From evaporation to precipitation:
the atmospheric moisture transport

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ORAL COMUNICATIONS

SENIOR LEONARDO LECTURE 2016

What water vapor back-trajectory analysis can tell us about climate variability

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ABSTRACT

The Quasi-Isentropic Back Trajectory (QIBT) scheme traces sources of atmospheric water vapor that supply precipitation back to their regions of origin as surface evaporation using observational data and/or reanalyses. A probability distribution of evaporative sources for precipitation can be estimated for any location and time period. These probability distributions vary significantly across the annual cycle for most but not all locations, and they have substantial interannual variability for many locations. Such variations can be used as indicators of how circulation and remote conditions affect precipitation, and furthermore the effects of local atmospheric and land surface conditions on rainfall can often be implied. For instance, a key factor for many floods is the anomalous supply of evaporated moisture from remote oceanic sources, carried onto continents by so-called "atmospheric rivers" and other advective features. These and other key features of climate variability linked to atmospheric moisture transport will be discussed.

Keywords: atmospheric water vapor, Quasi-Isentropic Back Trajectory, climate variability.

YOUNG LEONARDO LECTURE 2016

On the role of evaporation during droughts and heatwaves

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ABSTRACT

Although the importance of land evaporation for hydrology and agriculture has long been recognized, its crucial role in climate has only been highlighted in recent years: (a) its high sensitivity to changes in radiation and temperature implies that anthropogenic emissions have an important impact on the global water cycle, (b) it plays a central role in critical processes such as the water vapour and cloud feedbacks, and (c) its coupling to photosynthesis connects the water and carbon cycles. Additionally, evaporation regulates climate through a series of land feedbacks acting on air temperature and precipitation that affect climate trends and hydro-meteorological extremes, like droughts or heatwaves. These land feedbacks originate first from the impact of drought and heatwaves on evaporation. The combination of rainfall deficits and increased atmospheric demand usually leads to an unequivocal decline in soil moisture (i.e. agricultural drought), and hydrological systems (i.e. hydrological drought). However, the impacts on evaporation are not unequivocal, since evaporation may temporarily increase while soils are still wet – accelerating soils' dry-out – and then decline as soils dry below a certain threshold. The decline in evaporation during droughts and heatwaves may reduce atmospheric humidity content and increase sensible heat fluxes, potentially suppressing subsequent rainfall and increasing air temperatures. In contrast, the extra convection triggered by the rise in sensible heat flux as evaporation is reduced may lead to convective storms. These processes ultimately depend on land cover and atmospheric boundary layer dynamics.

In this presentation, I will investigate the impact of recent droughts and heatwaves on evaporation at large scales using satellite data. In addition, local and teleconnected land feedbacks on precipitation and temperature during these extreme events will be analysed, using atmospheric boundary layer and vapour trajectory models. Results will contribute to further our understanding of how evaporation regulates land-climate feedbacks during climate extreme events and what the role of these feedbacks is in their occurrence.

Keywords: evaporation, heatwave, drought, soil moisture, land-climate feedback.

L01- Constraining the Sources and Transport History of Atmospheric Water Vapour in Models

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ABSTRACT

Model simulations of the atmospheric water cycle contain many components that, due to lack of observational constraints, are difficult to validate. Advanced moisture diagnostics allow the extraction of properties such as moisture origin, lifetime and transport distance from model simulations. During precipitation extremes, these quantities can provide insight into the dynamical contributions that amplify an event. However, atmospheric moisture transport pathways and processes are primarily model diagnostics and dependent also on model resolution and parameterisations. A comparison of two complementary approaches to diagnose moisture transport properties for selected events is presented. The Lagrangian diagnostic based on backward trajectories agrees well with the results from the Eulerian method based on water tracers in a regional model. This underpins the validity of the transport scales of water vapour, namely the atmospheric moisture residence time and the transport distance for a particular data set. In order to tie both model diagnostics to reality, stable water isotopes can be employed. The direct interpretation of stable water isotopes is however often complicated by the fact that they represent the integrated atmospheric transport history of water vapour. Using airborne field data from the recent HYMEX campaign in the Mediterranean it is outlined how stable water isotopes can support the interpretation of model-derived scales of water vapour transport.

Keywords: Moisture sources; Water vapour transport; Stable isotopes; Recycling.

L02-The Residence Time of Water in the Atmosphere and Contrasting Roles of Interception and Transpiration

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ABSTRACT

This research revisits the state-of-the-art knowledge on the residence time of water in the atmosphere. Based on state-of-the-art data of the hydrological cycle we derive a global average residence time of 8.9 ±0.4 days (uncertainty given as one standard deviation). The 1th and 99th percentile of this estimate are 7.9 and 9.8 days respectively.

We use two different atmospheric moisture tracking models to obtain atmospheric residence time characteristics in time and space. We apply both forward tracking of evaporation and backward tracking of precipitation. With the Eulerian moisture tracking model WAM-2layers, forced with ERA-Interim, we calculate both the amount and age of tagged water. From these calculations we derive global spatial maps of residence time, attributed to evaporation and precipitation, and we show a movie of atmospheric water age. With a 3D-Lagrangian water particle tracking method, also forced with ERA-Interim, we analyze the probability density function of the atmospheric residence time of evaporated water particles. We find a long-tailed distributions, which show that the median residence time is much lower than the mean.

Replacing the evaporation field with output from the large scale hydrological model STEAM we separately track direct (interception, soil moisture) and delayed (transpiration) components of evaporation through the atmosphere. Direct evaporation is found to have atmospheric residence time of 8 days, while transpiration typically resides 9 days in the atmosphere. We find lower residence times in the tropics compared to the temperate and boreal zones. Over the ocean the residence time is about 1 day lower than over land.

With both moisture tracking models using ERA-Interim data the global mean residence time is around 9 days. We conclude that a recent study, claiming the global average residence time of water in the atmosphere to be 4-5 days, is not correct. In fact, our research confirms the more traditional estimate of 8-10 days.

Keywords: residence time, atmosphere, hydrological cycle, evaporation, precipitation.

L03: A Novel Mathematical Framework for Analysis of Numerical Water Tracers and the Aerial Moisture Source-Sink Relationship

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ABSTRACT

Aerial moisture transport is fundamental to the climate system, and numerical water tracers (WTs) are a powerful tool for understanding this transport. Here, we present a novel matrix operator framework that permits systematic, rather than ad hoc, analysis of WT results. We use this framework to study moisture transport, from evaporation (or sublimation) to precipitation, in a state-of-the-art global climate model (GCM) which incorporates WTs. This framework separates moisture divergence over a given tagged region into local divergence (the export of locally-evaporated moisture) and remote convergence (the import of remotely-evaporated moisture). The remote convergence term may be further subdivided into zonal, meridional, intrabasin, and interbasin parts, and can also be used to predict precipitation given a particular spatial pattern of evaporation.

Many of the findings from analysis of the preindustrial mean state concur with findings from earlier moisture transport studies. New insights from the method reveal fundamental differences between the major ocean basins, with the Atlantic basin having the largest local divergence, smallest remote convergence, and greatest interbasin moisture export.

With quasi-equilibrium CO_2-doubling, we find that a greater fraction of locally-evaporated moisture is exported, moisture exchange between ocean basins increases and moisture convergence within a given basin shifts towards greater distances between moisture source and sink regions. These changes can be understood in terms of a greater moisture residence time with warming, or, equivalently, a robust increase in the advective length scale of moisture transport. We conclude by discussing the effect of the increasing atmospheric moisture transport length scale on ocean state, and implications for the interpretation of water isotope records.

Keywords: Mathematical Methods, Moisture Source-Receptor Relationships, Aerial Hydrological Cycle, Numerical Water Tracers, Climate, Climate Change.

L04: Global Atmospheric Moisture Budget

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ABSTRACT

The seasonal global atmospheric moisture budget (precipitation minus evaporation) was calculated using the National Centers for Environmental Prediction (NCEP)—National Center for Atmospheric Research (NCAR) reanalysis data for the period 1949–2012. In this study, the atmospheric moisture budget equation proposed by Trenberth and Guillemot (1995) which was derived from the equation of state, the hydrostatic equation, and the continuity equation was used. We focus on mid-season months (January-April-July,October) circulation patterns for explaining the moisture sources and changes in atmospheric moisture conditions. The atmospheric eddy moisture fluxes and its convergence were also investigated to show the contribution of eddies to the atmospheric moisture budget.

Keywords: Global; Atmospheric Moisture Budget; Moisture Flux; Convergence.

L05- Global changes in relative humidity: connection with climate trends, humidity sources and moisture transport processes

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ABSTRACT

Climate models and observations suggest that atmospheric humidity is increasing as a consequence of warmer air temperatures according to the Classius-Clapeyron relationship. In addition, given unlimited water availability in oceans it is suggested that relative humidity (RH) would remain constant. Nevertheless, recent global and regional studies have pointed out that RH may be decreasing in large areas of the world, and there are different hypotheses that could explain the possible decrease in RH as related to changes in: (i) the atmospheric circulation and moisture transport processes; (ii) precipitation; (iii) air vapour saturation given different warming in lands and oceans; etc.

In this study we analyse changes in RH observed at the global scale for 1979-2014. For this purpose we have used 3462 stations across the world from the HadISDH data set. RH data have been also calculated from daily records of specific humidity, air pressure and air temperature from the ERA-Interim Reanalysis data set. The comparison results between observations and ERA-Interim show a strong agreement in the spatio-temporal variability and magnitude of trends of RH.

In this research we have also analysed the relationship between the variability and changes in RH, precipitation and air temperature at the global scale, concluding that the observed spatial patterns of RH are not well explained by the observed changes in precipitation and air temperature. However, when de-trending RH, precipitation and air temperature series, it is finding that the temporal variability of RH is mostly controlled by precipitation whereas the trend is more determined by air temperature trends.

To improve the knowledge of the possible drivers of the observed trends in RH, we have selected 16 representative areas that showed a different temporal behaviour and applied a Lagrangian model (Flexpart). This has served to identify the humidity sources corresponding to each region, and to know the behaviour showed by Sea Surface Temperature (SST) and the evolution of oceanic and continental evaporation. The results show high variety of conditions globally but the observed trends of RH in some of the analysed regions may be related to the water evaporation and the difference between air temperature and SST in the oceanic source region.

Keywords: atmospheric humidity, atmospheric evaporative demand, ERA-Interim, Flexpart, trends.

L06- Factors influencing regional precipitation variability attributed using an airmass trajectory method.

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ABSTRACT

Using a Lagrangian framework, this work attributes monthly precipitation variability to physical processes. The precipitation variability is partitioned into a combination of 5 factors: air mass origin location, origin surface temperature variation, ascent intensity, mass of ascending air and the number of `wet' analysis

times per month (>1 mm/6hrs). The moisture content of air masses is calculated along trajectories, linking precipitation in a target region to `origin' locations of air masses where the water vapour mixing ratio was last set by boundary layer moistening and is a maximum along back trajectories.

Applying the technique to the England and Wales region, the factors together account for 83-89% of the observed summer precipitation variability. The dominant contributor is the number of `wet' analyses, which is shown to be associated with cyclone statistics. Results will be presented suggesting that the wettest summer months are mainly associated with anomalous cyclone duration rather than the number of cyclones.

In addition, surface temperature and saturation humidity at the `origin' locations are found to be below their climatological averages (1979-2013) for the wettest months. Therefore, the direct thermodynamic effect of anomalous surface temperature on marine boundary layer humidity acts to reduce monthly precipitation anomalies. Changes in cyclone statistics overwhelm the direct thermodynamic factor in both monthly and decadal precipitation variability.

Keywords: Precipitation estimation, Era-Interim reanalysis, natural variability.

L07- Moisture origin and transport processes in Colombia, Northern South America

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ABSTRACT

We assess the spatial structure of moisture flux divergence and its relationship with the subregional precipitation regimes and transport processes over Colombia, in northern South America. We also describe the seasonal moisture transport mechanisms of the well-known low-level westerly and Caribbean jets that originate in the Pacific Ocean and Caribbean Sea, respectively. We find that these dynamic systems play an important role in the convergence of moisture over western Colombia, one of rainiest regions in the World.

Moisture sources that contribute to precipitation over Colombia are identified by using three independent methods: the Dynamic Recycling Model (DRM), FLEXPART and the Quasi-isentropic back-trajectory (QIBT) models. We find that moisture from the Atlantic and Pacific oceans and terrestrial recycling are the most important sources of moisture for Colombia, highlighting the importance of the Orinoco and Amazon basins as regional providers of atmospheric moisture. The results show the influence of long-range cross-equatorial flow from the Atlantic Ocean into the target region, the regional sensitivity to land-surface processes of surrounding basins and the markedly seasonal influence of pacific sources. The intra-annual differences in the moisture amount that each source contributes evidence that this study area behaves as a passage of moisture across Americas in a seasonal time scale.

Keywords: Colombian climate and variability, atmospheric moisture transport processes, recycling and terrestrial moisture sources, oceanic moisture sources.

L08- Variability in moisture transport and precipitation recycling over East Africa

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ABSTRACT

While the climatic characteristics and controlling mechanisms across parts of Africa, notably the Sahel, have been extensively studied, a lot less is known about the climate across the complex terrain of East Africa. In recent decades, East Africa has experienced major climatic changes, in particular, a significant decline in precipitation during the "long rains" (March-May). In addition, the future climate projections of precipitation over East Africa are subject to great uncertainty, hampering policy planning and calling into question the reliability of state-of-the-art climate models. A better understanding of the mechanisms involved in the East African climate variability and change is therefore a necessity.

This study is part of the Future Climate For Africa's HyCRISTAL project that aims to understand the variability and change of the East African hydrological cycle. We exploit several observational and reanalysis products to explore the processes involved in the inter-annual variability and the long-term trends of seasonal rainfall over East Africa, with a focus on precipitation recycling and large-scale atmospheric moisture transport. Our initial findings, based on the ERA-Interim reanalysis, suggest that the recent decline in the long rains may be explained, at least in part, by a reduction in recycled precipitation. Further analyses are underway to test the robustness of this finding for a range of reanalyses and observations.

Keywords: East Africa, climate, variability, moisture transport, recycled precipitation.

L9- Moisture Transport to East Antarctica in Radiosoundings and Reanalyses

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ABSTRACT

East Antarctica's contribution to sea-level rise results from the imbalance between snowfall on the ice sheet and iceberg calving on the coast. Instead of measuring accumulation inland, the input term can be studied upstream as the quantity of moisture entering the domain. Unlike the forbidding plateau, a dozen research stations cover the coast of East Antarctica, many of which run a radiosonde program. The onshore moisture flux is thus directly observed and can then be analysed. In contrast, accumulation is forecasted by reanalyses: it is more model dependent and subject to spin-up problems.

We use quality-controlled radiosoundings from fourteen stations over the 1979-2013 period and seven global atmospheric reanalyses to evaluate the mean moisture convergence into East Antarctica and its variability. The moisture import results from the interplay between transient eddies and katabatic winds, which are particularly sensitive to the orography. While trends from reanalyses are ambiguous, the coastal radiosonde sites have measured significant increases of the southward moisture fluxes.

Keywords: surface mass balance, Antarctica, moisture transport, radiosounding, reanalyses.

L10- The relationship between column water vapor and climatic variables over East Asia in the summer

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ABSTRACT

We investigated the statistical relationships between summer time column water vapor (CWV) and various climatic variables in the East Asia summer monsoon (EASM) using stepwise regression analysis. The sign of the relationships shows strong regional and seasonal dependence. In general, zonal wind removes water vapor content for monsoon-free regions and supplies moist air to monsoon-controlled and transition regions. The sign of the statistical relationship between evaporation and CWV is more relevant to the value of CWV, negative (positive) for regions where CWV is higher (lower) than 340 kg/m^2. Surprisingly, we found the low-level air temperature not necessarily positively related to the vapor content. The statistical relationship between outgoing longwave radiation (OLR) and CWV is quite stable, always negative, in the EASM region.

By using the proportional marginal variance decomposition (PMVD) method, the relevant importance of each climatic variable was estimated. Again, the variable dominating the CWV shows strong regional and seasonal dependence. The moisture removing effect of the westerlies, the drying out, indicated either by OLR or by evaporation, and the moistening effect from evaporation show up as the primary drivers of the vapor content at various locations in different seasons. While recognizing the importance of the Clausius-Clapeyron relation to estimate the water holding capability of the atmosphere, our research calls for a more objective and comprehensive understanding of the causes of water vapour variability.

Keywords: EASM, water vapor, removing effect, moistening effect.

L11- Bridging the gap between thermal remote sensing, physically-based evapotranspiration modeling and ecohydrology: An Ozflux synthesis

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ABSTRACT

Land surface temperature (LST) measured by thermal infrared (TIR) remote sensing provides direct information on soil moisture availability, surface energy balance (SEB) partitioning and evapotranspiration (E). Likewise, the Penman-Monteith (PM) and Shuttleworth-Wallace (SW) models are some of the most preeminent physical models for estimating E and water stress in terrestrial ecosystems. The intrinsic link between the PM-SW model and LST emanates through the first-order dependence of biophysical conductance on LST and soil moisture. However, the use of PM-SW in thermal remote sensing-based E modeling is hindered by the unavailability of direct methods to integrate LST into existing models and due to the lack of physical models expressing biophysical states of vegetation as a function of LST. Therefore, a majority of E modeling approaches strongly rely on surface reflectance and meteorology; whereas thermal approaches require significant parameterization of land surface properties which are very empirical in nature.

To bridge this gap, we present a novel thermal-based biophysical scheme for directly estimating E over terrestrial ecosystems by leveraging the combined strength of LST observations and physically-based models. The Surface Temperature Initiated Closure (STIC) model physically integrates LST observations into a combined PM-SW framework for simultaneously estimating E, sensible heat flux (H), surface and aerodynamic conductances, surface moisture status and E components (evaporation, E_E and transpiration, E_T). STIC consists of a feedback describing the relationship between LST and E, coupled with canopy-atmosphere components relating E to aerodynamic temperature and humidity. By blending LST with standard SEB principles and vegetation - atmosphere exchange theory, STIC formulates multiple state equations to eliminate the need for exogenous parametric submodels of the surface and aerodynamic conductances, aerodynamic temperatures, and land-atmosphere coupling. Performance evaluation of STIC against high temporal frequency (half-hourly) E measurements from 15 OzFlux eddy covariance sites revealed the evidence of strong ecohydrological controls in determining the error structure of the physically retrieved E and H. Errors relative to E observations were substantially smaller than or comparable to those achieved by models that require empirical parameterization of vegetation biophysics and boundary layer dynamics. STIC shows immense promise to capture the extended dynamics of drought over natural systems, as demonstrated across Australia during the drought conditions of recent years.

