S6 Physics of the atmosphere and the ocean
Física de la atmósfera y el océano (GEFAO)

12/07 Tuesday afternoon, Aula 1.2

15:30-15:40 José Manuel Vaquero (U de Extremadura)
The meteorological observations of Jovellanos in the castle of Bellver

15:40-15:50 I. Tovar (U Extremadura)
Recovering meteorological information from the "Extremadura" newspaper (1924-1927)

15:50-16:00 Albenis Pérez-Alarcón (U Vigo)
Overview of moisture sources for the precipitation of tropical cyclones through a Lagrangian approach

16:00-16:10 José Carlos Fernández-Alvarez (U Vigo)
Atmospheric Rivers moisture sources projections landfalling the Iberian Peninsula

16:10-16:20 Eloisa Raluy (U Murcia)
Impact of aerosols on atmospheric rivers in regional climate simulations: development of an identification algorithm and a climatological analysis

16:20-16:30 Roger Sori (U Vigo)
The oceanic and terrestrial origin of precipitation in the great world river basins: their role in drought severity

16:30-16:40 Gleisis Alvarez-Socorro (U Vigo)
Global climatology of nocturnal low-level jets with the ERA5 reanalysis

16:40-16:50 David Barriopedro (IGEO-CSIC-UCM)
A multiparametric perspective of the North Atlantic eddy-driven jet

16:50-17:00 Marie Drouard (IGEO-CSIC-UCM)
Contrasting dynamics of short and long atmospheric blocks in the Northern Hemisphere

17:00-18:00 **Posters and Coffee**

18:00-18:10 J. Manuel Garrido Pérez (U Complutense)
Storyline description of the summer air stagnation response to anthropogenic warming forcing in Europe and the contiguous United States

18:10:18:20 Juan A. Añel (U Vigo)
Stratospheric contraction caused by greenhouse gas emissions

18:20-18:30 Samuel Benito Barca (U Complutense)
Driving mechanisms for boreal winter stratospheric ozone response to ENSO

18:30-18:40 Gines Garnés (U Murcia)
On the role of Aerosols on Atmospheric Circulation in Regional Climate Experiments

18:40-18:50 Leandro Cristian Segado-Moreno (U Murcia)
Spatial and temporal variability of surface ozone in a climate simulation over Europe and its relationship with climate parameters

18:50-19:00 Susana Bayo.Besteiro (U Vigo)
The impact of climate change on photovoltaic power generation for solar installations in the Atacama desert

Posters:

1 Jose M. Garrido-Perez, D. Barriopedro, R. García-Herrera and C. Ordóñez
How climate change is affecting the patterns of electricity demand in Spain?

2 C. Ordóñez, Jose M. Garrido-Perez, R. García-Herrera
Did the meteorology affect the near-surface ozone concentrations over Europe during the COVID-19 lockdown of early spring 2020?

3 A. Bernáldez, J.M. Vaquero, M. Antón, A. Sánchez-Lorenz
Preliminary results about long-term trends in downward surface shortwave radiation over Spain (1985–2021)

4 Xavier Navarro, Ricard Kirchner, Raúl Rodríguez-Solà, M. Carmen Casas-Castillo
Análisis de escala simple de veinticinco años de registros de la red pluviométrica de Barcelona

5 Jesús Rodríguez-Camacho, Sergio Toledo-Redondo, Jorge Portí, Jesús Fornieles, David Blanco, Juan Francisco Gómez-Lopera, Alfonso Salinas, María del Carmen Carrión
Long-term analysis of Schumann Resonance measured at the Sierra Nevada ELF station

The meteorological observations of Jovellanos in the castle of Bellver

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The development of meteorology in Spain began in the 18th century, just as it occurred in other European countries. Anduaga [1] has shown that there were three communities that led to the first systematic meteorological observations [2]. In the first place, the astronomical observatories of Cádiz and Madrid encouraged this kind of observations. In addition, the medical community also made a notable effort in this regard and, finally, the "Sociedades Económicas de Amigos del País" promoted meteorological studies related to agricultural activities.

Until now, no one has revealed the interest of Gaspar Melchor de Jovellanos (1744–1811) in atmospheric sciences, despite his evident connexion with the Economic Societies and agricultural sciences. I began to read his correspondence (Obras Completas, volumes II-IV [3]) expecting to find numerous references to weather or climate, and the first results were quite discouraging. However, I continued to consult his diary (Obras Completas, volumes VI-VIII) and there I found an enormous collection of comments of a meteorological nature.

But the surprise was capital when I saw in the last notebook of his diary, the twelfth, a complete set of systematic meteorological observations made during his imprisonment in the Bellver castle in Mallorca for almost a year (which practically coincides with the year of 1806). For all these reasons, the objective of this work is twofold: (i) I am going to show the enormous interest in meteorology by Jovellanos and (ii) I am going to describe in detail the barometric record obtained by Jovellanos at Bellver castle.

[1] A. Anduaga Egaña, *Meteorología, ideología y sociedad en la España contemporánea*, Madrid: CSIC (2012).
[2] F. Domínguez-Castro et al., "Early Spanish meteorological records (1750-1850)", *International Journal of Climatology* **34**, 593 (2014).
[3] G.M. Jovellanos, *Obras Completas*, 14 tomos, Gijón: KRK Ediciones (1984-2010).

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Recovering meteorological information from the "Extremadura" newspaper (1924-1927)

I. Tovar, M. C. Gallego*, V. M. S. Carrasco, N. Bravo-Paredes, J. M. Vaquero

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Preliminary results of the analysis of meteorological, geophysical and space phenomena found in the review of the Extremadura regional press during the years 1923-1927 are presented. We are developing a database of news of interest for Earth and Space sciences from the Extremadura regional press. It will be very useful to know and study the different geophysical and space events that have taken place in Extremadura and, in particular, to know details of the past climate that help us to understand the effects of global warming.

