Exploiting the MJO in extended range forecasts of mid-tropospheric circulation anomalies over the North American region

Emily Riddle, Nat Johnson, Michelle L'Heureux,
Dan Collins, Steven Feldstein

NOAA/NCEP Climate Prediction Center
University of Hawaii
Wyle Science Technology and Engineering
Pennsylvania State University

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CTB Proposal Goal:

Can the MJO be used to statistically enhance model-based extended-range forecasts over North America?

This talk:

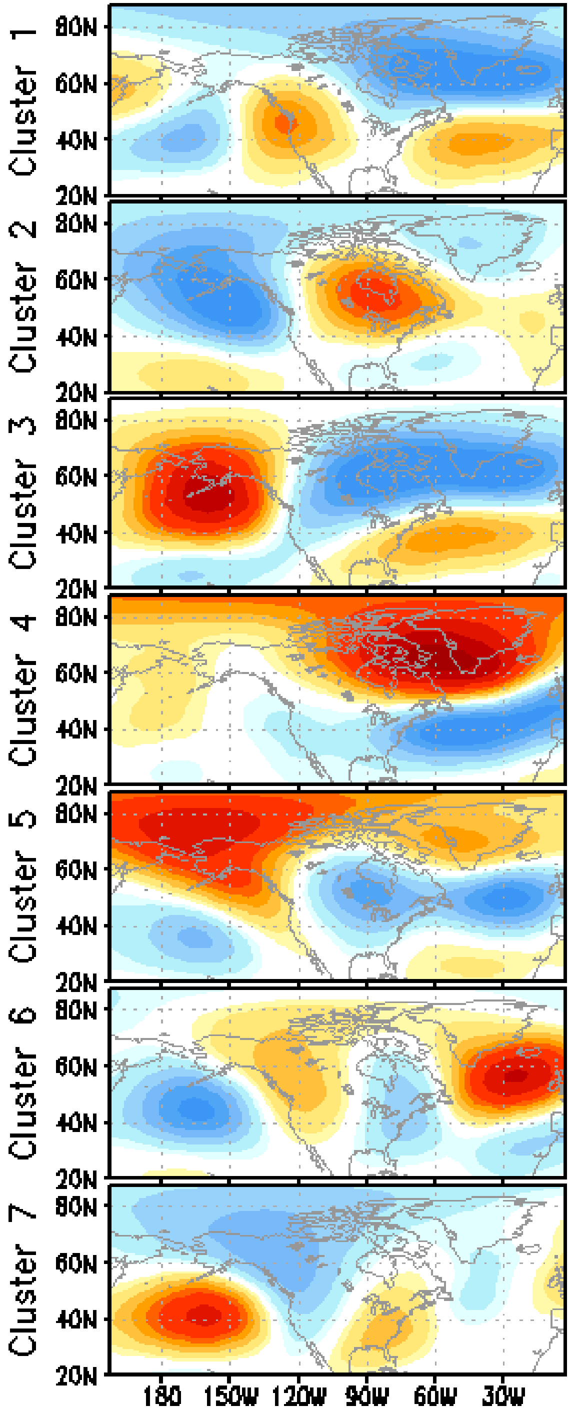
Examine the skill of simple statistical forecasts of circulation patterns over North America identified using a cluster analysis.

Overview of the Strategy:

1) **Cluster Analysis:** **Identify common intraseasonal circulation anomaly patterns over North America and the surrounding oceans (presented at last year's CDPW.)**

2) **Probabilistic Forecasts:** **Create Bayesian forecasts of cluster occurrence using only the state of ENSO and the MJO.**

Step 1: Cluster Analysis Results



Positive AO/NAO

Negative AO/NAO

Positive PNA

Negative PNA

- 500 mb heights NCEP/NCAR reanalysis
- Winter: December – March
- Intraseasonal: 7-day running mean

(From Riddle et al, 2012)

Step 2: Create probabilistic forecasts of cluster occurrence

- Forecasts **dependent only on the state of ENSO and the MJO**.
- 48 different MJO/ENSO states that we consider:

MJO: Active /Inactive (WH index > 1?)

MJO phase: 1-8 (WH index phase)

ENSO: La Nina, El Nino, Neutral

Compare different forecast strategies:

1) "Simple Counts" Forecasts (uniform prior)
   ENSO-only and ENSO/MJO

2) Bayesian Forecasts (with prior informed by pooled data)
   ENSO-only and ENSO/MJO

