

Weather regime diagnostic tools for wintertime sub-seasonal ensemble forecasts

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Outline

1. Weather Regimes over North America from Reanalysis; ENSO/MJO relationships; surface impacts
2. ECMWF model regimes
3. CFSv2 subseasonal forecast regime diagnostics



Weather Regimes

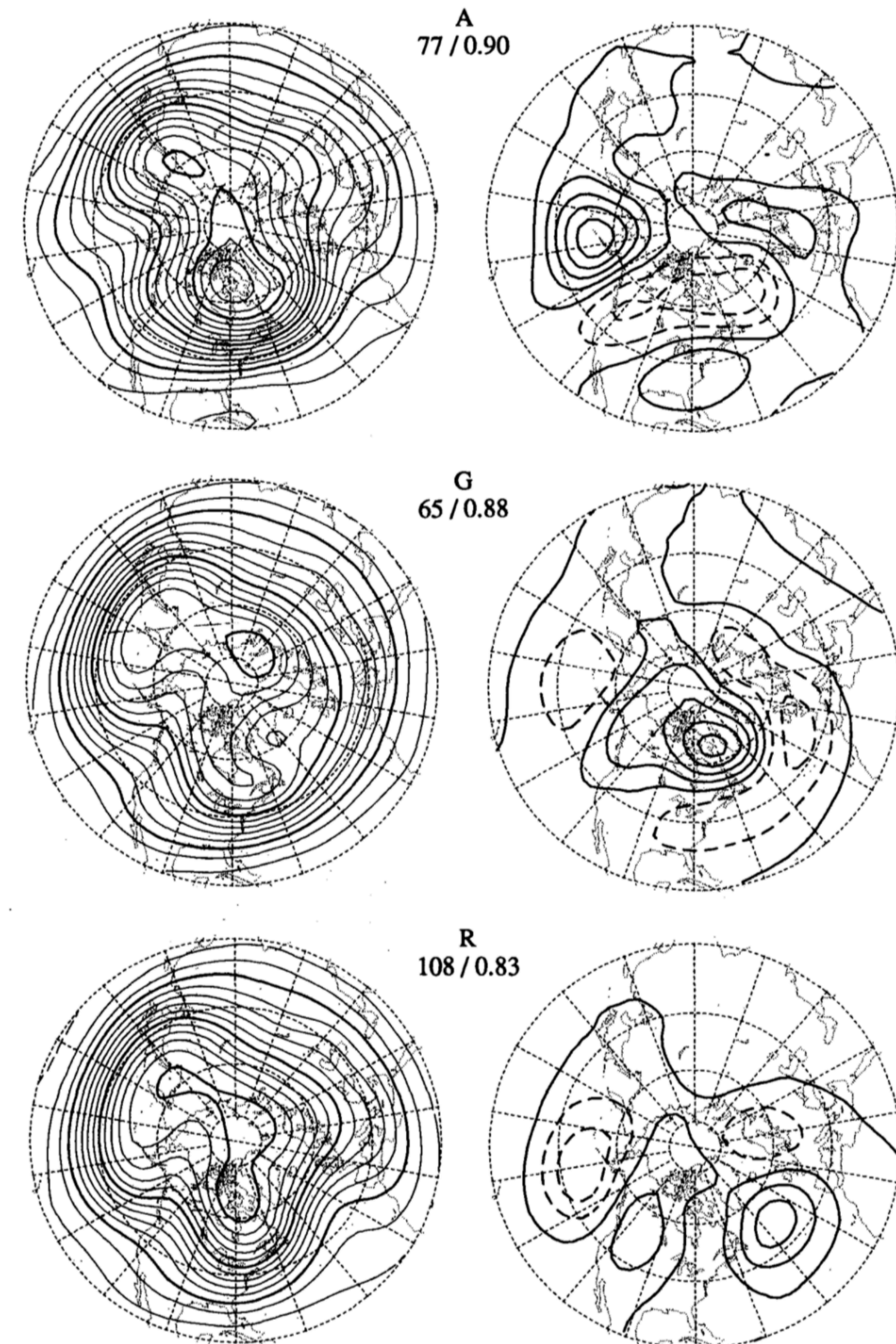
aka Large Scale Meteorological Patterns

- 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?

15 AUGUST 1993

CHENG AND WALLACE

2681



Alaskan
Ridge
(RNA)

Greenland
High
(NAO-)

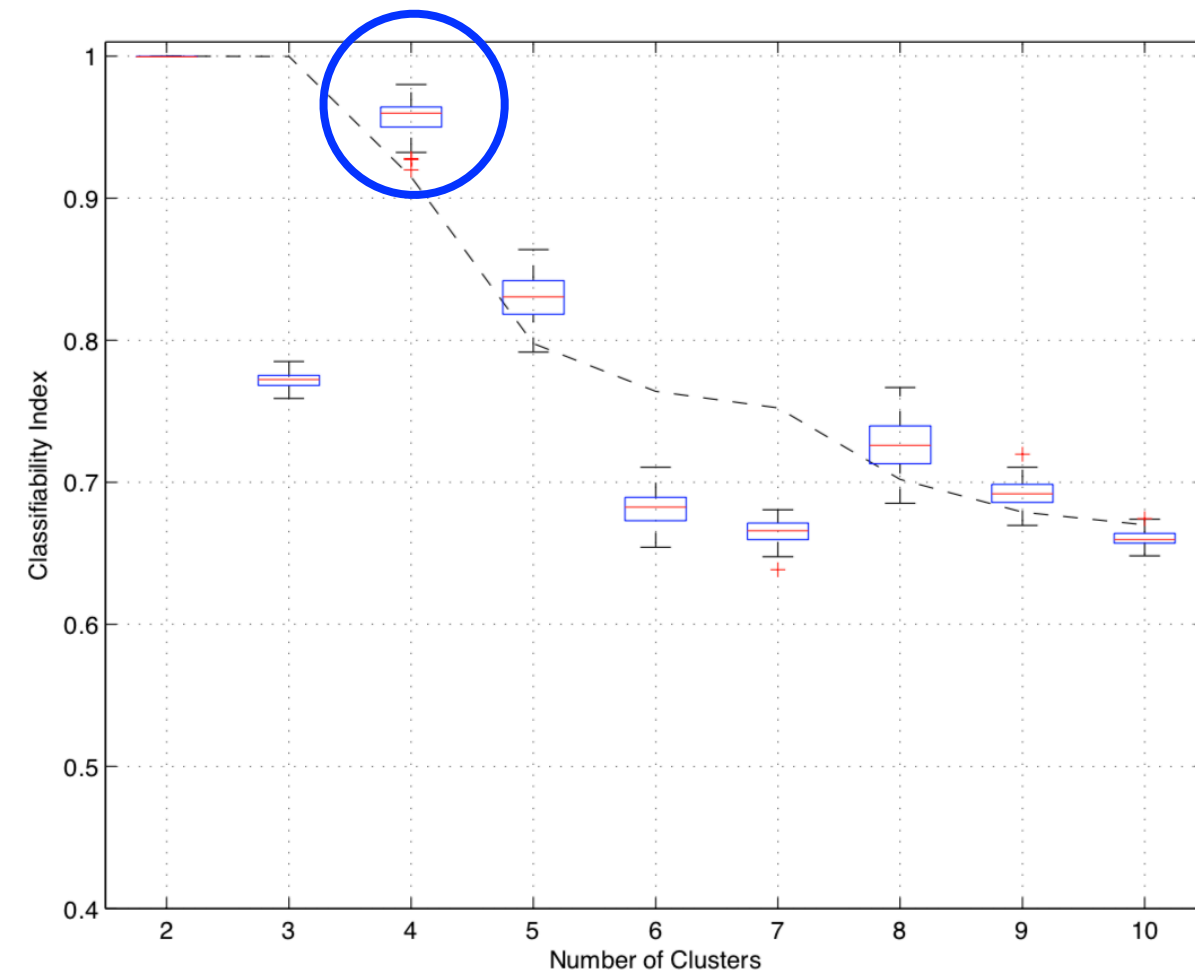
Pacific
Trough
(PNA)

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.

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

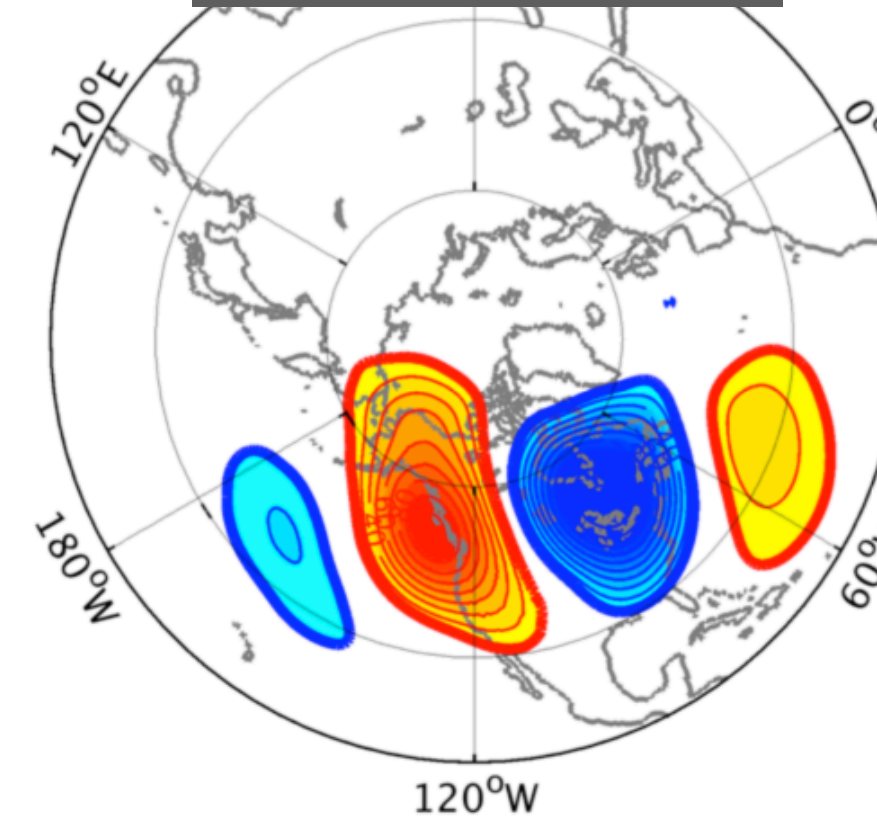
Maximum classifiability for 4 clusters



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

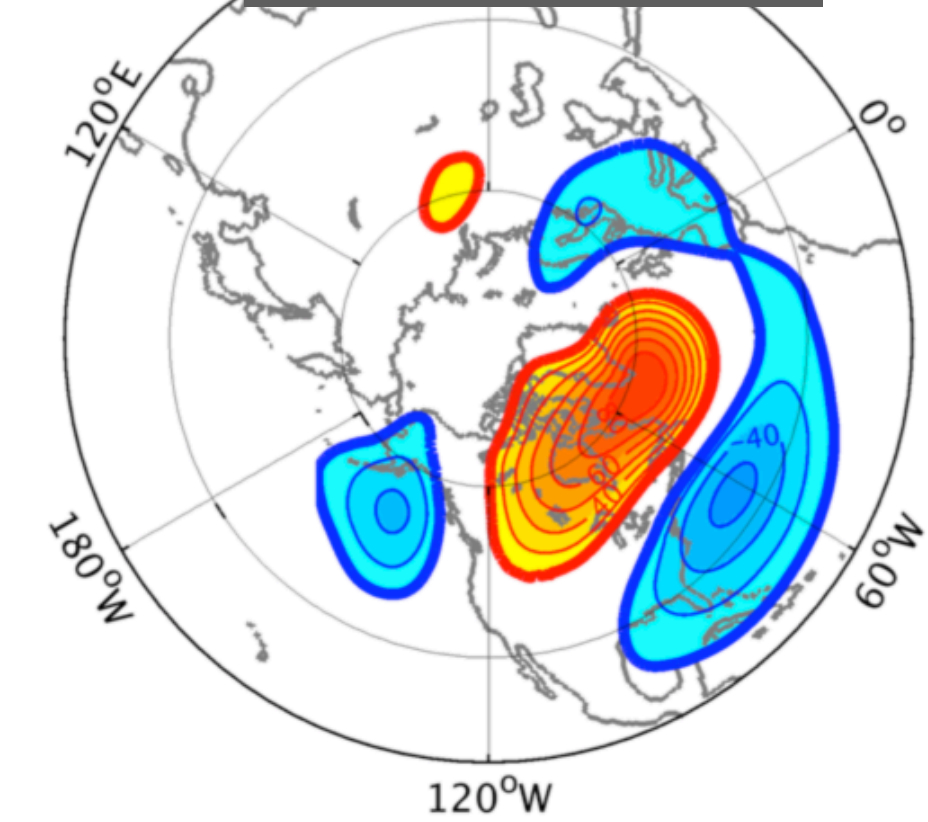
a) MERRA CLASS1

Alaskan Ridge



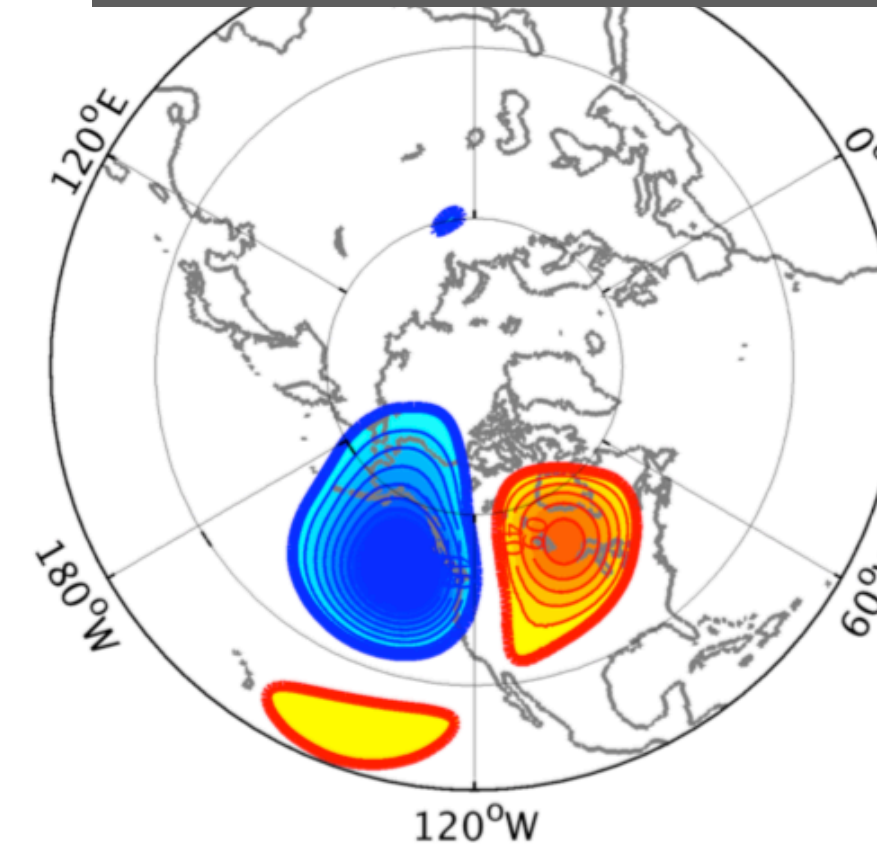
b) MERRA CLASS2

NAO Negative



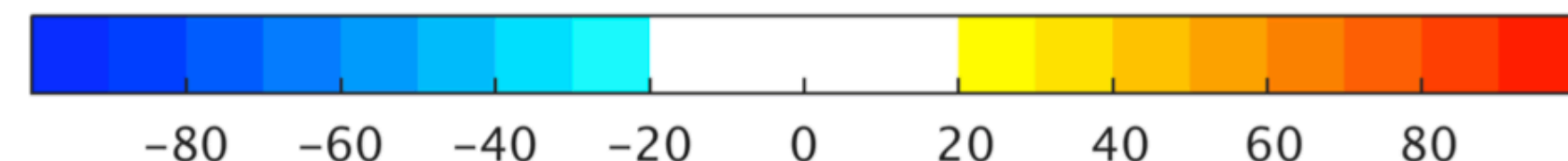
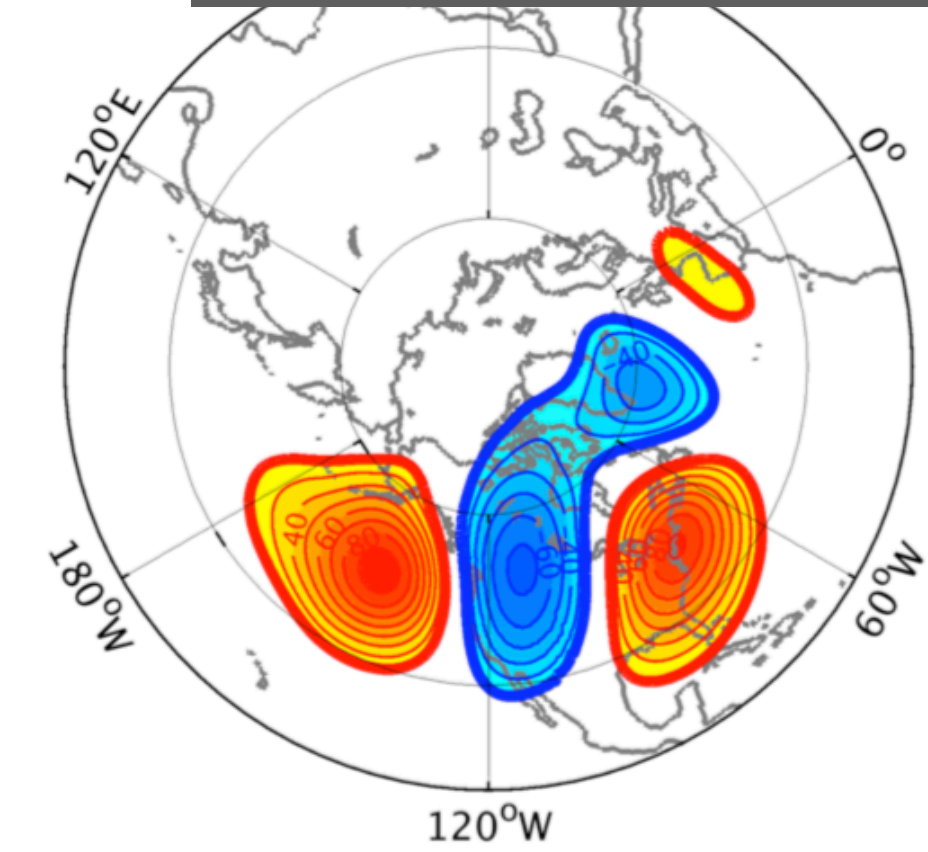
c) MERRA CLASS3

Pacific Trough/PNA



d) MERRA CLASS4

Pacific Ridge/RNA



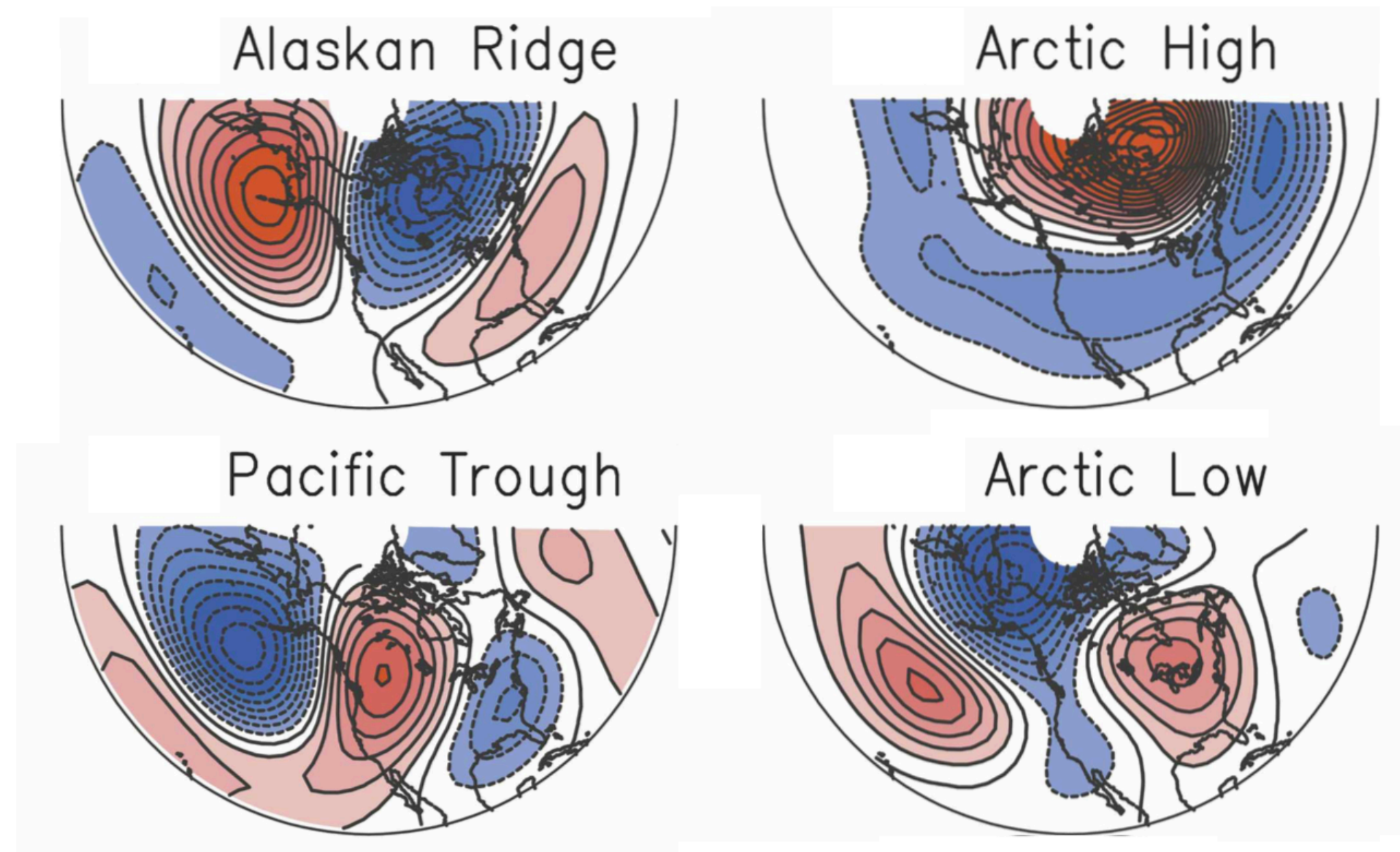
Weather Regimes over North America from Reanalysis

