GLOBAL WARMING TREND IN CLIMATE NETWORKS
Hanna Schultz1,2,*, Jonathan F. Donges1,4, Norbert Marwan1, Jürgen Kurths1,3
1 Potsdam Institute for Climate Impact Research, Research Domain IV
2 Institut für Physik, Humboldt Universität zu Berlin
3 Institut für Physik, Freie Universität Berlin
4 Institut für Physik und Astronomie, Universität Potsdam

Introduction
The idea of constructing networks from climate time series taken at geographical grid points states a quite young and promising approach to provide novel insights into the dynamics of the climate system [1-4]. Working on this method aims at a better understanding of the current change in the global climate regime by spotting the climate system’s internal dynamics (such as circulation or oscillation patterns) on a global and local scale.

In this work we intend to capture the 1970’s warming trend [5,6] by comparing two climate networks constructed from data before and after 1974, respectively. Data is taken from NCEP/NCAR reanalysis, Data, Jan 1948 - Dec 2008, resolution 2.5x2.5.

Network Construction
A network consists of vertices and edges (in our case, $N$ geographical grid points and their eventually synchronized behaviour). The climate networks are constructed by thresholding the $N \times N$ correlation matrix $A_{ij}$ representing the correlation strength between all spatial grid points calculated from Pearson Correlation Coefficient. The threshold $\tau = r(\rho)$ is chosen according to a prescribed link density $\rho$.

The resulting $N \times N$ adjacency Matrix $A_{ij}$ represents the climate network:

$$A_{ij} = \begin{cases} 0 & \text{if } M_{ij} < r(\rho) \\ 1 & \text{if } M_{ij} \geq r(\rho) \end{cases}$$

Vertex Centrality
Vertex centrality $V_C$ measures the number of nodes a single vertex $v$ is connected to:

$$V_C = \sum_{i,j} A_{ij}$$

Regions with high $V_C$ can include local as well as long range connections and can therefore be interpreted as important in sustaining the network structure.

Betweenness Centrality
Betweenness centrality $BC$ measures the number of topologically shortest paths $\sigma_{ij}$ containing vertex $v$:

$$BC_v = \sum_{i,j} \frac{\sigma_{ij}(v)}{\sum_{\sigma_{ij}} 1}$$

Assuming that climate information (e.g., climate dynamics) is circulated along the shortest path, areas with high $BC$ imply playing a crucial role in information flow within the climate network on a global scale (citation Jona).

Preliminary Results and Conclusions
The trend analysis reveals a change of network structure in the tropics, as the density of connections between nodes ($V_C$) decreased significantly mainly in the Pacific Ocean which might be connected to the reported change of the El Nino Southern Oscillation Pattern ENSO in the 1970’s [6,8].

As for the BC centrality measure, formerly pronounced and coherent current like structures appear to have weakened, almost dissolving. This points to a loss of internal connectivity of the climate system and suggests a decrease of its ability of global information transport.

Further investigation aims at analyzing more in detail the relation to the dynamics of climate change.

References

INTRODUCTION

The idea of constructing networks from climate time series taken at geographical grid points states a quite young and promising approach to provide novel insights into the dynamics of the climate system [1-4]. Working on this method aims at a better understanding of the current change in the global climate regime by spotting the climate system’s internal dynamics (such as circulation or oscillation patterns) on a global and local scale.

In this work we intend to capture the 1970’s warming trend [5,6] by comparing two climate networks constructed from data before and after 1974, respectively. Data is taken from NCEP/NCAR reanalysis, Data, Jan 1948 - Dec 2008, resolution 2.5x2.5.

Network Construction
A network consists of vertices and edges (in our case, $N$ geographical grid points and their eventually synchronized behaviour). The climate networks are constructed by thresholding the $N \times N$ correlation matrix $A_{ij}$ representing the correlation strength between all spatial grid points calculated from Pearson Correlation Coefficient. The threshold $\tau = r(\rho)$ is chosen according to a prescribed link density $\rho$.

The resulting $N \times N$ adjacency Matrix $A_{ij}$ represents the climate network:

$$A_{ij} = \begin{cases} 0 & \text{if } M_{ij} < r(\rho) \\ 1 & \text{if } M_{ij} \geq r(\rho) \end{cases}$$

Vertex Centrality
Vertex centrality $V_C$ measures the number of nodes a single vertex $v$ is connected to:

$$V_C = \sum_{i,j} A_{ij}$$

Regions with high $V_C$ can include local as well as long range connections and can therefore be interpreted as important in sustaining the network structure.

Betweenness Centrality
Betweenness centrality $BC$ measures the number of topologically shortest paths $\sigma_{ij}$ containing vertex $v$:

$$BC_v = \sum_{i,j} \frac{\sigma_{ij}(v)}{\sum_{\sigma_{ij}} 1}$$

Assuming that climate information (e.g., climate dynamics) is circulated along the shortest path, areas with high $BC$ imply playing a crucial role in information flow within the climate network on a global scale (citation Jona).

Preliminary Results and Conclusions
The trend analysis reveals a change of network structure in the tropics, as the density of connections between nodes ($V_C$) decreased significantly mainly in the Pacific Ocean which might be connected to the reported change of the El Nino Southern Oscillation Pattern ENSO in the 1970’s [6,8].

As for the BC centrality measure, formerly pronounced and coherent current like structures appear to have weakened, almost dissolving. This points to a loss of internal connectivity of the climate system and suggests a decrease of its ability of global information transport.

Further investigation aims at analyzing more in detail the relation to the dynamics of climate change.

References