Regime-Dependent Predictability of Extreme Weather Events: Characteristic Event Types

Andrew C. Winters, Lance F. Bosart, and Daniel Keyser

Department of Atmospheric and Environmental Sciences
University at Albany, State University of New York, Albany, NY 12222

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Project Motivation

- One or several extreme weather events (EWEs) during a single season can contribute disproportionately to temperature and precipitation anomaly statistics for a particular season.

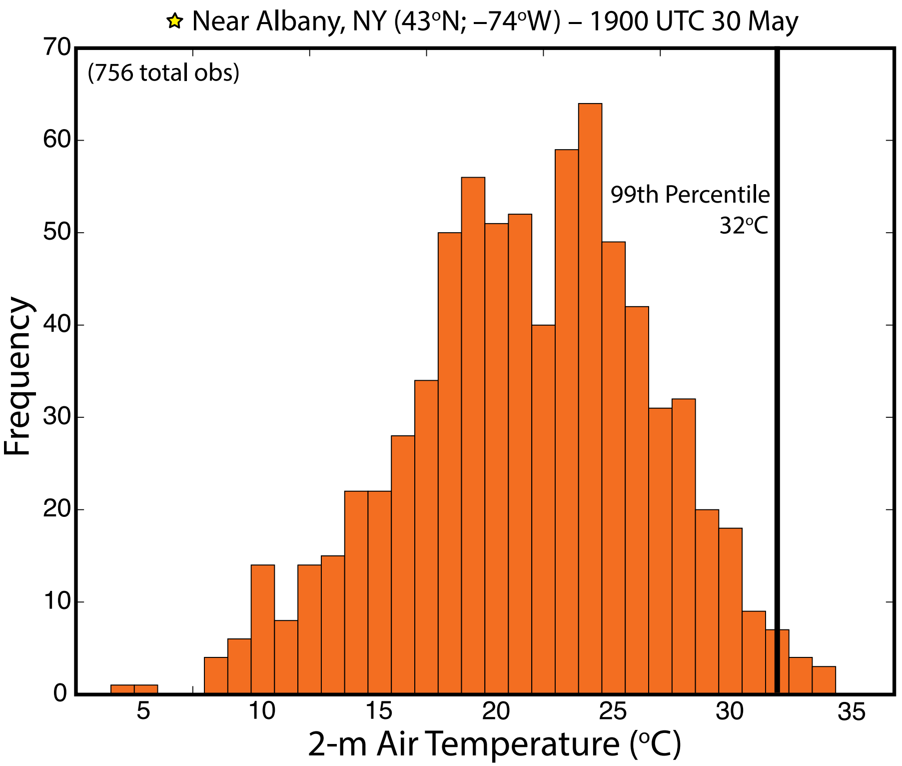
- The disproportionate contribution of EWEs to seasonal temperature and precipitation anomaly statistics suggests that EWEs need to be considered in understanding the dynamical and thermodynamic processes that operate at the weather–climate intersection.

- Consideration of EWEs may improve operational probabilistic temperature and precipitation forecasts in the 8–10 day time range.

