Incorporating MJO and ENSO information into probabilistic temperature forecasts over North America

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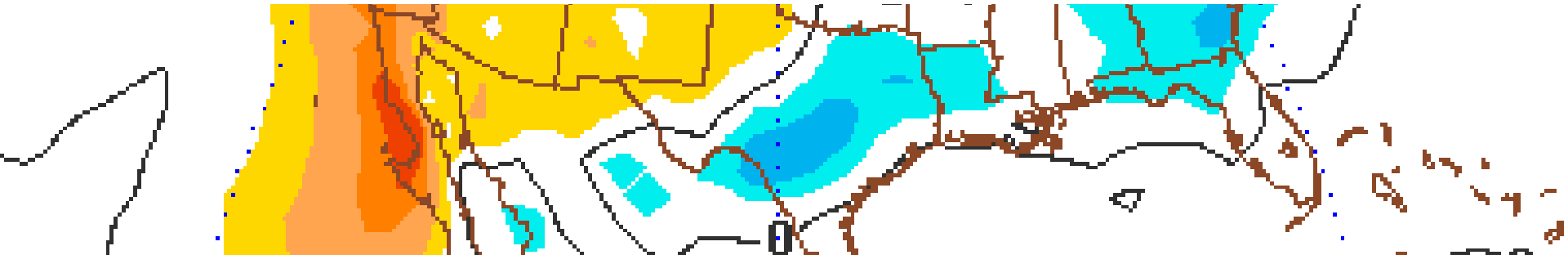
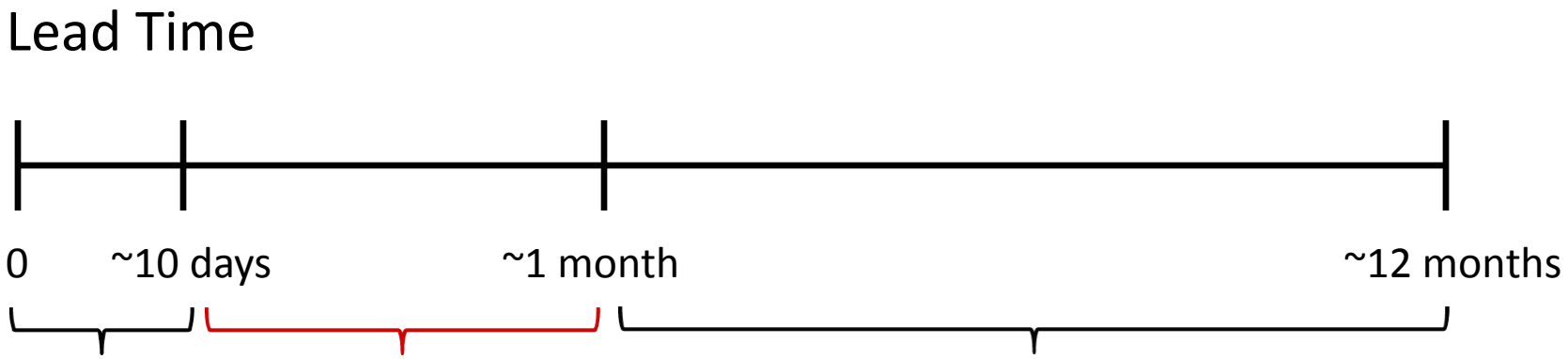


Weather and Climate Prediction



• Based on **initial conditions**

• Rely on numerical weather prediction (NWP) model integrations

Predictability gap:

• Large growth of initial errors

• Timescale too short for boundary condition effects

• Based on slowly varying **boundary conditions**

• Rely on NWP model integrations and statistical forecast methods

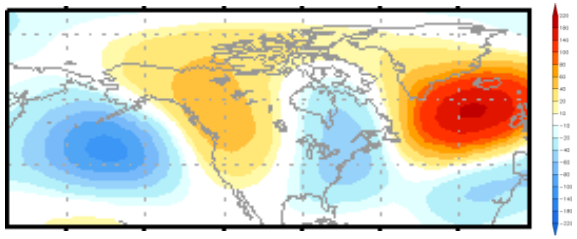
❖ **But Madden-Julian Oscillation (MJO) may help to fill the gap**

Our recent work demonstrates that the MJO strongly influences North American wintertime circulation for lead times of up to four weeks.

