9th International Conference on Meteorology and Climatology of the Mediterranean

Genoa (Italy) 22-24 May 2023

Book of Abstracts

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General Information

Location of the Meeting
Sala Quadrivium, Piazza Santa Marta, 2, Genoa (Italy)

Organization
University of Genoa; Italian Association of Atmospheric Sciences and Meteorology (AISAM); Associació Catalana de Meteorologia (ACAM)

Support
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Welcome to the 9th MetMed!

The peculiar characteristics of the Mediterranean basin, the complex topography and coastal shape of a nearly enclosed and isolated sea, where a remarkable part of the world population lives, make it very important to observe and understand in depth the physical processes controlling weather and climate, to properly forecast them, also through improved performance of weather and climate prediction models. A combined inspection of observations and numerical simulations, covering spatial ranges from local to basin scale, are needed to improve our knowledge of the region and to make the best decisions, especially under severe weather situations, or to mitigate climate change impacts.

The International Conference on Meteorology and Climatology of the Mediterranean (MetMed) is a perfect forum for researcher and professionals to discuss about the current knowledge of the Mediterranean weather and climate. Every two years the Associació Catalana de Meteorologia (ACAM) and Tethys, the Journal of Mediterranean Meteorology & Climatology are the co-organizers of the MetMed, together with partner Institutions and Associations, through the Organizing and Scientific Committees. Past meetings were in Spain, France, Italy, Croatia, Turkey, and online during the covid pandemic.

The current 9th MetMed edition comes back to Italy and will take place in Genoa during 22-24 May 2023. It is co-organized with the University of Genoa, the Italian Association of Atmospheric Sciences and Meteorology (AISAM) and the Universitat de les Illes Balears (UIB). More than 140 researchers will present 67 orals and 86 posters in 6 sessions. The first four sessions are the same in every edition: 1) Climatology, 2) Processes and mechanisms, 3) Remote and in-situ measurements, 4) Numerical modelling, while the remaining two, proposed as usual by the hosting Institutions, are 5) Interdisciplinary studies and 6) Statistical and AI-based methods.

On behalf of the Partner Institutions and of the Organizing and Scientific Committees, it is a pleasure to welcome you all, and wish very fruitful and stimulating discussions, for advancing our understanding of Mediterranean weather and climate.

Maria A. Jiménez
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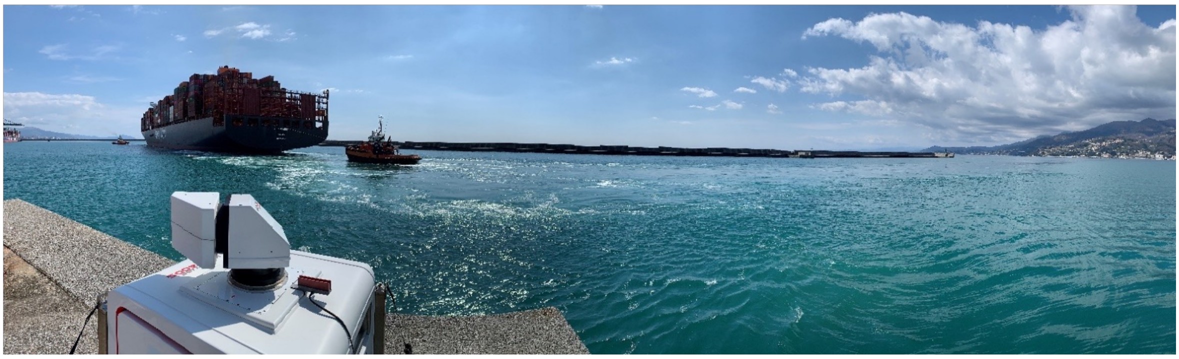

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S1. Climatology

Invited talk: Present trend and future projections of climate impact drivers in the Mediterranean region

Piero Lionello

University of Salento

This presentation will discuss the main Climate impact Drivers, which are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems and the level of confidence on their past and future evolution in the Mediterranean region. In fact, the Mediterranean region is affected by mean warming, increase of warm extremes, large variability and decrease of precipitation, increase of heavy precipitation events in some areas and droughts. Mean sea level is increasing with impacts on coastal floods and coastal erosion. In the marine environment water temperature is increasing, heat waves becoming more intense and longer, pH is decreasing. Impacts of these drivers have been observed across the entire basin and they are reinforced by other forcings of environmental change such as pollution, overexploitation of resources and ecosystems, non-indigenous species, with consequences on marine and terrestrial ecosystems and societal sectors. Impacts and risks are expected to increase during the 21st century as climate change is projected to intensify throughout the region. Criticalities are specifically related to warming and changes of the hydrological cycle, whose mechanisms will be briefly discussed in this presentation. Further, sea level rise, which in the Mediterranean Sea is expected to progress at a pace similar to the global mean sea level, can have important impacts on Mediterranean coasts, where concentration of population and economic sectors are associated with large risks.

O1.1. Precipitation climatology in Europe and the Mediterranean Basin through observations and EURO-CORDEX simulations (1979-2016)

Elsa Cattani, Vincenzo Levizzani

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The objective of this work is studying the climatology and trends of precipitation in Europe and the Mediterranean Basin at yearly and monthly scales using high-resolution (0.15°) daily precipitation data for the period 1979-2016. Diversified sources of precipitation data are considered, i.e., rain gauge precipitation measurements provided by the E-OBS dataset, estimates from the MSWEP product merging MW and IR satellite sensors' precipitation estimates with reanalysis and rain gauges, and regional climate modeling data from the EURO-CORDEX (EUR-11) project. The analysis is focused on the precipitation indices' time series calculated at annual and monthly scales using the ClimPACT software (https://climpact-sci.org) developed by the Expert Team on Sector-Specific Climate Indices (ET-SCI). The presence of trends in the indices' time series is evaluated using the Mann-Kendall trend test. Comparisons of MSWEP and EUR-11 with E-OBS precipitation climatology at annual and monthly scales highlight an overestimation of the extreme precipitation indices (R20mm, RX1day, Rx5day, R95p, R99p). More limited differences characterize other indices (CDD, CWD, R1mm, PRCPTOT, and SDII) with a general overestimation of EUR-11 data. Regions with the major differences are the Iberian Peninsula, the Mediterranean Basin, and the Alps. Significant (confidence level ≥ 90%) positive annual trends are shared among all products only in Eastern Europe and Scandinavia. Positive trends on the Mediterranean are perceived only by E-OBS (almost for all ET-SCI) and MSWEP (R1mm and PRCPTOT). A complex scenario characterizes the Alps, where the agreement among the products is limited and both positive and negative trends are present.

O1.2. Analysis of past and future temperature extremes in the Greater Alpine Region (1951-2050)

Beatrice Diana

University of Trento

The aim of this study is to evaluate whether extreme temperature events (heatwaves and cold spells) differ for plain versus mountain regions and for the four alpine sub-areas of the Greater Alpine Region (GAR) for past versus future; the average number of hot and cold days per year and the circulation patterns associated with these extremes are then investigated. ERA5 has been used to understand the observed past - 1951-2020 with 1951-1980 as the reference period - extreme temperature statistics and how future extremes will change by the middle of the century is estimated using high-resolution data from a CMIP6 model (EC-Earth 3P-HR). We find that during the 1991-2020 heatwaves occurrence, intensity and duration have increased (with respect to the 1951-1980), especially in the plains and the Southern region (mostly during summer). What we find as novel is that the Southern area is more affected by hot spells with respect to the Northern one. This is more evident in the future (2021-2050) when all the considered sub-regions show an increased number of hot spells as well as longer duration and higher intensity. Cold spells statistics show a decrease in the occurrence as well as their intensity and duration; even greater decreases are predicted for the future; there are no significant differences among seasons, plains, mountains and in the GAR. The Southern region again exhibits, mainly in the future, a higher (lower) number of hot (cold) days per year, with respect to the Northern area. Concerning the circulation patterns associated with temperature extremes, it is found that hot (cold) spells are associated with jet stream pattern modifications, bringing warm (cold) air from the African continent (North Pole) towards Italy. However, there are no differences in the composite of the circulation for heatwaves and cold spells occurring in plain, mountain and the four alpine sub-regions.

O1.3. On the inaccuracy of CMIP6 models in capturing the observed long-term variability of the NAO

Amar Halifa-Marín[1], Miguel Ángel Torres-Vázquez[1], Enrique Pravia-Sarabia[1], Ricardo M. Trigo[2], Sergio M. Vicente-Serrano [3]; Sonia Jerez[1], Marco Turco[1], Pedro Jiménez-Guerrero[1], Juan Pedro Montávez[1]

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This study assesses how the CMIP6 simulations capture the non-stationarity of the main source of winter climate variability in the Euro-Atlantic region, the North Atlantic Oscillation (NAO), observed in the recent past. For that purpose, we characterise the NAO long-term variability in climate reanalysis, analysing their features in several 30-year periods since 1851; and we evaluate whether CMIP6 historical simulations capture all the observed NAO "types". Although the literature sometimes assumes that the NAO pattern is stationary, three groups of NAO pattern have been proved in the reanalyses depend on the location of their Action Centres (ACs): 1) the north AC locates over Iceland and the south AC in Azores, 2) the north AC locates over Southern Greenland and the south AC in the Western Mediterranean, and 3) the north AC locates over Northern Scandinavia and the south AC in the Azores. Our main finding is that the NAO long-term variability is not accurately captured by all CMIP6 models. In particular, the overestimation of the NAO group 3 is remarkable in most simulations. This NAO group mainly represents the last decades, which the literature has addressed with much interest for its exceptional features (e.g. NAO+ strengthening and northeastward shift of its north AC), and which has been generally associated with the anthropogenic warmer climate. We also found underestimation of NAO group 2. We have also found that each NAO group could be associated with precipitation anomalies in Europe. For example, the NAO group 3 implies drier(wet) conditions in the south(north). While group 2 implies the opposite pattern of anomalies. Therefore, we have reason to suggest that the lack of accuracy of models reproducing the non-stationarity of NAO may explain some of the bias in the expected changes of winter precipitation in Europe for future scenarios.

O1.4. Hail climatology in the Mediterranean basin using the GPM constellation (1999-2021)

Sante Laviola, Giulio Monte, Elsa Cattani, Vincenzo Levizzani

CNR-ISAC

The impacts of hailstorms on human beings and structures and the associated high economic costs have raised a high interest in studying storm mechanisms and climatology thus producing a substantial amount of literature in the field. To contribute to this effort, we have explored the hail frequency in the Mediterranean basin during the last two decades (1999-2021) on the basis of hail occurrences derived from the observations of the microwave radiometers on board of satellites of the Global Precipitation Measurement Constellation (GPM-C) from 2014 (date of GPM Core Observatory launch) onwards and merging multiple other satellite platforms prior to 2014 (Laviola et al., 2022). According to the MWCC-H method (Laviola et al., 2020) two hail event categories (hail and super hail) are identified, and their spatio-temporal distributions are evaluated to identify the hail development areas in the Mediterranean and the corresponding monthly climatology of hail occurrences. Our results demonstrated as the northern sectors of the domain (France, Alpine Region, Po Valley and Central-Eastern Europe) tend to be reached by hailstorms from June to August, while the central sectors (from Spain to Turkey) are more affected as autumn approaches. The trend analysis shows that the mean number of the hail events over the entire domain tends to increase, showing a higher increment during 2010-2021 than during 1999-2010. This behavior was particularly enhanced over Southern Italy and the Balkans. Our findings point to the existence of “sub-hotspot”, i.e. Mediterranean regions most susceptible to hail events and thus possibly more vulnerable to climate change effects.

O1.5. Modelling hail hazard over Italy with ERA5 large-scale variables

Riccardo Henin[1], Veronica Torralba[1], Antonio Cantelli[1,2], Enrico Scoccimarro[1], Stefano Materia[1], Agostino Manzato[3], Silvio Gualdi[1]

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Hail is a meteorological phenomenon with adverse impacts that affects multiple socio-economic sectors such as agriculture, renewable energy, and insurance. Nevertheless, the understanding of the favourable environmental conditions for hail formation and the models' inadequacy to represent these phenomena have been limited by the scarce temporal and spatial coverage of hail observations. This is a major concern for the mitigation of hail-related risk in sensitive regions such as Italy, which is one of the more hail-prone areas in Europe. In this work, we present a hail model that has been developed to describe the hail hazard over Italy. This model relies on several ERA5 large-scale meteorological variables and convective indices that are combined following the statistical method described in Prein and Holland (2018). The identification of the best set of variables to be used as predictors in the hail model has been performed by a systematic machine learning procedure based on a genetic algorithm. The hail model estimates the hail probability over Italy in the 1979–2020 period, on the ERA5 spatial grid resolution ($\sim$ 30 km). The output of the hail model has been used to characterize the seasonality and long-term variability of hail events in Italy. Furthermore, the categorical verification of the hail probability over the Friuli Venezia Giulia region has revealed that the hail model is able to effectively estimate the hail occurrences in specific Italian regions.

O1.6. Classification of daily torrential rainfall patterns and associated synoptic types in the Campania Region (southern Italy)

Vincenzo Capozzi, Clizia Annella, Giorgio Budillon

Department of Science and Technology, University of Naples Parthenope, Centro Direzionale di Napoli, Isola C4, 80143 Italy

Using a 20-year (2002-2021) dataset of daily precipitation collected by 107 rain gauges during the October-to-May period as well as global and regional reanalysis products, we analyze the spatial distribution of torrential precipitation in the Campania Region (southern Italy) and the synoptic and mesoscale types that explain their development. To achieve these goals, we apply a cluster analysis on the most relevant principal modes extracted from a principal component analysis of the between-day correlation matrix. Six different patterns for heavy precipitation episodes have been identified. The first four patterns exhibit a rainfall amount distribution strongly connected with the local orography. In such scenarios, the orographic lifting, the low-level wind convergence induced by the orography and the transport of moisture along the tropospheric column (mainly from southern Mediterranean) can be regarded as the primary forcing of heavy rainfall. In the other two patterns, the highest precipitation is generally observed in the coastal areas (Gulfs of Naples and Salerno) and in the northwestern side of the region (Caserta district), respectively. In such circumstances, the abundant precipitation is closely linked to convective activity over the Tyrrhenian Sea, which is sustained by a low-level convergence and, in the sixth pattern, by a moisture plume coming from tropics. The results of this study provide new insights about the links between torrential precipitation spatial distribution and atmospheric circulation schemes in the southern Italy and promise to add a useful contribution for civil protection activities related to the management of environmental risks.

O1.7. Variability and trends of the total cloud cover over Italy (1951-2018)

Veronica Manara[1], Michele Brunetti[2], Martin Wild[3], Maurizio Maugeri[1]

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With this contribution we present a new quality-checked and homogenised dataset of total cloud cover (TCC) series over Italy for the period 1951-2018 and we discuss the variability and trends of the obtained regional series. The TCC diurnal cycle highlights the relevant role of convection induced by solar radiation that, as expected, is more relevant at medium and high elevations and in summer. In parallel, the annual cycle presents a strong minimum in July and a maximum during winter for southern Italy, while it exhibits a more complex behaviour with strong differences between low elevations and high elevations in northern Italy. Moreover, the seasonal and annual TCC series are characterized by a significant negative trend over the whole considered period, which is mainly due to the 1951-1990 period. Even if small differences between northern and southern Italy can be observed, the two regions exhibit a coherent behaviour both for long-term trends and decadal time-scale variability suggesting that the causes of variability and trends of the Italian TCC records are more related to large scale factors rather than to local scale changes. Indeed, the comparison with sea level pressure and 500 hPa geopotential height data highlights that large-scale atmospheric circulation explains a relevant fraction of the signal of the Italian TCC records. Finally, the new TCC dataset shows that the long-term evolution of sunshine duration and surface solar radiation in Italy is only partially influenced by changes in TCC.

O1.8. Quantifying dynamical contributions to Mediterranean cyclonic activity using the Localized Finite Amplitude Wave Activity diagnostic

Dor Sandler[1], Christopher Polster[2], Hadas Saaroni[1], Baruch Ziv[3], Nili Harnik[1]

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Finite Amplitude Local Wave Activity (FALWA; Huang & Nakamura, 2016) is a diagnostic that keeps track of the wave activity ”stored” within circulation undulations, relative to a zonalized flow. Therefore, it has potential in quantitative investigations of Mediterranean cyclonic activity, as it is uniquely influenced by the North Atlantic region upstream (via highly distorted PV streamers and interaction with "parent cyclones"). FALWA obeys an exact conservation relation, thus its local rate of change is dominated by three components: flux convergence, baroclinic growth and non-conservative source terms. This work presents a FALWA-based mechanistic framework for analyzing Mediterranean cyclones. Using ERA5 data, we investigate the intra-seasonal and interannual variability of FALWA and its components, and link them to cyclone characteristics in the region (distribution, intensity, vertical profile). A particular focus is given to the relative contributions of the different FALWA budget terms as they are reflected in a cyclone-centered analysis. Concretely, significant budget differences were found between cyclone cases developing under streamers, and those that are mainly driven by diabatic processes.

O1.9. Large-scale characteristics of Mediterranean Tropical-like cyclones in ERA5

Lisa Bernini[1], Claudia Pasquero[2], Fabien Desbiolles[2], Leone Cavicchia[3], Enrico Scoccimarro[3]

[1] *University of Genoa, CIMA Foundation*
[2] *University of Milano - Bicocca*
[3] *Euro-Mediterranean Centre on Climate Change (CMCC)*

Cyclones from a reference dataset of Mediterranean tracks (Flaounas, 2023) and cyclones tracked using ERA5 reanalysis with a method adapted from Ragone et al. (2018) have been classified based on thermal winds. This classification allowed us to explore the major differences between extra-tropical cyclones with a cold inner core (the majority) and tropical like cyclones with a deep inner warm core (a minority). The time evolution along the cyclones lifetime of different environmental characteristics have been analysed to better understand the transition of cold core extra-tropical cyclones into warm core tropical like cyclones. The variables studied are vertical gradients of wind, of temperature, and of specific and relative humidity, but also translation speed of the cyclones, air-sea heat fluxes and air-sea enthalpy difference.

O1.10. Climatological analysis of cyclone tracks in the Western Mediterranean

Dario Hourngir[1], Massimiliano Burlando[1], Djordje Romanic[2]

[1] University of Genoa
[2] McGill University

Cyclones are the main weather patterns in the mid-latitude climates. They are often associated with heavy precipitation and wind extremes. A detailed knowledge of their source and path—namely, the cyclonic tracks—as well as their modification due to anthropogenic effects or climate variability are fundamental in forecasting weather and determining future impacts on regional climates. Over the last decades, several objective methods for cyclone detection and tracking have been implemented. Each of them is based on different dynamics or numerical techniques. For this work, we chose the Melbourne University cyclone finding and tracking scheme, which uses a quasi-Lagrangian framework, originally developed for the Southern Hemisphere, but equally accurate for the Northern Hemisphere to investigate the kinematics and dynamics features of the western Mediterranean cyclones. The input dataset consists of the ERA5 reanalyses of mean sea level pressure on a 0.25° × 0.25° regular latitude-longitude grid. This dataset was used to perform the analysis on a domain between 315°W–25°E and 25°N–60°N in order to take into account the development of cyclones in the early stages of their lifetime over the Atlantic Ocean that can affect the central and western parts of the Mediterranean Sea. The study compares the algorithm outcomes with the time series of some relevant climatological teleconnection indexes, such as the North Atlantic Oscillation (NAO) and the Western Mediterranean oscillation (WeMO), to identify possible trends and correlations between them.

O1.11. Changes in wave extremes in the Mediterranean Sea due to climate change

Andrea Lira-Loarca, Giovanni Besio

MeteOcean research group, Department of Civil, Chemical and Environmental Engineering, University of Genoa, Italy

Climate change poses a significant threat to coastal areas worldwide, driven by rising sea levels. The Mediterranean Sea is particularly vulnerable, as higher sea surface and air temperatures, combined with sea-level rise and high exposure and vulnerability of 20 million people in low-lying coastal areas, make it a vulnerability hotspot. The projected changes in waves also vary on a regional and local scale and play a crucial role in future extreme coastal water levels and coastal impacts. Wave projections on a regional scale are needed for an accurate characterization of wave climate at a local scale, crucial for coastal impact assessment and adaptation studies in the Mediterranean Sea. This study presents an analysis of extreme waves using a regional ensemble of projections developed with the numerical wave model Wavewatch III. The model is forced by surface wind field data from 17 GCM-RCMs. Future changes are evaluated for a weighted ensemble mean against a validated hindcast used as a reference for the bias correction. Extreme wave events are analyzed by means of the ETCCDI (Expert Team on Climate Change Detection and Indices) extreme indices, rough wave days, and high wave days. Additionally, to analyze the future temporal and multimodal variability in wave extremes, a seasonal analysis is done and the changes in the 2D directional spectra are analyzed. Overall, this study provides a comprehensive examination of the potential future changes in waves in the Mediterranean Sea and highlights the importance of high-resolution models in assessing climate change impacts on coastal areas.

O1.12. Statistical downscaling of global climate projections along the Egyptian Mediterranean coast

Mohamed Shaltout, Mohamed ElBessa

Oceanography Department, Alexandria University, Egypt

The climatic parameters (surface air temperature, surface relative humidity, surface wind regime, and mean sea level pressure) are known to be important in addressing adaptation/mitigation to the climatic changes. In particular, recent, and future of these climatic parameters along the Egyptian Mediterranean Coast (EMC) were analyzed based on hourly real observed data (2007—2020), and hourly reanalysis (ERA5) database (1979—2020) together with daily GFDL (Global climate model) mini-ensemble mean (2006—2100). Recent climatic studies along the study area have not given enough attention to the downscaling approach, underscoring the need to set up a statistical downscaling technique for a better understanding of the forces that govern climatic change. Here we analyze the current climatic and future scenarios for the studied parameters calls for three steps. The first step is to study the short-term (14 years) current weather variabilities using the real observed data. The second step is to describe the long-term (42 years) current weather variabilities using reanalysis ERA5 database after bias removal by comparing with the observations. The third step is to statistically downscale the GFDL mini-ensemble means to describe the future projection along the study area up to 2100. The used statistical downscale technique is built on developed a bias correction statistical model by matching cumulative distribution functions (CDF) of the mini-ensemble mean and corrected ERA5 during the overlapped period (2006—2020). The results show that ERA5 describes efficiency the weather characteristic of the five studied stations. This data along the Egyptian Mediterranean Coast (EMC), 2006—2020, displays a significant positive trend for surface air temperature, and significant negative trends for surface wind speed, relative humidity, and sea level pressure. The GFDL mini-ensemble mean projection, up to 2100, has a significant bias with the studied weather parameters. This is partly due to GFDL coarse resolution (2˚x2˚). After removing the bias, the statistically downscaled simulations from the GFDL mini-ensemble mean show that the study area's climate will experience a significant change especially surface air temperature and relative humidity with a great range of uncertainties according to the scenario used and regional variations. Our results are the cornerstone for better understanding and developing statistical downscaling to project future climatic studies over EMC.

O1.13. Identifying storm types leading to precipitation extremes events in the Western Mediterranean using a physics-based classification method

Yseut Bahuet-Bourret, Daniel Argüeso

Physics Department, University of the Balearic Islands, Palma, Spain

The Mediterranean Region is one of the few regions where there is no agreement on the evolution of extreme rainfall events in the context of Climate Change. Even the latest intercomparison model projects are subject to large uncertainties on how such extremes may change in the region. Therefore, there is a need to investigate the matter using alternative tools and approaches. Here, we study the processes involved in the formation of extreme rainfall events in the Western Mediterranean in a present-day climate using convection-permitting experiments at continental scales. Heavy rainfall is produced by deep convection and clouds with high vertical growth, which can originate in different ways and can organize in various types of storms (cyclones, front storms or thunderstorms). We expect future climate change to affect precipitation events differently depending on the storms nature and their genesis processes. In this work, we identify, classify and quantify storms leading to extreme precipitation events in Western Mediterranean under present climate conditions. Using a regional climate model (WRF) at convection permitting resolution (2 km) and covering most of the Mediterranean Sea, we have built a database of precipitation extremes that compare well with high-frequency intense precipitation rates from rain gauges. High spatial resolution in our experiments significantly improve extreme precipitation, partly due to convection being explicitly resolved. The model also provides finer detail of storm structures, a feature that is exploited in this study. Indeed, a combination of relevant variables (Mean Sea Level Pressure, lightning occurrence, geopotential fields etc…) allow us to build proxies of thunderstorms, cyclones, and front storms. We determine the density of storms in the Mediterranean, as well as their trajectories and speeds, which is a key factor in determining their impacts. This will set the path for the analysis of future climate experiments using a Pseudo-Global Warming approach and estimate possible changes in the preferred regions of storm occurrence and their intensity.

O1.14. Attributing heatwaves to climate change in mountainous areas. An analysis of the summer 2022 heatwaves in the Pyrenees

Marc Lemus-Cánovas[1], Sergi Gonzalez-Herrero[2], Laura Trapero[1], Anna Albalat[1], Damian Insua-Costa[3], Martin Senande-Rivera[3], Miguez-Macho[3]

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The field of extreme event attribution (EEA) seeks to quantify how recent extreme events are directly exacerbated by ongoing climate change. As this is a relatively new field in climate science, there is a noticeable knowledge gap in EEA analysis in mountain areas. Precisely, this work performs an attribution to climate change of the two greatest heatwaves (HWs) occurred during June and July 2022, both hitting the Iberian Peninsula and southern France, and therefore, the Pyrenees Mountain range. We used the analogues technique on 500 hPa geopotential height composites to identify the 30 days closer to the dynamical structure of both heatwaves for the counterfactual (1950-1985) and factual (1986-2021) period, using ERA5 daily data. Results showed that factual HWs analogues in the factual period have a spatial structure closer to the 2022 HWs events than those analogues extracted from the counterfactual period. At the Pyrenean scale, we observed that 2-meter air temperature differences consisted of a positive non-uniform pattern in a factual world, with a significant increase in the southern slope of the mountain range and in the nearby depressed areas. However, most of the mountain range exhibited a small increase of the HW air temperature in a factual world. We also provided an explanation of the physical process involving the abovementioned 2-meter air temperature differences. In this study, we revealed the complexity of conducting the attribution of extreme heatwaves to climate change in mountain areas, both because of the scarcity of in-situ data, as well as due to the physical processes involved during these extreme events in an area of complex terrain.

O1.15. Climate scenarios of weather extremes affecting the Italian energy system with a multi-hazard approach

Arianna Trevisiol, Paola Faggian

RSE S.p.A.

Extreme weather events may represent serious hazard for the Energy System, regarding both generation plants and transmission/distribution lines, which will have to face even more critical situations in a changing climate. In fact, energy infrastructure may suffer during their lifetime a plurality of threats that might cause cascading effects in terms of risk and vulnerability above all if they are overlapping in spatial and/or time. In this study single WMO indices have been analysed and a multi-hazard approach have been applied at different 30-year periods until 2100 by using 12 high-resolution Euro-CORDEX models under the RCP8.5, RCP4.5 and RCP2.6 hypotheses. In particular, the research aims to characterize the Italian regions prone to hot days and droughts conditions (Hotdays index), as well as strong winds and heavy rainfalls (Storm index), and the areas likely affected by occurrences of several threats not necessary simultaneous. The outcomes highlight that Western Po Valley is expected as the area most exposed to both storm and drought conditions, but no Italian region will be safe from an enhancement of climate change hazards both in frequency and intensity during the Century in all three RCPs, with more and more severe conditions from RCP2.6 to RCP8.5. The coasts will suffer particularly from storms, and North-eastern Italy from more frequent extreme precipitations, whereas the South and Islands will have to deal with a significant increase of drought conditions, already at short term in RCP4.5 and RCP8.5 hypotheses.