Some recent studies have shown us the interest of using newspapers in rural areas, relatively sparsely populated and little studied by researchers, as the region of Extremadura. Bravo-Paredes et al. (2020) [1] located various rogations for rain in the press at the end of the 19th century and the beginning of the 20th century. This information helped establish a clear relationship between the celebration of rogations for rain in Extremadura and the well-known NAO index. Another interesting example is the article by García-Garrido et al. (2020) [2]. They studied a landslide event that took place on January 1831 at the Pedregoso Mountains, Cabeza del Buey, SW Spain. This landslide had not been documented to date and was only described in the local press. This event involved an estimated amount of dislodged material in the order of 10^4 m^3 being one of the largest landslides reported in Extremadura.

We are presenting here a review of the newspaper "Extremadura" from April 1923 to December 1927. A total of 332 episodes of interest for Earth and Space sciences have been found, which indicates how profitable this kind of press reviews are.

Among the most interesting episodes that have been located, the following stand out: (i) strong thunderstorms during the month of June 1925, which caused considerable damage in many towns in Extremadura, (ii) an exceptional fireball in Don Benito on December 27, 1926, and (iii) two railway accidents caused by landslides (February 10, 1924; February 18, 1927) probably caused by rain.

[1] N. Bravo-Paredes, M.C. Gallego, F. Domínguez-Castro, J.A. García, J.M. Vaquero, Pro-pluvia Rogation Ceremonies in Extremadura (Spain): Are They a Good Proxy of Winter NAO?, *Atmosphere* **11**, 282 (2020); https://doi.org/10.3390/atmos11030282

[2] J.P. García-Garrido, M.C. Gallego, T. Palacios, R.M. Trigo, J.M. Vaquero, Heavy rainfall and landslides in January 1831 at Pedregoso Mountains (Cabeza del Buey, SW Spain), *Atmosphere* **11**, 544 (2020); https://doi.org/10.3390/atmos11050544

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Overview of moisture sources for the precipitation of tropical cyclones through a Lagrangian approach

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Tropical cyclones (TCs) not only produce heavy rainfall in tropical latitudes but also in mid-latitudes. In this work, we investigated the moisture sources for the precipitation of TCs in each basin, namely the North Atlantic Ocean (NATL), Central and East Pacific Ocean (NEPAC), Western North Pacific Ocean (WNP), South Pacific Ocean (SPO), North Indian Ocean (NIO) and South Indian Ocean (SIO). To do this, we applied the Lagrangian moisture source diagnostic method developed by Sodeman et al. [1] and implemented in the TRansport Of water VApor (TROVA) tool to the trajectories of all air parcels that precipitated over the TCs location. The pathways of atmospheric parcels were from the global outputs of the FLEXPART model [2]. Meanwhile, the National Hurricane Center and the Joint Typhoon Warning Center provided the 6-hourly information of all TCs through the best track archives.

Our results revealed that the moisture often came from ocean sources. Nevertheless, the Central America and Indian Peninsula terrestrial sources played an important role in supplying moisture for TCs over the NEPAC and NIO basins, respectively. In summary, the contributions from the western NATL, the Caribbean Sea and the Gulf of Mexico accounted for ~91% of moisture in the NATL basin. In NEPAC, the eastern tropical Pacific Ocean and Central America mainland supplied ~92% of total moisture, while the western North Pacific Ocean, the Philippine Sea and the South China Sea contributed ~90% in WNP. The Arabian Sea, the Bay of Bengal and the Indian Peninsula supported approximately 95% of moisture in the NIO basin. Most of the moisture (~91) that precipitated over the TCs location in the SIO basin was supplied from the tropical Indian Ocean, while the Coral Sea and the western SPO provided substantial moisture (~91%) for the precipitation of TCs in the SPO basin

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[2] Stohl, A., Forster, C., Frank, A., Seibert, P., & Wotawa, G. *Atmospheric Chemistry and Physics* **5**, 2461 (2005).

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Moisture sources projections under climate change for Atmospheric Rivers landfalling the Iberian Peninsula

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In the field of moisture transport, Atmospheric Rivers (ARs) are known as narrow corridors of water vapor, generally 2000 km or more in length. These account for more than 90% of the meridional moisture transport and latent heat associated with storm tracks in the extratropical atmosphere [1]. The ARs are associated with extreme precipitation events, floods, landslides, extensive property damage, and losses of life [2, 3]. In the context of climate change, it is projected that the water-holding capacity of the atmosphere increases about 7 % K^{-1} at lower troposphere and for the column integrated moisture [4], however the future changes in moisture sources contribute to moisture transported by ARs to higher latitudes by the end-century are not known. To determine these changes simulations of the Weather Research and Forecasting (WRF-ARW) model forced with Community Earth System Model (CESM2) and the FLEXPART-WRF model forced with the WRF-ARW outputs are used. The analysis was carried out mainly by determining the anomaly moisture uptake for the mid-century (MC, 2049-2053) and end-century (EC, 2096-2100) periods, considering the annual and seasonal changes of the variable. It was obtained that the moisture uptake anomaly increased with maximum values, ~ 7-8 % K^{-1}, in winter for MC and EC. In addition, a latitudinal increase in the anomalous moisture uptake pattern is projected over the central Atlantic and a longitudinal expansion towards the Gulf of Mexico.

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[2] Ramos, A. M., Trigo, R. M., Liberato, M. L., Tomé, R. Daily precipitation extreme events in the Iberian Peninsula and its association with atmospheric rivers, *Journal of Hydrometeorology* **16**, 579 (2015).
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[4] Gershunov, A. et al., Precipitation regime change in Western North America: the role of atmospheric rivers, *Scientific Reports* **9**, 1 (2019).

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Impact of aerosols on atmospheric rivers in regional climate simulations: development of an identification algorithm and a climatological analysis

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Atmospheric rivers (ARs) play an essential role in extreme precipitation phenomena. To predict such events, a correct simulation of ARs becomes indispensable. Since most of the regional climate models do not take aerosols into account in an interactive way, the main objective pursued in this project is to analyse the role of aerosols in the intensity and location of ARs.

