The wintertime impact of the MJO and ENSO on intraseasonal climate patterns over North America

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Outline:

I. Cluster Analysis to identify common 500 mb geopotential height patterns over North America in the wintertime.

II. How do the MJO and ENSO impact the frequency of occurrence of these patterns?

III. How well do CFSv2 hindcasts capture the observed enhanced/suppressed probabilities of these patterns?

Finding common geopotential height patterns: K-means cluster analysis

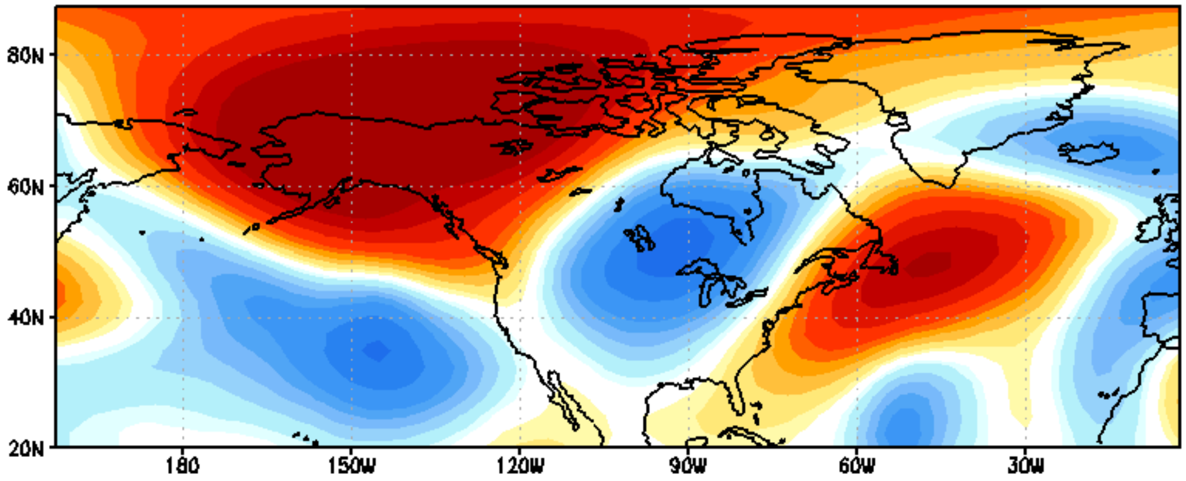
Dataset: 500 hPa heights from NCEP/NCAR Reanalysis

Domain: Centered on North America but including the whole PNA region. We have repeated the analysis for the whole northern hemisphere as well, with similar results

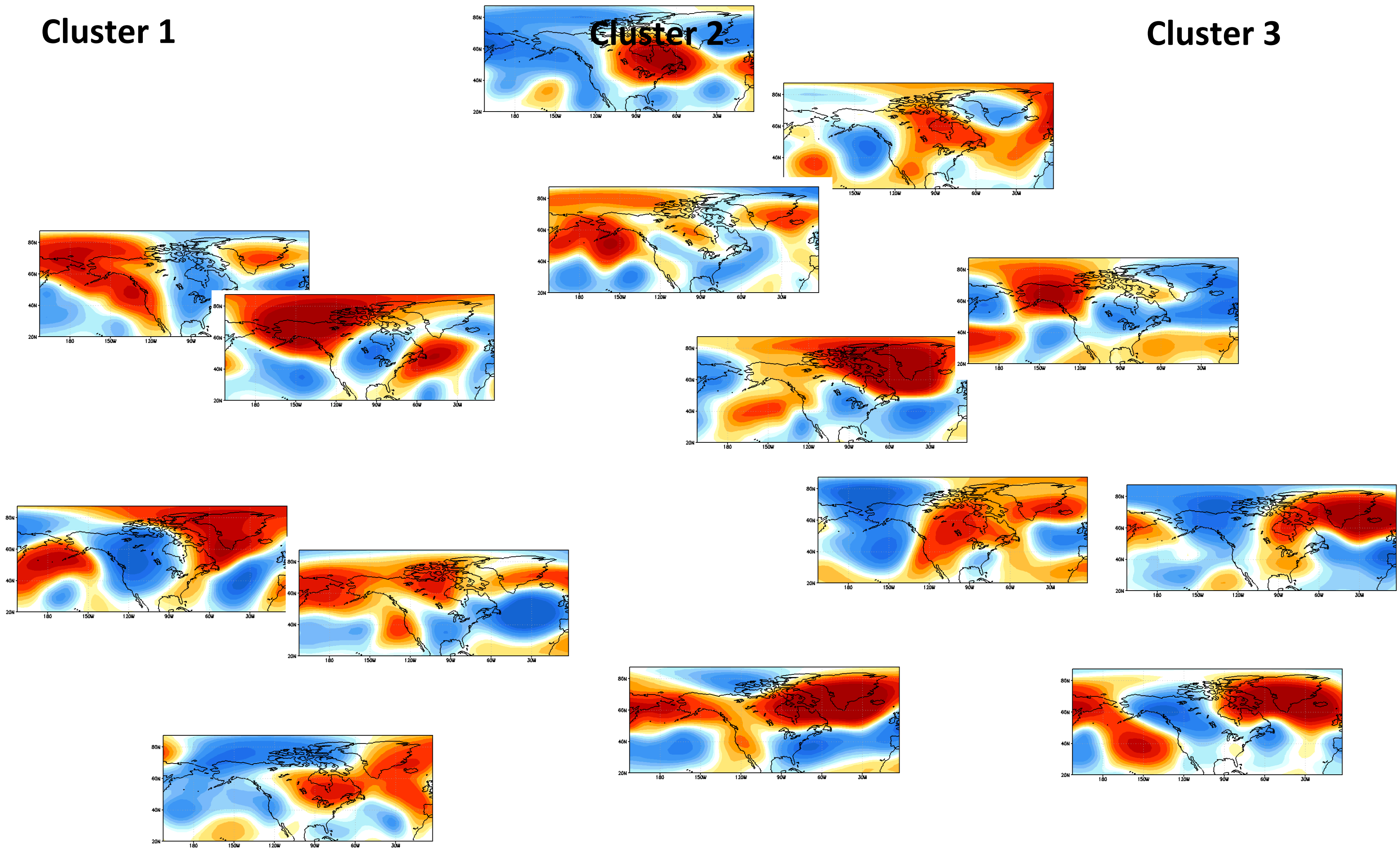
Averaging: 7-Day running mean

Time Range: December – March (Winter months) 1979-2011, total of 3962 overlapping 7-day periods go into the analysis

