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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What are “Weather Regimes”?

aka Large Scale Meteorological Patterns

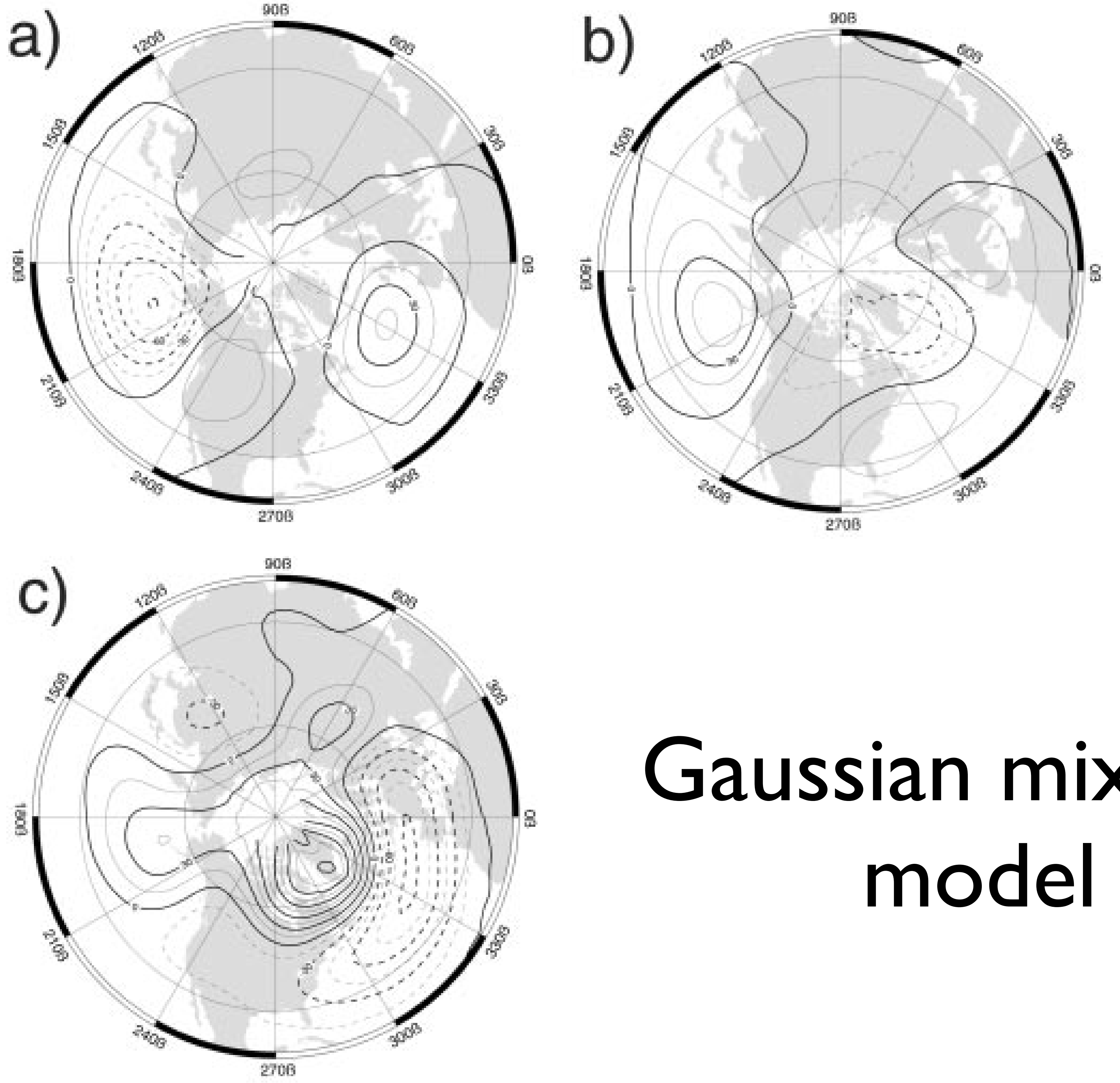
- Long history in dynamical meteorology of the midlatitudes of so-called low frequency variability (LFV: 10–50 days) that organizes synoptic-scale weather: index cycles, blocking, quasi-equilibria, Grosswetterlagen, …

- 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?

Observational Characteristics of LFV

Classification of daily Geopotential Height Maps



Gaussian mixture model

Smyth et al (1999)

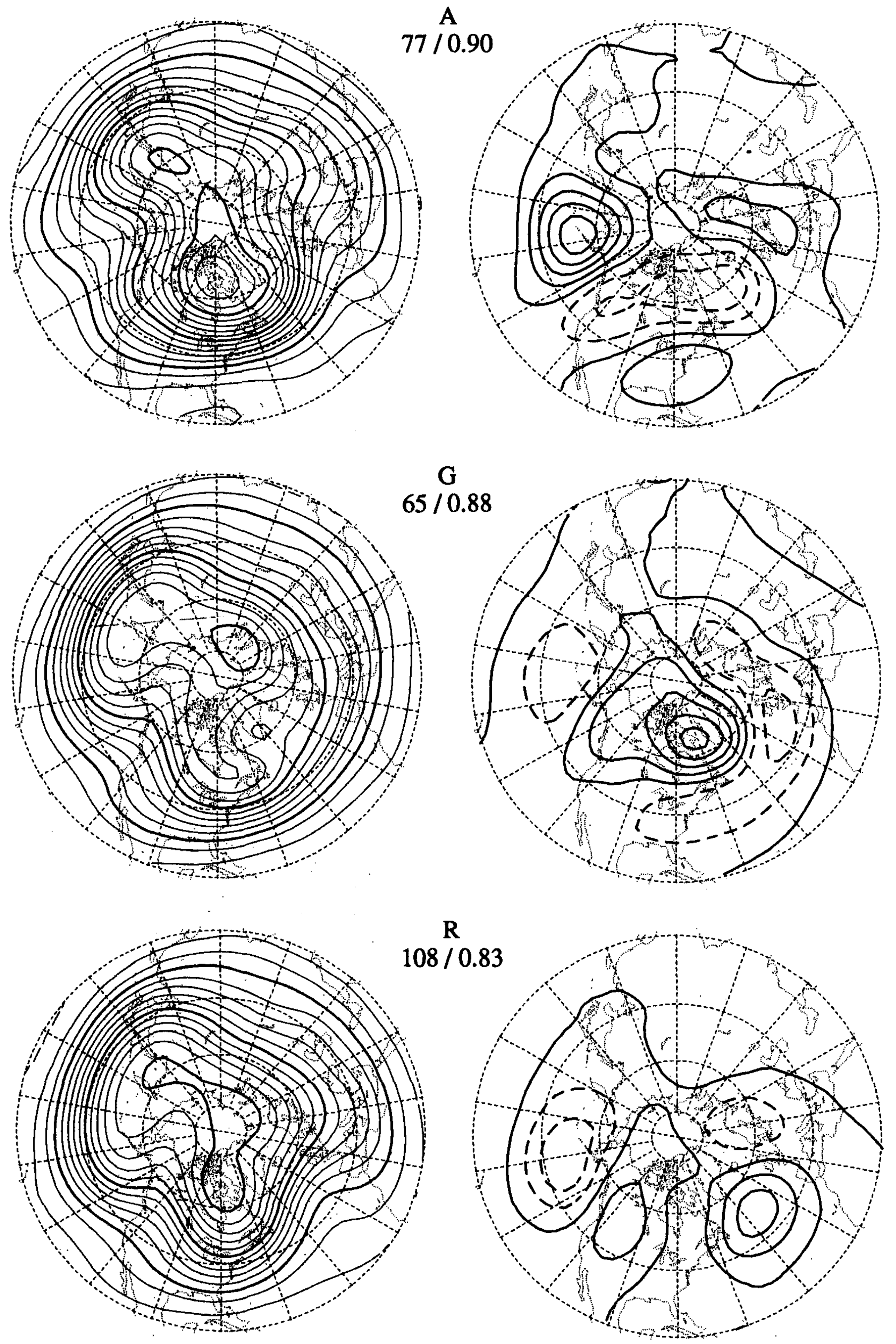


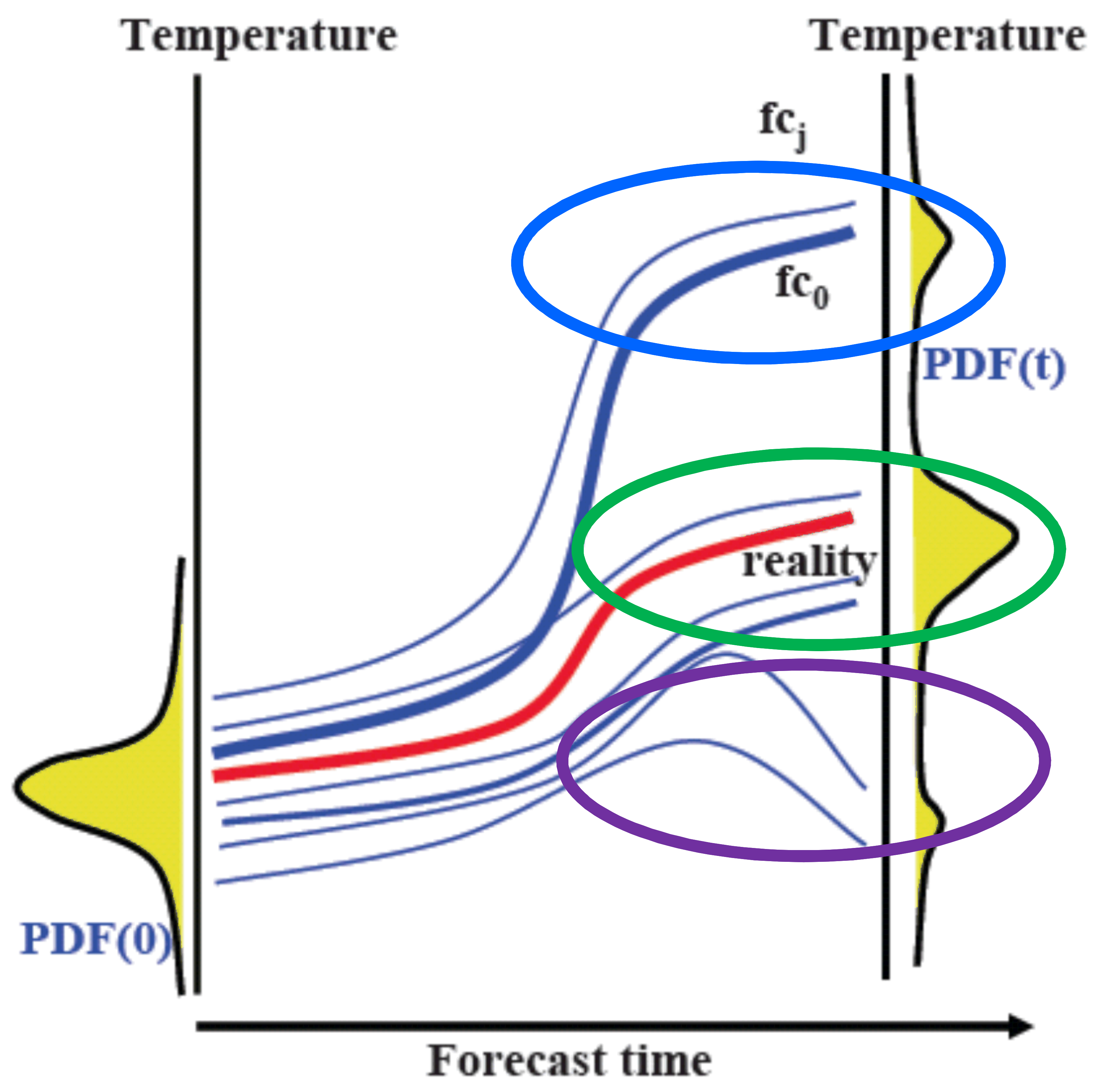
FIG. 4. Left: 500-hPa maps for the points in phase space that correspond to the centroids of the clusters labeled A, G, and R (indicated by boldfaced type in Fig. 3); contour interval 60 m. Right: The corresponding composite anomaly maps; contour interval 50 m, negative contours are dashed. Printed at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

