Finding Climate Indices and Dipoles Using Data Mining

Michael Steinbach, Computer Science

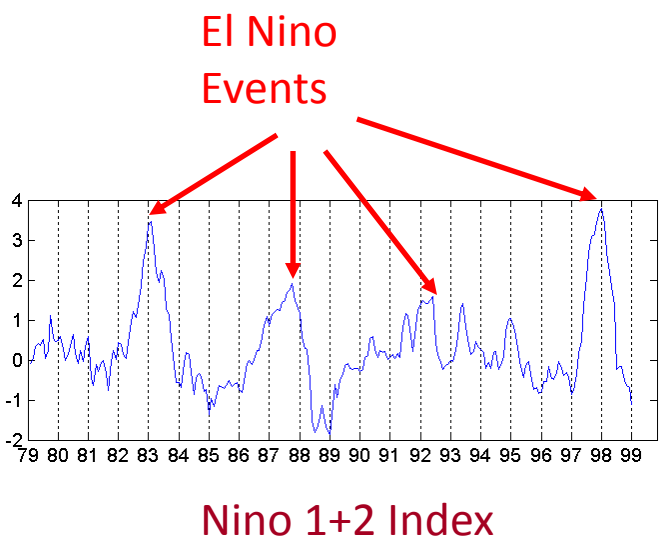
Contributors: Jaya Kawale, Stefan Liess, Arjun Kumar, Karsten Steinhauser, Dominic Ormsby, Vipin Kumar

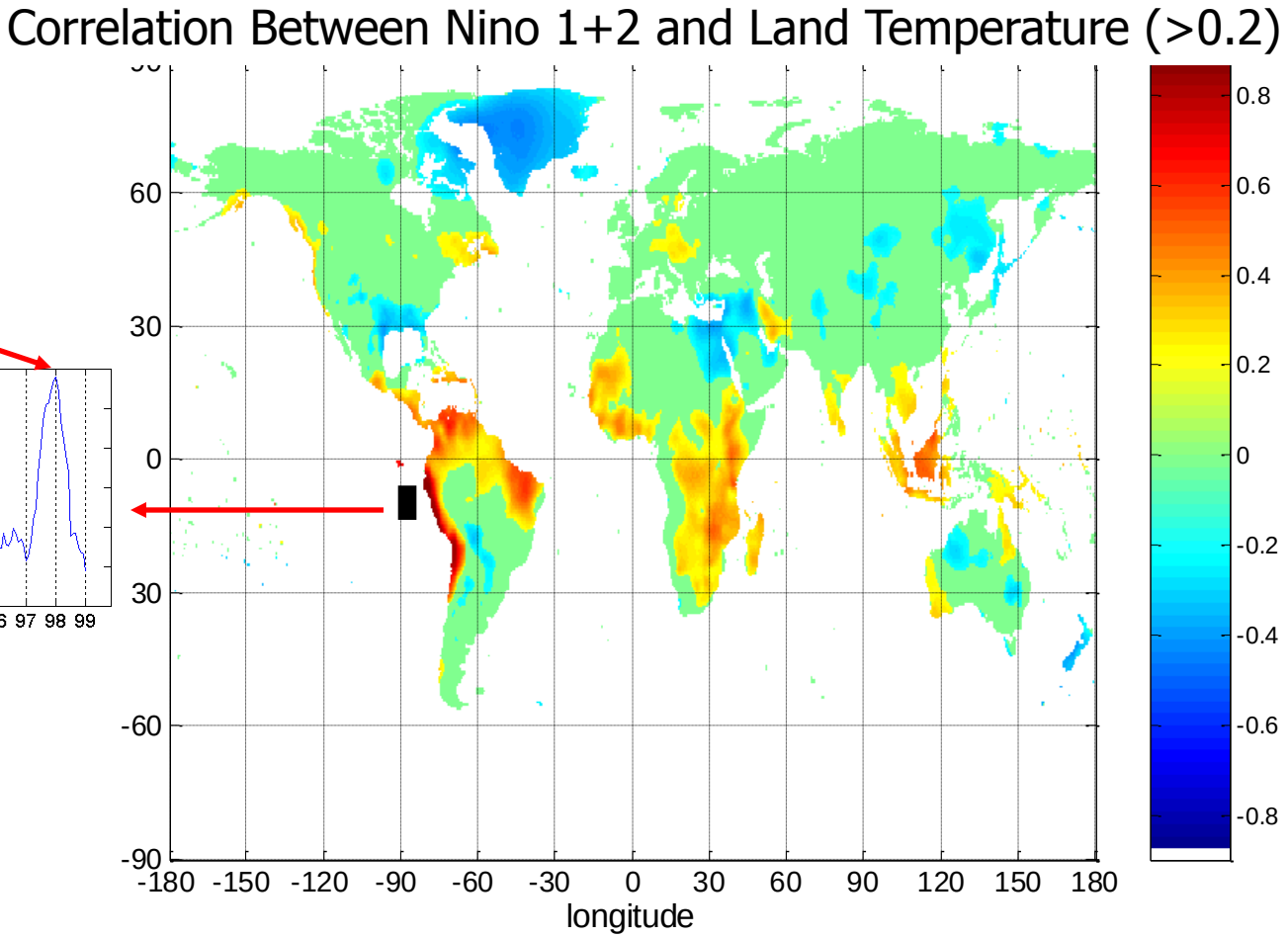
Climate Indices: Connecting the Ocean/Atmosphere and the Land