The identification of ARs has always been carried out in global climate simulations with algorithms developped for those models. However, these algorithms may not be valid in regional climate models, due to the presence of boundaries in the simulation domain. In this project, a new identification algorithm of ARs in regional climate models (AIRA) is presented. The implemented algorithm has been proved to be able to properly identify the vapor structures associated with ARs.

AIRA was applied to a set of hourly data from three regional simulations (BASE, ARI and ARCI), covering a period of 20 years. In BASE, aerosols are prescribed, while in both ARI and ARCI the model incorporates aerosols dynamically. In ARI, aerosols are only taken into account in radiation and in ARCI they are taken into account in radiation and in the processes associated with cloud formation and precipitation.

AIRA has identified a similar number of ARs in the three simulations (about 250 ARs), with a mean duration between one and two days and with a mean direction of 40° from the East. These ARs explain up to a 30% of the total precipitation in the Iberian Peninsula. The differences between the three simulations are significant in the spatial distribution of the precipitation and in the trajectory of some ARs. Although the number of detected ARs is similar, the temporal steps with ARs common to the three simulations are only a 37% of the total BASE steps with ARs.

The behavior of ARs in the different simulations is modified depending on the present aerosols and the meteorological situation. A preliminary analysis of the physical causes that explain the different behavior of the ARs in the three experiments shows that both the displacement and the intensification of ARs are due to a change in the thickness gradient. This is caused by changes in the temperature field, mainly due to processes related to the microphysics of the clouds (indirect effects), while radiative effects have turned out to be less significant on this aspect.

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The oceanic and terrestrial origin of precipitation in the great world river basins: their role in drought severity

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In this study, we initially investigated the origin of the precipitation over 50 major world river basins. For this aim, the global monthly outputs from the Lagrangian Particle Dispersion Model (FLEXPART), considering a forward in time experiment from the entire oceans and continents were used. The horizontal resolution was 0.25º and the period of study is from 1980 to 2018. These outputs permitted to estimate a "Lagrangian precipitation" from the oceanic (PLO) and terrestrial (PLT) origin, which sum is close to the precipitation over the basins. Following this approach, the percentage of precipitation from oceanic and terrestrial origin was determined for each river basin, and compared with the precipitation from the Multi-Source Weighted-Ensemble Precipitation (P_{MSWEP}) (Beck et al., 2019). The results show a great amount of PLT over the major number of river basins, confirming the importance of terrestrial recycling and moisture export across the continents. However, the influence of PLO seems to be dominant over a great part of the western North American river basins, and some basins located in western Eurasia and Southeast Asia. The multivariate Standardised Precipitation Index (SPI) (McKee et al., 1993) was utilised to assess the temporal evolution of dry/wet conditions in the river basins. It was calculated at 1- and 3-months temporal scales using the P_{MSWEP} as well as PLO and PLT series, resulting in the series of SPI_{MSWEP}, SPI_{PLO}, and SPI_{PLT}. Afterwards, was calculated the number of drought episodes that affected each river basin. The results showed that at the 1-month temporal scale the number of drought episodes is larger than at 3-month, due to the greater variability of the SPI_{MSWEP}, which result in a major number of flash droughts. Those basins more (less) affected by drought episodes according to the SPI_{MSWEP} at a 1-month temporal scale are located in northern Eurasia and North America (tropical South America and Africa). In addition, we present the relationship between the severity of drought episodes and the correspondent severity computed with the SPI_{PLO}, and SPI_{PLT}. Finally, a copula analysis revealed the conditional probability of occurrence of drought, severe and extreme drought, and extreme drought conditions according to the SPI_{MSWEP} with the SPI_{PLO} and SPI_{PLT}, confirming the crucial role of PLO (PLT) deficit in North America (Eurasian) river basins.

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Global climatology of nocturnal low-level jets with the ERA5 reanalysis

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Nocturnal low-level jets (NLLJs) can be defined as filamentary regions or corridors of anomalously high wind speeds found within 1 km of the troposphere [1]. They are common global meteorological phenomena and are considered an important global mechanism of moisture transport, since their changes in frequency will lead to modifications in local and even global hydrological cycles [2], hence the importance of knowing their behavior. For this study, reanalysis data from ERA5 (~0.25°) [3] from 2014 to 2018 were used to find global NLLJs. The methodology applied to calculate the NLLJs index (INLLJs) is based on the temporal evolution of the vertical wind structure and the diurnal-nighttime variation of the wind fields at the surface and at ~4 km height [1]. It was analyzed for July and January in the Northern (HN) and Southern Hemispheres (HS) respectively, because of its main association with the warm season [1]. The results show similarity with previous investigations, but greater detail was observed in geographycal distribution of the NLLJs due to the higher spatial resolution of ERA5. For the HN, the maximum INLLJs values were observed in the Great Plains region, southern Asia and in a large part of the African continent. Frequencies of days with NLLJs ranging from 60-100 % were determined for HN. However, for HS, the areas with the highest INLLJs and frequency of NLLJs days (~ 45-80%) correspond to Australia, central and southern Africa and South America.

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A multiparametric perspective of the North Atlantic eddy-driven jet

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The North Atlantic eddy-driven jet (EDJ) is an essential component of the Euro-Atlantic atmospheric circulation. It has been typically described in terms of latitude and intensity, but this is not enough to fully characterize its variability and complex EDJ configurations. Here, we present a set of daily parameters of the EDJ based on low-tropospheric zonal wind data for the 1948-2020 period. They describe the intensity, sharpness, location, edges, tilt and other zonal asymmetries of the EDJ, therefore dissecting its structure beyond the latitudinal regimes. This allows for assessments of specific EDJ aspects and a multi-parametric treatment of EDJ configurations in a manageable way.

Overall, variations in EDJ parameters reflect distinctive patterns of eddy forcing and wave breaking, with anticyclonic eddies playing a major role in shaping the EDJ structure. A multimodal behavior of the EDJ is only detected in latitude, which largely influences the longitudinal position of the EDJ. Other aspects of the EDJ are less constrained by the latitude and display a variety of configurations. Four multi-parametric states (northern, central, tilted and split EDJs) provide a satisfactory description of recurrent patterns of the EDJ. They participate in meridional migrations of the EDJ, but yield less dramatic transitions than viewed from the latitudinal perspective. Finally, the EDJ parameters help to better understand the EDJ influence on European climate. In many regions, latitude and intensity contain limited information on near-surface anomalies, and their signals can be masked by the additional effect of other EDJ parameters (Figure 1).

