making through the national hydro-meteorological and climate services, research institutes and universities. We present the PannEx in the light of international efforts to provide scientific support and involve international research community in integrated approach towards identifying and increasing adaptation capacity in the face of climate change in the Pannonian Basin. For this purpose, five main objectives (established as the flagship questions) and three transversal/interdisciplinary subjects (the cross-cuts) have been identified, combining the current scientific challenges with the related societal needs. The flagship questions address the challenges in agriculture, air quality, sustainable development, water management and education. The three cross-cut actions are dedicated to data and knowledge rescue, process modeling, and development and validation of the modeling tools.

LIFE ADAPT2CLIMA TOOL: A DECISION SUPPORT TOOL FOR ADAPTATION TO CLIMATE CHANGE IMPACTS ON THE MEDITERRANEAN ISLANDS' AGRICULTURE

C Giannakopoulos (1), M Moriondo (2), M Papadopoulou (3), A Karali (1), KV Varotsos (1), G Lemesios (1), C Papadaskalopoulou (3), P Merante (2), D Charchousi (3)

1) National Observatory of Athens, Athens, Greece
2) Institute of Biometeorology, CNR, Florence, Italy
3) National Technical University of Athens, Athens, Greece

cgiannak@noa.gr

Agriculture is one of the most vulnerable economic sectors to climate change, since it directly depends on climatic factors such as temperature, solar radiation, and precipitation. The EU LIFE ADAPT2CLIMA (http://adapt2clima.eu/en/) project aims to facilitate the development of adaptation strategies for agriculture by deploying an innovative decision support tool. The ADAPT2CLIMA tool will make it possible to simulate the impacts of climate change on crop production and the effectiveness of selected adaptation options in decreasing vulnerability to climate change in three Mediterranean islands, namely Crete (Greece), Sicily (Italy), and Cyprus. The project is expected to contribute significantly to increasing climate resilience of agriculture areas in Sicily, Cyprus and Crete as well as at EU level by developing, implementing and demonstrating ADAPT2CLIMA decision support tool for adaptation planning in agriculture that estimates future climate change impacts on local water resources, as well as the climate change vulnerability of the studied crops' (olives, vineyards, wheat, barley, tomatoes and potatoes) production in the project areas. The tool construction was closely monitored by the project steering committees comprising of climate and crop scientists, policy makers as well as farm association executives who were interacting to tailor make the final product perfectly suited to their needs. In particular, the tool provides: i) current climate and future climate projections for the areas under study for two different IPCC RCP scenarios; ii) water resources projections; iii) vulnerability indicators of selected crops relevant to crops' phenology, physiology, production and quality; (iv) socio-economic indicators; (v) vulnerability and adaptation assessments for each crop together with an evaluation of the proposed adaptation options.

AN ONLINE WEB APPLICATION TOOL FOR REGIONAL CLIMATE DATA EXTRACTION: DEAR-CLIMA

P Zanis (1), A Tsikerdekis (1), D Akritidis (1), H Kontoes (2)

1) Aristotle University of Thessaloniki, Thessaloniki, Greece
2) National Observatory of Athens, Athens, Greece

zanis@geo.auth.gr

The Data Extraction Application for Regional Climate (DEAR-Clima) is a user friendly interactive web application tool that visualizes and provides time series of essential climate variables and climate indices (http://datahub.geocradle.eu/dataset/dear-clima). It is based on high horizontal resolution Regional Climate Model (RCM) simulations from the Coordinated Regional Downscaling Experiment (CORDEX) research program. Reliable and user friendly open access of future climate change data from high resolution RCM projections are essential to support decision makers, stakeholders, intermediary users and end-users for climate change impacts, mitigation and adaptation. The RCM data processed in this web application tool have a high spatial resolution (0.11°) over the European domain and cover a time period from 1950 to 2100. The historical period of each experiment refers to 1950-2004, while the future period is 2006-2100 under the influence of three Representative Concentration Pathways (RCPs) adopted by the IPCC for its fifth Assessment Report (AR5); rcp26, rcp45 and rcp85. The simulation experiments are a product of various RCMs driven by several Global Climate Models (GCMs). Acknowledgments: This work is supported by the project GEOCRADLE (Coordinating and integrating state-of-the-art Earth Observation Activities in the regions of North Africa, Middle East, and Balkans and Developing Links with GEO related initiatives towards GEOSS), grant agreement no. 690133, funded through the European Union Horizon 2020 Programme – Topic: SC5-18b-2015, Integrating North African, Middle East and Balkan Earth Observation capacities in GEOSS.