Hierarchical clustering

Cheng & Wallace (1993)

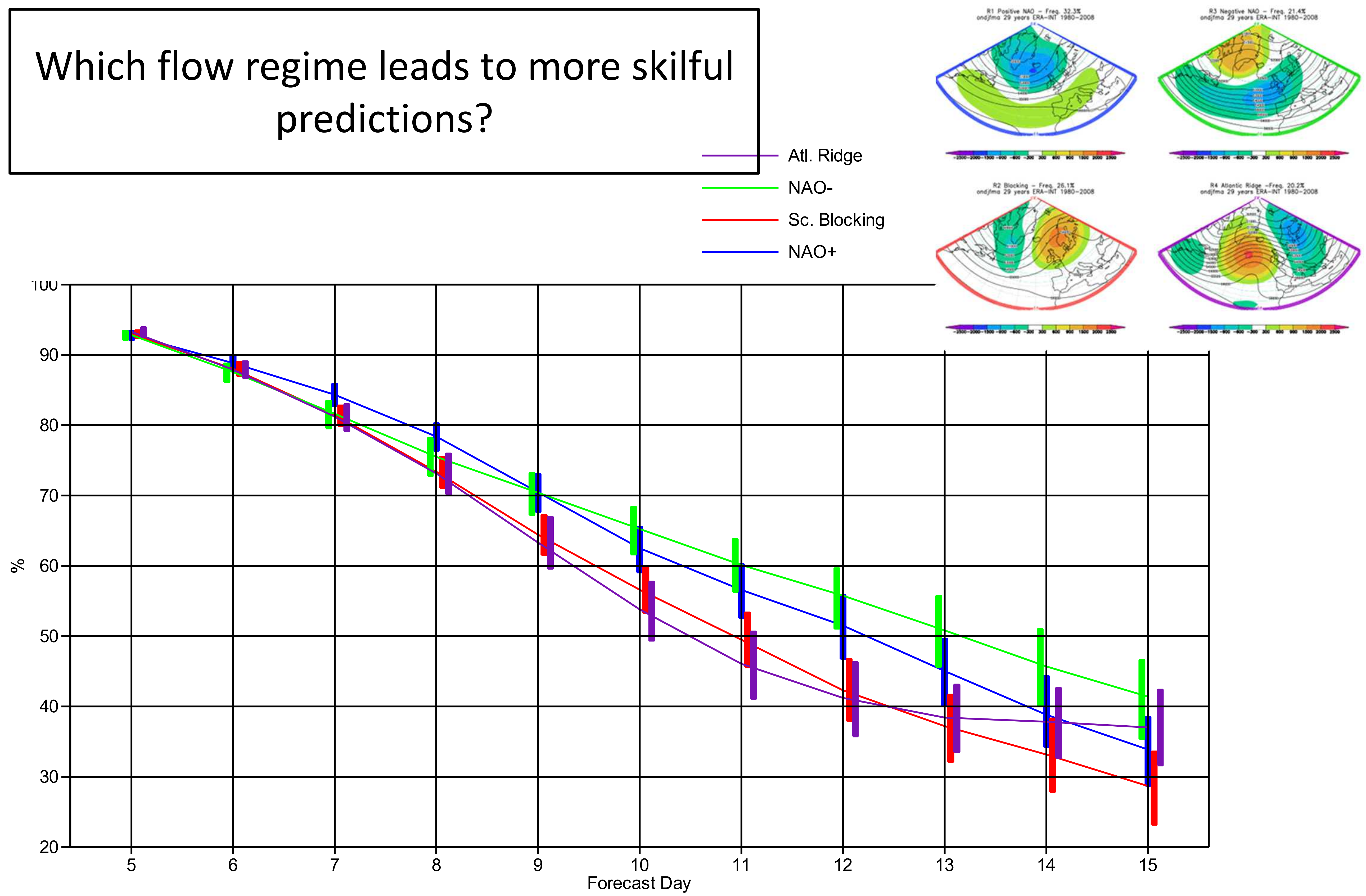
Why use a regime approach to S2S forecasts?

Low-order Diagnosis of Forecast Ensembles



Regime-Dependent Predictability?

Which flow regime leads to more skilful predictions?



Anomaly correlation of the ensemble means for the four forecast categories as a function of forecast range. The bars, based on 1000 subsamples generated with the bootstrap method, indicate the 95% confidence intervals.

From L.Ferranti

Scientific objectives

- 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.

- 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.

- 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.

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

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

North American Circulation Regimes in Data and S2S Forecasts

1. Perform 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

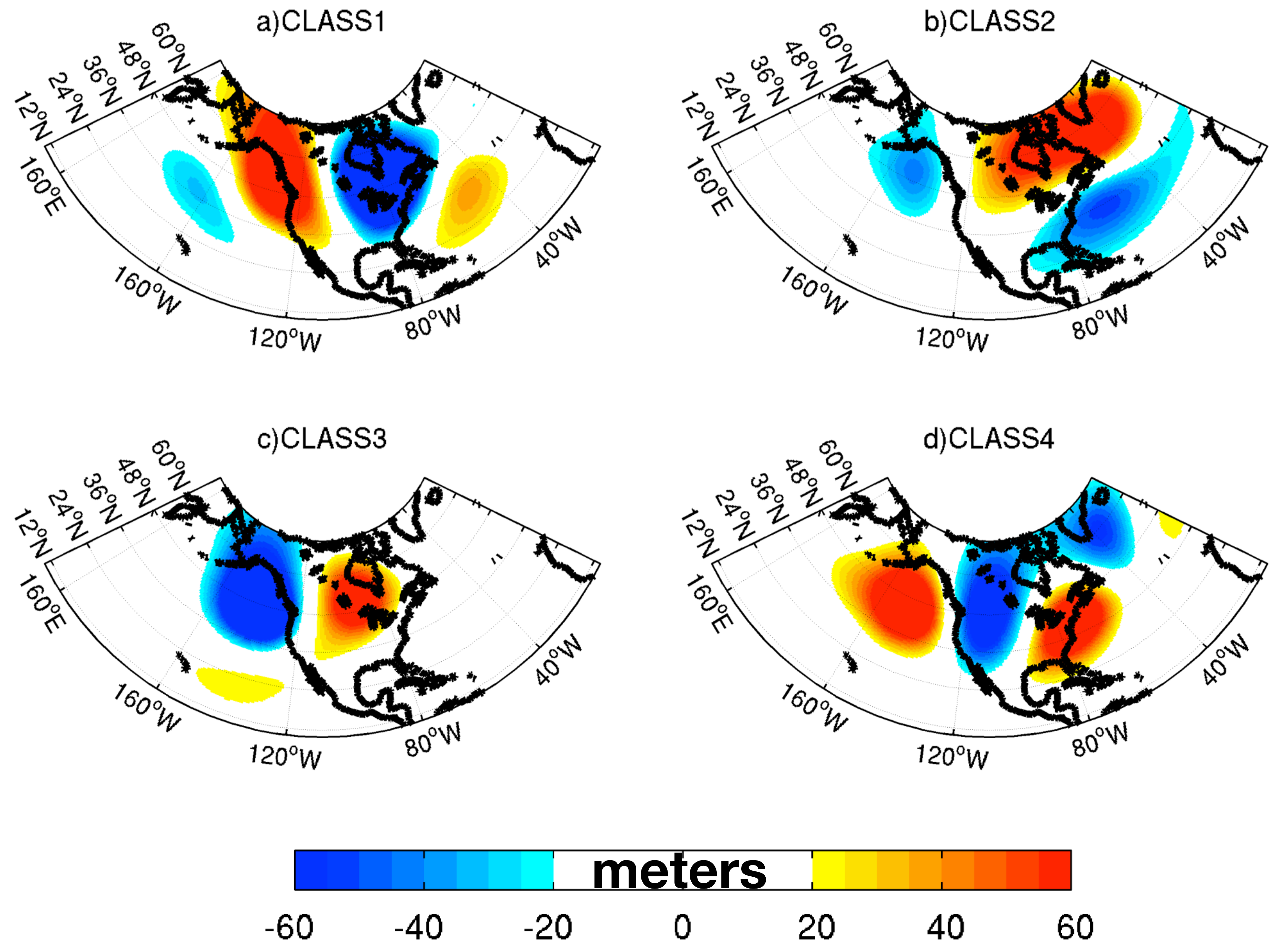
2. Repeat using ECMWF days 1-7 reforecast ensemble means; Monday starts concatenated Oct-Mar, 1995-2014: *Can ECMWF model capture regime structures and transitions in weather Forecasts?*

3. Then project Week 1-4 Forecasts onto MERRA Regimes: *Does the model have skill at predicting the subseasonal scale transitions?*