“Simple Counts” Forecasts

$$P_{J,L} = \frac{(y_{J,L})(r) + 1}{(N)(r) + 7}$$

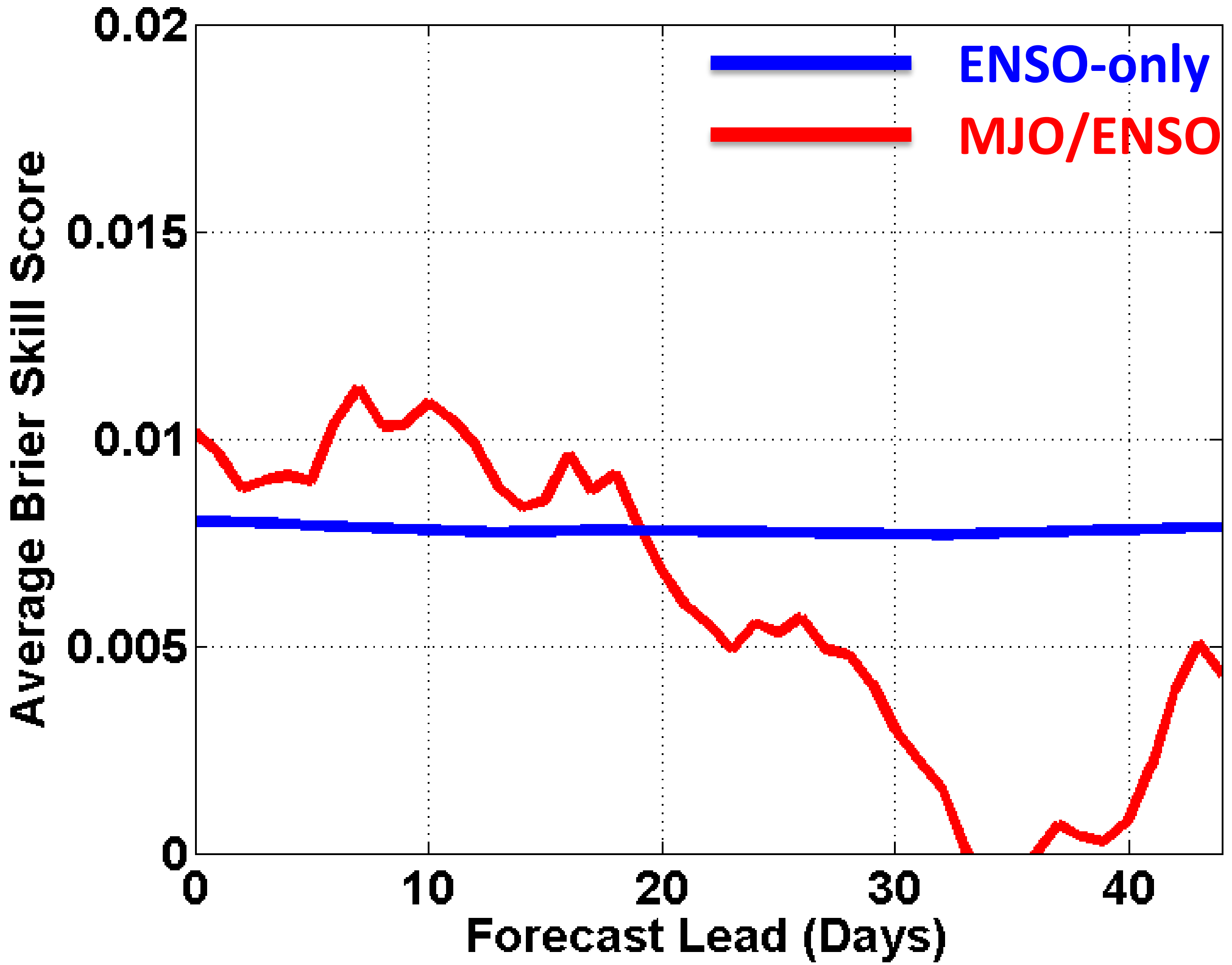
$P_{J,L}$: L-day lead forecast for cluster J as a function of the MJO/ENSO state

N: Total historical occurrences of the MJO/ENSO state

$y_{J,L}$: Number of the N historical MJO/ENSO occurrences that were followed L days later by cluster J

r: Counts reduction factor that corrects for autocorrelation in the cluster timeseries

“Simple Counts” Forecasts



Bayesian Forecasts

Bayes Theorem:

$$Posterior(\boldsymbol{\theta} \mid \mathbf{y}) \propto Likelihood(\mathbf{y} \mid \boldsymbol{\theta})\ Prior(\boldsymbol{\theta})$$

$\boldsymbol{\theta}$ Parameter vector:
Multinomial distribution parameter indicating cluster probabilities

$\mathbf{y}$ Data vector:
Observed cluster counts
(reduced by counts reduction factor)

Multinomial Distribution:

$$M(\mathbf{y};\boldsymbol{\theta}) = A(\mathbf{y})\left(\prod_{i=1}^{k-1}(\theta_i)^{y_i}\right)(1-\sum_{i=1}^{k-1}\theta_i)^{y_k}$$

Dirichlet Distribution:

$$D(\boldsymbol{\theta};\boldsymbol{\alpha}) = B(\boldsymbol{\alpha})\left(\prod_{i=1}^{k-1}(\theta_i)^{\alpha_i-1}\right)(1-\sum_{i=1}^{k-1}\theta_i)^{\alpha_k-1}$$