TEMPERATURE, PRECIPITATION AND HYDROLOGIC CHANGES IN SERBIA AND INFLUENCE OF SELECTION OF OBSERVED DATA ON OBTAINED RESULTS

D Dimkic (1)

1) Institute Jaroslav Cerni, Belgrade, Serbia

ljiljana.dimkic@jcerni.co.rs

Great majority of Serbia's domestic rivers registered a downward trend in 20th and first decade of 21st century. Like in many parts of the world, important decrease in river discharge is influence of three factors: climate change (CC), changes in human use of water (HU), and land use changes (LU). The impact of CC has been noted at all hydrologic stations, but its significance varies. Paper present these variations across Serbia and, in addition to spatial trend distribution, try to find correlations between observed temperature (T), precipitation (P) and river discharge (Q) for a numerous T, P and Q stations. Quite strong average relationships between an increase in air temperature and changes in river discharges has been found for central Serbia, and is presented in the paper. This methodology for forecasting mean river discharge changes in near future could be of interest to other regions. The importance of measured data, selected stations and selected period for analyses of observed values of T, P and Q are discussed in the paper.

BRINGING INNOVATION TO ONGOING WATER MANAGEMENT (BINGO)

A Bruggeman (1), G Zittis (1), U Ulbrich (2), HW Rust (2), E Meredith (2), KA Kpogo-Nuwoklo (2)

1) The Cyprus Institute, Nicosia, Cyprus
2) Institute for Meteorology, Freie Universität, Berlin, Germany

ulbrich@met.fu-berlin.de

The H2020 project BINGO aims to provide knowledge and tools to end users affected by near-future climate variations, i.e. water managers, decision and policy-makers, etc., so that they can better plan for regional changes in the hydrological cycle and develop adaptation strategies for climate-change-related challenges, such as a changed risk of drought and floods. The BINGO project includes three research catchments in the Mediterranean region – two in Iberia and one in Cyprus – for which improved and downscaled climate variables, based on the present and near-future are produced. The time horizon of main interest is from the present out to 2024, though climate scenarios are also considered. A key aspect of the BINGO project is a strong interaction between hydrological modellers and stakeholders at the different catchments. Here we present an overview of the BINGO project, focusing on the climate services required by hydrologists and other stakeholders for flood/drought management, and the methodologies employed by BINGO to generate the necessary data. In particular, hydrologists benefit greatly from high-resolution climate data O(1 km) to model their catchments, though such data are rarely available, either due to the computational expense associated with running climate simulations at such high resolution, or insufficiently dense observational networks. To overcome this problem, BINGO adopts a two-pronged approach based on (1) targeted high-resolution dynamical downscaling of episodes with an increased likelihood of extreme precipitation; and (2) conditional stochastic weather generators, which inexpensively produce large ensembles of spatio-temporal forcing data. The first approach relies on the identification of characteristic "extremal" weather patterns for the relevant catchment, while the latter involves the setting-up of a weather generator which realistically simulates relevant variables for the recent climate at the catchment, before applying it to the future period. The overarching goal is to provide better estimates of potential extreme event intensities and probabilities at the research catchments. Our overview of the BINGO project will be illustrated with specific examples and outcomes from our three Mediterranean catchments.

DYNAMICAL PROXIES AS A TOOL FOR MEDITERRANEAN SEASONAL FORECAST

MC Alvarez-Castro (1,2), S Materia (1), D Faranda (2), S Gualdi (1)

1) CMCC, Bologna, Italy
2) LSCE, Gif-sur-Yvette, France

carmen.alvarez-castro@cmcc.it

Seasonal forecasts are essential tools to offer early-warning decision support, that can help to reduce the socio-economics related risk associated with anomalous events. Advances in statistical prediction are often linked with the enhance of understanding that usually leads to improve dynamical forecast. Thereby, both approaches are frequently combined in order to increase the robustness of the forecast. Atmospheric dynamics are described by a set of partial differential equations yielding an infinite-dimensional phase space. However, the actual trajectories followed by the system appear to be constrained to a finite- dimensional phase space, i.e. a strange attractor. The dynamical properties of this attractor are difficult to determine due to the complex nature of atmospheric motions. A first step to simplify the problem is to focus on observables which affect – or are linked to phenomena which affect – human welfare and activities, such as sea-level pressure, t2m temperature, and precipitation frequency. We make use of recent advances in dynamical systems theory to estimate two instantaneous dynamical properties of the above fields for the North Atlantic sector and the Mediterranean region: local dimension and persistence. Combining this information with bias correction techniques, we present forecasts computed from one to six months ahead. The dynamical forecast of daily precipitation is provided by the new Copernicus C3S Seasonal Prediction System. ENSEMBLES daily gridded observational dataset (EOBS) are used for validation with observations.