Example of 500 hPa geopotential height anomalies for one 7-day period: January 1st – January 7th 1979



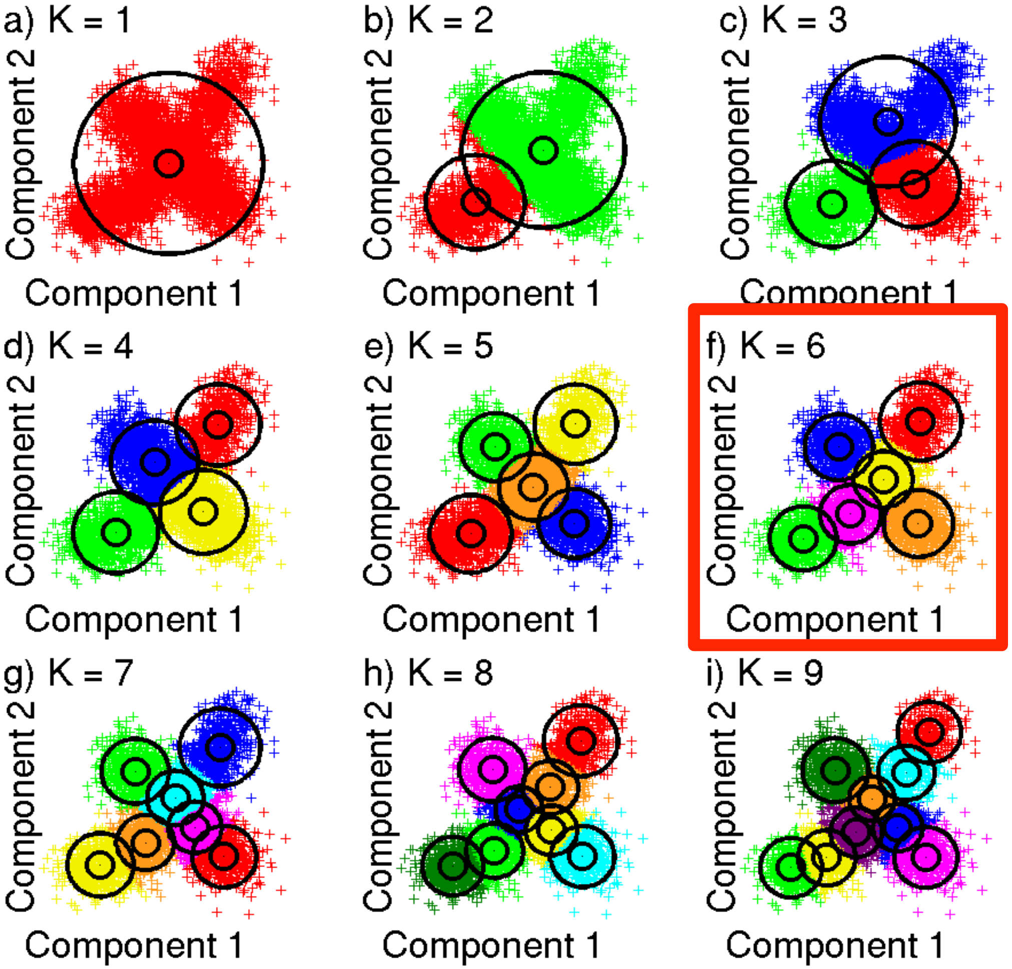
K-means Cluster Analysis



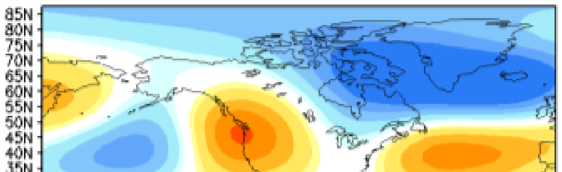
New method for choosing an optimal number of clusters:

How well do hyperspheres centered on the cluster centers cover the phase space, minimizing gaps and overlap?

2-Dimensional Example



Results: Composites of the 7 Clusters



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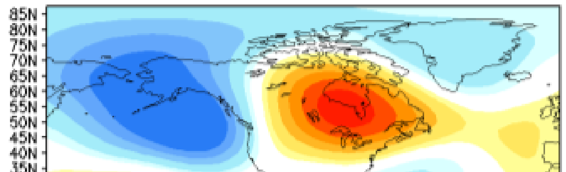

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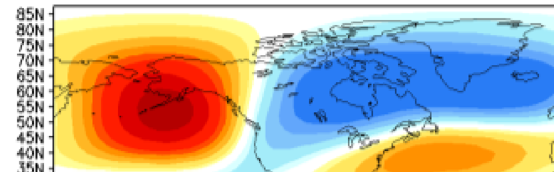

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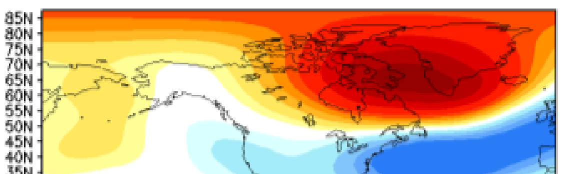

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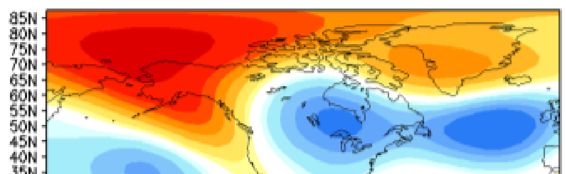

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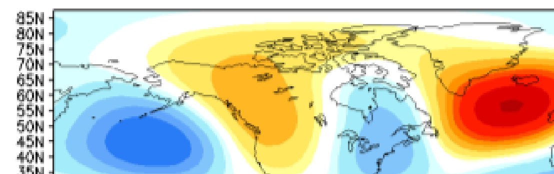

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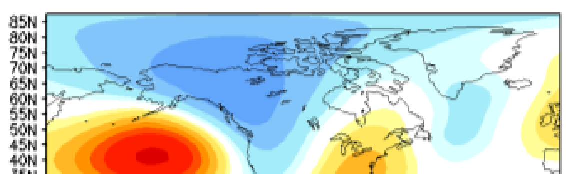
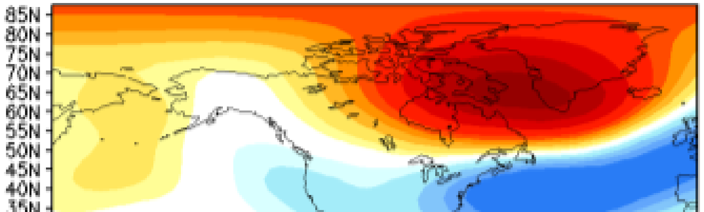


