

Detecting and Describing Teleconnections

Stefan Liess

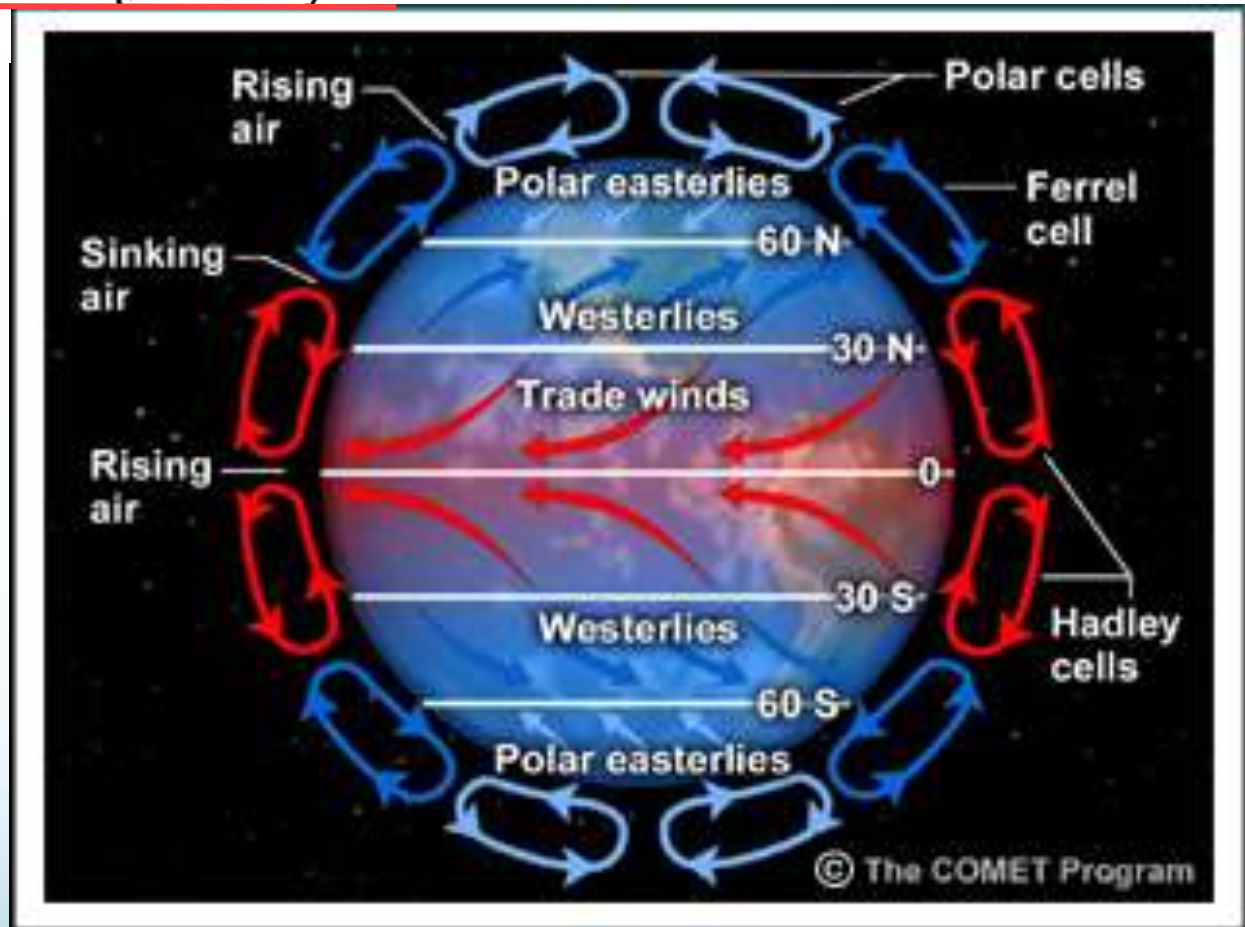
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General Circulation

VI. Concerning the Cause of the General Trade-
Winds : By Geo. Hadley, Esq; F. R. S.
... the N. E. and S. E. Winds within
the Tropicks must be compensated by as much N. W.
and S. W. in other Parts, and generally all Winds
from any one Quarter must be compensated by a
contrary Wind ...

(Hadley Phil. Trans. 1735)



http://www.meted.ucar.edu/tropical/textbook_2nd_edition/media/graphics/ch3_overview_image.jpg

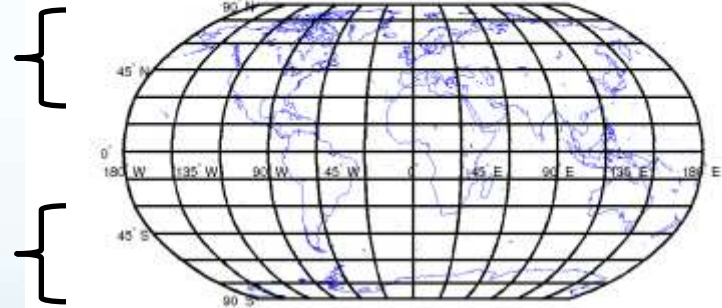
Related Work to find Teleconnections

- Discovered earlier by human observation.
 - North Atlantic Oscillation observed in 1770-1778¹
 - Southern Oscillation observed by Sir Gilbert Walker as a sea-saw like oscillation of sea level pressure in the Pacific Ocean in 1923²
- EOF analysis used to identify individual Teleconnections for the Northern and Southern Annular Modes (NAM and SAM)³

EOF decomposes the time series into orthogonal basis functions.

NAM: EOF Analysis of 20N-90N Latitude
(aka Arctic Oscillation)

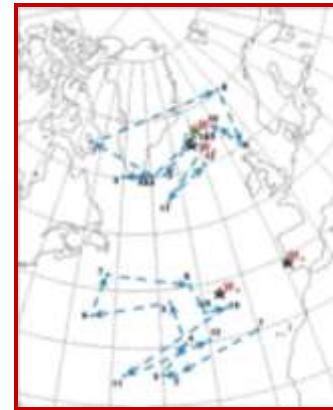
SAM: EOF Analysis of 20S-90S Latitude
(aka Antarctic Oscillation)



1. H. van Loon and J. C. Rogers. The seesaw in winter temperatures between Greenland and Northern Europe. Part I: General description. *Monthly Weather Review*, (1978)
2. G. Walker. Correlation in seasonal variations of weather, viii. a preliminary study of world weather. *Memoirs of the India Meteorological Department*, (1923)
3. H. Von Storch and F. Zwiers. *Statistical analysis in climate research*. Cambridge University Press, (2002)
4. Portis, D. H., Walsh, J. E., El Hamly, Mostafa and Lamb, Peter J., Seasonality of the North Atlantic Oscillation, *J. Climate*, (2001)

Motivation for Automatic Discovery of Multiple Teleconnections

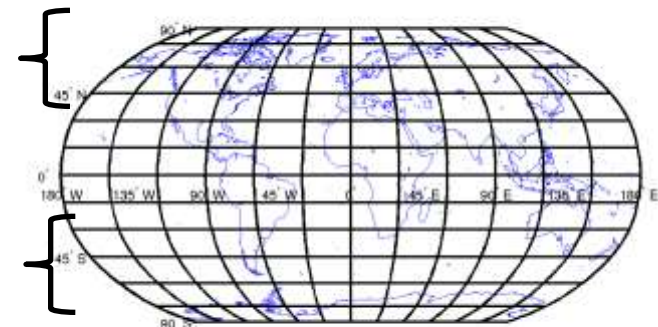
- The known Teleconnections are defined by static locations but the underlying phenomenon is dynamic
- Manual discovery can miss many Teleconnections
- EOF and other types of eigenvector analysis finds the strongest signals and the physical interpretation of those can be difficult.
- Enables analysis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



