The Testing of an Ensemble Based Canonical Tool For Prediction in the Day 8-10 Forecast Period at the Weather Prediction Center Hydrometeorological Testbed

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Motivation for Work

WPC began conducting a biweekly Extended Range Forecast Experiment (ERFE) in January 2017

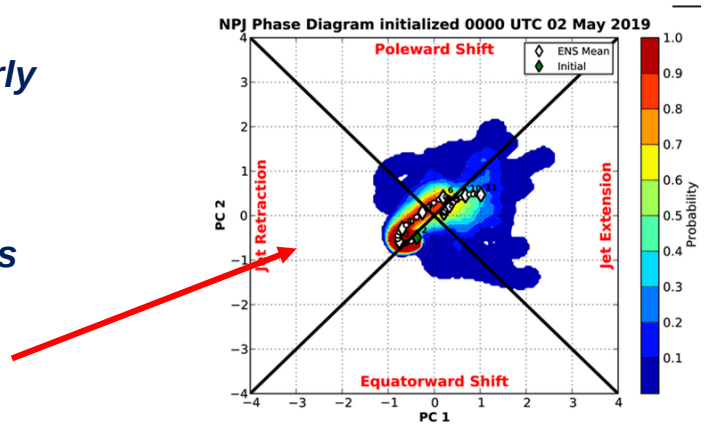
Experiment Goals:

Assess the skill and predictability of temperatures in a daily forecast format for the Day 8-10 period

Test the predictability of anomalous and impactful weather events over the CONUS and Alaska

Since there were relatively few tools available to assist in the creation of these forecasts at this early week 2 time period, collaborative work between University at Albany and WPC resulted in the development and application of a canonical forecast tool leveraging global ensemble forecasts

North Pacific Jet (NPJ) forecast phase space



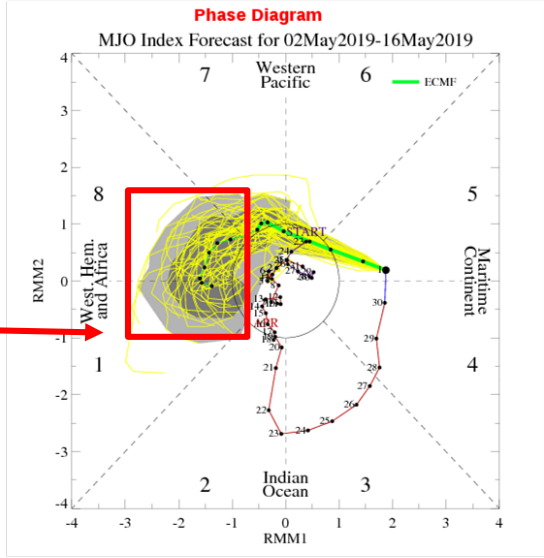
Standard Week 2 Forecast Tools

NWP guidance, both deterministic and ensembles

Traditional annular mode indices (AO, NAO, PNA) to assess large scale teleconnections

Ensemble forecasts of the Madden-Julian Oscillation (MJO) to assess tropical forcing and its impact on the mid-latitude flow

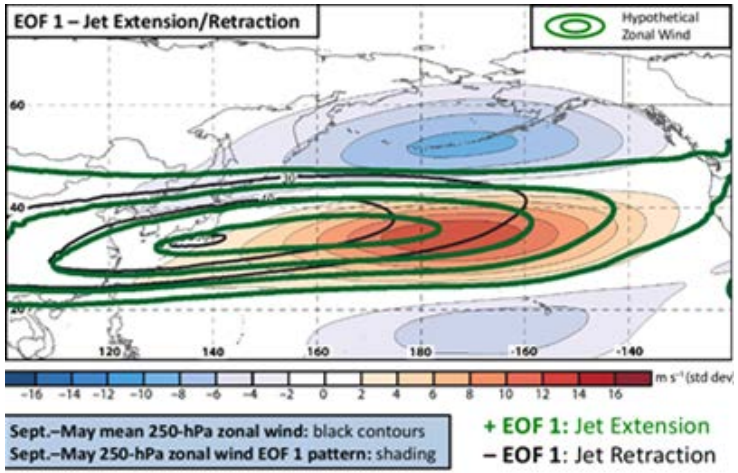
MJO Phases Space Forecast



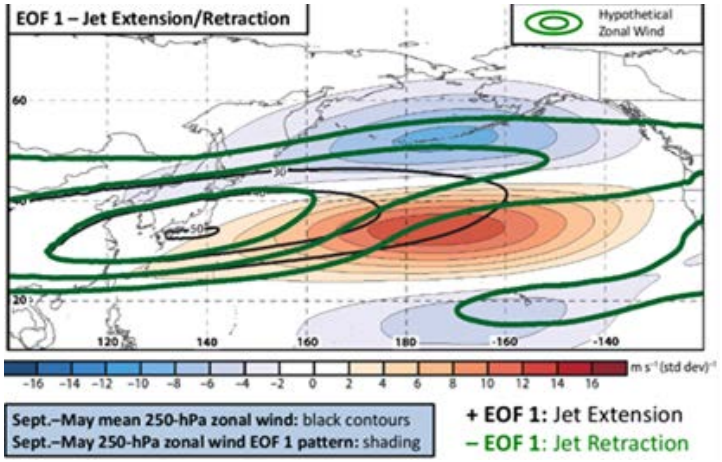
Introducing the North Pacific Jet (NPJ) Tool

The application of empirical orthogonal function (EOF) analysis to 250-hPa zonal wind anomalies over the North Pacific reveals two leading modes of the NPJ variability that prevail during the cool season (September - May)

First mode corresponds to the zonal extension or retraction of the exit region of the climatological jet