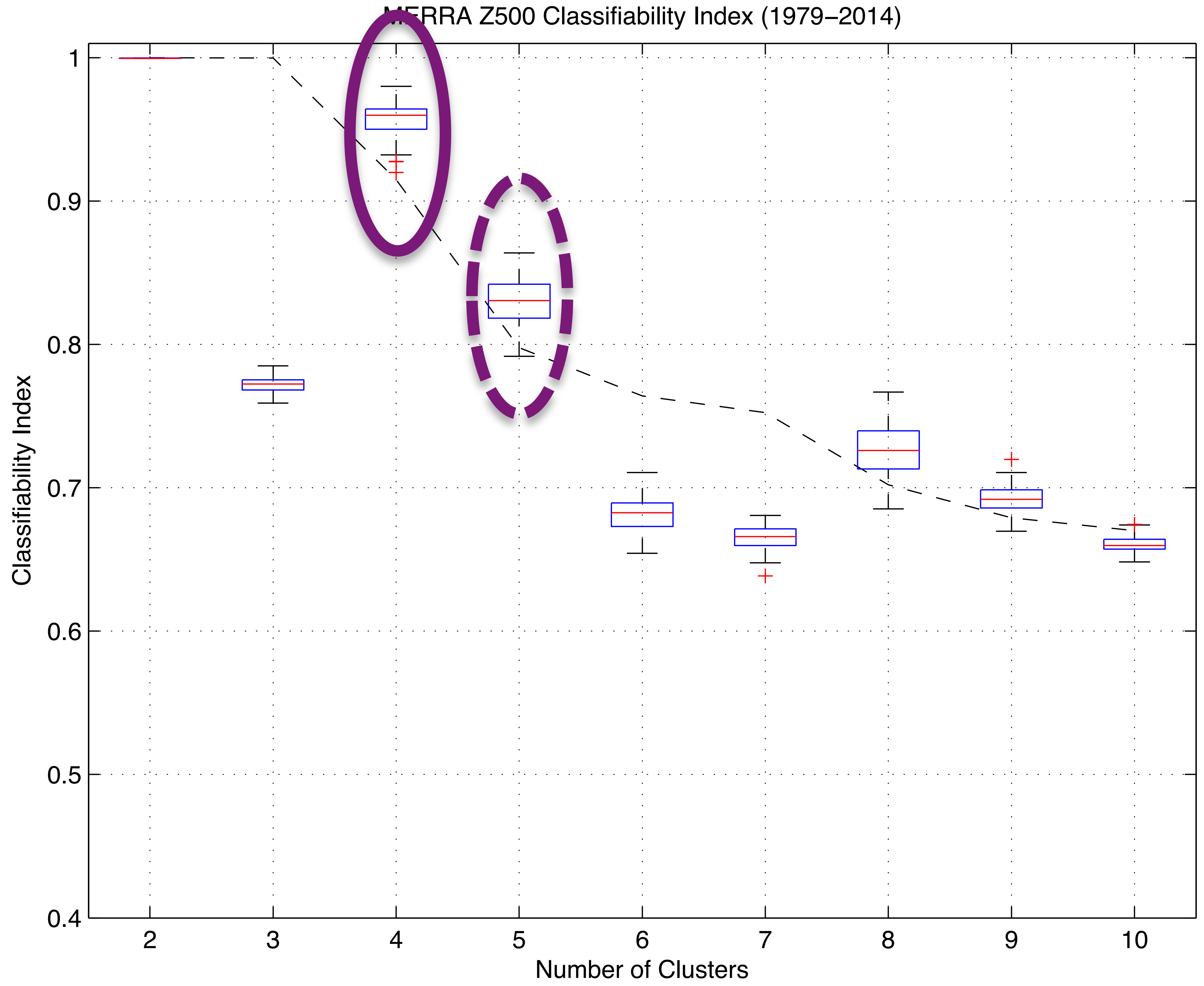
K-means of MERRA Z500 Anomalies

[150W-40W;10-70N]

K=4 Regime Composites



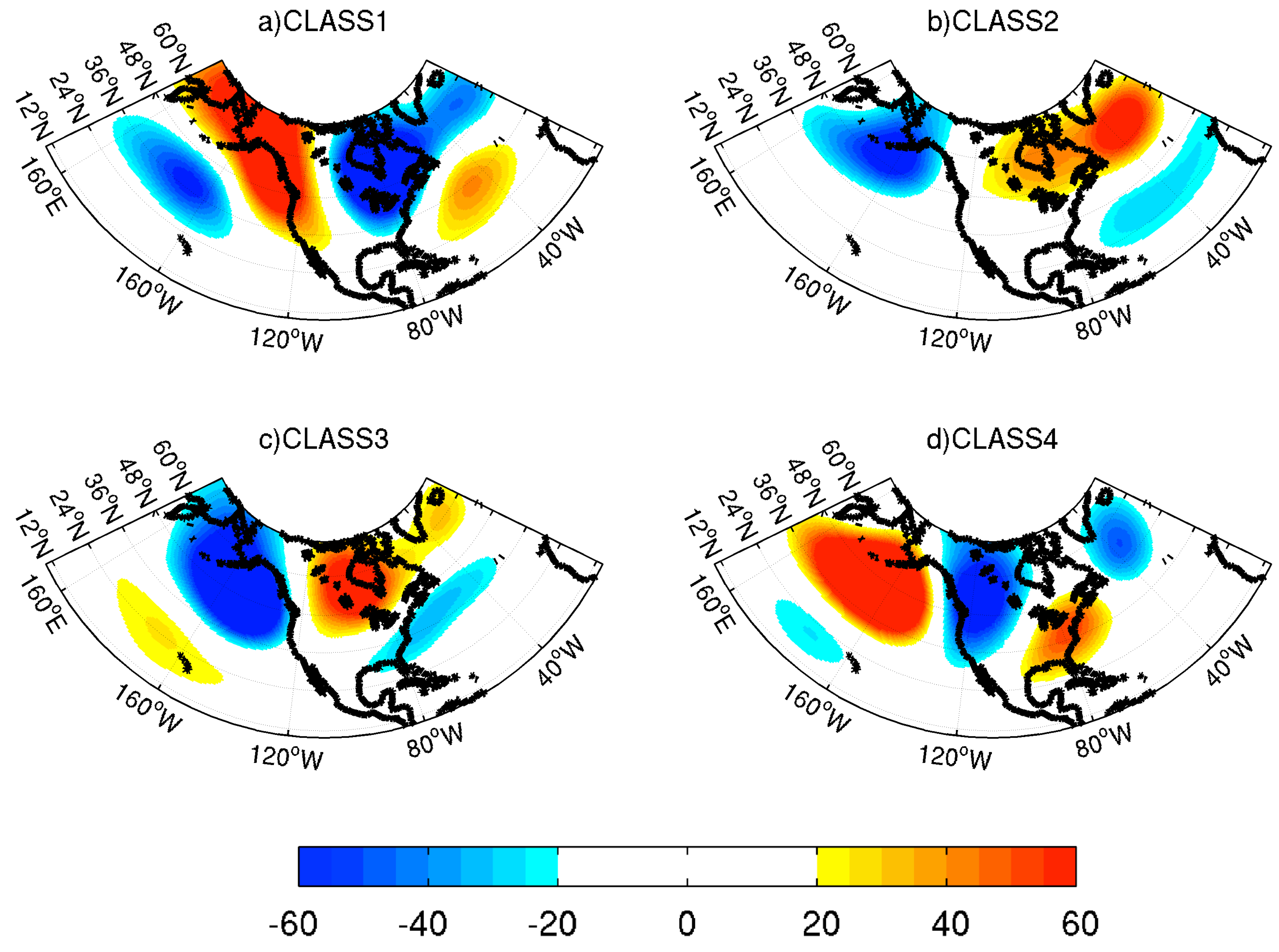
4 clusters partition



Domain Sensitivity: Larger Domain

[150E-20W;10-70N]

K=4 Regime Composites



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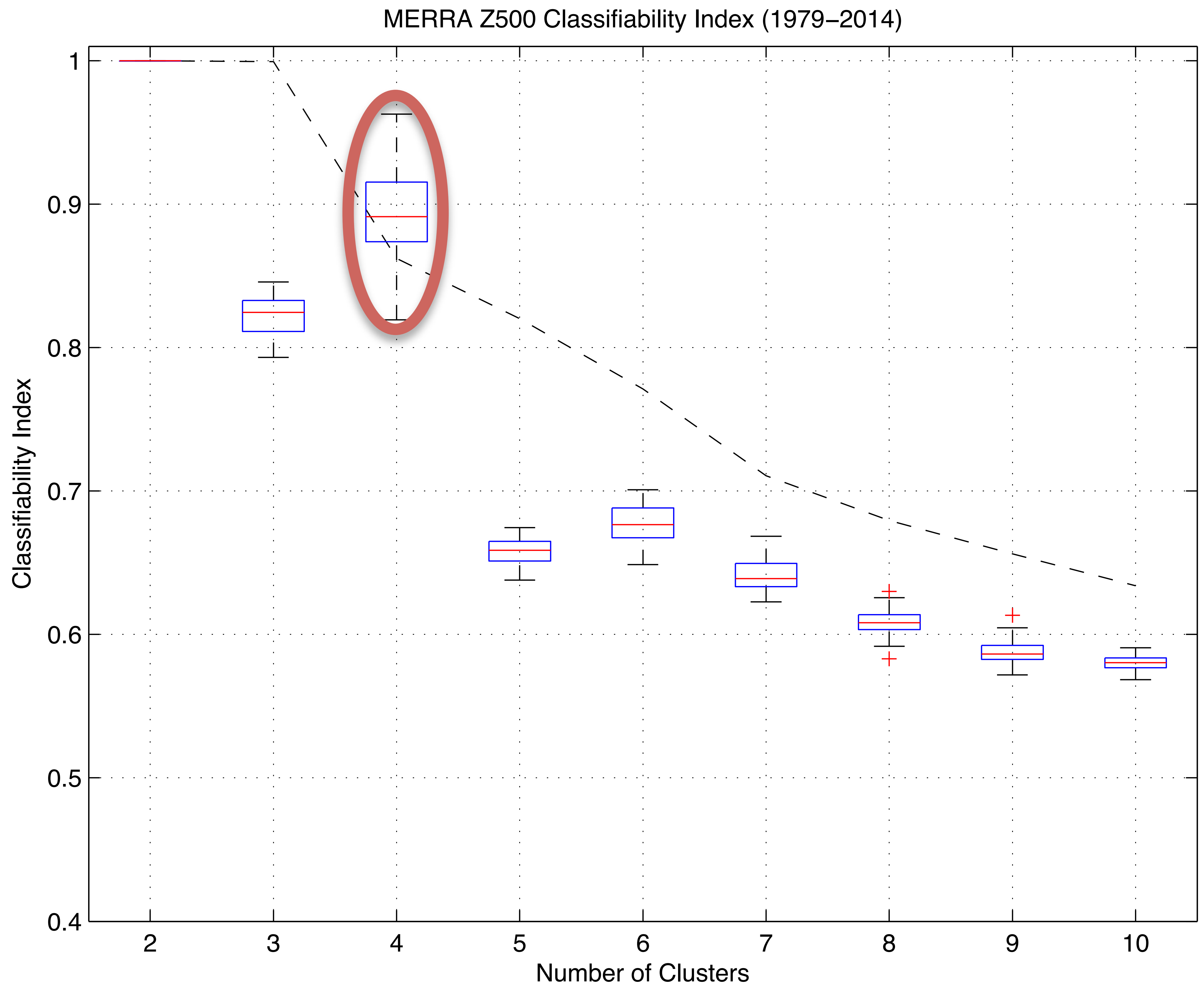
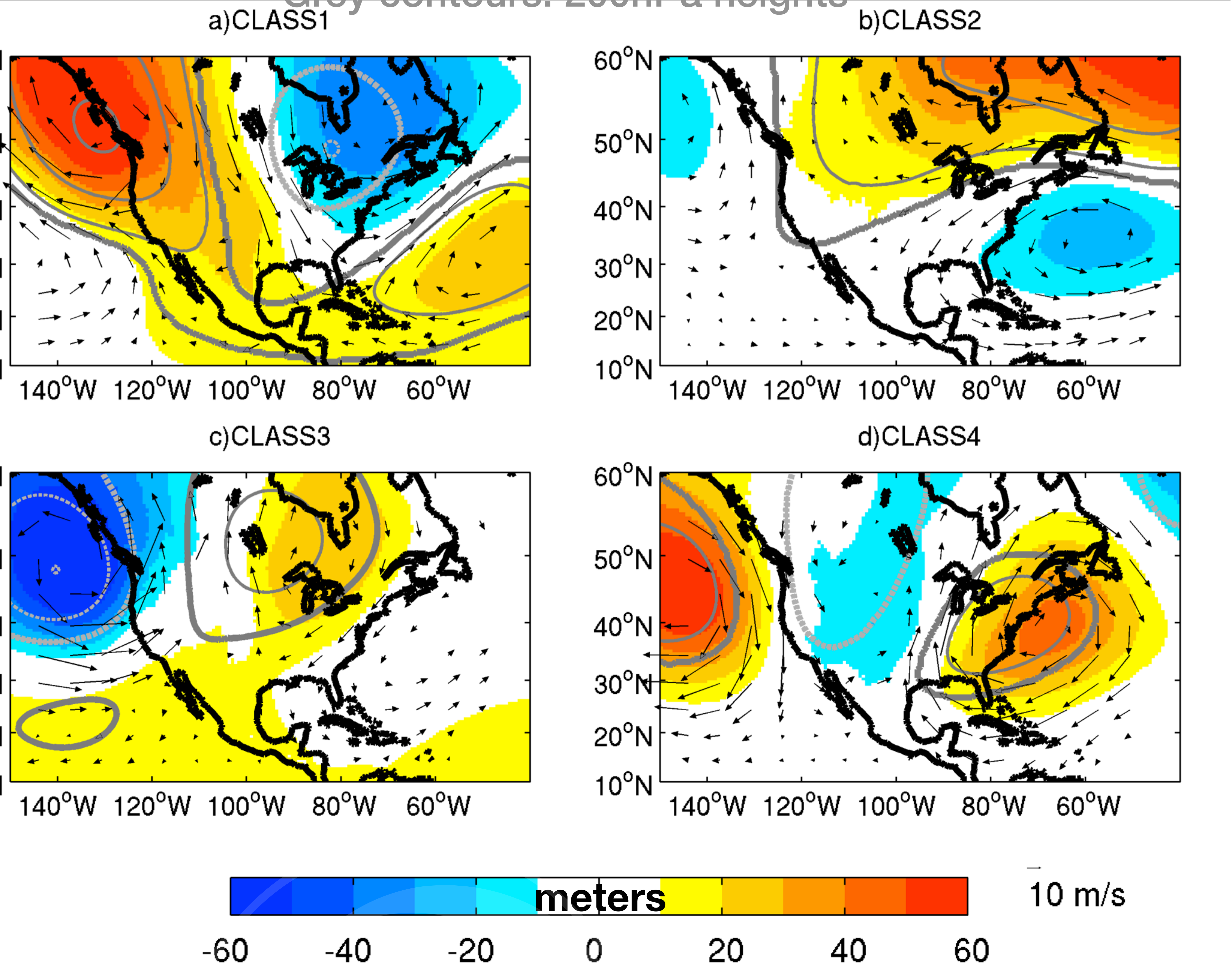