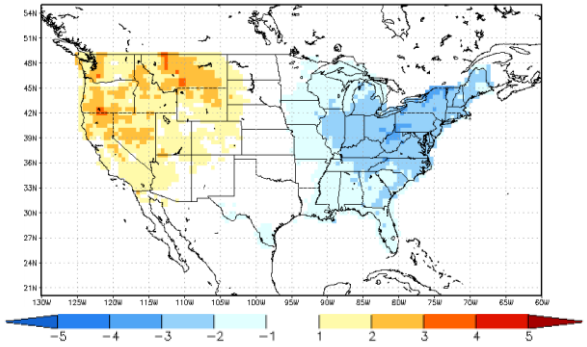
One of the dominant winter atmospheric patterns (top left) strongly affects U.S. temperatures (bottom left).

A weekly cluster pattern

500-hPa height anomalies (m)



Temperature anomalies (°C)

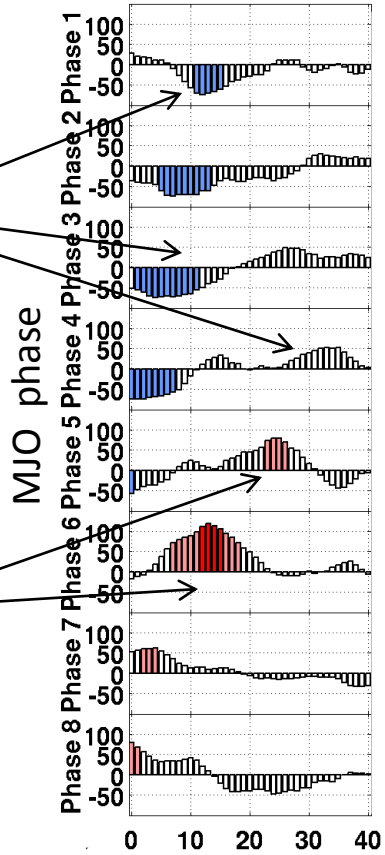


Riddle, Stoner, Johnson, L'Heureux, Collins, and Feldstein (2012, *Climate Dynamics*)

MJO influence on cluster pattern

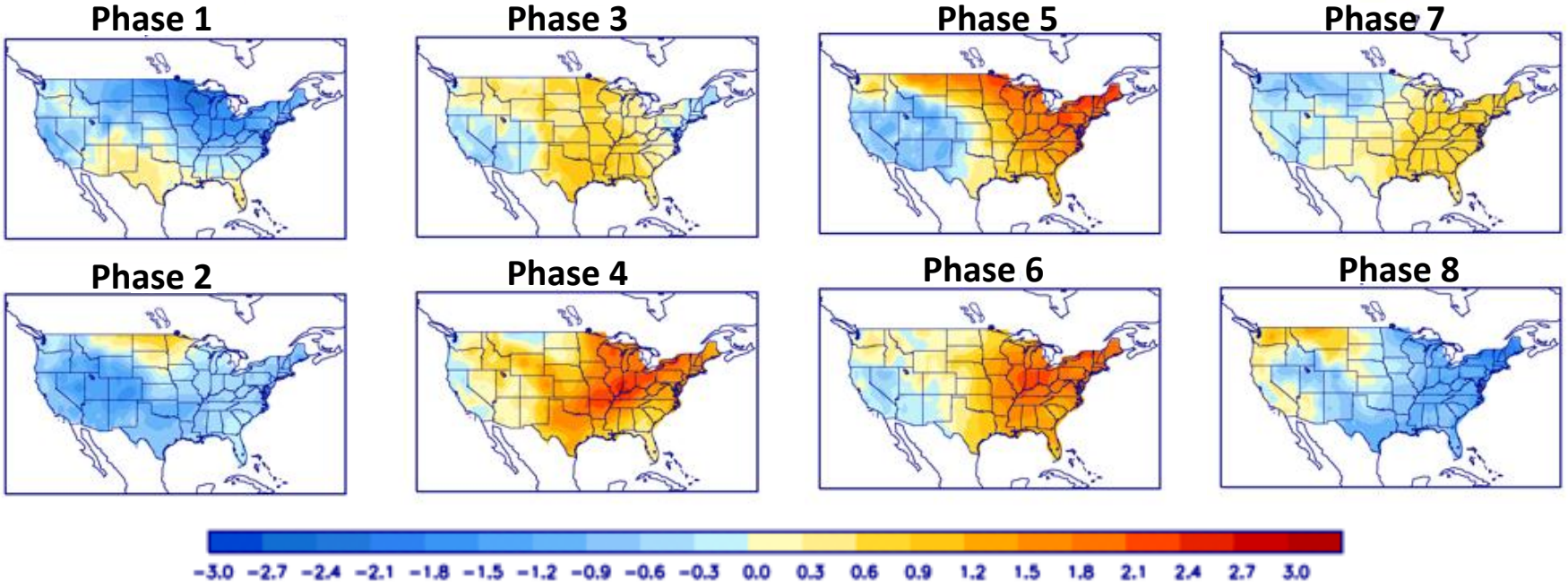
Anomalous frequency of cluster pattern (top left) occurrence (%)