O1.16. Climatological analysis of precipitation on Mount Baldo (Italian Alps) over the years 1879 - 2019

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Mount Baldo is a mountain subrange in the central Italian Alps, laying along the easterm side of Lake Garda and separating it from the Adige River Valley. The southern side of the chain is prominent onto the Po Plain and well exposed to inflows from the Mediterranean area. Results from a climatological analysis of precipitation data in the area and surroundings are presented. Data recorded from rain gauges at various points and different altitudes, spanning 1879-2019, were collected and quality-controlled. A total of 26 long time series of monthly totals were obtained and homogenized by means of the Standard Normal Homogeneity Test (SNHT). A significant (Mann-Kendall p value < 0.05) diminution of spring precipitation and an increase in winter and autumn are observed. The spatial distributions of the annual and seasonal mean rainfall was also evaluated. Particular attention was paid to the elevation dependence of precipitation, whose gradient are required to extrapolate data at higher altitudes, where no stations are available. Using the KED (Kriging with External Drift) interpolation method, with elevation and geographic coordinates as auxiliary variables, spatial maps of annual and seasonal precipitation were finally obtained. Various patterns of precipitation were ascertained on the basis of the above mapping."

O1.17. A Citizen Science project for the digitization of Italian secular precipitation and temperature records

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A wealth of data from past meteorological observations in Italy from 1725 to 1950 are published as monthly records for hundreds of stations in several official monographies edited by the Ministry of Public Works. However only a limited fraction of these data is currently available in computer-readable format. A Citizen Science project was initiated in spring 2022 involving Italian high-school students in the digitization of these data More than 350 students from 13 high schools joined it. Each involved school received a PDF copy of the pages to digitize, together with a spreadsheet template for data entry and a tutorial. Then, each student had to digitize the assigned data and the schools provided us with the filled spreadsheets. Students also had the opportunity to join a training program consisting in a list of seminars and in specific training activities to make them more aware of the potentialities of the recovered data. The expected contribution from students in terms of data digitization is estimated in about 5000 man-hours. Besides the contribution of students, the project requires a great effort also from their teachers and from the authors for organising and coordinating the activities and revising the data. However, we believe the project has a great educational value making young students aware on how science investigates past climatic trends. This contribution aims to present the project and its first results.

P1.1. Inter-comparison of high-resolution reanalysis products over Italy: surface temperature analyses

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In recent years, the importance of reanalysis data to reconstruct past and present climate has increased constantly. Reanalyses are available even where observational data are missing; therefore, they are helpful for several applications in climate change assessment and mitigation. Since its release in 2019 by ECMWF, ERA5 has represented the state-of-the-art for global reanalyses, also providing initial and boundary conditions for many regional reanalysis products. In particular, higher-resolution regional reanalyses products have been recently developed, using parametrizations and observations optimized for specific locations. Among them, we considered CERRA (Copernicus European Regional ReAnalysis), MERIDA (MEteorological Reanalysis Italian DAtaset) and MERIDA-HRES. While CERRA is a European high-resolution reanalysis developed under the framework of the Copernicus Climate Change Services, MERIDA and MERIDA-HRES are developed by the Italian company R.S.E. S.p.A. to provide energy stakeholders with reliable meteorological data, in order to implement effective adaptation strategies and to increase the resilience of the electro-energy systems. Our work aims to perform an intercomparison of five reanalyses (ERA5, ERA5-Land, MERIDA, MERIDA-HRES, CERRA) over the Italian territory for the period 1991-2020, validating them against an observational dataset. This dataset was obtained through the anomaly method projecting more than 2000 series on the same grid for which the reanalyses are available, to reduce the risk of inconsistencies due to a different orographic description. With this contribution, we will present our first results regarding monthly climatologies (1991-2020) of the 2m temperature variable, showing some potential in the higher resolution reanalyses datasets in representing small-scale characteristics of surface temperature climatologies over different seasons. Adding more variables to the comparison, we can give useful tools to understand better the characteristic atmospheric processes over the Italian peninsula, characterized by complex orography and coastal-sea interaction: an enhanced spatial resolution may be an asset in studying the occurrence of extreme events."

P1.2. Elevation Dependent Warming: does climate change depend on the altitude in Italy?

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During the last years, an interesting hypothesis connected with the observed global warming is that the temperature trend can be dependent on the elevation. This phenomenon is called Elevation Dependent Warming (EDW). Many papers have been published in literature on this topic but a coherent observation of the phenomenon is still missing with some areas showing an EDW (i.e. a positive correlation between temperature trend and the elevation) and some others showing a reversed EDW (i.e. a negative correlation between temperature trend and the elevation). With this contribution some results on the relation between temperature trends and elevation over the Italian territory will be shown using reanalysis data (ECMWF ERA5-Land). The obtained results show for the Apennines a behaviour coherent with a reversed EDW while for the Alps the situation is less clear although a negative correlation seems to be more common than a positive one.

P1.3. Comparing temperature profiles in valleys of different shape in the Pyrenees.

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The Cerdanya Valley (Catalonia, Spain) and the Conflent Valley (Occitanie, France) are two consecutive valleys in the Pyrenees linked by the Col de la Perche (aprox. 1500 m). The Cerdanya Valley is U-shape, relatively flat at the bottom and surrounded by mountains which is prone to experience Cold Air Pool (CAP) formation, on the other hand Conflent Valley is a V-shape valley, steep and open to the Mediterranean Sea, which has strong drainage and is not prone to have CAP formation. During more than 10 years the Meteorological Service of Catalonia and the University of Porsmouth are collaborating in a project collecting temperature and relative humidity data from sensors distributed across both valleys. In total there is 50 sensors, mainly located in the Cerdanya valley, which are located at differents transects covering heights ranging from 1000 to 2000 metres with a vertical resolution of 200 metres. In this work we used this data to study the differences between the vertical temperature profiles of the sensors located in an enclosed valley (Cerdanya Valley) and the ones located in an open valley (Conflent Valley). An statistical analysis of the temperature vertical profile differences between both valleys will help to characterize the synoptic events associated to them and with this information, study of how the changes in the synoptic patterns could affect the behaviour of the temperature profiles in valleys with different characteristics.

P1.4. Trend analysis of monthly temperatures at 3 main pressure levels of the troposphere over Turkey

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Istanbul Technical University

At the point reached today as a result of the uncontrolled greenhouse gases released into the atmosphere with the Industrial Revolution, with the global average temperature of the atmosphere rising above 1°C, the first step passes from meteorological information in terms of being least affected by the global climate change process, we are facing, and adapting to climate change. Due to its location, Türkiye is among the countries that will be most affected by the effects of global warming. In this study, trend analysis of temperatures at 850 mb, 700 mb and 500 mb pressure levels in the 1960-2020 period of Turkey's 6 radiosonde stations will be performed. The effects of global climate change will be revealed at the 3 main pressure levels of the troposphere by using Innovative Trend Analysis (ITA) as a method.

P1.5. Climatological characterizations of the city of Verona from time series of meteorological observations

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The exploitation of meteorological data may not be very useful at first glance. However, it does allow us to draw noteworthy conclusions concerning the climate of areas and its changes. Over the past decades, many measurements of meteorological variables (in particular air temperature and precipitation) have been regularly performed at various points in the city of Verona and its surroundings, and long time series of data have been produced. However, a series spanning over 50 years has never been defined. The project “Percorsi Digitali Veronesi” (“Digital paths for Verona”) has launched an accurate search of the available meteorological measurement series in order to summarize the availability of historical data in the urban area of the City of Verona. So far, 19 series have been rescued, ranging from 1945 to the present days. Not all measurement series were found to be equally valid for climatic purposes. However, for a large number of them climate indices (as per recommendations by the World Meteorological Organisation), such as heat waves, cold spells, hot days, cold days, dry days, etc., have been evaluated. The series composed by the observations taken by meteorologist Emilio Bellavite in his own weather station in the city center in the timespan (1945-1996) was adopted as the basis for all other stations, especially for defining the average in the period within 1961-1990. From the preliminary results, climatic trends are clear for temperatures, while less so for rainfall. The goal for the future steps is to extend backward the above series and recover as much data as possible in view of building a series of daily rainfall and temperature measurements covering at least 100 years. In this way it will also be possible for Verona to have its own centenary series to compare with the others already available in Northern Italy.

P1.6. A new dataset of daily observations from a dense network of weather stations covering the Extended Alpine Region (1991-2020)

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The Alpine area is one of the most vulnerable and sensitive mountain regions of the Mediterranean area to the continuous warming of climate and it is considered an important hotspot of climate change. In particular, climate change is expected to exert a strong influence on all components of the hydrological cycle, including river regimes, with consequent effects on the services offered by the freshwater ecosystem, as well as on water availability for users, thus affecting several socio-economic sectors. Several observational products of key climate variables are available to the scientific community and have been widely used to evaluate the extent of the ongoing effects of climate change in mountain regions. However, most products suffer from some limitations: for example, some have not been updated to recent decades, or their spatial coverage is quite limited, especially in view of reliably assessing trends at higher elevations. Therefore, more efforts must be dedicated to produce new harmonised and high-resolution products able to permit more robust assessments of climate change in mountain regions. Even though the Alpine region is densely covered with a high number of in-situ weather stations, the collection and management of such data for the whole Alpine area is a challenging task due to strong fragmentation and diversity of data sources. We present here a new observational dataset gathering in-situ daily measurements of meteo-climatic variables provided by a variety of meteorological and hydrological services within the Extended Alpine Region (EAR) for the period ranging from 1991 to 2020. The observational network consists of more than 9000 in-situ weather stations, and its high density allows for an extended and homogeneous coverage both in space and elevation. The data collected, after a preliminary phase of pre-processing, have been subjected to a quality control aimed at checking internal, temporal, and spatial consistency of time series, addressing the problem of outlier removal. In addition, different techniques were exploited to assess data homogeneity. A preliminary climatological analysis is carried out on homogenised time series, making use of the most common climate statistics. The dataset represents a powerful tool for better understanding Alpine climate changes over the last decades and improving the reliability of future scenarios.

P1.7. Changes in precipitation over a 70-year period (from 1952 to 2021) in a hydrological recharge "hot spot" located in the eastern Iberian Peninsula

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This study analyzes how the volume of precipitation recorded in a key area for the recharge of several of the most important rivers in the eastern half of the Iberian Peninsula has changed over a period of 70 years (1952-2021). For this purpose, 353 pluviometric stations have been selected, whose rainfall data have been filled in and homogenized by means of statistical procedures. This procedure has provided a dense network of pluviometric information capable of detecting local variations, which is of great importance in the current context of climate change. These rainfall stations are distributed in 4 different hydrological basins (the Guadiana and Tagus river basins, whose waters flow into the Atlantic Ocean, and the Ebro and Júcar river basins, which flow into the Mediterranean Sea). The procedure for analyzing the evolution of precipitation was to divide the 70-year period into two 35-year periods (1952-1986 and 1987-2021) and compare the volumes recorded in each of them. In turn, precipitation has been classified according to its daily intensity: weak (1-10 mm/d), moderate (10-40 mm/d), intense (40-100 mm/d) and torrential (≥ 100 mm/d) rainfall. The results have shown a significant reduction in precipitation recorded over the last 35 years (1987-2021), with greater losses in weak and moderate precipitation, which are the most important ones for the recharge of hydrological systems.

P1.8. SPI characterization in the North of Algeria using the ERA5-Land dataset

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Over the last decades, floods, storms, heatwaves, droughts, and other weather-related events have caused a huge number of natural disasters. The Mediterranean region is particularly subjected to extreme meteorological, climatological and hydrological phenomena. These events are expected to increase in frequency and intensity because of climate change. Against this background, relationships between climate impacts on water resources and water supply systems with advance monitoring and modeling techniques are a crucial issue to be analyzed and quantified in order to understand past, current and even future scenarios around the world, particularly in least developed countries as the Algerian region where this study is focused on. The aim of this study is to perform a drought analysis using the SPI, at different month scales, evaluated from the ERA5-Land monthly dataset provided by ECMWF under the framework of Copernicus Climate Change Service Programme. With this aim, some of the main characteristics of the drought events (e.g. quantity, duration, severity, and intensity) that affected several hydrological basins located in the North of Algeria from 1950 to 2022 have been analyzed. In this analysis, the use of the ERA5-Land monthly dataset data allowed us to obtain a much more detailed distribution of the drought characteristics in northern Algeria, close to the Mediterranean Sea, than those usually carried out by means of data from rain gauges, whose distribution is not homogenous on the whole territory.

P1.9. Wet winter seasons in Croatia and related weather types

Dunja Placko-Vrsnak

Krunoslav Mikec

In this study an overview of weather types for wet winter seasons in Croatia in period 2011-2021 according to the climate assessment is done. Climatic conditions on monthly/seasonal scale at meteorological station locations are assessed by mean daily air temperature [°C] and precipitation [%] anomalies with respect to the corresponding multi-annual average of the reference climatological period (1981-2010 or 1961-1990). Wet winter season means that at least one of the 5 regions in Croatia has the climate assessment (according to the percentile values) “wet”, “very wet” or “extremely wet”. The classification of surface weather types (developed by Poje, 1965) for wet months/seasons is done according to daily surface and monthly upper-level pressure fields (ERA5 reanalysis). The method is subjective, based on experience of forecaster. This approach is highly sensitive to minor differences in the route or location of synoptic systems in conjunction with the complex topography and sea-land exchange. In the 2011-2021 period, 5 winters with positive precipitation anomalies with respect to the corresponding multi-annual average were observed. In almost every season in all three months positive precipitation anomalies were observed (the exceptions are December 2013, January 2018 and February 2021). The mean monthly upper-level pressure charts were analysed to determine the prevailing large-scale flow that existed in the situations with positive precipitation anomalies. The most common flow regime is the SW, but also the trough over Croatia was noticed. Out of 29 surface weather types, the most common during the wet winter seasons is related to the influence of the depression, especially type C1 – eastern (front) sector of cyclone where the centre is positioned westward of Croatia, most often over Gulf of Genoa and the North Adriatic. The synoptic situation related to atmospheric fronts or transitional states between baric systems were less common. In general, we can confirm that cyclone tracks in the Mediterranean affect the amount of precipitation in winter in Croatia."

P1.10. Recent trend and variability of extreme precipitation indices in the Campania Region (Southern Italy), 2002-2021

Armando Rocco, Viviana Cretella, Clizia Annella, Giannetta Fusco, Giorgio Budillon, Vincenzo Capozzi

Università degli Studi di Napoli "Parthenope"

This work aims to investigate the recent changes in rainfall regime observed over the last two decades (2002-2021) in the Campania region (Southern Italy), an area very vulnerable to the effects of extreme precipitation events due to its complex orography, to the very high population density and to the intrinsic fragility of its territory. To meet this goal, a dataset including daily precipitation records collected at 107 stations managed by different institutions was adopted. After a quality control check, the rainfall dataset was analysed through nine indices developed by the Expert Team on Climate Change Detection and Indices (ETCCDII) in order to detect signals of changes in frequency, duration and magnitude of extreme precipitation events. The Mann-Kendall non parametric test was employed to evaluate the trend and its significance in the indices time series. The main evidences emerging from this work are (i) an increasing tendency in heavy and extreme rainfall events in summer and fall seasons, mainly localized in the northern part of the region and in the mountainous areas, and (ii) an increasing trend in the number and duration of dry periods in winter and spring, respectively, in the southern area (Salerno district).

P1.11. Indicators for study the temporal evolution of snow depth in the Pyrenees

Anna Albalat, Laura Trapero, Marc Lemus-Cánovas, Marc Pons

Andorra Recerca + Innovació

The CLIM-PY project (POCTEFA 2014-2020, Ref. AUEP002-AND / 2015) aimed to develop a cross-border database of temperature, precipitation, and snow depth for the regions of France, Spain, and Andorra. The database incorporated quality control and homogeneity of the instrumental information available from the meteorological services of each country. Specially, the study of snow depth has brought together data from manual and automatic stations, managed by meteorological services and organizations throughout the Pyrenees. The data was collected from stations located between 230m and 2500m altitude and was modelled using the Crocus model to fill gaps and cover the early and late seasons of ski resorts. The data covers a period of 40 years with an average altitude of 1700m, which is where most of the ski resorts in the Pyrenees are concentrated. The primary focus of the study was to characterise the climatic trends of the snow variable. The preliminary results characterised the snow depth from December to April in terms of severity and intensity, specifically by determining the number of days the snow depth was above the P50 and the excess amount. This classification has been completed with an analysis of the evolution over time of the most classic indicators. The objective of this study is to respond to the need for characterizing the evolution of snow cover for the management of snow as a resource in other sectors such as hydrology, energy, and natural hazards. The results of this study have important implications for the sustainable management of snow resources in the Pyrenees region."

P1.12. On the role of local and global atmospheric variability in snow cover duration: a case study of Montevergine Observatory (Southern Italy)

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Snow cover is a crucial variable in several fields and applications. This work aims to provide the first evidence about snow cover variability in the Italian Southern Apennines and investigate the forcing mechanisms controlling it. To this purpose, we present a new historical long-term (from 1931 to 2008) series of snow cover duration data observed at Montevergine Observatory, a mountainous site located at 1280 m above sea level. From the analysis of this series, it emerged a strong interannual variability, an overall reduction over time of snow cover days until mid-1990s and a recovery in the last 10-years. We model snow cover duration employing a multiple linear regression, considering both local and large-scale climate factors as explanatory variables. Our findings show that snow cover duration appears to be primarily dependent on temperature, which exhibits a positive trend in the considered time interval. However, the interannual fluctuations of the examined parameter are also strongly modulated by two large-scale patterns, the Arctic Oscillation and the Eastern Mediterranean Pattern. In the last segment of the considered time interval, the increase in temperature is not consistent with the dominant patterns of large-scale indices, which proved to be more effective in capturing the recent rebound in snow cover duration. The results of this work demonstrate that snow cover duration is linked to the global warming by a non-trivial relationship and that its behavior, in specific periods, can be largely independent from rising temperature tendency, according to the prevailing phase of large-scale atmospheric patterns."

P1.13. Trend analysis and climatology of hail in Croatia

Maja Telišman Prtenjak, Lucija Blašković, Damjan Jelić, Barbara Malečić, Branimir Omazić

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A hail climatology provides knowledge used by other governmental, public, and private institutions for better adaptation to this extreme. Croatia is a small country with a complex topography including the lowland part of eastern Croatia which turns into a hilly part as one goes westward, and the Dinarides rise further south, followed by the Adriatic coast. Thus, diversity of hail climatology throughout the Croatia is analyzed. The results are based on hail data from 199 stations and multiple periods. The results showed significant interannual and spatial variability, due to which three subregions were recognized based on the annual cycle of hail. On the South and central part of Croatian coast, the highest hail activity is present in the colder part of the year while the Northern most parts of the coast and continental part of Croatia shows increased summer hail activity. There is also a transitional area located in between, that records the most hail in spring and fall. The trend analysis was made for three time periods from 1900. to 2020., from 1964. to 2019., and from 1995. to 2019. First two periods have shown negative and significant trend in the number of hail days, while recent, 25 yearlong trend, shows change of sign towards positive but not significant trend. Daily patterns of hail show a shift in the daily maximum from morning to afternoon hours as we progress from the coast towards inland, and the coastal part of Croatia generally records higher hail frequencies compared to the continental part. Most dominant air mass (over 50% of time) responsible for the hail is coming from the SW. Winter hail, is usually induced in stronger sheered environments with lower instability. Climatology of hail duration reveiled a log-normal distribution patter further suggesting that most of the hail lasts between 1 and 5 minutes.

P1.14. How have temperature and atmospheric constituents changed in the Rome are (Italy) during the last two decades?

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Due to its geographical position, the Rome area, located on the western coast of the Italian peninsula, in the heart of the Mediterranean basin, is typically subjected to the sea/land breeze regime and to the synoptic interaction between high/low circulation systems over the Central-Eastern Mediterranean basin and Continental Europe. In this work, the two-decade (2000-2020) temporal trends of daily temperatures (average, minimum and maximum) and in-situ pollutant concentrations (nitrogen oxides, ozone, and particulate matter with aerodynamic diameter less than 10 um) measured in Rome and in the surrounding area are investigated. Data are provided by in-situ stations located in downtown Rome and in the neighbouring coastal area. In addition, the trends of the total columnar amount of ozone (1992-today) and nitrogen dioxide (1996-today) are analysed. Total amounts of atmospheric ozone and nitrogen dioxide are collected by a MkIV Brewer spectrophotometer and a co-located Pandora spectrometer, both installed in the city centre of Rome and belonging to the Boundary-layer Air Quality-analysis Using Network of Instruments (BAQUNIN, www.baquinin.eu) supersite. All datasets are undergone an accurate pre-processing. Moreover, meteorological datasets have been subjected to a homogenisation procedure, in order to identify and remove non-climatological signals. The statistical analysis, performed using the Seasonal Kendall test, reveals a positive trend for the average, minimum, and maximum daily temperatures both in the city and in the coastal area, confirming the intense warming occurring in the Mediterranean area, with serious implications on human health and thermo-hygrometric well-being. Otherwise, the analysis of in-situ concentrations and columnar amounts shows that the urban air quality level is improving. The results of this study provide a baseline to be used as a benchmark for present climate observations and as a reference for future measurements and offer useful indications to policymakers for the optimal design and implementation of local actions for climate change adaptation and air pollution mitigation.

P1.15. Underlying causes to the observed changes in the atmospheric transparency in Italy during the last decades

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Many papers published during the last decades report a decrease in surface solar radiation until the mid of the 1980s (known as "global dimming") and an increase (known as "brightening period") in the subsequent period. The causes underlying these variations seem to be connected with the variations in the atmospheric aerosol content and in the total cloud cover. This contribution presents quality-checked and homogenised datasets of sunshine duration (SD, 1936-2013), surface solar radiation (SSR, 1959-2016) and visibility (1951-2017) for Italy. The datasets have been set up recovering as much as possible observational series which have been subjected to a detailed quality-control procedure. The results obtained for SD and SSR show also for the Italian territory the presence of a decreasing tendency in the first period and an increasing tendency in the subsequent one. On one side, the trends observed under clear-sky conditions are in agreement with that observed for visibility (fraction of days with visibility higher than 10 and 20 km) showing higher trends for the areas with a higher level of pollution (low-elevation areas), underlying in this way the significant role of changes in the aerosol concentrations in the transparency of the atmosphere. On the other side, the trends observed under all-sky conditions show also a significant role of the total cloud cover too especially until the mid of the 1980s where the decrease in surface solar radiation linked to the increase of the aerosol concentrations has been partially masked by the observed decreasing trend in total cloud cover."

P1.16. Influence of several teleconnection patterns on fog water collection in the eastern Iberian Peninsula for the 2003-2012 period

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In certain areas of the world, with specific geographic and climatic characteristics, fog collection can become an alternative to traditional sources of water supply. To date, most works focus on the study of its quantification and the potential uses, while there are few that analyze its relation with large-scale teleconnection patterns. Focusing on the Mediterranean Iberian Peninsula, this work aims to quantify the relationship between fog-water collection and the NAO (North Atlantic Oscillation), MO (Mediterranean Oscillation) and WeMO (Western Mediterranean Oscillation) teleconnection patterns. With this objective, daily fog-water collection observations from a network of stations distributed along the eastern coast of the Iberian Peninsula have been studied in relation to the NAO, MO and WeMO teleconnection patterns for the 2003-2012 period. For this purpose, we have analyzed: a) The statistical distribution of the daily values of the 3 patterns in relation to the fog-water collected; b) The percentage of the volume of water collected as a function of the daily value of each pattern. The main conclusions are: a) There is a clear influence of negative values on fog-water collection, more evident in WeMOi and MOi; b) In the case of MOi, more than 70 % of the water has been collected with negative daily values of this index; c) In the case of WeMOi, the influence of negative values in relation to water collection has been even greater.

P1.17. Development of an integrated index to characterize the remarkability of coastal compound events

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The Mediterranean coast is an area affected by frequent heavy rainfalls, windstorms severe weather and storm-induced coastal hazards. Especially relevant in this area are the compound events associated with the presence of heavy rainfall and coastal storms (high waves and surges). The growth and concentration of the population in this area has further increased the damage caused by these events. The C3RiskMed Project aims to characterize these compound risks on the Spanish Mediterranean peninsular coast, and how these risks will be affected by climate change. In this work, a dual approach (top-down and bottom-up) has been adopted to characterise the importance of univariate and compound events. To this end, a remarkability index has been developed that integrates data indicative of their induced damages (compensation data from the Spanish Insurance Compensation Consortium) and main variables that characterise the magnitude of the hazards, such as maximum rainfall and wave height. In addition to this, emergency management and public response data are being included to characterise the induced pressure on emergency services and the social impact. This communication will present the methodology developed to obtain the remarkability index and its application to the period 1996-2020, as well as a case study that includes complementary information on emergency and social impact.

P1.18. Differences in the two recent climate potentials of tourism on Croatian island in the northern Adriatic Sea

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Tourism is the main economic branch of Croatian island of Mali Lošinj, located in the northern Adriatic Sea. In order to maintain it as such in the future or improve it even more, it is necessary, among other things, to monitor and adapt to changes in local natural conditions. Among the most important, which greatly affect tourism based on staying in open space, are climate conditions and their changes. Two overlapping thirty-year climate periods, 1981-2010 and 1991-2020, were analyzed. It was detected that the climates of those periods belong to the same Köpen climate type. It is Csa type - moderately warm, rainy climate with dry summer. But it is also confirmed that the Köpen climate of the 1991-2020 period is close to the border with the Cfsa climate - moderately warm and rainy, in which summer is hot and the driest season, but without a dry period. The suitability of two overlapping climate periods in the morning, afternoon and evening hours for several types of tourism were compared. Analyzes were carried out using the climate index for tourism (CIT). Some parameters that are locally most significant for changes in climate potential for certain types of tourism, as well as possibilities for extending the tourism season for certain types of tourism, have been determined.

P1.19. Amateur observational network for high-resolution climatological analysis: a case study in the Aterno Valley, Abruzzo, Italy

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The ecological transition calls for an increasing need for local climate services. A fine spatial characterization of atmospheric relevant quantities (temperature, precipitation, humidity, wind, solar radiation, etc.) at long-term climatological scales is typically based on observational networks run by public entities such as the European Union (e.g. Copernicus services) and national and regional Agencies (e.g. National Met Office, Hydrographic Offices). The aim of this work is to verify if the density of these networks is adequate to represent the variability over the territory, with particular regard to a complex terrain area such as the Aterno river Valley in Abruzzo, Central Italy. We use a combination of public networks and the available dense amateur network of weather stations. We subject the database to careful data quality check both in terms of temporal and spatial anomalies. We found that the public network is generally adequate to represent the broad climate features of the area, but may not resolve local phenomena such as the urban heat island or the acceleration of wind in the valley. We suggest that an integration of public and amateurs' observational networks is desirable for a finer climatological characterization of a complex territory, in order to better inform mitigation and adaptation measures with respect to climate change.

S2. Processes and mechanisms

Invited talk: Process-based classification of Mediterranean cyclones

Shira Raveh-Rubin, Yonatan Givon

Weizmann Institute of Science

Mediterranean cyclones are responsible for extreme weather events extending from the Mediterranean basin to Europe, Africa, and the Middle East, affecting the lives of hundreds of millions. Despite continuous research and improved understanding of Mediterranean cyclones in the last decades, their accurate simulation and prediction remain a significant challenge at the weather and climate scales. A central challenge is the non-linear, multi-scale interactions that govern cyclogenesis and cyclone deepening, and their interaction with topography. Mediterranean cyclones are dominated by large-scale forcing for baroclinic instability, joined by diabatic processes in the mid-troposphere, and interactions with the land/ocean surface. While past studies classified cyclones in the region, none systematically distinguished different cyclone types in terms of the governing processes, limiting our understanding of their occurrence, impacts, predictability, and long-term changes. Here, we aim to classify Mediterranean cyclones across the basin, year round, by the governing processes during their deepening. To this end, we rely on the recent Mediterranean cyclones “best tracks” dataset from the MedCyclones COST Action for 1979-2020, and using a self-organizing map approach, we classify the cyclones into types depending on their potential vorticity (PV) distribution in the upper troposphere. The analysis reveals 9 distinct PV distributions, reflecting different flow structures associated with Rossby wave structures and breaking life cycles. Each cyclone type exhibits unique spatio-temporal distribution, (thermo)dynamical evolution and relative contributions of diabatic processes. The impacts of cyclones vary dramatically across the different types, suggesting the usefulness of adopting a process-based approach to cyclone classification. Based on this work, future directions for studying cyclone prediction will be put forward.