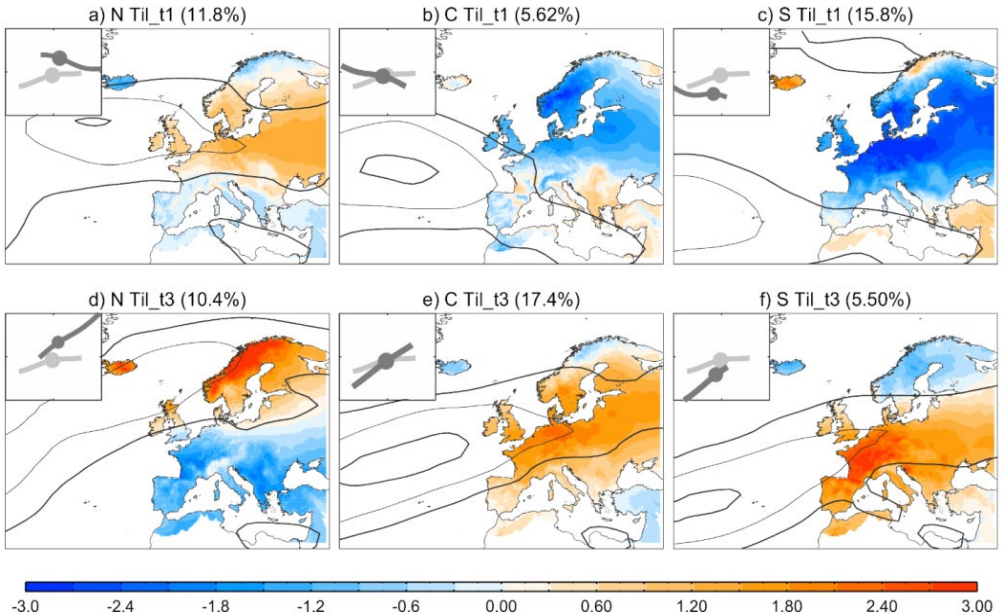

Figure 1. Composites of zonal wind at 850-700 hPa (contours, with contour interval of 5 m s^{-1} starting at 5 m s^{-1}) and 2 m temperature anomalies (shading, ºC) for EDJs of the three latitudinal regimes with: a-c) low (lower tercile, t1); d-f) high (upper tercile, t3) tilts. Panel columns represent the northern (N, a, d), central (C, b, e) and southern (c, f) EDJ regimes. The inset of each panel represents snake-plots of the EDJ for the climatology (light grey) and the composite (dark grey). The percentage of winter days included in the composite is shown in the title

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Contrasting dynamics of short and long atmospheric blocks in the Northern Hemisphere

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Atmospheric blocking is a phenomenon of major importance for daily weather due to its long persistence (up to 4–5 weeks). It corresponds to a localized large-scale reversal of the atmospheric circulation that, as its name indicates, blocks the westerly zonal flow. In winter, blocks are associated with cold spells and in summer with hot days and sometimes heatwaves.

The aim of this work is to better understand why some blocks last only five days (short blocks in the following) and other more than ten days (long blocks), to better characterise long blocks.

We show that long blocks often involve cyclonic Rossby wave breaking, while short blocks are equally associated with both cyclonic and anticyclonic wave breakings. This main result is reproduced in several coupled climate models. Three mechanisms might explain the lower number of long anticyclonic blocks: 1/ a downstream reinforcement of the anticyclone during anticyclonic blocks might be associated with a stronger downstream advection of the block; 2/ the mean zonal wind is reinforced by synoptic eddies towards a more northward position during anticyclonic blocks, whereas synoptic eddies force the mean zonal wind to the south of the block during cyclonic blocks, which has been previously shown to be associated with more persistent weather patterns; 3/ strong and/or sustained eddy feedback is needed to maintain long anticyclonic blocks. A combination of these three mechanisms might explain why some blocks last longer and why anticyclonic blocks are less present at extreme durations.

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Storyline description of the summer air stagnation response to anthropogenic warming forcing in Europe and the contiguous United States

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Air stagnation situations are characterized by stable weather, weak winds within the lower troposphere and lack of rainfall. These conditions minimize the horizontal dispersion and vertical mixing of air masses as well as the scavenging of pollutants, favouring their accumulation in the lower atmospheric layers and the occurrence of poor air quality events. Climate model projections suggest that air stagnation will increase north of the Mediterranean and in large areas of the contiguous United States in the future (Figure 1), but these projections are subject to large uncertainties. Storylines of atmospheric circulation change, or physically self-consistent narratives of plausible future events, have recently been proposed as a non-probabilistic means to represent uncertainties in climate change projections. This work [1] applies the storyline approach to 21st century projections of summer air stagnation over Europe and the United States. For that purpose, we use a Climate Model Intercomparison Project Phase 6 (CMIP6) ensemble to generate stagnation storylines based on the forced response of three remote drivers of the Northern Hemisphere mid-latitude atmospheric circulation: North Atlantic warming, North Pacific warming, and tropical versus Arctic warming.

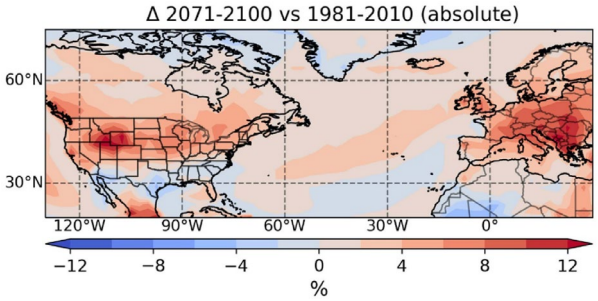

Figure 1. Absolute change in stagnation occurrence (%) from 1981–2010 to 2071–2100 for a high radiative forcing scenario.