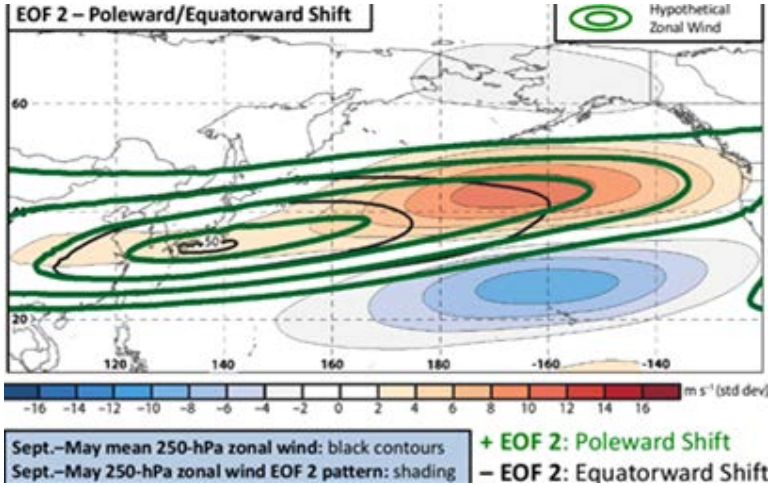


+ EOF 1 Jet Extension

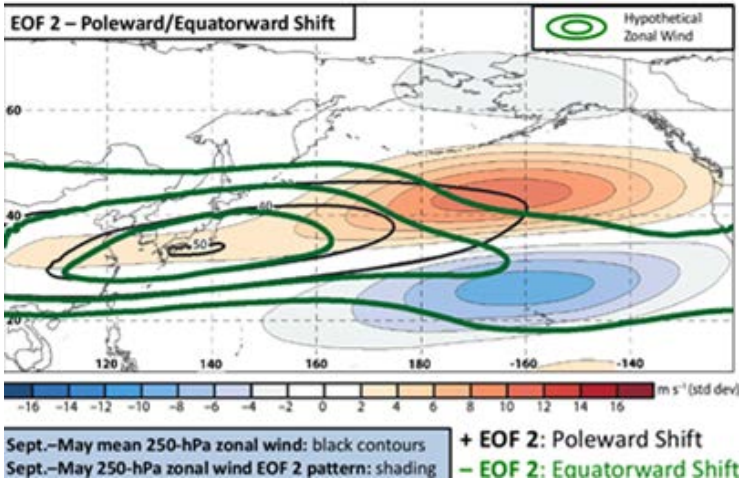


- EOF 1 Jet Retraction

Second mode corresponds to the poleward or equatorward shift of jet exit region



+ EOF 2 Poleward Shift

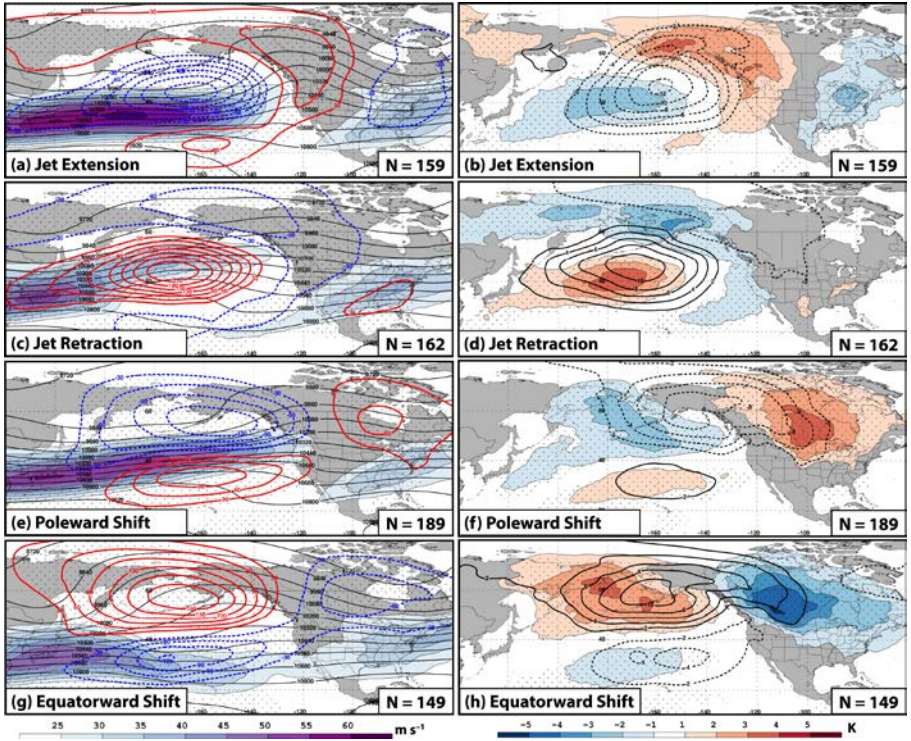


- EOF 2 Equatorward Shift

Composite mean 250-hPa wind speed (m s^{-1}) is shaded in the fill pattern

250-hPa geopotential height is contoured in black every 120 m

250-hPa geopotential height anomalies are contoured in solid red and dashed blue every 30 m for positive and negative values



Composite anomalies of mean sea level pressure are contoured in solid and dashed black every 2 hPa for positive and negative values