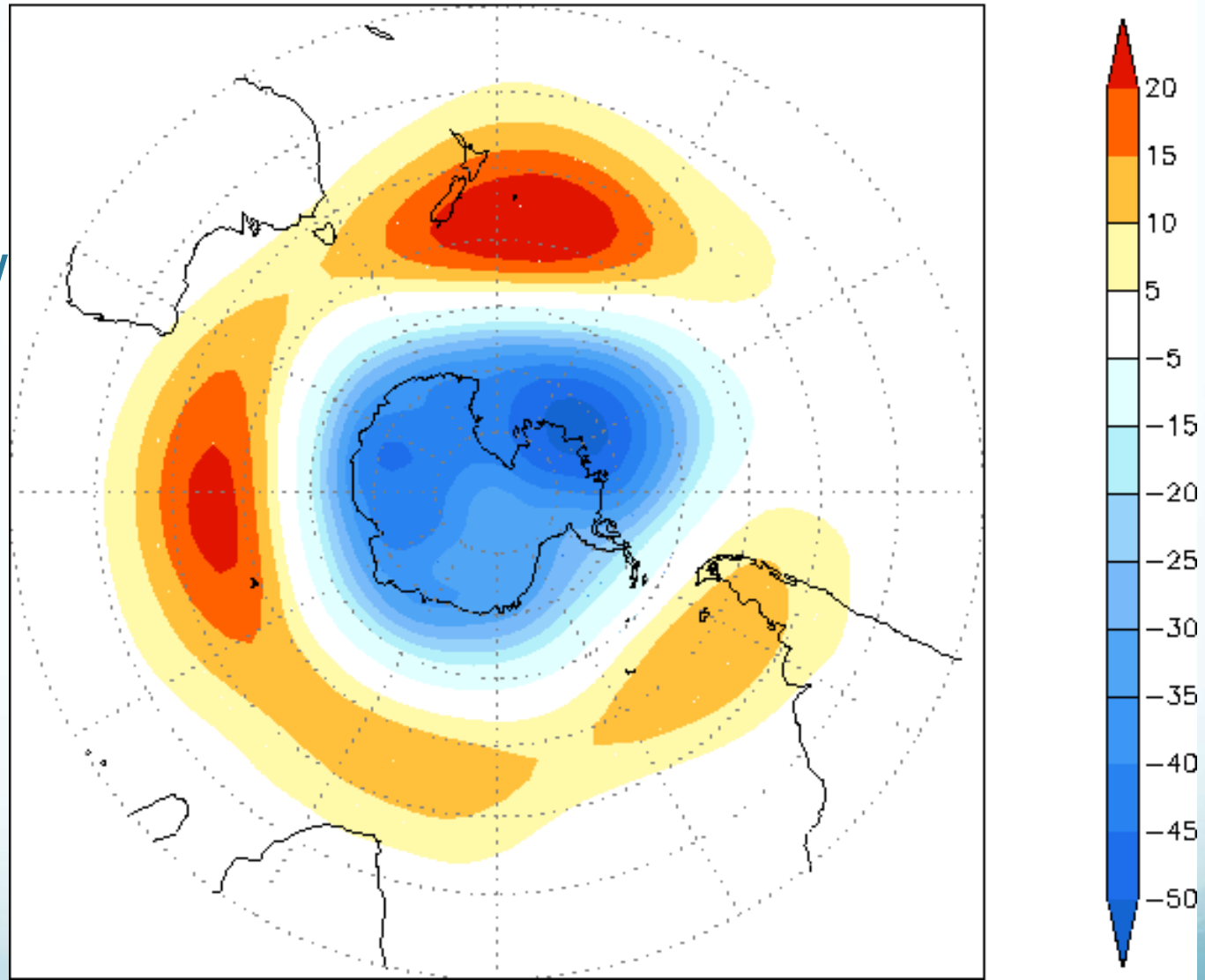
Dynamic behavior of the high and low pressure fields corresponding to NAO climate index (Portis et al, 2001)

AO: EOF
Analysis of 20N-
90N Latitude

AAO: EOF
Analysis of 20S-
90S Latitude



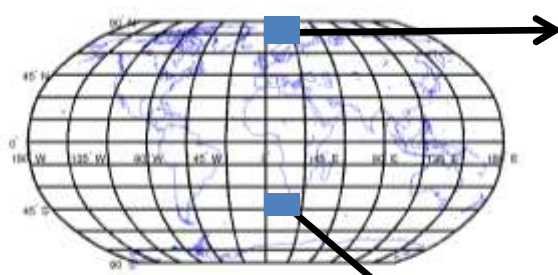
Leading EOF (27%) shown as
regression map of 700mb height (m)



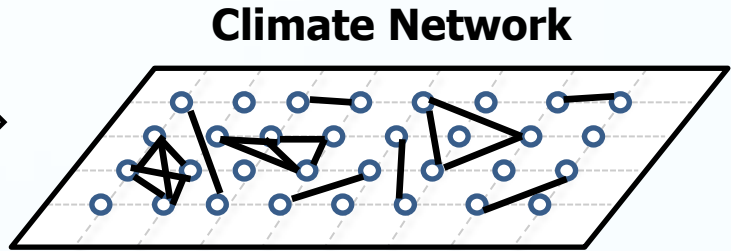
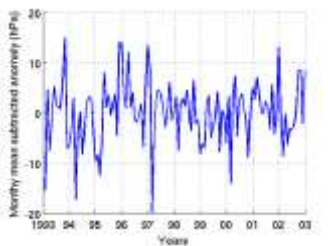
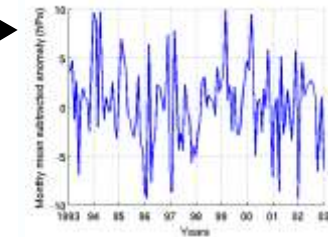
Antarctic
Oscillation now
defined as
Southern
Annular Mode

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/aao/aao.loading.shtml

Graph-Based Approach for Teleconnection/Index Discovery with Sea Level Pressure (SLP) Data

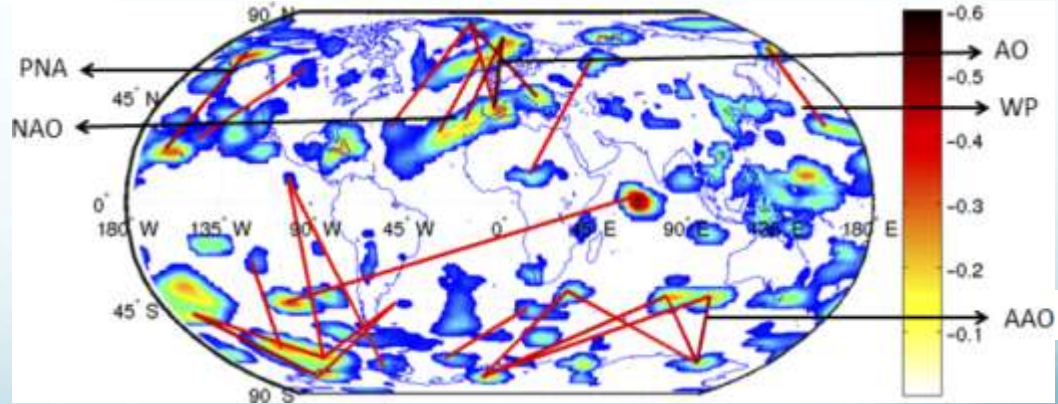


Nodes in the Graph correspond to grid points on the globe.



