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Climate Change in the Mediterranean Region: Lessons Learned and New perspectives from regional to local scales

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Content

Session 1

Observing and understanding the processes relevant for the Mediterranean climate system

Conveners:

Ileana Bladé (University of Barcelona, Barcelona, Spain),

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Investigating the added value of the Convection Permitting Model CNRM-AROME over the Mediterranean Island of Corsica

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For the Mediterranean region, recent studies have shown the added value of Convection Permitting Models (CPMs) when compared to Regional Climate Models (RCMs), in particular for extreme precipitation. However, the added value is yet to be determined for Mediterranean islands, where the complex orography, coastal line, and the specific island atmospheric processes are especially important to simulate climatic conditions. For these reasons, Islands are ideal testbeds to explore the potential of using CPMs. The objective of this study is to investigate the added value of the 2.5 km resolution CPM CNRM-AROME for the mountainous Mediterranean island of Corsica. For that, hourly simulated data from: a) the 12 km resolution RCM ALADIN (following the EURO-CORDEX protocol), and two simulations of the CPM CNRM-AROME over two different domains, b) the pan-Alpine domain (following the CORDEX FPS Convection project) and c) the northwestern European domain (defined through the EUCP H2020 project) are compared with 17 hourly weather station data across Corsica for the 2000-2018 period. Preliminary results show an improvement of the simulated distribution of hourly precipitation of CPM simulations when compared to the RCM simulation. These results can be attributed, not only to the better simulation of convective processes by the CPMs, but also to a better representation of the complex orography of Corsica.

Northern Hemisphere subtropical expansion: time-of-emergence of forced signal versus internal variability and regional impacts

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The Northern Hemisphere mid-latitudes will be exposed to hydroclimatic risk in next coming decades because the subtropical expansion. However, it is not clear when the anthropogenic signal will emerge from the internal climate variability. For this purpose, we investigate the time of emergence (ToE) of the hemispheric and regional shift of Northern subtropical margins in the Max Planck Institute Grand Ensemble. For several indicators, the ToE of the poleward shift of Northern subtropical margin will not occur by the end of the 21st century, neither at regional nor at hemispheric scale. The exceptions are the Mediterranean/Middle East and, to a lesser degree, Western Pacific, where the ToE would occur earlier. According to our results, given the fundamental role played by internal variability, trends of Northern Hemisphere subtropical expansion that have been identified over last decades in reanalyses cannot be considered as robust signals of anthropogenic climate change.

Impact and Variability of the Mistral and Atmospheric Forcing on Deep Convection in the Gulf of Lion

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The vertical stability of the ocean in the Gulf of Lion responds to the atmospheric forcing on both the seasonal and anomaly timescale, with the latter predominantly driven by the Mistral winds. The inter annual variability of the atmospheric forcing on both timescales determines the occurrence of deep convection in the gulf. Deep convection is the major process in the Western Mediterranean Basin leading to dense water formation, which assists with the general circulation of the Mediterranean Sea, and also leads to years of phytoplankton blooming, due to increasing the oxygen and nutrient content along the water column. Yearly NEMO ocean simulations were run over the span of 20 years, from 1993 to 2013, through the RegIPSL regional climate model and forced by atmospheric outputs from a coupled WRF/ORCHIDEE simulation, also produced through the RegIPSL model. Two ocean simulations per year were run, a control and a seasonal run, with the latter forced by a filtered atmospheric forcing, to separate the oceans response at the seasonal and anomaly timescales. These simulations revealed the importance of the magnitude and variability of the seasonal atmospheric forcing regarding the vertical stability, or stratification, of the Gulf of Lion. On average, roughly 50% of the relative destratification over the course of the preconditioning period (the period leading up to a potential deep convection event) came from the seasonal change in stratification. Years with deep convection not only had a less than average yearly maximum stratification, but also had a greater than average (greater than 50%) seasonal contribution to the preconditioning destratification. The anomaly timescale contribution typically only provided, on average, about 27% of the destratification required for deep convection to occur, with its contribution during deep convection years hovering slightly above, at around 30%. The necessary additional 70% required came from the above average seasonal contribution mentioned beforehand, demonstrating the importance of the seasonal contribution and its variability. The increased seasonal contribution was explained by the use of a simple model that relates the seasonal atmospheric heat flux components to the stratification index, a diagnostic for the vertical stability. The seasonal forcing varied greatly over the 20 year span, and years with larger upward latent and sensible heat fluxes and lower downward shortwave radiation fluxes were more likely to be deep convection years. The latent and sensible heat fluxes were in turn driven by higher levels of wind speed. The anomaly forcing also showed variability, and years with more frequent and stronger Mistral events were also more likely to be deep convection years. If future years shift towards having weaker upward latent/sensible heat fluxes, such as years with warmer advected air masses out over the gulf, then deep convection may occur less often. This could then lead to a shift in the Mediterranean Sea circulation and alter biological processes in the region.

Comparing and combining different approaches for the objective definition of the Mediterranean seasons

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Multiple objective methodologies are followed for the purpose of defining the seasons for the Mediterranean region during the period 1950-2018. The first method utilizes the mean intra-annual variations of 12 meteorological parameters obtained from NCEP/NCAR. The application of “spectral analysis”, which includes the successive use of Principal Component Analysis (PCA) and Cluster Analysis (CA), on the matrix of the aforementioned variations lead to the classification of the dates of the year into four distinct and homogenous time periods, which can be characterized as the objectively defined seasons. Another method of seasons’ definition, involves the use of weather types (WTs). As such, spectral analysis is applied on the daily values of the above-mentioned parameters and 8 WTs are determined. Then, spectral analysis is applied again, this time on the mean intra-annual variations of the frequencies of the 8 WTs, resulting in the definition of the seasons and four seasons are defined. In the third approach, a cyclone detection and tracking algorithm is applied for the Mediterranean region by utilizing 6-hourly high spatial resolution mean sea-level pressure data from the ERA5 reanalysis database. Then, spectral analysis is performed in order to classify the detected cyclone trajectories into groups and 12 cyclone clusters are constructed. In the next step, spectral analysis is applied on the mean intra-annual variations of the frequencies of the 12 cyclone clusters and four seasons are defined. Finally, a composite method is performed which combines the preceding three methods. According to the composite method the objectively defined seasons are: "winter" (November 16 - March 25) with a duration of more than 4 months, "spring" (March 26 - June 11) which lasts approximately 2.5 months, "summer" (June 12 - September 12) with a duration of about 3 months and finally "autumn" (September 13 - November 15) which lasts about 2 months. Long-term changes of the limits and duration of the seasons are also investigated.

New insights on the dynamics of El Haouz aquifer: a comprehensive analysis of hydrological and climate data

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The Haouz aquifer experiences several environmental and socio-economic challenges due to the growth of the agricultural sector and the intensity of irrigation. As a result, the groundwater is undergoing, in addition to climatic aridity, an anthropic pressure largely related to the agricultural sector. Several studies have been conducted to better understand the problem of overexploitation in the Haouz aquifer. However, it is still very important to perform an innovative and comprehensive analysis of hydroclimatic data, in order to define the relationship between the hydrogeological, meteorological, hydrological and agricultural parameters, using statistical tools. In the present study, special attention was given to the main factors that have a direct impact on the fluctuations of the groundwater table, with an emphasis on piezometric level, rainfall, surface water flow, and vegetation. The data was mainly collected from Tensift Hydraulic Bassin Agency and satellite data. The analysis of the relationship between these factors has shown the presence of two distinct operating systems. The first is manifested in areas where pumping is low, characterized by a natural balance between rainfall, surface water, vegetation cover and the piezometric level, whereas the second is perceptible in areas with high irrigation and where the natural balance of the water cycle is disturbed. This study allowed us to produce relevant results and graphical material and illustrations that will help decision-makers to better understand the risks and challenges of groundwater vulnerability in the Haouz region, to promote efficient and integrated groundwater management.

Cyclones in the Mediterranean Basin as a component of mechanisms in teleconnection schemes

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Activity of synoptic systems (cyclones and anticyclones) is a form of atmospheric circulation in the middle latitudes. In the cold half of the year, cyclones prevail and can lead to extreme precipitation and winds and related dangerous phenomena (floods, landslides, mudslides, storm surges). The temporal variability of cyclones associated with the main fronts in the atmosphere shows quasi-periodic changes of the interannual-decadal scale, which are important for the forecast, associated with the influence of the global climate system in general and the ocean-atmosphere system in particular. The main statistical signals of the ocean-atmosphere interaction processes reflect fluctuations in the intensity and location of large-scale anomalies (centers of action) of atmospheric baric field or sea surface temperature. These centers of anomalies are characterized by the strongest correlation with regional climate anomalies and are considered to be the most active ocean–atmosphere interaction zones. In the atmosphere, they correspond to the semi-permanent pressure Highs and Lows, and in the ocean, they are linked to the regions with the maximum sensible and latent heat fluxes, such as the Gulf Stream region near Newfoundland. These global interaction processes are referred to as teleconnection patterns and are described by simple indices (calculated using spatial correlation analysis or principal component analysis), which can be used as predictors for regional climate anomalies. Teleconnection patterns are associated with the modes of the general atmospheric circulation by influencing its elements, such as the mean flow, baric anomalies, gradients and fronts, synoptic systems, heat and moisture transport, intensity and location of jet stream and storm track. The main North Atlantic teleconnection patterns, according to NOAA Climate Prediction Center (https://www.cpc.ncep.noaa.gov), NOAA Physical Science Laboratory (https://psl.noaa.gov), NOAA National Climatic Data Center (https://www.ncdc.noaa.gov), are the following atmosphere oscillations: the North Atlantic Oscillation (NAO) and Arctic Oscillation (AO), East Atlantic (EA) pattern, East Atlantic/Western Russia pattern, Scandinavia (SCAND) pattern, Polar/Eurasia pattern, Tropical/Northern Hemisphere (TNH) pattern; and oceanic Atlantic Multidecadal Oscillation (AMO). The aim of the study is to compare the elements of atmospheric circulation, as well as the number and trajectories of cyclones in the Mediterranean Basin for different phases of teleconnection modes over the North Atlantic–European region. The results of the study will show the anomalies of the sea level pressure, 1000 hPa and 500 hPa geopotential height, jet stream, wind vector, temperature and precipitation, storm track over the North Atlantic–European region associated with the positive and negative phases of the main oscillations. Finally, teleconnection schemes will be shown with focus on cyclones in the Mediterranean Basin.

Recent anticyclonic activity changes in the Black Sea–Mediterranean region

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The climate features of the Black Sea-Mediterranean region (BSMR) are mainly caused by the unique geographic conditions. The region includes three continents, interior seas, surrounding mountains. The mountain groups influence strongly on the frequency of baric objects, as well as their trajectories, the deformation of the thermobaric fields when cyclones or anticyclones pass over a mountain range, and reduce their movement speed and block lower anticyclones. Now, the numerous publications on the long-term changes of anticyclonic activity cover the entire Northern hemisphere or separate regions but not specifically in the BSMR. The associated conclusions do not completely show the changes of anticyclone parameters including frequency, height, and area in the BSMR in the second half of the 20th century. That is why, the main aim of present study is to analyze the climatology and trends of the anticyclones parameters in the BSMR in 1951-2017. The data on 1000 hPa geopotential height between 20 and 80° N in 1951–2017 were extracted from the NCEP/NCAR Reanalysis 1. The method by Bardin described in detail in (Bardin, 1995, 2007, 2019) was used to identify anticyclones and calculate their parameters. Anticyclones' parameters (frequency, height, area) were calculated within the following three BSMR subregions: the Black Sea region (40 – 50° N, 27,5 – 45° E), the Western Mediterranean region (35 – 47,5° N, 6° W – 17,5° E), the Eastern Mediterranean region (30 – 40° N, 17,5 – 37,5° E). These subregions are different by the physical and geographic features of region. The climatology of anticyclones' parameters includes the assessment of their averages, root mean square deviations (RMS) and seasonality, as well as linear trends. The linear trend coefficients were calculated using the least-squares method. The statistical significance of linear trends was assessed using Student's t-test. In BSMR, the highest frequency and height of anticyclones in the second half of the 20th century were revealed in the Black Sea region, and the lowest height and area of anticyclones were found in the eastern Mediterranean region. At the same time it was found RMS maximum of the anticyclone height and area in the Western Mediterranean, while RMS minimum was shown in the anticyclone frequency there. Significant trends of anticyclone parameters in the BSMR for analyzed period were identified. In winter, the anticyclone frequency was increased in the Black Sea and the Western Mediterranean regions. In spring, the anticyclone frequency in the Eastern Mediterranean was decreased. In summer it was note the anticyclone frequency decrease in the Black Sea region and in the Eastern and Western Mediterranean, while anticyclone area is increasd in Western Mediterranean. In autumn, anticyclone height decreases in the Black Sea region and anticyclone frequency decreases in the Western and Eastern Mediterranean. This includes the anticyclone frequency in the Black Sea region, as well as the anticyclone frequency and height in the Eastern Mediterranean. Thus, obtained results provides the knowledge on the recent climatology and trends of the anticyclone parameters in the BSMR in 1951-2017.

ENSO related signal and predictable components of atmospheric circulation in the North Atlantic-European region

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Abstract: Tropical sea surface temperatures (SSTs) can act as a source of boundary-forced predictability for the atmosphere in the extratropics, which is characterized by its strong internal variability. If the strength of atmospheric response to this remote SST forcing is large enough to overcome the chaotic intrinsic variability of the extratropical atmosphere, then the boundary-forced circulation can be established and potential predictability increased. One of the strongest phenomena with such an influence on the climate variability throughout the world is the El Niño-Southern Oscillation (ENSO). Using an intermediately complex atmospheric general circulation model (ICTP AGCM), five experiments were conducted to detect the potential impact of tropical sea surface temperatures (SSTs) on the late-winter atmospheric circulation in the North Atlantic-European (NAE) region. Each of the AGCM experiments is a 35-member ensemble of 156-year long simulations forced with observed SST anomalies prescribed in different ocean areas: globally, in the entire tropical zone, tropical Atlantic region, and tropical Pacific. Additionally, an experiment containing only climatological SSTs was analysed. The late-winter 200-hPa geopotential heights signal was estimated by the difference between the ensemble mean of each experiment and the climatological mean of the ensemble mean for the considered period, following. To further inspect the impact of ENSO, the signal was calculated for subsets containing only ENSO or non-ENSO years, sorted according to the strength of the late-winter Niño3.4 index. We also compared the monthly signal averaged over the NAE region in different AGCM experiments. Results have shown that the signal is the strongest in the late-winter months (January-March) in all experiments. Among the experiments containing lower-boundary forcing, the experiment with SST anomalies prescribed only in the tropical Atlantic consistently yielded the least amount of signal. Overall, the geopotential height signal is more pronounced over the NAE region in ENSO years, than in non-ENSO years. Alongside the “classical” analysis of the signal, the signal-to-noise optimal patterns method was applied to the geopotential heights at 200 hPa. The optimal patterns method seeks patterns which maximize the signal-to-noise ratio. Results have shown that the lower-boundary forcing from the tropical Pacific increases potential predictability of the late-winter atmospheric circulation in the North Atlantic-European region.

The role of small-scale sea features in the January 2020 flooding in Israel

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On January 8, 2020, an extreme storm event took place in the Eastern Mediterranean Sea, during which 100-130mm of rain fell in the northern part of Israel in one day. The heavy precipitation event resulted in seven deaths and damage to homes, vehicles, and infrastructure. At the same time, about 100 km to the west of northern Israel, the sea was characterized by a mesoscale eddy with a warm core. In recent years, it was established that small-scale sea features not only affect the atmosphere above but may also affect large-scale circulation patterns, including rainfall. Yet, it is unclear how these features may affect propagation and intensity of individual storms, such as the January 8, 2020 event. Recently, the WRF (The Weather Research and Forecasting) atmospheric model was coupled with the ocean model MITgcm (MIT general circulation model). The coupled model was named the SKRIPS (Scripps–KAUST Regional Integrated Prediction System) model. The two SKRIPS model components (WRF and MITgcm) are well tested at high resolutions, and the regionality of the coupled model allows us to isolate local features while maintaining the large-scale circulation as observed. In this talk, I will present results from a high-resolution (~5km) coupled atmosphere-ocean and uncoupled atmosphere-only regional simulation using the SKRIPS (WRF) model performed during the January 8, 2020 event. The importance of mesoscale sea activity in determining the storm intensity and propagation will be discussed, elaborating on the role of air-sea coupling and the model resolution. Understanding the effect of such mesoscale eddies on extreme atmospheric events may improve their representation in weather and climate models, extending models prediction skill.

A Factor Separation Study of the Effect of Synoptic-Scale Wind, Atmospheric Moisture and of Their Synergy on the Diurnal Temperature Range During the Israeli Summer

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Global mean temperatures are the most widely used and accepted meteorological variable for investigating climate change, however, they alone do not capture the complexity of the processes leading to the observed increasing trend. One of the clearest examples of this is the observed decrease in the global mean diurnal temperature range (DTR), defined as the difference between daytime maximum and night-time minimum temperatures (Tmax and Tmin, respectively). Regionally, DTR trends exhibit large variations. Despite the abundance of studies on DTR, the factors contributing to the observed trends remain poorly understood, highlighting the problem in identification of the physical causes. Water vapor is one of the most important greenhouse gases in the atmosphere, resulting in increased surface temperatures (i.e., 2 m temperatures). The relative increase in Tmax and Tmin will determine whether the DTR increases or decreases, and to what extent. In Israel, a statistical analysis conducted by Barkan et al. (2019) based on observations found that relative humidity was strongly correlated to DTR magnitude, across all studied locations and seasons. Winds are known to influence the DTR in a number of ways. Diurnal variations in wind direction can affect the DTR through advection of different air masses; an example of this is the sea breeze, which transports cool and humid air from the sea inland during the day, thereby reducing Tmax. Wind speeds can affect surface sensible and latent heat fluxes, thereby changing surface temperatures. Variations between day and night will lead to differences in DTR. Strong nocturnal winds can increase mixing in the lower atmosphere, with air temperatures higher above. This mixing of air can increase Tmin and thus reduce DTR. We conducted a factor separation analysis investigate the impact of atmospheric moisture, synoptic-scale winds, and their synergy on the DTR during the Israeli summer. The Weather Research and Forecasting (WRF) Single Column Model was run for summer representative days, at four locations in Israel. In almost all cases, the contribution of the factors and of their synergy to the DTR was dominated by their contribution to Tmin. The largest contribution resulted from atmospheric moisture, reducing the DTR. The contribution of synoptic-scale winds showed more variability, with significant differences in both magnitude and sign on different days. The sign of the effect on Tmin depended on the relative direction and magnitude of the nocturnal synoptic-scale wind with respect to the local wind, which in turn determined the effect on the low-level jet (LLJ) and vertical mixing. The contribution from synergy between the two factors depended on the effect of moisture on the LLJ and on the effect of the synoptic-scale winds on moisture advection in or out of the atmospheric column. All cases were classified into groups depending on the sign of contributions of the single factors and of their synergy when analyzing the DTR observed trends. These results highlight the importance of the synoptic wind, of its synergy with atmospheric moisture and of the feedback mechanisms. Significant changes in both studied single factors, atmospheric moisture and synoptic-scale winds, are projected in future climate scenarios. The methodology exploited in this research can be further applied under future atmospheric conditions. Such numerical experiments can be conducted by modifying the present atmospheric variables used in our study according to future climate predictions.

References

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Investigating the role of sea eddies on the intensity of cyclones in the Mediterranean Sea

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The Mediterranean Sea (MS) region is characterized by diverse and unique geography. The complex geographical features of MS, as well as remote effects from the Atlantic sector, facilitates favorable conditions for cyclone genesis and maintenance. Despite the crucial role of warm-core eddies (WCEs) in the intensification of the cyclones, they are insufficiently explored, especially over the MS. In this study, the role of WCEs (size, intensity, and area) on the track and intensity of the atmospheric cyclones have been analyzed in the MS, considering four cyclones, namely Zorbas (27 Sep-2 Oce 2018), Boron (20-23 Sep. 2018), Numa (15-20 Nov 2017) and Messala (30 Sep -2 Oce 2015). For this analysis, Sea Level Anomaly (SLA), Ocean temperature and salinity profiles archived from the Copernicus marine services (CNMS), together with high-resolution daily SST data from NOAA OI SST V2, have been utilized. Atmospheric parameters (Latent heat Flux, Sensible heat fluxes, pressure, wind at 10-meter height, and total precipitation) are obtained from the ERA5 reanalysis. Analysis infers a sudden drop (increase) in the pressure (wind speed) over the WCEs. It is also observed from the analyses that the size and extent of the eddy strongly modulate the latent and sensible heat flux exchange, leading to cyclone intensification. It is observed that larger (smaller) size and extent eddies are responsible for more (less) heat exchange and more (less) precipitation. The Brunt–Väisälä frequency (N square) analysis reveals relatively stable subsurface over eddies locations compared to non-eddies locations. Thus, less mixing in the stratified ocean restricts the entrainment of the subsurface cooler water to the surface and leads to surface warming, which results in an intensification of the cyclones in the presence of WCEs.