Extreme Event Identification

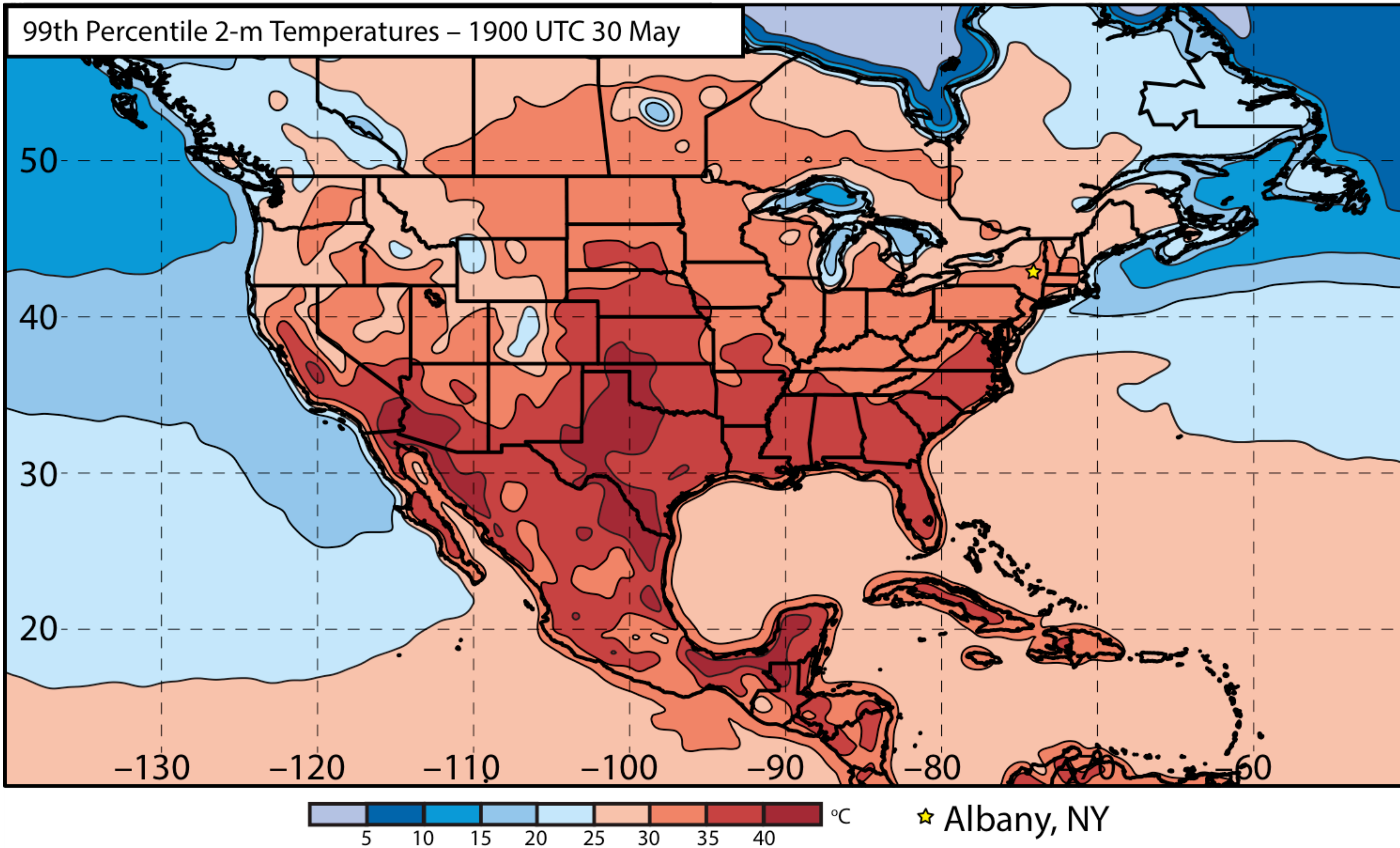
Extreme Warm Events:

- Employed 1-h forecasts of 2-m temperature from the CFSR (0.5°× 0.5°) at 6-h intervals
- Compiled data for each grid point within 21-day windows centered on each analysis time for 36 years, 1979–2014
  - Each grid point has 756 (21×36) data points for each analysis time
- Determined the temperature that corresponds to the **99th percentile** for each grid point at a given analysis time