Edge weight corresponds to correlation between the two anomaly time series

Discovered Indices

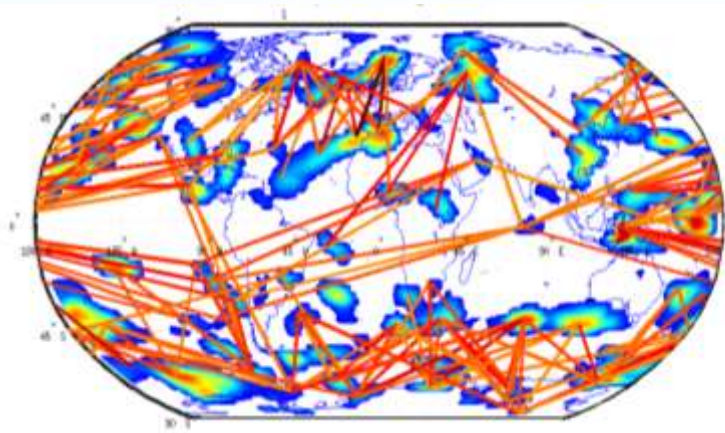


- Most known indices discovered
- New indices may represent new phenomena
- Enables analysis of relationships between different indices

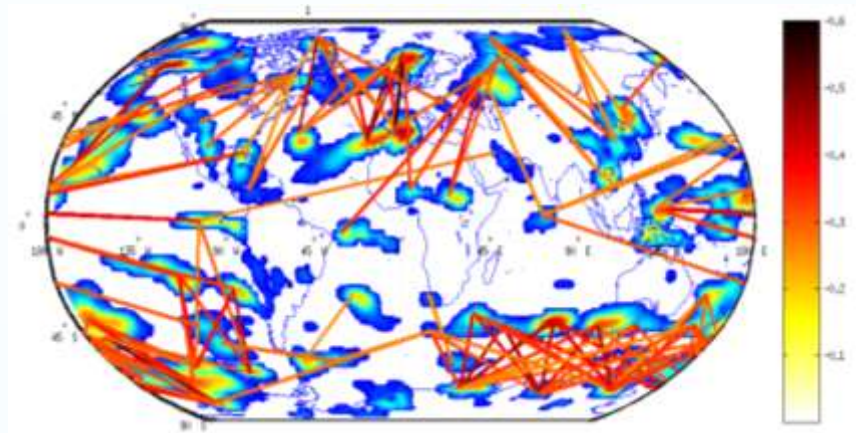
(Kawale et al. SADM 2013)

Comparing Teleconnection Structure in Historical (Reanalysis) Data

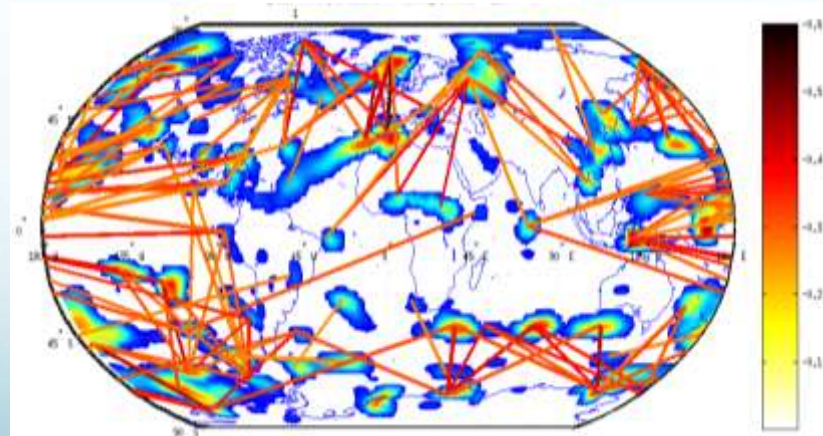
NCEP 1979-2000



ERA-40 1979-2000



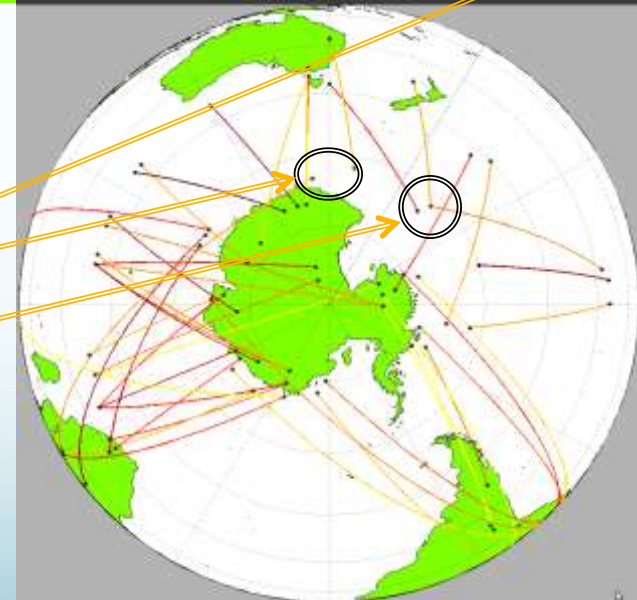
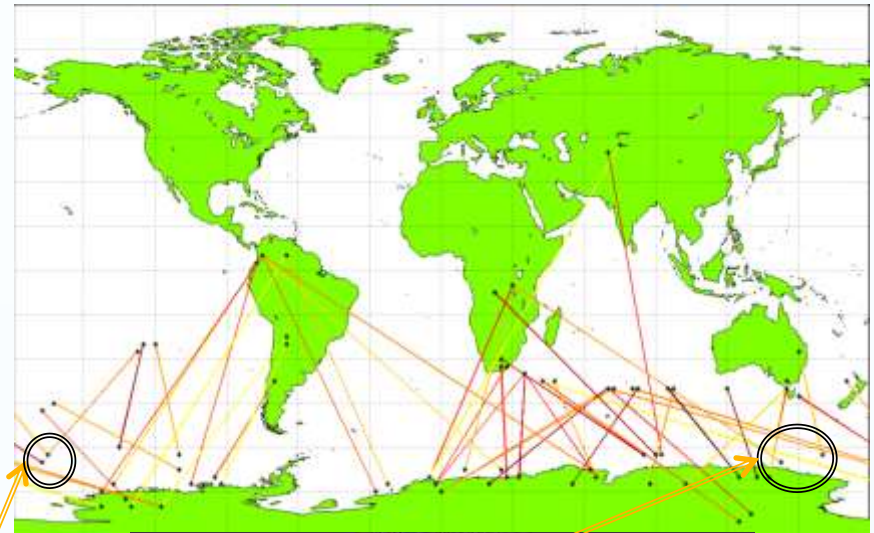
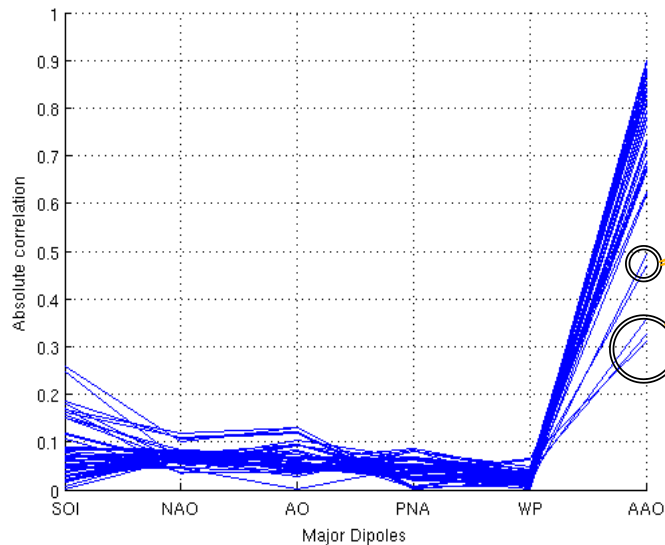
JRA-25 1979-2000