7 19%

Mean 500 hPa Geopotential height anomalies (m)

Focus on three of the seven clusters



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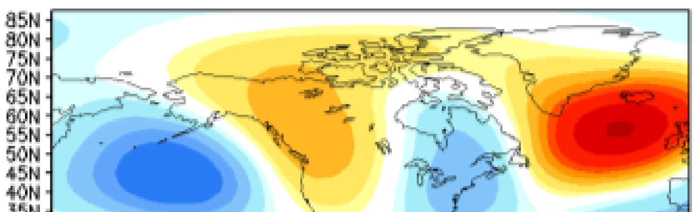

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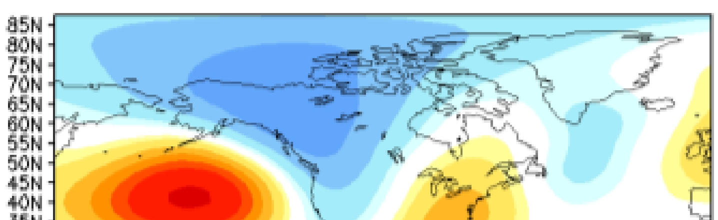

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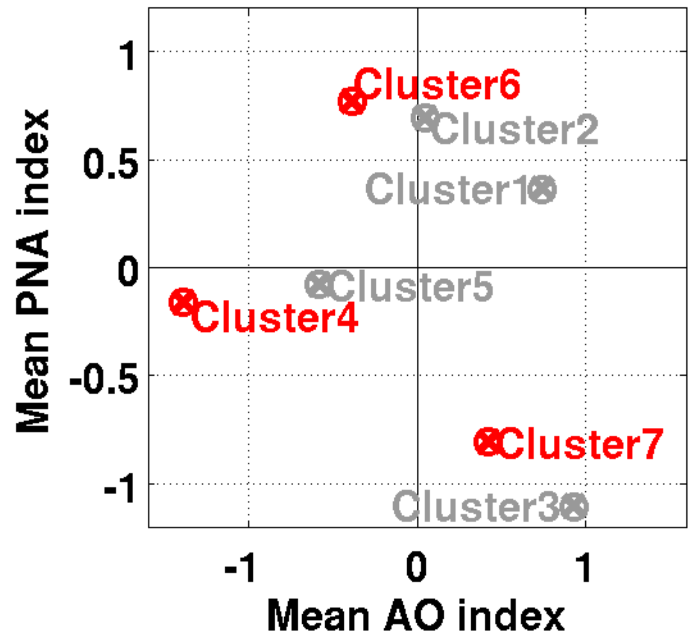


Impact of the Madden-Julian Oscillation:
The Wheeler-Hendon Index

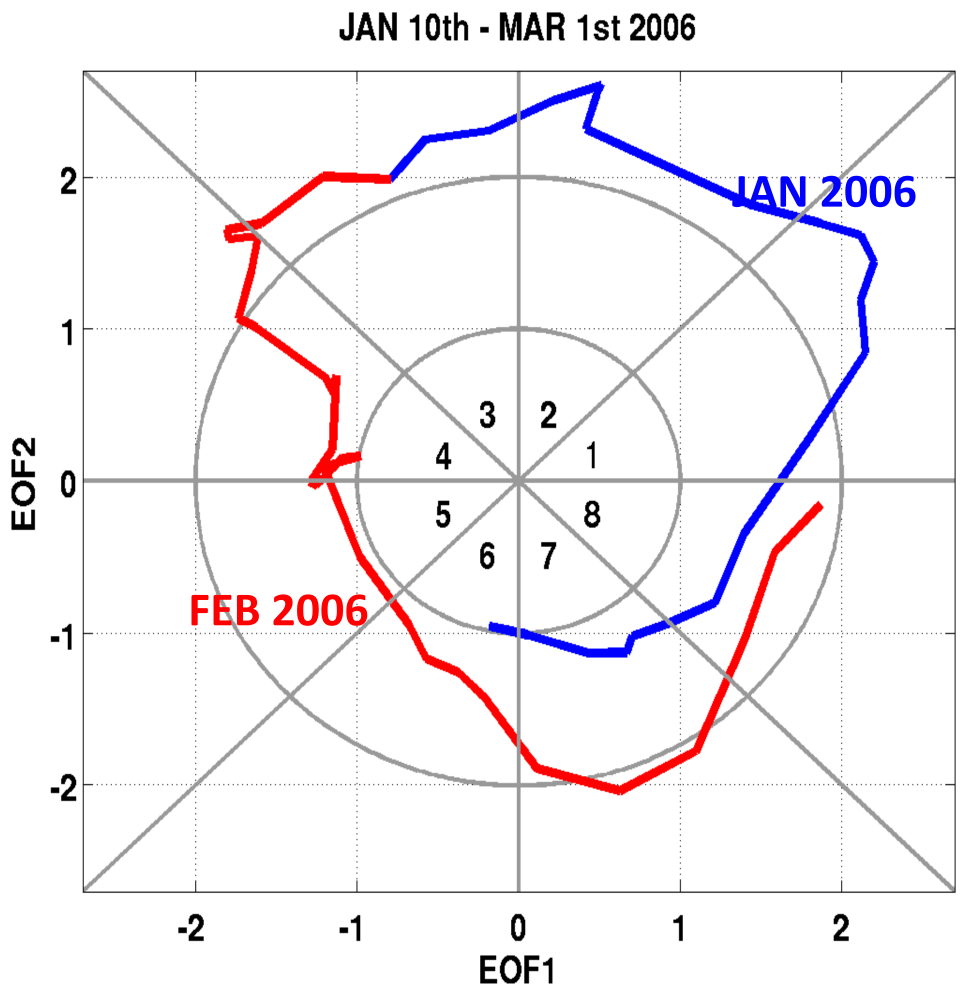
EOF analysis of OLR, 850 hPa zonal winds and 200 hPa zonal winds

First two EOFs are in quadrature and together describe an eastward propagating wave of precipitation and circulation anomalies (30-60 day period)

