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Spatio-temporal global patterns of 70 years of daily temperature using Fisher-Shannon complexity measures

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Spatio-temporal patterns of temperature distributions

Background:

- climate is characterised by strong nonlinearity and chaotic behaviour, but most of the study in climate science adopt statistical methods valid only for stationary/linear systems.

Aim:

- investigate the complex nature of temperature trends;
- study the maximum temperature at two meters above ground using the NCEP CDAS1 daily reanalysis data, with spatial resolution of 2.5° by 2.5° and covering the time period from 1 January 1948 to 30 November 2018;
- study the dynamics and non-stationarity of the corresponding temperature time series using methods from Information Theory.

Methods

For each spatial location we analyzed the temperature using the Fisher Information Measure (FIM), an ordering measure of the data, and the Shannon Entropy Power (SEP), which quantify the uncertainty – or the disorder – of the data.

The theoretical value of FIM given the probability density $f(x)$ of a signal x and its derivative $f'(x)$ is expressed as:

$$FIM = \int \frac{(f'(x))^2}{f(x)}\, dx,$$

while the Shannon Entropy Power (SEP) is measured as

$$SEP = \frac{1}{2\pi e} \exp\left\{2 \int f(x) \log f(x)\, dx\right\}.$$

Temporal changes of unpredictability patterns

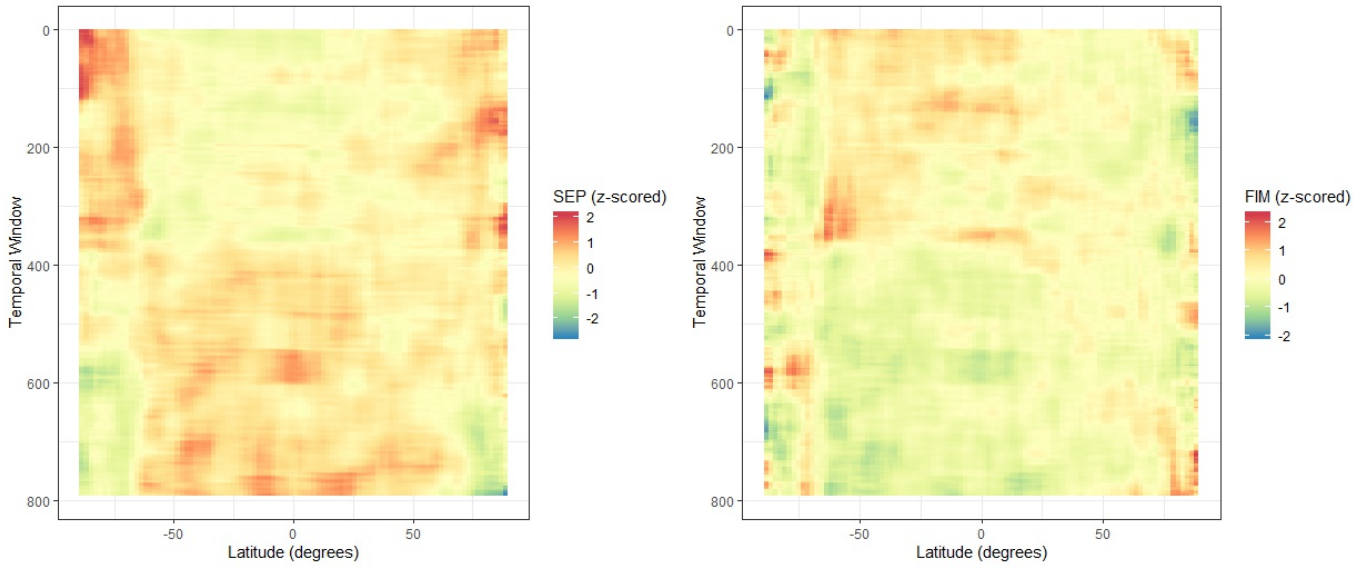

Figure 1: **Hovmöller plot for the latitude of FIM and SEP.** The values of FIM and SEP have been standardized usign a z-score tranformation. In the period from 1948 to the early 80', the latitudes higher than $60°N$ and lower than $-60°S$ show high levels of SEP and low levels of FIM. The situation completely revers starting from 1980.