- A climate index is a time series of temperature or pressure
  - Similar to business or economic indices
  - Based on Sea Surface Temperature (SST) or Sea Level Pressure (SLP)
- Climate indices are important because
  - They distill climate variability at a regional or global scale into a single time series.
  - They are a way to capture teleconnections, i.e., climate phenomena occurring in one location that can affect the climate at a faraway location
  - They are well-accepted by Earth scientists.
  - They are related to well-known climate phenomena such as El Niño.

Dow Jones Index (from Yahoo)

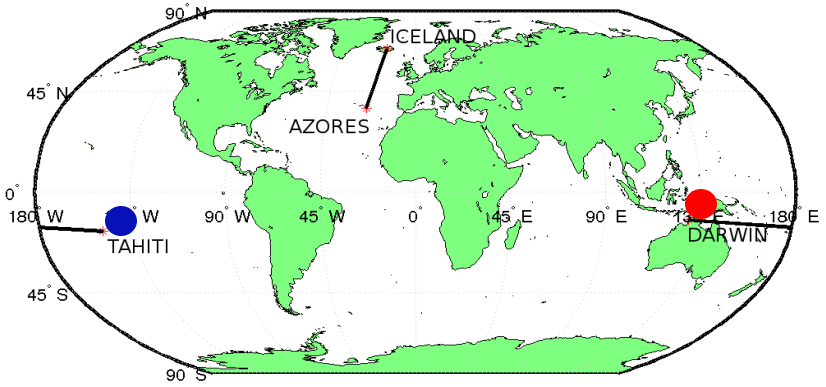
A Temperature Based Climate Index: NINO1+2