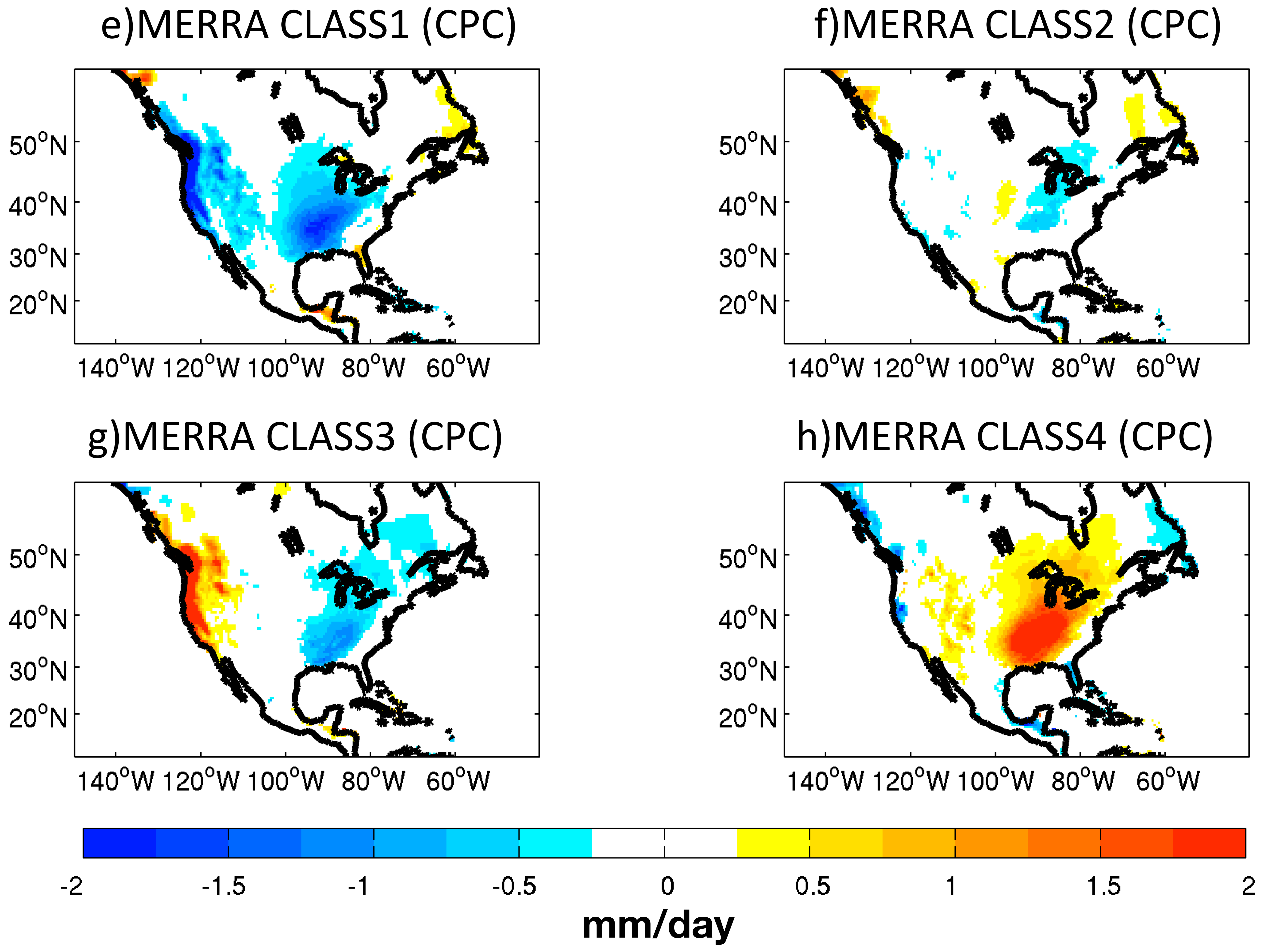
Meteorological Anomaly Composites

850hPa Heights & Winds

Grey contours: 200hPa heights



CPC Unified Precip.



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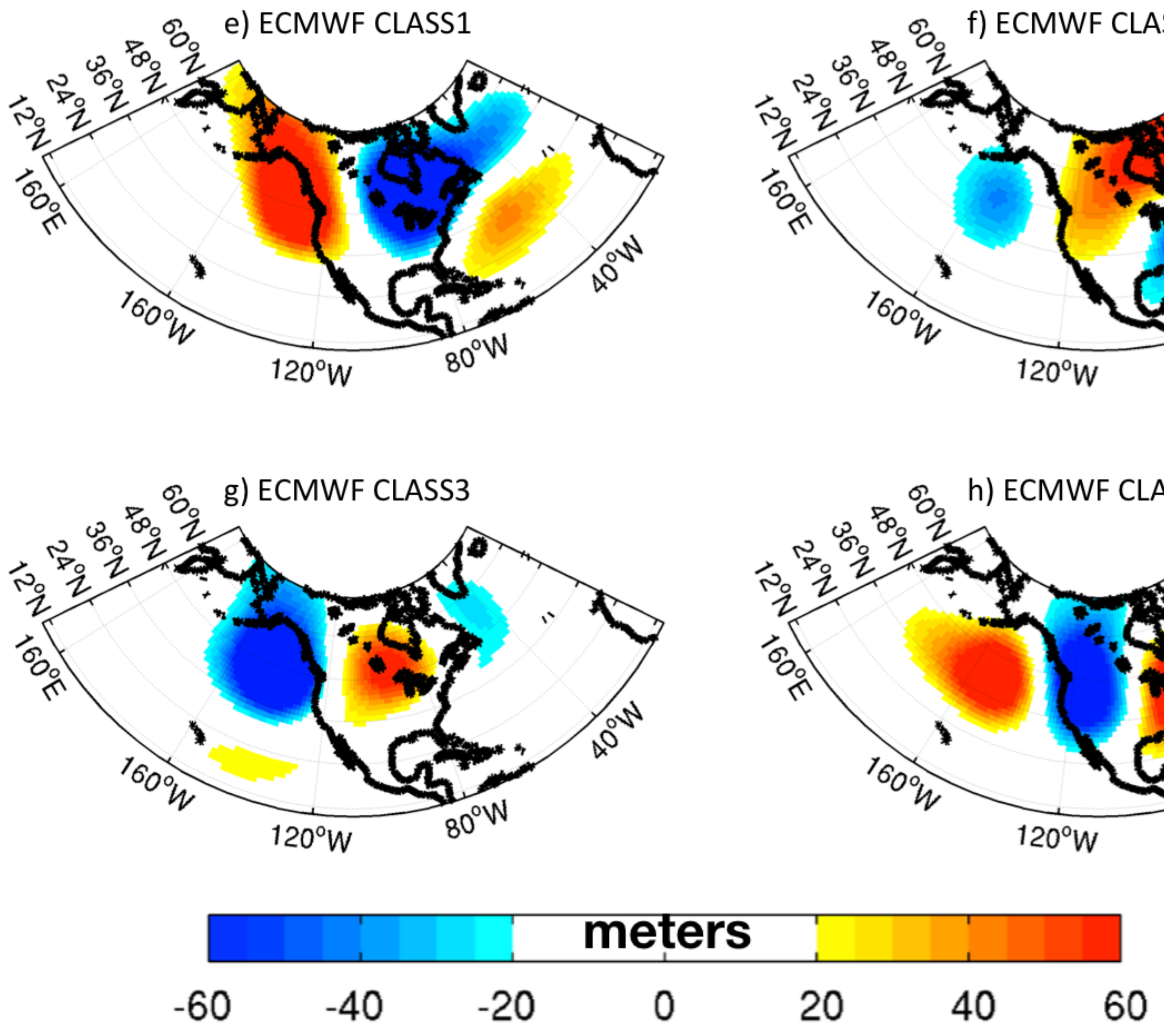
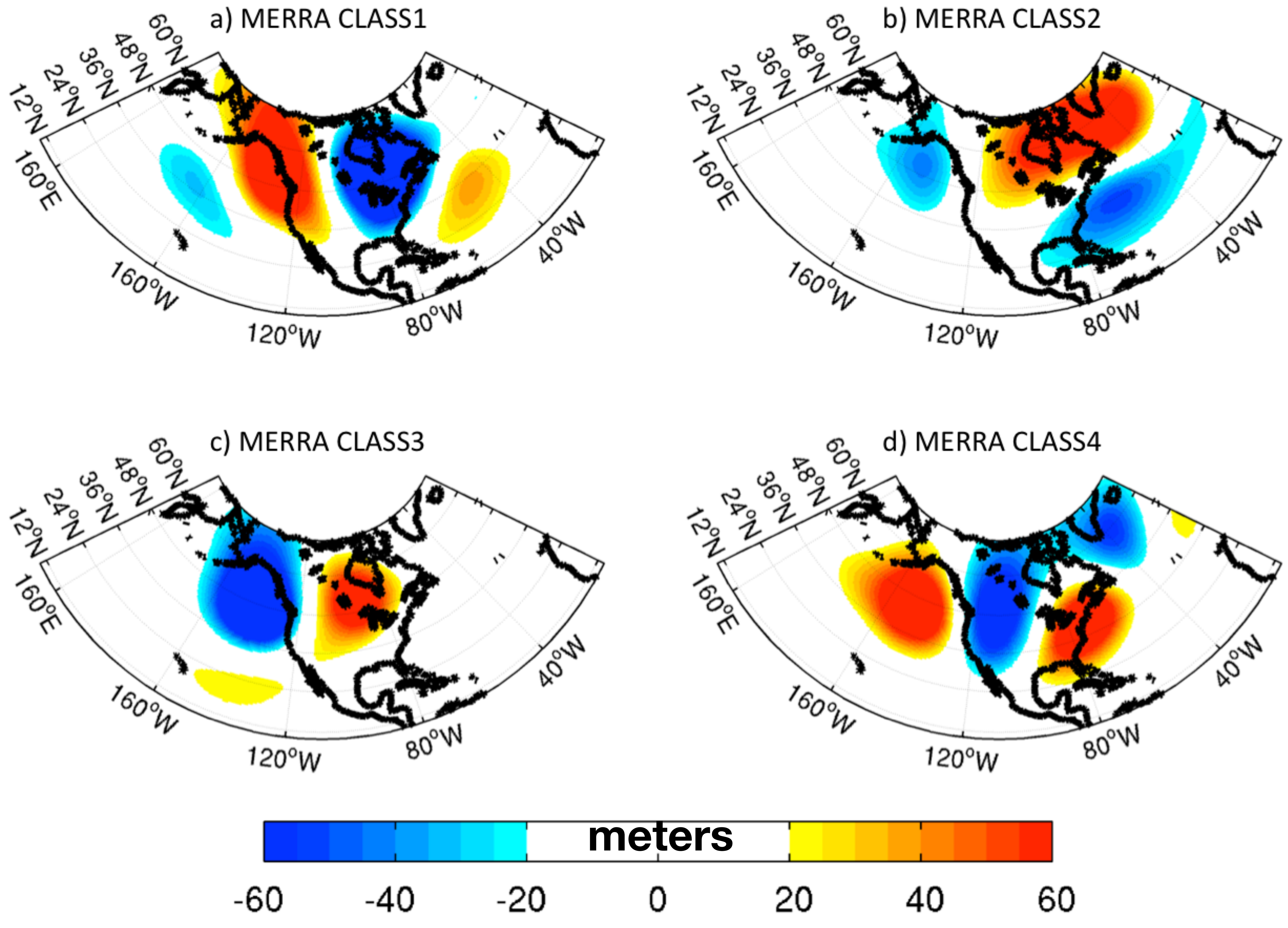
K-means of ECMWF Week-1 Z500 Anomalies