Evaluation of PERSIANN CCS-CDR precipitation product for drought assessment in a semi-arid watershed in Morocco

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Precipitation estimation products are becoming more vital for climatological and hydrological studies. Satellite-based precipitation products, with simultaneously, high spatial and temporal resolutions are mostly needed to assess climate change repercussions in regions suffering from data-scarcity. Past researches focused on datasets either with a poor spatial or a poor temporal resolution, therefore, showing weak performances. Precipitation estimations from Remotely Sensed Information using Artificial Neural Networks-Cloud Classification System-Climate Data Record (P-CCS-CDR) are one of the projects aiming to remedy these limitations. The P-CCS-CDR dataset provides precipitation estimates at 0.04° spatial resolution, the product is covering the period 1983 to present over the global domain of 60°S to 60°N. The main goal of this study is to evaluate the accuracy of the P-CCS-CDR product compared to observed precipitation at monthly scale and its suitability for drought assessment in a semi-arid watershed in Morocco. Several statistical indices are computed, and drought SPI (Standardized Precipitation Index) is calculated with P-CCS-CDR to estimate its suitability to simulate drought during the period from 1983 to 2020. The preliminary comparison and evaluation results of both datasets are promising, showing good correlation coefficient (CC) of 0.77 on a basin scale for monthly precipitation, poorly overestimating the observed precipitation with a 3.9% PBias and a Nash-Sutcliff efficiency coefficient (NSE) criteria of 0.40. At the basin scale the SPI for 3 and 9 months (SPI3 and SPI9) were calculated using both observed and P-CCS-CDR datasets, the precipitation PBias were not corrected during this study, the results showed that comparing to the observed SPI, the P-CCS-CDR SPI overestimated the drought risk with 225.9% and 101.4% PBias respectively for SPI9 and SPI3, the NSE were very low compared to the previous precipitation evaluation, scoring 0.1 and 0.27 for SPI3 and SPI9. However, the correlation and determination coefficients have average scores with a 0.67 CC and a 0.44 R2, demonstrating that we need to correct the PBias before using the P-CCS-CDR data for SPI calculation. This study provides a framework for future use of the P-CCS-CDR to assess climate change impacts over semi-arid watersheds, providing an important alternative to observed precipitation datasets.

Snow cover changes in the Atlas Mountains: from observations to large scale models

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In the context of climate change, the Mediterranean region is qualified as a hotspot due to the vulnerability of its human and natural systems. Temperature increase translates into more intense and frequent heatwaves in the region including Morocco. Reduced rainfall amounts and snow cover in the mediterranean mountains affect water resources, with impacts on drinking water supply, irrigation, and hydroelectric power generation. Mountainous regions such as the Atlas generates orographic precipitation and allows the establishment of a seasonal snowpack which constitutes a reservoir of water distributed downstream during periods of melting. These mountains are also orographic barriers explaining the heterogeneous climates on the different sides of them. Satellite observations as well as atmospheric models based on fine resolution are useful tools to investigate the links between the climate and the snow cover in these complex topography areas. In this study, the snow-cci satellite dataset http://snow-cci.enveo.at/ is used over 1982-2018 to describe the variability of the snow cover fraction in the Moroccan Atlas mountains. The missing values related to cloud cover, especially pronounced over mountain areas, are gap-filled to get a more complete dataset. Spatially contrasted trends are highlighted, that depend on both the elevation and the regional climate features. This observational dataset is finally compared with the outputs of the LMDZ atmospheric model https://lmdz.lmd.jussieu.fr/ applied with different resolutions. This validation step is essential before exploring the long-term trends of the Atlas snow cover over the past century as well as in future projections.

Evaluation of Heat Waves and Climate Indexes Correlation Between Northern and Southern Mediterranean

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Mediterranean regions are likely to pay a heavy price for global warming, despite having contributed little to its cause. This paper presents an analysis of heat waves and possible tele connected climate indexes between southern (Matrouh in Egypt) and northern (Antalya in Turkey) Mediterranean. Temperature and precipitation data Gathered from High-resolution gridded datasets of Climatic Research Unit (CRU) from 1950 to 2019. The negative relationships were founding between February-NAO and May-NAO with average annual precipitation over Antalya and Matrouh respectively. Negative correlation observed between average annual precipitation of Matrouh and September-AMO. Negative relationships were strengthened and attained higher significant levels between monthly NAO and average monthly winter temperatures. It is noted that March-NAO attained the highest significant with average winter temperature of both Antalya and Matrouh. Positive correlation found between average winter temperature of Matrouh and Antalya with March-IOD and February-IOD respectively. The results of this study lead to the conclusion that the North Atlantic atmospheric circulation (NAO) has strong impact and significant connection to the temperature and precipitation variability over northern and southern Mediterranean. Negative NAO is associated with warmer temperature and bring more than average precipitation conditions, the opposite with positive NAO. In the warm phase of the Atlantic Multidecadal Oscillation (AMO) there is a large increase in precipitation over the Southern Mediterranean. There is a direct relationship between Indian Ocean Dipole (IOD) and North Atlantic Oscillation (NAO). The difference in heat waves indices between the north and south of the Mediterranean is only in heat wave amplitude (HWA). Decreased in the number of discrete cold wave events begins nearly from 1957 and continue until 2019 for Antalya. The impact of climatic changes on the northern Mediterranean is more pronounced than on the southern Mediterranean.

Heat Content from Gliders and Satellites: Eastern Mediterranean case study

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Heat Content from Gliders and Satellites: Eastern Mediterranean case study Heat content measured directly by ocean gliders in the Eastern Mediterranean (EM) Sea is compared to heat content inferred from remotely sensed sea surface properties, assuming a simple reduced-gravity model. Since the Middle East is one of the most responsive regions to climate changes, expected to be warmer and dryer, monitoring and studying the sea heat capacity and the effects on the local weather regime is of great importance. For example, EM heat content during fall was found to be significant in predicting the amount of precipitation over Israel in the following winter. Heat content is a function of both the mixed layer thickness and its mean temperature. Using temperature profiles observed by gliders, we can verify heat content inferred from remotely sensed sea surface temperature and sea level anomalies under reduced gravity approximation and study its spatial and temporal variability. Sea gliders missions, conducted in high temporal resolution, provide detailed information on the water column thermal structure along its path. The comparison between the heat content obtained from gliders and the heat content calculated from remotely sensed properties shows that there are places and periods where a distinct separation between the surface and subsurface is found in the EM. This separation occurs when a subsurface dynamical eddy, for example, is observed in the profiles collected by the glider but has no surface signature, hence is not detected by satellites. Furthermore, satellite products seem to poorly represent the heat content of coastal water which exhibit a different thermal structure than an open-water thermal structure. Another finding from the heat content comparison, obtained by two different methods, is that the subsurface is better represented by the surface during summer than during winter. This indicates that the strength of the stratification is also crucial when remotely monitoring heat content. In summary, heat content obtained directly by gliders, remotely by satellites, and the comparison between the two provides several important insights about water column thermal structure variability in one of the most sensitive regions to climate change. Ocean gliders mapping is needed when accurate heat content estimation is required.

Variability of Mediterranean Sea Winter Surface Heat Loss Over the Past 70 Years

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Variability of Mediterranean Sea winter surface heat loss over the past 70 years is discussed using the ERA5 and 20CRv3 reanalyses. The focus is on the North-west Mediterranean and Aegean Seas which are the sites of strongest winter variability. In the North-west Mediterranean, the winter heat loss has weakened by 16 Wm-2 between the two halves of the period spanned by ERA5 (from -154 Wm-2 in 1951-1985 to -138 Wm-2 in 1986-2020) primarily because of reductions in the latent and sensible heat fluxes. In contrast, the Aegean Sea winter heat loss has remained unchanged with a value of -172 Wm-2 in both halves; similar results in each region are obtained with 20CRV3. The contrasting behaviour of the North-west Mediterranean and Aegean is shown to be primarily due to variations in the time evolution of the sea-air humidity and temperature gradients in each region. These gradients have weakened over the past 70 years in the North-west Mediterranean, due to more rapid warming of the near surface atmosphere than the sea surface. The corresponding sea-air temperature gradient in the Aegean has remained near-constant. The different time evolution of these quantities potentially reflects the combined effects of global heating and regional changes in atmospheric circulation (the hypothesis being that circulation changes offset the near surface atmospheric heating in the Aegean Sea but not in the North-west Mediterranean). The shift in the relative strength of the heat loss in the North-west Mediterranean and Aegean Seas has potentially significant consequences for dense water formation at these two sites, the wider Mediterranean Sea circulation and outflow to the Atlantic.

GRobs-01: A gridded dataset of daily temperatures and precipitation for Greece.

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We present a new observational gridded dataset of daily maximum, daily minimum and daily mean temperatures and precipitation for Greece and for the period 1981-2020 (hereafter GRobs-01). The dataset has an horizontal resolution of 0.1o and is derived through interpolating observational data collected from two national weather stations networks: the National Hellenic Meteorological Service and the National Observatory of Athens. To reduce the uncertainty of the gridded product, quality control procedures and homogenization of the time series is performed prior to interpolation. A comparison of GRobs-01 and E-OBSv25 available data for the common period, 1981-2004, for both the mean and extreme values indicates that the two data sets exhibit similar spatial variability over the Greek domain for temperatures and precipitation with GRobs-01 showing lower absolute and relative biases for both variables, respectively, when compared to the observations. It should be mentioned that due to the methodology GRobs-01 is derived, higher horizontal resolution versions can be easily produced which can then be used to evaluate, bias adjust and statistically downscale climate change projections.

Connection between geopotential-jet North-Atlantic weather regimes and surface weather and climate extremes over Morocco

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Morocco belongs to a region that is highly vulnerable to climate change. Nowadays, the frequency and impacts of extreme weather in this country are very sensitive, both socially and economically. Hence, enhancing the understanding of the changes in the Moroccan climate is of great importance. In this work, we investigate the link between the large-scale modes of variability and the local climate in Morocco. Weather conditions over Morocco are, in fact, influenced by the North Atlantic atmospheric circulation which is usually described in terms of regimes: a discretization of the continuous atmospheric state into a small number of qualitatively distinct, recurrent, quasi-stationary, and persistent flow patterns. The literature shows two main approaches for diagnosing North-Atlantic weather regimes. The first one consists of applying clustering algorithms to geopotential height at 500 hPa or to mean sea level pressure. The second approach uses the latitude of the North Atlantic jet. Recently, a hybrid approach that combines both the jet and geopotential height data was developed in order to compute North-Atlantic weather regimes. It has been shown that these regimes are particularly suited for the analysis of climate data, with considerable reductions in sampling variability compared to classical regime approaches. The hybrid method is used here to evaluate how weather regimes are connected to surface weather, in particular extremes, over Morocco. Comparisons with the classical regimes are done to check whether the geopotential-jet regimes are better correlated with the Moroccan observations. The obtained results will be used for climate model capabilities assessment and analysis of potential changes of regime behavior under global warming and related effects on Moroccan climate.

Characteristics of Medicanes using ERA-5 reanalysis

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Several Medicanes, which have been previously analyzed in the literature, have been studied using ERA-5 reanalyses to identify the environment in which they develop and possibly distinguish tropical-like cyclones from warm seclusions. Initially, the cyclone phase space was analyzed to identify changes in the environmental characteristics. Subsequently, the temporal evolution of several parameters was considered, including sea surface fluxes, CAPE, coupling index, potential intensity, baroclinicity. Although the results are not consistent for all cyclones, some general characteristics can be identified: cyclones develop in areas of moderate-to-high baroclinicity associated with intense jet streams, while in the mature stage the environment becomes less baroclinic. A general reduction in the horizontal extent of the cyclone can be observed as the cyclones begin to show a shallow warm core. In this phase a progressive reduction of the CAPE can be observed in proximity of the cyclone center. Finally, the wind speed appears strongly underestimated compared to the observations, raising some concerns about the applicability of ERA-5 for the detection of wind features.

Comparison between statistics of observed and the ERA-Interim reanalyses for the northern region of Tunisia at rainfall event scale

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In general, the rainfall data sets produced by the numeric models have the advantage of being complete over a long period of time. Therefore, it is important to assess their quality in relation to the observations before using them as an alternative source of data. We aim to analyse the ability of ERA-Interim rainfall data to reproduce the structure of spatial and temporal variability of rainfall Northern Tunisia. Thus, a comparative statistical analysis of daily precipitations observed by a dense rain gauge network and aggregated into rainfall events with those produced by the ERA-Interim reanalysis model is undertaken for the 30 years period (1980-2009) and the winter season (December to February). As a first step, the rainfall events (or wet spells) are extracted from DJF daily timeseries from 70 rain gauge stations and equally from 9 ERA-Interim grid boxes covering the study area. Then, DJF seasons are characterized by six descriptors indicating the structure and the frequency of rainfall events over the season. DJF descriptors are: 1) event number, 2) rainy day number, 3) total accumulation, 4) average accumulation per event, 5) average duration per event and 6) average accumulation per rainy day. We compare sample histograms as well as classification results obtained by using self-organizing maps (SOM) method combined with a hierarchical classification. The preliminary statistical analysis of the obtained descriptors from the two data sources highlights very significant differences for specifics rainfall descriptors. Indeed, the average accumulation and the duration of rain events, the number of rainy days over the season are overestimated by Era-interim data. Clustering approaches yield to four typical classes of rainfall events in both cases (observed and reanalysed). The comparison of the spatial and temporal distributions of the four classes between observations and Era-interim data give a good coherence of the temporal structures. However, the spatial representation quality varies from one region to another of the study domain. The rainfall regime is better represented by Era-interim data in the southern region of the study area but is missing representation in the northern one, i.e., in the Mediterranean coastal part.

Associations between atmospheric fronts and day-to-day temperature changes: A preliminary study

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Recently, a number of studies have appeared that related atmospheric fronts with precipitation. For that purpose, the position of fronts has been identified by objective (computer-assisted) algorithms. The geographical extent of these analyses ranged from global to regional, including the Mediterranean region. Although fronts are usually defined by temperature contrast of two adjacent air masses, the behaviour of temperature near Earth's surface during the passage of a front is far from trivial The reason is that fronts are defined by the temperature gradient aloft, not at surface, and that a number of small-scale (regional and local) processes play a role in modifying surface temperature. Therefore, an analysis of how fronts relate to surface temperature and its temporal changes (or, alternatively, spatial gradient) is needed. This is particularly so because fronts are a likely contributor to the asymmetry of statistical distributions of day-to-day temperature changes, which are an important indicator of weather variability. This contribution is a preliminary study attempting to identify the mutual relationships of atmospheric fronts with surface temperature day-to-day changes. The objective algorithm utilizing the thermal frontal parameter (second derivative of 850 hPa temperature across the frontal line) is used to define the frontal position. Reanalysis and other gridded datasets are used as data sources. The focus of the study is on the Mediterranean region.

Comparison between statistics of observed and the ERA-Interim reanalyses for the northern region of Tunisia at rainfall event scale

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In general, the rainfall data sets produced by the numeric models have the advantage of being complete over a long period of time. Therefore, it is important to assess their quality in relation to the observations before using them as an alternative source of data. We aim to analyse the ability of ERA-Interim rainfall data to reproduce the structure of spatial and temporal variability of rainfall Northern Tunisia. Thus, a comparative statistical analysis of daily precipitations observed by a dense rain gauge network and aggregated into rainfall events with those produced by the ERA-Interim reanalysis model is undertaken for the 30 years period (1980-2009) and the winter season (December to February). As a first step, the rainfall events (or wet spells) are extracted from DJF daily timeseries from 70 rain gauge stations and equally from 9 ERA-Interim grid boxes covering the study area. Then, DJF seasons are characterized by six descriptors indicating the structure and the frequency of rainfall events over the season. DJF descriptors are: 1) event number, 2) rainy day number, 3) total accumulation, 4) average accumulation per event, 5) average duration per event and 6) average accumulation per rainy day. We compare sample histograms as well as classification results obtained by using self-organizing maps (SOM) method combined with a hierarchical classification. The preliminary statistical analysis of the obtained descriptors from the two data sources highlights very significant differences for specifics rainfall descriptors. Indeed, the average accumulation and the duration of rain events, the number of rainy days over the season are overestimated by Era-interim data. Clustering approaches yield to four typical classes of rainfall events in both cases (observed and reanalysed). The comparison of the spatial and temporal distributions of the four classes between observations and Era-interim data give a good coherence of the temporal structures. However, the spatial representation quality varies from one region to another of the study domain. The rainfall regime is better represented by Era-interim data in the southern region of the study area but is missing representation in the northern one, i.e., in the Mediterranean coastal part.

Thermohaline temporal variability of the SE Mediterranean coastal waters (Israel) - long-term trends, seasonality, and connectivity

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In the framework of the National Monitoring Program of Israel's Mediterranean waters (INMoP), Israel Oceanographic & Limnological Research (IOLR) operates two continuous observation posts with near-real-time data transfer to IOLR server (https://isramar.ocean.org.il). These stations are located at the westernmost edge of the coal terminals in Hadera (north) and Ashkelon (south), 2.2 kms offshore at water depths of 26 m (Figure 1). Using the data from these stations we perform a comprehensive analysis of the decadal (March 2011 to June 2021) thermohaline variability of the East Levantine Basin (LB) coastal waters, its predominating temporal trends and their linkage with atmospheric forcing and advection. We identify statistically significant long-term warming and salinification trends with yearly rates of 0.048°C and 0.006, respectively. Through the use of the X11-ARIMA method temperature and salinity inter-annual trends are examined and associated with previously published open ocean dynamics as well as model reanalysis. We study the linkage between Northern and Southern coastal locations, and identify the along shore northward current as a primary cause of positive temperature anomalies arriving from the south. The coastal salinity long-term trend demonstrates a connection to local precipitation. A less coherent seasonal sequence is found with a bimodal behavior, where salinity values drop in August on several summers. This drop is attributed to the intensification of the along shore current in the period of June-July, potentially advecting more Atlantic Water. The observations emphasize the relatively strong coupling between coastal water and the open ocean, the influence of the general surface circulation of the LB on the coastal zone and the faster response time and higher sensitivity of the coastal environment to atmospheric forcing.

The role of natural variability over the historical period in the Mediterranean region

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Internal climate variability is the one source of uncertainty in model projections of future climate that is unlikely to be reduced in the future, even as the uncertainty due to structural differences amongst climate models (structural uncertainty) diminishes or as certain emission scenarios become more plausible (emission uncertainty). It is therefore crucial to examine how much the amplitude of natural variability varies with location and season and how it affects the long-term trends. Here, the IPSL-CM6 climate model is used to assess this internal variability in recent temperature and precipitation trends in the recent Mediterranean climate. A 32-member ensemble of historical simulations was conducted with the same observed external forcing and almost identical conditions in the ocean, land and sea-ice model components. The spread among the different members illustrate how much regional trends may vary due solely to random internal fluctuations. Preliminary results show that natural variability contributes substantial uncertainty to temperature and precipitation trends over the Mediterranean region on both local and regional scales during the recent historical period (1950-2014).