O2.1. The integrated analysis of a summer urban flash flood in Croatia

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Accurate information about high intensity precipitation of short-duration are of a great importance for issuing warnings to flash floods and for designing urban drainage systems in the wider Mediterranean area, which is especially conducive to such events. In this study, an extreme rainfall event in summer 2020 which caused an urban flood in the city of Zagreb, Croatia, was analyzed from the climatological, synoptic and hydrological aspects including a numerical analysis using the mesoscale ALADIN-HR model. The study showed that the 2-hour extreme precipitation event in summer 2020 over the city center was an exceptional one with the return period higher than 100 years. According to the analysis, the major ingredients for deep moist convection were present before the event. Formation of cut-off low and the presence of an intense positive upper-level potential vorticity anomaly as well as advection of the warm unstable moist air from the Mediterranean were the main synoptic scale processes which promoted heavy precipitation. In addition, the surface convergence line played an important role in localizing and triggering deep convection. Thus, in context of several recent studies of heavy precipitation events performed in the wider Adriatic area within the context of the HyMeX programme, surface convergence line is identified as a common and prominent component of such events. Our analysis suggests that numerical models are, despite remaining uncertainties, capable of guiding forecasters to issue warnings to such events, but also that current extreme precipitation estimates, as well as the capacity of the main sewerage system of Zagreb should be redesigned and adapted to climate change."

O2.2. A conceptual model for the development of tornadoes in the Po Valley

Francesco De Martin[1], Silvio Davolio[2] Mario Marcello Miglietta[2], Vincenzo Levizzani[2]

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[2] CNR-ISAC

Why is the Po Valley a hot spot in Europe for tornadoes? In this study the authors address this issue, studying a tornado outbreak that affected the Po Valley on 19 September 2021. During that event seven tornadoes (four of them ranked as F2 according to the Fujita scale) developed in the area in a few hours. The case study was analysed using observations and numerical simulations obtained with the convection permitting MOLOCH model. Observations showed that during the event there were two low-level boundaries in the Po Valley: a cold front coming from the Alps and a dry line generated by the downslope winds from the Apennines. A strong correlation between the area of tornadoes development and the low-level boundaries was observed. Numerical simulations with 500 m grid spacing proved that the cold front was important to the supercell development due to the baroclinic production of streamwise vorticity. Furthermore, the dry line played a key role creating locally large amounts of instability and windshear near the surface: kinematic and windshear parameters were comparable to those observed in US-tornado events only along a narrow path near the dry line. Finally, it was found that a warm and moist air tongue from the Adriatic Sea was fundamental in generating the supercells. In conclusion, comparing these results with previous papers, a conceptual model for the development of tornadoes in the Po Valley is proposed, which explains why tornadoes are relatively common in Northern Italy."

O2.3. Boundary layer and precipitation changes by introducing irrigation parameterization in WRF

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This study aims to explore the impact of land irrigation in the lower atmosphere and in the precipitation field using WRF simulations. Simulations are run for July 2021 in order to analyze the special observation period (SOP) of the LIAISE field campaign (15-31 July 2021) for a control case and for the irrigated case that includes the irrigation parameterization (Valmassoi et al. 2020), which modifies the amount of water in the land-surface model. In addition, sensitivity tests are done varying the spin-up time of the irrigated land. The comparisons between WRF and the automatic weather stations show better statistics for temperature, humidity and wind speed and direction when including the irrigation parameterization. The warm bias in maximum 2-m temperatures are highly reduced when introducing the irrigation effects, although the minimum temperatures are not improved. Errors in 2-m specific humidity and 10-m wind speed are also reduced in irrigation simulations. Using the tower measurements of sensible and latent heat fluxes at la Cendrosa it is also seen a better energy partitioning representation in simulations that include the irrigation at the site, where the latent heat flux is prevailing over the sensible heat flux. The boundary layer height is lowered in the area nearby where the irrigation is applied. These modifications lead to decreases in the lifting condensation level and the level of free convection, which also cause increases in CAPE and CIN indexes. Regarding precipitation, there are hardly any differences between control and irrigated simulations for the biggest area of study, but they become more relevant for smaller areas, close to the irrigated lands. Simulations including irrigation tend to produce lower rainfall intensities than the control ones, which seem to be related to the less enhancement of convective initiation. However, the precipitation systems that occurred during the SOP in LIAISE affecting the area around the Urgell channel did not seem to be highly influenced by the lower atmosphere processes.

O2.4. Nocturnal evaporation and condensation processes at the surface in the semi-arid Eastern Ebro Basin

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Between June 2021 and July 2022, in the frame of the LIAISE initiative in the Eastern Ebro Basin, several equipments were installed over a rainfed semi-arid terrain with natural vegetation, near the town of Bellpuig (Catalonia). LIAISE stands for ""Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment"" and is a program intended to study these interactions for irrigated and rainfed areas as well as the influence of human activities over evaporation. In this work we analyze the observed annual cycle of evaporation and non-rainfall water inputs (i.e., dew/frost and fog) at night, by means of data obtained from different observational sources: turbulent fluxes obtained with an eddy-covariance system, water fluxes from weight changes of a portion of the soil given by a weighable lysimeter, detection of liquid water over two leaf-wetness sensors at two different levels and the observation of the vertical gradient of the atmospheric specific humidity close to the surface. The results will be presented by seasons, and it will be shown that, despite this period was extremely dry in Catalonia, nocturnal non-rainfall water inputs from mainly dew formation were present most of the days, whereas nocturnal evaporation was important in windy situations. Some particular cases will be analysed in detail. As the turbulent fluxes are often not of good quality in stably stratified nights, for condensation the analysis is based mostly on the lysimeter data and the vertical gradient of specific humidity, the leaf-wetness sensors will be used as independent indicators of dew formation while significant positive latent heat fluxes will provide indication of significant nocturnal evaporation. The soil and atmospheric conditions leading to dew formation will be inspected as well as the impact of the latter in the thermal state of the nocturnal surface layer.

O2.5. Flux-gradient relationships for heat and water vapour in semi-arid environments

Daniel Martínez-Villagrasa[1], Belén Martí[1,2], Jeremy Price[3] , Joan Cuxart[1]

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The exchange processes of water and energy between the air and the underlying surface play a key role in the description of our climate system. These fluxes at the land surface are driven by turbulence, which is parametrised in atmospheric models according to similarity theory. Under this framework, it is possible to relate such surface fluxes with the vertical gradients of the corresponding transported variables through empirical functions that depend on the airflow stability. Despite its application requires ideal conditions such as surface homogeneity and stationarity, and that the empirical functions were derived under certain conditions, in practice similarity theory is used ubiquitously. Moreover, the latent heat flux does not contain specific adjusted functions and the same coefficients derived for the sensible heat flux are typically applied. The latter assumption implies that the turbulent transport of heat and water vapour is the same. In the current work, two Mediterranean sites with different soil water availability and natural vegetation cover will be used to assess the flux-gradient relationships for sensible and latent heat under semi-arid conditions. One site is located at the University Campus in the island of Mallorca (ECUIB), while the other belongs to a rainfed area (Els Plans) of the western Ebro river basin in the Iberian Peninsula, recently instrumented during the Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) campaign. Both sites contain vegetated surfaces and soils that progressively dry out in the warm seasons, when precipitation is scarce and water demand is high. The results show that sensible heat flux needs new empirical functions when latent heat predominates in conditions of high soil water content and large solar radiation. Latent heat flux needs to be estimated with their own empirical functions except for those cases in which the soil is dry but with enough water on the surface (i.e., after a rain event). For the rest of conditions, the turbulent transport of heat and water vapour are equivalent only when latent heat predominates over sensible heat."

O2.6. Characterisation of the marine-air intrusion Marinada in the eastern Ebro subbasin

Maria Antònia Jiménez, Antoni Grau, Daniel Martínez-Villagrasa, Joan Cuxart

Universitat de les Illes Balears

The eastern Ebro basin is composed of an extensive irrigated plain, surrounded by rainfed slopes and wooden mountain ranges and open to the west to the agricultural western Ebro basin. The sea breeze generated at the coast is able to surmount the Catalan prelitoral range through its lowest heights, reaching the basin in the afternoon by its easternmost part. It is a well-known feature in the region, called Marinada. A network of Automatic Weather Stations is used here to analyze a period of 19 years (2003-21). A filtering procedure is developed which selects the events when the Marinada is present, based on detecting clear sky, weak wind conditions and the wind direction from the coast in the afternoon. The analysis of these days show that the Marinada propagates along the basin, while observations of the specific humidity show a sudden increase as the temperature cools down, indicating a cold and humid advection. It is also found that the timing of the arrival of the Marinada depends on the mesoscale/synoptical circulations already present in the region (westerlies or a thermal low). As a example, the Marinada events reported during the intensive period of the LIAISE are further analyzed."

O2.7. Two-way interactions between a small temperate lake and the atmosphere: A case of Kozjak, Plitvice Lakes, Croatia

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Same as ocean-atmosphere interactions, two-way interactions between lakes and the atmosphere occur through fluxes in momentum, heat, moisture and mass at water surfaces, modifying thus weather and climate of their surrounding areas. In the present study, we investigated two types of these interactions: 1) the response of a small, elongated, temperate lake (Kozjak, Plitvice Lakes; the lake fetch is 2.3 km, and the maximum depth is 46 m) to atmospheric forcing; and 2) the atmospheric response to the presence of the same lake, i.e., the occurrence of a thermal, lake-land breeze circulation. Three-year time series of observed data (specifically, standard meteorological data and lake-temperature experiment data with the temporal resolutions of 1 h and 2 min, respectively) were analyzed. In addition to the standard statistical procedures, spectral and wavelet analyses were employed. It is shown that due to the atmospheric forcing, the lake stratifies during the warm part of a year with a thermocline deepening from spring to late fall. Additionally, if the lake is stratified and the sirocco wind blows above the Adriatic, internal standing waves (internal seiches) occur within the lake. Under undisturbed atmospheric conditions, atmospheric response to the lake presence is seen as an establishment of a lake-land breeze circulation despite the small lake size. In contrast to findings for the Lake Garda, results of this study suggested a clear relationship between the lake-land temperature difference and the strength of breezes.

O2.8. Decomposing the contribution of dry intrusions for evaporation in the Gulf of Lion during Mistral

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The Mistral wind is a northerly gap-wind regime blowing through the Rhone Valley in Southern France. It is held responsible for the sea-surface cooling necessary to produce deep convection in the Gulf of Lion through turbulent ocean heat loss. The Mistral is tightly connected to lee-cyclogenesis in the Gulf of Genoa, where topography forces substantial downward motion. Dry Intrusions (DIs) are Lagrangian air trajectories flowing along the descending branch of extra-tropical cyclones. Known to induce cold and dry surface anomalies, DIs are potential contributors to enhanced surface evaporation during Mistral. In this study, a climatological database (ERA-INTERIM, 1981-2016) of DI-Mistral co-occurrence is constructed, allowing us to quantify the impact of DIs on the Mistral evaporative hot-spot for the first time. We find that DI-Mistral evaporation rates are more intense by up to 100%, compared to Mistral without DIs. Daily latent heat flux anomalies in the GOL are decomposed into contributions from the various atmospheric parameters to quantify the Mistral evaporation response to DIs. DI-Mistral events are shown to produce extreme evaporation rates, mainly through increased Mistral wind speeds and wind gusts. The results indicate the downward momentum flux delivered by DIs as the primary driver of the Mistral amplification.

O2.9. Heatwaves in Rome (Italy) during summer 2022: interaction with sea breeze, urban heat island, and thermo-hygrometric comfort

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Heatwaves are extreme meteorological phenomena characterised by persistent conditions of statistically unusual hot weather. Recent studies suggest that, in the near future, these events might become more intense and long-lasting due to climate change, especially in the Mediterranean region. The negative effects of overheating are exacerbated in metropolises, which can be also affected by the Urban Heat Island (UHI) phenomenon, i.e., the increase in temperatures in built-up areas compared to the rural surroundings. This can lead to public human health consequences such as higher thermal stress and, therefore, to higher thermal discomfort. Furthermore, the presence of the sea/land breeze regime must be considered in coastal urban areas. The sea breeze develops when the difference in temperature between sea and land causes an onshore pressure gradient, determining the advection of cool and humid air masses from the sea to the warmer land. In this study, the in-situ meteorological observations collected in Rome (Italy) during summer of 2022 are analysed. The selected period was characterised by abnormal high temperatures over Europe and Italy. The aim of the study is to evaluate the differences between heatwave and not-heatwave days in terms of sea breeze development, UHI intensity, and thermo-hygrometric well-being. In fact, the effects of heatwaves on human health and ecosystems are quite clear, while the presence/absence of synergy between heatwaves and local atmospheric phenomena is not straightforward and needs further investigation. Here, a severe heat event is classified as a heatwave if the average daily temperature exceeds the 95th percentile of the reference period for at least four consecutive days. The results show that the heatwaves influence the sea breeze only in terms of cooling effect, which is intensified. In contrast, there are no significant effects on sea breeze onset time, duration, and intensity. The UHI is intensified during night-time, while the outcomes reveal the absence of synergy between the heatwaves and the daily-averaged UHI intensity. The thermo-hygrometric stress, evaluated by applying the Mediterranean outdoor comfort index, is intensified during the heatwaves, although they do not represent a sufficient condition to identify extreme overheating phenomena since the latter depends on several weather variables.

O2.10. Towards the detection of extreme sea level rises along the Mediterranean coastline using meteorological observations

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Extreme sea levels along coastlines result from a combination of factors, including increases in local mean sea levels and tidal levels, storm surge events, waves and changes in coastal morphology. In the Mediterranean basin, due to its semi-enclosed nature, coastal extreme sea levels are mainly caused by storm surges driven by atmospheric pressure and surface winds from extratropical cyclones and medicanes. Therefore, extreme sea level rises here are primarily wind driven and their occurrence is controlled by meteorological and climatological processes. This study investigates the meteorological conditions (e.g., wind state, air pressure) which favor the sudden rise of sea level along the Italian coastline. This work aims to design an algorithm that can identify the occurrence of extreme sea level rises by only using meteorological information. This can improve the prediction of the occurrence of extreme sea level events.

P2.1. Explosive cyclones in the Mediterranean Sea exploiting ERA5 dataset: detection, classification, statistical and synoptic analysis of their occurrence

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In the semi-enclosed basin of the Mediterranean Sea, a wide variety of cyclone mechanisms are known to develop, including baroclinic waves coming from the Atlantic, Mediterranean cyclones originating from the cut-off of baroclinic waves, Warm Seclusions, Tropical-Like Cyclones (TLC), Rapid-Cyclogeneses (RC) and Intense Mediterranean Cyclones (IMC). Depending on the cyclone's type, the characteristic frequency of appearance can vary, ranging from tens per month to around 1-1.5 per year, as in the TLC case. RCs are among the rarest and probably most intense and destructive cyclone events that can develop in nature; they usually originate at high latitudes, during wintertime, and mainly over the sea, preferring areas with high Sea Surface Temperature (SST) gradients. It is generally accepted that these events are described by a quick drop of pressure, close to 1hPa/hr for 24 hours, within the eye of the cyclone. Several recent studies investigated the formation of RC's over Mediterranean Basin (MB). RCs formation is an extremely complicated process, and in the MB it is mostly driven by dry air intrusions from the stratosphere and by the trigger of Atmospheric Rivers. Using ERA5 dataset, we firstly conducted a physical and dynamical analysis of the most intense cyclone events that occurred in the Mediterranean basin in the period 1979-2020, identifying factors that triggered, generated, and contributed to the intensification of such events. According to Sanders' and Gyakum's definition of Bergeron, a parameter that describes RCs' deepening rate and varies from 28mb/(24h) at the pole to 12 mb/(24h) at latitude 25°N, we were able to classify them in the three aforementioned categories. With the help of EOF analysis, we outlined synoptic configuration more likely to drive the phenomena, highlighting the role of SCAND index and NAO-. Moreover, we have investigated the deepening with a new promising approach involving the use of 6 hours timespans, in order to single out the cyclones with higher gradients of pressure and faster evolution in semi-enclosed basins. Further analysis is being undertaken to determine the cyclones' phase and their main morphological characteristics, as well as their correlation with atmospheric rivers and SST anomalies exhibited by the Central Mediterranean Basin."

P2.2. Extreme precipitation and urban flooding in Rijeka, Croatia on 28th September 2022

Dunja Placko-Vrsnak

Natasa Strelec Mahovic, Tanja Renko, Petra Mikus Jurkovic

The western parts of Croatia, in particular Istria peninsula and the city of Rijeka, were hit by a strong thunderstorm accompanied by heavy rain and strong winds on 28th September 2022. The greatest material damage occurred in the city of Rijeka. Unfortunately, one person died in the flash flood. The 24-hour precipitation amount, measured by the rain-gauge at the Rijeka meteorological station (287,5 mm), was the highest on record for that station (measurements have been available since 1948.). The synoptic situation that resulted in extreme rainfall and flash flooding was caused by a strong upper-level south-westerly flow on the front side of a deep trough, bringing large amounts of moist and unstable air from the Mediterranean. The mesoscale thermodynamic conditions were favourable for deep moist convection, especially the ingredients for heavy precipitation. Radar and satellite products showed that convective cells were quasi-stationary, forming one after the other over approximately the same area, reaching their maturity with the maximum amount and intensity of precipitation over approximately the city of Rijeka and surrounding area. A detailed analysis of the case with the help of NWP analyses and forecasts as well as different satellite and radar products will be presented. Additionally, the ability of different products and tools to capture extreme precipitation amounts will be assessed.

P2.3. Numerical simulation of a thunderstorm event in the Mediterranean using a full-cloud model: sensitivity analysis to different microphysical schemes

Dario Hourngir, Massimiliano Burlando

University of Genoa

Thunderstorms represent one of the major threats among the atmospheric mesoscale phenomena worldwide. The difficulty to properly predict their behavior and the capability to cause large damages at the local scale through extreme phenomena like windstorms, hailstorms and intense rainfall, are still a major challenge both from an operational and a scientific point of view. In some areas of the globe, their intensity can be enhanced by local specific conditions, like the presence of steep orography or strong surface heat fluxes. In this work, we focus on the analysis of the local-scale mechanisms which occur in the Northern Mediterranean, by performing high-resolution simulations of a thunderstorm event through the use of the Cloud Model 1 (CM1). The domain of analysis is the Ligurian Sea, an area prone to the development and triggering of deep-convective thunderstorm events. A thunderstorm hitting the city of Genoa on the 14th August 2018, with an associated downburst, is chosen as a case study for our investigation. Different schemes for the microphysics are tested, in order to compare the numerical outcomes with measurements of wind and temperature fields at the ground. The results show the crucial role of the complex orography, characterizing this geographical region, in triggering the strength of the thunderstorm and affecting the development of the downburst at the surface.

P2.4. Toward a dedicated warning system of severe storms in Italy: the PRETEMP project

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A dedicated warning system can significantly reduce economic and human losses during severe storm events. While in the USA a well-tested warning system exists since many years, a corresponding institutional warning system has not been established so far in Europe. ESTOFEX has been the first attempt of a severe weather forecasting system at a European-scale, very appreciated by the meteorological community, but on a voluntary basis. PRETEMP is an initiative carried on by a group of students and young meteorologists who aim to replicate the ESTOFEX initiative at a national scale: it has been publishing a severe weather outlook specific for Italy every day since 2015. Italy is a country with very complex orography mostly surrounded by the sea. Therefore, a national dedicated warning system may allow to capture local mesoscale features, important for severe storm development, better than an outlook on a continental scale. Like ESTOFEX, PRETEMP is a volunteer group, but it has informal collaboration with local weather agencies: hopefully, in the near future it can be an example for an institutional warning system. The PRETEMP forecast is based on four levels of severity, ranging from level 0 (generic thunderstorms) to level 3 (extremely severe storms). Furthermore, PRETEMP has been collecting severe storm reports from Italy since 2018, exploiting the Storm Report Database created by Meteonetwork, an Italian amateur association. These reports, collected by many volunteers and local meteorological associations, ensure a capillary network of storm spotters: it represents an effective example of citizen science applied to severe weather. They have been automatically submitted to the ESWD (European Severe Weather Database) since 2019 representing the main source of storm reports from Italy. In addition, in case of tornado events, PRETEMP contribute to the path damage reconstruction and tornado classification, in collaboration with ESSL. More recently PRETEMP is testing some forecast verification techniques to increase the reliability of the forecast product and to assess and improve the forecaster performance. Initially the forecast verification was qualitative, based on a simple overlay of storm report locations on the outlook map. PRETEMP is now moving toward a more quantitative approach, testing both dichotomous (to create performance diagrams) and probabilistic approaches (using the Brier Skill Score index), to find the most suitable method to assess the outlooks."

P2.5. Analysis of the vertical structure of first- and second-order turbulence moments in anabatic winds from field observations in three case studies

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University of Trento, Italy

The turbulence structure of anabatic winds is investigated analysing data from measurement campaigns performed over different slopes under the projects METCRAX (Whiteman et al, 2008), MATERHORN (Fernando et al, 2015) and MAP-RIVIERA (Rotach et al, 2004). The three field studies are representative of different topographical configurations and surface conditions and are used to identify the main characteristics and near-surface structure of the first and second-order moments of velocity and temperature associated with these circulations, as well as their relation with the environment in which they develop. Results show similar behaviours, in terms of both first and second-order moments vertical structures, for anabatic winds developing in different environments. In particular, both the wind velocity, local temperature gradients and turbulent variables display a similar structure and assume values in the same range. For all the case studies considered, time windows suitable for the observation of clean anabatic flows are quite short (i.e., $\sim 2 - 3$h). TKE shows increasing values in the first meter above the ground, and then an almost constant profile above that height. The w'T ' flux increases within the first 5.0 meters above the ground, while the opposite behaviour is observed in u'T '.

P2.6. Seasonal variability of the boundary layer-height over coastal-mountain-valley topography: theoretical study over central Israel

Sigalit Berkovic

IIBR

The boundary layer height (BLH) is one of the key factors in influencing the dispersion of the air pollutants in the troposphere and, hence, the air pollutant concentration on ground level. For this reason, understanding and characterization of air pollutant concentration depends on the knowledge of BLH variability. The special variability of the BLH over Israel was not determined due to lack of comprehensive 3-dimensional data. This work presents climatological examination of the daytime BLH variability during non-summer months according to WRF simulations with 3 km horizontal resolution during 5 years. The center of Israel presents relatively simple vertical topographical cross-section: The eastern Mediterranean coast on the west, Judea and Samaria mountain in the center and the deep steep Jordan valley on the east. The monthly average BLH above the mountain peak and its easterly slope is found to be lower than that over the coastal area (1-2.5 .vs. 2-3 km) during the winter months, November-February, while during the rest of the year (except March) the situation is reversed. In order to track the mechanism responsible for the reduction of the BLH over the mountain peak area during winter, an examination of the BLH variability during 10-13 UTC was performed. Accordingly, events with relatively weak pressure gradients and weak (< 5 m/s) easterly flow were found to be responsible for minimal BLH (< 350 m). The synoptic pressure during these events is characterized by ridge from the south in the middle troposphere (500 hPa) and central Red Sea Trough or high to the east or to the north of Israel next to the surface. Fohn winds which locally reduce the humidity and enhance the temperature due to subsidence flow over the eastern slope of the valley and the western slope of the mountain. In such cases, the mild synoptic pressure gradients are responsible for the maintenance of the local cooling over the mountain peak. The advection of hot air to the mountain peak is limited and therefore relatively stable thermal stability is obtained over the mountain peak and its eastern slope."

P2.7. Characterization of the morning transition from downslope to upslope winds and its connection with the nocturnal inversion breakup at the foot of a gentle slope

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Thermally driven winds observed in complex terrain are characterized by a daily cycle dominated by two main phases: a diurnal phase in which winds blow upslope (anabatic), and a nocturnal one in which they revert their direction and blow downslope (katabatic). This alternating pattern also implies two transition phases, following sunrise and sunset respectively. Here we propose the study of the surface layer processes associated with the morning transition from nighttime downslope winds to daytime upslope winds over a semi-isolated massif based on the MATERHORN experiment, performed in Salt Lake Desert (Utah) between Fall 2012 and Spring 2013. We provide an insight into the characteristics of the transition and its connection with the processes controlling the erosion of the temperature inversion at the foot of the slope. First, a criterion for the identification of days prone to the development of purely thermally driven slope winds is proposed and adopted to select five representative case studies. Then, the mechanisms leading to different patterns of erosion of the nocturnal temperature inversion at the foot of the slope are analyzed. Three main patterns of erosion are identified: the first is connected to the growth of the convective boundary layer at the surface, the second to the descent of the inversion top, and the third to a combination of the previous two. The first pattern is linked to the initiation of the morning transition through surface heating, while the second pattern is connected to the top-down dilution mechanism and so to mixing with the above air. The discriminating factor in the determination of the erosion pattern is identified in the partitioning of turbulent sensible heat flux at the surface.

P2.8. Evaluation of eddy diffusion coefficients for thermally driven slope winds

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Slope winds are part of the system of thermally driven circulations typically developing over complex terrain. They flow up-slope due to surface heating during the daytime and down-slope due to surface cooling during the nighttime. Our understanding of these circulations still suffers from some gaps, especially for what concerns the diurnal component (due to the additional complexity determined by convection). In particular, the dispersion and diffusion properties within the boundary layer associated with slope winds are poorly understood. Here an analysis of the mixing processes in the surface boundary layer in which down and upslope winds develop is proposed. The slope-normal structures of the heat and momentum fluxes, turbulent kinetic energy and diffusion coefficients are investigated. Moving from a review of the available datasets from intensive field measurements over complex terrain, comprehensive measurements of turbulence performed at towers over the slopes, case studies from three different field experiments are identified and the eddy coefficients for heat and momentum diffusivity are found and presented together with their observed vertical structure. The datasets are from the experimental campaigns of MATERHORN (Fernando et al, 2015), METCRAX (Whiteman et al, 2008) and MAP-RIVIERA (Rotach et al, 2004). Existing formulations on the dependence of these coefficients on the distance from the surface are tested on the basis of their ability to reproduce the observed structures.

P2.9. A 24-h cycle of a persistent winter fog event in the Eastern Ebro basin

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In the frame of the LIAISE initiative in the Eastern Ebro Basin, several equipments were installed over a rainfed semi-arid terrain with natural vegetation, near the town of Bellpuig (Catalonia) between June 2021 and July 2022. LIAISE stands for ""Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment"" and is a program intended to study these interactions for irrigated and rainfed areas as well as the influence of human activities over evaporation. Fog in the LIAISE area is an important meteorological feature. It takes place in the wintertime and it can be persistent, lasting even for several weeks, reaching depths of a few hundreds of metres and covering most of the lower part of the Ebro basin, about 40000 km2. In December 2021 a deep (up to 500 m above ground) persistent fog event took place that lasted 11 days and was explored vertically through radiosonde releasing and the use of a BASTA Radar. In this poster the soundings, the radar and the surface observations are an inspected together in order to describe a selected 24-h period, highlighting the lack of a diurnal cycle at the surface and the special behaviour of the terms of the surface energy budget.

P2.10. The Cerdanya Cold Pool Experiment 2015 (CCP15): Thermally driven wind system and large-scale airflow interaction in the largest Pyrenean valley

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The Cerdanya Cold Pool Experiment 2015 (CCP15) aimed to study the air thermal structure and wind circulation within the Cerdanya valley (eastern Pyrenees, Catalonia) under fair-weather conditions. The field campaign took place between 6 and 15 October 2015, focusing in the vertical column of the first hundred meters above the valley together with the surface energy balance at its centre. The Cerdanya valley, east-west oriented, is the largest of the Pyrenees mountain range with a wide bottom at 1000 m above sea level (asl) and bounded by high mountain ranges both to the north and south (peaks above 2500 m asl). Its topographical configuration favours the development of a diurnal valley wind system with the formation of a cold-air pool at night. During the campaign, four of a total of six intensive observation periods (IOPs) were affected by the intrusion of a strong wind channelised down valley during the afternoon and evening periods, followed by the development of a strong surface-based thermal inversion at might. The analysis of the observations leads to the following findings, also supported with high-resolution numerical simulations: The wind channelling observed in the valley centre requires the presence of a large pressure gradient in the north-south direction, i.e. perpendicular to the mountain range (orographic dipole). The wind channelling has a diurnal evolution, occurring during the afternoon and evening periods. The exact onset time and endurance depends on the particular synoptical configuration and on the valley wind dynamics. The presence of the wind channelling affects the evolution of the thermodynamic variables at the surface layer and the exchange fluxes at the surface interface, modifying the initial conditions of the nocturnal boundary layer within the valley. A strong surface-based thermal inversion develops over the valley under both fair-weather conditions or the presence of such channelled wind. The latter fosters the vertical growth of such inversion and dumps its intensity. The thermal inversion separates the lowest levels close to the ground from the wind channelling flow influence.