Similar to

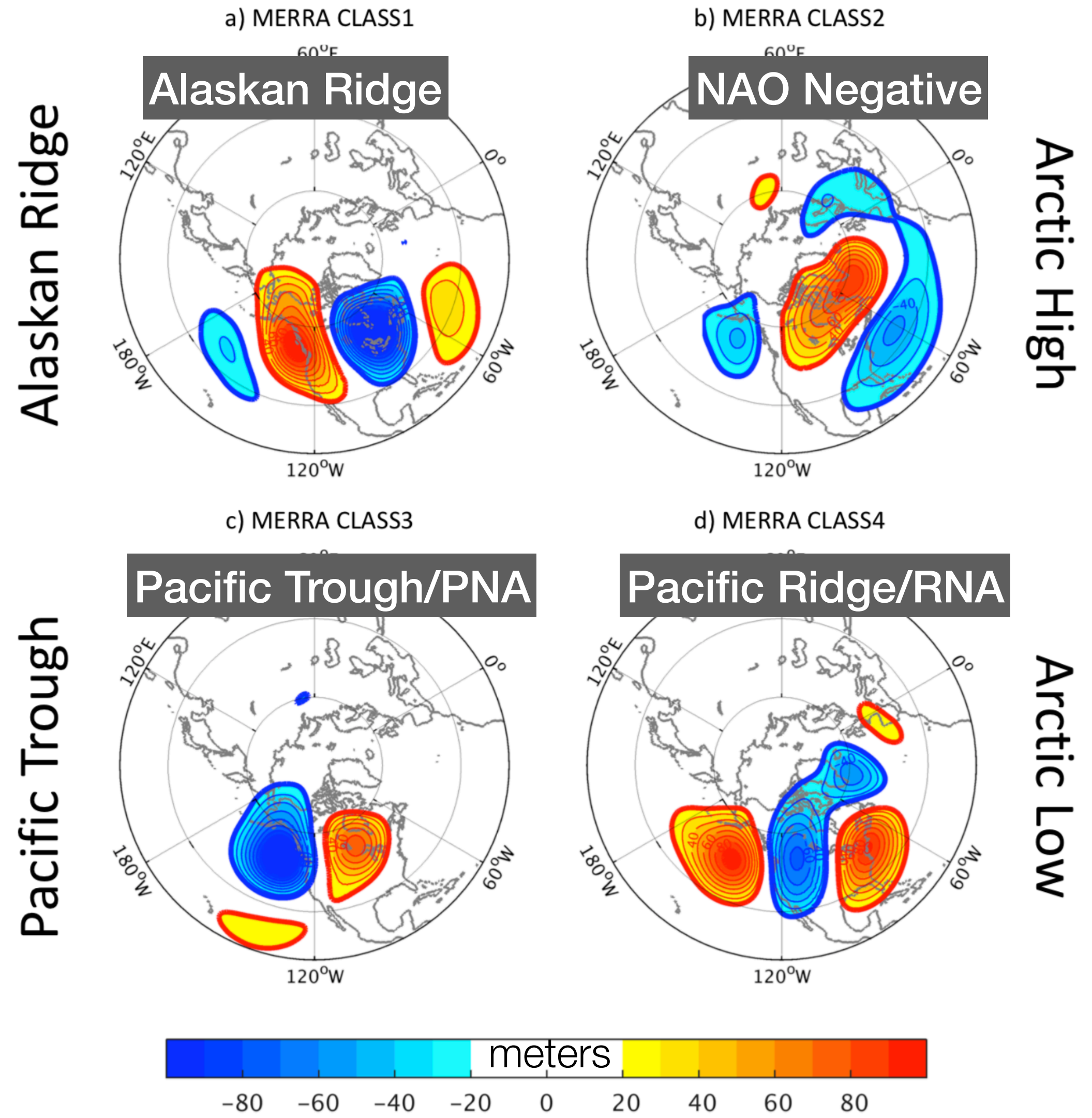
Strauss and Molteni (2004)

Strauss et al (2007)

Stan and Strauss (2007)



Based on NCEP Z200

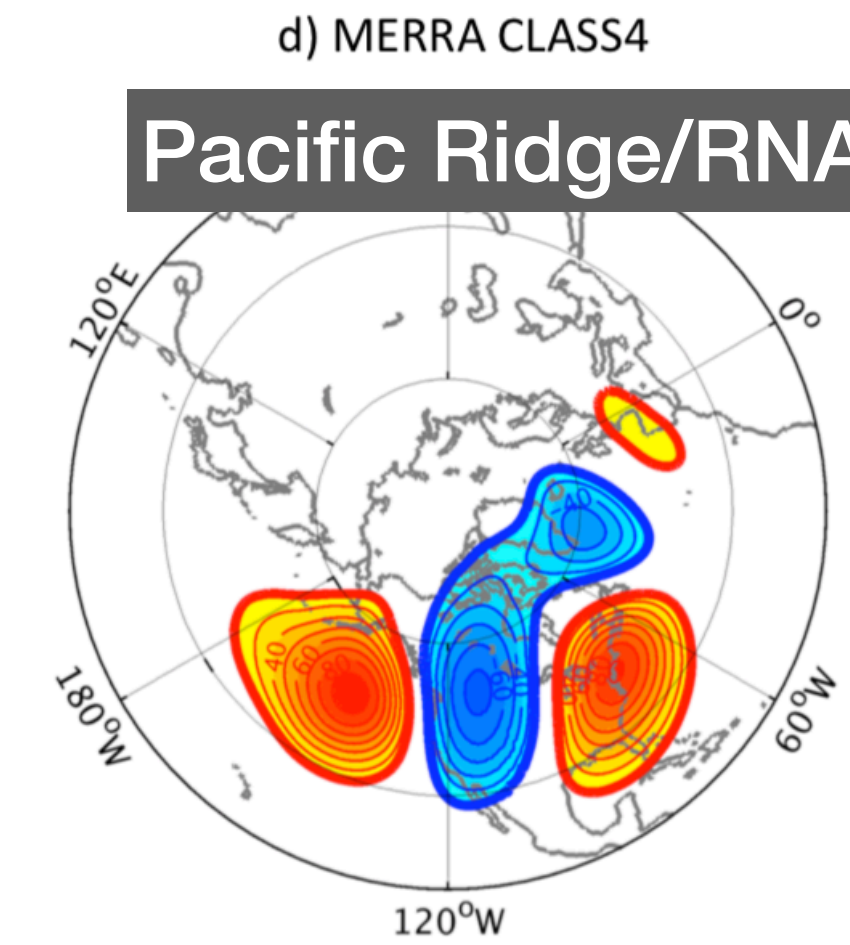
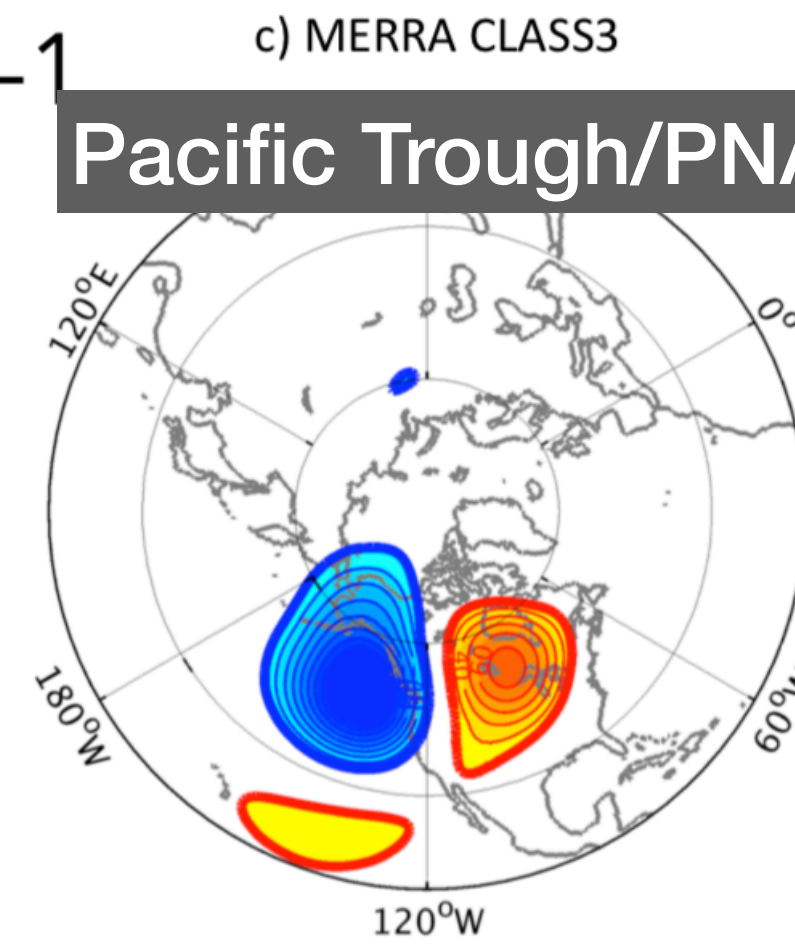
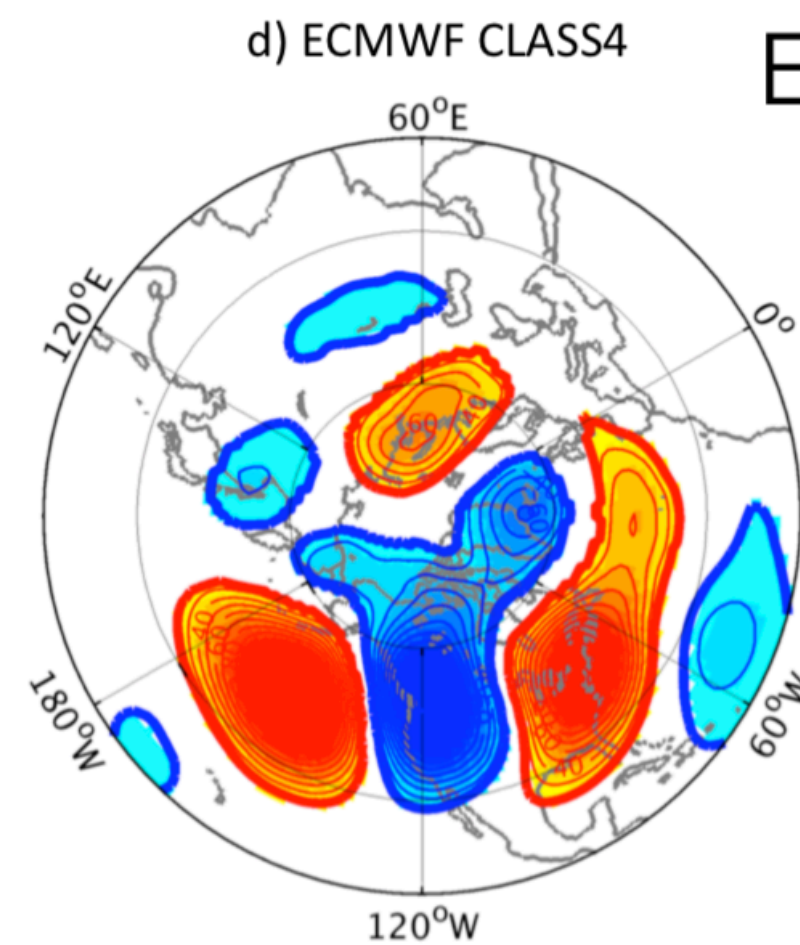
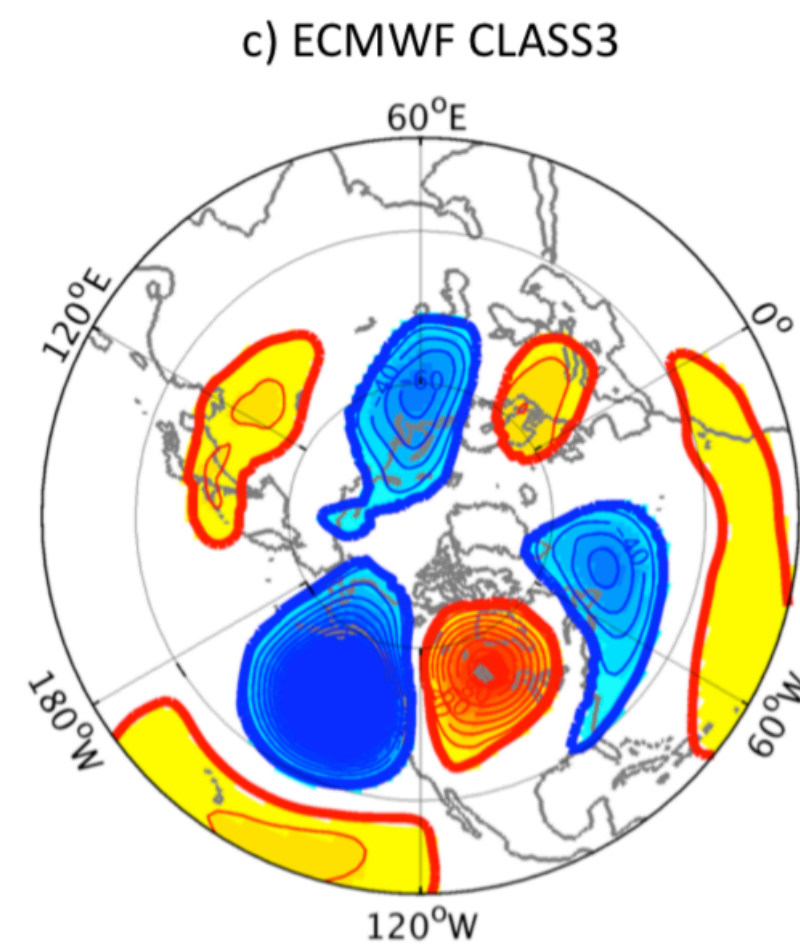
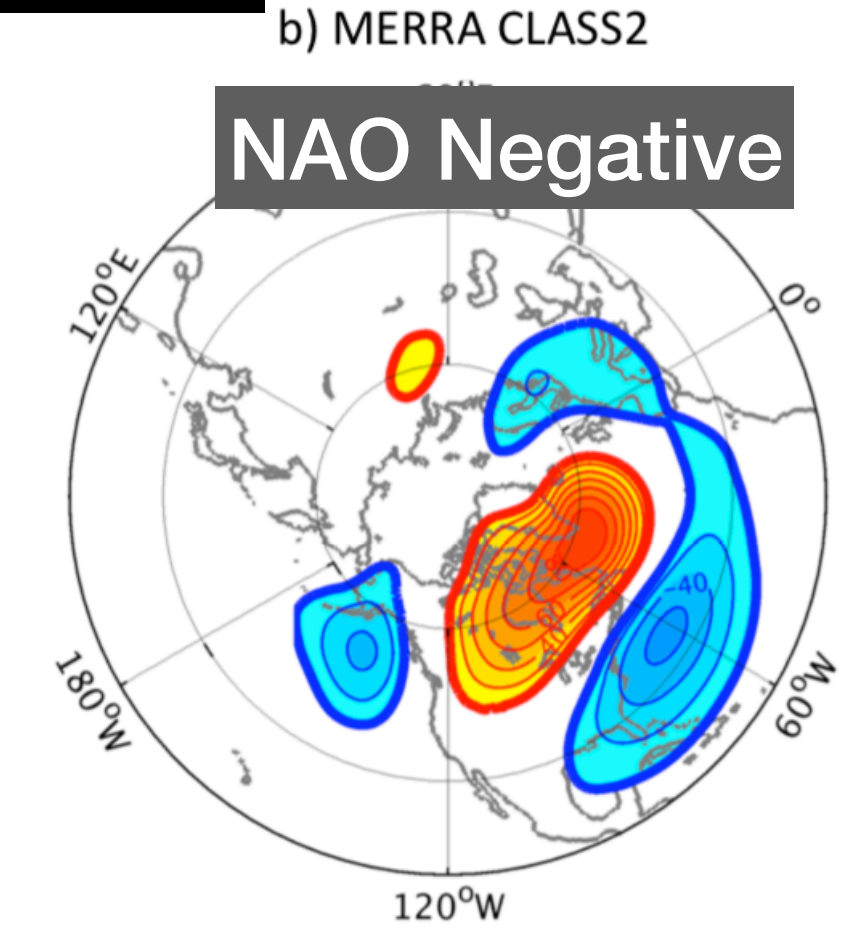
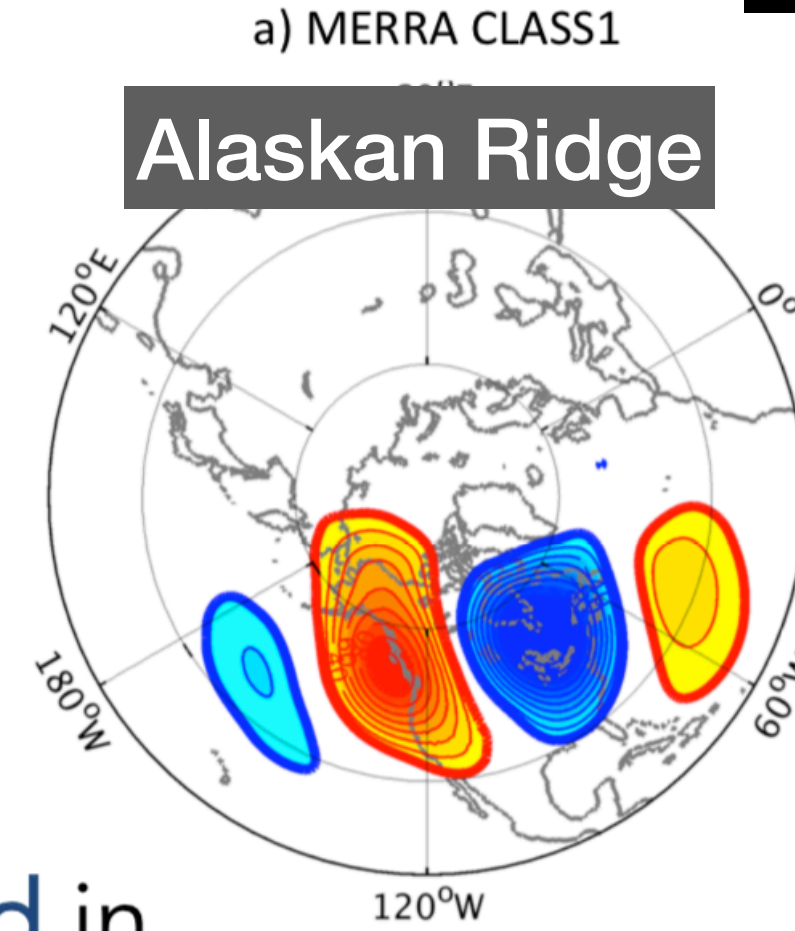
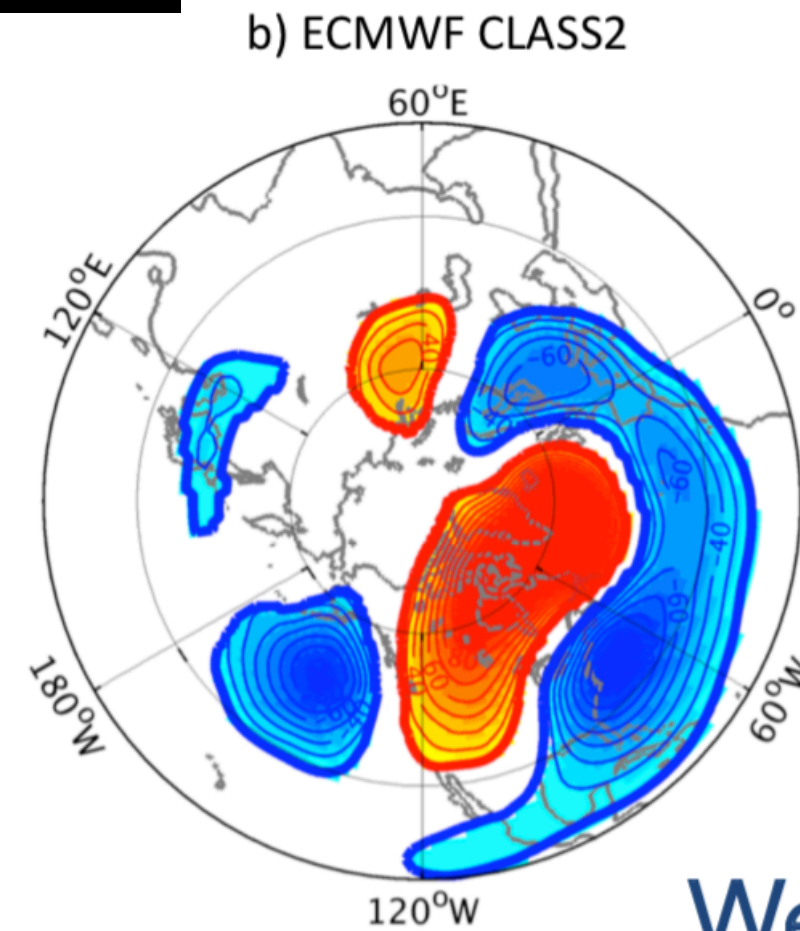
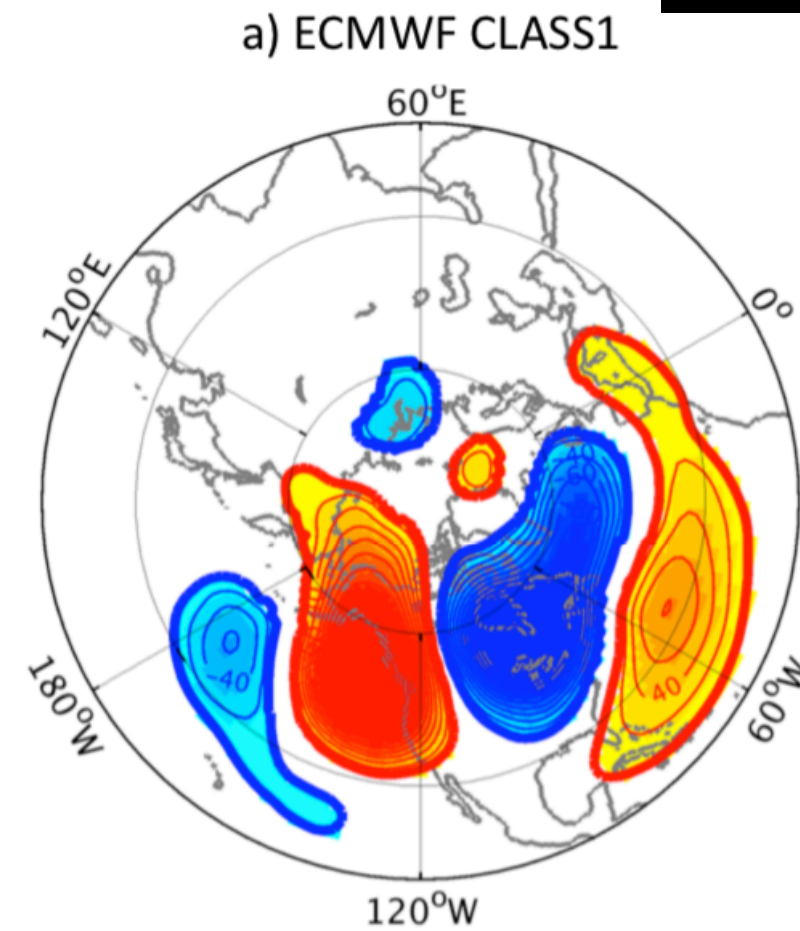