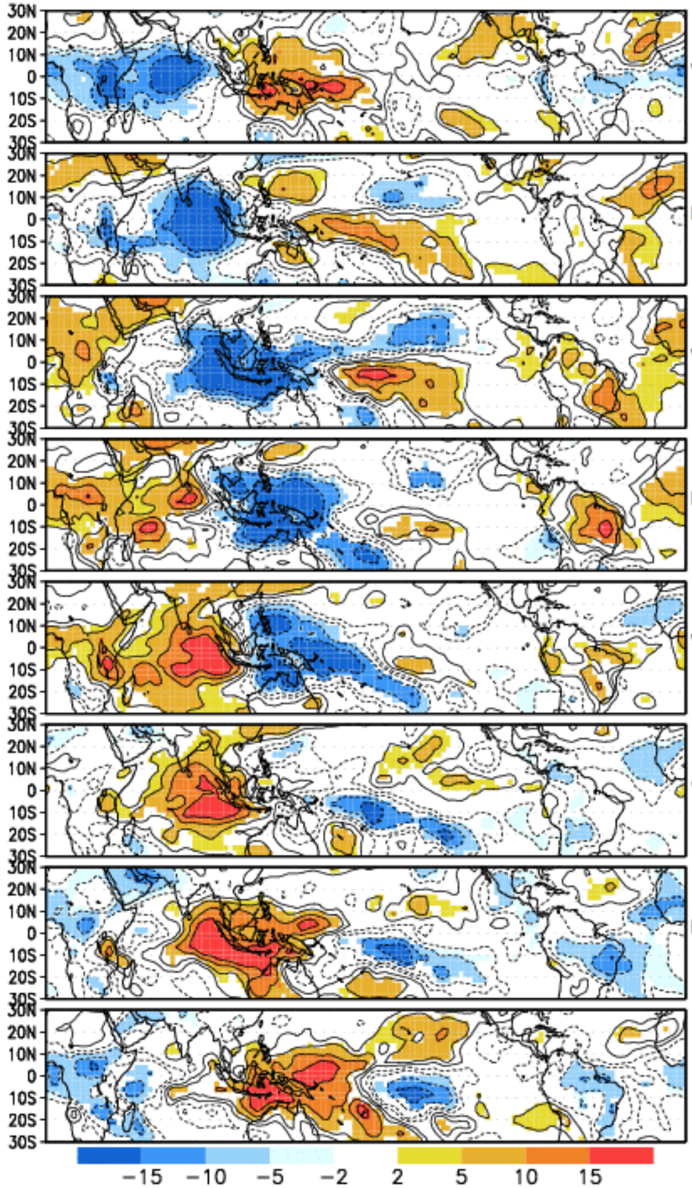
We use phase of the index (1-8) to describe the location of MJO related precipitation.

We also use the magnitude of the index to determine whether MJO is active or inactive. This determination is also based on the persistence and direction of propagation.

An MJO event is represented by a counter-clockwise propagation in the EOF-1 vs. EOF-2 phase space



