The Emergence of El-Niño as an Autonomous Component in the Climate Network

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Introduction

The temperatures and pressure fluctuations of different locations characterize the same atmospheric layer can be viewed as dynamical systems with interactions. It is possible that l and r have correlated behavior (sometimes with a time lag) due to common mechanisms (such as solar modulation), meridional flow (solar, dust, water, air) between l and r, direct pressure of l on r and each other, and heat flow between them. These correlations are studied with the aid of eigenvalues such as principal component analysis, yielding a few fluctuation profiles that are typical.

However these correlations are quite robust field on their own right, and the profiles of this field, which we call “the climate network” have been the topic of recent studies [A1-4,B1-5]. We have demonstrated [B1-3,A2] that during El-Nino times large portions of this field have a reduced value, corresponding to a less correlated atmosphere. We are now able to propose a peculiar and rich pattern in this effect: the unique autonomous component in the eastern pacific [B4]. We have elaborated a four attractors fields (temperature and geopotential height)1000 snapshot (corresponding to 10 days resolution over 30 years) survey of the climate network, which points the behavior of this autonomous component. This includes the distribution of phases that strongly correlate with this component, the distribution of its time delays with the environment, and an interesting altitude dependent profile of its interactions with the northern and southern hemispheres. We have also compiled the leading profiles of this information (main principle component), which are shown to be related to the different stages of the El-Niño Southern Oscillation (see an animation of the fields in [A5]).

Methods

We compute for a time shift $t_{1}$ for each pair of sites l and r on the grid, their cross covariance function $\rho_{l,r}(t)$. The correlation strength of the link is chosen to be $\rho = \max(\rho_{l,r}(0),\rho_{l,r}(-t))$. As seen in Fig. 1a, there is a group of nodes, C, that have lower values at any time, and are specifically distinct during El-Nino (wide yellow stripe). We find that measuring the dynamics of the interactions of the C region with its surroundings yields a sensitive test to quantify the response of l and r to El-Nino events. Fig. 3a shows $\rho_{l,r}$ and $\rho_{l,r}^{e}$, the in- and out-weighted degree of C (which includes 14 nodes, respectively).

In,Out, and Total

Direction: $W_{l,r} = |\rho_{l,r}(0)| - |\rho_{l,r}(-t)|$

Fig. 1 Weighted degrees as a function of time (y axis) and the node index (x axis). (a) Total weighted degree $\rho_{l,r}(t)$. (b) The microscopic contributions to the weighted incoming degrees of $\rho_{l,r}(t)$, $\rho_{l,r}^{e}$. The microscopic contributions to the weighted outgoing degrees $\rho_{l,r}^{o}$. One should note in mind that each point is compiled from records of 565 days $\times 365$ days $\times 200$ days of shifts. The representative point in all figures for each 565 period in the beginning date of the period.

Results

The interaction of the autonomous cluster C with its environment is highly asymmetric with respect to the equator. This might have several explanations, mostly regarding the asymmetrical distribution of the lands. However, this asymmetry is reversed in high altitudes as shown in Fig. 5.

Fig. 2: Spatial distribution of the weighted degrees of nodes (in and out, upper and lower panels respectively) averaged over El-Nino times.

For further information

http://physionet.ph.biu.ac.il/~gozolaa/PRL_ENSOPMgozyamhav

Literature cited

A5. http://www.springerlink.com/content/9p196n2313672033/

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Conclusions

We have found a new dynamical pattern that reflects the coupling between the El-Niño basin (ENB), and the rest of the world. ENB becomes significantly more autonomous during El-Nino, losing a large fraction of its in-links, while still having out-links. This kind of topology is reminiscent of pacemakers in network models (A6). The major impact of events inside ENB on world climate on one hand, and the weakened correlations during El-Nino episodes on the other hand, are not contradictory. In fact, the uni-directional interaction of ENB with large parts of the climate network might suggest the origin for its significant dynamical role in the global climate.

The autonomous property of ENB exist even in high altitudes, but the detailed structure, and the interactions of this component with its environment is altitude dependent.

One of the most pronounced detailed altitude behavior is the north- south asymmetry. Near sea surface, ENB is forced more by the northern hemisphere than by the southern, and forces the southern hemisphere more than it forces the northern. In higher altitudes this asymmetry is reversed. This is an example in the two hemispheres in opposite, this north–south asymmetry might be related to the known (not yet fully understood) partial phase locking of the ENB cycle with the annual cycle (see e.g. [A7,A8]).

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