Hammam Effect:
How a warm ocean enhance large scale predictability

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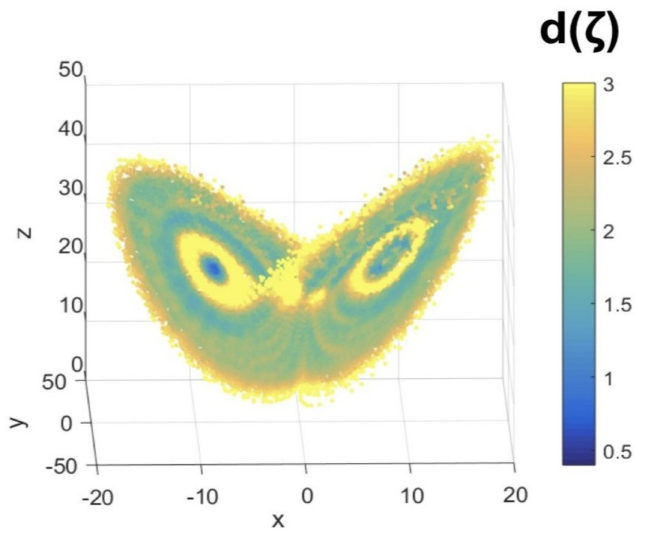
The atmosphere's chaotic nature limits its short-term predictability. Furthermore, there is little knowledge on how the difficulty of forecasting weather may be affected by anthropogenic climate change. Here, we address this question by employing metrics issued from dynamical systems theory to describe the atmospheric circulation and infer the dynamical properties of the climate system. Specifically, we evaluate the changes in the sub-seasonal predictability of the large-scale atmospheric circulation over the North Atlantic for the historical period and under anthropogenic forcing, using centennial reanalyses and CMIP5 simulations. For the future period, most datasets point to an increase in the atmosphere's predictability. AMIP simulations with 4*K*warmer oceans and 4 × atmospheric CO_2 concentrations highlight the prominent role of a warmer ocean in driving this increase. We term this the hammam effect. Such effect is linked to enhanced zonal atmospheric patterns, which are more predictable than meridional configurations.

DYNAMICAL PROXIES IN ATMOSPHERIC FLOWS

Dynamical Systems

Compute Dynamical Systems metrics to characterize atmospheric states, verifying that a long series of observations sample the underlying attractor.