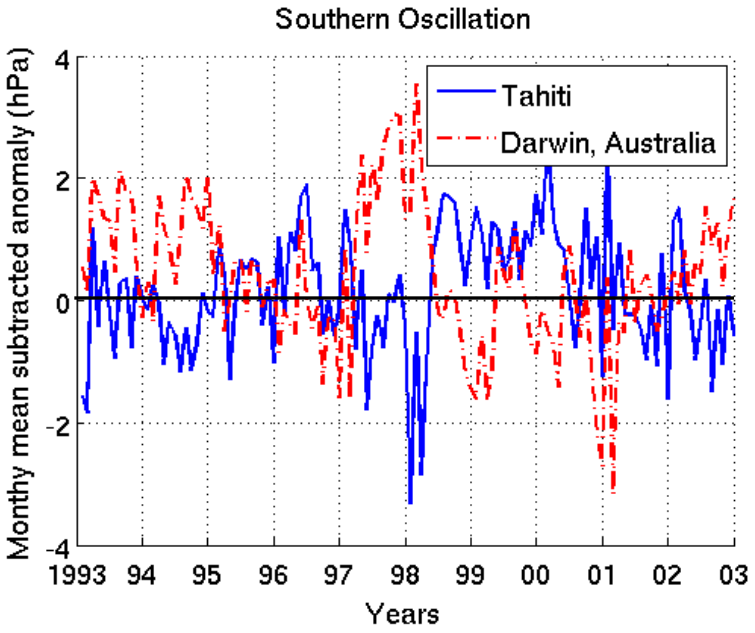


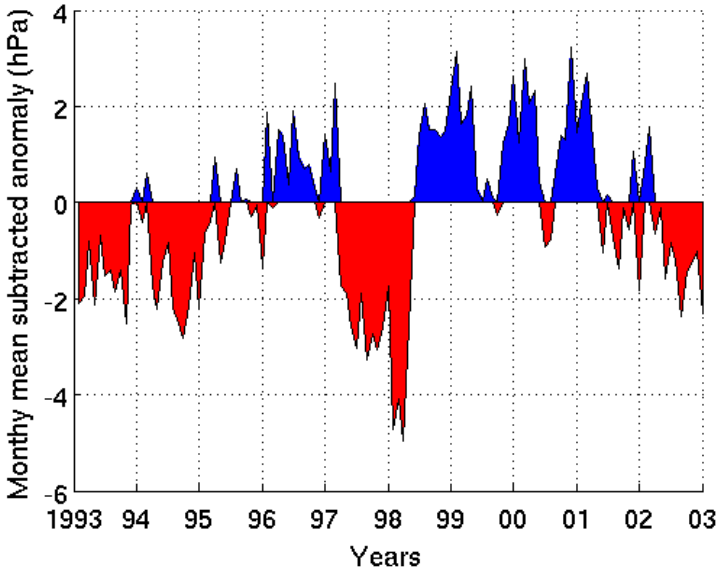


Pressure Based Climate Indices: Dipoles

Dipoles represent a class of teleconnections characterized by anomalies of opposite polarity at two locations at the same time.



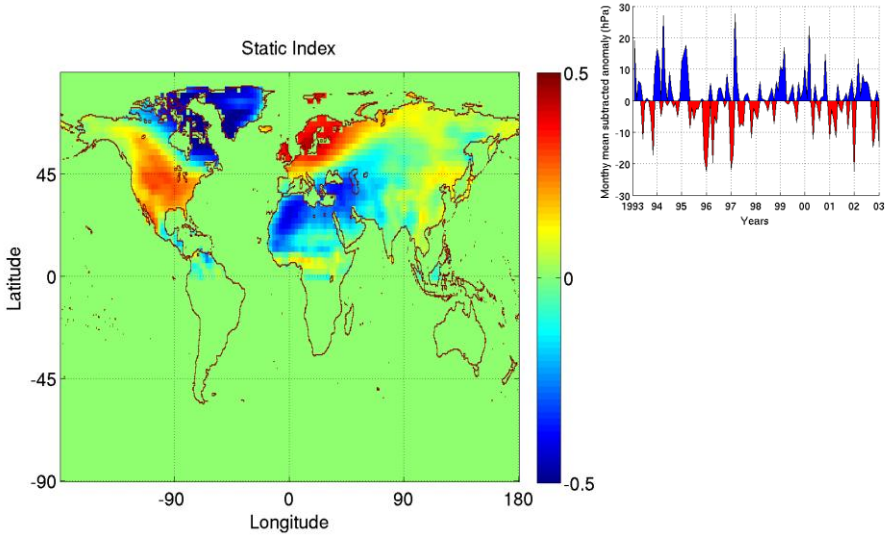




Importance of Climate Indices and Dipoles

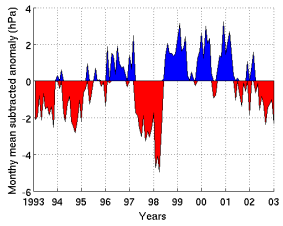
Crucial for understanding the climate system, especially for weather and climate forecast simulations within the context of global climate change.