Keywords: Evaporation, thermal remote sensing, Penman-Monteith, Shuttleworth-Wallace, ecohydrology, Australia.

L12- Estimating surface evapotranspiration based on Remote Sensing and Meteorological data

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ABSTRACT

Evapotranspiration (ET) plays an important role for water resource management in water scarcity areas. Compared to the water balance method or to in situ measurements, an operational integrated monitoring method - ETWatch based on remote sensing data and meteorological data is a potentially useful approach to achieve water saving, which include the radiation improvement based on FY-2 cloud product, soil heat flux models based on remote sensing parameters, aerodynamic roughness length model involved in microwave information, the surface resistance model considering soil moisture, the ABL (Atmospheric Boundary Layer) algorithm based on AIRS temperature and moisture profile product. This paper objective was to present the features of the ETWatch algorithm and its validation over the Heihe River Basin in the Northwest of China. ETWatch was proved to be an operational integrated monitoring method of regional surface ET from remote sensing data, and it can also be expanded to other areas on the globe.

Keywords: Evapotranspiration, Remote sensing, ETWatch, Heihe River Basin.

L13- The influence of local evapotranspiration on deep convection activity during the North American Monsoon season

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ABSTRACT

Various observational data sets available for the period 2002-2015 have been assembled to evaluate the role that evapotranspiration has on the organization of deep convection in the Sonora-Arizona region during the monsoon season (June-September). The approach is to focus on the transitional periods and the peak of convective activity. Cloud top temperatures from IR GOES data, evapotranspiration, precipitation, and soil moisture measurements from several sites in Arizona and Sonora serve to establish case events where the potential to link surface conditions and convective organization at the regional scale is maximized. This observational framework is used to design the numerical experimental set up with the regional atmospheric model WRF. Simulations where aerodynamic evaporation resistance set at very large values to supress evapotranspiration during the organized convection events is compared to control simulations. Preliminary results show some sensitivity to reduced evapotranspiration, suggesting an possible path into how surface water is processed aloft

Keywords: evapotranspiration, soil moisture, regional modeling.

L14- Moisture recycling in Europe: analysis and impact on the precipitation in a changing climate

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ABSTRACT

Land-atmosphere interactions are known to play a key role on climate and are expected to be critical to understand its evolution as a consequence of climate change. These land-air feedbacks are of utmost importance in those regions and periods when the intensity of evapotranspiration is high and, at the same time, controlled by soil moisture availability. In the Mediterranean Basin, the amount of rainfall coming from evapotranspiration over land represents a relevant fraction of the total precipitation in the year. Furthermore, many of these areas are affected by water limitations and are expected to be more sensitive to the impact of climate change along the upcoming decades. In this work, the WRF model, is used to explore 3D land-atmosphere coupling over the different regions within the European CORDEX domain, at 50 km horizontal resolution and for a high resolution domain (9km) over the Iberian Peninsula (IP). We start our analysis by computing the recycling ratio, for the hindcast (1989-2009), through the method of Eltahir and Bras, as a first approach to quantify the intensity of land-atmosphere feedbacks and their impact on the rainfall regime. This method, much more accurate than analytical Integral Moisture Budget recycling models, allows us to explore the spatial distribution of recycling over IP and therefore focus our analysis on the most sensitive regions. Both historical (1971-2000) and future (RCP8.5) simulations (2006-2100) were carried out to assess to what extend climate change may have an impact on land-air fluxes and the subsequent recycling and amplification mechanisms.

Keywords: Moisture recycling, Climate Change, EURO-CORDEX, WRF, land-air fluxes.

Acknowledgments: *The authors wish to acknowledge the projects SOLAR (PTDC/GEOMET/7078/2014).*

L15- Moisture balance over the Iberian Peninsula computed using a high resolution regional climate model. The impact of 3DVAR data assimilation.

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ABSTRACT

A numerical downscaling exercise over the Iberian Peninsula has been run nesting the WRF model inside ERA Interim. The domain covers the Iberian Peninsula with a 15 x 15 km² grid with 51 vertical levels. Two experiments have been run during 2010-2014 after a one year spin-up (2009). In the first experiment (N), boundary conditions drive the model after the initialization. The second experiment (D) is configured as N, but 3DVAR data assimilation is run every six hours (00Z, 06Z, 12Z and 18Z) using observations from the PREPBUFR dataset. Both experiments use the NOAH land surface model.

For both N and D runs, the moisture balance of the model runs has been evaluated over the Iberian Peninsula, both internally according to the model results (moisture balance in the model) and also in terms of the observed moisture fields from observations (precipitable water and precipitation). The verification has also been performed for ERA Interim.

Results show that the leading terms that must be considered are the tendency in the precipitable water column, the divergence of moisture flux, evaporation and precipitation. Both mesoscale model runs close better the moisture balance over the whole Iberian Peninsula than ERA Interim. The N experiment shows a better closure than D because of the lack of analysis increments in it. Both ERA Interim and the D experiment produce a negative residual in the balance equation, compatible with excess evaporation or increased convergence of moisture over the Iberian Peninsula.

The seasonal cycle of evaporation is much closer in the D experiment to the one in ERA Interim, with a higher evaporation during summer months. However, both runs show a lower evaporation rate, particularly during summer months.

Comparing the data with some atmospheric soundings in the Iberian Peninsula, the D experiment reproduces the precipitable water better than ERA Interim and N. The correlation coefficient after removing the seasonal cycle is also better for D experiment. A bias is observed for the N experiment.

Keywords: Atmospheric moisture, WRF model, Iberian Peninsula, Data Assimilation, 3DVAR.

L16- Rankings of widespread extreme dry and wet events on the Iberian Peninsula using the multiscalar SPEI gridded dataset

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ABSTRACT

Extensive, longstanding dry and wet episodes are one of the most frequent climatic extreme events on the Iberian Peninsula. Here, we present a method for ranking regional extremes of persistent, widespread dry and wet events, considering different time scales. The method is based on the multiscalar Standardized Precipitation Evapotranspiration Index (SPEI) gridded dataset for the Iberian Peninsula that incorporates the effect of temperature on dry and wet events assessment. SPEI was computed using the Climatic Research Unit (CRU) between 1901 and 2012 and the Potential Evapotranspiration (PET) was computed through the Penmann-Monteith equation and the log-logistic probability distribution. The ranking classification method is based on the evaluation of the magnitude of an event, which is obtained after considering both the area affected respectively by the dryness or wetness – defined by SPEI values over a certain threshold –, as well as its intensity in each grid point. A sensitivity analyses on the impact of different thresholds to define dry and wet events was performed. A comprehensive dataset of rankings of the most extreme, prolonged, widespread dry and wet periods on Iberian Peninsula is presented, for time scales 6, 12, 18 and 24. Results show that the regions of Iberia more affected during these long-term (dry and/or wet) most extreme events do not present any regional preference. If we consider the entire Iberian Peninsula the largest droughts at the 12-month scale occurred on the years of 2005, 2012, 1945, 1995 and 1999, whilst at the longer 24-month scale the most intense dry episodes correspond to the events of 2004/06, 1943/45, 2010/2012, 2003/2005 and 1993/1995. When considering the most intense wet episodes in the entire Iberian Peninsula at the 12-month scale occurred on 1936, 1969, 1941, 1963 and 2010 while at 24-month scale the most intense wet episodes correspond to the years 1939/1941, 1935/1937, 1958/1960, 1910/1912 and 1961/1963.

Keywords: dry and wet extremes; natural hazards; Iberian Peninsula, Standardized Precipitation Evapotranspiration Index (SPEI); teleconnections.

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L17- Major Mechanisms of Atmospheric Moisture Transport and their Role in Extreme Precipitation Events

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ABSTRACT

The transport of moisture from the oceans to the continents is the primary component of the atmospheric branch of the water cycle and forms the link between evaporation from the ocean and precipitation over the continents. The two major mechanisms of atmospheric moisture transport in the Earth are low-level jets (LLJs) and atmospheric rivers (ARs). A detailed study of the transport by these both meteorological structures could provide us a better understanding of any observed changes and some physical evidence in support of the many available projections of future climates. The knowledge of their structure, geographical distribution, and the role of these mechanisms in the modifications of moisture transport in terms of quantity or linked with changes in their position and occurrence, are the key to understanding the climatological precipitation regional pattern in terms of extreme precipitation or drought. Here we review any of these aspects and do use of a Lagrangian approach to exemplary them in two testing regions.

Keywords: Atmospheric moisture transport, Atmospheric rivers, Low-level jets, precipitation extremes, floods, droughts.

L18- CHOCO-JEX: A Research Programme Focused on the CHOCO Low-level Jet over the Far Eastern Pacific and Western Colombia- First Results

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ABSTRACT

The CHOCO-JEX experiment is investigating the dynamics and thermodynamics of the CHOCO low-level jet and its linkages with the formation of large and frequent Mesoscale Convective Systems over the far eastern Pacific Ocean and inland over the world-record rainy region of western Colombia. CHOCO-JEX is a joint initiative of Universidad Nacional de Colombia at Medellín, the Colombian Air Force, the General Maritime Directorate of the Colombian Navy, and the Desert Research Institute at Reno, Nevada, USA, funded by COLCIENCIAS. The experiment is designed to characterize the seasonal and diurnal cycles through four 8-day intensive observations periods (IOPs) using upper-air soundings (4 times per day) over the Colombian Pacific maritime and costal regions. The first CHOCO-JEX IOP took place during January 2016 on board the ARC Gorgona vessel, coinciding with the regular reconnaissance marine campaign aiming to monitoring El Niño/Southern Oscillation (ENSO) over Colombian coastal waters known as Estudio Regional del Fenómeno de El Niño (ERFEN). Preliminary results of the first campaign showed two distinct low-level air masses over the far Eastern Pacific: (i) a moist, northerly low-level flow, likely related to northerly branch of the Caribbean basin; and (ii) a drier stronger easterly winds immediately above 800 hPa, likely related to the easterly trade winds flow over the Andes in Colombia. Upper-air day-to-day variation show periods of mid-level wet, cool spells related to weakening of the easterly trade winds. In this presentation, we will also show further results of the in-land IOP held during June 2016, contrasting the in-situ, independent observations with analysis and reanalysis products of various resolutions from which some striking differences are observed.

Keywords: Choco low-level jet, precipitation, moisture transport, water cycle, Colombia.

L19- The future evolution of the western Iberian Coastal Low level jet in a warming climate

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ABSTRACT

The Iberian coastal low-level jet (CLLJ) is one the less studied boundary layer wind jet features in the Eastern Boundary Currents Systems (EBCS). These regions are amongst the most productive ocean ecosystems, where the atmosphere-land-ocean feedbacks, which include marine boundary layer clouds, coastal jets, upwelling and inland soil temperature and moisture, play an important role in defining the regional climate along the sub-tropical mid-latitude western coastal areas. Recently, the present climate western Iberian CLLJ properties were extensively described using a high resolution regional climate hindcast simulation. A summer maximum frequency of occurrence above 30% was found, with mean maximum wind speeds around 15 ms^{-1}, between 300 and 400m heights (at the jet core). Since the 1990s the climate change impact on the EBCS is being studied, nevertheless some lack of consensus still persists regarding the evolution of upwelling and other components of the climate system in these areas. However, recently some authors have shown that changes are to be expected concerning the timing, intensity and spatial homogeneity of coastal upwelling and of CLLJs, in response to future warming, especially at higher latitudes, namely in Iberia and Canaries.

In this study, the first climate change assessment study regarding the Western Iberian CLLJ, using a high resolution (9km) regional climate simulation, is presented. The properties of this CLLJ are studied and compared using two 30 years simulations: one historical simulation for the 1971-2000 period, and another simulation for future climate, in agreement with the RCP8.5 scenario, for the 2071-2100 period. Robust and consistent changes are found: 1) the hourly frequency of occurrence of the CLLJ is expected to increase in summer along the western Iberian coast, from mean maximum values of around 35% to approximately 50%; 2) the relative increase of the CLLJ frequency of occurrence is higher in the north off western Iberia; 3) the occurrence of the CLLJ covers larger areas both latitudinal and longitudinal; 4) the CLLJ season is enlarged extending to May and September; and, 5) there are shifts for higher occurrences of higher wind speeds and for the jet core to occur at higher heights.

L20- The lifecycle of an Atmospheric River – from Moisture Sources to Socioeconomic Impacts

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ABSTRACT

In December of 2007, an Atmospheric River (AR) impacted the U.S. west coast causing intense flooding in the Chehalis River basin in western Washington state. The AR drew significant amounts of moisture from the tropical Pacific Ocean, which generated extreme precipitation and the maximum flooding recorded in several stream gauges. The flooding resulted in approximately $ 680 million in damages in three counties in the region (Grays Harbor, Lewis and Thurston). We present an integrated modeling system that is able to realistically simulate the atmospheric-hydrologic-hydraulic and socioeconomic processes of this extreme AR.

The question we pose in our study is: what would happen if the December 2007 AR occurred in a warmer climate? With increasing surface temperatures, saturation vapor pressure increases nonlinearly and ARs are able to transport more water vapor – creating a greater potential for extreme precipitation and flooding. We use a pseudo-global warming approach in which the lateral boundary conditions of the atmospheric model (the Weather Research and Forecasting model) are perturbed to simulated an atmosphere with increased greenhouse gas forcing. The changes in atmospheric conditions lead to changes in precipitation, streamflow, flooding extent and inundation depth – which then translate into changes in socioeconomic impacts. Uncertainties in atmospheric forcing are included in our analysis.

This type of integrated modeling approach can provide communities with information about possible future changes related to ARs and vulnerabilities in the system that could lead to severe economic and social impacts. The method can help with adaptation efforts in AR-affected regions.

Keywords: Atmospheric Rivers, Climate change, Socieconomic Impacts.

L21- Atmospheric Rivers as Lagrangian Coherent Structures

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ABSTRACT

The transport of moisture from the tropics to mid-latitudes is not continuous and uniform, but rather intermittent. More than 90% of poleward water vapour is transported by narrow and elongated structures (longer than 2000 km and narrower than 1000 km). These structures, referred to as Atmospheric Rivers (ARs), are a key process for the latent heat redistribution and atmospheric mixing. They are responsible for extreme precipitation and flood events as they approach coastal areas.

Based on an integrated water vapour flux obtained from the ERA-Interim database, AR events have been clearly identified with attracting Lagrangian Coherent Structures (LCS) (Chaos 25, 063105 (2015)) that shape the water vapour filaments moving towards the east for several days up to a week.

We will address their contribution to the atmospheric mixing in the troposphere. To that end, a 35-year Lagrangian "climatology" based on the calculation of the backward and forward Finite-Time Lyapunov Exponents (FTLE) has been calculated. Different geophysical drivers as ENSO and ARs were identified in the FTLE climatology. Our results suggest that ARs contribution to the atmospheric mixing ranges from 15 to 25%.

Keywords: Atmospheric rivers, Lagrangian coherent structures, Lyapunov exponents.

L22- On the origin of the moisture in Atmospheric Rivers using a WRF tracers tool

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ABSTRACT

Atmospheric rivers (ARs) are defined as narrow structures that transport significant amount of moisture in the lower troposphere. It is well accepted that the large amount of water vapor carried by ARs has two different origins; i) convergence of local moisture in mid-latitudes and ii) advection of moisture from (sub)tropical regions. Nevertheless, some recent analysis neglects the importance of the latter, claiming that ARs are the footprint left behind by cyclones, and that moisture predominantly comes from the convergence mechanism in the surrounding areas.

In this study, we usea newly-developed moisture tracking tool in the Weather Research Forecast (WRF) model to investigate the origin of the water vapor and precipitation in two important AR events that led to significant precipitation and flooding.The first event developed over the Pacific Ocean and impacted the west coast of the United States, while the second event developed in the Atlantic basin and impacted the Iberian Peninsula.

The results suggest that the largest part (more than 70%) of the moisture forming these two ARs has its origin in the tropical regions. Similar ratios are also found in the contribution from the tropics to the AR-related precipitation.

However, the results also suggest that the strength of the "tropical connection"-the ratio of precipitable water advected from the tropics to total precipitable water- depends upon the latitude of the event as well as the synoptic evolution of the dynamical system.

Keywords: moisture tracers, atmospheric rivers, extreme precipitation.

L23- Fidelity in Global Model Simulations and Predictions of Atmospheric Rivers

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ABSTRACT

Systematic examinations and quantitative assessments of the fidelity of our global models to simulate and predict of the global distribution and variability of atmospheric rivers (ARs) has yet to be undertaken and documented. In this presentation, we will discuss the results of our ongoing research to develop and apply model diagnostics and performance metrics for ARs. This work is being performed on: 1) global weather/climate simulations using the WCRP-WWRP/THORPEX MJO Task Force and GEWEX GASS multi-model physical processes experiment, that includes 20-year simulations from 27 current generation global climate models (GCMs), and 2) the WCRP-WWRP Subseasonal to Seasonal (S2S) Prediction Project's database of subseasonal (e.g. out to ~45 days) reforecasts from 11 operational forecast centers. The latter will include estimates of model forecast skill at medium-range to subseasonal lead time, as well as analogous estimates of predictability of ARs.

L24- Increased frequency and intensity of atmospheric rivers affecting Europe during the XXI Century

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ABSTRACT

Atmospheric Rivers (ARs) are elongated bands of high water vapor concentration extending to the mid-latitudes which can be associated with intense precipitation and floods over continental areas. We analyze ARs reaching Europe in simulations from six CMIP5 global climate models (CGMs) to quantify possible changes during the current century, with emphasis in five western European prone coastal areas. ARs are represented reasonably well in GCMs for recent climate conditions (1980-2005). Increased vertically integrated horizontal water transport is found for 2074- 2099 (RCP4.5 and RCP8.5) compared to 1980-2005, while the number of ARs is projected to double on average for the same period. These changes are robust between models and are associated with higher air temperatures and thus enhanced atmospheric moisture content, together with higher precipitation associated with extra-tropical cyclones. This suggests an increased risk of intense precipitation and floods along the Atlantic European Coasts from the Iberian Peninsula to Scandinavia.

Keywords: Atmospheric Rivers, climate projections, Europe, CMIP5 models, precipitation.