Session 2

Climate Predictions and their applications in the Mediterranean region

Conveners:

Silvio Guadi (CMCC, Bologna, Italy),

Kristina Fröhlich (DWD, Offenbach, Germany)

Predicting precipitation at decadal timescale - Developing a climate service for the energy sector in Southern Europe

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Decadal predictions have rapidly evolved in the last decade, and now are produced operationally worldwide to bridge the gap between seasonal predictions and climate projections. Skillful decadal predictions present an emerging opportunity for the development of climate services to assist planning and decision making by governments and businesses in various socio-economic sectors. On these grounds, the EU Copernicus Climate Change Service (C3S) aims at revealing the potential benefits of decadal predictions for different industries and at developing real-time, sector-specific decadal prediction products. Four European institutions participated in the C3S_34c tender, each one developing a decadal climate service working with an end user from a specific sector (insurance, agriculture, infrastructure and energy). CMCC developed a prototype climate service based on decadal predictions for ENEL Green Power in the energy sector, focusing on hydropower investments and operations in three European drainage basins, Guadalquivir and Ebro in Spain and Po in northern Italy. The end user was particularly interested in the amount of water available in the reservoir, which is primarily affected by the basin-integrated precipitation, and the safety of the dams related to precipitation extreme events that can cause dam failure and flooding. After discussing with the end user different forecast possibilities and challenges, it was decided to proceed with forecasting precipitation amounts over each of the three catchment areas. Using initialised experiments from four decadal prediction systems (DePreSys4, EC-Earth3, CMCC-CM2-SR5, MPI-ESM-HR), we first assessed the direct multi-model output for different calendar seasons and forecast year-ranges. Even though statistically significant skill was found in some cases, it was too low for the purposes of the climate service. Therefore, in order to meet the needs of the end user we explored the possibility of using large-scale predictors that can influence the precipitation in the basins. The North Atlantic Oscillation (NAO), one of the leading modes of atmospheric variability in the Euro-Atlantic sector, can drive climatic anomalies in the mediterranean area and strongly controls precipitation in the three catchment areas. Focusing on the extended cold season, from November to March, we found that NAO drives a large part of the precipitation variability in the drainage basins with high (anti-)correlations in decadal timescales. Moreover, statistically significant skill was obtained for the NAO index during the extended cold season, especially after integrating over more forecast years. The skilful NAO predictions and the high (anti-)correlations between NAO and the aggregated precipitation anomalies over each basin, allow the usage of the NAO index as a statistical predictor for precipitation. Therefore, we built a hybrid model to predict precipitation using the dynamically predicted NAO from the multi-model ensemble and the statistical (linear) relationship between the observed NAO and precipitation in each basin. Taking into account both the available skill and the needs of the end user we focused on the extended cold season for the forecast range 1-10 years. Using this hybrid approach, the precipitation predictive skill was increased significantly in all drainage basins. Last, we investigated whether developing similar hybrid models could lead to skillful predictions of precipitation extremes and indices of interest for the end user. No statistically significant skill was found for the precipitation extremes, defined as the 95th percentile of the aggregated precipitation in each basin. However, good skill was obtained for the number of wet days (number of days with at least 0.1 mm of rain) during the extended cold season which can be valuable information for the end user, since it is a good indicator of the distribution of the precipitation events during the specific season. Climate services on multi-annual timescales are still at an early stage, and various challenges remain to be addressed, e.g. finding ways to increase skill and the spatial resolution of the forecasts. However, this study shows the high potential of the decadal predictions to become useful to end users for their operations and planning. Large-scale predictors, can significantly improve the regional predictions and provide useful sector-specific information.

Predicting Mediterranean climate on annual-to-decadal timescales — perspectives from the CMCC Decadal Prediction System

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Climate fluctuations are the end result of a number of processes acting on a multitude of timescales. For a long time, century-scale climate change simulations initialized from arbitrary model states and forced with prescribed anthropogenic and natural forcings have been the only available product to inform decision-makers on future climate-related risks. A major limitation of non-initialized climate projections is their lack of information regarding the current state of the Earth's climate system. Decadal climate predictions, obtained by constraining the initial conditions of an ensemble of model simulations through a best estimate of the observed climate state, provide an accurate assessment of climate fluctuations in the near-term range (typically up to 10 years) and a useful tool to inform decision makers on future climate-related risks. First, we present results from the CMIP6 DCPP-A decadal hindcasts produced with the operational CMCC decadal prediction system (CMCC DPS), based on the fully-coupled CMCC-CM2-SR5 dynamical model. A 20-member suite of 10-year retrospective forecasts, initialized every year from 1960 to 2020, is performed using a full-field initialization strategy. The predictive skill for key quantities is assessed and compared with that of an ensemble of non-initialized historical simulations, so as to assess the added value of initialization. In particular, the CMCC DPS is capable to skilfully reproduce past-climate surface temperature fluctuations, while, in terms of precipitation, decadal predictability is bounded to a few specific regions, significantly improving predictions over central Europe and the Iberian peninsula. Second, we assess the predicted near-term climate of the Mediterranean region, one of the most sensitive to climate change. This region has undergone an intense warming and drying trend during the last decades, dominantly caused by the increase of anthropogenic greenhouse gasses. Using the aforementioned CMCC DPS and the respective ensemble of non-initialized projections, we evaluate future climate changes focusing on both the annual mean and seasonal responses. Beyond the contribution of external forcings, the role of internal variability is also investigated since part of the detected predictability arises from internal climate variability patterns affecting the Mediterranean.

Sources of predictability over the Mediterranean at seasonal time scale: building up an empirical forecasting model

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Although most operational seasonal forecasting systems are based on dynamical models, empirical forecasting systems, built on statistical relationships between present and future at seasonal time horizons conditions of the climate system, provide a feasible and realistic alternative and a source of supplementary information. Here, a new empirical model based on partial least squares regression is presented. Originally designed as a flexible tool, the system is able to automatically select predictors from an initial pool and explore spatial fields looking for additional predictors. the model can be run with many configurations including different predictands, resolutions, leads and aggregation times. The model benefits from specific predictors for the Mediterranean region unveiled in the frame of the MEDSCOPE project. We present here 2 sets of results: the first one from a configuration producing probabilistic forecasts of seasonal (3 month averages) temperature and precipitation over the Mediterranean area, their verification and comparison against a selection of state-of-the-art seasonal forecast systems based on dynamical models in a hindcast period (1994-2015). The model is able to produce spatially coherent anomaly patterns, and reach levels of skill comparable to those based on dynamical models. To explore the potential of the model for producing skilful forecasts over reduced areas, a second set of results are calculated using higher resolution predictands over Iberia, again comparing its skill with that of a set of state of the art models. Examples of the model usage for evaluating the impact on skill of certain predictor helping in the search and understanding of new sources of predictability are also shown.

A drought climate service for society in the Mediterranean

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As a consequence of the increasing interest in the change of natural resources available due to climate change, many studies properly invest their efforts to address the management of such resources. Among others, the water management plays a key role since water scarcity will be one of the main issues to be addressed by human beings, especially because of its subsequent effects on, but not limited to the agricultural sector. To tackle this challenge, the Drought Observatory, of CNR-IBE, developed an operational chain to forecast, at seasonal time scale, the Standardized Precipitation Index (SPI) to support drought and fire risks management over the Mediterranean area. The forecast tool is based on the most recent and evolute version of the ECMWF numerical seasonal forecast system, named SEAS5. Each month, from 1993 to the present, SEAS5 provides an ensemble of daily simulations, lasting 7 months each; these simulations are free accessible from the Copernicus Data Store. The SEAS5 system is used to derive the seasonal predictions of the SPI index to evaluate drought conditions a few months in advance starting from the daily precipitation ensemble simulations. This effort is made for increasing the amount of forecast information available for decision making processes. The SEAS5 daily precipitation seasonal forecasts, with a horizontal resolution of 1°x1°, are bias adjusted using the Multi-Source Weighted-Ensemble Precipitation (MSWEP) dataset (version 2.8). MSWEP is a global precipitation product with an original 3-hourly, 0.1° resolution available from 1979 to the present; it merges gauge, satellite, and reanalysis data to obtain a high quality precipitation estimates at every location. The bias adjustment is performed by using the CSTools R Package (CSTools: Assessing Skill of Climate Forecasts on Seasonal-to-Decadal Timescales) applying a quantile-quantile mapping algorithm. This algorithm adjusts/corrects the quantiles of the modelled distribution (the raw SEAS5 daily precipitation distribution) by using an observed distribution set as reference (the MSWEP daily precipitation distribution). Thus each SEAS5 grid-points of each ensemble member is 1) reprojected onto the highest resolution MSWEP dataset, and then 2) the resulting high resolution daily time-series precipitation distribution is adjusted using a quantile transformation. A 1993 – 2016 period is used for the adjustment. The resulting high resolution and bias-adjusted daily rainfall forecast dataset are then used to compute the SPI index for a series of timescales: 1, 2, 3, 4, 5 and 6 months, for the period 1993 to the present. These new bias adjusted forecasts, along with the empirical seasonal forecasts and other monitoring drought and vegetation indices, are free accessible through the Drought Observatory Climate Service (DO - https://drought.climateservices.it).

Mediterranean high resolution seasonal forecast using Analogs

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Global seasonal forecasts of precipitation are currently produced by the major weather centers. These predictions are available several months in advance at horizontal resolutions of 200 km grid-size. They have proved useful to providing an estimate of the expected precipitation over large areas. However, their value is limited for regional applications, for example, hydrological applications such as water resources planning and flood forecast in areas characterized by complex terrain, where information at finer temporal and spatial resolutions is required. Downscaling of global precipitation forecasts to the regional scale is possible through statistical and dynamical approaches. Each of these strategies possesses advantages and limitations in physical, computational and real-time implementation aspects; these have been widely reviewed and discussed in literature. For instance, statistical downscaling is computationally cheap but it relies on reliable long-term records of observed precipitation. These may be sparsely distributed. In contrast, dynamical downscaling techniques which produce regional scale gridded precipitation forecasts using regional climate model nested down from global models, may fill the gaps in sparsely observed areas, but the technique is computationally demanding, in particular if real-time forecasts are desired. The present work combines statistical downscaling methods and dynamical information to provide realtime seasonal forecasts of precipitation and temperature at high horizontal resolution. The statistical downscaling it is based on dynamical properties of the system using analogs, which makes use of predictors from CMCC model outputs and high resolution observations/reanalysis data in several variables of interest for hydrological or agriculture application in the Mediterranean region. A comparative discussion of this methodology and preliminary results will be presented. These forecasts will serve hydrological/agriculture applications, where, for instance, the water budget strongly depends on the fine spatial distribution of seasonal precipitation.

Reviewing seasonal forecasting tools for the agricultural and forestry sectors

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Climate predictions at seasonal time scales are compelling instruments able to anticipate upcoming climate risks. Thus, the development of sectoral applications based on seasonal forecast systems might benefit users for guiding tactical decisions to adapt to out of the norm events. In this work we review tailored tools for the agricultural and forestry sectors developed under the framework of the MEDSCOPE project. The applications cover different type of approaches ranging from those based on climate indicators to process based models for yield forecasting. Furthermore, we assess the performance of these applications in terms of predictions accuracy and explore different factors affecting the performance of these approaches.

Data-driven seasonal forecasts of European and Mediterranean heat wave propensity

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Seasonal Forecasts are critical tools for early-warning decision support systems, that can help reduce the related risk associated with hot or cold weather and other events that can strongly affect a multitude of socio-economic sectors. Recent advances in both statistical approaches and numerical modeling have improved the skill of Seasonal Forecasts. However, especially in mid-latitudes, they are still affected by large uncertainties that make their application often complicated. The MSCA-H2020 project ARTIST aims at improving our knowledge of climate predictability at the seasonal time-scale, focusing on the role of unexplored drivers, to finally enhance the performance of current prediction systems. This effort is meant to reduce uncertainties and make forecasts efficiently usable by regional meteorological services and private bodies. An empirical forecast is here designed throughout a statistical model based on advanced Machine Learning (ML) techniques. Such an approach, in combination with the more classical dynamical one may become critical to improve climate forecasts. In fact, a hybrid model would combine the theoretical foundation and interpretability of physical modeling with the power of Artificial Intelligence (AI), that can reveal unknown or disregarded spatiotemporal features. ARTIST focuses on seasonal prediction of temperature hot/cold extremes in Europe, and here we present a first attempt to predict heat wave propensity across a target season. From a list of possible candidate drivers, a feature selection approach is used to identify the best variable subset for the prediction of seasonal extreme heat propensity. The solution of this selection problem relies to a Genetic Algorithm wrapped around a Random Forest, that repeatedly works with a different variable subset to minimize a cost function. Land-surface candidate predictors, often overlooked by previous literature, represent a large portion of the initial feature set. We also try to improve the physical interpretability of our results by focusing on the Mediterranean area, where we link predictors and targets throughout a regularized regression approach. Preliminary results are encouraging. Future works foresee the hybridization with dynamical predictions, that will hopefully help overcoming the problematics of purely dynamical seasonal forecasts for extreme events in mid-latitudes.

Session 3

Paleo-climate at multiple time scales including the human-climate co-evolution in the recent millennia

Conveners:

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Martin Finné (Uppsala University, Uppsala, Sweden),

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Modelling of the the isotopic compositions of neodymium and oxygene in the Mediterranean Sea using a high-resolution regional model

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Our present knowledge of ocean ventilation relies on the distributions of hydrographic tracers such as oxygen and neodymium; (i) the oxygen isotopic composition (δ18O) of ocean water varies as a function of the evaporation–precipitation balance and water mass mixing. There is thus a direct relationship between salinity and δ18O values, which follow in a similar way the modifications of the water budget. (ii) the Nd isotopic composition (εNd) is one of the most useful tracers to fingerprint water mass provenance, εNd values of the water masses are conserved up to long distances from the source of lithogenic inputs when the local inputs are negligible. In such a context, it could be used to tag water masses with distinct isotopic compositions in order to constrain water mass mixing and pathways, as well as the thermohaline circulation in modern and past oceans. We have implemented these proxies in the high-resolution regional modeling platform NEMO/MED12/PISCES, and here, we present the calibration and evaluation with observations for the modern climate simulations. We have performed the first simulation of dissolved Nd concentration ([Nd]) and (εNd) in the Mediterranean Sea with an explicit representation of all Nd inputs, and the internal cycle, i.e. the interactions between the particulate and dissolved phases. The high resolution of the oceanic model (at 1/12°), essential to the simulation of a realistic Mediterranean circulation in present-day conditions, gives a unique opportunity to better apprehend the processes governing the Nd distribution in the marine environment. This work highlights that the exchange with the margins is the main source of Nd, and that the impact of river discharge on [Nd] is localized near the mouths of the main rivers. In contrast with the global ocean, the atmospheric dust input has a basin-wide influence, and improves the agreement of simulated [Nd] with field data in the Mediterranean Sea. This work also suggests that the parametrisation of the vertical cycling (scavenging/remineralisation) considerably constrains the ability of the model to simulate the vertical profile of εNd. We use the same high-resolution model to simulate the δ18O distribution for the first time in this basin. Atmospheric hydrologic fluxes (evaporation and precipitation, and their isotopic content) are provided by the isotope-enabled atmospheric LMDZ model. A reasonable east–west gradients of δ18O is simulated by the model, which separates the less-evaporated and more-productive western basin from the more-evaporated and less-productive eastern basin. The intermediate waters constitute a homogeneous layer in good agreement with the in situ observations. The knowledge of the present-day variability of the isotopic composition of the Mediterranean waters should help further studies dedicated to Mediterranean paleoceanography.

Mechanisms for past and future changes of atmospheric moisture budget in the Mediterranean region

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The sensitivity of Mediterranean atmospheric moisture budget (P-E) and mechanisms for its seasonal changes have been investigated in model simulations of the Last Glacial Maximum (LGM) and Representative Concentration Pathway scenario (rcp8.5) relative to pre-Industrial (PI). The decomposition of (P-E) in thermodynamic, dynamic, transient eddy and surface terms revealed that mechanisms for (P-E) changes in the Mediterranean do not follow a simple temperature scaling and they cannot be simply described by the thermodynamic contribution associated with the “wet-get-wetter, dry-get-drier” paradigm. Winter changes are caused by the anomalous mean atmospheric circulation (dynamic and transient eddy terms), while summer changes are largely associated with the thermodynamics. The Mediterranean response to climate change differs from the averaged behavior of other regions at the same latitudinal belt. The complex spatial interplay of the atmospheric moisture budget components makes the Mediterranean a peculiar region, which seasonal hydroclimate variations rely on different physical mechanisms not simply linked to changes of global mean temperature.

Datasets linking societal and climatic change: examples from SW Turkey and directions for future research

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It is often stated that the large number of case-studies of human-environment-climate interactions provided by archaeology might hold the key for mitigating against the impacts of future climate change. In the last two decades, these case-studies have grown in number and the nature of climatic impacts is being seen as more and more complex, with increased recognition of human agency in mitigating (or intensifying) these impacts. In this talk, I synthesise the available evidence from Late Antique Lycia-Pamphylia, SW Turkey. Utilising such a small study region is often not viable due to a lack of comparable archaeological, palynological and palaeoclimate datasets. However, in Lycia-Pamphylia, an archaeological synthesis of 381 settlements, 15 pollen records, and 3 palaeoclimate records are now available. I will use this data to test three previous hypotheses that link climate change to “prosperity“ (or lack thereof), commenting on whether these hold true at a smaller regional scale and on the quality of the data itself. The final part of the talk will be a discussion of what additional data or analyses are required to increase confidence in such analyses, and whether these are currently attainable.

Storms, coastal submersions, climate change: what human societies had to face to settle on the Mediterranean coast during the Holocene

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The Mediterranean, one of the cradles of civilization, is a key region to understand the gradual artificialization of coastal ecosystems. Since mankind settled along its coastlines during the early to mid-Holocene, human societies have acted as veritable motors of change, exploiting resources at the land-sea interface and developing a complex maritime network of trade, between countries and continents. During the Holocene, the Mediterranean has undergone profound changes, acting as the backdrop for intense human activity in which the pressures on coastal ecosystems have gradually grown. While man has progressively left his mark on coasts, he had to deal with extreme climatic or meteorological events, such as coastal storms, submersions, drought and temperature variations. Sometimes defined as rare events (because of their high intensity, duration or spatial extent) or as intense events with high impact, these upheavals affected his subsistence systems and pushed human societies to adapt. Here, we will show, from Croatia to Lebanon, how Mediterranean coastlines are evolving spaces where extreme events have been concentrated for thousands of years. We will reconstruct, for the last 8 millennia, climate shifts, relative sea-level changes, the evolution of Sea Surface Temperatures, storm dynamics as well as phases of coastal submersion/erosion to compare and contrast them with anthropogenic records. Our goal is to be able to place the dynamics of extreme events during the Holocene into a long-term perspective of human settlement along the coasts.

The Aegean: a paleoclimate synthesis

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The Aegean has a long history of human presence that has left rich archaeological and paleoenvironmental remains that have been extensively studied. This, combined with a growing number of palaeoclimate records, makes the region a suitable testbed for human-environment-climate interactions at different time scales and in different environmental settings. In the past decade, the number of palaeoclimate records published from the Aegean has skyrocketed to ~35, thus making it one of the most densely covered regions globally. Most commonly, proxies in the Aegean have been interpreted to reflect changes in various aspects of the hydroclimate: lake water balance, effective moisture, and precipitation. The density of data enables spatial analysis of palaeoclimate at a higher resolution to gain a better understanding of Holocene climate evolution over decadal and centennial timescales. The opportunity also arises for more local comparisons with archaeological data; however, obtaining more records also increases complexity, especially for non-experts. The data comes from a range of different archive types and proxies that each come with their own specific uncertainties and weaknesses. A synthesis of palaeoclimate data that includes discussions around data quality, limitations, coverage, and utility is therefore needed to improve and simplify projects examining past human-environment-climate interactions. This will lead to a stronger base for conversations around the role of climate change in the formation, development, and longevity of ancient societies, which contributes to discussions of resilience against future climate change. In this project, we have collated all available Holocene palaeoclimate data from the Aegean region into standardized centurial and decadal (where they are appropriately high resolution) bins, thus enabling direct comparison through numerical and spatial analyses. A complex picture emerges of heterogenous climatic conditions that vary through space and across time.

Early Pliocene environmental conditions in the South Aegean Sea (NE Mediterranean): calcareous nannofossil paleofluxes and evidence of the Zanclean reflooding in the Cretan basin.

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The DSDP Leg 42A Site 378 located in the South Aegean Sea (Cretan basin) offers an exceptional opportunity to investigate in detail the Early Pliocene paleoenvironmental conditions through the study of calcareous nannofossil paleofluxes. In the DSDP sediment record we focus on the “warm Pliocene” interval, following the Zanclean reflooding event of the Aegean Sea after the Messinian Salinity Crisis (MSC) of the Mediterranean Sea. A detailed investigation on marine primary producers-calcareous nannofossils response to a high CO2 world will reveal their paleoproductivity trends affected by 23-kyr monsoon variability and their re-colonization in the Cretan basin after the "post-Messinian flood". Based on the produced age model, we present a composite dataset of the two Holes (Z and A) of Site 378 for the interval 3.8-5.09 Ma. The calcareous nannofossil paleofluxes are in accordance with the δ13Corg trend in the sapropel layers, suggesting that the sapropels presented in our study are not only formed by preservation factors but also reflect enhanced accumulation and increased primary productivity conditions. Reticulofenestra spp. prevailed in the calcareous nannofossil paleofluxes. The prevailing taxa of calcareous nannofossil assemblage support in general the occurrence of warm paleoclimatic conditions during the Early Pliocene. In addition, the two principal components that influence the calcareous nannofossil assemblage are the temperature and the stratification of the water column. The sapropelic layers of the present study, are characterised by intervals with increased temperature and low oxygen conditions as revealed by δ18O and δ15N isotopic analyses and by calcareous nannofossil species related to warmer and oligotrophic conditions. Moreover, a change in sapropel formation is depicted at 4.4Ma, with the low OC content sapropels do not capture the sapropel formation mechanism signal as intense as presented in the high OC sapropels of the same interval. Finally, the presence of PLG evaporites of the first stage of the MSC, suggests a fast evaporation and a possible isolation of the Cretan Basin. According to the present study and the produced age model, the oldest Zanclean sediment, dated at 5.09 Ma, is placed above the PLG gypsum (5.97–5.6 Ma), giving a first insight of the age of the deep-water marine paleoenvironment that was re-established in the Cretan Basin, thus the potential age of the Cretan Basin reflooding.