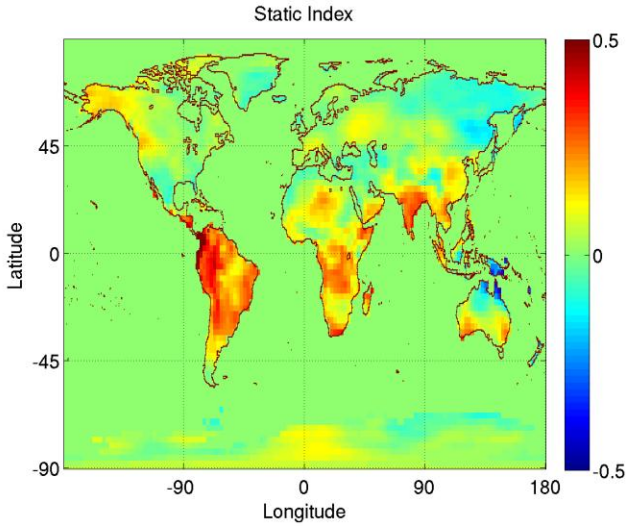
NAO influences sea level pressure (SLP) over most of the Northern Hemisphere. Strong positive NAO phase (strong Islandic Low and strong Azores High) are associated with above-average temperatures in the eastern US.



Correlation of Land temperature anomalies with NAO

SOI dominates tropical climate with floodings over East Asia and Australia, and droughts over America. Also has influence on global climate.





Correlation of Land temperature anomalies with SOI

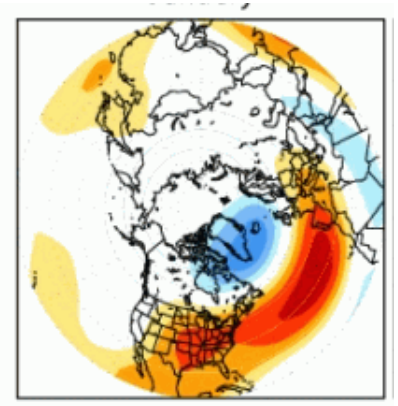
Teleconnection Patterns

As Defined by the Climate Prediction Center

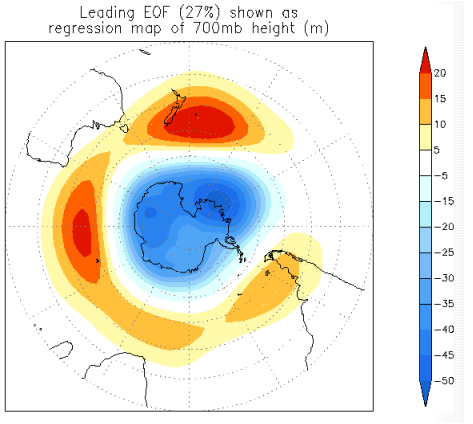
Discovered primarily by human observation and EOF Analysis

1. **Southern Oscillation Index** (SOI – also defined as ENSO in SSTA)
2. **Antarctic Oscillation** (AAO – also known as Southern Annular Mode)
3. **Arctic Oscillation** (AO – AO&NAO: also known as Northern Annular Mode)
4. **North Atlantic Oscillation** (NAO)
5. **East Atlantic** (EA)
6. **East Atlantic/Western Russia** (WR)
7. **Scandinavia** (SCAND)
8. **Polar/Eurasia** (PE)
9. **West Pacific** (WP)
10. **East Pacific-North Pacific** (EP-NP)
11. **Pacific/North American** (PNA)
12. **Tropical/Northern Hemisphere** (TNH)
13. **Pacific Transition** (PT)

