Weather regime diagnostic tools for sub-monthly ensemble forecasts

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The goal of this proposal is to develop a new diagnostic package based on WRs (i.e. LSMPs) to assist forecasters in forecast interpretation, model evaluation, model inter-comparison, and downscaling of week 3–4 forecasts.

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International Research Institute for Climate and Society
Earth Institute | Columbia University

Weather Regimes

aka Large Scale Meteorological Patterns

- Long history in dynamical meteorology of the midlatitudes of so-called low frequency variability (LFV: 10–50 days) that organizes synoptic-scale weather: index cycles, blocking, quasi-equilibria, Grosswetterlagen, …
- WRs are typically defined through classification of weather maps, using geopotential height data
- Can the concept of discrete circulation regimes lead to improved sub-seasonal to seasonal forecasts, by providing a low-order coarse-graining of S2S forecast evolution?

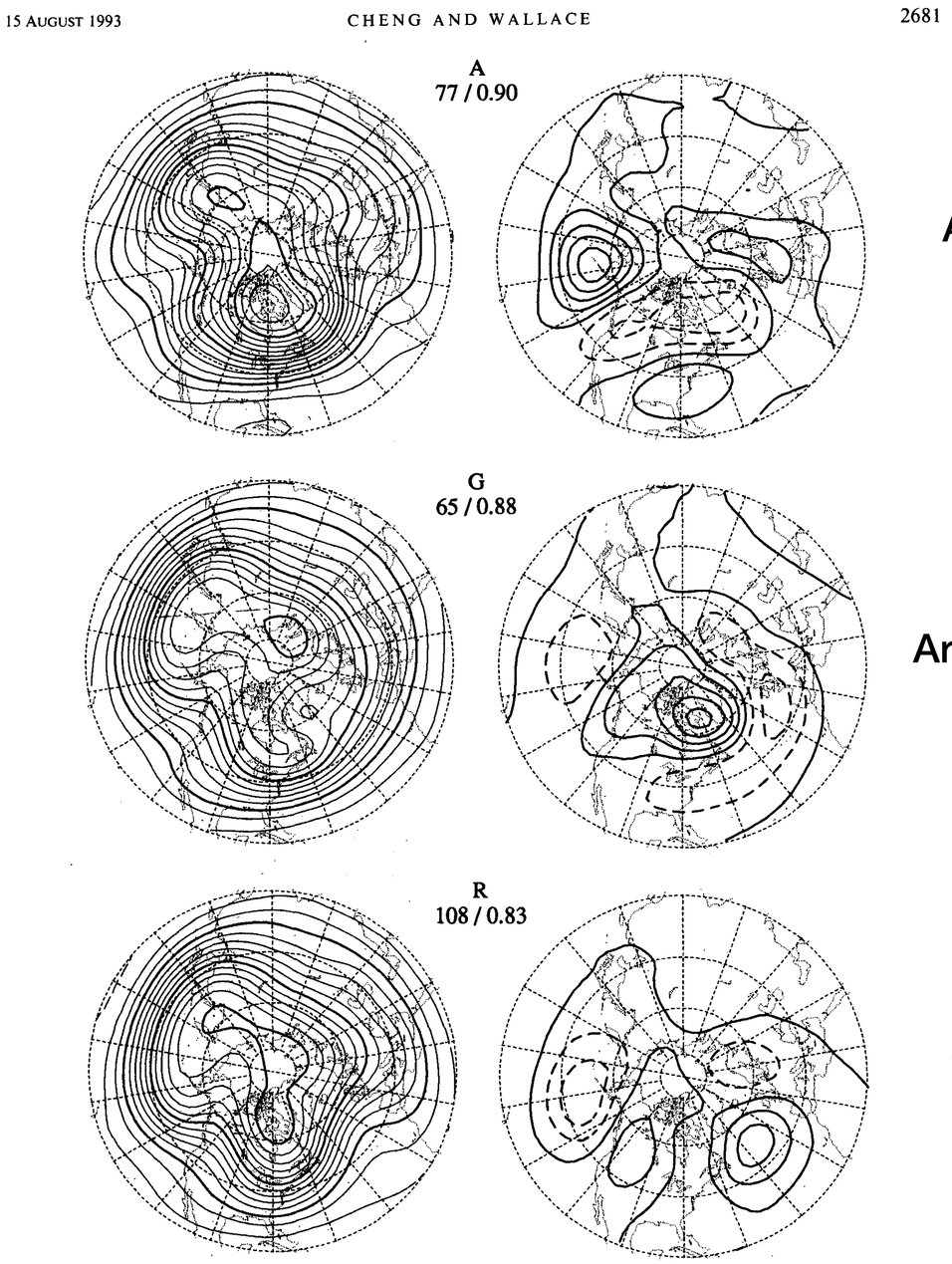


FIG. 4. Left: 500-hPa maps for the points in phase space that correspond to the centroids of the clusters labeled A, G, and R (indicated by boldfaced type in Fig. 3); contour interval 60 m. Right: The corresponding composite anomaly maps; contour interval 50 m, negative contours are dashed. Printed at the top of each panel is the number of maps in the cluster and the reproducibility parameter.

Outline

1. Weather Regimes over North America from Reanalysis; ENSO/MJO relationships; surface impacts

2. ECMWF model regimes and forecast skill

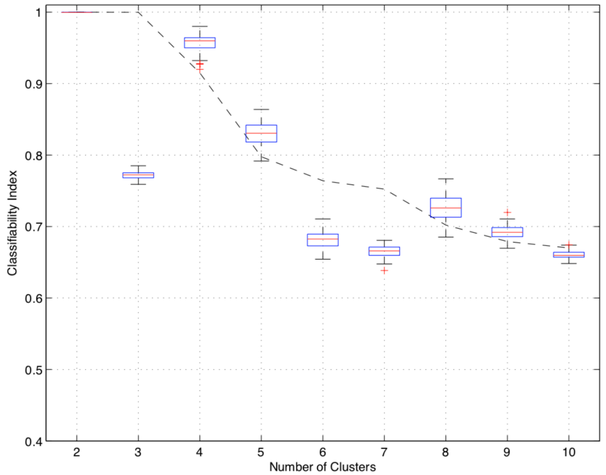
3. CFSv2 model regimes and forecast diagnostics

