The Development of the North Pacific Jet Phase Diagram at NCEP-WPC as an Objective Tool to Characterize the Upper-Tropospheric Flow Pattern

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Project Motivation

- The antecedent environments associated with continental U.S. extreme temperature events are characterized by considerable North Pacific Jet (NPJ) variability during the medium-range forecast period

- This NPJ variability motivated the development of the NPJ phase diagram as an objective tool to characterize the instantaneous state of the upper-tropospheric flow pattern over the North Pacific

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- The antecedent environments associated with continental U.S. extreme temperature events are characterized by considerable North Pacific Jet (NPJ) variability during the medium-range forecast period

- This NPJ variability motivated the development of the NPJ phase diagram as an objective tool to characterize the instantaneous state of the upper-tropospheric flow pattern over the North Pacific

- **This presentation explores the potential of the NPJ phase diagram to increase confidence in operational probabilistic temperature forecasts during the medium-range period**

The Development of the NPJ Phase Diagram

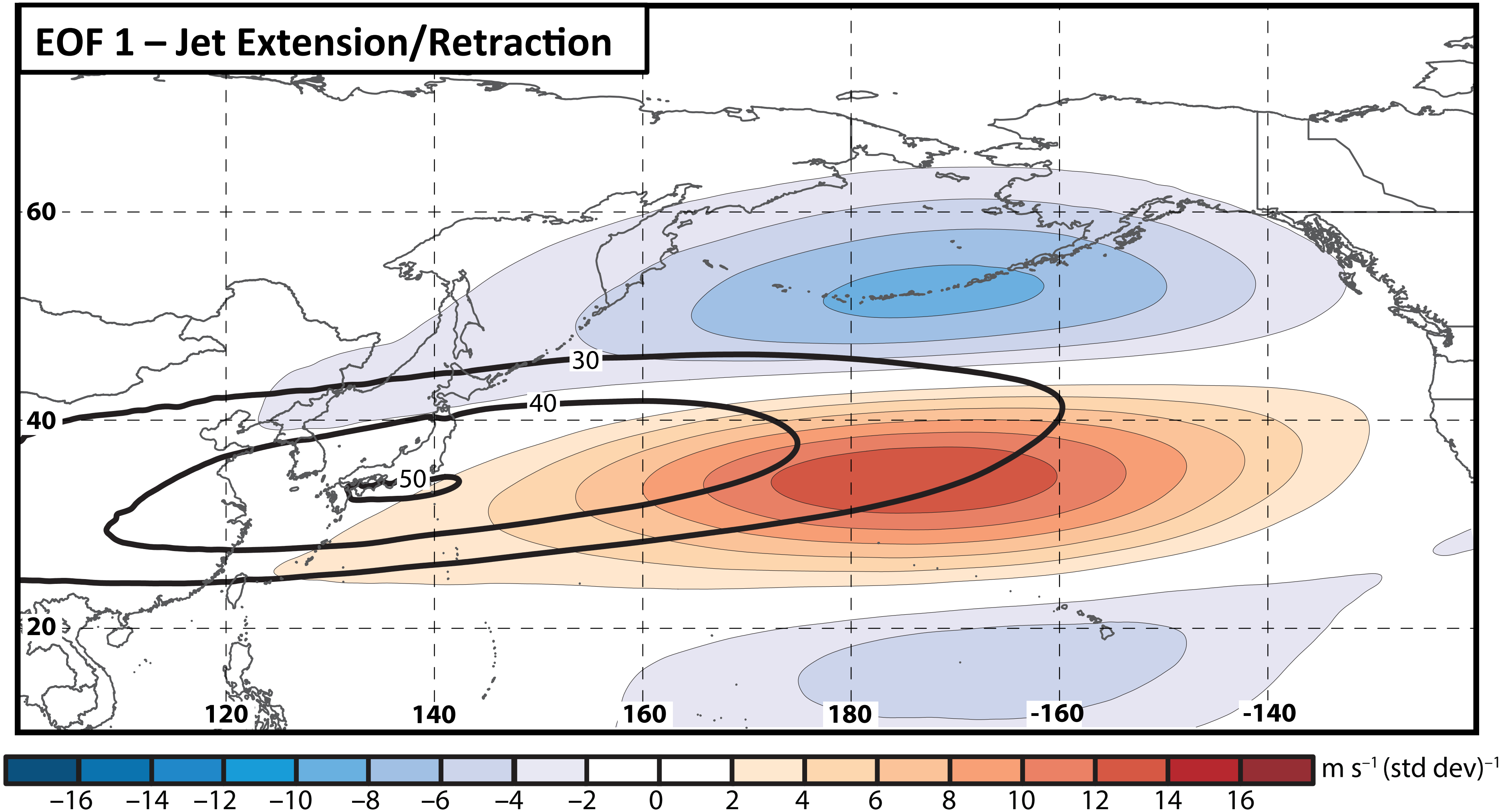
The NPJ Phase Diagram

- Removed the mean and the annual and diurnal cycles from 6-hourly, 250-hPa zonal wind data from the CFSR (1979–2014) (Saha et al. 2014)
- Restricted data to the cool season (Sept.–May)
- Performed an EOF analysis on the zonal wind anomalies within the domain: 10–80°N , 100°E–120°W

Analysis techniques and resultant EOF patterns are consistent with related work on the NPJ:

- Athanasiadis et al. (2010)
- Jaffe et al. (2011)
- Griffin and Martin (2017)

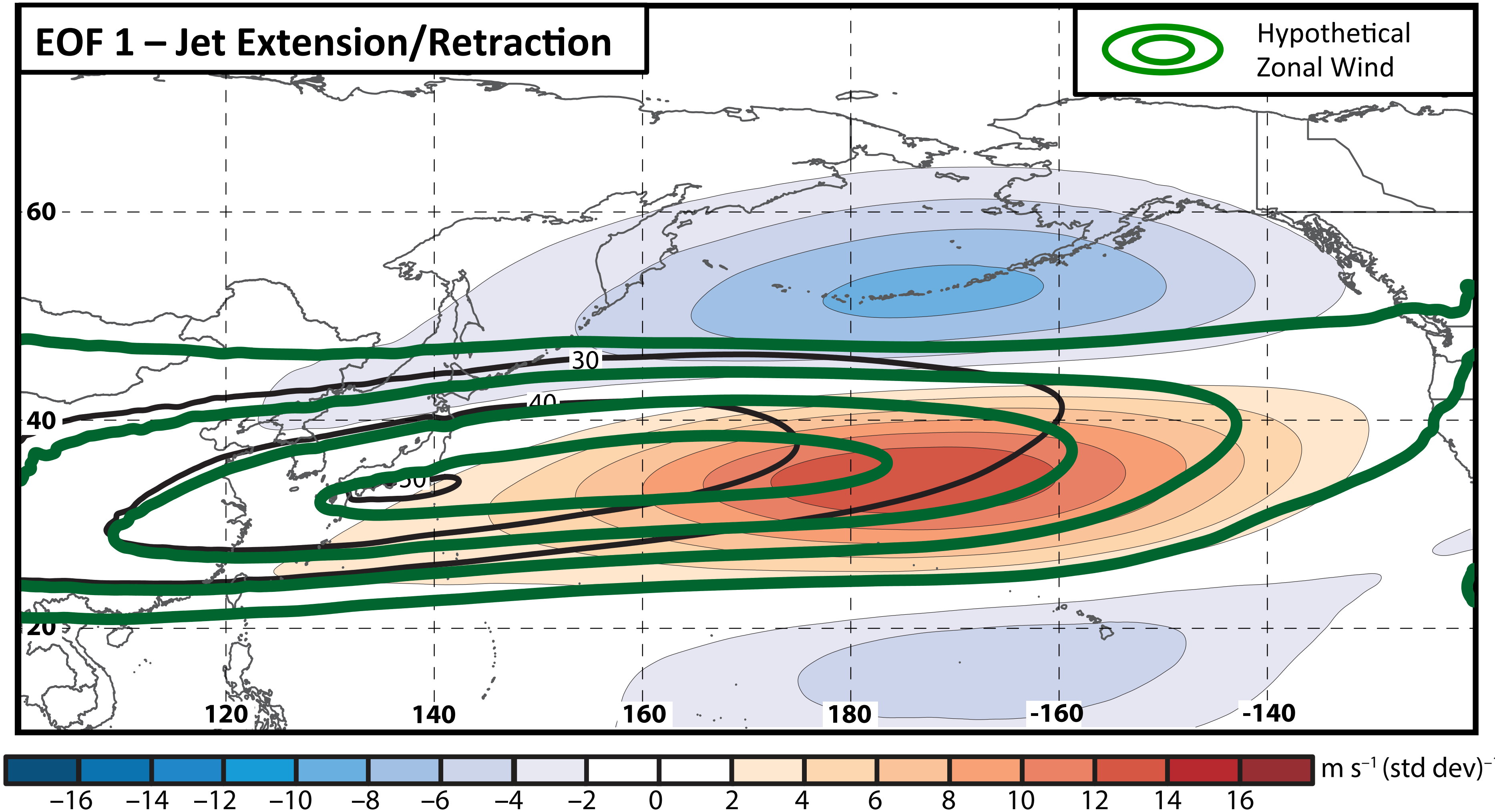
The NPJ Phase Diagram



Sept.–May mean 250-hPa zonal wind: black contours
Sept.–May 250-hPa zonal wind EOF 1 pattern: shading

+ EOF 1: Jet Extension
– EOF 1: Jet Retraction

The NPJ Phase Diagram



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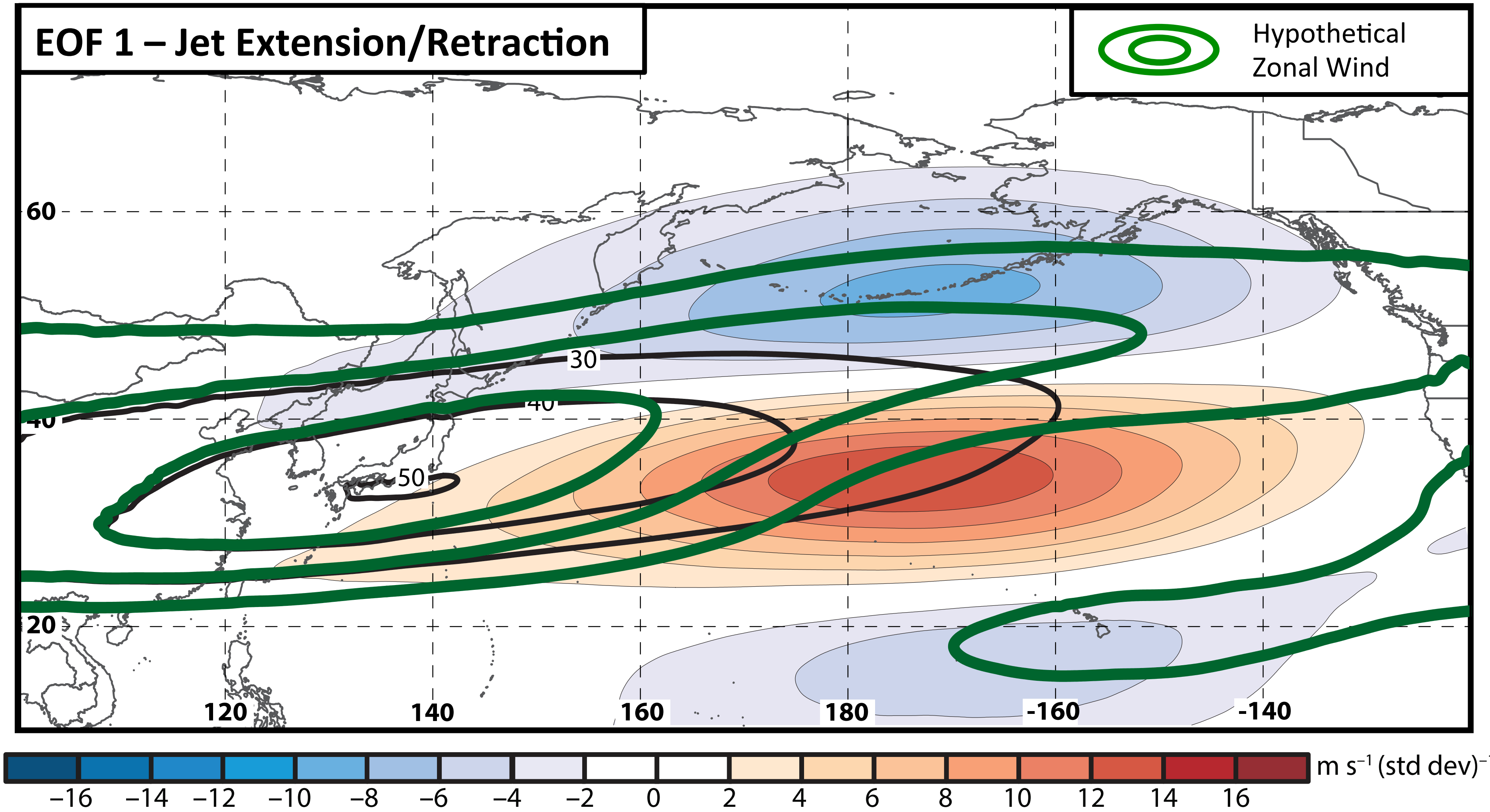

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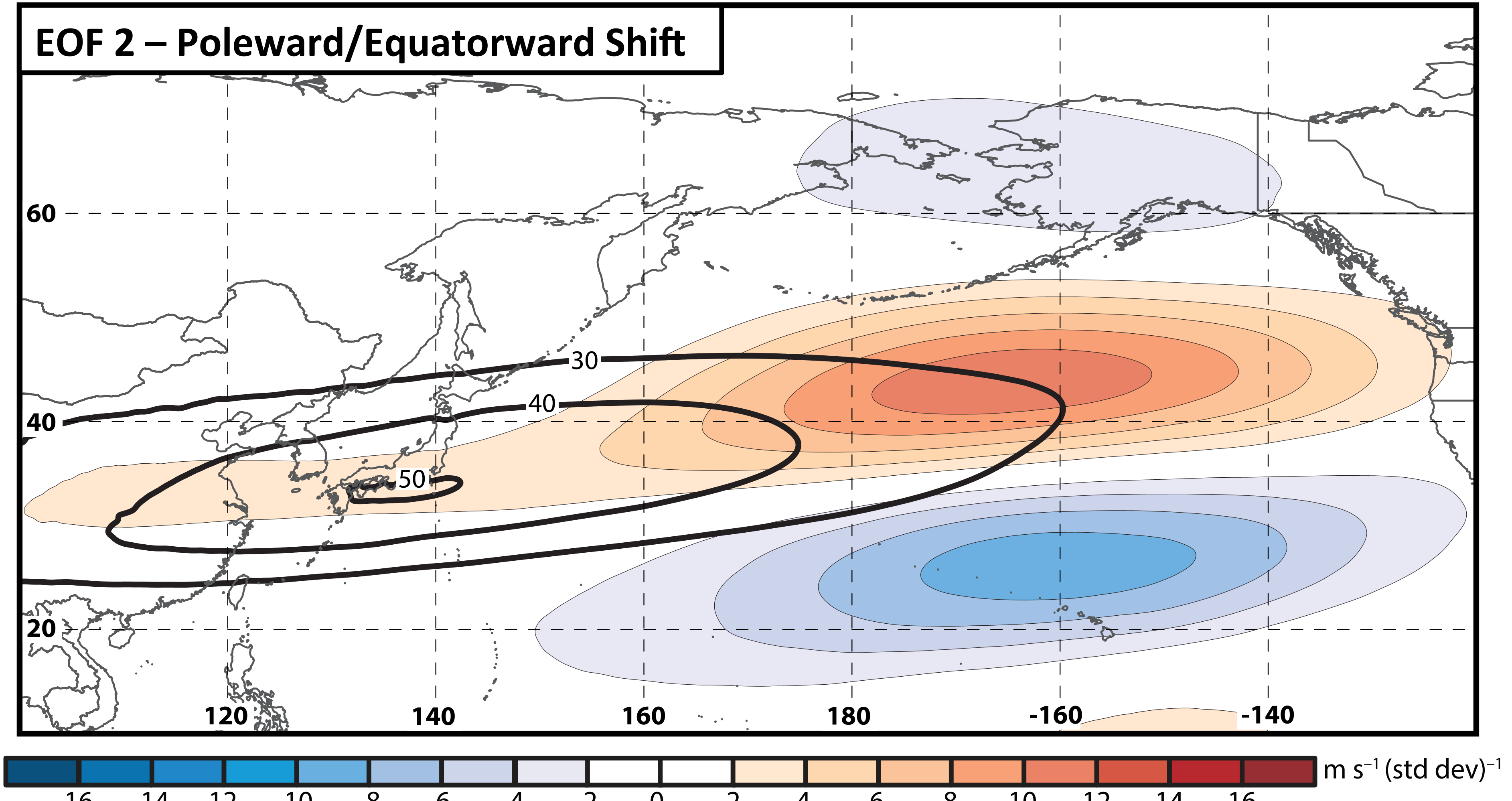
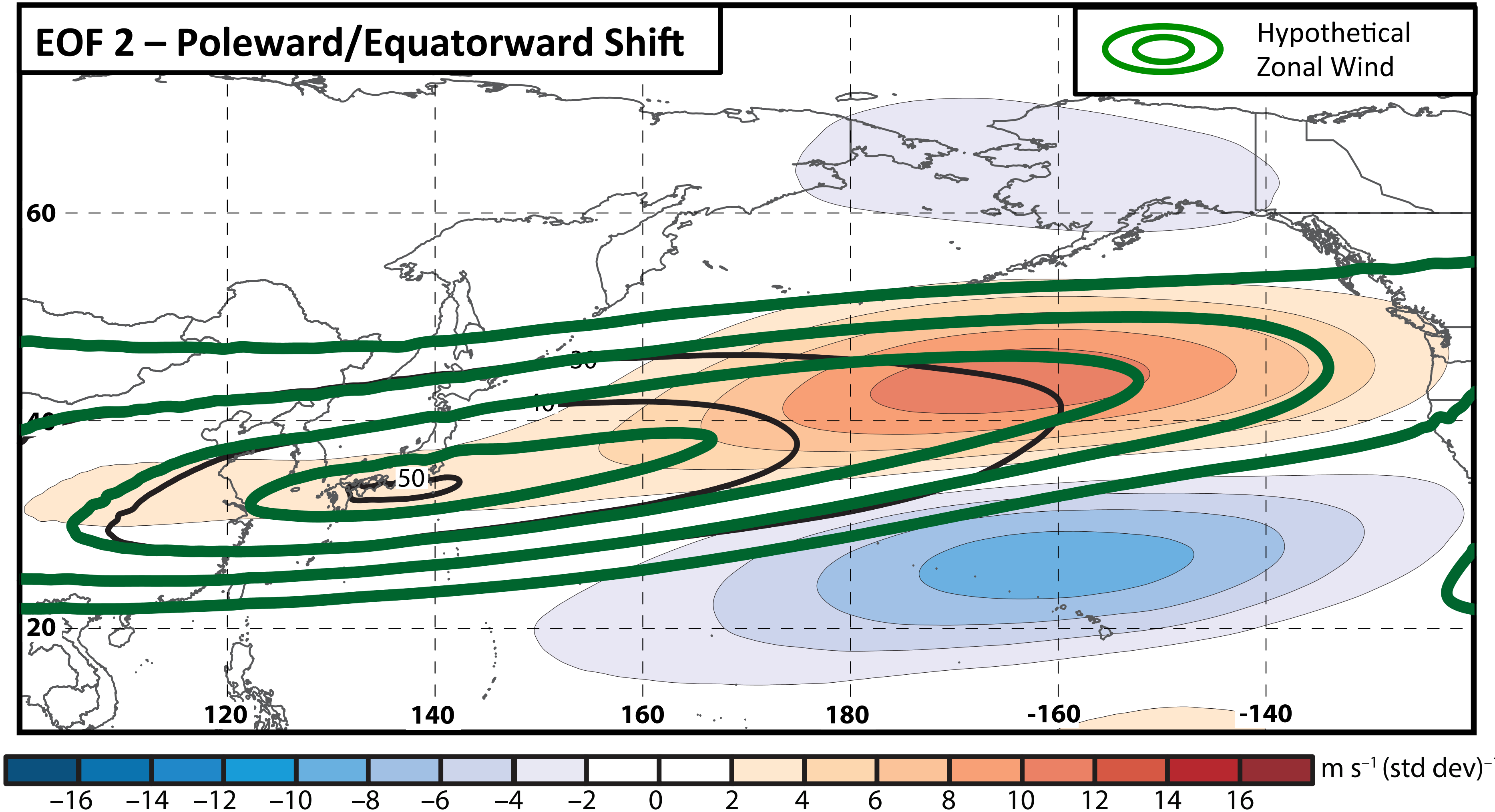


Sept.–May mean 250-hPa zonal wind: black contours
Sept.–May 250-hPa zonal wind EOF 2 pattern: shading

+ EOF 2: Poleward Shift
– EOF 2: Equatorward Shift

The NPJ Phase Diagram



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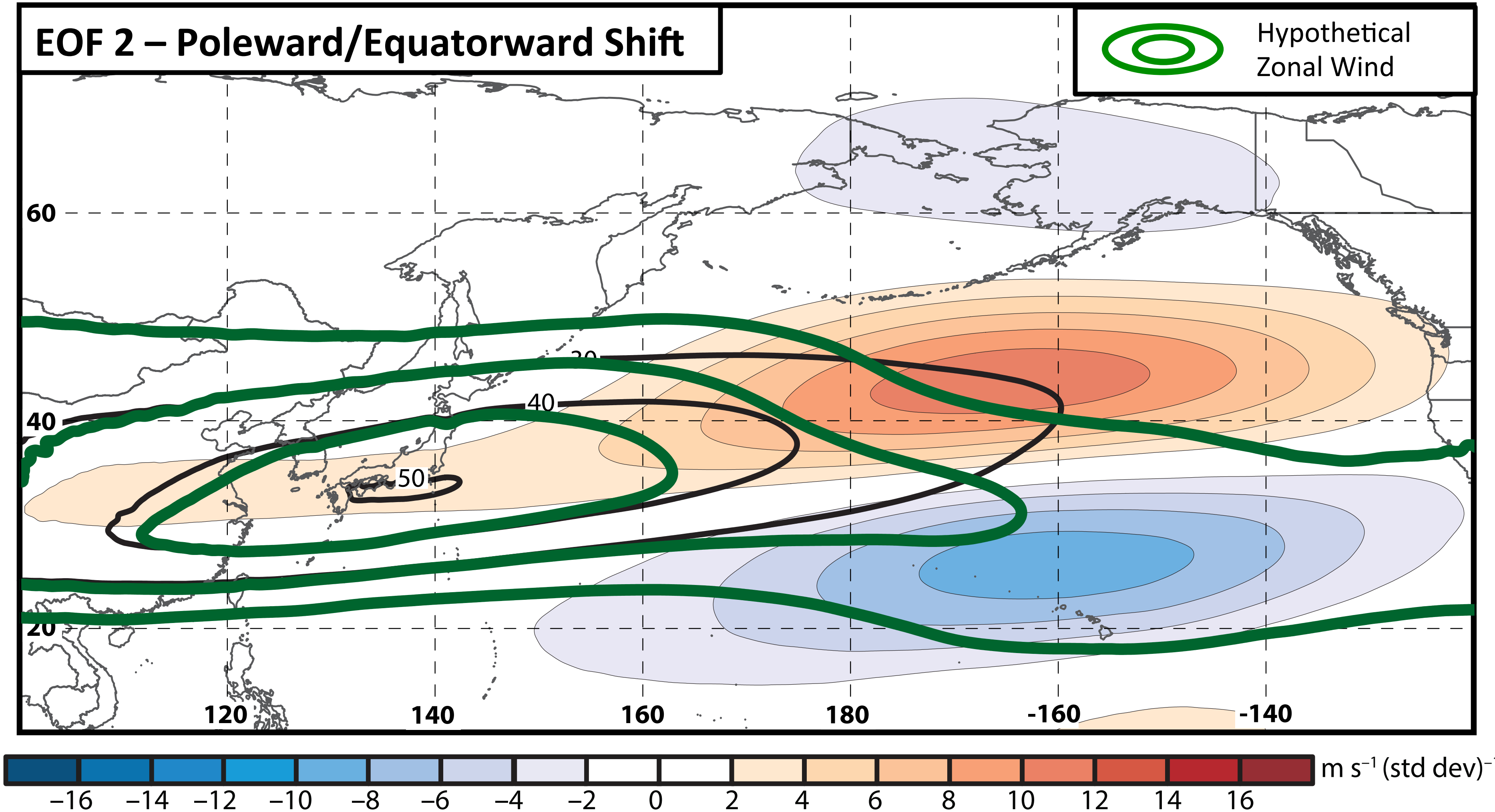

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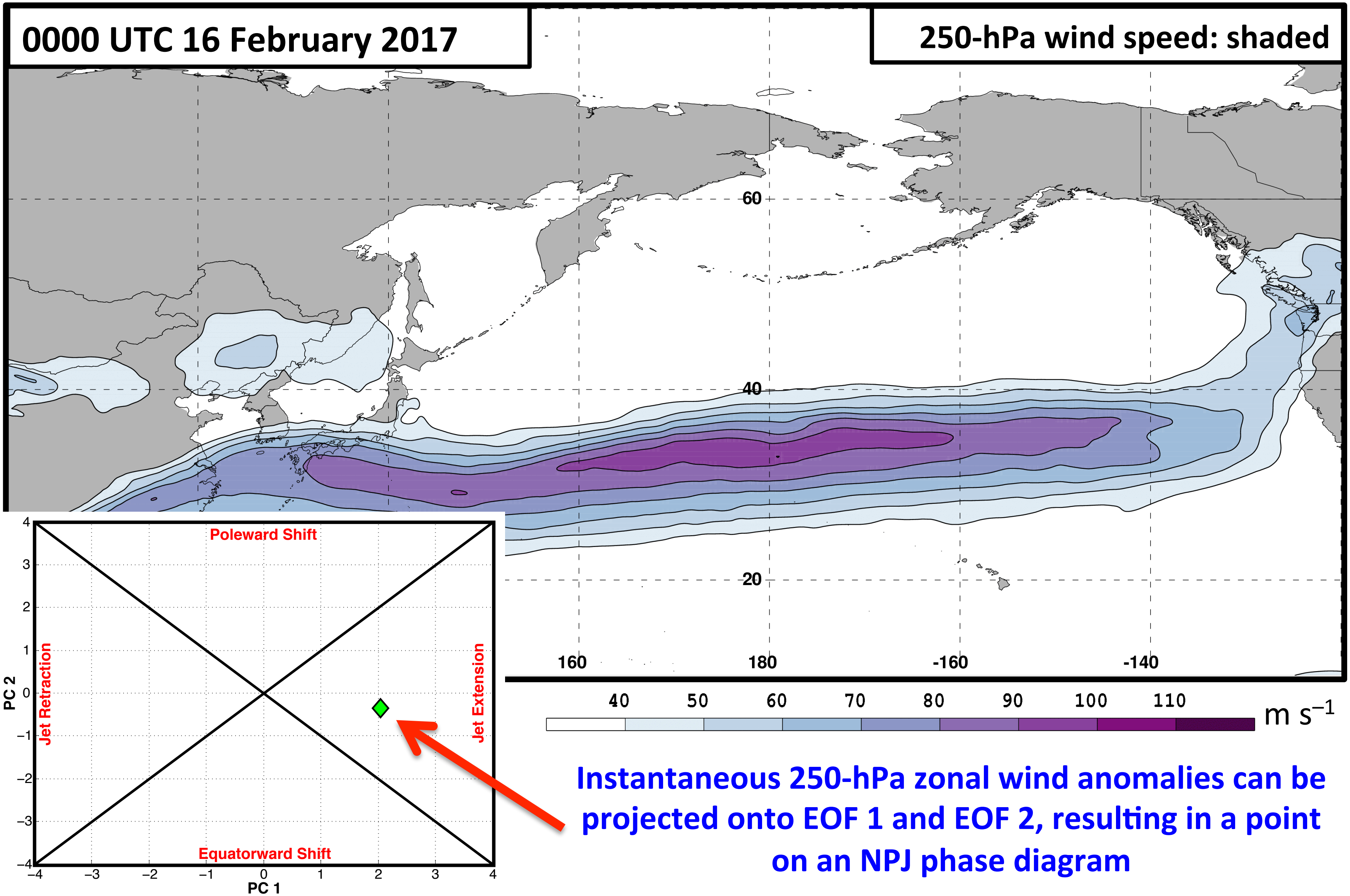
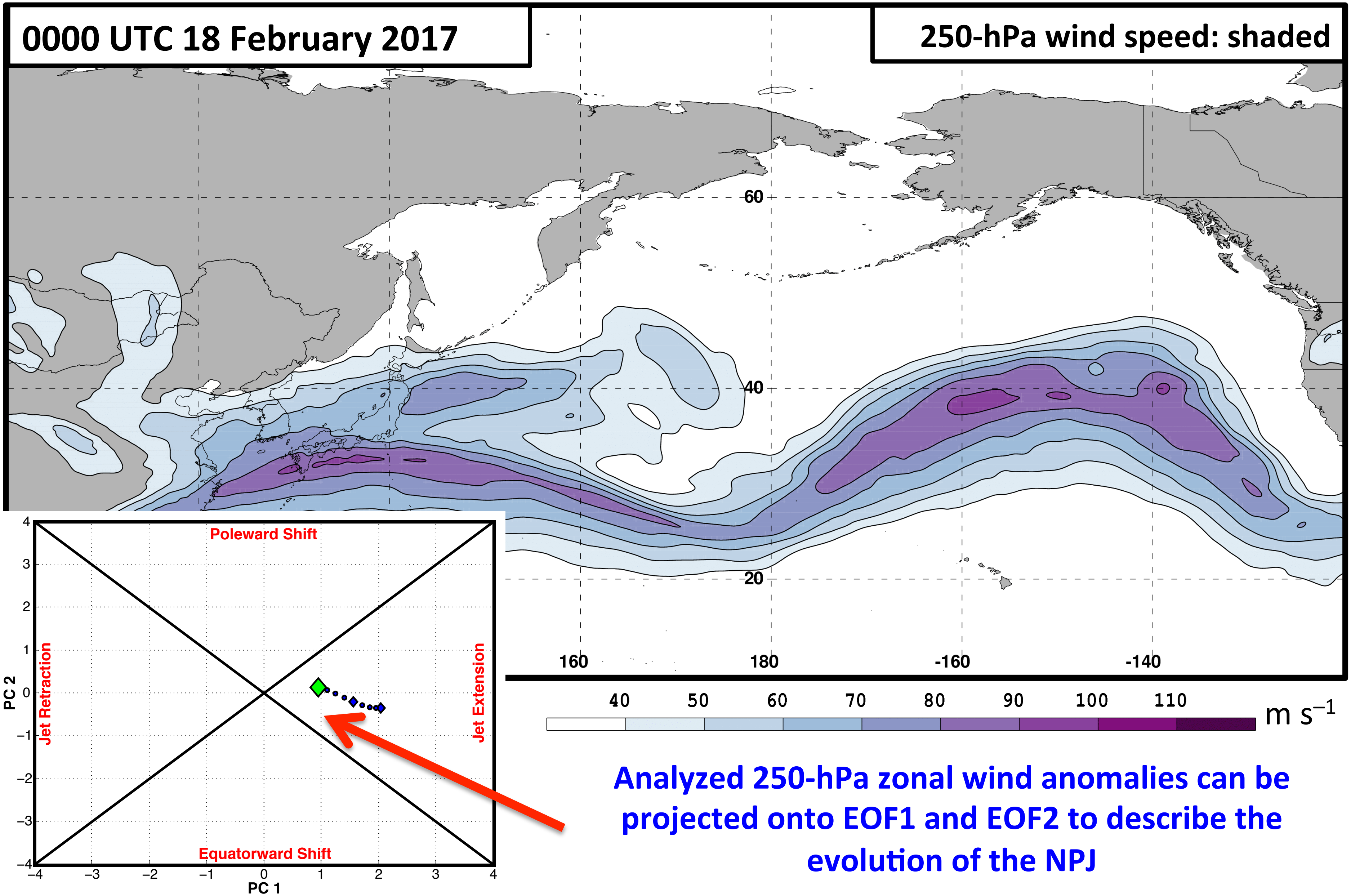


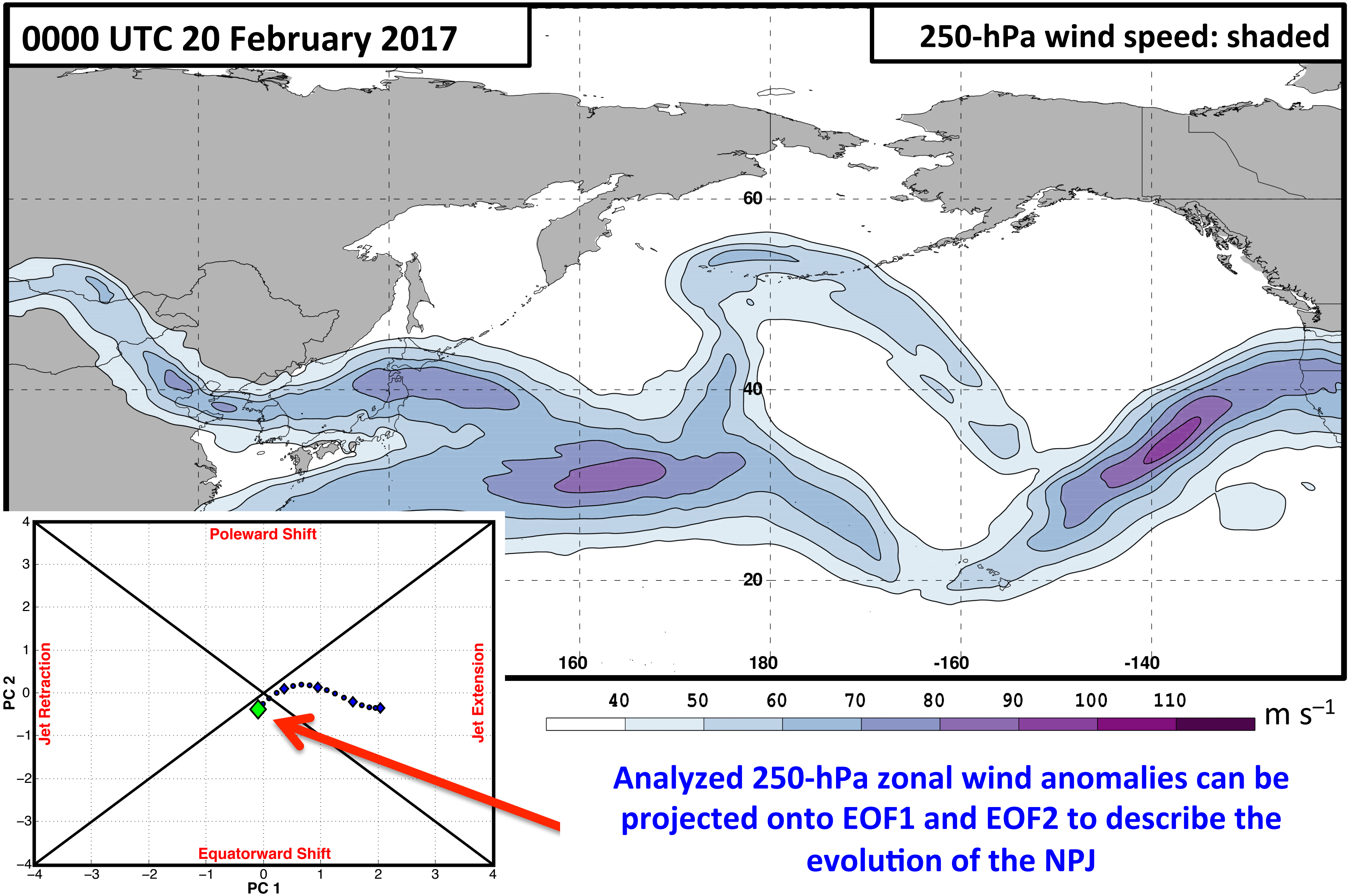
Instantaneous 250-hPa zonal wind anomalies can be projected onto EOF 1 and EOF 2, resulting in a point on an NPJ phase diagram