L25- Assessing the climate-scale behavior of Atmospheric Rivers and related precipitation extremes affecting California in the present and future climates

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ABSTRACT

In California's Mediterranean climate, the precipitation regime is projected to progressively favor extreme precipitation events at the expense of the moderate events. Meanwhile, the atmospheric branch of the hydrologic cycle is projected to intensify. We suspect that Atmospheric Rivers (ARs) provide the essential link connecting these trends. A novel automated methodology for the detection of ARs (ARDT) based on both Integrated Vapor Transport (IVT) and Integrated Water Vapor (IWV) has been developed and applied to yield a new 68-year catalog of ARs that made landfall at the west coast of North America during 1948-2015. This catalog (SIO-R1) provides a large array of variables that can be used to examine AR cases and their climate-scale variability in exceptional detail. The new record of AR activity provides a perspective on the seasonal cycle and on interannual-interdecadal variability of AR activity affecting the hydroclimate of the North American West. Links to precipitation are demonstrated using high-resolution observational precipitation data. Applying our ARDT to choice CMIP5 GCMs and studying modeled ARs in conjunction with statistically downscaled precipitation, we validate ARs diagnosed in GCMs against the SIO-R1 as follows. We assess the realism of the seasonal march of AR landfalls from the Gulf of Alaska coastline in late summer-early fall to California by the late fall-early winter as well as the contribution of AR-related precipitation to seasonal totals and especially extremes. We also validate linkages between seasonal AR activity and climate variability expressed in Pacific sea surface temperatures. Using the most successful GCMs, we will finally assess projected trends in land-falling AR behavior along with their contribution to projected extreme precipitation trends over California.

L26- Atmospheric rivers moisture sources from a Lagrangian perspective

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ABSTRACT

An automated atmospheric river (AR) detection algorithm is used for the North Atlantic Ocean basin, allowing the identification of the major ARs affecting western European coasts between 1979 and 2012. The entire western coast of Europe was divided into five domains, namely the Iberian Peninsula (9.75° W, 36–43.75° N), France (4.5° W, 43.75–50° N), UK (4.5° W, 50–59° N), southern Scandinavia and the Netherlands (5.25° E, 50–59° N), and northern Scandinavia (5.25° E, 59–70° N). Following the identification of the main ARs that made landfall in western Europe, a Lagrangian analysis was then applied in order to identify the main areas where the moisture uptake was anomalous and contributed to the ARs reaching each domain. The Lagrangian data set used was obtained from the FLEXPART model global simulation from 1979 to 2012.

The results show that, in general, for all regions considered, the major climatological areas for the anomalous moisture uptake extend along the subtropical North Atlantic, from the Florida Peninsula (northward of 20° N) to each sink region, with the nearest coast to each sink region always appearing as a local maximum. In addition, during AR events the Atlantic subtropical source is reinforced and displaced, with a slight northward movement of the sources found when the sink region is positioned at higher latitudes. In conclusion, the results confirm not only the anomalous advection of moisture linked to ARs from subtropical ocean areas but also the existence of a tropical source, together with midlatitude anomaly sources at some locations closer to AR landfalls.

Keywords: Atmospheric Rivers, moisture sources, Europe, Lagrangian models, precipitation.

L27- Aerial river passage over a forested Indian reservation in the Amazon explains increased grain harvest downwind

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ABSTRACT

Tropical wet forests with large leaf area index (LAI typically above 6) are known to transpire at great rates, typically above 3.6 mm/day. Root access to large underground stores of water allows for continued transpiration, even during times of high water vapor deficit like in dry seasons and pronounced climatic droughts. If not water limited, pastures, savanna and agriculture with LAI smaller than 2 and shallow roots, have evapotranspiration usually not exceeding 1 mm/day. Under water stress the ET of such systems plunge to very low values. For large continents, rainfall in areas far inland has been shown to depend on moisture-laden air masses traversing over forested areas upwind. We've compared the water balances for two localities 400 km apart, lying in Mato Grosso grain belt State (Brazil) on similar latitudes and on equivalent distances south of the Amazon forest. The location to the West (Lucas do Rio Verde) produces grain in two consecutive crop cycles per year. The location to the East (Querência) produces grain in only one crop cycle per year. In between the two locations, and slightly to the North, lies the Xingu Indian Reservation, boasting a large tract of dense mostly undisturbed rainforest. Using 15 years of Era-interim reanalysis data (80 km grid, up to 5.5 km tropospheric height), we obtained 10 days lagrangean back trajectories (daily average of 6-hour time steps) with which we generated monthly aerial-river (AR) climatology for both places. We found that the AR delivering rainmaking moisture to Lucas, always pass over the Xingu reservation in its final stretch, crossing approximately 150 km over rainforest. In contrast, the ARs arriving to Querência, upwind of the reservation, cross mostly agriculture, drier savanna and deforested land. This difference in upwind ET source-areas explains two months longer rainy season in Lucas, which gives enough rain to sustain a second crop cycle that Querência cannot have due to its shorter wet season (5 months). Our findings highlight the importance of high resolution lagrangean climatological studies in the understanding of precipitationsheds (sensu Keys et al 2016). AR delineated precipitationsheds have wide range of applications in land-use management, creating new opportunities for assessing the impacts of land-cover changes on ET. Apt estimation of atmosphere-mediated provision of environmental services requires credible knowledge about where winds come from and how much moisture they carry.

L28- The Role of Atmospheric Rivers in East Antarctic Precipitation and Accumulation: Merging Modeling and Remote Sensing Techniques

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ABSTRACT

Several strong snowfall events over Dronning Maud Land (DML) in 2009 and 2011 produced a positive mass anomaly over the East Antarctic ice sheet, counterbalancing the increasing ice discharge from West Antarctica in these years. Using in situ accumulation measurements and radar-derived snowfall rates from Princess Elisabeth station (PE), located in the DML escarpment zone, along with the European Centre for Medium-range Weather Forecasts (ERA) Interim reanalysis, it was shown that the most intense precipitation events at PE (up to 30 mm water equivalent per day) were associated with atmospheric rivers (ARs) *(Gorodetskaya et al, 2014, Geophys. Res. Lett.)*. ARs were represented by enhanced tropospheric integrated water vapor amounts and strong poleward moisture transports concentrated in narrow long bands stretching from subtropical latitudes to the East Antarctic coast. Several ARs reaching the coastal DML contributed 74–80% of the outstanding SMB during 2009 and 2011 at PE. These AR events linked DML snowfall and accumulation to the subtropical moisture sources, namely, the southern Indian and Atlantic Oceans. Moreover, large contribution (46%) to climatologically 'normal' annual snow accumulation amount during 2012 comes from only one intense snowfall associated with an AR. The important role of ARs in the Antarctic ice sheet surface mass balance suggests that climate models require adequate representation of ARs. Two coupled land-atmosphere regional climate models - MAR and RACMO-ANT - are used to simulate DML climate and surface mass balance. The models are run at ~5 km horizontal resolution using initial and boundary conditions from the ERA-Interim re-analysis atmospheric and oceanic fields. We analyze representation of the AR events in the two models, including their extent, intensity, as well as time and location of where the AR moisture bands are reaching the Antarctic coast. Model-simulated snowfall events associated with ARs are evaluated using the Passive and Active Microwave TRAnsfer model (PAMTRA), which allows direct comparison of the radar-measured snowfall at PE and model-based vertical profiles of the radar reflectivity and Doppler velocity.

Keywords: Antarctica, precipitation, clouds, atmospheric rivers.

L29- Are the droughts busters in Iberian Peninsula associate with atmospheric rivers?

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ABSTRACT

The Iberian Peninsula has been stricken by major drought events since the early 21th century, namely the extreme events during the hydrological years of 2004/2005 and 2011/2012. The need for a deeper knowledge on the frequency, duration, starting and ending phases of droughts over the Iberian Peninsula is reinforced by the consistent climate projections for an increase of drought conditions in the coming decades (Hoerling et al., 2012), which will tend to exacerbate dryness-related problems.

Within the context of understanding the water cycle, special attention has been devoted, in the last decade, to the role played by Atmospheric River (ARs). ARs are relatively narrow regions of concentrated water vapor (WV) and strong wind responsible for intense horizontal moisture transport in the lower atmosphere (Ralph et al., 2006). In the case of Iberian Peninsula the relation with ARs and extreme precipitation days is notorious in the western domains (Portugal, Minho, Tagus and Duero) (Ramos et al., 2015). On the other hand, in California about 1/3 of all persistent drought endings from 1950-2010 have been taken by the arrival of ARs storms, whereas in Pacific Coast of U.S Northwest it was occurred for around 2/3 of all persistent drought endings (Detinger, 2013)

In this work we aim to establish a connection between drought ends and ARs over Iberian Peninsula. The list of AR events that affected the Iberian Peninsula over the 1948–2012 period was obtained thought the automated atmospheric rivers (ARs) detection algorithm of Ramos et al. (2015). The evolution of drought in the IP was analysed through the computation of indices SPEI for the time scale of 6 months, as obtained from CRU TS3.21 database between 1901 and 2012 with a spatial resolution of 0.5º (Russo et al, 2015).

Spatial distribution of drought duration and drought ends over Iberia was analysed. The frequency of drought ends were assessed separately for each season, presenting the summer and fall high frequency of drought ends. Special attention was paid to the regions with more than ten drought ends, namely evaluating the percentage of these drought ends that are coincident with ARs occurrence, showing spring and summer high percentage of coincidence.

Keywords: Western Iberia, Drought ends, Atmospheric Rivers, Standard Precipitation-Evapotranspiration Index (SPEI),

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L30- Predictability and earlier awareness of extreme hydrological events across Europe

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ABSTRACT

Extreme hydrological events can cause large socioeconomic damages in Europe. In winter, a large proportion of these flood episodes are associated with atmospheric rivers, a region of intense water vapour transport within extratropical cyclones.

When preparing for such extreme events, forecasts of precipitation from global weather models or river discharge forecasts from hydrological models are generally used. Given the strong link between water vapour transport (integrated vapour transport IVT) and heavy precipitation, it is possible that IVT could be used to warn of extreme events. Furthermore, as IVT is located in extratropical cyclones, it is hypothesized to be a more predictable variable due to its link with synoptic-scale atmospheric dynamics.

In this study, we provide an overview of the predictability of IVT and precipitation forecasts and introduce the ECMWF Extreme Forecast Index (EFI) for IVT. An assessment of the EFI forecasts for winter 2015/16 will also be given, with results suggesting that the IVT may be used to give earlier awareness of extreme events across Europe.

Keywords: Floods, atmospheric rivers, integrated vapour transport, predictability, ECMWF Extreme Forecast Index (EFI).

L31- Variability and Changes in the Summertime Hydrological Cycle over European Regions

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ABSTRACT

A variety of observations-based hydrological variables from different data sets are used to investigate interannual variability and changes in the summertime hydrological cycle over four European regions – Iberian Peninsula (IP), British Isles (BI), Central Europe (CE) and European Russia (ER).

An analysis performed on seasonal means (June, July and August: JJA) suggests that soil moisture variability is impacted almost equally by precipitation and air temperature in BI and ER regions. However, stronger links between soil moisture and precipitation are revealed for CE region and between soil moisture and air temperature for IP region. In all except IP regions summertime interannual variability of column-integrated water vapour is strongly linked to air temperature consistent with the dominating influence of the Clausius-Clapeyron equation. In BI, CE and ER interannual variability of regional precipitation is driven by variations in atmospheric moisture transport into these regions. In IP the link between precipitation and moisture transport is relatively weak.

Based on monthly data, analysis of the lag-lead correlations revealed specific regional relationships between different hydrological variables. In particular, it is shown that in some regions (and months) interannual variability of soil moisture is linked more strongly to precipitation and air temperature anomalies in the previous month, rather than in the coinciding month.

An analysis of the vertical structure of regional atmospheric moisture transport has revealed that the more continental the climate of the region is, the larger deviation from the mean (i.e., climatological) profile might be observed during anomalously dry/wet summers.

Keywords: hydrological cycle, Europe, summer season, interannual variability.

L32- A thermodynamic Earth system's approach to the sensitivity of the water cycle to radiative change

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ABSTRACT

The strength of the water cycle is determined by evapotranspiration which is driven by the turbulent heat fluxes which mix heat and water vapour into the atmosphere. Thus to predict evapotranspiration we need to take a step back and have to predict the partitioning of the radiative and turbulent energy exchange at the surface.

Here we invoke a system's perspective and make use of the first and second law of thermodynamics which set the constraints and direction of energy conversions. Treating the atmosphere as a heat engine allows us to determine how much power can be maximally be done when converting the temperature gradient between the atmosphere and the surface into motion. Thereby the interaction of the temperature gradient with the heat flux results in a trade-off for power which we use to predict the turbulent heat fluxes under a given solar radiative flux without empirical parameters.

This approach is thus ideal to diagnose the sensitivity of the turbulent heat fluxes and evaporation for a given change in radiation. With our simple estimates being in general agreement with more complex GCMs we find that radiative effects of greenhouse gases altering the longwave radiative transfer result in different surface climate sensitivities than shortwave radiative effects. Thereby turbulent heat fluxes have a higher sensitivity to shortwave changes as the system heating is effected. Whereas greenhouse gases reduce the ability to cool the surface and which results in stronger surface heating.

This finding emphasises, that it is highly important to distinguish the nature of radiative forcings for climate change assessment and that radiative feedbacks within the atmosphere and the surface are key to assess the impacts on the water cycle.

Keywords: Thermodynamic limits, heat engine, turbulent heat fluxes, evaportranspiration.

L33- Factoring global warming in design flood estimation

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ABSTRACT

While the link between greenhouse gas emissions and temperature rise is now well established, questions continue to persist on whether this link can be extended to flooding or not. This talk attempts to establish this link by breaking it into the three components that all impact the magnitude of an extreme flood event. These components are – (1) change in the intensity of extreme rain, (2) change in pre-storm wetness or antecedent conditions, and, (3) change in the spatial and temporal pattern associated with an extreme storm event. Recent research indicates that extreme rain intensities are increasing all over the world and especially for rain events in non-tropical settings resulting from an increase in the moisture carrying capacity a warmer atmosphere brings. The impact of this increase is complicated by changes in pre-storm wetness resulting from changes in both pre-extreme rainfall patterns as well as increased evaporation from the surfaces impacted. The clearest indication of impact on flooding is, however, provided by the changes to spatial and temporal patterns for extreme rain events, with storms becoming increasingly concentrated (or intense) in both time and space across all climate zones in the world. Focussing just on urban catchments (where pre-storm wetness impact is smaller), one can conclude that the combination of increased intensity and more concentrated storms will overwhelm existing stormwater infrastructure in ways not seen before. So how can we estimate the "new" design flood that new stormwater infrastructure should be designed to withstand? A framework that explicitly models the changes noted above is proposed and argued as the best way forward for re-designing our flood infrastructure in urban settings the world over.

Keywords: Design Flood, Rainfall Extremes, Temporal Pattern, Spatial Pattern, Global Warming.

L34- Extreme Hot Events Associated to Drought Occurrence over the Southwest Mediterranean

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ABSTRACT

The Southwest Mediterranean is often affected by extreme events. Particularly, severe drought events, which in the last decades faced an increased likelihood due to the higher atmospheric evaporative demand. On the other hand, Europe has also experienced multiple and unprecedented mega heat waves, namely over Western Europe in 2003 and Eastern Europe in 2010.

As global warming increases, the likelihood of occurrence of hot extremes also rises. In this context it is becoming increasingly relevant to improve the early identification and predictability of such events, as they impinge negative impacts on several socio-economic activities. Both diagnostic and modelling experiments have confirmed that hot extremes are often preceded by surface moisture deficits in some regions throughout the world.

In this study we propose to analyse if such a relationship, between the occurrence of hot extreme months and drought events, is observed throughout the Southwest Mediterranean area. In order to achieve this purpose, the number of hot days in the regions' hottest month will be associated with a drought indicator.

The evolution and characterization of drought was analysed using the Standardized Precipitation Evaporation Index (SPEI) as obtained from CRU TS3.21 database for the period 1901-2012. We have used SPEI for different time scales between 3 and 18 months with a spatial resolution of 0.5º.

The number of hot days per month (NHD) was determined based on the ECAD-EOBS daily dataset using a spatial resolution of 0.5º. The NHD was calculated as the number of days with a maximum temperature exceeding the 90th percentile. In the main analyses, the most frequent hottest months are July and August and results were analysed towards the identification of the regions of strongest correlation between surface moisture deficits and temperature extremes.

Keywords: Hot extremes; Droughts; Iberian Peninsula, Standardized Precipitation Evapotranspiration Index (SPEI).

Acknowledgments: *This work was partially supported by national funds through FCT (Fundação para a Ciência e a Tecnologia, Portugal) under project IMDROFLOOD (WaterJPI/0004/2014). Ana Russo thanks FCT for granted support (SFRH/BPD/99757/2014).*

L35- Severe Convective Environments across South Africa

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ABSTRACT

Severe thunderstorms pose a considerable risk to society and the economy of South Africa during the austral summer months. Annual lightning related deaths in the country are typically higher than that found in most developed countries as well as being higher than the global average. Yet, the frequency and distribution of such severe storms is poorly understood, which stems out of the inadequate observation network, inherent in many developing countries. Given the lack of observations, alternative methods have focused on the relationship between severe storms and their associated environments. One such approach is to use a combination of covariant discriminants, derived from gridded datasets, as a probabilistic proxy for the development of severe storms. These covariates describe some key ingredient for severe convective storm development, such as the presence of instability, sufficient moisture or potential organization.

Using a combination of convective available potential energy (CAPE) and deep-layer vertical shear, from Climate Forecast Reanalysis (CFSR), this study establishes a 30-year climatology of severe convective environments across South Africa. It is found that during the early austral summer months of October and November, environments over the interior of South Africa are most likely associated with conditions that are conducive to the development of severe storms. The east coast of the country is a hotspot for severe convective environments throughout the summer months (Oct-Mar). This is likely due to the close proximity of the core of the Agulhas Current, which produces high latent heat fluxes and acts as a key moisture source. A weak relationship established here between the frequency of severe convective environments and the main large-scale modes of variability in the Southern Hemisphere, such as ENSO, suggest that several factors, possibly more localised, may modulate the spatial and temporal frequency of severe thunderstorms across the region. Results indicate that moisture flux anomalies originating from the neighbouring subtropical Indian Ocean may be one such factor.

Keywords: Convective environments, CFSR reanalysis, South Africa, inter-annual variability, ENSO.

L36- Human alteration of moisture recycling through land-use change

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ABSTRACT

Humans have changed the Earth's land surface significantly, altering the terrestrial evaporation and climate in various way. Nevertheless, the human impact on the atmospheric transport of moisture has not yet been quantified. Here, we investigate how human through changes in land cover and land use has changed the terrestrial moisture recycling.