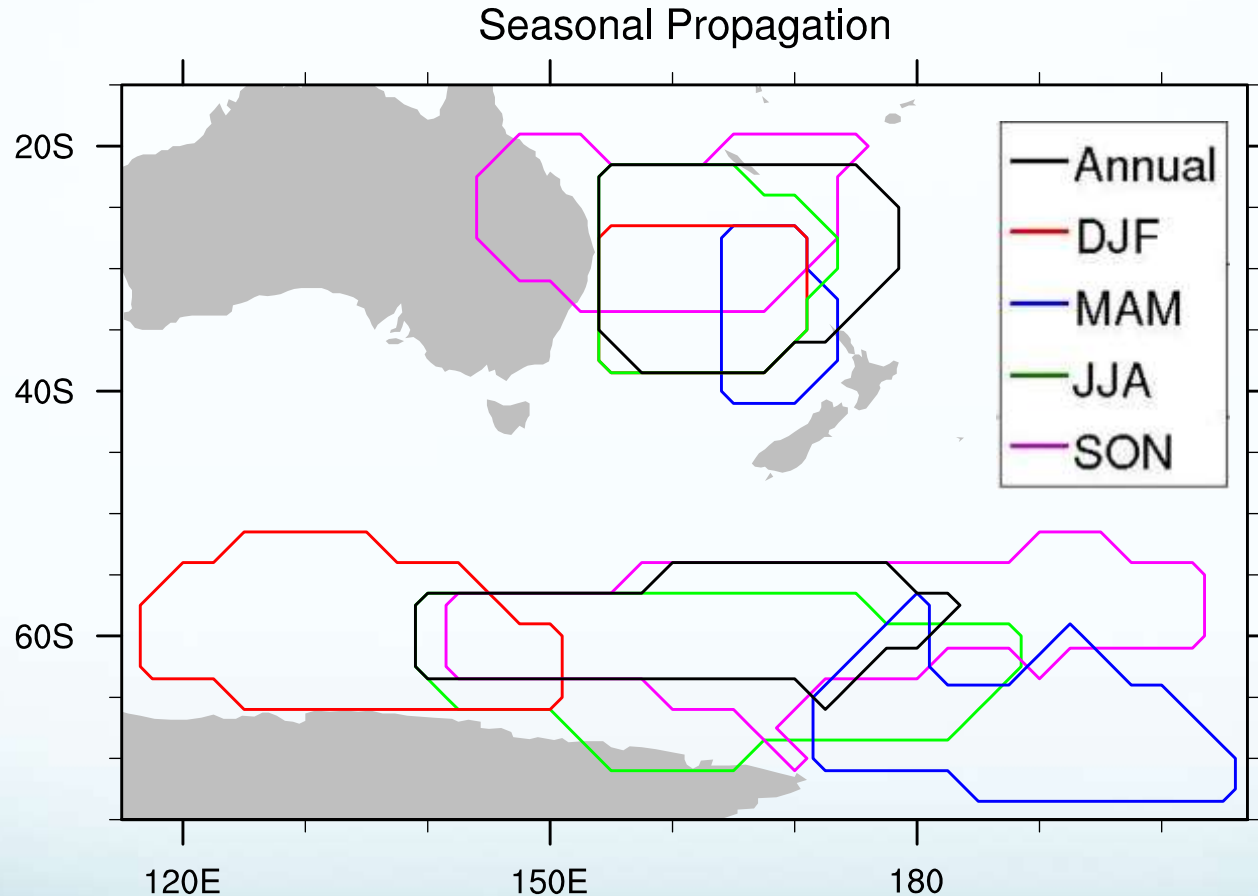
A New Teleconnection near Australia?

- 3 Teleconnection structures near Australia:
- SAM, and two other more regional features
- A newer phenomenon which is not captured by the EOF analysis?

Correlation with major Teleconnections



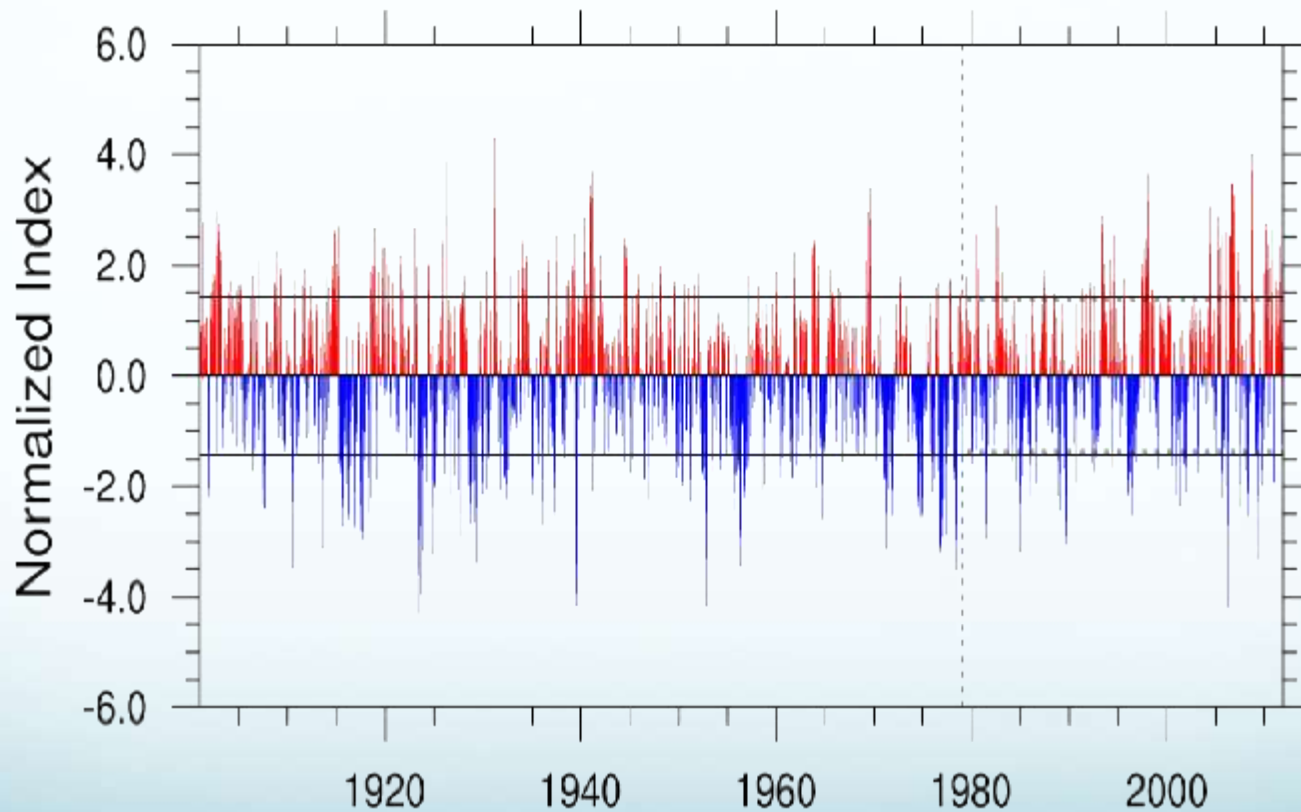
Graph-Based Results Identify 2 Centers of Action