Weather Regimes over North America from Reanalysis

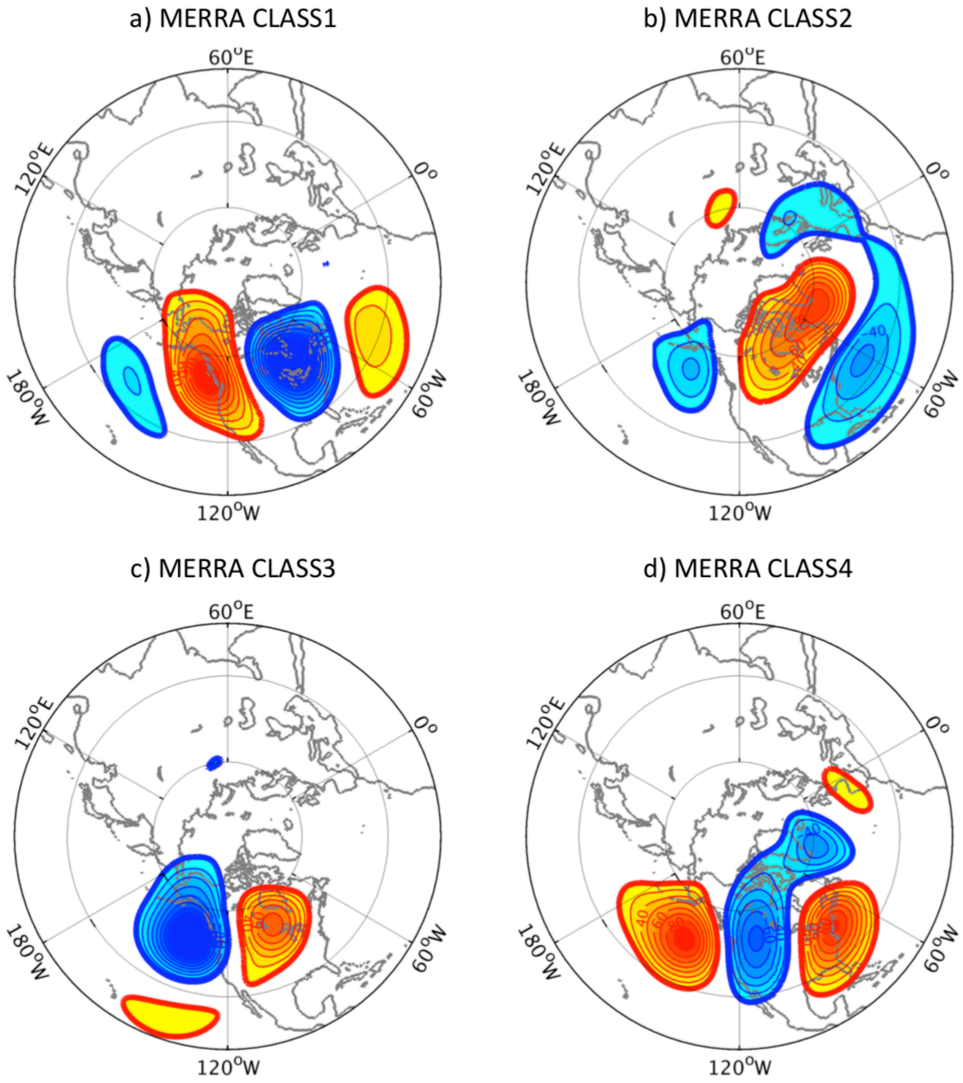
• K-means analysis of Z500 daily Oct-Mar fields from MERRA reanalysis data [150E-40W, 10N-70N], 1982-2014

• Anomalies from the mean seasonal cycle, filtered to retain larger scales using 10 leading EOFs

Maximum classifiability for
4 clusters



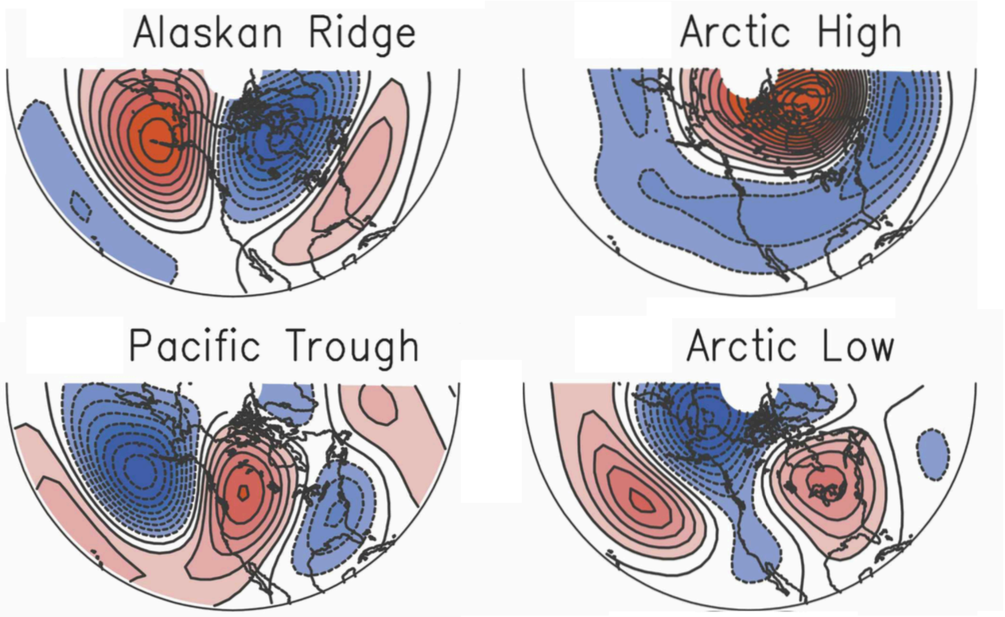
(the dashed line indicates 10% significance level according to a first-order Markov process)



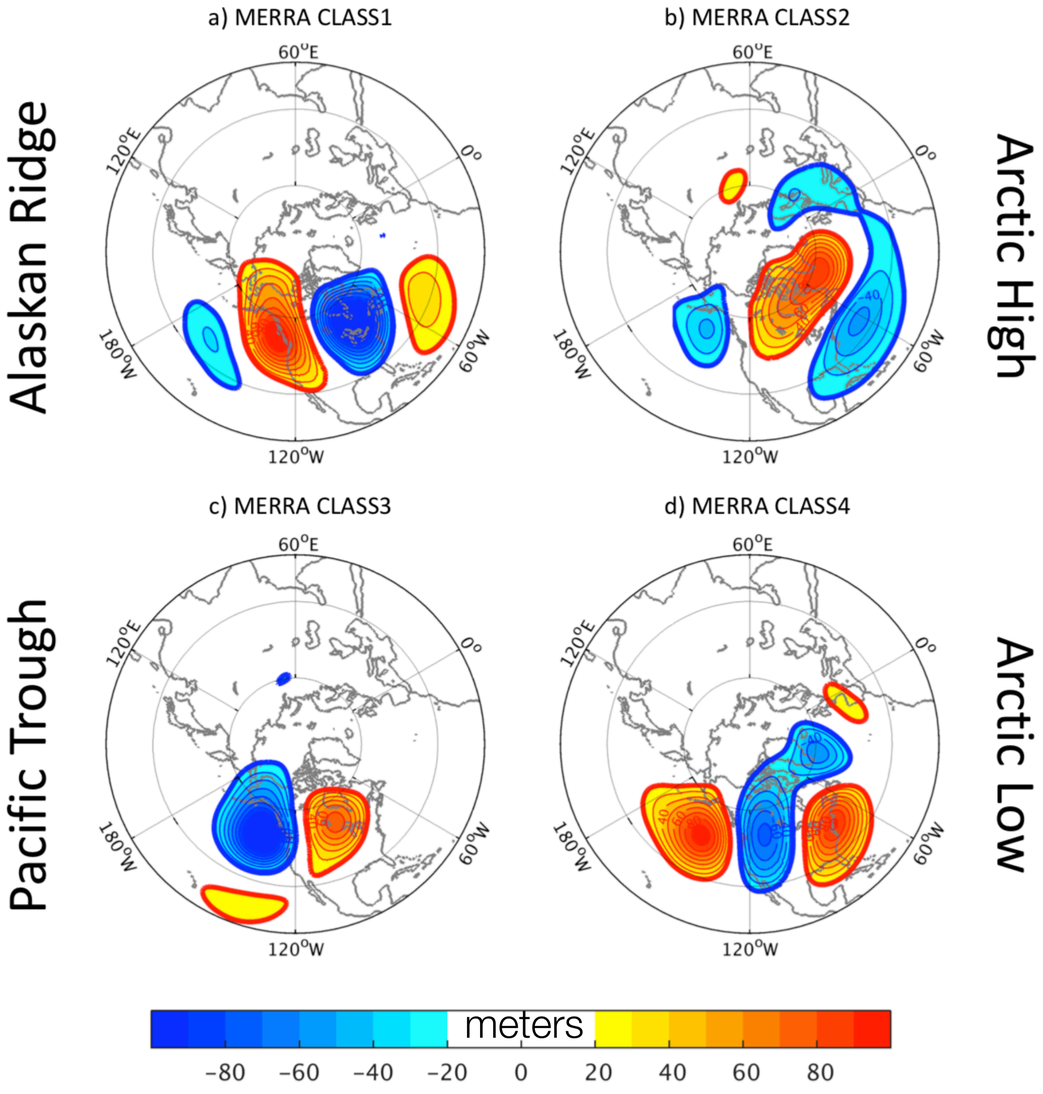
Weather Regimes over North America from Reanalysis