P2.11. Statistical characterization of the sea breeze physical mechanisms in the three main basins of the Mallorca island

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The physical mechanisms that take place under sea-breeze (SB) conditions in the island of Mallorca (western Mediterranean Sea) are analysed through the inspection of data from automatic weather stations (AWS) from the Spanish Meteorological Agency (AEMET) during the period 2009–2022. Hourly satellite-derived land-surface and sea-surface temperatures (LST and SST, respectively) are used to compute the surface temperature difference (LST–SST) in the three main basins. Besides, a method (Grau et al, 2020) is taken to select the SB events in the three main basins using data from AWS during the warm months of the year (from April to September). Results from the statistical analysis of the selected SB events show that the ranges of the temperature difference change in the three main basins pointing to the presence of other physical mechanisms in the setup of the sea breeze in each basin. For instance, it is explored the role of the large-scale winds, the influence of the shape of the basin in the propagation of the SB front and the vertical temperature gradient (T850hPa – LST). It is found that there are differences in the SB features of the three basins (maximum wind speed, initiation and duration of the SB) and SB conditions that are not simultaneously met in the three basins. For a particular basin, the SB interacts with the already present locally-generated winds within the same basin but also with the SB generated in the other basins.

P2.12. Mediterranean sea-surface responses to large-scale atmospheric forcing in evaluation Med-Cordex simulations

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Dominant Euro-Atlantic modes of large-scale atmospheric variability, such as the North Atlantic Oscillation (NAO), the Eastern Atlantic pattern (EA), the Eastern Atlantic Western Russian pattern (EAWR) and the Scandinavian pattern (SCA) are known to significantly affect interannual-to-decadal climatic and hydroclimatic variability of the Mediterranean region especially during the winter season. Whereas previous studies assessed the impacts of these modes on air-sea heat and freshwater fluxes over the Mediterranean Sea, few studies explored the effects of these modes on the sea surface properties of the Mediterranean Sea and mostly they relied on the use of single model simulations. In this contribution we investigate the Mediterranean Sea surface thermohaline response to winter forcing from NAO, EA, EAWR and SCA using a multi-model analysis of evaluation simulations belonging to the Med-Cordex initiative. We present results from a composite analysis around strong positive and negative phases of these modes to assess the responses of the associated signals on the Mediterranean Sea surface. Different simulations show only a partial agreement as far as the identification of the modes mostly contributing to changes in the Mediterranean surface thermohaline properties is concerned.

P2.13. Is synoptic meteorology a driving mechanism of airborne pollen dynamics in the NE Iberian Peninsula?

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Several studies have shown the occurrence of atmospheric transport events that favour the arrival of allergenic pollen in Catalonia (NE Iberian Peninsula) from specific source areas in Europe, or synoptic meteorological patterns that facilitate the emission of pollens during their pollination period, and produce, consequently, high concentrations of airborne pollen of local/regional origin. In this study we have analyzed the influence of the six most frequent patterns of synoptic circulation in the Iberian Peninsula, obtained by cluster analysis of the sea level pressure fields, on the dynamics of airborne pollen recorded at the Barcelona Aerobiological Station (BCN). To this end, six pollen types (Urticaceae, Cupressaceae, Olea, Graminiae/Poaceæ, Platanus, Chenopodiaceae/Amaranthaceae) and one fungal spore (Alternaria) have been selected for their high allergenic effect in sensitive people. The local meteorology conditions associated with each one of the synoptic meteorological patterns (SMP) has been stablished using statistical tools. The study has been focused in the 19-year period 2001-2019. Preliminary results have shown that the synoptic scenario led by an anticyclone centred on the Azores Islands and a low-pressure centre situated between the United Kingdom and the Scandinavian countries is the most influent, with relevance in the concentration levels of five of the six pollens studied here. This pattern, frequent in spring-summer, presented the highest values of temperatures and solar irradiance, and the lowest values of relative humidity, as well as moderate winds from the SW. On the other hand, regarding the timing of pollination, it was another scenario that turned out to be the most relevant: the synoptic situation of high atmospheric stability produced by high pressures on the Iberian Peninsula causing blockage of air-masses. This typically winter SMP had significant influence on the start occurrence of Urticaceae pollination and on the peak date of Platanus. The identification of an interaction between SMP and concentration levels of pollens will allow better abatement measures, reducing adverse health effects on sensitive population.

P2.14. Future trend in the start of pollination in Barcelona in relation to global warming

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The effects of warming are numerous and some studies reveal that they can affect the timing of pollination. In Catalonia the average annual air temperature has increased by +0.23 °C/decade, and in the last fifty years the warming is slightly higher than that obtained on a global scale. Projections point to an increase in temperature in the coming decades, which would be more marked towards the middle of the century. Among the meteorological variables, temperature is the one that presents a clearer relationship with the start of the pollination season of most of the observed airborne pollen taxa. In previous studies, a forecasting model that predicts a statistical starting day from the cumulative sum of the daily mean temperature in daylight hours has been applied obtaining a very good approximation of the start of the pollen seasons. The aim of the present study is the application of this model to a set of projected future temperatures in Barcelona for the last three thirds of the 21st century to estimate the possible future trend in the start of the pollen seasons of the city. Future temperatures in Barcelona have been estimated by RESCCUE, a European project devised to analyse future urban impacts due to climate change.

P2.15. Vitamin D weighted UV irradiance from erythemal UV measurements

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The most common effect of ultraviolet (UV) solar radiation on humans is erythema or sunburn. The greatest benefit of exposure to UV radiation is the synthesis of vitamin D. It is therefore necessary to determine the amount of UV solar radiation that represents a balance between avoiding the risk of erythema and maintaining sufficient production of vitamin D. The UV irradiance weighted of the spectral action of vitamin D (UVVitD) is calculated from measurements of erythemal UV irradiance (UVER) measured with a UVB-1 by YES radiometer. The calculations have been made for the summer and winter solstices that correspond to the longest and shortest days of the year, with more and less UV solar radiation respectively, and the autumn and spring equinoxes. Previous studies have retrieved the UVVitD based on UV spectral measurements, such as Fioletov et al. (2009), McKenzie et al. (2009) and Guzilowski et al. (2018). A comparison has been made between them and with our model obtained from the standard calibration of the UVB measurement radiometers. The results show the variation in the values of UVER and UVVitD irradiance and futhermore high agreement in the results of all the models studied.

P2.16. Meteorological drivers and modulators of extreme compound Ozone concentration episodes over Europe

Francisco Sánchez-Jiménez, Eloisa Raluy-López, Leandro C. Segado-Moreno, Ester García-Fernández, Juan Pedro Montávez, Pedro Jiménez-Guerrero

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Ground-level ozone can be polluting and toxic to living things, including humans. The main source of polluting ozone is vehicle traffic and industries that emit volatile organic compounds and nitrogen oxides. That is why it is in large cities and surrounding areas where this pollutant is of most concern. The effects of ozone pollution include respiratory problems, damage to plants, and the environment. This study aimed to understand the factors that contribute to extreme ozone levels in Europe. For this purpose, the study analyzed extreme ozone levels at more than 2500 measuring stations in Europe. The study identified the extreme ozone levels and then analyzed the meteorological situations associated with them. This analysis was performed using multivariate techniques (machine learning) to identify the composite nature of the extremes. The results of the study showed that depending on the location, the factors that explain these events can be very different. The most important factors that contribute to extreme ozone levels were found to be temperature and radiation. However, other factors such as the pressure gradient and the associated transport were also found to be relevant in certain locations. Additionally, the importance of persistence in these extremes was also studied. Persistence refers to how long the extreme ozone levels last and how long the meteorological conditions associated with them persist. This information is important for understanding how to mitigate and prevent extreme ozone levels."

S3. Remote and in-situ measurements

Invited talk: Validation of CCI LST products using in-situ measurements from six globally distributed station networks

Lluís Pérez-Planells, Frank-M. Göttsche

Karlsruhe Institute of Technology (KIT)

The main objective of the Climate Change Initiative on Land Surface Temperature (LST_cci) project funded by the European Space Agency (ESA) is to develop long term global LST data records that meet the Global Climate Observing System (GCOS) requirements for climate applications, i.e. an accuracy and precision better than 1 K. Archived data from low Earth orbit (LEO) and geostationary (GEO) satellites are used to generate LST products from a variety of sensors that have operated over the past 28 years. The LST_cci Validation Team lead by KIT works independently of the data producers of the Earth Observation Science Team and provide an impartial assessment of the LST_cci products. Here we present validation results obtained for several LST_cci version 3 products, which include the following data sets: 7 LEO – Thermal Infrared, 3 LEO – Microwave and 7 GEO – Thermal Infrared. The in-situ data sets were obtained from 23 globally distributed stations belonging to six different networks. They comprise 6 sites from Karlsruhe Institute of Technology (KIT), 2 sites from Atmospheric Radiation Measurement (ARM) network, 6 sites from Surface Radiation Budget Network (SURFRAD), 1 site from Baseline Surface Radiation Network (BSRN), 3 sites from Heihe River Basin network and 5 sites set up by the Copernicus LAW project. The stations are located in a wide variety of land covers and climate zones, which allows for a globally representative and comprehensive validation analysis. The in-situ data from the six networks have been converted into a harmonized data format so that they can be handled efficiently and the same criteria for creating in-situ – satellite matchups over all sites can be applied. For consistency between the analyses performed for the LEO and GEO satellites, for the 1 km LEO satellite LST the 5 x 5 pixels, which were centered on the station and classified with as the same land cover, were averaged. Additional filtering was applied to remove potentially cloud-contaminated matchups from the validation database. The validation analysis considers daytime and night-time differences and seasonal variations, as well as a possible influence of observation geometry and land cover type at each station. Furthermore, the uncertainty of each LST_cci product is validated by considering satellite LST uncertainty, the in-situ LST uncertainty and spatial and temporal mismatching. The validation results obtained for the LST_cci products and their uncertainty will be presented and discussed.

O3.1. Are satellite imagery estimates and climate models able to explain the observed surface solar radiation trends over Europe?

Leandro C. Segado-Moreno[1], José Antonio Ruiz-Arias[2], Juan Pedro Montávez[1]

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Downward surface solar radiation (SSR) is a main component of the surface energy balance and the climate system, and the fundamental source of energy in renewable solar applications. It is therefore of great importance to know in detail the spatio-temporal variation of solar radiation at the surface, as well as its long-term trends. Scientific evidence has shown that the amount of solar radiation incident on the Earth's surface is not stable over the years, but undergoes significant variations every decade. Several studies suggest a generalised decrease in global surface solar radiation between the 1950s and 1980s, followed by a positive trend since the beginning of the 21st century. Ground-based observations are generally the most reliable data source for SSR monitoring, but they are scarce. In contrast, satellite-derived SSR estimates have a better spatial and temporal coverage, though the scientific literature on the use of satellite imagery for the study of the long-term trend of surface solar radiation is still limited. This study covers two purposes. First, multi-annual SSR trends have been calculated in detail for both ground-based and satellite-derived datasets over Europe for the 1994-2019 period. Monthly averaged time series of land stations from the GEBA (Global Energy Balance Archive) ground dataset have been compared to those estimated from satellite imagery by the Solargis model, over the same locations. To calculate the different variables related to the solar resource, the Solargis model uses data inputs from geostationary satellites and meteorological models. In addition, GEBA and Solargis SSR time series have been also compared with those from ERA5 and CMIP6 models. The results show a general increase of SSR over the study period, with an average trend of 3.4 Wm−2/decade (2.4%) for the observational data and 1.9 Wm-2/decade (1.4%) for the satellite estimations. For the period 2004-2019, the average trend is 2.8 Wm-2/decade (2.0%) for both datasets. This increase in SSR may be associated with changes in the transmission of the atmosphere due to variations in cloud properties and aerosols. Additionally, CMIP6 average over all models for RCP8.5 scenario and the ERA5 time series also show positive trends, although slightly lower than those of the GEBA and Solargis datasets, which suggests that there are still some variables that these climate models are not considering correctly.

O3.2. Impact of orographic features and climatic conditions on precipitation estimates of GPM IMERG products over Catalonia

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The Quantitative Precipitation Estimates (QPE) of the Integrated Multi-satellite Precipitation Retrieval System (IMERG) provide crucial information on the spatio-temporal distribution of precipitation in semi-arid regions with complex orography, such as Catalonia (NE Spain). The network of automatic weather stations of the Meteorological Service of Catalonia is used to evaluate the performance of three IMERG products (Early, Late and Final) at a semi-hourly scale. The analysis considered three different orographic features (valley, plain and ridge) and various climatic conditions (BSk, Csa, Cf and Df). Overall, IMERG showed a high bias and very low correlation values, indicating the challenge that satellite sensors still face in estimating precipitation at high temporal resolution. This behaviour was more evident in flat areas and cold semi-arid climates, where overestimates of more than 30% were found for IMERG_E and IMERG_L. However, in the case of IMERG_F, a tendency towards underestimation is observed in high mountain areas such as the Pyrenees. This marked underestimation is related to the low density of GPCC reference stations in high altitude areas used for calibration. Finally, orographic factors and mesoscale conditions generate an uneven distribution of precipitation over the territory, resulting in a very poorly spatially correlated precipitation field and thus an added challenge for satellite estimates.

O3.3. Long-term statistical results on lightning strokes recorded by the LINET network in Italy

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Was 2022 the year with the most lightning in the last decade? In which areas are there the most lightning strokes? What is the average electric discharge height? Is it correlated with the height of terrain? Does the strokes typology rate depend on season? This work provides the answers to these and other questions by illustrating the statistical analyzes carried out on 13 years of lightning data, between 2010 and 2022 over Italy. The attention to lightning data is growing and is very actual as demonstrated by the Meteosat Third Generation (MTG) mission of Eumetsat, which satellite payload, launched last December 2022, includes the first European sensor for detecting lightning from space, the Lightning Imager (LI). The interest in lightning data is related to many aspects with significant impacts in economic, scientific, meteorological and climatological terms. ISAC-CNR institute in Rome collects, manages and stores a long dataset of lightning data over Italy (actually a slighter larger area than Italy), provided by LINET network, thanks to an agreement with the German company Nowcast owner of the network and based in Munich. LINET includes several sensors at ground distributed all over the world to triangulate the electromagnetic signal in VLF waves emitted by electric discharges and to identify with high accuracy the position of the discharge emission in space (3D) and time, both intra-cloud (IC) or cloud-to-ground (CG). Since 2010, we have been receiving LINET data in Italy in Near Real Time (NRT), every minute. Recently, a MySQL database – named MyLightning – has been created to organize the LINET dataset and it is updated in real time. MyLightning allows to manage the dataset with a new approach and provides automatic and constantly updated statistics for the following parameters: number of strokes, typology (IC, CG), polarity (positive or negative), altitude and intensity of electric discharge. Statistics are computed for different temporal (hour, day, month, season, year) and spatial (land, sea, coast) frames allowing comparing and integrating with other sources of data. Until today, MyLightning has over 246 million of records (between data and statistical results) of which over 165 million strokes archived.

O3.4. Detection and characterization of Medicanes' warm core and deep convection

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Mediterranean hurricanes (Medicanes) are, similarly to the tropical cyclones, characterized by the presence of a quasi-cloud-free calm eye, strong winds and absence of lightning close to the vortex center, and a warm core during the tropical-like cyclone (TLC) phase. Temperature sounding (50 GHz) channels of passive microwave (PMW) radiometers can be used to identify and observe/characterize Medicanes' warm core evolution throughout their lifetime, while high frequency channels are able to identify deep convection. Moreover, diagnostic tools and PMW radiometry products have been developed to provide information on cloud properties (e.g. cloud top height and ice water path). In this study, PMW radiometry and derived products are used to provide new insights about cloud properties and deep convection intensity in relation with the development of the warm core for six Medicanes that have occurred since 2014. The goal is to understand whether a relation exists between the evolution in deep convection features (including cloud properties and lighting activity) and the occurrence and characteristics of the warm core from the development to the TLC phase, as observed in several studies. Deep, symmetric warm core, and deep convection features in proximity of the center are associated with the most intense Medicanes during the TLC phase, although lightning activity is hardly detected. Shallower warm core is associated with the weakest Medicanes. Both Medicane groups show limited cloud vertical extension and very similar ice water path values during the most intense phase. This study reveals the usefulness of PMW observations and diagnostics to provide new and insightful information about Medicanes, with a particular emphasis in understating if warm core and deep convection features can be used as a proxy for the intensity of Medicanes.

O3.5. Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) Project: Overview of the field campaign and current status

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The objective of the Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) project is to improve the understanding and prediction of land-atmosphere-hydrology interactions in a semi-arid region characterized by strong surface heterogeneity between the natural landscape and intensive agriculture. The study region is located over the Pla d'Urgell region within the Ebro basin in NE Spain. This area was selected since it is a breadbasket region, but consensus of current climate projections predicts a significant warming and drying over this region in upcoming years thereby increasing the potential evaporation and water needs for irrigation. Here we present an overview of the current status of the LIAISE project, starting with an overview of the LIAISE observational campaign, that took place in the growing season of 2021 when land surface heterogeneity was at a maximum. A network of 7 stations provided continuous measurements of the surface energy and water budget components for multiple representative land cover types, including irrigated surfaces, along with detailed surface biophysical measurements from the leaf to field scale. Lower atmospheric measurements were obtained from tethered balloons, lidar, UHF profilers, frequent radio-sounding releases, UAVs and several aircraft. Finally, airborne instruments measured solar induced florescence, surface temperature over several spectral bands and soil moisture over a transect cutting across the rain-fed and irrigated areas. The main outcome of this project is to provide the underpinnings for improved models leading to better water resource impact studies for both the present and under future climate change. We will also give a summary of current and future project plans.

O3.6. A machine learning approach to study the aerosol typing and properties: the case of the unusually warm summer 2022

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We purpose a machine learning supervised classification to studying aerosols. It is based on AERONET measurements in different sites, carefully chosen to be representative of a single aerosol type (urban, dust, maritime and smoke). We consider 5 aerosol variables (AOD440nm, AE, SSA, dSSA, sphericity) that account for the aerosol load, size, absorption capability and shape. We use a Random Forest method that has been fed with 20000 data, previously classified. Each 25% of the data corresponds to a different aerosol type. Our validation indicates a model overall accuracy of 80 %, with different success rate depending on the aerosol type considered. Dust and maritime aerosols are correctly identified in the 92 and 84 % of the cases, respectively. Some difficulties to disambiguate urban and smoke aerosols appear since they show similar properties. Therefore, the success rate reduces to 77 and 75 % for urban and smoke aerosols, respectively. Our method has been also tested during summer 2022 in Burjassot site. The method has been able to correctly identify several dust events during summer and a strong wildfire took place close to the site. Even if further research is needed to refine our method, especially regarding to the urban and smoke misclassification, it produces interesting and promising results that can be useful in climatological studies in which aerosols play an important role."

O3.7. Column optical properties of Saharan dust outbreaks over the western Mediterranean coast

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The deserts of North Africa are the main source of mineral dust in the world, being this aerosol the second most abundant of natural origin. Certain synoptic situations favor the transport of mineral dust over long distances covering large areas, such as the western Mediterranean coast. In the present work, several physical and optical properties of aerosols during Saharan dust intrusions have been analyzed at 4 stations located on western Mediterranean coast: Granada (37.2º N), Burjassot (39.5º), Barcelona (41.4º) in Spain and Haute Provence (43.9º) in France. These stations have been part of the Aerosol Robotic Network (AERONET) for many years, which has made it possible to analyze the period 2007-2021. The selection of the Saharan intrusion episodes was based on a cluster analysis of the 5-day backward trajectories at each of the stations for the whole period, determined with the HYSPLIT model. In order to better identify the North African region from which they originated, clustering was applied twice. Air masses transporting dust particles at high altitude are more frequent in extended summer months, from June to September, when similar synoptic situations contribute to the northward transport. The highest frequency is observed in Granada due to its proximity to the source, which also favors an important number of intrusions throughout the year. Both in winter and spring more than 13% of the days are affected by dust at altitude. On the other hand, in Haute Provence the number of episodes is quite similar although less frequent in summer. During the summer months, the Saharan dust outbreaks are more intense, with a higher column concentration, as shown by the aerosol optical depth (AOD). In parallel, the Angstrom exponent (AE) presents the lowest mean values, confirming the larger size of these particles. In general, trajectories originating in North Central Africa could be considered the more intense episodes, with lower AE and higher AOD. Finally, analysis of the spectral dependence of the single scattering albedo (SSA) has shown the mixing of dust particle with other aerosol types (mainly from biomass burning for heating) and the effect of stagnant situations in winter. On the other hand, in summer and autumn the increasing absorption at short wavelengths confirms the predominance of dust particles. Authors would like to thank AERONET and the PI of the stations for the provision of data and maintenance of the instruments. We thank the use of HYSPLIT, supported by NASA."

P3.1. Validation of Land Surface Temperature products derived from data acquired by the EUMETSAT's Polar System of MetOp weather satellites

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The Meteorological Operational (MetOp) satellite programme is a European initiative providing weather data to evaluate climate change and improve weather forecasts. A series of three MetOp satellites forms the space segment of EUMETSAT 's Polar System (EPS). In this paper, we evaluated the land surface temperature (LST) product generated operationally by EUMETSAT from MetOp AVHRR/3 data, i.e., the EPS Daily LST (EDLST) product. LST was defined as an Essential Climate Variable by the Global Climate Observing System of the World Meteorological Organization. The algorithm used to retrieve the EDLST product was the so-called Generalized Split-Window (GSW) but with a term that quantifies the model error. Additionally, we proposed and evaluated an alternative SW algorithm to retrieve LSTs from MetOp-AVHRR/3 data. Ground thermal-infrared radiance data measured from a fixed station placed at a rice paddy site (with different land covers through the year) were used to evaluate the performances of the LST products from 2016 to 2020. The evaluation of two different versions of the operational EDLST product (v100, and current v111) showed significant systematic uncertainties and robust root-mean-square differences (R-RMSD) even higher than 3 K. Thus, we proposed an alternative SW algorithm with coefficients regressed for the MetOp-AVHRR/3 bands. The evaluation results for the alternative LST algorithm showed lower systematic uncertainties (mainly for night-time) and R-RMSD lower than 2 K both for day- and night-time LSTs at the site.

P3.2. Ground TIR radiance measurements for calibrating Landsat 9 TIRS data and evaluating TIRS-retrieved land surface temperatures

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Land surface temperature (LST) was defined as an Essential Climate Variable by the Global Climate Observing System of the World Meteorological Organization and Landsat series allow retrieving LSTs at high spatial resolution. Landsat 9 (L9), a joint mission of NASA and the U.S. Geological Survey, was launched in September 2021 and started operational phase by the end of January 2022. Thermal Infra-Red Sensor (TIRS-2) is on board L9 and acquires TIR data with two spectral bands (bands 10 and 11 centered at 10.8 and 12.0 micrometers) at a spatial resolution of 100 m. Reference ground thermal radiance data measured along transects in a rice crop site through 2022 were used to evaluate the calibration of the L9 TIRS-2 bands and the derived LSTs provided in the L2 product, which uses a single-channel correction algorithm for band 10. The site has different land covers due to the crop changes through the year, from null to full vegetation cover, and water surface when flooded, which makes it interesting for CAL/VAL and allow covering a wide range of LSTs. TIR emissivities were also measured at the site. The calibration results showed that both systematic and random uncertainties were lower than 1 K, with a slight underestimation shown for both L9 TIRS-2 bands. Negligible systematic uncertainties and root-mean-square differences lower than 1.5 K were obtained when evaluating the L2 LST product at the site.

P3.3. Study of land surface temperature trends associated to climate change in the Iberian Peninsula

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Land surface temperature (LST) is a fundamental parameter to study the effects of climate change according to the WMO. We studied the evolution of LST in the Iberian Peninsula (IP) over a 20 year period (2002-2021) with the aim of observing significant trends that can be associated to climate change. For that purpose, we used the LST retrieved from EOS-Aqua MODIS data through the product MYD11A1 (version 6.1) gridded at 1-km resolution. EOS-Aqua overpass the IP twice a day, one early in the afternoon (13-15 UTC) and the other deep at night (1-3 UTC), so the afternoon overpass is close to the time of daily maximum temperatures. Data registered as free-cloud days and with a viewing angle lower than 55º were used to avoid overlaps from different passes in the gridded product. The seasonal Mann-Kendall nonparametric test was used for the statistical performance. This test allows us to evaluate the magnitude of the trends through the Sen-slope estimator. It was calculated for every pixel in our area and for different LST indicators, such as the seasonal median and average, and the seasonal maximum and minimum temperatures registered at both passes. We present the results of the Mann-Kendall test for each season separately, but also for the entire year. Winter was found as the season with more significant trends in different areas of the IP, mainly with slopes lower than 0.1K/year.

P3.4. Machine-learning applied to land surface temperature disaggregation processes: comparison of models

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Applications involving observation of the Earth's surface from satellite platforms on a lower than regional scale, such as crop monitoring, require greater availability of thermal information, in particular land surface temperature (LST), with spatial resolutions appropriate for local studies. Therefore, numerous authors have proposed and developed methods to extract LST at the "subpixel" level, through the use of complementary remote sensing products, with results suitable at higher resolutions. Most of these methods are based on the correlation between vegetation indices, as is the case of the Normalized Difference Vegetation Index (NDVI), and LST, for land covers with specific characteristics. These methods are based on the implementation of "traditional" statistical models, such as linear or quadratic regressions. The availability of other vegetation indexes, or indixes related to water availability has enormous potential, thanks to the contribution offered by possible new estimators. This fact, together with the development of advanced computing methods, based on machine learning techniques, can lead to create more robust disaggregation algorithms. This study analyzes the behavior and contribution of several spectral indices, as well as other complementary variables, for the development of advanced models, which have their origin in the field of Artificial Intelligence. Through these models, it is intended to bring the original resolution (regional scale) of the dependent variable LST to the local scale. In particular, we generate LST maps at the high resolution of the MSI sensor (20 m), on board the Sentinel 2 platforms, starting from the moderate resolution of the thermal bands of MODIS sensor (1000 m). This contribution shows the first results obtained by applying these disaggregation methodologies with different variables, both spectral and of other nature.

P3.5. Synergy Landsat-8 and Sentinel-2 to estimate high spatiotemporal LST maps with downscaling techniques

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Disaggregation methods allow downscaling Thermal Infrared coarse resolutions to finer ones, after applying synergistic techniques involving orbiting sensors with high spatial resolutions and low revisit periods, and oppositely sensors with coarse spatial resolutions but high frequency. These methods provide Land Surface Temperature (LST) maps at high spatiotemporal resolution (i.e., LST maps at 10-m spatial resolution every 3-5 days), which brings a significant advance in energy balance modeling at the land-atmosphere interface. This study carried out in the experimental test site of Barrax (Spain), applied a thermal sharpening technique, based on the quadratic relationship between LST and Normalized Difference Vegetation Index (NDVI), with the objective of deriving LST maps using only Sentinel-2 scenes, together with some weather data from meteorological stations available nearby the studied site. A 4-year database of Landsat-8 (LST data at 100-m resolution, every 8-9 days) and Sentinel-2 (10-m NDVI maps every 5 days) cloud-free satellite scenes was implemented for that purpose. An evaluation based on the comparison with in-situ ground data showed that a simple linear relationship between LST and NDVI is sufficient to estimate LST maps with a RMSE of ±2.8 K. A cross-validation was also conducted to evaluate the operational application of the introduced methodology using upscaled results and Original Landsat-8 LST images at a different location far from the Barrax test site. Results showed a RMSE of ±3.0 K in this case, in good agreement with the vicarious validation.