We compare moisture recycling in potential and current land land-use scenarios by coupling a global hydrological model (STEAM) with a moisture tracking scheme (WAM-2layers). First, we map out the changes in moisture recycling ratios, length scales, and time scales due to human land-use change. Second, we analyse changes in the temporal and spatial characteristics of evaporation and precipitation following changes in moisture recycling. Modifications in global and annual average moisture recycling are pronounced regionally and seasonally. In particular, reduced vegetation may shorten the dry season length, and decrease the dry season rainfall more than the mean annual. Finally, the effect on moisture recycling from shifts in transpiration ratio is analysed.

This study contributes to the understanding of land surface influence on moisture recycling, and reveals how humans have modified the atmospheric branch of the hydrological cycle through land-use change.

Keywords: moisture recycling, land-use change.

L37- What causes the recent intensification of the Amazon hydrological cycle?

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ABSTRACT

The Amazon basin is an important component of the Earth's climate system primarily because of its vast size (ca. 6.5 mio. km^2) and its location in the tropics. The high annual precipitation resulting from lower troposphere wind and moisture convergence and subsequent upwelling, and the high incoming solar radiation sustain also the largest area of tropical forests in the world. Potentially these forests are vulnerable in a warming climate and are also under pressure from agricultural and economic development of the region. While the perception in the scientific literature is that the basin is drying, thereby possibly posing a threat to the forests, most recent studies of existing climate, river discharge and atmospheric vapour transport data reveal a somewhat different picture. Over the last two to three decades there is an unprecedented increase of severe flood events in various parts of the basin and an overall increase in precipitation, and in contrast only a slight increase in dry events. Thus the seasonality of the hydrological cycle has become increasingly more pronounced. This period of increasing wet-dry season contrasts is paralleled by rapid warming of the tropical Atlantic. The changes may be the result of decadal scale variability or may have other causes. In this talk/poster we will present the evidence for an intensification of the Amazon hydrological cycle, and discuss its possible cause using new data and climate model based analysis.

L38- Integrated atmospheric water vapor in northern of South America and impacts in the regional climatology of rainfall

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ABSTRACT

Vertically integrated horizontal water vapor transport (IVT) is frequently used to characterize atmospheric rivers (ARs). In this study, the ARs were identified in the meridian 44°W and in the latitude band between 5°N-5°S. For ARs identification were considered the thresholds of: IVT larger or equal than 471.7054 kg m^{-1} s^{-1}, minimum distance of 2000 km, and time persistence of at least 18 hours. These criteria were applied in ERA-Interim reanalysis for the period 1979-2015. Global Precipitation Climatology Project (GPCP) dataset for the period 1997-2014 was used to evaluate the spatial pattern anomaly of rainfall during the ARs. The climatology shows a mean of 13.5 ARs events per year with a mean lifetime of 38.2 hours, which is larger than thresholds used in their identification. The occurrence of ARs presents large interannual variability. At seasonal scale, ARs are more frequent during austral autumn and winter, and less frequent during spring. In austral autumn and summer seasons, the spatial pattern of rainfall anomaly during ARs presents an intensification of rainfall in western side of Atlantic ITCZ, north-western Amazon basin and southeastern South America (SESA). The simultaneous increase of rainfall over the north-west Amazon and SESA occurs in association with the intensification of northwesterly winds in the low-level jet eastern Andes Mountain during ARs events. This probably increases the moisture transport from tropics to subtropics and fuels the convection over SESA. At same time, during ARs occurs less precipitation over eastern side of Atlantic ITCZ and center-north Brazil. During austral winter and spring seasons, the anomalous spatial pattern of rainfall also presents a dipolar pattern in Atlantic ITCZ and the intensification of rainfall over most of SESA in association with ARs events.

L39 - Unraveling the Drivers of the Drought over São Paulo (Brazil) using HadAM3

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ABSTRACT

Since ca. 2010, São Paulo has struggled with water shortage. Levels of reservoirs providing São Paulo, south-America's largest city hosting 20 millions inhabitants, with fresh water have been at a record low level by 2013. While climate must have played a role as precipitation refills the reservoirs primarily during the wet season (December, January, February) and 2013/14 has been anomalously dry, other factors like population growth and management may also play a role. With regards to climate anomalies it has furthermore been suggested that Amazon deforestation may be at least partially responsible. In order to plan water provision for Sao Paulo in the future it is important to understand how various controls contribute to the shortage. We use here both climate data and Climate model simulations with prescribed observed sea surface temperature and Amazon forest cover as well as Climate predictions to analyze this question. We find that climate anomalies are not solely to blame but rather that increasing demand linked to population growth is an important contributor to the recent shortage. Climate simulations forced by SST and dynamic Amazon vegetation reveal furthermore that SST's patterns alone reproduce 2013/14 anomalies and that deforestation in the Amazon is very unlikely related to the shortage as in the simulations there is no deforestation. A comparison of the 2013/14 DJF climate pattern with climate of previous years indicates that the 2013/14 pattern occurs infrequently and comparisons with CMIP5 climate simulations suggest similar patters will occur less frequently in the future. Altogether our results suggest that although the wet season 2013/14 was dry the primary reason for the water shortage is water release above safety margins of the reservoirs and natural variability of climate. Overall this is good news as neither climate change nor deforestation complicates future planning of robust water provision for the region.

L40- Reconstructing the past to understand the present: inferring Amazon climate from tree ring oxygen isotopes

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ABSTRACT

The water and carbon cycles are closely coupled in the Amazon basin, so perturbations in one system can have important consequences for the other, with implications for global climate. Rain gauge and river flux data from the region show a strengthening of the hydrological cycle since approximately 1990, predominantly during the wet season, which is at odds with previous suggestions that the Amazon may become drier in a warming climate. It remains unclear whether this intensification of the Amazon hydrological cycle is due to global climate change or part of natural variability. Long-term proxy data, e.g., from oxygen isotopes, can possibly shed some light on this question as they can be used to reconstruct past climate beyond the limit of the instrumental record. Here we present a chronology of oxygen isotope ratios in tree rings ($\delta^{18}O_{TR}$), a known proxy for precipitation over the Amazon basin. First we use a Lagrangian atmospheric transport model to simulate back trajectories, and large-scale water vapour transport analysis to identify mechanistic drivers of interannual variation in $\delta^{18}O_{TR}$ and thus strengthen our climatic interpretation of the record. We show that within-basin rainout is a key driver of variation in $\delta^{18}O_{TR}$, suggesting that $\delta^{18}O_{TR}$ can be reliably used to reconstruct Amazon precipitation. Following from this we inspect the full 150-year-long $\delta^{18}O_{TR}$ record, allowing us to place reported changes in Amazon hydrology in the context of historic variability. Our record shows a strong signature of change over the past 1–2 decades, consistent with an intensification of Amazon hydrology. We discuss the extent to which this might be unprecedented over the past 150 years.

Keywords: South America, climate change, hydrology, atmospheric transport, dendrochronology.

L41- Evapotranspiration under different methodologies

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ABSTRACT

Evapotranspiration is a water cycle component that includes two phenomena: evaporation, referring to a mass transfer from the ground to the atmosphere, and transpiration, related to water loss from plants into the atmosphere through stomata. Evapotranspiration is one of the components defining the hydrologic cycle and, moreover, the water-balance process.

In order to determine the evapotranspiration, three different adapted methodologies were tested at Guasca Municipality in Colombia-South America. Some of which were: SEBS algorithm (Surface Energy Balance System- Su), SEBAL algorithm (Surface Energy Balance- Bastiaanssen), and Potential Evapotranspiration- FAO). The studied variables from the different methodologies were obtained from remote sensing, meteorological stations placed on the studied zone, aerial photographs and softwares such as PCI, MATLAB and ILWIS. The former was used to generate de Digital Elevation Model. The second was used to determine the relationship among variables by means of regression analysis and Neural Networks, for example: Soil Heat Flux under the algorithms and the measured data, Normalized Vegetation Index (NDVI) versus Leaf Area Index (LAI), Photosynthetically active radiation (PAR) and Incoming Radiation, as well as the relationships among the data provided by the meteorological stations. The ILWIS software was used as a platform to visualize the collated data, as well as a mean to compute the potential evapotranspiration. A sunphotometer was also included to determine the aerosol optical thickness per channel, the corresponding transmission percentage and the atmospheric correction.

The results under the studied methodologies showed similar average evapotranspiration in mm per day. The SEBAL algorithm generated an actual evapotranspiration of 5.22 mm day^{-1}, FAO Calculated Potential Evapotranspiration was 5.47 mm day^{-1}, from the ILWIS Software the Potential Evapotranspiration was 5.69 mm day^{-1}. The SEBS algorithm with the use of the sunphotometer resulted on an average of 6 mm day^{-1}, while without the use of it, underestimates the actual evapotranspiration value in 3 mm day^{-1}.

Keywords: SEBS, SEBAL, FAO, PCI, ILWIS.

L42- Precipitation Regime for the Southeast Brazil: a case study analyses for future actions at Paraiba´s Valley region.

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ABSTRACT

It is well know the importance of the water availability for the Society and there is a strong concern about the modifications of the precipitation regime for the end of 21 century. Although the convergent concern is that there is a global warming, the water budget expectation is controversy and site dependent. In order to contribute for this discussion, we have used a climatic simulation initialized with the UK HADGM3 and downscaled using a regional meteorological model ETA for a specific region (Paraiba´s River Valley) between 2 megacities in Brazil (São Paulo and Rio de Janeiro). The simulations started in 1960 and lasted up to 2100 based on the augmentation of GHG (A1B scenario). The past (base line 1960-1991) simulations was compared with in situ observations in order to quantify the uncertainty of the model for this site. Future simulations were classified in 3 time slice intervals (2011-2040, 2041-2070, 2071-2100). Considering the daily average rainfall, there will be a consistent increase from typical value of 3.8 mm/day for the base line period to a value around 4.4 mm/day at the end of 21 century (representing an increase of approximately 17% of the total annual rainfall), associated with an earlier onset of the rainy season. The yearly total number of days with precipitation higher than 1 mm/day will increase by 5 days as the number of consecutive days without rainfall which will change from 4 to 9 events. Consequently, the extremes events will be more frequently with a higher risk of natural disasters (dry spells, land slices and flash flood due to the complex terrain of the region studied). Although there is an increase of amount of rainfall, the water budget shown an increase of water deficit period (1 month longer) due to the higher temperatures (around 3 ºC) and, consequently, higher values of evapotranspiration.

Keywords: Climatic simulations, evapotranspiration, dry spells, dry days, intensive rain.

L43- Recent decadal change of ocean evaporation and its association with the Hadley cell expansion

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ABSTRACT

Evidence has been accumulating that the Hadley cell is expanding poleward in both hemispheres and that the subtropical dry zones, where evaporation exceeds precipitation, are also expanding. Using the evaporation time series constructed by the WHOI OAFlux project, the study found that the global ocean evaporation has overall increased since 1979. The rate of increase in ocean evaporation was largest in the 1990s and remains weak or flat during the hiatus period since 2000. The change is closely associated with the pace of the poleward expansion of the subtropical evaporation zones. Mechanisms responsible for the change are examined. Two mechanisms have been suggested. One is thermodynamic based that relies on the increase in specific humidity owing to increased water-holding capacity of the atmosphere, and the other is dynamic based that relies on the change in the mean circulation associated with the Hadley cell. Much of the basic pattern of change in ocean evaporation is accounted for thermodynamically as the increase of specific humidity in a warmer atmosphere enhances the vertical flux of vapor from the ocean surface, and enhances the existing pattern of evaporation. On the other hand, changes in mean circulation is required to explain the change of ocean evaporation in the tropical warm pool region, where the evaporation is not temperature dependent but driven by surface moisture convergence. The change of the mean circulation also accounts for the polward expansion of the subtropical evaporation zones. Interestingly, the study found that the center of the evaporation zones was not strengthened but weakened. The areas of evaporation increase are most evident along the subtropical flanks of the existing subtropical evaporation zones, suggesting that the poleward expansion of the subtropics may be more on the shift of the center of the maximum evaporation and less on the strengthening of the subtropical evaporation zones.

Keywords: Ocean evaporation, specific humidity, subtropical dry zones, Hadley cell.

L44- The Contrast Between Atlantic and Pacific surface water fluxes

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ABSTRACT

Sea surface salinity (SSS) is greater at all latitudes in the Atlantic Ocean than in the Pacific Ocean. This asymmetry is associated with the Atlantic Meridional Overturning Circulation (AMOC) and the deep water formation in the North Atlantic, a phenomenon which is not present in the Pacific. The higher Atlantic salinity is at least partly due to an asymmetry in the surface water flux (evaporation minus precipitation; E-P) with higher E-P over the Atlantic.

By comparing seven estimates of the net freshwater flux (E-P-R, where R is runoff) which were calculated using different methods and a range of data sources (e.g. ocean and atmospheric re-analyses, flux products, hydrographic sections), it is shown that E-P-R over the Atlantic is consistently positive and greater than over the Pacific where some estimates are near neutral. Further analysis of ERA-Interim E and P with a runoff dataset demonstrates that the asymmetry in E-P-R is dominated by an evaporation asymmetry in the northern high latitudes (north of about 45°N), but by a precipitation asymmetry everywhere south of that limit. An excess in precipitation over the Pacific dominates the asymmetry at basin scale. The asymmetry is present throughout the year and is steady in time. Investigation of the interannual variability suggests that trends in ERA-Interim precipitation are not reliable. However, upward evaporation trends over recent decades appear to be a physical signal, consistent with sea surface temperature increases. Implications for inter-basin moisture transports and controls on the localization of the AMOC will be discussed.

Keywords: evaporation, precipitation, runoff, moisture flux divergence, salinity.

L45- Data assimilation with stable water isotope information

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ABSTRACT

The data assimilation with stable water isotope circulation models and spectroscopic observations for vapour isotopes has been realized recently. This tendency is most likely due to the rapid improvements in both the modelling and the measuring (both in-situ and remote sensing). The recent study revealed that it is possible to constrain the atmospheric moisture transport by putting vapour isotope observations into the data assimilation system (Yoshimura et al., 2014). This technique would help us to more understand the atmospheric cycle system and/or the land-atmosphere interaction. On the other hand, the data assimilation directly using isotopic information in climate and paleoclimate studies has also been regarded important since it is known that the relationship between isotope and climate is not stationary in time and space. In our group, we have performed that our isotope offline data assimilation worked very well to reproduce ENSO variation from for 20th century without any other observation.

Keywords: data assimilation, vapor isotope, LETKF, atmospheric moisture transport.

L46- Global and long-term remote sensing of tropospheric {H2O,δD} pairs: status and perspectives after the project MUSICA

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ABSTRACT

The insufficient understanding of tropospheric moisture and its coupling to atmospheric circulation is a major challenge of climate system modelling (e.g. Steven and Bony, 2013). The different water vapour isotopologues record the air mass history of moisture uptake, exchange, and transport, thereby offering potential for tracking the moisture pathways and for progressing in this research field (e.g. Sherwood et al., 2010).

The aim of the European Research Council project MUSICA (MUlti-platform remote Sensing of Isotopologues for investigating the Cycle of Atmospheric water) has been the development and validation of water vapour isotopologue remote sensing retrievals for thermal nadir radiances, measured from space by the operational meteorological instrument MetOp/IASI, and for solar radiances, measured on ground by the high resolution FTIR spectrometers of NDACC (Network for the Detection of Atmospheric Composition Change). For this purpose, MUSICA integrates the remote sensing techniques with ground- and aircraft-based in-situ measurement techniques.

In our presentation we give a review on the MUSICA achievements. We demonstrate that the {H2O,δD} pair distribution obtained from NDACC/FTIR and MetOp/IASI can identify distinct lower/middle tropospheric moisture pathways. We document the possibilities of the NDACC/FTIR instruments for climatological studies (due to long-term monitoring) and of the MetOp/IASI sensors for observing diurnal signals on quasi global scale and with high horizontal resolution. We give a brief outlook on how such remote sensing data sets can be used to validate the moisture pathways of models.

L47- Presence of continental and Bay of Bengal moisture in the rainwater $\delta^{18}O$ signature at Kolkata, India during South-West monsoon

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ABSTRACT

The air mass trajectories (HYSPLIT) during the summer monsoon suggest that the vapor generated over Arabian Sea moves inland over Bangalore and takes two routes: over the subcontinent or over the Bay of Bengal before reaching Kolkata. Under the presumption of complete mixing, the vapor as it moves from Bangalore under the prevailing wind direction is subject to modification by addition of evaporated moisture from Bay of Bengal and rainout which is modelled using Craig and Gordon model and Rayleigh fractionation model respectively. The moisture generated during the process of evaporation from Bay of Bengal Surface Ocean gets advected towards the continent and precipitates as rainfall or snowfall in the Indo-Gangetic plain. Using satellite and ground based measurements of the hydro-meteorological variables and rain water isotopic composition, an effort has been made to quantify the moisture source in precipitation collected at Kolkata, India during the SW Monsoon. We assumed based on our observation that the initial isotopic composition of vapor originating from the peninsular continental source is similar to observation recorded at Bangalore. It is found that the isotopic signature of Bangalore is completely lost albeit the significant contribution of the moisture from Bay of Bengal. To explain the isotopic composition of precipitation at Kolkata during the SW-Monsoon, it is necessary to invoke 55-65% moisture from the Bay of Bengal whereas the peninsular contribution varies from 35%-45%.

Keywords: Stable isotope, Monsoon, Vapour Mixing.

L48- Unveiling the nature of rain producing systems and drought drivers affecting Costa Rica from stable isotopic composition

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ABSTRACT

The isotopic composition of water vapour has become a powerful tool for studying the hydrological cycle. In this work, heavy rainfall events are analyzed in light of the precipitation drivers and the isotopic composition of rainfall samples at selected sites across Costa Rica. The main objectives were a) to explore how sensitive is the $d^{18}O$ enrichment and depletion signal to the main rainfall producing systems in the country and b) to determine whether the occurrence and intensity of a sustained drought period were recorded in the stable isotope composition . Based on daily meteorological data, heavy rainfall events were identified for the 2013-2015 period. A multi-scale classification of weather patterns was used to classify the heavy rainfall events according to the rain producing systems. Using the same record, the dry conditions in the Pacific slope of Costa Rica were monitored to characterize the intensity and duration of the most recent drought. From the continuous stable isotope network (8 daily sites), information on the composition of $d^{18}O$ and $d^{2}H$ was analyzed for the individual events. First, we evaluate if the isotopic composition captures particular features of precipitation linked with rainfall types (convective, stratiform and orographic) to better understand the history of the rainfall producing mechanisms. Secondly, we aim to test the memory of the air parcels to reconstruct the subsequent drying in the region driven by the most recent warm ENSO episode.

Keywords: isotopes, enrichment, deep convection, precipitation, ENSO.