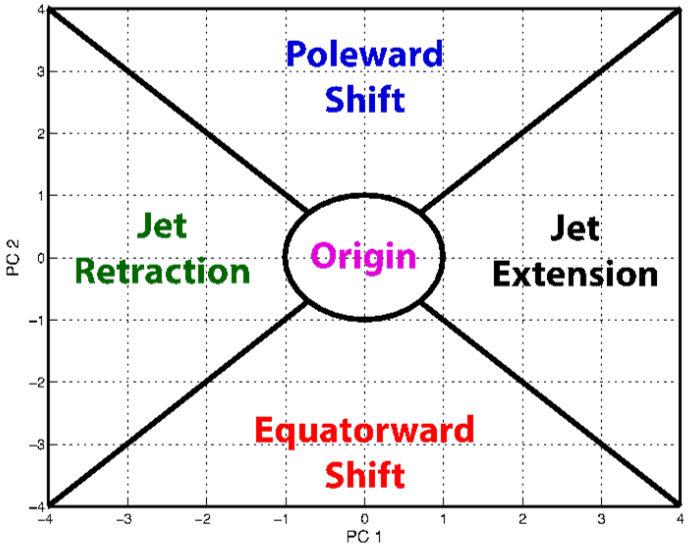
850-hPa temperature anomalies are shaded in the fill pattern

Large scale flow patterns for NPJ regime
4 day after beginning of the regime

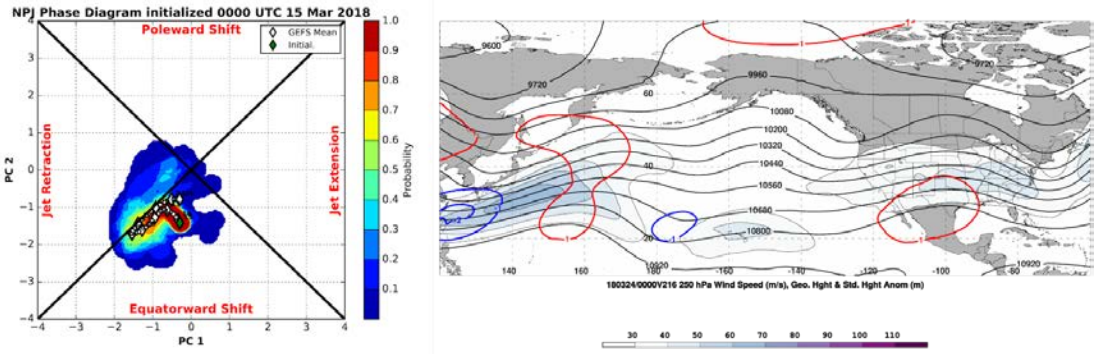
Upper tropospheric plots (left) and lower (right)

N = number of cases in each composite

A NPJ phase space diagram based on these two leading modes was constructed by Winters et al. (2019) to illustrate a canonical relationship in the Climate Forecast Reanalysis (CFRS) to the observed NPJ regime and the mid troposphere flow regime over the CONUS

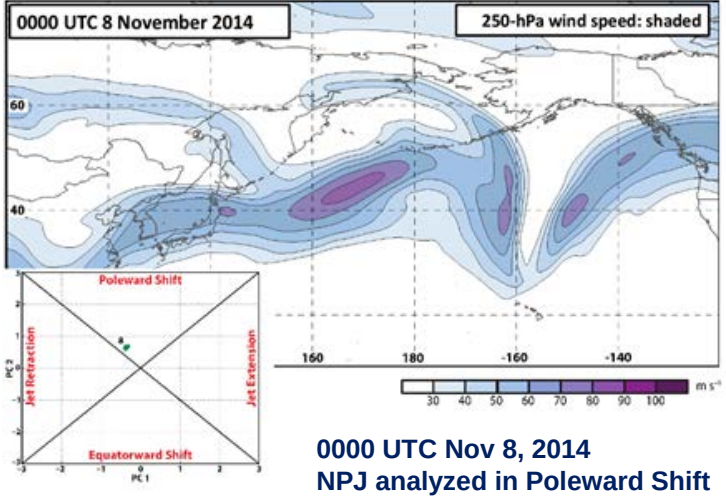


North Pacific Jet (NPJ) Tool - Phase spaces of NPJ regimes

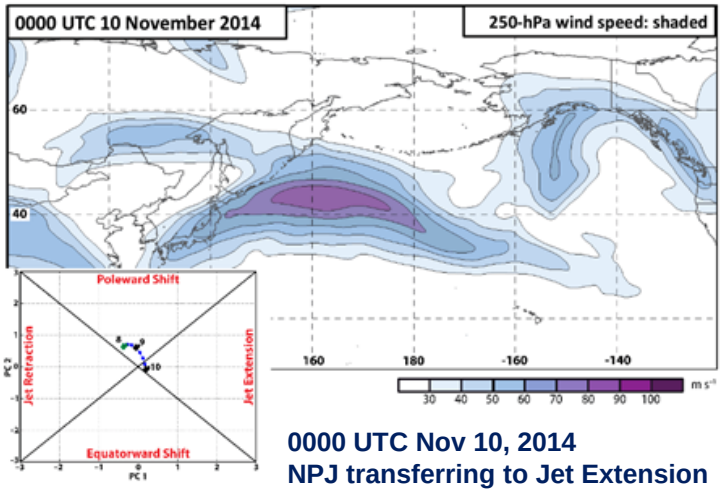


North Pacific Jet (NPJ) Tool - Forecast phase space (left) and corresponding 250-hPa heights (right)

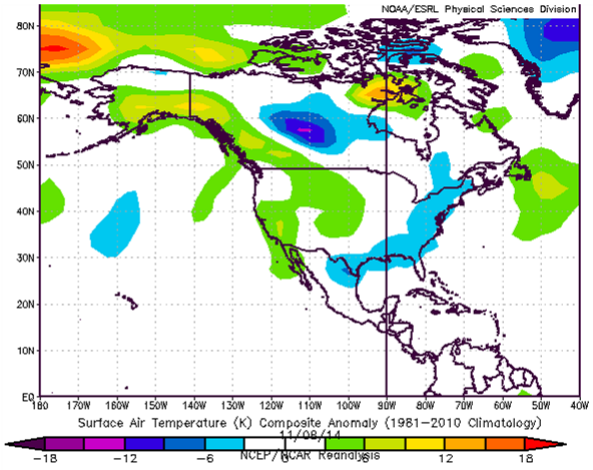
Next two slides show the construction of the NPJ phase space and corresponding tropospheric flow regime over a 10-day period leading up to a November 2014 record cold outbreak over Central and Eastern U.S.