P3.6. The "Unclosed" surface energy balance problem addressed from the view of the advection flux term

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The "unclosed" Surface Energy Budget (SEB) problem relies on the fact that the traditional expression of total available energy (Rn-G, Rn are the net radiation ground heat fluxes, respectively) should match the sum H+LE, (being both the sensible and latent heat fluxes, respectively). However, these fluxes do not fully match experimentally, resulting in the so-called SEB closure problem. The lack of closure is typically in the range of 10-35% and this "problem" has not been widely addressed in the last decades. Some past studies concluded that such imbalance could be attributed to the influence of the Advection (Ad) flux term in the SEB budget, and that it could be significant at hectometric scales. The present study addressed such SEB problem by using high spatial resolution land surface temperature (LST) maps, obtained from a TIR camera assembled to a drone, which flew over the heterogeneous sub-kilometric site of the University of Balearic Islands, (Spain). Results showed that Ad contributes significantly to the SEB imbalance after using the 60 m LST maps, but the most plausible spatial scale to compare such term with the imbalance registered in the ECUIB station is 200 m. Most of the cases at such hectometric scales have estimates of the advection similar in magnitude to the energy imbalance and mostly their sign goes in the sense of reducing the imbalance.

P3.7. Evaluation of quantitative precipitation estimates (QPEs) in the Iberian Mediterranian basin

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One effect of climate change is the alteration in precipitation regimes around the globe, leading to increases in frequency and intensity of extreme meteorological events. The study of trends through last decades, along with an accurate monitoring of precipitation, can contribute to mitigate their consequences. Quantitative precipitations estimates (QPEs) based on satellite data, in contrast with ground rain gauges networks, allow for spatially continuous precipitation monitoring; however, their accuracy is lower due to them estimating precipitation instead of measuring it. Therefore, QPE accuracy must be first evaluated. In this study, we evaluated three QPEs (NOAA's CMORPH, NASA's IMERG and GloH2O's MSWEP) at daily scale in the Mediterranean Iberian Basin for each QPE available period, using AEMET ground data as reference. We did both a global and spatial analysis of statistical metrics, categorical indexes and uncertainty components. Our results show that MSWEP (CMORPH) performs the best (worst) overall, with Correlation Coefficients ~0.6 (~0.5), RMSE ~5 (~5) mm/day and POD ~0.8 (~0.6). All of them tend to overestimate (underestimate) light (heavy) precipitation, and an important part of their uncertainty comes from erroneously detected precipitation (> 0.3 mm/day in average). The spatial analysis reveals that these QPEs perform worse in mountainous regions, i.e., in Mariola, Cazorla and Gredos mountain chains and the Pyrenees.

P3.8. An open sky laboratory for a climate observatory of water resources in the Roia basin

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The present contribution describes the activities carried out by University of Genoa (Italy) within the context of the Concert-Eaux project [1], funded by INTERREG V-A France – Italy – E.U. ALCOTRA program 2014-2020, with the overall goal to set up a climate impact observatory in the French-Italian catchment area of the Roia River. The project proposes to start from a greater knowledge of the climatic assets of the river basin, and then to define evolutionary scenarios to set up a climate observatory on the area, particularly concerning the water resources. This will make it possible to adapt planning tools for land use and natural resources, with regard to the definition of predictable minimum and maximum outflows in watercourses. As a partner in the Concert-Eaux project, the University of Genova cooperated in the activities aimed to the set-up of the Alpine Microclimatic Laboratory in the valley of the Bendola stream, a left tributary of the Roia River in French territory, near the village of Saorge. Bendola basin is particularly significant for its topographical, geological and ecological-environmental values. In this pilot basin, UNIGE installed two kind of sensors, namely the SRS (Smart Rainfall System) and the GNSS (Global Navigation Satellite System) sensors, with the aim of characterizing the meteoclimatic parameters. In particular, SRS is able to estimate the rainfall intensity in real-time by processing the attenuation of satellite-to-Earth microwave signals measured by IoT sensors properly deployed on the territory; on the othe hand, the precipitable water vapour (PWV) in atmosphere, is obtained thanks to an innovative procedure that analyzes the GNSS observations from low-cost permanent stations. Processing of data obtained from both SRS and GNSS systems allows to create maps representing the spatial-temporal evolution of meteorological phenomena. The contribution will describe the installations, that represented an important implementation stage due to issues related to sites accesibility, satellite visibility, and internet coverage for data transmission, and the elaboration of the data related to some peculiar events observed in the Bendola valley during the course of the project.

P3.9. Satellite, radar and raingauge investigation of severe flash flood events in mountain Mediterranean catchments

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A multi-instrument approach has been used to study four events of severe flash floods over mountain areas. Heavy rainfall occurring on hill or mountain may cause the erosion of soil or trigger extensive movement of soil slipping as landslides and debris flow. The investigation of heavy precipitation in mountain regions is very challenging and often affected by several limitations due to the complexity of area and limits of ground-based instruments to better quantify the severity of phenomena. Therefore, the combination of satellite, radars and ground-based measurements can improve the characterization of heavy rainfall events in terms of detection and tracking of deep convective clouds, identification and time-space distribution of most intense cores, quantification of rainfall volumes reaching the hydrographic basin. The events of 1) Monte Pinu (Sardinia) that occurred on 18 October 2013 and caused three victims as a result of the collapse of an earthfill road embankment, of 2) Rio Rotiano on 29 October 2018 that caused one victim and a total volume of deposit on the alluvial cone of 155,000 m3, of 3) Rio Vallaro (Valle Camonica) of 28 August 2020 causing a severe debris flow with about 34,000 m3 of deposits and 4) the Rio Cobello debris flow triggered on 27 July 2022 by an exceptional short duration storm were investigated in a multi sensor framework including satellite images (1, 2, 3, 4) , radar (1, 2, 3), raingauge (1, 2, 3, 4) and streamflow data (2). In this study, satellite data will be used to feed the Multi-sensor Approach for Satellite Hail Advection (MASHA). The MASHA technique is a new satellite hybrid technique conceived for the real time advection of severe storms and hail clouds. Operationally, MASHA combines the strengths of the MWCC-H method to detect hail through the whole GPM constellation (Laviola et al., 2020) with the high temporal rate (5 min) of the Meteosat Rapid Scan Service. The original scheme has been experimentally improved by the ingestion of radar data in order to improve the tracking capability of MASHA when no GPM satellites are available. The results of this study draw new perspectives to optimally investigate hydro-meteorological events over mountain areas where more traditional methodologies might underestimate the severity of events. The MASHA scheme provides a useful tool in support to nowcasting systems of severe weather over complex areas.

P3.10. Detection of hail using Passive Microwave data

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There are a lot of hazardous events occurring in the world. One of them is hail, which can cause crop loss in agricultural areas but also injury or death to living beings in towns. Hail event estimations and detections can be done using remote sensing techniques. For example, active remote sensing like meteorological radars and passive remote sensing by satellite equipment. In this study, brightness (BT) temperature data of Advance Microwave Sounding Unit Module B (AMSU-B) and Microwave Humidity Sounder (MHS) sensors which are mounted on METOP and NOAA satellites will be used. This data contains 90, 150, 184, 187, and 190 GHz channels. The relationship between the depression of BT and the probability of hail, and hailstone size will be studied in 6 different hail events that occurred in Türkiye. Regarding relationships, this study aims to develop algorithms that can detect hail events and the size of the hailstone.

P3.11. Use of EOBS and AgERA5 dataset for seasonal forecasting application in Croatia

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Reference crop evapotranspiration, ETo, plays a significant role in planning and managing water resources, irrigation and drought monitoring and is of importance in the fields of hydrology, climatology and agriculture. Knowlege of values on all temporal and spatial scales makes water management as efficient as possible and is valuable in real time decision making. ETo calculataions based on recomended FAO-56 Penman Monteith method includes multiple meteorological variables, such as temperature, vapor pressure, winds speed and global solar radiation. In seasonal climate forecasts most of these variables have low skill of prediction, especially in the southeastern Europe. Therefore it is necessary to use alternative temperature based ETo calculation method which might reduce the overall reliance on the limited skill of seasonal predictions of above-mentioned meteorological variables. The presented results will show comparisson of different empirical methods for ETo calculation with the reference Penman Monteith method over different climates of Croatia using national meteorological dataset in comparison with EOBS and AgERA5 datasets in the period from 1981-2020. The results on the annual, seasonal and vegetation scale will be presented and will give an insight into how much the right dataset usage affects the choice of the most suitable temperature based method for ETo seasonal forecast calculations, all in view of acquiring a better skill of seasonal predictions.

P3.12. Overall Ozone variability in Turkey with satellite and surface data for selected cities

Nedret Irem Uzden

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Ozone (O3) is one of the important gases in the atmosphere. Although it can cause pollution in the near-earth regions of the troposphere, it protects human, animal and plant life against harmful ultraviolet (UV) rays from the sun. Therefore, it is important to follow the changes in the ozone layer, and for this, besides the surface measurement stations, satellite observations are also used. In this study, consistency analyzes were carried out on Ankara, Athens, Thessaloniki, Goloseyev, Kislovodsk, and Aleppo for the period 2007-2013. As satellite data, the total ozone data obtained from the GOME-2 device of the METOP satellite operated by EUMETSAT were used and surface data and satellite data were used. By taking the data, a correlation of 0.90 and above was obtained in general.

P3.13. The Boundary-layer Air Quality-analysis Using Network of INstruments Supersite (BAQUNIN) for atmospheric research and satellite validation

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This contribution presents the Boundary layer Air Quality-analysis Using Network of Instruments (BAQUNIN) supersite. BAQUNIN has been promoted by the European Space Agency to create an experimental research infrastructure in order to contribute to the validation of present and future atmospheric satellite products and to the in-depth investigation of the phenomena characterising the planetary boundary layer in urban, semi-rural, and rural areas. To the best of our knowledge, BAQUNIN is one of the first observatories in the world to involve several active and passive ground-based remote sensing instruments installed in multiple measurement locations, covering a highly urbanised area near the Tyrrhenian coast. BAQUNIN collects continuous surface and columnar atmospheric measurements of thermodynamic variables, particulate matter, and trace gases since 2017, also providing long-term datasets for climatological studies. Data is made available to citizens, scientific and Cal/Val communities, both through the project website (www.baqunin.eu) and the portals of international networks (e.g., Pandonia Global Network, International SKYNET DataCenter, Aerosol Robotic Network, European Brewer Network), to which some of the BAQUNIN instruments belong. Currently, BAQUNIN consists of three observation sites located in downtown Rome, Italy (Physics Department of the Sapienza University of Rome) and in the semi-rural (National Research Council, Institute of Atmospheric Sciences and Climate, CNR-ISAC) and rural (National Research Council, Institute of Atmospheric Pollution Research, CNR-IIA) areas surrounding the Italian capital. The conformation of the city, its geographical position in the middle of the Mediterranean basin, and its anemological peculiarities make it a convenient site for studies focused on: (i) monitoring atmospheric pollution and atmospheric constituents, (ii) providing an urban boundary layer characterisation, and (iii) providing reference products for satellite and models validation in urban, semi-rural, and rural contexts. Moreover, BAQUNIN collaborates with several research institutes (e.g., National Research Council, Italian National Agency for New Technologies, Energy and Sustainable Economic Development, National Institute of Geophysics and Volcanology) to ensure continuous instrumentation operation and excellent product quality. BAQUNIN supersite is suitable for testing new instruments and operation modes, hosting long-term inter-calibration/comparison campaigns and education initiatives (e.g., summer schools). Here, the main characteristics of the three sites are described, providing information on the complex instrumental suite and on the numerous datasets produced, also showing an example of the potential of the observatory thanks to the synergistic use of the data acquired.

P3.14. The ALICENET lidar ceilometer network: retrievals and long-term analyses of aerosol vertical profiles across Italy

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ALICENET is the Italian network of Automated Lidar-Ceilometers (ALCs) monitoring 24/7 aerosol vertical profiles and clouds (up to 15 km with a vertical resolution of 15 m) across the country. It is a growing consortium network coordinated by CNR-ISAC, involving different institutions and contributing to the E-PROFILE EUMETNET program. The network, extending from the North to the South of Italy, covers a wide range of atmospheric and environmental conditions within the Mediterranean area. The ALC data processing is centralized at CNR-ISAC and the multi-year database already available in different Italian sites allow inferring quantitative and vertically resolved information on aerosol properties and related long-term variability across the country. In this study, a fully re-processed 7-year ALC dataset including four ALICENET stations (Aosta, in the Alps; Milan, within the Po Valley; Rome, the main urban site in Central Italy; Messina, a maritime site in Sicily) is presented. It is also analyzed in synergy with in-situ meteorological measurements and model reanalyses (ERA5) to investigate the long-term characterisation of aerosol vertical profiles and main transport dynamics in the different areas. The results of the analyses and possible developments will be presented.

P3.15. Cloud-aerosol transition zone detection from ceilometer measurements

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Cloud and aerosol contribution to the Earth's radiative budget constitutes one of the most significant uncertainties in future climate projections. To distinguish between clouds and cloud-free air, atmospheric scientists have been using a wide range of instruments, techniques, and algorithms with various thresholds. However, since the transition from a cloudy to a cloud-free atmosphere may be gradual and, in some cases, far from obvious, recent research questions where those threshold limits should be established. Thus, leading to consider a transition zone between cloud and cloud-free. In the present study, backscatter profiles retrieved by a Vaisala CL31 ceilometer located at a Mediterranean site (Girona, NE of Spain) were processed to assess the frequency of transition zone situations. Two widely used cloud detection algorithms have been applied and compared: the method provided by the ceilometer manufacturer, and the algorithm from Cloudnet (integrated into the Aerosol, Clouds and Trace Gases Research Infrastructure, ACTRIS). Furthermore, we have modified the thresholds related to backscatter signal, signal-to-noise ratio, and background noise from Cloudnet lidar processing algorithms. This methodology has allowed us to evaluate the occurrence of transition conditions between cloud and cloud-free, by distinguishing situations with relaxed, predefined, and strict thresholds. Our results along with other recent research, show that the transition zone frequency of occurrence (and spatial coverture) is quite remarkable. This prompts the need to either include an additional phase between 'pure clouds' and 'pure aerosols' or treat them as a continuum of suspended particles in the atmosphere.

P3.16. Assessing the capability of a new lidar system in observing atmospheric and boundary layer processes in an urban, coastal environment

Andrea Bisignano, Federico Cassola, Roberto Cresta, Alessio Golzio, Davide Sacchetti, Marco Tizzi

Ligurian Environmental Protection Agency (ARPAL)

The new advanced Lidar ceilometer (ALC) Vaisala CL61 is now operating at the Ligurian Environmental Protection Agency (ARPAL) in Genoa. Here we present some first case studies highlighting the ALC's capability to capture a wide range of atmospheric and boundary layer processes over a coastal city. CL61 is located at the mouth of Polcevera valley, in a densely built environment, surrounded by the Apennine mountains and the Ligurian Sea. Hence, the site is simultaneously influenced by sea-land, mountain-valley breezes and urban effects, leading to very complex atmospheric dynamics. For instance, the different heat fluxes over land and sea translate into the development of an internal boundary layer over the land; at the same time, this is not a purely thermal layer because of the mechanical turbulence produced by the buildings. In such a challenging situation, proper observations enhance the understanding of the boundary layer and related processes, such as the pollutant dispersion. First, we focus on estimating the mixing layer height through the CL61 measurements of atmosphere's attenuated backscattering. The trend evolution of mixing height from the ALC is compared to the estimation from the radioactivity of atmosphere. In particular, we make use of radon measurements collected by a FAI SWAM 5a Dual Channel Monitor. This natural radionuclide is continuously produced by the ground and emitted into the air at an almost constant rate. Therefore, the radon concentration levels are strictly related to the mixing ability of the atmosphere and, hence, to the mixing height. Then, we analyze the automatic estimation of the cloud base height and cover provided by CL61. Both mixing layer and cloud base heights are compared with the corresponding outputs of the MOLOCH NWP high-resolution model, operationally adopted for weather forecasting at ARPAL. We finally investigate the new CL61 capability of providing the total linear depolarization ratio which allows to categorize particles; we analyze two possible applications; first, we present a case study devoted to the differentiation between liquid and solid clouds; second, we examine a case of particulate matter transport from Po Valley to Genoa, through the Polcevera Valley.

S4. Numerical modelling

Invited talk: The New TRAM model: Achievements at Meteo-UIB towards numerical modelling capabilities aimed at a wide range of time-space scales

Romulado Romero

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Development and maintenance of ambitious numerical weather models are prevalently framed within big institutional projects dealing with fundamental research or practical applications, including commercial use. But occasionally there have been modest (in terms of size) research units or university groups with outstanding contributions in this field. With this motivation, a new limited area model has been built at UIB-Meteorology Group using a nonhydrostatic and fully compressible (NHFC) version of the Navier-Stokes equations. Our TRAM model was built from scratch, and this required a sequential completion of steps, from the formulation of the advection scheme at the very beginning to the inclusion and mutual coordination of the physical parameterizations as the last step. I will present the actual chronology of milestones reached during TRAM development, describing the sequence of conceptual/methodological building blocks of the model along with the corresponding validation tests (many of them extracted from the literature). A new model must not only successfully pass benchmark tests but also involve original or uncommon aspects in its formulation, such as our horizontal discretization of the equations using triangles (this giving rise to the acronym TRAM, for "Triangle-based Regional Atmospheric Model"). I will stress these and other innovative aspects in the description while also justifying other important choices of the formulation based on the experience with companion NHFC numerical models (e.g., MM5, WRF and CM1). In conclusion, the new Meteo-UIB model appears to perform as well as state-of-the-art numerical models and opens a myriad of academic and research applications. It is suitable to simulate circulations ranging from small-scale thermal bubbles ($\asymp$ 100 m scale) to synoptic-scale baroclinic cyclones (> 1000 km size), including orographic circulations, thermally driven flows, squall lines, supercells, all kinds of precipitation systems and medicanes. Various examples of the great versatility offered by TRAM will be presented, with special emphasis on Mediterranean case studies. In addition, TRAM regional weather forecasts with three different horizontal resolutions are now being published, twice daily, at meteo.uib.es/tram website.

O4.1. Implementation of the urban canopy land surface scheme TERRA_URB in ICON: preliminary results over Italy

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The possibility to increase the resolution of atmospheric models for numerical weather prediction (NWP) or climate simulations allows a more accurate description of the physical processes at urban scale. Furthermore, beside the relevance for the meteorological and climate modelling, there is a common trend in most countries that the number of people living in towns keeps on increasing remarkably, making urban or metropolitan areas significantly warmer than their surrounding rural areas. In all this scenario, during the past years, the interest in proper modelling the physical processes in urban areas has received wide attention from the research community. In order to tackle this issue a bulk urban canopy parameterization, TERRA_URB, has been developed for the multi-layer land surface scheme of the COSMO regional atmospheric model. This parameterization has already demonstrated to be able to correctly reproduce the prominent urban meteorological characteristics for different European cities, and in the framework of the transition from the COSMO model to the new Icosahedral Nonhydrostatic (ICON) Weather and Climate regional model, TERRA_URB needs to be implemented in ICON. In this work, we present preliminary results related to the porting activities of TERRA_URB into the ICON limited-area model, NWP version, for different cities of interest over the Italian peninsula. Even if the porting needs to be completed and an updated version of the external parameter dataset needs to be provided, the first results, here presented, are very encouraging, since some urban key features are already properly represented, like the urban heat island phenomenon.

O4.2. Microclimate investigation to study the behavior of urban heat islands in the city of Turin

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Heatwaves are annually increasing in terms of intensity and frequency. In urban areas, the impact could be further exacerbated by the urban heat island (UHI) effect. This work carries out an urban microclimate analysis to evaluate the behavior of the UHI in the city of Turin during a Heatwave event. Turin is located in the North-West region of Italy, boarded by the Alps mountain ranges in the west and hills in the East. The study utilizes the WRF/MLUCM model and considers the heatwave period in June 2019 [2]. The high-resolution urban land use/land cover data is taken from local climate zone (LCZ) maps provided by the World Urban Database and Access Portal Tools (WUDAPT) repository [3]. The simulation is validated with the data provided by ARPA meteorological stations located over the region[4]. The lower root mean squared error of air temperature and higher index of the agreement show that the simulation is in good agreement with the observational data. The model is then used to analyze the rural-urban temperature distributions over the diurnal cycle. According to the results, the city of Turin has higher near-surface UHI intensity during the night and early morning (with maximum intensity >3 degC), whereas the intensity is diminishing during the mid-day hours. The examination of near-surface air temperature shows that, at some particular day times, the air temperature of the city is less than its rural counterparts indicating a reduction of UHI during Heatwave events as observed by [5]

O4.3. SWING, the Score-Weighted Improved NowcastinG algorithm

Martina Lagasio[1], Lorenzo Campo[1], Massimo Milelli[1], Vincenzo Mazzarella[1], Maria Laura Poletti[1], Francesco Silvestro[1], Luca Ferraris[1], Stefano Federico[2], Silvia Puca[3], Antonio Parodi[1]

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Because of the ongoing climate change, the frequency of extreme rainfall events at the global scale is expected to increase, resulting in higher social and economic impacts. Thus, improving the forecast accuracy and the risk communication is a fundamental goal to limit social and economic damages. Both Numerical Weather Prediction (NWP) and radar-based nowcasting systems still have open issues, mainly in terms of precipitation correct time/space localization predictability and rapid forecast accuracy decay, respectively. Trying to overcome these issues, this work aims to present a nowcasting system combining an NWP model (WRF), using a 3 h rapid update cycling 3DVAR assimilation of radar reflectivity data and lightning nudging data assimilation, with the radar-based nowcasting system PhaSt through a blending technique. Moreover, an innovative post-processing algorithm named SWING (Score-Weighted Improved NowcastinG) has been developed to take into account the timely and spatial uncertainty in the convective field simulation. The overarching goal is to pave the way for an easy and automatic communication of the heavy rainfall warning derived by the nowcasting procedure. The results obtained applying the SWING algorithm over a set of case studies suggest that the algorithm could improve the predictive capability of a traditional deterministic nowcasting forecast system, keeping a useful forecast timing and thus integrating the current forecast procedures. Eventually, the main advantage of the SWING algorithm is also its very high versatility, since it could be used with any meteorological model also in a multi-model forecast approach and the possibility to use it coupled with hydrological models using a complete hydro-meteorological chain.

O4.4. The 29 August 2020 event in the Balearic Islands: Exploring severe weather environments with CM1 simulations

Maria-del-Mar Vich, Romulado Romero

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A supercell developed to the west of Mallorca (Balearic Islands, Spain) and then crossed the island on the morning of 29 August 2020. The storm produced strong winds, at least one EF2 category tornado, heavy precipitation and large hail. The affected areas suffered power and landline phones outages, massive falling of trees and material damages on properties and infrastructures. Assessment of the Convective Available Potential Energy and Storm Relative Helicity present in the prior environment highlights the area where the actual supercell developed. However, neither the severity of the convective system nor other important properties such as its trajectory, can be predicted by the classic analysis of large scale ingredients. A novel approach is proposed aimed at obtaining this additional information via the application of the CM1 model. This cloud-resolving model was developed precisely to study convective storms and therefore emerges as the ideal tool to provide clues on the likelihood of a supercell and its severity and trajectory. Specifically, we test the systematic run of several CM1 simulations over the favorable area highlighted by the classic analysis and explore the convective structures that can develop and evolve in such environments. The results point out the ability of the CM1-based method to capture for the 29 August 2020 event the supercell formation, its trajectory and severity parameters. Therefore, a CM1-based strategy can provide useful details about eventual convective structures and their characteristics, allowing forecasters to issue better weather warnings at operational level.

O4.5. Cascade sensitivity tests to model deep convective systems in complex orography with WRF

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The simulation of extreme precipitation events is a major challenge when dealing with numerical weather models. Due to the high frequency of intense events and devastating floods, North-West Italy is a natural laboratory where the performances of numerical models can be tested. Here, the interaction between a very steep and complex orography provided by the Alps and Apennines ranges and a deep sea, as in the case of the Ligurian Sea, supply natural ingredients for the development of extreme events. Furthermore, the high population density that characterizes these areas makes the development of reliable weather prediction system fundamental. Motivated by these assumptions, the goal of the present study is to perform a wide cascade sensitivity test involving parameterizations expected to play a major role in the description of precipitation in case of deep convective events: cloud microphysics (CM), planetary boundary layer (PBL), surface layer (SL) and land-surface (L-S) models. Furthermore, an objective analysis method able to emphasize also small differences present in the analyzed simulations has been set up. The numerical forecast model exploited is the Weather Research and Forecasting (WRF) model, Version 4.3.3. To perform the sensitivity study, four significant precipitation events which were associated to deep convective systems and occurred between 2019 and 2021 in Lombardia and Liguria regions, have been simulated according to 45 different WRF setting. Proper description of precipitation related to deep convective systems requires to explicitly resolve convection. High resolution simulations are thus required, introducing the problem of exploiting a reliable verification method to evaluate performances of the model. In fact, when the model resolution is increased up to a few km, traditional point-wise verification methods become critical due to the 'double penalty' error that results in a fictitious penalty of high-resolution simulations when compared with coarser ones. To overcome this problem, new-generation spatial verification methods, based on the identification of patterns (i.e. areas above a certain precipitation threshold) in forecast and observed fields and the evaluation of their similarity through the calculation of a coupling index (CI), have been developed. However, they have some drawbacks in treating false alarm cases. In the present work, traditional statistical indexes and the CI have been merged to evaluate the quality of the high-resolution simulations preformed, and to individuate the best-performing WRF setting in simulating intense convective events.

O4.6. On the influence of ocean mixed layer depth and sea surface temperature development of the Tropical-like cyclone "IANOS"

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Many studies focusing on past TLCs events have found that SST anomalies play a crucial role in modulating the intense air-sea energy exchange, hence drive evolution of TLCs. However, given the connection between ocean mixed layer, ocean heat content and surface temperature, it is important to also explore the role of the mixed layer depth (MLD). In this study we investigated the role of both SST, SST anomaly and MLD profile on development of a recent record-breaking TLC IANOS. IANOS TLC that originated over the southern Ionian Sea around 14 Sept 2020, moved over the Central Ionian Sea from south-west to North-East, and made landfall around 19 Sept 2020 over Greece mainland coast. It developed over a basin where SST close to 29 °C and a positive SST anomaly up to 4 °C, in particular over sea area where it reached the maximum intensity. We conducted a series of experiments using an atmospheric model (WRF - Weather Research and Forecasting system) driven by underlying SST (standalone configuration) with daily update or coupled to a simple mixed-layer ocean model (SLAB ocean), with SST calculated at every time step using the SLAB ocean for a given value of the MLD. WRF was implemented with 3 km grid spacing, forced with ECMWF-IFS analysis (9 km resolution), while SST or MLD initialization, for standalone or coupled runs, respectively, are provided by the MFS-CMEMs Copernicus dataset at 4 km of horizontal resolution. For the studied TLC, the mean MLD is modified by increasing or decreasing its depth by 10 m, 30 m, 50 m, 75 m, 100 m, and investigate the impact of SST and SST anomaly; the Results show that the MLD influences not only the intensity of the cyclone but also the structure of the precipitation field both in terms of magnitude and location. At first the MLD thickness was characterized for the days in which the cyclone developed using ocean modeling data. Then we identified possible past and future climatological scenarios of MLD thickness. Starting from these data, we simulated the impact of the MLD, and consequently of the Ocean Heat Content, on the TLC. The preliminary results show that the MLD influences not only the intensity of the cyclone but also the structure of the precipitation field both in terms of magnitude and location. The results deserve further investigation particularly in context of climate change scenarios.