L49 - From Advection to Precipitation: Reconstructing the Monsoons in Historical Times by Using Old Wind Measurements.

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ABSTRACT

The precipitation associated to the West African Monsoon is strongly modulated by the ocean-atmosphere interaction in the tropical North Atlantic. During the last four decades, this monsoon has experienced a strong decline in its strength which has resulted in large shortages of precipitation in populated areas such as the Sahel, with the consequent humanitarian crisis. The improvement of our understanding of the long term variability of this monsoon and its relation to its moisture sources is therefore, of paramount importance.

The historical evolution of the West African Monsoon has been usually addressed by combining instrumental precipitation series in northwest Africa. Unfortunately, reliable meteorological series in this region are only available since the beginning of the 20th Century thus limiting our understanding of the significance of the unusually persistent drought period.

As most of the moisture involved in the generation of monsoonal precipitations came from the ocean, it is feasible the construction of an index characterising the monsoon strength by using wind records. In this work, by using exclusively wind direction measures taken aboard thousands of sailing ships circumnavigating Africa, we have assembled a new index measuring the strength of the West African Monson since 1839. Our new reconstruction has evidenced for the first time, that this monsoon can experience persistent periods of high activity, as it seems to have occurred between 1840 and 1890.

Additionally, we have been able to study the relation of the West African Monsoon with several climatic patterns. Our results suggests that since the beginning of the weak monsoon period starting in the 1970s, the correlations with different climatic patterns such as the Atlantic "El Niño" have changed significantly in relation to those of the previous century.

Keywords: Monsoons, Sahel, Climate Indices.

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POSTERS

P01- Long-term variability of moisture transport over Europe as inferred from ships' logbook records

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ABSTRACT

The strength and direction of near-surface winds over the Oceans are a key component of the hydrological cycle and its variability, determining moisture fluxes and precipitation signatures over land. The marine meteorological observations found in old ships' logbooks provide a valuable source of climatic information over the oceans since the XVII century with which to improve our understanding of the low-frequency climate variability and the long-term changes in extreme events such as droughts.

We present a monthly index (the Westerly Index, WI) based on the persistence of the westerly wind over the English Channel for 1685-2012 using daily data from ships' logbooks and marine meteorological datasets. The WI has a significant year-round signature on precipitation over large areas of Europe associated with anomalies in moisture transport over the eastern Atlantic. The results also indicate that European drought variability is well explained by the WI and the North Atlantic Oscillation (NAO) index. Thus, in northern and central Europe the variability of drought severity is strongly associated with the WI, whereas the influence of the NAO on southern Europe droughts is stronger than that exerted by the WI.

Further analyses between the WI and the NAO reveal several multidecadal periods of weakened correlation during the industrial era. These decoupled periods are associated with non-stationarity issues affecting the centers of variability of the North Atlantic and their teleconnections. Comparisons with long instrumental indices extending back to the 17th century suggest that similar situations have occurred in the past.

To better understand the lack of stationary relationships, model simulations accounting for all sources of tropospheric variability are required, including the stratosphere, which plays a decisive role in shaping the extratropical atmospheric circulation through the stratosphere-troposphere coupling. Within the PALEOSTRAT project, a suite of coupled simulations with a stratosphere-resolving Earth System Model is currently underway for the Last Millennium (850-1850 CE). These simulations will allow exploring the internal variability and the responses of the Earth's System hydrological cycle to different forcings.

Keywords: Climate variability, Atmospheric circulation, Early instrumental data, paleoclimate, Standardized Precipitation Evapotranspiration Index, Drought.

P02- Are the Mesoscale Convective Systems the Major Precipitating Sources in Amazon Basin?

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ABSTRACT

The Mesoscale Convective Systems (MCSs) are considered in the scientific literature as the major precipitating mechanism over the Amazon basin. However, the amount of rain generated by these systems is unknown. Recently a climatology of occurrence of the MCSs over the Amazon basin was obtained. The MCSs were identified through brightness temperature, considering the 235 K threshold. They have durations above 3 hours and at least 2400 km² of area during their lifecycle. The monthly distribution of MSCs follows the annual cycle of the precipitation, but there is not a clear relationship between the interannual variations. For example, in 2005, which was an El Niño year, there was negative precipitation and negative occurrence of the MCS. However, in 2010, which was a strong wet year in the Amazon basin, during other El Nino, the MCSs was above average. Therefore, important questions emerge: are the Mesoscale Convective Systems the major precipitating sources in the Amazon basin? How the intensity of these systems can vary across the basin and according to the year? Which is the amount of rain caused by those systems over the Amazon basin? The convective and stratiform rainfall over the Amazon is all affected by those systems? What are the different types of MCSs that occur over the Amazon basin? Currently we are investigating these questions and it was found that there is not a linear correlation between the rainfall and MCSs over the Amazon basin during the wet season and transition months. However, there is better correlations (about 0.7) during the winter. In the dry season, the MCSs and rainfall are displaced and concentrated to the north part of the basin. On the other hand, during the wet season the distribution of the MCSs is more homogeny along the Amazon. There is any correlation between the MCSs and topography, and the rainfall and topography. However the spatial correlations between MCSs and topography are more evident over the region of precipitation hotspots close to the Andes Mountain.

Keywords: Amazon Basin, precipitation, mesoscale convective systems.

P03- A Lagrangian Analysis of the Moisture Transport Associated with Drought Conditions in the Amazonas River Basin

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ABSTRACT

Amazonia has suffered from severe droughts in recent years, generating serious socio-economic impacts, particularly in water resources, ecosystems and agriculture. We propose a Lagrangian diagnostic scheme to investigate possible changes in the moisture transport associated with drought conditions in the Amazonas River Basin (ARB). The main advantages of the Lagrangian approaches are the tracking of trajectories and a more realistic source–receptor analysis. Our approach uses the model FLEXPART integrated with the ERA-Interim reanalysis data set at 1º horizontal resolution for the period 1979-2012. It computes budgets of evaporation minus precipitation (e-p) by calculating changes in the specific humidity along particle trajectories. In this method, the moisture sources are defined as those areas in which the evaporation exceeds the precipitation (E- P >0) in the moisture budget of the particles tracked in a backward analysis. Complementing, regions presenting (E-P) < 0 are the sinks of the moisture transported by the particles tracked in a forward run. The drought episodes over the ARB are identified and characterized through the Standardised Precipitation-Evapotranspiration Index (SPEI). In order to study the role of the ARB as a receptor of moisture during the drought episodes, the anomalies of its moisture sources are computed through backward analysis. The effect of the dryness over the ARB on its climatological moisture sinks is estimated through the forward runs. The mentioned analyses are complemented with the fields of precipitation, potential evapotranspiration, ocean and terrestrial evaporation, and vertically integrated moisture flux. A deeper understanding of the relationship between the sources and sinks and the associated moisture transport contribute to the advances in the weather and climate prediction, helping to minimize the consequences of these natural hazards.

Keywords: Lagrangian approach, moisture transport, drought, SPEI, Amazonas River Basin.

P04- A Lagrangian Perspective of the Hydrological Cycle in the Congo River Basin

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ABSTRACT

In this work the Lagrangian model FLEXPART has been applied to assess the impact of the atmospheric moisture transport on the hydrological cycle in the Congo River Basin (CRB). The climatological annual cycle of the precipitation is characterized by high values (> 4mm/day) between October and April (the austral summer), and minimum rainfall peaks in June and July, while the documented ITCZ latitudinal migration over central equatorial Africa impacts on the spatial variability of precipitation. FLEXPART computes the evaporation minus precipitation (E – P) taxes by calculating changes in the specific humidity along 10-days backward trajectories of air parcels identified over the CRB; regions where evaporation exceeds precipitation are considered moisture sources, thus, four oceanic and five continental sources have been selected. A forward analysis from these sources lead us to know their seasonal role on the moisture supply to the basin, determined by the condition (E – P) < 0. Among all sources investigated, the CRB itself is the most important source along the year, suggesting a key role on local recycling process, followed by the sources located on the equatorial Atlantic Ocean, the western Indic Ocean, the Arabian Sea and the eastern continental African´s lands. An analysis of drought conditions over the CRB through the SPEI index revealed five main episodes according to the twelve months' time scale of the index, characterized by a long duration, high severity and intensity. During these episodes the precipitation and the moisture supply from the selected sources over the basin accumulated negative anomalies, mainly from the CRB itself.

Keywords: Moisture transport, Precipitation, Drought, Congo River Basin.

P05- Lagrangian hydrologic analysis for the Arctic region: source-receptor relationship and the role of atmospheric circulation

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ABSTRACT

The Arctic is a complex system strongly influenced by the climate change. Hydrological processes are a key factor on the Arctic climate, and recent changes related with the transport of moisture toward the system may have important implication on it. With the purpose of analyse moisture transport, the model FLEXPART was applied to establish the source-sink linkage. This model allows to locate main moisture sources for a specific area (following backward trajectories), and to analyse source's contribution to precipitation over the area (following forward trajectories). In this work, main Arctic moisture sources were located for the period 1980-2012, as well as being analysed their contribution to moisture supply into the system and the role of atmospheric circulation.

Four major sources were found for the system: Pacific Ocean, Atlantic Ocean, North America and Siberia. Oceanic appears all along the year and have a greater importance on winter, however continental ones are relevant only in summer. Every source supplies moisture into a different Arctic region, being the sink associated with every source slightly influence by atmospheric circulation. Taking into account different circulation patterns over the source-sink paths, differences up to 30% on the moisture supply were found over the region.

Keywords: arctic system, moisture supply, lagrangian method.

P06- Anomalies in the moisture transport during floods episodes in the Danube River Basin through a Lagrangian approach

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ABSTRACT

Natural climate variability often leads to the occurrence of extreme weather events such as floods, droughts, heat waves, etc. These events may have negative impacts on agricultural yields, water resources, infrastructure, and human systems. In the last few decades, many significant floods episodes were recorded in Europe, any of the most catastrophic covering the Danube River Basin, a highly diverse region where the total amount of annual precipitation is estimated about 2000 mm/year in the high regions and about 500 mm/year in the plains. In this study, we investigate the anomalies in the moisture transport during floods episodes in Danube River Basin, as the transport of anomalous amounts of water vapour and its associated convergence may trigger extreme precipitation events and cause flooding. For this research, we used a Lagrangian approach which uses FLEXPART dispersion model together with ERA-Interim reanalysis data to calculate changes in specific humidity. The temporal period for the study covers 35 years, from 1980 to 2014. The aim of this study is to analyse the moisture sources for the floods episodes and to compute anomalies in the moisture transport during these events over the Danube River Basin. A better understanding of the changes in the moisture transport is very important for minoritized the consequences of these extreme climate events.

Keywords: Floods, Lagrangian approach, Danube River Basin, Moisture transport.

P07- A Lagrangian analysis of the moisture transport during drought episodes in the Danube River Basin

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ABSTRACT

Drought is one of the most important phenomena which can affect different systems such as ecology, water resources, economy, agriculture and can lead to the negative consequences on them. Our study area, Danube River Basin has a large catchment basin extending from Central Europe to southeastern Europe. Because of its large extension and diverse topography, the Danube River Basin shows large climatic differences and that is one of the reasons why is interesting for researching extreme climate events such as drought. In this study, we apply a Lagrangian approach to investigate changes in the moisture transport over Danube River Basin during the drought episodes configured in the region. This methodology computes budgets of evaporation minus precipitation (e-p) of each air particle by calculating changes in specific humidity during its trajectory. The method has been successfully applied in previous studies concerning moisture source-sink analysis in various areas worldwide. It uses the outputs of the FLEXPART model integrated with 1º horizontal resolution and 60 vertical levels ERA-Interim data set. The most important drought episodes in the Danube River Basin occurred in the period from 1980 to 2014 have been identified and characterized via the Standardized Precipitation Evapotranspiration Index (SPEI). Forward and backward in time experiments have been done in order to investigate possible changes in the moisture transport from and toward the selected area during these episodes.

Keywords: Moisture transport, Lagrangian method, Danube River Basin, Drought, SPEI.

P08- Moisture sources of East Asian hydrological cycle

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ABSTRACT

China with its broad boundary and varied orography spans across several climate zones. Therefore, instead of investigating moisture sources of the hydrological cycle over China as a whole, we divide China into five regions according to differences in the orography and the water budget (P-E, P is precipitation and E is evaporation). Examination over these regions show that the hydrological cycle operates differently in these regions. Therefore, examining moisture sources over these regions separately is necessary. We calculate precipitation recycling ratio ρ following Brubaker et al. (1993). ρ is larger over the Tibetan Plateau and arid regions, but it is smaller over southeast where the East Asian Monsoon (EAM) is active. The seasonal cycle of r is dominated by moisture influx over the southeast, but is largely affected by the local evaporation elsewhere. Except the ρ, proportions of precipitation from moisture influxes are also computed, and are separated according to the entering direction of moisture influx to the region of interest. Results show that, the EAM is the dominant moisture source for southern China. However, for northern China, the mid-latitude moisture transport is another importance source. The interannual variability of these moisture sources will be investigated.

Keywords: moisture transport, precipitation recycling ratio, monsoon.

P09- A Lagrangian analysis of the moisture budget over Fertile Crescent during strong drought episodes

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ABSTRACT

The historical region of Fertile Crescent (FC), located on the eastern coast of Mediterranean and northern of Arabian Peninsula, is a semi-arid region with cool wet winters and hot dry summers. FC suffered for two strong drought episodes, separated by a 7-year period, during 1998-2000 and 2007-2009. These two prolonged droughts are considered the most severe episodes within the region in the last 50 years, and they led to a deterioration in the agricultural production, rural livelihoods, migration, urban, economic sectors and ecosystem decline in the countries involved (Syria, Iraq, Jordan, small strip from south of Turkey).

A Lagrangian approach was applied using the model of FLEXPART running with data from ERA-Interim (with a 1°x1°lon-lat resolution) to identify the main climatological sources of moisture and their characteristics over the FC during the wet season (from October to May) from 1980 to 2014. After that, we illustrate the changes in these sources during the two commented drought episodes.

Based on the backward analysis, the main moisture sources (those areas where the evaporation exceeds the precipitation, E- P >0) are: the FC itself, the eastern Mediterranean Sea, the Red Sea, the Persian Gulf, Arabian Sea, Caspian, and Black Seas, and the central and western of Mediterranean Sea. FLEXPART permits also a forward analysis to determinate where the particles that leave a region lose humidity (E-P<0), so we estimate the contribution to the moisture budget from each source over the FC.

The highest values associated with the air masses traveling to FC are achieved by the FC itself, the eastern Mediterranean, and the Red and Caspian Seas by 25%, 19%, 17%, and 12%, respectively. Most of the moisture lost is concentrated in the mountainous terrain over northern and eastern FC, and precisely, those are the areas that suffered the highest precipitation deficit during both drought extreme episodes. The shortage in the moisture losses related to the Red and Caspian Seas was the most remarkable common element between both episodes since this shortage repeated in the two wet seasons of each episode. In addition, there was a shortage in the contributions of many sources during the wet season before the drought of 2007-2009 that lead in a slightly precipitations deficit, which helped to increase the severity of this episode.

Keywords: Fetile Crescent - Lagrangian approach – drought.

P10- Residence Time of Atmospheric Moisture Sources in Colombia

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ABSTRACT

Moisture sources that contribute to precipitation over Colombia were determined using three independent methods: the Dynamic Recycling Model (DRM), FLEXPART and the Quasi-isentropic back-trajectory (QIBT) models. Moisture from the Atlantic Ocean, adjacent Tropical Pacific and terrestrial recycling are the most important regional sources, show the influence of long-range cross-equatorial flow from the Atlantic Ocean into the target region and the regional sensitivity to land-surface processes of surrounding basins.

The residence time of water vapor (RT-WV) from each source-region is determined by measuring the integration time of the trajectory of the maximum moisture transference in the FLEXPART model. Our results show the RT-WV varies among sources and differs from the 10-day average atmospheric residence time. Regionally, this time depends of the dynamical processes underlying in the transport mechanisms, the distance between source and target region and the seasonality related to general circulation.

We found recycling from terrestrial sources has shorter RT-WV compared with far Atlantic sources while Pacific sources have a markedly seasonal RT-WV. This characterization is useful to minimize the under/over estimations of moisture contributions related to time integration since the shape of annual cycle and the amount of precipitation are strongly linked to the moisture transport processes in tropical areas.

Keywords: atmospheric moisture sources, Colombia, water vapor residence time, transport processes.

P11- Moisture sources for the North American Monsoon and their influence on Precipitation Events

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ABSTRACT

The North American monsoon system (NAMS) is the large-scale atmospheric circulation system that drives the dramatic increase in rainfall experienced in the desert southwestern US and northwestern Mexico during the summer months of July, August, and until mid-September. Seasonal reversals of the wind are less pronounced than in other monsoons of the world, and complex interactions between surface heating, topography, and large-scale circulation patterns can modulate the moisture amount that reach this tropical and subtropical region.

There has been a considerable debate on the relative role of the oceanic sources of monsoonal moisture. A heat low over the southwest US steers moisture up from the waters of the Gulf of California and eastern Pacific. Moisture at higher levels in the atmosphere from the Gulf of Mexico and the Caribbean Sea may also contribute to monsoon precipitation. In addition to these two sources, more recent works also highlight the role of moisture recycling over the core monsoon region (i.e., the western slopes of the Sierra Madre Occidental) mainly due to seasonal greening of local vegetation.

The purpose of this work is to achieve a better understanding of the role of moisture transport within the NAMS. A lagrangian approach (FLEXPART model) is used to track the evaporation minus precipitation (E-P) evolution along trajectories of particles initially situated over the NAM region. FLEXPART simulations were performed from 1981 to 2014 by using one degree resolution and 60 model vertical levels available in ERA-Interim Reanalyses every 6 hours. We find that both Eastern Pacific and the Caribbean Sea are moisture sources for the NAM. While the Caribbean Sea contributes to precipitation from June to September the influence of Eastern Pacific to precipitation is more limited to the monsoon peak. Local moisture recycling is also relevant, and interestingly, we identify an additional terrestrial moisture source over the western US that could affect the precipitation development over the NAM.

Keywords: moisture, monsoon, North America, precipitation, lagrangian method.

P12- Investigating the Mechanisms Involved in the Sensitivity of Atmospheric Moisture Transport to Global Climate Models' Resolution

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ABSTRACT

Demory et al (2014) have demonstrated that the global water cycle is sensitive to global climate model (GCM)'s horizontal resolution, up to about 60 km, where the results converge. While ocean precipitation decreases with higher resolution, land precipitation and moisture convergence over land increase. The contribution of moisture transport to land precipitation also increases, whereas moisture recycling, a quantity that is known to be overestimated by state-of-the-art GCMs, tends to decrease.