Similar to

Strauss and Molteni (2004)
Strauss et al (2007)
Stan and Strauss (2007)

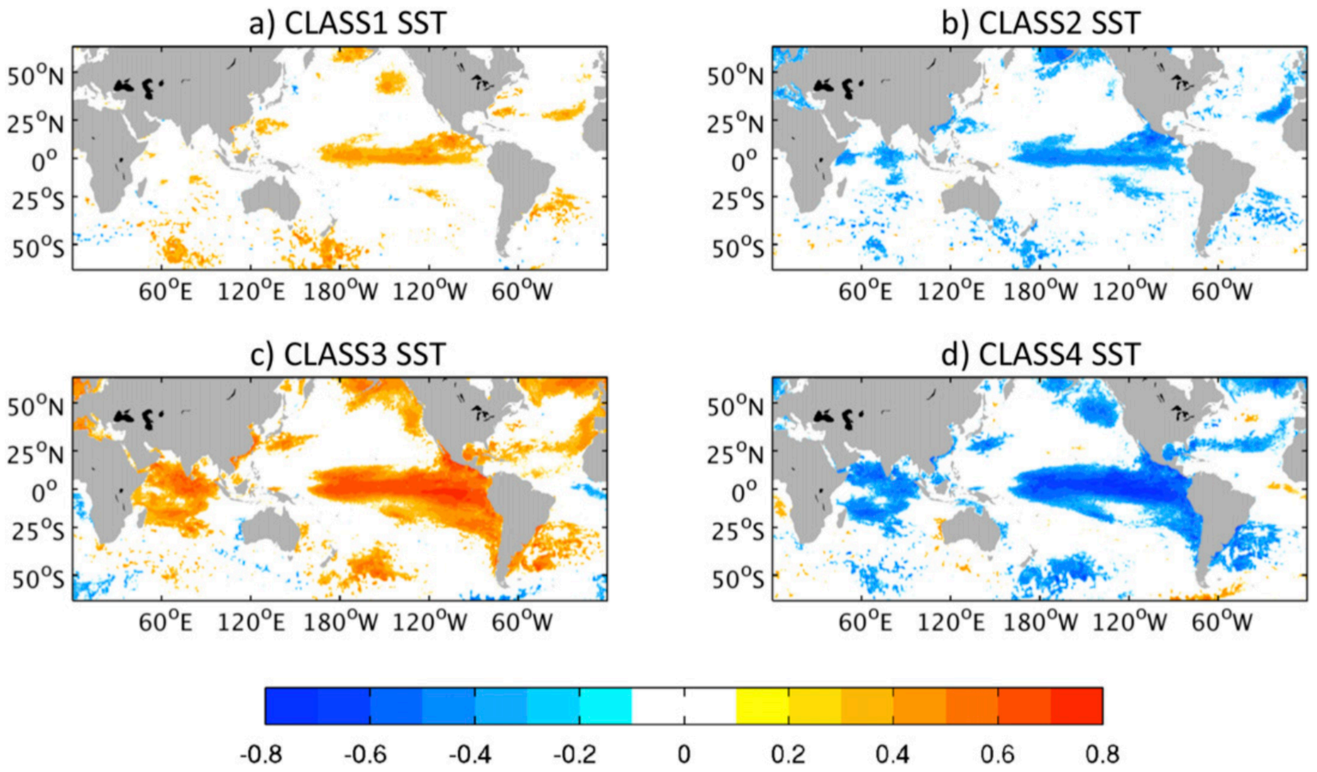


Based on NCEP Z200

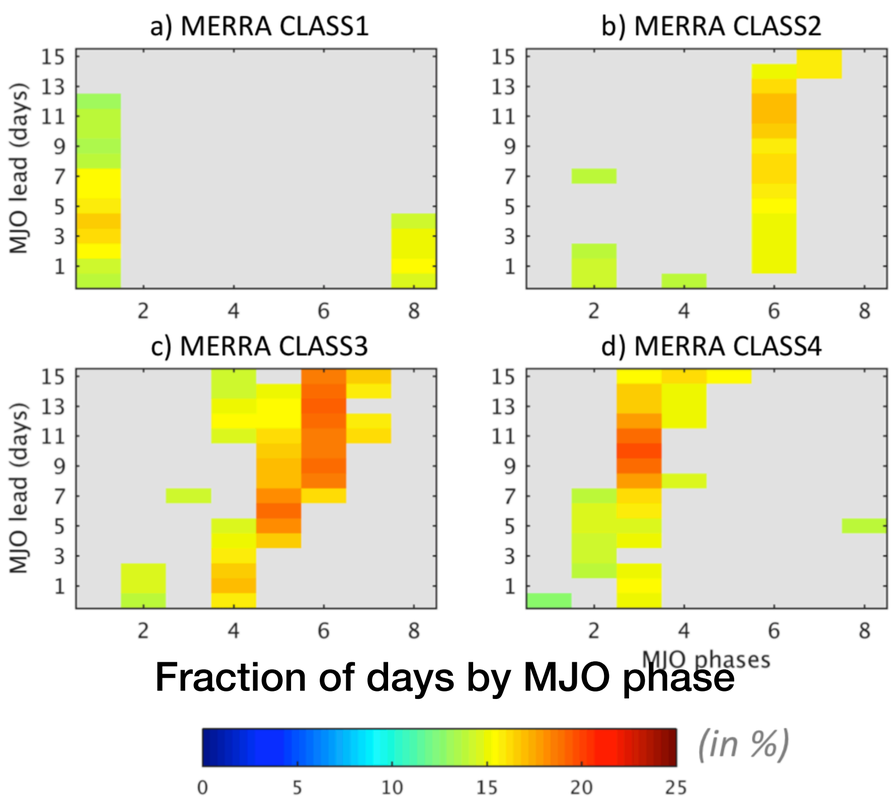


Drivers of Regime Occurrence

SST Year-to-Year Correlations

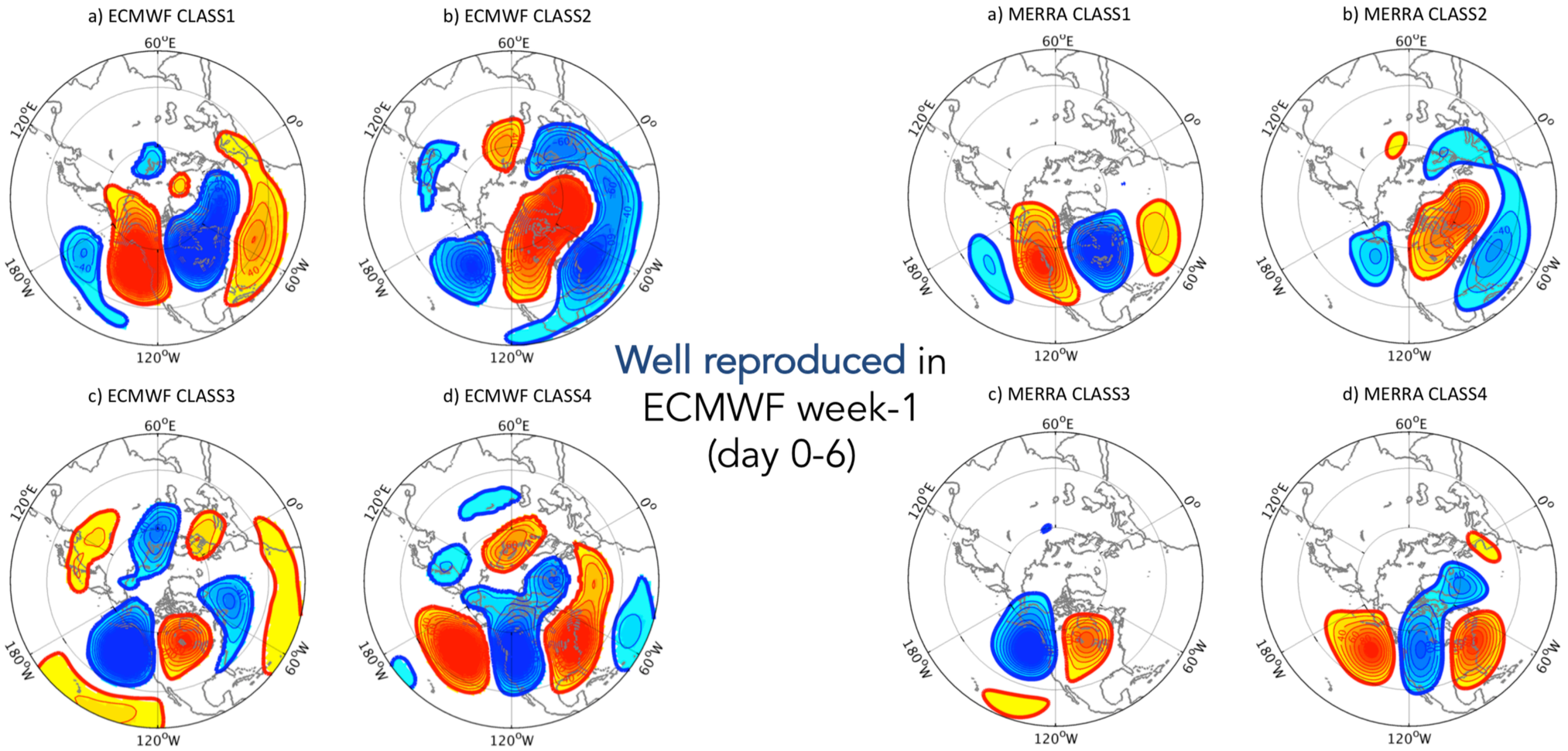


Precursor MJO Phase