ECMWF Reforecasts

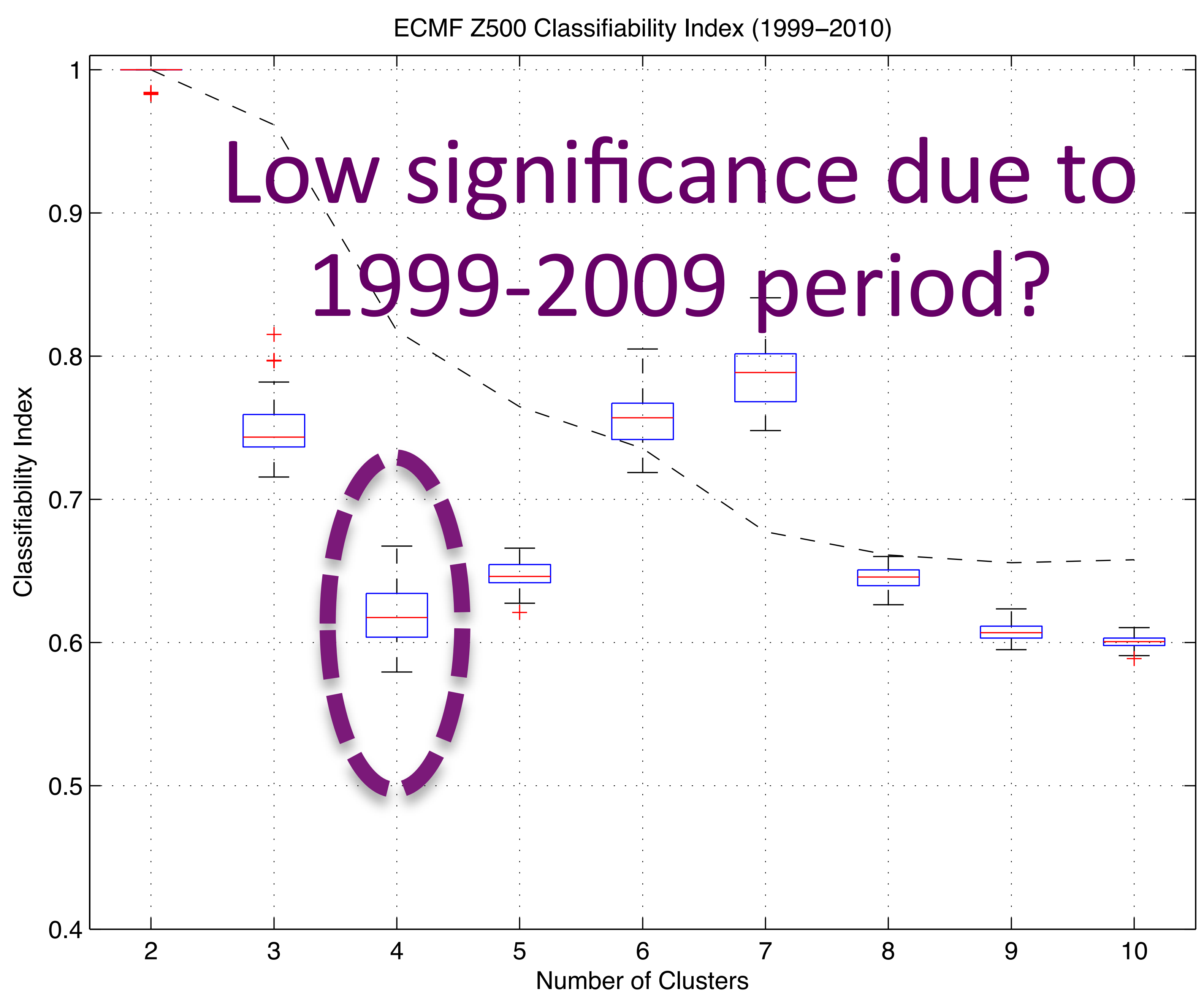


MERRA Reanalysis

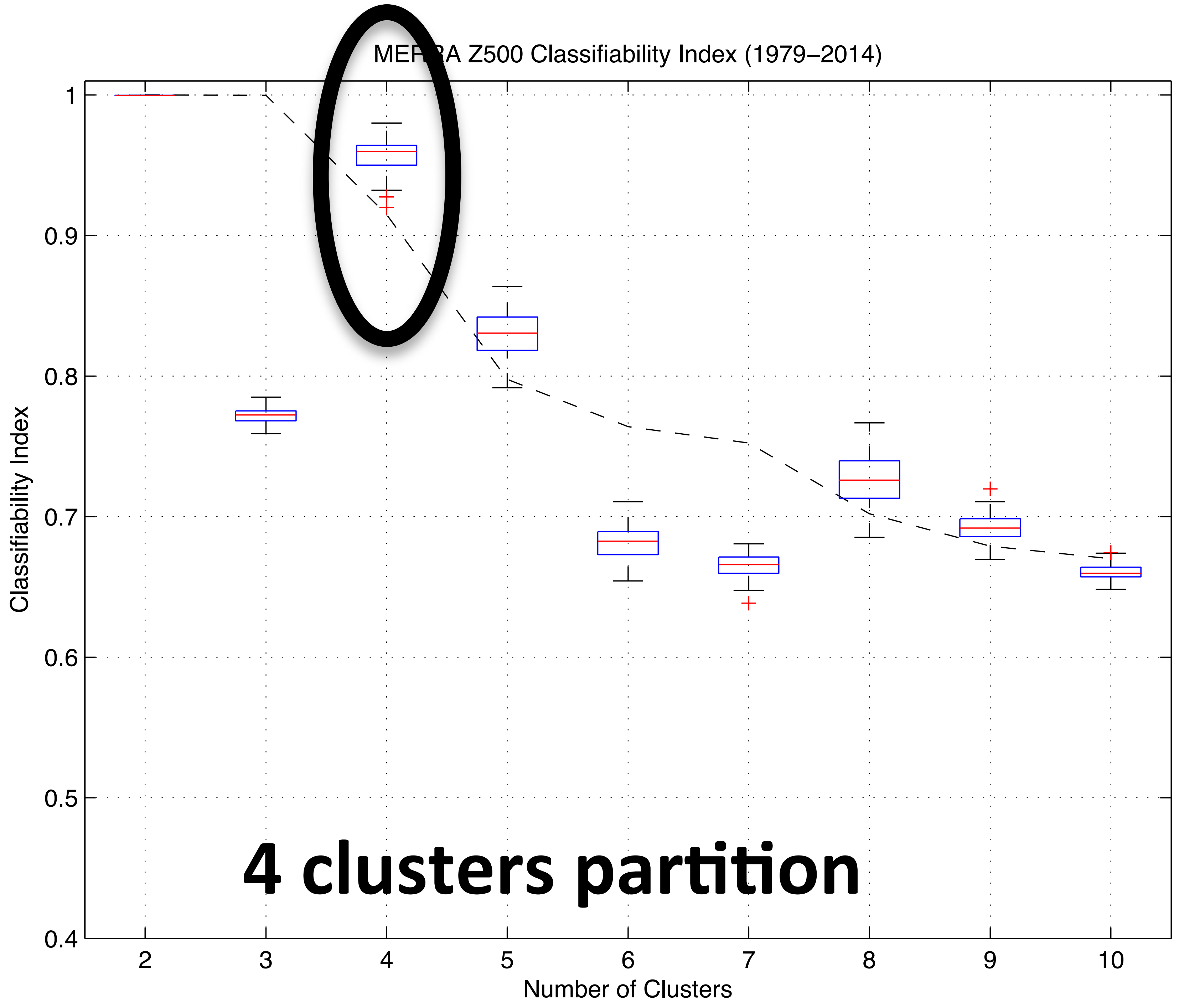


Classifiability Index

ECMWF Reforecasts