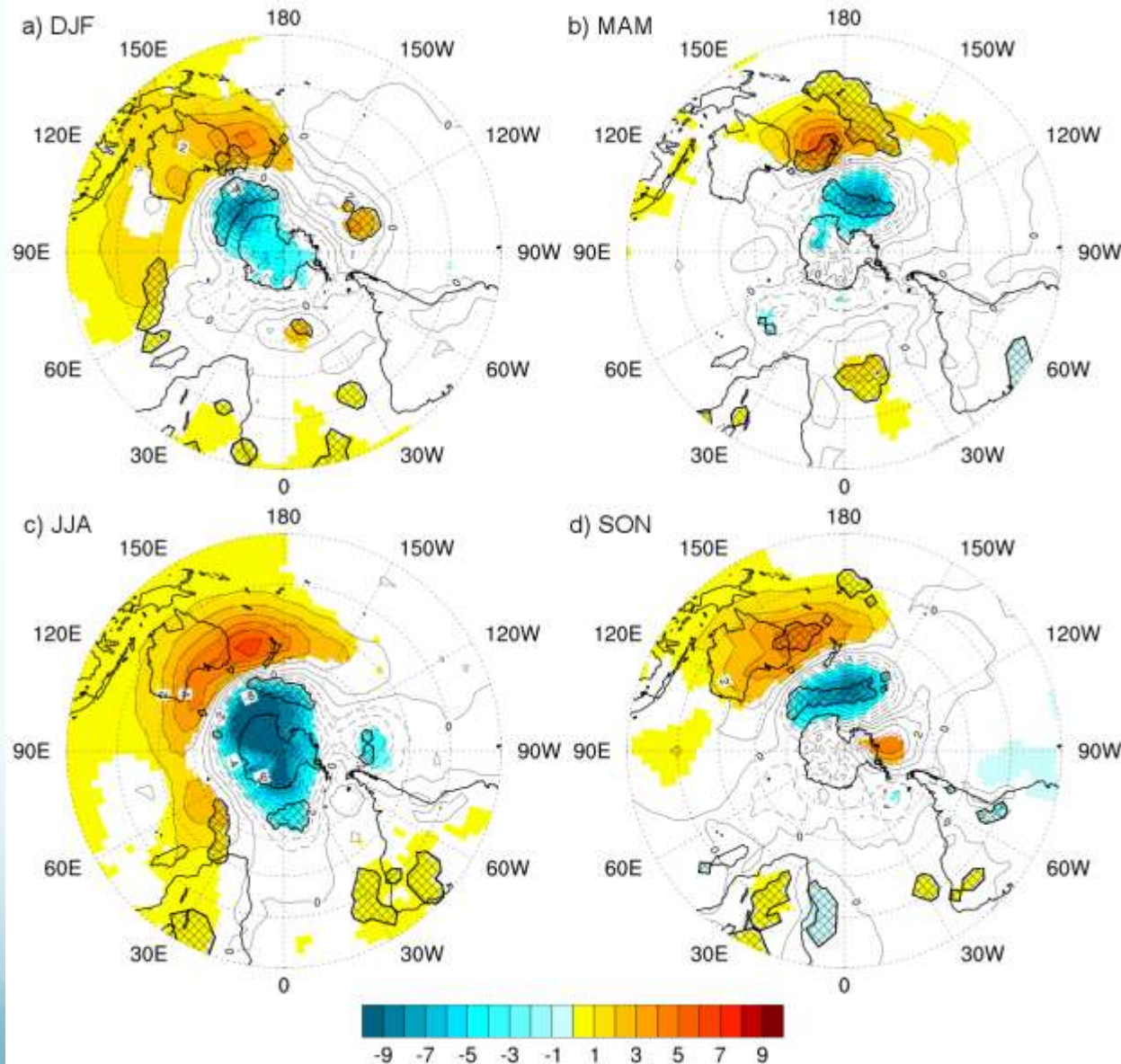
Northern and southern centers (north and south of 45°S , respectively) of the hybrid teleconnection shown for each of the four seasons and annually.

Annual Index

(Normalized by Standard Deviation at Each Location)



New Teleconnection vs. Hybrid Approach

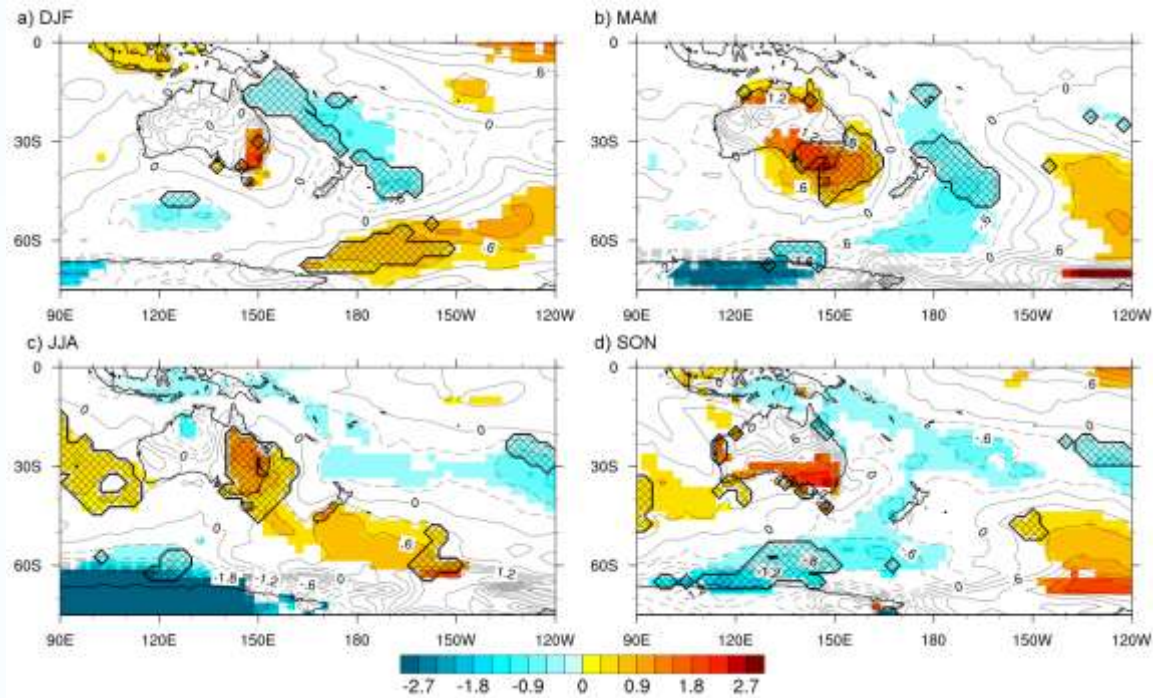


SLP composites in hPa.

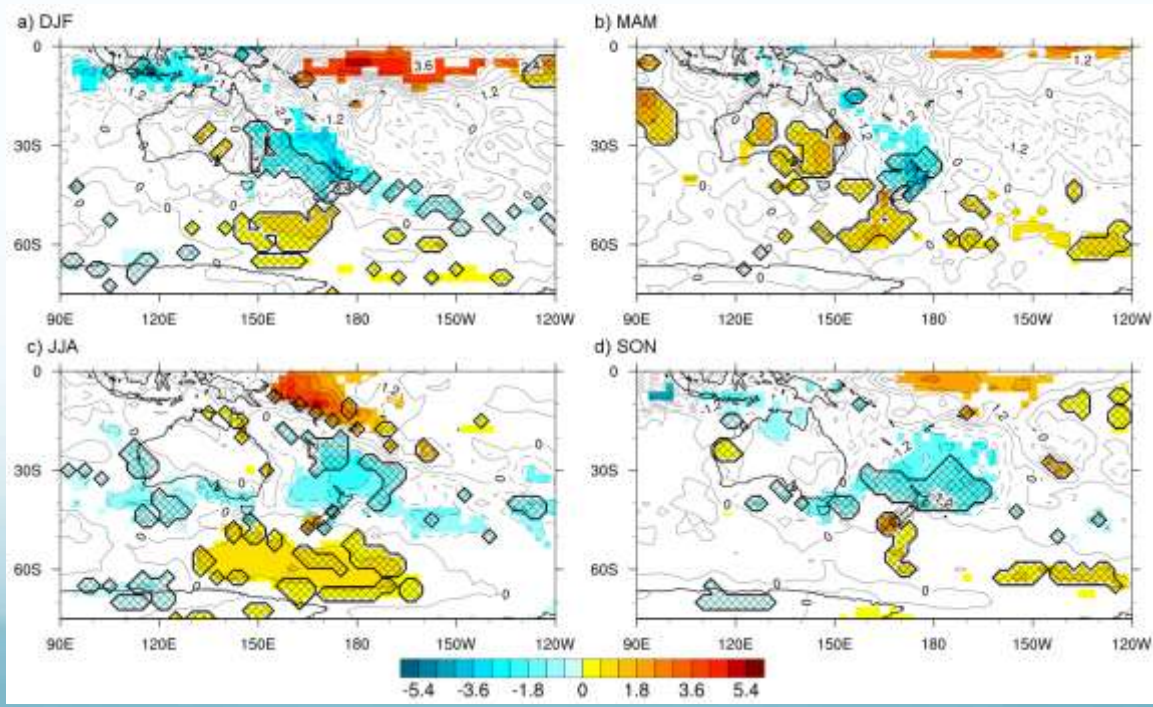
Shading: Significance at 95% confidence level.