Under a high radiative forcing scenario (SSP5-8.5), strong tropical warming relative to Arctic warming is associated with a strengthening and poleward shift of the upper westerlies, which in turn would lead to decreases in stagnation over the northern regions of North America and Europe, as well as increases in some southern regions, as compared to the multi-model mean. On the other hand, North Pacific warming tends to increase the frequency of stagnation over some regions of the U.S. by enhancing the frequency of stagnant winds, while reduced North Atlantic warming does the same over Europe by promoting the frequency of dry days.

Given the response of stagnation to these remote drivers, their evolution in future projections will substantially determine the magnitude of the stagnation increases. This is especially true in Europe, where differences of ~2 summer stagnant days per degree of global warming are found amongst the different storyline combinations. For example, the greatest projected increase in stagnation for most European regions leads to the smallest increase in stagnation for southwestern Europe; i.e. limited North Atlantic warming combined with near-equitable tropical and Arctic warming. In the U.S., only the atmosphere over the northern Rocky Mountain states demonstrates comparable stagnation projection uncertainty, due to opposite influences of remote drivers on the meteorological conditions that lead to stagnation.

[1] Jose M. Garrido-Perez, C. Ordóñez, D. Barriopedro, R. García-Herrera, Jordan L. Schnell and Daniel E. Horton, A storyline view of the projected role of remote drivers on summer air stagnation in Europe and the United States, *Environmental Research Letters* **17**, 014026 (2022).

Stratospheric contraction caused by greenhouse gas emissions

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Rising emissions of anthropogenic greenhouse gases (GHG) have led to tropospheric warming and stratospheric cooling over recent decades. Consequently, the troposphere has expanded, and the rise of the tropopause has been suggested as one of the most robust fingerprints of anthropogenic climate change. Conversely, at altitudes above ~ 55 km (in the mesosphere and thermosphere) observational and modelling evidence indicates a downward shift in the height of pressure levels or decreasing density at fixed altitudes. Here we show that the stratosphere has contracted substantially over the last decades and that the main driver for this are increasing concentrations of GHG. Also, we show that this trend will continue, and the mean climatological thickness of the stratosphere will decrease by 1.3 km following RCP 6.0 by 2080. The short emergence time of this trend (less than 15 years) makes it a novel and independent indicator of GHG induced climate change. Also, we present the ability of the different state-of-the-art reanalyses to monitor this phenomenon and how sulfate aerosol injection in the stratosphere can affect it.

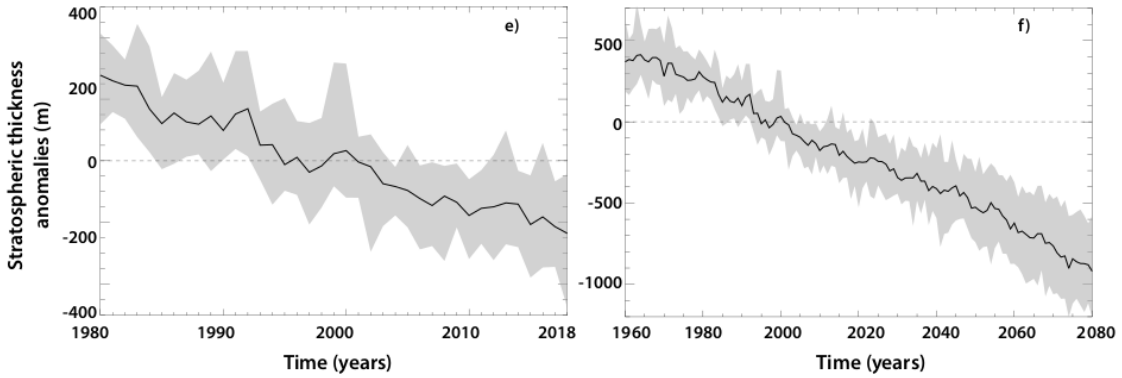

Figure 1. Anomalies of stratospheric thickness for the period 1960-2080 from CCMI models. Solid line: mean. All the simulations correspond to the AllForcings experiment. The grey areas cover the maximum and minimum of the CCMI models used.

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Driving mechanisms for boreal winter stratospheric ozone response to ENSO

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Stratospheric ozone is an important component in the climate system. It plays a key role in the radiative budget and protecting Earth from harmful solar ultraviolet (UV) radiation and can exert a significant influence on the Northern Hemisphere (NH) surface climate. Previous studies have shown that El Niño-Southern Oscillation (ENSO), which is the main source of interannual variability in the global climate, has impacts on stratospheric circulation, but its effects on stratospheric ozone have been less investigated. The present study constitutes the first comprehensive analysis of the NH stratospheric ozone signal and its driving mechanisms in response to different El Niño flavors (Eastern Pacific and Central Pacific El Niño) and La Niña in boreal winter. The use of simulations from the Whole Atmosphere Community Climate Model (WACCM), a chemistry-climate model with a well resolved stratosphere, allows us to evaluate the contributions of the advection by the residual circulation of the Brewer Dobson Circulation (BDC), the isentropic mixing and the chemical processes to ENSO-related ozone variations.

The examination of total column ozone (TCO) reports a reduction in the tropics and an increase at middle and high latitudes from December to March during EP El Niño events and the opposite behavior during La Niña. Interestingly, no significant impact on extratropical TCO has been found during CP El Niño. The analysis of the continuity equation for zonal-mean ozone concentration reveals that tropical ozone variations in the lower stratosphere are mainly driven by advection through changes in tropical upwelling, with a contribution from changes in chemical process above 30 hPa. In the extratropical stratosphere, ENSO ozone variations result from a combination of changes in advection by downwelling in the shallow and deep branches of the residual circulation and also changes in horizontal mixing linked to Rossby wave breaking and polar vortex anomalies. In contrast with the large impact of EP-El Niño and La Niña on the residual circulation, the effect of CP El Niño on the shallow branch is small, and no significant impact is found on the deep branch. This results in the lack of extratropical signal in TCO during CP El Niño events.