O4.7. The role of aerosols in atmospheric rivers behaviour

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Atmospheric rivers (ARs) play an essential role in extreme precipitation phenomena. To predict such events, a correct simulation of ARs becomes crucial. Since most of the regional climate models do not take aerosols into account in an interactive way, the main objective pursued in this work was to analyse the role of aerosols in the intensity and behaviour of ARs. A new regional-scale ARs identification algorithm (AIRA) was applied to a set of hourly data from three regional simulations (BASE, ARI and ARCI), covering a period of 20 years. In BASE, aerosols were prescribed, while the model incorporates aerosols dynamically in both ARI and ARCI. In ARI, aerosols are only incorporated interactively in aerosol-radiation interactions. In ARCI, they are also included in the microphysical processes. About 250 ARs were identified in the three simulations. Autumn ARs were the most frequent, intense and long-lasting, while they were less frequent, shorter and weaker in summer. The identified ARs explain up to a 30% of the total precipitation in some areas of the Iberian Peninsula. The differences between the three simulations are significant in the spatial distribution of the precipitation and in the trajectory and intensity of some ARs. Although the number of detected ARs is similar, the temporal steps with ARs common to the three simulations represent only a 37% of the total BASE steps containing ARs. This indicates that the sensitivity to the inclusion of aerosols is relevant. The common ARs events showed that the BASE and ARI simulations presented similar trajectories and intensity in most cases. However, important differences appeared regarding ARCI, especially when ARs were not quite intense. The analysis of the ARs shows that there are relevant differences between the ARS obtained in the different experiments, which are dependent on the amount and distribution of aerosols contained in the atmosphere. The physical mechanism identified is regional heating/cooling, mainly due to indirect effects, which causes a change in the thickness field that modifies both the intensity and the position of the ARs.

O4.8. Evaluation of aerosol effects on extreme precipitation events over Liguria (Italy)

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Liguria region in recent years has been affected by devastating floods as result of severe convective precipitation episodes. During these events, extreme precipitation values were observed close tot the Genoa city setting new records at the Italian scale, such as 181 mm/1h on November 4th, 2011 (Vicomorasso station), and 741 mm/12h on October 4th, 2021(Rossiglione station). From a synoptic point of view, similar configurations characterize the extreme events that affected Liguria region, i.e., the presence of a deep pressure minimum west of the region and a strong high pressure over eastern Europe. Such conditions are favorable to the triggering of quasi-stationary mesoscale convective systems over the Ligurian Sea. Furthermore, this kind of configuration is favorable to the formation and transport of wide plumes of aerosol, mainly mineral dust from the Sahara Desert and sea salt aerosol generated under high wind condition in the Mediterranean basin. The present study aims to evaluate the impact that these aerosol plumes can have on the triggering and evolution of the deep convective systems responsible for Liguria flooding events. This study is carried out through numerical simulations performed with the WRF (Weather Research and Forecasting)-Chem model, version 4.0. WRF-Chem is the WRF model coupled with the Chemistry: the model simulates the emission, transport, mixing, and chemical transformation of trace gases and aerosols as well as the meteorology. In particular, the object of the present study is to investigate the influence that cloud-aerosol-radiation interactions may have on the physics and dynamics of the rainfall events, primarily by means of the so-called direct (aerosol-cloud) and indirect (aerosol-radiation) interactions. For this purpose, 3 different sets of simulations were performed: a control run, in which the chemical part of WRF-Chem model is been activated, i.e., the production and transport of aerosol and its direct and indirect effects on atmosphere are not taken into account; a second run in which the dust transport is considered and only aerosol direct effect are accounted for; a final run in which both direct and indirect effects are taken into account.

O4.9. Impacts of the ECMWF Integrated Forecasting System (IFS) ensemble simulation with physical parameterizations perturbations on Mediterranean Tropical-like cyclone forecasts

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Predicting and simulating Mediterranean tropical-like cyclones, “Medicanes” is a difficult task due to the complexity of the processes involved, to the limits to the predictability of mid-latitude weather, to the contrast in the density of observations between land and sea, and to the complex orography of the region. Medicanes present a multiscale nature and their track and intensity have been recognized as very sensitive to different physical parameterizations in multi-physics modelling approaches. Thus, improving the accuracy, and reliability of forecasts for these cyclones is a complex task that requires advances in both large and convective-scale initial condition uncertainty representations. This study indeed is aimed at forecast improvement and at understanding medicanes sensitivity to physical parameterization by using ensemble forecast simulation. The objectives of the work are to investigate the prediction of medicanes intensity and tracks using the European Centre for Medium-Range Weather Forecast (ECMWF) Integrated Forecast System (IFS) ensemble forecasting system and compare ensembles with the inclusion of the physics uncertainties and ensembles with the inclusion of initial conditions uncertainty. Thus, a comparison between three ensemble forecast experiments is set up. One ensemble is run with only initial condition perturbation (Ensemble Data Assimilation, EDA), one is run with the perturbation of physical parameterizations, and one is run with only the convective parameterization perturbations. The physical parameterization perturbation has been carried out employing the Stochastically Perturbed Parametrisations (SPP), a novel but promising scheme developed at ECMWF. The study is carried out for three medicanes, among the strongest in recent years: Ianos, Zorbas, and Trixie. The impacts of the ensemble forecast perturbations on the simulation of the three medicanes are presented. It was found that, in general, the forecasts are accurate at reproducing both the thermal structure and symmetry of the cyclones in comparison to the operational analysis value. It was also found that the use of SPP, and specifically, the perturbation of convective parameters, improves the forecast compared to the initial condition perturbation ensemble, in terms of tracking spread and precipitation intensity, based on the computation of statistical scores. Given, that the ECMWF ensemble forecasts model can adequately reproduce medicanes with their tropical-like features, then, the role of the convective parameterization and its perturbation has been investigated in connection to the development and deepening of these cyclones.

O4.10. High resolution WRF modeling of extreme heat events and mapping of the urban heat island characteristics in Athens, Greece

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In recent decades, large scale urbanization has developed rapidly, resulting in significant changes in the local and regional environment and climate. Large metropolitan areas worldwide induce significant changes on local atmospheric circulation and boundary layer meteorology by modifying the underlying surface characteristics and through the emission of anthropogenic heat and pollutants into the atmosphere. We investigate the Urban Heat Island (UHI) characteristics in the city of Athens, Greece, which is one of Europe's largest Metropolitan complexes with a population of approximately 3.7 million inhabitants. The UHI effect is intense due the city's size, the dense construction, high incident solar radiation, and almost complete lack of natural vegetation, with previous studies suggesting a temperature rise of 4°C on average in the city centre compared to summer background conditions. Athens has been experiencing increased warming during the last decades, which in summer amounts to approximately +1°C/decade since the mid-1970s, attributable to both global warming and growing urbanization. Heat waves are nowadays common during the summer months, with temperatures exceeding 40°C, which strongly increases the thermal risk and vulnerability for urban residents. We use high-resolution WRF simulations (1km horizontal grid) driven with ERA-5 re-analysis data, to produce surface temperature maps in the city of Athens and the surrounding areas (Region of Attiki), during the summer period of 1st July to 20th August 2022. Different model parameterizations are tested, both in respect to urban characteristics and physical parameters. Daily minimum and maximum temperatures (Tmin and Tmax) derived from the model are validated against observational data from a dense network of weather stations covering Metropolitan Athens and surrounding locations. We further investigate the influence of different meteorological conditions on the UHI gradients as produced by the model and the observational dataset, including the extreme heat wave of 28th July to 5th August 2022, during which persistent maximum temperatures of > 40°C were recorded for 9 consecutive days. Results indicate a strong correlation between WRF output and recorded minimum and maximum temperatures, and reveal the intensity and spatio-temporal variability of the UHI phenomenon in the city of Athens, with UHI magnitude reaching 8-10°C at times.

O4.11. Multi-model assessment of the next-decade climate over the Mediterranean region

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The Mediterranean region is one of the most sensitive to climate change since it has undergone an intense warming and drying trend during the last decades, dominantly caused by the increase of anthropogenic greenhouse gases' concentrations. In the context of decision-making processes, there is a growing interest in understanding the near-term climate evolution of this region. In this study, we explore the climatic fluctuations of the Mediterranean region in the near-term range using two different products: projections and decadal predictions. The former are century-scale climate change simulations initialized from arbitrary model states to which were applied anthropogenic and natural forcings. A major limitation of climate projections is their limited 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 a better understanding of the next-decade climate (typically up to 10 years) and thus an invaluable tool in assisting climate adaptation. Using forecasts from several decadal prediction systems — performed within the CMIP6 Decadal Climate Prediction Project (CMIP6 DCPP) — and the respective ensemble of non-initialized projections, we evaluate future climate changes of the Mediterranean region for some key quantities so as to assess the added value of initialization. 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 by atmospheric teleconnections.

O4.12. What will Mediterranean convective storms look like under climate change conditions?

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The Mediterranean is a climate change hotspot due to its potential vulnerability to changes, but large uncertainties still exist in future projections of rainfall. It is thus urgent to better understand the sources of uncertainty and the mechanisms that may alter precipitation in the region. This is particularly true for extremes, since large parts of the region gather most of their total annual precipitation from a few intense events, for which trends have proven difficult to detect. Here, we use a convection-permitting model (2-km) over the western Mediterranean to study possible changes in convective rainstorms. We completed two decade-long experiments: one for present climate (2011-2020) and another where end-of-the-century climate anomalies were added to present climate conditions (Pseudo Global Warming). This setup allows us to quantify the thermodynamic and large-scale dynamic climate change impacts on convective storms in the western Mediterranean. Using a storm-tracking algorithm, we identify convective systems producing high rainfall rates and measure a range of characteristics. This provides a complete description of convective rainstorms and help us determine which features may be most affected by climate change. Our analysis covers storms throughout the year with focus on late summer and early fall, when the most damaging episodes tend to occur. The model experiments suggest that storms will be less frequent but considerably larger in size. Our results also show a strengthening of short-lived extreme rainfall events. We link changes in convective storm features to heavy rainfall intensification to identify the physical processes behind precipitation changes in the region.

P4.1. LIAISE-1st mesoscale model intercomparison: what have we learned?

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In order to prepare the LIAISE experimental field campaign and future numerical simulations, a first mesoscale modelling inter-comparison for a summer event in the LIAISE area is intended to evaluate the performance of the MesoNH, Moloch, UM and WRF models compared to the observations and explore the differences between them. Participant models are run at their standard configurations to evaluate the representation of the surface features in the numerical models and its impact in the organisation of the flow at lower levels. Nevertheless, they are run with similar grid meshes in the horizontal (2km x 2km and 400m x 400m for the outer and inner domains) and the vertical (4m at lower levels and stretched above). A 48-h integration is made between 16 and 18 July 2016 for a case with well-developed thermally-driven circulations in the Ebro Basin. Furthermore, some sensitivity tests are made (initial and lateral boundary conditions, resolution or representation of the surface features, among others) to identify the importance of some model parameters in the model results. Model results are validated using data from the surface stations of the Servei Meteorològic de Catalunya network and satellite-derived land-surface temperature fields. It is found that each model has a different representation of the surface heterogeneities affecting the grid values of the surface fluxes. Nevertheless, the mesoscale circulations generated by the models are very close being the differences lying mostly at the small scales, namely the values of the exchange fluxes at the surface or the state of the surface and the soil. Model biases are related to the particularities of the parameterisations, specially those related to the surface model, and of the physiographic data bases used by each model. From this exercise we have learned which is the best configuration of each model setup to best reproduce the observations. These configurations will be used to perform simulations of cases corresponding to the LIAISE experimental field campaign, for which there is a larger amount of available observations.

P4.2. Synoptic analysis and WRF simulation of thunderstorm and hail event in istanbul on 29 september 2020

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A thunderstorm is a meteorological event caused by convection conditions in the atmosphere. They occur as a result of instability that occurs in places where air masses at different temperatures meet. Warm and moist air rising rapidly causes thunderstorms. Hail, on the other hand, is a meteorological event that occurs as a result of the drops in a vertically developed cloud descending to the surface as ice masses. Hail is usually effective in strong winds and storms. Thunderstorms and hail events are regional and short-lived. Therefore, it is difficult to predict. For the occurrence of storm and hail events; conditions such as instability, wind shear, lifting mechanism, and moist air must be provided. On September 29, 2020, a severe storm and hail event occurred in Istanbul. As of September 28, 2020, 00Z, the polar jet and pressure systems in the mid-upper latitudes over Europe have strengthened. This system, which entered Turkey from Thrace, developed a low-pressure system and an occlusion front in Istanbul on September 29, 2020. Cumulonimbus (CB) formations have occurred with the resulting rising air movements. This situation caused thunderstorms, heavy rain, and hail. The incident, which lasted for about 2 hours, had a negative impact on his life. Hail occurred in Istanbul's Avcılar, Kadıköy and Ümraniye districts. In this study, the storm and hail events that occurred in Istanbul on September 29, 2020, will be analyzed synoptically. In addition, in this study, model outputs were obtained by using the Weather Prediction Forecast (WRF) model. ECMWF ERA-5 Reanalysis data was used for model data. The outputs obtained with different parameterization combinations in the simulation will be discussed. At the same time, the outputs obtained from the model and synoptic observations will be compared and evaluated.

P4.3. Sensitivity study of WRF microphysics for a thunderstorm event: A case study over Istanbul, Türkiye

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Thunderstorms are meteorological events that cause rain, hail, thunder, and lightning, which have serious effects varying locally. Thunderstorm forecasting is crucial in terms of reducing potential damage with precautions taken by authorities and citizens. In this study, atmospheric simulations were made to better understand the relationship between microphysics schemes and thunderstorms. A severe thunderstorm event that occurred in Istanbul on July 18th, 2017 was investigated by running six WRF simulations with different microphysics schemes (WSM7, WDM7, Purdue Lin, Goddard, Morrison 2-moment, Thompson) and Global Data Assimilation System (GDAS) data with 0.25 degree resolution. The simulations were run using three nested domains with resolutions of 9 km, 3 km, and 1 km respectively. The results of the simulations were compared to observations at 8 different stations in Istanbul, to investigate the representativeness of different geographical regions over the city. Mean absolute error (MAE), root mean squared error (RMSE), percent bias (BIAS%), and Pearson correlation coefficient are used for statistical analysis. The results indicate that topographical features can affect the choice of microphysics and among the six runs, Purdue Lin represented the event better and Goddard was the least representative.

P4.4. Simulation of extreme precipitation events in Athens, Greece, with the use of high resolution WRF modeling

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Extreme precipitation events are occuring with higher frequency in recent decades and can be responsible for severe flash floods and loss of infrastructure and human lives, especially in urban environments where high population density and terrain modifications increase the risk. We investigate how such events can be accurately simulated with the use of high-resolution WRF modelling in the city of Athens, Greece, which is one of Europe's largest Metropolitan complexes with a population of approximately 3.7 million inhabitants. We use simulations (3km horizontal grid) driven with ERA-5 re-analysis data, to produce hourly and daily precipitation maps in the city of Athens and the surrounding areas (Region of Attiki), during three separate heavy precipitation events and subsequent flooding. Different model parameterization schemes are tested, both in respect to the underlying urban characteristics and physical parameters affecting precipitation. Model output is validated with the use of observational data from a network of ground weather stations covering the vicinity of Metropolitan Athens Area, which are spatially interpolated to produce maps of hourly and daily total precipitation. Results indicate that changing parameterization schemes can have a strong effect on model output and that fine tuning of the urban canopy model and cumulus and physical parameterization can produce precipitation simulations of increased accuracy. The overall aim of the present study is to identify the best parameterization schemes to be used in high-resolution numerical forecasting of extreme precipitation and flash-floods events.

P4.5. WRF hindcast of tropical cyclones over the South-West Indian Ocean basin

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Tropical Cyclone (TC) is among the deadliest natural weather phenomena associated with strong winds, storm surges, strong waves, and heavy rainfall leading to floods or flash floods. The evolution of TC is predominantly favored in large water bodies like oceans and seas with triggering mechanisms depending largely on the warm sea surface temperature (SST), and low-pressure systems. Areas, where TCs develop, are named basins. In the South-West Indian Ocean (SWIO) basin, TCs are typical weather phenomena occurring in the long rainy season mostly from November to April. The occurrence of TCs causes huge economic losses and impacts on society for land areas and coastal waters and for the high seas. Thus, accurate hindcast of TCs on ground wind fields, precipitations, and the maximum wind speed (Vmax), minimum central sea level pressure (CSLP) and trajectories. is paramount in reducing and preventing the impacts associated with the weather phenomenon. The recent work is focused on the hindcast of TCs over the SWIO basin and their impacts on the ground wind fields, precipitations, and Vmax, CSLP, and trajectories of the TCs. The hindcast is studied using Numerical Weather Prediction (NWP) model called the Weather Research and Forecasting (WRF) model with one vortex-following nest. Different WRF model simulations are performed based on the sensitivity of model horizontal resolutions, and physics parameterization schemes using ERA5 as Initial Boundary Conditions (IBCs). The model is run in a rolling mode every 24-hr (1 day) for the entire span duration of the TC. At first glance, the different model configurations are performed on TC-Kenneth (21-28, April 2019), and the best model configuration sorted is used to create the WRF hindcast of TCs over the basin of SWIO that occurred in the past 33 years between 1990 to 2022. The performance of the WRF hindcast of TCs on ground wind fields and precipitations is examined using observations from ground station data closest to the TC passage. The hindcast of Vmax, CSLP, and, trajectories coming from the vortex-following nest of the WRF model is investigated using the best track data from the Joint Typhoon Warning Centre (JTWC) and the La Réunion (Météo-France) which are regional specialized meteorological centres for TCs storm track. Lastly, various empirical approaches are used to improve the WRF hindcast of TCs on the ground wind fields, Vmax, CSLP, and trajectories.

P4.6. Sensitivity study of WRF soil initial conditions during summer 2022 in Catalonia

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During the summer of 2022, the reference model of the Meteorological Service of Catalonia (WRF- ARW v4.3), compared to previous seasons and years, has increased the difference between the forecasted daily maximum temperature (at 2 m height) and the observations. To find the source of this error, we have run a study on the sensitivity of the maximum temperature of the model to different physical parameterizations and initial conditions. In this poster, we will focus our view on the soil moisture and temperature variables and different soil categorizations and the parameters defined in them: leaf area index, vegetation fraction, surface emissivity, shadow factor, thermal inertia and roughness length, quantifying their impact on the surface temperature.

P4.7. Mediterranean dust outbreaks: dynamic meteorological patterns and weather types

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Long range transport of desert dust may be responsible of high PM10 concentration events frequently recorded over wide areas in remote regions with respect to the dust origin sites. Over the Mediterranean basin several of such events are recorded each year, that may contribute to the exceedance of legal limit values for PM10 concentration. For this reason the quantitative estimation of the desert dust episodes is very relevant. Such events are the result of a sequence of dynamical mechanisms, beginning in desertic areas where uplift mechanisms raise from the surface relevant amounts of dust and lift them high in the troposphere. These are followed by a long range transport due the strong winds frequently present at that altitude, and terminate over remote regions with the onset of dust deposition. As a result a sound study of such events requires the suitable combination of synoptic modelling resources, for the high altitude long range transport, and detailed models to characterize the peculiar dynamics in the deposition areas. Observed air quality data can be used to complete the analysis and confirm numerical modelling results. In the present study, several dust outbreak events are picked out from a five years (2018-2022) dataset of dust concentration estimates from the large scale CHIMERE model, provided by PrevAir. The study is focussed on the area of Central Italy. The availability of observed PM10 data from two background measuring stations of Tuscany Region Air Quality monitoring network allowed to check and confirm the real occurrence of the dust outbreaks. Moreover the availability at Consorzio LaMMA of a recently implemented Weather Types classification has been exploited to relate the studied episodes with the relative meteorological patterns both at the synoptic and at the local level. As from the widespread evidence in literature, most of the dust outbreaks in the Mediteranean basin have their sources in the Sahara Desert area, but a minority set of these events originates in remote areas farther east from Europe. This study has been performed also in the perspective of an operational application, for implementing a dust outbreak warning system, based on the real-time recognisance of each meteorological configuration and its eventual tracing to one of the Weather Types identified as strongly correlate with relevant dust transport. A correct implementation of such an operational warning system could require an ad-hoc specific Weather Types classification, that will be the subject of further developments this study.

P4.8. Identification and analysis of rare extreme CO2 concentration events at the Plateau Rosa site using meteorological and dispersions models

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The Alpine station of Plateau Rosa (measurement station belonging to Integrated Carbon Observation System – ICOS and Global Atmosphere Watch – GAW, ID: PRS) monitors since 1989 (continuously since 1993) the concentration levels of major greenhouse gasses (GHG). The elevated and isolated position of PRS (45.93436° N, 7.70778° E, 3480 m a.s.l.) near Mt. Cervino, not far from the mountain border between Italy and Switzerland, makes its data series a good representation of the background levels of GHG in the atmosphere (Apadula et al., 2019). In our work we applied the Background Data Selection (BaDS) algorithm to the PRS data series spanning almost thirty years (from 1993 to 2022) in order to exclude any significant deviation from the background. Once the background data were successfully obtained, we performed a comparison between their monthly averages and the daily averages of the original unfiltered series. This process resulted in the recognition, in the series, of 13 events with extreme concentration of CO2, which set above the 6σ threshold given by the Gaussian fit that was performed. The scarcity of these events confirms that the vast majority of observations gathered at PRS are fully representative of the background state of the atmosphere. However, in rare occasions air masses with a high concentration of pollutants can reach the station generating extreme outliers in the data. We then studied one of these events, which happened on the 8th November 2017, using the FLEXPART-WRF and MILORD Lagrangian particle dispersion models in backward mode. The CO2 concentration levels at PRS in the days before and after the event were plotted against the data covering the same period and belonging to two other mountain monitoring stations (Jungfraujoch in Switzerland and Sonnblick in Austria). It was found that only the Swiss station of Jungfraujoch detected the same peak in CO2 levels while Sonnblick did not. To investigate the source areas additional runs were performed with releases located in each observation point. The outputs from the models suggest that the most plausible sources of the event observed by PRS and Jungfraujoch are polluted air masses coming from the highly industrialized areas of the Po Valley between Lombardy and Veneto.

P4.9. Numerical modeling of a passive tracer dispersion from a continuous point source in a steady thermally driven slope wind

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An Eulerian model for the dispersion of a passive tracer over a simplified slope driven by a thermally driven circulation is presented. The source of the tracer is pointwise and the emission is continuous, the local circulation is a pure anabatic flow modelled following Prandtl's (1942) steady-state model. The eddy diffusivity is considered constant along the vertical direction. The limits of a classical gaussian model to forecast the concentration field is shown through a comparison between the results of a Gaussian, an Eulerian and a Lagrangian model. A sensitivity analysis of the concentration field to the position of the source and to the maximum values of the wind field is proposed. Two different regimes are identified, depending on the relative position of the source and the velocity maximum. Moreover, a mathematical relationship between the position and the intensity of the ground concentration field, along with its dependence on the environmental parameters is found.

P4.10. Comparison of two wind farm parametrization schemes in mesoscale Weather Research and Forecasting model

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This study compares two wind farm parametrizations (EWP and Fitch) used in mesoscale Weather Research and Forecasting model in terms of wind farm wake impact on atmosphere. TKE advection issue is corrected in the model when Fitch scheme is used. In the model simulations, five domains are used. Hower, three inner domains cover the same area with the same horizontal resolution. One of them has no wind farm, the others have Fitch and EWP schemes. The study area is Ezine district of Çanakkale province in Turkey. Three one day cases from different seasons are selected. These cases provide relatively strong wind farm wake, and allow to easily compare the both parametrization schemes' results. A relatively large-scale hypothetical wind farm is designed in the study area. Our results show difference between both scheme is more pronounced at nighttime. For nighttime, Fitch scheme systematicaly provide stronger wind farm wake impacts on hub-height (wind speed and turbulent kinetic energy) and near-surface (air temperature and water vapor mixing ration) variables. This systematic difference is probably because both scheme propose different calculation methods for TKE generation from wind farm.

P4.12. Seasonal forecasting of subsurface marine heat waves

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Marine heat waves (MHWs) cause devastating damage to ecosystems and ocean services, with effects being identified mostly below the ocean surface. Current forecasting efforts, however, focus only on metrics based on sea surface temperature. To create a more user-relevant detection system, it is necessary to provide forecasts of subsurface events. Here, we demonstrate the feasibility of seasonal forecasting of subsurface MHWs by using ocean heat content, a more relevant indicator than surface temperature for marine stakeholders. We validate summer MHW indicators in a fully-coupled seasonal forecast system against a global ocean reanalysis and satellite data. Our main result is that subsurface summer MHWs are predicted with greater skill than surface MHWs across much of the global ocean. Sub-surface MHWs are typically longer-lasting than surface events, rendering them easier targets for forecasting systems. Despite the long-lasting nature of subsurface MHWs, we also show that the dynamical forecast system used here typically outperforms a MHW-persistence model, indicating the capability for capturing the onset and decay of MHWs. Lastly, we highlight the role of warming oceans in MHW detection skill, by removing linear trends. This work highlights the need for a wider appreciation of subsurface ocean phenomena and the increased uptake of seasonal forecasting indicators by marine stakeholders such as marine protected areas and fisheries.

P4.12. Seasonal forecasting of Alpine snow depth

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Mountain glacier shrinking, seasonal snow cover reduction and changes in the amount and seasonality of meltwater runoff are already affecting water availability for both local and downstream uses. Water is needed by different competing sectors including drinking water supply, energy production, agriculture, forestry, tourism, and extremely dry seasons can lead to economic losses. Reducing potential impacts of changes in water availability involves multiple time scales, from the decadal time scale, for the realization of water management infrastructures, to the seasonal and sub-seasonal scales, to plan the use of water resources and to allocate them with some lead time. In the framework of the ERA4CS MEDSCOPE project we focused on the seasonal time scale and we developed a climate service prototype to estimate the temporal evolution of the depth and the water content of the snowpack with up to 7 months lead time. Forecasts are initialized on November 1st and run up to May 31st of the following year. The prototype has been co-designed with and tailored to the needs of water and hydropower plant managers and of mountain ski resorts managers. We present the modeling chain, based on the seasonal forecasts produced by the ECMWF and Météo-France seasonal prediction systems, made available through the Copernicus Climate Change Service (C3S). Seasonal forecasts of precipitation, near-surface air temperature, radiative fluxes, wind and humidity are bias-corrected and downscaled to three high elevation sites in the North-Western Italian Alps, and used as inputs for a physically-based multi-layer snow model (SNOWPACK). The RainFARM stochastic downscaling procedure, adapted for mountain regions, is used for downscaling precipitation data, and stochastic realizations are employed to estimate the uncertainty due to the downscaling method. The skill of the prototype in predicting the monthly snow depth evolution from November to May in each season of the hindcast period 1995-2015 is demonstrated using station measurements as a reference. We finally discuss implications of the forecast quality at different lead times as well as the added value of bias-correction and downscaling of precipitation data on snow depth forecasts.

P4.13. Elevation dependence of biases and trends of climatic indices from EURO-CORDEX regional climate models in the European Alps

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Climate change is a global phenomenon with regionally varying peculiarities and sensitivities, such as in the Mediterranean region, which is characterised by observed climatic changes that exceed global means. A significant impact on Mediterranean weather and climate is due to one of its mountain range systems, the European Alps, that are especially sensitive to climatic changes. At the same time, the complex local topography of the Alpine region modulates meteorological and climatic patterns which makes the projection of the evolving mountain environment and climate even more complex. To put estimates of future climate change patterns in the Alpine area, in this study we evaluate the representativeness of historical climate simulations in function of the elevation over the European Alps by using the EURO-CORDEX ensemble of regional climate models at 0.11° resolution. In addition to the raw simulations, we also evaluate the models and bias adjustment methods as available within CORDEX-Adjust. The model data are compared to high-resolution observational datasets over the entire Alpine region, such as APGD and EOBS, and to national observational datasets. Besides climatic averages, also climatic indices that sample extreme conditions are evaluated. We identify potential advantages and weaknesses of bias-adjustment methods depending on elevation, region, and climatic index. Based on the results, we can evaluate which are the most appropriate indices for studies including climate change adaptation, and defining physical mechanisms at play.

