Dynamical Patterns of Climate Networks: Blinking Links and Stable Structures

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Introduction

Using measurements of atmospheric temperatures we create climate networks in different regions on the globe. A link in these networks is related to the temporal correlation between records of temperature and height (pressure) level between two places (nodes). Response of the intermediately strong links in these networks to global patterns such as the El-Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) is, in general, much sharper than the response of non mixed moments (mean, variance) of temperature or height level [1]. In particular, the response to El-Niño has the quality of links that repeatedly appear and disappear - like blinking [2]. The response to NAO has the quality of very slow gradual decrease in the number of links, which is much more delicate and hard to detect. A phenomenological model that captures the behavior during El-Niño is suggested.

Stronger links also play important role, as they sometimes arrange in rigid autonomous patterns that persistently influence their surrounding environment.

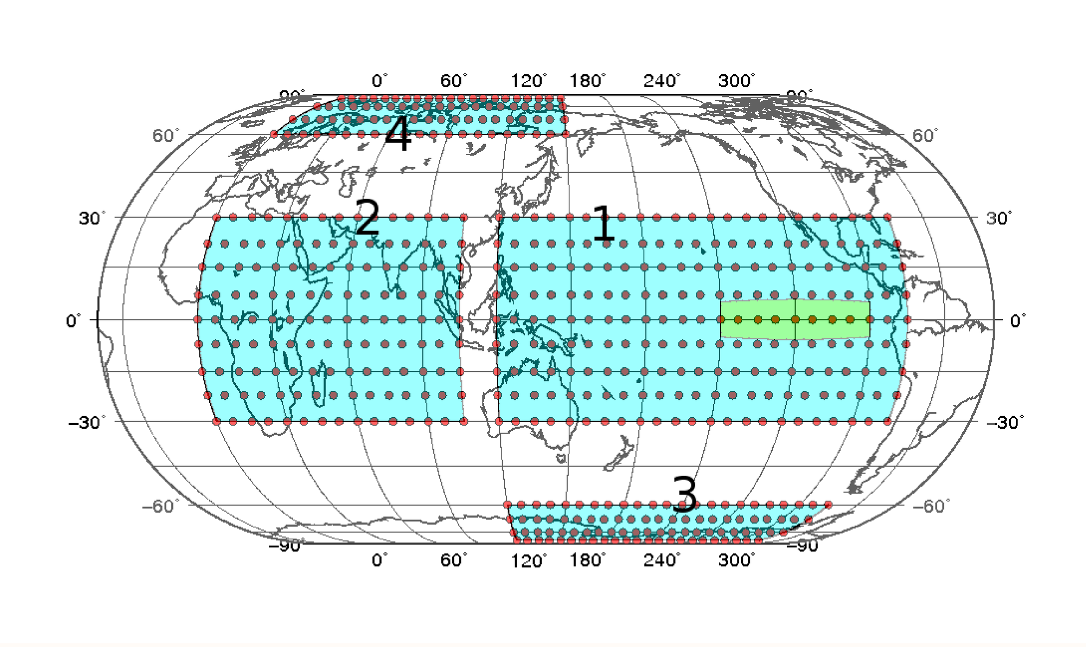


Figure 1. The four geographical zones used for building the four climate networks studied. The dots represent the nodes of the network. The rectangular geographical zone inside zone 1 shows the standard basin for which El-Niño effects on temperature and pressure is significantly observed

Methods

We compute for a time shift $\tau \in [-\tau_{\max}, \tau_{\max}]$ days for each pair of sites **l** and **r** on the grid, their cross correlation function

$$X^{y}_{l,r}(\tau > 0) = \frac{1}{365}\sum_d T^{y}_{l}(d)T^{y}_{r}(d+\tau)$$

The correlation strength of the link is chosen to be

$$W^{y}_{l,r} = \max(X^{y}_{l,r})/\mathrm{std}(X^{y}_{l,r})$$

we are able to set a physical threshold Q so that only pairs that satisfy W>Q, are regarded as significantly linked.