The NPJ Phase Diagram



Analyzed 250-hPa zonal wind anomalies can be projected onto EOF1 and EOF2 to describe the evolution of the NPJ

The NPJ Phase Diagram



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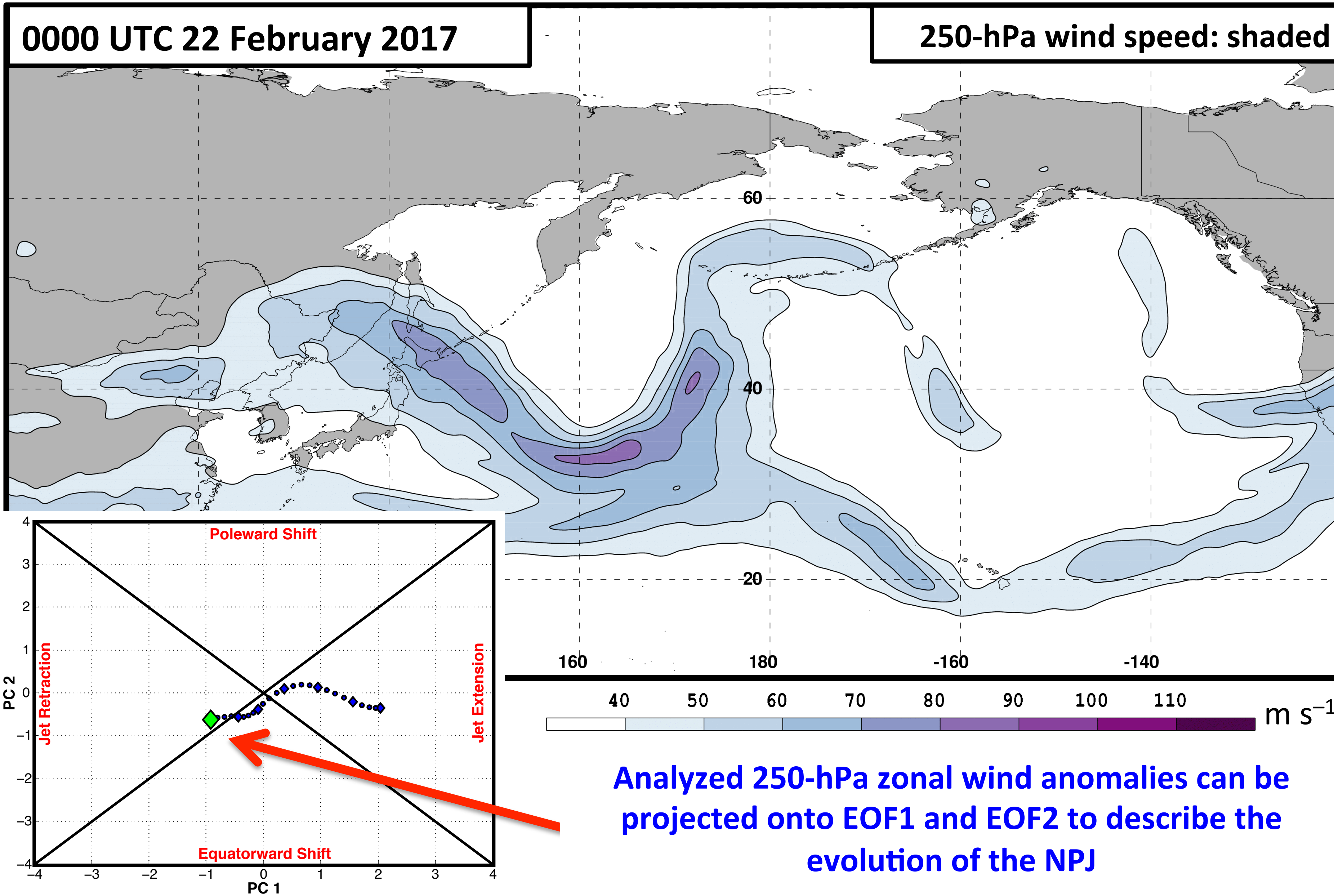

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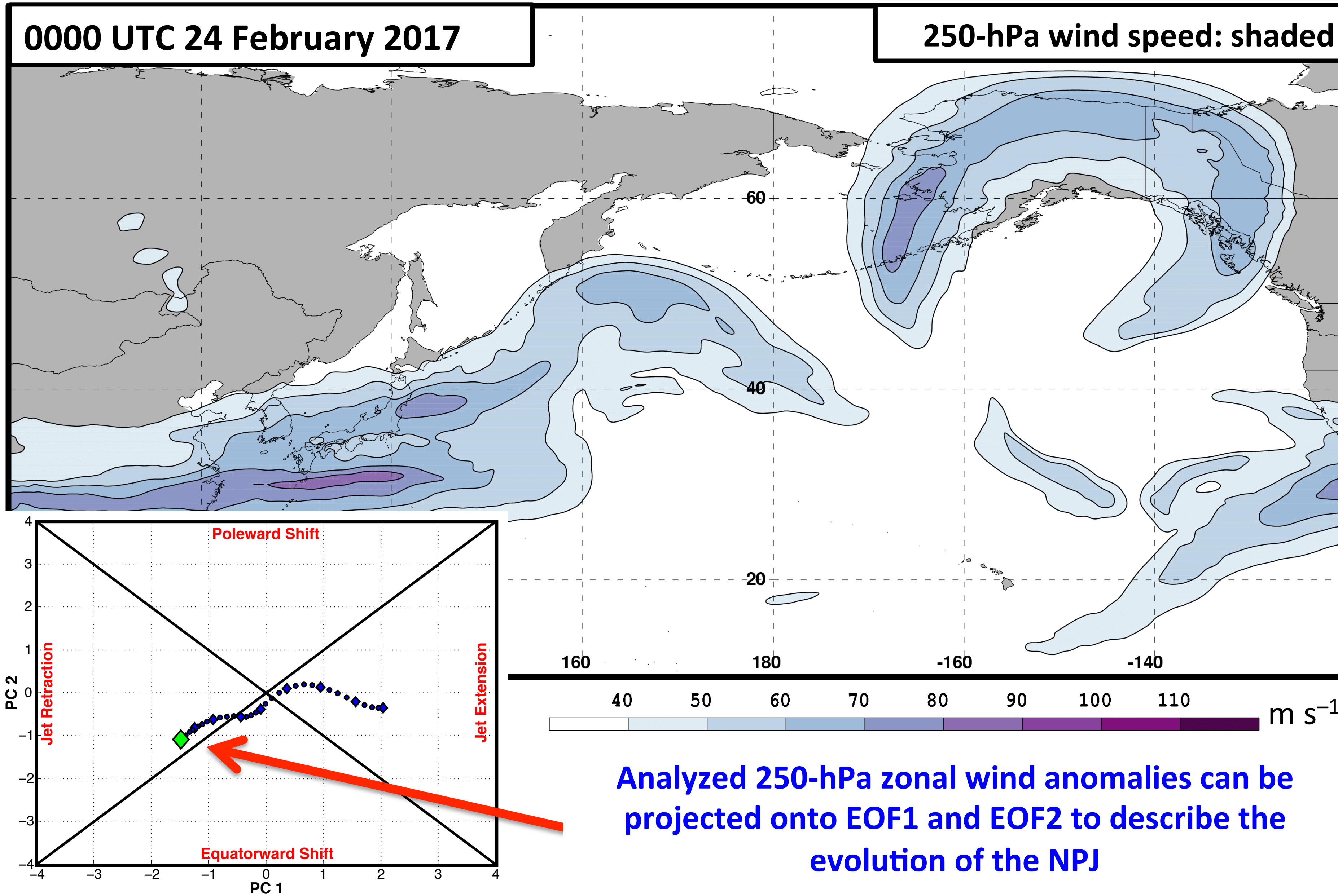

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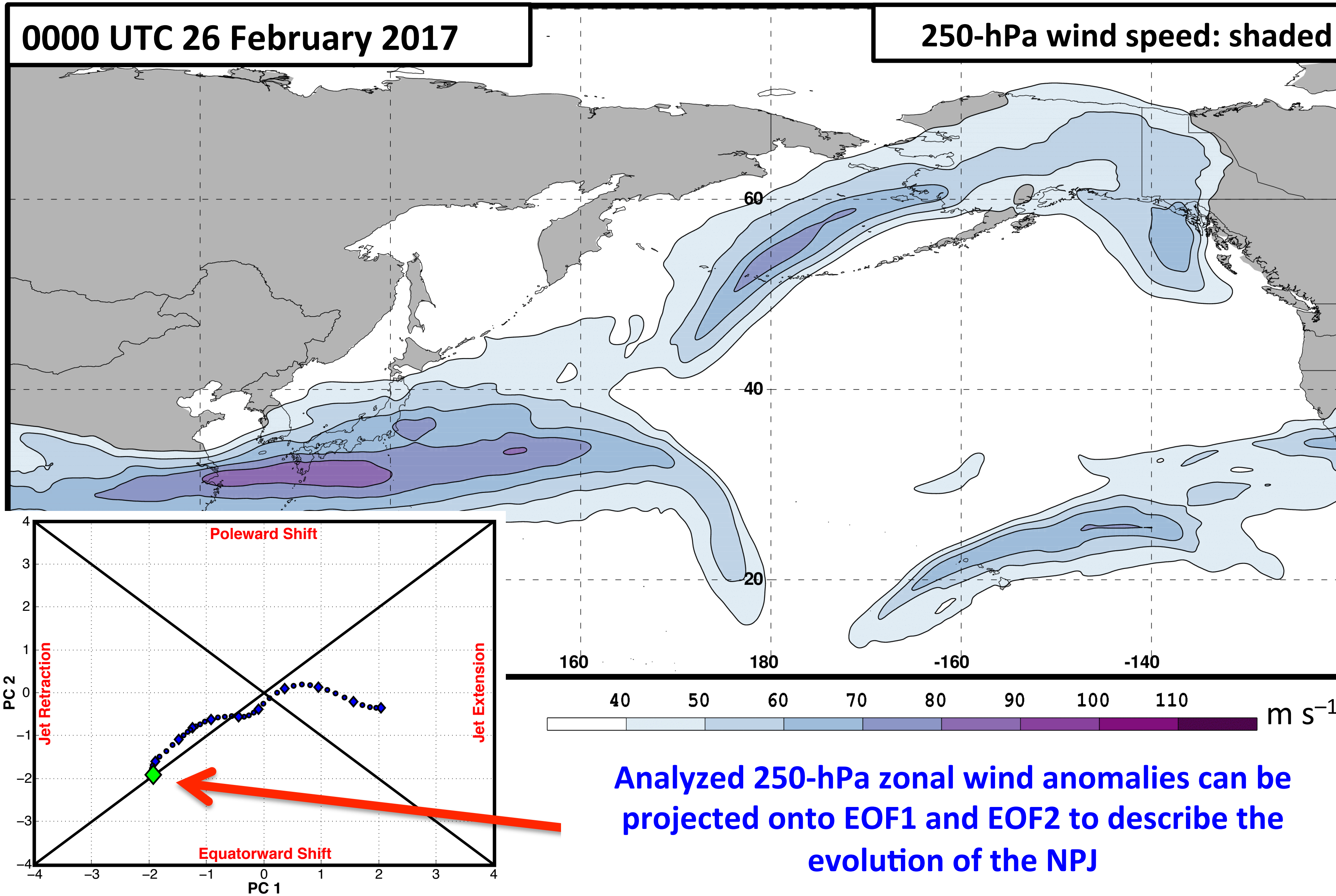
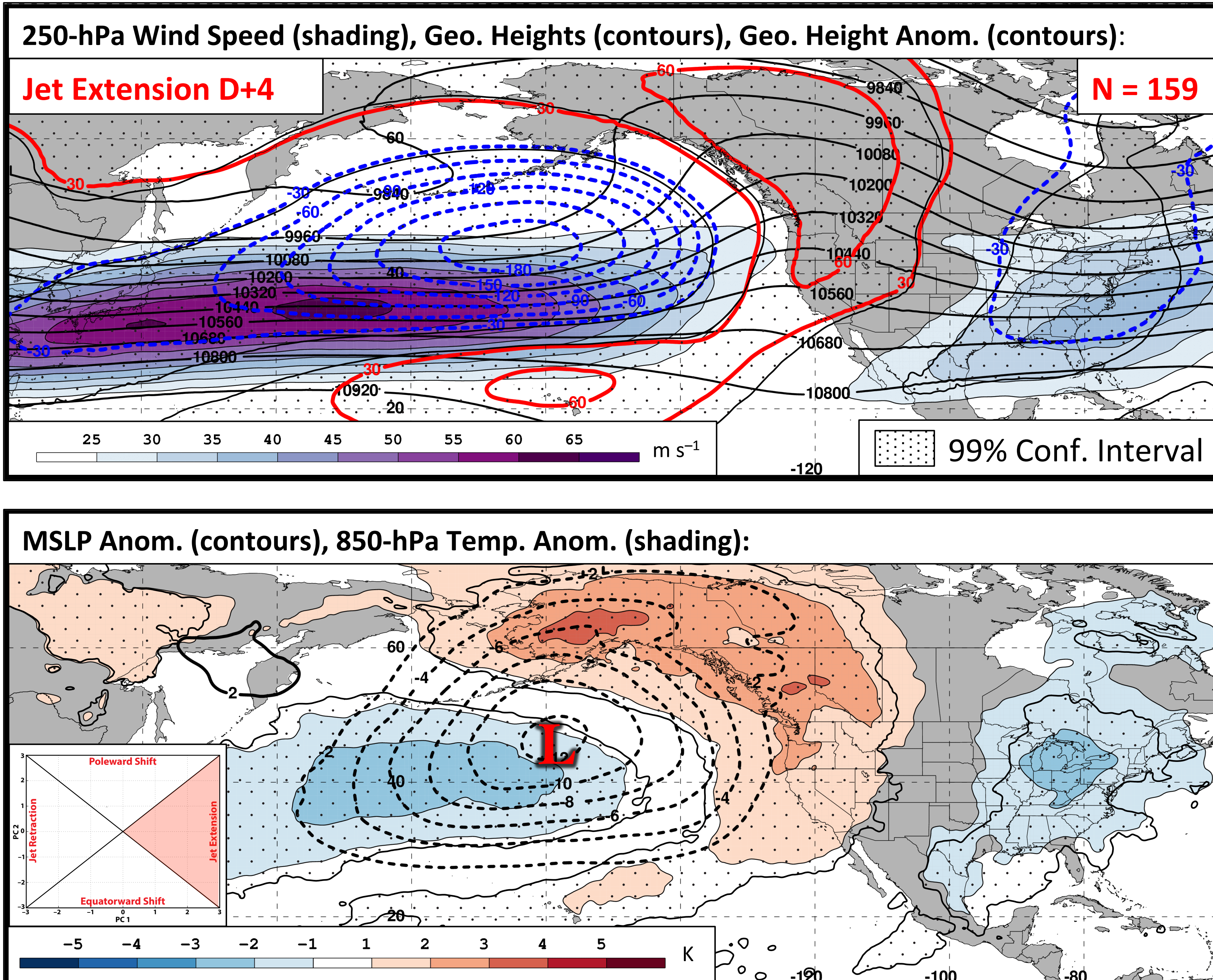
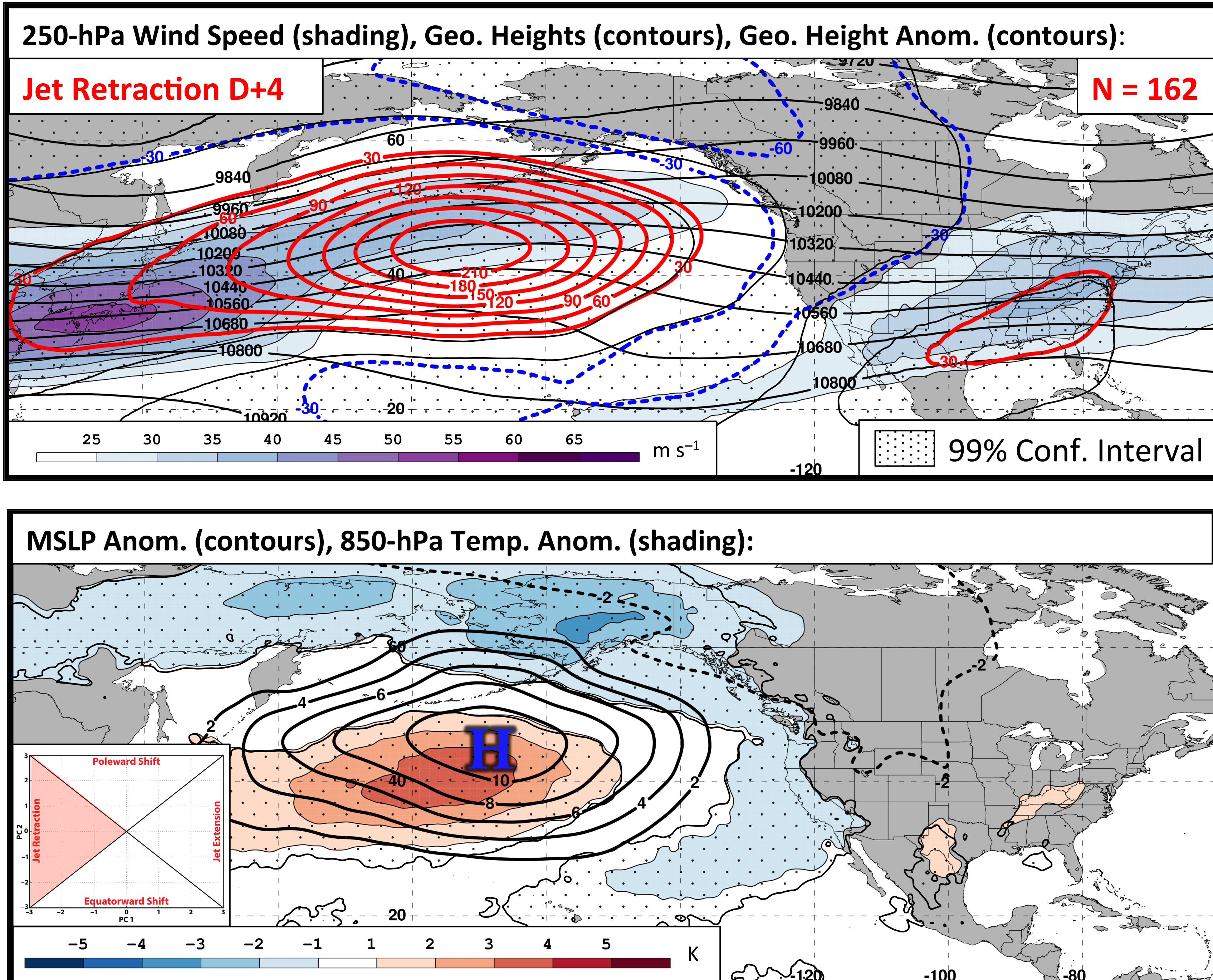


Analyzed 250-hPa zonal wind anomalies can be projected onto EOF1 and EOF2 to describe the evolution of the NPJ

Influence of the Prevailing NPJ Regime on North America


250-hPa Wind Speed (shading), Geo. Heights (contours), Geo. Height Anom. (contours):
Jet Extension D+4
N = 159
25 30 35 40 45 50 55 60 65
m s⁻¹
99% Conf. Interval
9840
9960
10080
10200
10320
10440
10560
10680
10800
10920
-30
-60
-90
-120
-150
-180
30
60
-120
MSLP Anom. (contours), 850-hPa Temp. Anom. (shading):
L
−5 −4 −3 −2 −1 1 2 3 4 5
K
Poleward Shift
Equatorward Shift
Jet Retraction
Jet Extension
PC 1
PC 2
-120
-100
-80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Jet Retraction D+4
N = 162
9720
9840
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10080
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10320
10440
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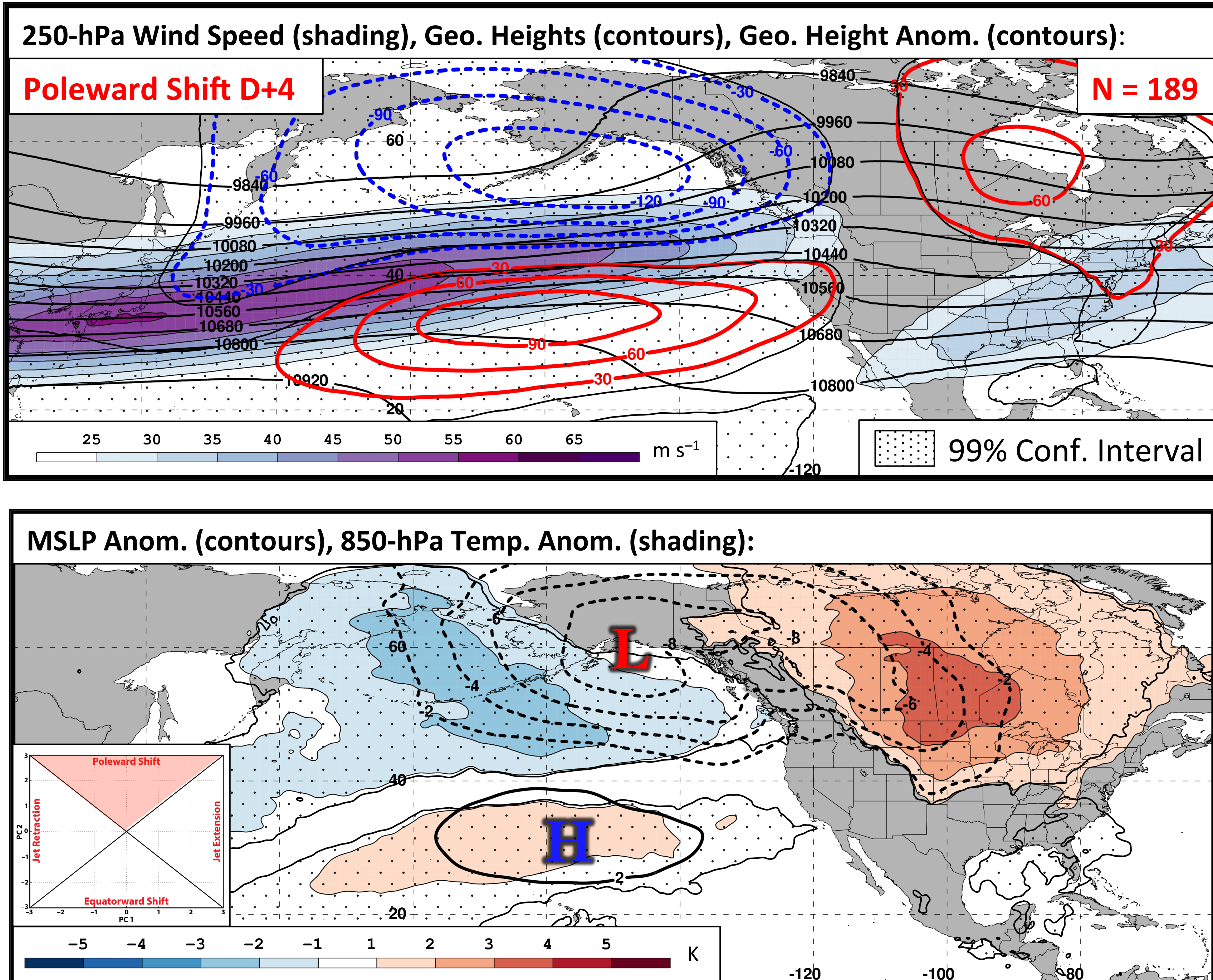
10680
10800
10920
-30
-60
30
60
90
120
150
180
210
25 30 35 40 45 50 55 60 65
m s⁻¹
99% Conf. Interval
-120
20
40
60
MSLP Anom. (contours), 850-hPa Temp. Anom. (shading):
H
-2
2
4
6
8
10
Poleward Shift
Equatorward Shift
Jet Retraction
Jet Extension
PC 1
PC 2
−5 −4 −3 −2 −1 1 2 3 4 5
K
-120
-100
-80



250-hPa Wind Speed (shading), Geo. Heights (contours), Geo. Height Anom. (contours):
Poleward Shift D+4
N = 189
9840
9960
10080
10200
10320
10440
10560
10680
10800
10920
-30
-60
-90
-120
30
60
90
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25 30 35 40 45 50 55 60 65
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20
-120
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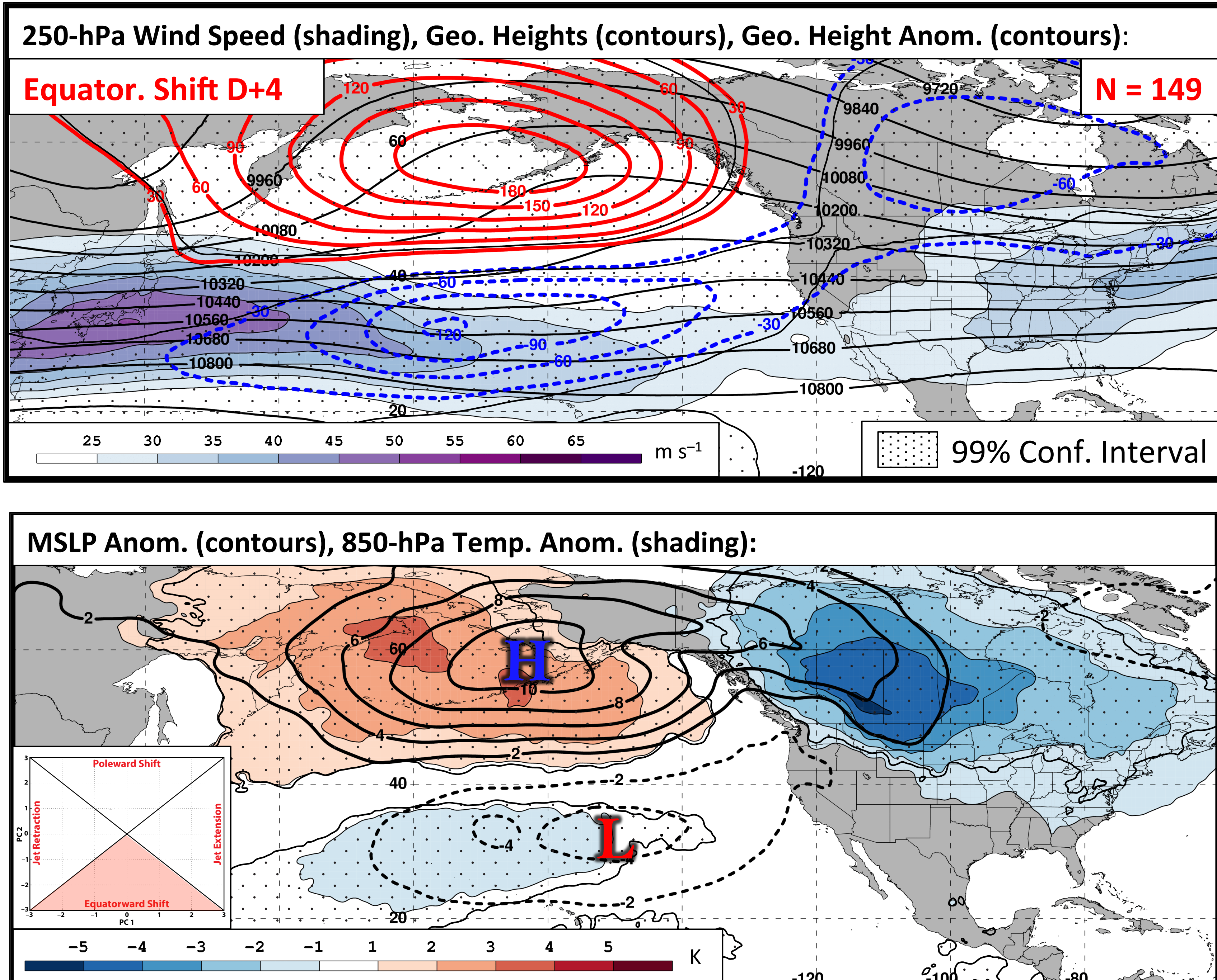
-80
Poleward Shift
Jet Retraction
Jet Extension
Equatorward Shift
PC 1
PC 2
−5 −4 −3 −2 −1 1 2 3 4 5
K


250-hPa Wind Speed (shading), Geo. Heights (contours), Geo. Height Anom. (contours):
Equator. Shift D+4
N = 149
9720
9840
9960
10080
10200
10320
10440
10560
10680
10800
180
150
120
90
60
30
-30
-60
-90
-120
40
20
-120
25
30
35
40
45
50
55
60
65
m s−1
99% Conf. Interval
MSLP Anom. (contours), 850-hPa Temp. Anom. (shading):
H
L
10
8
6
4
2
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-4
40
20
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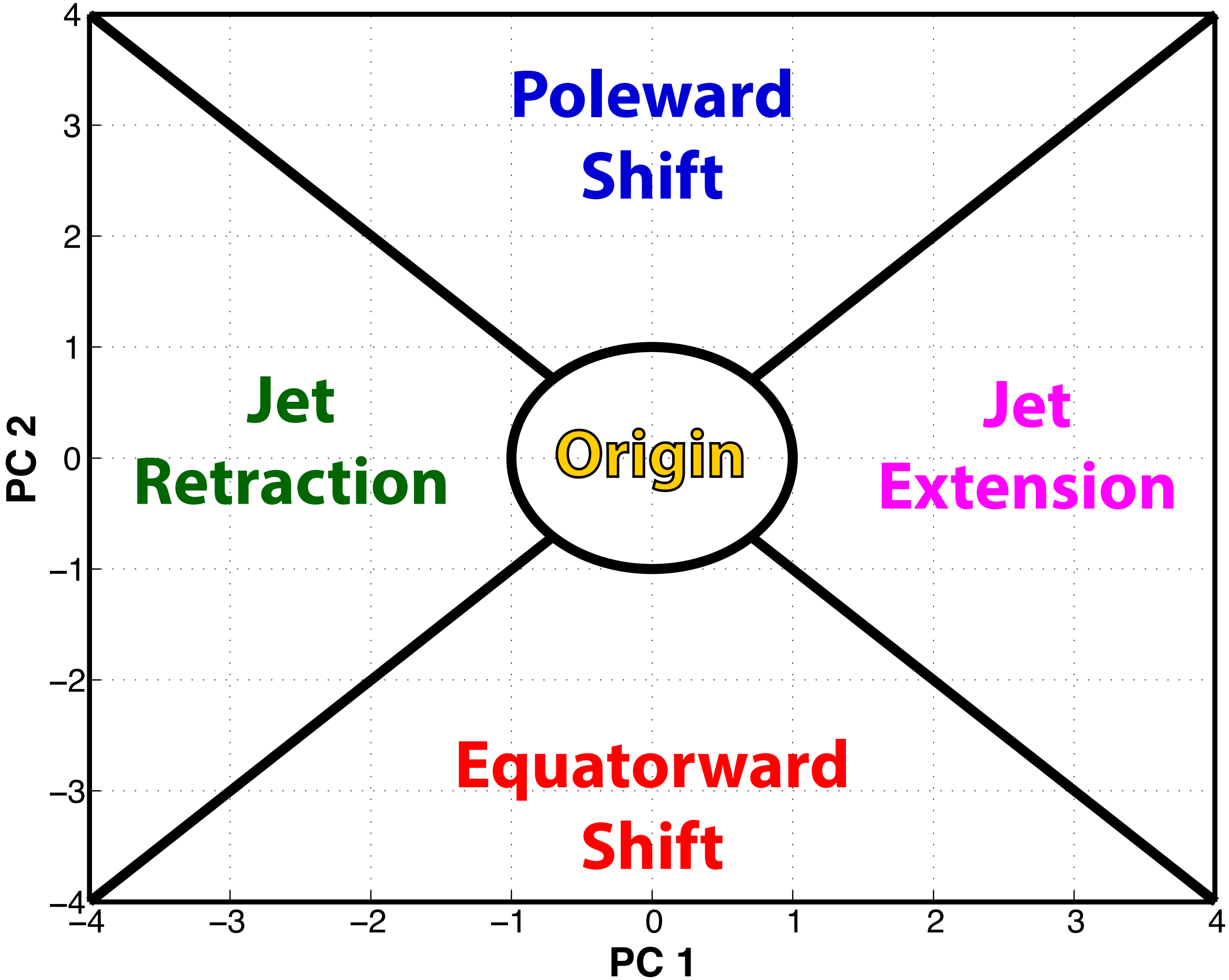
Poleward Shift
Jet Retraction
Jet Extension
Equatorward Shift
PC 1
PC 2
−5
−4
−3
−2
−1
1
2
3
4
5
K

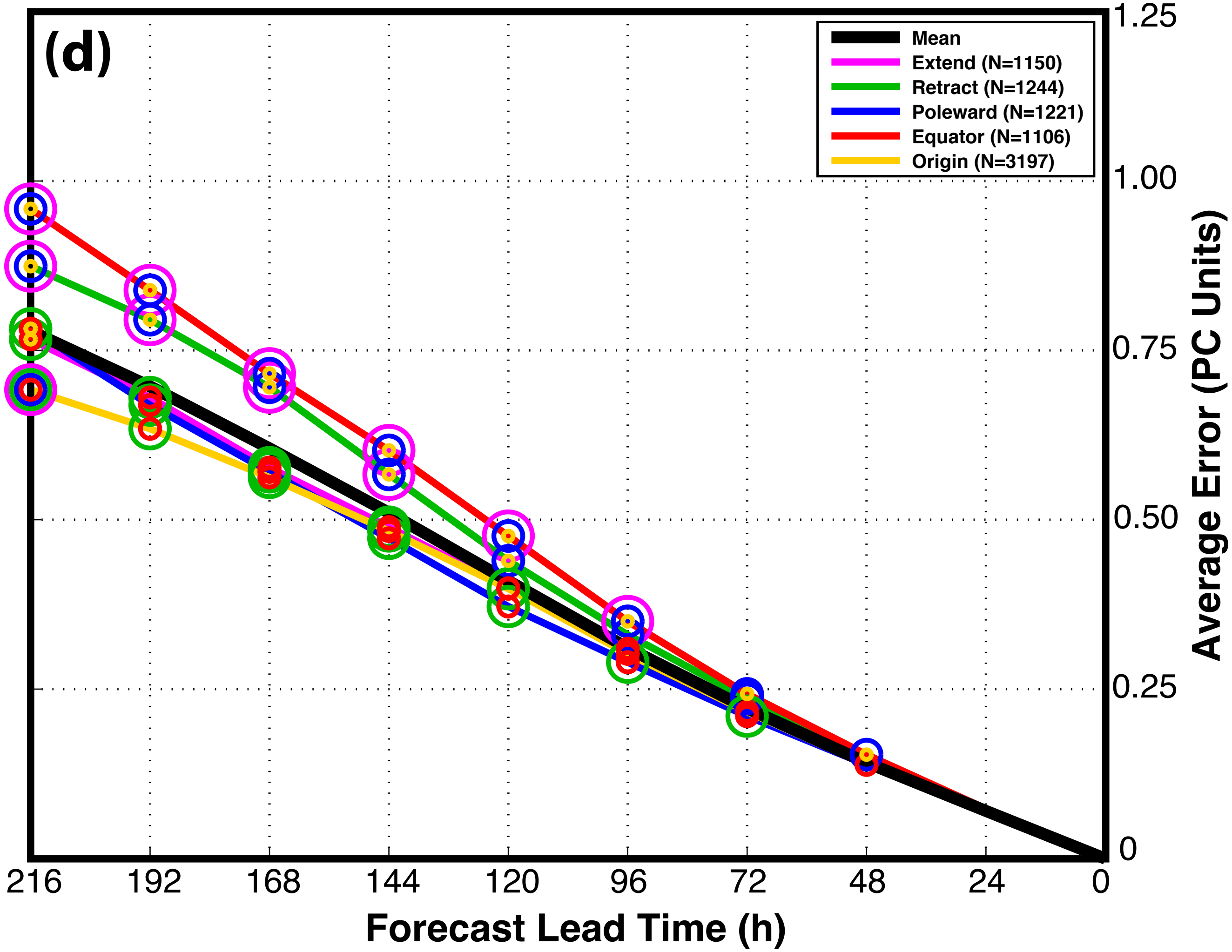
GEFS Forecast Skill in the Context of the NPJ Phase Diagram