ECMWF Week-1 Forecast Regime Structure

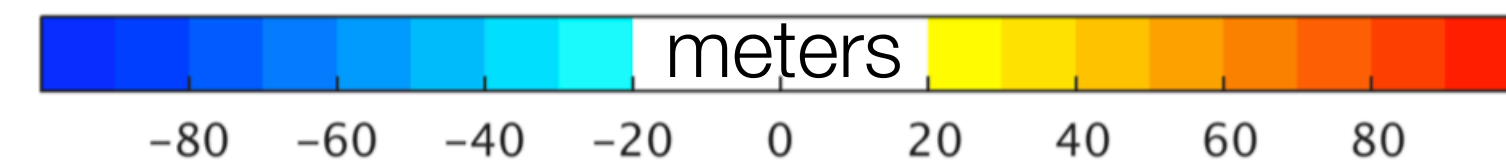
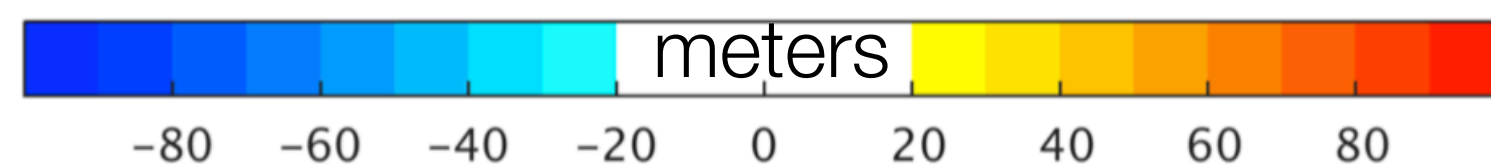
Days 0–6, Ensemble mean Z500 anomalies

ECMWF

MERRA



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



Weather Regime Surface Impacts

Precipitation

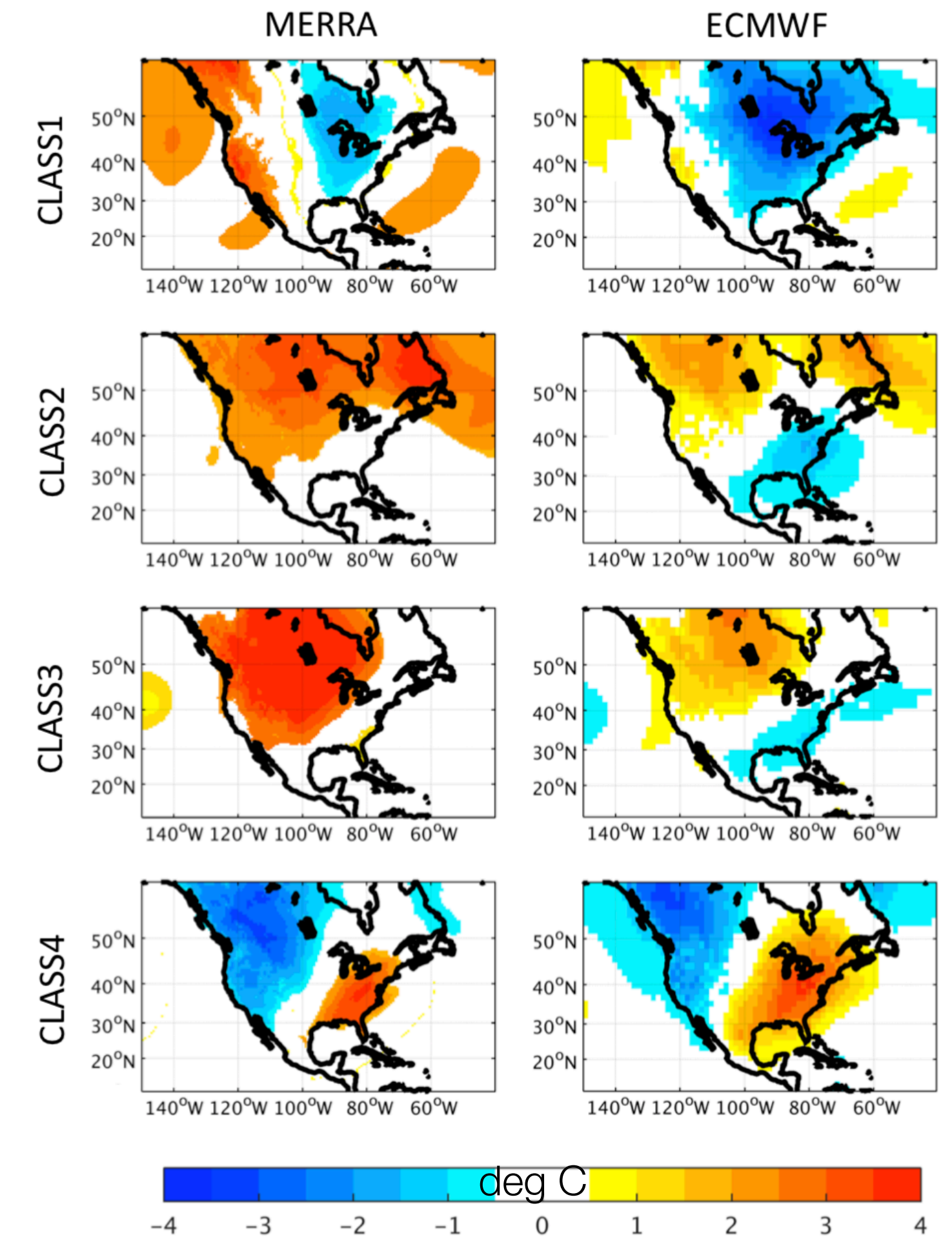
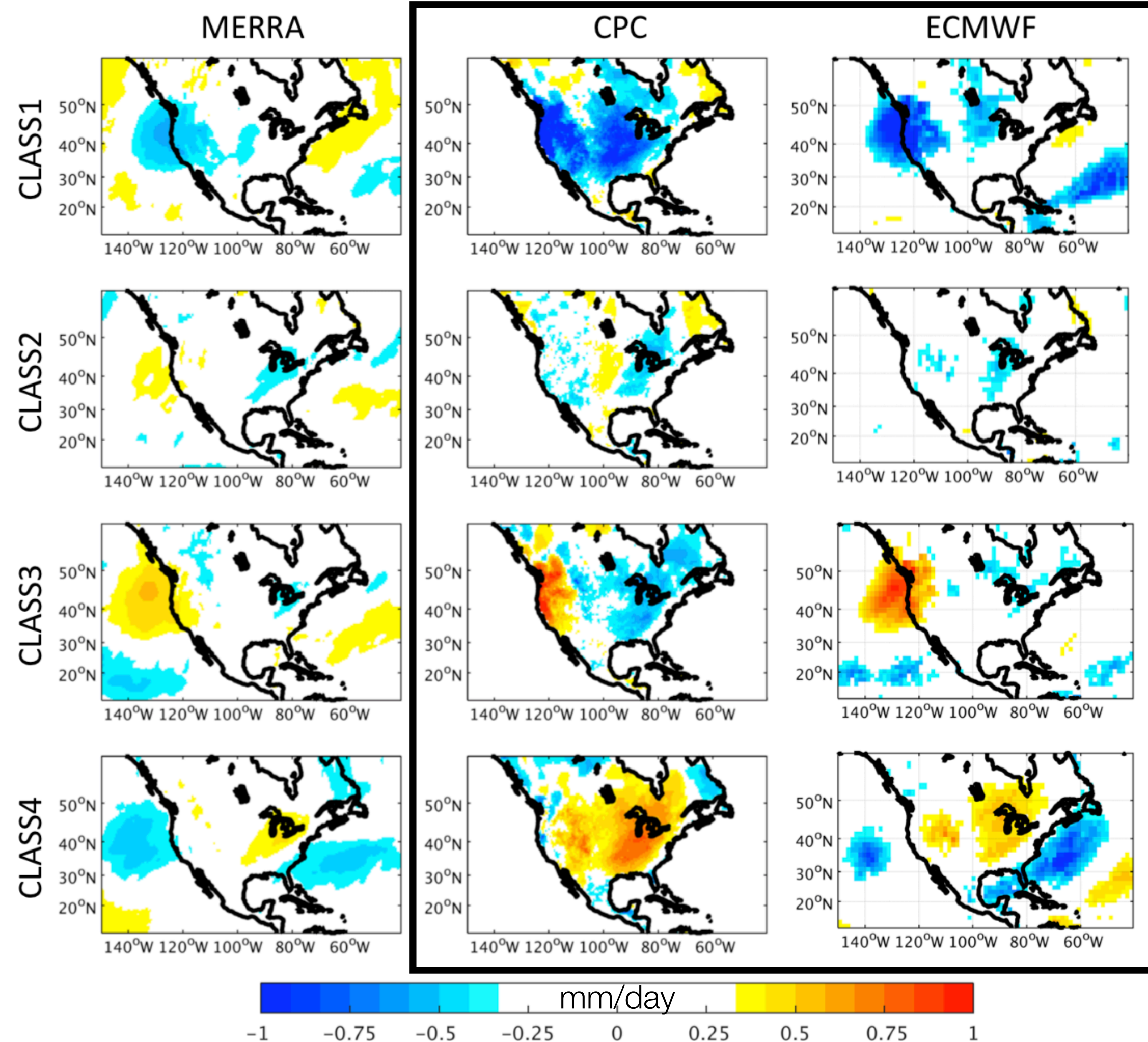
Temperature

Alaskan Ridge

Arctic High (NAO-)

Pacific Trough (PNA)

Pacific Ridge (RNA)



Similar overall patterns between observed-data impacts and model's own surface impacts,

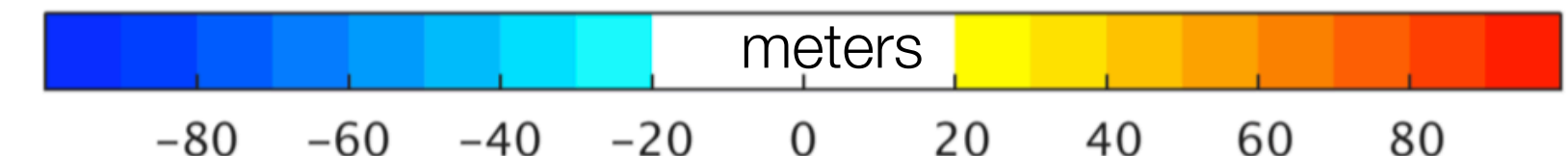
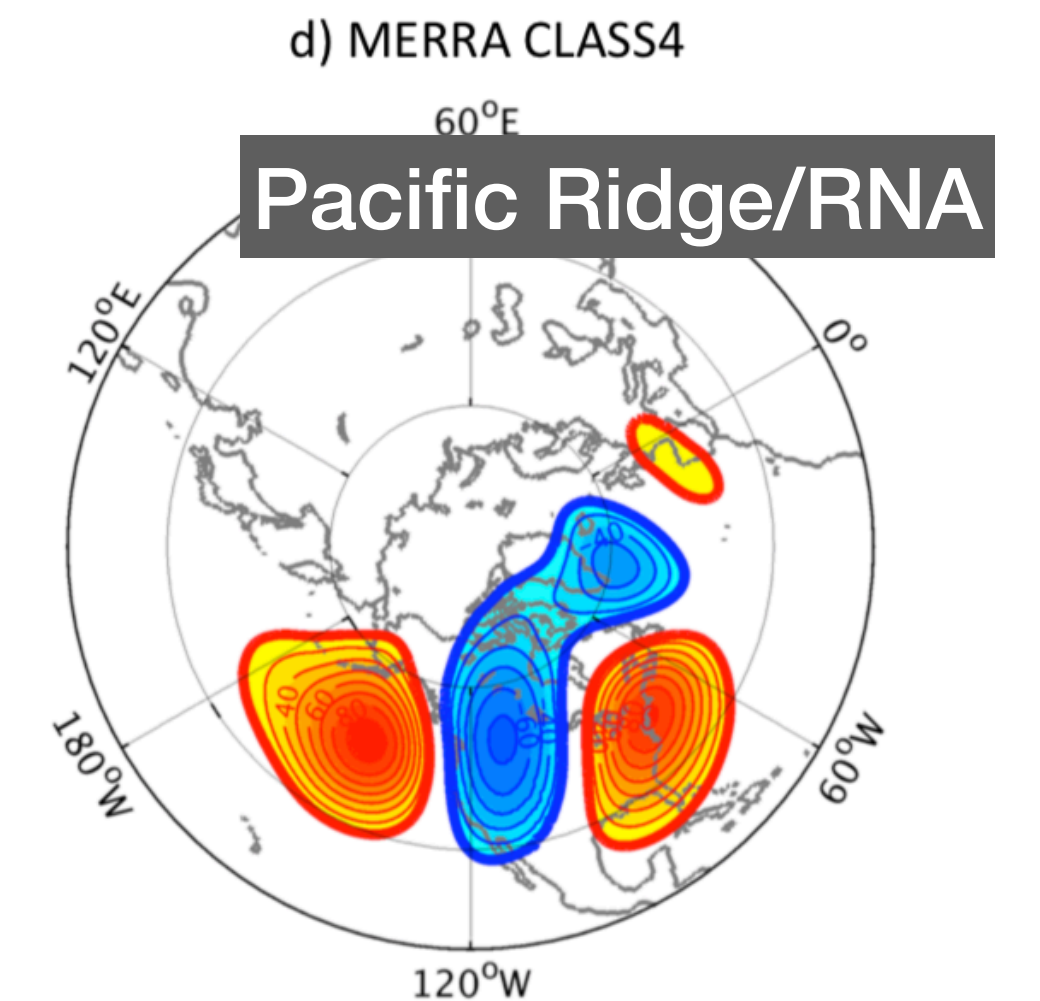
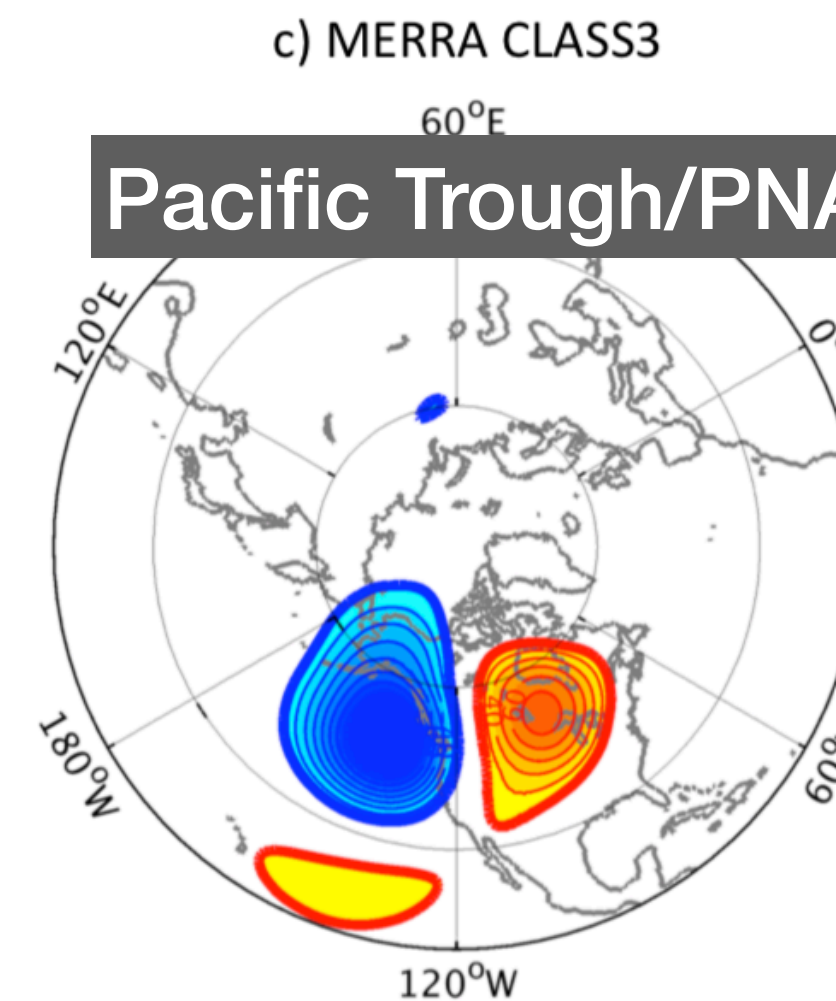
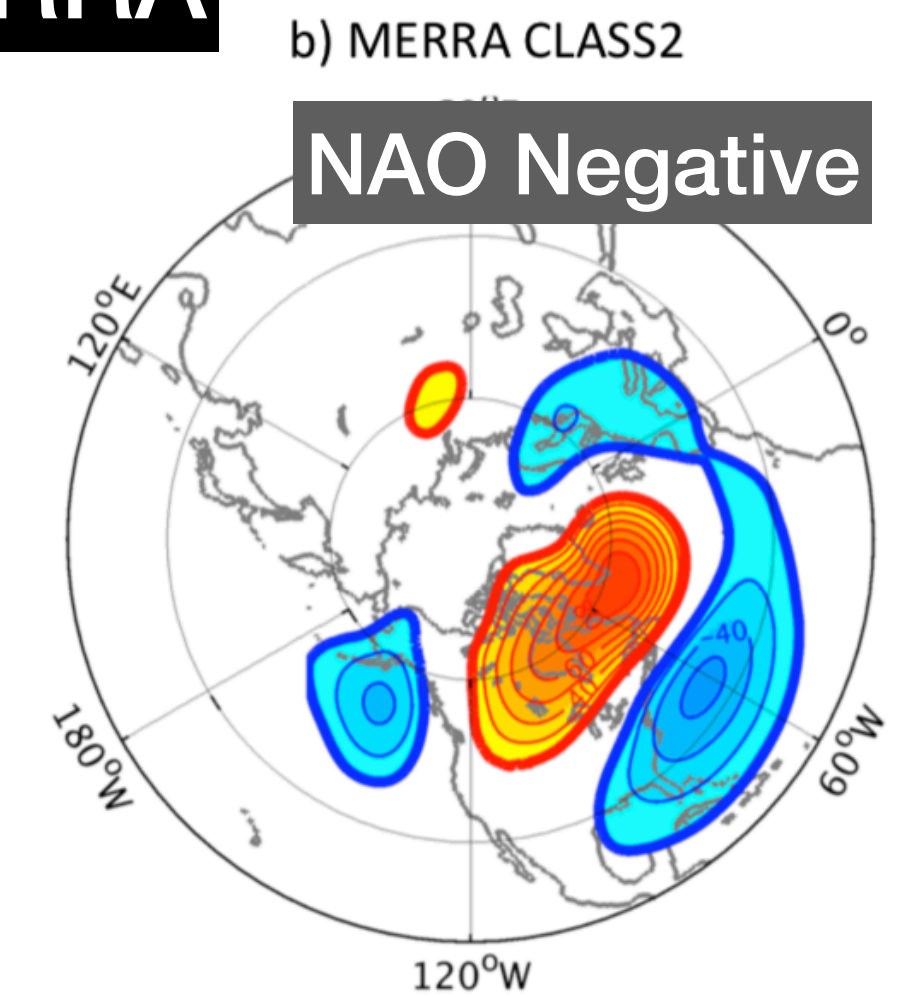
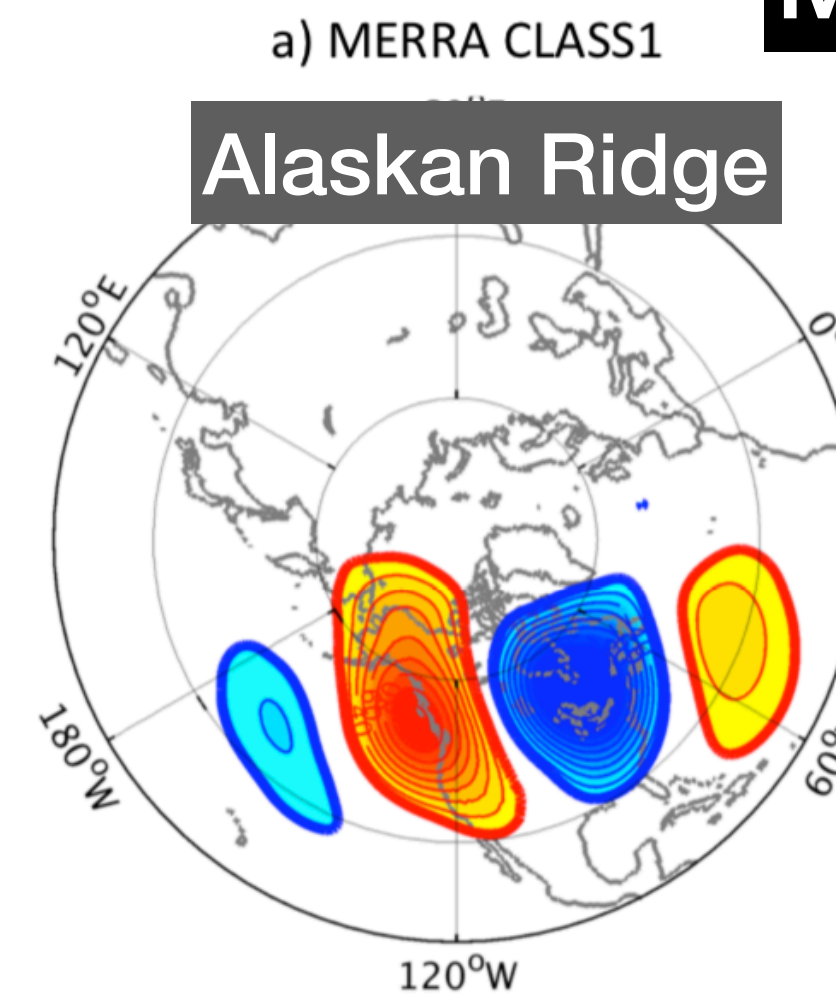
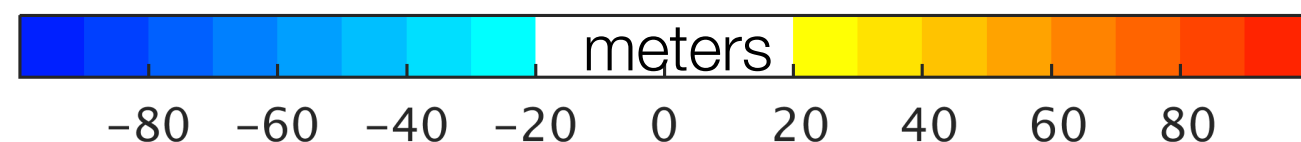
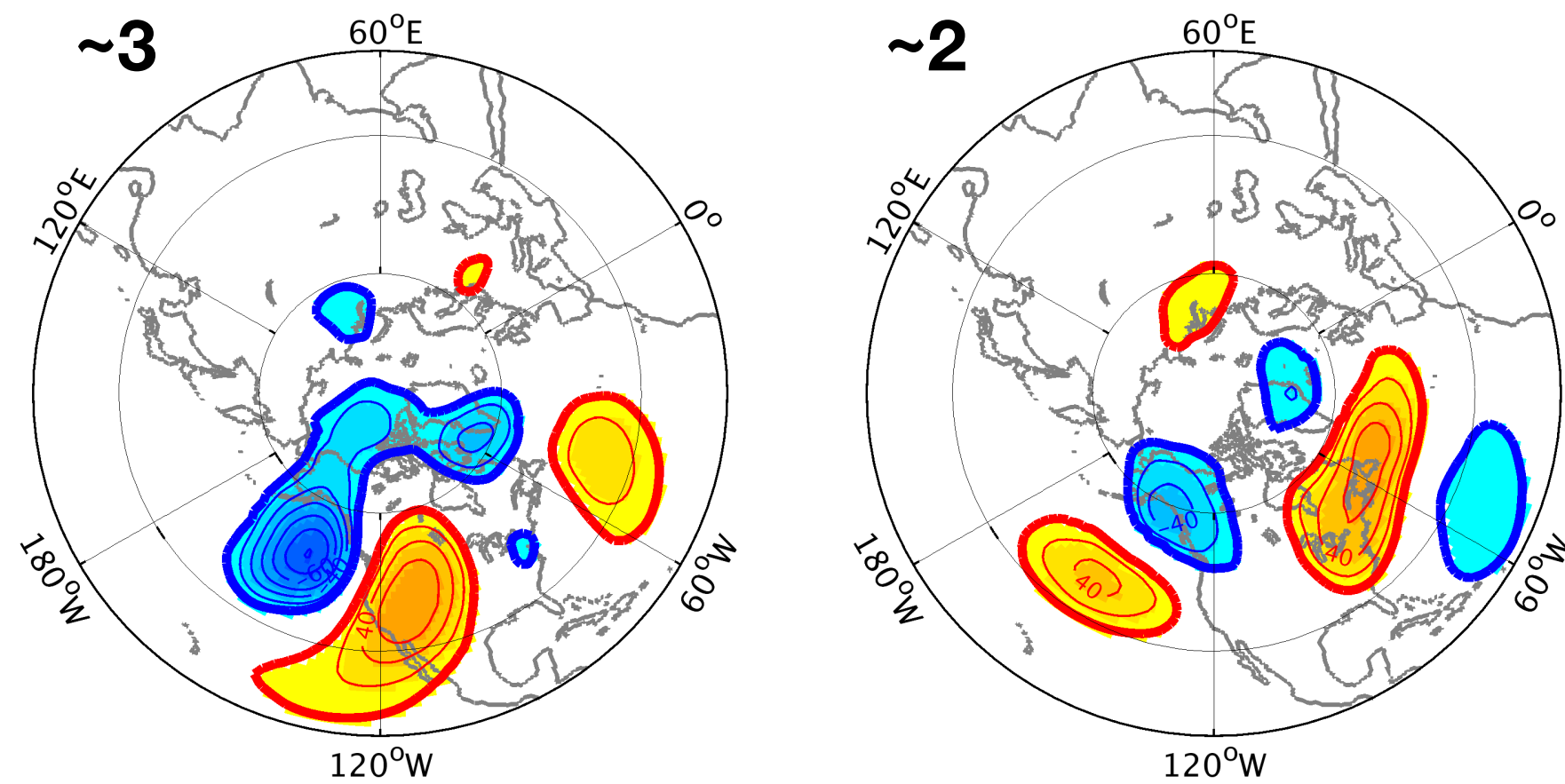
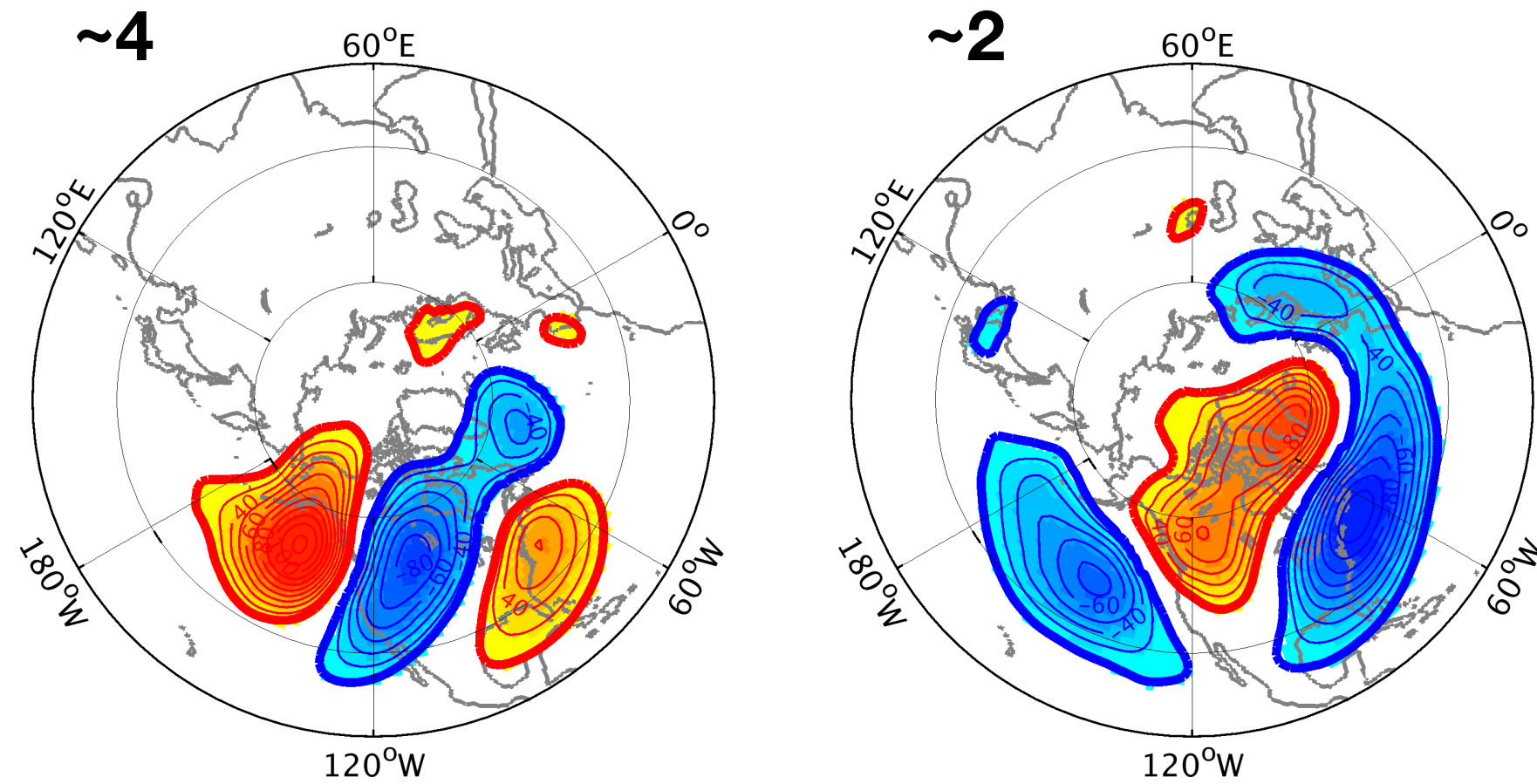
*But **substantial regional differences***