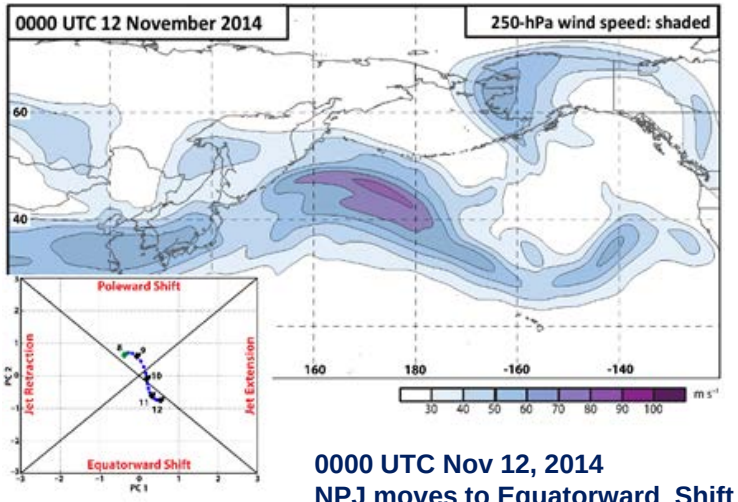
0000 UTC Nov 8, 2014
NPJ analyzed in Poleward Shift



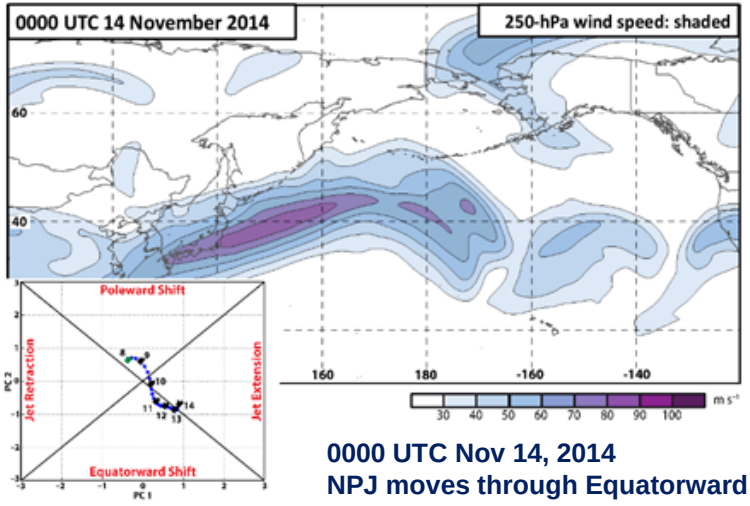
0000 UTC Nov 10, 2014
NPJ transferring to Jet Extension



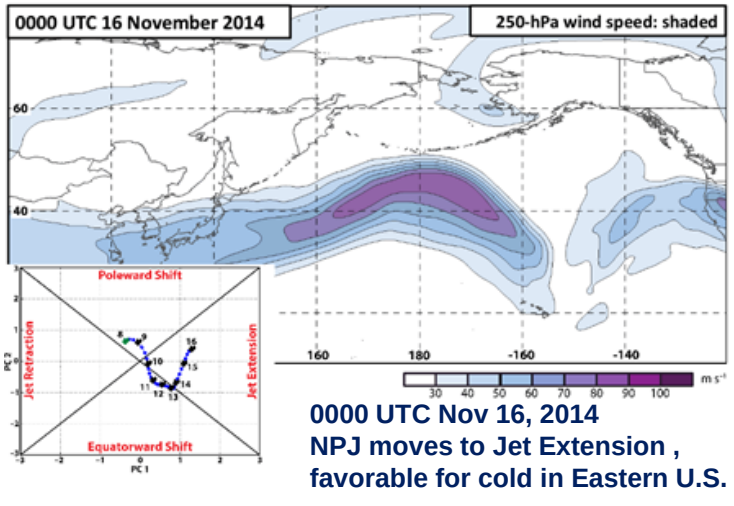
Surface Temperature Anomaly
November 8, 2014



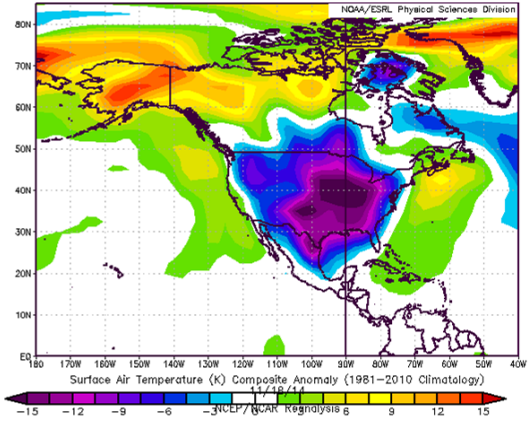
0000 UTC Nov 12, 2014
NPJ moves to Equatorward Shift