NPJ Phase Diagram Forecast Skill

Determined the position within the NPJ phase diagram for all 0-h forecasts during Sept.–May 1985–2014 in the GEFS Reforecast v2 (Hamill et al. 2013)



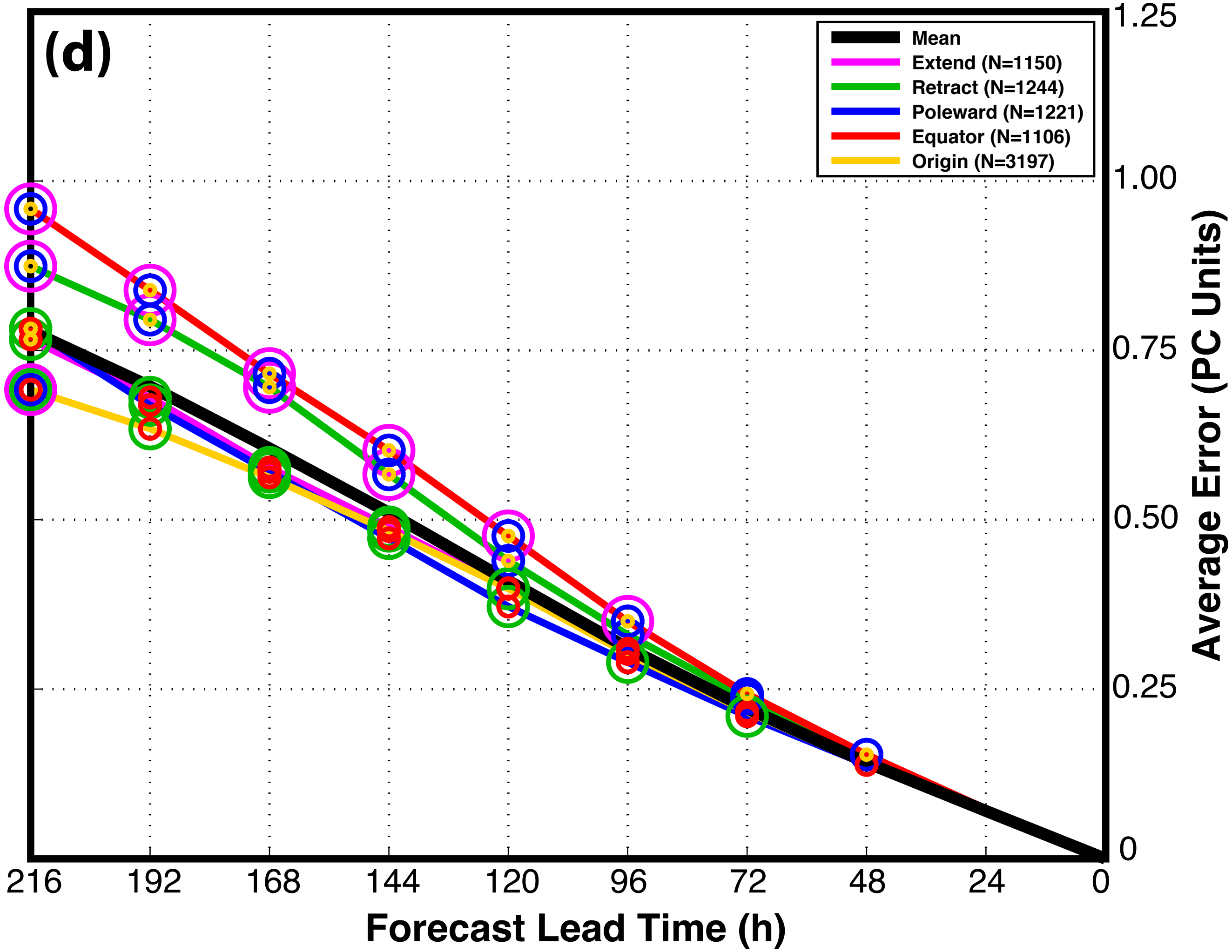
GEFS Ensemble Mean Error by NPJ Regime



GEFS Reforecasts *verifying* during a particular NPJ regime

Circles on a particular line indicate statistically significant differences at the 99% confidence level with respect to another NPJ regime

GEFS Ensemble Mean Error by NPJ Regime



GEFS Reforecasts *verifying* during a particular NPJ regime

Circles on a particular line indicate statistically significant differences at the 99% confidence level with respect to another NPJ regime

Forecasts verifying during **equatorward shifts** and **jet retractions** exhibit significantly larger errors than **jet extensions** and **poleward shifts** in the 96–216-h forecast period

Best/Worst NPJ Phase Diagram Forecasts

Comparison between the periods characterized by the best/worst medium-range forecasts

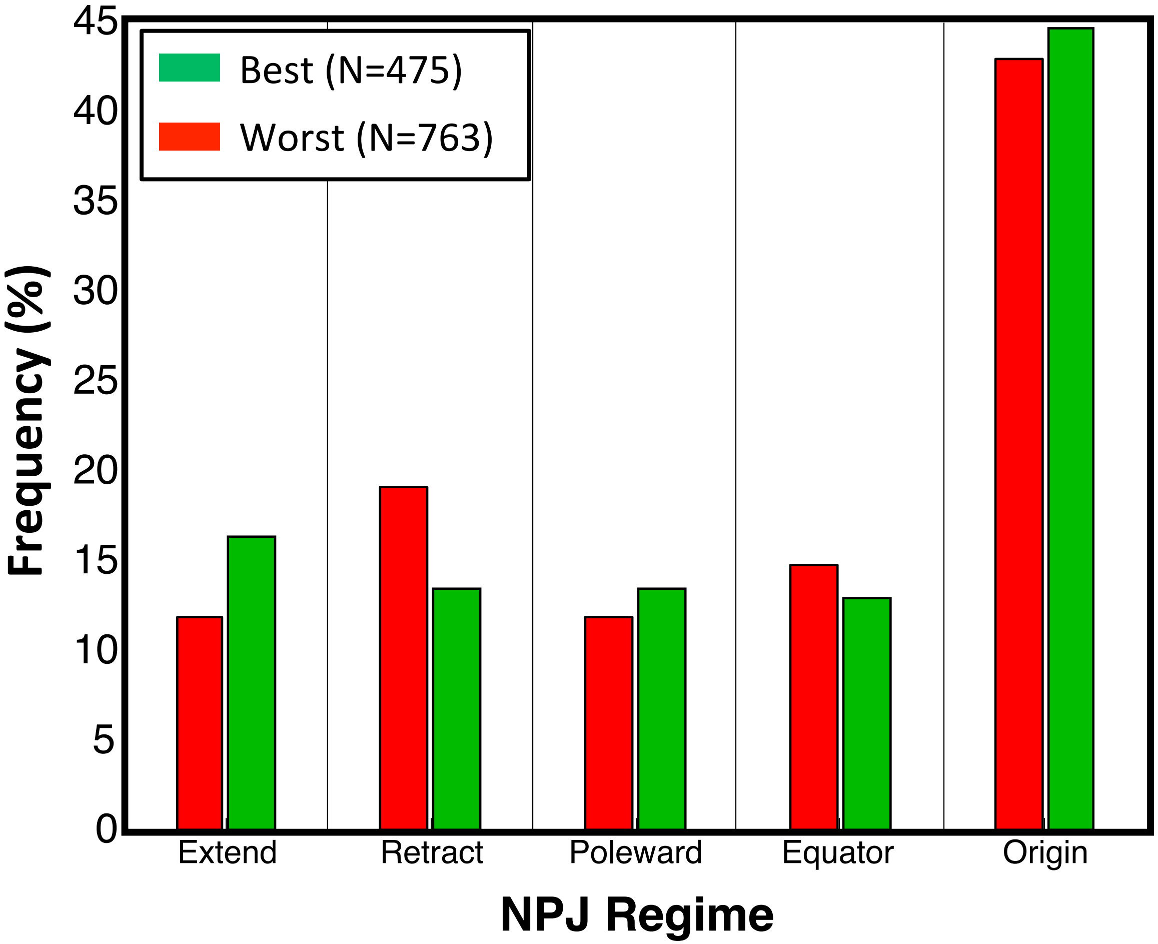
Criteria: Forecasts must rank in the top/bottom 10% in terms of *both*:

(1) The average GEFS ensemble mean error for the Day 8 and 9 forecasts

(2) The average GEFS ensemble member error for the Day 8 and 9 forecasts

Best/Worst NPJ Phase Diagram Forecasts

Comparison between the periods characterized by the best/worst medium-range forecasts



- The best forecasts occur disproportionately more during **jet extensions** and **poleward shifts**
- The worst forecasts occur disproportionately more during **jet retractions** and **equatorward shifts**

Best/Worst NPJ Phase Diagram Forecasts

Comparison between the periods characterized by the best/worst medium-range forecasts

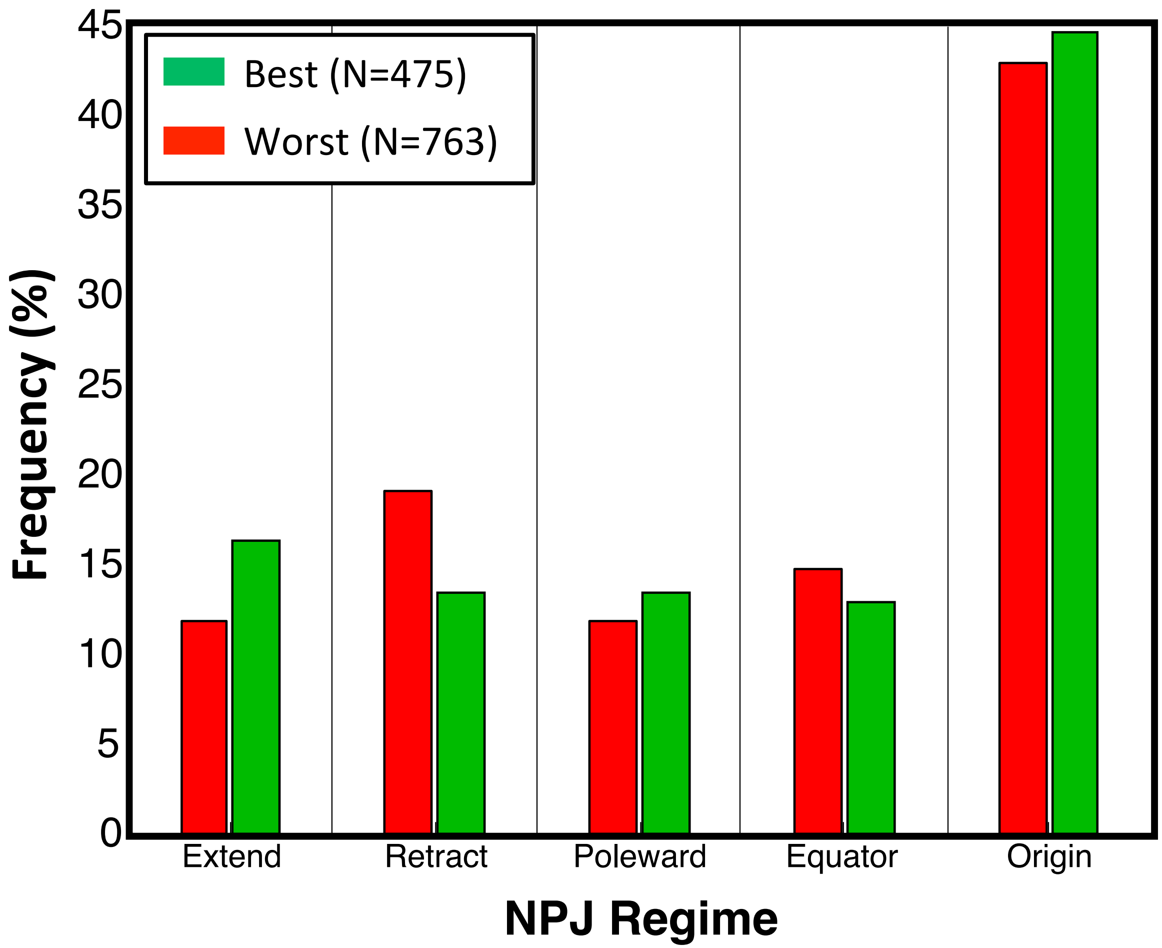
	Avg. ΔPC1	Avg. ΔPC2	Avg. 10-d Traj. Length.
Best Forecasts (N=475)	0.09	0.16 **Poleward Shift**	3.50 PC units
Worst Forecasts (N=763)	0.01	–0.21 **Equatorward Shift**	4.33 PC units

Statistically significant at the 99.9% confidence interval

- The best forecast periods are typically characterized by **poleward shifts** over the next 10 days and anomalously short trajectories within the NPJ phase diagram
- The worst forecast periods are typically characterized by **equatorward shifts** over the next 10 days and anomalously long trajectories within the NPJ phase diagram

Best/Worst NPJ Phase Diagram Forecasts

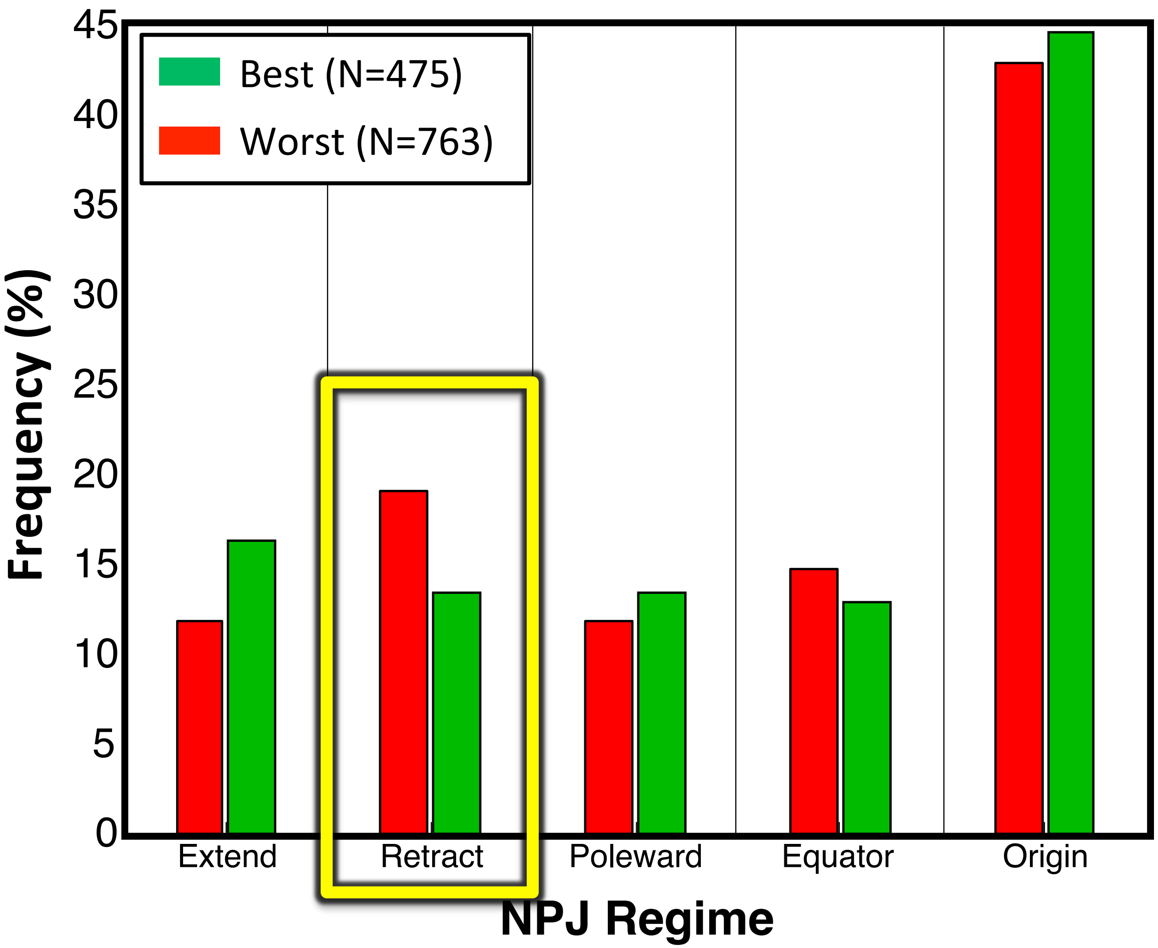
Comparison between the periods characterized by the best/worst medium-range forecasts



What are the synoptic flow patterns associated with the best and worst forecasts initialized during a particular NPJ regime?

Best/Worst NPJ Phase Diagram Forecasts

Comparison between the periods characterized by the best/worst medium-range forecasts



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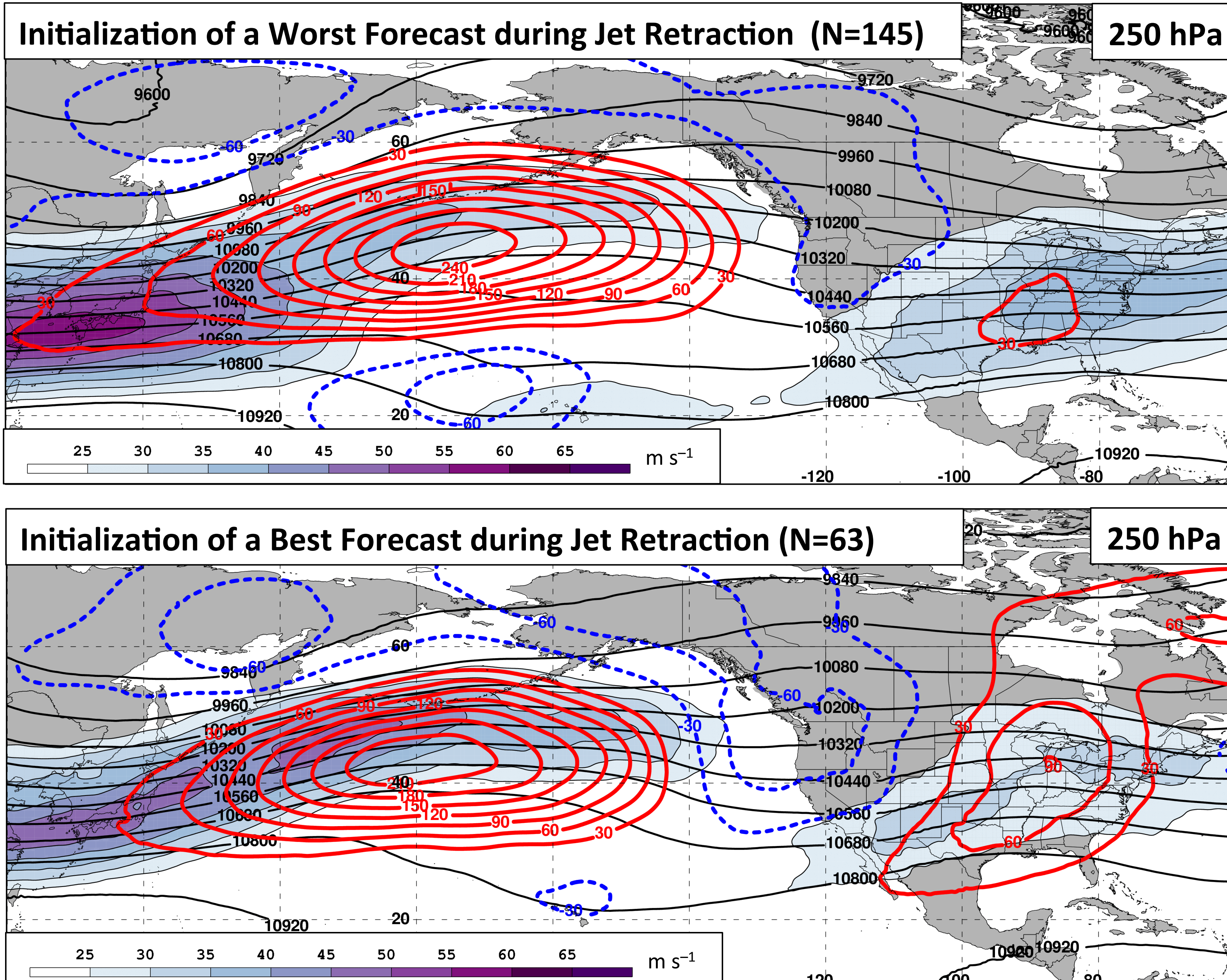
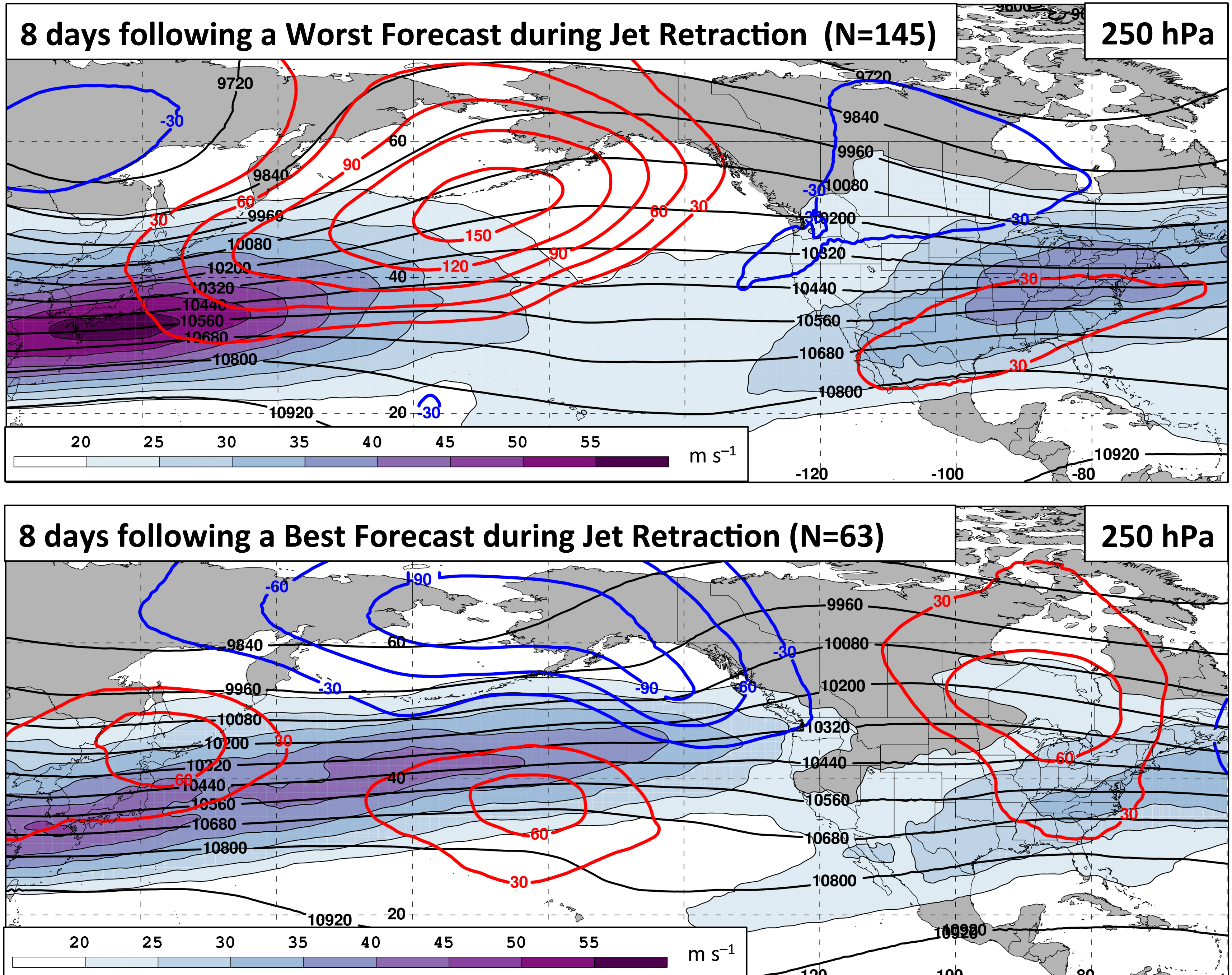
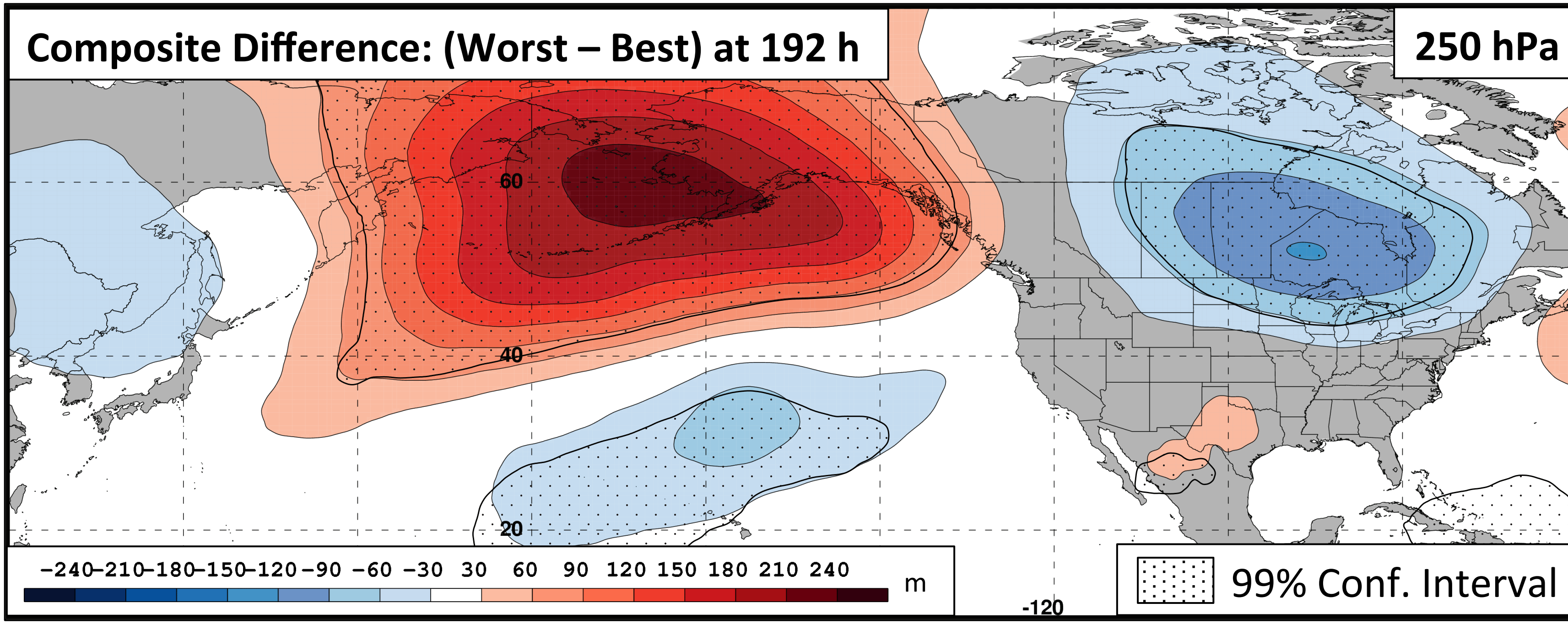

Initialization of a Worst Forecast during Jet Retraction (N=145)
250 hPa
25 30 35 40 45 50 55 60 65
m s⁻¹
-120
-100
-80
Initialization of a Best Forecast during Jet Retraction (N=63)
250 hPa
25 30 35 40 45 50 55 60 65
m s⁻¹
-120
-100
-80


8 days following a Worst Forecast during Jet Retraction (N=145)
250 hPa
20 25 30 35 40 45 50 55
m s⁻¹
-120 -100 -80
8 days following a Best Forecast during Jet Retraction (N=63)
250 hPa
20 25 30 35 40 45 50 55
m s⁻¹
-120 -100 -80



- Relative to the best forecast periods, the worst forecast periods are frequently characterized by significantly higher heights at high latitudes and significantly lower heights at low latitudes over the North Pacific

- The above composite difference pattern suggests that the worst forecast periods are often associated with upper-tropospheric blocking events over the North Pacific

Summary

- Forecasts verifying during **jet retractions** and **equatorward shifts** are characterized by substantially larger errors than those verifying during **jet extensions** and **poleward shifts**
- The worst forecasts are more frequently initialized during **jet retractions** and **equatorward shifts**
- The worst forecast periods are associated with **equatorward shifts** and longer trajectories within the NPJ phase diagram during the 10-day period following forecast initialization
- The worst forecast periods are often associated with upper-tropospheric blocking events over the North Pacific

NPJ Phase Diagram Web Interface

This work is supported by NOAA Grant NA15NWS4680006

Real time | Archive | Verification | Composites | About

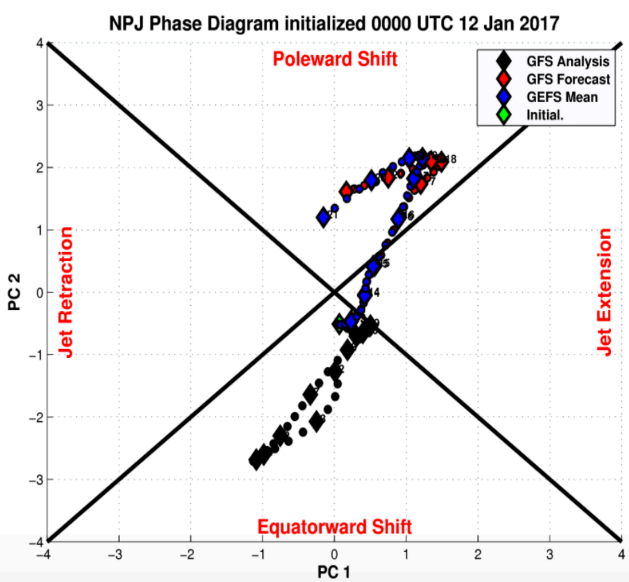
Phase Diagram (left): Shows the GFS analysis trajectory over the previous 10 days in black with diamonds corresponding to a position in the phase diagram at 00Z on the day labeled to the upper-right of its respective diamond. The red and blue symbols show the forecasted GFS and GEFS ensemble mean trajectories, respectively, within the phase diagram over the next 9 days with diamonds corresponding to a position in the phase diagram at 00Z on the day listed to the upper-right of its respective diamond. The green diamond shows the position within the phase diagram at 00Z on the day listed in the title.

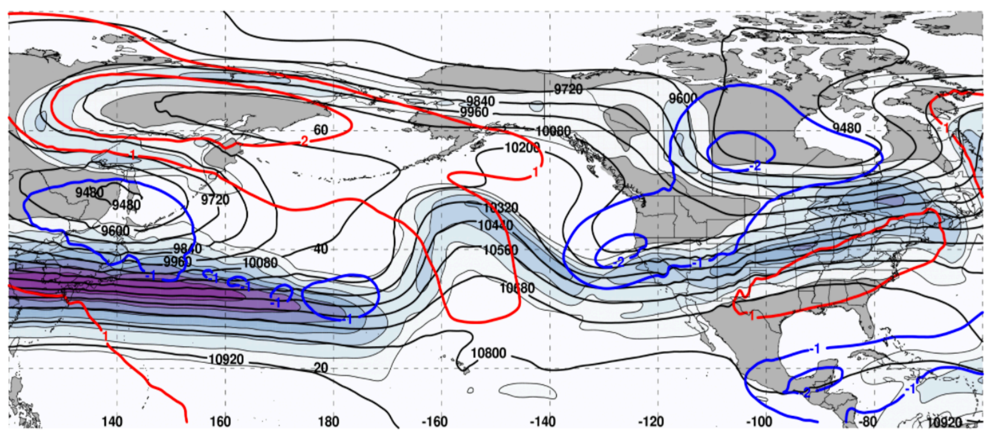
Synoptic Maps (right): Depicts GFS deterministic forecasts of (1) 250-hPa wind speed, geo. heights, and standardized geo. height anomalies, (2) 500-hPa relative vorticity, geo. heights, and standardized geo. height anomalies (3) mean sea level pressure, 1000-500-hPa thickness, and 850-hPa standardized temperature anomalies, and (4) 24-h accumulated precipitation. The 24-h forecasted accumulated precipitation is also used as 'verification' in Days -10 to 0.

Deterministic Forecast | Probabilistic Forecast | Ens. Spread Forecast | D(prog)/Dt

Arrow keys for navigation | Space = play/pause | Swipe for navigation on touchscreen

250-hPa Jet/Hght/Hght'	10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9
500-hPa Vort/Hght/Hght'	10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9
MSLP/Thick/Temp'	10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9
24-h Accum. Precip	10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9





170112/0000V000 250 hPa Wind Speed (m/s), Geo. Hght & Std. Hght Anom (m)

NPJ Phase Diagram Web Interface

- A web interface has been developed that offers real time NPJ phase diagram forecasts and extreme event composites:

http://www.atmos.albany.edu/facstaff/awinters/realtime/About_EOFs.php

Contact: acwinters@albany.edu

Collaborators: Mike Bodner (WPC), Arlene Laing (NOAA), Dan Halperin (ERAU), Bill Lamberson (WPC), Josh Kastman (WPC), and Sara Ganetis (WPC)

Supplementary Slides

References

Athanasiadis, P. J., J. M. Wallace, and J. J. Wettstein, 2010: Patterns of wintertime jet stream variability and their relation to the storm tracks. *J. Atmos. Sci.*, **67,** 1361–1381.