The MJO gives information on pattern occurrence 10-25 days in advance



Climate Prediction Center (CPC) MJO composites page

Temperature anomalies (°C, DJF)



- Based on the 8 phases of the Wheeler-Hendon MJO index
- **Can the MJO phase be used for probabilistic temperature forecasts?**
- **How would such forecasts depend on the phase of the El Niño-Southern Oscillation (ENSO)?**

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/Composites/Temperature/

Generating probabilistic temperature forecasts based on the initial state of the MJO and ENSO

- ERA-Interim 2-m temperature (T2m) data, December – March 1979-2010, North America domain, 7-day running mean anomalies

- forecasts for days 4-10 and weeks 2-6 with leave-one-year-out cross-validation

- Main forecast steps:

    1) Partition initial state by phase of MJO (amplitude > 1) and ENSO

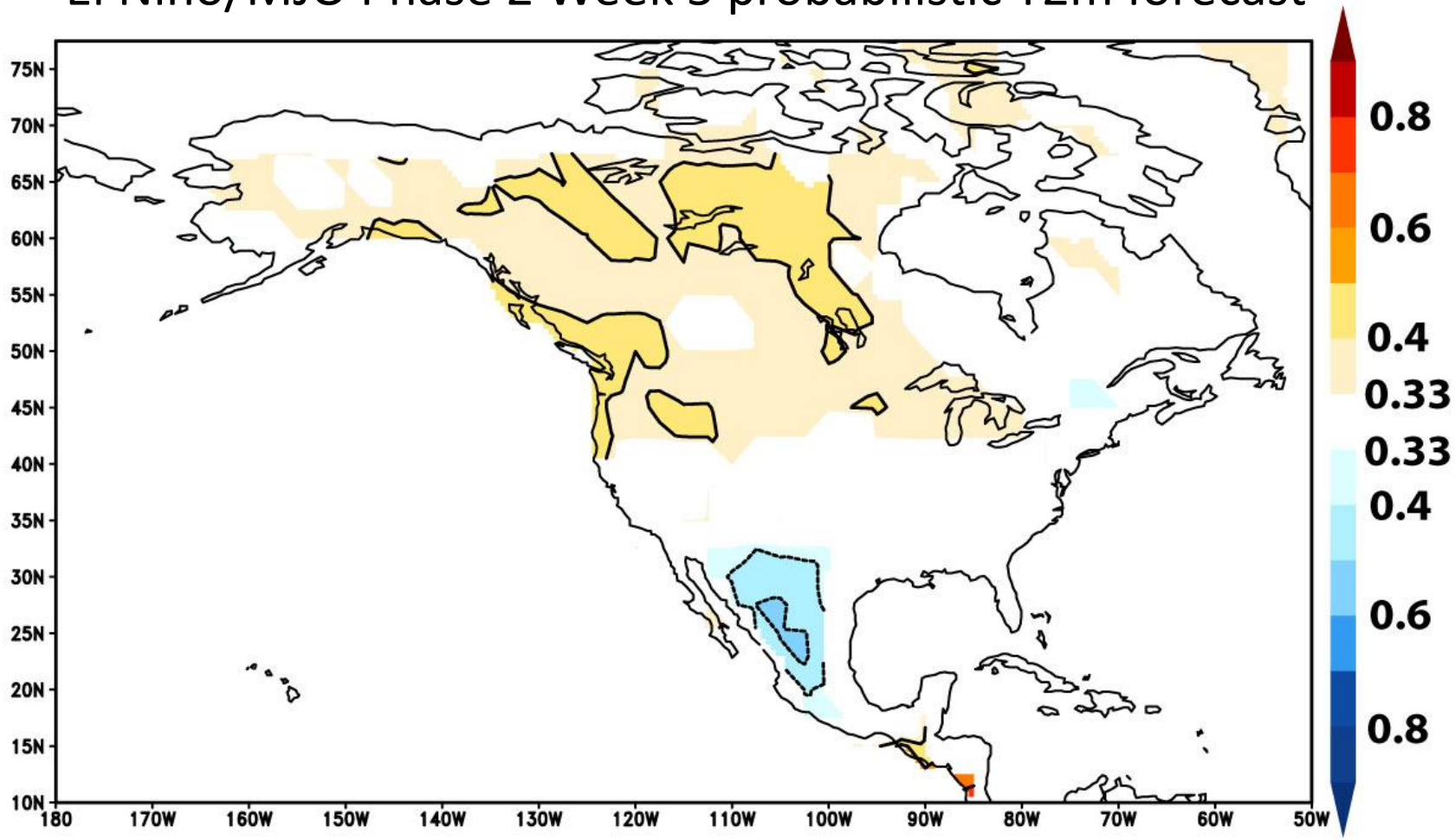
    2) Calculate mean and variance of T2m anomaly corresponding to MJO+ENSO state for each grid point and forecast lag

