Invited talk (Mathematics in atmospheric science and Climate change)

Applications of dynamical systems theory in the study of extreme climate events.

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Abstract

Atmospheric motions are chaotic, which implies an unavoidable loss of predictability with increasing lead time. Extreme events such as heatwaves, intense cyclones, droughts and floods are becoming more frequent, intense and more lasting in a warming climate. Even though studies on the detection and characterization of extreme events in Europe are numerous, little is known about the predictability of these events. It has been recently demonstrated that applying the dynamical systems theory to the atmospheric conditions we can study the intrinsic predictability of an extreme event [1], and so, we can know the capacity we have to anticipate it, thus being able to take action for the minimization of its impacts by using early warning systems.

Climate information on the most predictable or unpredictable atmospheric configurations can be understood by applying the dynamical systems theory and using two properties of the underlying attractor: persistence and local dimension [1]. The argument is that low-dimension, high persistence atmospheric patterns should afford a higher predictability than high-dimension, low persistence cases.

To illustrate this, the predictability of several extreme events affecting the Iberian Peninsula [2], such as the intense low-pressure systems Filomena and Gloria, recent heatwaves, and record-breaking summers, among other events, will be examined during this talk. Additionally, the different applications and potential of this technique in seasonal forecasting [3] will be discussed, with the aim of enhancing our understanding and early warning systems for these great impact extreme events.

References

[1] Faranda, D., Alvarez-Castro, M. C., Messori, G., Rodrigues, D., Yiou, P.(2019): *The hammam effect or how a warm ocean enhances large scale atmospheric predictability.* **Nature communications 10(1), 1316**. https://doi.org/10.1038/s41467-019-09305-8

[2] Faranda, D., Messori, G., Alberti, T., Alvarez-Castro, C., et al (2024): *A statistical physics and dynamical systems perspective on geophysical extreme events.* Physical Review E (pre-print) https://arxiv.org/abs/2309.15393

[3] Pérez-Zanón, N., Caron, L.-P., Terzago, S., Van Schaeybroeck, B., Lledó, L., Manubens, N., Roulin, E., Alvarez-Castro, M. C., et al (2022): *Climate Services Toolbox (CSTools) v4.0: from climate forecasts to climate forecast information.* **Geosci. Model Dev., 15, 6115–6142**. https://doi.org/10.5194/gmd-15-6115-2022

Short CV

Carmen holds a PhD in Climatology from the University of Pablo de Olavide (Spain). Her PhD thesis focused about the development of an index, using documentary sources, to measure westerlies in the English Channel to study the atmospheric circulation in the North Atlantic region during the past. During her PhD, she spent 3 months as a visiting researcher at the University of Lisbon in Portugal, 7 months at TNA-University of Sunderland in the United Kingdom, and 9 months at the Joint Research Center of the European Commission in Italy. Following her PhD, she gained further expertise in atmospheric circulation and extreme events during her 3-year postdoctoral tenure at the Laboratory of Climate and Environmental Sciences (LSCE-IPSL) in France. There, she worked on techniques to study analogs of circulation and weather regime classifications, applied dynamical systems theory to extreme events, and utilized bias correction techniques. She then spent 2 years as a postdoctoral researcher and 3 years as a Junior Scientist at the Euro-Mediterranean Center on Climate Change (CMCC) in Italy, within the Climate Variability and Predictions Division. At CMCC, she focused on climate services, the predictability of extreme events, and applying dynamical and statistical techniques for seasonal forecasting.

In 2023, Carmen returned to her alma mater, Pablo de Olavide University in Seville, as a distinguished Beatriz Galindo researcher, a position granted by the Ministry of Universities in Spain and keeps the affiliation with CMCC due to her collaborations. Her current research is focused on understanding the role of atmospheric circulation in the occurrence of extreme events, studying their predictability, and applying this knowledge to climate services using seasonal forecasts. Since 2019, Carmen has also been teaching several courses in the Environmental Sciences degree at the University of Pablo de Olavide, Spain, and a postgraduate course on atmospheric modeling at the University of Bologna, Italy.