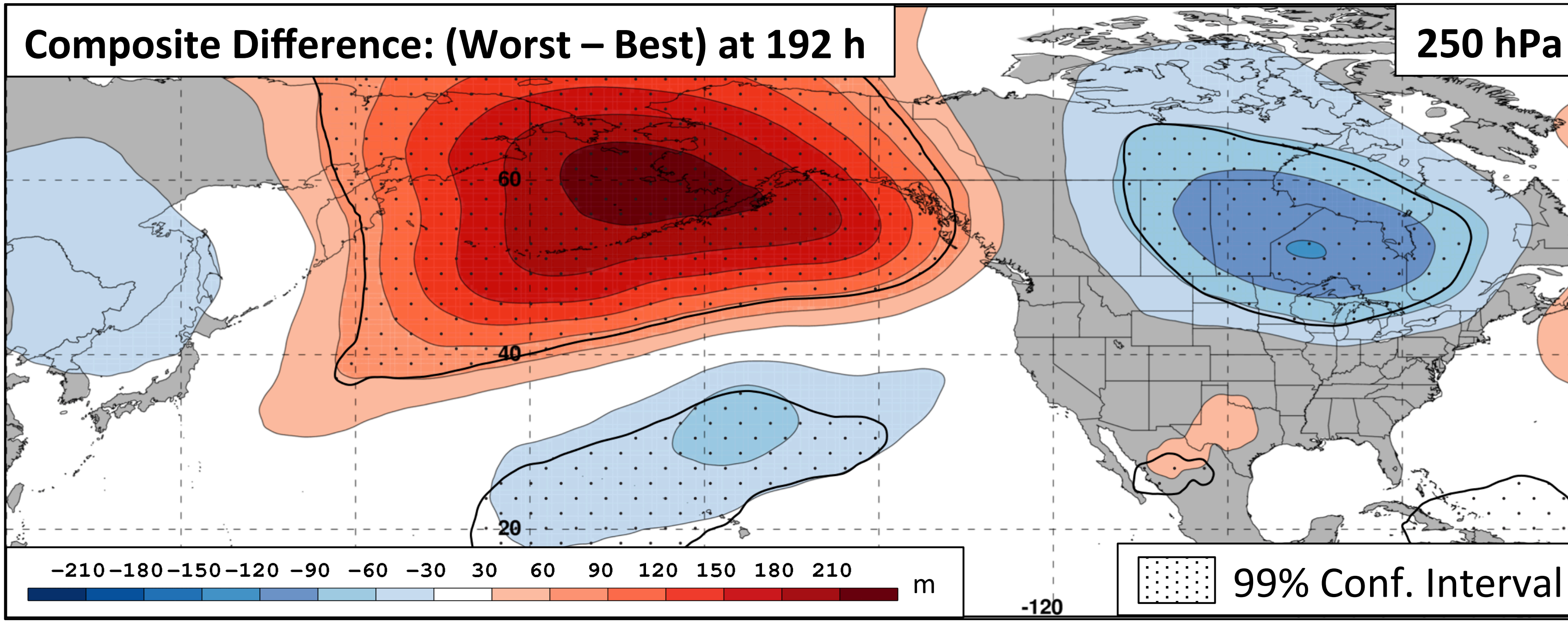
Griffin, K. S., and J. E. Martin, 2016: Synoptic features associated with temporally coherent modes of variability of the North Pacific jet stream. *J. Climate, **29**,* in press.

Hamill, T. M., G. T. Bates, J. S. Whitaker, D. R. Murray, M. Fiorino, T. J. Galarneau, Y. Zhu, and W. Lapenta, 2013: NOAA's Second-Generation Global Medium-Range Ensemble Forecast Dataset. *Bull. Amer. Meteor. Soc.*, **94,** 1553–1565.

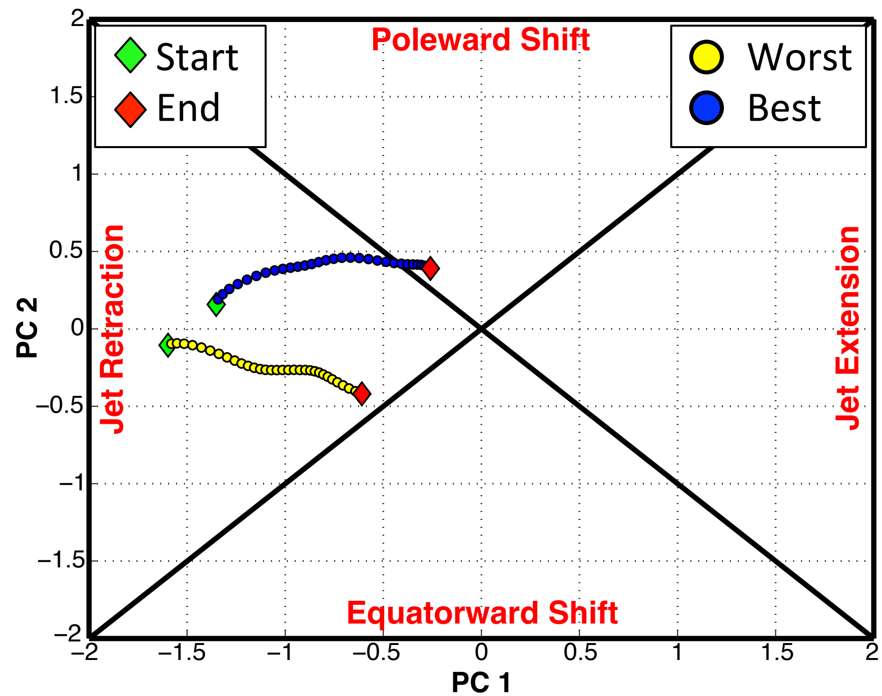
Jaffe, S. C., J. E. Martin, D. J. Vimont, and D. L. Lorenz, 2011: A synoptic climatology of episodic, subseasonal retractions of the Pacific jet. *J. Climate*, **24,** 2846–2860.

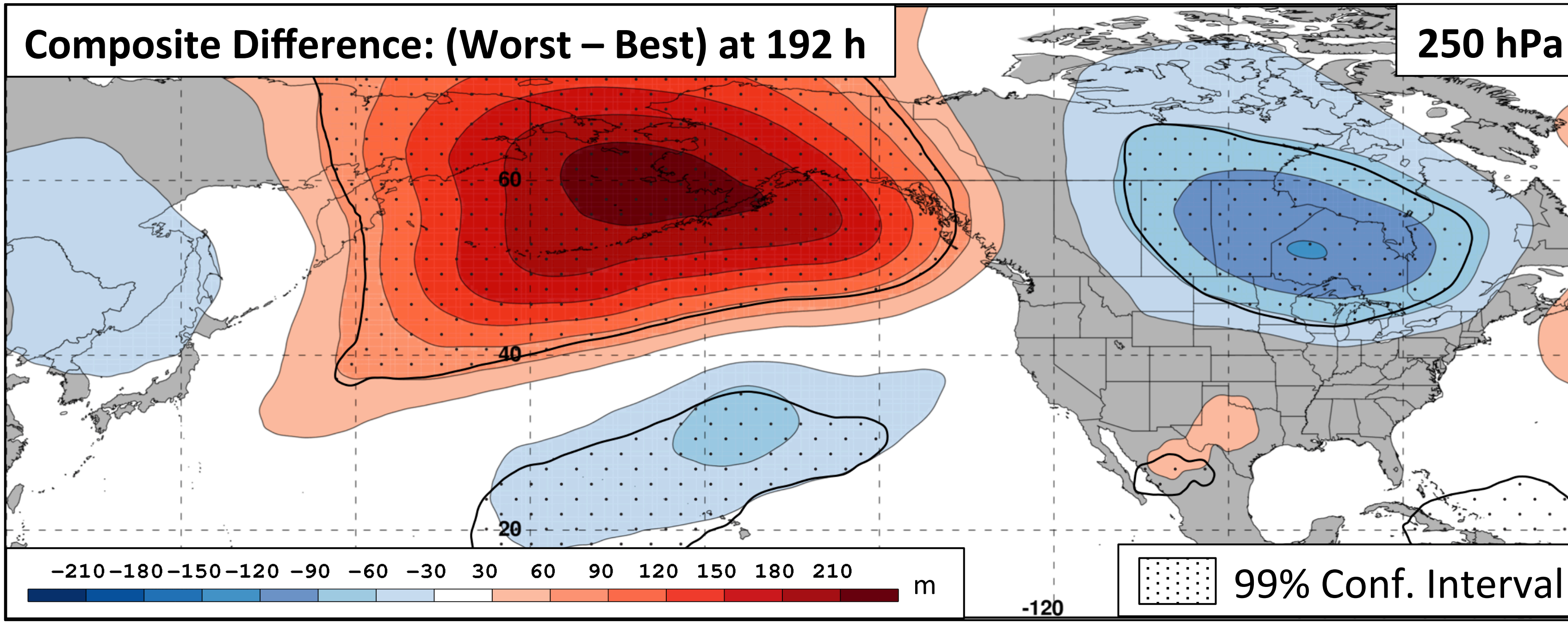
Saha, S., and Coauthors, 2014: The NCEP Climate Forecast System Version 2. *J. Climate*, **27,** 2185–2208.

NPJ Regime Composite Patterns

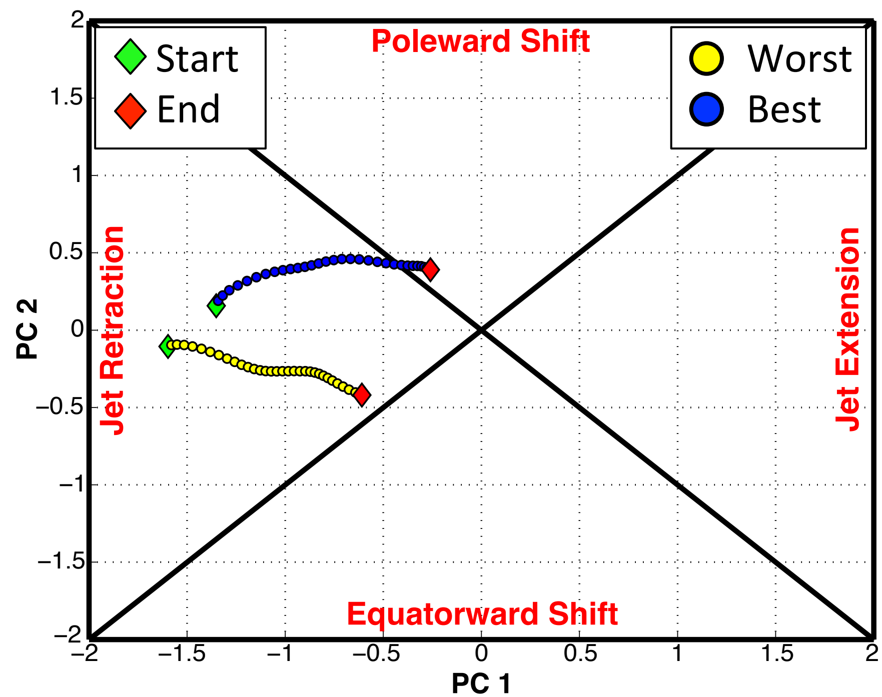


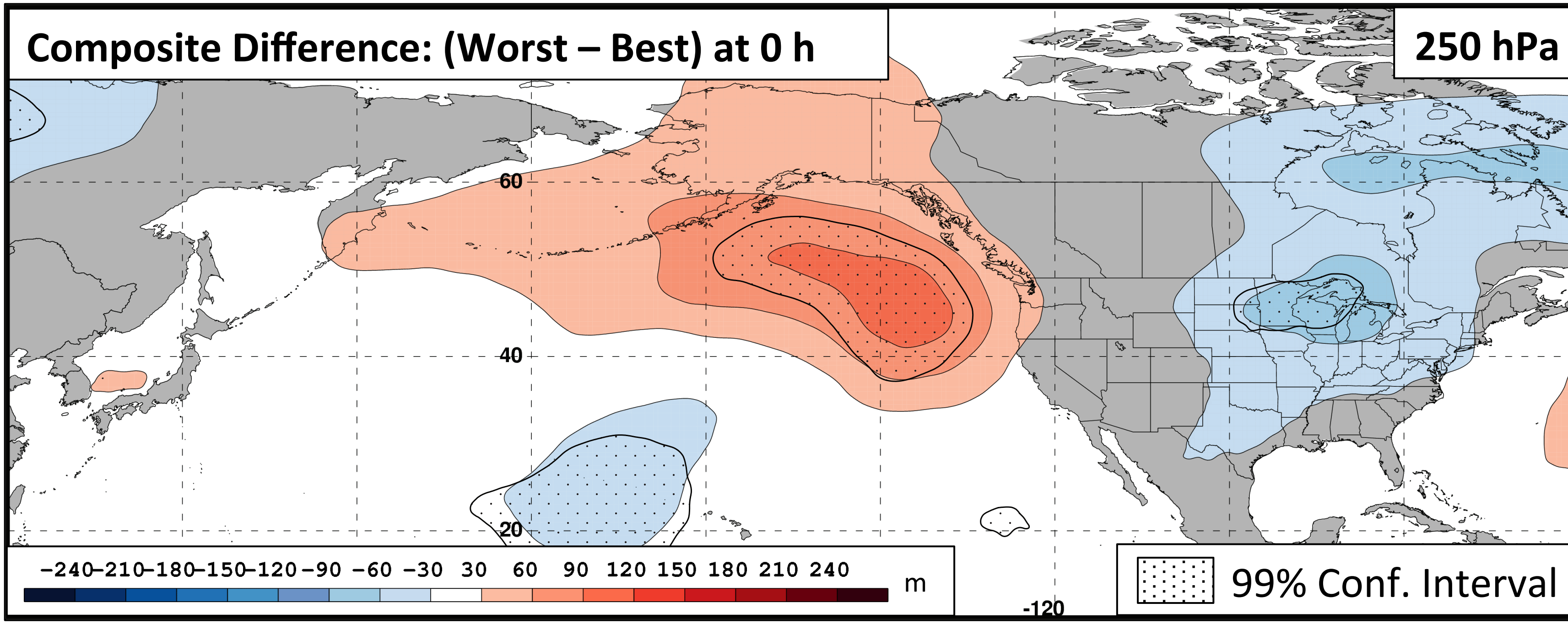
- The worst forecast periods are frequently characterized by significantly higher heights over the North Pacific and lower heights over North America
- The composite difference pattern suggests that the worst forecast periods are often associated with upper-tropospheric blocking events





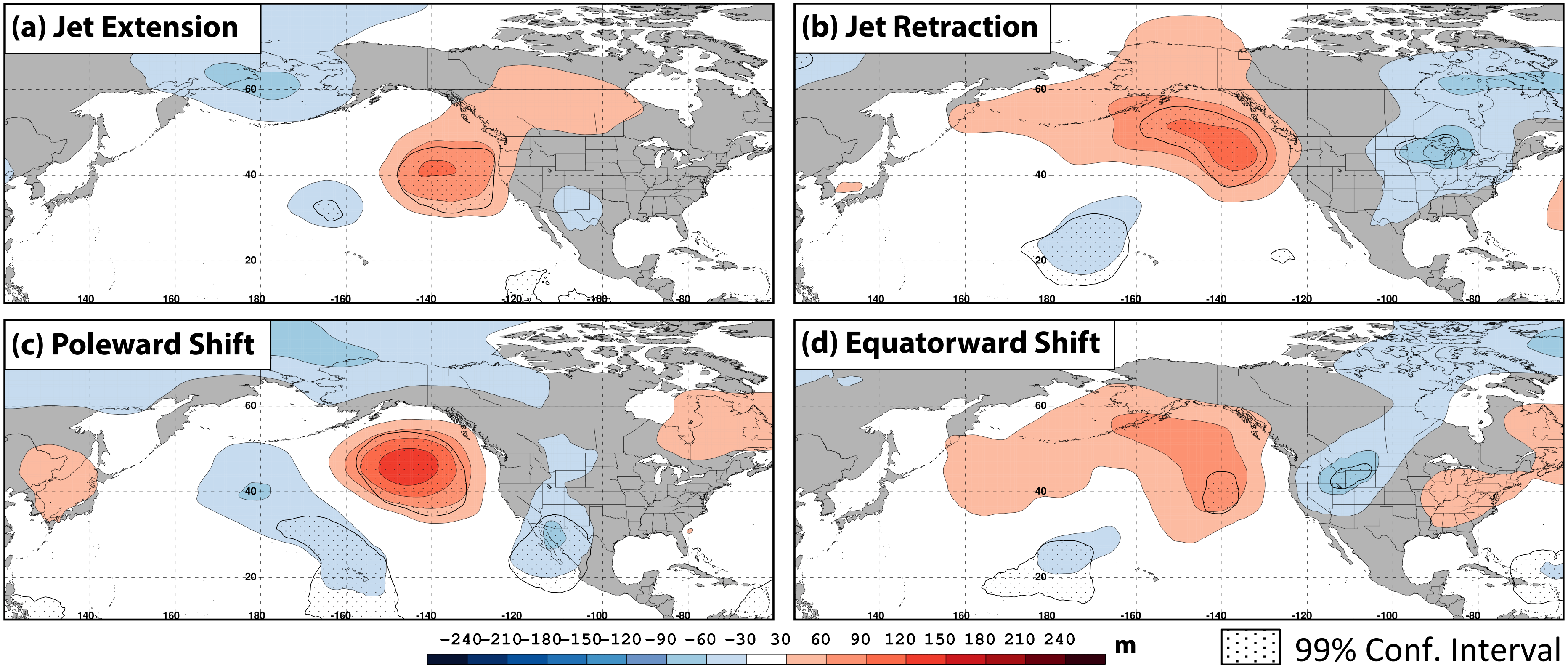
- The worst forecast periods are typically characterized by an equatorward shifted trajectory within the NPJ phase diagram
- The best forecast periods are typically characterized by a poleward shifted trajectory within the NPJ phase diagram





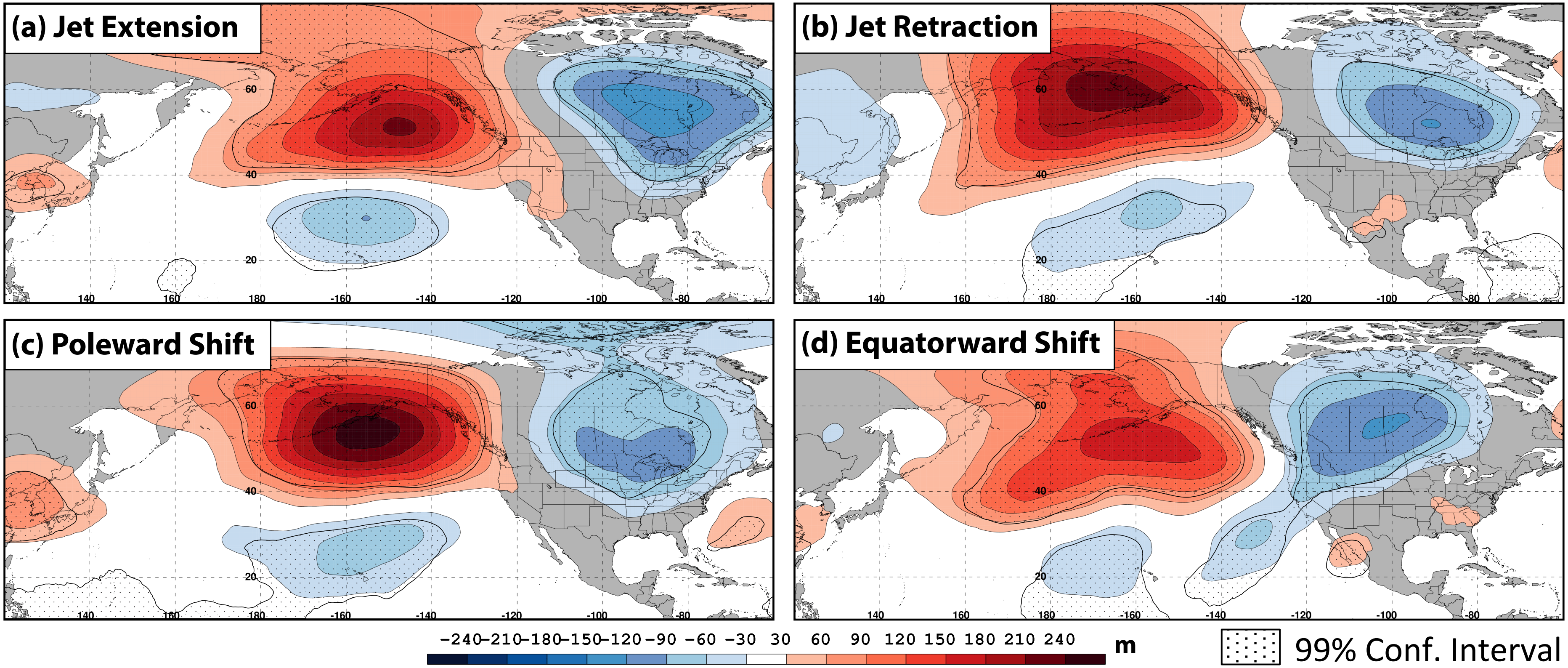
- Relative to the best forecast periods, the worst forecast periods are frequently characterized by significantly higher heights over the eastern North Pacific at the time of forecast initialization

Composite Difference: (Worst – Best) at 0 h



- Relative to the best forecasts, the worst forecast periods exhibit significantly higher heights over the eastern North Pacific irrespective of the NPJ regime at the time of forecast initialization

Composite Difference: (Worst – Best) at 192 h

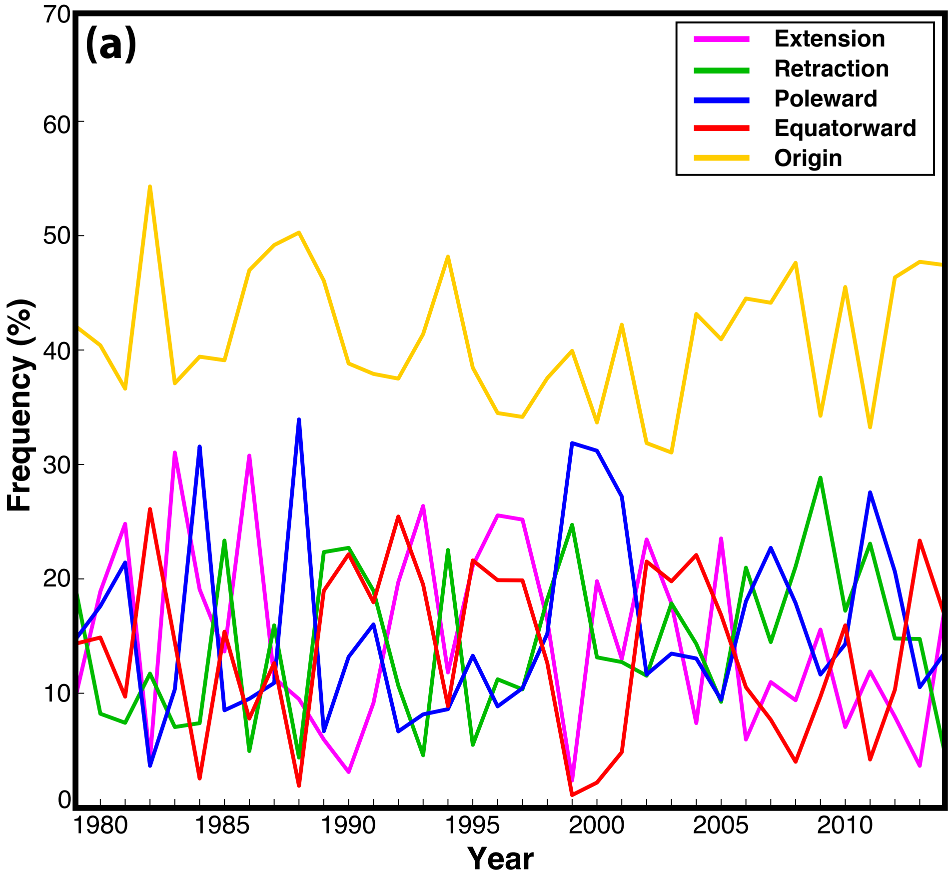


- The composite differences suggest that the worst forecast periods are often associated with upper-tropospheric blocking events over the North Pacific 8 days following forecast initialization irrespective of the NPJ regime at the time of forecast initialization

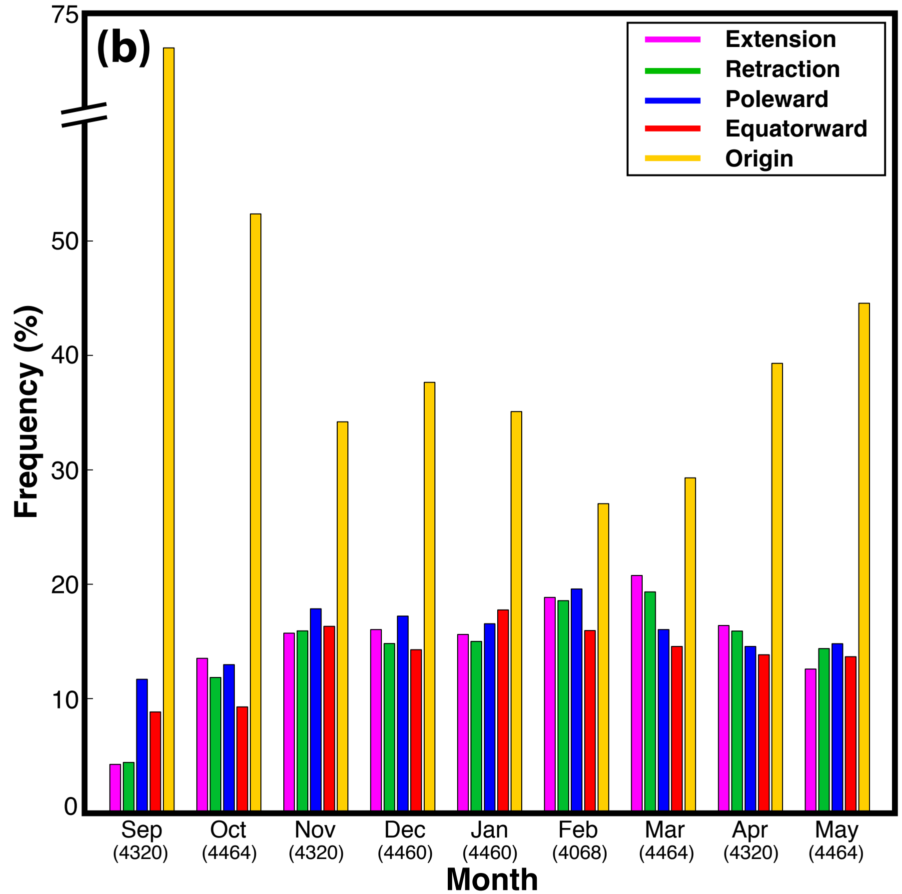
NPJ Regime Distributions

NPJ Regime Characteristics

Inter-annual Variability

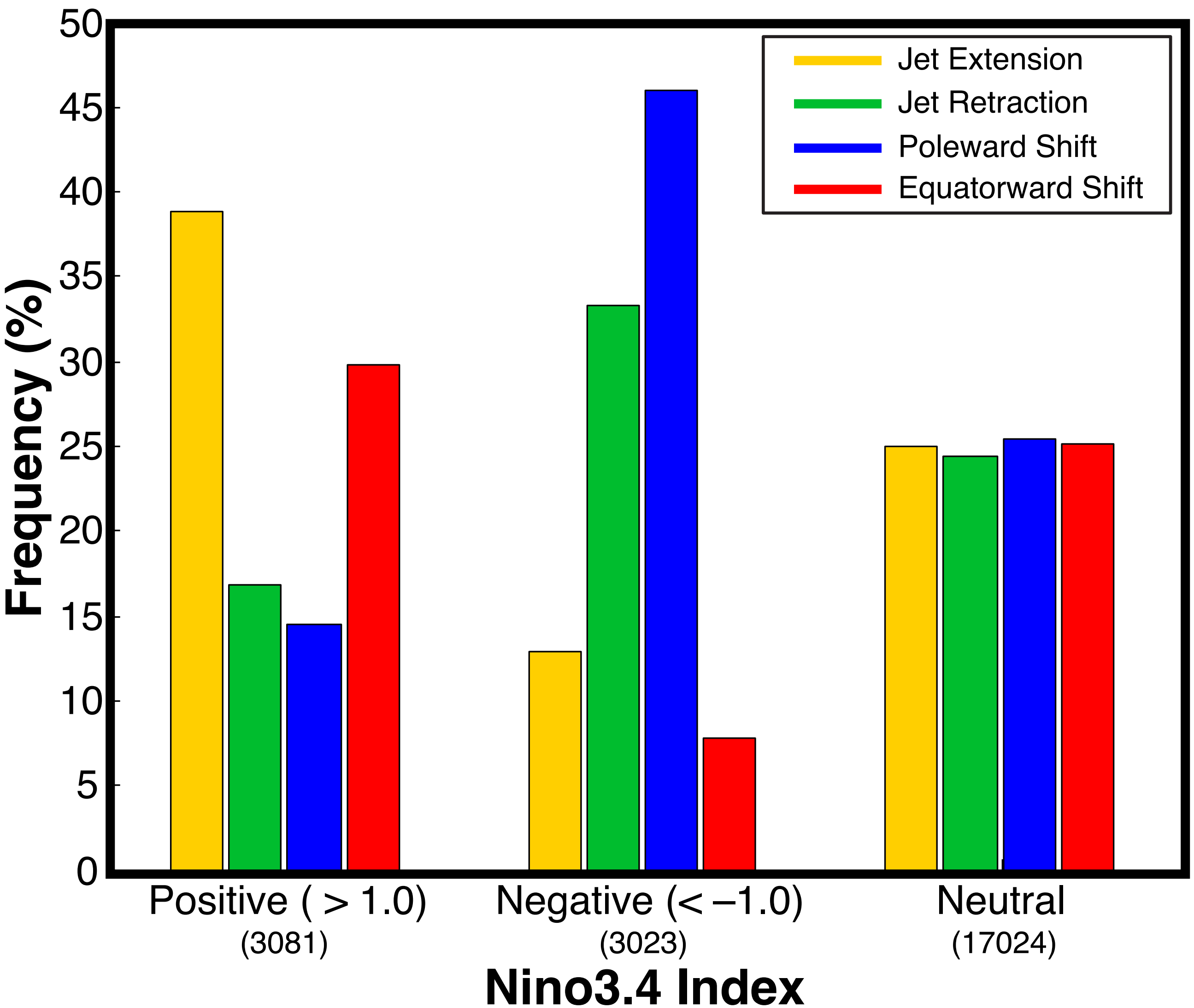


Intra-annual Variability



- The frequency of each NPJ regime exhibits considerable inter-annual and intra-annual variability

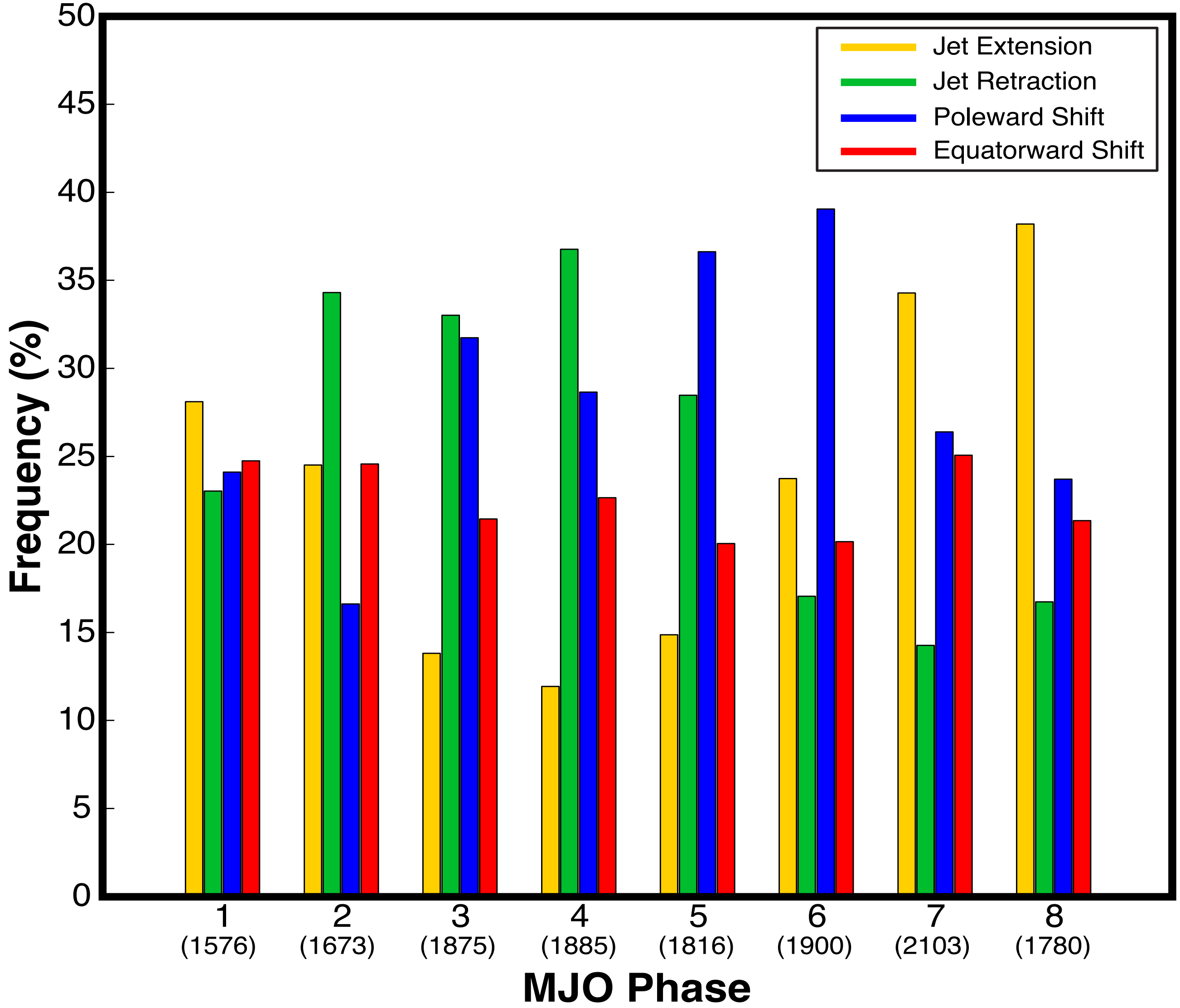
NPJ Regime Frequency and ENSO



- Jet Extensions and Equatorward Shifts are favored during an El Niño

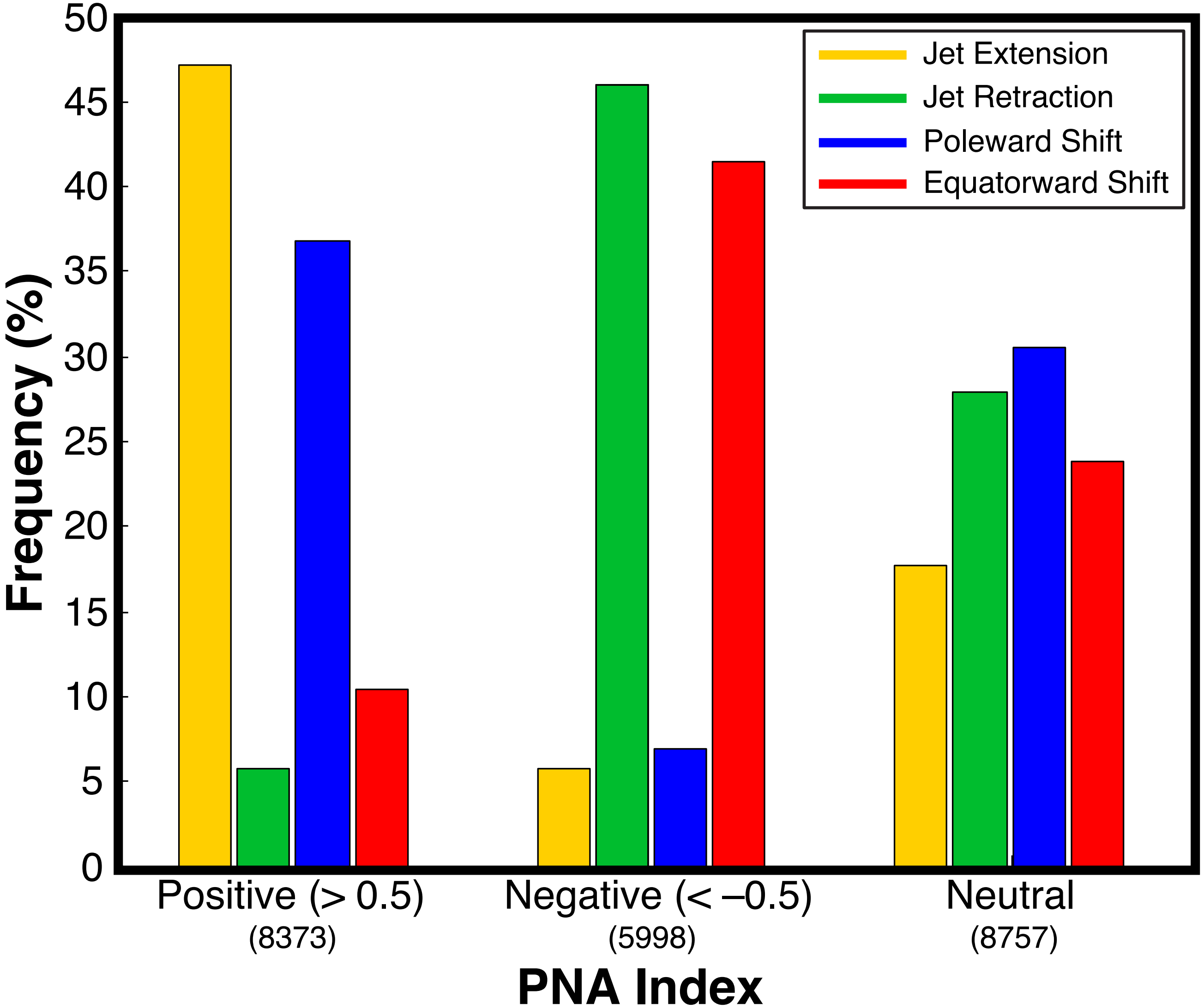
- Jet Retractions and Poleward Shifts are favored during a La Niña