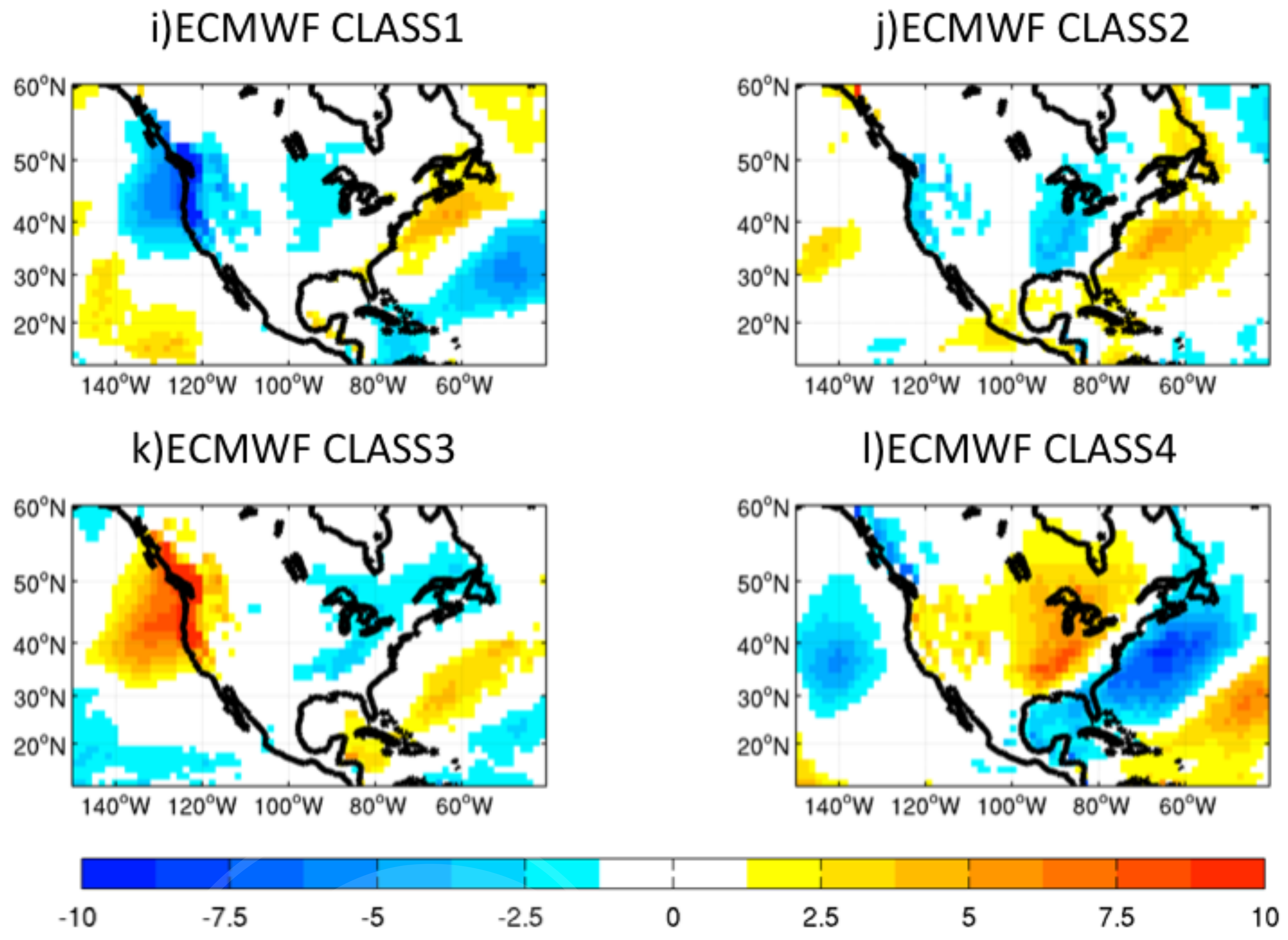


MERRA Reanalysis



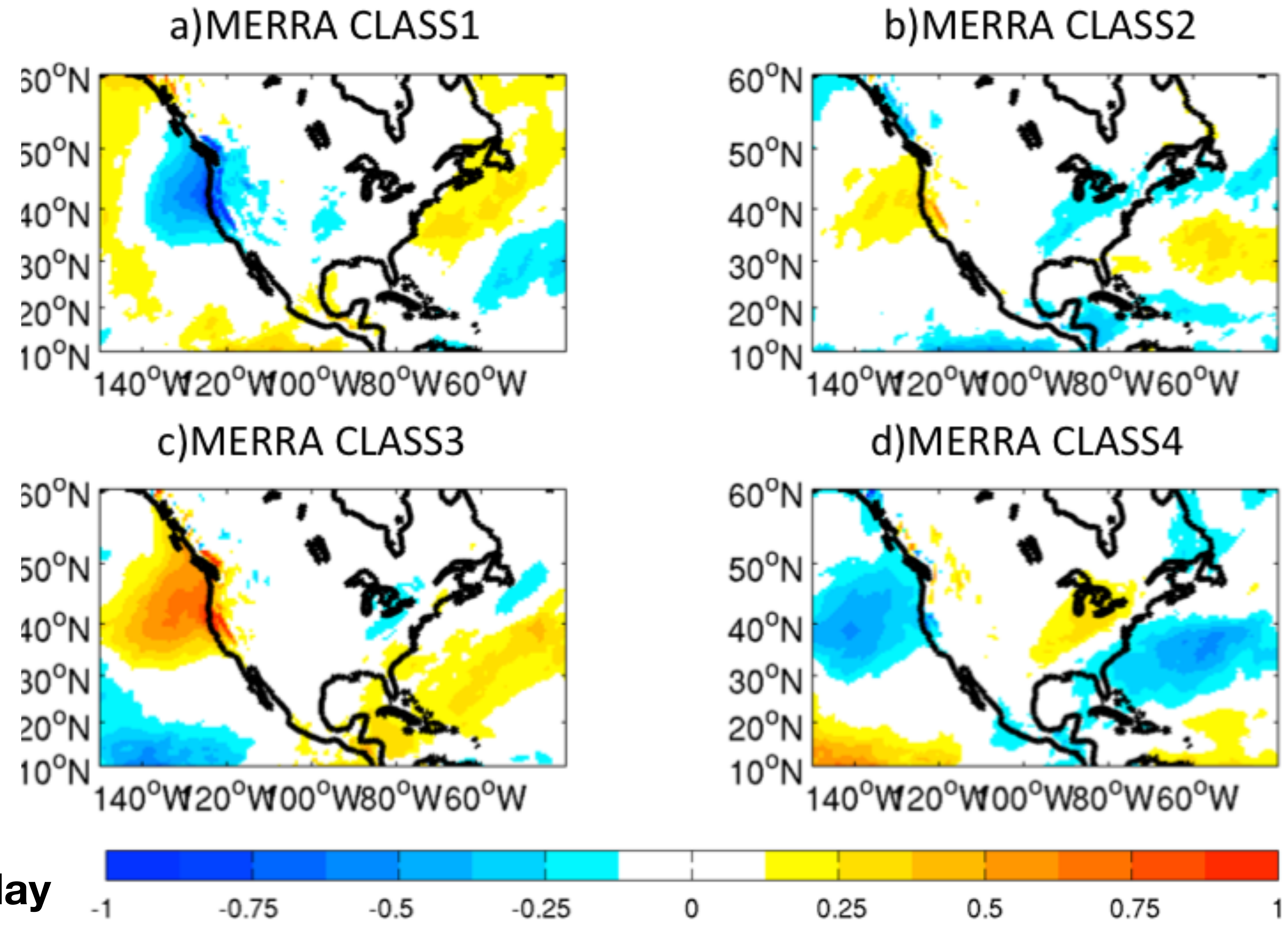
ECMWF vs MERRA Regimes
PRECIPITATION Anomaly Composites