In this study, we pursue Demory et al (2014) analysis using a newer version of their model. At each resolution, the total moisture transport is further decomposed into the contributions of mean circulation, stationary eddies and transient eddies. The sensitivity of these different terms to resolution and their contribution to the mean precipitation are assessed at the global scale, in the Tropics and mid-latitudes, and over each continent taken separately (North and South Americas, Asia, Africa, Australia and Europe).

The second part of the study focuses on the European water cycle. We seek to identify large-scale drivers of precipitation variability over land, at inter-annual to decadal timescales, that may have been overlooked due to the too coarse resolution of the current generation of climate models. To do so, we evaluate the response of both the mean and eddy components of moisture transport over land to potential drivers such as the North Atlantic sea surface temperature anomalies and weather regimes, with a special focus on the sensitivity of this response to resolution.

A better knowledge of the impact of resolution on the physical mechanisms transporting moisture over land has the potential to improve the prediction of precipitation. Obviously such mechanisms might be model-dependent. The third part of this study will therefore assess the robustness of the drivers of land precipitation across models using the simulations provided by the European modelling centres involved in the EU-PRIMAVERA project . This ensemble of five global climate models, spanning a range of resolutions from 200 km to 20 km, offers an unprecedented opportunity to look at the systematic sensitivity of moisture transport to resolution.

Keywords: moisture transport, drivers, resolution, global climate models.

P13- Analysis of Changes on Moisture Sources Contributions for Arctic Region in Future Climate Scenarios in CMIP5

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ABSTRACT

With a potential global temperature increase in future scenarios of climate change, the expected impacts on several regions of the world are alarming with respect to the occurrence of extreme events. The studies for Arctic region, in particular, are pessimist and indicate a huge increase for the temperatures. The concern for the Arctic region occurs because these scenarios could lead to a decrease on Arctic sea ice extent and on snow cover extent. Some studies suggests that the Northern Hemisphere mid-latitude weather could contribute to changes on Arctic region via changes in the atmospheric moisture transport and that the Mediterranean Sea, North Atlantic Ocean and North Pacific Ocean are the mains regions that contribute as moisture sources to the Arctic Region.

The objective of this work is to use an ensemble of 22 CMIP5 Models to identify where occur the main changes on moisture sources that contributes to the Arctic Region in two future scenario (RCP4.5 and RCP8.5). The future period (2073-2096) where compared to the present period (1980-2000). For both scenarios analyzed, the results suggest that the contribution for Arctic moisture by the regions located on North Atlantic Ocean, North Africa and Middle East enhanced. The increase in the contribution is bigger in RCP8.5 scenario. These results may indicate an increase in moisture transport from these regions to Arctic.

Keywords: Moisture Transport, Arctic Region, Climate Change, CMIP5.

P14- Moisture transport and associated MJO prediction skill in a global model

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ABSTRACT

Improvement of Madden-Julian Oscillation (MJO) prediction is crucial in light of the link between operational weather and climate predictions. This motivates to study the MJO prediction skill of the operational Global Spectral Model (GSM) at the Japan Meteorological Agency (JMA) over Indian Ocean, focusing on the moisture transport due to organized cloud-clusters.

Results of comparison of the GSM prediction with special observations conducted during the Dynamics of the Madden-Julian Oscillation (DYNAMO) period over the Indian Ocean suggest the poor prediction skill in the convectively active phase when dry air intrudes into the eastward propagating MJO.

Sensitivity tests of relative-humidity-dependent entrainment (RHDE) rate are conducted in the operational multi-plume convection scheme with a prognostic closure. Experiment with the higher RHDE rate reproduces a better eastward propagation of convectively organized cloud-clusters with a backward-tilt vertical structure of MJO near the Maritime Continent. Data assimilation and forecast cycle experiment reveals the forecasted moisture and temperature fields are statistically closer to the satellite observation in the short-range forecast, which explains smaller error growth of the moisture transport and precipitation after that. The balance of prediction skills between MJO and other tropical waves are also investigated, and the results will be discussed.

Keywords: MJO, convection, entrainment.

P15- The role of the entrainment flux at the top of the boundary layer for the Amazonian evapotranspiration

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ABSTRACT

The Amazon region is well known as a locally and regional source of convection and atmospheric water vapor in Brazil and South America. The boundary layer (BL) processes is the link between the surface and the base of the clouds and its characteristics and growth are very important to be fully understood. Locally, it can be assumed as horizontal homogenously and all exchange occurs in the vertical by eddies. The lower boundary (surface evapotranspiration) has been studied for a long time either using observations (eddy correlation measurements) or modeling techniques (e.g. Penman-Monteith formulas). However, the upper part (top of the boundary layer) was not addressed sofar. The Go Amazon 2014/15 field campaigns was held at central Amazonia during the 2014 wet (feb-mar Intensive Observational Period IOP1) and dry seasons (sept-oct IOP2) and it provides new and original data set in order to understand better the water cycle inside this Boundary Layer (BL) box. They include in situ (eddy correlation), remote sensing (ceilometer, minisodar, windprofiler, microwave radiometer) and aircraft measurements (airplane twin propeller) as well routine rawinsounding data (6 launchings per day). This unique observational data has been analyzed and provide new information about some of the characteristics of the BL. For instance, the fast response data (temperature, humidity and vertical windspeed) at 20 Hz were measured and the entrainment fluxes (both sensible and latent heat) were computed from aircraft data (25 flights between 11 and 14 local time). The height of the boundary layer was computed using different techniques (soundings, ceilometers, etc) and it has a maximum depth about 1100 for IOP1 and 1600 m for IOP2. The sensible heat flux profile follows the linear trend and shows a ratio between the top and surface in the range from -0.1 and -0.2. The latent heat fluxes at the top of BL shows high values (typically around 600-800 $W.m^{-2}$) and this is mainly due to the entrainment of dry air at free atmosphere inside the humid BL. This paper is a contribution of the Brazilian National Institute of Science and Technology (INCT) for Climate Change funded by CNPq Grant Number 573797/2008-0 and FAPESP Grant Number 2008/57719-9.

Keywords: Aircraft turbulent measurements, Go Amazon 2014/15, turbulent fluxes, entrainment ratio, height of boundary layer.

P16- The role of evapotranspiration in spring precipitation in the Iberian Peninsula: recycling or amplification or precipitation dynamics?

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ABSTRACT

Evapotranspiration fluxes determine the intensity of land-atmosphere coupling and the relevance of recycling or precipitation amplification processes in the local hydrology cycle.

In this study we focus on the role of terrestrial ET in the intensification of spring precipitation in the Iberian Peninsula.

Simulations with the WRF regional meteorological model are performed over the Iberian Peninsula, during may 2001-2010.

The recycling ratio is calculated with a moisture tagging capability in the model.

A set of experiments is performed where ET is gradually removed without affecting the partition of energy at the land surface , and the impact on precipitation is assessed.

The decrease of precipitation when ET is removed is quite significant, suggesting a prominent role of local ET in Iberian precipitation during springtime.

The response of the system shows a rather linear behaviour, with similar reductions in ET and precipitation.

This allows us to estimate the role of ET fluxes in precipitation dynamics by comparing the recycling ratio with the impact of a complete removal of land ET fluxes.

Recycling is on average about one third of the the total impact, suggesting that the effect of ET on precipitation is largely via indirect or amplification mechanisms, such as the increasing of moist static instability in the column, conducting to stronger or new convection development.

The main source of moisture for the extra precipitation induce by local ET is therefore largely non-local.

Keywords: water cycle, Iberian Peninsula, Recycling, Amplification.

P17- Real evapotranspiration evolution in the southern of Iberian Peninsula

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ABSTRACT

This paper analyzes the evolution of real evapotranspiration in the Guadalquivir basin, located in the south of the Iberian Peninsula in the last 30 years. The different components of the real evaporation are connected to the soil moisture content. These variables can be important when analyzing the intensity of droughts and heat waves, and particularly relevant in the impact study of the climate change

The actual evapotranspiration data consists of simulations obtained with the hydrological model Variable Infiltration Capacity (VIC). This model is a large-scale hydrologic mode and allows estimates of different variables in the hydrological system of a basin Land surface is modeled as a grid of large and uniform cells with sub-grid heterogeneity (e.g. land cover), while water influx is local, only depending from the interaction between grid cell and local atmosphere environment.

As input variables for VIC model will be used observational data of temperature and precipitation from Spain02 dataset. Additionally, estimates of actual evapotranspiration will also be analyzed using as input variables for VIC temperature, precipitation, wind, humidity and radiation obtained from a dynamical downscaling of ERA-Interim data with the Weather Research and Forecasting (WRF) model. The simulations have a spatial resolution about 9 km. The analysis will be done on a seasonal time-scale.

Preliminary results from Spain02 data show a decrease in actual evapotranspiration in the southeast of the basin, particularly significant during spring.

Keywords: Actual evapotranspiration, Guadalquivir Basin, trends.

P18- Preliminary evaluation of the soil moisture in Taiwan

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ABSTRACT

Cooperating with Taiwan Central Weather Bureau and NSC/TW, the soil moisture observed stations in Taiwan were established. Various land-use types are involved in the stations, including urban, grassland, mountain forest and rice paddy. In this study, we have used FDR method to observe soil moisture underground 10, 30, 70, 100 and 150 cm, and in situ measurement from June, 2013 till now. The range of soil moisture is from 2~50%, soil texture is also investigated.

This study focus on the behavior of surface soil moisture after a rainfall event. Result shows a positive correlation between the soil moisture and precipitation. After a rain fall event, the short-term and long-term variation of soil moisture decreased with soil depth which followed by gravity and transpiration, respectively. In addition, deeper soil was less affected by rainfall. Sandy loam soil in the Tainan and Hengchun stations make the soil water easy to penetrate and made soil moisture keep in a stable status (8~15%) during a year in the surface soil. Temporal precipitation patterns in Taiwan concentrated on May to September caused from plum rains and typhoon. Therefore, significant seasonal variations in Taichung, Sun Moon Lake and Chiayi station where the lower soil moisture had in winter. On the other hand, spatial characteristic of surface soil moisture reflect in the high-altitude stations; Sun Moon Lake and Mt. Peitungyen with higher soil moisture (25~30%) due to mountains are frequently covered with mist and rain. In addition, the soil moisture is also available derived from HRLDAS and GLDAS. Compared with our measurements, both can catch the spatial distributions on surface soil, but overestimated in deep soil (20~30% soil moisture) in HRLDAS from April to May, 2014.

Keywords: Soil moisture, precipitation, HRLDAS, GLDAS.

P19- Comparison of Different Geostatistical Methods for Estimating Evaporation in Namak Lake Watershed

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ABSTRACT

Because the mean value of potential evaporation is one of the important parameters in water resources studies and geostatistical methods are the most suitable techniques, the present study was done. In the present study, all stations existed in the Namak Lake watershed were considered out of which 82 stations with data collection period of longer than 20 years and suitable spatial distribution were selected for the analysis. Three methods of ordinary kriging, cokriging and moving average using inverse distance with powers of 1 to 3 were then applied for analyzing annual evaporation data with the help of Arc/GIS and GS+ geostatistical softwares. The results show that the Kriging and weighing moving average through inverse distance with power of 1 are the best methods for the analysis of data. According to the results obtained through analysis of variogram model, spherical model is supposed as the best models. The results of the analysis also show that the optimal distance between meteorological stations should be considered some 40 km in the study area.

Keywords: Geostatistic, Annual potential evaporation, Pan class A, Namak Lake watershed, Iran.

P20- Spatial and Temporal Variabilities in Air Moisture Sources and Stable Isotope Compositions of Precipitation in Hungary

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ABSTRACT

Hungary is a sensitive region to detect changes in the atmospheric circulation as it is located in a transition zone which is influenced by meteorological (climatological) conditions of Atlantic, Mediterranean and North/East regions. In this study we present the first result of the investigation about the determination of air moisture source regions for six localities in Hungary. To reconstruct the path of the air moisture from the source region, we ran the NOAA HYSPLIT trajectory model using the GDAS database with 1° spatial and 6 hours temporal resolution for every precipitation event, for heights of 500, 1500 and 3000 m. We determined the location where water vapour entered into the atmosphere by calculating specific humidity along the trajectories. Five possible moisture source regions for precipitation were defined: Atlantic, North European, East European, Mediterranean and continental (local/convective). Additionally, this study evaluates the regional differences in stable isotope compositions of precipitation based on hydrogen and oxygen isotope analyses of daily rainwater samples. Stable isotope variations show systematic and significant differences between the regions. The variability of moisture source shows also systematic seasonal and spatial distribution. Interestingly, the most dominant among the identified source regions in all stations is the Mediterranean area; while the second is the Atlantic region. The ratio of the precipitations originated in Eastern and Northern Europe seem to correlate with the geographic position of the meteorological station. Furthermore, the ratios of the different moisture sources show intra annual variability.

In each location, the amount weighted d-excess values were calculated for the identified moisture sources. The precipitation originated in the Mediterranean regions has systematically higher d-excess values than that originated in the Atlantic sector, independently from the absolute value which apparently changes from station to station. The precipitation fraction attributed to the Northern European sector has also relatively elevated d-excess values that might be related to the cold-season domination of moisture transport from this region.

Keywords: moisture source, stable isotope, d-excess.

Acknowledgments: *The study was financially supported by the Hungarian Research Fund (project No. OTKA NK 101664 and SNN118205). György Czuppon also thanks for the support of the János Bolyai Research Scholarship of the Hungarian Academy of Sciences.*

P21- Variability of Stable Isotope Composition of Precipitation at Different Location in Central Europe: Implication for Moisture Source Variability and the Effect of Evapotranspiration

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ABSTRACT

In general, ratio of land surface originated moisture in land surface precipitation is 4:6 based on global hydrologic evaluation. However, the cyclone routes and their moisture sources show systematic spatial and temporal (seasonal) variation. Additionally, the evapotranspiration can play a significant role during the precipitation formation affecting also the stable isotope composition.

In Hungary at six stations an event based precipitation stable isotopic composition measurement system exists since 2012. Based on HYSPLIT analyses the source regions were also determined, however the stable isotopic composition varies significantly between precipitation events originating from the same region and similar thermal condition. It is theorized that these fluctuations are caused by land surface evaporation and different microphysical formation processes.

In order to assess the initially the probable causes the WRF model is used to estimate evapotranspiration - with refined land use and soil moisture initial conditions - and analyse the microphysical properties. The simulated precipitation is compared to the precipitation and stable isotopic compositions measured at the six Hungarian locations.

The study was financially supported by the Hungarian Research Fund (project No. OTKA NK 101664 and SNN118205). György Czuppon also thanks for the support of the János Bolyai Research Scholarship of the Hungarian Academy of Sciences.

Keywords: stable isotope, evapotranspiration, WRF model.

P22- Climate Change Effects on Precipitation Extremes in Central Europe

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ABSTRACT

Precipitation extremes are associated with large negative effects on environment and human society due to floods, landslides, and other hazards. There is also growing evidence that the hydrological cycle, including heavy precipitation, is affected by climate change. Many studies have dealt with evaluation of precipitation extremes in regional climate models (RCMs) and their projected changes for the 21st century, but relatively little attention has been given to differences between scenarios for i) sub-daily and multi-day precipitation extremes, and (ii) convective (sub-grid) and stratiform (large-scale) precipitation. While extreme convective (sub-daily) events are associated with flash floods, heavy stratiform (often multi-day) precipitation may trigger regional floods affecting large areas. We analyse projected changes of precipitation characteristics and extremes in Central Europe for the late 21st century (2071–2100) in ensembles of RCM simulations from ENSEMBLES and EURO-CORDEX projects. We find increases in heavy precipitation and extremes in both winter and summer, in the latter case in spite of pronounced drying (declines of seasonal precipitation) in most RCMs. Both convective and large-scale precipitation amounts tend to increase in all seasons except summer when large-scale precipitation amounts decrease. Extreme precipitation is projected to increase for both convective and large-scale precipitation. The changes of precipitation characteristics are more pronounced in simulations driven by the high concentration RCP8.5 scenario, with a larger increase of temperature, and they are larger for precipitation with higher intensity. Increasing proportion of convective precipitation in summer and generally increasing intensity of precipitation may have important consequences, e.g. for soil erosion, replenishment of soil moisture, and occurrence of flash floods and droughts.

Keywords: precipitation, extremes, climate change, regional climate models, Central Europe.

P23- Non-stationary Future Return Levels for Extreme Rainfall over Extremadura (SW Iberian Peninsula)

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ABSTRACT

A new method for the calculation of non-stationary return levels for extreme rainfall is described and applied to a south-western Spanish Region – Extremadura. It is based on Extreme Value Theory (EVT), specifically the peaks-over-threshold (POT) approach. Both all-days and rainy-days-only data sets were considered, with different thresholds in each case. The 20-year return levels (RLs) expected in 2020 were estimated taking different trends into account: first, for all days, considering a time-dependent threshold and the trend in the scale parameter of the Generalized Pareto Distribution (GPD); and second, for rainy days only, considering the role of how the mean, variance, and number of rainy days evolve. The results of the two methods agree in general, but sometimes the trend in the scale parameter is sensitive to the threshold selection, leading to unrealistic RLs. Thus the method based on the extrapolation of the temporal evolution of the mean, variance, and number of rainy days seems to be the more robust. Its results point to a decrease of future RLs in 2020 for spring and winter, but an increase for autumn, which becomes the season with the greatest extreme events in Extremadura.

Keywords: Generalized Pareto Distribution, Return Levels, Extreme Value Theory.

P24- A study on the applicability of atmospheric-hydrological coupled model for flash flood forecasting

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ABSTRACT

Quantifying hydro-meteorological information such as precipitation, soil moisture, evapotranspiration, and runoff based on the coupled model comprising atmospheric model with land surface models and hydrological modules is being a hot topic. In this study, WRF-Hydro (Weather Research and Forecasting Model Hydrological modelling extension package), atmospheric-hydrological coupled model developed by the National Center for Atmospheric Research, is used for assessing its applicability on the flash flood forecasting system. National Institute of Meteorological Sciences (NIMS) has been developed TOPLATS (TOPmodel-based Land Atmosphere Transfer Scheme) column model based hydrometeorological information system(HIS) for flash flood forecasting over the complex terrain and been operated. Here, in order to overcome the weakness of column model based one, lessons from the atmosphere-hydrological coupled model are ingested. The heavy rainfall induced flash flood cases in the Korean Peninsula are selected and the simulation periods are 60 hours. As a result of the comparison of TOPLATS offline system and WRF-Hydro, soil moisture and run-off from WRF-Hydro is sensitive to precipitation compared to those of TOPLATS. For soil moisture, WRF-Hydro tends to underestimate compared to TOPLATS. On the contrary, run-off of WRF-Hdyro is greater than that of TOPLATS. The result is similar to the difference of the coupled mode and the uncoupled mode of WRF-Hydro. The difference is added to NIMS HIS and its evaluation results for flash flood forecasting will be presented.

