Structural Interrelationships between Evaporation and Precipitation:

Application of Complex Networks to Satellite based Fields

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In attempt to get closer to real climate systems and associated with them system of interactions a concept of coupled climate networks was introduced by *Donges et al., 2011*. Investigating topology of interacting networks conclusions on dominant connectivity "tunnels", spatial and temporal dependence variability and vulnerability of one filed relative to another can be done.

Analyzing coupled topology of evaporation (E) and precipitation (P) fields the conclusions on major teleconnections, topological and dynamical features, temporal and spatial connectivity variability of the observed and modeled E/ P networks, as well as similarity measures were carried out.

Motivation :

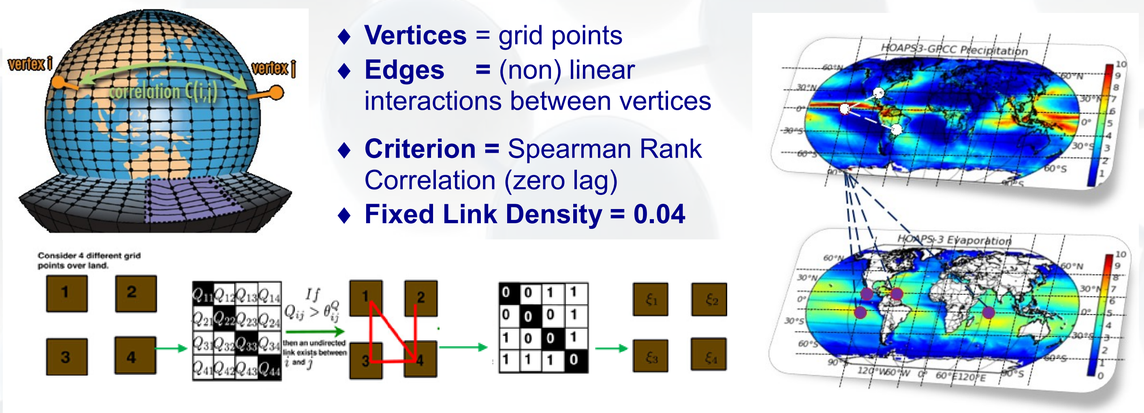
- Studying and understanding complex interactions and system of feedbacks between E and P
- Connectivity features of observed E and P from the HOAPS-3 product
- Improvement / validation of the numerical simulation schemes

Objectives :

- Analyze topology of single/ coupled precipitation and evaporation networks
- Investigate prominent global teleconnection patterns in the constructed networks
- Identify physical properties within the climate network fields
- Compare observed (HOAPS) and modelled (MPI-ESM) network features

Method of Complex Networks (CCN) :

The information stored in a node of a climate network reflects the physical state of corresponding spatial grid-point. Thus, depending on the spatial and temporal scale under research the connections or links between these nodes will represent certain (non-) linear interactions between each other. In order to exclude unwanted and insignificant connections between the vertices, a preprocessing of the knowledge data should be done.



- **Vertices** = grid points
- **Edges** = (non) linear interactions between vertices
- **Criterion** = Spearman Rank Correlation (zero lag)
- **Fixed Link Density = 0.04**

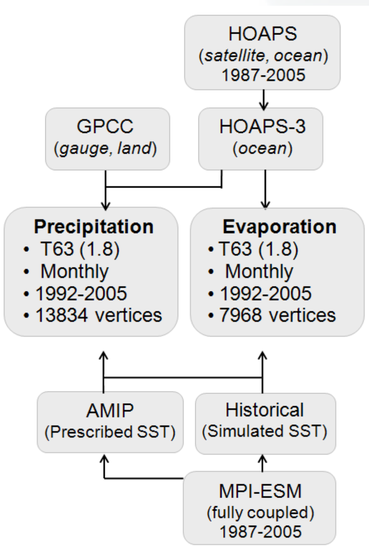
Fig 1. *Main steps to construct Climate Network (left) and principle idea of Coupled Network Connectivity (right)*

Observed HOAPS-3 and modelled MPI - ESM Data :

Construction of any network strictly depends on the knowledge (collected) data to be used. Imperfect retrieval algorithms and data merging of the atmospheric parameters fields cause uncertainties and lower quality of the final product.