Impact of the Madden-Julian Oscillation:
The Wheeler-Hendon Index



Phase 1 West Indian Ocean

Phase 2 East Indian Ocean

Phase 3 West Maritime Continent

Phase 4 East Maritime Continent

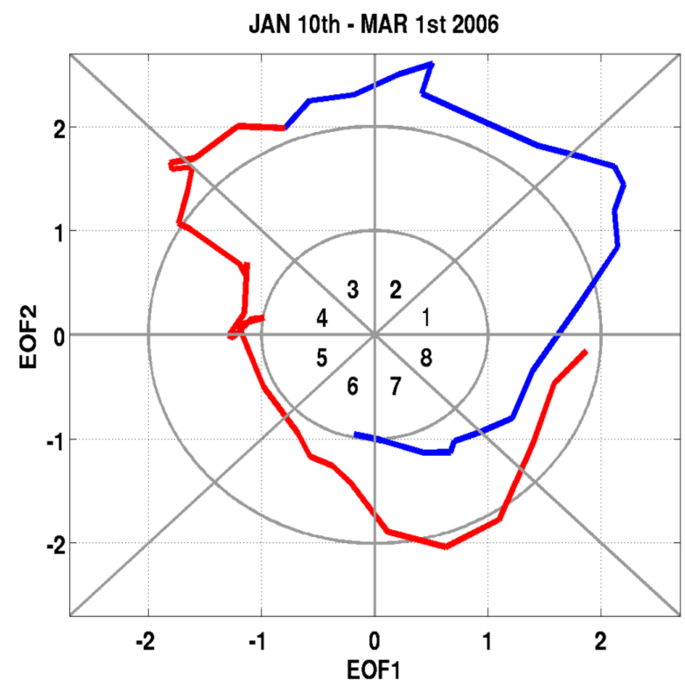
Phase 5 West Pacific Ocean

Phase 6 Central Pacific Ocean

Phase 7 East Pacific Ocean

Phase 8 Western Hemisphere

OLR anomalies associated with MJO propagation from phase 1 – phase 8

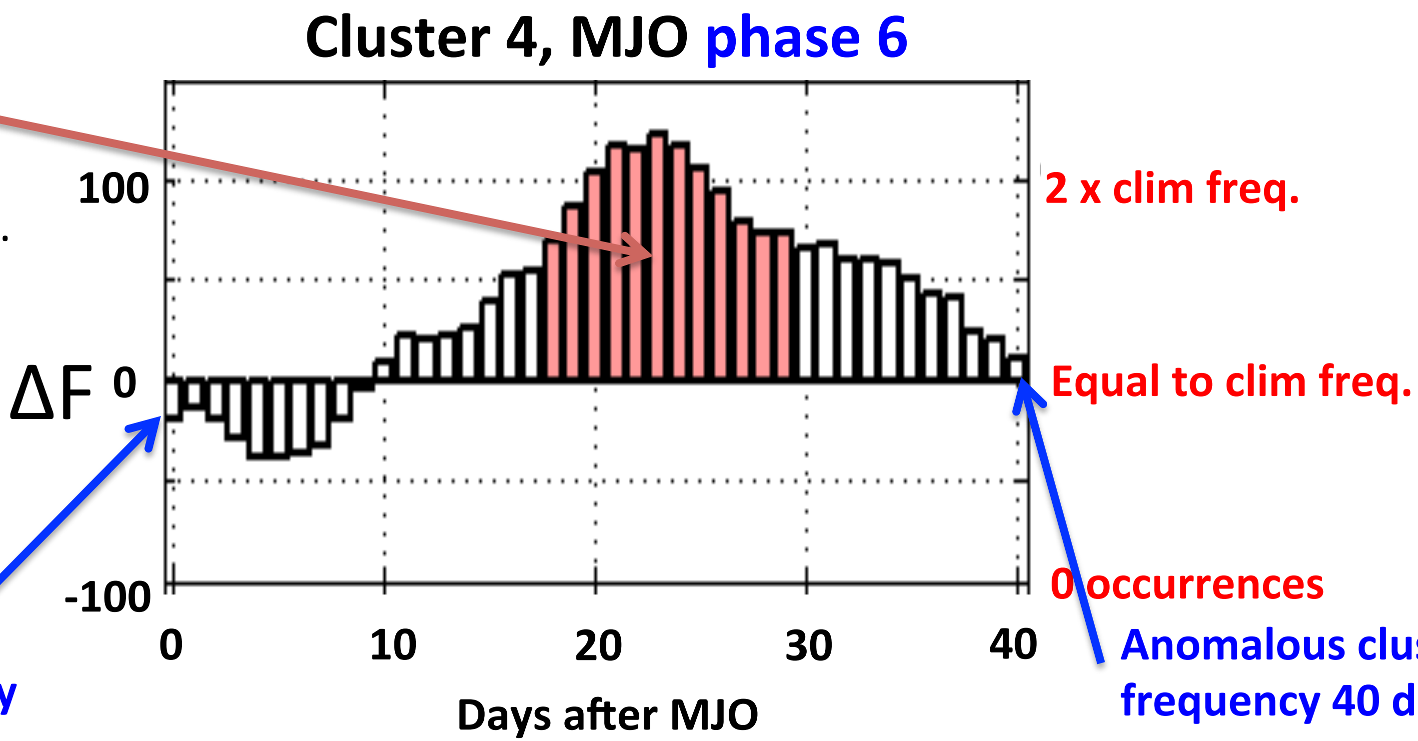


Impact of the Madden-Julian Oscillation:

Example: Anomalous cluster frequencies

$$\Delta F = 100 * [(P(clust|MJO - P(clust))/P(clust)]$$

Shading indicates significant anomalies at the 95% level.

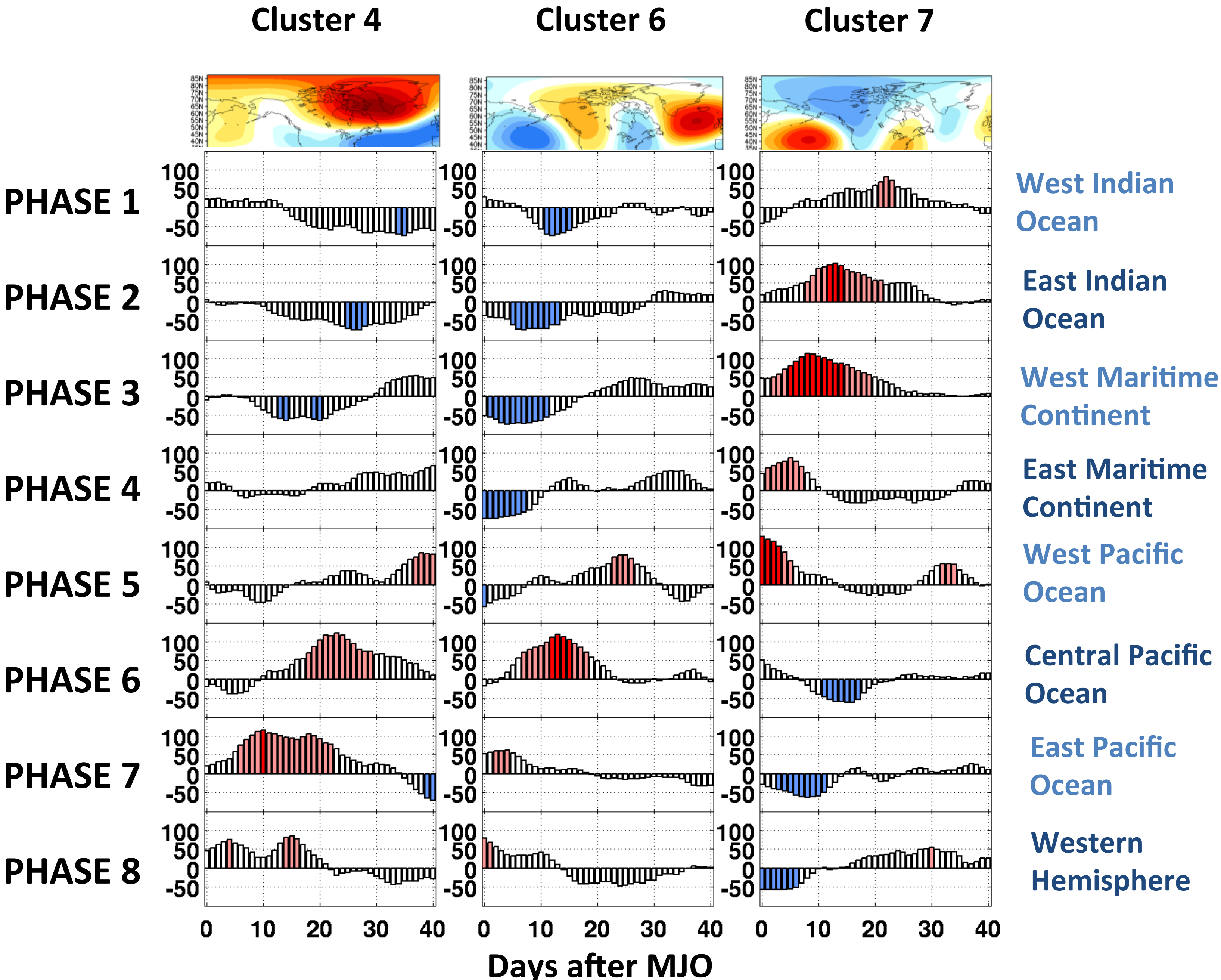


Anomalous cluster frequency concurrent with MJO activity in phase 6

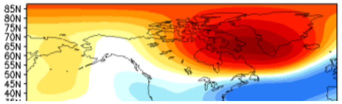
Anomalous cluster frequency 40 days after MJO activity in phase 6