Hatching: Areas that are significant for the hybrid teleconnection, but not for SAM, SOI or IOD.

Impacts on Regional Climate



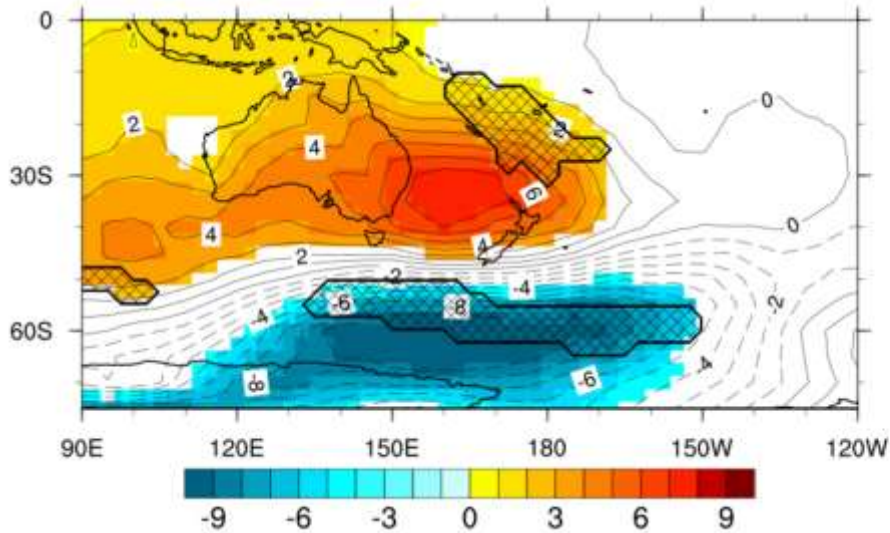
Surface Temperature Anomalies [K]



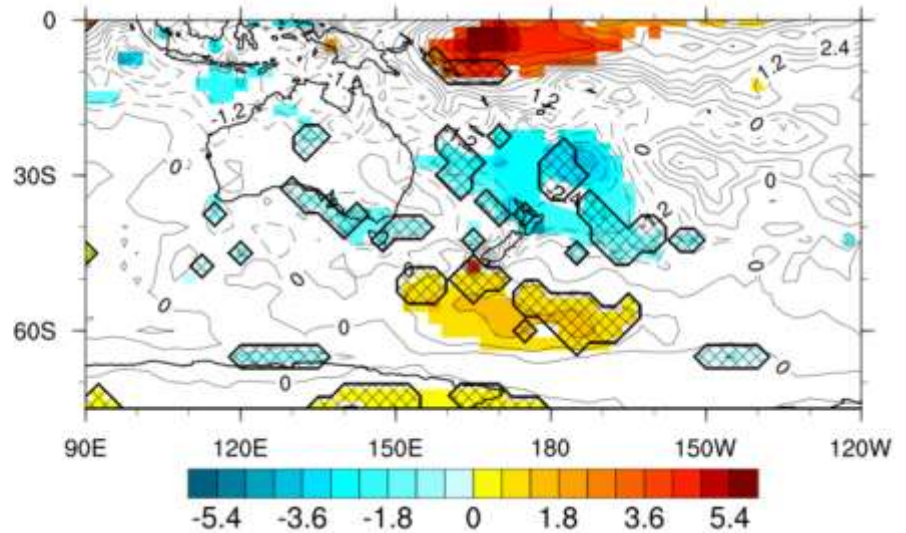
Precipitation Anomalies [mm d⁻¹]

Strong Events

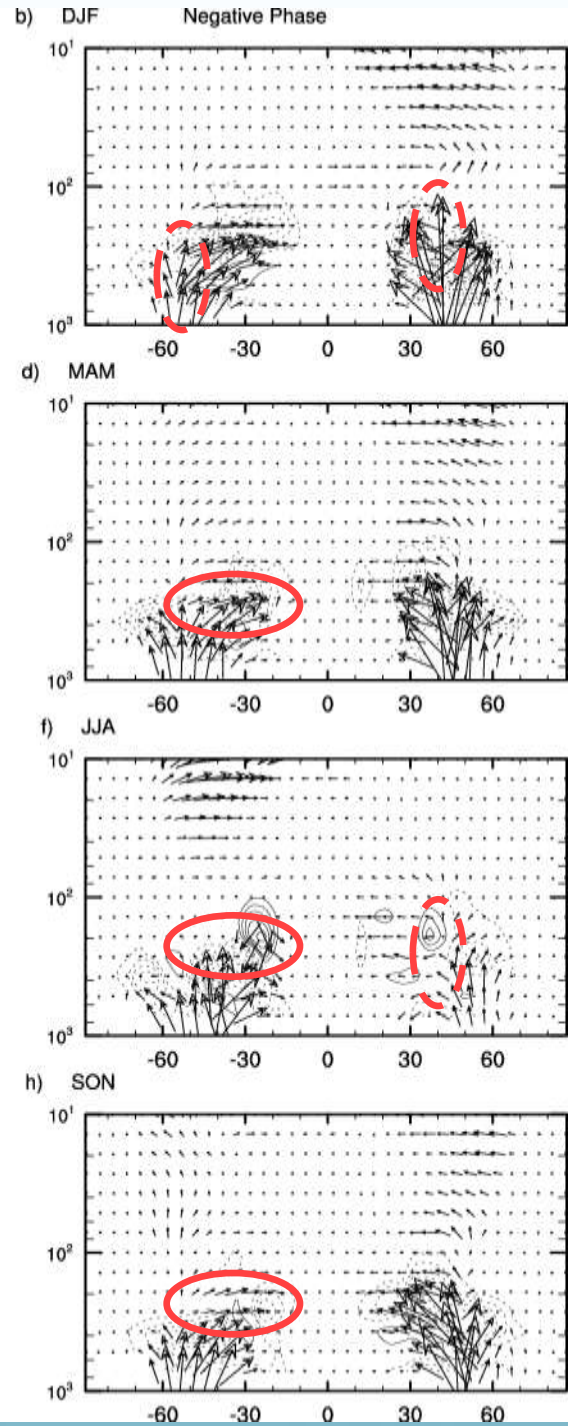
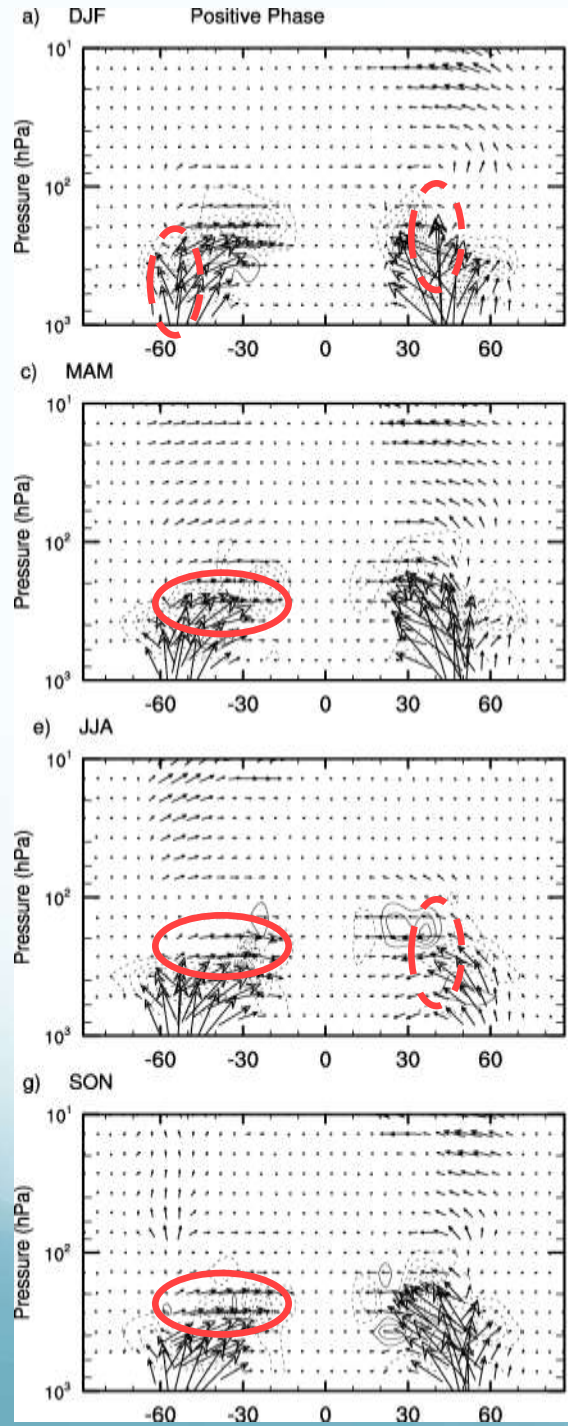
a) SLP