Combined HOAPS-S and GPCC:

In order to obtain consistent and representative evaporation and precipitation fields the **fully satellite-based HOAPS-3** (Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data, (www.hoaps.org) and **combined HOAPS-3 / GPCC** (Global Precipitation Climatology Center, (www.gpcc.dwd.de) datasets were used.



Earth System Model of MPI-M :

A **fully coupled MPI-ESM** model is composed of the atmospheric module (ECHAM6, *Stevens et al., 2012*), ocean (MPIOM, *Jungclaus et al., 2012*) and land (JSBACH, *Raddatz et al., 2007; Brovkin et al., 2009*) components.

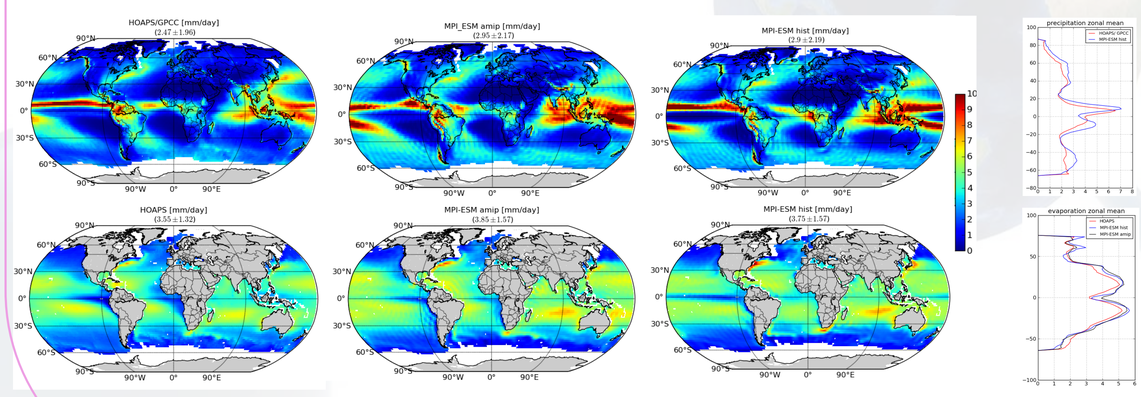


Fig 2. *Climatological annual means of Precipitation (upper) and Evaporation (lower), and corresponding zonal means*

Global Teleconnections :

Area Weighted Connectivity (AWC) fields reveal **ENSO and NAO** related connectivity patterns and associated teleconnections over western coast of USA, Pakistan, South to Madagascar and the area of NAO– influence over Greenland.

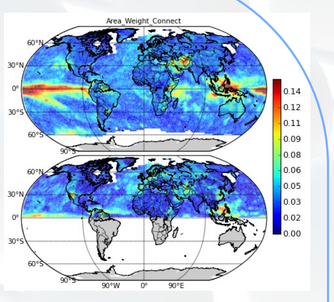


Fig 3. *AWC of the Precipitation Network from HOAPS / GPCC*

- What does degree see?
- Where the areas of high connectivity are located?
- Super nodes?
- What reveals the mis-match of model and observed networks?