Climate variations in the Mediterranean Sea during the last 21,000 years: insights into biogeochemical implications with a regional ocean model

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Sapropels in the eastern Mediterranean Sea (MedSea) during the early Holocene are the most pronounced signal of changes in biogeochemistry over the last deglaciation. The building and preservation forces of these organic-rich layers are not yet fully understood. In addition, the nutrient distribution for the entire MedSea at the onset of deglaction is poorly constrainted. We perform simulations with a regional general ocean circulation model including biogeochemistry in the water column and sediments over the last 21,000 years. Atmospheric forcing fields, river discharge and oceanic boundary conditions at the western model domain are adapted from transient simulations with an Earth System Model. We find a more sluggish zonal overturning circulation in the MedSea during the Last glacial maximum (LGM). Colder temperatures lead to a lower basin-wide evaporation rate. In combination with a shallow sill depth at the Strait of Gibraltar, the baroclinic water exchange with the North Atlantic reduces by about 35% compared to present day. Enhanced river discharge during the LGM supplies more nutrients to the basin, but the overall net primary production decreases due to circulation changes and an increased remineralisation length scale. LGM nutrient concentrations below 200 m are more than twice as high as today. Elevated nutrient concentrations at depth are present until 6000-8000 years BP and could play an essential role on the temporal variability of biogeochemistry over the simulated deglaciation.

What do past interglacials teach us about the response of climate of the Levant and the East Mediterranean to external forcing and to global climate variations?

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The Levant region, at the eastern margin of the Mediterranean Sea, has been subjected to periods of droughts and water scarcity throughout human history. This region is now undergoing a slow drying trend, together with the entire Mediterranean region, as the world warms due to increasing atmospheric greenhouse gas concentrations. A unique view of the historical and pre-historical climate of the Levant has been gleaned through the continued study of the sedimentary and geochemical records of the lakes that filled the tectonic basin of the Dead Sea. Here we revisit the sediment record retrieved during the 2010-2011 Dead Sea Deep Drilling Project. During interglacials lake levels were lower than during the adjacent glacial intervals, and thick deposits of salts accumulated at the Lake bottom, indicate significant regional aridity. In the previous interglacials, particularly during MIS 5e, around 125,000 years ago, during peak summer insolation, the conditions of regional aridity were interrupted by penetration of rains fed by tropical systems. This likely included that period intensified and more northward extended African summer monsoon. Evidence also exists that the normal winter wet period also intensified during peak summer insolation. The occurrence of summer rains was likely weaker or not present during the Holocene, which exhibited repeated severely dry intervals throughout the epoch. During the last interglacial, as summer insolation declined, and the African monsoon system contracted to its present-day state summer rains the Levant grew progressively drier and episodes of severe drying including evidence for a collapse of the winter rain regime occurred. This presentation will describe these findings in detail and their relation to the epochal insolation cycles, to the larger Mediterranean region and to global climatic variations in high and low latitudes, primarily in the Atlantic Ocean. We will discuss what these past connections imply for the projected greenhouse forced climate change.

Mediterranean climate at multiple temporal scales, from Deep Time to the recent Past

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This review article will consider the evolution of the Mediterranean climate since the establishment of its present paleogeography at the base of the Pliocene Epoch (ca. 5.33 million years ago). It will summarise the most important available evidence across different time scales (annual-to-millennial), reinforcing past-present-future connections and highlighting the short-to-long term external forcings and internal dynamics relevant to current regional climate issues under rising greenhouse gas concentrations. Selected Deep Time paleoclimate windows will include geohistorical analogues of the current climate such as the mid Pliocene Warm Period, when ice-sheet extension was reduced, and the cooling progression towards the 100-kyr Quaternary glacial-interglacial cycles, till our present interglacial, the Holocene, with emphasis on the Common Era, i.e. the past 2k up to the beginning of the instrumental record. It will also investigate the last millennia human-climate co-evolution, providing a context for today's unprecedented climate-emergency situation. In paleorecords, responses of slow components of the climate system are documenting the carbon cycle, ice sheet dynamics and the deep ocean perturbations with fast-reacting atmospheric processes. This enables us to inform on mechanisms of abrupt and irreversible changes, as projected for future climate at a global scale. The connection between short and long temporal changes is not trivial in the Mediterranean, due to variable regional impacts of past global climate changes, and to strong sub-regionalization of environmental patterns, often hard to simulate with current modelling of local atmospheric and oceanic processes. Hence, the review will aim to facilitate data-model comparison, integrating the use of paleoclimate data to help with testing future climate model predictions in the Mediterranean.

Relating the Mediterranean climate to the green Sahara

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The greening of the Sahara during the Holocene is still challenging the paleoclimate community. A strengthening of the African monsoon caused by increased summer insolation is usually invoked to explain why the Sahara was vegetated from 14,000 to 5,000 years ago (called the African Humid period or AHP). Recent paleoclimate studies and syntheses suggested that the monsoon front may have reached some Mediterranean latitudes (up to 31°N - 32°N) during the Holocene optimum. Here, we provide a unique climate record of quantified winter, spring, and summer precipitation from Lake Tislit (32°N) in Morocco over the past 18,500 years. This record shows that the NW Mediterranean region was wetter than today during the AHP because of increased winter precipitation and was not influenced by the monsoon. We explain that the increased seasonal contrast of insolation during the Holocene led to an intensification and southward shift of the Mediterranean winter precipitation system in addition to the intensified summer monsoon and we suggest that a winter rainfall zone must have met and possibly overlapped the monsoonal zone in the Sahara during the AHP Using a mechanistic vegetation model in Early Holocene conditions, we show that moisture contributions from the Mediterranean area and the North Atlantic Ocean in winter, were as important as an expanded summer monsoon up to the Mediterranean alone, for the greening of the Sahara during the African humid. In this talk we will provide both a past climate reconstruction and different vegetation model simulations for a better interpretation of the seasonal rainfall distribution over the Sahara. This conceptual framework should be taken into consideration in Earth system paleoclimate simulations used to explore the mechanisms of African climatic and environmental sensitivity. This study will help to better understand and simulate climate variability over northern Africa, including the African Mediterranean.

Session 4

Detection and attribution of the recent human-induced climate evolution including extremes.

Session dedicated to the study of the recent past

Conveners:

Philippe Drobinski (CNRS and Ecole polytechnique, Paris, France), Gianmaria Sannino (ENEA, Rome,Italy)

Long term changes in the deep sea: examples from two Mediterranean Channels

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The Mediterranean Sea is a mid-latitude marginal sea, particularly responsive to climate change as reported by recent studies. Straits and channels divide it into several sub-basins and the continuous monitoring of these choke points allows us to intercept different water masses, and thus to document how they changed over time. This monitoring, in many cases, is done under the umbrella of the CIESM Hydrochanges program. Here we report the long-term time series of thermohaline data collected in two of these choke points: the Sardinia Channel (1900 m, 17 years of T and S data) and the Sicily Channel (400 m, 27 years of T and S data). The Sardinia Channel allows the Western Mediterranean Deep Water (WMDW) to enter the Tyrrhenian Sea (depths > 3000 m), connecting it with the Algerian Sea (depths > 2500 m). This water mass has experienced a significant increase of heat and salt content over the past decades, due both to a gradual process and to an abrupt event, called Western Mediterranean Transition (WMT). The monitoring at the sill (1900 m) of the Sardinia Channel since 2003 shows this very clearly, and the interannual trends are significantly stronger than the global average trends. The Sicily Channel (sill up to 400-500 m) separates the Mediterranean in two main basins, the Eastern Mediterranean Sea and the Western Mediterranean Sea. Here the thermohaline properties of the Intermediate Water (IW) have been monitored since 1993, showing increasing temperature and salinity trends at least one order of magnitude stronger than those observed at intermediate depths in the global ocean. We investigate the causes of the observed trends and discuss the role of a changing climate over the Mediterranean, especially in the eastern basin, where the IW is formed. The long-term records in two Mediterranean channels reveal how fast the response to climate change can be in a marginal sea compared to the global ocean, and demonstrates the essential role of long time series in the ocean.

Regional Precipitation Index: ranking storms in Greece

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The METEO unit of the National Observatory of Athens has developed a methodology for ranking rain storms in Greece, following a similar procedure in the USA, where ranking of snow storms is routinely performed. The rain storm ranking in Greece is performed through the calculation of the Regional Precipitation Index (RPI) which takes into account: a) The daily accumulated precipitation and its exceedance of specific percentile thresholds. b) The total area where these exceedances occur. c) The population of the area that these exceedances occur. First, RPI calculations were applied in ERA5-Land rainfall re-analysis, available at 0.1 deg resolution, for a 30-year period spanning from 1991 to 2020 and all major storms that occurred within this period were ranked and correlated to the reported societal impacts. The ranking of the storms is performed based on the percentiles of all non-zero RPI in the examined period. As major storms we define the top 2% of RPI. Then, a proposed methodology for the application of the methodology on daily forecast fields provided by high-resolution numerical weather prediction models is tested and discussed. This work, was funded by the European Climate Foundation.

Long term climatology and trend of heatwaves over Greece from 1950 to 2020

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Extreme temperatures are of major concern in the scientific community as they directly affect the natural and human environment. Many studies have shown that the average global temperature is rising at a rate of 0.18 °C per decade, while the frequency, intensity, and geographic extent of heat waves are expected to increase in the future. In Greece in particular, it is estimated that the season of hot extremes will increase by about 1 month in the near future (2021 – 2050) and by 2 or more months up to 2100, resulting to prolonged periods of thermal stress, which can lead to heat-related illnesses and premature deaths. Thus, the need to study heat waves and their characteristics becomes imperative. The current work, which is funded by the European Climate Foundation, focuses on the study of the long-term variability and trends of various characteristics of heatwaves at country-scale in Greece. The analysis covers the period 1950-2020 and it is based on the global reanalysis data set ERA5-Land, provided by the European Center for Medium-Range Weather Forecasts at the high spatial resolution of 0.1O × 0.1O (~ 9km). The heatwaves were determined using two different exceedance criteria according to the following indices: (a) the 95th percentile of the maximum daily temperature, and (b) a modified version of the Excess Heat Factor index, based on the 90th percentile of the apparent temperature. A heatwave was defined when both criteria were met for at least three consecutive days. The investigation of the heatwaves spatiotemporal characteristics was conducted using several indices, including the intensity, frequency, number and duration of heatwaves and the peak temperature and heat stress hours during the heatwaves. Results showed that Greece experienced an average of approximately 50 heatwaves during the examined period, while the heatwave occurrence presents an increased trend after the 1990s, in agreement with previous studies. Overall, Greece experiences 0.8 heatwaves per summer, with each of them lasting about 5 days on average. The analysis demonstrates a strong increasing tendency in almost all the applied heatwaves indices during the examined period.

Risk assessments of longest dry spells phenomenon in Northern Tunisia

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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 600 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 3.6 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. In relation to adaptation measures in response to long droughts in the basin, the drought management system is based on three phases: (i) before drought, preparedness and early warning; (ii) drought management, mitigation in the event of drought; and (iii) subsequent drought, when the drought is over. During each of the three phases, different measurements are applied and executed. Key words: dry event, rainfall event, precipitation threshold, climate vulnerability, adaptation measures.

Recent Changes in the Rain Regime over the Mediterranean Climate Region of Israel and its application on coastal floods

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Previous observational analyses have shown a declining rainfall trend over Israel, mostly statistically insignificant. Analysis of the rainfall regime combining data of river's flow discharge from the northwestern coastal area undermines these findings, and the alarming future projections. No consistent trend is found for the annual rainfall for the period 1975-2020. This is explained by a combination of negative trend in the number of rainy days and positive trend in the daily rainfall intensity, each in the order of 2.0 %/decade. In the mid-winter, the rainfall and the daily intensity is increasing, while they both are declining in the autumn and spring, implying a contraction of the rainy season. The time span between accumulation of 10% and 90% of the annual rainfall, being 112 days on the average, has shortened by seven days during this period. This is also expressed by an increase of the Seasonality Index, indicating that the regional climate is shifting from "Markedly seasonal with a long dry season" to "Most rain in ≤ 3 months". The increase in the daily rain found significant at the northern coastal plain goes in line with an increase in flow discharge. The intra-seasonal course of the rainfall trend corresponds to that of the occurrence and intensity of the Cyprus Lows and the Mediterranean Oscillation. The sea-surface temperature was found to increase significantly, which may explain partly the increase in the daily rain intensity. The contraction of the rainy season and the increase in the daily intensity have far-reaching environmental impacts in this vulnerable region.

Pyrenees streamflow trend analysis combining observations and simulations

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The Pyrenees, located at the isthmus that connects the Iberian Peninsula with the European continent, presents large climatic diversity, ranging from Atlantic to Mediterranean climates, with high environmental value and being particularly sensitive to global climate change. In parallel, this mountain range is the water tower for more than 15 million inhabitants, also providing this resource for industry, agriculture and ecosystems. Therefore, studying and understanding its evolution is crucial for its management. It is especially important to assess probable changes in the water cycle, particularly in surface flows, in the context of climate change. However, in addition to climatic considerations, non-climatic factors such as land use can have a significant impact on river flows. Gauging station streamflow records are the primary method for defining the hydrological regime of watercourses in this regard. These data can also be used to analyze possible hydrological changes over time, as well as trends in water resources availability, when they cover a sufficient time period and especially when they are supported with complementary tools like hydrological modeling. Hydrological modeling helps to understand the underlying processes by simulating variables that are difficult or impossible to observe (e.g. soil moisture, snowpack, or land evaporation) and by performing experiments impossible to conduct in the real world (e.g. fixing land use to assess the impacts of climate change only). However, all those valuable contributions are subjected to model uncertainty, an issue that should not be neglected and should be carefully assessed. We studied the historical evolution (1980–2013) of the natural river streamflows of the Pyrenees using observation values from non-influenced gauging stations and two hydrological model results (the fully distributed model SASER and the semi-distributed model SWAT). The comparison of observational data with models allows us to detect, evaluate, and analyze changes in flow rates, their trends, and attribution, as well as the main sources of uncertainty. The performance of the simulated time series from SASER and SWAT is evaluated using the non parametric Kling-Gupta efficiency test. After that, we computed monthly and seasonal statistics for two time periods (1980–2013 and 1990–2013) and computed the trends of the different statistics using Sen s slope estimator. The significance of the trends was estimated with the Mann-Kendall test on the pre-whitened time series, with the statistical significance tested at the 95% level. Finally, these trends have been analyzed using binary classification techniques and a visualization tool based on the contingency table. In most cases, no statistically significant trends have been observed, but when they do exist, we can attribute the trend, depending on the results of the models and observations, to climatic changes or changes in land use. Another thing that the results show is the acceleration of the effect of climate change on streamflows, as this trend is more clear in the shorter period than in the longer. Finally, applying two different models, we obtained different results. Thus, we conclude that the uncertainty is large and confirm that it was a good choice to use different models. This work is a contribution to the EFA210/16 PIRAGUA project.

Evolution of precipitation regimes in the Mediterranean region with climate change: from drought to extreme rainfalls

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Climate change is known to have consequences on both mean and extreme precipitations, with potentially threatening impacts on societies. The Mediterranean region is particularly concerned, being a hotspot of temperature and precipitation changes: this region is expected to get much drier, but with more intense extremes. The research on precipitation evolution has mainly focused on either the absence of rain (drought, dry spells, …) or on the extreme rainfalls, letting the rest of the rain distribution quite overlooked. Looking at the whole distribution instead of small portions of it might help to get a broader and more coherent picture of the situation. In this presentation, we will look at how the whole rain distribution changes, in the Mediterranean region over the recent past. We are using observational data covering the whole 1950-2021 period with a daily resolution and at a spatial resolution of 0.25° (EOBS gridded data set). It enabled us to compute statistically significant trends of the rain percentiles values over the last 70 years. We found that the situation in the Mediterranean is more complex spatially speaking than the image of a homogeneous region with decreasing mean and increasing extremes. In fact, three main behaviors are observed: as expected regions with decreasing rain percentiles up to a given threshold and then an increasing distribution tail, but also regions with the whole distribution decreasing, and even a few other regions which have a behavior more representative of Northern Europe (the whole rain distribution increases). Finally we are able to reduce the information of the whole distribution trend to just two parameters, using a log-normal distribution model, which accounts very well for the three behaviors described above.

The Mistral wind: large-scale controlling mechanisms and impact on evaporation from the Mediterranean Sea

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The Mistral is a low level, northerly wind blowing through the Rhone Valley and towards the Gulf of Lion (GOL). Accompanied with a Genoa cyclone, Mistral events are often associated with severe weather is southern France, with impacts varying from extreme wind gusts and rainfall to severe wildfire outbursts. While the Mistral wind and its impacts have long been studied in the mesoscale context, the synoptic and large-scale dynamics controlling the Mistral wind are still unclear. Specifically, the synoptic-scale upper-tropospheric conditions dictating the Mistral's duration, amplitude and frequency have not been identified and quantified. In this study, using ERA5 reanalysis and a combined Eulerian-Lagrangian investigation, we demonstrate that the onset of severe Mistral cases can be linked to a synoptic-scale dry intrusion (DI). Such DI airstreams initiate in the upper troposphere at high latitudes and descend slantwise into the Rhone Valley and out to the GOL. Different classes of upper-tropospheric troughs are conductive for DI flows that govern the Mistral characteristics. The DI outflows are accompanied by surface cooling, drying, wind acceleration and intense surface latent heat fluxes. The intense evaporation is potentially conductive for the seasonal buildup of dense water formation, thereby impacting the Mediterranean overturning circulation.

Climate change and air pollution impact on present and future mortality in Rome and Milan

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High temperatures can cause excess mortality in exposed populations, particularly among the elderly. Temperature effects can be amplified further by the simultaneous presence of air pollution, which can act synergistically on the same target organs increasing the risks to human health. Mortality related to high and low temperatures and air pollution in EU will be significantly influenced by future climate and demographic changes. In existing multi-country and multi-city studies published on the association between temperature and mortality, little attention has been given to the combined influence exerted by temperature and air pollution, especially in Europe and particularly in perspective terms. Using nonlinear time series approaches with delayed effects (Distributed Lag Nonlinear Models, DLNM), by means of a Poisson model with overdispersion, we assess the combined short-term impact of temperature and air pollution on mortality from natural causes, for the two most populated cities in Italy, Rome and Milan. The short-term relative risk (RR) is estimated for the decade 2004-2015 and for the future (2050), assuming climate and air pollution scenarios consistent with the representative concentration pathways RCP2.6 and RCP8.5. For the exposure variables we used, for the temperature, the daily mean (T) and the daily apparent mean (AT), the SOMO35 indicator for ozone (sum of the surpluses from the threshold of 35 parts per billion of the maximum daily average on 8-h) and the maximum daily value for PM10. The RRs for mortality are estimated for the overall population and the most vulnerable age group (over 85 years of age; 85+), also defining the "minimum mortality temperature" (Tmm) for each city, conceived as an indicator of human adaptability to the local climate. For each of the exposure-response relationships considered (temperature-mortality, O3-mortality and PM10-mortality) a specific and different functional form is assumed after testing different models, controlling for seasonality and long-term effects. The results show that in the period 2004-2015 the two cities recorded a similar mortality pattern with no significant differences in terms of overall death numbers, in proportion to their reference population (about 1000 people per 100,000 inhabitants die every year from natural causes). On the other hand, the relative risk coefficients, the RRs, are higher in Milan than in Rome, both at warm and cold temperatures. The exposure-response associations for each variable – temperature, O3 and PM10 – show comparable patterns for both cities and a greater influence of temperature on mortality risk than that of pollutants. In particular, the number of attributable deaths is mainly associated with low temperature conditions, rather than temperatures higher than the optimum one (Tmm), which is lower in Rome and increases if we consider only the older age group. With regard to pollutants, their seasonal effect is appreciated: while PM10 affects the risk values mainly related to Milan, and above all, in association with the values of low temperatures, O3 - which affects both cities but with greater effects in Rome - concerns a wider temperature range, although it exerts its greatest influence especially in conjunction with high temperatures. Projecting the RRs to 2050, the results show that when standardizing deaths according to the reference population, the largest fractions of total attributable deaths are recorded in Milan. For both cities and climate scenarios, projections to the year 2050 do not show a significant difference in mortality load compared to historical values. However, they capture an increase in attributable mortality associated with warmer temperatures. Although cold mortality fractions (including the effects of air pollution) decrease in all cases, projected global warming in 2050 partially offsets the benefit of this reduction, increasing mortality fractions for temperatures above Tmm in both RCP scenarios, both cities and age categories. This generalized 'substitution effect' between hot and cold mortality is most evident in the RCP8.5 scenario and for the 85+ age group. In conclusion, the results suggest that a more rigorous and internationally coordinated climate policy, implying more stringent emission scenarios, can lead to significant co-benefits in terms of reducing the future health burden, reducing air pollution, achieving climate objectives, containing global warming below the 2 °C recently recalled at COP26 in Glasgow. Indeed, when the effects of climate change and air pollution are contained with climate policy action (RCP2.6), the number of fatalities (absolute cases) could decrease by 8 times in Rome and by 1.4 times in Milan, compared to the historical values.