- *Regime 3 (Pacific trough/PNA) is related to El Niño and 10–15 days after MJO phase 6*
- *Regime 4 (Arctic low/RNA) is related to La Niña and after MJO phase 3*

ECMWF Model's Regimes



Well reproduced in ECMWF week-1 (day 0-6)

Weather Regime Surface Impacts

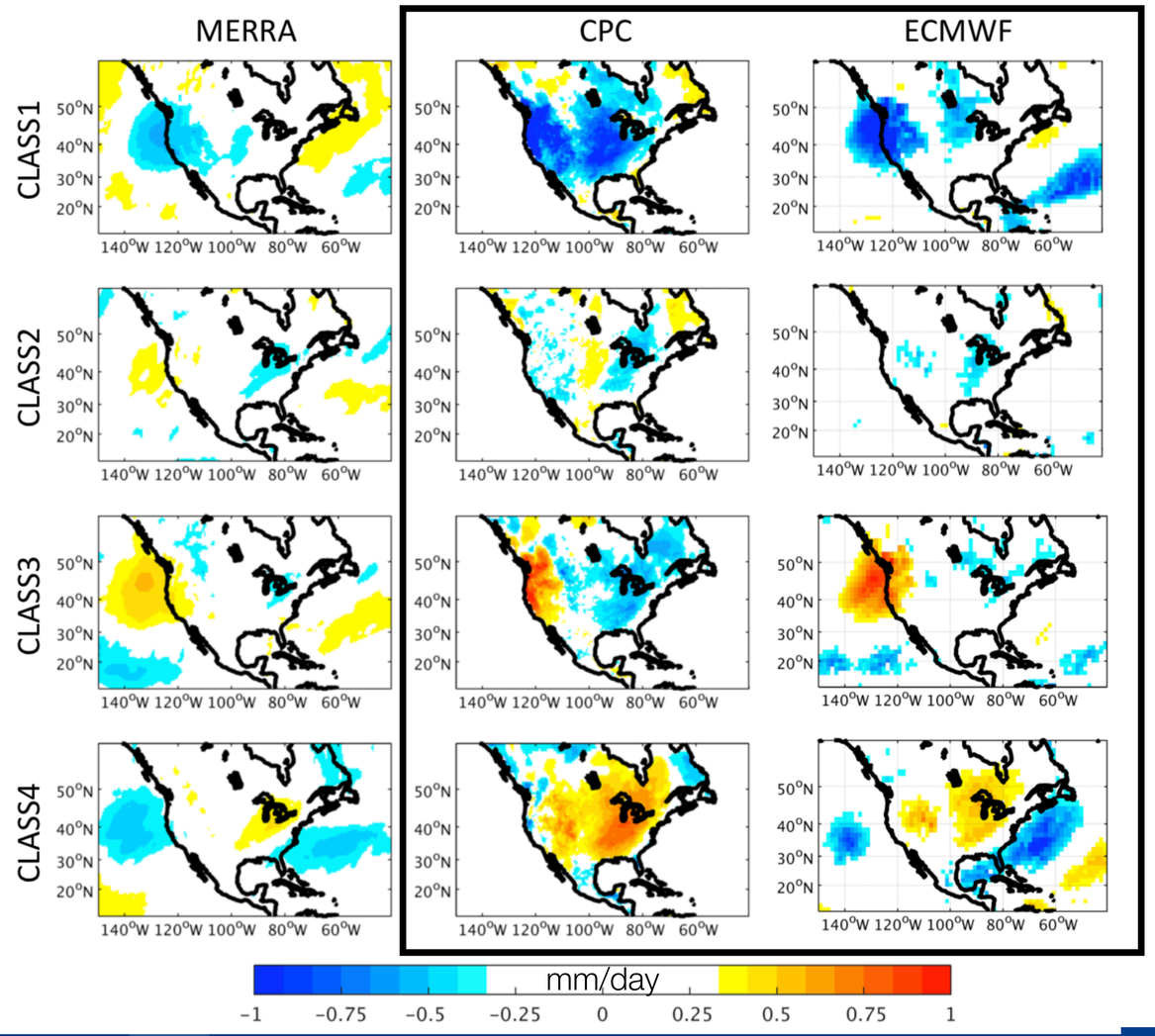
Alaskan Ridge

Arctic High (NAO-)