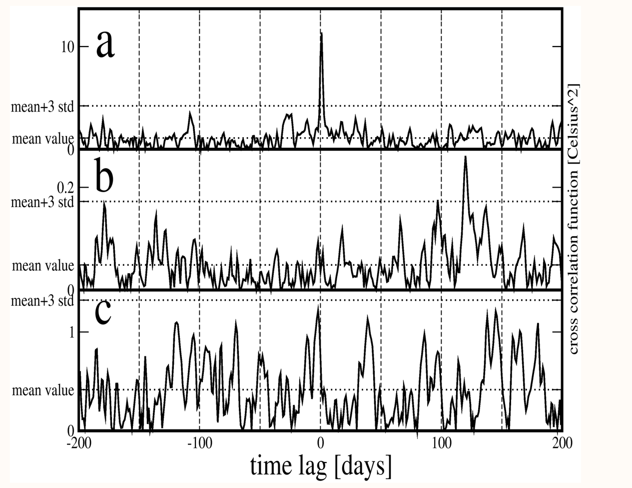


Figure 2. Three typical profiles of the cross correlation function of temperature anomalies. (a) A strongly correlated (SC) link, with small time delay. (b) An intermediately correlated (IC) link, with a few significant time delays. (c) A weakly correlated (WC) link, where the different local maxima cannot be distinguished from noise.

Results

Links in the current network, that appeared k times in a row, represent long lasting relations between temperature