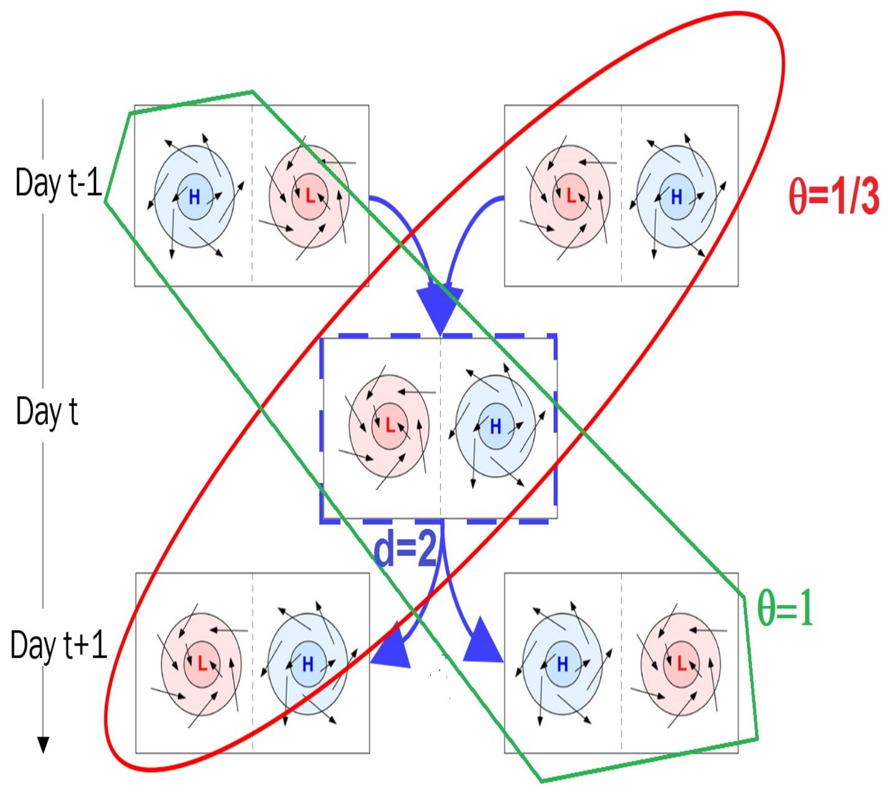


Local Dimensions *d*

t is proportional to the number of possible configurations (**number of degrees of freedom**) originating and resulting from the atmospheric field analyzed.

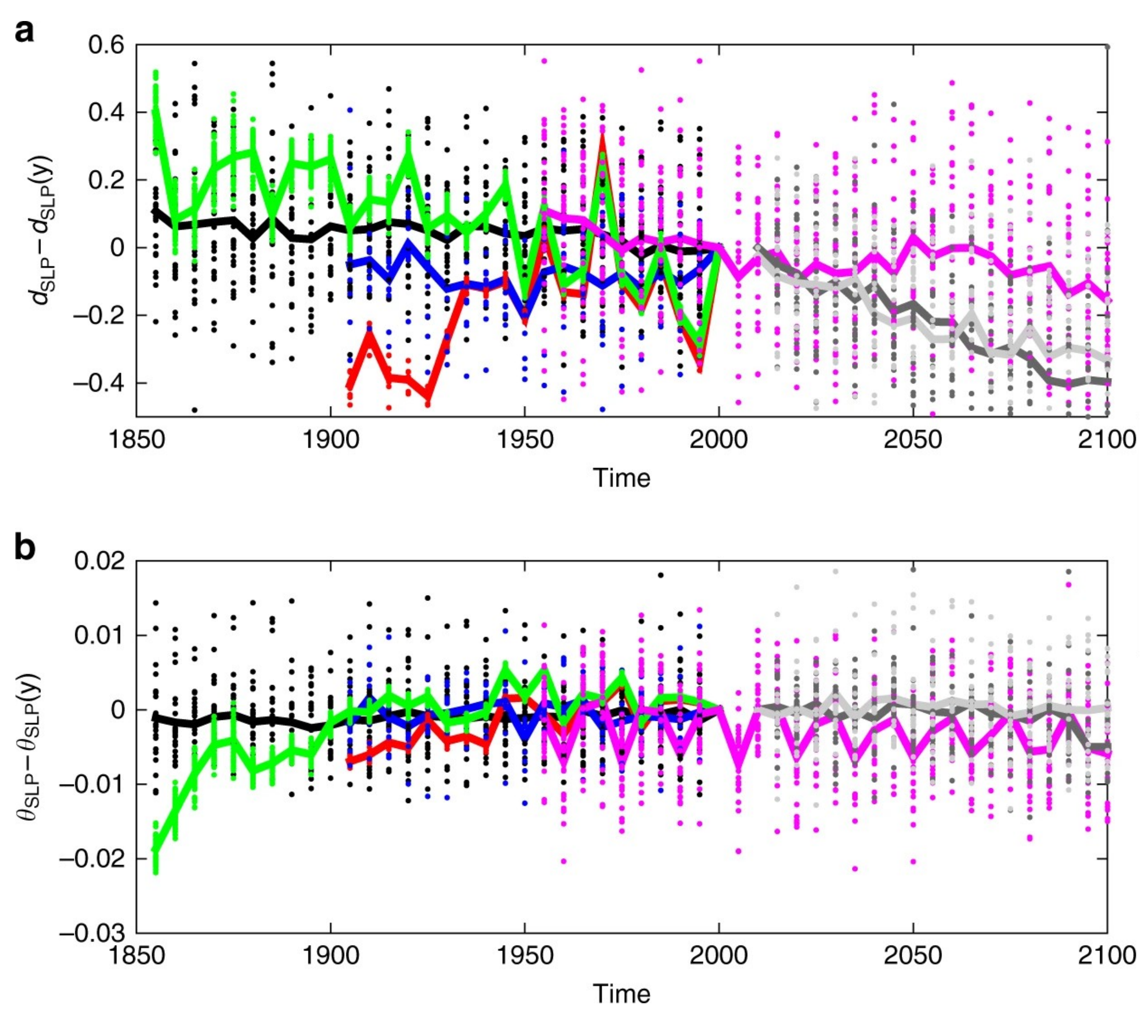
Persistence Θ

its inverse tells for **how long the atmospheric field will look like the one under examination**. For the present analysis Θ is an inverse number of persistance days.