Keywords: WRF-Hydro, TOPLATS, Flash Flood Forecasting, Hydro-meteorological information.

P25- Does evidence support the hypothesis of an intensification of Costa Rica hydrological cycle?

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ABSTRACT

As part of the so-called Central American climate change hotspot, Costa Rica offers a unique opportunity for studying long term changes for meteorological variables. Costa Rica is featured by a contrasting Caribbean-Pacific precipitation signal driven by multiscale processes. In recent years, despite climate projections suggest the region to become more humid, observational studies have clearly shown non significant precipitation trends. However, temperature shows a coherent increasing signal for several locations for which observations are available. The latter, added to a proposed intensification of low level winds has been pointed out as a trigger for an intensification of Costa Rica hydrological cycle. This study provides a detailed analysis of a comprenhensive observations dataset to evaluate the hydrological cycle intensification hypothesis for Costa Rica. The results, so far, show a marked height sensitivity

for temperature trends. According to observations, long term changes of precipitation are not likely to be strong neither significant enough. Nonetheless, the analysis of detected changes in the diurnal temperature range in terms of the diurnal temperature response to heating and convection reveals a surface feedback which may be relevant to link surface conditions with changes in local precipitation. The results also suggest that under specific conditions, the Caribbean-Pacific precipitation contrast is enhanced. The latest result is used as an example on how future warm ENSO-like scenarios might affect regional rainfall.

Keywords: hydrological cycle, diurnal temperature range, rainfall, Caribbean, Pacific.

P26- Influence of Amazonian Convection Over Tropical North Atlantic SSTs

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ABSTRACT

We propose a physical mechanism that describes the influence of the Amazon River basin (AM) over the Tropical North Atlantic (TNA) region during anomalous convection over the continent. The Amazon driest (wettest) months are characterized by a decrease (increase) in rainfall (P), which in turn increases (decrease) atmospheric surface pressure in the AM thus reducing (increasing) the pressure gradient between the TNA and AM regions (G), which in turn causes a slowing down (speeding up) of the zonal trade wind velocities (W) at the TNA region. The weakening (strengthening) of the trade winds over the TNA is related with a reduction (increase) in evaporative cooling and a subsequent increase (reduction) of TNA SSTs. We searched for dynamical evidence by computing composites of zonal wind velocities anomalies and SST anomalies in the TNA for the dry (JASO) and the wet (NDJF) seasons. When the AM region experiences reductions of convective processes the TNA region is characterized by an evident reduction of zonal wind velocities in July over the northeast of the TNA above 15°N and near the African coast, and the SSTs are colder near the Americas. By August the slower zonal winds towards the AM cover a broader band above 10°N and the SST's above the equator are increased in almost 1°C above the conditions found in July. While the reduction of the winds appears to be in phase with the beginning of the dry season, increasing temperatures in the ocean are found from zero to three months. While the AM is in the wet season, starting in November, the conditions are similar to those at the end of the dry season, with a warming of almost 2°C above the mean conditions in the northern TNA, and slower zonal wind velocities near the coasts of South America. When the convective processes become more intense from December to February in the peak of the South American Monsoon the zonal winds start to increase their velocities towards the continent and the SSTs become colder reaching values even 3°C below normal conditions. During extreme AM droughts (2005-2010) January reaches values of P almost 20 mm/month below the mean, this implies the reduction of convective processes during the peak of the wet season. One month later in February G reaches a minimum value in phase with the minimum values of W towards the AM, and during the first three months there is an ongoing warming of the SSTs. On the contrary, during extreme AM floods (1999-2009) there is an increased P followed by higher G, faster winds in the AM direction and a cooler TNA SSTs. The timing in the mechanism by which AM influences the TNA is well observed and can be identified in the aforementioned results spanning a period of three months.

Keywords: Amazonia, convection, pressure gradient, Tropical north Atlantic, SST.

P27- Seasonal and Interannual Variations of Atmospheric Water Cycle in Siberia and Polar Regions

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ABSTRACT

We have investigated seasonal and interannual variations of water cycles in Siberia, the Arctic and Antarctic based on vertically integrated moisture flux and estimated net precipitation (precipitation minus evaporation). There were some similarities and differences in the water cycles.

The Arctic and Antarctic are regions of moisture flux convergence through the year, where the precipitation exceeds the evaporation and the net precipitation is positive. Therefore, the atmospheric moisture transport is a primary input of water into the polar regions. While over Siberia, moisture flux convergence is also seen most of the year, there are some areas of divergence and negative net precipitation in summer due to large evapotranspiration. The net precipitation over this region affects the Siberian river discharge.

Poleward transient moisture flux associated with cyclone activity plays an important role in the climatological seasonal cycle of net precipitation. The poleward transient flux dominates over the Arctic and Antarctic. The transient moisture flux also dominates over eastern Siberia, while stationary moisture flux associated with seasonal wind dominates over western Siberia. As a result, there is a regional difference in moisture transport processes over Siberia.

On the other hand, stationary moisture flux is important for the interannual variations. The Arctic Oscillation and the Antarctic Oscillation as an atmospheric internal variability in the Northern and Southern Hemispheres change not only large-scale atmospheric circulation but also moisture transport over the Arctic and Antarctic. Over Siberia in the summer, east-west seesaw pattern of atmospheric circulation emerges as an internal variability. This seesaw pattern affects out-of-phase variations of precipitation over western and eastern Siberia, and results in negative correlation of the river discharges. Consequently, the atmospheric internal variability is one of the key factors controlling the water cycles in Siberia, the Arctic and Antarctic. In addition to these, recent climate changes may have some influence on the water cycles in these regions. This is a future work.

Keywords: Atmospheric moisture flux, net precipitation, Siberia, Arctic, Antarctic.

P28- The East Asian Water Cycle and Monsoon Circulation in the Met Office Unified Model

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ABSTRACT

The hydrological cycle is a key element in global and regional climate variability, acting through various processes and connecting many of the climate system components. Changes in the components of the water cycle, natural or induced by anthropogenic global warming, have the potential to produce substantial impacts on human society and the natural environment. China is one of the most populated nations in the world and increasing water consumption as a consequence of population growth and rapid economic development makes water resources in the region vulnerable to variations in precipitation, representing a serious challenge for food security and environmental degradation. Understanding and predicting how natural variability and anthropogenic climate change affect East Asian climate and China's hydrological cycle is of major importance. A key issue is to both understand and then represent the physical and dynamical mechanisms driving those changes in the models we use to make regional predictions at different time scales from seasonal to multi-annual to centennial.

In this work we study the East Asian water cycle in the latest generation Met Office Unified Model, GC2, placing it within the context of the wider Asian-Pacific monsoon circulation. We first look at the capability of the MetUM to represent the Asian summer monsoon flow and then focus in the climatological water cycle over China, studying in detail regional water budgets and relevant moisture transports. Given the importance of moisture convergence and monsoon circulations in China's hydrological cycle, we look at the role that key model systematic errors in the large-scale circulation may play in determining the regional hydrological cycle. An initial assessment of intra-seasonal and interannual variability is also presented.

Keywords: regional water cycle, East Asian water cycle, East Asian monsoon, Climate model evaluation.

P29- Wavetrains and South America Climate on Decadal Scale

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ABSTRACT

Diagnostic analysis of geopotential height and wind data from NCEP-NCAR, JRA and ERA20C reanalysis and GPCC precipitation associated with Pacific Decadal Oscillation (PDO) phases observed during 1970 and 2003, over South Pacific and South America are presented. Comparison of wind and geopotential height NCEP-NCAR, JRA and ERA20C reanalysis allows to conclude that, in general, all three datasets show similar patterns for the subperiods 1970-1976, 1977-1996 and 1997-2003. Anomalies of geopotential height at high levels show opposite patterns during positive and negative PDO phases. During negative (positive) PDO phases, central eastern South America is characterized by positive (negative) geopotential height anomalies. The observed patterns over South America during distinct PDO phases are due to distinct low frequency mean patterns over South Pacific. Associated with the geopotential height analysis, vector wind mean anomalies showed anticyclonic and cyclonic anomalies over the central-eastern South America during negative and positive PDO phases. Anticyclonic and cyclonic anomalies observed at high levels can respectively be associated with dry and wet periods over this region assuming a barotropic troposphere. During the negative PDO phases, 1st and 3rd subperiods (1970-1976 and 1997-2003), anticyclonic anomalies are observed over central-eastern South America, while during the positive PDO phase, an opposite signal is observed. Considering the three datasets, NCEP-NCAR wind data show the more intense anomalies. NCEP-NCAR and JRA are more similar between themselves. ERA20C show more discrepant results in relation to NCEP-NCAR and JRA reanalysis for wind anomalies. Analysis of precipitation patterns show negative and positive anomalies over the northwest-southeast belt over central South America during negative and positive PDO phases, respectively. The strengthening (weakening) northerly flow over the central areas of South America is associated with negative (positive) anomalies of precipitation over the NW-SE belt during negative (positive) PDO phases. At the same periods, the strengthening (weakening) of easterly flow over the north-eastern South America and tropical Atlantic, bringing moist air (bringing less moist air) from tropical Atlantic Ocean to continental areas, is associated with negative (positive) precipitation anomalies on the NW-SE belt.

Keywords: South Pacific-South America mode; Pacific Decadal Oscillation; South America circulation; South America precipitation.

P30- Validation of Integrated Water Vapor from GOME-2 satelite instrument against reference GPS data at the Iberian Peninsula

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ABSTRACT

This study shows the results of the validation of integrated water vapor (IWV) measurements retrieved from the satellite instrument GOME-2 (Global Ozone Monitoring Experiment – 2) using nine ground-based GPS stations as reference at the Iberian peninsula. The study period covers from 2007-2012. The influence of IWV, CF, SZA and season were studied. GOME-2 shows a tendency to overestimate the reference data, particularly for low IWV measurements. This tendency is stronger for high SZA, with increasing mean biased error (MBE), up to +25%. Standard deviation (SD) increases with SZA (up to 40%). The effect of clouds (using the parameter cloud fraction, CF) is to underestimate the IWV (up to -8%). For very low IWV, GOME-2 IWV data tends to overestimate (+50%) the GPS measurements, while it is lower for high IWV (-10%). Standard deviation also decreases as IWV increases, from 45% at lower values to 20% for higher values. Regarding seasonal dependence, spring and autumn have a slight tendency to underestimation (MBE around -10%). Summer months present a slight overestimation (around +10%) and winter a larger overestimation (MBE up to +50%). SD is lower in summer (20-30%) and higher in winter (around 40%).

Keywords: Integrated Water Vapor, GOME-2, GPS, Iberian peninsula.

P31- Future Central European Summer Drying in a High-Resolution Global Climate Model

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ABSTRACT

Using the SST forced high-resolution (~25km) Ec-Earth global climate model we have investigated the future central European summer drying. Compared to the standard resolution model (~150 km) a large increase in severe summer droughts for the end of the 21st century is observed. The mechanisms responsible for these differences are analyzed. They are related to changes in large scale atmospheric circulation patterns and moisture transport and changes in local surface moisture budget that involve precipitation, evaporation and runoff. The different contributions of these drivers to the occurrence of future droughts and their representation in climate models are analyzed and discussed.

Keywords: High-resolution climate modelling, summer drying, Europe.

P32- Study of future changes in drought and soil patterns over Spain using WRF

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ABSTRACT

In recent years, the Mediterranean region has experimented severe drought events causing numerous economic, social and environmental losses. This fact makes necessary to evaluate the potential future changes of drought patterns, especially in vulnerable areas such as Spain. This study explores the projected drought changes using two different drought indices: The Standard Precipitation Index (SPI) and the Standard Precipitation Evapotranspiration Index (SPEI), at different time-scales, and trying to relate these with soil moisture patterns. For that, the Weather Research and Forecasting (WRF) model was used in order to obtain future (2021-2050) climate fields to compute these drought indices. A current simulation (1980-2010) also was carried out with validation purposes.

All WRF runs were performed over a domain encompassing the Iberian Peninsula with a spatial resolution of 0.088º, and nested in the coarser EURO-CORDEX domain (0.44° resolution). WRF model was driven by the global bias-corrected climate model output data from version 1 of NCAR's Community Earth System Model (CESM1), using two different Representative Concentration Pathways (RCP) scenarios: RCP 4.5 and RCP 8.5.

Due to the SPEI takes into account changes in the temperature while SPI is based only on precipitation data, the comparison between these two drought indices could help to understand how the increase of the temperature could affect to the drought variability in Spain in a context of climate change. Additionally, the drought patterns found will be compared with the soil moisture ones, being this variable also provided by WRF simulations.

Preliminary results suggest that WRF is a very useful tool to detect and monitor future drought patterns in Spain properly.

Keywords: droughts, SPEI, SPI, WRF, climate change projections.

Acknowledgments: *This work has been financed by the projects P11-RNM-7941 (Junta de Andalucía-Spain) and CGL2013-48539-R (MINECO-Spain, FEDER).*

P33- Climate change signal on the Portuguese precipitation: high-resolution simulations using WRF and EURO-CORDEX RCMs

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ABSTRACT

The newer and higher resolution regional climate simulations, covering Portugal, are evaluated in present climate and used to investigate the rainfall projections for the end of the 21st century, following the RCP8.5 emission scenario, by the use of individual models and multi-model ensembles. The two EURO-CORDEX ensembles, at 0.11º and at 0.44º resolution, are evaluated against gridded observations of precipitation in Portugal, a small but complex region with very large mean precipitation gradients and large interannual variability, in the west limit of the Mediterranean subtropics. An extra simulation, at even higher resolution (9km) with WRF is also analysed. In present climate, the models are able to describe the precipitation temporal and spatial patterns as well its distributions, although there is a large spread and an overestimation of larger rainfall quantiles. The multi-model ensembles show that selecting the best performing models adds quality to the overall representation of rainfall. The high-resolution simulations augment the spatial details of precipitation, but objectively do not seem to add value with respect to the coarse resolution. For future, WRF and the multi-model ensembles consistently predict important losses of precipitation in Portugal in spring, summer and autumn, ranging from -10% and -50%. For all seasons, the changes are more severe in the southern basins. Regarding the precipitation distributions, all models show important reductions of the contribution from low to moderate/high precipitation bins and augments of days with strong rainfall. Furthermore, a prominent growth of high-ranking percentiles is predicted reaching values over 70% in some regions.

Keywords: Climate Change, Extreme precipitation, Regional Climate Modelling, Added Value, EURO-CORDEX.

P34- Modelling Pinus Pinaster wood radial growth in Portugal

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ABSTRACT

Trees are responding physiologically to the prevailing climatic conditions. Wood formation and growth are also recognized to be strongly affected by climate conditions and mostly constrained by water availability, namely in drier regions of Mediterranean basin.

Using monthly means of climate variables (maximum, minimum and mean temperature, precipitation), climate indices (dry spell, heat sum) and drought indicators (SPEI for the times scales from 1 to 24 months), we modelled the vulnerability of Pinus Pinaster wood radial growth to climate variability and change. Wood ring cores were sampled in Companhia das Lezirias (38º 47' 24.01 N; 8º 54' 11.10 W) located in the northern-east part of the Alentejo region. The sampling size was limited to ten cores and only one core by tree.

Wood radial growth highly benefit from the strong decline of cold days and the increase of minimum temperature. Yet the benefits are hindered by long term water deficit, which results in different levels of impact on wood radial growth.

Two linear regression models were developed with the aim of forecasting Pinus Pinaster wood radial growth in Alentejo region using climate variables and indices by one hand, and different time scales of SPEI by the other. Both models performed well in terms of robustness and reliability. Some limitations may result from the linear nature of the model, and from the disregarding of the effects of the increase in CO2. Nevertheless, our results reflects the strong impact of changes in minimum temperature and precipitation on interannual variability of Pinus Pinaster wood radial growth. The ability of the models to forecast Pinus Pinaster woog radial growth according to the scenario RCP 8.5 will be further assessed.

Keywords: Pinus Pinaster wood radial growth, drought, climate variability, Standard Precipitation-Evapotranspiration Index (SPEI), regression models.

Acknowledgments: *This work was partially supported by national funds through FCT (Fundação para a Ciência e a Tecnologia, Portugal) under project PIEZAGRO (PTDC/AAG-REC/7046/2014).*

P35- How recent spring precipitation changes compromised Maritime pine radial wood growth and density in southern Portugal

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ABSTRACT

We investigated whether Pinus pinaster (Ait), one of the main agroforestry pine species explored in Portugal, has been affected by changes in monthly/seasonal precipitation patterns in a semi-arid region of south Portugal since the late 1950s. In this study we analyze how wood radial growth and density responded to those changes.

There was a sharp decline of spring precipitation from 1950 to 2012, progressively spreading from spring to the prior late winter. Besides, maximum daily precipitation (Pmax) weakened in February-March while it tended to intensify in fall since the 1980s. The depletion of spring precipitation resulted in the raise of the dry period length mostly in March. A combined raise of temperature since the late 1970s induced a higher evapotranspiration rate driving the local water balance towards unfavorable spring water deficit.

This most probably led to early water stress for P. pinaster during the usual peak of the growth period. Tree radial growth was consistently and positively correlated to winter total precipitation and intensity while negatively correlated to winter dry spells. The significant correlations were mostly concentrated in November-January preceding the ring formation. Ring growth positively responded to increased Pmax since the 1990s with a shift from October to December, matching Pmax seasonal changes. By contrast, the depletion of spring precipitation had a growing negative impact on wood xylogenesis and density mostly since the 1990s. Eventually, P. pinaster wood growth showed to be more sensitive to intra-annual changes of precipitation since the 1990s rather than inter-annual fluctuations since the 1950s.

Our results highlight the relevance of deep water storage and the depth of the groundwater table for Maritime pine in a semi-arid environment, which are mostly affected by fall to winter and even recently spring precipitation preceding the growing period. The accumulation of recent inauspicious years with insufficient stored water at the beginning of the growing season tended to decrease the length of the growing period resulting in thinner cell walls and thus in lower wood width, density and quality.

Keywords: Spring precipitation changes, aridity increase, wood growth/density, Pinus pinaster.