CLIMATE SERVICES: WHAT IS THE CURRENT STATE OF ART?

A Panenko (1), C Lutoff (1), E George (2)

1) Pacte, Grenoble, France
2) Irstea, Grenoble, France

anastasia.panenko@umrpacte.fr

Nowadays, negative impacts of climate change can be observed to a greater extent on the whole planet: increasing/decreasing precipitations, rising sea levels, melting glaciers, and so on (IPCC, 2014). According to EEA, compared to average global increase of 0.8°C, European land temperature has increased by 1.3°C (2016). Moreover, some parts of Europe appear more sensitive than others, such as Mediterranean and mountain regions, where a higher temperature rise was registered (EEA, 2016). It is in this optics that Climate Services appear as an emerging topic in CC adaptation domain. Defined by WMO as "a decision aide derived from climate information that assists individuals and organizations in society to make improved ex-ante decision-making", or by EU as "transforming climate-related data and other information into customized products such as projections, trends, economic analysis, advice on best practices, development and evaluation of solutions, and any other climate-related service liable to benefit that may be of use for the society" (wmo.int; ec.europa.eu). Among several "actions" of "EU strategy on adaptation to climate change", climate services are seen as "knowledge adaptation" and as a tool for better resilience (EU COM (2013) 216). Climate services can provide information for decision-making bodies and contribute to risk and adaptation mechanisms. Moreover, these tools can be largely deployed in different sectors of our economies. As this domain has registered a growing interest only recently, these tools are still being experimented and assessed. Today, climate services can offer tailored information in terms of predictions on major climate variables and this requires the ability to transform this scientific data into something useful and user-friendly for potential beneficiaries. As many scholars argue, not always scientific data meets the needs/demands of users: different institutional logics, spatial scales and timing (Dilling&Lemos, 2011; McNie, 2007; Sarewits&Pielke, 2007). As Pita Spruijt et al (2014) point out, "policy makers seek certainties and solutions, whereas scientists typically offer probabilities, uncertainty and multiple scenarios" (2014:17). Therefore, in order to close the so-called "science-policy gap", several authors argue for production of socially robust science in terms of active involvement of public in scientific processes (Choi et al, 2016; Jasanoff, 2003). The co-construction of climate services can enable scientific community to provide useful data which will be actually used by society. As most of the literature argues for co-production of these tools, it is interesting to discuss the ways to co-build climate services. What is an appropriate spatial or time scale? Which stakeholders to involve, when and how? What has been done so far? The aim of this contribution is to offer an overview on climate services from historic, practical and "design" perspectives and to raise questions for further debates.

STOCHASTIC PRECIPITATION DOWNSCALING IN COMPLEX OROGRAPHY FOR CLIMATE SERVICE APPLICATIONS

J Von Hardenberg (1), S Terzago (1), E Palazzi (1)

1) CNR-ISAC, Torino, Italy

j.vonhardenberg@isac.cnr.it

The application of climate model projections and forecasts to impact studies at small scales, such as hydrological modeling or ecological modeling, requires to bridge the large gap between the spatial resolution currently achieved by global and regional climate models and the scales necessary for a correct representation of the spatial and temporal structure of precipitation at fine-scales (~1 km) and of the probability of extreme precipitation events. In absence of a dynamical physically based representation, a useful approach to bridge the scale mismatch is the use of stochastic rainfall downscaling techniques. In particular the Rainfall Filtered AutoRegressive Model (RainFARM) method is a weather generator which has only one free parameter (which can be derived from the large scales) and which requires no further calibration. It is currently being implemented for use in climate service applications at temporal scales ranging from seasonal prediction to climate projections, in the framework of different on-going projects (H2020 Ecopotential, Copernicus C3S MAGIC, ERA4CS MEDSCOPE), with a particular focus on the Mediterranean area. Stochastic downscaling techniques usually provide a statistically homogeneous distribution of fine-scale precipitation in each large-scale grid element of the field to downscale, so they usually do not take into account heterogeneities in local precipitation patterns, due for example to orographic effects, at spatial scales finer than those resolved by the large-scale input field. For this reason, stochastic downscaling techniques may be less reliable in areas with complex topography or specific sub-grid precipitation patterns. Here we test a simple method to introduce realistic fine-scale precipitation patterns into the downscaled fields (Terzago et al. 2018). The proposed method relies on the availability of a reference fine-scale precipitation climatology from which corrective weights are derived and used to adjust to the downscaled daily precipitation fields. We demonstrate the method by applying it to the RainFARM algorithm for the Alpine region. The modified RainFARM method has been tested on an area of complex topography encompassing the Swiss Alps, first, in a perfect model experiment in which high resolution (4 km) simulations performed with the Weather Research and Forecasting regional model are aggregated to a coarser resolution (64 km) and then downscaled back to 4 km and compared with the original data. Second, the modified RainFARM is applied to the E-OBS gridded precipitation data (0.25 degrees spatial resolution) over Switzerland, where high-quality gridded precipitation climatologies and accurate in-situ observations are available for comparison with the downscaled data. The results of the perfect model experiment and of the real case experiment are discussed and compared, showing the strengths of the method and providing ideas for possible further developments.