Multiple drivers of extreme sea levels in the northern Adriatic Sea in the recent past

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Many coastal locations are already experiencing an alarming growth of flood threat due to global warming and consequent rise of the level of the oceans. It is likely that within the next decades what we now consider to be extreme events will happen at every high tide. Extreme sea levels (ESLs) at the coast result from the combination of astronomical tides with atmospherically forced fluctuations at multiple time scales. Seiches, river floods, waves, inter-annual and inter-decadal dynamics and relative sea-level rise can also contribute to the total sea level. While tides are usually well described and predicted, the effect of the different atmospheric contributions to the sea level and their trends are still not well understood. Meso-scale atmospheric disturbances, synoptic-scale phenomena and planetary atmospheric waves act at different temporal and spatial scales and thus generate sea-level disturbances at different frequencies. In this study, we analyze tide-gauge time series, model reanalyses and climate simulations to investigate the relative role of the different driving factors in the extreme sea levels distribution in the recent past. The adopted approach consists in isolating the different contributions to the sea level by applying least-squares fitting and Fourier decomposition and evaluating the capacity of reanalysis and climate modelling in reproducing the observed variability. While storm surges are the main drivers of the most extreme events, tides and long-term forcing associated with planetary atmospheric waves and seasonal to inter-annual oscillations are predominant in determining recurrent nuisance flooding. Numerical models adequately capture the variability of the main ESL drivers in the northern Adriatic Sea, thus demonstrating that they can be used for predicting the future evolution of coastal flood risk. This work has been partially supported by the Interreg Italy-Croatia AdriaClim project (Climate change information, monitoring and management tools for adaptation strategies in Adriatic coastal areas; project ID 10252001).

The rainfall extreme indices in the Northern Coast of Egypt based on CMIP5 models projections

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Projected changes in rainfall extreme indices were investigated in the Northern Coast of Egypt as simulated by the CMIP5 multimodel ensemble under RCP4.5 and RCP8.5 forcing scenarios. Climate projections in 2071-2100 highlight general warming that can result in economic and environmental consequences. For most of the cases, the sign of the climate change signal remains the same for both scenarios, but the intensity of the signal is much greater for RCP8.5. In general, the future projections of the temperature are statistically significant and usually highlight robust warming, while for precipitation, results mostly show decreases and a reduction of precipitation extremes in the future warmer world. It was shown that a general intensification in the yearly mean of both maximum and minimum temperatures are projected throughout the domain with about 2-5 ◦C when comparing the period 2071–2100 and 1971–2000. Concerning precipitation, decreases are probable for the northerly coast part of Egypt, with relative reductions reaching ~10% in RCP4.5 and ~20% for RCP8.5. A general growth in the number of CDDs and a lessening in the number of CWDs. Annual whole rainfall quantity (PRCPTOT), usual daily precipitation rate (SDII), and the extreme precipitation of RX1day are all expected to decrease. Abrupt and inclusive strategies are mandatory to report the negative impressions of climate change.

Validation of cold season extremes in Greece

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In this study we conduct a validation of simulation data on extreme events from reanalysis (ERA5, WRF ERA-INTERIM) and EUROCORDEX models (ALADIN63/CNRM, KNMI/EC-EARTH, CLMcom/HadGEM2, SMHI/MPI, DMI/NCC-NorESM1-M) as well as downscaled data by WRF EC-EARTH-GCM, using observations provided by the Hellenic National Meteorological Service (HNMS) from 21 stations in Greece. These models are validated upon extreme cold or wet events for the cold season between October and March of the period of 1980-2004. We apply two different methods of characterizing extreme values, using (a) fixed thresholds such as cold events under 0 °C for daily minimum (TN) or daily maximum temperature (TX) and events over 20mm for daily accumulated precipitation (RR), and (b) percentile thresholds concerning the distribution of the data. In the latter case, we examine events where TN or TX is lower than the 5th percentile or RR is higher than the 95th percentile of the corresponding distribution. The validation is held also for the return levels calculated for 20, 50 and 100 years for these variables. In general, the results by both methods reveal that temperature extremes are simulated comparably well by the majority of models, while precipitation extremes are underestimated not only by the projection models but also by the reanalysis simulations.

Climatology and long-term variations in short-term variability of temperature and precipitation

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Atmosphere is varying on all temporal scales. While much effort has been devoted to analyzing long-term changes (trends) in mean values and extremes, studies on changes in variability have been rather scarce. Additionally, there is no agreement on whether the atmospheric variability has changed already or not and in which direction; previous studies of trends in temperature variability have produced conflicting results. This contribution provides climatology and long-term trends in intraseasonal variability of temperature and precipitation for individual seasons, with focus on winter and summer. The temperature variability is quantified by seasonal standard deviation, persistence (temporal autocorrelation with lag of 1 day), and mean absolute day-to-day temperature difference; precipitation variability is quantified by wet-wet and dry-wet transition probability and length of dry and wet spells. Wherever feasible, we compare climatology and trends among different datasets, including station data, gridded datasets, and reanalyses. We also analyze outputs of climate models (both global and regional) for current climate conditions. Our study is conducted for Europe together with neighbouring regions (Middle East, North Africa), with a focus on the Mediterranean area.

Session 5

Characterizing and understanding the future climate evolution. Session dedicated to the future projections including climate extremes

Conveners:

Fatima Driouech (University Mohammed VI Polytechnic, Benguerir, Morocco)

Georgios Zittis (The Cyprus Institute,Nicosia,Cyprus)

Mediterranean cyclones in a warmer world: an analysis using the Med- CORDEX ensemble of coupled regional climate system models

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The Med-CORDEX ensemble of coupled regional climate system models (RCSMs) is here used to characterize cyclones crossing the Mediterranean region and related wind and precipitation fields at the end of the 21st century under the worst-case emission scenario (RCP8.5). In comparison to ERA5, all the RCSMs are shown to be able to capture the spatial distribution and features of the systems crossing the region. All the models tend to agree to show a decrease of the frequency and intensity of the systems crossing the region at the end of 21st century, with some of them also projecting a decrease in their mean size. Moreover, an increase/decrease in the associated precipitation and wind intensity in the Central/Southern part of the region is projected. The projected tendencies in the precipitation will partially compensate and amplify respectively the effect on the water budget of the region associated with the decrease of cyclone frequency in the Western and Eastern part of the region. On the other hand, a pronounced spread among the projections is found for other variables such as adjusted deepening rate, seasonal cycle occurrence and associated precipitation and wind patterns over some areas of the basin such as the Iberian Peninsula and Ionian Sea. The observed spread appears to be driven by the driving global circulation model (GCM) as well as by the physical parametrizations and by the internal variability of each model.

Fall Mediterranean Heavy Precipitation Events as seen by a large ensemble of CP-RCM future projections

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The northwestern Mediterranean is affected by Heavy Precipitation Events (HPE), occurring mainly during the fall season. With rainfall accumulations greater than 100 mm recorded in less than a day and often within just a few hours, these extreme events lead to devastating flash floods and landslides that may cause widespread destruction and even fatalities. Improving the future projection of these high-impact weather events is therefore highly policy-relevant. The rainfall extremes involved in Mediterranean HPE are essentially produced through small-scale to meso-scale convective motions, leading to short-duration precipitation extremes. Convection-Permitting Regional Climate Models (CPRCM) have shown a step-change in the quality of reproducing these short-duration precipitation extremes and especially fall Mediterranean HPEs (Caillaud et al. 2021) with respect to lower-resolution climate models. Moreover, this good behavior of CPRCMs allows us to go beyond the basic Eulerian statistical approach and to set up an object-oriented Lagrangian approach in order to explore the spatial and temporal connections that may exist within a given event. The object-oriented approach is applied to the CPRCM ensemble of the CORDEX Flagship Pilot Study on Convection (~15 models). After a model evaluation that demonstrates the ability of the ensemble to represent Mediterranean HPE' characteristics, the same approach is applied to investigate the projected changes at the end of the 21st century.

Biogeochemical dynamics response of the Mediterranean sea under two different levels of global warming: a study using eddy resolving projections for RCP4.5 and RCP8.5 emission scenarios.

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Eddy resolving projections of the physical and biogeochemical state of the Mediterranean Sea under the Representative Concentration Pathways (RCPs) 4.5 and 8.5 are used to assess the impacts of climate change on the main marine ecosystem properties of the basin in the middle and at the end of 21st century. In both RCP scenarios the numerical simulations project changes in the dissolved nutrient content within the euphotic and intermediate layers of the basin, as well as for net primary production, phytoplankton respiration and carbon stock. In particular, a uniform surface and subsurface reduction in the oxygen concentration occurs as a response to the warming of the water column and the increase in ecosystem respiration. The acidification of the upper water column is driven by the projected increase in the dissolved inorganic carbon content of the water column due to CO2 absorption from the atmosphere and the increase of the ecosystem respiration. The magnitude of projected changes is stronger in the RCP8.5 (worst-case) scenario, with a major impact in the Eastern Mediterranean due to the far limited influence of the exchanges at the Strait of Gibraltar. Conversely, the projections under RCP4.5 emission scenario show, for several variables in the second half of the 21st century, a tendency to recover the values observed at the beginning of the century. This result supports the idea that the reduction of CO2 emission could be, indeed, effective and could contribute to the foundation of ocean sustainability science and policies.

Regional Climate Model emulator based on deep learning: concept and evaluation of a novel hybrid downscaling approach to study the Mediterranean climate change at fine scale

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Delivering reliable regional and local climate change information for the next decades that is both at fine scale and taking into account all sources of uncertainty is currently an unsolvable problem with currently available dynamical climate models. In particular, current Regional Climate Model (RCM) ensembles strongly undersample the uncertainty range in future projections. To tackle this issue, we propose a completely new approach called "RCM-emulators". The RCM emulators belong to the family of the hybrid downscaling approaches, combining the physical basis of the dynamical downscaling approach (typically RCM) with the flexibility and the low computational cost of the empirical statistical downscaling (ESD). More specifically, we train a deep neural network to learn the downscaling function of a RCM within existing simulations covering a large range of climate states (past and future). The RCM emulator can then be used to emulate, statistically and at a very low cost, fine scale climate information for century-long time series of daily temperature and precipitation maps. Learning from a given RCP-GCM-RCM triplet, the emulator can emulate the RCM behavior for other socio-economic scenarios, other members of the same GCM or other driving GCMs. We present here the chosen approach and its detailed evaluation thanks to existing simulations not used during the training phase. The RCM-emulator's evaluation covers temperature and precipitation over a Mediterranean climate area for the mean climate state, the climate change signal and the extreme events.

Validation of multiple reanalysis data against Egyptian Meteorological Stations

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The main objective of this work is to analyze the observational seasonal temperature of Egypt over the period 1968-2020. This period is divided to two segments: the first one is integrated from 1968 until 1995, while the second one starts at 1996 and it ends at 2020. Trend of the temperature extreme indices is calculated over the period 1968-2020 using Egyptian Meteorological (EMA) daily data for minimum and maximum temperatures. Thirteen extreme temperature indices are investigated; such as summer days, warmest and coldest days. Also, the amount of hot days, heat wave and cold wave numbers are computed for five stations: Dabaa, Matrouh, Cairo, Aswan and Hurghada. Furthermore, ERA5 reanalysis is validated with respect to EMA observed daily maximum and minimum data for the five stations over the period 1981 to 2020. The results show that increasing in the mean minimum seasonal temperature is greater than increasing in the mean maximum seasonal temperature. Also, it shows that the trend of the amount of hot days, heat wave numbers for all stations is significantly positive; meanwhile the trend of the amount of cold days, cold spell duration indicator, cold wave numbers for the same stations is significantly negative. In addition, the ERA5 reanalysis product shows a good performance for simulating the daily maximum temperature for all stations except for Matrouh station in Autumn, Spring and Summer Seasons. Regarding daily minimum temperature, ERA5 data shows a good fit with respect to station data in all seasons except for the winter Season. Future projection of extreme temperature indices is conducted by using two regional climate models: 1) COSMO-CLM - downscaled by the EC-Earth CMIP6 global climate model – under the ssps-8.5 scenario and 2) RegCM4 - downscaled by MPI-ESM-MR global climate model - under the two representative concentration pathway scenarios: RCP4.5, RCP8.5. COSMO-CLM and RegCM4 outputs are validated in comparison with EMA observed daily maximum and minimum temperature (for the base period 1985-2005). Results show that COSMO-CLM performs better than RegCM4 in simulating the daily minimum temperature particularly during the summer season, but there is no model performs better than the other regarding the daily maximum temperature. Regarding the future projection, RegCM4 model shows: 1) a significant increase in the number of heat wave numbers more than the COSMO-CLM under the RCP4.5 and RCP8.5 and 2) shows a significant decrease in the cold wave numbers under the RCP4.5 scenario more than the RCP8.5 and COSMO-CLM.

What future evolution of the ocean surface off the large Mediterranean cities? A study based on the Med-CORDEX high resolution coupled multi- models ensemble.

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Fisheries, aquaculture, forestry and agriculture as resource-based activities, are among the main economic sectors driving the development in the Mediterranean coastal regions (1). On the ocean side, any change in seawater characteristics affects those activities by impacting the coastal vegetation, deltas, aquifers, the pelagic ecosystem, and the fish population, among others. The Med-CORDEX international initiative provides the historical and scenarios simulations of atmosphere-ocean coupled models following the CMIP5 Global Coupled Model (GCM) scenarios runs, and the last generation of CMIP6 GCM scenarios runs. We focus on the sea surface temperature and salinity of about 15 zones off large Mediterranean cities all around the basin. Their evolution and the associated robustness and uncertainty provided by the multi-model ensemble are shown. In a second step, dynamic sea level is studied, to help understand the spatial patterns of temperature and salinity results in term of changes in local sea surface circulation. Reference:(1) Dos Santos M., S. Moncada, A. Elia, M. Grillakis, N. Hilmi, 2020, Development. In: Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report [Cramer W, Guiot J, Marini K (eds.)] Union for the Mediterranean, Plan Bleu, UNEP/MAP, Marseille, France, 23pp.

Next-generation atmospheric-ocean climate modelling for extreme sea level hazard projections in the Adriatic Sea

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Today, about 10% of the world population lives not more than 10 km from the coastline, being extremely vulnerable to coastal floods and extreme sea-levels. Aside from mean sea level rise, extreme sea levels are strongly influenced by local processes driven by coastal topographies and geomorphologies. For example, in the Adriatic Sea, sirocco-driven storm surges may vary substantially within the lagoons (e.g., Venice Lagoon) or meteorologically-driven tsunami waves may change for several times over a few kilometres, like in Vela Luka Bay. Adriatic storm surge models are nowadays capable to provide coastal flood forecasts (with some reliability) at (sub-)kilometre-scale resolution in operational mode. However, till recently, climate projections of extreme sea levels at kilometre-scale (or higher) resolutions, were relying on atmospheric forcing coming from regional climate models available at about 10 km resolution and thus strongly underestimating local processes, such as the bora wind, in the Adriatic Sea. Consequently, we developed the AdriSC (Adriatic Sea and Coast) coupled atmosphere-ocean kilometre-scale climate model to better assess extreme sea level hazards along the Adriatic coast. The AdriSC climate modelling suite is composed of two modules, which can be used independently or together to quantify a variety of climate-related processes. The general circulation module – coupling online an atmospheric model (Weather Research and Forecasting, WRF) at up to 3 km resolution and an ocean model (Regional Ocean Modelling System, ROMS) at up to 1 km resolution – has been run for 31-year long periods at an extreme computational cost (i.e., each simulation took 18 months using 260 CPUs on the European Centre for Middle-range Weather Forecast (ECMWF) supercomputing facility). Further, the extreme event module – coupling offline the WRF model downscaled to 1.5 km resolution and the unstructured ADCIRC-SWAN storm surge model at up to 10 m resolution – has been used for the most extreme sea level events previously extracted from the long-term simulations following classical hazard assessment techniques (i.e. about 80 short-term simulations). In this talk, we will present (1) the evaluation of the extreme sea-levels provided by the AdriSC model, (2) the changes in kilometer-scale extreme sea-levels under extreme climate warming over the whole Adriatic, inside some vulnerable sub-basins, and along the coastline, (3) the present and projected kilometer-scale extreme sea level hazard assessments and finally, (4) the resulting sub-kilometer scale distributions of wind speed, wind direction, sea level, significant wave height, peak wave period, etc. With this study we will also demonstrate the importance to use higher-resolution climate model to help local decision makers better mitigate the impact of extreme sea-level under climate warming.

Added value of kilometer-scale coupled atmosphere-ocean climate modelling in the Adriatic region

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The Adriatic climate, which strongly depends on the complex orography and geomorphology of the basin, presents many challenges for coupled atmosphere-ocean climate models. For example, during atmospherically-driven extreme events, global and regional climate models (from 100 to 10 km resolutions) can't properly reproduce the atmosphere-ocean dynamics while kilometer-scale models better capture critical processes such as precipitations, winds, surface energy balance, etc., but are prohibitive to run for long-term simulations. The Adriatic Sea and Coast (AdriSC) modelling suite was thus developed to reproduce the atmospheric and oceanic processes at different temporal and spatial scales over the Adriatic and northern Ionian Sea. For climate studies, two approaches have been applied. First, long-term AdriSC climate simulations have been set-up to cover the present climate for the 1987-2017 period (evaluation run) and a far-future high-emission climate under the Representative Concentration Pathway (RCP) 8.5 scenario for the 2070-2100 period. Second, short-term simulations over a significant number of extreme events under present (1977-2017 period, evaluation runs) and projected future climates (RCP4.5, RCP8.5, 2060-2100 period) have been used to prove the added value of the AdriSC model. All far-future simulations were derived with the pseudo-global warming (PGW) methodology – recently extended to coupled atmosphere–ocean models – which imposes an additional climatological change (e.g., a temperature change representative of the increase in temperature between past and future climate) to the forcing used to produce the evaluation runs. In this presentation we will (1) present an overview of the AdriSC applications, (2) demonstrate the added value of kilometer-scale modelling in the Adriatic and (3) discuss the perspectives of adding a biogeochemical component to the AdriSC model to study the environmental conditions beneficial to the growth of bivalves in the Adriatic Sea.

Heat waves in the eastern Mediterranean – Dynamics, predictability, projections and impacts

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Skillful forecasts of weather extremes have a major socioeconomic importance. Here, I present a shift in our understanding of the drivers and predictability of heat waves [1]. I will further shed light on how climate change may influence these aspects in the eastern Mediterranean [2]. I will specifically focus on summer heat waves. These are identified using the climatic stress index (CSI), which was explicitly developed for the summer weather conditions in this region [3]. I will compare two complementary approaches to diagnose the predictability of heat waves: recent developments in dynamical systems theory and numerical ensemble weather forecasts. The former allows us to describe atmospheric configurations in terms of their persistence and local dimension, which provides information on how the atmosphere evolves to and from a given state of interest [4]. I will further provide projections of heat wave characteristics based on a suit of CORDEX simulation scenarios. Finally, I will offer estimates on how heat waves may affect mortality in Israel. The analysis framework I will present outlines an important avenue for future research, which can potentially be fruitfully applied to other regions and other types of weather extremes [5].