Acknowledgements: *This work was partially supported by the project PIEZAGRO (PTDC/AAG-REC/7046/2014) funded by the Fundação para a Ciência e a Tecnologia, Portugal.*

P36- Impact of irrigation over the California Central Valley on regional climate

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ABSTRACT

Irrigation, while being an important anthropogenic factor affecting the local to regional water cycle, is not typically represented in regional climate models. We incorporated an irrigation scheme into the Noah land surface scheme of the Weather Research and Forecasting (WRF) model that has a calibrated convective parameterization, and used a tracer package to tag and track water vapor. To assess the impact of irrigation over the California Central Valley (CCV) on the regional climate of the U.S. Southwest, we ran simulations (for 3 dry and 3 wet years) both with, and without, the irrigation scheme. Incorporation of the irrigation scheme resulted in simulated surface air temperature and humidity that were closer to observations, decreased the depth of the planetary boundary layer over the CCV, and increased the convective available potential energy. The result was an overall increase in precipitation over most of the model domain. Water vapor rising from the irrigated region mainly moved northeastward and contributed to precipitation in Nevada and Idaho. Specifically, the results indicate increased precipitation on the windward side of the Sierra Nevada Range and over the Colorado River Basin. The former is possibly linked to a sea-breeze type circulation near the CCV, while the latter is likely associated with a wave pattern related to latent heat release over the moisture transport belt.

Keywords: regional modeling, tracers.

P37- Determination by Isotopic method of the origin of mineralization of the costal aquifer North-eastern Tunisia

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ABSTRACT

The coastal aquifer of Ras Djebel is located in North-eastern Tunisia. This aquifer covers 15 Km from Cap Zebib to RasSidi Ali El Mekki and occupies an area of 50 Km².It is limited by Djebels bouchoucha, Touchela and Bab Banzart in NW, Djebels Ennadhour and Demna in South, the Mediterranean sea in the North and NE. The study area is characterized by a sub-humid Mediterranean climate. The mean annual precipitations are about 534 mm. The annual average temperature is around 18°C and the potential evapotranspiration reach 1197 mm/year. Some wadis drain this basin and oued Beni Ata and Oued El Ma are the most important streams draining the plain of Ras Djebel. To study the groundwater quality, fifty water samples were collected from the shallow aquifer of the RasDjebel-RafRaf plain during October 2013. The groundwater samples were analyzed for chemical and isotopic compositions. Major elements (SO_4^{2-}, Cl^-, NO_3^-, Ca^{2+}, Mg^{2+}, Na^+ and K^+) were analyzed at the Laboratory of National Center for Nuclear Sciences and Technologies. The total dissolved solids and the electrical conductivity (EC) values range from 0, 2 to 7,09mS/cm. The spatial distribution of this element shows that salinity increase in the direction of groundwater flow. The Piper diagram shows that nearly all samples have a chemical facies enriched in Cl- and Na+ ions. The nitrates concentration in the groundwater varies between 7.5 and 144 mg/L. Forty two percent of the groundwater samples collected during this study, show nitrate concentrations exceeding the maximum European admissible nitrate concentration limit in drinking water. The examination of the nitrate distribution map reveals that high nitrate concentrations appear to be related to agricultural land use patterns. Consequently, the zones characterized by high nitrate concentrations, exceeding 50 mg/L, reflect the presence of agricultural influences that introduce a long-term risk of groundwater pollution by excess fertilizers and pesticides leaches downward. The groundwater samples shows an under-saturation with respect to gypsum and anhydrite indicating the eventual dissolution of these sulphate minerals and contributing to an increase of water salinity. The relationships between 180 and deuterium isotopes in groundwater samples indicated the presence of modern recharge from rainfall and a probably occurrence of an evaporation process related to the long-term practice of flood irrigation.

Keywords: Tunisia, coastal aquifer, Salinity, Hydrochemistry, isotopes.

P38- Origin of mineralization in the groundwater of lower valley of Medjerda, Northern Tunisia

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ABSTRACT

Groundwater quality is affected by diverse factors such as irrigation activities, urbanization and industrialization. These causes result mineralization and degradation of its hydrochemical quality and salinization. The objective of this study is the characterization of the aquifer by hydrochemical and isotopic approaches to determinate the salinity and its potential origins. This work focuses on the aquifer of Low Valley of Medjerda, which is located in the North of Tunisia and constitutes one of the main important aquifers in Tunisia. The study area is located in North-East of Tunisia and extended from Ghar Melh to Mediterranean Sea. This zone is characterized by a semi-aride climate, the annual average precipitation is about 477 mm. The main geologic features of this study area are the Trias, the upper cretaceous, the quaternary and the Mio-Pliocene. During the sampling campaign, fifty water samples were collected for geochemical and isotopic analyses. The aquifer salinity show an average salinity close to 3.2 g/l. The results show that salinity is mainly due to the dissolution of salts, halite, gypsum and anhydrite. On the other hand, irrigation water, soil leaching and training of agricultural products affect groundwater and participate in the mineralization. The approaches used in this study demonstrate that groundwater mineralization in is controlled by natural and anthropogenic processes. The Piper diagram shows that nearly all samples have a chemical facies enriched in Cl- and Na+ ions. The calculation of saturation indices shows that all the samples of water are under-saturated in evaporate minerals (Halite, Gypsum) contributing to increase the salinity of the water. The nitrate contamination of groundwater was confirmed by the return of water irrigation. Geochemical (ions Na+/Cl- , Br-/Cl- , Ca2+/Cl-) and the few isotopic (18O, 2H) analyses (10) were compared with the hydrodynamic information and salinity map for identifying the main processes involved in the increase in mineralization. Irrigation development that induces leaching of soils was identified as the main source of mineralizaiton. However, it is not the only cause of the qualitative degradation as the salinity of the groundwater is also impacted by dissolution of evaporate rocks (gypsum and halite minerals) in the aquifer. There is an indication of presence of water enriched in ^{18}O and ^{2}H and indicating a mixing with seawater.

Keywords: Tunisia, Salinity, Hydrochemistry, Hydrogeology, isotopes.

P39- The importance of Atmospheric Rivers in the development of explosive cyclogenesis in the North Atlantic and North Pacific basins

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ABSTRACT

Extratropical cyclones and particularly explosive cyclogenesis are one of the major natural hazards in mid-latitudes and are responsible for socioeconomic impacts.

Explosive cyclogenesis result from different mechanisms that includes upper-level cyclonic vorticity advection, low-level warm air advection, and latent heat release. Several studies confirm the occurrence of a maximum of latent and sensible heat availability in the lower troposphere, near the warm sector, supporting the contribution of moist diabatic processes, such as latent heat release by cloud condensation processes, results in the intensification of extratropical cyclones.Cyclones with deepening rates of at least (24*sin φ / sin 60º) hPa in 24 hours, where φ represents latitude in degrees of the cyclone center position, are referenced in the literature as explosive cyclogenesis / developments or simply as "bombs". ARs are identified as narrow plumes of enhanced moisture transport that are usually present in the core section of the broader warm conveyor belt occurring over the oceans along the warm sector of extra-tropical cyclones. They are usually W-E oriented steered by pre-frontal low level jets along the trailing cold front and subsequently feed the precipitation in the extra-tropical cyclones. The large amount of water vapor that is usually transported in ARs can lead to heavy precipitation and also to latent heat release along its path.

The main objective of this work is to analyze systematically the importance of the ARs on the development of extratropical cyclones, with special emphasis on the explosive cyclogenesis. The two different databases (explosive cyclogenesis and ARs) are analyzed simultaneously in order to study the importance of the ARs in the different stages of the explosive cyclogenesis in the North Atlantic and North Pacific basins.

Results confirm the link between these two phenomena, with no significant differences between both regions.

Keywords: explosive.

P40- How does the interplay between atmospheric rivers and circulation weather types affect precipitation over the northwestern Iberian Peninsula?

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ABSTRACT

Currently, one of the hot topics in the investigation of atmospheric dynamics are Tropospheric Rivers or Atmospheric Rivers (ARs). The advection of moisture by ARs is a key process for the Earth's sensible and latent heat redistribution and has a key influence on the water cycle of the mid-latitudes. ARs can contain high amounts of water vapor, strong winds and impact on vulnerable flood basins. However, not all ARs cause damage. Most of them only provide beneficial rain and snow.

The main focus of this work is twofold:

1) to look for a relationship between the ARs that affected the NW of the Iberian Peninsula (IP) during the extended winter months [October–March (ONDJFM)] and extended summer months [April–September (AMJJAS)] and the typical Circulation Weather types (CWTs) of this area.

2) To assess whether the presence or absence of an AR significantly modifies a) the mean precipitation amount and b) the intensity of rare precipitation events for some weather types.

This work aims to contribute to the understanding of the annual and inter-annual variability of ARs along the NW of IP using long term data through the quantification of the CWTs influence on ARs; a finding that is both useful for conceptual understanding and the development of statistical prediction schemes.

Keywords: Atmospheric river, circulation weather type, precipitations.

P41- Twentieth-century atmospheric river activity along the west coasts of Europe and North America: algorithm formulation, reanalysis uncertainty and links to atmospheric circulation patterns

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ABSTRACT

A new atmospheric-river detection and tracking scheme based on the magnitude and direction of integrated water vapour transport is applied separately over 13 regions located along the west coasts of Europe (including North Africa) and North America. Four distinct reanalyses are considered, two of which cover the entire 20th-century: NOAA-CIRES Twentieth Century Reanalysis v2 (NOAA-20C) and ECMWF ERA-20C. Calculations are done separately for the OND, JFM and ONDJFM seasons. Comparing the AR-counts from NOAA-20C and ERA-20C with a running 31-year window looping through 1900-2010 reveals differences in the climatological mean and inter-annual variability which, at the start of the 20th-century, are much more pronounced in western North America than in Europe. Correlating European AR-counts with the North Atlantic Oscillation (NAO) reveals a pattern reminiscent of the well-know precipitation dipole which is stable throughout the entire century. A similar analysis linking western North American AR-counts to the North Pacific index (NPI) is hampered by the aforementioned poor reanalysis agreement at the start of the century. During the second half of the 20th-century, the strength of the NPI-link considerably varies with time in British Columbia and the Gulf of Alaska. Considering the period 1950-2010, AR-counts are then associated with other relevant large-scale circulation indices such as the East Atlantic, Scandinavian, Pacific-North American and West Pacific patterns (EA, SCAND, PNA and WP). Along the Atlantic coastline of Iberia and France, the EA-link is stronger than the NAO-link during OND and the SCAND-link found in northern Europe is significant during both OND and JFM. Along the west coast of North America, teleconnections are generally stronger during JFM in which case the NPI-link is significant in any of the five considered subregions, the PNA-link is significant in British Columbia and the Gulf of Alaska and the WP-link is so along the U.S. West Coast. During OND, these links are significant in the Gulf of Alaska only. If AR-counts are calculated upon persistent (instead of instantaneous) ARs, the link to the NAO weakens over the British Isles and western Iberia. For the experimental set-ups most closely mirroring those applied previous studies, the NAO-links are completely or partly insignificant indicating that the inclusion of the persistence criterion notably alters the results. Visual support for the present study is provided by an exhaustive historical atmospheric river archive built at *http://www.meteo.unican.es/atmospheric-rivers.*

Keywords: Atmospheric rivers, 20th century, dataset uncertainty, teleconnections.

P42- Does ENSO affect atmospheric river activity in southwestern Europe?

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ABSTRACT

While ARs are typically seen as large-scale precursors of local-scale hydrological (extreme) events, in this study, we ask for the precursors of below- or above-normal AR activity. Namely, it is asked whether the El Niño - Southern Oscillation (ENSO), known to be associated with climate anomalies in many regions of the World, also influences the number of ARs affecting the west coasts of Europe and northwestern Africa. The focus is put on the October-through-December (OND) season, during which such a relationship has been documented for precipitation in southwestern Europe.

To this aim, the ENSO-AR link is first assessed with statistical methods and (quasi) observational reanalysis data. On its own, however, this commonly applied approach is unable to detect causal relationships and, therefore, the proposed links are additionally assessed by means of idealized numerical modelling experiments run with the Community Atmosphere Model version 3.1, forced with prescribed SSTs varying in the equatorial Pacific only. These experiments are complemented with the six-member ensemble of IPSL-CM5a-LR Earth System Model run under AMIP conditions, in which case the atmospheric component of this model is run uncoupled and is forced with prescribed SSTs varying all around the globe. The teleconnection patterns found in observations are roughly reproduced by both experimental set-ups, pointing to the fact that they are indeed causal.

Keywords: Atmospheric Rivers, ENSO, Community Atmosphere Model, AMIP, Europe.

P43- The relationship between Atmospheric Rivers and Cyclones over Subtropical South America: a precipitation analysis

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ABSTRACT

There are three main regions of cyclogenesis in South American continent and southwestern South Atlantic Ocean: south/southeast Brazil, southeast Uruguay, and south coast of Argentina. The Atmospheric Rivers (ARs) may be characterized by integrating the water vapor transport in the atmospheric vertical column. In this study, it is analyzed the relationship between ARs in tropics and the cyclones development over subtropical South America. Over subtropics, defined by the area 25°S-40°S and 40°W-65°W, for the period 1979-2011 cyclones were tracked and the dates of cyclone occurrence were compared with that of ARs. It was found a strong positive correlation (0.88) between the days with ARs in the tropics and the presence of cyclones in the subtropics of South America. In average, 10% of cyclones occurring in subtropics are associated with the ARs. The frequency of cyclones associated with ARs shows a strong interannual variability. For the period 1997-2011, Global Precipitation Climatology Project (GPCP) dataset was used to evaluate the spatial pattern of the rainfall anomaly during cyclones associated and not associated with ARs. It was observed that for cyclones occurring during ARs the daily precipitation positive anomaly is enhanced over a larger area of subtropical south. For the cyclones without the presence of ARs the positive rainfall anomalies are weaker and occur mainly in southern of Brazil and the adjacent Ocean. The rainfall anomaly is more intense for austral autumn (which has more ARs) and winter than in summer for cyclones associated with ARs. Wind and potential vorticity composites will be analyzed further.

Keywords: Cyclones, Atmospheric Rivers, South America, Precipitation.

P44- Global Warming, New Climate, New Atmospheric Circulation and New Water Cycle in the North Atlantic Ocean

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ABSTRACT

Global warming has now reached the energetic phase of H2O's return to the ground after the saturation of the atmosphere in evaporation since the 80s and 90s of the last century, which were characterized by severe droughts, mainly in Africa.

This phase is the result of the accumulation of thermal energy exchanges in the Earth-Ocean-Atmosphere system that resulted in the thrust reversal of the energy balance toward the poles. This situation is characterized by a new thermal distribution: above the ocean, the situation is more in surplus compared to the mainland, or even opposite when the balance is negative on the land, and in the atmosphere, warm thermal advection easily reach the North Pole (planetary crests), as well as cold advection push deep into North Africa and the Gulf of Mexico (planetary valleys).

This "New Ground Energy Balance" establishes a "New Meridian Atmospheric Circulation (MAC)" with an undulating character throughout the year, including the winter characterized by intense latitudinal very active energy exchanges between the surplus areas (tropical) and the deficit (polar) on the one hand, and the atmosphere, the ocean and the continent on the other.

The excess radiation balance increases the potential evaporation of the atmosphere and provides a new geographical distribution of Moisture and Water worldwide: the excess water vapor is easily converted by cold advection (polar vortex) to heavy rains that cause floods or snow storms that paralyze the normal functioning of human activities, which creates many difficulties for users and leaves damage and casualties, but ensures water availability missing since a long time in many parts of the world, in Africa, Europe and America.

The new thermal distribution reorganizes the geography of atmospheric pressure: the ocean energy concentration is transmitted directly to the atmosphere, and the excess torque is pushed northward. The Azores anticyclone is strengthened and is a global lock by the Atlantic ridge at Greenland, which imposes on the jet stream a positive ripple, very strongly marked poleward, bringing cosmic cold advection of polar air masses winter over from Europe to North Africa. Hence the enormous meridian heat exchanges north-south, and south-north.

This new spatial thermal provision therefore imposes on the jet-stream a positive ripple on the North Atlantic (Greenland) and eastern Pacific (Alaska); this is the cause of the heat and drought of California, followed by negative waves in eastern US, and Europe.

This is the "New Atmospheric Circulation" predominantly "Meridian", due to the "New Climate" caused by global warming.

Keywords: New Climate, New Meridian Atmospheric Circulation (MAC), New Water Cycle, New Geographical Distribution of Moisture and Water.a.

P45- Different regimes of the Western North Pacific Monsoon throughout the 20th Century

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ABSTRACT

The concept of the Western North Pacific Summer Monsoon (WNPSM) appeared for the first time in 1987. It is, unlike the Indian Summer Monsoon (ISM) and the East Asian summer monsoon (EASM), an oceanic monsoon driven fundamentally by the meridional gradient of sea surface temperature. Its circulation is characterized by a northwestsoutheast oriented monsoon trough with intense precipitation and low-level southwesterlies and upper-tropospheric easterlies in the region [100º-130º E, 5º-15ºN].

By using solely daily observations of wind direction from ships' logbooks which circumnavigated Asia for hundreds of years, it has been possible to compute a new index, the Western North Pacific Directional Index (WNPDI), to reconstruct the WNPSM back to the middle of the 19th Century. The WNPDI is defined as the sum of the persistence of the low-level westerly winds in [5º–15ºN, 100º–130ºE] and easterly winds in [20º–30ºN, 110º–140ºE]. It is an instrumental index and widens almost 100 years the Western North Pacific Monsoon Index (WNPMI), an primary index based on reanalysis data which characterises the WNPSM throughout the 1949-2013 period. Both indices show a high correlation ($r=+0.87$, $p<0.01$) for summer of the 1949-2009 period.

Due to the length of the WNPDI, now it is possible to study the multidecadal variability of the WNPSM. Our results show that the WNPDI has a strong impact on the precipitation in densely populated areas in South-East Asia, such as the Philippines or the west coast of Myanmar where the changes in precipitation between well developed and weak monsoons can reach up to 400 mm and seems to be driven by profound changes in the moisture transport from oceanic areas. Besides, two different regimes in the 20th Century have been found. The first period (1919-1939) was characterised by the persistence of strong monsoons whereas the second (1990-2010) shows higher variability and more cases of extremely weak monsoons. The patterns of precipitation, wind and moisture transport anomalies for each period are opposite. The existence of different monsoon regimes, the high temporal variability of the WNPSM and its dependence on the moisture transport from extratropical areas could explain why the relationships between the WNPDI and global climatic patterns such as the PDO, the ENSO or El Niño Modoki are extremely complicated and highly non stationary.

Keywords: Monsoons, Asia, Climate Indices

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