Bayesian Forecasts

	Uniform Prior	Dirichlet prior
Forecast Probabilities :	$\dfrac{\bar{\mathbf{y}}+1}{n+7}$	$\dfrac{\bar{\mathbf{y}}+\bar{\boldsymbol{\alpha}}_{prior}}{n+\alpha_{0,prior}}$

$\bar{\mathbf{y}}$ Cluster counts from the historical record

n Sum of the components of $\bar{\mathbf{y}}$

$\bar{\boldsymbol{\alpha}}_{prior}$ Dirichlet prior parameters

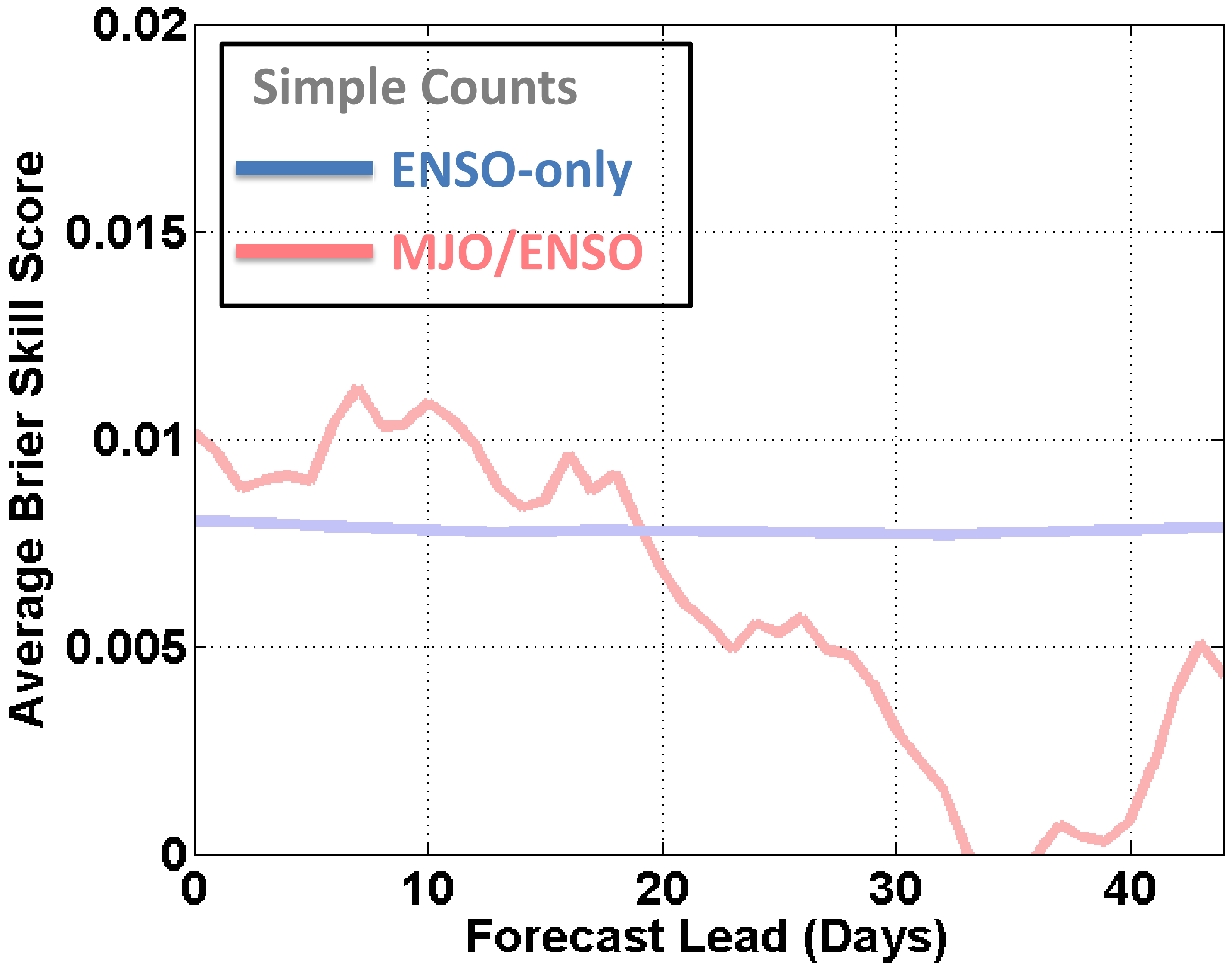
$\alpha_{0,prior}$ Sum of the components of $\bar{\boldsymbol{\alpha}}_{prior}$

Fitting the Dirichlet prior parameters: Method of Moments

	ENSO-only forecast	ENSO/MJO forecast
Prior is determined:	Before knowing the state of ENSO	Assuming the state of ENSO is known, but before knowing the state of the MJO
The **mean vector** of Dirichlet prior is fit to equal the relative cluster frequencies in:	The full climatological dataset	The ENSO-only forecast
The **variance** of the Dirichlet prior depends on the variance in cluster frequencies:	Between different phases of ENSO	Between different phases of the MJO

BIG PICTURE: The prior is based on pooled data with larger sample sizes and better statistics than the sub-divided data.