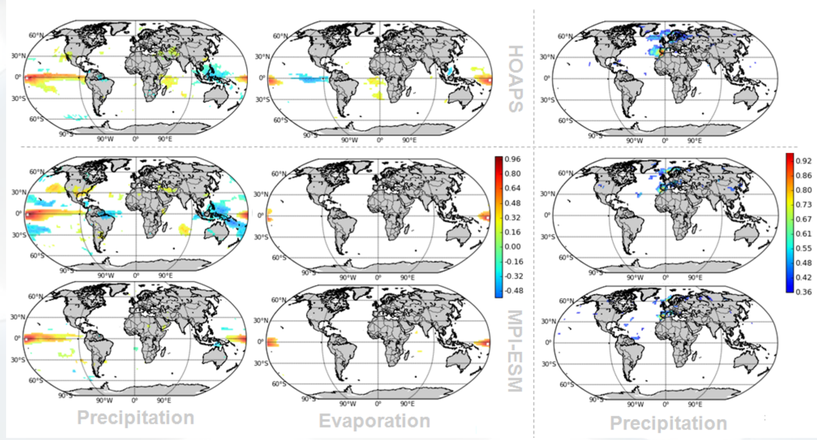
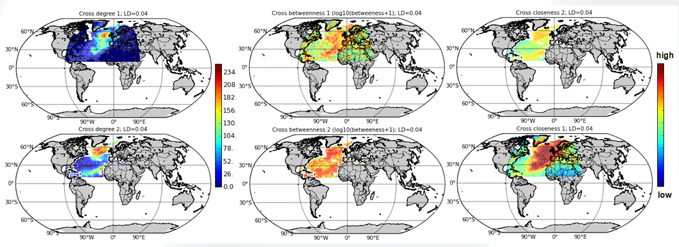


Fig 5. *Correlation Values of source-point neighbours in HOAPS and MPI-ESM based Evaporation and Precipitation Networks*

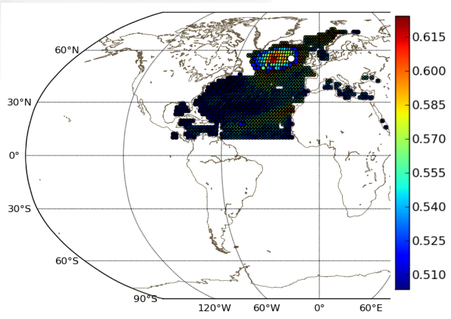
North Atlantic Coupled Networks :

High connectivity areas of the **Coupled CCN** lie around 20°N and 60°N, and can be partly explained by the NAO variability.



Cross- Betweenness and Closeness centralities designate areas of major importance for cross – functionality and informational transport between the networks.

The **downstream source feature** of High DC indicates the source area of precipitation within the evaporation field. It is consistent with the wind fields and prominent for the whole high connectivity region.



SVD/ EOF Analysis and Complex Networks :

The EOF approach investigates the covariance structure of a parameter evolving in time which makes it being similar to the correlation based method of CCN, especially to the Degree. Joint variability of two fields can be assessed using **SVD analysis**. Potential (dis-) similarities between Coupled Networks and SVD were analyzed.

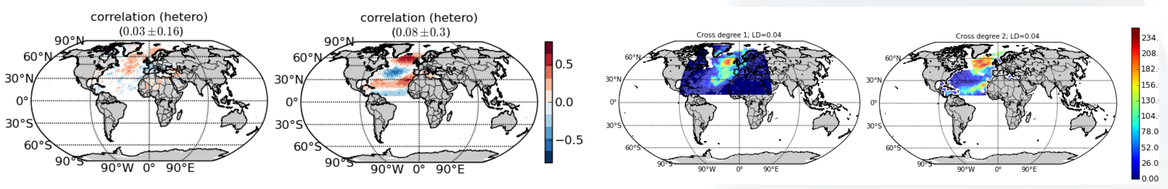


Fig 6. *SVD analysis (mode2, 21%) and Cross Degree Centrality of HOAPS E and P fields*

Conclusions :

- E/ P Network structure resembles major teleconnection patterns
- High DC area of coupled E/ P Networks reveal spatial source-receptor feature
- Uncertainties in E/ P variability associated to NAO/ ENSO in *amip* and *historical* experiments of MPI-ESM model were identified
- (Dis-)similarities between SVD and cross DC were investigated

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