CFSv2 Week-1 Forecast Regime Structure

CFSv2

Days 0–6, Ensemble mean Z500 anomalies

MERRA



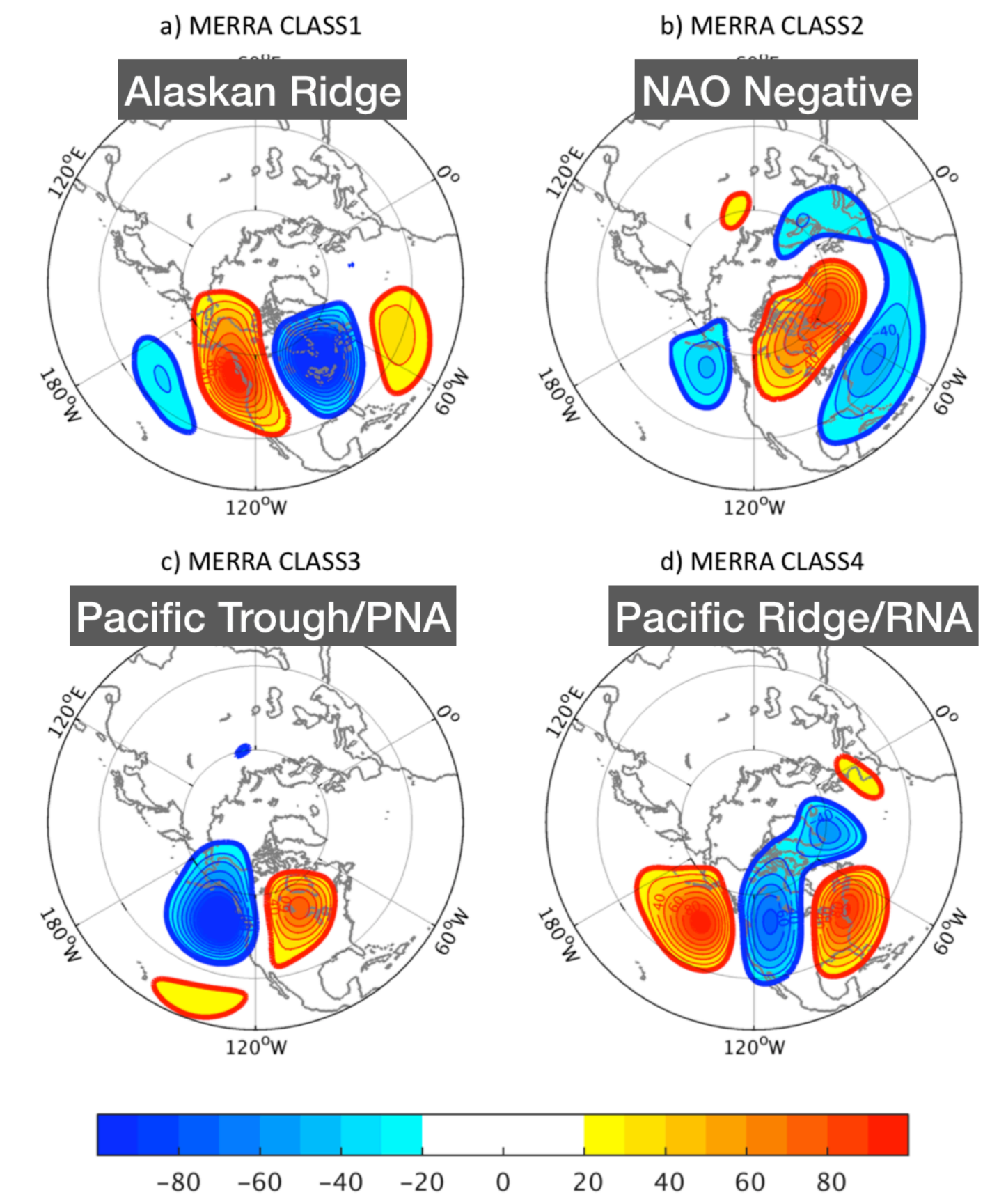
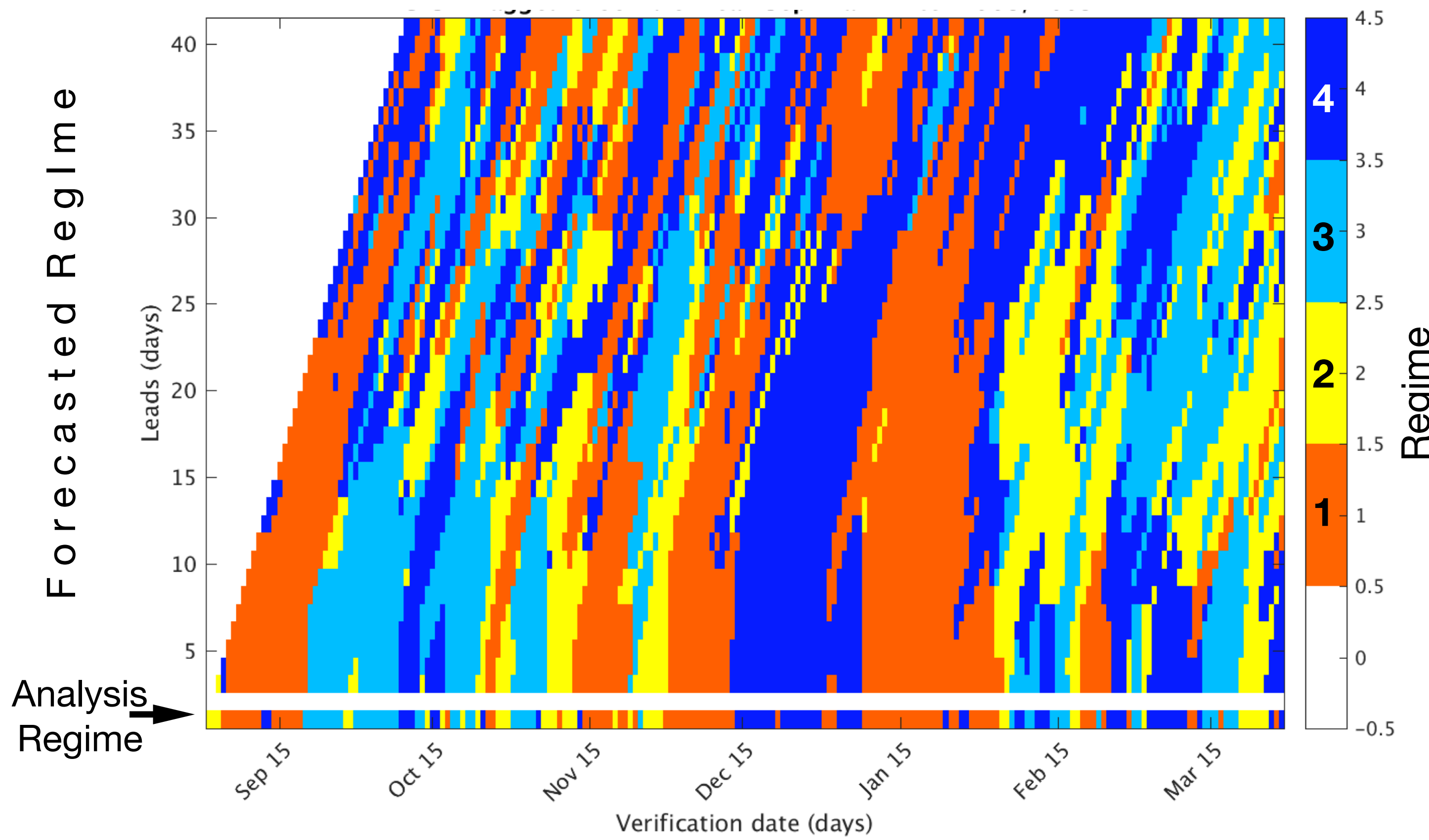
*Weaker
correspondence
in structure
than seen in
ECMWF model*

Forecast Evolution in WR Space

- Use the 4 MERRA regimes to define a low-order subspace for large-scale Z500 flow
- Circulation evolution is portrayed by regime persistence and transitions
 - ➔ We track the forecast evolution by projecting 5-day running means of the CFSv2 forecast ensemble means onto the MERRA-regime subspace
 - ➔ On each day, the forecast Z500 pattern is assigned to the most-similar MERRA regime pattern
- Similarity is defined by pattern correlation of anomalies from a seasonally-varying (and lead dependent) model climatology

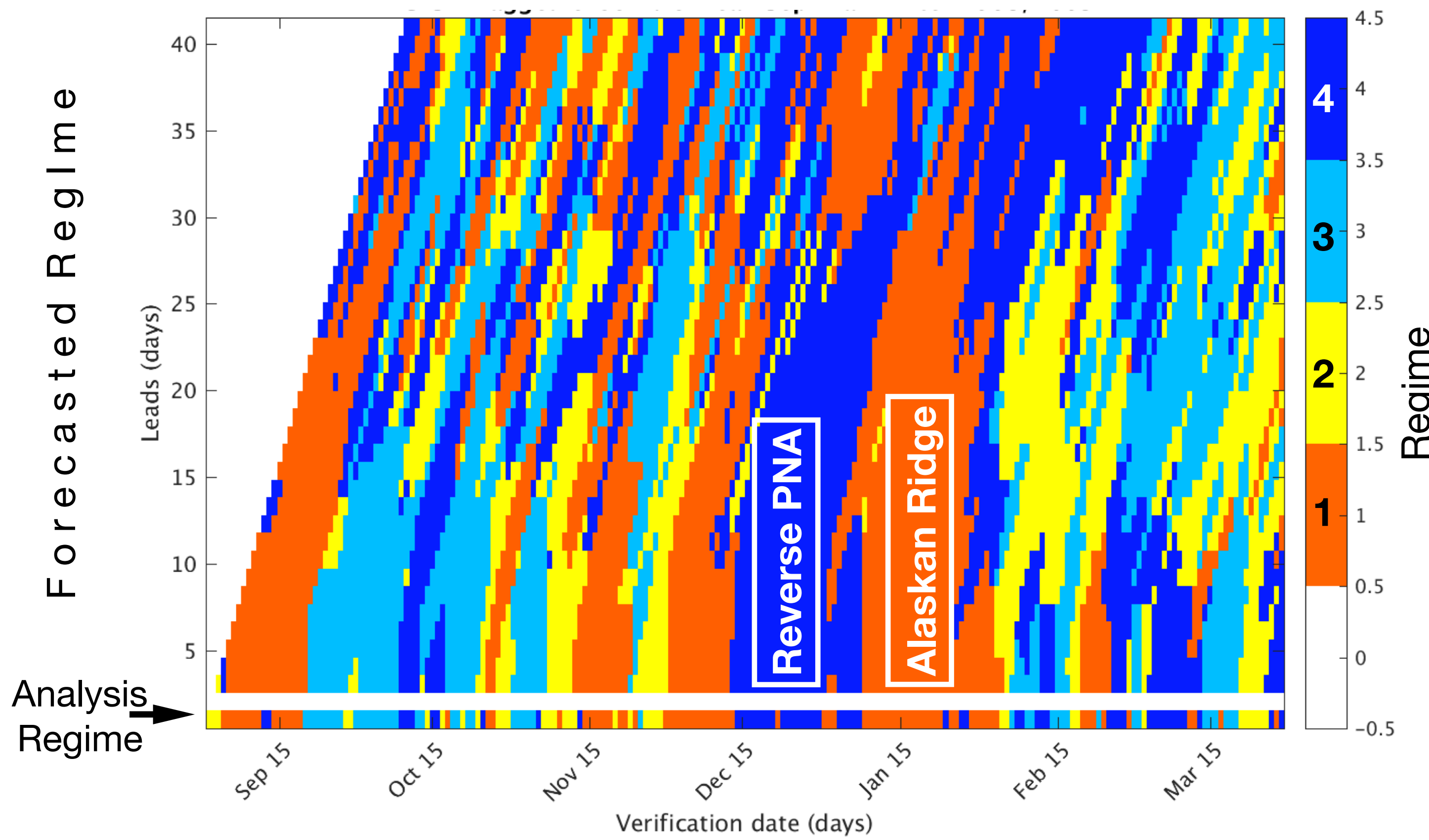
CFSv2 Hindcasts of 2008/9 Winter Projected on MERRA Regimes

