Global Warming Trend in Climate Networks

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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 NCAR/NCEP Reanalysis Project [7]. Monthly averaged surface air temperature (SAT), 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 NxN correlation matrix M_{ij} representing the correlation strength between all spatial grid points calculated from Pearson Correlation Coefficient. The threshold $\tau = \tau(\rho)$ is chosen according to a prescribed link density ρ.
The resulting NxN adjacency Matrix A_{ij} represents the climate network:

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

Vertex Centrality

Vertex centrality VC_ν measures the number of nodes a single vertex ν is connected to:

$$VC_\nu = \sum_{i=1}^{N} A_{\nu i}$$

Regions with high VC_ν 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_ν measures the number of topologically shortest paths σ_{ij} containing vertex ν:

$$BC_\nu = \frac{\sum_{i,j\neq s}^{N} \sigma_{ij}(\nu)}{\sum_{i,j=1}^{N} \sigma_{ij}}.$$

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 (VC) 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 connetivity 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.

1948-74

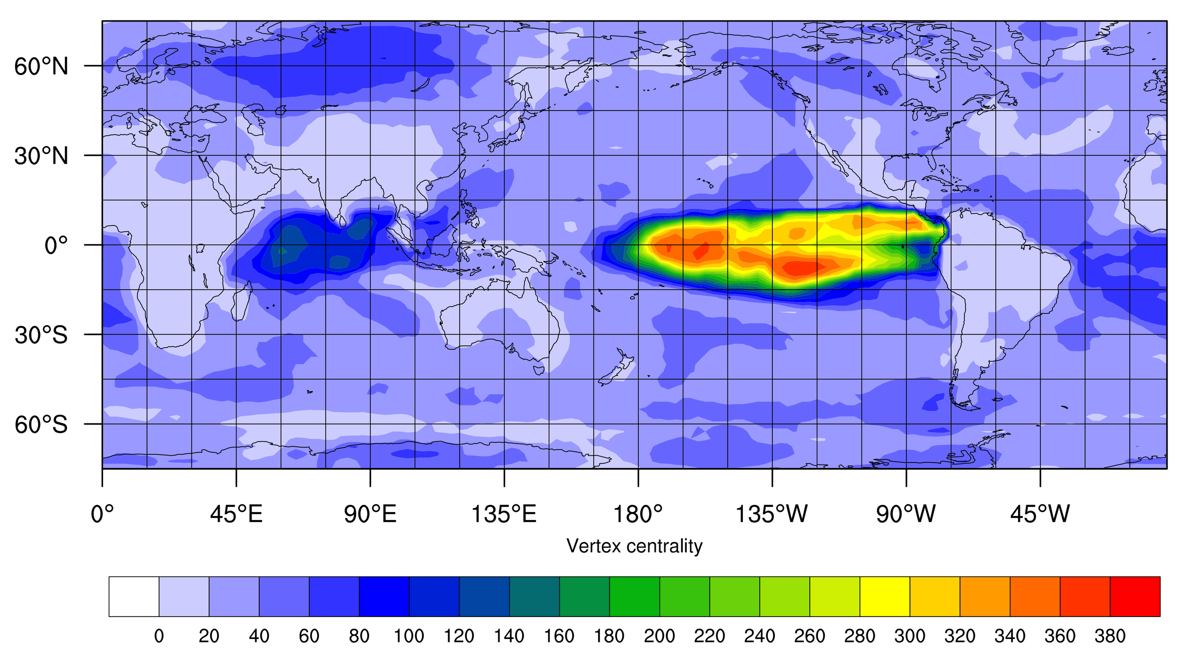


FIGURE 1: Vertex Centrality for SAT network, 1948-1974, NCEP/NCAR reanalysis, $\rho = 0.005$