NAO



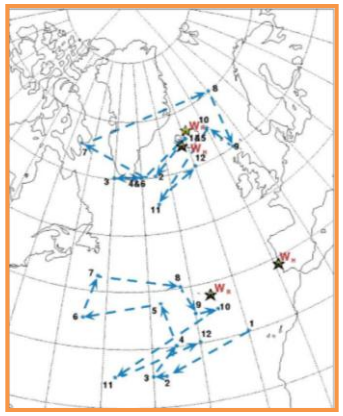
AAO



http://www.cpc.ncep.noaa.gov/data/teledoc/telecontents.shtml

Motivation for Automatic Discovery of Climate Indices and Dipoles

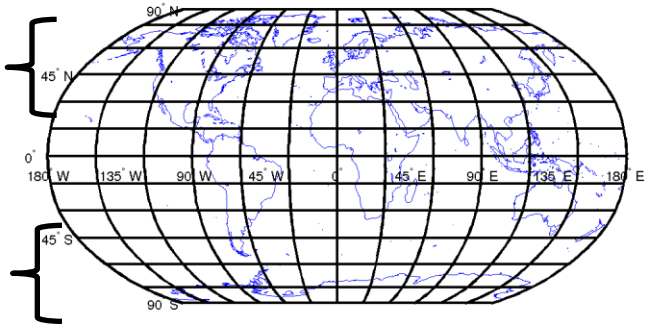
- The known dipoles are defined by static locations but the underlying phenomenon is dynamic
- Manual discovery can miss many dipoles
- EOF and other types of eigenvector analysis finds the strongest signals and the physical interpretation of those can be difficult.



Dynamic behavior of the high and low pressure fields corresponding to NAO climate index (Portis et al, 2001)

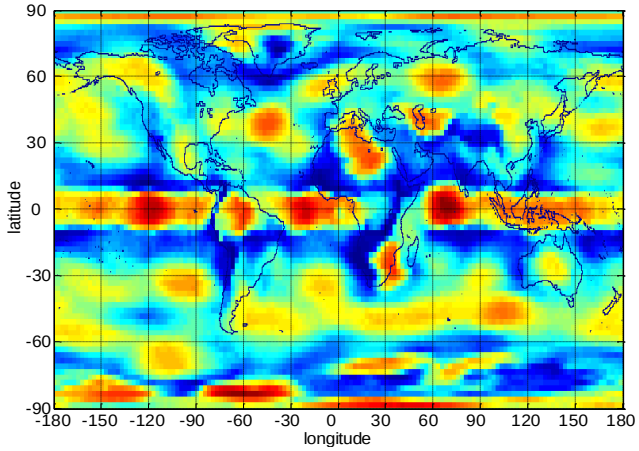
AO: EOF Analysis of 20N-90N Latitude

AAO: EOF Analysis of 20S-90S Latitude

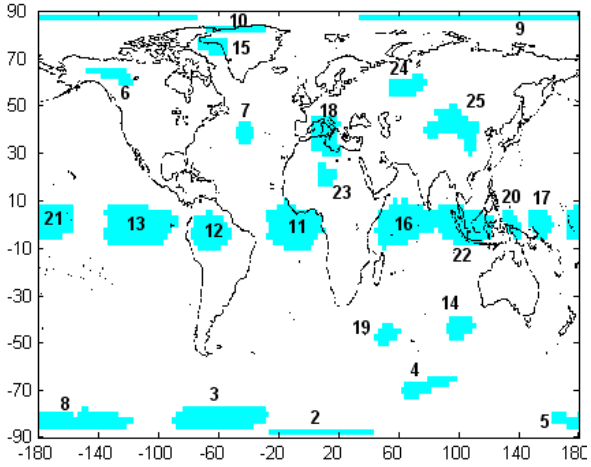


Shared Nearest Neighbor (SNN) Density Based Clustering

- Density based clustering approach
  - Determine the density of each point (time series)
    - Density is high for points with which you share most of the same neighbors
  - Perform the clustering using the density
    - Identify and eliminate noise and outliers, which are points with low density.
    - Identify core points, which are time series with high density.
    - Build clusters around the core points.



SNN density of points on the globe computed using Sea Level Pressure. Red areas are high density.