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On the role of Aerosols on Atmospheric Circulation in Regional Climate Experiments

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Nowadays, the regional climate models used to generate the necessary synoptic information in order to describe the atmospheric circulation do not take into account aerosols interactions with radiation nor clouds. The purpose of this work is to determinate whether the inclusion of interactive aerosols (aerosol-radiation interactions, ARI, and aerosol-cloud interactions, ACI) in the model leads to significant changes in the circulation by means of circulation types (CTs).

This study covered Europe for winter (DJF). A principal component analysis (PCA) and the K-means clustering method were employed to classify CTs using the sea level pressure (SLP).

The results reflected significant differences in winter SLP patterns. Focusing on the two most important CTs, in BASE scenario (with no interactive aerosols), CT1 is characterised by a western zonal flux, whereas CT2 is mainly depicted by a low-pressure area centered in Italy and a light pressure gradient. Both interactive-aerosols simulations (ACI and ARI) produce a SLP reduction in the Center-East of Europe, what entails an inclination southwards of the flux direction. The effects on the second weather type is an increase of SLP, also in the Central-East part of the continent, what means a weakness of the Mediterranean low and a intensification of pressure field in Scandinavia. Even though both ACI and ARI simulations lead to variations of equal sign, those of ARI's are stronger. In other words, the inclusion of aerosol interactions with cloud microphysics makes that ARI effects diminish.

Regarding the differences in CTs frequency, CT1 and CT2 decrease in both ACI and ARI simulations, although they are not quite remarkable.

Moreover, an analysis of the aerosol optical depth (AOD) anomaly in ARI and ACI scenarios and its relation to SLP was carried out. According to AOD anomalies, negative SLP differences in CT1 correspond with a decrease of black aerosols (radiation absorbent aerosols) and an increase of white aerosols (radiation reflective aerosols). This causes a minor storage of energy in the atmosphere, reducing temperature and therefore the thickness of atmospheric layers. On the contrary, positive differences of SLP observed in CT2 match with an increase of black aerosols and a decrease of white ones. As a result, temperature in atmospheric layers and thickness rise. Therefore, aerosols modifies the energy balance, thickness driving changes in the atmospheric circulation patterns.

Spatial and temporal variability of surface ozone in a climate simulation over Europe and its relationship with climate parameters

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Ozone (O_3) is one of the atmospheric pollutants of greatest concern due to its adverse effects on human health, as well as on other animals and plants. However, despite the fact that the causes of tropospheric ozone formation are known in detail, the variables that control its concentrations in areas near the surface are not entirely clear. Although initially the emission of nitrous oxides (NOx), together with temperature and surface radiation are the main factors which determine the formation and concentration of tropospheric ozone, observations over Europe show large concentrations of ozone in regions in which emissions of NO_x are very limited. This leads us to think that pollutants transport must play a main role in the concentrations obtained in many locations.

In this work, data on tropospheric ozone concentrations between 1991 and 2010 in the European area is analyzed, along with its relationship with climatic variables, both in space and time. Specifically, the relationships of tropospheric ozone with temperature, surface solar radiation (rsds) and nitrogen dioxide concentration (NO_2) are analyzed. Likewise, the relationship between tropospheric ozone concentration and surface atmospheric circulation is studied in detail, by means of composites and analysis of the Empirical Orthogonal Functions (EOFs), in order to determine the degree of relevance of the atmospheric circulation in those situations in which anomalous concentrations of ozone on the surface occur. The results obtained show that the relationships of ozone with temperature and radiation depend to a great extent on the studied site, being especially notable the area of North Africa, in which extreme ozone events are associated with a decrease in temperature, opposite to the expected result, being the main causes related to transport from polluted European regions.

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The impact of climate change on photovoltaic power generation for solar installations in the Atacama desert

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The solar power installed capacity has experienced significant development in the last years worldwide. The irradiance is the essential variable to produce solar power, although the temperature plays an essential role too in the efficiency of a solar installation. The Atacama desert in South America is one of the regions on our planet with some of the greatest irradiance levels; thus, its solar power installed capacity has experienced a significant boost in the last ten years. One of the keys to improving the profitability and the efficiency of a solar installation is to know the future power generation. For example, such knowledge lets to make appropriate geographical choices of the areas to be exploited.

In this work, we analysed variations in photovoltaic (PV) generation in the Atacama desert during the period 2021-2060 by means of an ensemble of three regional climate models from the CORDEX project. We validated the accuracy of these simulations by comparing them with data from the ERA5 reanalysis. The results show that for 2021-2060 the number of days with high-temperature values will increase compared to 1980-2005. For the case of irradiance, the number of days with high values will decrease; meanwhile, low irradiance days will increase, especially for the period 2041-2060. Overall, a decrease in PV generation is projected along the period studied (higher for (2041-2060)). The changes in the distribution of temperatures are expected to be the main responsible for reducing PV generation.

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Did the meteorology affect the near-surface ozone concentrations over Europe during the COVID-19 lockdown of early spring 2020?

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Over the last two years non-pharmaceutical intervention measures in the form of social distancing and lockdowns have been applied to reduce the transmission of SARS-CoV-2. At the beginning of the pandemic, from mid-March to late April 2020, most European countries were under strict lockdowns. This caused unprecedented falls in industrial activity and vehicle use, two of the main sources of air pollution.

This work [1] focuses on the impact of that lockdown on the near-surface ozone concentrations in Europe. For that purpose, we have analysed 1-h daily maximum nitrogen dioxide (NO_2) and maximum daily 8-h running average ozone (MDA8 O_3) observations at ~1300 background sites of the European Environment Agency's air quality database (AirBase) as well as daily meteorological fields form a reanalysis.

As expected, NO_2 concentrations decreased considerably, with relative reductions ranging from 5% to 55% with respect to the same period in 2015–2019 for 80% of the sites. However, surface O_3 decreased in the Iberian Peninsula and increased over northwestern and central Europe. In some countries like Germany, O_3 concentrations were typical of the summer season. Atmospheric conditions were also unusual, with anomalously stable, dry, and warm weather over large parts of the continent and meteorological anomalies of opposite sign in the southwest. This could have raised the O_3 concentrations over most of Europe except in Iberia.