ECMWF Reforecasts



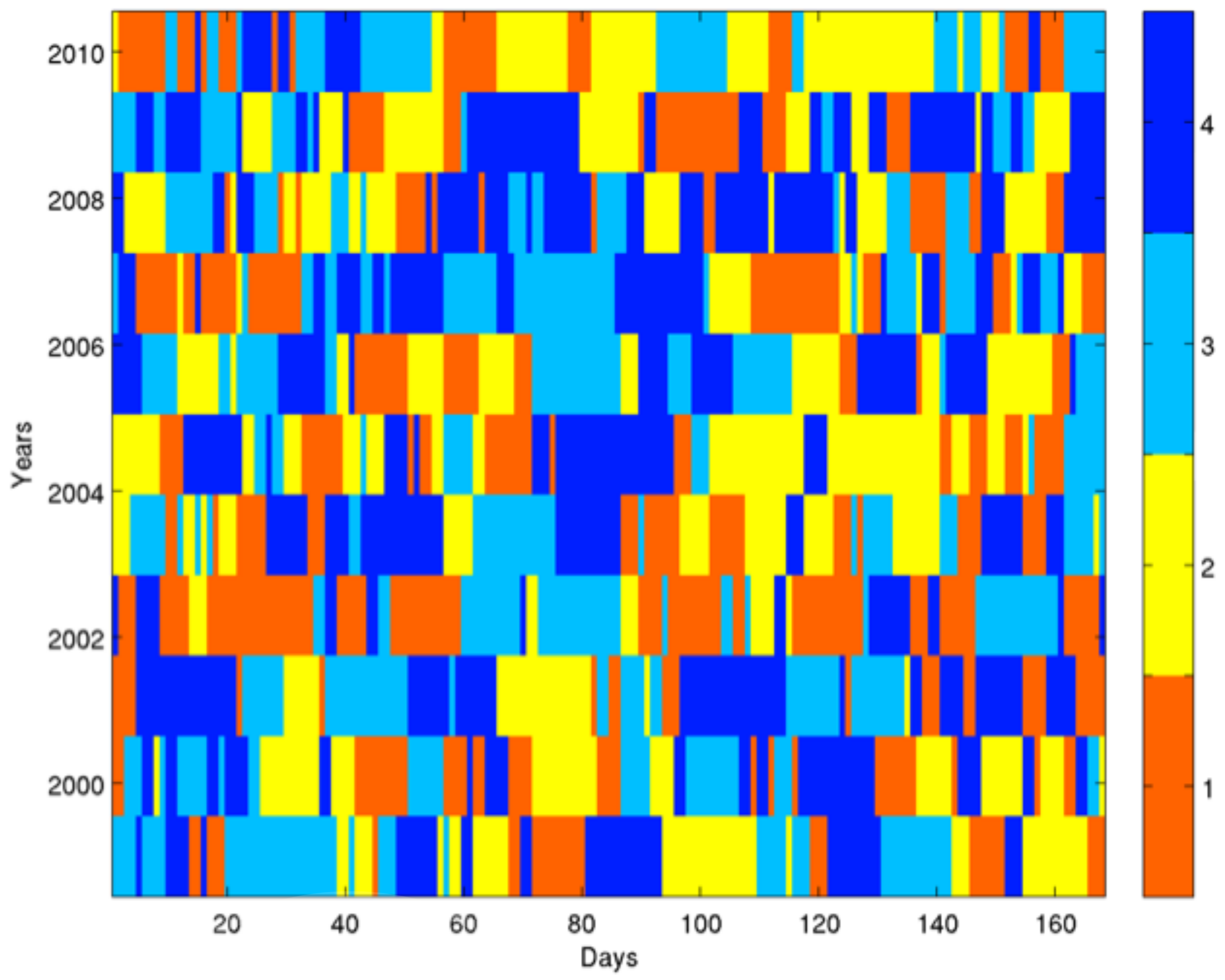
mm/day

MERRA Reanalysis

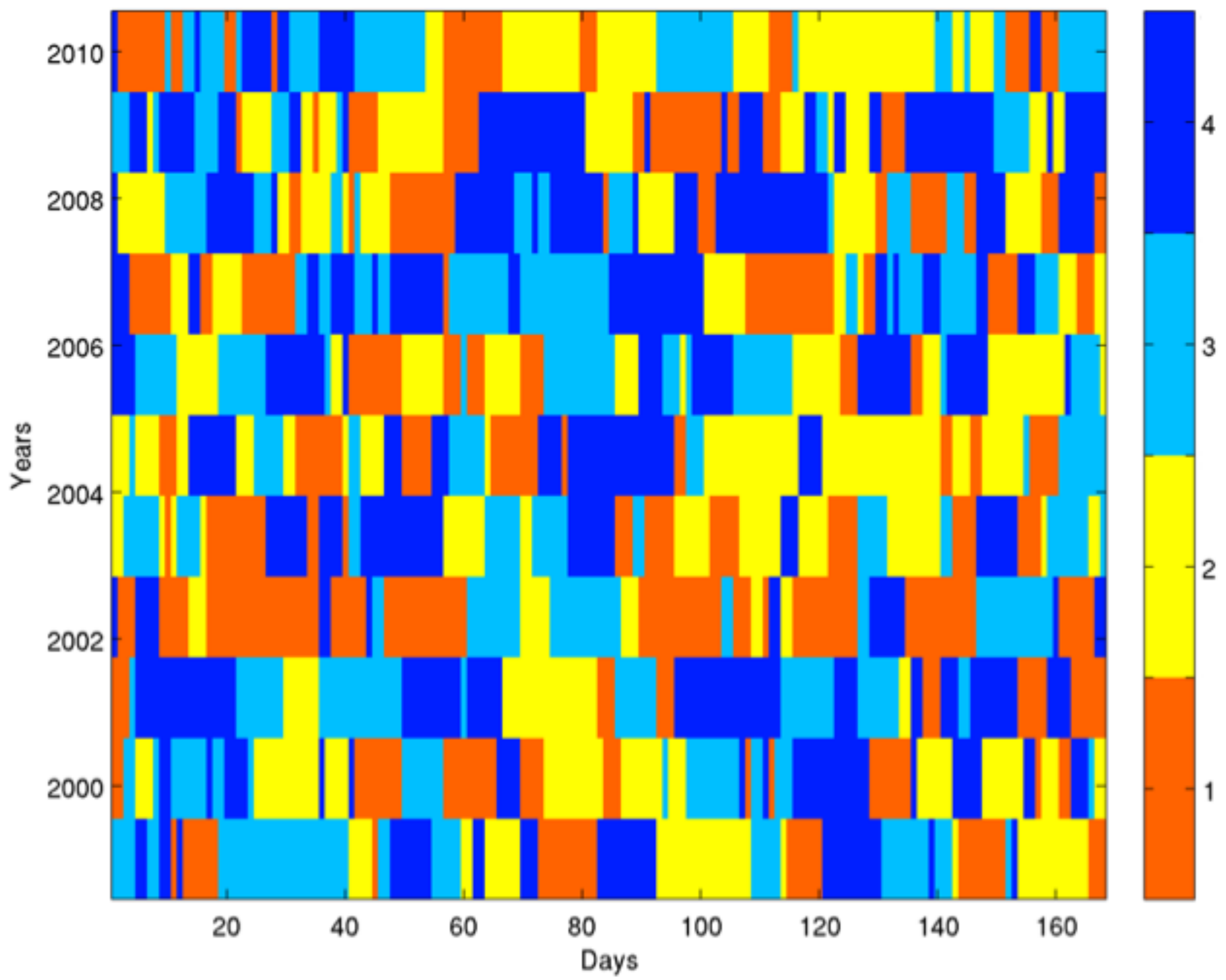


Daily state sequences in Week 1 Forecasts

ECMWF Reforecasts



MERRA Reanalysis



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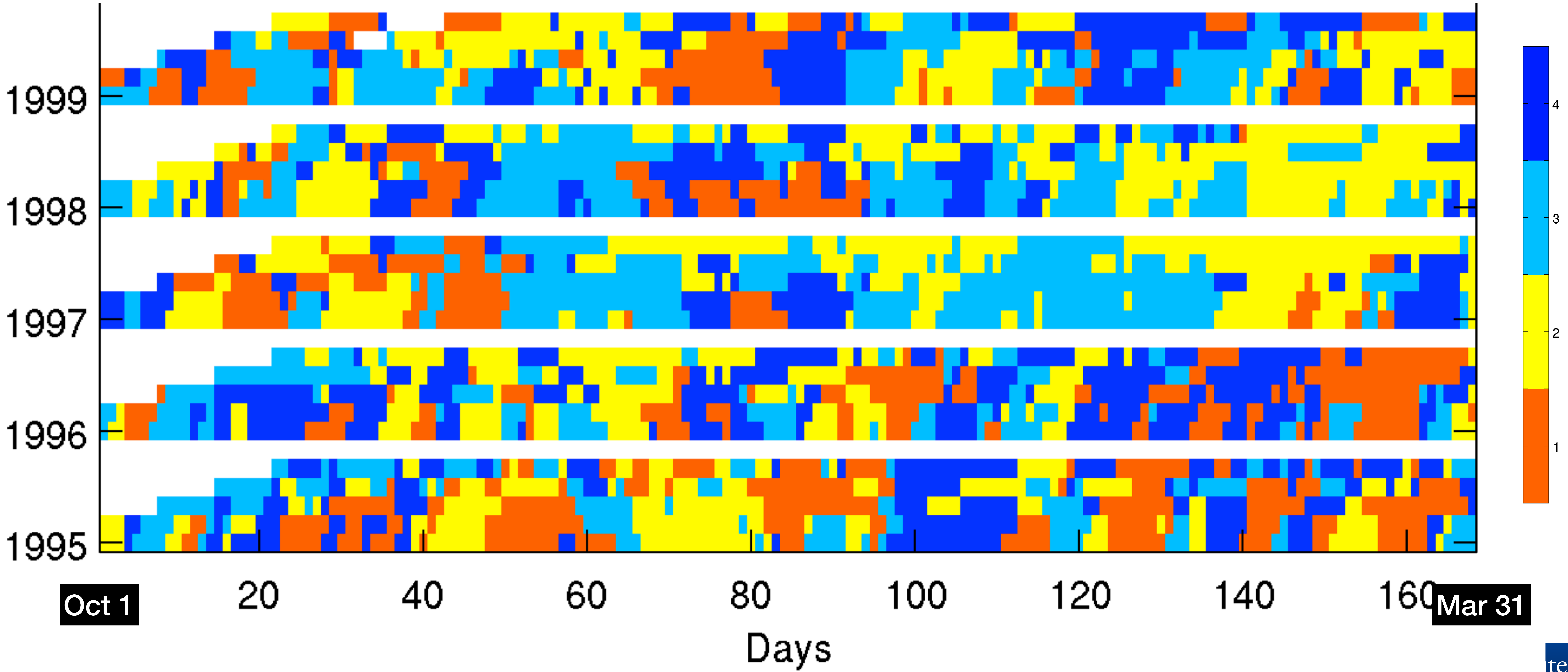
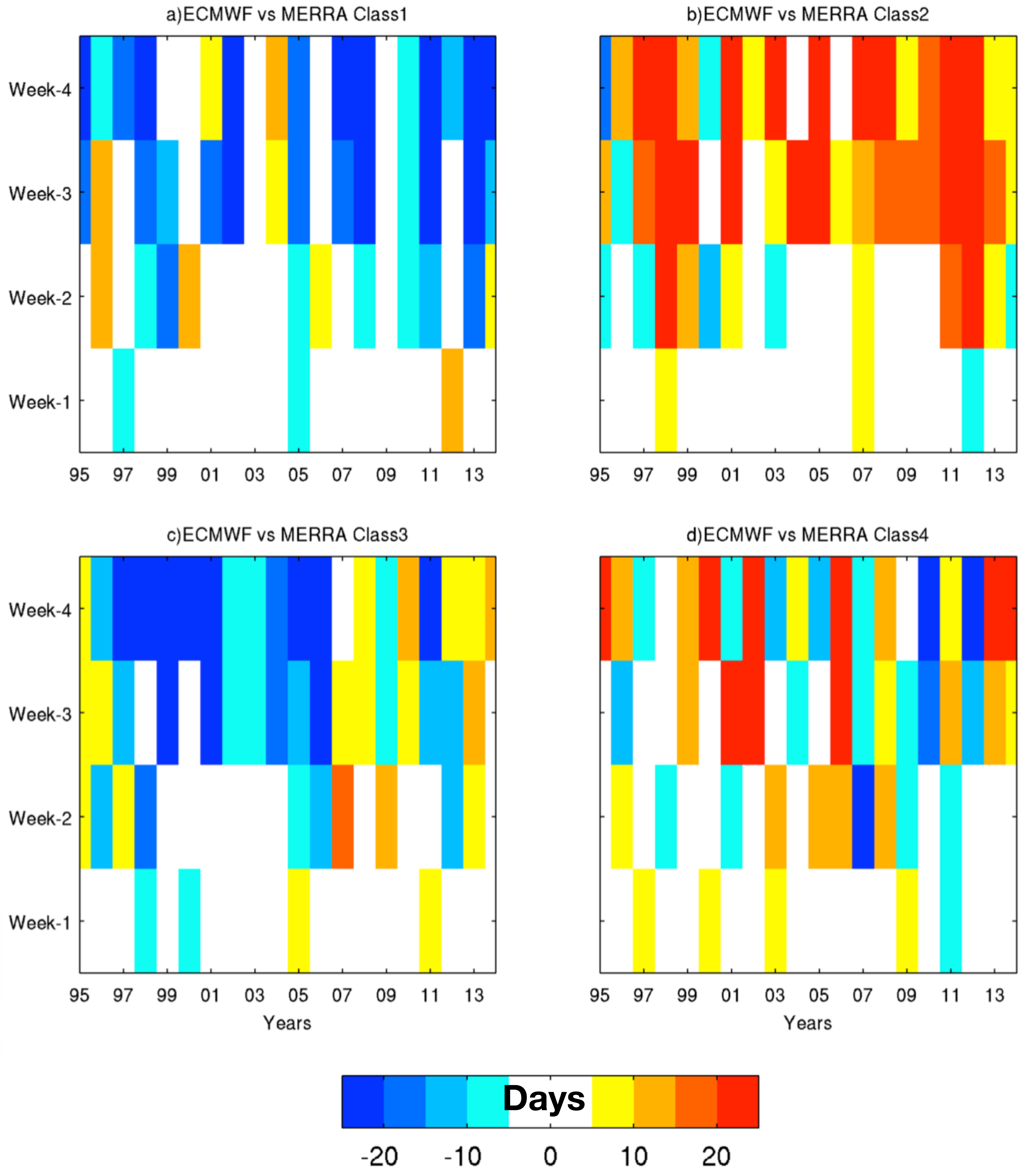
Week 1–4 Forecasts in Regime Space