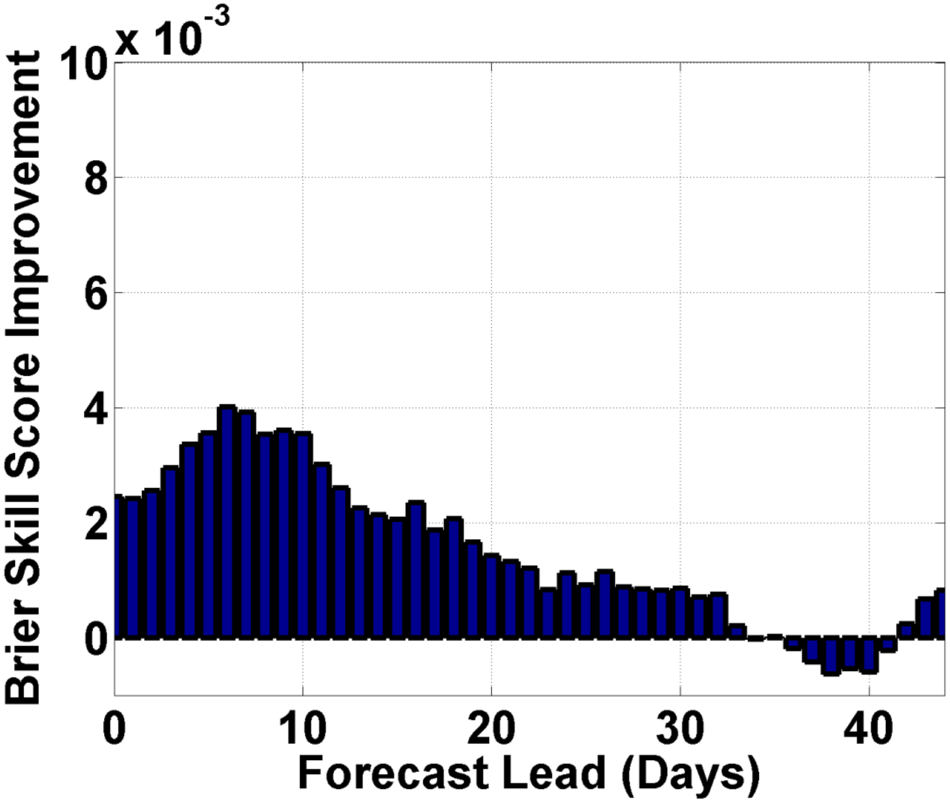
Bayesian Forecasts



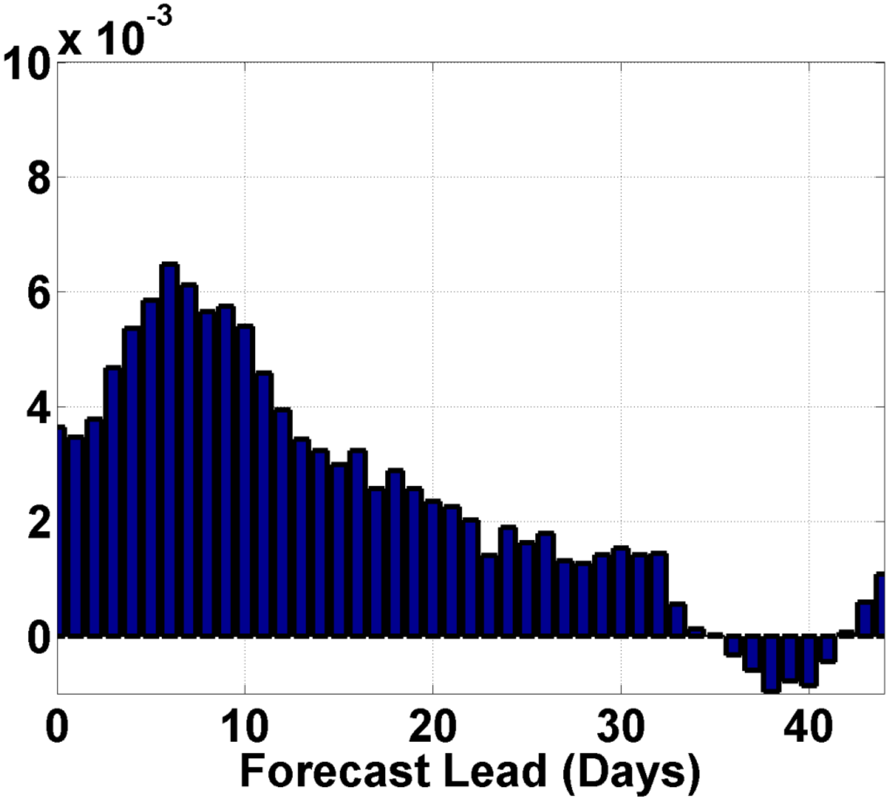
Increase in skill associated with the MJO