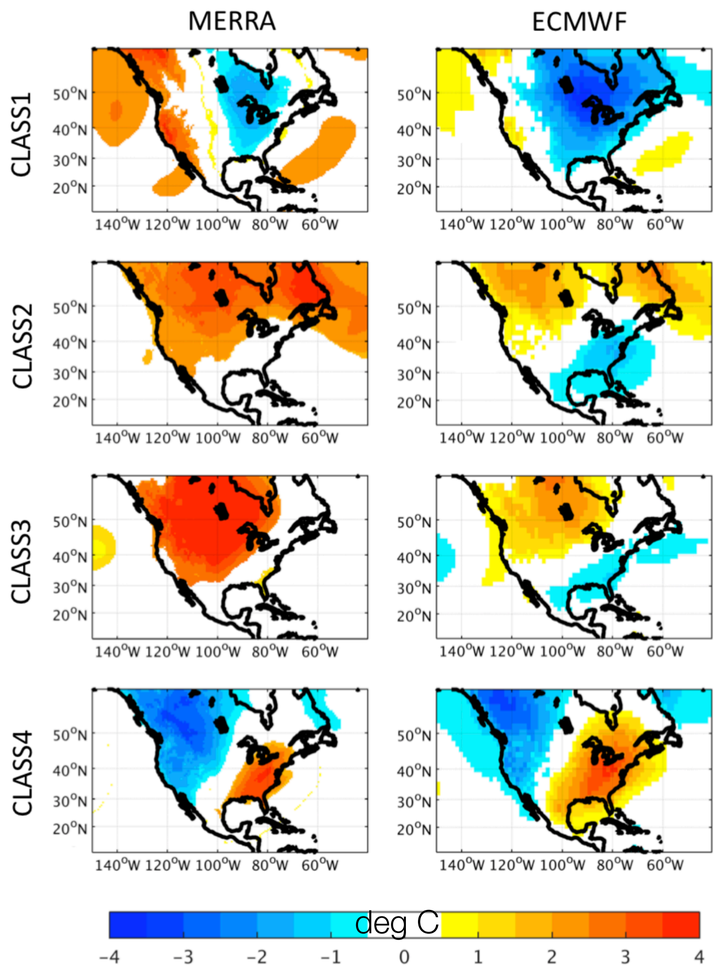
Pacific Trough (PNA)

Arctic Low (RNA)

Precipitation

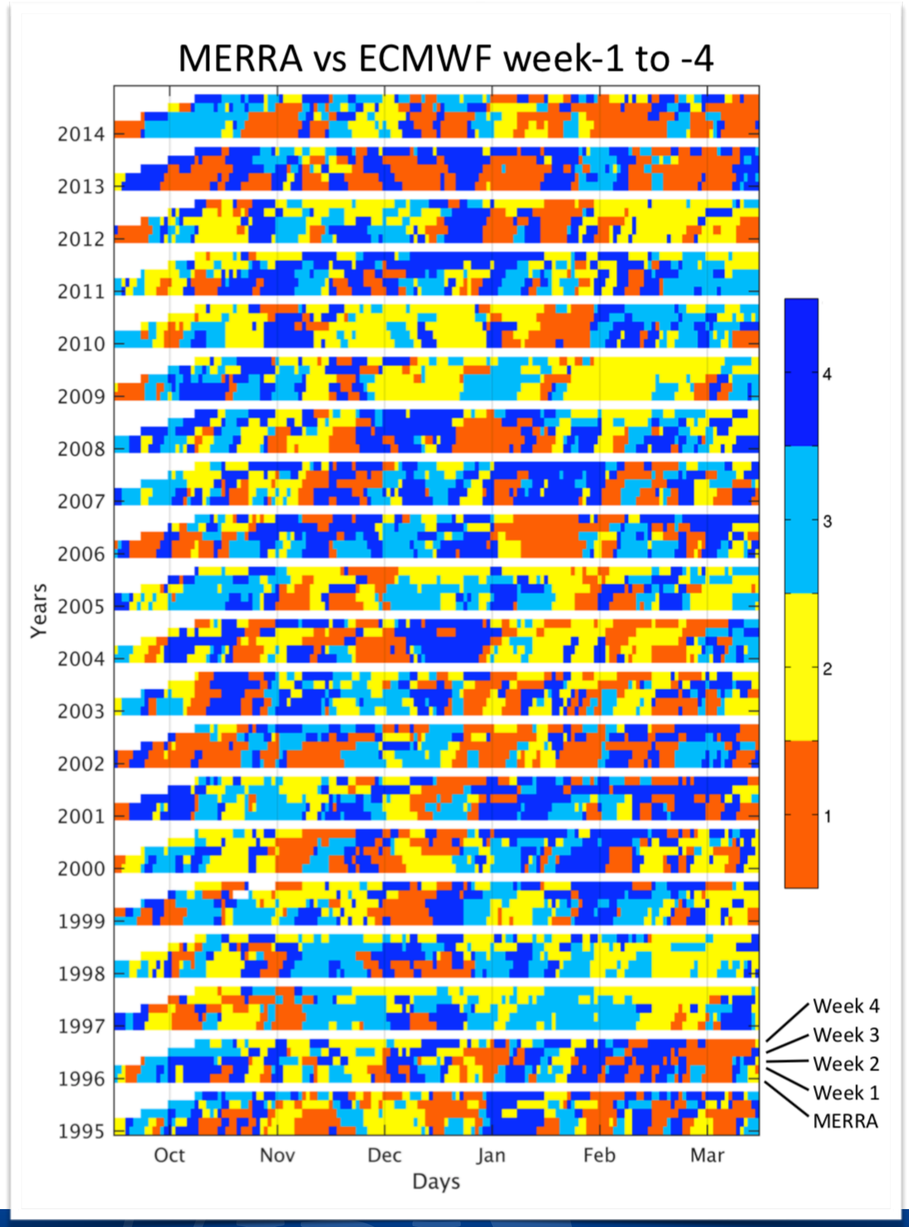


Temperature



Similar overall patterns between observed-data impacts and model's own surface impacts,
*But **substantial regional differences***

Are subseasonal transitions well forecasted?

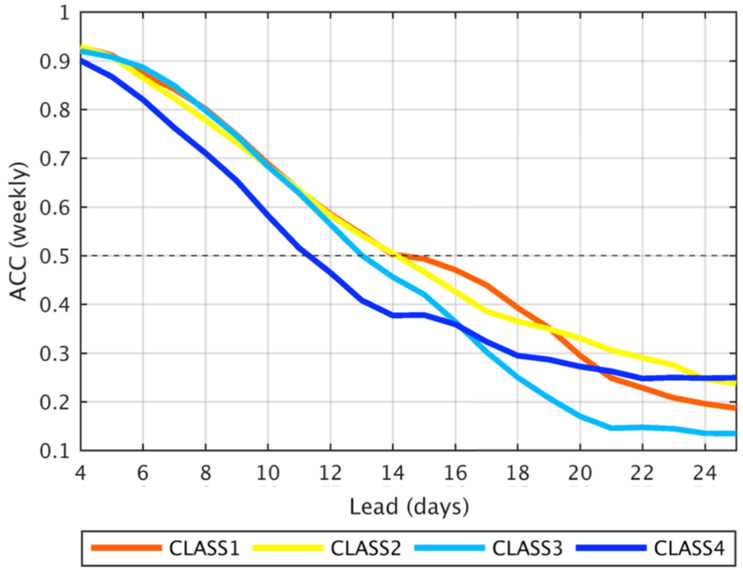


For each year, the first strip is the MERRA sequence.
The 4 strips above correspond to week-1 to week-4 leads.