Schematic representation of the dynamical indicators on fictive sea-level pressure maps. H indicates high and L low pressure systems; the arrows mimic horizontal wind fields. The local dimension ***d*** is proportional to the number of possible configurations preceding and following the day analyzed (here d=2). *Θ* is the inverse of the persistence time of a given configuration. If the pattern persist for three days (red path), then Θ=1/3. If the patterns change every day (green path), then *Θ*=1.

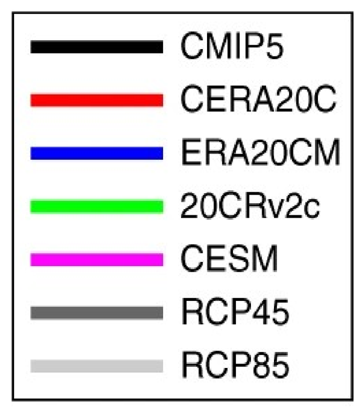
CHANGES IN DYNAMICAL PROPERTIES FROM 1850 to 2100



By **averaging the daily dimensions** and persistence over 10 years and over the single members of each reanalysis or model simulations (dots) we get the results displayed as continuous lines. There are large discrepancies among datasets

a) The dimension decreases except for CERA20C (this implies an increase in predictability).

b) The persistence is steady

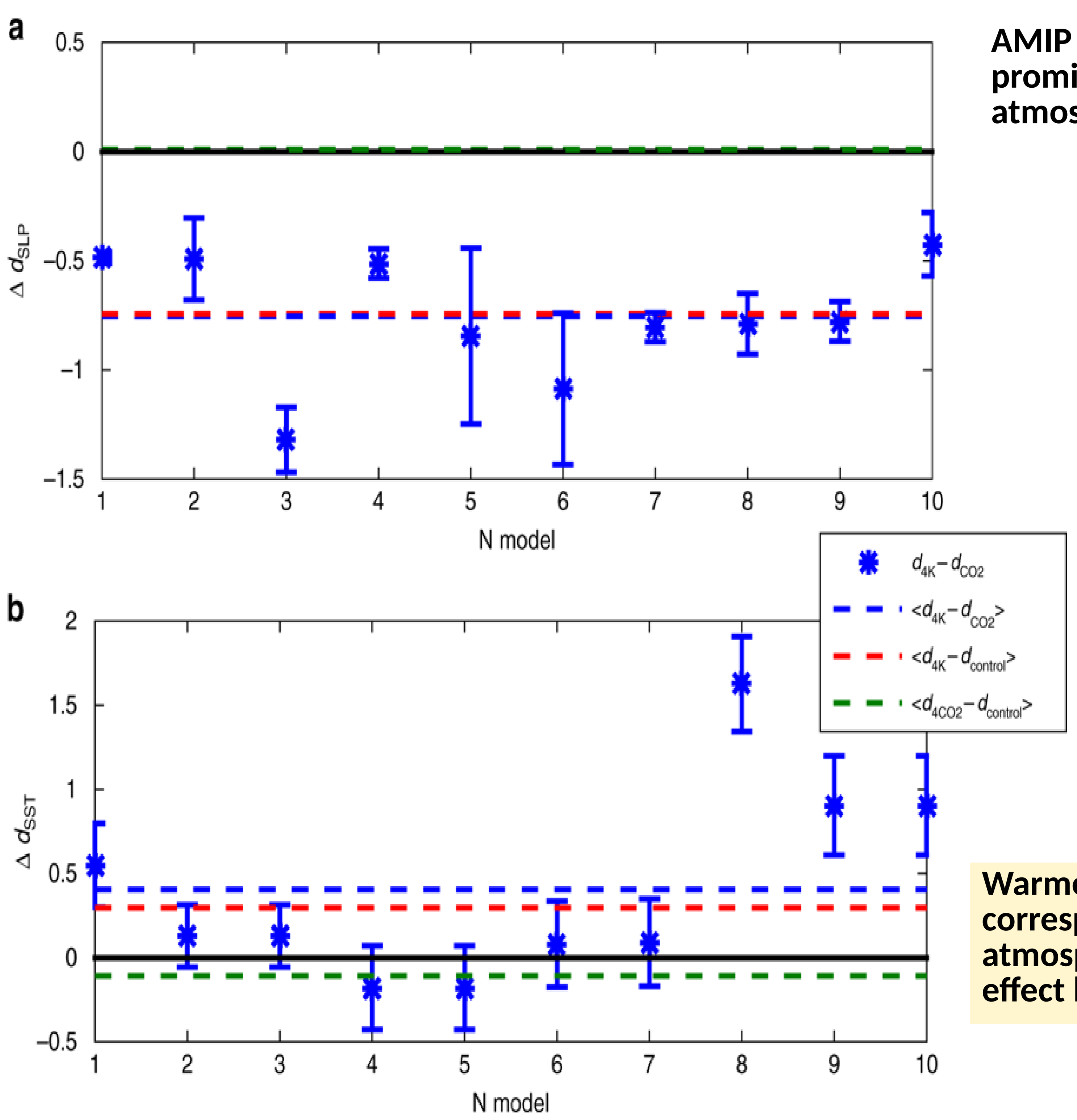


The analysis covers :
- -26 CMIP5 historical simulations
- -10 CERA20C reanalysis members
- -10 ERA20C reanalysis members
- -56 20CRv2C member
- -30 CESM historical and future simulations
- -26 CMIP5 RCP 4.5 and 8.5 scenarios simulations

Climate change will increase the atmosphere's intrinsic predictability.

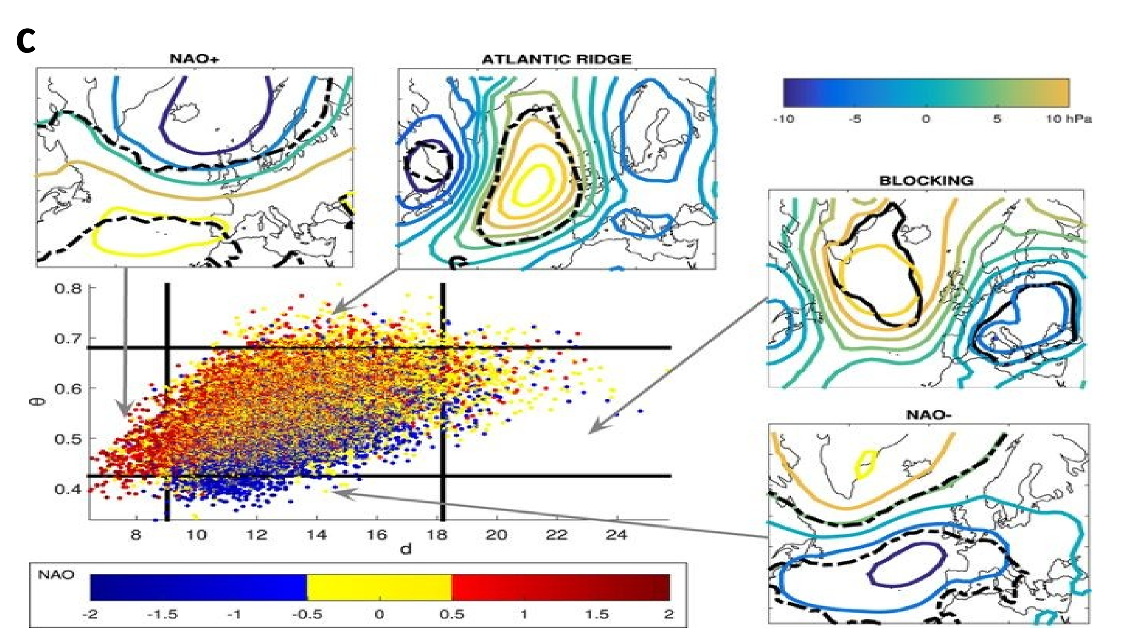
THE HAMMAM EFFECT

AMIP simulations with 4K warmer oceans and 4 × atmospheric CO2 concentrations highlight the prominent role of a warmer ocean in driving this increase. Such effect is linked to enhanced zonal atmospheric patterns, which are more predictable than meridional configurations.