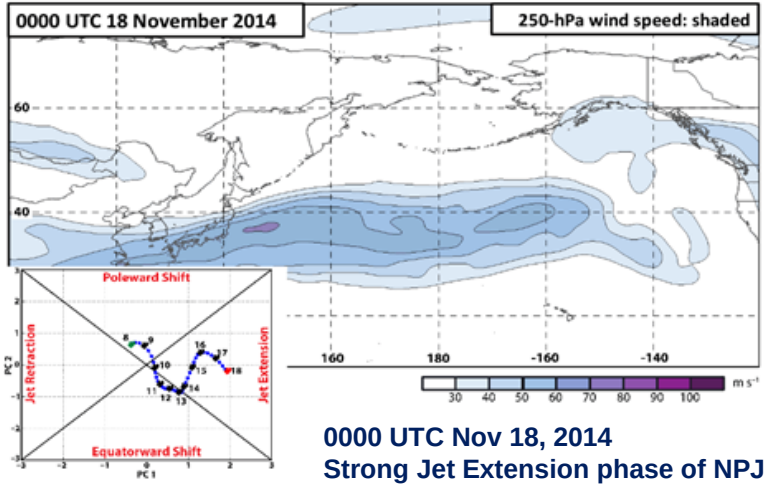
0000 UTC Nov 14, 2014
NPJ moves through Equatorward Shift phase space



0000 UTC Nov 16, 2014
NPJ moves to Jet Extension , favorable for cold in Eastern U.S.



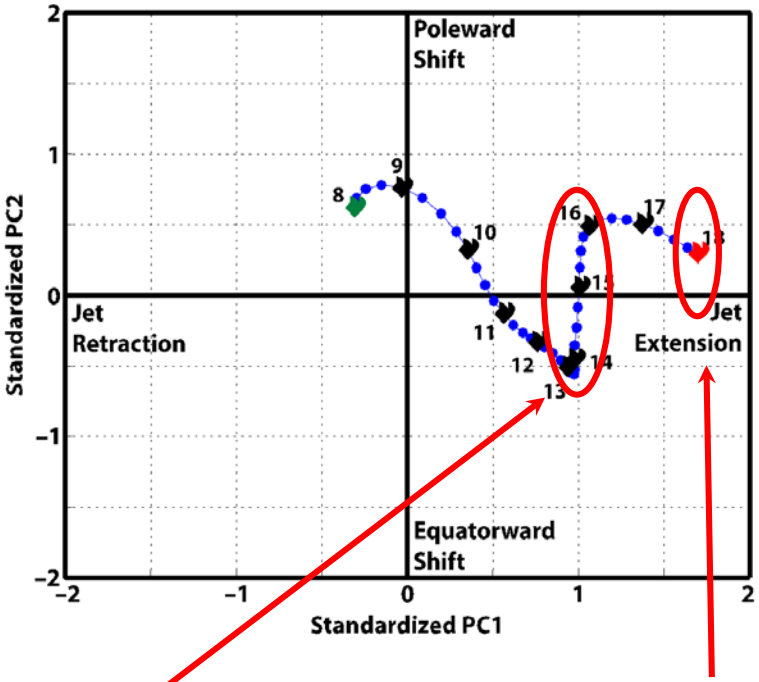
Surface Temperature Anomaly
November 18, 2014



0000 UTC Nov 18, 2014
Strong Jet Extension phase of NPJ
Record cold and heavy lake effect snow

Phase Space Depiction Tool
U.S. Record Cold Nov 2014

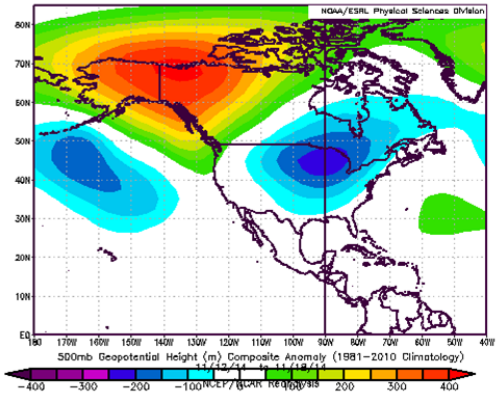
Observed NPJ Trajectory



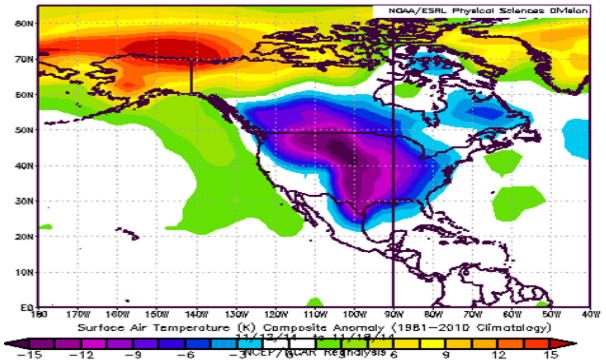
Peak transition and amplification of pattern Nov 14-16

Record Buffalo, NY Snow Event Nov 18

500-hPa Composite Height (m) Nov 14-18, 2014

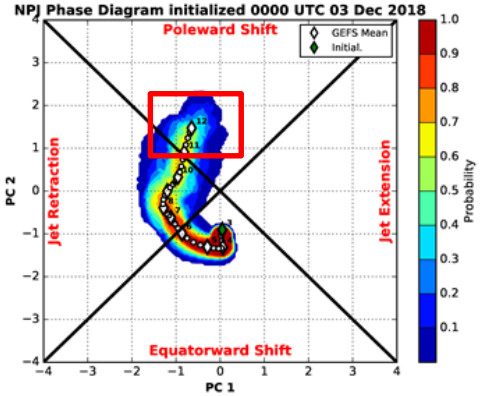


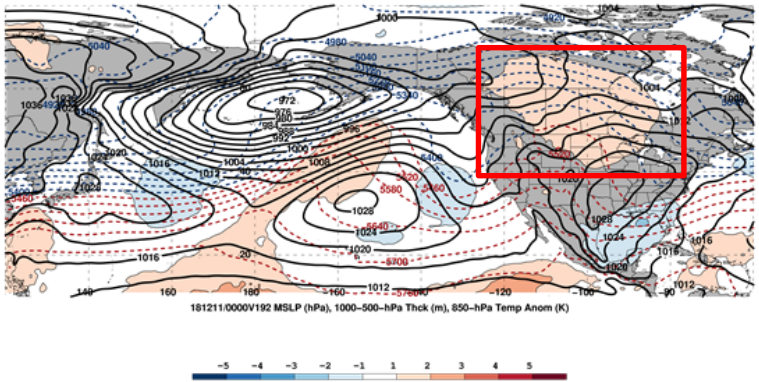
Composite Surface Temperature (°C) Nov 14-18, 2014