P4.14. Regional climate change projections derived by using reduced complexity models of global climate change

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Given the increased recognition of climate change on water, land, energy, health, and economic systems across the world researchers from different fields (ecologists, hydrologists, engineers, economists, etc.) and various countries are interested in better understanding of climate systems and using outcomes of climate models. However, the complexity of the climate system models developed by climate research centers by using super powerful computers often restrict their usability and mostly countable number of climate specialists can benefit. Reduced complexity models (RCMs) of climate change which can effectively replicate key indicators assessed by using complex models are gaining traction to support the wider uses of climate research outcomes and enhance interdisciplinary scientific dialogue. Yet, difference in coding languages used for the RCM and Integrated Assessment Models (IAMs) is another hurdle that restricts a wider learning and uses of RCMs. This paper presents GAMS coding of FAIRv2 model (which was originally coded in Python) to support wider uses of improved RCM by IAM community. Additionally, we include a component that allows to assess regional climate change (including Mediterranean region) knowing global climate change dynamics. Based on this model, the study elaborated modeling outcomes on global radiative forcing effects of various greenhouse gases, and temperature and precipitation dynamics in the Mediterranean region under RCP-SSP scenarios.

P4.15. Decadal predictability of European temperature extremes

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Accurate predictions of climate variations at the decadal timescale are of great interest for decision-making, planning and adaptation strategies for different socio-economic sectors. Notably, decadal predictions have rapidly evolved during the last 15 years and are now produced operationally worldwide. The majority of the studies assessing the skill of decadal prediction systems focus on time-mean anomalies of standard meteorological variables, such as annual mean near-surface air temperature and precipitation. However, the predictability of extreme events frequency may differ substantially from the predictability of multi-year annual or seasonal means. Predicting the frequency of extreme events at different timescales is of major importance, since they are associated with severe impacts on various natural and human systems. In the current study we evaluate the capability of state-of-the-art decadal prediction systems to predict the frequency of temperature extremes in Europe. More specifically, we assess the skill of a multi-model ensemble from the Decadal Climate Prediction Project (DCPP, 163 ensemble members from 12 models in total) to forecast the number of days belonging to heatwaves episodes during summer (June–August). We find statistically significant predictive skill over Europe, except for the United Kingdom and a large part of the Scandinavian Peninsula, most of which is associated with the long-term warming trend. We are progressing with the evaluation of other statistical aspects of extreme events, including warm and cold episodes during winter, and we are also investigating whether there is predictive skill beyond that stemming from the external forcing.

P4.16. Wave modeling with unstructured mesh in the Mediterranean Sea

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This contribution presents the development of an unstructured mesh for wave modeling in the Mediterranean Sea. The mesh allows for high spatial resolution (i.e., up to ≍300 m) at nearshore, where bathymetry effects are more relevant, being coarser in deep waters where such effects are negligible (distance between nodes in the order of km). It is employed along with the wave model WAVEWATCH III v6.07 (WWIII), forced with 10-m wind fields obtained from the non-hydrostatic mesoscale Weather Research and Forecast model with initial and boundary conditions from the National Center for Environmental Prediction Climate Forecast System Reanalysis and Climate Forecast System Version 2. WWIII is used to hindcast the wave climate in the Mediterranean Sea in the 1979-2020 period (although it is going to be updated on a yearly base). Besides, five days wave climate forecast is set up, providing both integrated wave parameters and 2D directional spectra. The hindcast is validated against buoys and satellite missions; comparisons show that the model is capable to provide good performances for storm events and mean conditions in the MS.

P4.17. Impact of different physics schemes on a mesoscale model performance over the Aegean Sea, Greece

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The accurate representation of meteorological processes is important for the improvement of meteorological predictions. The use of appropriate tools such as weather forecasting models could improve the capability for monitoring, mitigation, and assessment of the impact of climate change and/or monitoring marine pollution events over an area of interest; especially when this area is characterized by complex coastline and topography associated with a high spatial and temporal variability of surface parameters. Such variability underlies much of the spatial complexity observed in the associated mesoscale weather phenomena in case studies like the Aegean Sea, Greece. This basin faces major environmental change pressures and the preservation of the natural resources at sea and coastal areas, which are nowadays at risk, is considered of high importance. In this direction, a detailed sensitivity analysis study was carried out using the Weather Research Forecasting model (WRF). The objective of this research was to investigate and decrease the uncertainty in the model results throughout the identification of parameters which considerably influence the model performance for long-term simulations. Appropriate statistical measures were used to evaluate the model results with the use of data from an extensive network of more than 40 surface meteorological stations for the year 2021. A geodatabase was designed and developed for this purpose in the framework of a Geographical Information System. As a result, insights on the reliability of different physics parameterization schemes in view of climatic model applications over the Aegean Sea were provided and further discussed.

P4.18. The transition zone between clouds and aerosols in radiative transfer models

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Atmospheric transmissivity depends on many physical and optical properties of aerosol and clouds that increase the difficulty of estimating radiative fluxes and consequently their radiative effect (RE). Most radiative transfer models allow characterizing separately aerosol and cloud properties without considering them as a continuum with a transition zone (TZ) between both types of suspended particles. [1] described it as a region with forming/evaporating clouds and hydrated aerosol particles. [2] presented a complete review. This study performed a sensitivity analysis of the ability of two radiative transfer models to estimate the RE of clouds and aerosol, with characteristics approaching those of the TZ, at the top and the bottom of the atmosphere (TOA, BOA) in the shortwave and longwave ranges. The selected models were: SBDART [3] and libRadtran [4]. We performed several simulations covering optical depths (OD) between 0.01 and 2.0, which can be representative of the TZ in averaged and polluted environments. For each case, the RE was defined as the difference between fluxes with a cloud or aerosol layer and a situation without them. We considered four aerosol models included in both transfer codes that were modified by the defined AOD and the relative humidity of the aerosol. With an analogous procedure, the cloud layer was defined with the OD and the effective radius. The optical properties of each aerosol model defined in the aerosol layer strongly influence the shortwave RE at the TOA for a fixed OD. The differences were smaller for a cloud layer, especially for ice clouds. The different definition in each radiative model introduces larger differences in simulations with clouds than with aerosols. On the other hand, the longwave RE was more sensitive to differences in ice and water cloud layers. When aerosols are highly hydrated (high relative humidity), the RE can be similar to that of water clouds with small droplets, especially in the shortwave diffuse component. However, a mismatch in radiative fluxes between aerosol and cloud simulations is observed. This study has highlighted the limitations of radiative transfer models to simulate the RE of transition zone if treated separately.

S5. Interdisciplinary studies

Invited talk: An interdisciplinary approach to the analysis of extreme events over the Mediterranean

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Although extreme events have always been important in meteorological research, they are receiving special attention in the context of climate change. There are a number of extreme events (e.g. frost, wildfires, gusty winds, severe convection with its byproducts, etc.) which have in common that they can cause significant material damage/losses and human casualties. Therefore, their study is of great interest not only for the meteorological community, but also represents a great need for a comprehensive interdisciplinary approach. Through this lecture, more detailed knowledge will be given about several recently conducted interdisciplinary research with agronomists, foresters, chemists and biologists on several different topics. The first of them includes the impact of climate change on viticulture and winemaking, since it is one of the important economic branches of most Mediterranean countries. Many studies show that changes in temperature and precipitation (and often deep moist convection) have a great impact on viticulture, considering that plants are among the first to react to climate changes, e.g., changes in temperature and humidity. Recent studies have shown that the impact of climate change is often visible in the earlier beginning of the phenological phases of the vine, such as budbreak, flowering, veraison and harvest. An earlier onset of budbreak indicates a potentially significantly higher risk of early frosts. Another theme includes extreme wildfire analysis and fire weather research involving fire management and fire risk awareness in the Mediterranean. The possibility of wildfire modeling will be demonstrated, which enables research into the occurrence of pyroconvection, and the strong interaction between the atmosphere and fire evolution. The third topic includes the analysis of the transport of Saharan dust over long distances across the Mediterranean. Mineral dust, as one of the most widespread types of aerosols, is an extremely important factor in climate change assessments. It affects atmospheric radiation, cloud formation, and during deposition it transfers micronutrients to both land and ocean ecosystems. The Sahara desert is one of the main global sources of dust that, through atmospheric transport, has an impact on the Mediterranean. Deposition of mineral dust in the atmosphere plays an important role in supplying the sea with nutrients. In this interdisciplinary research, the frequency of these rare events is analyzed as well as their impact on the marine biosphere and biological activity.

O5.1. Seasonal predictions in the Mediterranean region. Application in the control of climate-sensitive diseases

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Climate change is exacerbating the risk of infectious diseases in the Mediterranean —one of the fastest-warming places on Earth—, and these are highly dependent on essential climate variables like temperature or relative humidity. Seasonal predictions can anticipate anomalies of climate variables with an advance of one to six months approximately. Its usability for real applications, however, is still far from that of weather forecasts. One of the reasons is that seasonal predictions are produced with global models that have low spatial resolution, thus preventing the prediction of local climatological features that happen at finer scales. For example, in big cities, seasonal prediction systems do not "see" the so-called urban heat island effect, which can substantially increase the summer mean temperature compared to the surrounding areas. In order for these climate predictions to be useful for the control of infectious diseases that are sensitive to climate variations, it is necessary to increase their spatial resolution and correct systematic errors, as well as evaluate their forecast quality. This work focuses on increasing the spatial resolution, while maintaining or improving the skill of predictions, over some mediterranean climate-sensitive infectious diseases hot-spots. Different statistical downscaling methods are applied and the results are analysed and intercompared by using a bunch of verification metrics (e.g. correlation, RPSS) that allow the selection of the most appropriate method depending on the region or variable studied.

O5.2. On the seasonal prediction of nighttime heat waves in Europe

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Extreme climate events such as heat waves cause enormous stress on human health and ecosystems and economic losses have been detected in different industrial sectors such as agriculture, energy or water management activities. In particular, the combined effect of above-normal nighttime temperatures and high humidity prevents the human body's recovery from daytime high-heat exposure. Hence, seasonal forecasts of the nighttime heat waves might be used as a tool to anticipate the risks of the nighttime heat and to better manage their social and economic impacts. However, the ability of the seasonal forecast systems to predict these extreme events has not been explored so far. This work provides insight into the potential of four seasonal forecasting systems (CMCC Seasonal Prediction System 3.5, DWD System 2.1, ECMWF SEAS5 and Météo-France System 7) to provide skillful and reliable predictions of the nighttime heat waves in Europe during the boreal summer season. Different potential proxies for the assessment of nighttime heat waves have been considered: nighttime apparent temperature computed from temperature and humidity at night, the temperature at night and the daily minimum temperature. There are different indices that can be used to investigate extreme temperatures, but the heat wave magnitude index has been chosen in this study. This index is very suitable for seasonal forecast analysis because it is invariant to the mean biases and provides an integrated view of the nighttime heat waves for the entire season with information on their duration, frequency and intensity. The forecast quality assessment has revealed that state-of-the-art seasonal forecast systems are able to provide useful information on the nighttime heat waves inSouthern Europe. This is an encouraging result because this region is particularly vulnerable to climate variability and change and the timely climate information can benefit decision-making processes in different socio-economic sectors.

O5.3. Urban heat and dry island effects: a novel approach to characterize the metropolitan area of Turin

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The joint action of increasing urbanization and global warming is becoming a bursting topic in modern times. In this context, among the most widely investigated effects we focused on the Urban Heat Island (UHI) and the Urban Dry Island (UDI). Both effects are computed as the temperature and absolute humidity difference between urban and rural sites, resulting in warmer (UHI) and drier (UDI) cities with respect to the nearby natural surroundings. Thus, the selection of appropriate urban-rural pairs of stations is a crucial task needed to quantify the phenomena. We show a novel metric – applied over the metropolitan area of Turin (Italy) – which highlights typical thermal behavior of the weather stations and clusters them into subsets showing similar thermal pattern, e.g., urban or rural. Once the stations are identified, the findings are capitalized to characterize the average seasonal thermal and moisture behavior of Turin with respect to its surrounding area. A set of ground level stations analyzed over 14 years (2007-2020) give evidence of a nocturnal UHI up to 4-5°C, while the average UDI reaches 3-4 g/m3. Within the same considered period, an investigation of the urban boundary layer – through three microwave radiometers – proved that the vertical limit of the UHI is found at 150-200 m above the ground level.

O5.4. Application of climate risk assessment framework for selected Italian airports: a focus on extreme temperature and extreme precipitation events

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Due to increased extreme weather events as a consequence of climate change, climate risk analysis has become an essential issue for all critical infrastructures, including airports. The aim of this paper is to apply a climate risk assessment framework to evaluate the impacts of extreme temperatures and extreme precipitation on several Italian airports: Malpensa, Linate, Bergamo, Ciampino, Fiumicino, Napoli, Catania, Palermo, and Cagliari. According to the risk definition recommended in the Fifth Assessment Report of IPCC (2014), specific hazard, exposure and vulnerability indicators were identified. The hazard indicators were calculated using the Uncertainties in Ensemble of Regional Re-Analyses dataset (UERRA) for the observed period (1981-2010), and then their climate variations were evaluated by means an ensemble of high-resolution climate projections from the EURO-CORDEX initiative for the short (2021-2050), medium (2041-2070), and long-term future period (2071-2100), under RCP 2.6 (Representative Concentration Pathway), RCP 4.5, and RCP 8.5 scenarios. Exposure and vulnerability data were collected from multiple sources, such as official airports documents or websites. The final risk index obtained from the combination of these three factors allowed us to identify which of the selected airports are likely to face the major impacts due to extreme temperature and precipitation events. This paper provides the knowledge base on risk assessment on Italian airports, with the aim to support the stakeholders for the selection and implementation of appropriate adaptation strategies and measures in relation to selected hazards.

O5.5. Efficiency of resource allocation in the suppression of European wildfires

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In recent years, particularly 2022, heavy losses of property, injuries and deaths have been caused by wildfires in many European countries. Increasing wildfires exert pressure to balance cost, benefits and risks of wildfire management. Wildfire studies are less developed in Europe compared to the US. Several groups of factors have to be considered in wildfire suppression decisions: loss, expenditure, allocation of resources, environmental and socio-economic parameters. Previous studies on wildfire suppression usually apply simple econometrical models to address the relationship between only two among the factors above. For example, some literature explore whether resource allocation is affected by socio-economic factors, while some analyze whether the cost incurred in wildfire suppression is affected by environmental factors. Such practices fail to consider other relevant factors and are thus partial and incomplete. To establish a framework to sistematically assess efficiency in wildfire suppression involving all the main factors, this study will construct a Stochastic Frontier model in the form of Cost-and-Loss Distance Function using cross-sectional data on European wildfires. The model measures whether wildfire suppression cases are efficient in minimizing cost and loss and whether environmental and socio-economic parameters contribute to such efficiency. Fire managers often face trade-offs between environmental/property losses and expenditure spent on fire suppression with constraints on resources (machines, crews, etc.) available at hand. The research outcome will provide a reference to improve this decision process by helping identify where more resource is needed and justifying budget increase since there are locations where potentially require more resource for wildfire suppression. This is an interdisciplinary study involving environmental economics and (other fields of) environmental sciences. This study will contribute to efficiency improvement in wildfire suppression, and thus help achieve SDGs 3, 11, 13 and 15.

O5.6. The trade-off between socio-environmental awareness and renewable penetration targets in energy transition roadmaps

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Recent years have seen a growth in the presence of renewable energy sources, being lead by the PV and wind technologies. However, additional installations will be necessary to meet the renewable penetration targets for the upcoming decades. The wind and utility-scale PV farms require vast extensions of territory, and the areas with the most exploitable climatic resource may not be suitable for such installations due to environmental, aesthetic, or technical concerns. In order to determine the optimal areas for renewable capacity installation while accounting for land uses, we propose an optimization of the system total cost that considers the suitability cost of the land. In particular, the suitability costs are estimated considering spatial fields of land use, population density, distribution and maintenance costs, along with constraints linked to flood-prone and natural protection areas. We identify three differentiated regimes in the trade-off between suitability cost and renewable penetration, and quantify the compromises that are required in terms of land use for each of them. These optimal results are compared to existing deployment plans in Spain, leading to an overall assessment of the current electricity system and official development plans.

O5.7. On the fires responses to climate variability and change: the ONFIRE project

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ONFIRE, a Spanish national research project supported by the State Research Agency and the Ministry of Science and Innovation, aims to advance the state of the art of knowledge on the impacts of climate on fires beyond its current limitations and applications. Furthermore, this project is open to any contribution. Specifically, we encourage any fire researcher/agency to join this initiative. As society's exposure to large fires increases, there is growing concern about potential changes in fire regimes due to climate change. Understanding the response of fires to climatic variations is essential for adapting fire management systems and designing future prevention strategies. However, there are still many aspects to be revealed on this topic. In this contribution we show some preliminary results related to the main objectives of the ONFIRE project: 1) The creation of a global, unified, open-access and user-friendly database, the first of its kind, composed of all available records of burned areas from in situ ground observations. 2) A better understanding of past trends in fire series and their attribution to the anthropogenic component of climate change. 3) An assessment of the spatio-temporal synchrony of fire danger. 4) The design and implementation of a public operational prototype system for global seasonal predictions of climate-driven fire risk for decision-making applications.

O5.8. Assessment of crop water use and its sustainability based on future projections, Aude Department (South-West France)

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In the next 30 years (2020-2050), the population living in the Mediterranean will increase by 90 million people, reaching 611 million. At the same time, the Mediterranean region has been identified as one of the main climate change hotspots, mainly due to water scarcity and high rates of human activities in coastal areas, especially agriculture and energy production. Since 1970, the south-western European regions (Iberian Peninsula and South France) have been subjected to an air temperature increase of almost 2 °C, while generally southern Europe assisted to a 20% drop in annual precipitation. Agriculture is by far the sector with the greatest freshwater withdrawals, therefore it is essential to assess a correct quantification of water consumption in the sector, to reduce water abstractions from the ecosystem while keeping the same food production levels. In this context, the objective of this work is the modelling of water consumption for agriculture in the Aude water basin (South-West France), in order to understand the water volumes needed for each crop in the current conditions, and in the future scenarios of climate change, according to different climate models. Aude agriculture is mainly dedicated to wine grapes growing and irrigation water is mainly extracted from the Aude river, however, intensive agriculture is putting pressure on freshwater resources which are supposed to become more scarce in the future. This project relies on the application of SIMETAW# model (Simulation of Evapotranspiration of Applied Water), which, from a set of climatic and soil input data, computes the daily reference, well-watered crop, and actual evapotranspiration (ETo, ETc, ETa), the evapotranspiration of applied water (ETaw), an irrigation schedule, and crop growth and yield for a specific site. For climate inputs, the work relies on the high-resolution data (0.11-degree resolution) supplied by the Copernicus Cordex platform, which provides historical records and future estimations according to three RCP (Representative Concentration Pathways), that is RCP 2.6, 4.5 and 8.5. Research focuses on the most relevant crops of the region, mainly wine grapes cultivations, plus forage crops, wheat, olives, almonds, vegetables and fruits. In this analysis, the model calculates the actual evapotranspiration in irrigated conditions, selecting the proper irrigation method for each crop, and in rainfed mode. Results show that, under every climate scenario, crop water requirements are expected to increase, however low water-demanding crops, such as winter wheat, are less sensitive to climate variations, while summer crops will require greater irrigation inputs.

O5.9. Frost climatology in Croatia

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The rise in temperature in recent years has significantly affected the entire biosphere, including the beginning and duration of the growing season. The earlier start of the growing season is visible in many crops and trees. Although an increase is generally visible in all temperatures (minimum, maximum, and mean daily), this does not exclude the occurrence of extreme weather conditions that can damage crops. In particular, a special danger is related to frost. farmers need information about changes in the number of days with frost, as well as the last days with frost in spring, not only in the current climate but also in the future. For this reason, changes in the number of days with frost in the period from 1981-2020 were observed in this research. In addition, the last day with frost in spring, the first frost day in autumn, as well as the vegetation season in the observed period were calculated. Since there is no simple method for determining a frost day using only measured values and not observations, a new approach was tested, which defines a frost day as a day in which Tmin < 3 °C and the dew point temperature, calculated with Tmin, < 0 °C. This method was more than 90% successful in forecasting frost. Using this method and regional climate models, the change in the occurrence of frost until the end of the century was examined. A decrease in the number of frosty days in the future is visible, but large changes in the occurrence of the last frosty day of spring are not pronounced. If we take into account the expected earlier onset of vegetation, this can be a big problem in the future.

O5.10. An action-oriented approach to make the most of the wind and solar power complementarity

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Solar and wind power are called to play a main role in the transition toward decarbonized electricity systems. However, their integration in the energy mix is highly compromised due to the intermittency of their production, at the expense of weather and climate variability. To face the challenge, here we present research about actionable strategies for wind and solar photovoltaic facilities deployment that exploit their spatio-temporal complementarity in order to reduce the volatility of their combined production at its minimum. The developed methodology has been implemented in an open-access step-wise model called CLIMAX. It first identifies regions with homogeneous temporal variability of the resources, and then determines the optimal shares of each technology over such regions. In the simplistic application performed here, we customize the model to narrow the monthly deviations of the total wind-plus-solar electricity production from a given curve (here, the mean annual cycle of the total production) across five European regions. The results show that optimal siting of the power units reduces the standard deviation of the monthly anomalies of the total wind-plus-solar power generation by up to 20% without loss in the mean capacity factor as compared to a base scenario with an evenly spatial distribution of the installations. This reduction further improves (up to 60% in specific regions) if the total shares of each technology come also into the optimization game, thus providing actionable information for the deployment of new installations in energy policy decision-making. These results encourage the use of CLIMAX for practical guidance of next-generation renewable energy scenarios.

O5.11. I-CHANGE Living Labs to promote citizen participation in change of individual habits in a context of Climate Change: a joint vision through their implementation plans.

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The I-CHANGE (Individual Change of HAbits Needed for Green European transition, 2021-2025) project promotes the active participation of citizens to address climate change. Thus, it intends to engage and motivate citizens and local stakeholders to take part in citizen science initiatives and support a behavioural and consumption shift towards more sustainable patterns. To this aim, a set of Living Labs located in very different socio-economic contexts (Amsterdam, Barcelona, Bologna, Dublin, Genova, Hasselt, Jerusalem and Ouagadougou) have been created to give citizens and the civil society a central role in the transition to more sustainable behavioural patterns. Hence, the I-CHANGE Living Labs address different environmental issues comprising: (i) extreme events, mainly focusing on heavy rainfall, floods, flash floods and heat waves (Amsterdam, Barcelona, Bologna, Genova, Jerusalem and Ouagadougou,), (ii) air pollution (mainly particulate matter, nitrogen dioxide, and ozone) and its linkages with sustainable transport (Dublin, Hasselt, Barcelona, Bologna, Genoa, and Jerusalem), (iii) the water cycle (Genova Barcelona and Jerusalem) and (iv) Waste Management (Ouagadougou). This contribution presents the implementation plans of the eight Living Lab participating in the project. These implementation plans compare different points of the structure and organization of the Living Labs. The points discussed are: (i) the specific challenges and objectives to be developed, (ii) the sensors and instruments used for scientific measures, (iii) the stakeholders involved, (iv) how they cope with citizen engagement, (v) the different co-creation methodologies put in practice, (vi) the designed citizen science activities, (vii) specific qualitative and quantitative indicators to use when evaluating the scientific and social impact, (viii) the planned strategy for the scientific analysis of the collected data, (ix) some insights for potential proposals to improve the behaviour of citizens, and (x) the different scientific dissemination activities

they plan to contribute with. This first insight has been very useful to highlight some recommendations for the Living Labs that may help to improve the outcomes of the project, such as: the possibility to work in common campaigns with the common low-cost sensors, the possibility to coordinate common indicators for the Living Lab evaluation, to debate about if the society coverage of all the activities is enough and the possibility to have common target groups and to improve the definition of the scientific objectives related with each activity.

P5.1. Evolution and synchronicity of fire weather index in Europe

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The expansion of synchronized fire potential may compromise fire management efforts. This study provides a better understanding of recent changes in the synchronicity of fire danger across Europe that may overwhelm fire suppression capabilities. We analyzed the spatiotemporal synchronicity of fire danger in Europe over the period 1979-2021 based on the Canadian Fire Weather Index, one of the most widely used fire indices globally (FWI; Vitolo et al. 2020). The daily synchronicity index indicates the total area with a FWI level above 50, which represents the threshold of extreme fire danger according to the European Forest Fire Information System (EFFIS) classification. The mean annual area affected by extreme synchronous fire danger increased by about 100000 km2 during the 42-year study period (i.e. 57% of the historical mean value).

P5.2. Offshore CO2 capture and utilization using floating wind/PV systems: Site assessment and efficiency analysis in the Mediterranean

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A methanol island, powered by solar or wind energy, indirectly captures atmospheric CO2 through the ocean and combines it with hydrogen gas to produce a synthetic fuel. The island components include a carbon dioxide extractor, a desalinator, an electrolyzer, and a carbon dioxide-hydrogen reactor to complete this process. In this study, the optimal locations to place such a device in the Mediterranean Sea were determined, based on three main constraints: power availability, environmental risk, and methanol production capability. The island was numerically simulated with a purpose built python package pyseafuel. Data from 20 years of ocean and atmospheric simulation data were used to “force” the simulated methanol island. The optimal locations were found to strongly depend on the power availability constraint, with most optimal locations providing the most solar and/or wind power, due to the limited effect the ocean surface variability had on the power requirements of methanol island. Within this context, optimal locations were found to be the Alboran, Cretan, and Levantine Sea due to the availability of insolation for the Alboran and Levantine Sea and availability of wind power for the Cretan Sea. These locations were also not co-located with areas with larger maximum significant wave heights, thereby avoiding areas with higher environmental risk. When we simulate the production at these locations, a 10 L s−1 seawater inflow rate produced 494.21, 495.84, and 484.70 mL m−2 of methanol over the course of a year, respectively. Island communities in these regions could benefit from the energy resource diversification and independence these systems could provide. However, the environmental impact of such systems is poorly understood and requires further investigation.

P5.3. Exposure assessment of ambient PM2.5 levels during a sequence of dust episodes: a case study coupling the WRF-Chem model with GIS-based postprocessing

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A sequence of dust intrusions occurred from the Sahara Desert to the central Mediterranean in the second half of June 2021. This event was simulated by means of WRF-Chem chemical regional transport model. In this context, the population exposure to the dust surface PM2.5 was evaluated with the open-source quantum geographical information system (QGIS) by combining the output of the chemical transport model with the resident population map of Italy. The output of the numerical model are compared with the Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) reanalysis for PM2.5 surface dust concentration. The analysis of the WRF-chem output showed that surface dust PM2.5 is overestimated for about 4.5 µgm-3 compared to the area averaged value from MERRA-2. The comparison of exposure classes calculated for Italy and its macroregions shows that the exposure to the sequence of dust events varies with the location and entity of the resident population. The lowest exposure class (up to 5 µgm-3) had the highest percentage (38%) of the population of Italy and most of the population of North Italy, whereas more than a half of the population of Central, South and Insular Italy had been exposed to dust PM2.5 in the range 15–25 µg m-3. The coupling of WRF-Chem model with QGIS is a promising tool for the management of risks posed by extreme pollution events and severe meteorological storms. Specifically, the present methodology can be also applied for operational dust forecasting purposes and in case of occurrence of any natural hazards in order to deliver safety alarm messages to the areas with the most exposed population.