As the meteorology seemed to play a substantial role, we have built statistical models to separate the effect of meteorology and emissions, and to estimate the expected O_3 concentrations during that period in the absence of a lockdown. The results indicate that a considerable fraction of the observed O_3 enhancements in northwestern and central Europe can be explained by elevated temperatures, low atmospheric humidity and high solar radiation (Figure 1). On the other hand, the O_3 reduction in Iberia is attributable to low solar radiation and high specific humidity, and to a lesser extent low temperatures, while weak zonal winds partly compensated those effects.

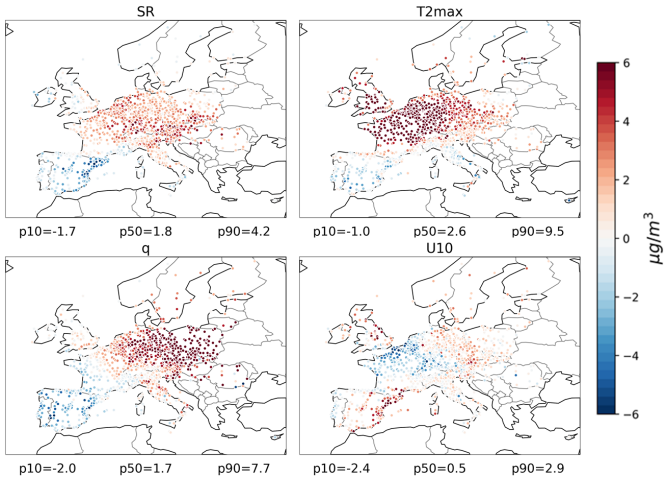

Figure 1. Average differences between predicted MDA8 O_3 using daily meteorology of 15 March – 30 April 2020 and after replacing the daily values of a meteorological field (incoming solar radiation at surface, SR; 2-m daily maximum temperature, T2max; 2-m specific humidity, q; 10-m zonal wind, U10) by the climatological values in 2015–2019.

While this analysis shows a dominant role of the meteorology during the early-spring lockdown, it is well known that other factors (e.g. sharper decreases in emissions of nitrogen oxides than those of volatile organic compounds) have yielded regional ozone enhancements over some regions during the pandemic.

[1] Ordóñez C., Garrido-Perez J.M., García-Herrera R, Early spring near-surface ozone in Europe during the COVID-19 shutdown: Meteorological effects outweigh emission changes, *Science of The Total Environment* **747**, 141322 (2020).

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Preliminary results about long-term trends in downward surface shortwave radiation over Spain (1985–2021)

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The downward surface shortwave radiation (SSR) is a component of the solar radiation that plays an important role in our planet life by driving the main processes that occur in the atmosphere and oceans. Not only is the study of solar radiation important because it modulates the global energy balance but it has also important impacts in different socio-economic sectors such as agriculture and solar energy production [1].

There has been a growing interest in the study of solar radiation tendencies in the last decades since there is strong evidence showing that this variable has not remained constant over the years but instead significant decadal changes have been reported [1]. A widespread reduction in SSR has been proved to have occurred from the 1950s to the 1980s, a phenomenom that has been called *global dimming*. In contrast, a recovery and subsequent increase in SSR since the 1980s have been reported (*brightening period*).

Although previous studies have focused on SSR trends in Spain [2], no one has done an update up to the present days. Thus, the main objective of this study is to examine SSR temporal changes for a long period (+30 years, from the 1980s up to the present time) over different stations.

The radiation dataset was obtained from the Spanish Agencia Estatal de Meteorología (AEMET). SSR measurements were permofed using Kipp & Zonem pyranometers, which were periodically calibrated against international standards in order to ensure the reliability and traceability of the measurements.

Daily radiation data (measured in kJ m^{-2}) of 70 stations are available, but for this study only the series starting at least in the early 1980s were considered. Taking into account this constrain, the number of series available is reduced to 13, from which Bilbao, Oviedo and Valladolid are discarded as several temporal inhomogeneities have been detected, which results in a final dataset consisting of 10 stations (Albacete, Cáceres, La Coruña, Logroño, Madrid, Málaga, Murcia, Palma de Mallorca, San Sebastián and Santander).

Daily radiation data was averaged to obtain monthly values for each station and monthly anomalies were calculated as differences to the 1985-2021 mean. Individual annual anomalies have been calculated by averaging the monthly anomalies and individual seasonal annomalies have been computed in a similar way. The seasons were defined as: winter (DJF), spring (MAM), summer (JJA) and autumn (SON). Both annual and seasonal mean series for Spain have been computed by the arithmetic mean of the individual annual and seasonsal series of the 10 stations, respectively. An analysis of the trends in SSR have been performed, both for individual stations and the average of Spain.

The results show a significant positive trend of +3.85 Wm^{-2} per decade for the annual series of SSR during the 1985-2021 period. The seasonal series also exhibited an increase with the strongest and significant ($p < 0.05$) rates in summer (+6.94 Wm^{-2} per decade) and autumn (+3.72 Wm^{-2} per decade). These results are in agreement with those obtained in previous studies but there are small differences in some values due to corrections in the dataset and homogenization methods applied, as well as the longest period considered in this study.

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Análisis de escala simple de veinticinco años de registros de la red pluviométrica de Barcelona

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El área metropolitana de Barcelona, de aproximadamente $100\,km^2$ de extensión, dispone de una red densa de pluviómetros de balancín que se empezó a instalar en 1983, y ha ido siendo gestionada desde entonces por diferentes empresas (CLABSA, Aqualogy, y actualmente BCASA). Se dispone de los registros 5-minutales de lluvia de una veintena de pluviómetros, a lo largo de 25 años de funcionamiento desde 1994 hasta 2019. A partir de estos registros de lluvia ha sido posible realizar un análisis de escala simple específico para cada pluviómetro, con el fin de poner de manifiesto las características, ligeramente diferentes, de la precipitación recogida en cada una de las zonas del área urbana.