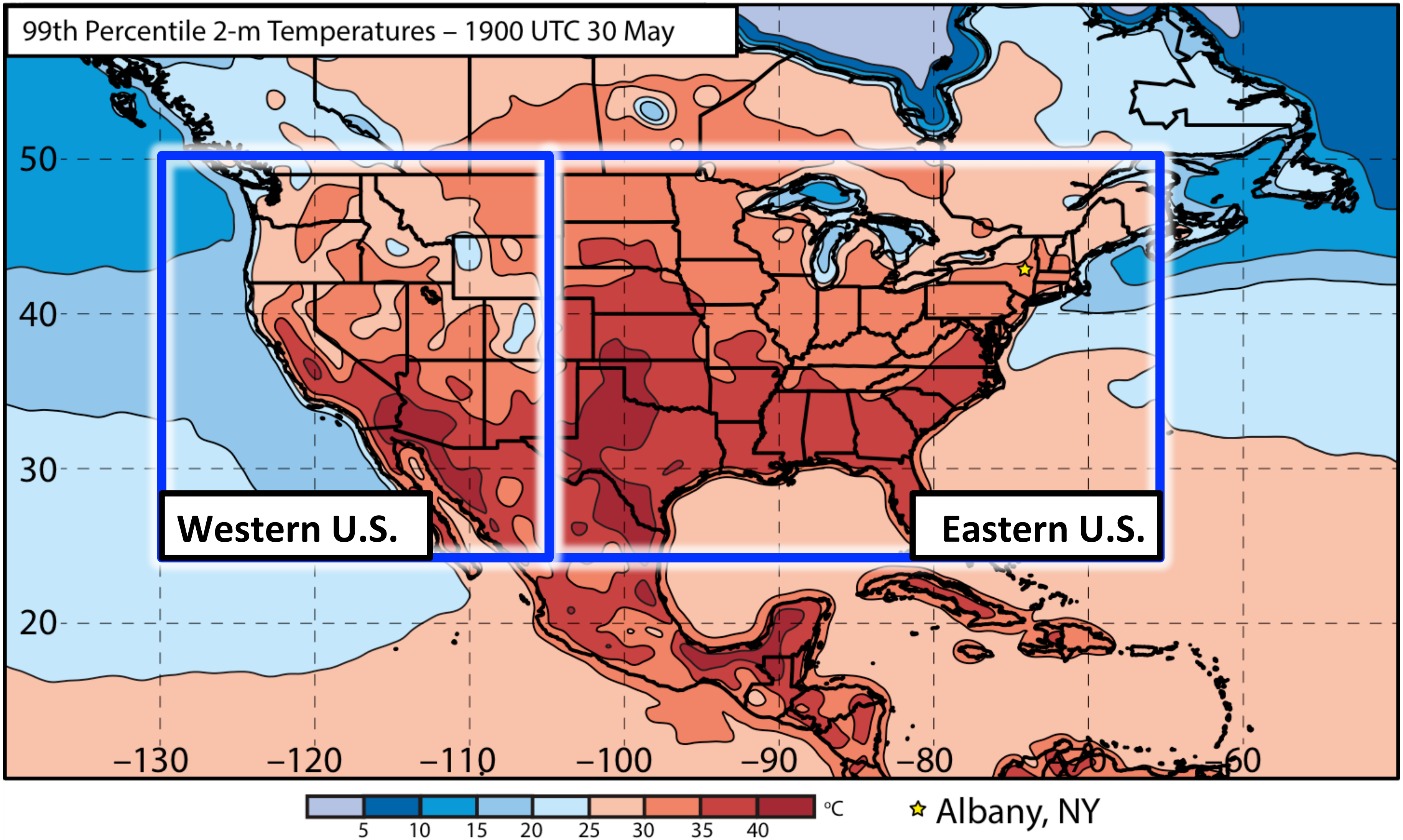


Frequency distribution of 2-m temperature at 1900 UTC 30 May for a grid point near Albany, NY

Extreme Event Identification



Extreme Event Identification



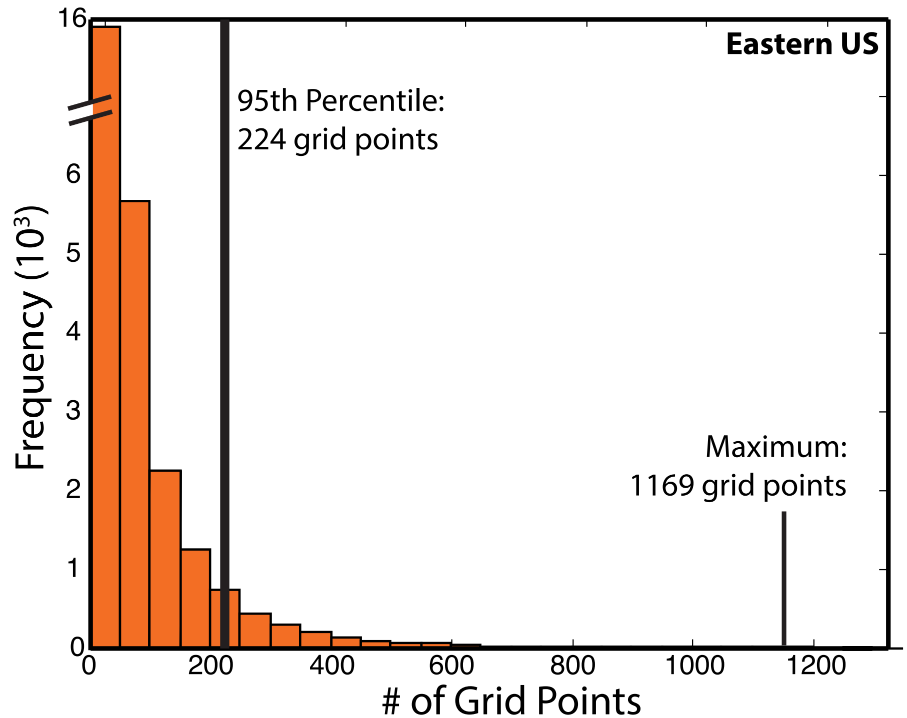
Extreme Event Identification

Extreme Warm Events:

- Cataloged times during which at least one grid point was characterized by a temperature > **99th percentile**

- Ranked times within each domain by the number of grid points > **99th percentile**

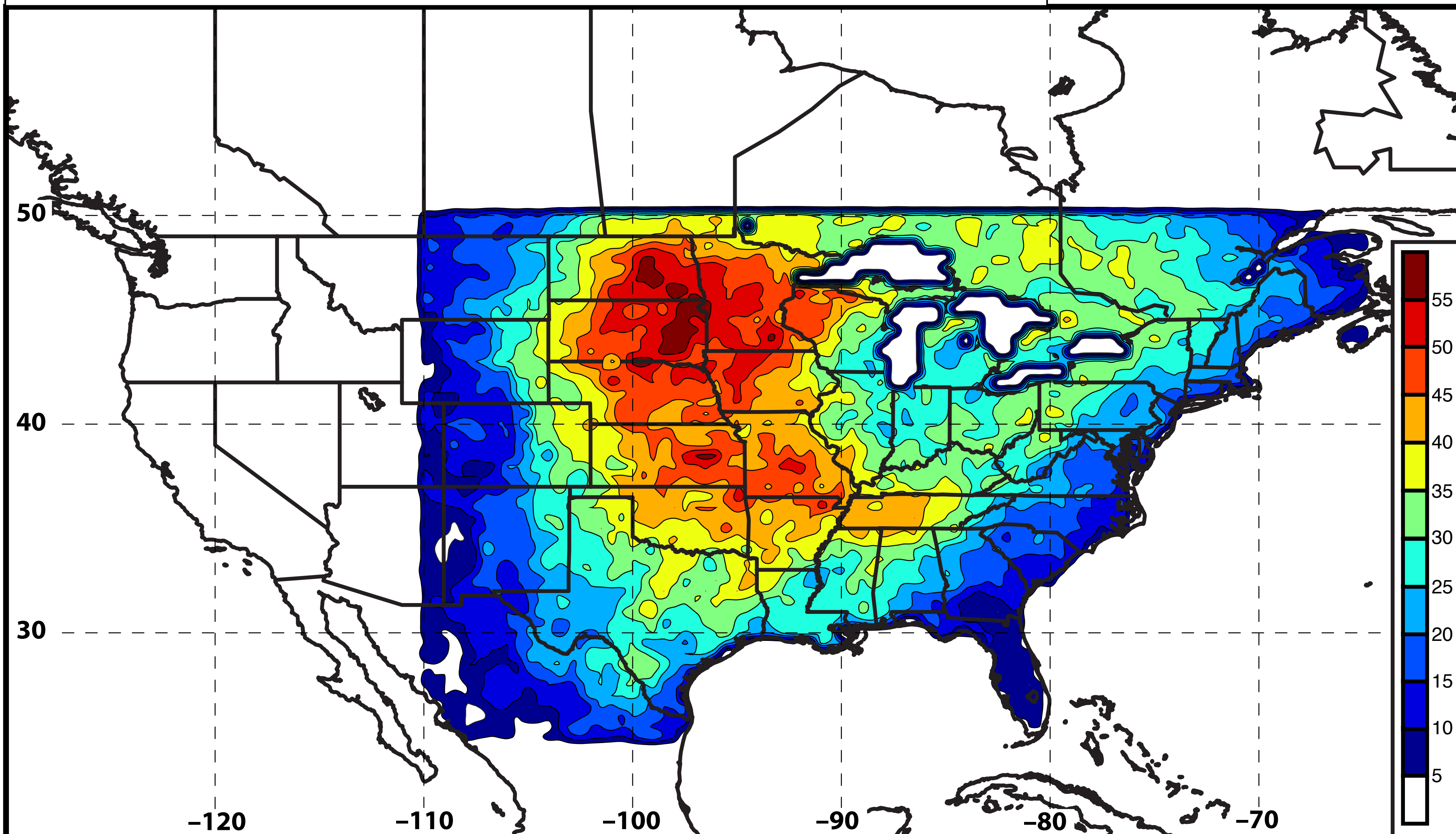
- Identified times that rank in the **top 5%** in terms of the number of grid points > **99th percentile** within each domain as **extreme warm events**