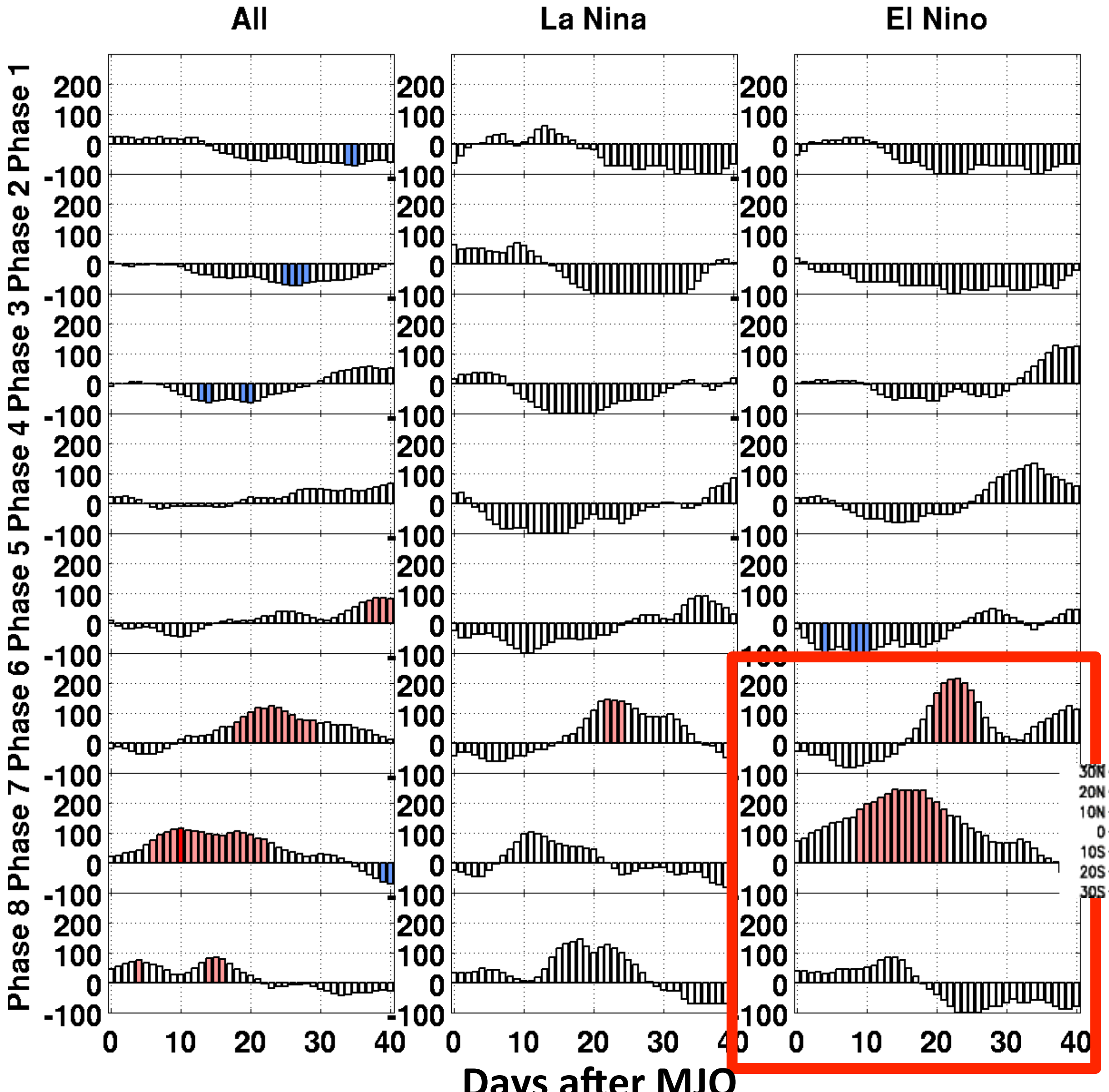
Similar to plots in nature paper by Cassou (2008)

