Complex Networks from Event Synchronization of rainfall events over South America

Niklas Boers[1,2], Bodo Bookhagen[3], Norbert Marwan[1], Jürgen Kurths[1,2]

[1]Potsdam Institute for Climate Impact Research, [2]Department of Physics, Humboldt University, Berlin, [3]Department of Geography, University of California, Santa Barbara

SUMMARY

Complex Networks have been successfully used to analyze the dependency structure of various climate variables [1]. Here,we construct a network from synchronization of strong rainfall events over South America. The distribution of centrality measures on the network reveals several key machanisms of South American Climate, such as the low-level jets (LLJ) east of the Andes, the intertropical convergence zone (ITCZ) and the South Atlantic Convergence Zone (SACZ) for the austral summer and winter season.

DATA

> TRMM 3B42 daily satelite product, 1998-2010 [2], spatial resolution 0.5°x0.5°

> Rainfall Events: threshold at 90thpercentile of daily rainfallvalues at each grid point

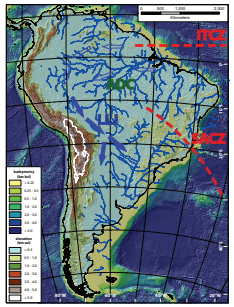

Figure 1. Topography and main atmosph. systems

METHODS

Event Synchronization

For grid points $i, j \in \{1, \dots N\}$, count the number of times an event at i can be uniquely associated with an event at j and vice versa [2]. Uppon normalization, we obtain a measure for the synchronicity of the N time series as an $N \times N$- matrix Q with $0 \leq Q_{ij} \leq 1$.

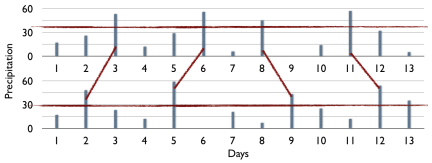

Figure 2. Schematic synchronization of rainfall events

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Network Construction

A graph $\mathcal{G}$ consists a set of nodes $\mathcal{N}$ and a set of links $\mathcal{E}$ between them. In our case, $\mathcal{N}$ is the set of grid points, which we connect by links if $Q_{ij} \geq \tilde{Q}$ for $\tilde{Q}$ such that the density of links is 5%. In terms of the adjacency matrix A, for which $A_{ij} = 1$ if i and j are connected and $A_{ij} = 0$ otherwise, this is captured by

$$A_{ij} = \Theta(Q_{ij} - \tilde{Q}) - \delta_{ij}$$

where self loops have been excluded.

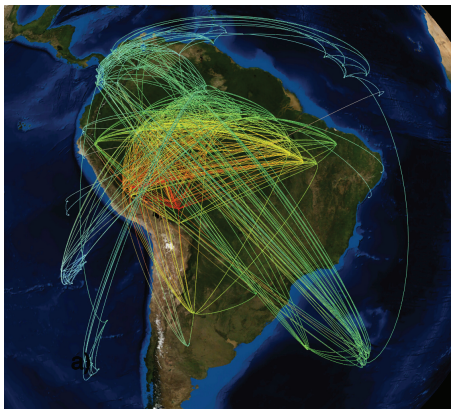

Figure 3. Network from synchronization of rainfall events

Degree Centrality:

$$k_v = \sum_{j \in \mathcal{N}} A_{vj}$$

Betweenness Centrality:

(σ_{kl} denotes the number of shortest paths from node k to node l and $\sigma_{kl}(v)$ the fraction of them going through v)

$$b_v = \sum_{k,l \in \mathcal{N}, k \neq v \neq l} \frac{\sigma_{kl}(v)}{\sigma_{kl}}$$

Closeness Centrality:

($d_{\mathcal{G}}(v,v) = 0$ by definition)

$$c_v = \sum_{j \in \mathcal{N}} 2^{-d_{\mathcal{G}}(v,j)}$$

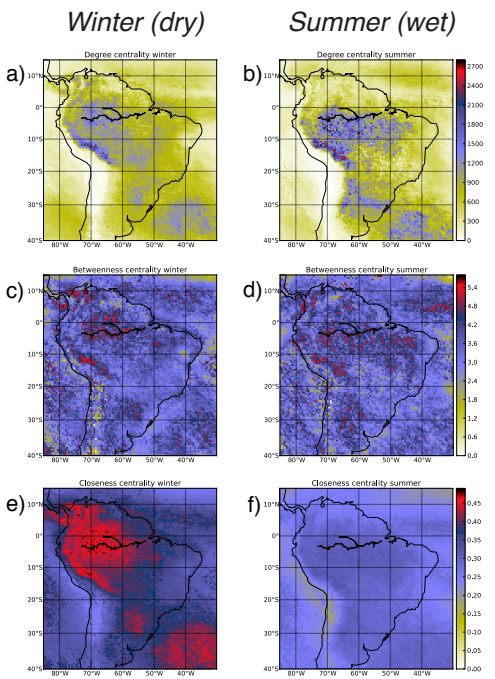

Figure 4. Network centrality measures degree, betweenness & closeness for austral winter (dry) and summer (wet)

RESULTS

Multiple climatic features (e.g. [3,4]) can be inferred from the spatial distributions of the 3 centrality measures (Fig. 3):

> The Amazon deep convection zone, shifting NE-wards from summer to winter (Figs. a,b);

> The ITCZ, shifted N-wards during austral summer (Figs. c,d,e) and the SACZ (Fig. d);

> Intensified and weakened phases of the SACZ (corresponding to the 2 branches of high degree over the SE Amazon Basin in Fig. b);

> The low-level jets, enhanced during summer (Figs. b,c,d);

> Surprisingly, closeness centrality is strongly increased over the entire continet during the dry season (Figs. e,f)

OUTLOOK

> The temporal evolution of network measures will be investigated and put into relation with known incidents like drought years or El Niño/La Niña-events.

> Other similarity measures such as rank correlations of anomaly time series have been used to construct networks for South American Rainfall. Networks for other variables such as land and sea surface temperature, air pressure and carbon concentration will be constructed in an analogous fashion.

These Networks will then be coupled to construct a Network of Networks, aiming at a representation of the key interdependency structures of the South American environmental system.

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Contact Niklas Boers, Research Domain IV, Transdisciplinary Concepts and Methods, PIK, boers@pik-potsdam.de