ECMWF Forecasts in Regime Space

Weekly counts

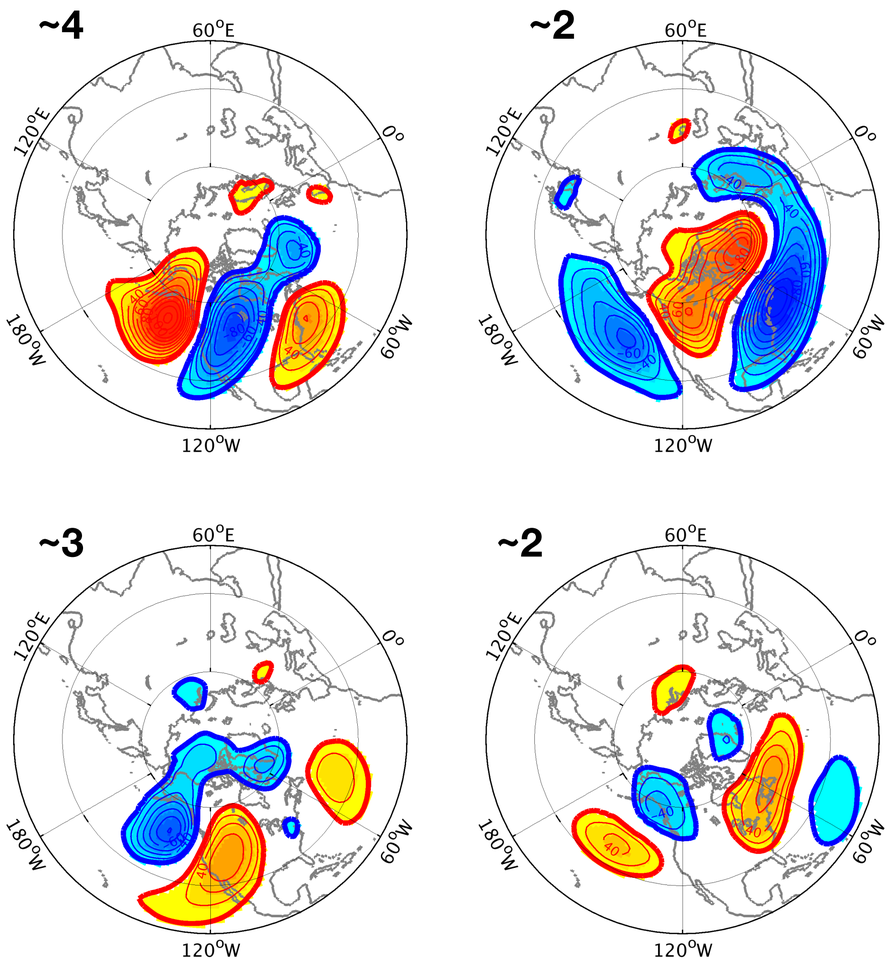
(7-day sliding window targets i.e., [d-3,d+3] for a lead of d days)



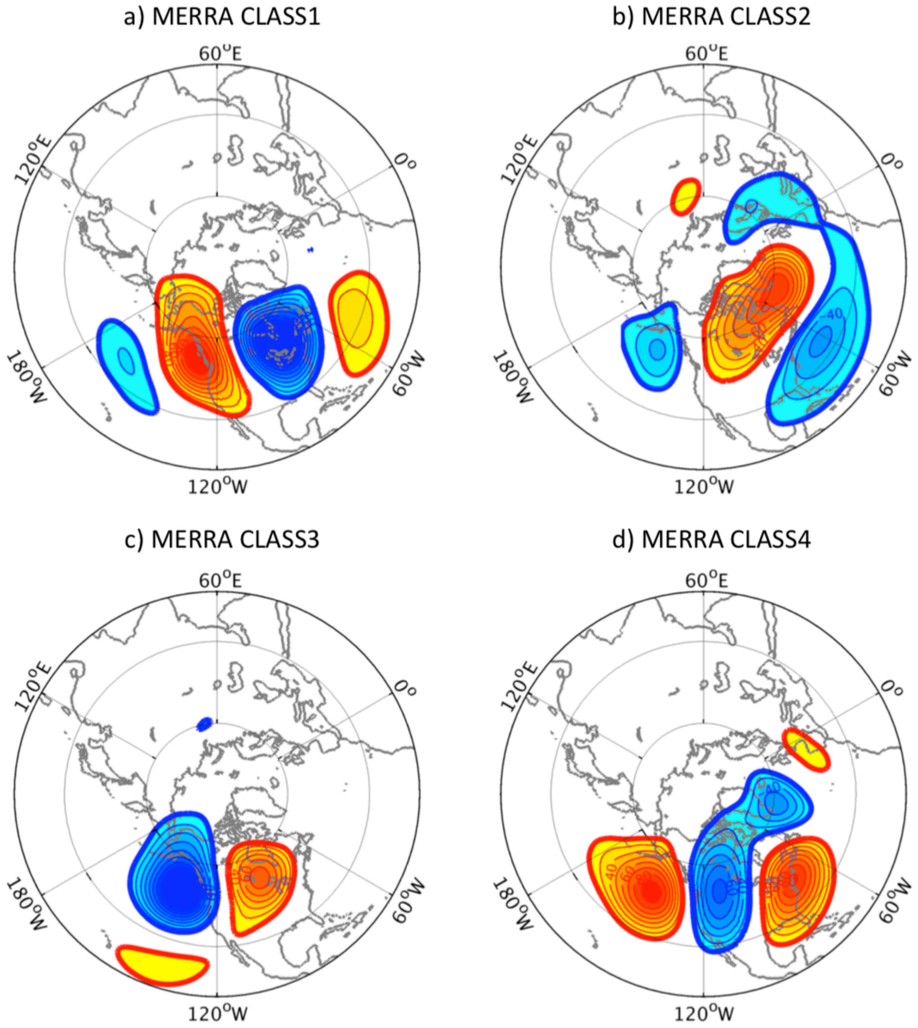
Limited skill after 2 weeks
consistent with probabilistic forecast skill