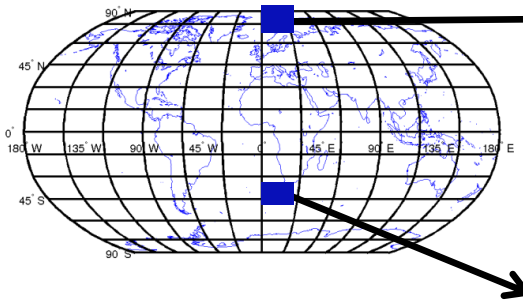
25 SLP Clusters

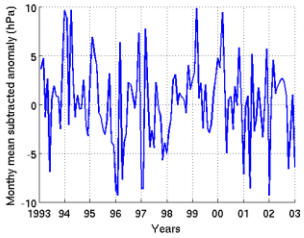
Key Extensions

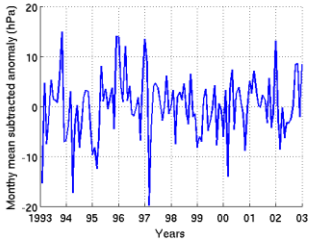
- Consider negative correlations
  - Negative correlations are useful for finding dipoles
- Dynamic climate index
  - Captures the fact that the climate system changes over time and even persistent phenomena will change in some ways
- These two improvements yield indices that can better capture the impact on land and better match current climate indices

Discovering Dipoles

Climate Network



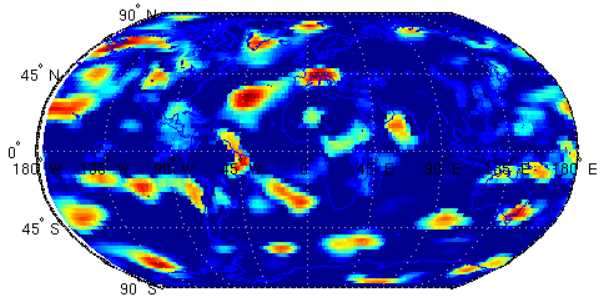




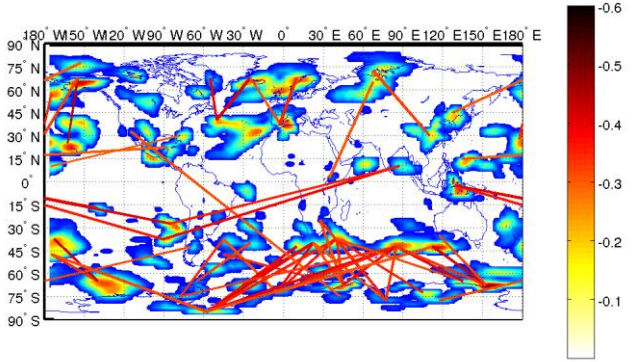
Nodes in the Graph correspond to grid points on the globe.

Edge weight corresponds to correlation between the two anomaly timeseries

Shared Reciprocal Nearest Neighbors (SRNN) Density



NCEP_144X73psl threshold=-0.3 (1980-2000)



Dipoles from SRNN density

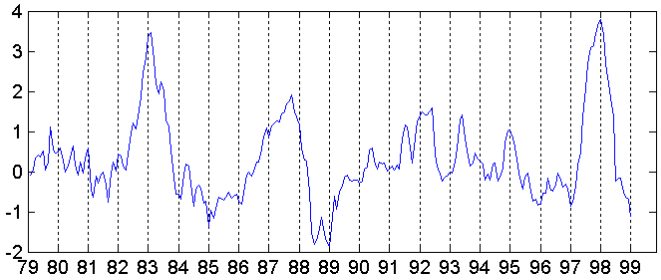
Benefits of Automatic Discovery of Climate Indices and Dipoles

- Detection of Global Dipole Structure
  - Most known dipoles discovered
  - New dipoles may represent previously unknown phenomenon.
  - Enables analysis of relationships between different dipoles
- Location based definition possible for some known indices that are defined using EOF analysis.
- Dynamic versions are often better than static
- Dipole structure provides an alternate method to analyze GCM performance