    3) With the assumption of a Gaussian T2m anomaly distribution and with a linear trend term added, calculate the probability of T2m in the upper and lower tercile for each lead time

    4) With a second cross-validation step, assign climatological probabilities if cross-validated temperature forecasts are not skillful

How skillful are North America T2m forecasts based solely on MJO+ENSO+trend relationships?

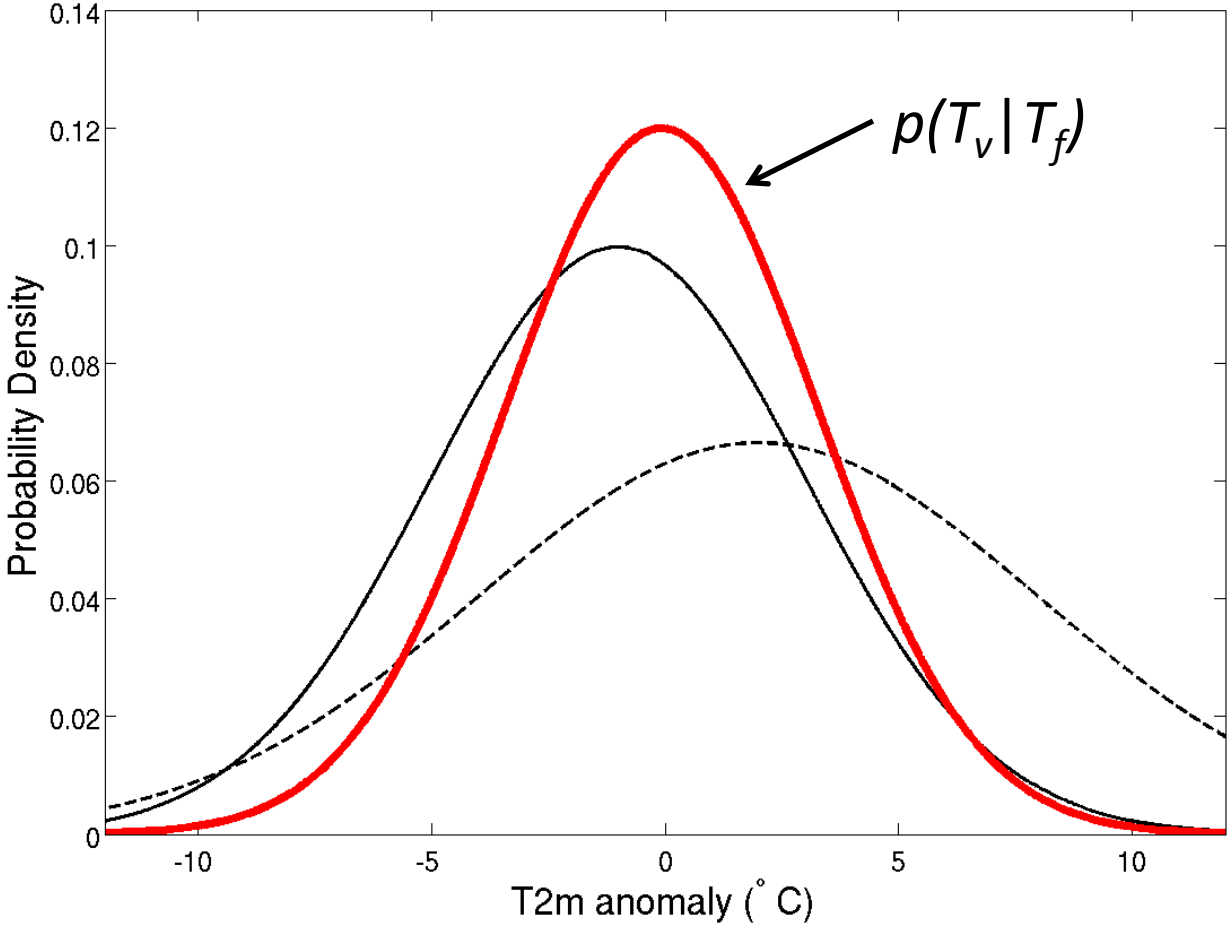
El Niño/MJO Phase 2 Week 5 probabilistic T2m forecast