Bayesian MJO/ENSO forecast
minus
Bayesian ENSO-only forecast

All Forecasts

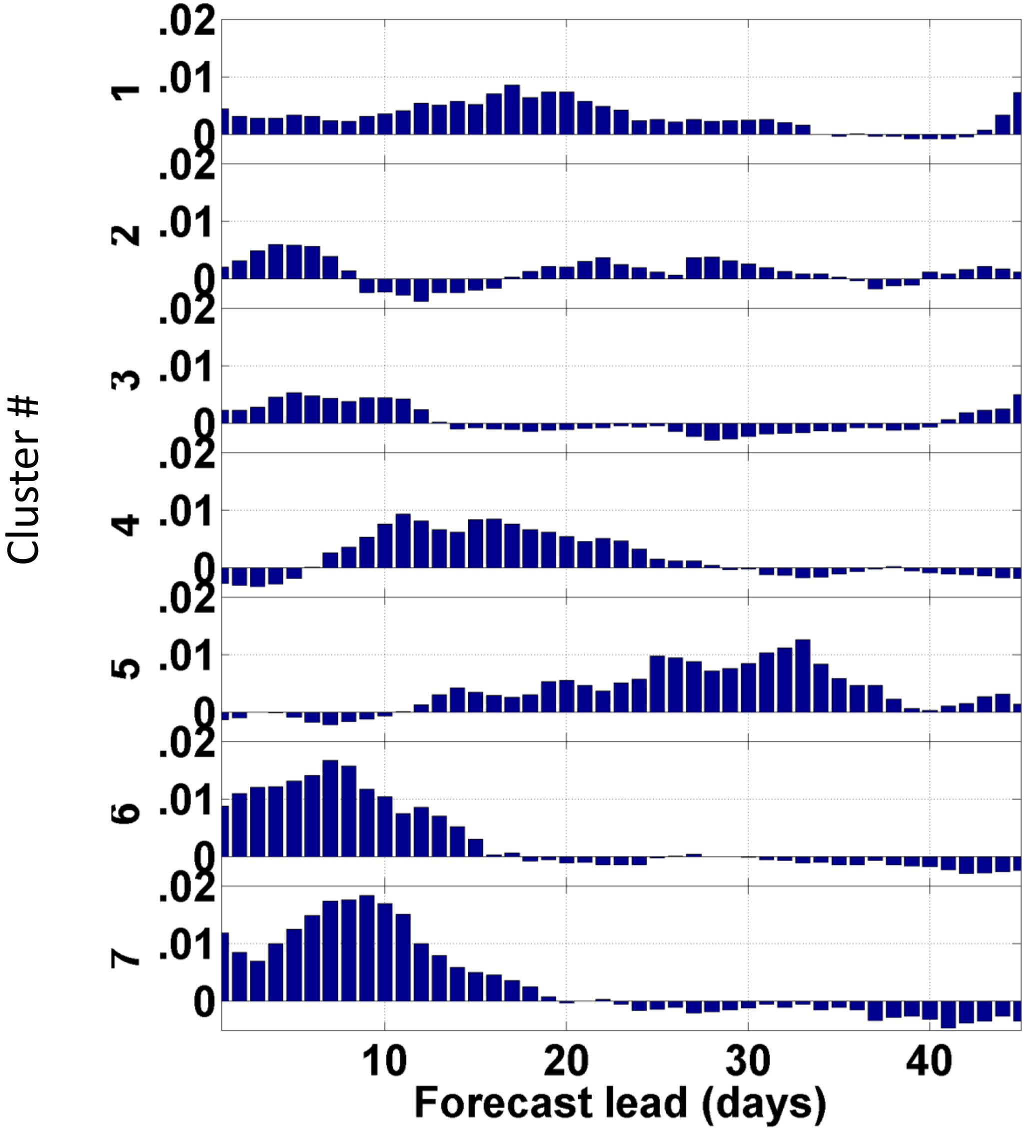


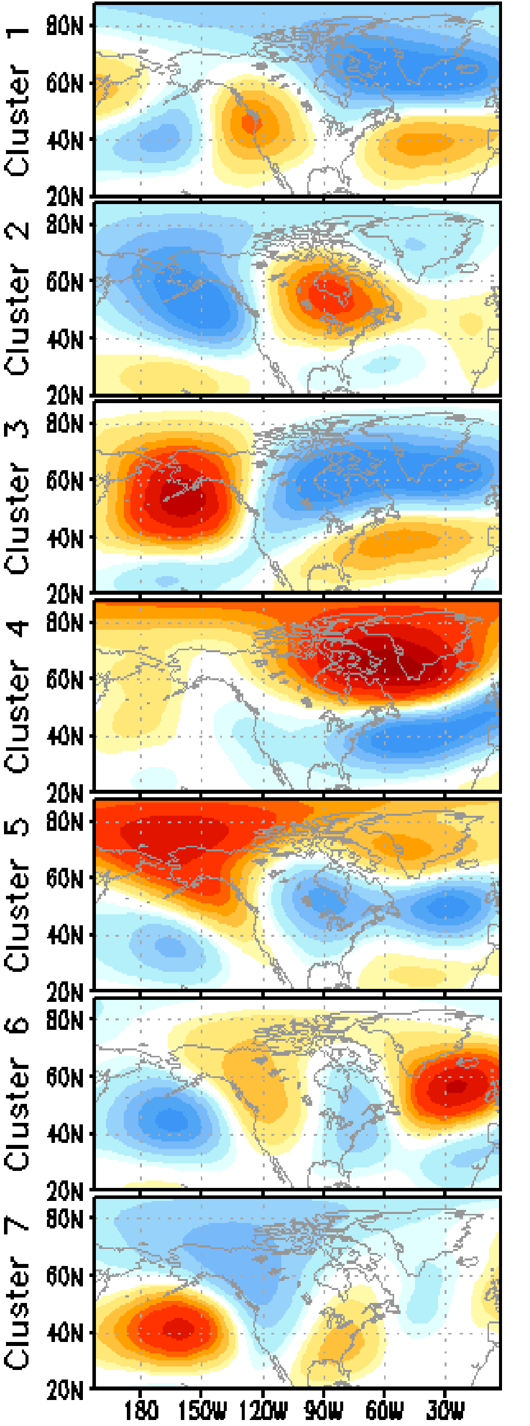
