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?
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

Vigaud et al. (2018, MWR)
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

Alaskan Ridge
Arctic High
Pacific Trough
Arctic Low

Pacific Trough/PNA
Pacific Ridge/RNA

Alaskan Ridge
NAO Negative
Arctic High
Arctic Low

a) MERRA CLASS1
b) MERRA CLASS2
c) MERRA CLASS3
d) MERRA CLASS4

meters

-80 -60 -40 -20 0 20 40 60 80
ECMWF Week-1 Forecast Regime Structure

Days 0–6, Ensemble mean Z500 anomalies

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

Vigaud et al. (2018, MWR)
Similar overall patterns between observed-data impacts and model's own surface impacts, but substantial regional differences.
CFSv2 Week-1 Forecast Regime Structure

Days 0–6, Ensemble mean Z500 anomalies

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

Analysis Regime

Verification date (days)

Lead5s (days)
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

Jan–Feb Regime 4→1 Episode and transition
Well forecast up to 4 weeks ahead
S2S Drivers of Regime Frequency

**SST Year-to-YearCorrelations with Frequency**

- 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

Forecasted vs Observed Regimes

Pacific Trough (PNA)

Verification date (days)

Analysis Regime

Forecasts Regime

- 1
- 2
- 3
- 4

Legend:
- Alaskan Ridge
- NAO Negative
- MERRA CLASS3
- MERRA CLASS4

Color Scale:
- -80 -60 -40 -20 0 20 40 60 80
CFSv2 Forecasts of 2015/16 Winter

Forecasted vs Observed Regimes

Pacific Trough (PNA)

Forecasted Regime Frequency

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.
Minimal bias in longer lead forecasts
Regime Frequency: CFSv2 vs MERRA

Mean Regime Occurrence vs Reanalysis

Interannual Correlations of Regime Counts vs Reanalysis

Minimal bias in longer lead forecasts

Regime 3 has best week 3-6 skill
CFSv2 Regime Counts Anomaly Correlation Skill

1999–2014 Hindcasts

2015/16 Forecasts

- skill limited to 2 weeks in general
- week 3-4 skill in 2015/16 in PNA/RNA regimes
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

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

Analysis Regime

Verification date (days)

Forecasts Regime

Leads (days)

Real-Time Forecasts

Alaskan Ridge

NAO Negative

Pac Trough

Pac Ridge

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Weather Regime Forecasts in Real Time

- **CFSv2 daily winter WRs forecast from Oct 1 to Oct 21 2018**
  - Forecasts from Oct 1 to Oct 21 2018
  - Observed Geopotential Height Anomaly
  - Alaskan Ridge
  - NAO Negative
  - Pac Trough
  - Pac Ridge

- **Observed Geopotential Height Anomaly**
  - Pressure 500 mb Time 8-12 Oct 2018
  - Colors represent geopotential height anomalies [gpm]

**Key Terms:**
- Forecasted Regime
- Analysis Regime
- Leads (days)
- Verification date (days)
- Regime (1-5)

**Regimes:**
- 1: Alaskan Ridge
- 2: Pac Trough
- 3: NAO Negative
- 4: Pac Ridge
- 5: Other

**Legend:**
- Blue: Low pressure
- Red: High pressure
- Green: Neutral

**Note:**
- This diagram illustrates the real-time forecasts and observed geopotential height anomalies for different weather regimes using the CFSv2 model data for the period from October 1 to October 21, 2018.
Weather Regime Forecasts in Real Time

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

Observed Geopotential Height Anomaly

Alaskan Ridge

NAO Negative

Pac Trough

Pac Ridge

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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.