Forecasted vs Observed Regimes

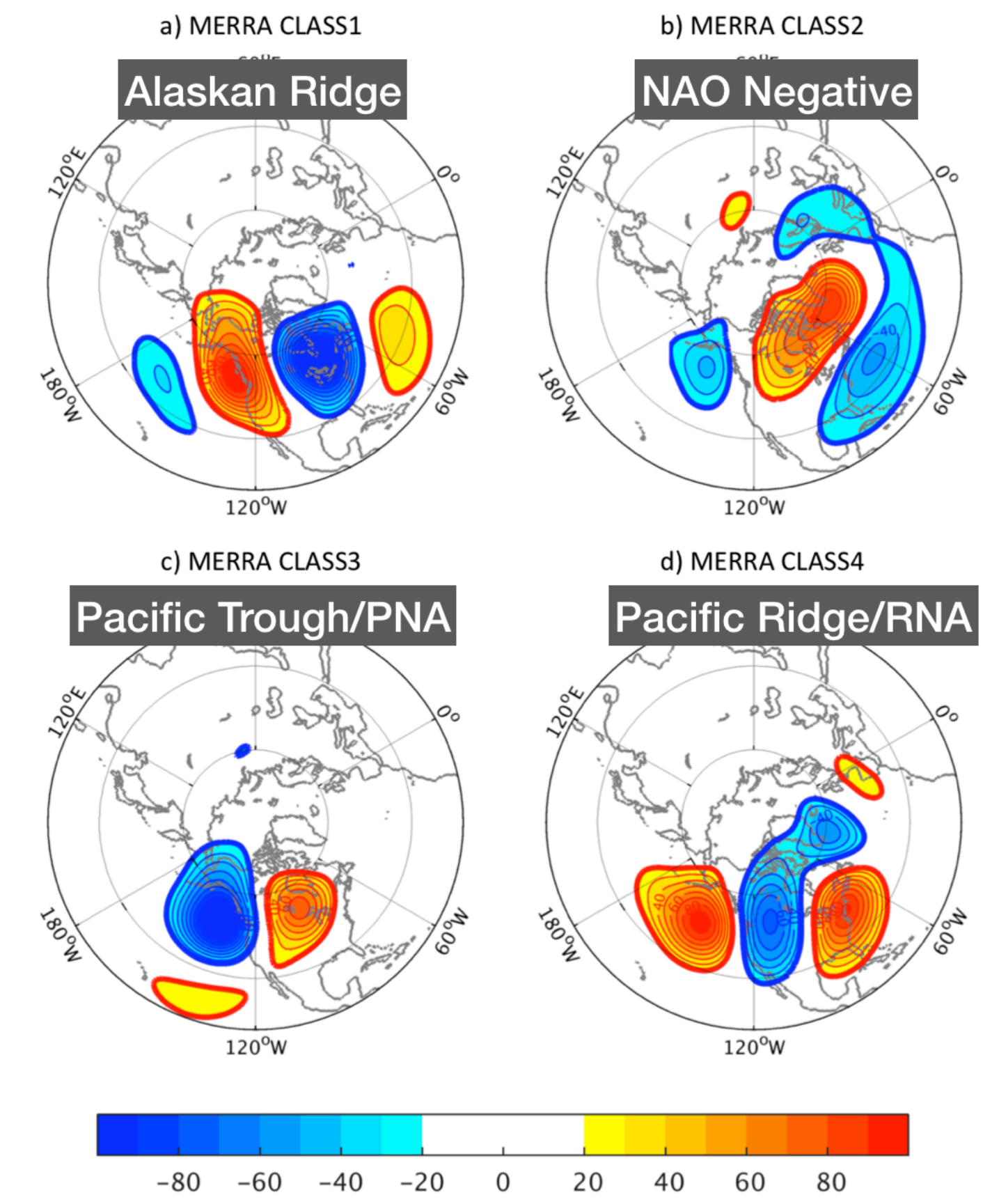


CFSv2 Hindcasts of 2008/9 Winter Projected on MERRA Regimes

Forecasted vs Observed Regimes

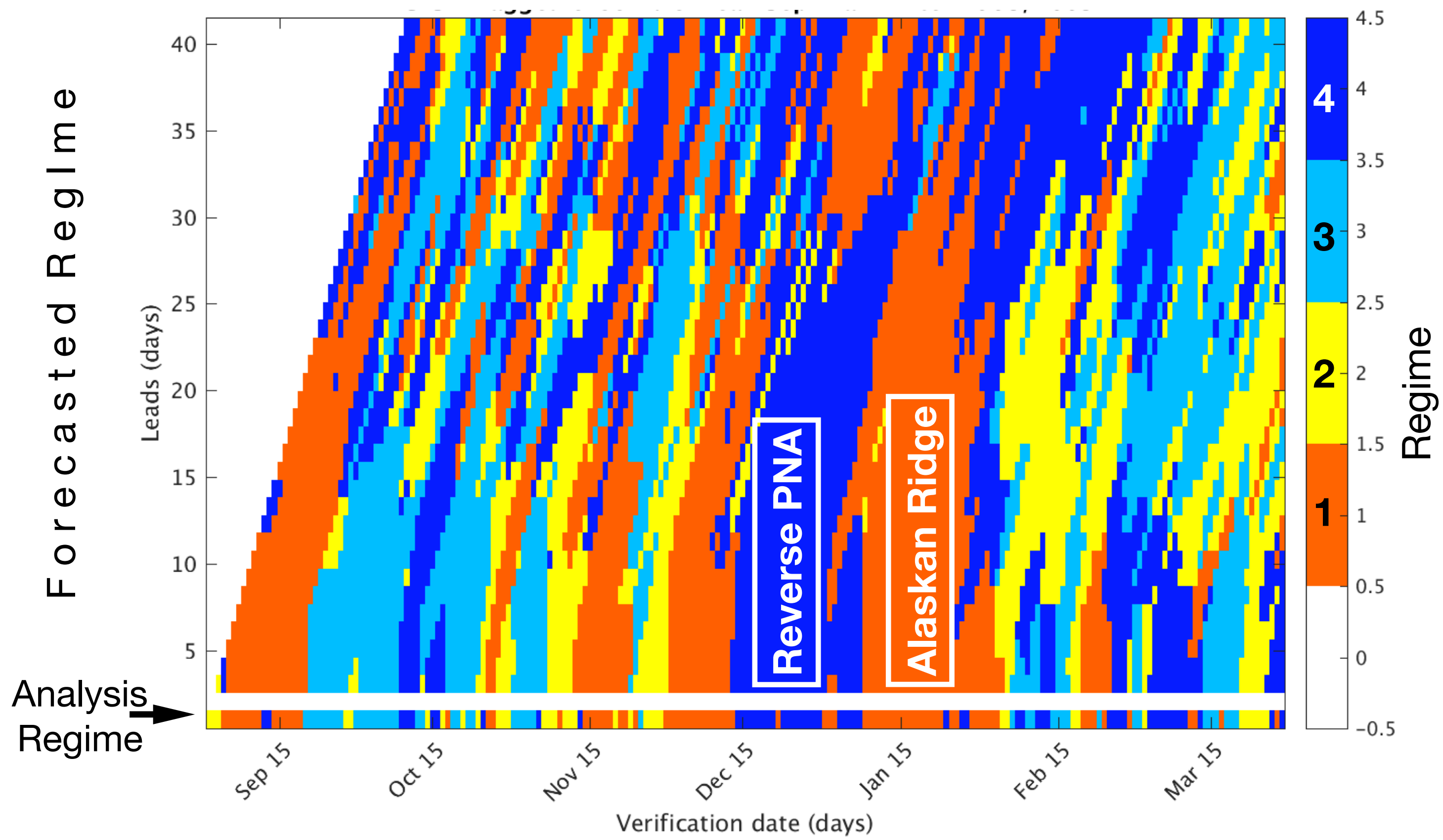


*Jan–Feb Regime 4→1 Episode and transition
Well forecast up to 4 weeks ahead*



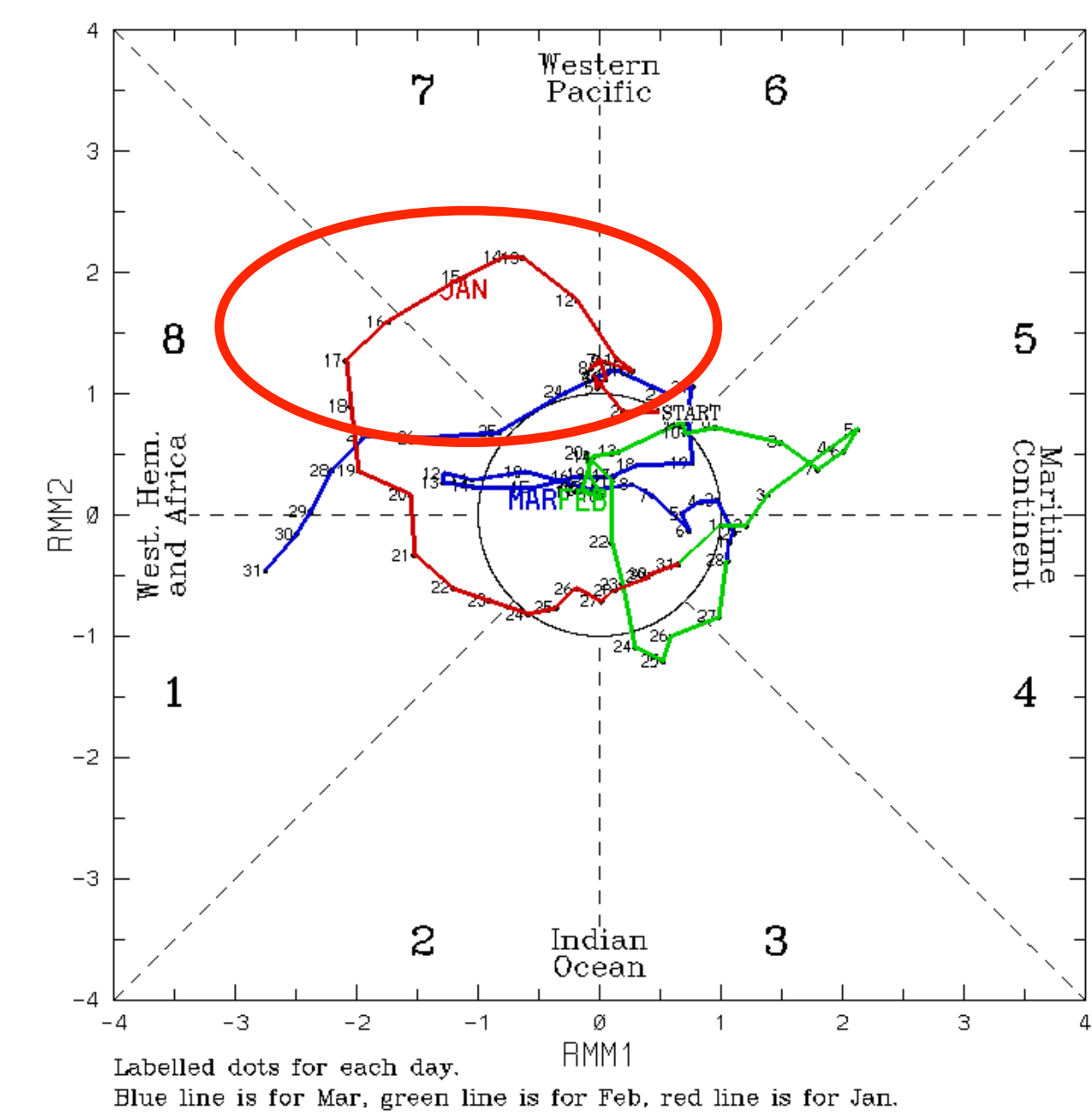
CFSv2 Hindcasts of 2008/9 Winter Projected on MERRA Regimes

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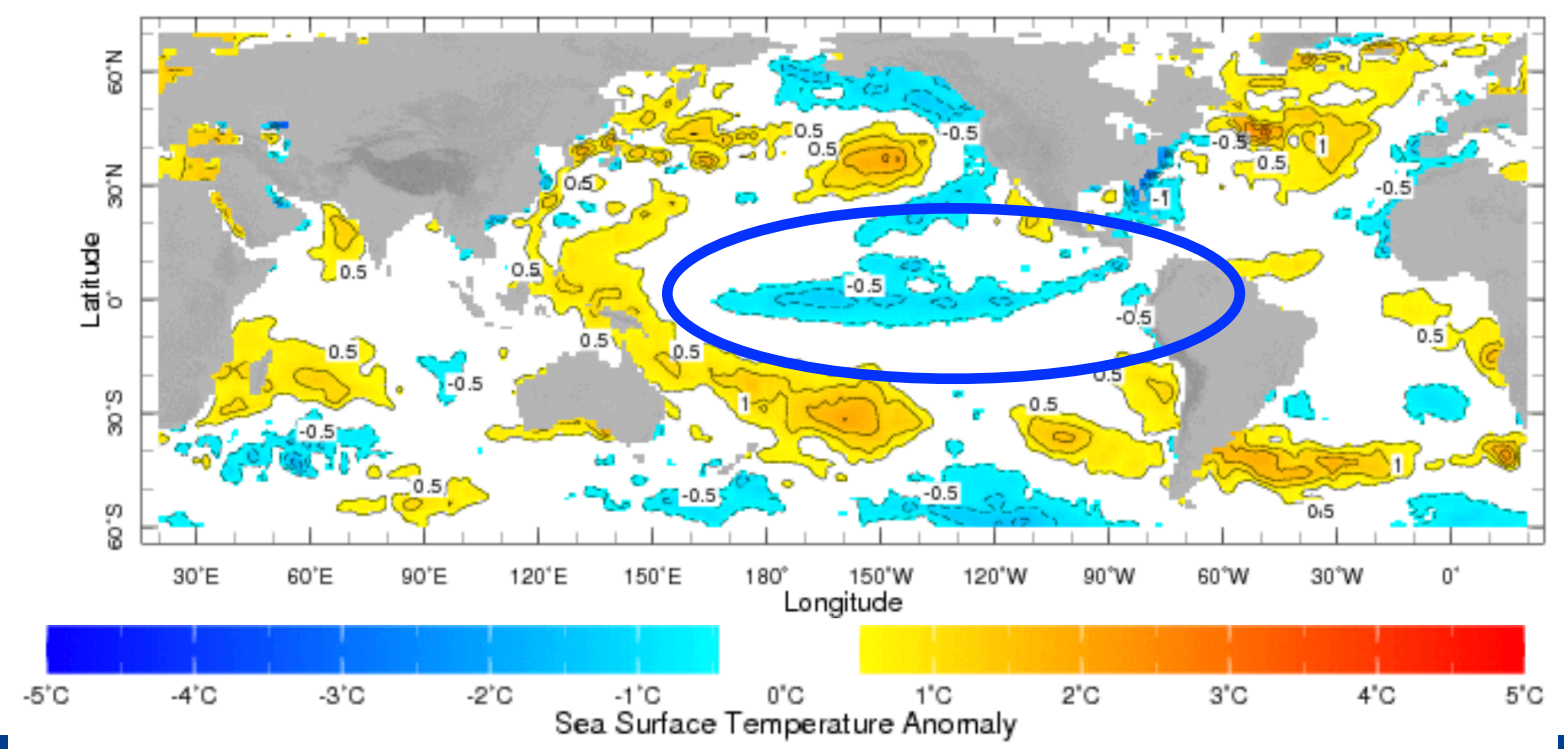
(RMM1,RMM2) phase space for 1-Jan-2009 to 31-Mar-2009



MJO

Labelled dots for each day. Blue line is for Mar, green line is for Feb, red line is for Jan.
(C) Copyright Commonwealth of Australia 2013. Bureau of Meteorology

