Potsdam Institute for Climate Impact Research

A Complex Network approach to investigate the spatiotemporal co-variability of extreme rainfall

N. Boers,[1,2] A. Rheinwalt,[1,2] B. Bookhagen,[3] N. Marwan,[1] J. Kurths,[1,2] H.M.J.Barbosa,[4] J. Marengo[5]

[1]Potsdam Institute for Climate Impact Research, [2]Department of Physics, Humboldt University, Berlin, [3]Institute of Earth and Environmental Science, Potsdam University
[4]Institute of Physics, University of Saõ Paulo, [5]CCST-INPE, Saõ Paulo

SUMMARY

We construct networks from synchronization of extreme rainfall events over South America for the monsoon season from December to February using 6 different datasets. This methodology is designed to complement PCA-based techniques in the case of extreme events. A climatological interpretation of various network measures reveals the most important features of the South American Monsoon System (SAMS) [1], allows to compare the representation of the spatiotemporal co-variability of extreme rainfall in different datasets and models [2], as well as to establish forecast systems of extreme rainfall [3].

DATA

90/99th percentiles of daily/3hly values 1998-2012

> TRMM 3B42 V7 [3]
> TRMM 3B42 RT V7 [3]
> GPCP 1DD V1.2 [4]
> ERA-interim [5]
> ECHAM6 GCM [6]
> ETA RCM [7]

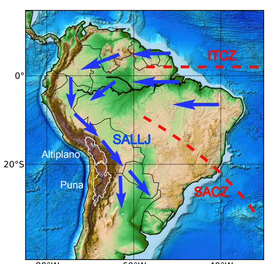

Figure 1. Topography and main atmosph. systems

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 [8]. Uppon normalization, we obtain a measure for the synchronicity of the N time series as an $N \times N$- matrix Q with $0 \leq Q_{ij} \leq 1$.

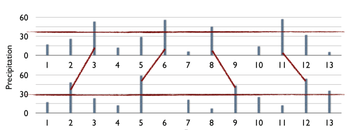

Figure 2. Schematic synchronization of rainfall events

Network Construction

A graph $\mathcal{G}$ consists a set of nodes $\mathcal{N}$ and a set of links $\mathcal{E}$ between them. Here, $\mathcal{N}$ is the set of grid points, which are connected by links if $Q_{ij} \geq \tilde{Q}$ for a given threshold $\tilde{Q}$. The network's adjacency matrix is thus given by

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

where self loops have been excluded.

REFERENCES

[1] N. Boers et al., *GRL* (2013)
[2] N. Boers et al., *under review at Journal of Climate* (2014)
[3] N. Boers et al., *Nature Communications* (2014)
[4] G. J. Huffmann et al., *J. Hydrometeorol.* 8 (2007)
[5] G. J. Huffmann et al., *J. Hydrometeorol.* 2 (2001)
[6] Dee et al., *QJRMS* 137 (2011)
[7] Hertwig et al., under review (2014)
[8] Mesinger et al., *Met. Atm. Ph.* (2012)
[9] R. Quian Quiroga et al., *Phys Rev E,* 66:041904-1 (2002)
[10] B. Liebmann, C. R. Mechoso, *The Global Monsoon System,* 608 pp. (2011)

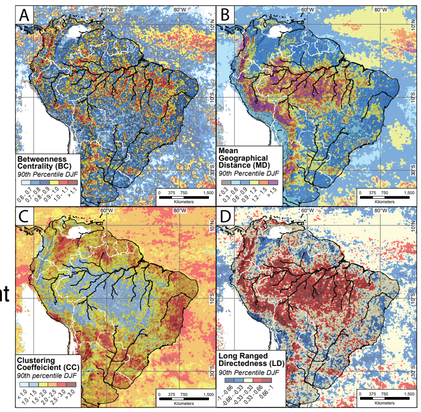

Figure 3. Network measures obtained for TRMM 3B42 V7 [1].

RESULTS I

Multiple climatic features (e.g. [9]) associated with the main moisture transport routes can be inferred from the spatial distributions of network measures obtained for TRMM 3B42 V7 ([1], Fig. 3):

> The Amazon deep convection zone
> The main convergence zones (ITCZ, SACZ)
> The South American Low-Level Jet
> Mesoscale Convective Systems

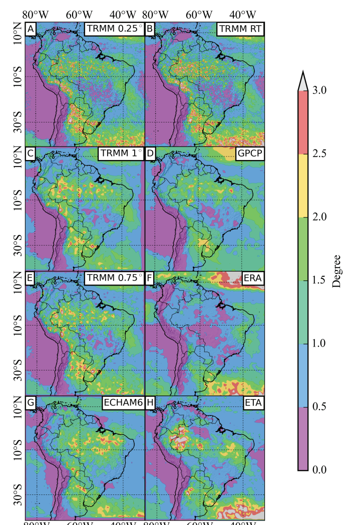

Figure 4. Network measure Degree for different spatial grid resolutions and multiple datasets [2].

RESULTS II

The spatial patterns exhibited by suitable network measures can be used to compare the representation of extreme rainfall events among different datasets. Based on the climatological interpretations of these measures, we can draw inferences about the dynamical mechanisms controlling extreme rainfall distributions. This can be particularly usefull for the evaluation of climate models ([2], Figure 4).

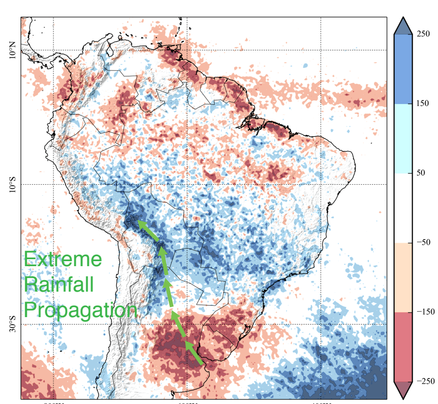

Figure 5. Extreme Rainfall Forecast: Network Divergence for 3-hly TRMM 3B42 V7 [3].

RESULTS III

To assess the predictability of extreme rainfall, we introduce the measure Network Divergence $\Delta\mathbf{S}$ on directed and weighted networks, defined as the difference of in-strength $\mathbf{S}^{in}$ and out-strength $\mathbf{S}^{out}$ at each node:

$$\Delta S_i = S_i^{in} - S_i^{out}$$

Negative values indicate sources, while positive values indicate sinks of extreme rainfall in the network ([2], Figure 5).
This measure identified a climatic mechanism responsible for the propagation of huge rainfall clusters from southeastern South America to the eastern Central Andes, against the direction of the low-level winds. On this basis, a forecast system could be developed, predicting 60%-90% of extreme rainfall events (above the 99th percentile) at the slopes of the eastern Central Andes. These events have devastating socio-economic impacts in form of floods and landslides.

Contact. Niklas Boers, Potsdam Institute for Climate Impcat Research
boers@pik-potsdam.de

Acknowledgements. This work was developed within the scope of the IRTG 1740 / TRP2011 / 50151-0 funded by DFG and FAPESP