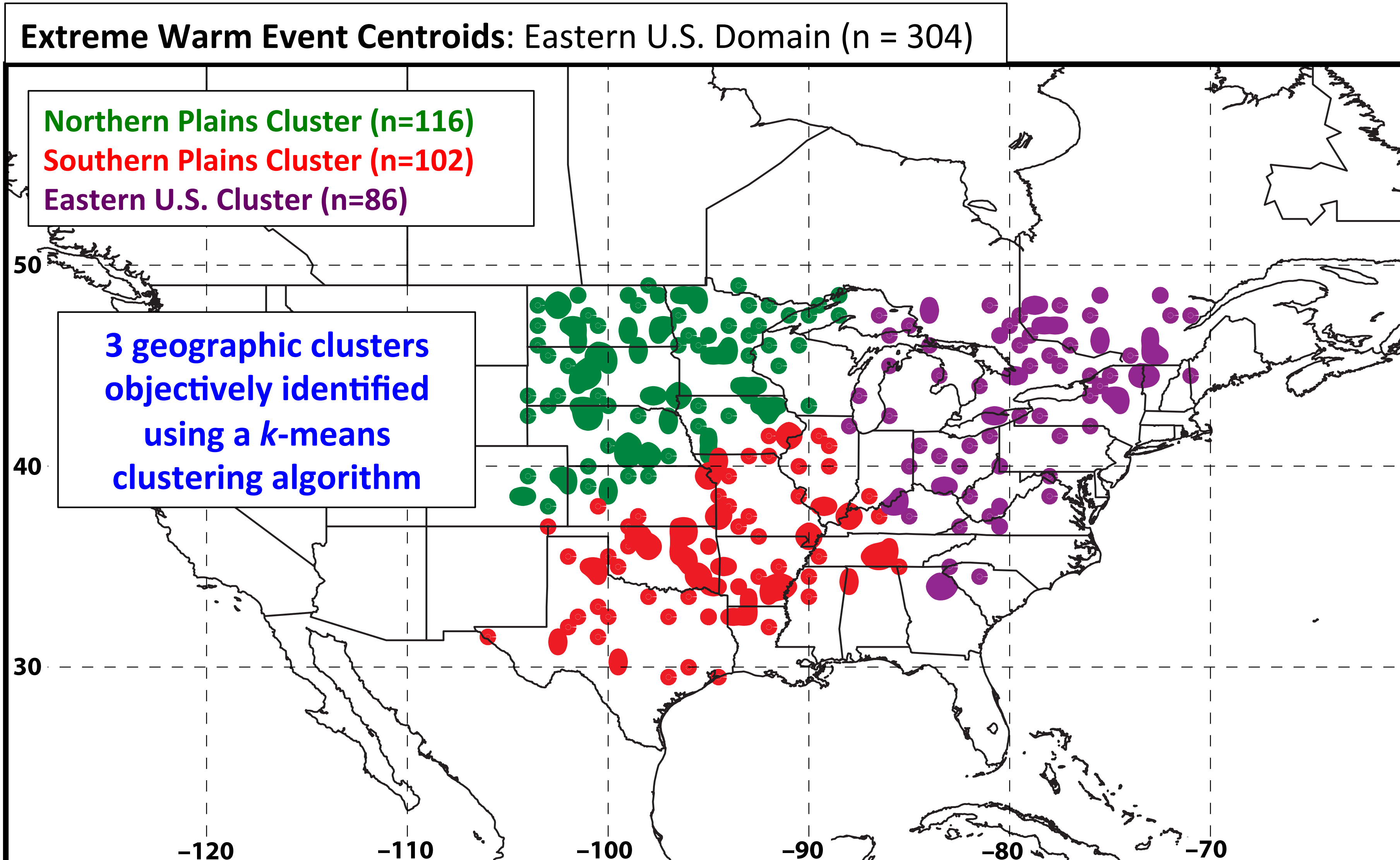
Frequency distribution of times exhibiting at least one grid point > 99th percentile