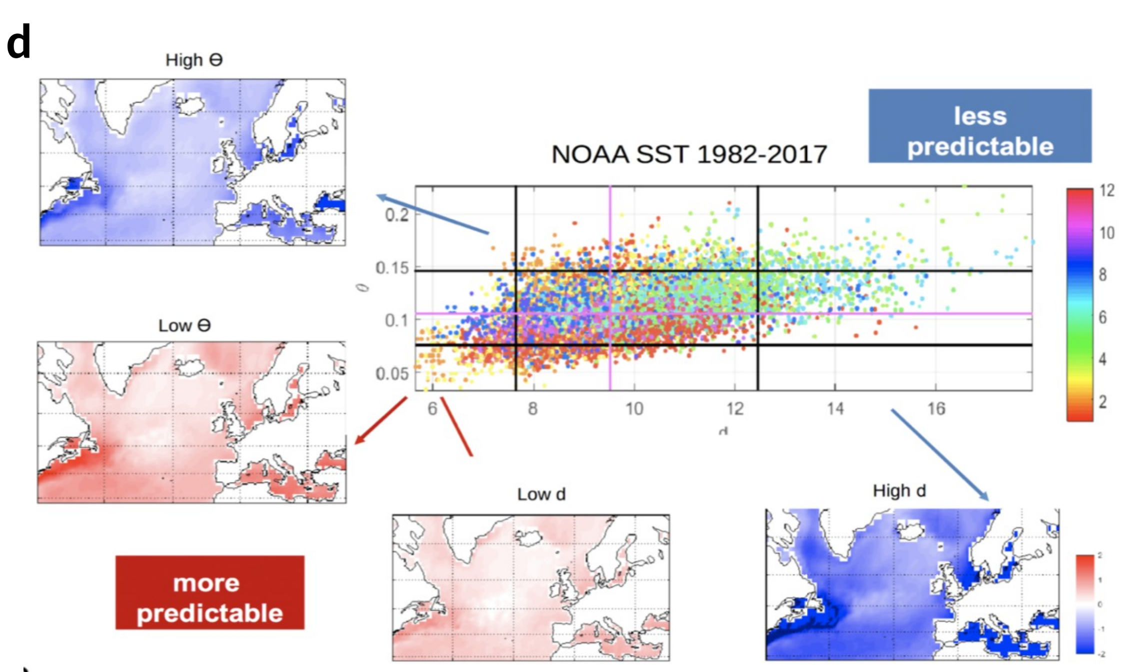


Differences of Δ*d* between average local dimension d_{SLP} for daily sea-level pressure (SLP) data (**a**, **b**) and d_{SST} for monthly sea-surface temperature (SST) fields for the 4 × CO_2 and +4 K AMIP simulations with respect to the control runs. Error bars indicate the standard deviation of the mean. Lines: means of the ensembles, indicated in the legend by angular brackets

SLP



SST



Warmer SSTs in the North Atlantic (d) correspond to more predictable atmospheric configurations (c), this effect has been named *hammam effect*

[1] *Davide Faranda, Gabriele Messori and Pascal Yiou. Dynamical proxies of North Atlantic predictability and extremes.* ***Scientific Reports****, 7-41278,* ***2017****.*
[2]*Rodrigues, D. et al. Dynamical properties of the north atlantic atmospheric circulation in the past 150 years in cmip5 models and the 20crv2c reanalysis.* ***Journal of Climate, 2018***
[3]*Davide Faranda, M Carmen Alvarez-Castro, Gabriele Messori, Pascal Yiou. The Hammam effect or how a warm ocean enhances large scale atmospheric predictability.* ***Nature Communications, 2019***