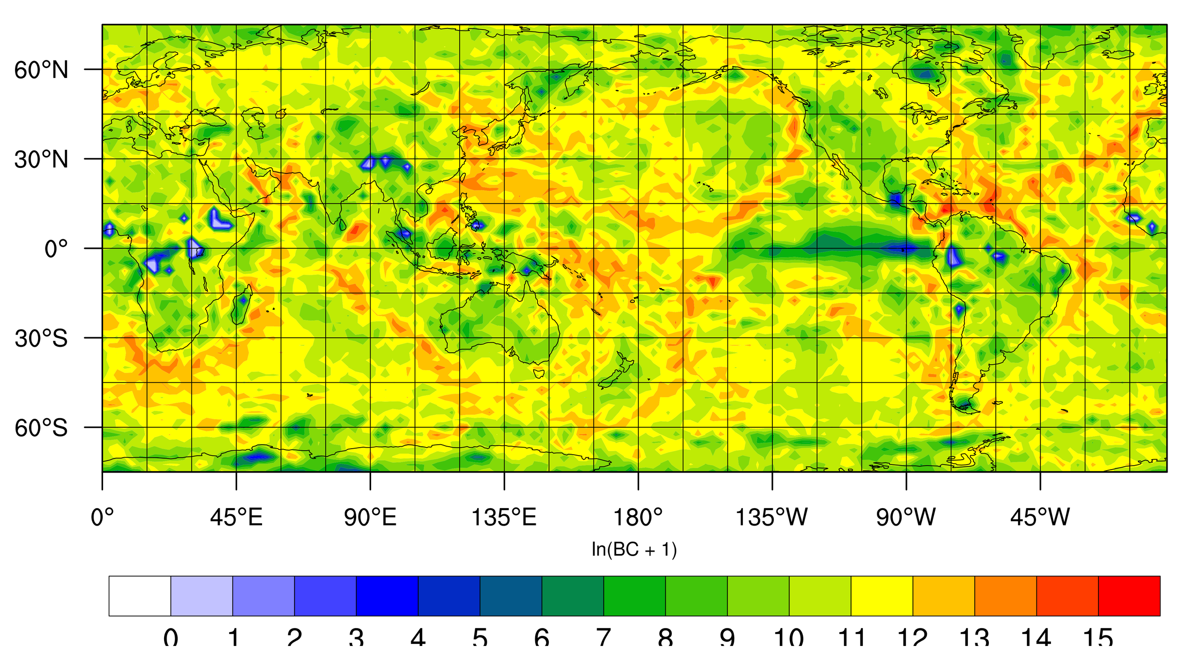


FIGURE 1: Betweenness Centrality for SAT network, 1948-1974, NCEP/NCAR reanalysis, $\rho = 0.005$