Combining statistical relationships with dynamical forecast model information: A Bayesian perspective

$$p(T_v \mid T_f) \propto p(T_v)\, p(T_f \mid T_v)$$

Verifying temperature Model forecast temperature



For Gaussian:

- posterior mean is precision-weighted mean of prior and likelihood
- means that more weight given to factor with lower error variance

Generating Bayesian probabilistic forecasts from CFSv2 T2m forecast fields

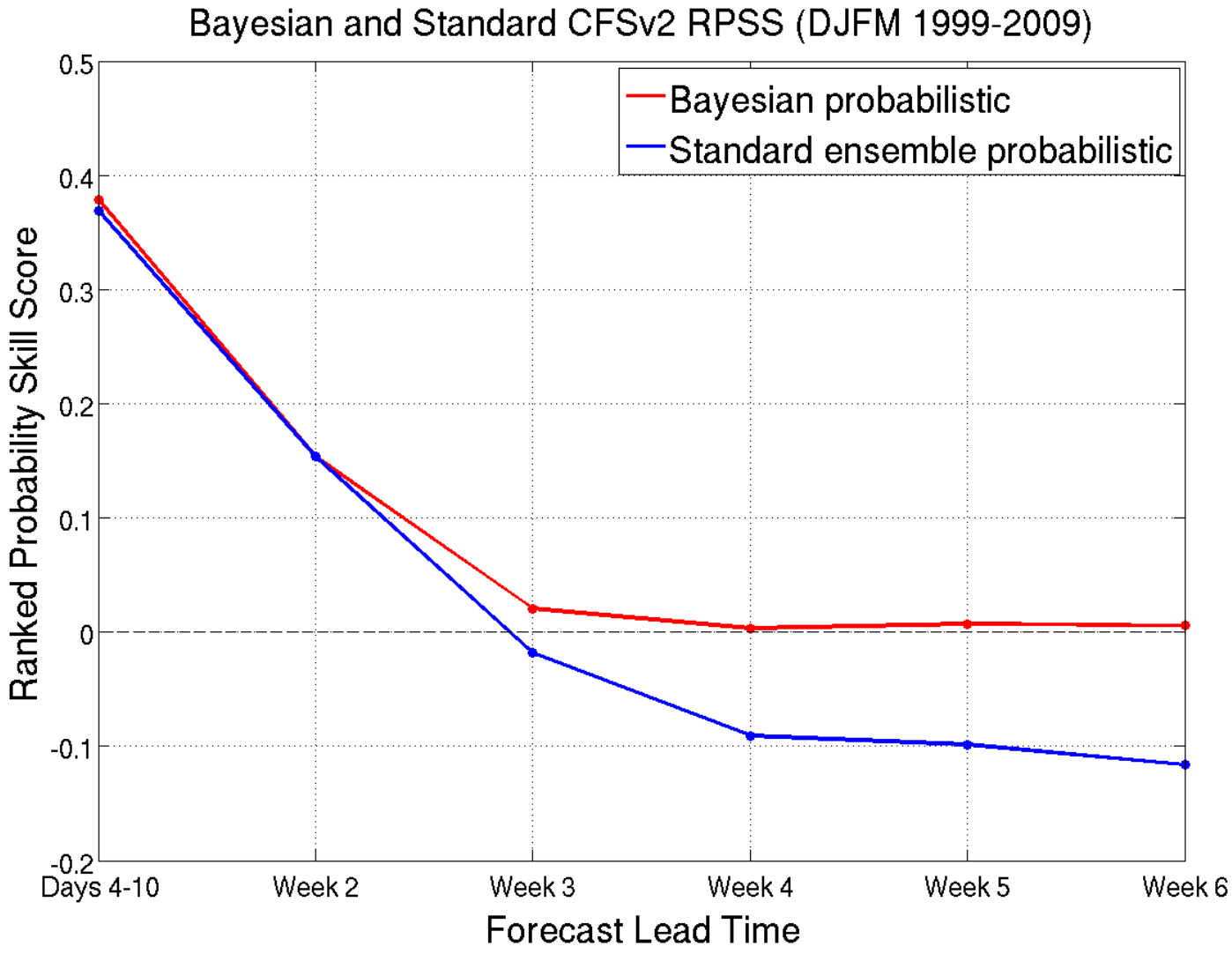
- 45-day retrospective forecasts of version 2 of NCEP's Climate Forecast System model (CFSv2), 4 x daily, December – March 1999-2009