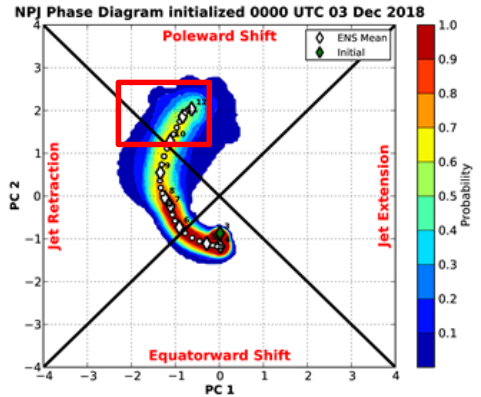
Probabilistic Application

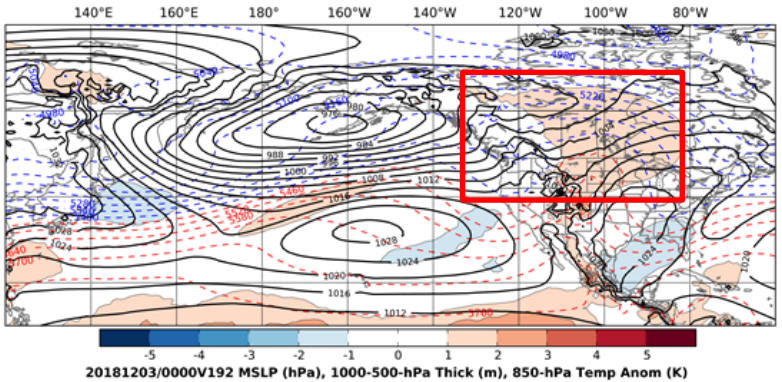
Days 1-10 probability forecast of NPJ Phase Space using GEFS membership; Day 8 (F192) corresponding GEFS mean sea level pressure, 1000-500 hPa thickness, and 850-hPa temperature anomaly forecast (right)





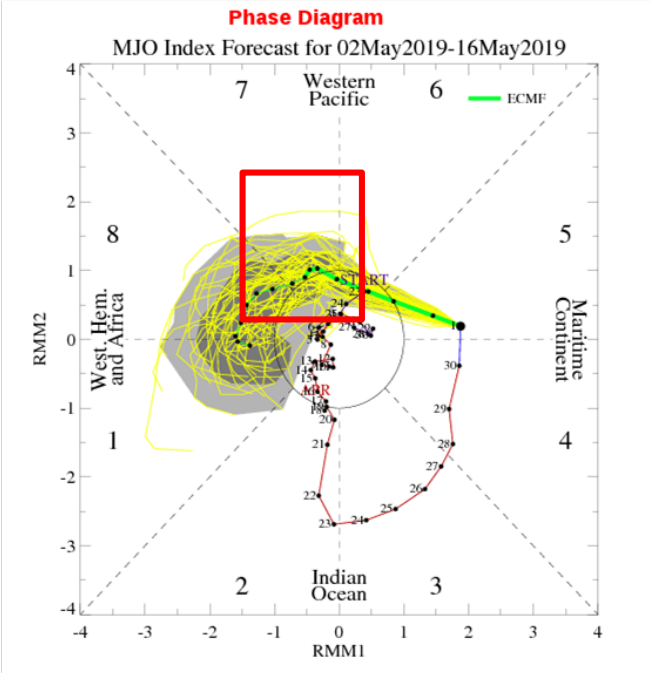
Same as above but with ECMWF ensemble membership



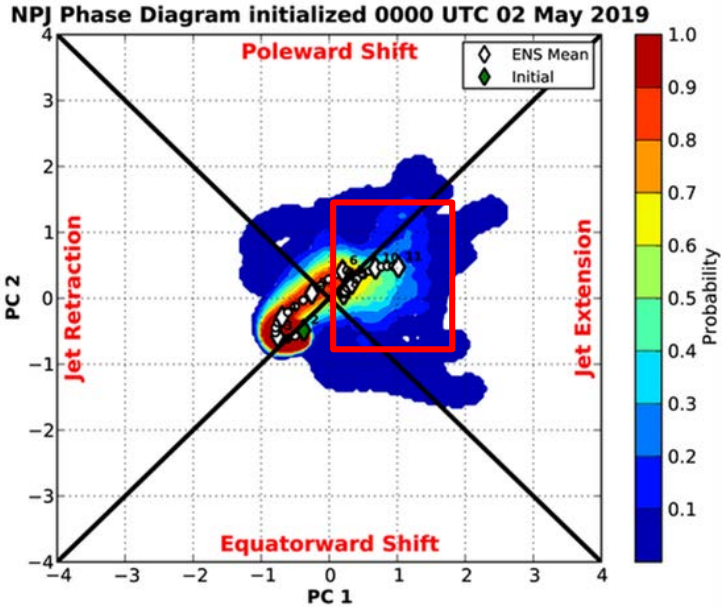


Both ensemble means show migration to Poleward Shift and warming over Canada and northern U.S.