NPJ Regime Frequency and the MJO



- Jet Retractions are favored during Phases 2, 3, and 4
- Poleward Shifts are favored during Phases 5 and 6
- Jet Extensions are favored during Phases 7, 8, and 1

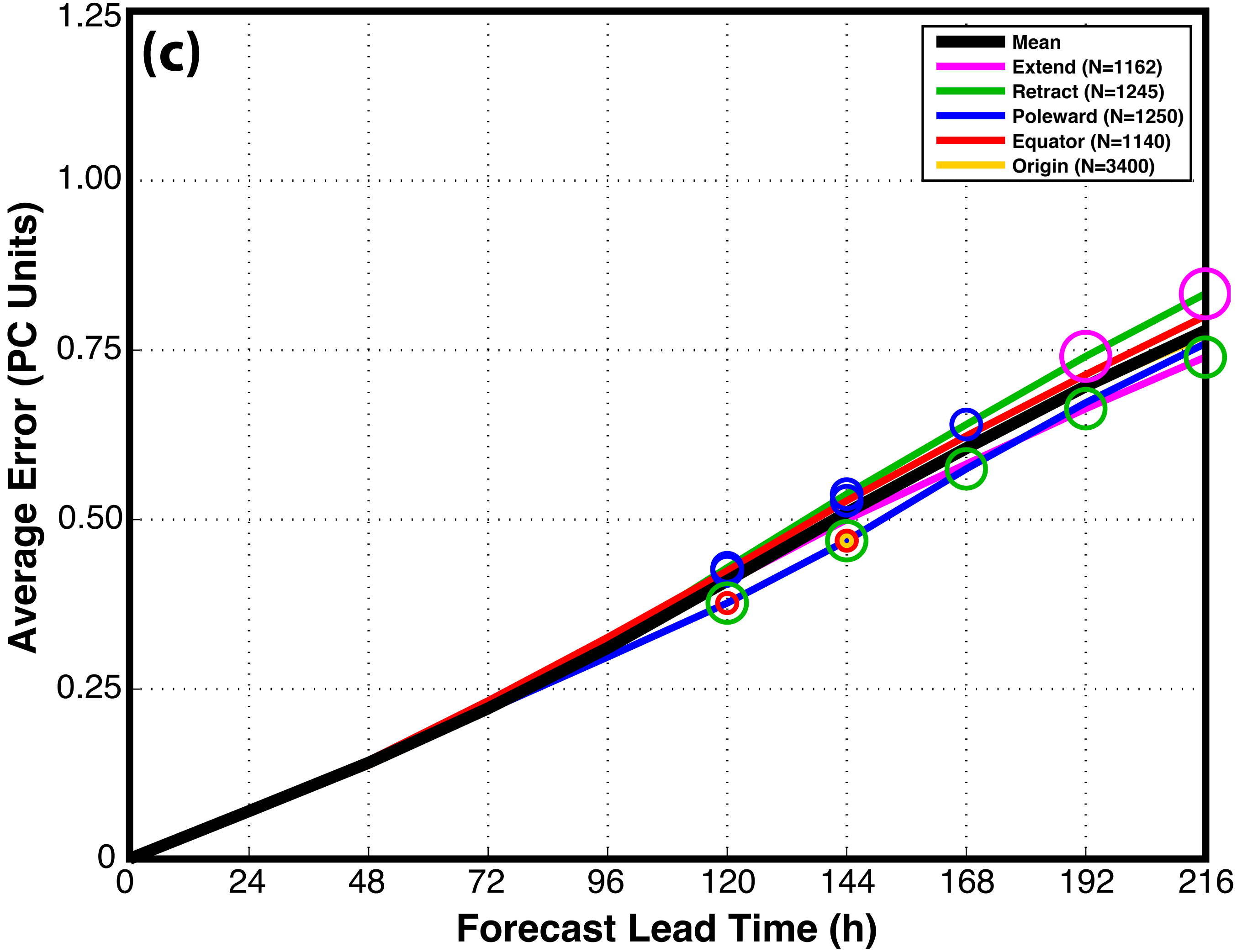
NPJ Regime Frequency and the PNA



- Jet Extensions and Poleward Shifts are favored during a positive PNA
- Jet Retractions and Equatorward Shifts are favored during a negative PNA

Additional NPJ Phase Diagram Verification Statistics

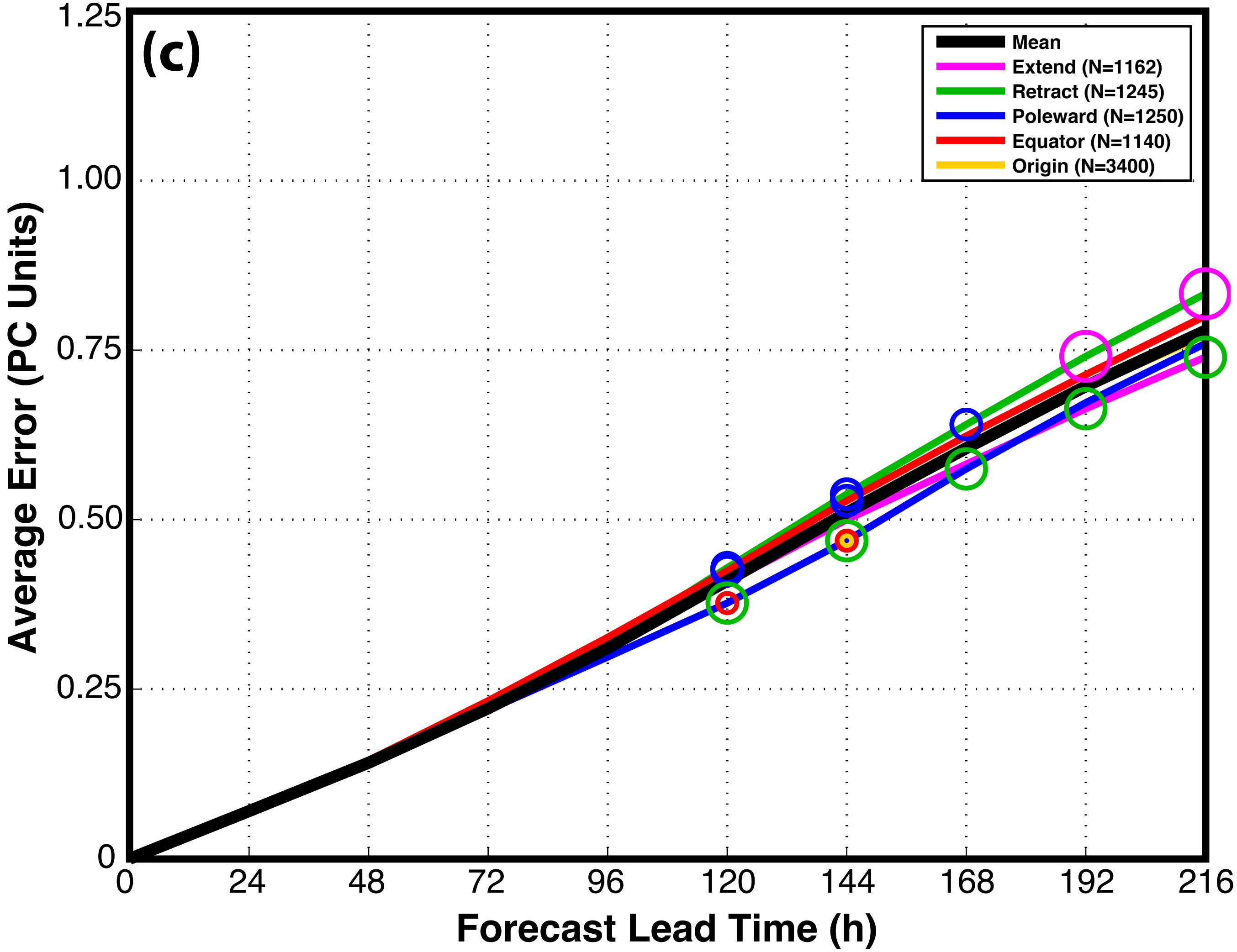
GEFS Ensemble Mean Error by NPJ Regime



GEFS Reforecasts *initialized* during a particular NPJ regime

Circles on a particular line indicate statistically significant differences at the 99% confidence level with respect to another NPJ regime

GEFS Ensemble Mean Error by NPJ Regime

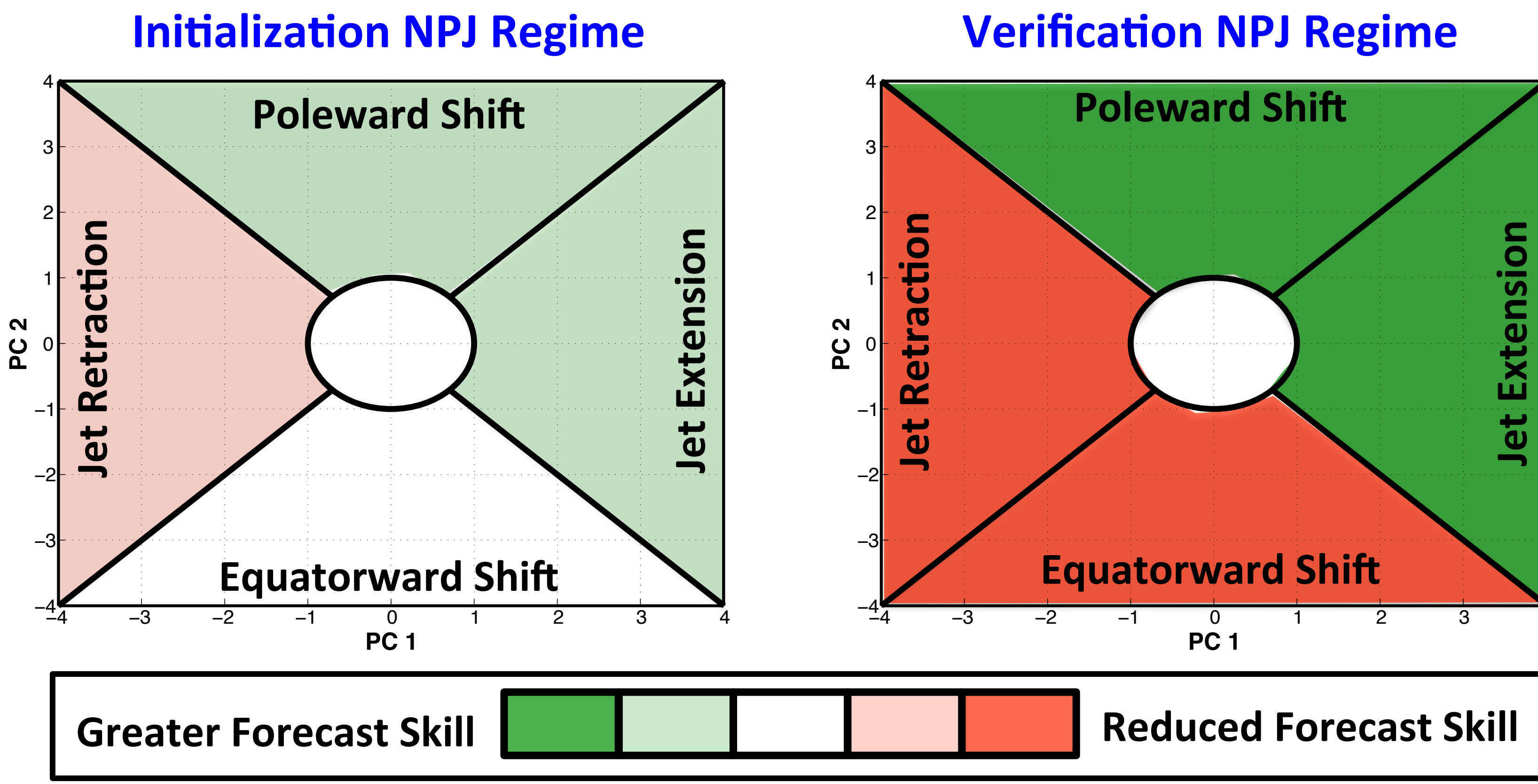


GEFS Reforecasts *initialized* during a particular NPJ regime

Circles on a particular line indicate statistically significant differences at the 99% confidence level with respect to another NPJ regime

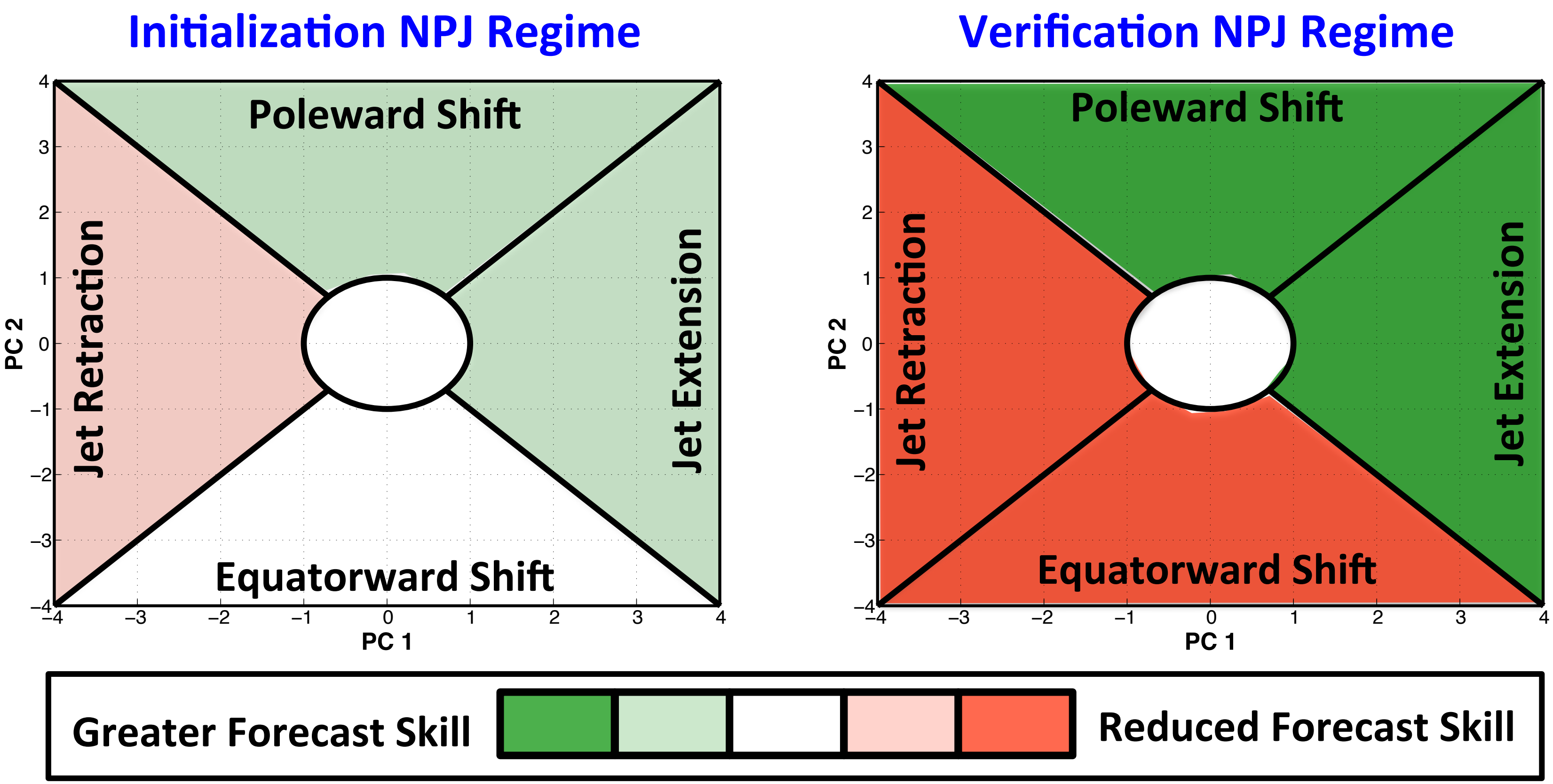
Forecasts initialized during **jet retractions** exhibit significantly larger errors than **jet extensions** in the 192–216-h forecast period

NPJ Phase Diagram Forecast Skill



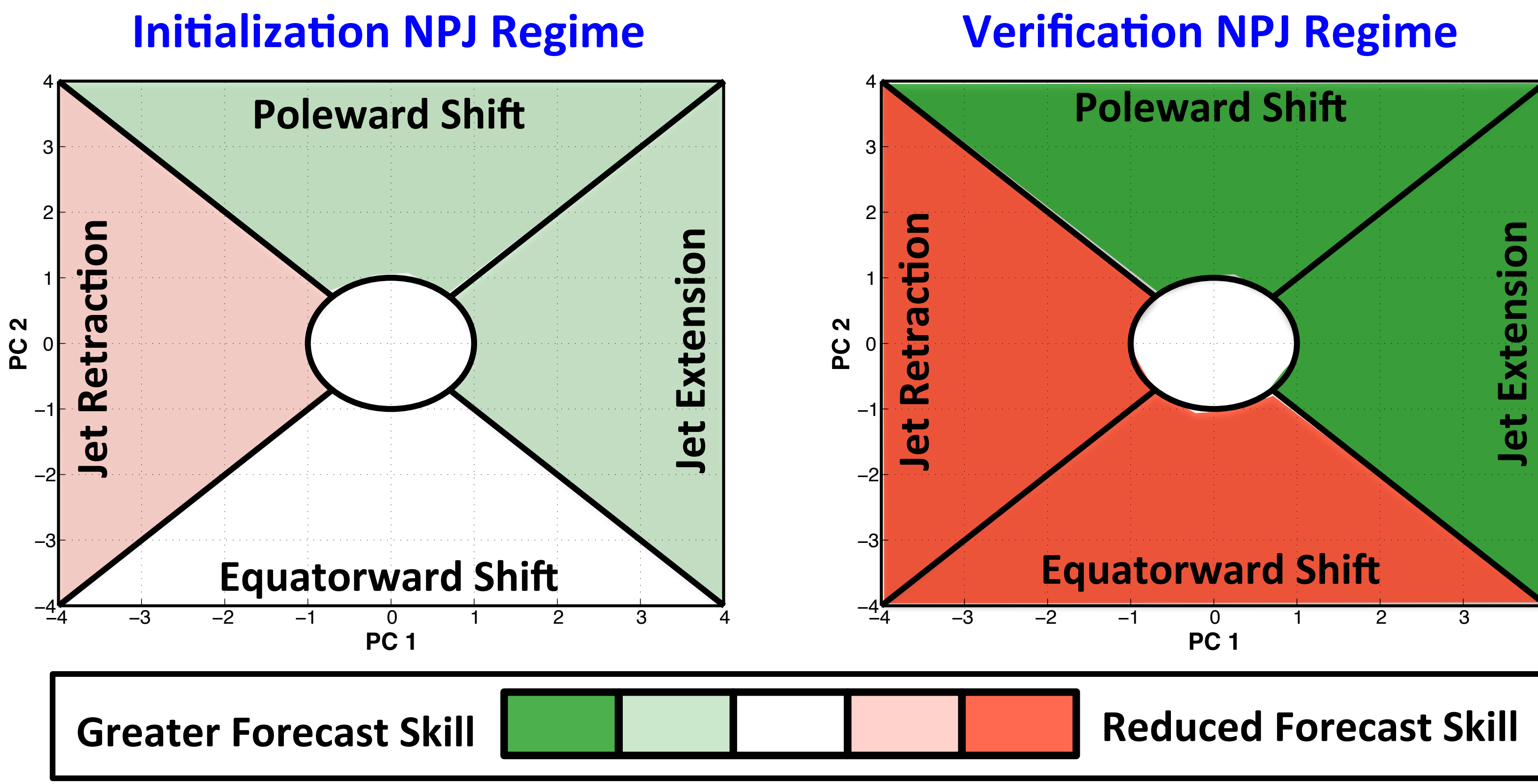
- Forecasts initialized during **jet retractions** are characterized by larger errors than those initialized during **jet extensions** and **poleward shifts**

NPJ Phase Diagram Forecast Skill



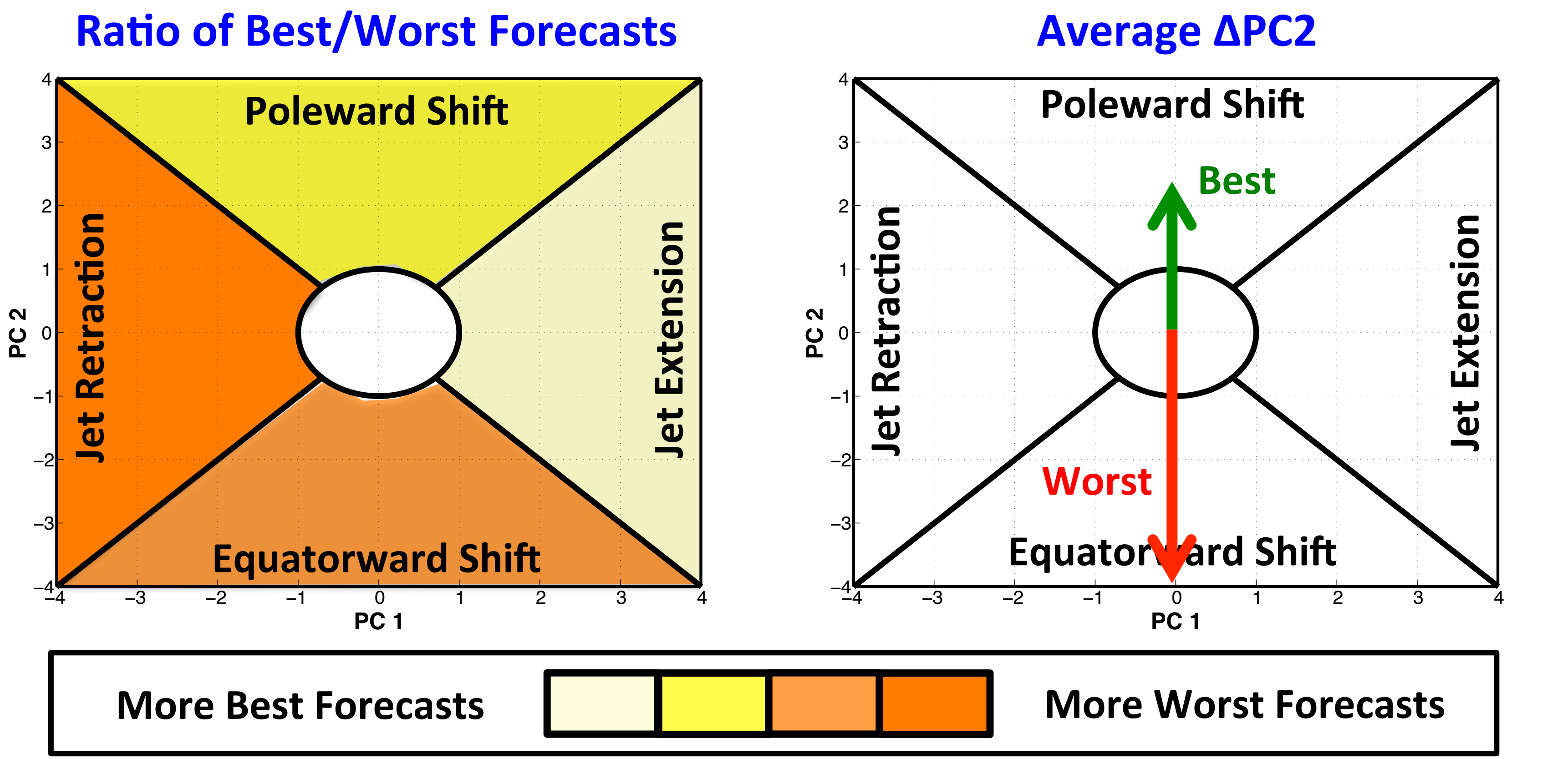
- Forecasts verifying during **jet retractions** and **equatorward shifts** are characterized by substantially larger errors than those verifying during **jet extensions** and **poleward shifts**

NPJ Phase Diagram Forecast Skill



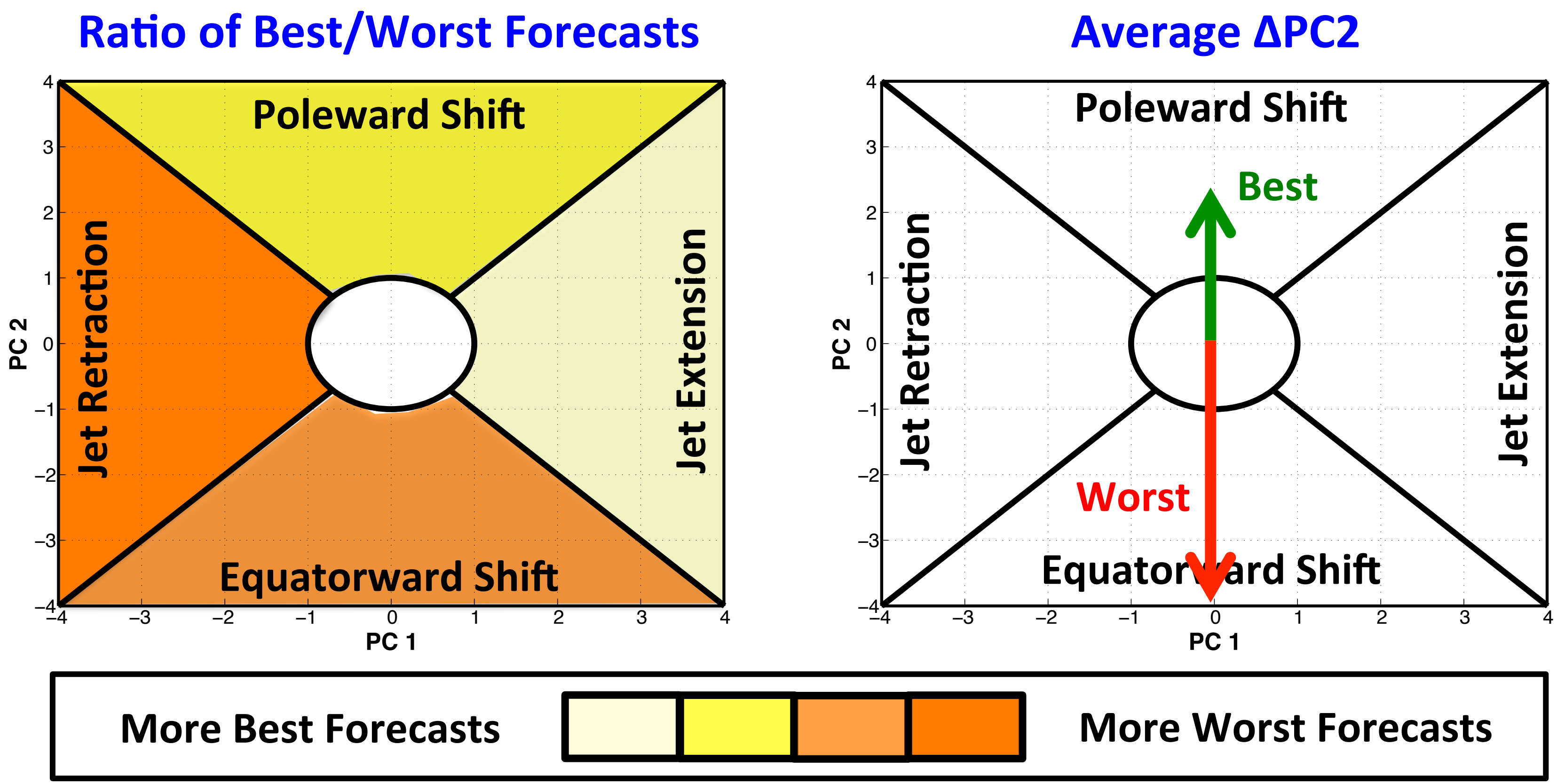
- **Jet retractions** and **equatorward shifts** are often characterized by high-amplitude and/or short-wavelength flow patterns over the North Pacific, which may be a contributing factor to the reduced skill

Best/Worst NPJ Phase Diagram Forecasts



- The worst forecasts are most frequently initialized during jet retractions and equatorward shifts
- The worst forecast periods frequently feature equatorward shifts during the 10-day period following forecast initialization

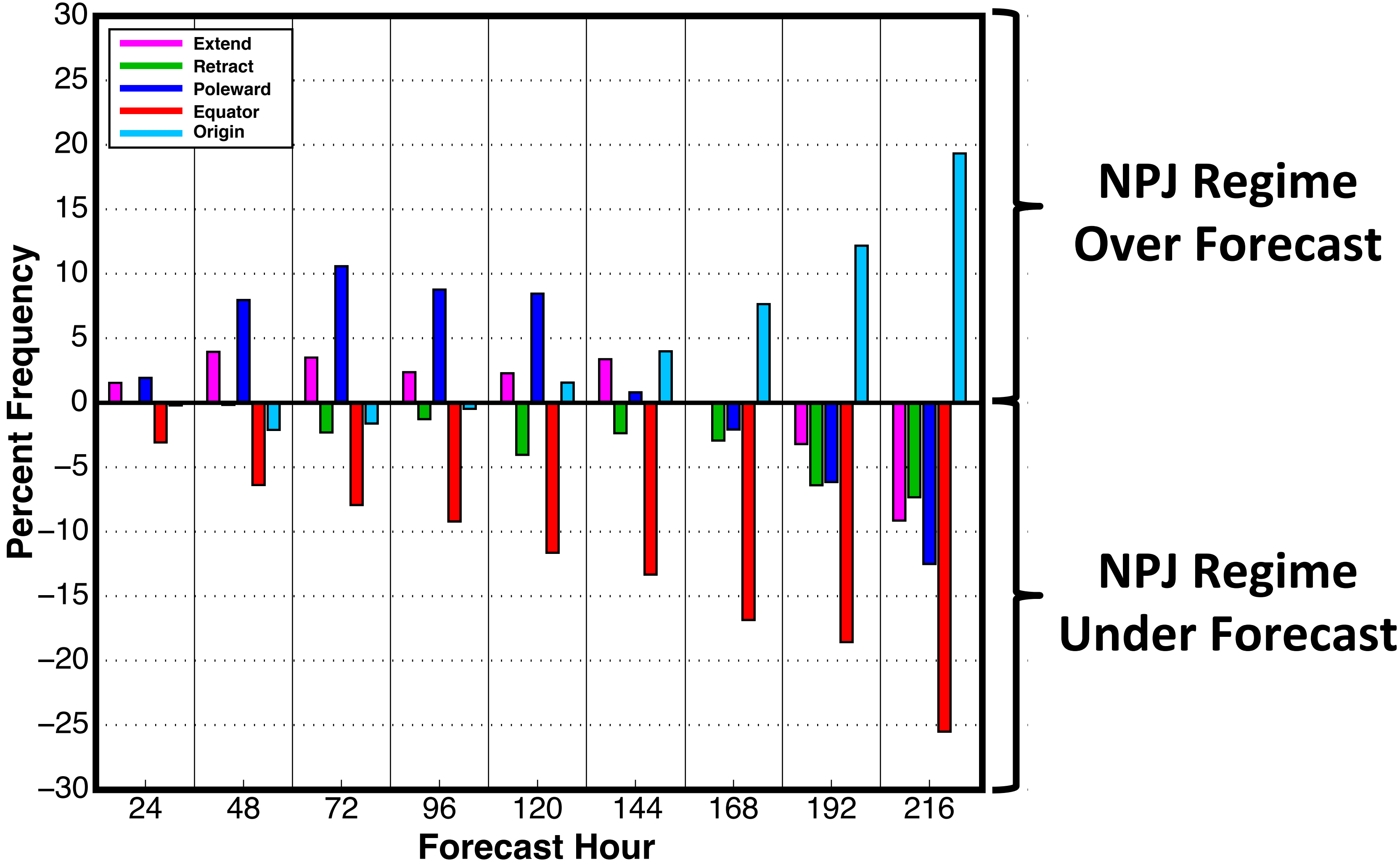
Best/Worst NPJ Phase Diagram Forecasts



- The worst forecast periods are associated with longer trajectories through the NPJ phase diagram following forecast initialization, suggestive of rapid NPJ regime change

NPJ Regime Forecast Frequency

The percent frequency that an NPJ regime is over/under forecast relative to verification at various forecast lead times in the GEFS ensemble mean reforecasts