fluctuations in the zone. Counting them enables us to distinguish between two qualitatively different groups of links, blinking links which are removed, and robust links which we include in the network. Our networks are built from measurements of temperatures close to sea level, and from measurements on a 500mb pressure level, on a grid of 7.5º resolution. The measurements are taken for the years 1979-2006.

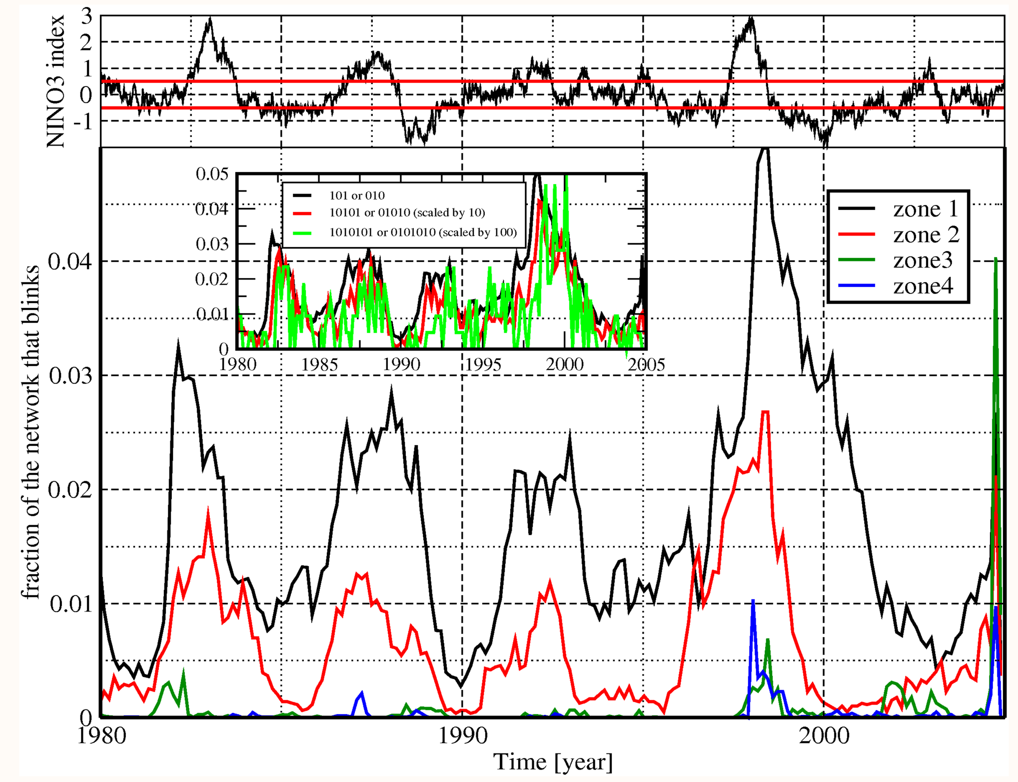
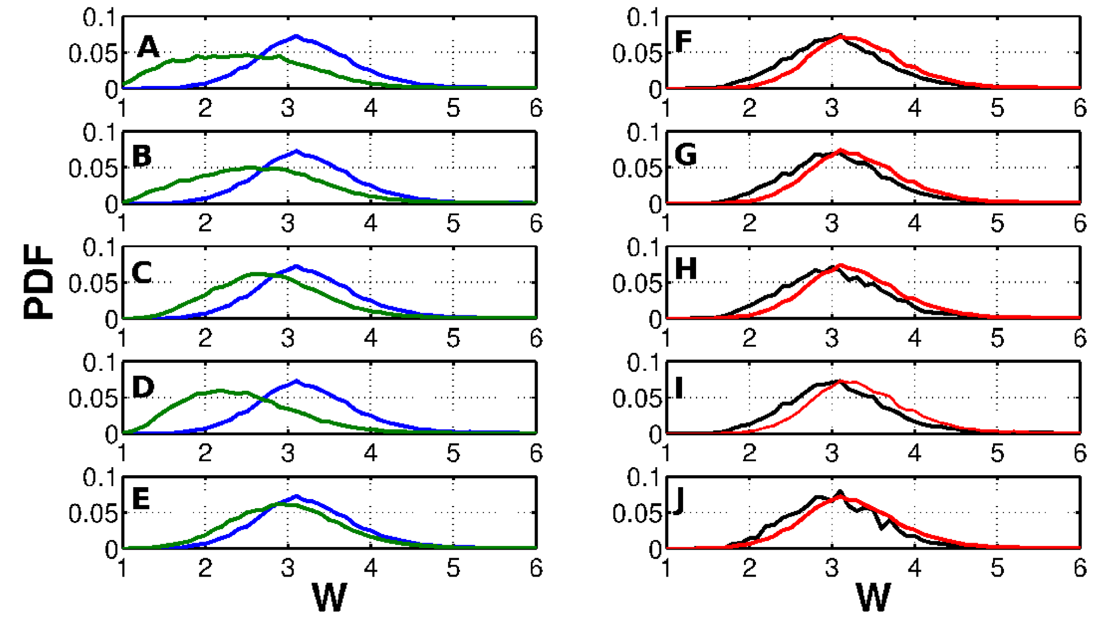