All ECMWF reforecasts projected onto MERRA weather regimes

CFSv2 Week-1 Regimes

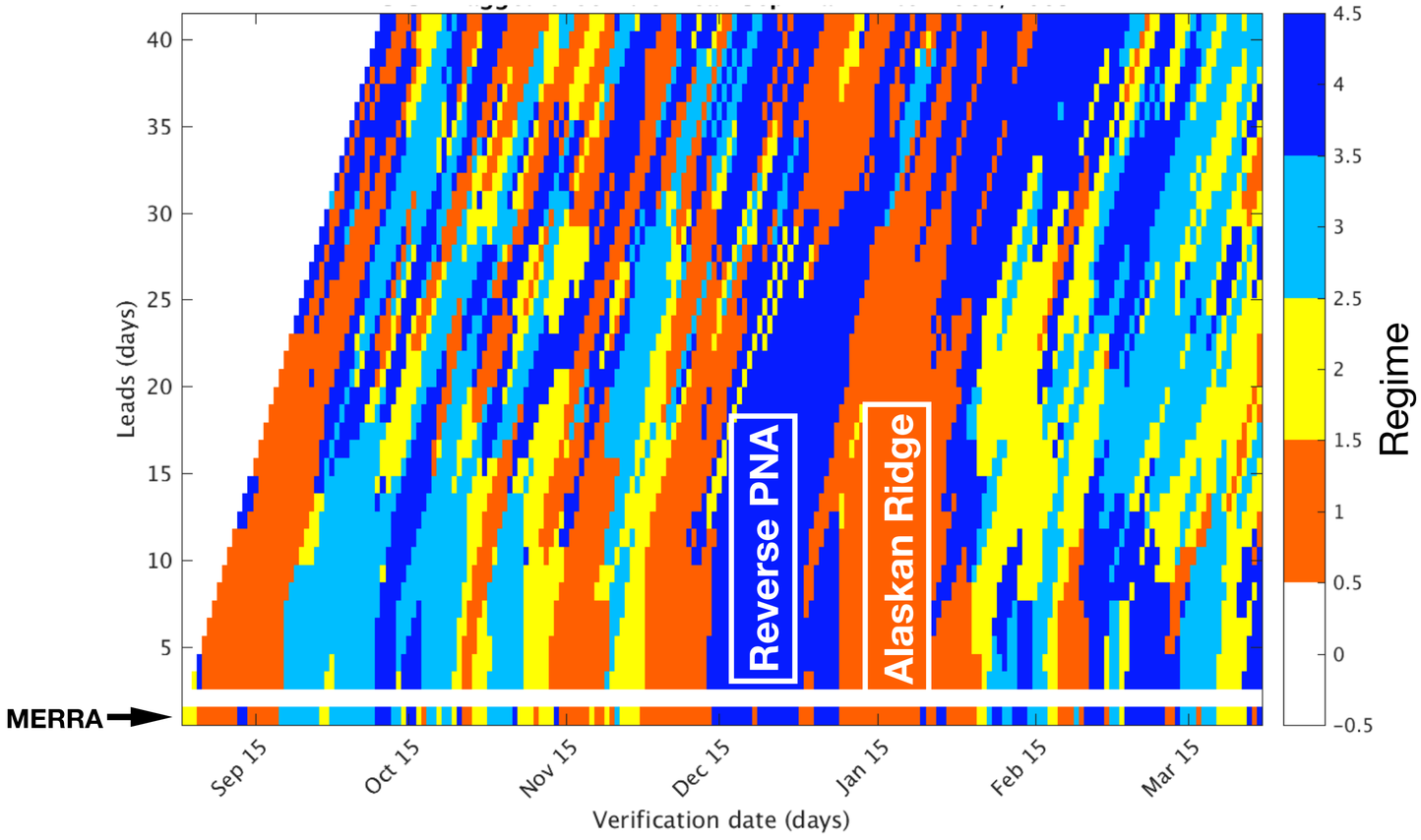


Weaker correspondence in structure than ECMWF model

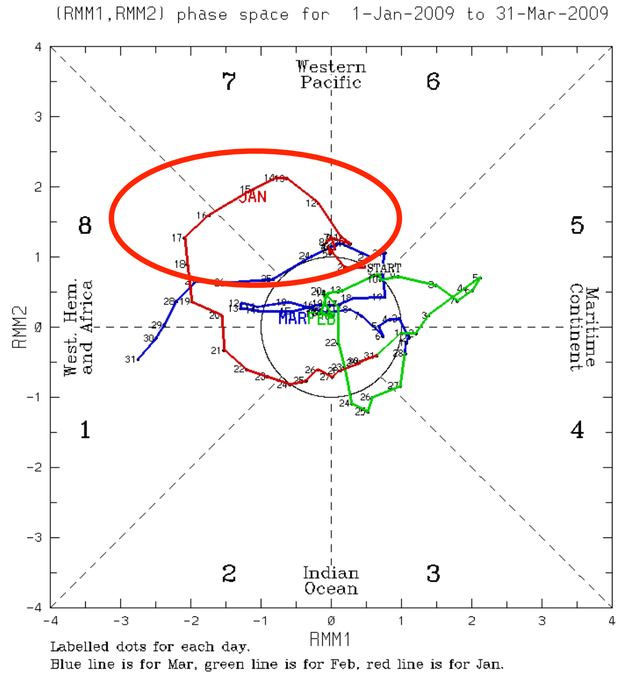


Diagnostics: CFSv2 Hindcasts of 2008/9 Winter

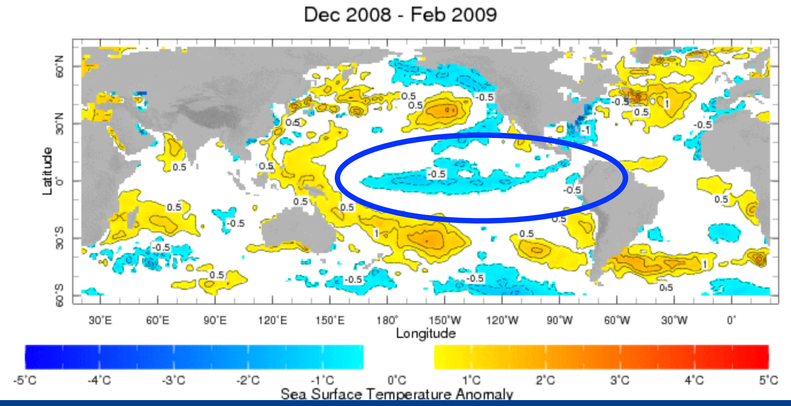
CFSv2 3-day lagged ensemble means, 5-day means projected on MERRA Regimes, 2008/9