Dec 2008 - Feb 2009

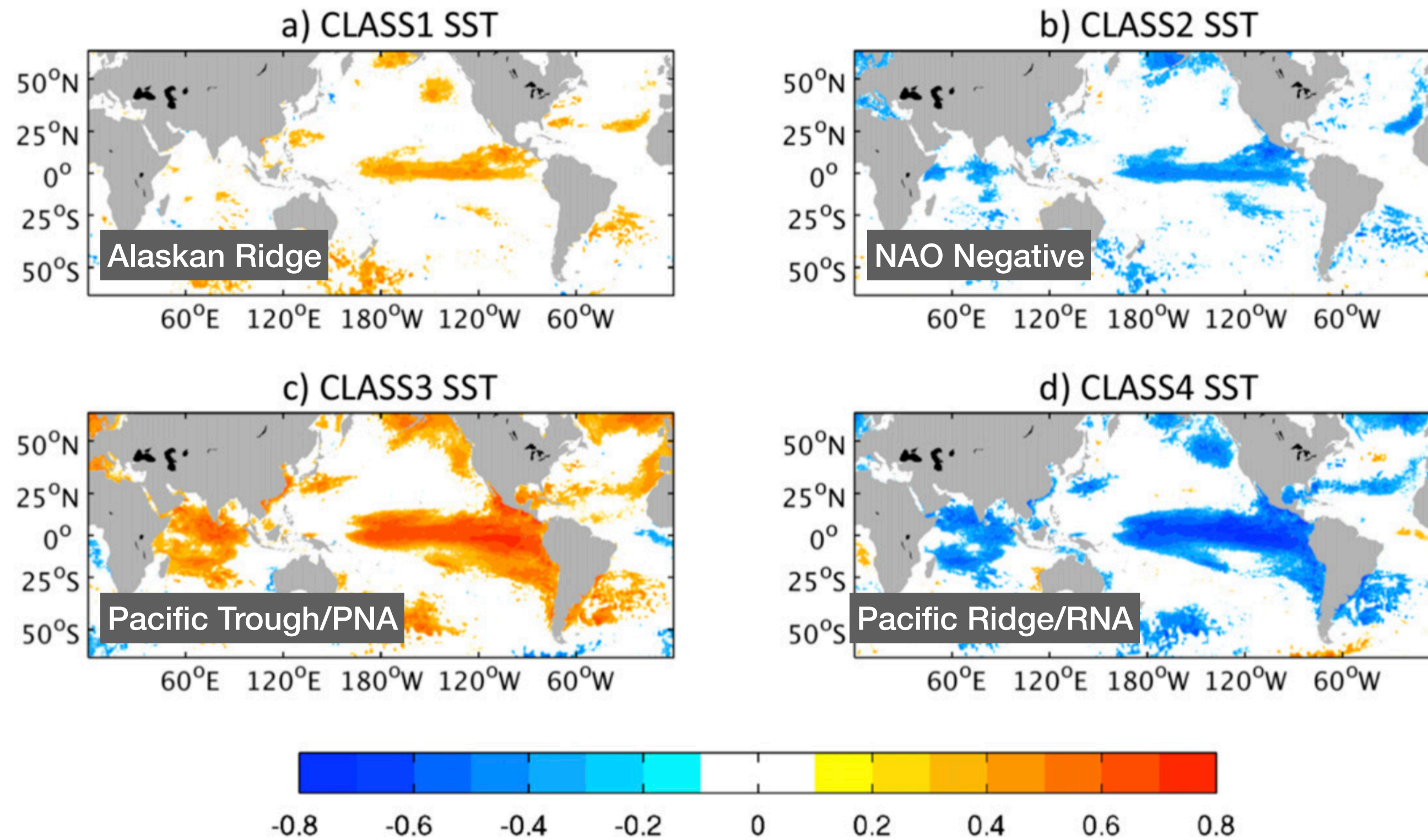


SST Anomalies

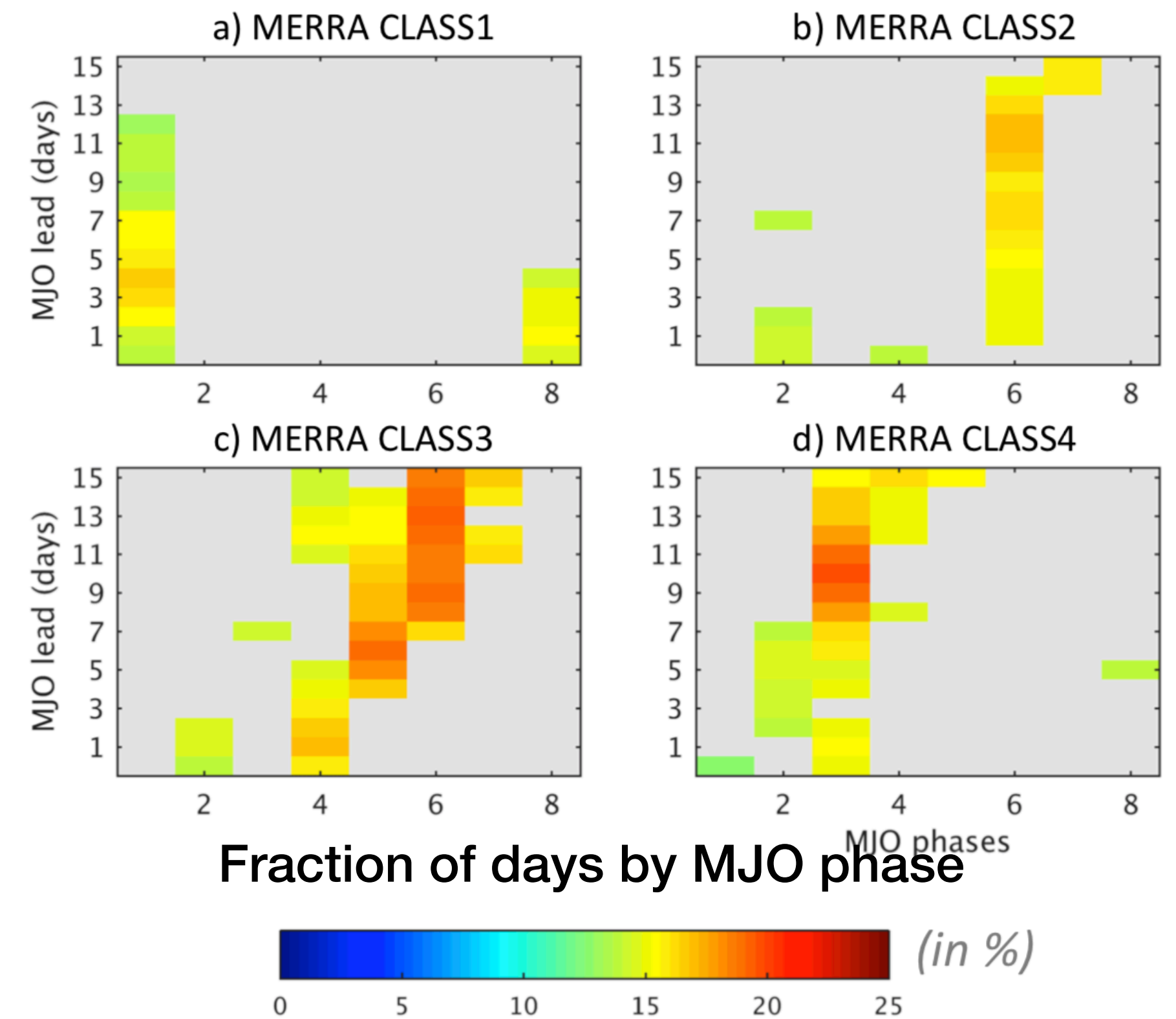


S2S Drivers of Regime Frequency

SST Year-to-Year Correlations with Frequency

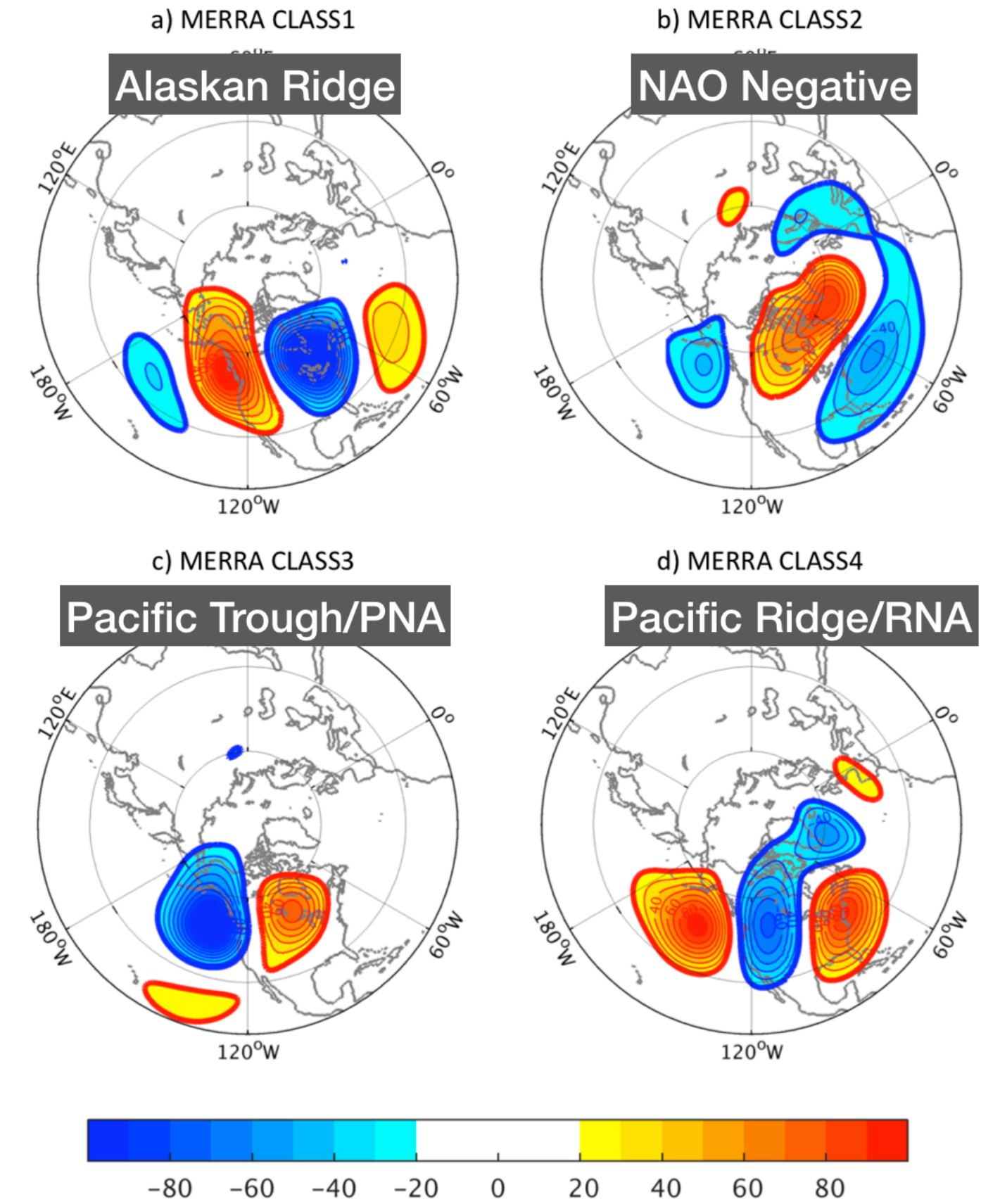
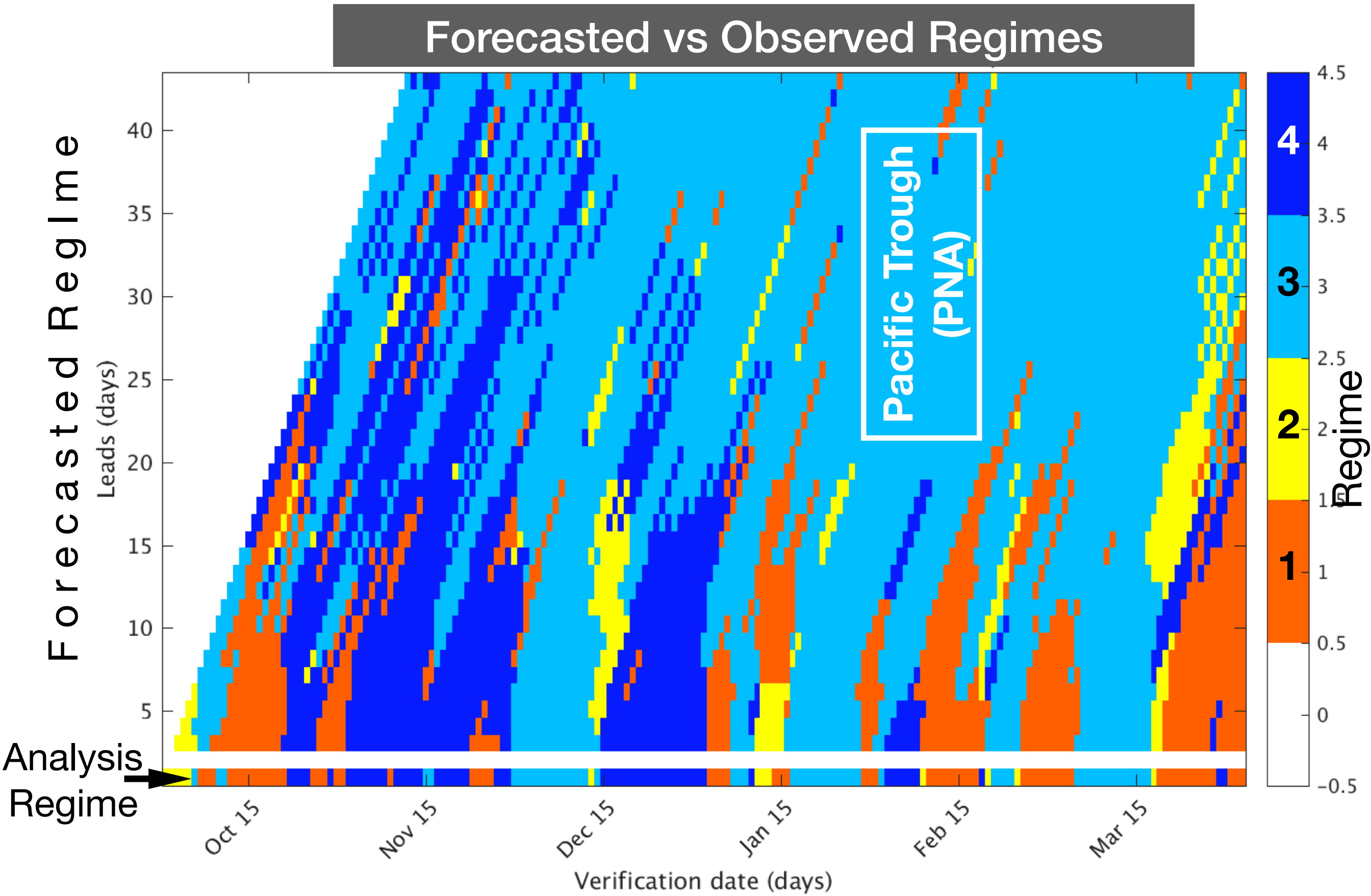


Frequency vs MJO Phase

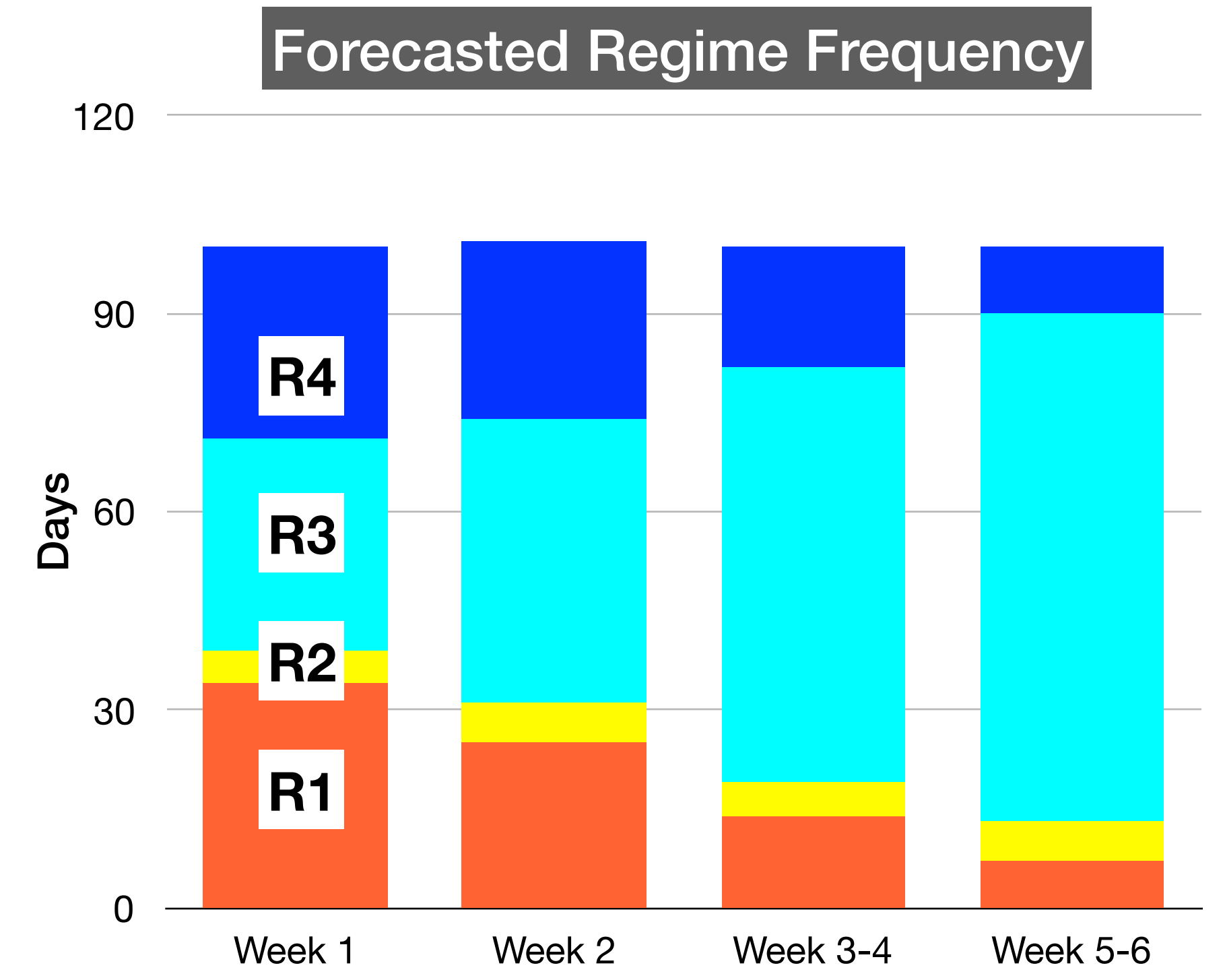
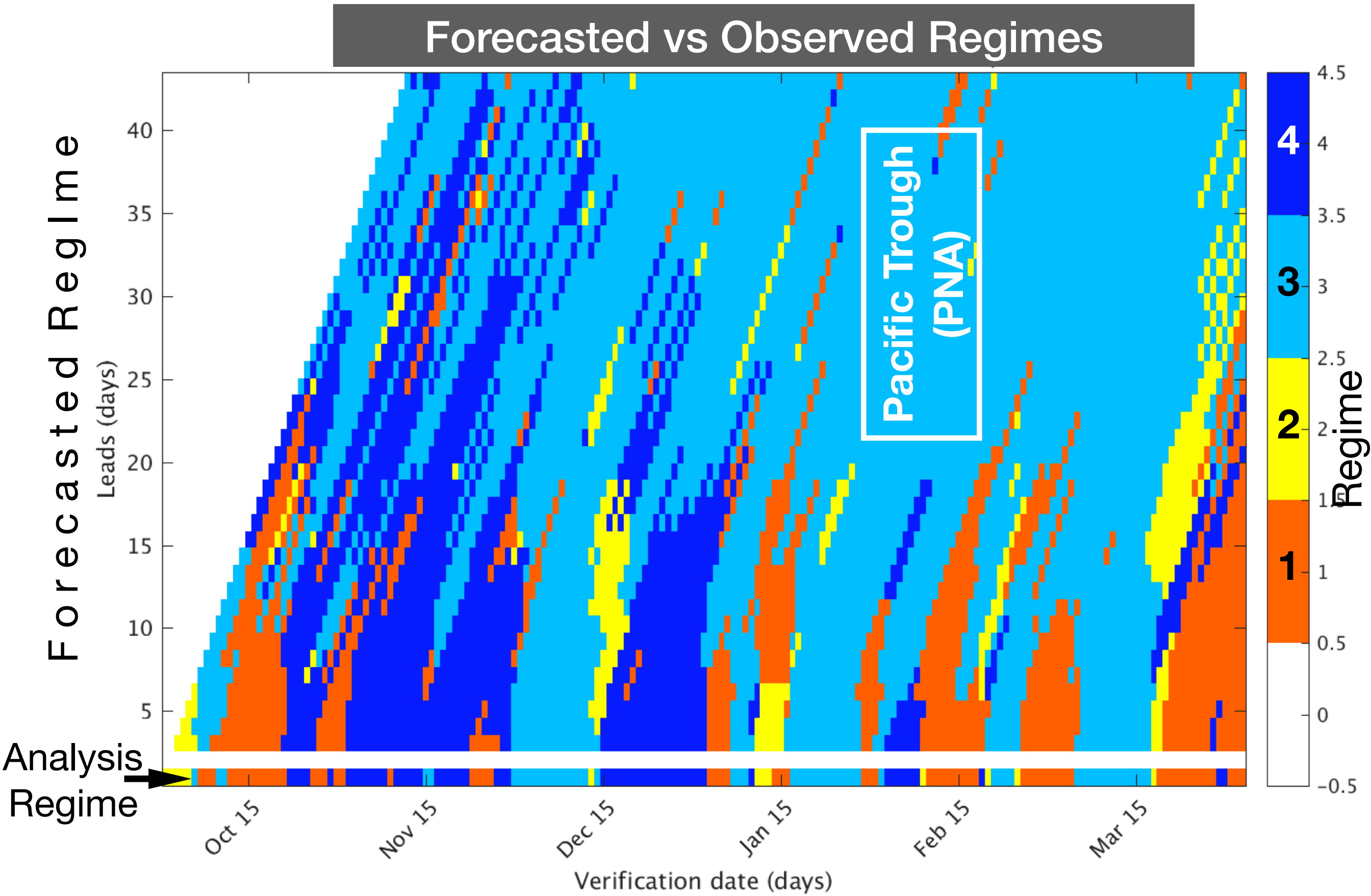


- Regime 3 (Pacific trough/PNA) is related to El Niño and 10–15 days after MJO phase 6
- Regime 4 (Pacific ridge/RNA) is related to La Niña and after MJO phase 3

CFSv2 Forecasts of 2015/16 Winter



CFSv2 Forecasts of 2015/16 Winter

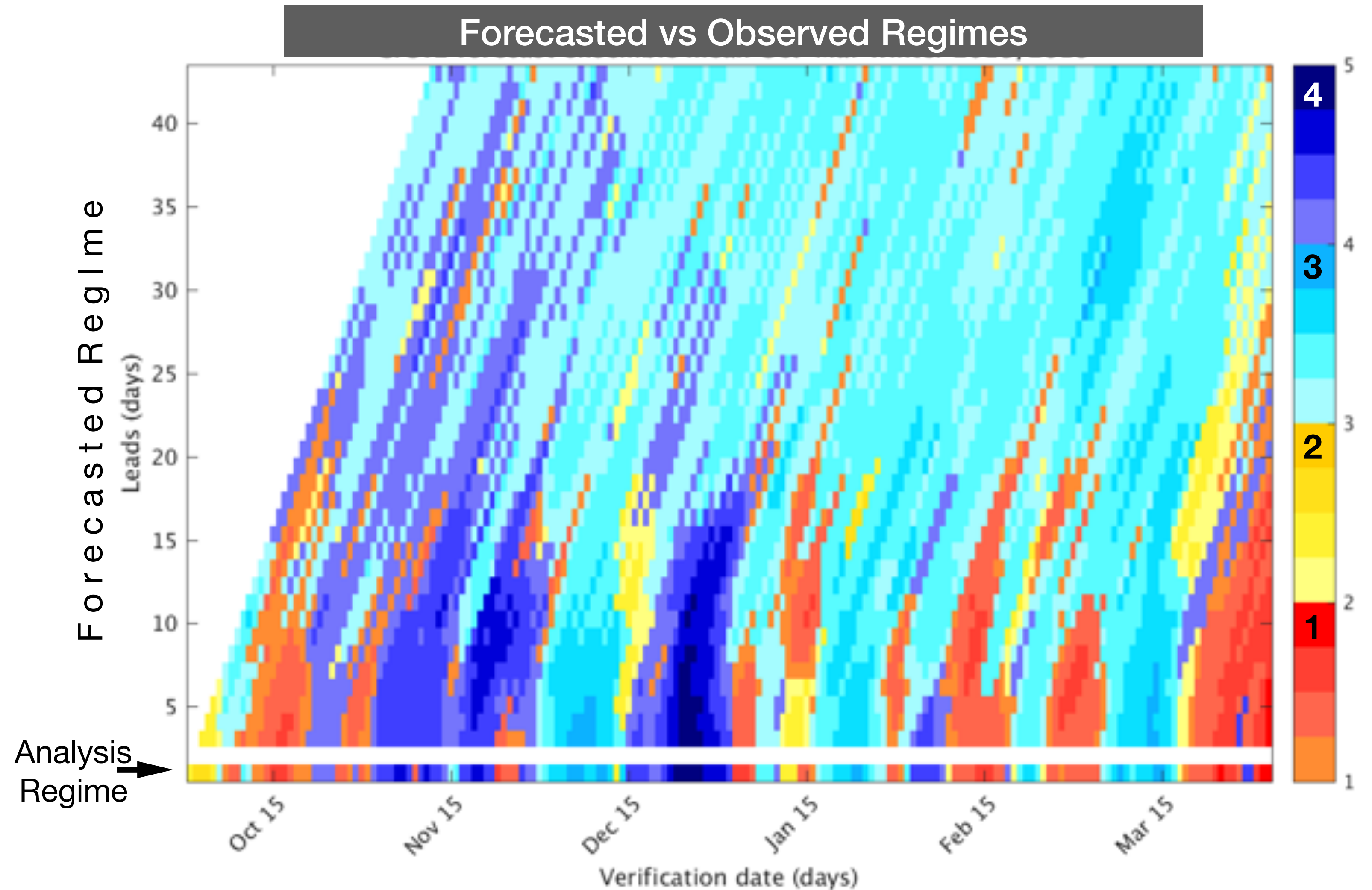


*Regime 3 was hugely **over-forecasted** beyond 2 weeks*



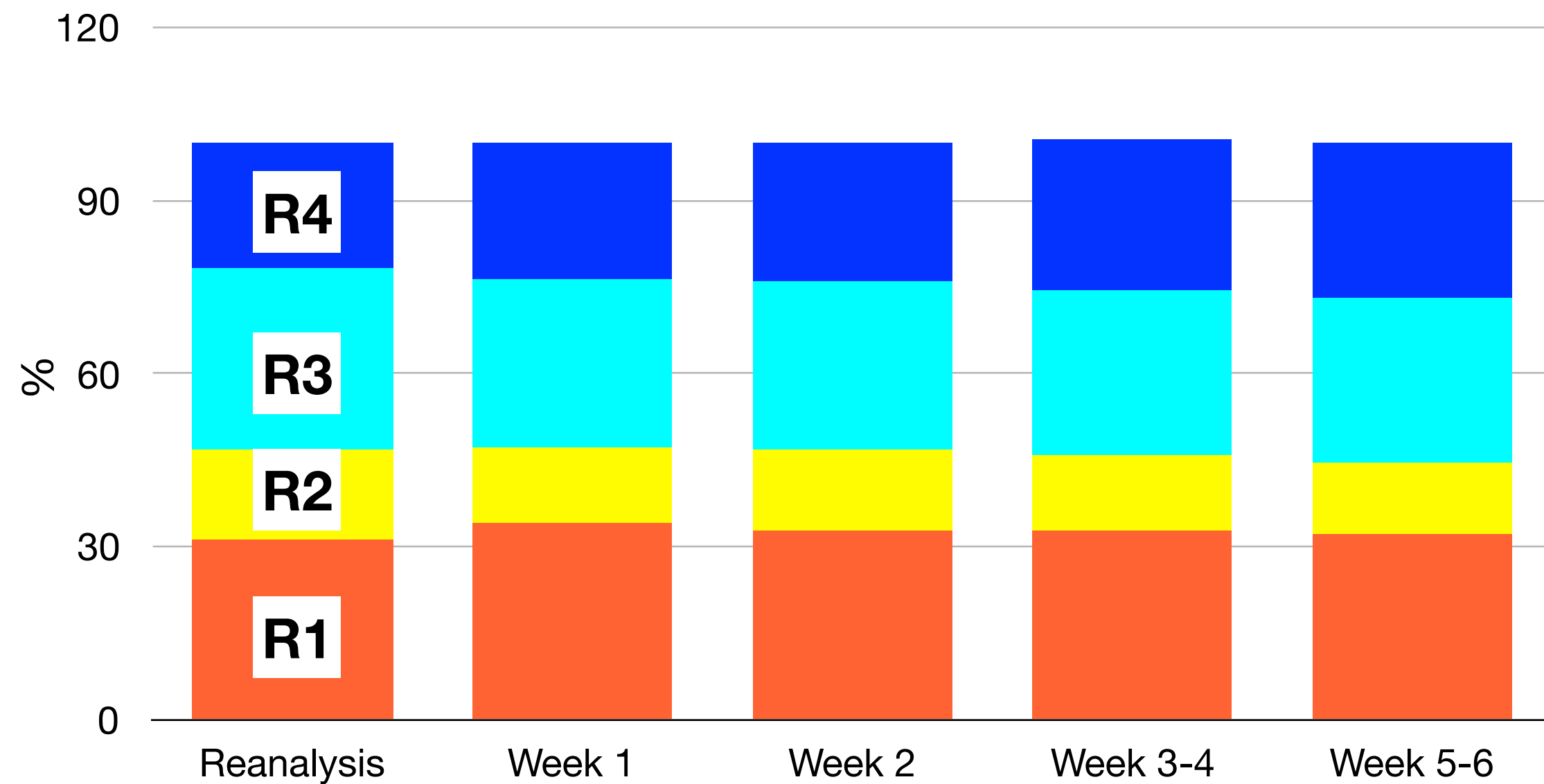
How close are model forecasts to the observed regime centroids?