Impact of the MJO on Clusters 4,6, and 7



Dependence on ENSO
Cluster 4





West Indian Ocean

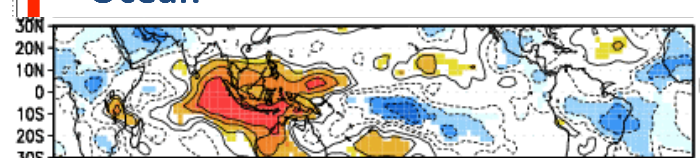
East Indian Ocean

West Maritime Continent

East Maritime Continent

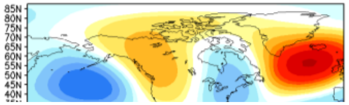
West Pacific Ocean

Central Pacific Ocean

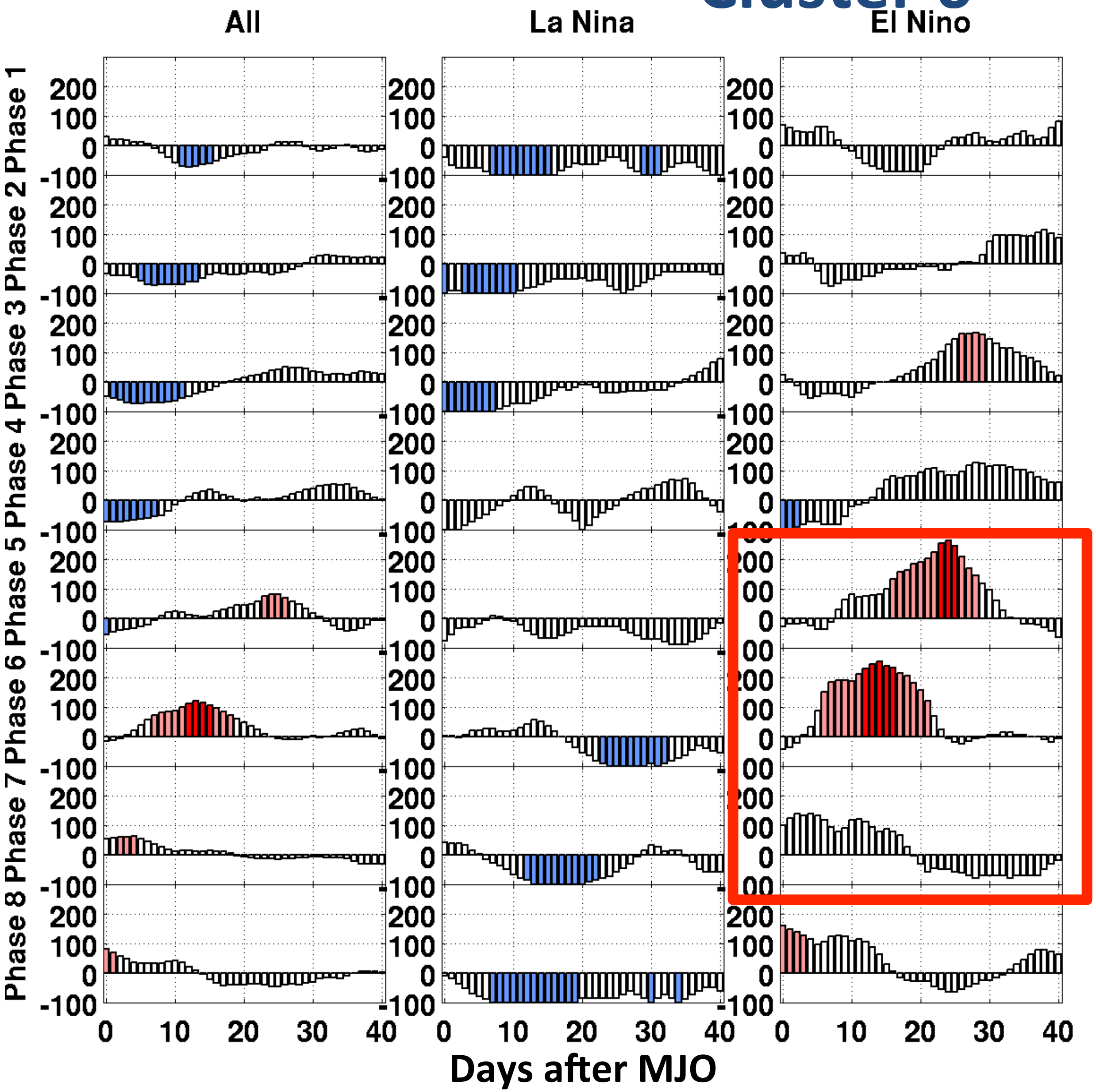


Western Hemisphere

Constructive interference between El Nino and MJO phase 7 convection patterns



Dependence on ENSO
Cluster 6



West Indian Ocean

East Indian Ocean

West Maritime Continent

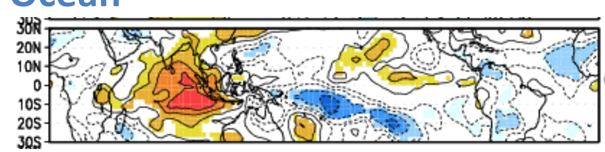
East Maritime Continent

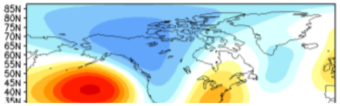
West Pacific Ocean

East Pacific Ocean

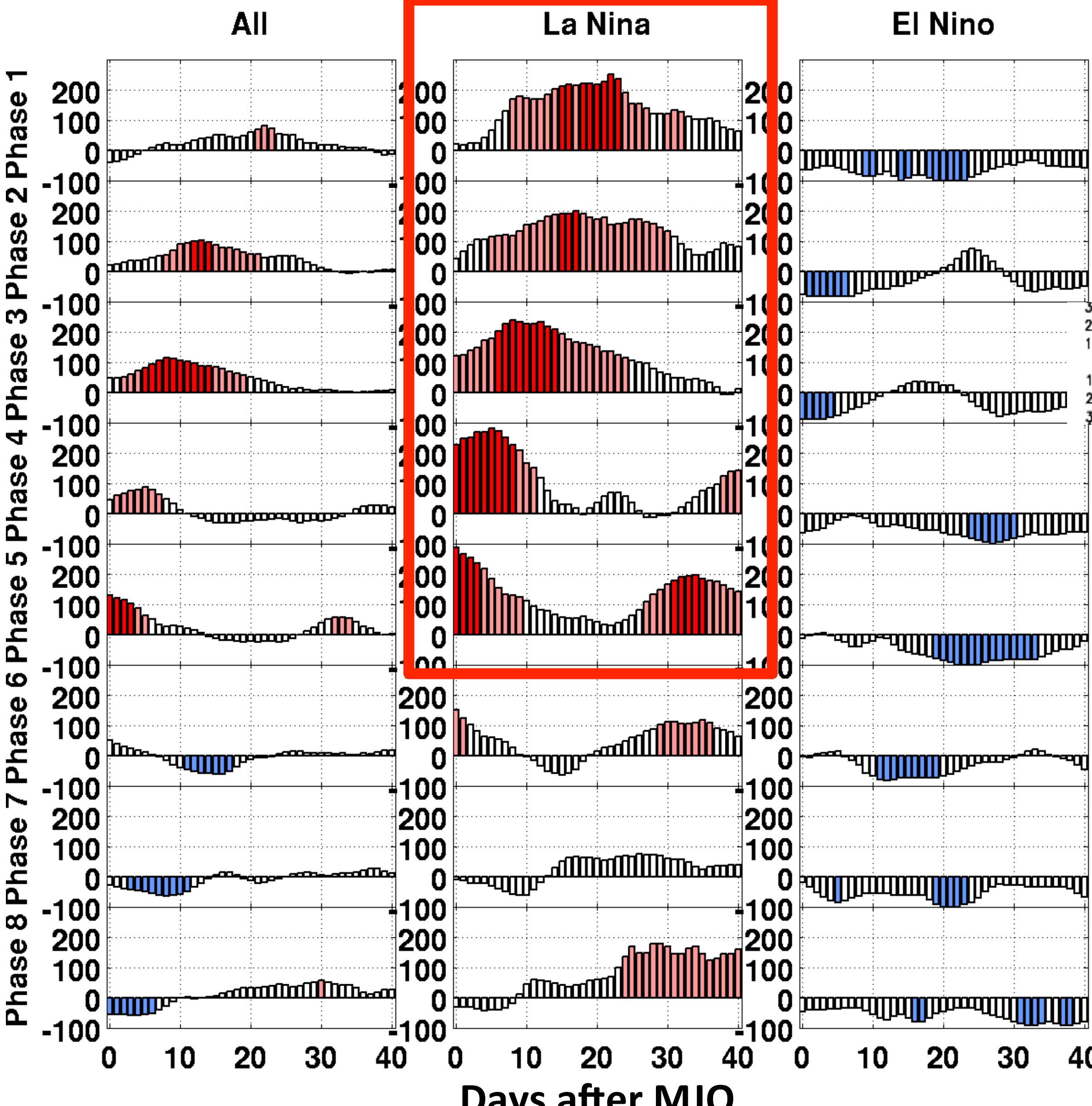
Western Hemisphere

Generally constructive interference between El Nino and MJO phase 6 convection patterns



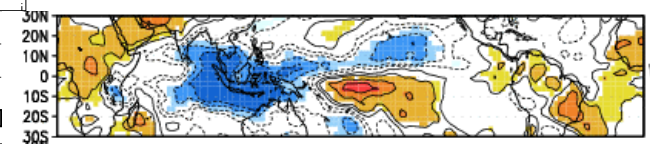


Dependence on ENSO
Cluster 7



West Indian Ocean

East Indian Ocean



East Maritime Continent

West Pacific Ocean

Central Pacific Ocean

East Pacific Ocean

Western Hemisphere

Generally constructive interference between La Nina and MJO phase 3 convection anomalies

CFSv2 Hindcasts

Dataset: 45-day Climate Forecast System version 2 hindcast runs. 4 runs initiated every day.