- Priors from historical MJO and ENSO relationship, likelihood from CFSv2 forecast performance (excluding forecast year), distributions assumed Gaussian

- Reasons for concern:
  - Gaussian not good everywhere
  - Small sample sizes
  - Non-stationary relationships
  - Redundant information in prior and likelihood?
- Calibration correction applied to forecast probabilities

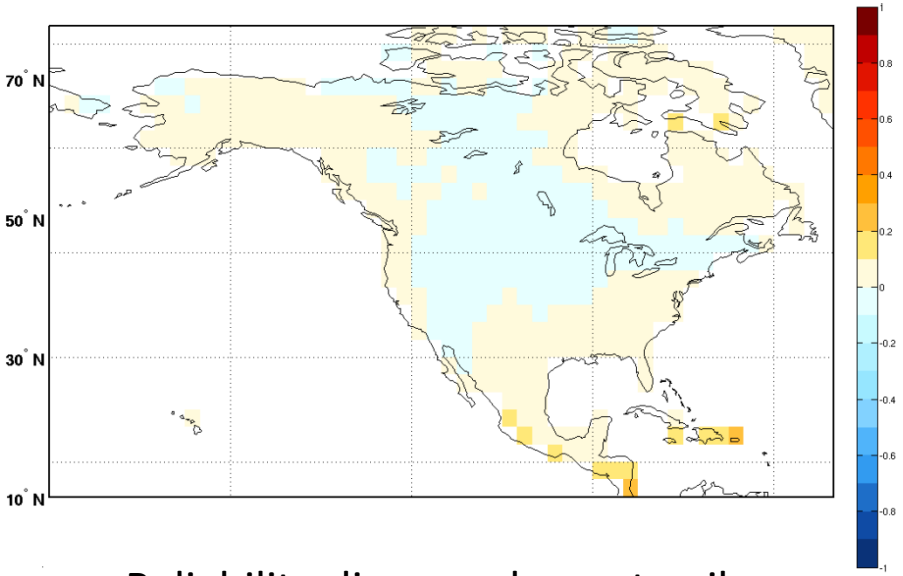
- Compared with standard ensemble: 12 bias-corrected CFSv2 T2m fields, probabilistic forecast = frequency of deterministic forecasts in upper or lower tercile

How well do these probabilistic T2m forecasts perform?