- Color saturation denotes strength of similarity between forecast ensemble mean and MERRA regime centroid
- Longer lead forecast ensemble mean Z500 anomalies tend to be less well categorized by regime pattern



Regime Frequency: CFSv2 vs MERRA

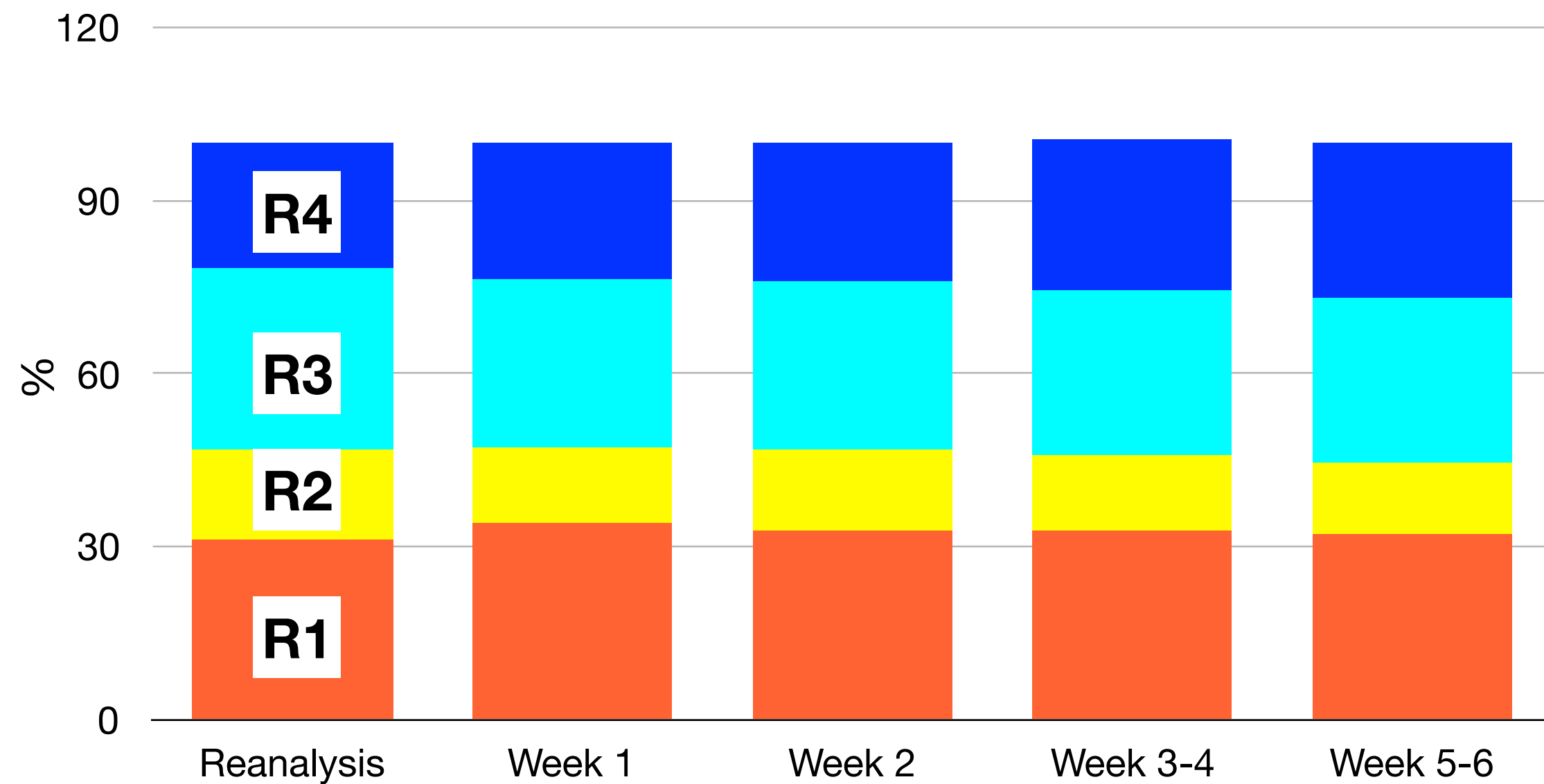
Mean Regime Occurrence vs Reanalysis



Minimal bias in longer lead forecasts

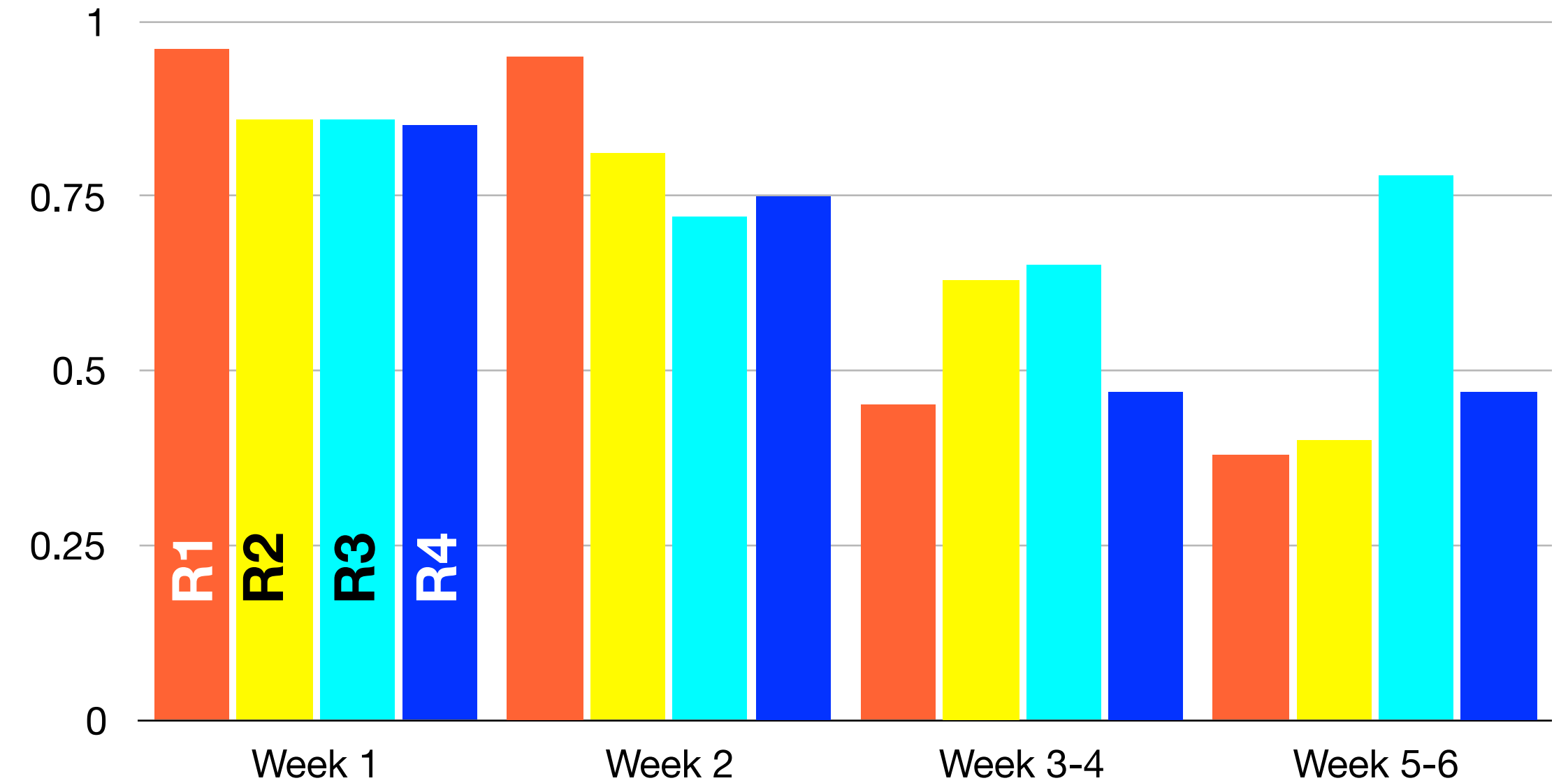
Regime Frequency: CFSv2 vs MERRA

Mean Regime Occurrence vs Reanalysis



Minimal bias in longer lead forecasts

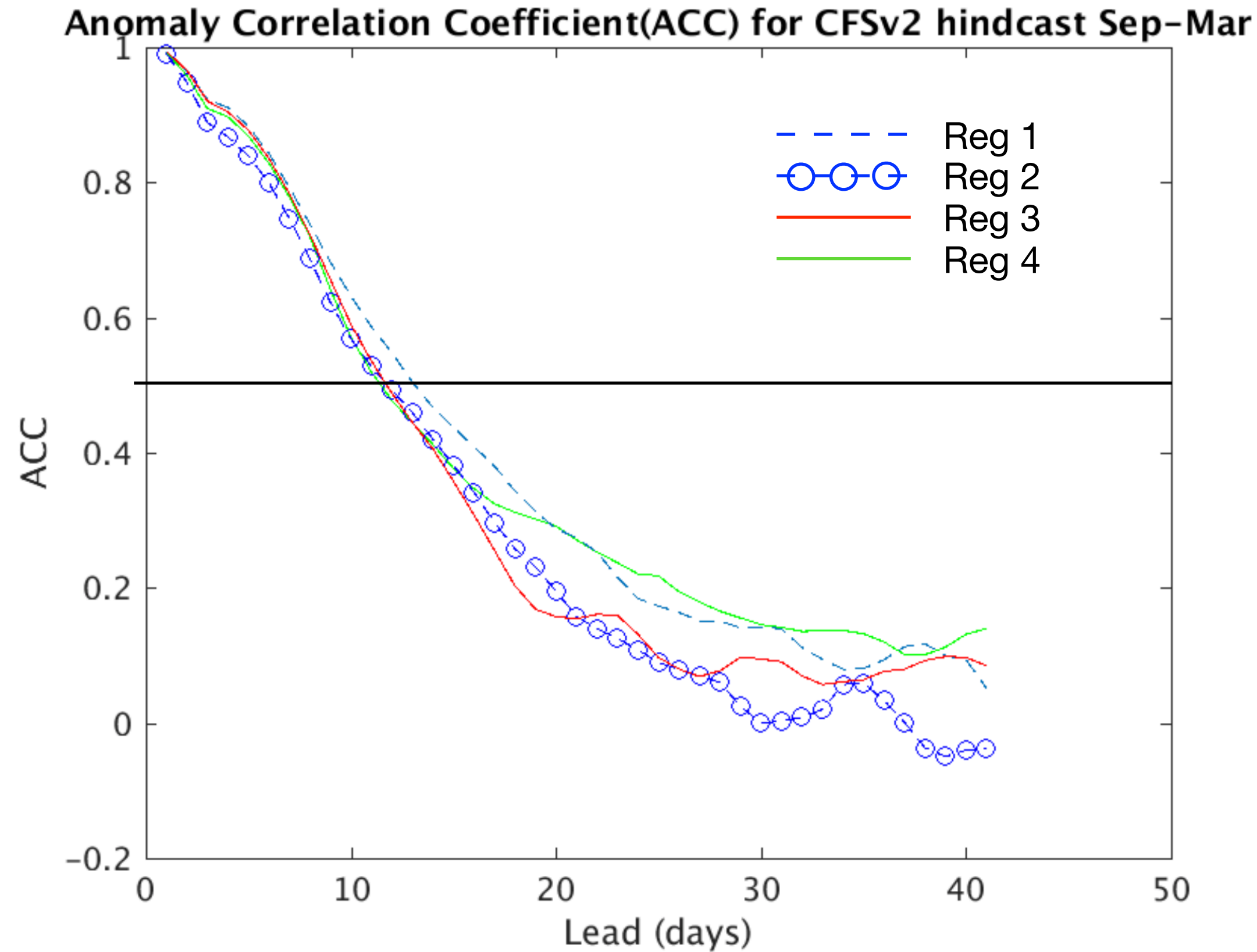
Interannual Correlations of Regime Counts vs Reanalysis



Regime 3 has best week 3-6 skill

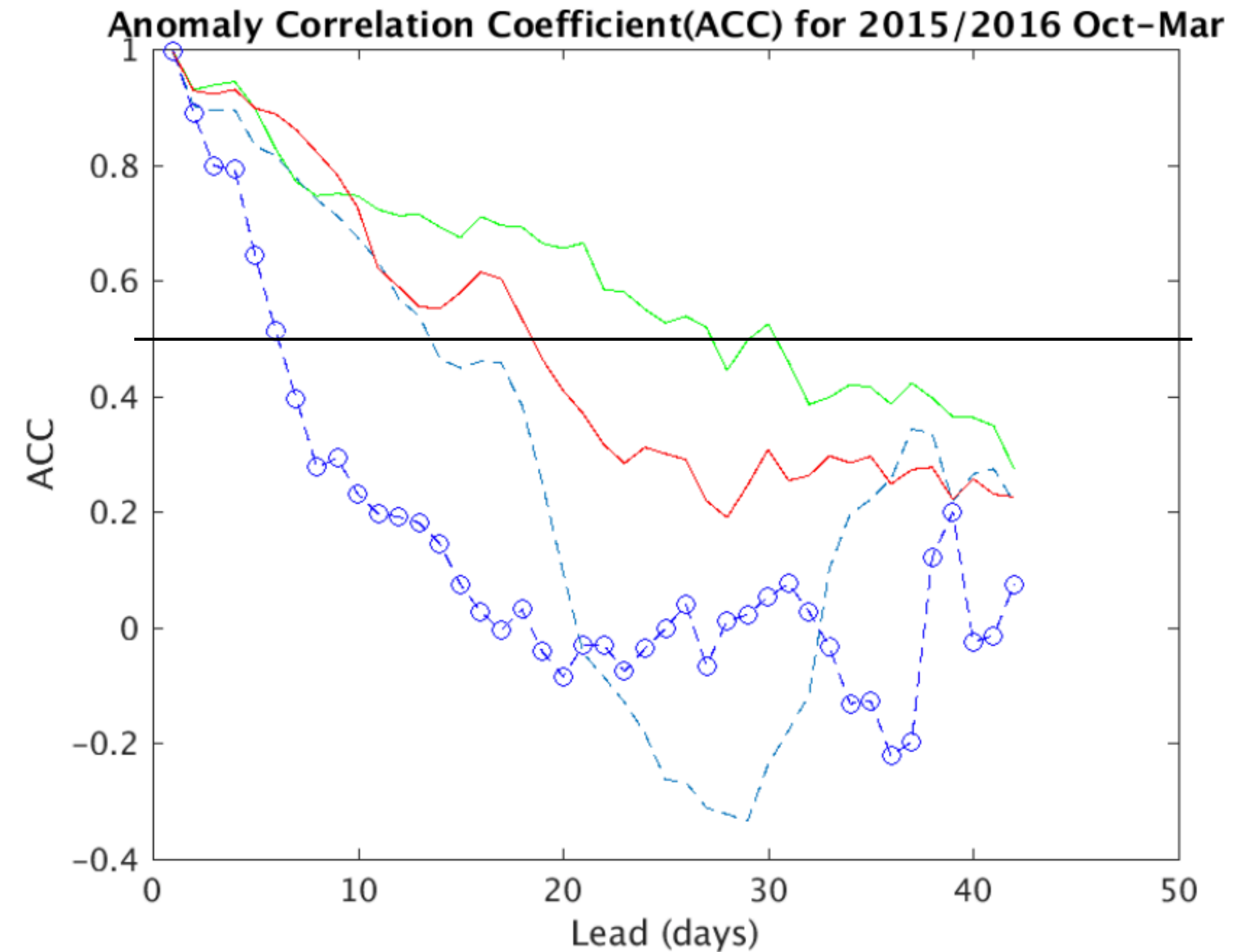
CFSv2 Regime Counts Anomaly Correlation Skill

1999–2014 Hindcasts



- skill limited to 2 weeks in general

2015/16 Forecasts



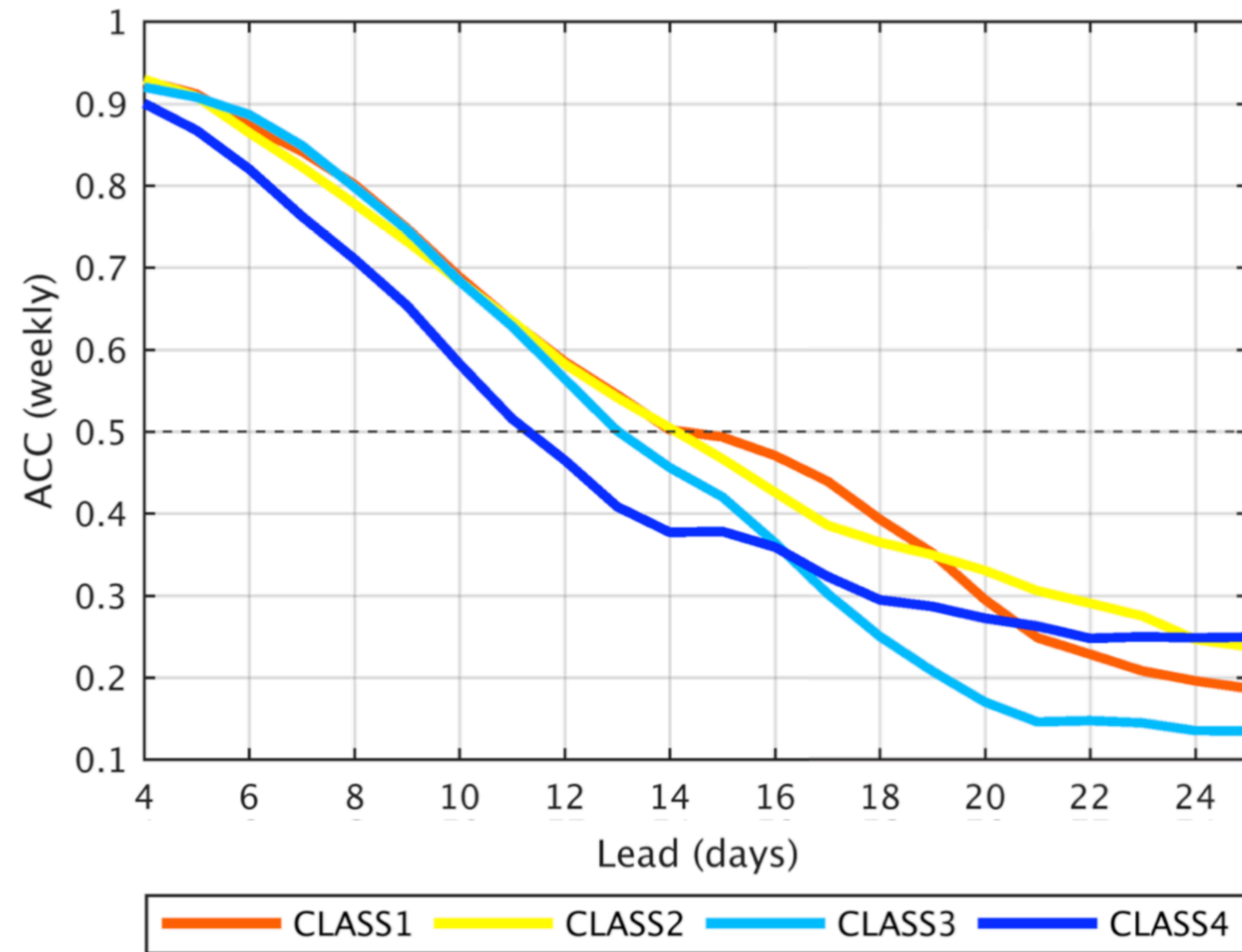
- week 3-4 skill in 2015/16 in PNA/RNA regimes