b) Precipitation



Annual a) SLP and b) precipitation composites for thresholds of twice the standard deviation.



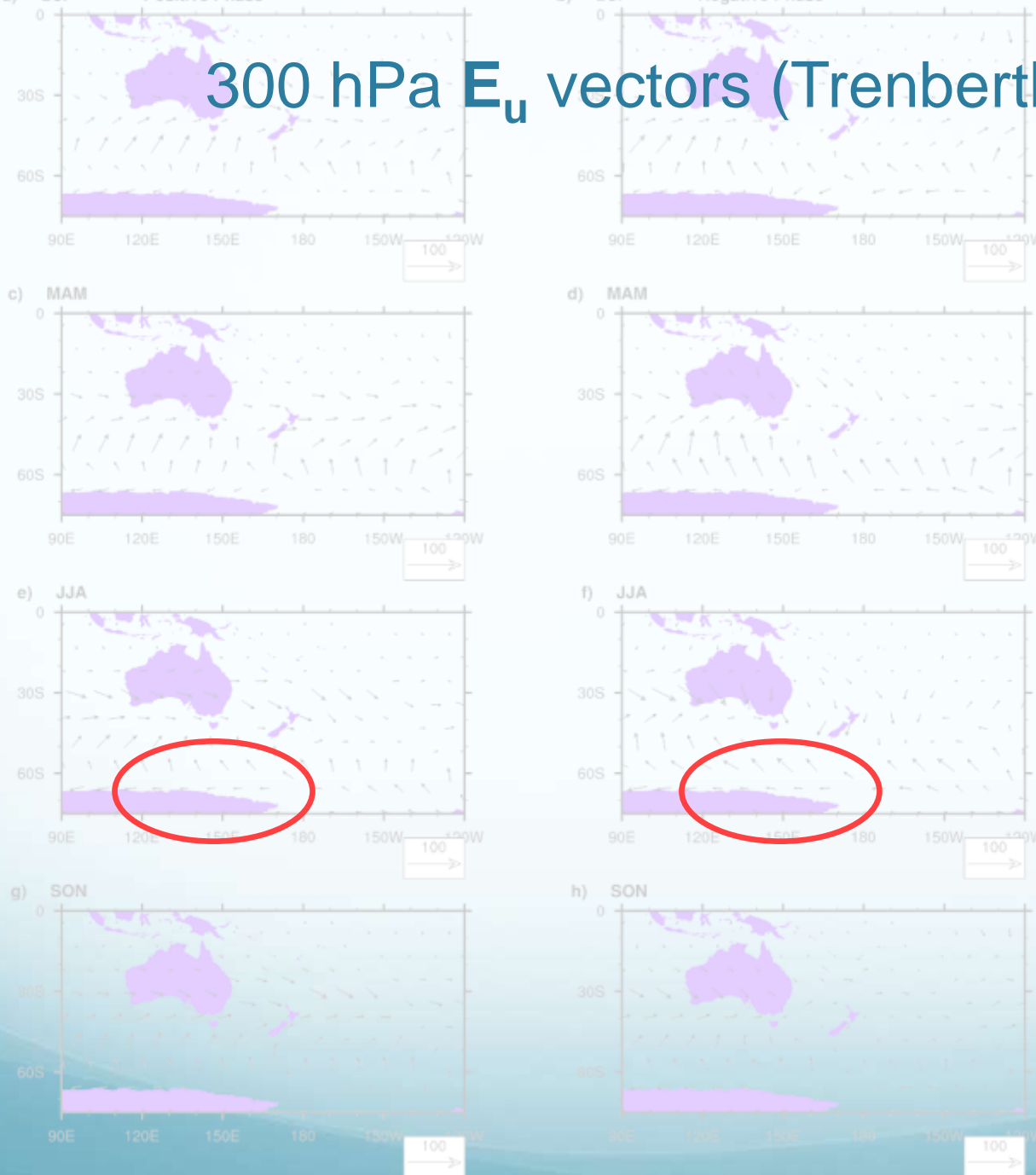
Eliassen-Palm flux points in direction of group velocity, EP flux divergence represents westerly forcing. (EP flux above 100 hPa is magnified by 5).

- 150°E-180°E:
- DJF: stronger meridional θ flux.
 - Other seasons: stronger meridional momentum flux.

Meridional component $-a \cos\phi \overline{v'v'}$

Vertical component $f a \cos\phi \frac{\overline{v'\theta'}}{\theta_p}$

300 hPa E_u vectors (Trenberth, 1991)



E_u points in direction of group velocity, E_u divergence represents westerly forcing.

- Pos.: E_u convergence around 30°S
- Neg.: E_u convergence around 45°S
- Largest differences in JJA

Zonal component $\frac{1}{2}(\overline{v'^2} - \overline{u'^2})$

Meridional component $-\overline{u'v'}$

Summary

- **Graph-Based Approach for Teleconnection/Index Discovery**
 - Not bound to orthogonality
 - Enables analysis of relationships between different indices
- **Extreme Events can have Different Spatial Extent**
 - SLP patterns are different for different thresholds
 - Precipitation patterns can cover different areas
- **Eliassen-Palm Flux shows Origin and Details of Teleconnections**
 - Interactions between eddy fluxes and mean flow
 - Contribution of momentum and heat fluxes

“Winter Weirdness”