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LIFE-IP AdaptInGR: climate change projections for Greece available at the national Geoportal, contributing to the implementation of national adaptation policies

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The latest IPCC report, (IPCC, 2022) provides new estimates of the chances of crossing the global warming level of 1.5°C in the next decades, and finds that unless there are immediate, rapid and large-scale reductions in greenhouse gas emissions, limitingwarmingto close to 1.5°C or even 2°C will be beyond reach. The observed and expected rise in air temperature for the Mediterranean region, including Greece, will be accompanied by an increase in heatwaves, a decrease in rainfall, and an increase in droughts and forest fires risk. Thus, the country has to include future climate change adaptation policies and plans, taking appropriate actions to address the expected damage and adverse impacts of climate change. The use of climate projections on higher resolution, through climate services is necessary to assess the national and regional climate change signal and their impact over the complex topographical area of Greece and will contribute to adaptation plans mainly on those sectors of activity that are most vulnerable to climate change (including water resources management, forest fire risk, flood risk management, coastal erosion, building environment, energy and tourism sector). In the framework of the integrated project "LIFE-IP AdaptInGR – Boosting the implementation of adaptation policy across Greece (https://www.adaptivegreece.gr/en-us/), the National Observatory of Athens and the Academy of Athens, have produced future climate change projections for several climatic parameters such as temperature, precipitation, wind speed and relative humidity at a national level with horizontal spatial analysis of approx. 0.11°. Climate simulations were extracted from seven pairs of Global Climate Models (GCMs)/Regional Climate Models (RCMs), developed within the EURO-CORDEX (http://www.cordex.org) initiative, after their evaluation against E-OBS v19 for the period 1971-2000 for the essential climate variables of temperature and precipitation. Future projections were based on three IPCC emission scenarios, namely: the RCP2.6 (stringent mitigation scenario), the RCP4.5 (stabilization, intermediate scenario) and the RCP8.5 (extreme scenario, very high greenhouse gas emissions). Twenty-two (22) climatic indices related to the vulnerable sectors to climate change have been produced based on the ensemble mean of seven selected climate models, for two future periods: the near future (2031-2060) and the distant future (2071-2100), under the three emission scenarios relative to the reference period 1971- 2000 (current climate/control period). Climate indices tailored to the climatic conditions of Greece were constructed, relevant to climate variability and risks: high temperatures (number of hot and very hot days, maximum and mean temperature), droughts (total precipitation, dry days, consecutive dry days), extreme rainfall (precipitation days, high and very high precipitation days), wind (wind speed), energy demand (heating and cooling degree days), low temperatures (night frost), thermal stress (tropical nights, relative humidity, humidex), fire risk (mean FWI for the fire season, extreme fire danger days). The produced climate projections, indices and maps were combined with geospatial data providing high quality future climate information to further support mainstreaming of adaptation across policies and projects in Greece. Maps of the 22 climate indices for Greece were integrated as an online tool in the Geospatial Information Portal of the Greek Ministry of Environment and Energy (http://mapsportal.ypen.gr/thema_climatechange) in order to provide a useful climate service to support public authorities and stakeholders in assessing the impacts of climate change in their areas for competence. Maps are easily accessible and downloadable through the GIS Mapsportal of the Greek Ministry of Environment and Energy. The resolution of the maps is approx. 500m after applying spatial interpolation methods to the initial data. The user can find detail climate information of a specific region of the country, focusing on the map of the online tool which provides the value of the respective climate index of the area. The incorporation of climate information, related to future climate risks, into the national mapsportal, through an easy-to-use online tool, is considered necessary for supporting adaptation planning to climate change on a national and regional level. Policy makers from the public, or private sector can use climate services to access scientific information offering best decisions to society, understanding current climate variability, reduce the economic and social damage caused by climate-related disasters and build resilience to climate change.

Projecting Burnt Area under future climate change scenarios in the Mediterranean: developing a robust approach

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Fires burn annually over 100,000 ha in the N Mediterranean and, during the 21st century, wildfires will account for an estimated 30% of GHG emissions in the region. One of the root causes of wildfires is inadequate land management practices leading to accumulation of dry biomass, burning of farmland waste and landscape simplification. Fire management policies rely heavily on fire suppression and do not sufficiently address land management issues behind the inception and spread of fires. However, over the past two decades the development of firesmart landscape management and Forest Landscape Restoration (FLR) highlighted the benefits of these integrated landscape management approaches, focused on fire prevention. Nonetheless, in southern European countries wildfire prevention is rarely transposed into existing knowledge management mechanisms and policies. In Southeast Europe, including Montenegro and Greece, inadequate landscape governance mechanisms also hamper a proactive approach to fire prevention. Here we present a robust science-based methodology for estimating the reduction in Burnt Area (BA) under future climate change scenarios in fire-smart, mosaic-like resilient landscapes, located in Greece, Montenegro and southern France. This methodology was developed for the project "MediterRE3 - REstoring REsilience of Mediterranean landscapes to REduce GHG emissions from wildfires" (https://www.euki.de/en/euki-projects/mediterre3/). This methodology will support Climate Change mitigation and climate-resilient landscape planning policies and strategies, providing quantitative information to the estimation of the Forest Reference Level (FRL) provided for by the "LULUCF (Land Use, Land Use Change and Forestry)" EU Regulation 2018/841. The methodology estimates of effectiveness of fire-resilient landscapes in reducing the total BA by forest fires, based on: (i) numerical estimates of the decrease in burnt area in fire-resilient landscapes derived from existing studies, and (ii) publicly available data that show numerical differences in the size of the total BA of adjacent areas with/without fire-smart landscape management. Such estimates are essential to calculate the possible reduction in BA when applying fire-smart management in the target areas, at present and under future climate change scenarios. At the target study areas, fire danger modelling, utilizing the Fire Weather Index (FWI) and gridded observational meteorological data, will establish current fire danger conditions. Subsequently, the FWI will be correlated against the regional BA data to establish linear correlation model per study area. Future fire danger will first be calculated under three future climate change scenarios (RCP 2.6, RCP4.5 and RCP8.5), with business-as-usual management, up to 2070. State-of-the-art regional climate models, at a horizontal resolution of 12km developed within the EURO-CORDEX initiative, will simulate future climate data that drive fire danger (FWI) and BA estimates. Subsequently, numerical correction factors will be applied to the future BA simulations, under different climate scenarios, to derive the potential BA reduction for landscapes under fire-smart management. The methodology outlined in this presentation permits up-scaling of the study results as it will enable stakeholders to formulate regional mitigation plans and help them access new funding instruments.

Does increasing horizontal resolution improve the model performance in the Mediterranean? Evidence from High-Resolution Model Intercomparison Project

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The Mediterranean region is reported as one of the climate change hot-spots, posing serious threats to society, making climate scientists highly conscious of minimizing uncertainties in the present climate model simulations and improving future projections on the regional scale. Despite the efforts of the modeling community to improve the representation of the sea surface temperature (SST) over the Mediterranean Sea (MS), models still have notable bias, possibly due to insufficient resolution that limits the model capability to resolve the complex topography over the region. This study examines the reliability of CMIP6 models from the High-Resolution Model Intercomparison Project in reproducing the Mediterranean climate, focusing on the mean and extremes. Additionally, the role of the oceanic and atmospheric resolutions of the model is also investigated. All models systematically underestimated the SST at lower resolution except CMCC, which prominently overestimates over western MS and slightly underestimates over eastern MS. A finer oceanic resolution improves not only the general representation of oceanic characteristics (i.e., SST) but also atmospheric processes (wind and precipitation). These results are broadly consistent for all models; however, different models show spatially varying skills and responses of resolution for different aspects. Most models show a tendency of warming in the high-resolution simulations compared to corresponding lower-resolution simulations, leading to reduced underestimation. CMCC and MPI-ESM models show cooling with increasing oceanic resolution, resulting in a reduction of warm bias over western MS and some patches along the eastern MS coast in the CMCC and increased cold bias in MPI-ESM. Likewise, the results for enhanced atmospheric resolution have clearly beneficial impacts on certain aspects. However, an inter-model spread can be attributed to factors other than spatial resolution. Additionally, some features appear to be insensitive and do not show improvement. Keywords: Mediterranean Climate; CMIP6; HighResMIP; Added Value

Application of the Spatial Weather Generator in Modelling Present and Future Wildfire Risk

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The occurrence and intensity of wildfires in Mediterranean has increased during the last decades and is assumed to further rise due to the forthcoming climate change (CC), which is in Mediterranean characterized (based on GCM and RCM projections) by increasing temperature (all seasons of the year) and decreasing precipitation (especially in summer). In our contribution we present a summary of results of the experiment, in which we model the present-climate and future-climate wildfire risk in two European regions: one Mediterranean region – Sardinia, where the wildfires represent a serious environmental issue, and one Central European region – Czechia, where the forest fires are not so frequent presently, but their occurrence shows an increasing trend as a reasult of the changing climate and the wildfires may soon become a significant problem. To characterize the dynamics of the wildfire risk, we produce daily time series of the Fire Weather Index (FWI) using the daily weather series coming from three sources: (a) weather observations made at irregulary distributed weather stations (125 stations in Czechia, 15 stations in Sardinia; these data are used only for the present climate simulations), (b) synthetic weather data produced by spatial multi-variate weather generator SPAGETTA (Dubrovsky et 2020, Theor. Appl. Climatol.) calibrated with the observed weather data, and (c) gridded surface weather series simulated by Regional Climate Models (CORDEX database). The main focus in our experiment is put on results obtained by the weather generator (WG). To produce synthetic series representing the future climate, the WG parameters calibrated with observational data are modified by change factors which are based on a comparison of WG parameters derived from future vs. reference time slices of RCM-simulated weather series. Appart from the speed of the WGs (which are much faster than RCMs and GCMs), their employment implies some advantages, especially: (a) Arbitrarily long series may be produced, which allows to make a probabilistic assessment of the CC impacts. (b) WGs may produce future-climate synthetic series even for emission scenarios, for which RCM or GCM simulations are not available (by using the pattern scaling approach, in which the standardized RCM/GCM-based CC scenarios related to 1 K rise in global mean temperature are scaled by change in global mean temperature projected by simple climate model MAGICC for selected emission scenario. (c) Only selected statistical characteristics of the multi-variate multi-site weather series may be modified (the complete CC scenario consists of changes in averages and standard deviations of weather variables, together with the changes in temporal and spatial correlations of the weather series); this allows to assess sensitivity of FWI characteristics to changes in individual statistical characteristics of the weather series. In assessing impacts of the climate change on wildfire risk, we focus on changes in (i) high FWI values, (ii) spatial extent of area with high FWI values, and (iii) duration of the periods with high FWI. The results based on weather series synthesized by SPAGETTA are compared with results based on direct use of RCM-simulated surface weather series.

Mashreq Domain Climate Modelling Outputs and the Impacts in Selected Basins in the Eastern Mediterranean

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Results from the IPCC Sixth Assessment Report (AR6) have signaled projected decreases in precipitation, rising fire risk, and decreasing wind speed across the Mediterranean region. Moreover, increasing drought at differing scales has been observed and expected to continue increasing. Such projections are not uniform across the region, however. Impacts can greatly vary between coastal, mountainous, and inland areas. The Mashreq domain regional climate modelling outputs, developed under the auspice of the Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR), have downscaled six CMIP6 driving GCMs at 10 km spatial resolution. Both raw and bias-corrected outputs have been made available to inform climate analysis across the greater Mashreq region, including the Eastern Mediterranean and the Arabian Peninsula. Based on the SSP5-8.5 scenario for the period 1961-2070, this fine-resolution data can be used to assess impacts at the basin level. The Jordan River Basin (Jordan), Nahr al-Kabir (Lebanon), and Nahr al-Kalb (Lebanon) in the Eastern Mediterranean all reveal increasing temperature and generally decreasing precipitation, although interannual and seasonal precipitation variability is projected to continue. Runoff is projected to follow a similar pattern. Evaporation (and evapotranspiration) typically increases with rising temperatures. However, in a water scarce environment like in areas of the Eastern Mediterranean, evaporation signals a general decrease. Such projected changes can have large implications on extreme events including drought.

Increasing droughts, sand and dust storms, and other extreme events across the Mashreq and North Africa

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The IPCC Sixth Assessment Report (AR6) has signaled projected decreases in precipitation and decreasing wind speed across the Mediterranean region, including North Africa. Observed data has revealed an increasing drought trend at varying scales, which is projected to continue. While such generalizations are important, they unveil only part of climate projections. Extreme events are a growing concern, which are more localized and often not captured by global climate models. The recently released Mashreq Domain outputs, developed under the auspice of the Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR), have downscaled six CMIP6 GCMs based 10 km spatial resolution. Results include both raw and bias-corrected outputs, facilitating climate applications across the Mashreq region, including the Eastern Mediterranean. These, coupled with other RCM domains to include North Africa, can be used to evaluate extreme events in selected locales. RCM outputs corroborate rising drought in the Mediterranean region, particularly across northern Morocco, Algeria, and Tunisia. However, flood risk still remains a threat, which is often followed by a drought period exacerbating its affects. For example, in the Algerois-Mitijda basin (Algeria), a seasonal drought frequency assessment based on SPI-3 signaled a projected increase in drought from 4 events every 5 years to annual occurrence probability. Yet, risk of extreme precipitation days is projected to persist, particularly in the eastern corner of the basin. Sand and dust storms are also a growing concern in the region, despite generally decreasing wind. Proxy indicators from meteorological and environmental parameters can be linked with RCM outputs to project SDS impacts. Here, we present preliminary results with anticipated outcomes.

Climate change in the Eastern Mediterranean and Middle East

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Observation-based and modelling studies have identified the Eastern Mediterranean and Middle East (EMME) region as a prominent climate change hotspot. While several initiatives have addressed the impacts of climate change in parts of the EMME, here we present an updated assessment, covering a wide range of timescales, phenomena and future pathways. Our assessment is based on a revised analysis of recent observations and projections and an extensive overview of the recent scientific literature on the causes and effects of regional climate change. Greenhouse gas emissions in the EMME are growing rapidly, surpassing those of the European Union, hence contributing significantly to climate change. Over the past half-century and especially during recent decades, the EMME has warmed significantly faster than other inhabited regions. At the same time, changes in the hydrological cycle have become evident. The observed recent temperature increase of about 0.45°C per decade is projected to continue, although strong global greenhouse gas emission reductions could moderate this trend. In addition to projected changes in mean climate conditions, we call attention to extreme weather events with potentially disruptive societal impacts.

The Mediterranean region in the IPCC AR6

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This contribution combines information from different chapters in the IPCC AR6-WG2 report with climate information for the Mediterranean region in WG1, also making use of a separate assessment made by the Mediterranean Experts for Environmental and Climate Change (MedECC). In particular it considers the impacts, adaptation and vulnerability issues in the Mediterranean region that are described in the AR6-WG2 cross chapter paper 4 (CCP4). Climate change exposes the Mediterranean to the impacts of several climate hazards: decrease of precipitation, increases in drought frequency and intensity, intense warming and heat waves (both in the terrestrial and marine environment), increase of precipitation extremes in some areas, accelerating sea level rise and potential flooding of coastal areas. The impacts of these climate drivers are observed and are projected to greatly increase in the future in the absence of successful mitigation efforts. The consequence will be substantial additional risks for human health, agricultural production, water availability, floods and the condition of both marine and terrestrial ecosystems. The specific vulnerability of the Mediterranean region is a consequence of climatic and non-climatic factors: a large and growing urban population exposed and vulnerable to heat waves; a large and growing number of people in coastal settlements at risk by sea level rise; serious and growing water scarcity, already experienced today by countries in North Africa and the Middle East; economic risks for the tourism sector (due to warming but also future requirements to rapidly decarbonize transport); climate-sensitive ecosystems (marine, wetlands, rivers, mountain areas) already endangered by unsustainable practices. In this context, the adaptive capacity of ecosystems and human systems is expected to encounter hard limits due to interacting, cumulative and cascading effects. Currently, progress towards achievement of the UN Sustainable Development Goals differs strongly between Mediterranean sub-regions, with north-western countries having stronger resilience than southern and eastern countries. This contribution aims at presenting these issues and show the importance of combining mitigation and adaptation strategies for effectively reducing risks in the Mediterranean region.

Towards an improved representation of the surface-atmosphere coupling over Moroccan semi arid plains with the LMDZ-ORCHIDEE climate model

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The Haouz plain in Morocco suffers from several changes in land use, coupled with water scarcity and exacerbated by climate change. Assessing the parameterisation of the surface couplings over semi-arid plains in climate models is critical to improve the reliability of future scenarios. The objective of this work is to assess and improve the representation of the physical processes driving the surface-atmosphere couplings over the Haouz plain in the IPSL-CM climate model. We set-up a simulation with the atmosphere-surface LMDZ-ORCHIDÉE component, with a grid refined over the Haouz plain. The model is nudged towards atmospheric reanalysis outside of the region of interest to guarantee consistent large scale meteorological fields. Model outputs are evaluated with local observations collected at 3 meteorological stations in the plain. Results show overall good performances of the model on reproducing rainfall events with a reasonable representation of the climate over the region. However, in-depth analyses hold an underestimated soil moisture, near-surface humidity and latent heat flux that can be primarily attributed to the absence of a parameterization of irrigation in the model. Hence, our current work is based on setting the new irrigation module of the ORCHIDÉE surface model with a routing version consistent with our zoomed configuration. Moreover, since the monitoring stations with orange (Agafay) and olive (Agdal) crops are not totally representative of the mesh-size region, a sensitivity test of land cover effect on near surface climate was performed. Results showed a significant decrease of wind speed biases attributed to the increase of roughness height, however, there was no significant impact on near surface temperature and humidity nor the energy and the radiative balances. We also investigate the surface dynamical and thermal couplings in order to explain the wind and temperature biases.

Simulation of the Moroccan climate using a variable resolution GCM

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Lying within the influence of the Atlantic, the Mediterranean, and the Saharan desert, together with very steep orography, Morocco is one of the most vulnerable territories to climate change in the Mediterranean and North Africa, where precipitation is expected to decline considerably and temperatures are getting warmer. The ongoing and projected climate changes can threaten the stability of many climate-sensitive sectors, including water and agriculture. A better understanding and assessment of the regional climate variability and change in Morocco is, therefore, necessary for supporting effective risk management in such sectors. Dynamical downscaling is classically done through limited-area Regional Climate Models (RCM) driven by large-scale fields from the global models. RCMs can improve the representation of many processes, such as mesoscale circulation and orographic effects but they also have flaws that can affect the reliability of climate change projections. For instance, potential inconsistencies between the physical parameterizations of the RCMs and their forcing GCMs or an incomplete description of some climate forcings. In this work, we are using a variable resolution global general circulation model, LMDZ (Laboratoire Météorologie Dynamique, Z stands for zoom), in a coupled configuration (atmospheric/land-surface component of the IPSL climate model) forced with observed SST and SIC. We developed a new configuration reaching 35km resolution over Morocco (using the model's grid stretching capacity: "zoom") in order to study regional characteristics of Moroccan precipitation and temperature events and their response to global warming. Our approach suggests a regional climate evaluation framework, where the model's behavior is isolated from any external inherited biases issued from driving models. A 36-year-long (1979-2014) simulation is produced and compared with a similar simulation where state variables are nudged towards reanalysis in order to constrain the large-scale dynamics and assess the model's physics-related biases. The regional climate simulations are then compared to a hierarchy of simulations, which includes intermediate resolution global simulations (50km) and low-resolution AMIP simulations(250km) generated within the framework of the CMIP6 exercise. They are also compared to several observational datasets (stations and satellite-based). Our results show good consistency in the mean global circulation fields and improvements due to the model's increased resolution over Morocco. For instance, the refined grid simulation reduces the wet bias (present in the other configurations) over the Atlas by reducing convective precipitation. On a regional scale, the seasonal cycle of precipitation is also improved in most regions. We also show improvements in terms of humidity transport especially compared to the intermediate global resolution (50km) which is 20% more expensive than our configuration. The developed model configuration and the obtained results will be used for the assessment of climate change projections in the region and the related uncertainties.

Influence of the Tropical Atlantic on the Euro-Mediterranean region under future climate conditions

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Internal variability plays a remarkable role in the uncertainty of near-future climate projections over the Euro-Mediterranean region. The standard transient historical and scenario runs do not allow to properly evaluate the effect of a changing climate on the variability. To overcome this limitation and as an alternative to a large ensemble, a set of 250-year long coupled simulations with EC-EARTH 3.3 (CMIP6 version) have been performed with fixed radiative forcing at year 2000 and 2050, representative of present and future climate conditions respectively. The changes in the leading modes of Tropical Atlantic variability (the Atlantic Niño and the Subtropical North Atlantic) as well as their teleconnections have been assessed in three target seasons: spring (MAM), summer (JJ) and early winter (ND). While the change in sea surface temperature (SST) climatology shows an homogeneous high degree of warming, the difference between future and present SST variability displays a distinct behaviour, consistent along the seasonal cycle, with a decrease in the equatorial region and an increase at subtropical latitudes. The impact of these changes on the tropical-extratropical teleconnections will be shown and discussed.

Spatial and temporal variability of the aridity index in the Mediterranean under different emission scenarios

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In the present study the spatial and temporal variability of the Aridity Index (AI) over the Mediterranean, is analyzed per decade, during the 30-year period (1971-2000). Besides, the projected changes in ensemble mean AI between the period 1971-2000 (reference period) and the periods 2031-2060 (near future) and 2071-2100 (far future), based on the simulation results, derived from21 Regional Climatic Models (RCMs), from the CORDEX EU project are presented. The projection of the future climate was done under RCP4.5 and RCP8.5. Additionally for the reference period, daily precipitation totals as well as mean air temperature from the E-OBS gridded climatic data are used. The estimation of the AI was carried out based on the potential evapotranspiration (PET) defined by Thornthwaite (1948). The future projections at the end of twentieth century, based on the ensemble mean simulations from 21 RCMs, show that drier conditions are expected to establish in Spain, Italy, Bulgaria, Greece, Turkey as well as in the North Africa.