ECMWF

Forecast Skill

Weekly counts

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

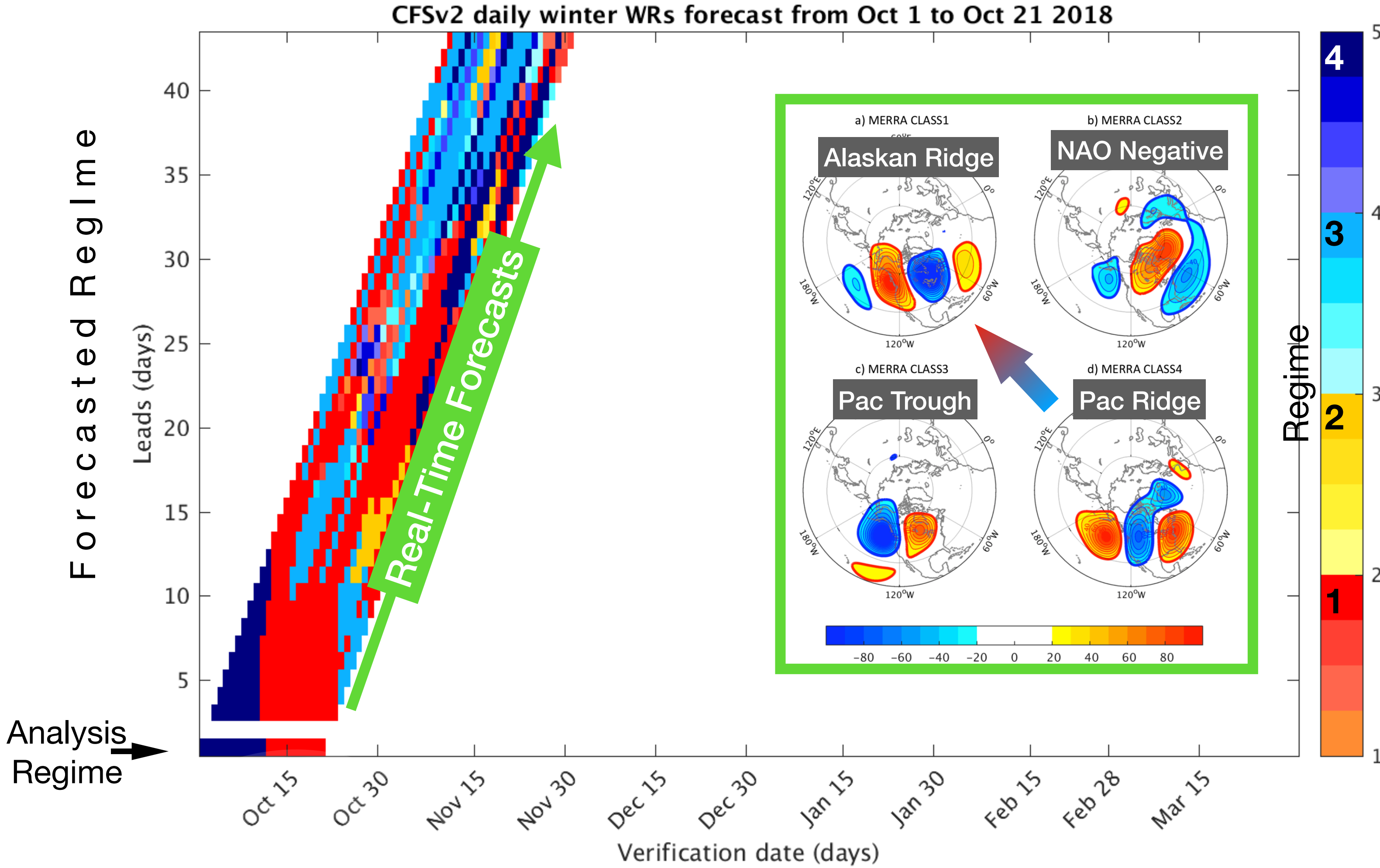


Limited skill after 2 weeks

consistent with probabilistic forecast skill

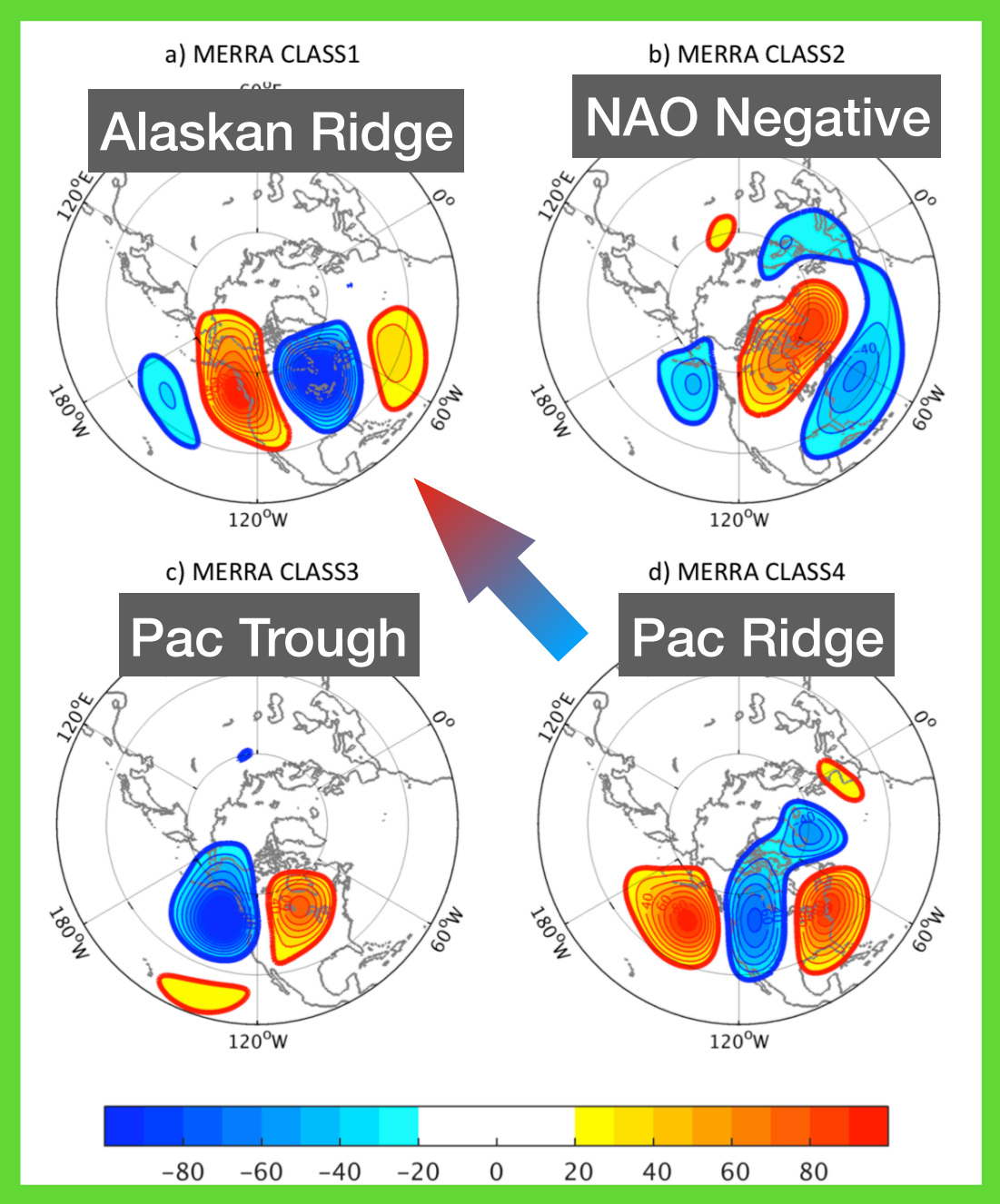
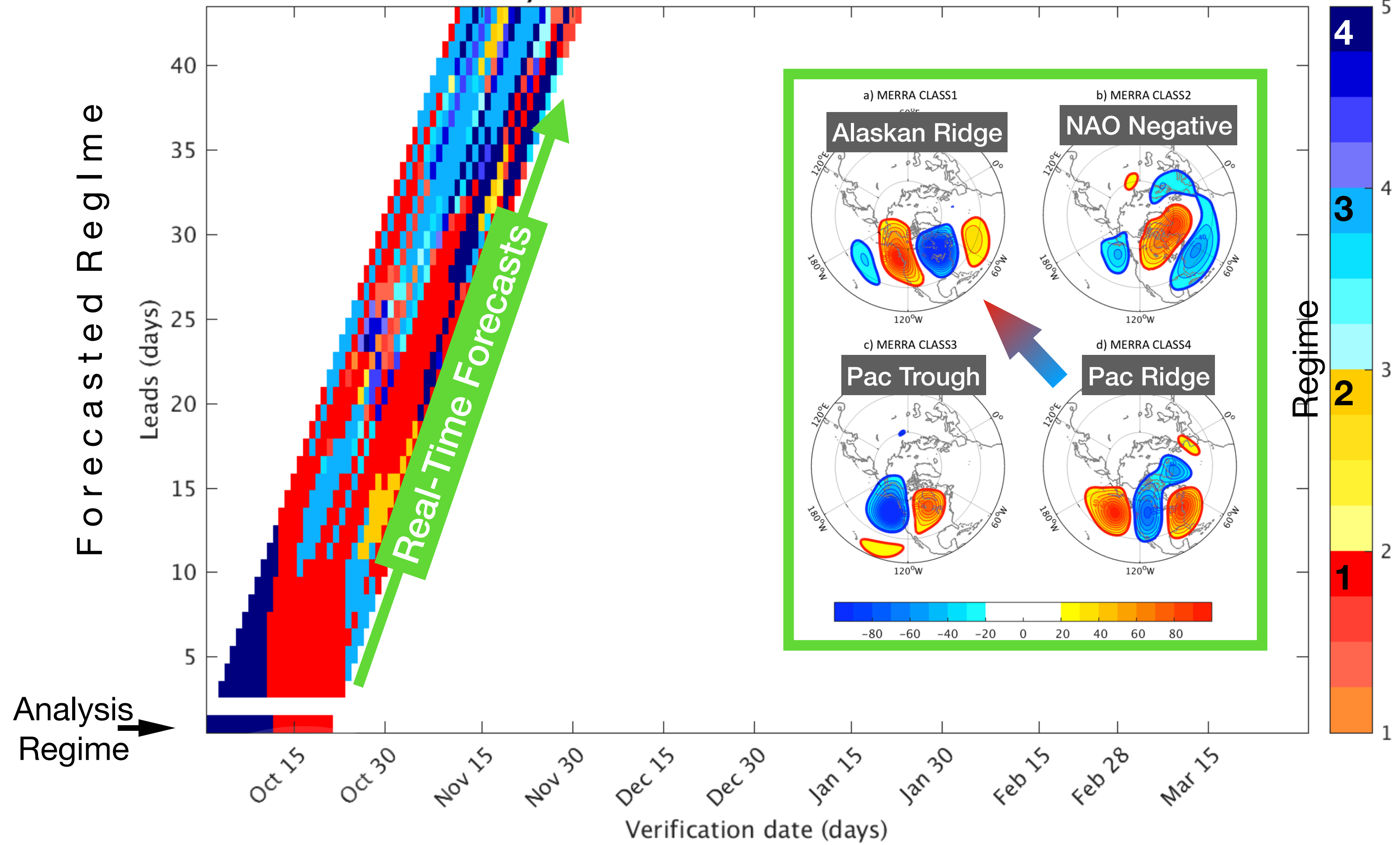
All ECMWF reforecasts projected onto MERRA weather regimes

Weather Regime Forecasts in Real Time

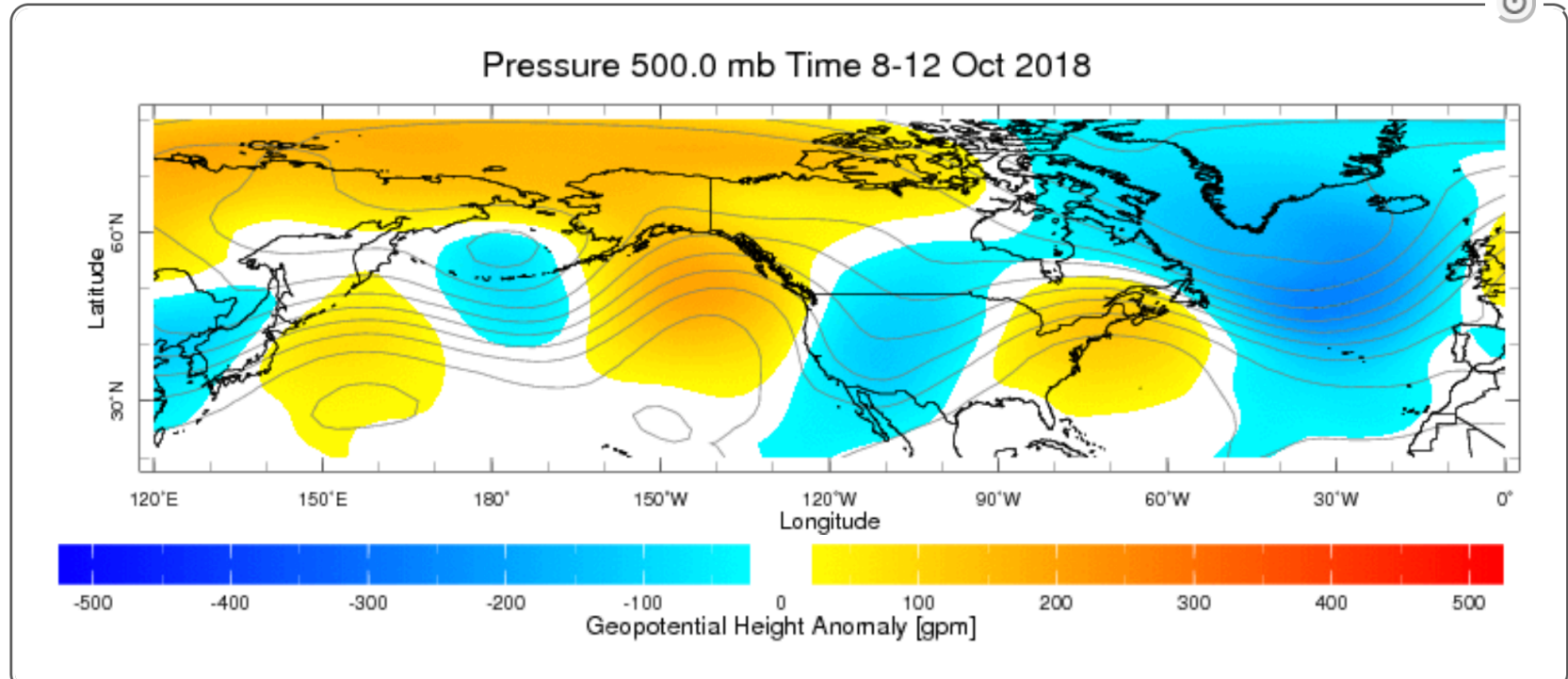


Weather Regime Forecasts in Real Time

CFSv2 daily winter WRs forecast from Oct 1 to Oct 21 2018

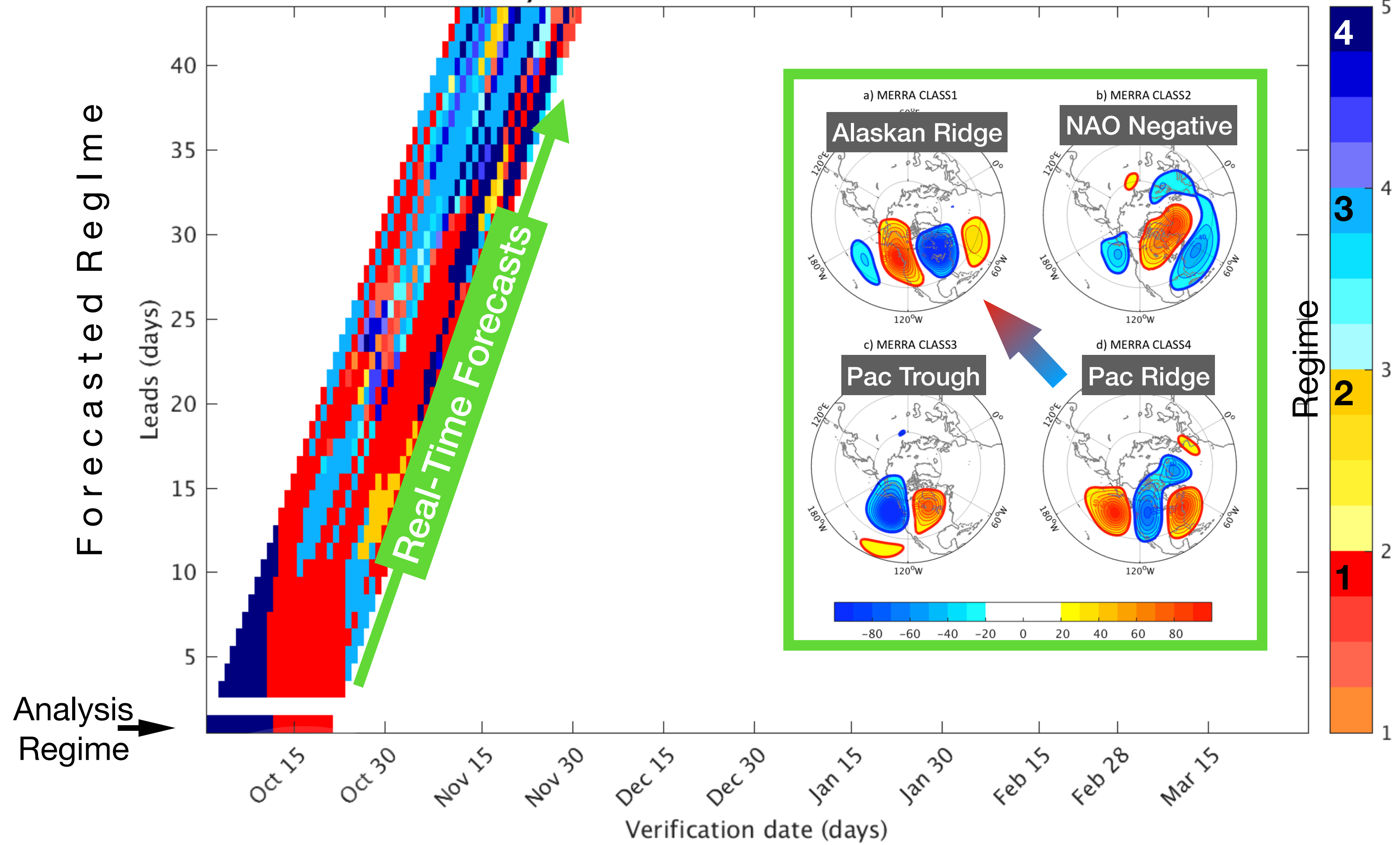


Observed Geopotential Height Anomaly

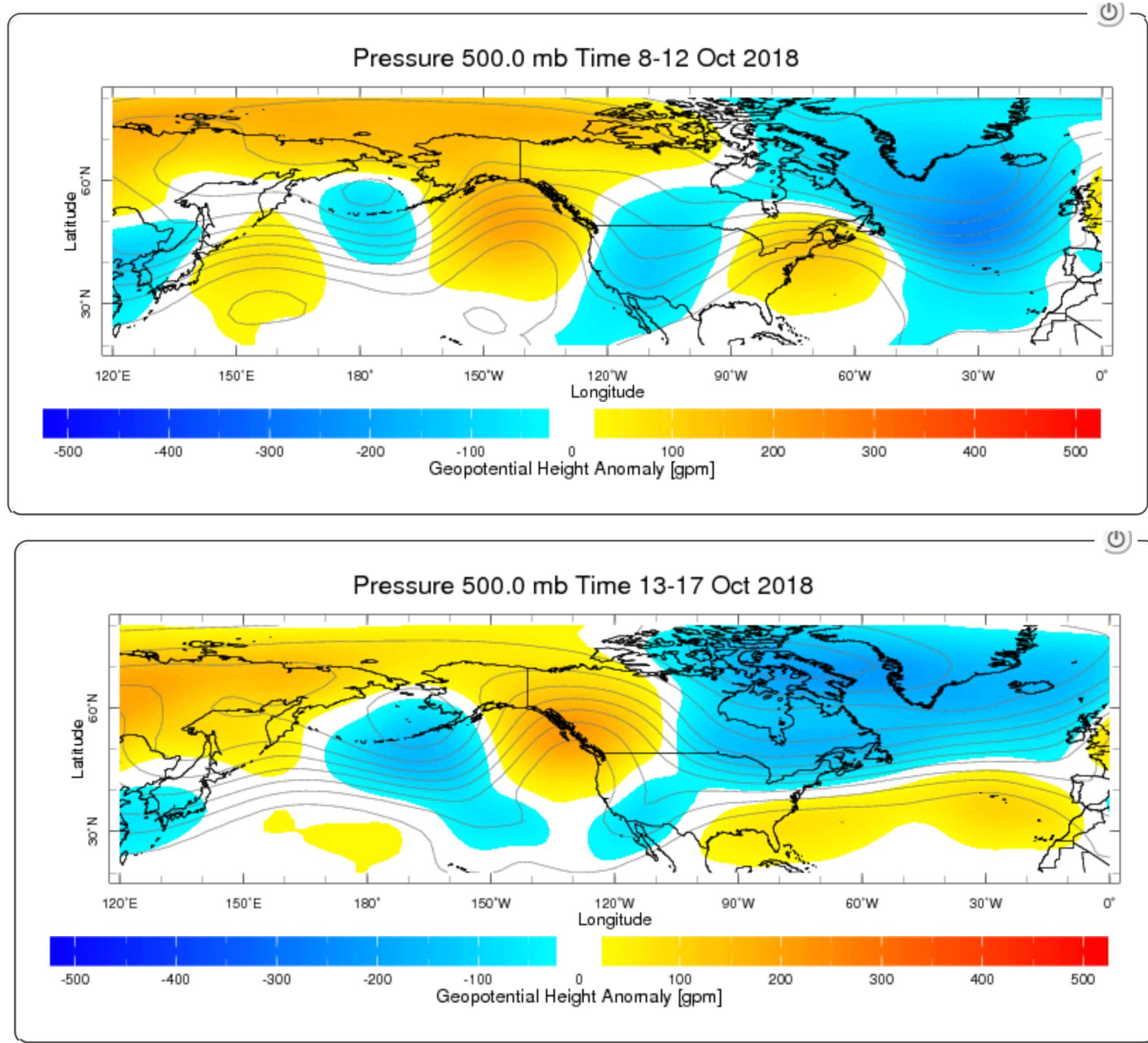


Weather Regime Forecasts in Real Time

CFSv2 daily winter WRs forecast from Oct 1 to Oct 21 2018



Observed Geopotential Height Anomaly



Summary

- Set of four 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.
- Both ECMWF & CFSv2 models skillful in MERRA-regime space to 10–15 days.
- Cases of good skill in CFSv2 up to 4 weeks ahead such as Dec-Feb 2008/9, associated with ENSO and possibly MJO. Pacific Trough Regime greatly over-forecasted in 2015/16.
- “Chiclet diagrams” provide a “tracker” of large-scale forecast evolution and assessment, highlighting past skillful intraseasonal episodes and real-time development.