NPJ Regime Forecast Frequency

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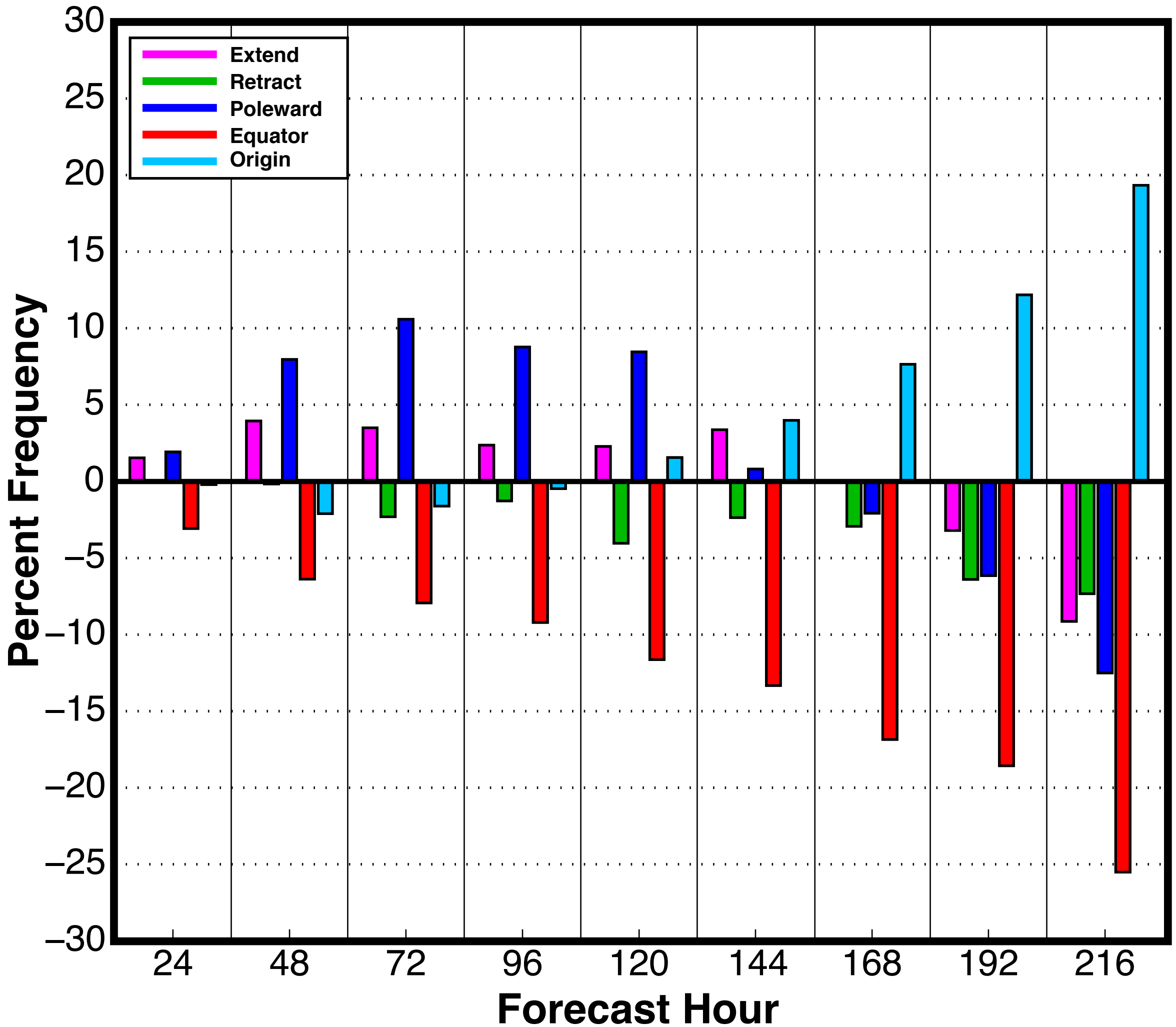
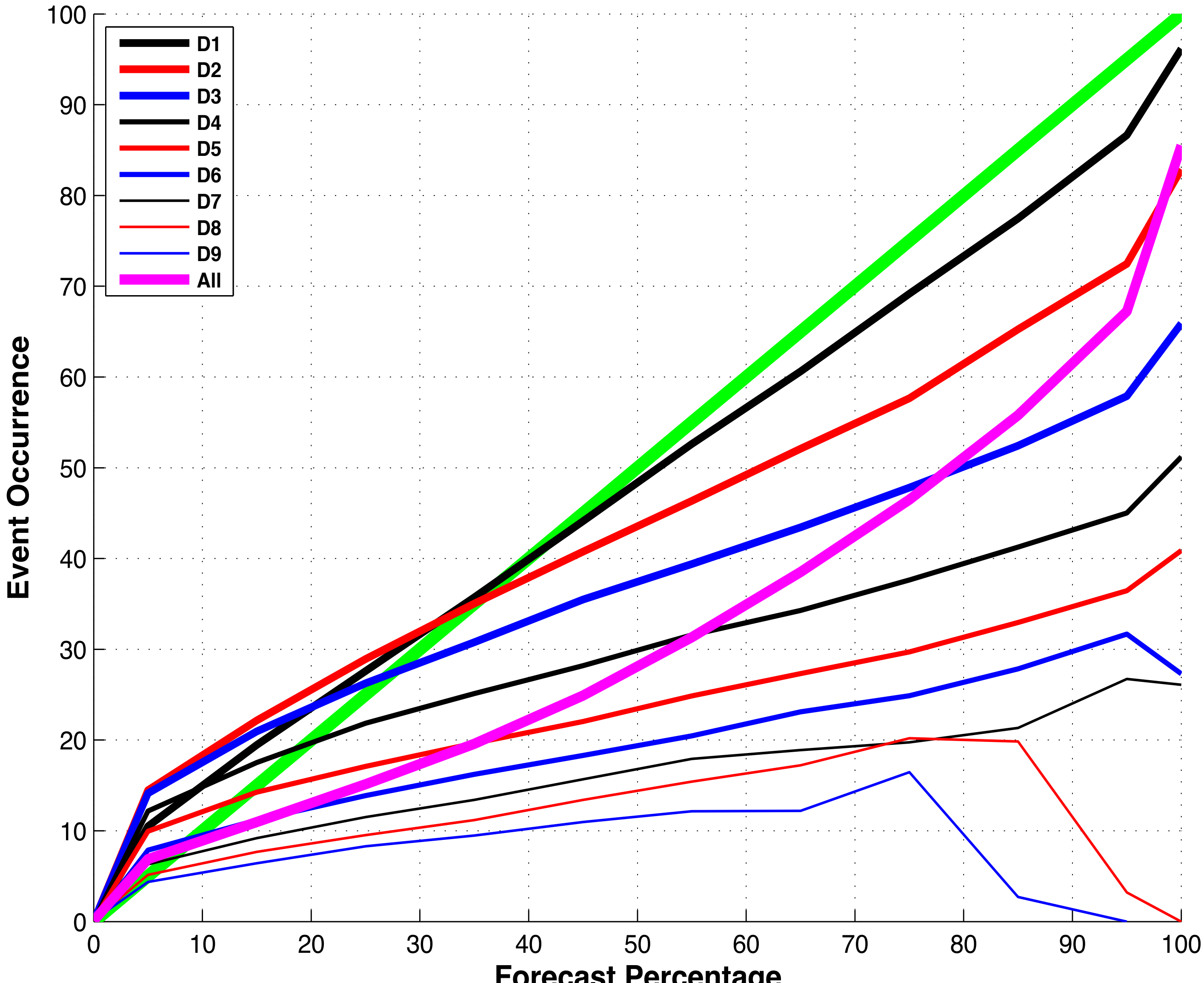


- **Equatorward shifts** are substantially under forecast at every forecast lead time compared to all other NPJ regimes
- The degree to which **equatorward shifts** are under forecast corroborates the reduced skill of forecasts verifying during **equatorward shifts**

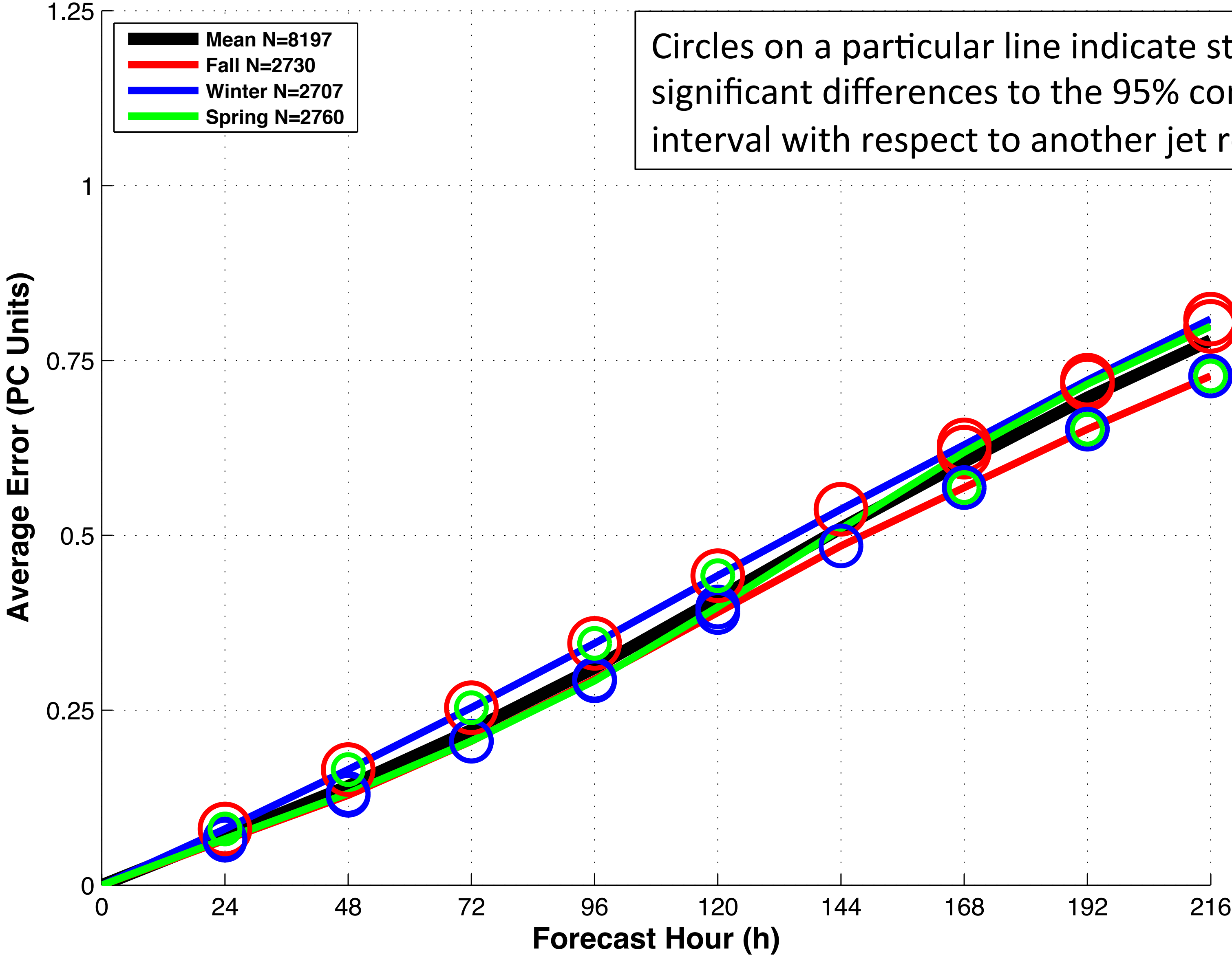
Reliability Diagram



Perfect Reliability

GEFS Reforecasts appear to be underdispersive with respect to medium-range forecasts of the North Pacific Jet in the phase diagram

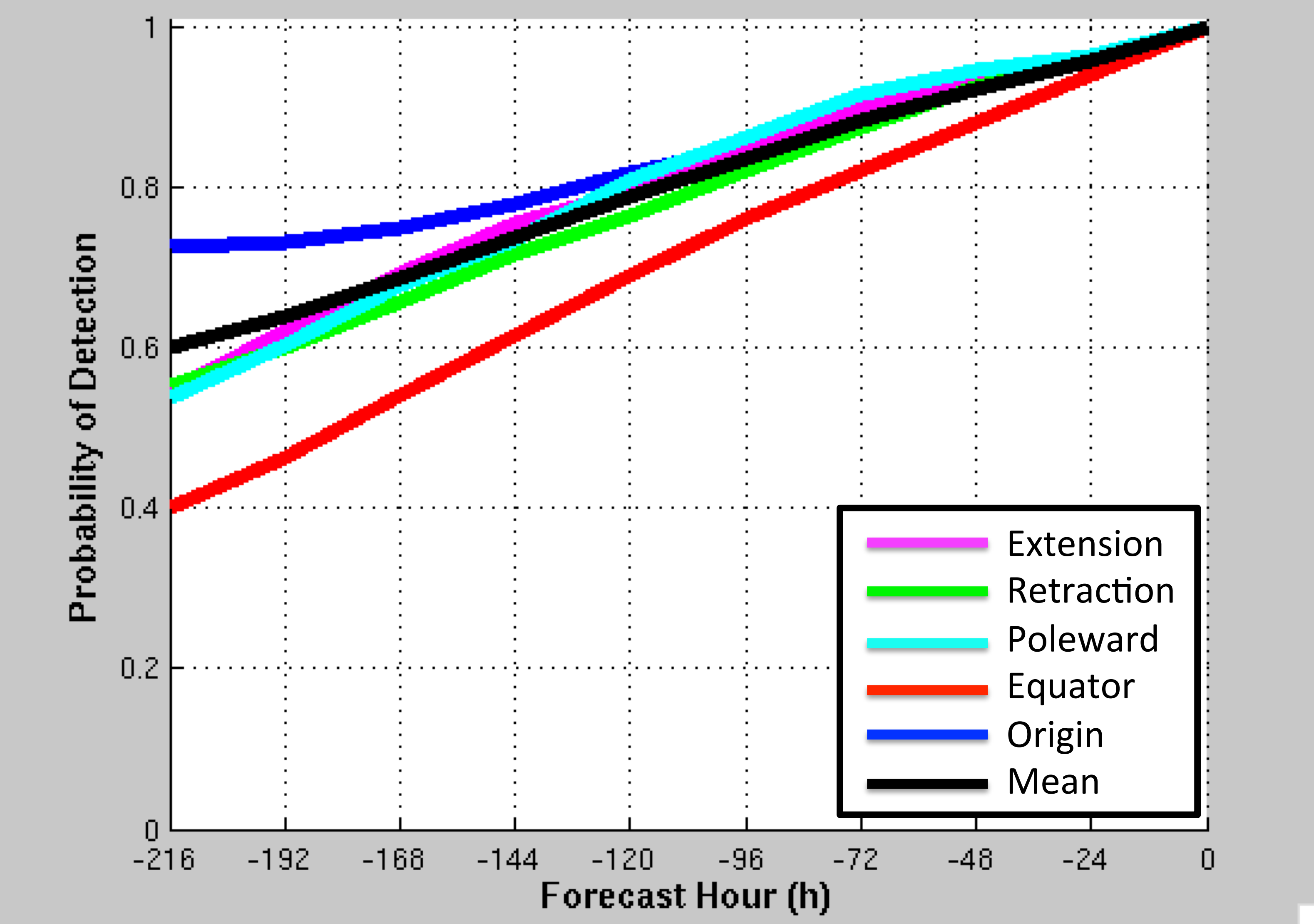
GEFS Ensemble Mean Error – Season



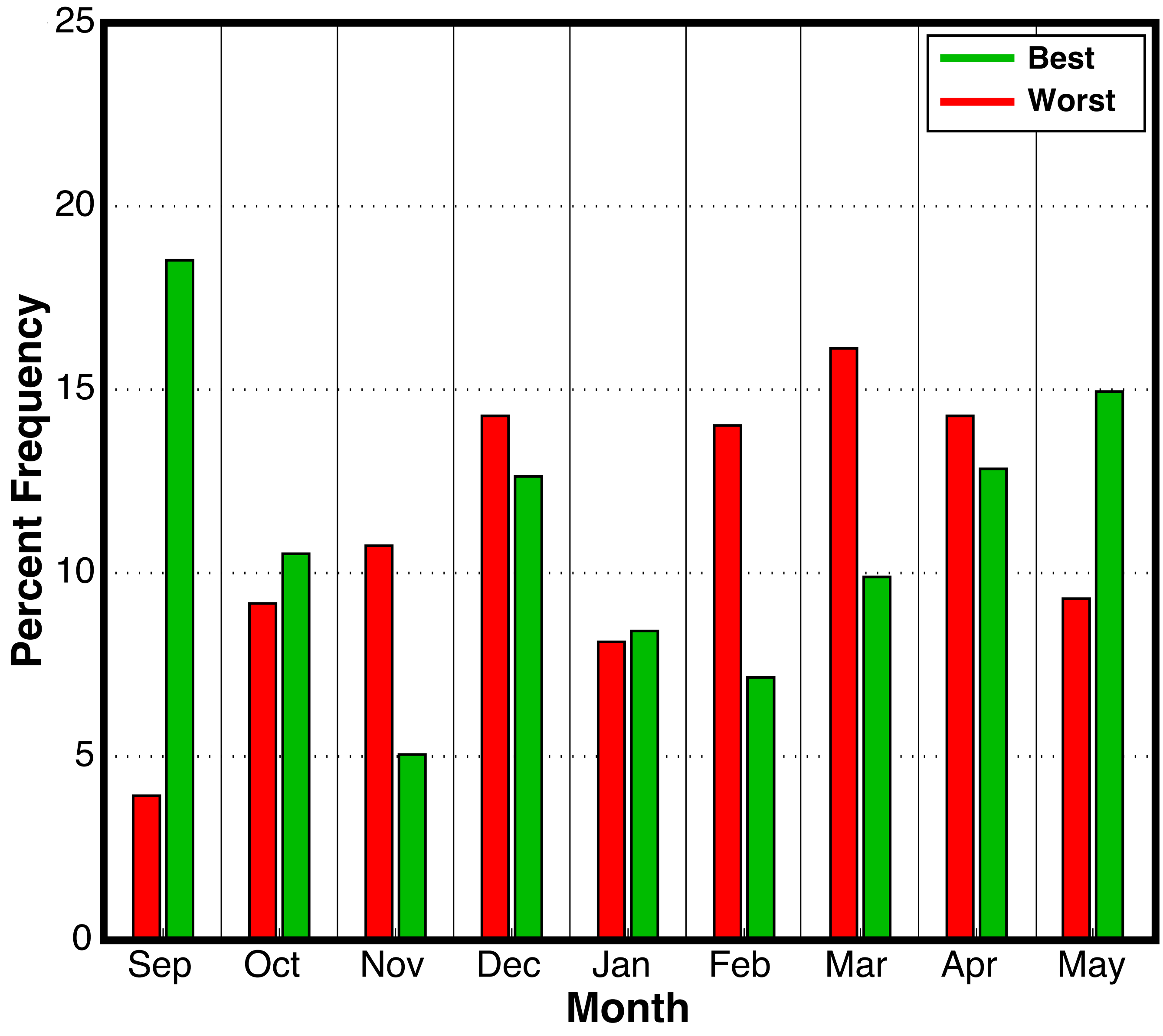
Circles on a particular line indicate statistically significant differences to the 95% confidence interval with respect to another jet regime.

GEFS Ensemble Mean POD by NPJ Regime

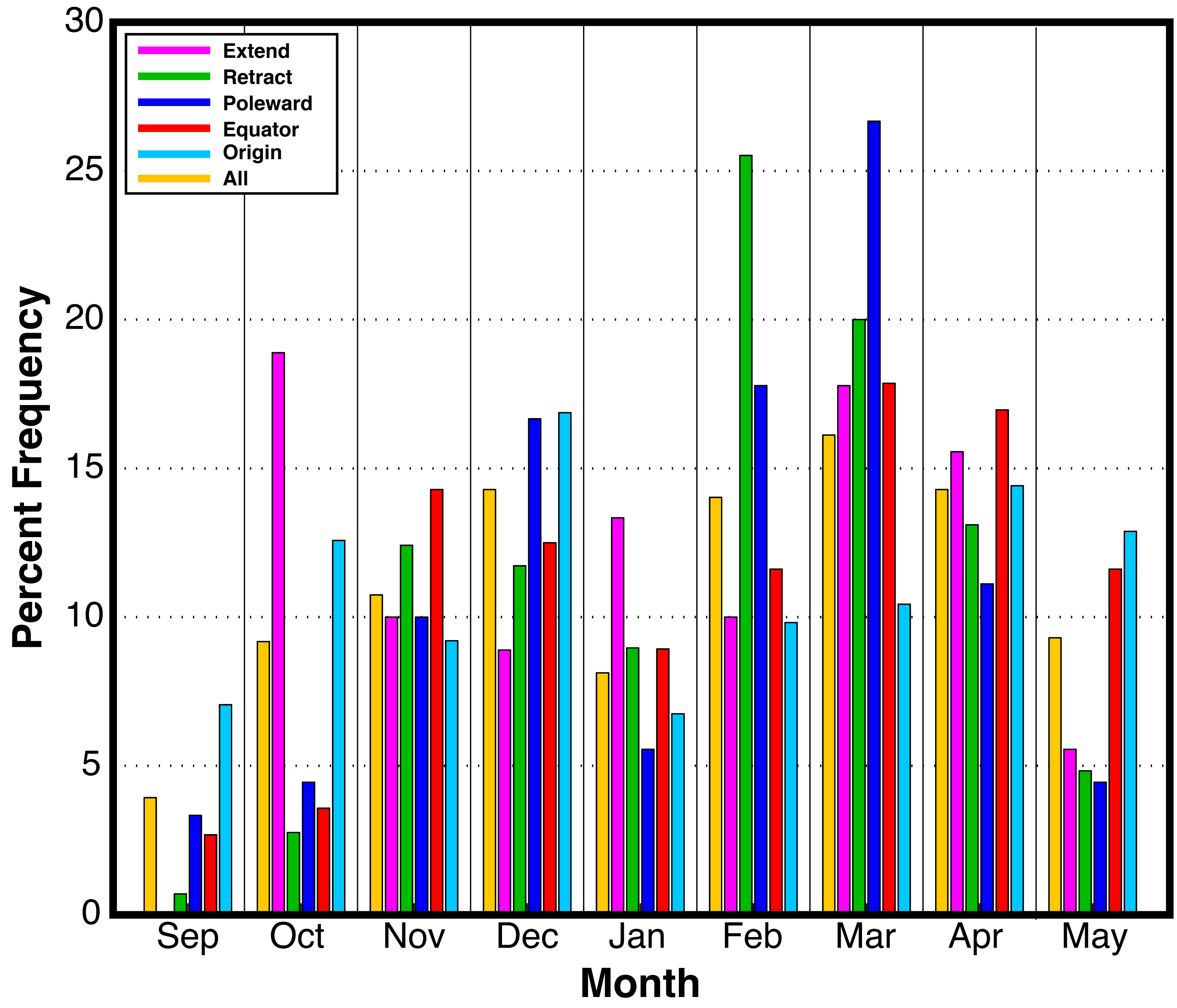
For forecasts verifying within a particular NPJ regime



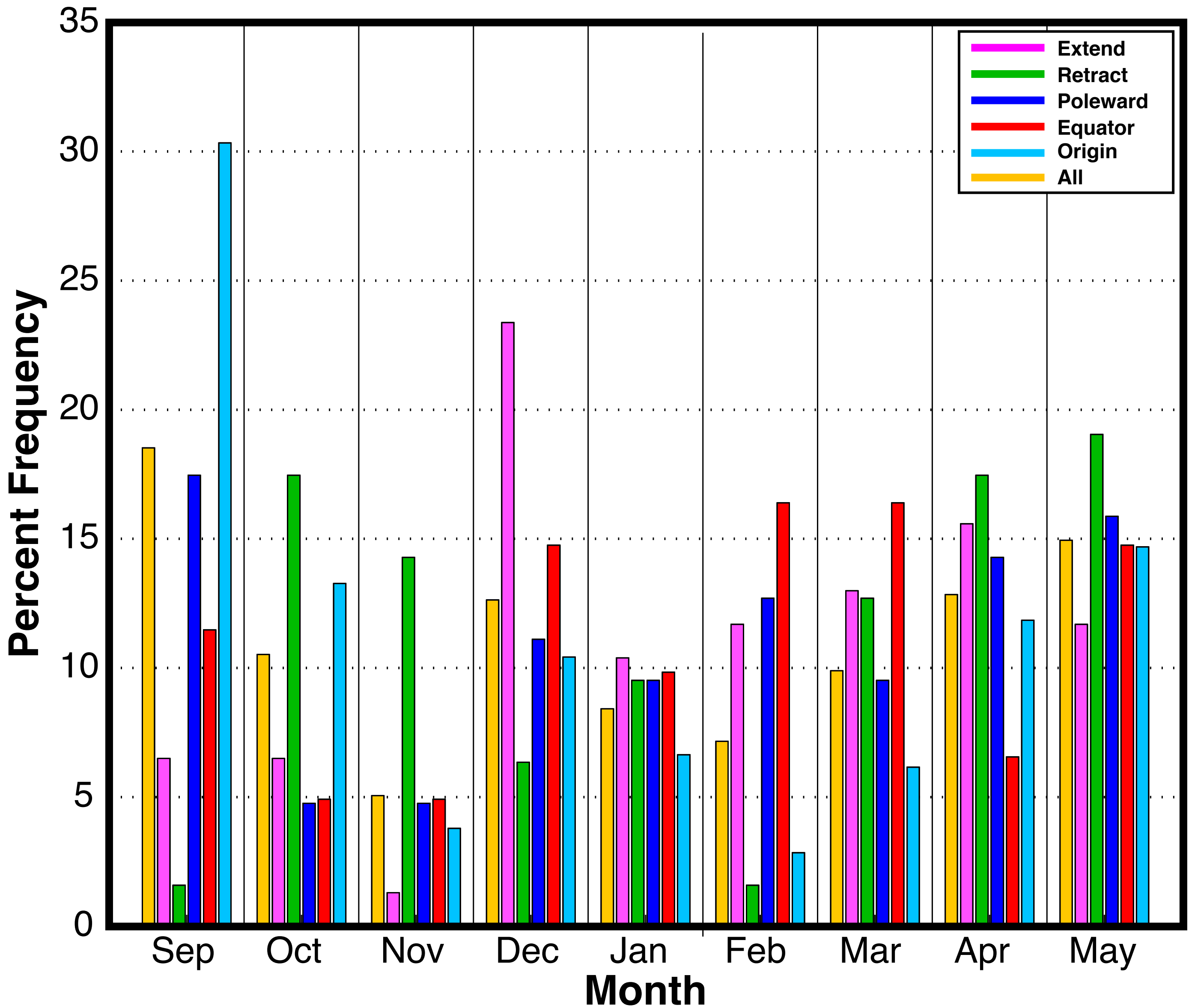
Frequency of Best/Worst NPJ Forecasts



Frequency of Worst NPJ Forecasts

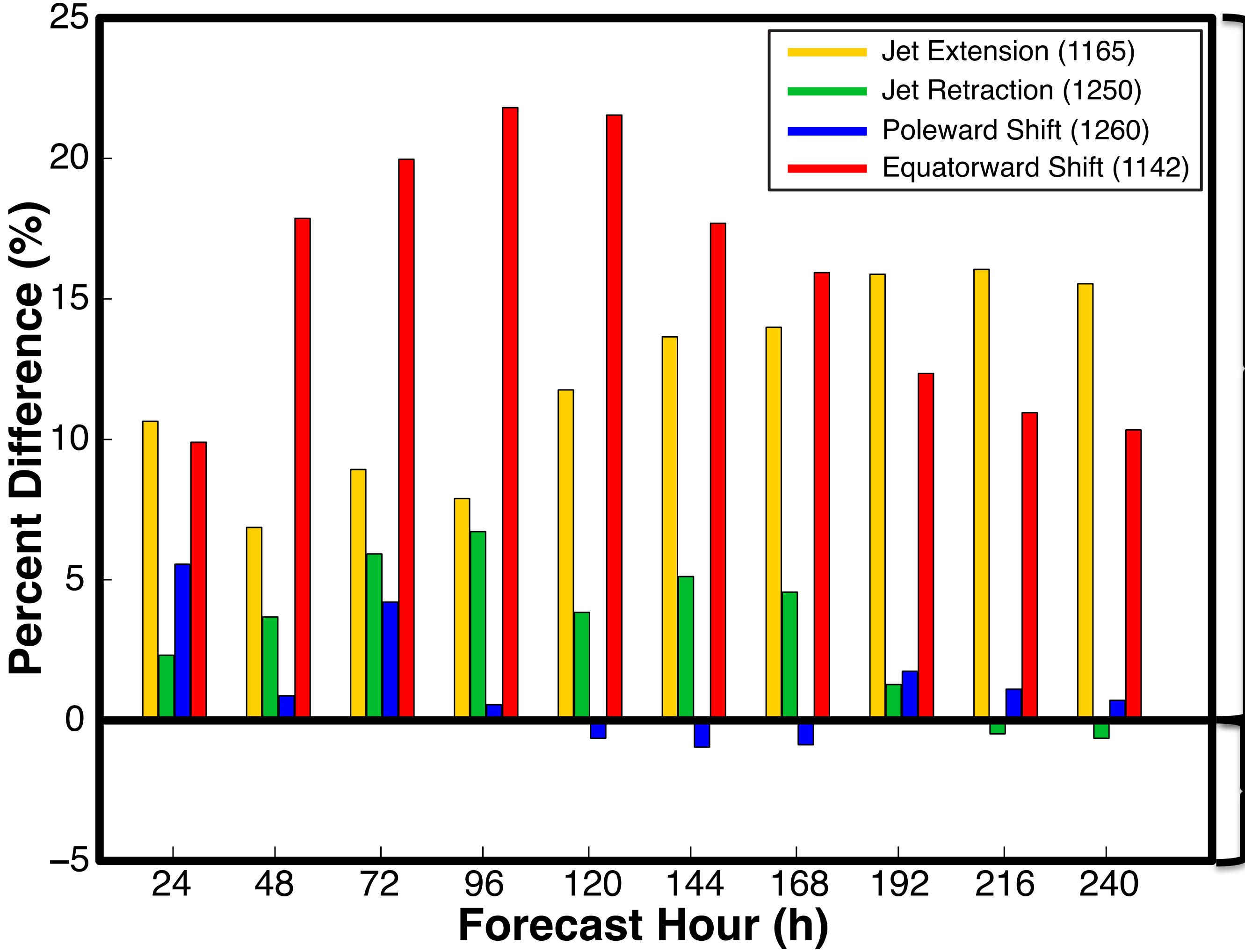


Frequency of Best NPJ Forecasts



Jet Regime-Dependent Forecast Skill

Percent Difference Between the Frequency of Forecasts with Below-Normal and Above-Normal RMSE over North America



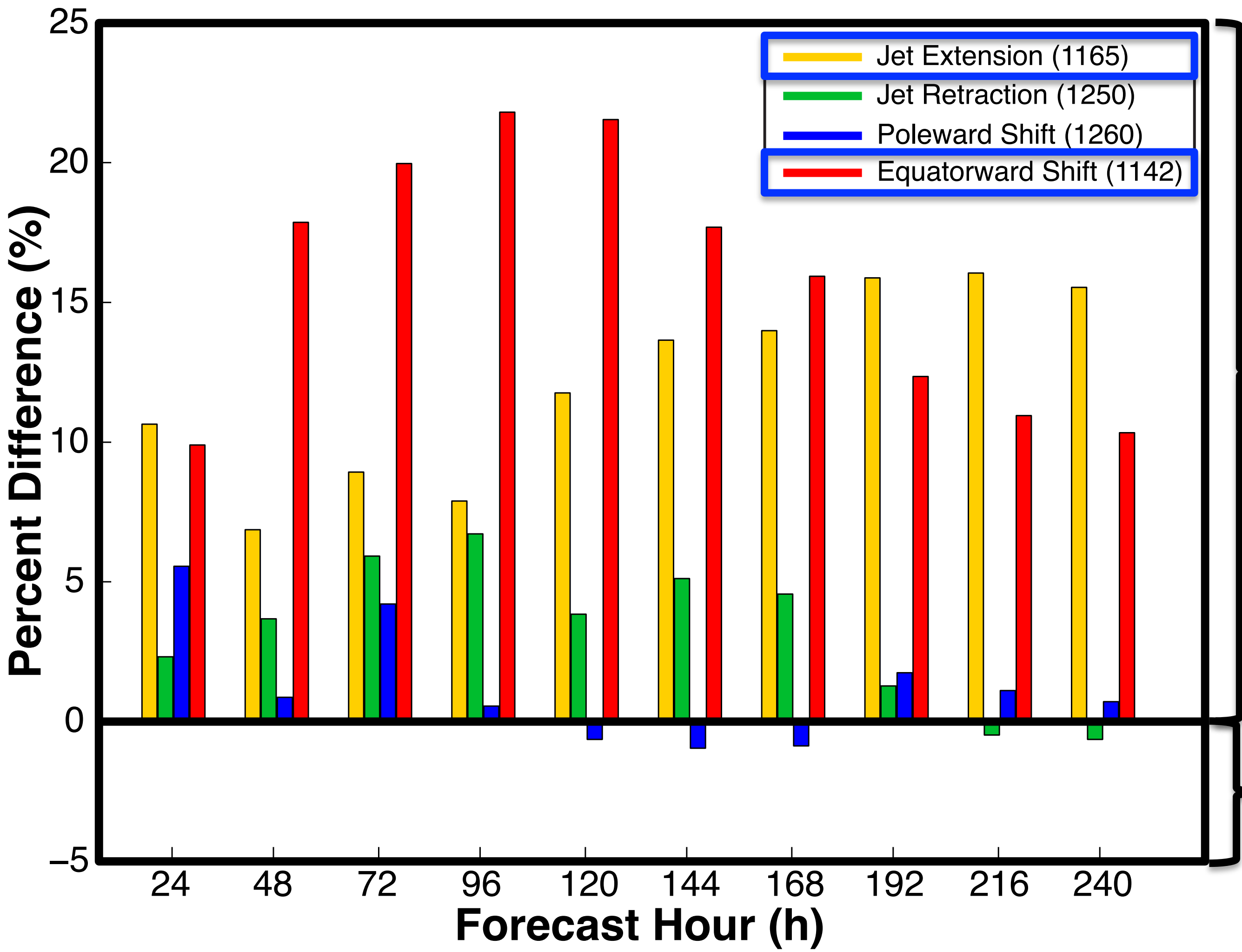
$$Freq_{below-normal} - Freq_{above-normal}$$

Higher frequency of forecasts with below-normal RMSE (i.e., more good forecasts)

Higher frequency of forecasts with above-normal RMSE (i.e., more bad forecasts)

Jet Regime-Dependent Forecast Skill

Percent Difference Between the Frequency of Forecasts with Below-Normal and Above-Normal RMSE over North America



$Freq_{below-normal} - Freq_{above-normal}$

Higher frequency of forecasts with below-normal RMSE (i.e., more good forecasts)

Higher frequency of forecasts with above-normal RMSE (i.e., more bad forecasts)

Best/Worst NPJ Phase Diagram Forecasts

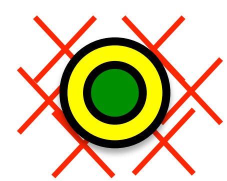
Comparison between the periods characterized by the best/worst medium-range forecasts

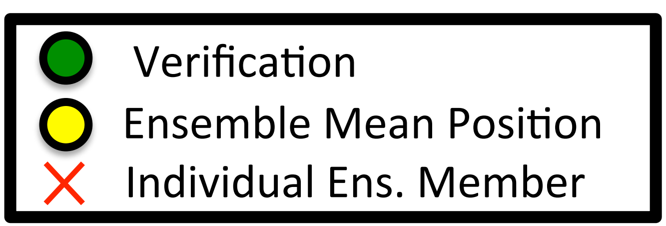
<u>Criteria</u>: Forecasts must rank in the top/bottom 10% in terms of *both*:

(1) The average GEFS ensemble <u>mean</u> error in the Day 8 and 9 forecasts

(2) The average GEFS ensemble <u>member</u> error in the Day 8 and 9 forecasts

Hypothetical Best Forecast





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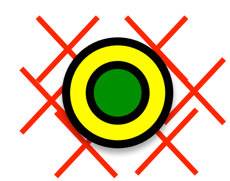
Represents a forecast with negligible ensemble mean error

(1) Ens. Mean error ≈ 0 ✓

Hypothetical Best Forecast



Verification
Ensemble Mean Position
Individual Ens. Member

Best/Worst NPJ Phase Diagram Forecasts

Comparison between the periods characterized by the best/worst medium-range forecasts

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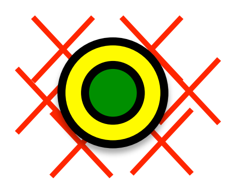

Verification

Ensemble Mean Position

Individual Ens. Member

Best/Worst NPJ Phase Diagram Forecasts

Comparison between the periods characterized by the best/worst medium-range forecasts

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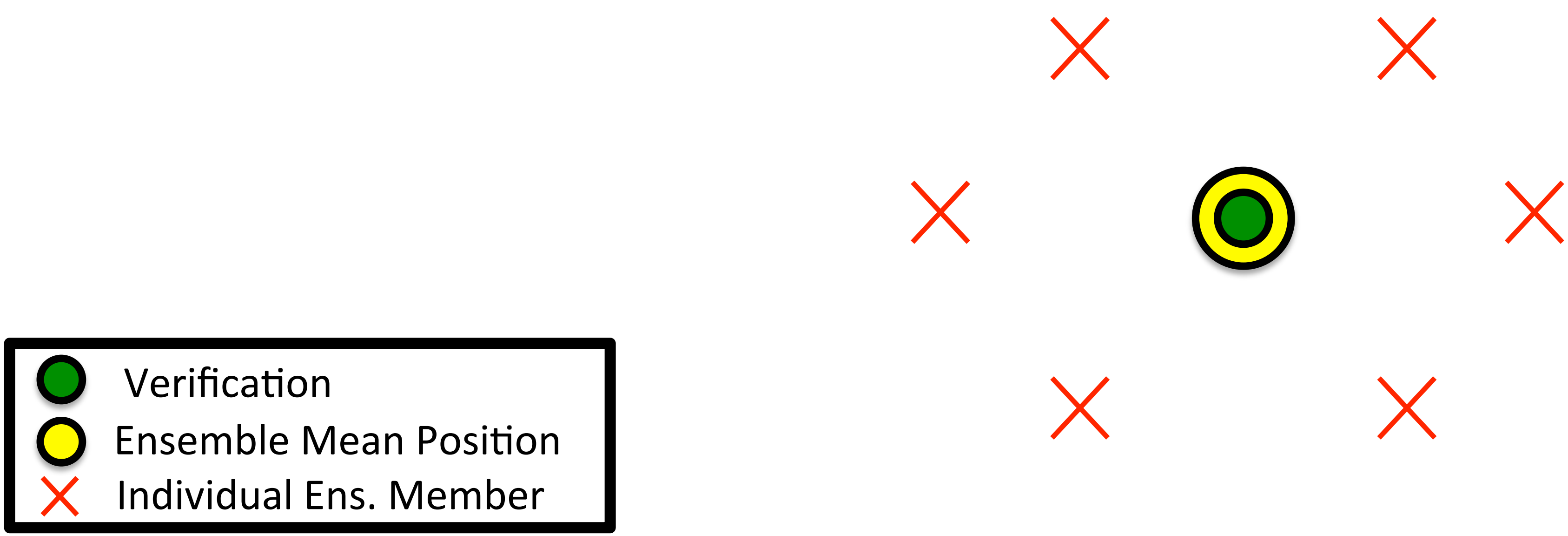
Hypothetical Intermediate Forecast



Best/Worst NPJ Phase Diagram Forecasts

Comparison between the periods characterized by the best/worst medium-range forecasts

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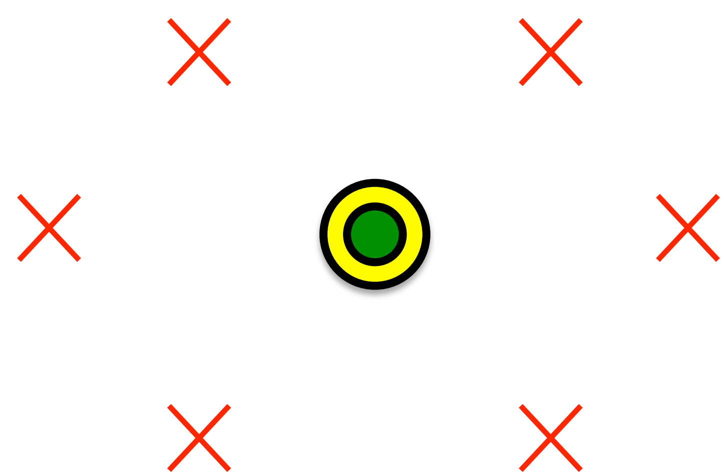
Hypothetical Intermediate Forecast



Verification

Ensemble Mean Position

Individual Ens. Member

Best/Worst NPJ Phase Diagram Forecasts

Comparison between the periods characterized by the best/worst medium-range forecasts

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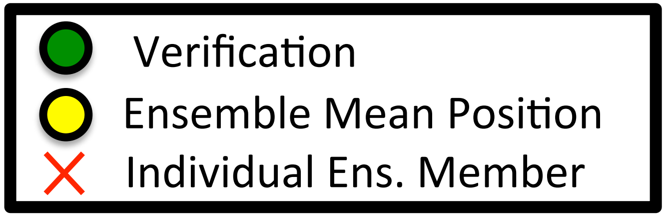
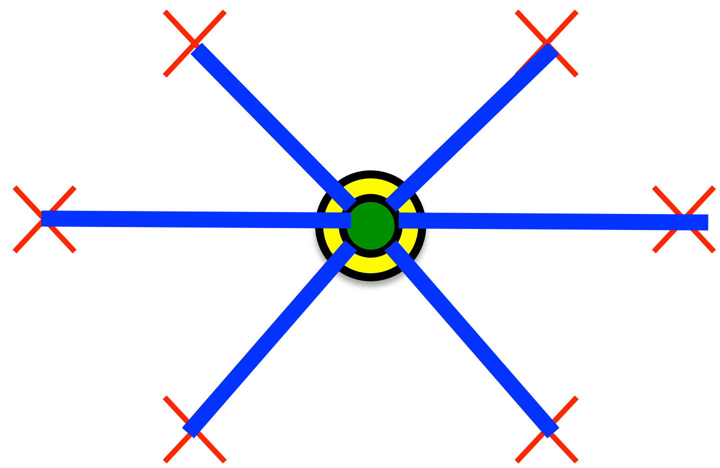
Represents a forecast with considerable ensemble member error

(1) Ens. Mean error ≈ 0 ✓

(2) Avg. Ens. Member error >> 0 ✗





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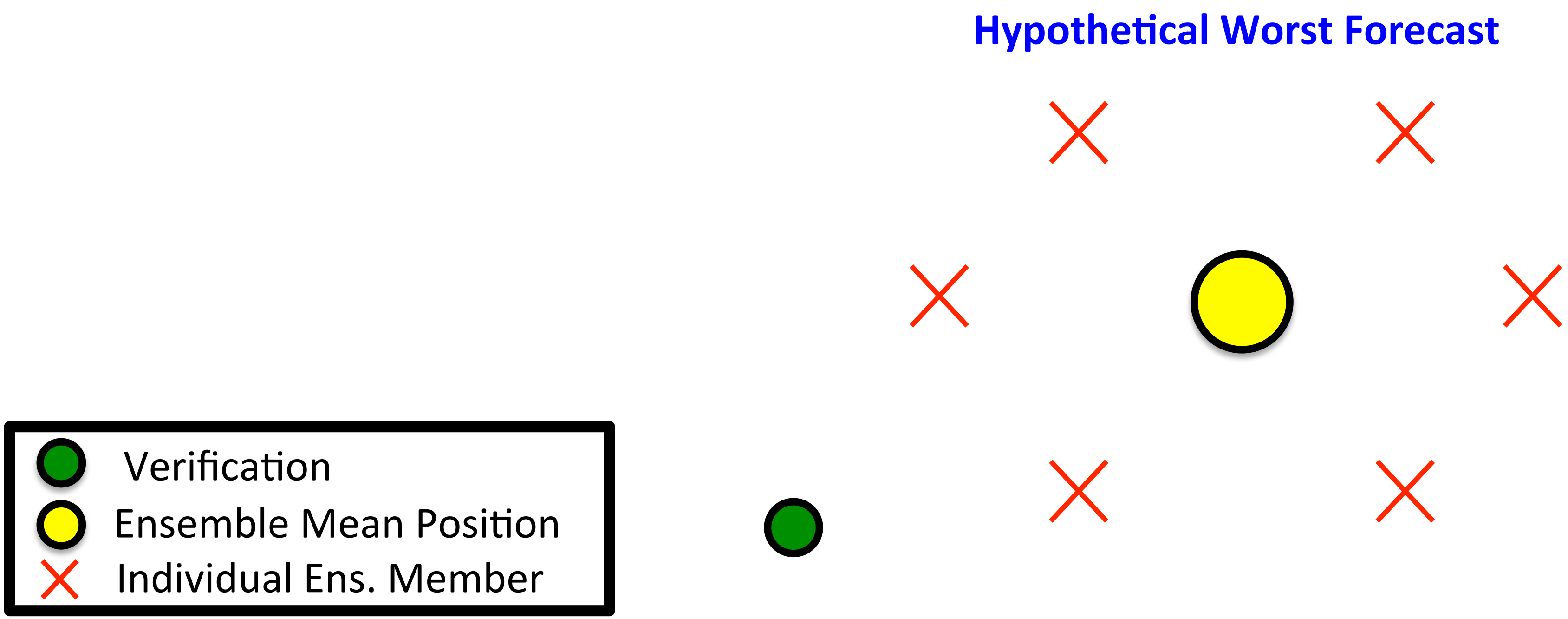

Best/Worst NPJ Phase Diagram Forecasts

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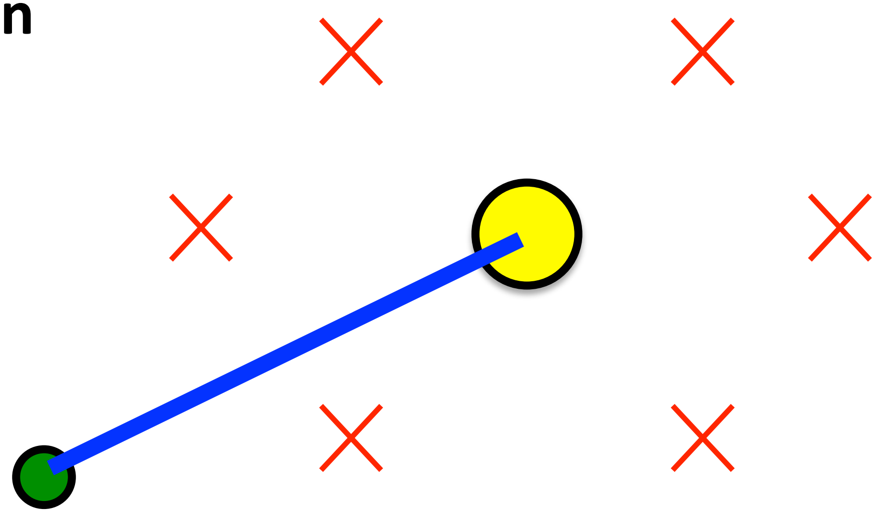
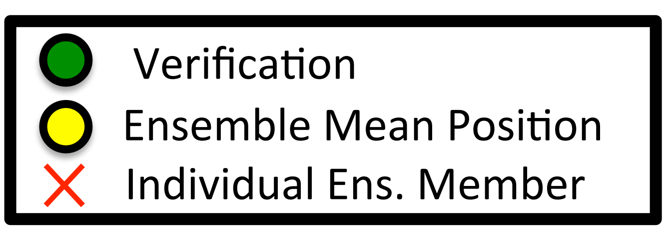
Hypothetical Worst Forecast





Best/Worst NPJ Phase Diagram Forecasts

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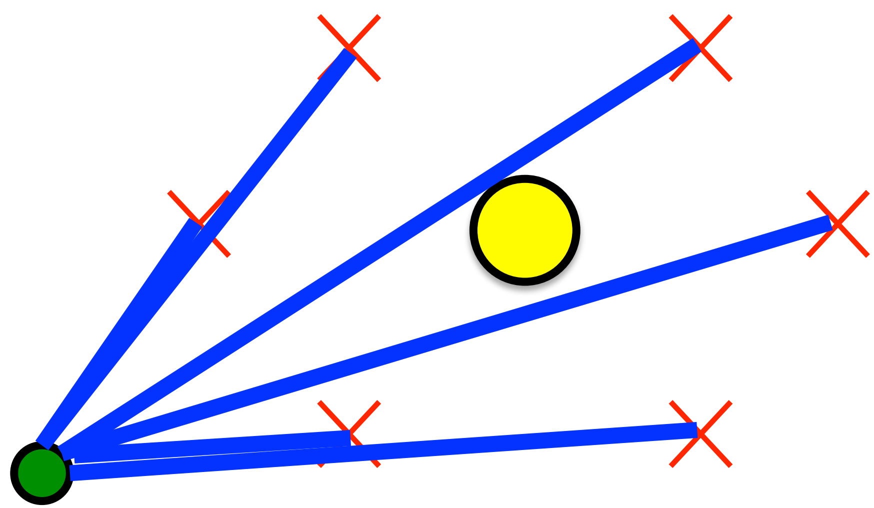
Represents a forecast with considerable ensemble member error

(1) Ens. Mean error >> 0 ✕

(2) Avg. Ens. Member error >> 0 ✕

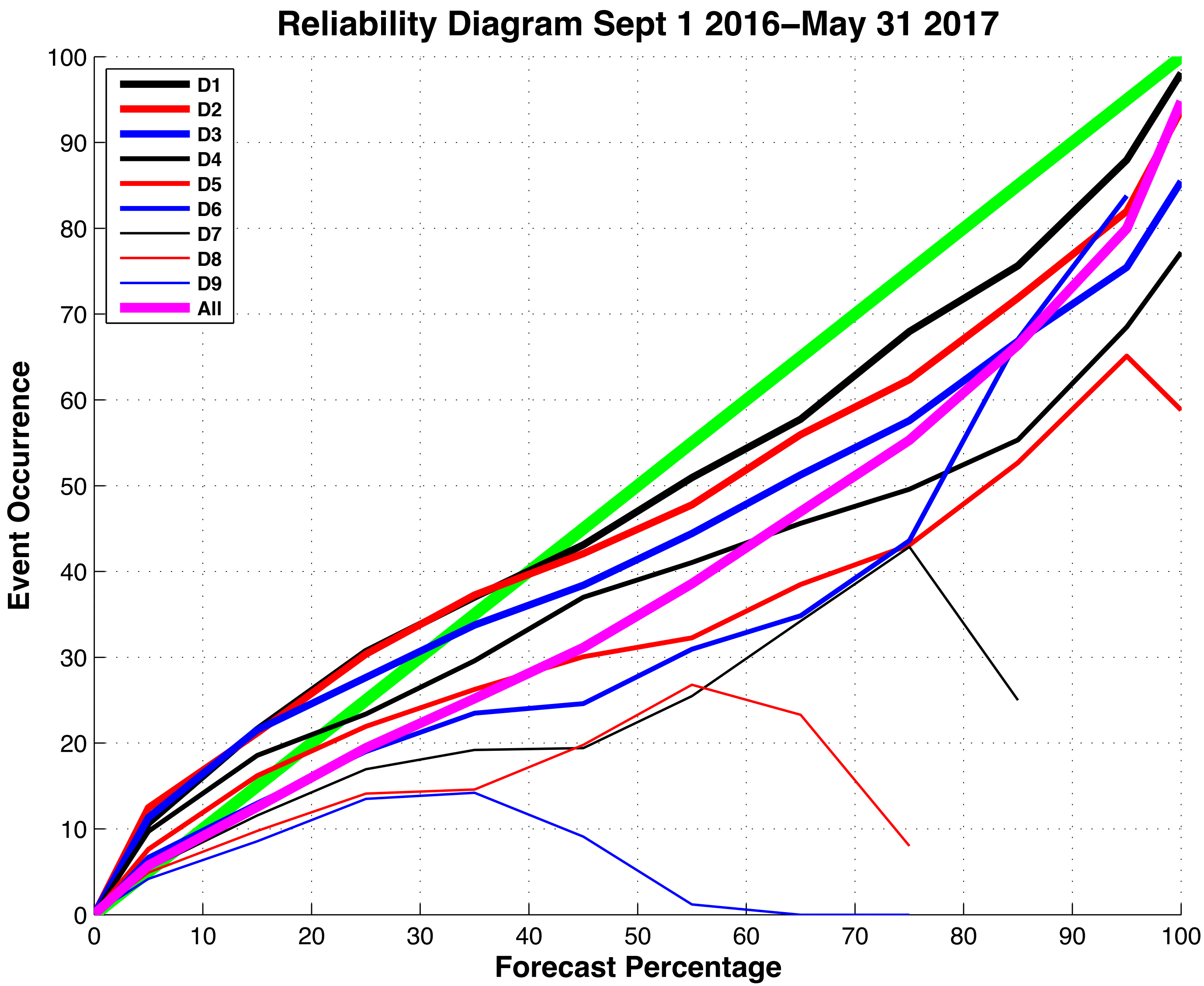
- ● Verification
- ● Ensemble Mean Position
- ✕ Individual Ens. Member

Hypothetical Worst Forecast



Real time NPJ Phase Diagram Verification Statistics 2016–2017

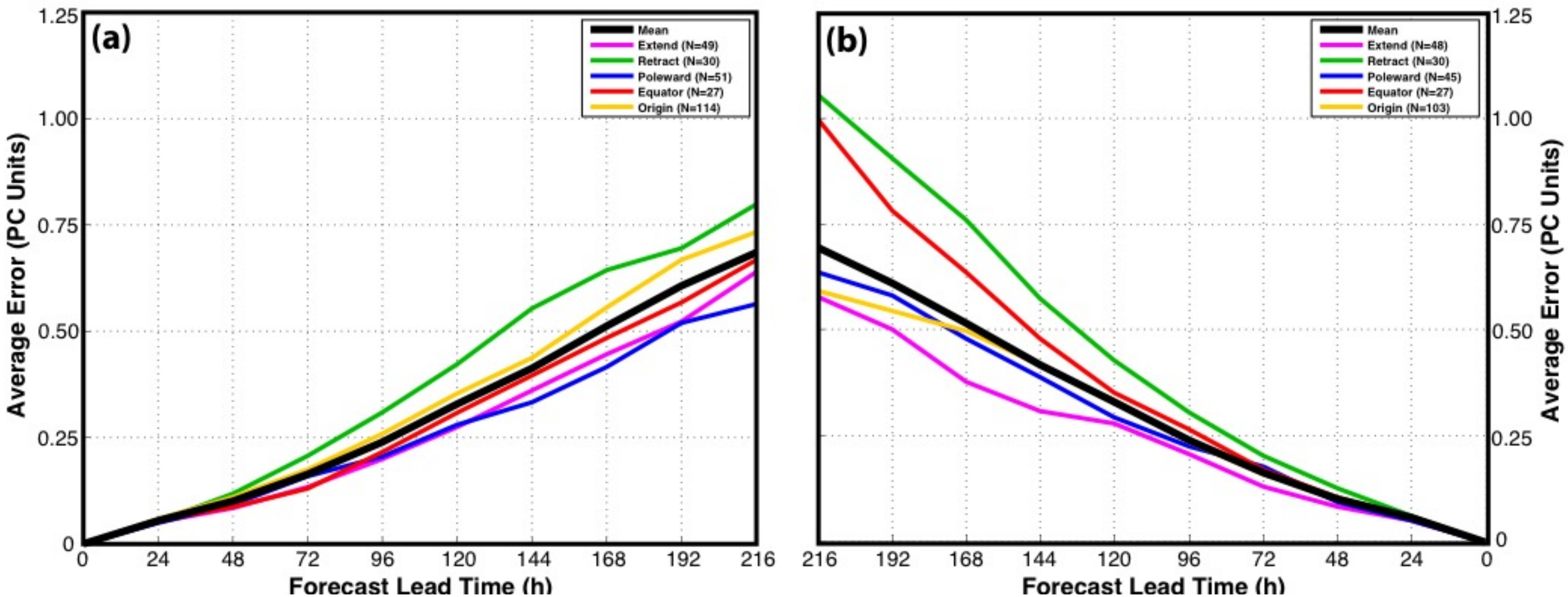
Reliability Diagram (Sept 1 – May 31)



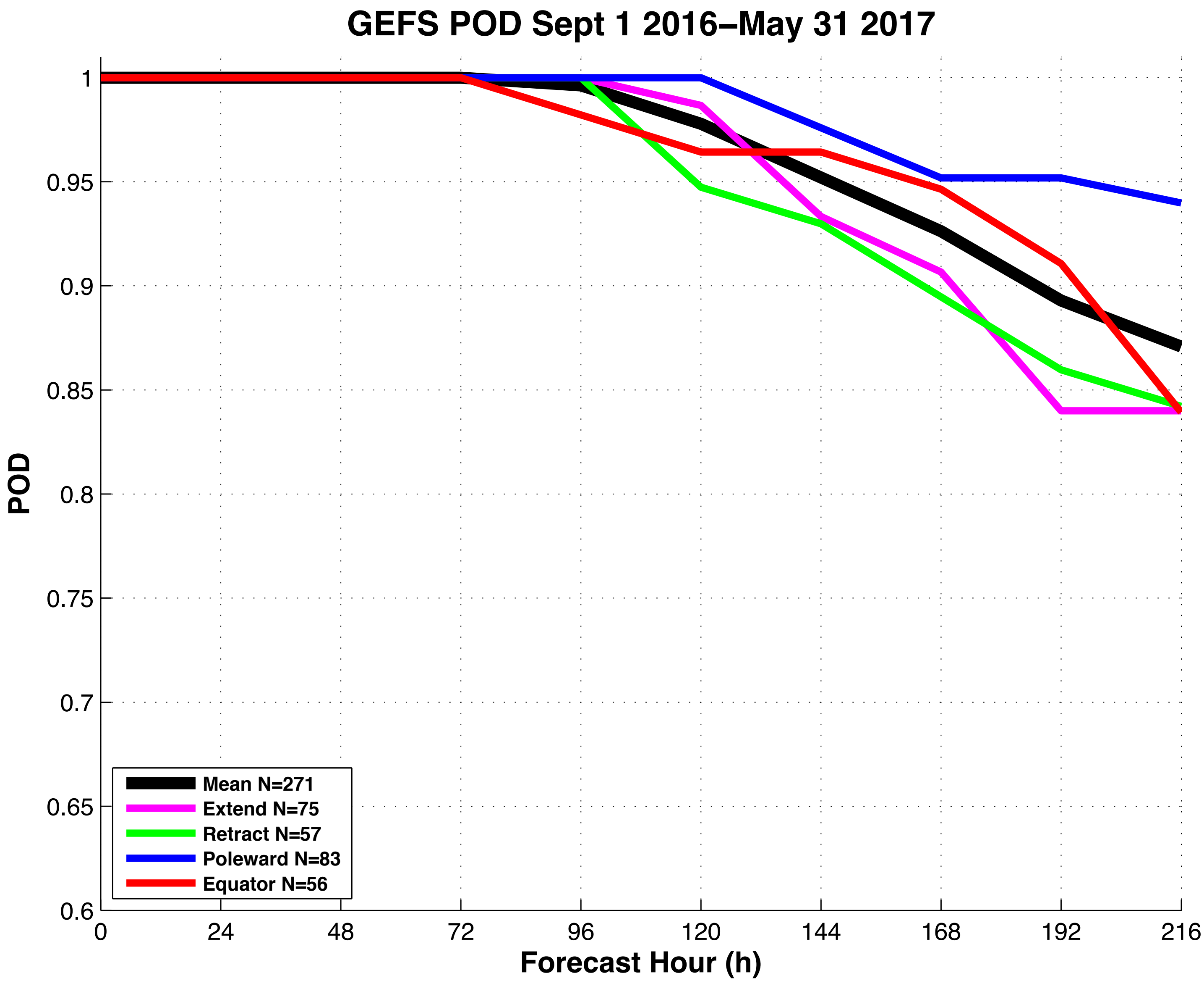
Perfect Reliability

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

GEFS Ensemble Mean Error – Regime

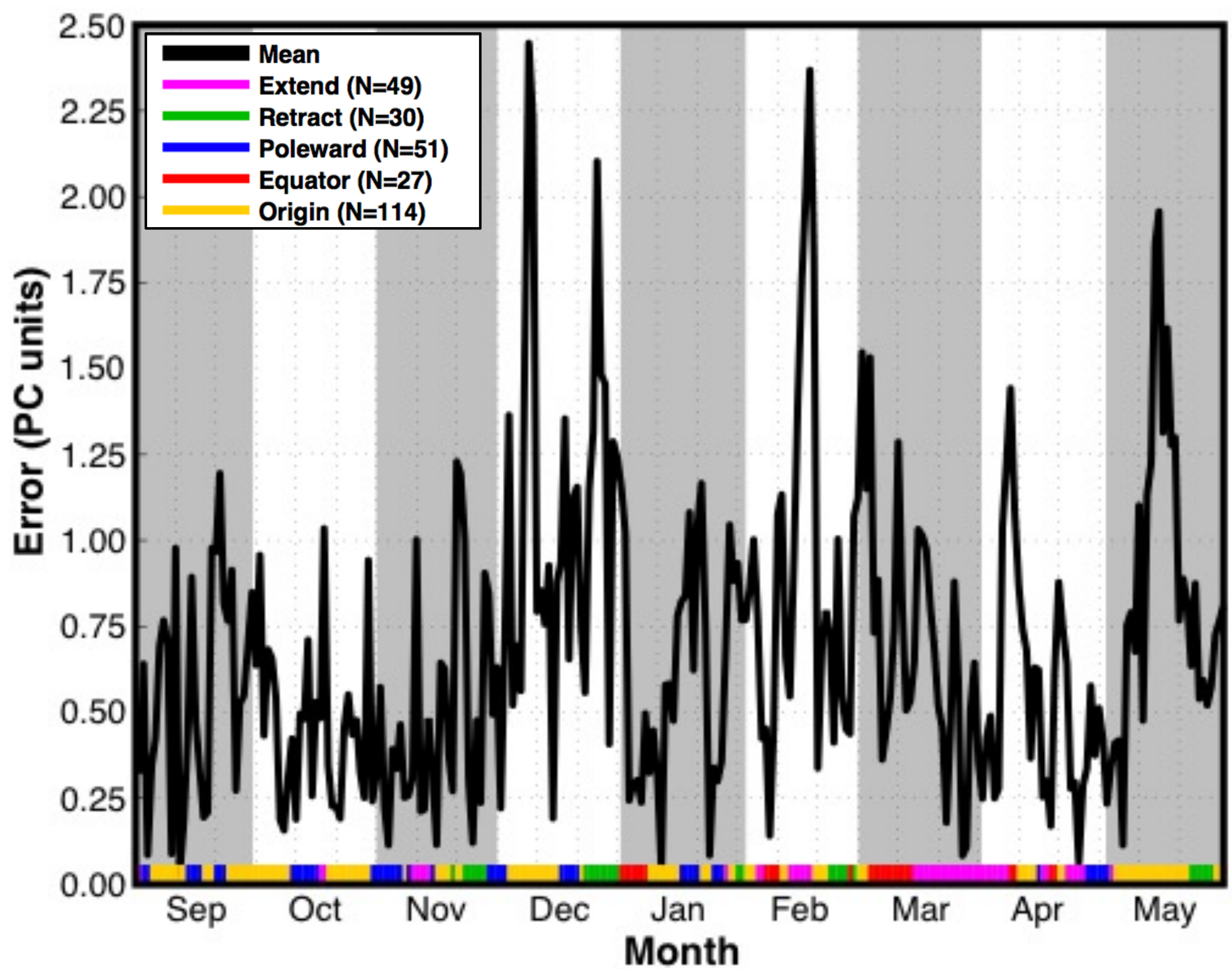


GEFS Probability of Detection – Regime



Real Time NPJ Phase Diagram Forecasts

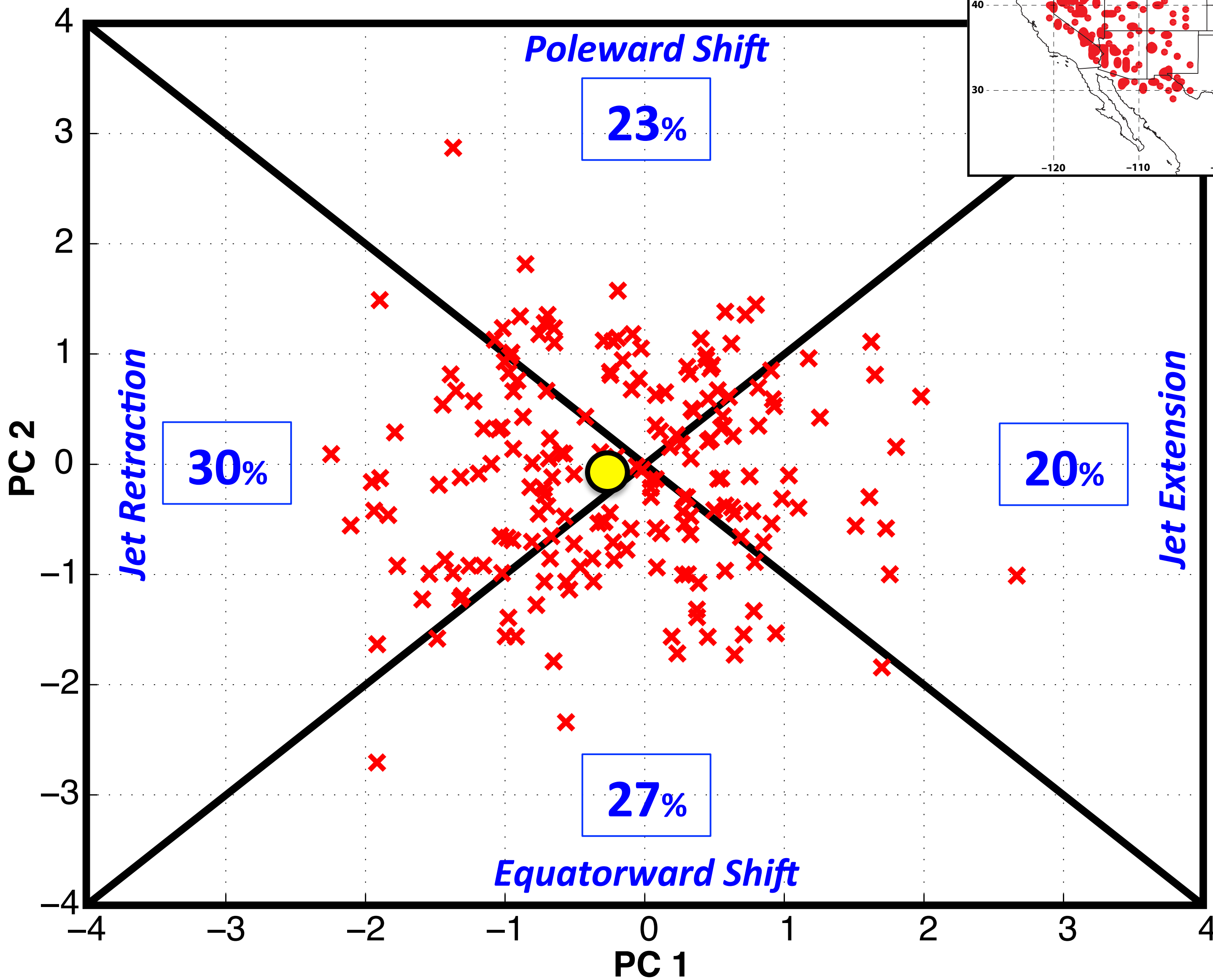
Time series of 2016–2017 GEFS ensemble mean 9-day forecast error classified by initialization date

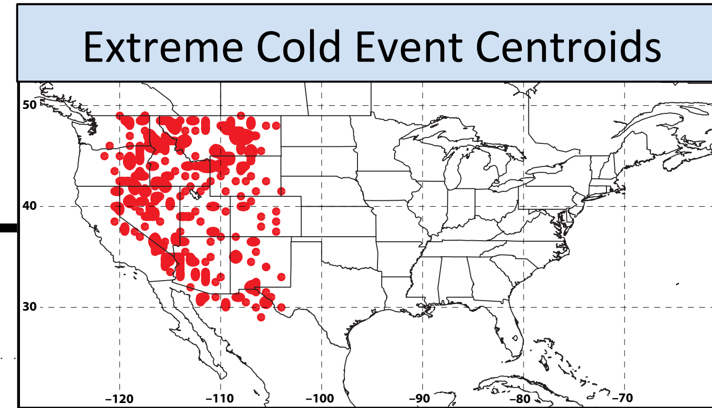


NPJ Phase Diagram and ETE’s

Western U.S. – All Events

EXTREME COLD EVENTS (N = 196)





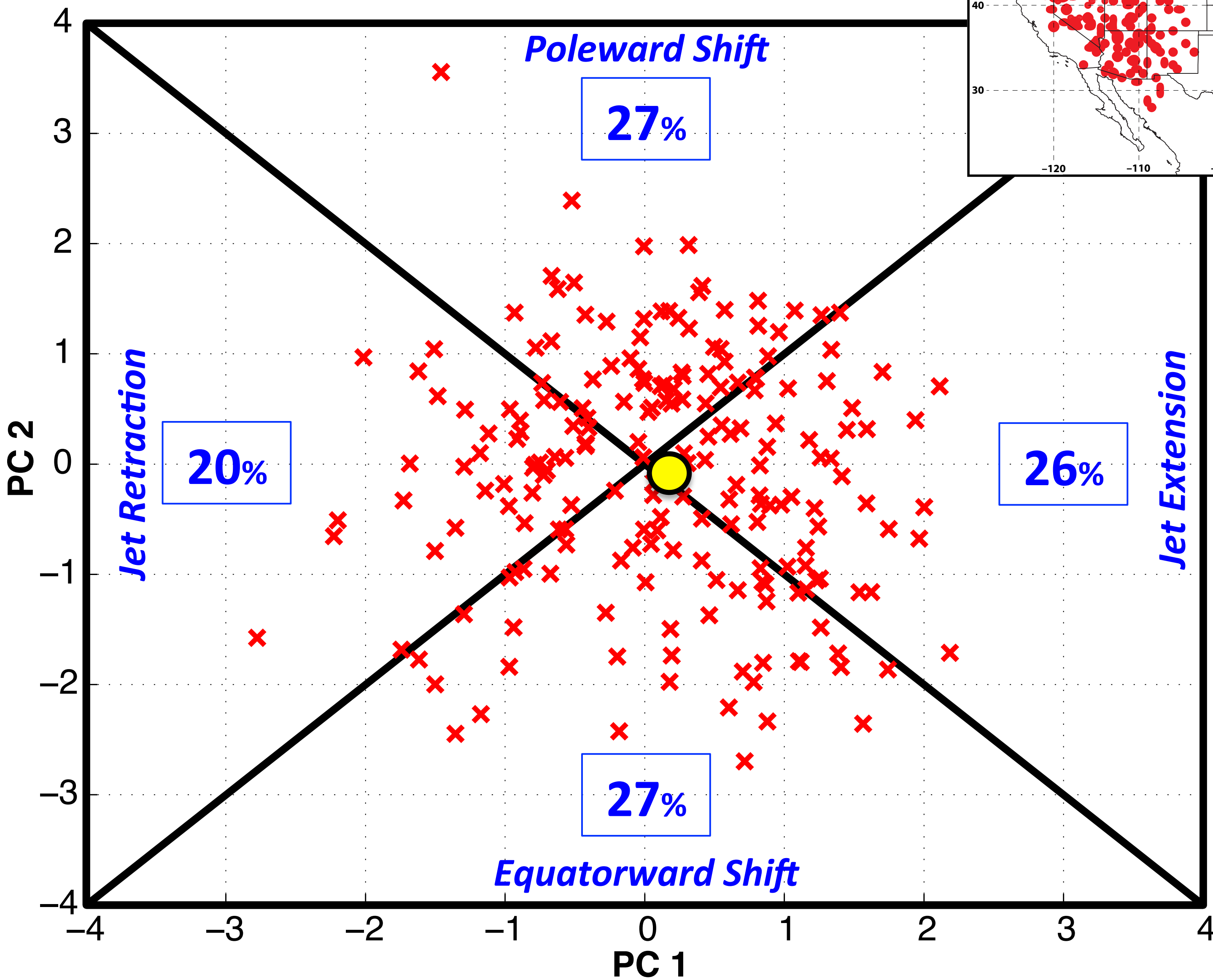
Events during Sept. – May projected onto phase diagram