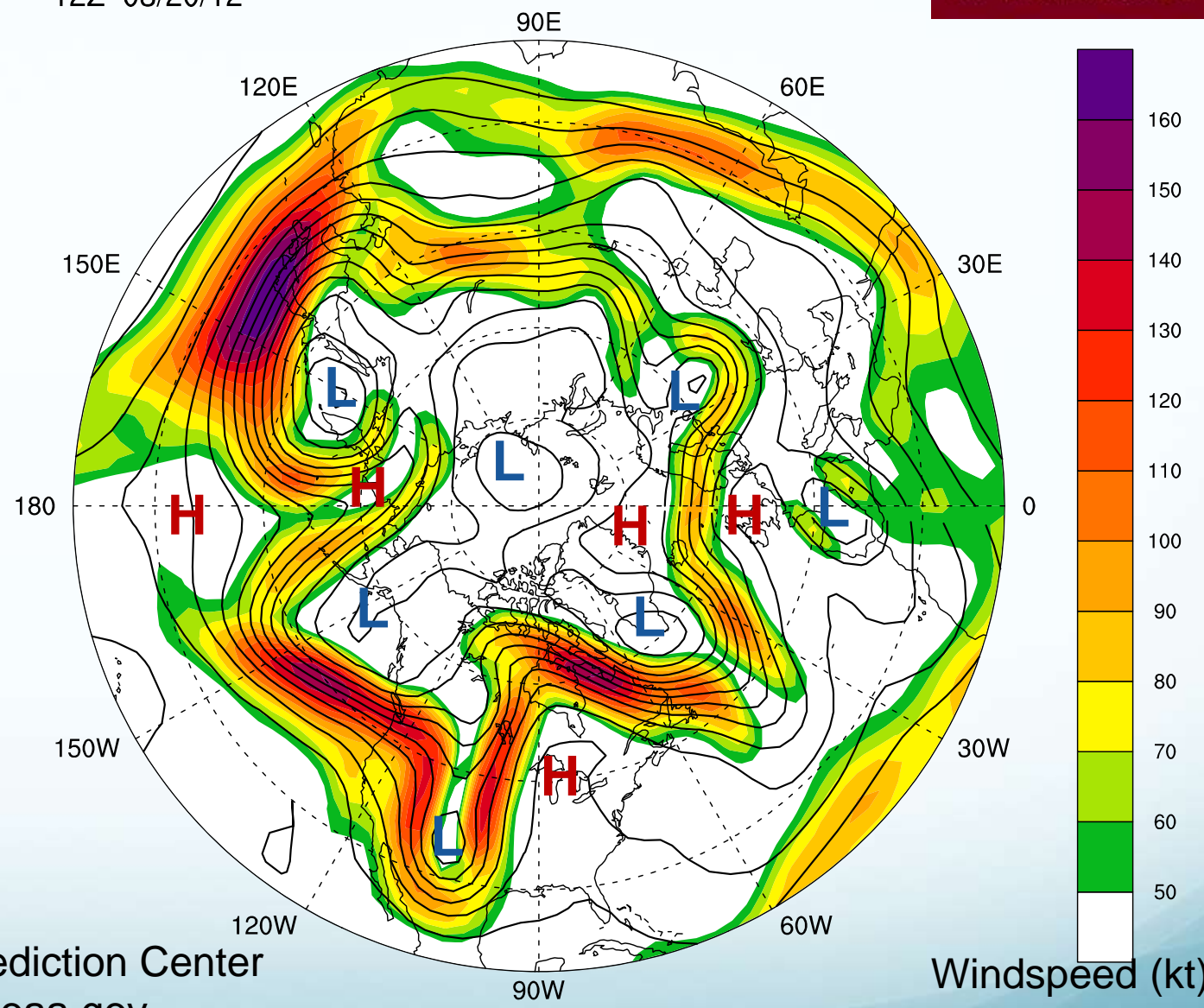
12Z 03/20/12

Mean Temperatures

:
March 20th
2012:
St. Paul: 60 °F
Tucson: 44 °F

March 20th
2013:
St. Paul: 14 °F
Tucson: 66 °F

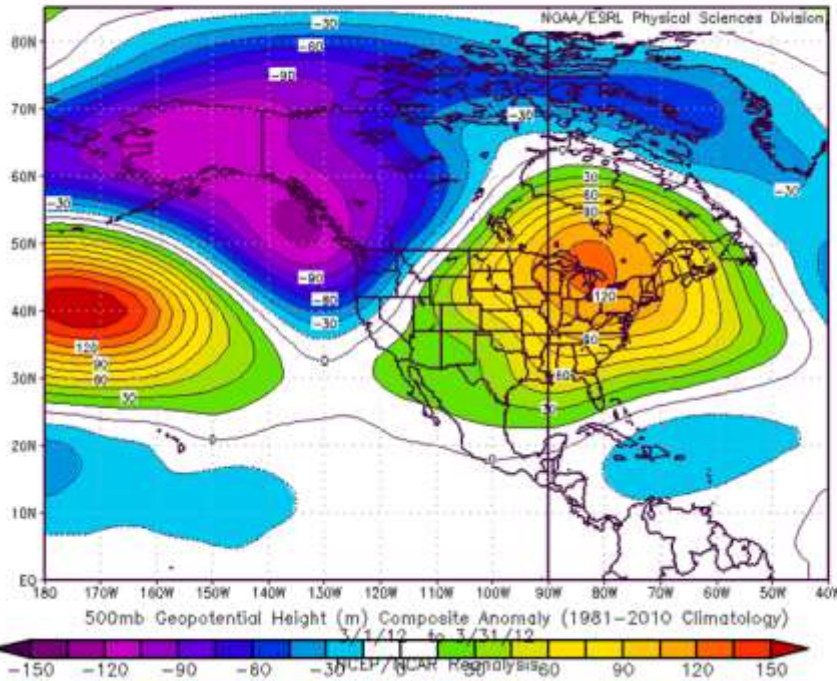
Data from Climate Prediction Center
<http://www.cpc.ncep.noaa.gov>



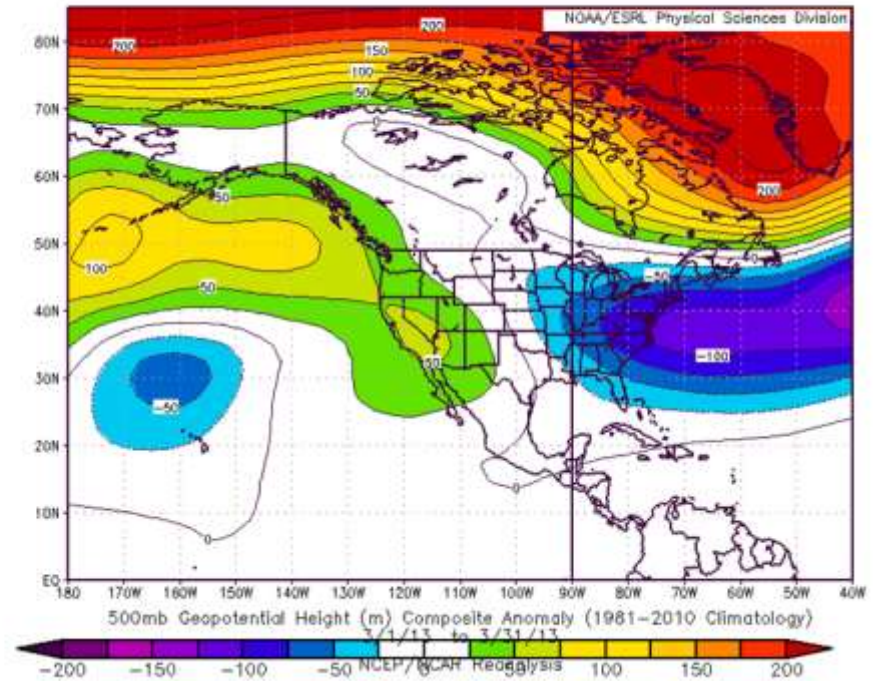
300 hPa Height (dm) & Isotachs (kt)

Detecting Climate Change from Data
Use Monthly

March 2012



March 2013



500 mb height anomalies from the Climate Prediction Center
<http://www.cpc.ncep.noaa.gov>:
 Positive anomalies correspond to warmer low-level temperatures

http://www.srh.noaa.gov/hun/?n=climatesummary_march2013