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

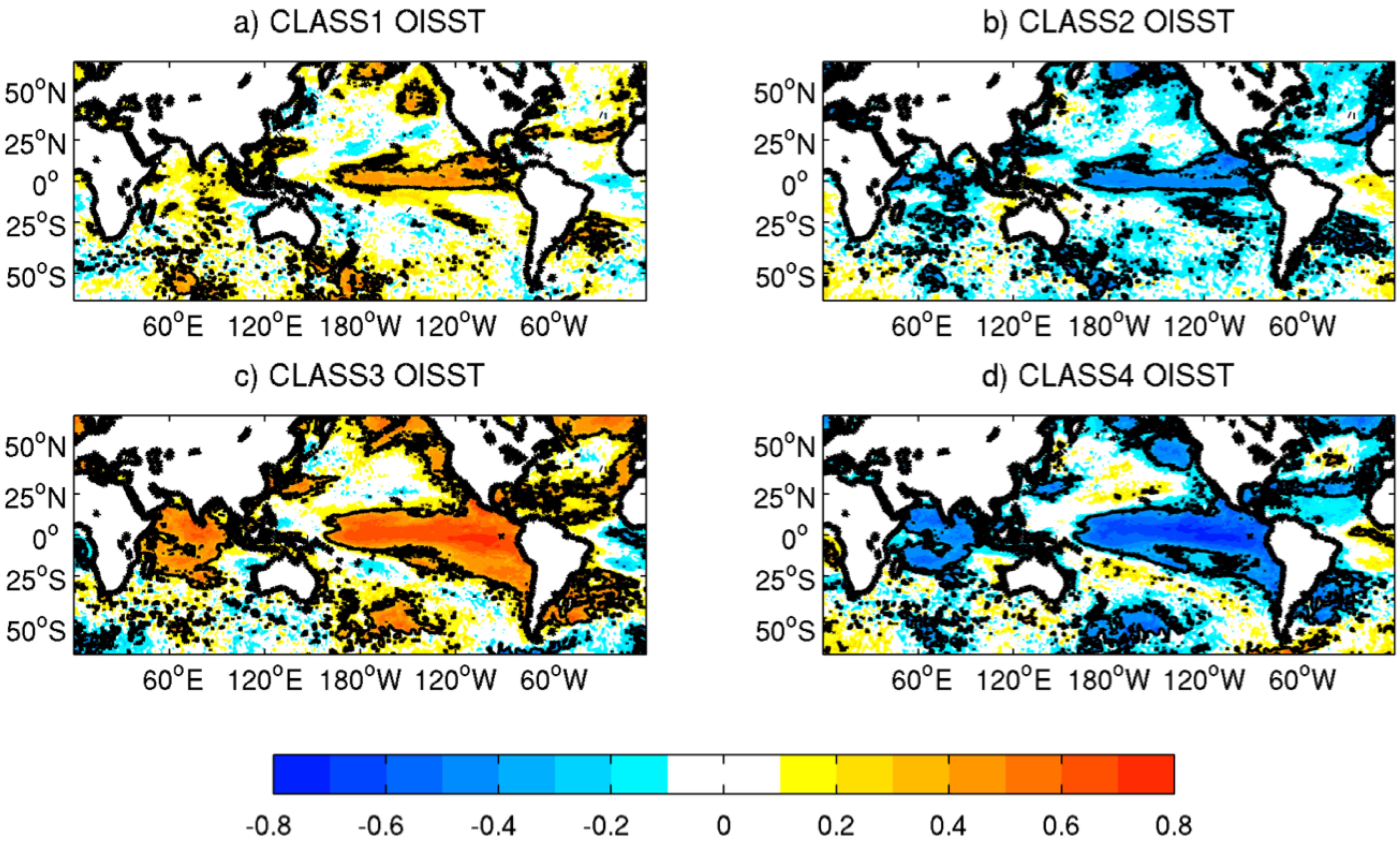


Regime Frequency Biases

Difference in numbers of days spent in Forecast Regimes vs Obs



Seasonal SST Associations with Regime Frequency



Summary

1. From MERRA reanalysis data, Four circulation regimes provides a statistically significant decomposition of z500 geopotential height anomalies during winter half year. Robust to changing the size of the geographical domain

2. Z500 regimes exhibit well-defined expressions in precipitation

3. ECMWF week-1 forecasts lead to a very similar 4-regime decomposition, in both spatial z500 anomaly patterns, associated precipitation anomalies, and day 1-7 transitions.

4. Regime Frequency in week 1 forecasts is modulated by ENSO (and MJO)

5. Week 1-4 forecasts are then tracked in the space of the 4 MERRA Regimes

6. Forecasts exhibit considerable S2S structure, both interannual and intraseasonal

7. Systematic biases in regime frequency appear in weeks 3-4

8. Next steps: apply to CFSv2; evaluate skill in WR space; include ensemble information; downscale WRs to precipitation

Subseasonal-to-Seasonal
S2S
Prediction Project

S2S Database now available in IRI Data Library

http://iridl.ldeo.columbia.edu/SOURCES/ECMWF/S2S

Data Library
ECMWF S2S

Description | Expert Mode

SOURCES ECMWF S2S

ECMWF S2S

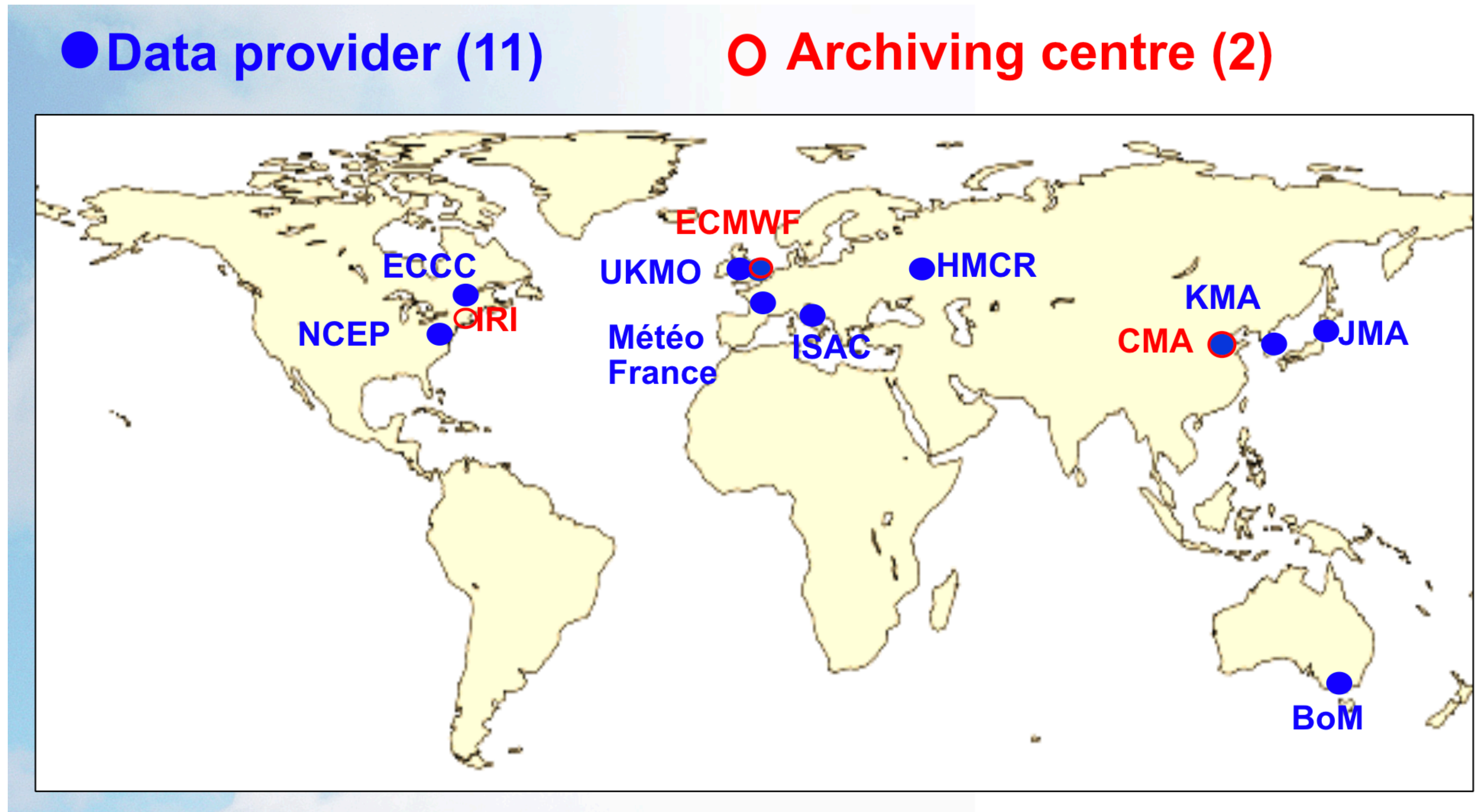
ECMWF S2S: Sub-seasonal to Seasonal Prediction Project.

Documents

overview an outline showing sub-datasets of this dataset
ECMWF ECMWF S2S Wiki Page
S2S Project S2S Project Page

Datasets and Variables

BOM BoM POAMA Ensemble.
CMA Beijing Climate Center (BCC) Climate Prediction System version 1 for S2S.
CNRM CNRM Ensemble Prediction System.
ECCC ECCC Ensemble Prediction System.
ECMF ECMWF Ensemble.
HMCR HMCR Ensemble.
ISAC ISAC-CNR Ensemble.
JMA JMA Ensemble System.
KMA KMA Seasonal Prediction System.
NCEP NCEP CFSv2 Ensemble.
UKMO UKMO Ensemble Prediction System.



Model	Time range	Resolution	Ens size	Freq	Rfc[a]	Rfc period	Rfc freq	Rfc size
BoM	Days 0–62	~2° × 2°, L17	33	Twice weekly	Fixed	1981–2013	Six per month	33
CMA	Days 0–60	~1° × 1°, L40	4	Daily	Fixed	1994–2014	Daily	4
ECCC	Days 0–32	0.45° × 0.45°, L40	21	Weekly	On the fly	1995–2012	Weekly	4
ECMWF	Days 0–46	0.25° × 0.25° days 0–10 0.5° × 0.5° after day 10 L91	51	Twice weekly	On the fly	Past 20 years	Two per week	11
HMCR	Days 0–61	1.1° × 1.4°, L28	20	Weekly	On the fly	1985–2010	Weekly	10
CNR-ISAC	Days 0–31	0.8° × 0.56°, L54	41	Weekly	Fixed	1981–2010	Every 5 days	1
JMA	Days 0–33	~0.5° × 0.5°, L60	25	Twice weekly	Fixed	1981–2010	Three per month	5
KMA	Days 0–60	~0.5° × 0.5°, L85	4	Daily	On the fly	1996–2009	Four per month	3
CNRM	Days 0–61	~0.7° × 0.7°, L91	51	Weekly	Fix	1993–2014	Two per month	15
NCEP	Days 0–44	~1° × 1°, L64	16	Daily	Fixed	1999–2010	Daily	4
UKMO	Days 0–60	~0.5° × 0.8°, L85	4	Daily	On the fly	1996–2009	Four per month	3

Forecasts available 3 weeks behind real time, on 1.5-deg grid