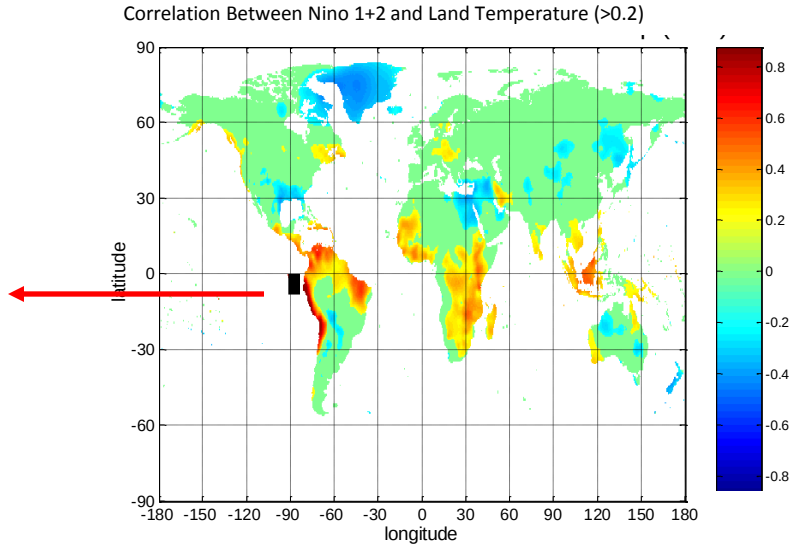
Influence of Climate Indices on Land: Area Weighted Correlation

- For each grid point, compute the correlation of the climate index with a time series representing the temperature at that point.
  - Use absolute correlation

- The area-weighted correlation is the weighted average of these correlations.
  - The weights are the areas of the grid points.
  - The area of a grid cell varies by latitude.

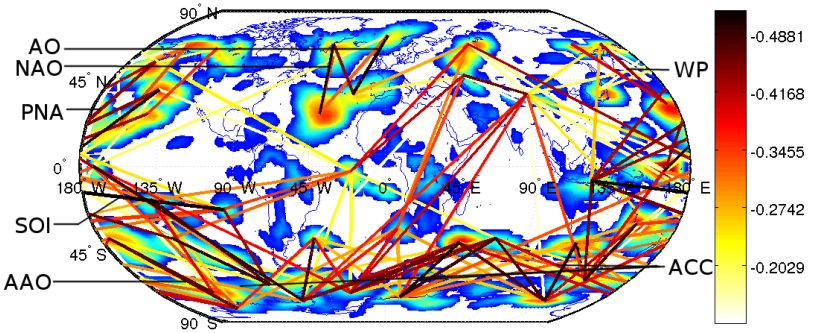


Nino 1+2 Index

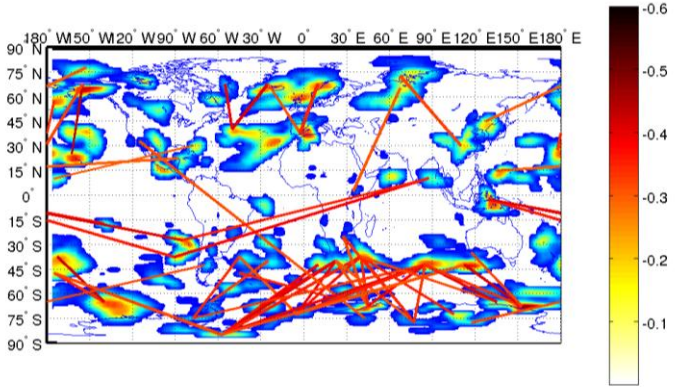


Detection of Global Dipole Structure

Dipoles found using NCEP (National Centers for Environmental Prediction) Reanalysis Data For Pressure



Without detrending



With detrending

- Most known dipoles discovered
- Location based definition possible for some known indices that are defined using EOF analysis.
- New dipoles may represent previously unknown phenomenon.