1975-2008

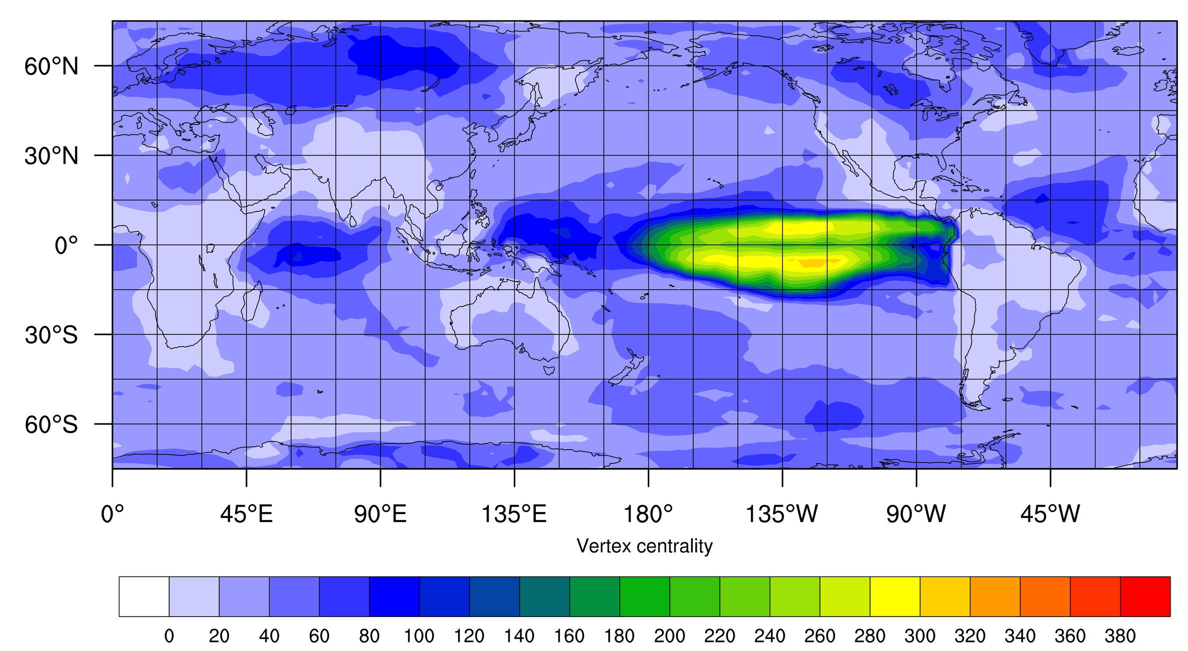
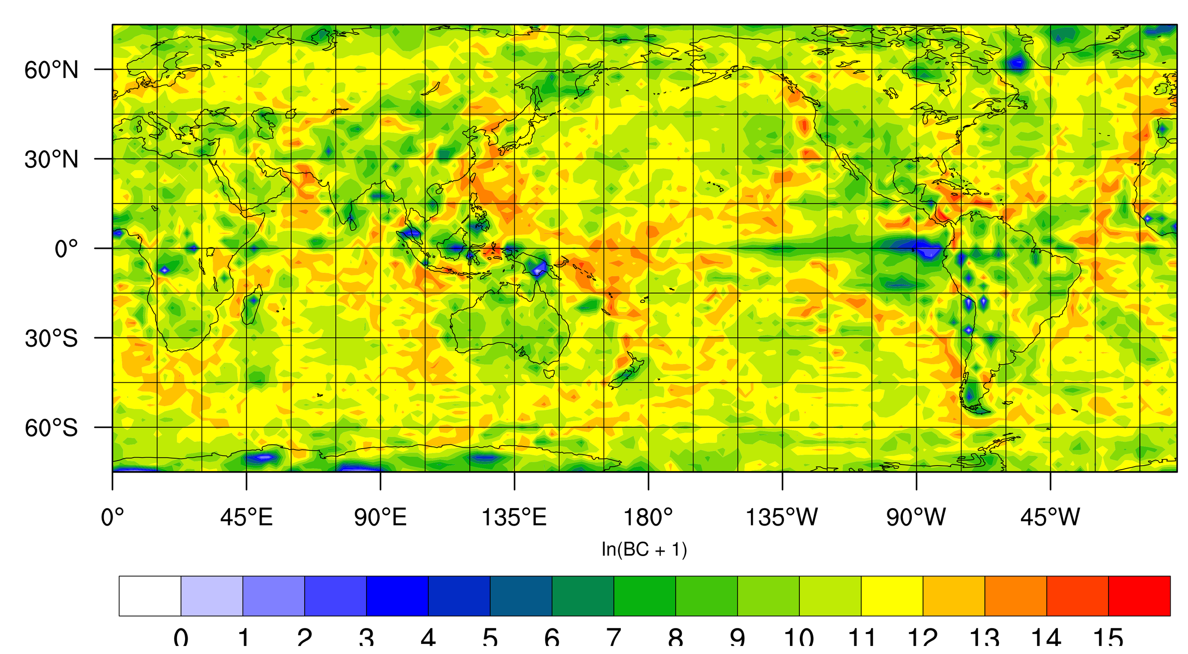


FIGURE 2: Vertex Centrality for SAT network, 1975-2008, NCEP/NCAR reanalysis, $\rho = 0.005$