Comparing Canonical Tools

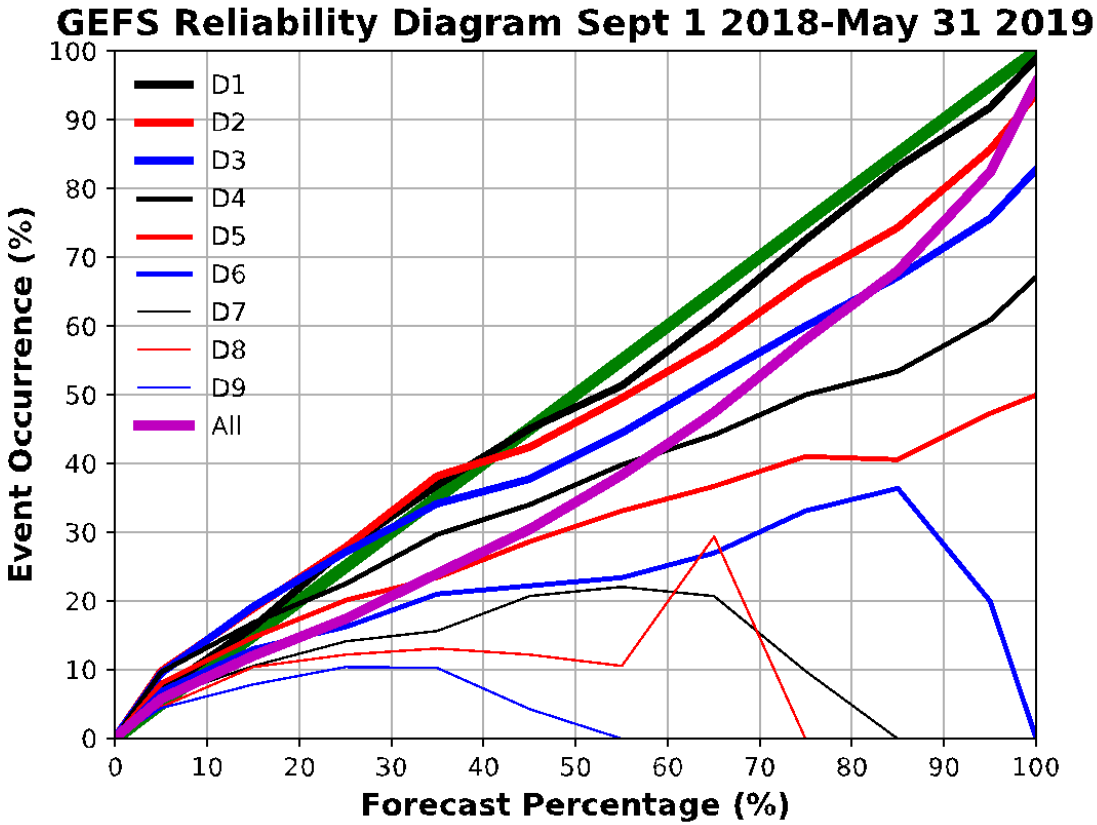


ECENS MJO forecast suggests propagation to Phase 8



NPJ probabilistic forecast suggests propagation to Jet Extension

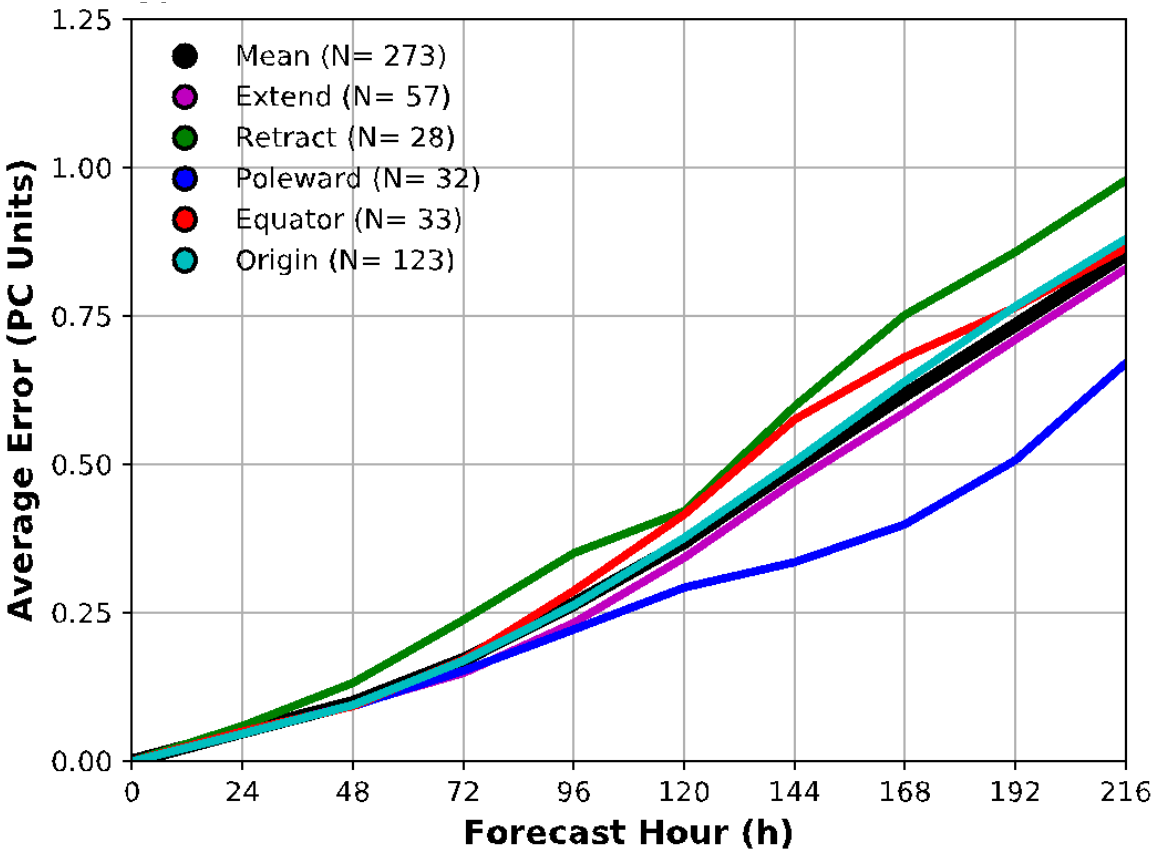
Reliability Diagram – GEFS Ensemble



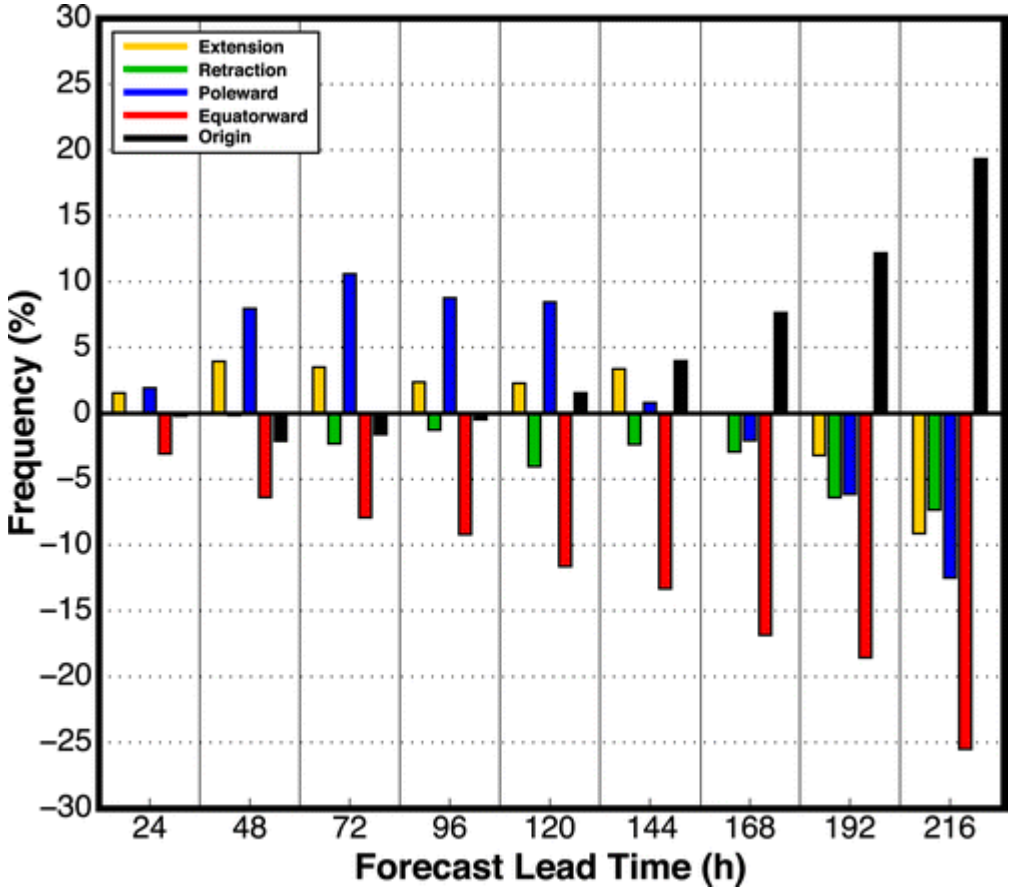
Perfect Reliability

The GEFS appears to be underdispersive with respect to medium-range forecasts of the NPJet in the phase diagram

Average GFS Error – Regime



GFS Verification
September 1, 2018 through
May 31, 2019



Forecast skill associated with each NPJ regime

Equatorward shifts are under forecast by ensemble mean NPJ phase diagram forecasts at all lead times (26% at F216). Equatorward regime aligned with blocking pattern over eastern North Pacific.

The overall trend is under forecasting for all regimes, however poleward shifts and jet extensions over forecast prior to F144

The over forecasting of NPJ regimes near the origin suggest a general reversion of the ensemble mean 250-hPa zonal wind towards climatology for long range lead times

Summary and Testing Takeaways

Tool has skill over cold season only (September through May).

Large-scale teleconnection patterns (AO, PNA) are strongly related to the frequency of each NPJ regime

NPJ can be objectively investigated with MJO variability.

Extreme Cold Events

Eastern U.S. extreme cold events most frequently follow Equatorward Shifts

Western U.S. extreme cold event most frequently following Jet Retractions

East and West cold events – NPJ evolves towards an Equatorward Shift and a slight Jet Extension during 10-days prior to initiation of event

Extreme Warm Events

Eastern U.S. warm events typically follow Jet Retractions and Poleward Shifts

Western U.S. warm events least frequently follow Jet Retractions and are characterized by an NPJ towards Jet extension and Equatorward Shifts during the 10-day period leading up to the event

Future Work

Test application of tool to the end of Week 2 (Days 11-14) and in the Day 4-7 medium range period

Explore evolution of NPJ phases spaces with merging polar and subtropical jet streams over North America

Further training of WPC forecasters on tool applicability

References

Winters, A.C., D. Keyser, and L.F. Bosart, 2019: The development of the North Pacific jet phase diagram as an objective tool to monitor the state of the upper-tropospheric flow pattern. *Wea forecasting*, **34**, 199-219.

Winters, A.C., L.F. Bosart, D. Keyser, 2019: Antecedent North Pacific jet regimes conducive to the development of continental U.S. extreme temperature events during the cool season. W*ea forecasting*, **34**, 393-414.