Domain: Same as before

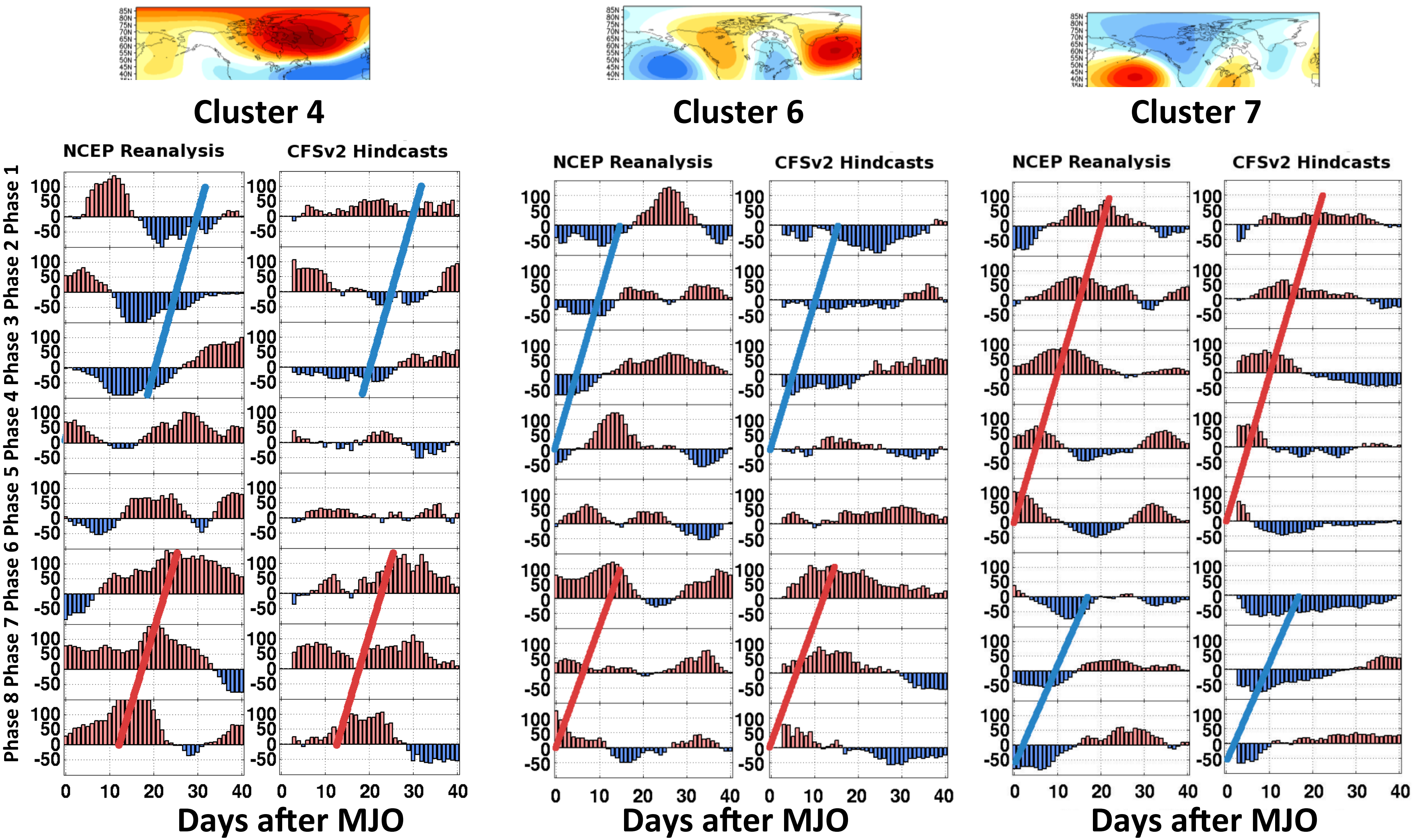
Time Range: December – March (Winter months) 1999-2009, shorter record than for full cluster analysis

Averaging: Average over 4 runs started each day, 7-day running mean

Assigning cluster numbers: Use nearest cluster centroid based on Euclidean distance

CFSv2 Hindcasts (1999-2009)

Slanted lines show the position of peaks and troughs from the full reanalysis record (1979-2011)



Summary and Conclusions

1) A new method is introduced for optimizing the number of clusters in a k-means cluster analysis

2) The resulting 7 clusters provide an efficient description of variability in 500 mb heights over PNA region. One advantage of the cluster analysis is that it allows for asymmetries between positive and negative phases of the leading modes of NH variability. Clusters tend to be mixtures of leading modes, such as the AO and PNA.

3) Cluster 4, 6 and 7 occurrences are strongly modulated by MJO. While Clusters 6 and 7 resemble the positive and negative phases of the PNA, respectively, they show stronger modulations than similarly sized clusters based on the PNA alone.

4) The enhanced probabilities of clusters 6 and 7 occur almost entirely during El Nino and La Nina, respectively, when ENSO convection anomalies constructively interfere with the MJO.

5) 45-day CFSv2 hindcasts generally capture the approximate timing of enhanced/suppressed cluster probabilities associated with MJO, though the magnitude of the anomalies is slightly weaker in the model and the anomalies may persist for slightly longer. This may suggest that the model is capturing at least some of the dynamics between the tropics and extratropics.

Questions

Results are consistent with previous studies

Relationship between MJO and PNA:
(e.g., Higgins and Mo, 1997; Mori and Wanatabe, 2008; Johnson and Feldstein, 2010)

✔ **Cluster 6**
A subtropical jet extension and a positive PNA is associated with enhanced MJO convection over the Central Pacific (phase 6/7)

✔ **Cluster 7**
A weakening of the subtropical jet and a negative PNA is associated with suppressed MJO convection over the Central Pacific (phase 2/3)

Relationship between MJO and AO/NAO:
(e.g., Cassou et al, 2008; L'Heureux and Higgins, 2008; Lin et al 2009)

✔ **Cluster 4**
A negative AO is common several weeks after enhanced MJO convection over the Central Pacific (phase 6/7)

A positive AO is common several weeks after suppressed MJO convection over the Central Pacific (phase 2/3)

Is the MJO impact on pure AO and PNA modes stronger or weaker than on Clusters 4,6 and 7?

Number of “significant” results ($p<0.05$)

Clusters 4,6, and 7		Clusters of the same size consisting of the most positive / negative AO/PNA values	
Cluster 4	49	**Negative AO**	64
Cluster 6	55	**Positive PNA**	42
Cluster 7	75	**Negative PNA**	7