Projected changes in temperature and precipitation over Syria based on CMIP6 projections

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The Coupled Model Intercomparison Project Phase 6 (CMIP6) dataset is used to evaluate projected changes in temperature and precipitation over Syria. The changes are analysed using an ensemble of 24 models for four future time scales (2021–2040, 2041–2060, 2060-2080 and 2080–2099) relative to the reference period (1970–2000) under two Shared Socioeconomic Pathways (SSPs; SSP1-2.6, and SSP5-8.5).Precipitation and temperature changes over Syria are robust both in terms of sign and magnitude even for the lowest emission scenario SSP126. The projected warming during the twenty-first century can span from 2.13 to 6.91°C in CMIP6 considering these two different scenarios. The most significant positive anomalies are found in summer and more pronounced under SSP585 (28.4%) vs 19.3% under SSP126 relative to the (1970-2000) baseline. By the end of the 21st century, the temperature is projected to increase by up to approximately 7.0 °C over northern and southwestern Syria of the domain under the high emission SSP585 scenario. Projection of precipitation changes also showed that the precipitation over most parts of Syria will decrease during the twenty-first century and extreme negative anomalies in annual precipitation are more prominent for late future (2081-2100) under SSP585 scenario (>15%) compared to the base period through western, southern and central parts.. However, a robust and significant precipitation decline is projected during winter and spring by the end of the century and for the high emission scenario (>20 %) relative to the reference period.

Mapping coastal inundation on regional scale, case of the Apulia region

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The high number of human assets along the coast and its morphology makes the Apulia region particularly at risk because of the ongoing sea level rise. Some risks are directly human-related, others are caused by climate change, others by natural variability and its effect on extreme weather events. In the last decades the expansion of coastal settlements, building of infrastructures, and touristic exploitation of the coastal areas of Apulia have contributed to the reduction of the sediments and affected their redistribution along the coast. Consequently, processes of erosion, coastal flooding and depletion of natural marine-coastal habitats have been triggered along Apulia coastal zones, causing loss of biodiversity, and impacting ecosystems (marine, terrestrial and transitional – e.g., wetlands). Many coastal problems in the Apulia region are attributable to sandy-gravelly beaches that are retreating and to rocky shores with cliffs in rapid evolution. The coastal erosion is influenced by many factors: sea level, currents, winds, and waves, which are all affected by climate change. In particular because of sea level rise and marine storminess, climate change can increase the likelihood of floods with significant social and economics consequences. For this reason, flooding maps are needed to identify population and infrastructure at risk to present and future levels of inundation. In this study we have used a static model (often called bathtub model), to map storm tide flooding at regional scale. This model determines flooded areas as those hydrologically connected to the coast and lower than the elevation of the storm tide. It makes use of a Digital Elevation Model (DEM) in addition to a projected flood water level to estimate the flood inundation. In this study we have used a Digital Elevation Model with a resolution of 8 m and different sea-level projections, namely 0.2 m, 0.5 m, describing likely condition in the next decades, and 10 m, describing a possible condition at the end of the 23rd century. Our results show flooded areas especially in the Gulf of Taranto (in the Ionian Sea) and along the coast of Gargano. These maps of flooding may be a very important contribution for understanding coastal inundation issues and for an assessment process. In this way government agencies, stakeholders and public can overlay the potentially impacted areas with other data, such as critical infrastructure, roads, ecologically sensitive areas, demographics, and economic information.

Session 6

Past, Present and Future change of Mediterranean-type climates

Conveners:

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Recent trends in impacts-relevant climate in the world's Mediterranean- type climate regions

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Mediterranean-type climate regions are heavily dependent on cool season precipitation for water resources and agriculture. Declines in cool season precipitation have been noted in the Mediterranean, Chile, southwest South Africa and southern Australia while California has also been experiencing recent droughts. These changes have been attributed with some confidence to rising greenhouse gases, a poleward shift of storm tracks and Hadley Cell expansion. However, from the perspectives of climate hazards such as fire and heat and ecosystem impacts, spring and summer climate change are also important. For example, recent work shows that summer burned area in California's Mediterranean-type climate depends on winter precipitation but also on precipitation, temperature and vapor pressure deficit in spring and early summer. Here we consider trends over past decades in the impacts-relevant quantities of precipitation, surface temperature, humidity and vapor pressure deficit throughout the seasons for all the world's five Mediterranean-type climate regions. Trends from reanalyses are compared to those from CMIP6 models to attribute changes to radiative forcing and natural variability and the connections between change in thermodynamic quantities and the atmospheric circulation are explored. A trend towards decreasing vapor pressure west of southern hemisphere Mediterranean climate regions is examined in relation to changes in mean winds and subsidence. We show that across the Mediterranean-type climate regions human-driven climate change throughout the year is generating changes in impacts-relevant climate quantities such as precipitation and humidity that will create substantial challenges to societies and ecosystems.

Decomposing temperature variability in global Mediterranean-type climate regions

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Mediterranean type-climate regions (MC) are characterized by a warm and dry summer season. Recent studies reveal that the observed temperature trends vary significantly between these regions, with the Mediterranean Basin warming faster than MC regions in the Americas, southern Africa and Australia. These differences in trends are attributed to various external or internal climate drivers. Nevertheless, the contribution of each driver is not well understood. We carried out two analyses in order to achieve a basic knowledge of surface temperature variability components related to anomalies of monthly temperature for the last four decades (1980 to 2020). First, a composite analysis using the ERA5 reanalysis dataset (2-m temperature and soil moisture), trying to identify the importance of land-atmosphere interactions. Second, a reconstruction of monthly anomalies based on the methodology by Lean and Rind (2008), which considers global Carbon Dioxide (CO2), Local Soil Moisture, Zonal Volcanic Aerosols, ENSO, and Global Total Solar Irradiance. We find that across the Mediterranean-type climate regions the local signal of temperature for the driest and wettest years varies. It is stronger in Mediterranean Basin, North America and southern Australia for dry and wet years (defined by the 10th and 90th percentiles respectively). Climate drivers play a fundamental role in surface temperature anomalies. For the northern hemisphere, the role of CO2 is more prominent (explains ~85% of temperature variability). Instead, in the southern hemisphere the relative importance of CO2 changes dramatically (below 50%), and other climate drivers, such as volcanic aerosols, explain most of the variability. Reference: Lean, J. L., & Rind, D. H. (2008). How natural and anthropogenic influences alter global and regional surface temperatures: 1889 to 2006. Geophysical Research Letters, 35(18), 1–6. https://doi.org/10.1029/2008GL034864

Session 7

Climate change impacts and adaptation in the Mediterranean agro-food systems: challenges, options and solutions

Conveners:

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The impacts of climate change on gastrointestinal and liver health problems related to the agro-food systems and possible solutions

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Climate change is global weather extreme challenge. These weather extremes could contribute to changes in the pattern of health problems. Climate change was found to have a major influence on the distribution and severity of hepatic and GIT health problems. These health problems are variable from hepatic toxicity due to exposure to huge amount of chemical pollutants specially with COVID-19 event and the usage of huge amounts of disinfectants, and the usage of huge amounts of pesticides in agriculture lands. Climate change could cause increasing chemical emissions, or change in its biodegradability, or restriction in its dispersion, which increases it`s hazardous effects, especially on liver. Also, the ordinary health impacts of climate change on the emerging and re-emerging of outbreaks of vector-borne and parasitic diseases. We cannot neglect the impacts of climate change on water or food-borne health problems and diarrheal diseases. The impact of climate change on the availability and quality of food and water resources were proved in many publications. Migration of infected people from endemic areas due to the climate change disasters results in rapid dissemination of infectious diseases that leads to outbreaks or endemicity of diseases in new unexpected areas. Therefore, this presentation will focus on the impacts of climate change on the liver and GIT health problems related to agro-food systems.

Research in Environmentally Induced Human Mobility: An Analysis of Methodological and Theoretical Dimensions

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Research in environmentally induced human mobility has seen an increase in the previous decades. However, the complexity of environmental change and the frequently subsequent human mobility raises challenges in the research process. The variety of theoretical and methodological approaches that can be applied to each of the phenomena contributes to different layers of analysis when focusing on the decision-making process of migrating due to environmental factors. Drawing from the theoretical and methodological frameworks used by the scholars of each area, this paper aims to analyze how they are applied in empirical studies that focus on environmental change and mobility in the Middle East and North Africa. Finally, the paper includes a proposal of a theoretical-methodological framework aimed at supporting researchers in conducting studies on the topic of environmental mobility supported by the need to articulate theories and methodologies between areas of knowledge that traditionally are not articulated. This proposal privileges the use of a qualitative methodology, by applying methods such as in-depth or semi-structured interviews, aimed at obtaining an overview of the individuals' experience. The data is analyzed by applying Nussbaum's capabilities approach adapted with environmental and intergenerational considerations, which supports the knowledge creation on how environmentally induced mobility is contributing to human and sustainable development.

A System Dynamics approach for sustainable water management under global changes: a case study from the Souss Massa region.

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A System Dynamics approach for sustainable water management under global changes: a case study from the Souss Massa region. The interactions between ecosystem degradation, high population growth rate, climate variability, and socio-economic variables need to be better understood because of their potential impacts on food security, water resource sustainability, and climate change. Decision-makers need to be aware of these interactions for science-based decisions making. The Souss Massa basin, which has a strategic and socio-economic role in the kingdom of Morocco, is experiencing severe water scarcity due to the changing climate and the high competition between agricultural, industrial, tourism and domestic water uses. This challenging situation is impeding the sustainable development of the region. Our study proposes a tool that can help decision-makers to achieve sustainable water management based on improved water use efficiency. A sustainability index (SI) is fitted to evaluate the sustainability of water supply with respect to water demand. The SI is defined as the ratio of the difference between water supply and demand divided by the total water supply. To avoid water stress situations, the goal is to attain an SI above 20% throughout the study period. The modeling approach is the System Dynamics that provides a unique framework for managers to integrate the physical and socio-economic systems that are both important to the successful management of water at the watershed scale. This approach provides a better understanding of the interactions between different drivers of the problem that intervene during the model development process. It starts with the development of a conceptual model based on a causal loop diagram that will serve as the basis for quantifying the model and developing the quantitative stock-flow diagram. The simulation model is expected to highlight that water scarcity requires a shift in management policies regarding the demand and supply balance. The simulation results will help in shaping different strategies based on actions on both demands (efficient irrigation, high added value crops) and supplies (water treatment, desalination, water transfer, leakage management). The designed strategies will take into consideration the different socio-economic development plans of the region as well as the projected climate change. The model will first be tested in the Souss Massa basin and later extended to other basins. The study will showcase the benefits of applying System Dynamics to solve complex water resource management problems in water-stressed basins and will contribute to the sustainable development agenda in arid and semi-arid regions.

Morocco's performance in climate change adaptation and mitigation

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Increase in frequency and intensity of climate extremes associated with climate change is a threat to sustainable development. Developing nations that contribute the least to greenhouse emissions are the most vulnerable to climate change impacts as compared to developed nations. There is growing need for effective climate change adaptation and mitigation strategies. This scoping review study explores some of the progress made by Morocco in adapting to and mitigating climate change as well as the challenges and opportunities of addressing climate change. The country has made a healthy and sustainable environment a human right, enshrined in its constitution. Morocco has enforced its national environmental and sustainable development policy to support its target to reduce its GHG emission by 45.5% by 2030. The policy is backed by relevant sectoral strategic development plans aimed at conserving the environment and promoting environmentally friendly programs mainly in water, agriculture, energy and transport sectors. The country's active involvement in environmental diplomacy exemplifies its exploits both locally, and internationally in promoting environmental awareness. Despite the gains, there are still issues such as gender equality and social inclusion in most environmental and climate initiatives. Morocco's exemplary response to climate change can be a reference for other nations, both developing and developed.

Climate Change Effects on Agriculture and Adaptation Measures in Mediterranean Regions

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The five Mediterranean climate zones of the world have distinct climatic regimes, with cold, rainy winters and hot, dry summers. Drought and high temperature occurrences are becoming more often as a result of climate change, putting agriculture in these areas at risk. In this study, we look at how climate change will affect agricultural systems, and different measures agricultural systems should adapt to Climate Change, the social and economic repercussions, and the techniques employed by producers to adapt to Climate Change. Water shortages are most common in rainfed environments during the blooming and grain filling stages, which has a significant impact on crop yield. due to a reduction in irrigation water availability and an increase in evapotranspiration. Agriculture's adaptation to Climate Change in Mediterranean zones necessitates integrated methods that involve several aspects, including the product, agricultural systems, and farming practices.

Adaptation of climate change in Morocco: impact and national strategies

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The world is already experiencing the dramatic effects of climate change, which is likely to lead to longer and more widespread heat waves, making some regions uninhabitable and soils unsuitable for agriculture. This rise in temperatures will put intense pressure on crops and already scarce water resources. This situation is further exacerbated by the impact of climate change. The increasing demand for water due to human, industrial, agricultural and repeated droughts at the national level has led decision-makers to consider wastewater as a valuable source. In Morocco, the water sector is facing the challenges of overexploitation of groundwater resources, the weak development of water resources mobilized especially in the agricultural sector, the effect of climate change and the deterioration of water resources quality due to the delay of sanitation, as well as wastewater treatment and reuse of treated wastewater. This study is used to make a comparative study between the methods used in the treatment of wastewater and to raise it by adapting renewable water resources.

Session 8

Living in the Mediterranean cities in the context of climate change

Conveners:

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Changing Climate, Changing Lives. Climate and Society in Greek cities from the antiquity to the present.

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There are several ways to interepret climate and its role for the formation of a society in several historical periods. The present study gives an overview of the climate conditions and the role they played for the developed of the Hellenic Civilization in the past and compares it with the situation that prevails nowadays. For this reason we shall use data from primary sourses as well as the secondary literature on the subject. An important part of the paper will deal with the relavant discussion between Greek and foreign scientits during the 19th century. Furthermore we would like to claim that though the climate in Greece has been more or less stable over the centuries, the formation of a different way of life in the modern cities has played a critical role for a new micro-climate within the cities limits and consequently the influence on the people's behavior. As a case study we'll focus our examination in Athens.

Investigation of SPI and SPEI trends for wet and dry periods under climate change in Greece

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According to IPCC 2021, droughts have become more frequent and intense, especially in the North Mediterranean, under moderate emission scenarios, and strongly enhanced under severe emission scenarios. Accordingly, Greece will face relatively severe drought conditions in the upcoming years. The present study investigates drought projected trends during wet and dry season over Greece based on the high-resolution output dataset of the Weather Research and Forecasting (WRF) model at 5-km grid spacing. WRF was driven by EC-EARTH-GCM output in the domain of Greece at very high resolution for the historical and future periods under two Representative Concentration Pathways 4.5 (RCP4.5) and 8.5 (RCP8.5). The standardized precipitation evapotranspiration index (SPI) and standardized precipitation evapotranspiration index (SPEI) data were calculated for an accumulation period of 6-months timescale for selected cities. This timescale distinction is according to the definition of the Hellenic National Meteorological Service (HNMS), as precipitation occurs in Greece during the wet season from October to March, while the dry season lasts from April to September with scarce intervals of rapid rain or thunderstorms of small duration mainly in mainland areas. Overall, the projected results using both indices showed both positive and negative trends, pointing out that a strong positive trend of severe drought events is expected, mainly under RCP8.5.

Climate knowledge in support of health systems resilience in the Mediterranean Region: The LIFE-RESYSTAL project

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Climate change has been identified as a major challenge in health systems, potentially stressing the capacities of health systems to cope with more exposed humans (excessive demand of services) and potentially reducing their operational capacity and causing structural degradation. The LIFE RESYSTAL project addresses the Climate Change Adaptation policy priority within the health sector aspiring to provide a better understanding of how on climate risks and vulnerabilities and best practices and solutions for climate change adaptation based on green and blue infrastructures. LIFE RESYSTAL assembles a highly innovative toolbox that will allow practitioners to identify climate risks, health infrastructures vulnerabilities and propose cost-beneficial measures to enhance their resilience through an extensive assessment of available adaptation actions. Additionally, the toolbox will target management of acute climate crisis thus forming a holistic approach to enhance resilience of health care facilities. It represents the first step to tackle climate change (CC) and will serve as groundwork for future adaptation projects. The project will develop and demonstrates innovative solutions and tools in 4 pilots (7 hospitals) in the Mediterranean, leading to the implementation of hard adaptation measures in terms of blue-green and grey infrastructures, and also operational measures. The pilots differ in terms of infrastructure characteristics and operations, climate pressures and anticipated adaptation measures.

Interconnection of floods, forest fires and mudflows under the prism of climate change. The case of Lamia airport, Greece

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Due to climate crisis, the number of forest fires and extreme precipitation events is expected to be significantly increased, in the following decades, especially in the Mediterranean area. The combination of these two phenomena can lead to extensive mudflows with devastating results to critical infrastructures, such as airports. In this direction, the destructive phenomena occurred in September 2020 in Lamia, central Greece, and their impact on the vulnerability of the local airport are analysed, and their interconnection is evaluated. In 2019 the Lamia prefecture was affected by huge wildfire events. More specifically 1074.81 acres have been burned, mostly consisted by forests, and cultivated areas. The extent of the burned area was significantly higher than the mean annual burned area in that region (347.19 acres) during the previous decade (2009-2018). The absence of suitable response measures resulted to the progressive soil erosion of the burned area. Moreover, on 18th September 2020, an extreme precipitation event, the “Ianos” Medicane (Mediterranean hurricane), affected the prefecture of Lamia. It is noted that the local meteorological station recorded 134.6 mm of precipitation, which was by far the highest value from the beginning of the meteorological station’s function (the second highest value recorded was 77m). As a result of these two extreme phenomena, a huge volume of mudflow by the burned area was created and headed towards to Maliac gulf through the local drain basin. The mudflow blocked the flow in the concrete sewer pipes under the local bridges. The outskirts of the Lamia city, including the Lamia airport, were flooded and the extensive mudflow inserted into the airport causing serious damages to the airport’s buildings, the airport’s electronic equipment and to two firefighting aircrafts (type PZL-Mielec M-18 Dromader) that that were landed at that time. The airport’s function was disrupted for almost a month. Using Sentinel-2 images, before and after the precipitation event, and the European Space Agency (ESA) classification algorithm it was evaluated that 35.33% of the total airport’s area was covered with mud and water. The main objective of this study is to highlight the increased vulnerability of critical infrastructures, such as airports, due to the impacts of climate change, and the necessity for adaptation measures.

Experimental investigation of suspended particles levels inside the stations and trains of Athens city Metro network, Greece

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In recent years, where air pollution issues are continuously growing and are receiving more attention from both worldwide health and political organisations, the issue of collecting data sustainably and efficiently for the observation and treatment of air pollution has been arose. A multitude of papers and studies have been conducted that deep further on the technical and economical aspects of data collecting and air quality monitoring with Low-Cost (LC) sensors showcasing a promising solution. Low-Cost sensors are called to solve the problem of portability, accessibility and budget friendly option for monitoring of air quality with a seemingly minor loss on reliability and precision. In this work the goal is to showcase, through a real-case scenario study, the capabilities of LC sensors as well as to pinpoint what are the drawbacks of using such devices. To achieve such goal the work was separated in two individual parts. The first part was the calibration and comparison of the LC sensor to a reference instrument of high accuracy over observatory "open field" conditions and the second part where the sensor was used to monitor a route from a suburb area of Athens, Varkiza, to a central area of Athens city, Aigaleo, through the use of public transportation and more in specific public buses and metro. The examined pollutant was particular matters (PM) with aerodynamic diameter of 1μm, 2.5μm, 5μm and 10μm, but the main focus was 2.5μm (PM2.5). The work studied the mass concentration of particular matter within the air (μm/m3) as well as the corresponding value of a well-known air quality index, AQI. The sequence in which the monitoring took place was modelled in such way of recreating the weekly route of a student resident or a full time working resident, to simulate the average exposure of an average user of public transportation. In the phase of processing data for the formation of graphs and conclusions temperature, humidity and pressure were also taken into consideration, provided by the LC sensor used for the monitoring of PM. The results showcase that the metro stations have the highest concentration of PM in comparison of public buses and walking routes and public buses have the lowest exposure to the passengers of PMs. The LC sensors also provided data for tracking phenomena of intense production concentration of PM in the air, while in the metro subway or the metro wagon (the effect of open windows or opening windows, the air created during the slowing down of a metro wagon etc.). Furthermore a comparison of the concentration of PM was showcased in the suburb area (Varkiza) and central area (Aigaleo) of Athens city and once again the LC sensor was able to track down the correlation between the car activity and phenomena of PM concentration intense increase. Finally during the monitoring sessions and through the graphs provided from the data collected it seems that the density of passenger play minor role in the increase of PM concentration and instead a major factor is the intensity of the activity of the passengers (the amount of passengers boarding and disembarking the wagon), even if the total amount of passengers is relatively low.