Only Forecasts when the MJO is active



Increase in skill associated with the MJO

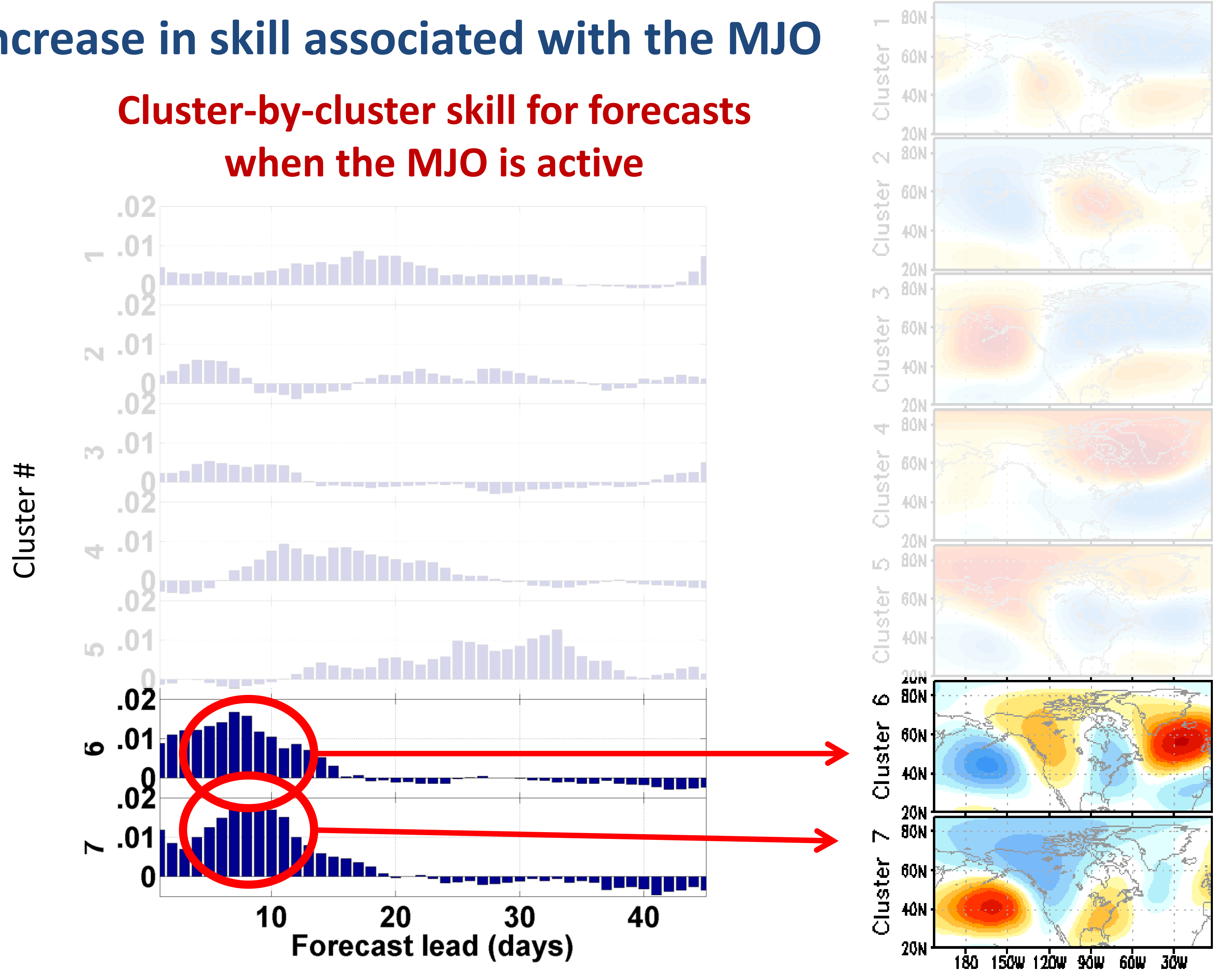
Cluster-by-cluster skill for forecasts when the MJO is active