Jan–Feb Regime 4–>1 Episode and transition
Well forecast up to 4 weeks ahead

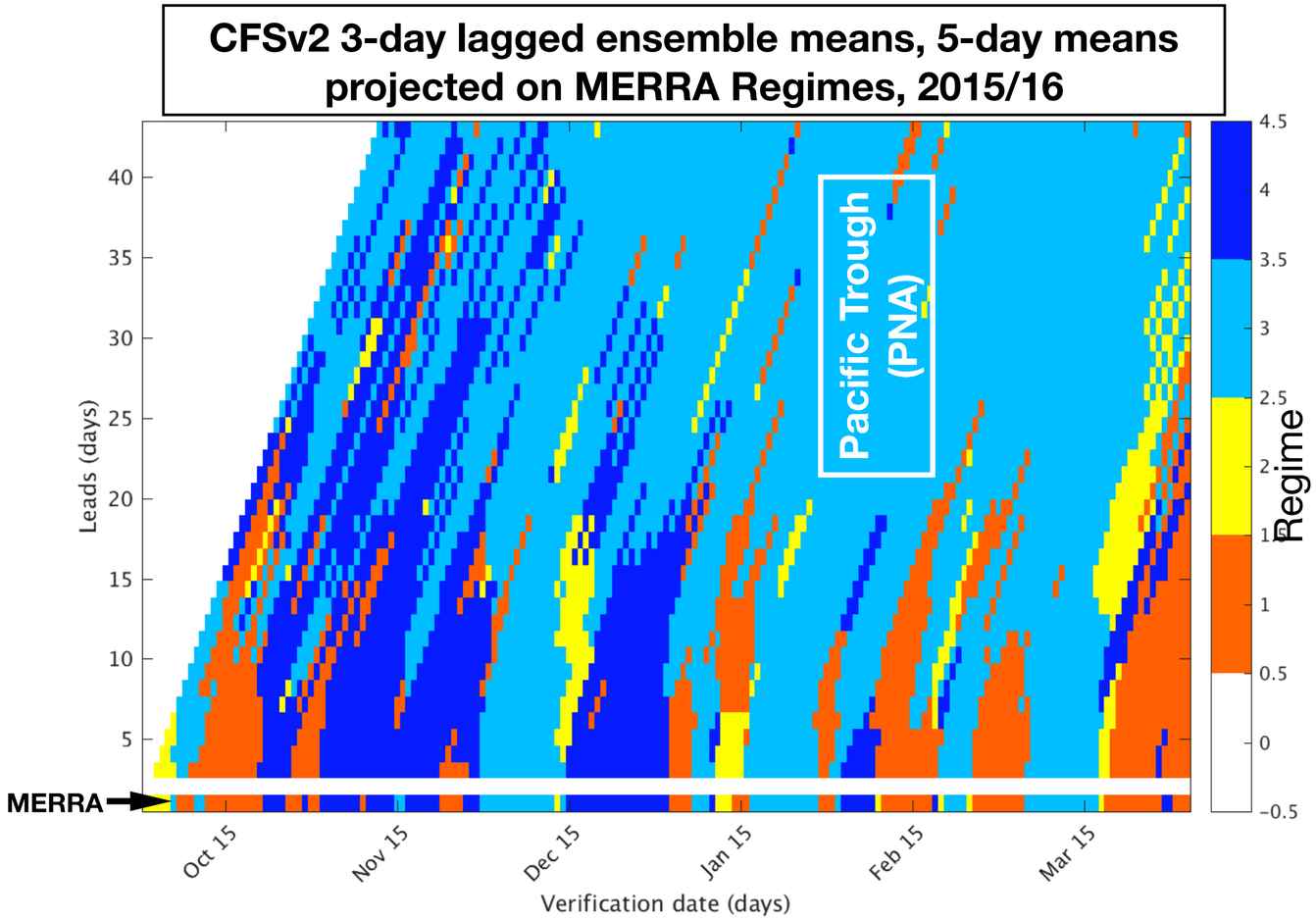


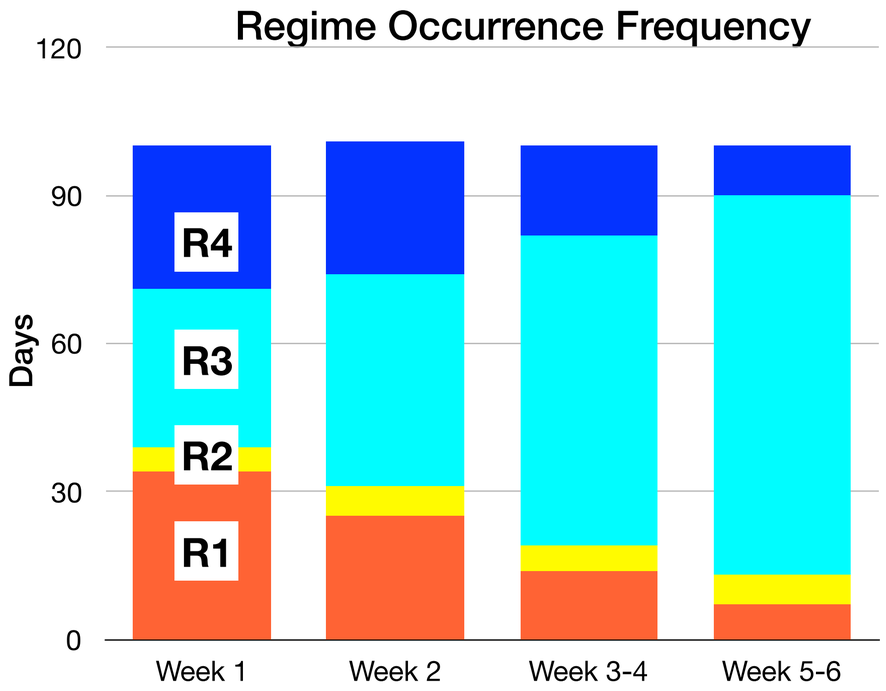
MJO



SST Anomalies

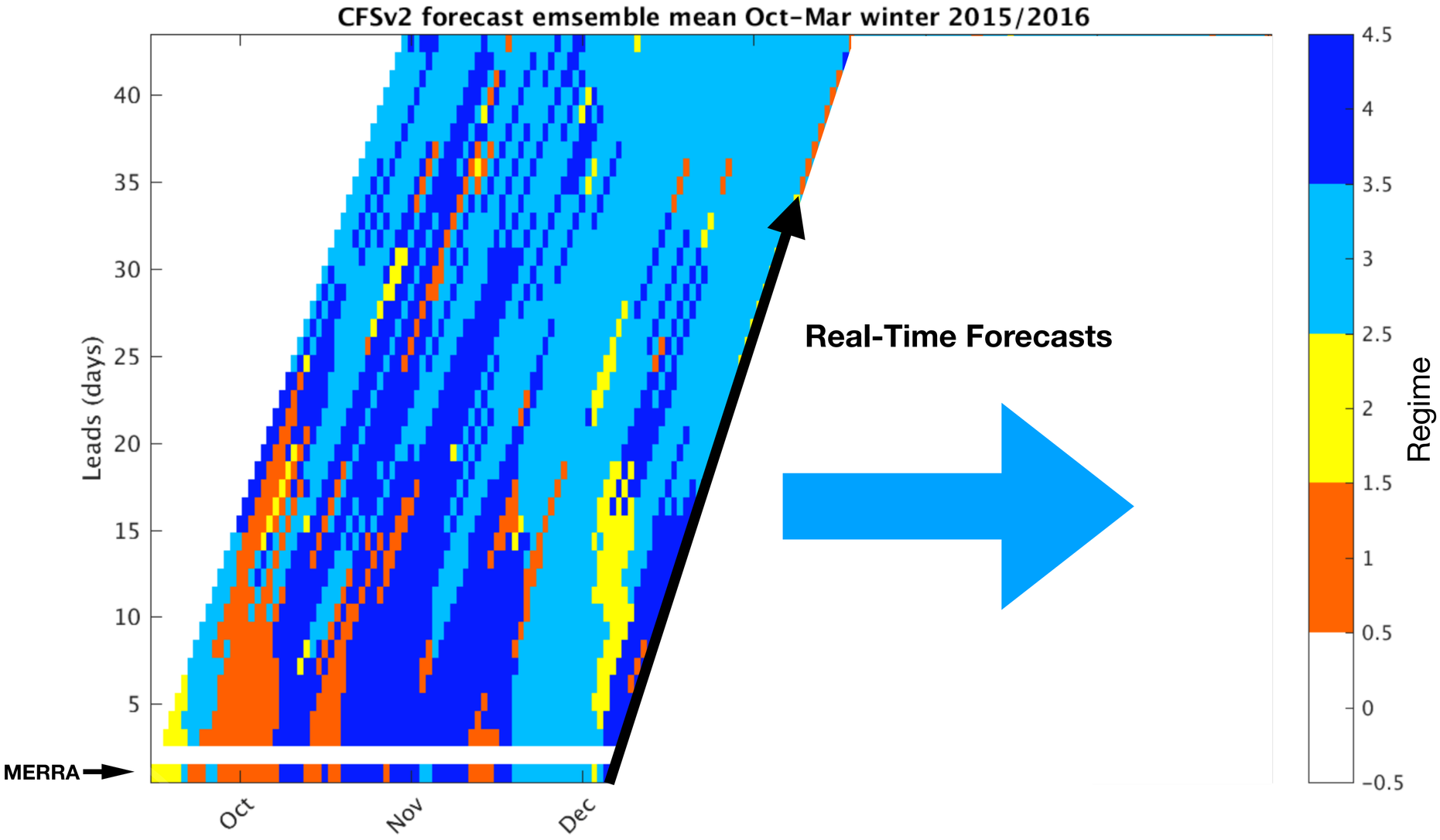
Diagnostics: CFSv2 Forecasts of 2015/16 Winter





*Regime 3 was **over-forecast** at S2S lead times*

Real-time Forecast Diagnostic Tool



Summary

Project Objectives

1. Develop a small set of **weather regimes**, based on previous work, from reanalysis extended winter (November–April) circulation fields that capture week 3–4 variability in precipitation and near-surface air temperature over the U.S., including extremes.

2. Evaluate the ability of CFSv2 and ECMWF reforecasts to represent the spatial structures and regime transition probabilities of these WRs in circulation, and identify model systematic errors in these LSMPs.

3. Identify specific cases of “windows of opportunity” in the WR subspace, in which potential predictability is high due to the combined impacts of MJO, ENSO and stratospheric modes, and diagnose forecast performance of these cases.

4. Develop forecast-guidance tools based on the WR subspace to visualize the current atmospheric initial state and forecast ensemble evolution.

5. Develop a perfect-prognosis downscaling from WRs to daily precipitation and temperature characteristics and hazards, to provide additional guidance to the CPC operational forecasters.

Key Results

- Set of 4 K-means daily Geopotential height map regimes, whose occurrence is related to ENSO and MJO phases and precip/temperature patterns over North America.
- ECMWF model at day 1–7 leads reproduces these regime structures well from independent analyses; CFSv2 less so.
- ECMWF & CFSv2 models good skill out to 10–15 days.

- Cases of good skill up to 4 weeks ahead such as Dec-Feb 2008/9, associated with ENSO and possibly MJO.
- Regime 3 greatly over-forecasted in 2015/16.

- Chiclet diagrams give graphic views of forecast performance in individual years, highlighting signal, noise & performance with lead time.
- Plan to implement as real-time forecast-guidance tool.