P5.4. The times they are A-Changin? Political changes and extreme weather events in the Spanish Mediterranean coast (1979-2022)

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Lejos de asumir posiciones deterministas, se ha demostrado que los eventos climáticos extremos tienen un fuerte impacto económico, político y social (Pörtner et al., 2022; Koubi, 2019). La historia deja una larga lista de relaciones causales EWE/disrupción social (Burke, Hsiang & Miguel, 2015). Suponiendo que, independientemente de las nuevas estrategias y técnicas de adaptación, las sociedades actuales se comporten de manera similar a las sociedades históricas en la absorción de un impacto, podemos prever que EWE será un desafío para lograr sociedades resilientes. El impacto de un EWE está directamente relacionado con su peligro, pero gran parte de la explicación está relacionada con la vulnerabilidad social. La vulnerabilidad depende de la gestión del territorio por parte de las autoridades. Por ello, la sociedad busca responsabilidades políticas cuando ocurren desastres naturales (Gil-Guirado et al, 2016). Este trabajo examina la posible relación causal entre EWE (inundaciones y sequías) y los cambios políticos ocurridos en las administraciones autonómicas y municipales de la costa mediterránea española entre 1979 y 2022. Para ello, partiendo de las bases de datos de eventos extremos de Gil-Guirado et al. Alabama. (2019) y Vicente-Serrano et al. (2017), añadimos un panel de datos con los resultados electorales a nivel municipal y autonómico. Con estos datos aplicamos un Análisis de Época Superpuesto donde los EWE son el momento Clave y los resultados electorales son el subconjunto de datos donde se busca la señal. Los resultados preliminares sugieren que las inundaciones más intensas, que ocurrieron cerca de una elección, tienen el potencial de provocar un cambio político. En cambio, las sequías severas son un refuerzo del poder previamente establecido en los casos en que existe conflicto social entre regiones vecinas.

P5.5. Main hydrometeorological and social factors involved in the unfolding of the 22 October 2019 hazardous flash flood in Catalonia, north-eastern Spain

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On 22 October 2019, a heavy precipitation event overwhelmed the Francolí river basin in Catalonia, north-eastern Spain. Maximum observed rainfall amount was close to 300 mm, two thirds of which fell in 4 h. The subsequent flash flooding resulted in death toll of seven and estimated economical losses above 44 million EUR. The main hydrometeorological and social factors that concurred in the unfolding of this catastrophic event are analysed through an interdisciplinary approach. First, the specific roles of the mesoscale processes and local orography are investigated by forcing the new Triangle-based Regional Atmospheric Model (TRAM) with large-scale meteorological grid analyses. Next, the organization of the convective systems and main features of precipitation are assessed by means of high-resolution quantitative precipitation estimates (QPEs) derived from radar and rain-gauge observations. QPEs, flood response from stream-gauges and postflood field observations are used in combination with a fully-distributed hydrological model to unravel the main hydrological processes and catchment dynamics. Finally, the hydrological and social response times in the course of this event are compared in order to examine whether current techniques for flash-flood forecasting, monitoring and warning issuance meet the needs of the population at risk. With this information at hand, stakeholders in charge of the development and implementation of flash flood risk management strategies could respond more effectively to the demanding challenge of local adaptation to these natural hazards.

P5.6. CO2 monitoring through pigeon-borne miniaturized sensors: the case study of Rome (Italy)

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The deterioration of air quality is today a source of growing concern due to the implications on human health and ecosystems, especially in metropolises and high-density built-up areas, where an ever-increasing fraction of the global population resides. In addition to greenhouse gases and atmospheric pollutants, such as atmospheric particulate matter, benzene, and nitrogen oxides, regulated by international protocols, carbon dioxide (CO2) has recently been included among the gases responsible for climate change, with serious consequences for human health. In urban areas, the concentration of CO2 is traditionally monitored by ground-based, point stations, the measures of which cannot be considered as representative of the entire Planetary Boundary Layer (PBL), i.e., the layer of atmosphere closest to the ground. In this context, atmospheric monitoring through small, dedicated air samplers attachable to birds freely moving in the urban environment might represent an innovative technique. The use of birds could be convenient, especially in cities, where the use of drones and the release of atmospheric probes are restricted and where most of the anthropogenic CO2 sources are located. The development of miniaturized sensors is pushing the frontiers of animal ecology through biologging, i.e., the use of devices collecting data about movement, behaviour, physiology of the animals and the abiotic parameters of the environment in which they move. Here, an innovative miniaturized active air sampler wearable by free-flying birds is presented and tested. The device consists of a set of calibrated atmospheric sensors for high spatial-temporal resolution measurements of chemical and physical parameters, such as CO2 concentration, atmospheric pressure, temperature, and relative humidity. Such devices were applied to homing pigeons to carry out measurements within the urban PBL. A field campaign, carried out from January to June 2021, involved the repeated release of homing pigeons from downtown Rome (Italy), to sample the air on their way back to the loft, located in a rural area out of the city. During their homeward journey, the birds were flying at variable altitudes across areas with different degrees of urbanization. A negative relation between CO2 levels and distance from the release point, month, and time of day was found, together with a positive relation with relative humidity and air temperature. The results highlight the importance of green urban areas in decreasing CO2 levels and suggest the potential of using free-flying birds as new tools for collecting atmospheric data to include in meteorological and climatic models.

P5.7. Application of the Weather Research and Forecasting model to the investigation of the time evolution of buildings cooling energy demand in Italy

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The increasingly hot and long summers due to the climate change are causing a significant increase in energy demand for cooling systems. The geographical features of Italy, extending in the Mediterranean Sea, make it a representative case study in terms of the evolution of energy demand for cooling buildings in the framework of the climate change. The cooling energy needs of buildings are proportional to the Cooling Degree Hours (CDH26), defined as the cumulative sum of the positive differences between the hourly outdoor temperature and the indoor comfort temperature (equal to 26°C in Italy according to the national regulations). This quantity is computed here using gridded air temperatures simulated by the Weather Research and Forecasting (WRF) model for the past, the present and the future based on initial and boundary conditions provided by a proper dataset. Two "Representative Concentration Pathways" (RCP) scenarios of the Intergovernmental Panel for Climate Change are applied, namely the intermediate RCP4.5 and the high emissions scenario RCP8.5. Results are analysed both with a mapping approach over the entire Italian territory and with a local approach for three cities located at different latitudes. The cases 2050-RCP8.5 and 2080-RCP4.5 manifest similar amounts of CDH26. The increase in the maximum level of CDH26 is higher in the recent past than in the future, even according to RCP8.5. From a geographical point of view, southern coastal areas together with the Po valley and the big cities will be affected by a significant increase of the cooling demand for buildings.

P5.8. A new framework for the identification and characterization of thermo-hygrometric stress events

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Several weather variables other than ambient temperature, namely wind speed, relative humidity, solar radiation, together with personal factors (i.e., clothing), influence human thermal sensations. Therefore, events characterized by severe thermo-hygrometric conditions need to be identified and investigated similarly to the heat waves and other weather extreme episodes. In this work, a new framework for the detection and characterization of thermo-hygrometric stress events is proposed. It is based on the rearrangement of indices typically involved in the identification of heat waves and on the Mediterranean Outdoor Thermal Comfort Index (MOCI), the latter being considered as the reference variable instead of the air temperature. A thermo-hygrometric stress event is defined as "a period of at least six consecutive days characterized by maximum daily values of MOCI always above the comfort threshold of 0.5" and is described in terms of frequency, intensity, duration, and cumulative values of temperature and MOCI. The summer of the year 2022 in Milan (Po valley, Italy) is used as a case study for the application of this framework since it is recognized as the hottest in the control period (1991-2020) and presents much higher minimum temperatures than those of the reference period. Results confirm the key-role of temperature in the occurrence of the severe MOCI events, as the indices in 2022 are comparable to those of other years characterized by analogous values of the maximum air temperature. On the other side, a cumulative daily MOCI higher than zero only occurs during 2022. Such findings emphasizes the relevance of the cumulative thermal and thermo-hygrometric loads and the associated "recovery conditions" for the human body.

P5.9. Micro-climate assessment of pilot areas through an installed meteorological network on Andros Island, Greece

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Here we present the preliminary results of the LIFE-TERRACESCAPE project. This project aims to demonstrate, at the Aegean island of Andros, the use of drystone terraces, a prominent element of the Mediterranean landscape, as green infrastructures resilient to climate change impacts. Therefore, selected sites were re-cultivated with barley. A network of twelve ‘small’ autonomous stations and two 2 fully automated online stations were installed on Andros, recording several meteorological parameters (i.e., temperature, humidity, precipitation, wind speed) at selected project plots. We assessed at the demonstration areas that experienced project interventions (renewed cultivation of abandoned terraces), if the anticipated improvement of air humidity (i.e. increase compared to non-intervention sites) and air temperature (i.e. decrease compared to non-intervention sites) is detectable. To this end, changes in air temperature and relative humidity between weather sensors at locations that did (not) experience project interventions were examined. The preliminary data and analyses suggest that terrace cultivation may help decrease the negative (direct) impacts of climate change, through decreasing local temperatures during heatwaves (days with very high temperature). Heatwaves will become more frequent in the future in the Aegean area, rendering this a key finding supporting the use of terraces as green infrastructure to combat the impacts of climate change. The benefits of terrace restoration are likely felt progressively over time, depending on the total extent of restored areas. The meteorological network will continue to provide base-line meteorological information that will be of crucial importance for future monitoring in the context of the “after-LIFE” program.

P5.10. Climate indices and return period analysis to assess the long-term impact of climate change on olive crops in Peloponnese, Greece

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Olive tree cultivation is the hallmark of the Greek food system. The objective of this study is to employ climate indices and return period analysis to investigate the long-term effects of climate change on olive crops in Peloponnese Region, one of the most important olive growing areas in Greece. Return periods of bad years in terms of olive yield along with i) threshold-based temperature related indices (SPR32, SU38, SU40) and ii) mean temperature and precipitation related climate indices (SPRTX, WINRR) are being calculated for the reference period 1971-2000 and for the near (2031-2060) and distant future (2071-2100) using an ensemble of three Regional Climate Models. The future projections were based on two IPCC emission scenarios i.e. RCP4.5 (moderately ambitious mitigation policies) and RCP8.5 (unambitious mitigation policies). Observational data from a representative meteorological station has been used for the validation of the model data. Robust increases of the threshold-based indices are found in all the lowland areas, while the mean temperature related index is projected to increase uniformly throughout the whole Peloponnese. Winter precipitation, which is strongly related to the expected olive yield, is projected to decrease by almost 20% in the distant future in Western Peloponnese and consequently the occurrence probability of bad years in terms of olive yield is found increased as well, pointing out the challenges for the olive sector in Greece due to climate change.

P5.11. Future projections of wet-snow frequency and sleeve load on overhead high voltage conductors over italy

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RSE S.p.A.

Heavy snowfalls represent some of the most serious hazard for transmission and distribution grids because they trigger the formation of sleeves on overhead power lines whose loads may cause outages and, consequently, prolonged disruptions of the energy supply. In order to provide useful information for planning and decision making to cope with wet-snow impacts and strength the resilience of the Italian Transmission Network, some future climate projections about the occurrences of wet-snow events and the related ice-sleeves loads on overhead power lines have been elaborated for 20-year periods until 2100 by using 12 high-resolution Euro-CORDEX models (spatial resolution of ~12km) under the two different emission pathways RCP8.5 (without mitigation) and RCP4.5 (with moderate reductions of greenhouse gases emission). In addition, the reanalysis dataset MERIDA has been used to bias-correct the climatic models as well as to implement a methodology aimed to elaborate climatic wet-snow scenarios, referring to Makkonen model. The results have been validated with sleeve loads data observed in the WILD station at Vinadio (Italy) and by considering the recorded failures in energy supply during some serious wet-snow events in Italy. Referring to Extreme Value Analysis, probability maps of sleeve loads exceeding some infrastructural hazard thresholds have been estimated by means of the "Generalized Extreme Values" distributions, assuming a stationary climate in each timeframe. To highlight the importance of non-stationarity in extremes analysis, the outcomes have been compared with two frequency indices calculated directly from the models' outputs for each timeframe. Lastly, an analysis of meteorological conditions and wet-snow loads has been carried out in some specific sites. The results point out relatively complex patterns of climate change effects: wet-snow events will generally decrease in frequency and intensity at medium-low altitudes, as rainfalls will prevail over snowfalls due to global warming. But, at the end of the Century in RCP4.5, they may intensify over elevated Apennine and Alpine regions so far spared because of their historical cold temperatures, whereas RCP8.5 projections highlight a sharply reduction of the phenomena, except for the highest Alpine mountains. Extreme Value Analysis scenarios and those computed by frequency indices confirm these trends, whose significance was verified by applying the Wilcoxon tests and investigating the model agreement.

P5.12. Analysis of Universal Thermal Climate Index in Croatia for extreme events

Ines Muić

Croatian Meteorological and Hydrological Service

Due to global warming, extreme events increase in frequency and intensity. One of those extreme events are cold and heat waves which affect people causing increased mortality and morbidity. Croatian Meteorological and Hydrological Service (DHMZ) must organize and ensure early warnings of heat and cold waves to reduce the risk and protect the population. To improve heat wave and cold wave forecasts and warning systems, DHMZ analyzed several thermal comfort/stress indices and implemented them operationally in test mode. Although there is no agreement on single comfort or physiological strain index to be used, Universal Thermal Climate Index (UTCI) is well-accepted worldwide. It integrates contemporary science to simulate the human response (physiological stress) to meteorological conditions by a sophisticated model. The UTCI is calculated for the domain over Croatia for the selected cases of a heat wave, a cold wave but also for strong wind episodes, such as local bora and jugo wind. Local bora and jugo wind can reach gale wind speeds and affect human health differently. The meteorological data used for the calculation of UTCI and other thermal indices are hourly NWP model ALADIN-HR output values of air temperature, relative humidity, wind speed and mean radiant temperature. The UTCI values are compared with other thermal comfort indices which are operational in DHMZ (Thermal comfort index) and show good agreement. Results for the cases of strong wind show UTCI sensitivity to the wind.

P5.13. Investigating the impact of environmental factors on hospital admissions for cardiovascular and respiratory diseases: A Machine Learning approach

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The aim of this study is to examine the correlation between environmental factors and hospital admissions for cardiovascular and respiratory diseases. To accomplish this objective, a database of daily emergency room admissions at the Giovanni XIII Polyclinic in the city of Bari (Southern Italy) was employed, including data on weather and air pollution. The data refers to a 10-year period from 2013 to 2021. Using a supervised machine learning model, obtained through a Random Forest algorithm, it was possible to obtain a reliable model in simulating the trend of hospital admissions for cardiovascular and respiratory diseases over time. Both the metrics adopted (an R2 of 0.97 for cardiovascular and respiratory diseases and a MAE of 0.36 for cardiovascular and 0.18 for respiratory) and the error analysis confirmed the validity of the proposed approach. Additionally, the use of cross-validation allowed to avoid overfitting phenomena. Finally, the Explainable Artificial Intelligence (XAI) techniques applied to these models allows not only to determine which environmental variables are most influential to simulate admissions for cardiovascular and respiratory diseases, but also which range of values are able to influence the phenomenon the most. Further elaborations involve identifying the most relevant weather and air pollution variable ranges that determine peaks of cardiovascular and respiratory diseases to an optimal management of emergency room admissions.

S6. Statistical and AI-based methods

Invited talk: Towards a Machine Learning system of sea level in the Northern Adriatic

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Coastal environments are exposed to rising extreme sea levels in view of climate changes. Prediction systems, able to identify extreme events such as storm surges that could potentially lead to flooding or property damage, have become fundamental tools for taking preventive measures in face of extreme events. Machine Learning (ML) is at the forefront of the research in this sector, as it can provide an efficient way to model coastal hazards, thanks to its ability to quickly capture complex patterns within large datasets. In this line, different authors have reported results for the prediction of oceanographic variables using ML approaches, mainly for significant wave height, sea level and surge component of sea level. Generally, these works use global and/or regional databases as training data for ML tools. The objective of this work is the development of a data-driven system for sea level downscaling, trained with the output of very high-resolution circulation models. Therefore, the results of a long-term numerical modeling of sea level are presented, carried out in the Northern Adriatic. We implemented the SURF-SHYFEM system, a 3-D finite element hydrodynamic model that solves the primitive equations under hydrostatic and Boussinesq approximations. As atmospheric forcing, mean sea level pressure, and meridional and zonal components of wind speed have been included, both from the ERA5 database. For the boundary conditions, sea level has been considered from two databases, the Copernicus Mediterranean Forecasting System (available from November 2020 to present, with tides included in sea level) and the Copernicus Mediterranean Sea Physics Reanalysis (available from 1987 to June 2021, without tides in sea level). Both databases were used for initial analysis in the representation of surge components of sea level, comparing the results when tides are or are not included. The validation of the results has been carried out by comparison with tide gauges located near the Venice Lagoon, from ISPRA and PSMSL. The results show that the model reproduces accurately the sea level (correlation 94% and RMSE 0.09 [m]) and the surge component of sea level (correlation 91% and RMSE 0.06 [m]) measured at the location of the tide gauge. The next step will consist of using such output as a training set for ML-based techniques, with the aim of developing an accurate and cost-effective downscaling tool.

O6.1. Physically driven wind field spatial interpolation

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University of Genova

Having weather forecasts more and more accurate and reliable has always been the biggest challenge in meteorology history. The impact of improved forecasts is immediately felt in the field of renewable energy generation, which needs accurate forecasts to manage power plants and the amount of energy sold on the energy market. Model calibration technique is the most powerful way to deal with this issue. Calibrating a model means the statistical process through which past observed data at station are used at level of post-processing to align model predictions and observations. In my research, the attention has been focused on the 10-meter wind speed (ws10). The goal of this work is to create an interpolation/regionalization algorithm, capable to correct not only the output of a Numerical Weather Prediction (NWP) model in specific grid points but to extend the procedure also in grid points where no past observations are available. Our algorithm is entirely physically driven and based on the fact that the the spatial structure of predictions correlates well with that of observations. In fact, using hourly data taken from the European hindcast model ERA5, choosing a target station, the most correlated stations with the target one, from the point of view of predicted ws10, are used to build and tuning a Machine Learning (ML) model (Neural Network or Random Forest) trained to predict the predicted ws10 of the target. Once the ML model is trained, the prediction is done by changing the features of predicted ws10 with those observed. This strategy shows superior results with respect to other tested observed ws10 interpolation techniques, that is Inverse Distance Weighted (IWD), Support Vector Machine (SVM), k-Nearest Neighbor, and Kriging. Moreover, Skill Scores (SS) with respect to ERA5 model show better performance in more than 70% of the cases.

O6.2. Improving forecast of precipitation extremes with machine learning

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The correct prediction of intense precipitation events is one of the main objectives of operational weather services. This task is even more relevant nowadays, with the rapid progression of global warming which makes these events intense in some climatic regions, like the Mediterranean. Numerical weather prediction models have improved continuously over time; however, a precise precipitation forecast is still challenging. Machine learning in this context could be very helpful in complementing the forecaster's experience with systematic knowledge of previous situations over a long period. In addition, it can help, with an appropriate diagnostic, to convey the underlying physical processes which make a meteorological event extreme. In this work, we describe a specific post-processing chain, based on a random forest pipeline, specialised in recognizing favourable synoptic and large-scale conditions leading to precipitation extremes and subsequently classifying the type of the predicted event. The application, focuses on northern and central Italy, taken as a testbed region. The choice of predictors is based on previous work done by the authors plus an innovative part on non-local predictors accounting for spatial composite patterns in the Euro-Atlantic region associated with precipitation extremes in our target region. We show that, with a long enough training period (last 20 years of ECMWF reforecast), the optimal blend of larger scales information with direct model output improves the forecast accuracy of extremes, especially in the medium-range.

O6.3. Deep Learning for nowcasting radar-derived sea surface currents

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Obtaining accurate forecasts of sea currents is a problem of paramount importance in many respects ranging from coastal management to civil protection activities. Short-term forecasts, the so-called nowcasting, are also useful because of their role to reduce the impact of natural disasters and other hazards on the population, thus, ultimately, saving lives. Our focus here is to propose a new data-driven AI-based strategy to predict sea-surface currents (direction and magnitude) for a time-horizon of six hours (hourly frequency). Our nowcasting strategy is based on HF-radar observations, collected in the Ligurian sea in the period 2018 - 2019. The AI architecture uses convolutional (CNN) and convolutional LSTM (ConvLSTM) modules inserted in an Encoding – Forecasting architecture, also known as UNet. The convolutional and recurrent layers are stacked repeatedly in the encoding and forecasting part of the model. The encoding network analyses spatiotemporal patterns of past data to generate latent vectors, and the forecasting network uses latent vectors of the encoding network to forecast future sea currents. An enhancement of the forecasting performance has been obtained by introducing the Bidirectional (ConvLSTM) layer in which two sets of hidden and cell states are maintained for each LSTM cell: one for a forward sequence and the other for a backward sequence in time. The Bidirectional (ConvLSTM) can thereby access long-range context in both directions of the time sequence of the input and thus gain a better understanding of the entire sequence. In order to train the model, the input is made by sequence of regular grids of 2 km X 2 km, with 16 cells per side, where in each cell u and v components of the sea current velocity are stored, with hourly frequency. Then, the objective is to forecast a new sequence, with hourly frequency, of the u and v components of the sea current up to six hours. The predicted current fields have been compared with the ground truth in terms of statistical indices, such as Normalized Root Mean Square (NRMSE) and Pearson correlation coefficient, by looking at the u and v velocity components, vorticity, divergence, and strain rate tensor. The results are promising, and have been compared with predictions from a base model, such as the persistence, showing skill scores of the statistical indices considered up to 25%.

O6.4. Evaluation of Kalman Filter based post-processing methods: focusing on the coastal region of Croatia

Ivan Vujec, Iris Odak Plenković

Croatian Meteorological and Hydrological Service

Analog-based methods have already shown good results in improving the NWP for point-based forecasts of temperature and wind speed and are thus implemented at the Croatian Meteorological service. Similarly, the algorithm based on the Kalman Filter (KF) shows potential for further forecast improvement if real-time measurements are available, especially when combined with the analog method. After the optimal parameters of the KF algorithm are found, several variations of the KF-based forecast are verified, with a special focus on the coastal area. The four forecasts presented in this work are KF (KF applied to the raw NWP time series), KFAN (KF applied to the simple analog method time series), KFAS (KF applied to NWP forecasts in analog space), and KF-KFAS (KF applied to the KFAS time series). The analog-based forecast is generated with optimal predictor values and additional correction for extreme values. The raw NWP model used is the ALADIN model with a 2 km horizontal resolution. The KF variations reduce the overall RMSE by simultaneously improving the correlation and reducing systematic errors. The KFAN and KF-KFAS forecasts show the best results overall. Nevertheless, the other KF variations have specific advantages. The benefits of including the KF algorithm in the post-processing chain are evident even for rare and more extreme events. Finally, although the results for the coastal area somewhat differ from those obtained for other terrain types, it is evident that including the KF algorithm in the forecasting process shows a great potential for the implementation in the operational suite.

P6.1. Towards a machine learning based multimodel for precipitation forecast over the Italian peninsula

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Direct model output forecasts by Numerical Weather Prediction models (NWPs) present some limitations caused by errors mostly due to sensitivity to initial conditions, sensitivity to boundary conditions and deficiencies in parametrization schemes (i.e. orography). These sources of error are unavoidable, and atmospheric chaotic dynamics make prediction errors spread rapidly in time in the course of the forecast, inducing both systematic and random errors. Nonetheless, in the last 50 years, NWPs had a significant decrease in the impact of these sources of errors, even in the long-term forecast, thanks for instance to an ever-increasing computational capability, but their relevance is still not neglectable. Moreover, different NWPs present specific different pros and cons which are findable empirically. For instance, in the case of precipitation forecast in north-west Italy, low-resolution models (e.g. ECMWF-IFS) are more reliable in terms of space and time in predicting the average precipitation, while high-resolution models (e.g. COSMO-2I) tend to forecast better the maximum precipitation. Research purposes apart, actual limitations must be seen in an operational context, where weather forecasts' skillfulness and associated uncertainty are information of the utmost importance to the forecaster and in general to the user of a certain forecasts system. To tackle these limitations of NWPs and the need for an uncertainty-quantified meteorological forecast, we propose a machine learning-based multimodel post-processing technique for precipitation forecast. We focus on precipitation since it is the most important variable in the issue of spatially localized weather alert notice by the Italian Civil Protection system and at the same time it is one of the most challenging variables to forecast. We use a Convolutional Neural Network (CNN) to obtain deterministic and probabilistic forecast grids over 24h up to 48h focusing on North-West Italy, using several high and low-resolution deterministic NWPs as input and using high-resolution rain-gauge corrected radar observations for the training. The effect of different convolutional parameters (e.g. stride, padding) is taken into account. The deterministic output grid is chosen as the grid with the lowest mean square error obtained during the training, and it is compared with the linear regression of the input NWPs and with every single model. The probabilistic output grid is generated by considering the statistical ensemble of the twenty grids with the lowest mean square error obtained during the training, and it is compared with the logistic regression of the input NWPs and with ECMWF-EPS as a benchmark, both at different precipitation thresholds.

P6.2. Assessing the impact of Machine Learning on WRF-based lightning forecasts over a wind farm in Balıkesir, Türkiye

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Buluttan Meteorology & Technology

Lightning is a hazardous meteorological phenomenon that is hard-to-predict and is typically formed in an unstable atmosphere. It can damage electronic structures in wind turbines, resulting in loss of production and requiring maintenance delays to ensure safety. Although the precise location of lightning cannot be forecasted, atmospheric conditions can provide clues as to potential areas where lightning may occur. This study aims to detect potential areas of lightning over a wind farm located in Balikesir, Turkey. The Weather Research and Forecasting Model (WRF) was used to downscale the time resolution of GDAS analysis data to 10-minute intervals for the whole time period of 2020-2021. Simulations were conducted using a single-domain configuration with four different parameterization sets at a resolution of 0.25°. Correlation coefficients and confusion matrices were calculated to compare the results with lightning observations obtained from the Turkish State Meteorological Service (TSMS). The simulation outputs were also improved using machine learning by adding upper level atmospheric variables into the algorithm as a feature to add the insight of atmospheric instability. The outputs of the machine learning-enhanced forecasts were also compared to the observations. The preliminary results indicate that precision varies by season, and the machine learning outputs have higher correlation coefficients compared to the raw simulation outputs.

P6.3. Evaluation of the analog-based wind speed forecasts during strong wind episodes in the coastal region of Croatia

Ena Kožul, Iris Odak Plenković, Ivan Vujec

Croatian Meteorological and Hydrological Service

In the coastal region of Croatia, wind speed often reaches gale values during the bora and jugo wind episodes and can cause damage to people and property. Thus, the need for correct and timely wind speed forecasts is evident. At the Croatian Meteorological and Hydrological Service, besides the raw wind speed forecasts calculated using the operational model ALADIN-HR, we use the analog-based method for point-based post-processing. Two variations of the method are presented: the one with optimized predictor weights (AnEnT) and the other with both optimized predictor weights and correction for high wind speed (AnEnK). The optimization process quantifies the impact of each predictor variable on the similarity search process in the analog method, leading to better analogs. Additionally, since the post-processing methods can be prone to underestimate extreme events, the correction for high wind speed is added to AnEnK forecast when raw NWP forecast exceeds a certain value. For the cases tested, the large errors occur mainly due to short-term weakening of the wind-speed within the strong wind episode, or because of the time delay of the beginning or the ending of the forecasted strong wind episode. The results show that the AnEnT and AnEnK methods outperform raw NWP in general, as well as for various range of cases. Finally, during the episodes of strong bora and jugo wind, the AnEnK method often brings the predicted values closer to the observed ones, thus fulfilling the main goal of correction applied.

P6.4. Predictability of the 2022 extreme summer at seasonal scale

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This past summer, Europe experienced an extreme and long-lasting heatwave, with record-breaking temperatures in most regions. Extreme events such as heatwaves are becoming more frequent, intense and more lasting in a warming climate. Even though studies on the detection and characterization of extreme events in Western Europe are numerous, little is known about the predictability of these events. By studying the intrinsic predictability of an extreme event, we can know the capacity we have to anticipate it, thus being able to take action for the minimization of its impacts by using early warning systems. Climate information on the most predictable or unpredictable atmospheric configurations can be understood by using two properties of the underlying attractor: persistence and local dimension. These two parameters have been shown to be good proxies for intrinsic predictability. In this work, we show first an overview of the summer 2022 extreme heat event using ERA5 reanalysis. We assess the seasonal predictability and forecasts, and, finally, we discuss the potential of specific indices to characterize the heatwaves in two regions: Europe and South Europe.