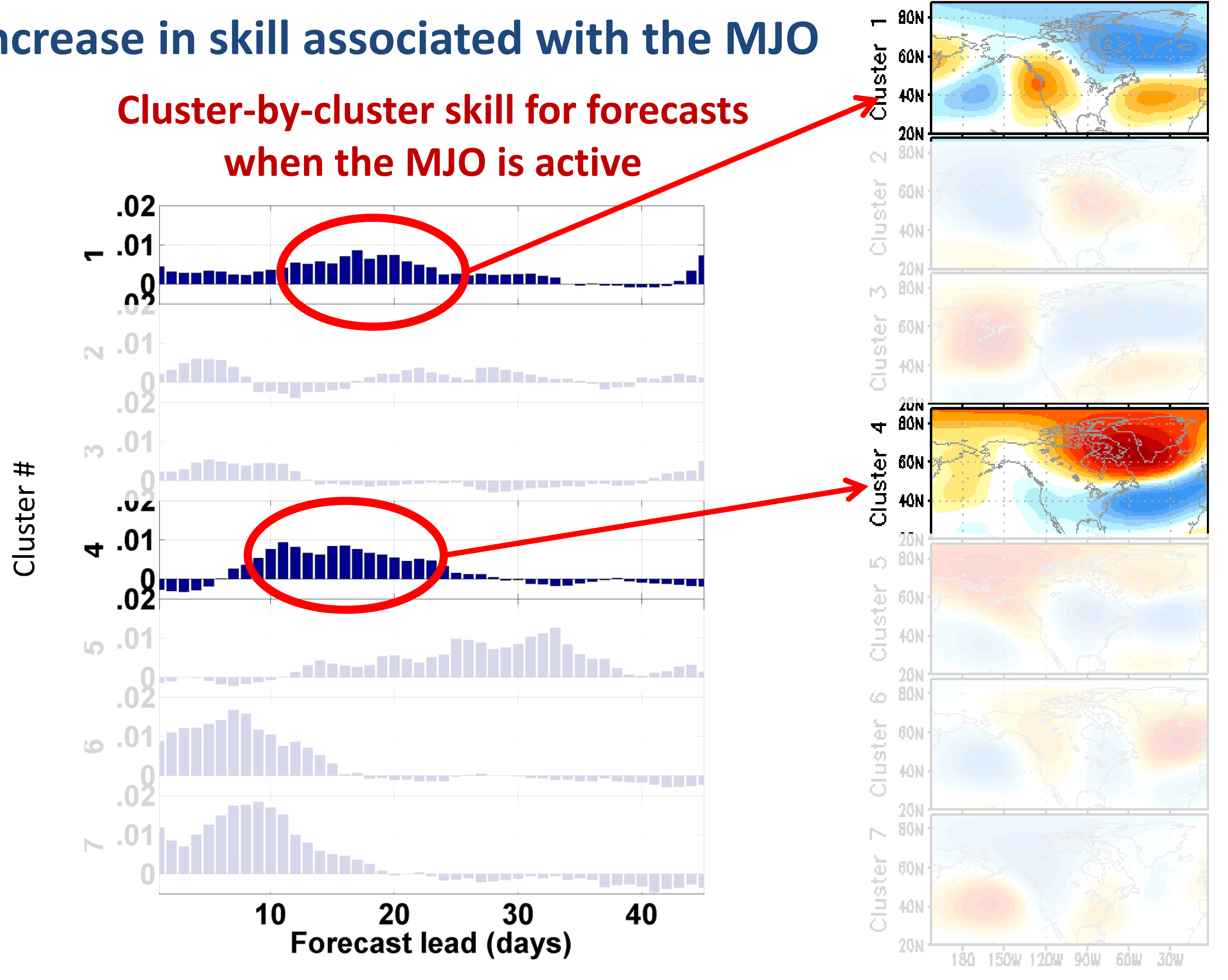


Increase in skill associated with the MJO

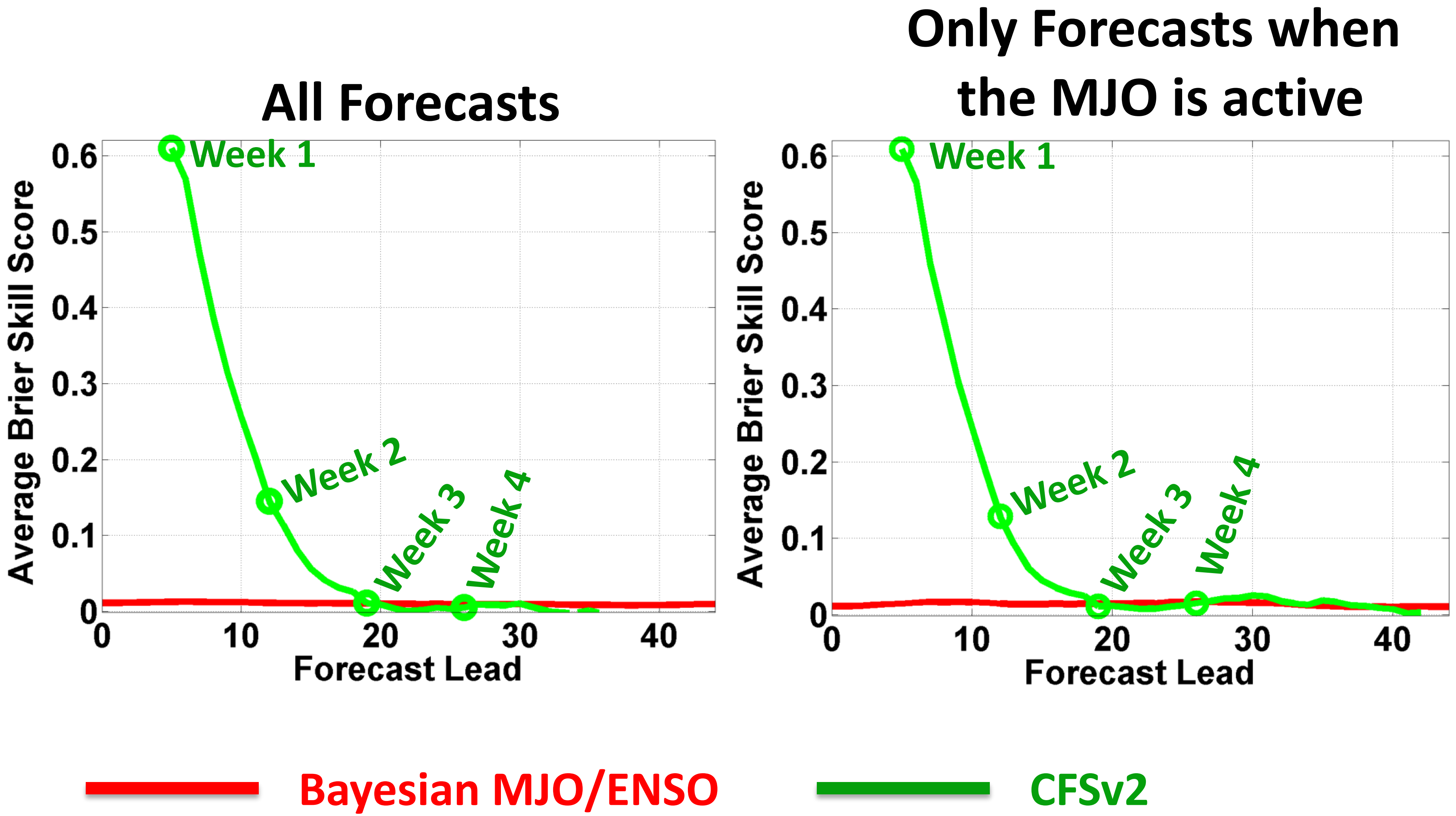
Cluster-by-cluster skill for forecasts when the MJO is active



Increase in skill associated with the MJO



Comparison with CFSv2 forecasts



Conclusions

1) Bayesian forecasts offer an improvement over the "simple counts" methodology. As desired, the Bayesian MJO/ENSO forecasts converge to the ENSO-only forecasts at long leads.

2) Skill improvements associated with the MJO are greatest at leads of approximately 1 week when the MJO is active, and are greatest for clusters that resemble opposing phases of the Pacific North America pattern. These characteristics are consistent with our physical understanding of the MJO's influence on the extratropics.

3) Despite the advantages of the Bayesian methodology, the overall skill associated with ENSO and the MJO in this study is very modest and not likely to significantly enhance CFSv2 forecasts.

4) Future steps: Combine statistical and dynamical model output, More complete hierarchical Bayesian treatment? Fewer subdivisions of MJO/ENSO phases? Logistic regression? Test other MJO indices? Identify cases (e.g., particular phases of the MJO) when greater skill might exist.