CLIMATE IMPACTS ON MEDITERRANEAN CROPS, ADAPTATION MEASURES AND THE MED-GOLD PROJECT.

M Zampieri (1), S Calmanti (2), A Ceglar (1), A Dell'Aquila (2), F Dentener (1), G Manfron (1), L Ponti (2), E Scoccimarro (3), A Toreti (1)

1) EC-JRC, Ispra, Italy
2) ENEA, Roma, Italy
3) CMCC, Bologna, Italy

matteo.zampieri@ec.europa.eu

We provide an overview of the recent advancements on the assessment of the effects of climate variability on crop production in the Mediterranean region. We present two case studies of adaptation to climate change for maize, where we demonstrate the potential of seasonal forecasts in predicting yields, and for rice, where we show how the experience developed in Italy can be exported in other warming temperate regions. We introduce a new project turning climate-related information into added value for traditional MEDiterranean Grape, OLive and Durum wheat food systems (MED-GOLD). MED-GOLD will demonstrate the proof-of-concept for climate services in the agriculture sector by developing climate services for these three hallmarks of the Mediterranean food system. In particular, MED-GOLD will co-design prototype services and applications involving both suppliers and users in the three major traditional Mediterranean crop systems to demonstrate the benefit of data/information-driven responses to changes in the climate system.

BUILDING DATA VALUE CHAINS: FROM CLIMATE DATA PRODUCTION TO IMPACTS. THE EXAMPLE OF CLIMATE-SENSITIVE VECTOR-BORNE DISEASES.

MC Karypidou (1), E Katragkou (1)

1) Aristotle University of Thessaloniki, Thessaloniki, Greece

karypidou@geo.auth.gr

In view of the observed and yet imminent climate change, climate data are exploited due to the impact they exert: on the environment, on human health, on agriculture and on economy. The emerging question is how raw scientific data can be transformed to actionable information, ready for use by stakeholders, the ones who are responsible to make the climate resilient decisions. This task requires that the raw climatic information is efficiently contextualized and made relevant to specific applications. In this work we attempt to map the path from raw climate data to tangible climate impacts. Emphasis is given on the production and collection of raw climatic information and its downscaling to an appropriate geographical scale that is defined by the application in concern, the quantification of its uncertainty, its post-processing to climate relevant indices and its integration to more complex statistical and dynamical algorithms. The data value chain we present in this work focuses on the climate sensitive vector-borne diseases and namely how we can estimate health risks in view of climatic changes that are in progress and are expected to intensify, using state of the art climate data and multidisciplinary analysis techniques. Malaria is used as a test case over Greece and the impact of climate on its distribution is assessed mainly by the impact of climate on its primary vector, over the study region. An observation that arises from such attempts of assessing climate impacts, is that the production of climate data at the very beginning of the data value chain should be designed in such a way, so as to be suitable for a specific application at the end of the chain. Thus, there will be a consistency between the data production process and their proper exploitation.

NATURE BASED SOLUTIONS IN THE MEDITERRANEAN REGION-GOVERNANCE AND SOCIAL IMPACTS

ES Tadić (1), NŽ Vujasinović (1)

1) University of Novi Sad, Faculty of Sciences, Novi Sad, Serbia

elenastadic@gmail.com

Currently, 60% of the Mediterranean's population is living in urban areas and, with its fastest urbanization rates, is expected to increase by an additional 22.5 million by 2030. This trend was followed by significant imbalances and dysfunctions territorial, economic, social and environmental levels. Mediterranean cities are also experiencing high vulnerability to the effects of climate change such as water scarcity, droughts, forest fires and heat waves.In the last decades, the awareness that nature can help is raised. Nature-based solutions are actions which are inspired by, supported by or copied from nature. They have tremendous potential to be energy and resource-efficient and resilient to change and thus they can provide sustainable, cost-effective, multi-purpose and flexible alternatives for various objectives. Nature-based solutions involve many different actors, from governments, stakeholders to even citizens and all ideas connected to nature-based solutions are largely becoming recognised. They include innovative governance, institutional, business, and finance models and frameworks. The aim of this poster is to summarise previous actions, current policies and social impact of the application of nature-based solutions in Mediterranean region while emphasising good practice examples.

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