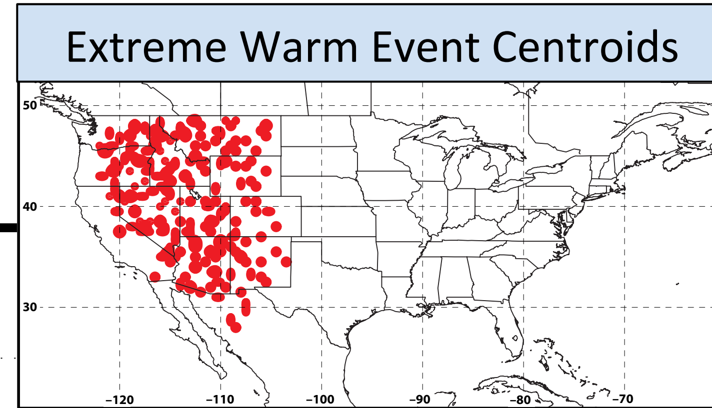
Each 'x' is an average of the PCs 3–7 days prior to an event

Mean Projection

Western U.S. – All Events

EXTREME WARM EVENTS (N = 204)



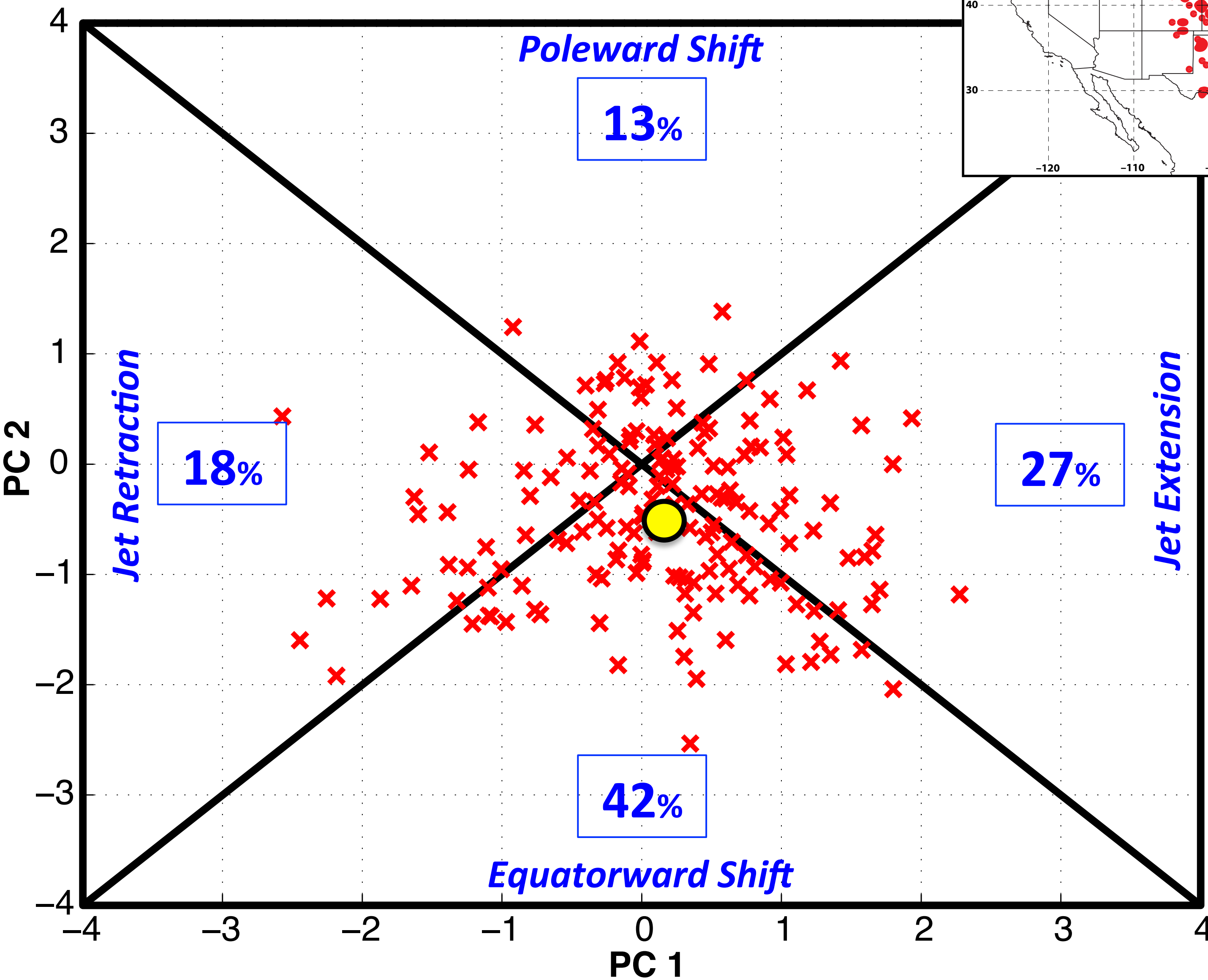


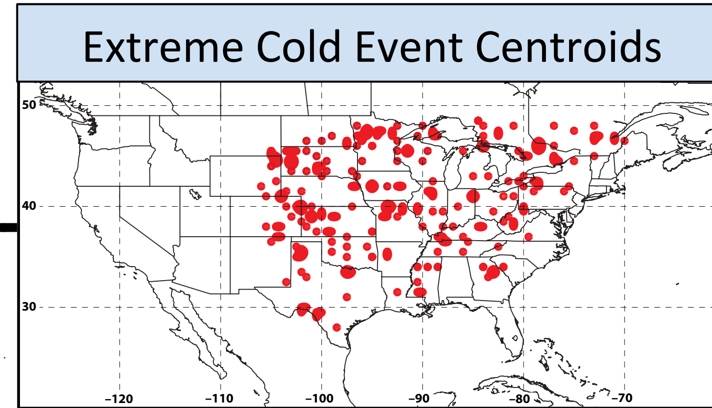
Events during Sept. – May projected onto phase diagram

Each 'x' is an average of the PCs 3–7 days prior to an event

Eastern U.S. – All Events

EXTREME COLD EVENTS (N = 173)





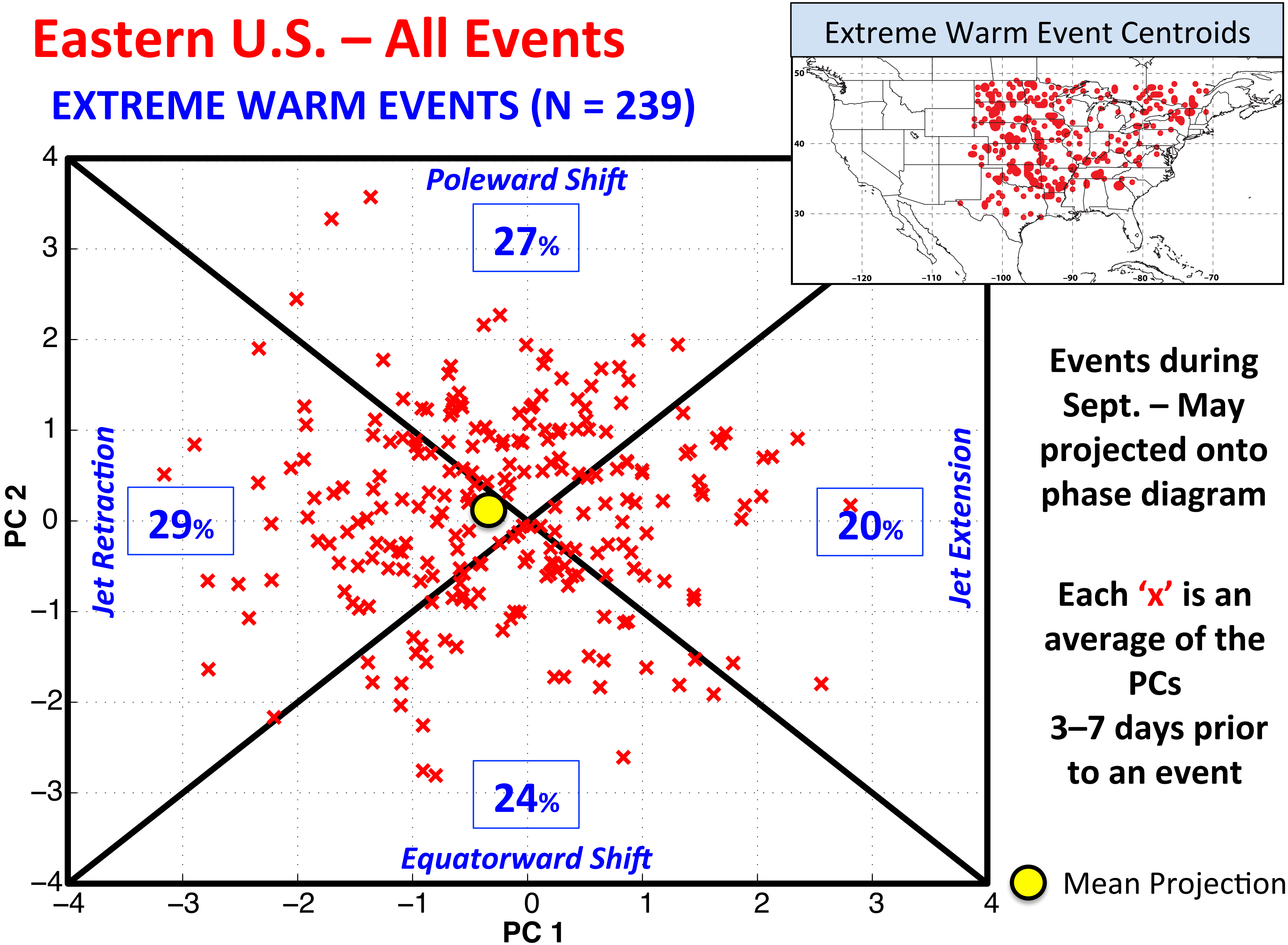
Events during Sept. – May projected onto phase diagram

Each 'x' is an average of the PCs 3–7 days prior to an event

Mean Projection

Eastern U.S. – All Events

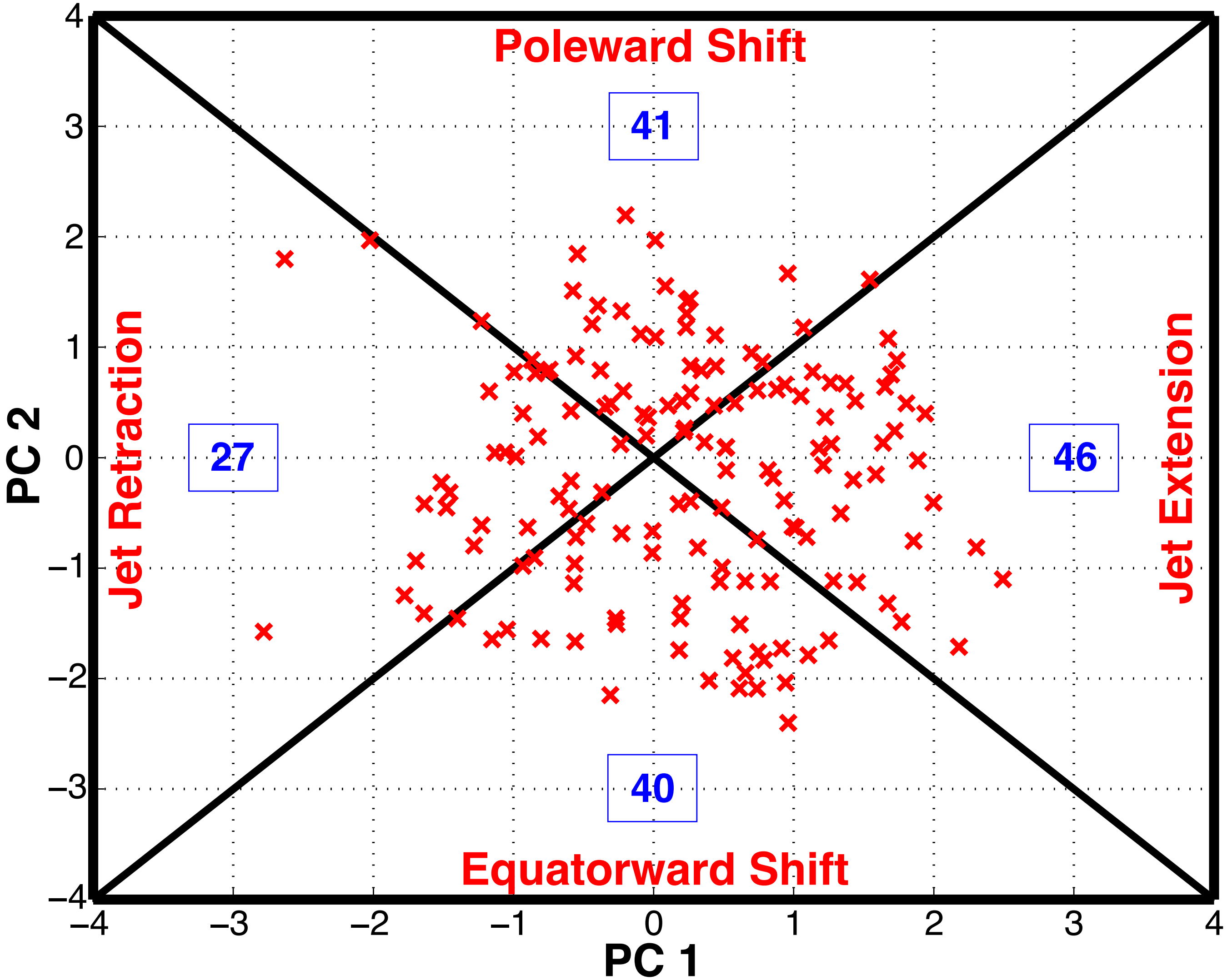
EXTREME WARM EVENTS (N = 239)



Events during Sept. – May projected onto phase diagram

Each 'x' is an average of the PCs 3–7 days prior to an event

West Coast Extreme Precipitation Events



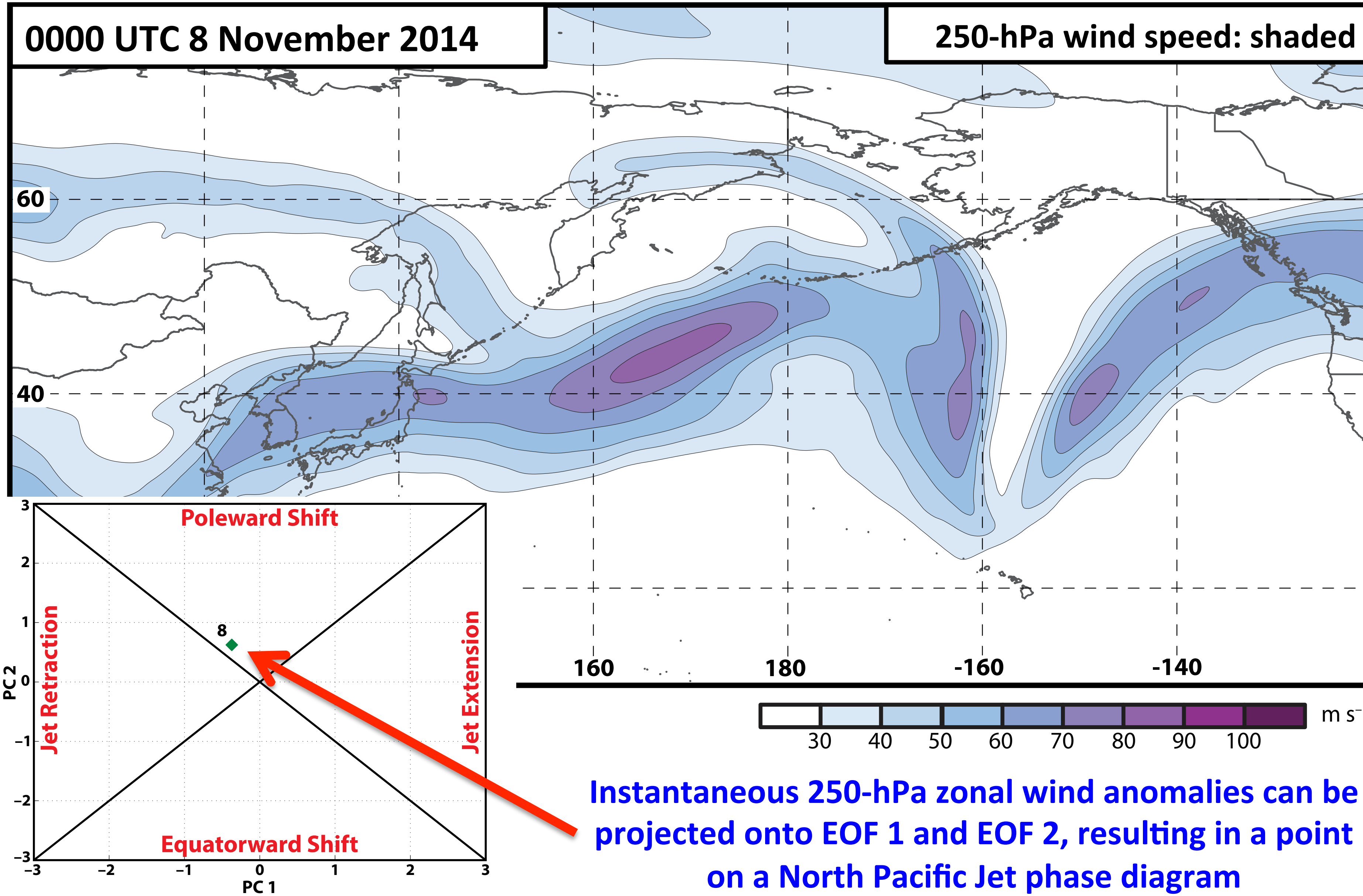
Events during Sept. – May 1979–2014 projected onto the NPJ phase diagram (N=154)

Each "x" is an average of the PCs 3–7 days prior to a precip. event

West Coast Extreme Precipitation Events are most often preceded by Jet Extensions

NPJ Phase Diagram Technical Slides

Real Time North Pacific Jet Phase Diagram

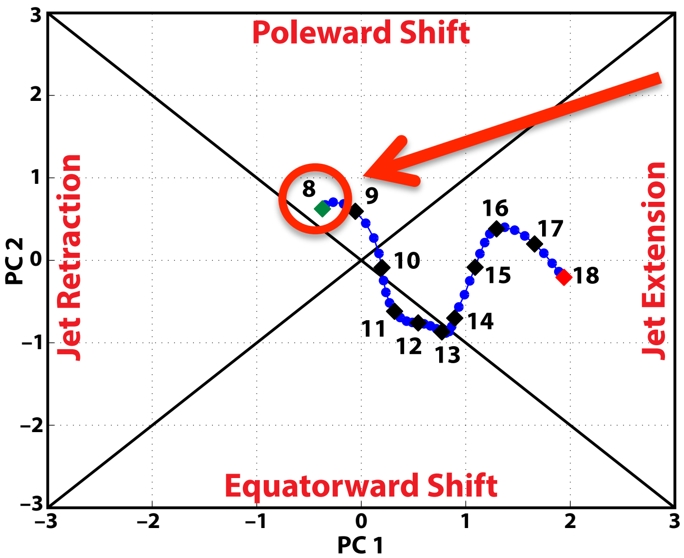


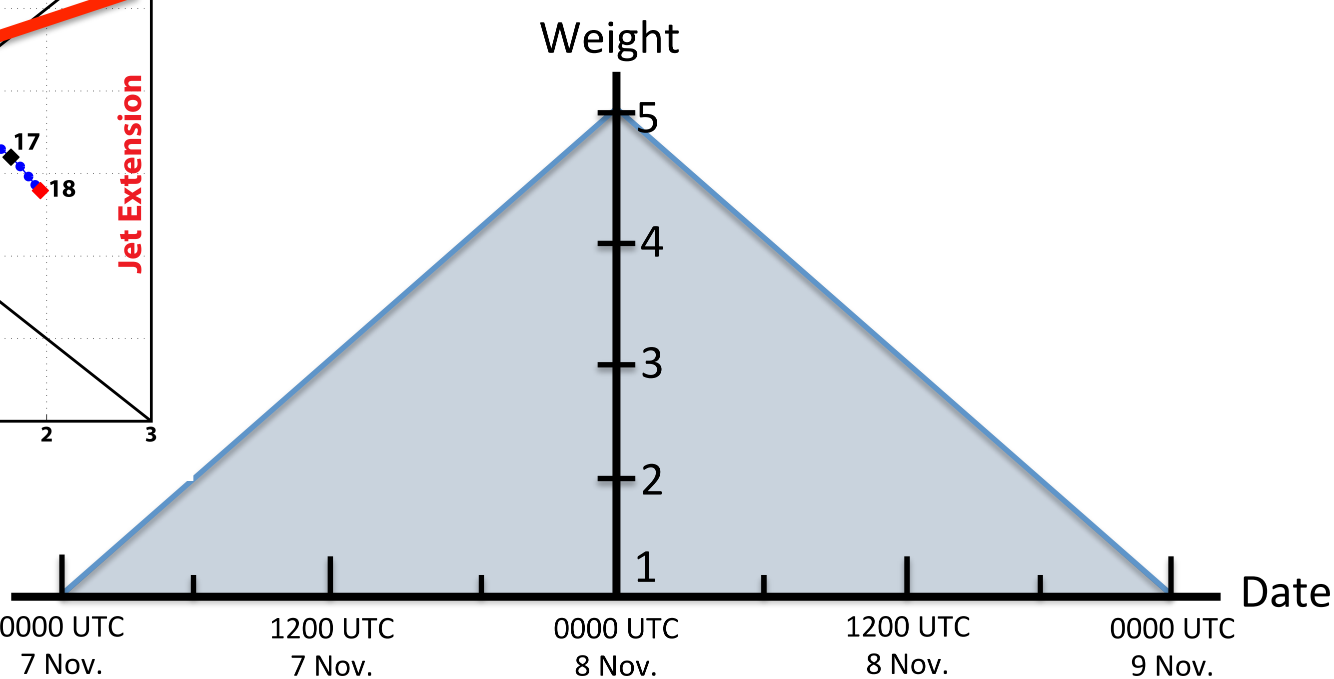
Instantaneous 250-hPa zonal wind anomalies can be projected onto EOF 1 and EOF 2, resulting in a point on a North Pacific Jet phase diagram

Real Time North Pacific Jet Phase Diagram

- Each point on the phase diagram is a weighted average of the principal components within +/− 1 day of the time under consideration

<u>Example</u>: 0000 UTC 8 November 2014





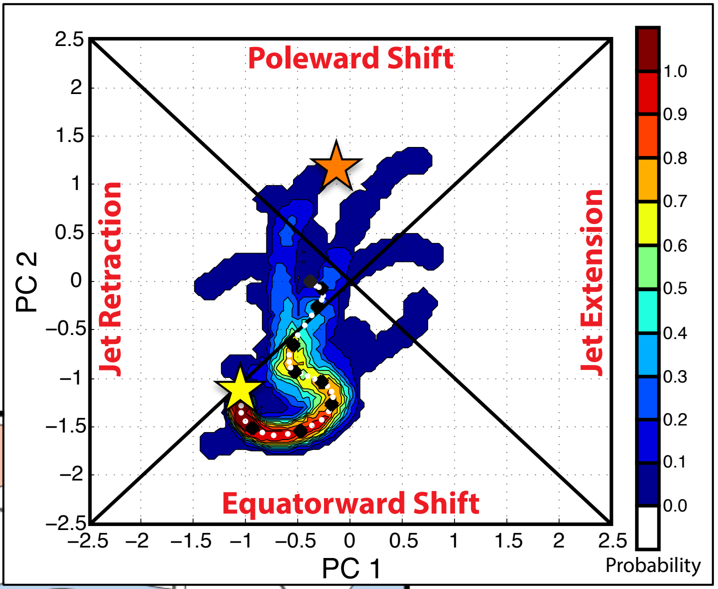
Real Time North Pacific Jet Phase Diagram

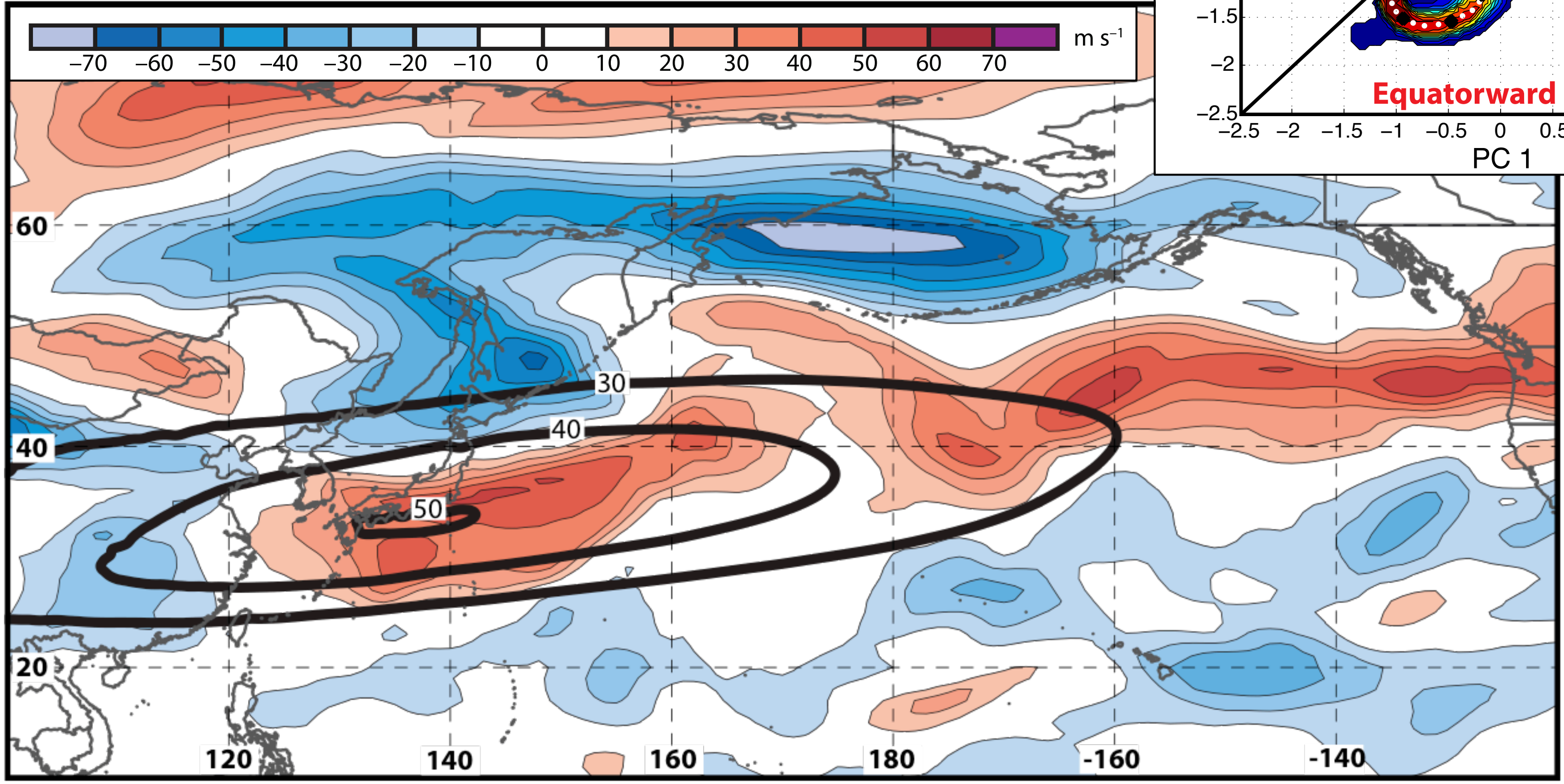
250-hPa zonal wind at 0000 UTC 2 Jun minus 250-hPa zonal wind at 0000 UTC 24 May (shading) in the GFS analyses shows the transition to a poleward-shifted jet regime

0000 UTC 24 May (0-h forecast)

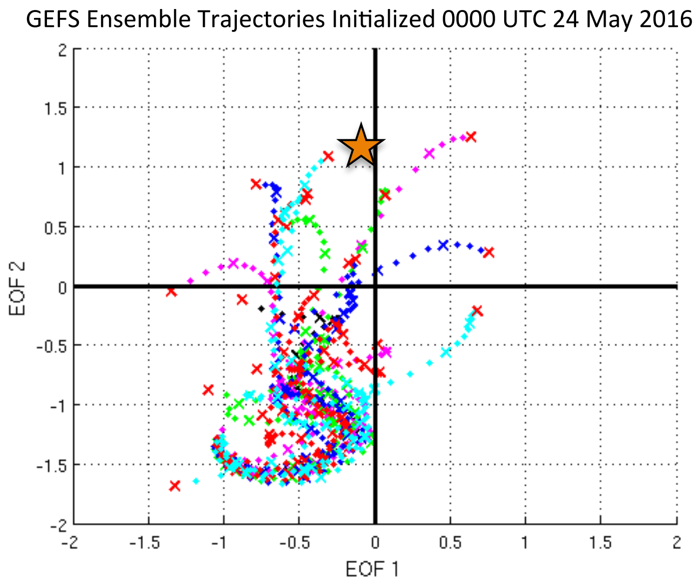
0000 UTC 2 Jun (verification)

Ensemble mean

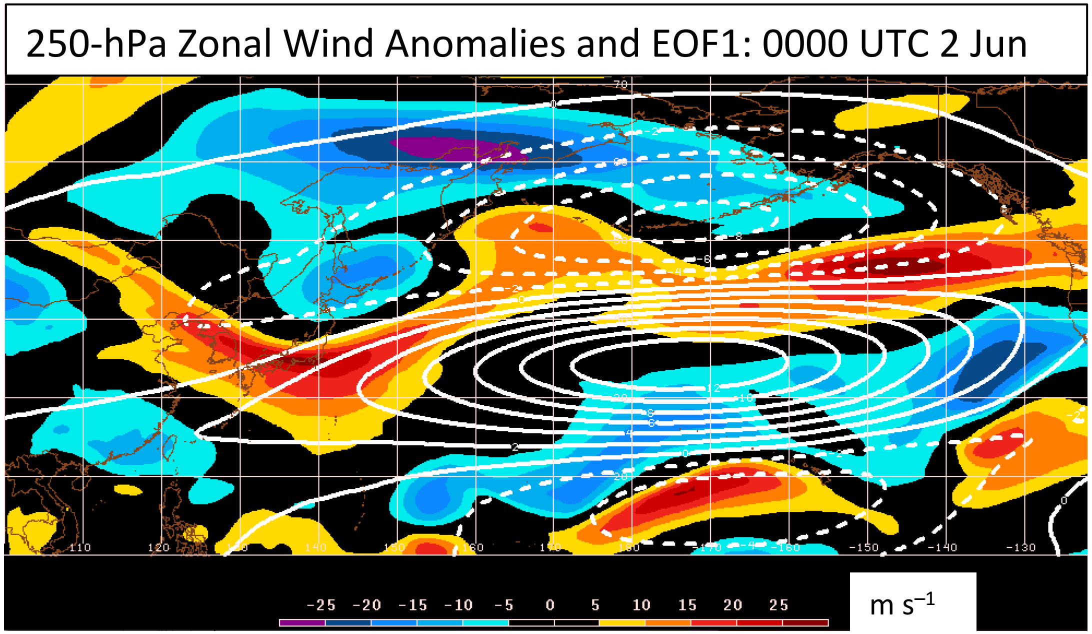


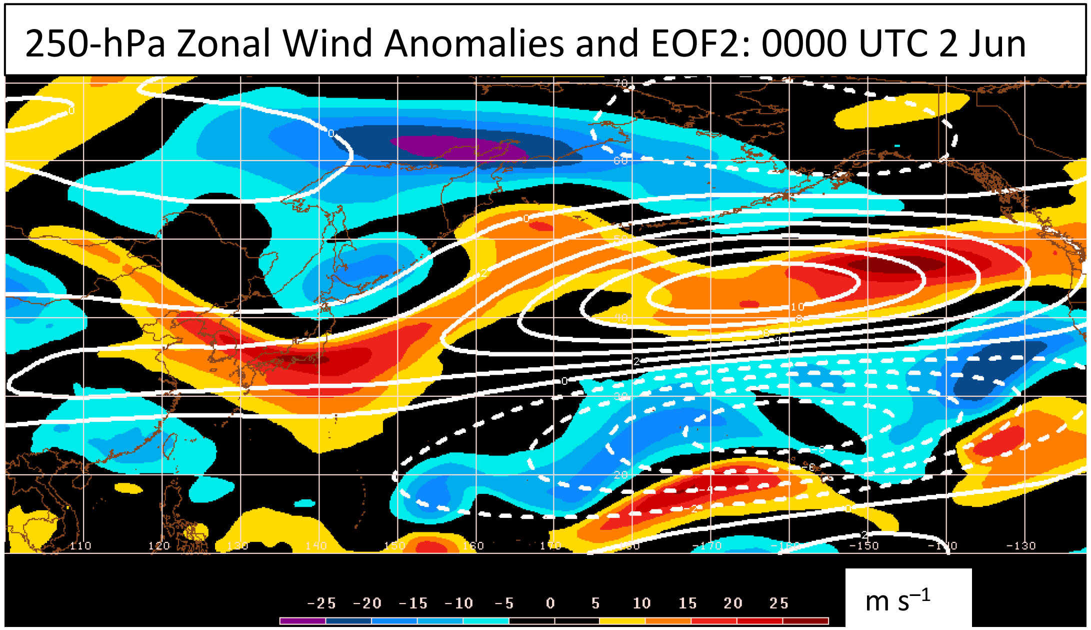


Sept.–May mean 250-hPa zonal wind: black contours



0000 UTC 2 Jun (verification)





250-hPa zonal wind anomalies at 0000 UTC 2 Jun project strongly onto EOF2 > 0