Regional dynamic behaviour of temperature distributions

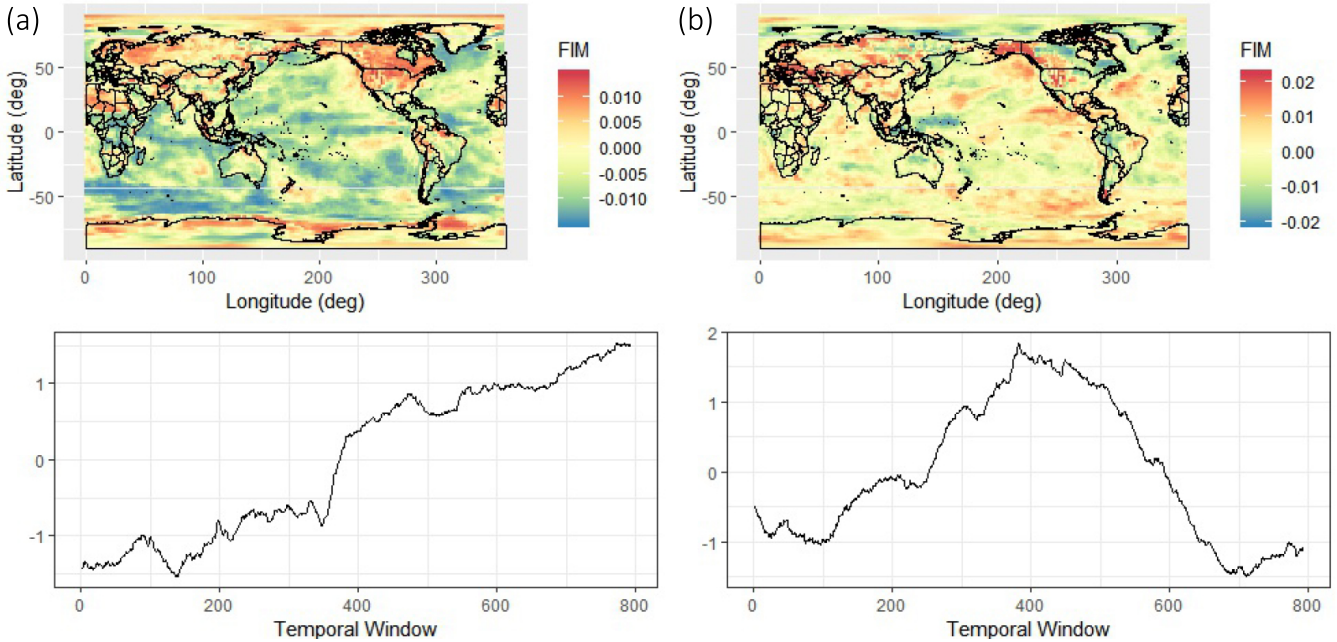

Figure 2: **Empirical Orthogonal Function (EOF) decomposition of FIM.** The first EOF (a) shows differences between oceans and lands surfaces, with the latter having increases of FIM. This could be partly due to the integration of TVOS satellite data in the reanalysis models from 1979. The second EOF (b) shows decreasing FIM values from 1980 in the continental interiors of Asia, western North America and central Brazil - regions known to be affected by high warming trend since the late seventies.

Discussion and conclusions

- Fisher Information identifies the level of order in data, while entropy could be used to spatially identify unpredictability patterns in surface temperature data;
- we highlighted how entropy spatial patterns have changed in time, possibly opening new questions in relation to the possibility of performing long-term forecasts;
- the predictability level may not be spatially constant over the entire globe and has probably been subject to a temporal shift since the eighties;
- next steps of this research is the analyses of other climate models (e.g. CMIP6) to compare the information/entropy patterns of historical data and baseline models.

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