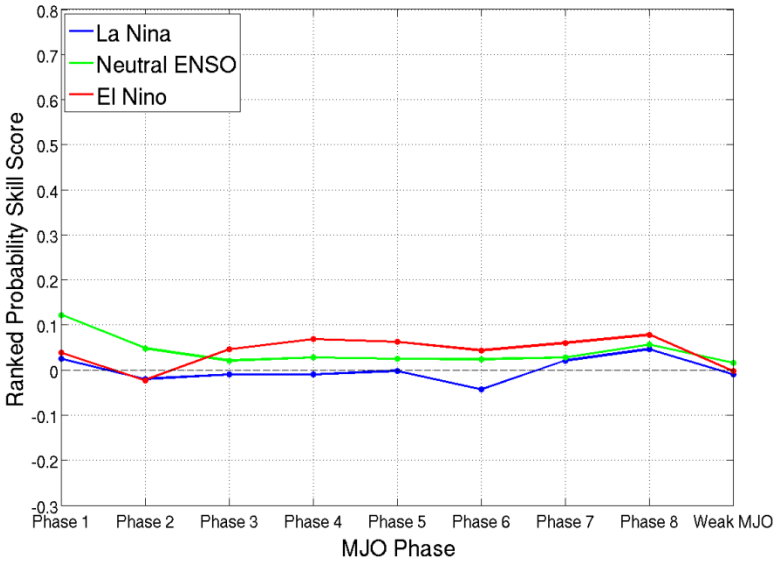


A closer look at forecast performance

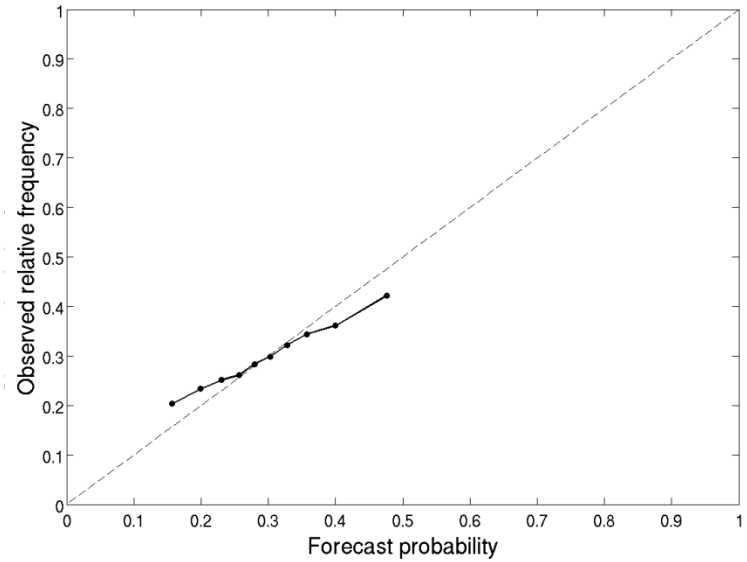
RPSS



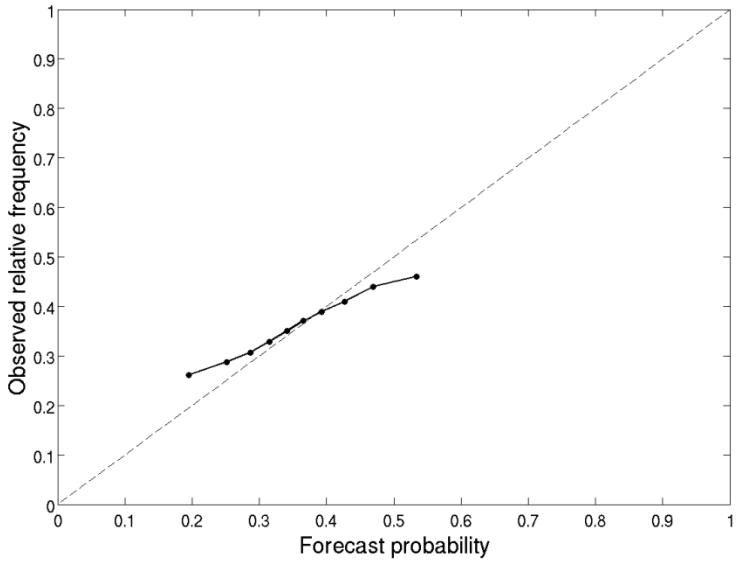
RPSS



Reliability diagram: lower tercile



Reliability diagram: upper tercile



Conclusions

- The statistical relationships between MJO+ENSO and North American temperature in winter can result in skillful probabilistic forecasts in weeks 1-6, though the skill is modest and the opportunities are limited with our efforts so far.

- The combination of statistical information from MJO+ENSO relationships and dynamical model forecast performance information can convert deterministic model forecast fields into probabilistic forecasts through a Bayesian approach. These forecasts:

  - are at least comparable in performance to standard methods in weeks 1 and 2

  - outperform a standard ensemble approach in weeks 3-6, and demonstrate promise of skillful forecasts for these lead times at least in some regions and for some MJO+ENSO states

- Lots of questions:

  - Why the max MJO+ENSO T2m HSS around weeks 5 and 6? Why are the neutral ENSO HSS so low, particularly in MJO phases 6 and 7? What physical processes are key? How much, if anything, do informative priors add to the Bayesian forecasts? Why is there a tendency for over-confident forecasts after week 2, even after calibration correction? Can we find a more optimal partitioning of the initial state?

- Archived hindcasts are a valuable resource for researchers and forecasters.