Climate dependent tourism over the Mediterranean cities based on human thermal perception under global warming

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More than 50% of the world's population and almost 75% of Europeans live in urban areas. It is estimated that in the cities of southern Europe, due to climate change, there will be a higher increase in heat stress. However, the increase in maximum temperature during heat waves is expected to be greater in Central European cities. These future climate forecasts are very likely to shape and influence the criteria for choosing a place as a touristic destination. In fact, there are two cases, which distinguish between climate dependent tourism and climate influenced tourism. In the first case the Mediterranean is mentioned as an example where the climate functions as a pole of attraction for tourists looking for favorable weather conditions, while in the second case the climate influences specific activities. The goal of this study is to highlight the human thermal perception anticipated to prevail in twenty Mediterranean cities, during midday and evening. One of the most popular and widely applied human thermal index, the Physiologically Equivalent Temperature (PET), based on human energy balance, is utilized to quantify the regime of present and simulated future bioclimatic conditions. Air temperature, humidity, wind speed and global solar radiation (estimated at 1.1m where is the gravity center of the human body and builds the reference level for human biometeorological studies) are the parameters needed for the assessment of PET, using the RayMan model. The meteorological datasets concern 3-hour data from the SMHI RCA4 regional climate model (Rossby Center, Swedish Meteorological and Hydrological Institute, Norrkoping Sweden, spatial analysis 11 km), for the historical period 1971-2000 (reference period), as well as for the periods 2021-2050 and 2071-2100 under the two Representative Concentration Pathways, RCP4.5 (intermediate) and RCP8.5 (extreme). The results of the bioclimatic analysis will help in the management/dissemination of climate information for tourism purposes. In addition, the methodology used, based on bioclimatic (PET) diagrams, can provide detailed information in order to assess and quantify the climate change impacts on the tourism potential in the Mediterranean cities.

Elemental analysis of PM2.5 in the center of Xanthi in Greece using X-RAY fluorescence

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Particulate Matter (PM) is a major air pollutant causing serious health problems. The aim of the present study was to focus on the measurement and the detection of the different chemical elements. A total of 12 samples were collected due to various problems during the sampling. Nuclepore filters with a diameter of 90 mm and a pore diameter of 2μm, were used to collect the particles. Prior to each sampling, the filters were rinsed with deionized water and allowed to dry. Sampling was carried out in one of the streets with the most traffic, in the center of Xanthi with the help of a medium- size virtual sampler. The measurements lasted about a year and started on 29.09.2013 and completed on 04.11.2014. Then, after samples were taken, their analysis took place with a particular spectroscopic instrument in the Atmospheric Pollution Laboratory, where its location is on Kimmeria, Xanthi, Greece, to make the detection of chemical elements that were in the filters. The survey results present high concentrations, especially in November and during the summer months. The conclusion of this period is that in summer, there is an increased traffic, and also during the winter months, because of cold generally prevailing in Xanthi, namely due to climate, we have large heating levels and then we have high concentrations of elements from fuel and general combustion. The elements that cause the greatest interest because of their high concentrations are nickel, iron, sulphur and chromium.

The contribution of electric vehicles to the reduction of thermal emissions to the urban environment

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In the proposed manuscript, an experimental study was conducted in order to investigate the thermal emissions of electric vehicles (EVs) compared to the corresponding thermal emissions from conventional internal combustion vehicles. The aim focused on investigating the reduction rate of thermal irradiation emitted by conventional vehicles, in Greece up to 2030, when these vehicles will be replaced by EVs. In particular, four different vehicles, two EVs and two conventional vehicles were examined. It should be noted that if EVs do not use an air conditioning system, there is no heat emissions to the environment, except the thermal emission due to the absorption of solar irradiation from their construction materials, in contrast to conventional vehicles. Valuable conclusions were drawn regarding the contribution of the use of EVs in shaping better biometeorological conditions for humans, in particular their contribution in order to be reduced the intensity of the urban heat island phenomenon. The main findings that emerged concern the emissions of thermal irradiation from vehicles and specifically: i. All vehicles emit thermal radiation from their shell with wavelengths in the infrared region. ii. The point of the vehicle shell (bonnet) under which the engine is located, seems to emit about 40.0% of the total heat energy emitted from the whole vehicle's shell. iii. The color of vehicle's shell seems to be not such an essential parameter in the reduction of thermal irradiation emitted from vehicle's shell. iv. In the year 2030, the total emissions of thermal energy to the environment from vehicles in Greece, will be reduced by at least 2.02%, due to electric vehicles penetration.

Daily precipitation maxima over Mediterranean cities; analysis on future monthly trends and spatial patterns

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Climate change affects the intensity and frequency of precipitation and is highly linked to flooding, especially in urban environments. In the Mediterranean Region, the seasonality of severe flood events was found to coincide with the seasonality of the daily precipitation maxima. The integrated flood risk management requires extensive analysis on the local precipitation regime, and, in terms of sustainability, this approach should also take into account the climate change perspective. This research work focuses on the analysis of daily precipitation maxima patterns for selected cities over Mediterranean, using the model simulations by the EURO-CORDEX. Particularly, trends and other statistics are analysed for two RCP scenarios and the results are provided for two periods: 2030-2060 and 2060-2090, and also on a mean monthly basis. The analysis focuses on determining specific spatial patterns regarding daily precipitation projections for both coastal and inland Mediterranean cities.

Health risks in the Mediterranean cities resulted by climate change

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Climatic changes impact the health of the Mediterranean cities population directly through extreme heat, drought or storms, or indirectly by changes in water availability, food provision and quality, air pollution and other stressors. All have the potential to impact both physical and mental health. The main health effects are related to extreme weather events (including extreme temperatures and floods), changes in the distribution of climate-sensitive diseases and changes in environmental and social conditions. The poorer countries, particularly in North Africa and the Levant, are at highest risk. The current presentation is focused on two main issues – heat related illness and vector-borne diseases: Heat-related illnesses and fatalities can occur when high ambient temperatures (in particular combined with high relative humidity) exceed the body's natural ability to dissipate heat. In general, elderly people, children, people with pre-existing chronic conditions are most affected. For example, in Israel, high ambient temperature was associated with stroke risk starting from the day before the stroke event, and increasing in strength over a six-day lag. Climate change contributes to the transmission potential of vector-borne diseases since the lifecycle dynamics of the vector species, pathogenic organisms and the reservoir organisms are all sensitive to weather conditions. In the Mediterranean Basin, several vector-borne diseases, sensitive to climatic variations, are common, while others are potential threat. Following the recent climatic and environmental changes, it is expected that VBDs outbreaks will be exacerbated in the region. An example is the West Nile virus (WNV), transmitted by mosquitoes, a vector-borne pathogen of global importance. Its transmission cycle involves both rural ecosystems and urban areas, where the virus circulates between birds and mosquitoes, particularly members of the genus Culex. Under certain environmental conditions it spreads to human settlements where it infects humans and equines, and may cause large epidemics. Ambient temperature plays an important role in viral replication rates and transmission of WNV, affecting the length of incubation, seasonal phenology of mosquito host populations and geographical variation in human case incidence. Elevated ambient temperatures increase growth rates of vector populations, decrease the interval between blood meals, and accelerate the rate of virus evolution Indeed, clear associations have been found during recent years between warm conditions and WNV outbreaks in various locations (mainly cities) in Mediterranean countries including France, Italy, Croatia, Slovenia, Greece, Turkey, Israel and the Mediterranean islands. Dengue, Chikungunya and Zika are also mosquito-borne arboviral diseases of interest to the region. The viruses are transmitted by Aedes aegypti and Ae. albopictus mosquitoes that exhibit widespread distribution throughout tropical, sub-tropical, and temperate zones. As a consequence, the recent establishment and rapid spread of Ae. albopictus in Mediterranean countries is a cause of major concern, in parallel with the potential risks of diseases transmission by Ae. Aegypti which currently exists in part of the region (e.g. Turkey, Israel or Egypt). Most cities in the Mediterranean Basin are compact and densely populated. Air conditioning is used in regions with advanced socio-economic level. Many activities, particularly social gatherings, occur in outdoor locations such as shaded balconies, courtyards, outdoor restaurants and in the countryside - all ideal for contact with the vector. In view of the climatic projections and the vulnerability of Mediterranean cities, climate change mitigation and adaptation become ever more imperative. In order to minimize climate-aggravated health impacts, health systems in the Mediterranean should: Implementing measures for adequate preparedness of emergency medicine institutions and professionals; Monitoring climate-related morbidity and mortality and designing interventions; Monitoring and surveillance of vector-borne diseases (and other climate sensitive diseases), including across borders with neighboring countries; Implementation of heat-health warning system and more generally heat-health action plans; Increase public awareness to climate change-related health risks, and recommended prevention of negative health outcomes, including behavior during heat waves, elimination of habitats for vectors, etc. Without an effective interventions and cooperation between the Mediterranean countries, parallel with mitigation actions to reduce greenhouse gas emission, climate change will lead to an increasing level of morbidity and mortality in the region, with a higher risk for the most vulnerable populations.

Made in the shade:Thermal stress and pedestrian behavior in a Mediterranean city

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In the face of local as well as regional warming trends, Mediterranean cities that are overheated for much of the year must be continually reimagined to make them more walkable and sustainable. While the "urban heat island" effect has been studied for many years through both modeling and empirical observation, the intensity of the UHI is typically quantified by spatial differences in air temperature, a measure which may not reflect the actual thermal stress experienced by pedestrians. On clear summer days, both biophysical heat stress and the perception of thermal discomfort are dominated by the body's exposure to solar radiation – and therefore one of the most effective ways to combat urban heat stress is the provision of shade, ideally by covering large portions of the pedestrian realm with healthy, broad tree canopies. This is a complex and expensive endeavor, however, and our research is aimed at developing tools with which urban planners can prioritize their interventions in order to plant trees where they can have the maximum benefit. This presentation summarizes two parts of the ongoing work: in the first part, we use an extensive campaign of mobile on-site microclimatic measurements in the city of Tel Aviv to calibrate a model for the mapping of pedestrian thermal stress, and in the second part we address the "walkability" of different urban street segments based on a large-scale observational study of pedestrian behavior and the tendency to choose shaded paths over those with differing extents of solar exposure. In the first part of the study we evaluate the correlation between exposure to solar radiation and overall heat stress on summer days, using a mobile monitoring station with a 6-direction net radiometer setup that allows for the collection of a large urban climatic database without compromising the accuracy of the results. The results indicate that solar exposure is responsible for a high percentage of the variation in pedestrian thermal stress according to three different thermal comfort indices, while air temperature differences in adjacent shaded and unshaded locations are found to be very small. The second part of the presentation builds on these findings by quantifying the relative volume of pedestrian traffic on sidewalks that are in shade, relative to those which are unshaded. Using high-frequency photographic documentation of pedestrian and bicyclist activity at 36 monitoring locations in central Tel Aviv during the summer, we identified a total of over 5,000 individuals – approximately 60% of whom travelled in the shade. At locations where the size and functionality of shaded and unshaded spaces were most closely comparable, this proportion rose to 71% of all pedestrians on foot. The relative tendency for traveling in shade was also found to increase systematically with the level of pedestrians' solar exposure, as a function of the sun's angle of incidence and intensity at a given time. These findings, together with the study's extensive sample size, increase our confidence in suggesting that in hot Mediterranean climates people are more likely to use sidewalks and public open spaces if they are well-shaded.

Climate change and cities: Insights from the latest IPCC AR6 report

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Cities need detailed information on urban climates at a decision scale that cannot be easily delivered using current observation networks, nor global and even regional climate models. Insight from the latest IPCC AR6 report is presented and recommendations are formulated for future priorities. Related publication: Doblas-Reyes, F. J,. A. A. Sörensson, M. Almazroui, A. Dosio, W. J. Gutowski, R. Haarsma, R. Hamdi, B. Hewitson, W-T. Kwon, B. L. Lamptey, D. Maraun, T. S. Stephenson, I. Takayabu, L. Terray, A. Turner, Z. Zuo, 2021, Linking Global to Regional Climate Change. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press

A look at the Cities' Climate Change Adaptation Action Plans for Mediterranean Coast of Turkiye: Challenges and Opportunities

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IPCC Sixth Assessment Report on Impacts, Adaptation and Vulnerability provides an in-depth assessment of Mediterranean Region where annual mean warming is projected to vary between 0,9 to 5,6°C under different emission scenarios by the end of the century while precipitation will decrease by 4% to 22% in most areas. Cities are hotspots of vulnerability to climate change impacts such as floods, drought and heatwaves, and need to adapt their operations in view of expected climate change impacts. On the other hand, cities are providing a unique ability to address those challenges as near-term measures implemented in urban infrastructure will determine global capacity for emission reductions and adaptation to climate change impacts. Urbanization influences climate change substantially and rapid urbanization may offer a unique potential for the creation of sustainable cities if decision-makers choose the right pathways and measures. Therefore, it is very important to make cities an integral part of the solution while combating climate change. Cities have significant effects on climate change due to Greenhouse Gas (GHG) emissions occuring within their boundaries. Meanwhile, they contain sensitive structures against the impacts of expected climate change. For this reason, a city action plan for climate change should consider actions both to reduce GHG emissions within the city and to increase the adaptation capacity of the city to climate change. This study discusses the general approach adapted by the local governments, and evaluates adaptation measures for southern cities along the Mediterranean coast of Turkiye. The study addresses economical, political, and social obstacles and opportunities in developing adaptation strategies and implementing adaptation measures. The study gives an example, and discusses in detail the following steps in developing cities' Climate Change Action Plan (CCAP): Determination of in-city GHG emission sources and factors, stakeholders' inclusion, preparation of GHG inventories, assessment of GHG emission reduction scenarios, sectors' vulnerability and risk assessments, identification of adaptation measures for the sectors, and finally preparation of the city climate change action plan.

Projecting the evolution of the urban climate of coastal Mediterranean cities using a convection-permitting model

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The Mediterranean region is projected to be one of the most responsive region to climate change and future climate extreme conditions (Giorgi, 2006 ; Diffenbaugh & Giorgi, 2012). According to Lionello et al. (2012), the climate over this region may become warmer and drier by the end of the century. Changes of extreme meteorological events are also expected (Sanchez et al., 2004): flood-producing events will become more frequent (Gao et al., 2006), and the number of summer days (Tmax > 25°C) and heatwave days will increase (Giannakopoulos et al., 2009). Such changes already caused severe environmental issues, economics damages, and many casualties, especially in urban areas where most activities and populations are concentrated. Understanding and evaluating the impacts of future extreme events on urban areas and population requires addressing the complex coupling between the local urban climate and regional-scale climate changes. The urban climate arises from the modification of various dynamical and physical processes of cities. The complex 3-D shape of the city disturbs air flows and turbulent exchanges, and combined to the radiative and thermal properties of artificial materials, enhances radiation trapping and heat storage (Oke et al., 2017). The modification of radiation and energy exchanges leads to higher near-surface air temperatures in the urban areas than in the surrounding rural areas, especially at night (so-called Urban Heat Island – UHI – phenomenon). The intensity of UHI is firstly dependent on the city characteristics (size, urban density, architectural features, materials, population, etc.), but also on the geographic and topographic contexts, and local atmospheric conditions (sunshine, cloudiness, and wind). Cities are very complex systems that require specific modeling tools. Most of current climate models do not consider explicitly urban areas with a dedicated surface model, and therefore the urban climate evolution by the end of the century is poorly simulated yet. The latest advances in regional climate modeling allow simulations to be performed over longer time periods with finer horizontal resolutions of up to few kilometer (Kendon et al., 2021). The scientific community emphasizes the considerable improvements in using Convection-Permitting Models (CPM), especially for the representation of small-scale phenomena (Shu et al., 2021), as well as extreme weather events such as extreme storms, floodings, and heat waves (Termonia et al., 2018). Also, CPMs offer a very interesting modeling framework for studying UHI effects, and also some urban impacts (Weverberg et al., 2008) through the explicit coupling of the atmospheric climate model with an Urban Canopy Model (UCM). In this study, the French numerical weather prediction model AROME adapted to long-term climate simulations (then called CNRM-AROME) and coupled with the Town Energy Balance (TEB—Masson, 2000) is used at 2.5-km horizontal resolution. Climate simulations were performed on an extended France domain (northwestern Europe) as part of the EUropean Climate Prediction system (EUCP) project (Lucas-Picher et al., 2022) over an historical period (1986-2005) and two future periods (mid-term, 2041-2050 and long-term, 2080-2099) using the RCP8.5 emission scenario. Here, scientific objectives are (1) to evaluate the urban climate evolution for some French Mediterranean cities, including the UHI, and (2) to quantify the evolution of specific meteorological hazards on cities and population. With this aim, we selected indicators related to heatwaves and Heavy Precipitation Event (HPE), considered as some of the most relevant extreme meteorological events on the Mediterranean coast. Heatwaves will be studied using the methodology of Ouzeau et al. (2016). Based on the precipitating system detection and tracking algorithm developed in Caillaud et al. (2021), we will represent the main characteristics of HPE according to their frequency, intensity, area, and duration. This original approach will be applied to 5 medium-size cities located over the Mediterranean coast, such as Marseille, Montpellier or Nîmes.

Climate Change and Its Impacts in Morocco

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As result of climate change, many extreme climate risks and events, such as heat waves, rainfall, and drought, could become more frequent and intense in many parts of the world. Other elements of climate change, because of various forms of pollution and inefficiencies in the transport systems, contribute to the air pollution. Air pollution reprehension unfortunate with the health risks of the most important, provoking environment 7 million deaths each year according to The IPCC (Intergovernmental Panel on Climate Change). There are significant opportunities to promote the policies that protect the climate in the world and the advancement of goods to the local community. Morocco disposes of the national health adaptation strategy, and the steps are carried out in design of the health adaptation system. The climatic projections for Morocco corroborate the tendencies to warming and aridity of the Moroccan climate. Based on the use of worldwide surveillance and atmospheric dispersion models. To use the donations to understand the structure of the architecture and process.

Climate Change Challenges for Cultural and Natural Heritage UNESCO Monuments in the Mediterranean Cities

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The study presents a climatological analysis of specific interest at 263 UNESCO sites of cultural and natural heritage in the Mediterranean. A set of indices of importance to this work are calculated based on 21 regional EURO-CORDEX simulations covering the period 1971-2100 for the RCP4.5 and RCP8.5 emission scenarios. The indices include the evolution of climatological parameters including the frequency of extreme weather events. A significant increase in climate change hazards is found in the decades to come at all UNESCO sites, especially for the RCP8.5 scenario. The selected heritage sites are expected to suffer from in-creased temperature, heatwaves and increased wildfire danger, extreme rainfall, floods and mean sea level rise. Deterioration of aridity conditions is also expected for several sites mostly along the north African coast, Spain, southern Italy and Greece.

Combined climate extremes occurrences driven by multi-scale atmospheric variability and their impacts on Mediterranean metropolitan cities

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Metropolitan areas with different climatic and topographic characteristics are increasingly impacted by weather and climate extreme events putting at risk their populations. Thus, the frequency and the multidecadal variability of combined climate extreme occurrences on selected highly populated Mediterranean cities are investigated, along with their association with the atmospheric variability on different spatiotemporal scales. Specifically, four combined extreme indices that reflect joint modes of temperature and precipitation extremes, namely the co-occurrence of Cold/Dry (CD), Cold/Wet (CW), Warm/Dry (WD), and Warm/Wet (WW) days (Beniston, 2009; 2011), are analysed on seasonal basis for the period 1950-2021 with the high-resolution E-OBS gridded daily mean temperature and precipitation datasets (0.1°x0.1°) from the European Climate Assessment & Dataset (ECA&D, Klein Tank et al. 2002, www.ecad.eu). The combined extreme occurrences are connected with the atmospheric variability of different scales, from large-scale teleconnection patterns to atmospheric blocking and synoptic activity, focusing as well on extreme seasons with exceptionally increased combined extreme occurrences. The analysis shows significant interdecadal and spatial differences of the combined extremes occurrences at the cities across the Mediterranean, connected with a non- uniform impact of the atmospheric variability. Specifically, NAO is not always and everywhere a dominant mode for the Mediterranean extreme occurrences, blocking position affects mainly the northwestern areas, while cyclonic activity is related to wet events, either cold or warm. The urban areas of western Africa are mostly affected by cold/dry events, while almost all urban areas around the Mediterranean experience high numbers of warm/dry events with increasing trends during the last decades. Acknowledgement: Cyclonic tracks data are based on work from COST Action CA19109 “MedCyclones”, supported by COST – European Cooperation in Science and Technology