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Difference

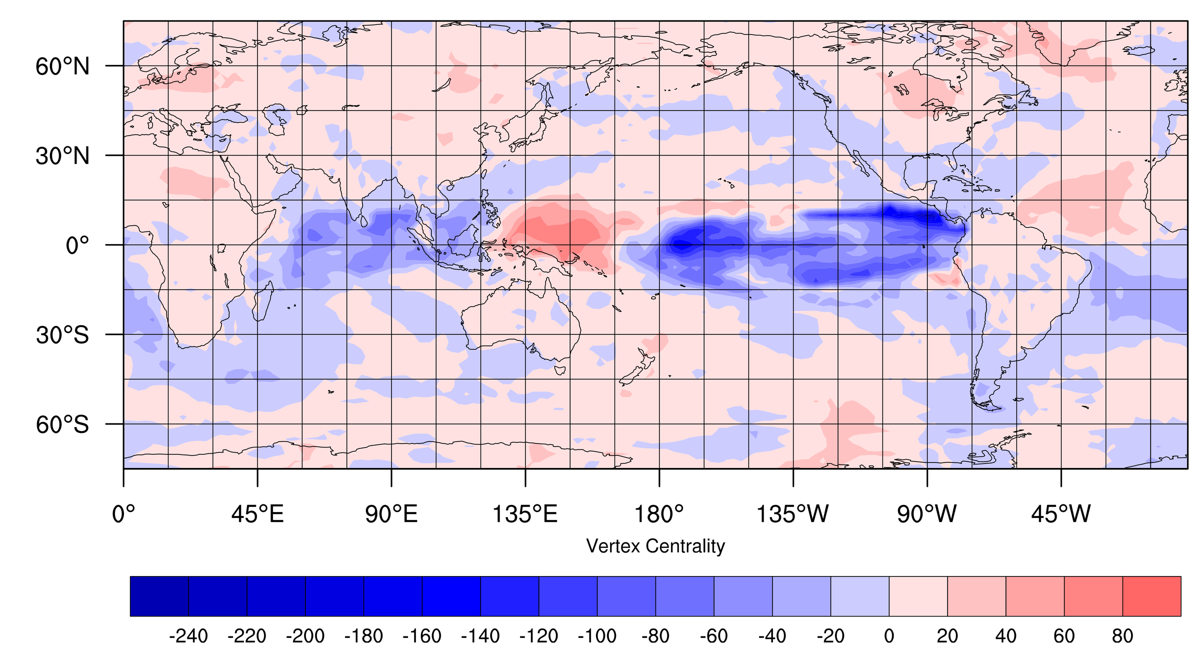

FIGURE 3: Trend Difference in Vertex Centrality

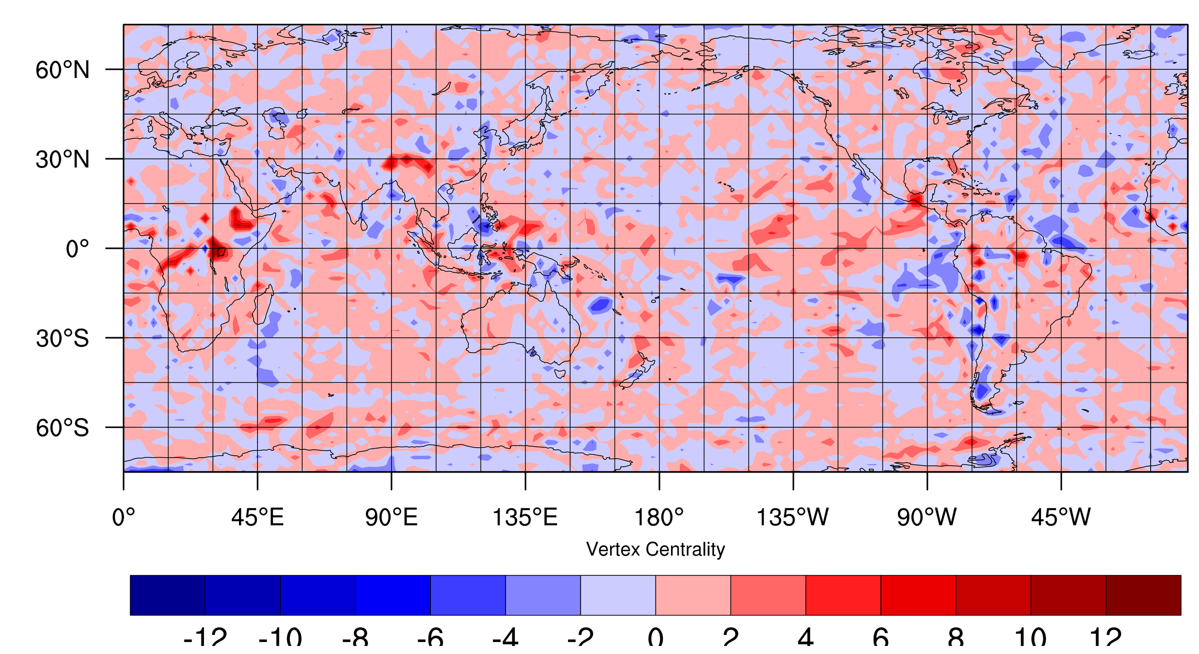

FIGURE 3: Trend Difference in Betweenness Centrality

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