Las series de máximos anuales de intensidad cumplen relaciones de escala del tipo $I_t \overset{dist}{=} \lambda^{K(q)} I_{\lambda t}$, expresión que indica que la intensidad I_t para una cierta duración t se puede describir por la misma distribución estadística que el segundo miembro de la ecuación, en el cual $I_{\lambda t}$ es la intensidad de lluvia para una duración diferente λt, siendo λ la relación de escala entre ellas. El exponente $K(q)$ es una función de escala del orden q de los momentos estadísticos: cuando puede aproximarse por una expresión lineal como βq se dice que la distribución está describiendo una magnitud monofractal o de escala simple; si no es así lo que se tiene es un multifractal. Existen varios estudios [1, 2] que muestran como el exponente de escala β suele ser un buen indicador del tipo de régimen pluviométrico, de su irregularidad. Así, cuando este exponente se calcula a partir de la agregación de registros diarios de lluvia, en los lugares en los cuáles estos registros son más regulares se obtienen valores más altos (sobre -0.5) que en donde es más frecuente tener máximos aislados de lluvia intensa y registros irregulares (más cercanos al valor límite -1). Para el Observatori Fabra, a 411 m de altura, se obtuvo [2] un valor del exponente β de -0.78, tanto para los registros del pluviómetro totalizador Hellmann como para los del pluviógrafo Jardí operando al unísono entre 1927 y 1992.

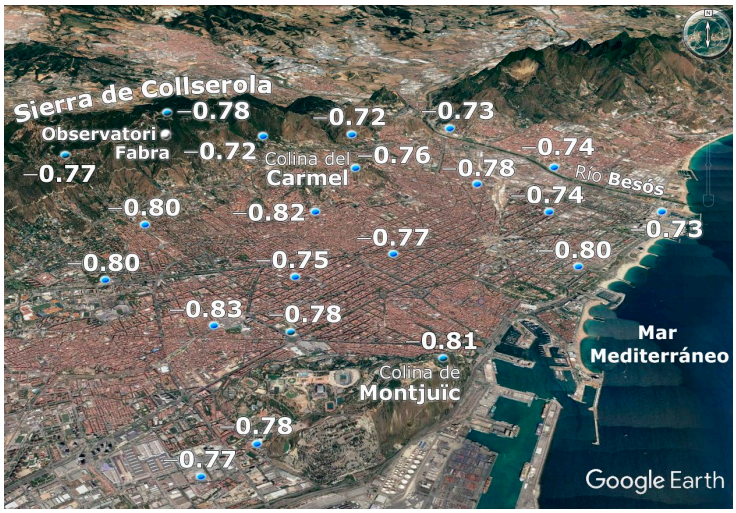

Figura 1. Valores de β en cada pluviómetro de la red de Barcelona.

El estudio detecta pequeñas diferencias pluviométricas entre las diferentes zonas urbanas mediante el análisis de escala simple. Se han obtenido valores de β para los diferentes pluviómetros entre -0.72 y -0.83 (Fig. 1). La distribución espacial de β muestra relación con características topográficas como la altura o la distancia al mar. A excepción de la zona central, en el llano de la ciudad se obtienen valores alrededor de -0.80 que van aumentando hacia las afueras, en especial en la cuenca del río Besós, con valores de -0.73 y -0.74.

[1] Casas-Castillo MC, Rodríguez-Solà R, Llabrés- Brustenga A, García-Marín AP, Estévez J, Navarro X. A Simple Scaling Analysis of Rainfall in Andalusia (Spain) under Different Precipitation Regimes. *Water* **14**, 1303 (2022). https://doi.org/10.3390/w14081303

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Long-term analysis of Schumann Resonance measured at the Sierra Nevada ELF station

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Schumann Resonance (SR) is a natural electromagnetic phenomenon that consists of the resonance of the EM field propagating within the cavity delimited by the surface of the Earth and the lower ionosphere, mainly excited by lightning activity. The SR appears in the Extremely Low Frequency (ELF) band of the electromagnetic spectrum, and the approximate values for the first three resonance modes are 8, 14 and 20 Hz. An ELF station was designed and deployed by the authors of this work at Sierra Nevada, Granada, Spain, which comprises two ground based magnetometers, oriented in the North-South (NS) and East-West (EW) directions, respectively. More details can be found in [1].

A methodology to process the time domain magnetic field recorded at this station has been proposed by the authors in [2]. The first part of the scheme is based on the Welch method to obtain the amplitude spectrum of the recordings. For this purpose, the data are split into 10-min long intervals, and each one of these intervals is also split into 10-sec long windows with a 5-sec overlap. After applying a Hann window, we obtain its FFT. We average the FFT of all the 10-sec long windows and the output of this first part of the scheme is the amplitude spectrum of each 10-min long interval of recordings. A second part of the process consists of the removal of the anthropogenic noise that may appear due to electrical machinery, transport systems or other sources near the ELF station. In a third step, a fitting curve made up of three lorentzian functions and a linear part is fitted to the amplitude spectrum, thus obtaining a value for each amplitude, central frequency and width of each one of the three first SR mode for each 10-min interval.

Finally, the analysis of the long term variations of the parameters of the resonances -amplitude, central frequency and width- gives information on the global lightning activity and other parameters concerning the state of the Earth's atmosphere. The authors have performed a study of the SR measured at the Sierra Nevada ELF station. In order to perform this study, a set of programs based on the Pandas package has been implemented. The code 'Variations.py' includes a wide range of functions which allow to analize the SR variations using different time-scales -seasonal, monthly and daily- and also spectrograms, analysis of the rate of saturations of the magnetometers and statistical studies. A masking process of anomalous intervals is applied to the recordings. Some python notebooks have been created to easily visualize the study of the SR and will be shared to the scientific comunity together with the experimental data.

The results have been compared to previous works. The general diurnal evolution of the three main storm centers on Earth -Africa, Asia, and America- is similar to that observed in previous works, and the results also corroborate an intesification of the SR during the transition months that precede the super El Niño episode that happened at the end of 2015 and the beginning of 2016. More detail of this study can be found in [3].

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