Figure 3. Upper panel : the NINO3 index, composed of sea surface temperature in the pacific ocean. The red lines are accepted threshold values [2]. Lower panel : number of blinking links as a function of the time . The inset shows higher order blinking patterns for zone 1. The 5th order fractions are scaled by 10 and the 7th order fractions are scaled by 100.



Figures 4. distribution of correlation strength in 5 major events. A-E . blue curves represent the distribution in a reference time, and green curves represent the distribution during an El-Nino event. F-J. Black curves represent the distribution during reference time of the links that disappear later, and red curves represent the distribution in a reference time of links that survive

The effects of NAO on the climate network are qualitatively similar to the El Niño effects, but the distribution of correlation values is modified in a different way. The two effects are easily distinguishable. Both types of events do not influence the strongly connected links, which have a different behavior.

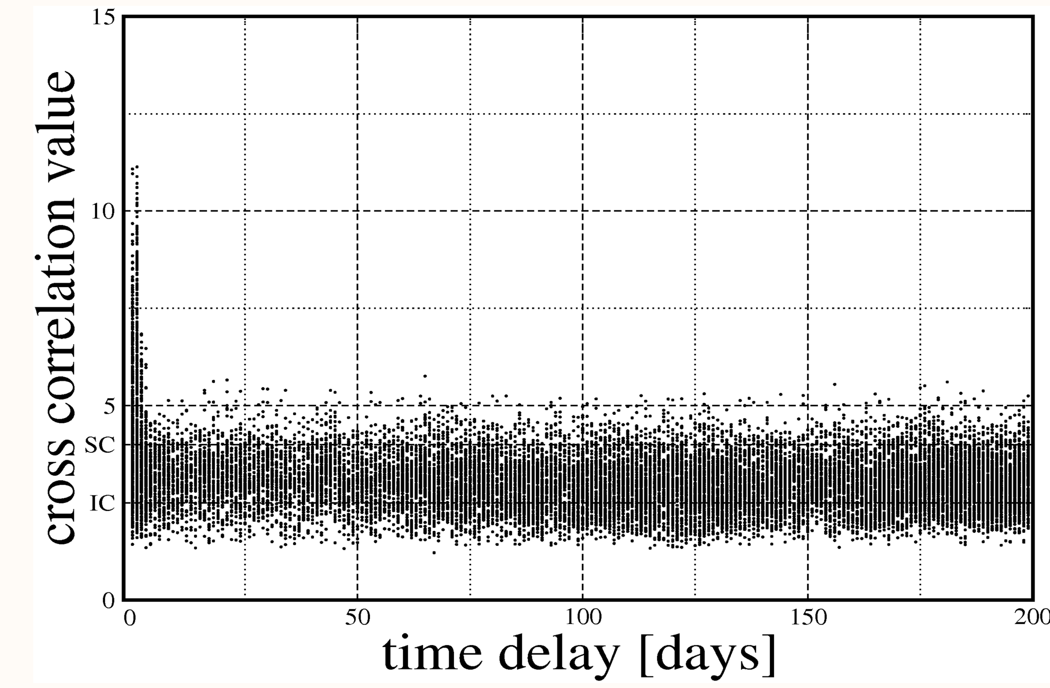


Figure 5. Scatter plot of cross correlation and time delays values. The ordinate grid-lines also include the ranges of the three groups. Below the line that is noted by IC is the range of WC links, above it and below the SC line is the range of IC links, and above the SC line only the strongest SC links exist.

Figure 6. Raster plot of structures of SC links that have almost autonomous behavior, but influence their surrounding environment. This figure, differently from the other figures, was constructed from a network based on evenly spaced grid of temperature measurements at the 1000mb isobar, that covers the world. Dots sharing the same color belong to the same structure. Some of the structures appear persistently, while other structures do not.

Conclusions

We have developed a method which enables one to follow large changes over time of an underlying network structure by observations of fluctuations in the correlations between nodes. The method tracks blinking links that appear and disappear in a short time, and assumes this behavior to be due to structural changes. Tracking the changes in the network of temperatures in several zones in the world reveals a deep violent response to El-Niño even in zones and heights where the mean temperature level is not affected. The links that break during El-Niño are mostly links that have large time delays. Response to NAO have different quantitative correlation profiles, but similar behavior.

Our explanation for the increased sensitivity of the blinking measure to the El-Niño influence, is as follows. While only few nodes in the far-away networks are directly related to the El-Niño basin, many of the pairs interact through indirect paths that is indeed influenced by El-Niño. Therefore, while the node's individual dynamics is almost not changed, the mutual relations of nodes within each zones do change.

Strongly connected links sometimes form rigid structure that persistently influence their surroundings. These structures are the topic of a new work, not yet published.

Other works were recently published about the climate network, including the pioneering work of Tsonis et. al. [4]. The unique feature of our analysis is the focus on the dynamics rather than the topology. The "take home message" is that the dynamical structural changes in the climate network are at least as important as the structure itself.

Literature cited

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3. http://www.ncdc.noaa.gov/paleo/ctl/clisci10c.html
4. A.A. Tsonis, K.L. Swanson, P.J.Roebber. 2006.What do Networks have to do with Climate, Bull. Am. Meteorol. Soc. 87, 585-595

Acknowledgments

We wish to thank Prof. Steve Brenner and Prof. Hans Von Storch for useful discussions.

For further information

Please contact avigoz@*gmail.com*. .

The results of this poster were published in two papers:

1. K Yamasaki, A Gozolchiani, S Havlin , Phys. Rev. Lett. 100, 228501, (2008)
2. A. Gozolchiani, K. Yamasaki, O. Gazit, S. Havlin, EPL 83, 28005 (2008)

... and were also reviewed in the popular science magazine "new scientist":

3. http://technology.newscientist.com/channel/tech/mg19926675.600-software-predicts-where-el-niño-will-strike-next.html