Applied Mathematics Seminar

UCC
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Coláiste na hOllscoile Corcaigh

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Fingerprinting Heatwaves and Cold Spells and Assessing Their Response to Climate Change using Large Deviation Theory

Extreme events provide relevant insights on the dynamics of the climate system and their understanding is key to defining useful strategies for mitigating the impact of climate variability and climate change. Here we approach the study of persistent weather extremes using the lens of large deviation theory. We first consider a simplified yet Earth-like general circulation model of the atmosphere and numerically estimate large deviation rate functions of near-surface temperature in the mid-latitudes. We find that, after a re-normalisation based on the integrated auto-correlation, the rate function one obtains at a given latitude by looking, locally in space, at long time averages agrees with what is obtained, instead, by looking, locally in time, at large spatial averages along the latitude. This is a result of scale symmetry in the spatial-temporal turbulence and of the fact that advection is primarily zonal. This agreement hints at the universality of large deviations of the temperature field. Furthermore, we discover that the obtained rate function is able to describe spatially extended and temporally persistent heat waves or cold spells, if we consider temporal averages of spatial averages over intermediate spatial scales. We then extend our analysis by looking at the output of a state-of-the-art climate model and at observational data. We show how to const ruction in a mathematically rigorous way the climatology of persistent heatwaves and cold spells in some key target regions of the planet by constructing empirically the corresponding rate functions for the surface temperature, and we assess the impact of increasing CO2 concentration on such persistent anomalies. In particular, we can better understand the increasing hazard associated to heatwaves in a warmer climate. We show that two 2010 high impact events - summer Russian heatwave and winter Dzud in Mongolia - are associated with atmospheric patterns that are exceptional compared to the typical ones, but typical compared to the climatology of extreme events. Finally, we propose an approximate formula for describing large and persistent temperature fluctuations from easily accessible statistical properties.

Refs:
V. Galfi, V. Lucarini, Fingerprinting Heatwaves and Cold Spells and Assessing Their Response to Climate Change using Large Deviation Theory, in review (2020)
V. Galfi, V. Lucarini, J. Wouters, A Large Deviation Theory-based Analysis of Heat Waves and Cold Spells in a Simplified Model of the General Circulation of the Atmosphere, J. Stat. Mech. 033404 doi:10.1088/1742-5468/ab02e8 (2019)

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