Extreme Event Identification

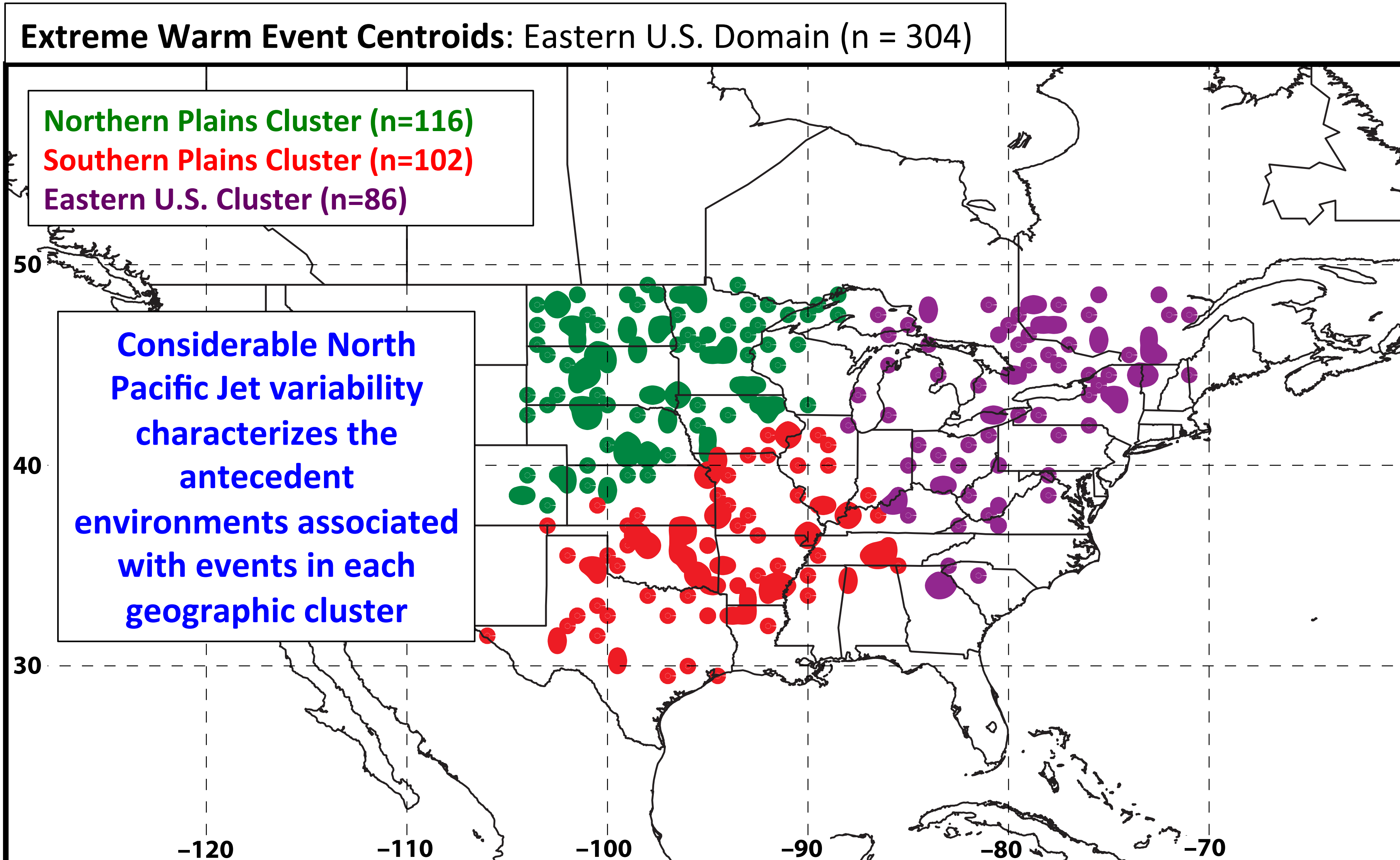
Extreme Warm Event Frequency: Eastern U.S. Domain (n = 304)



Extreme Event Identification



Extreme Event Identification



Antecedent Environments Associated with Cool-Season (Sept.–May) EWEs in the Context of North Pacific Jet Variability

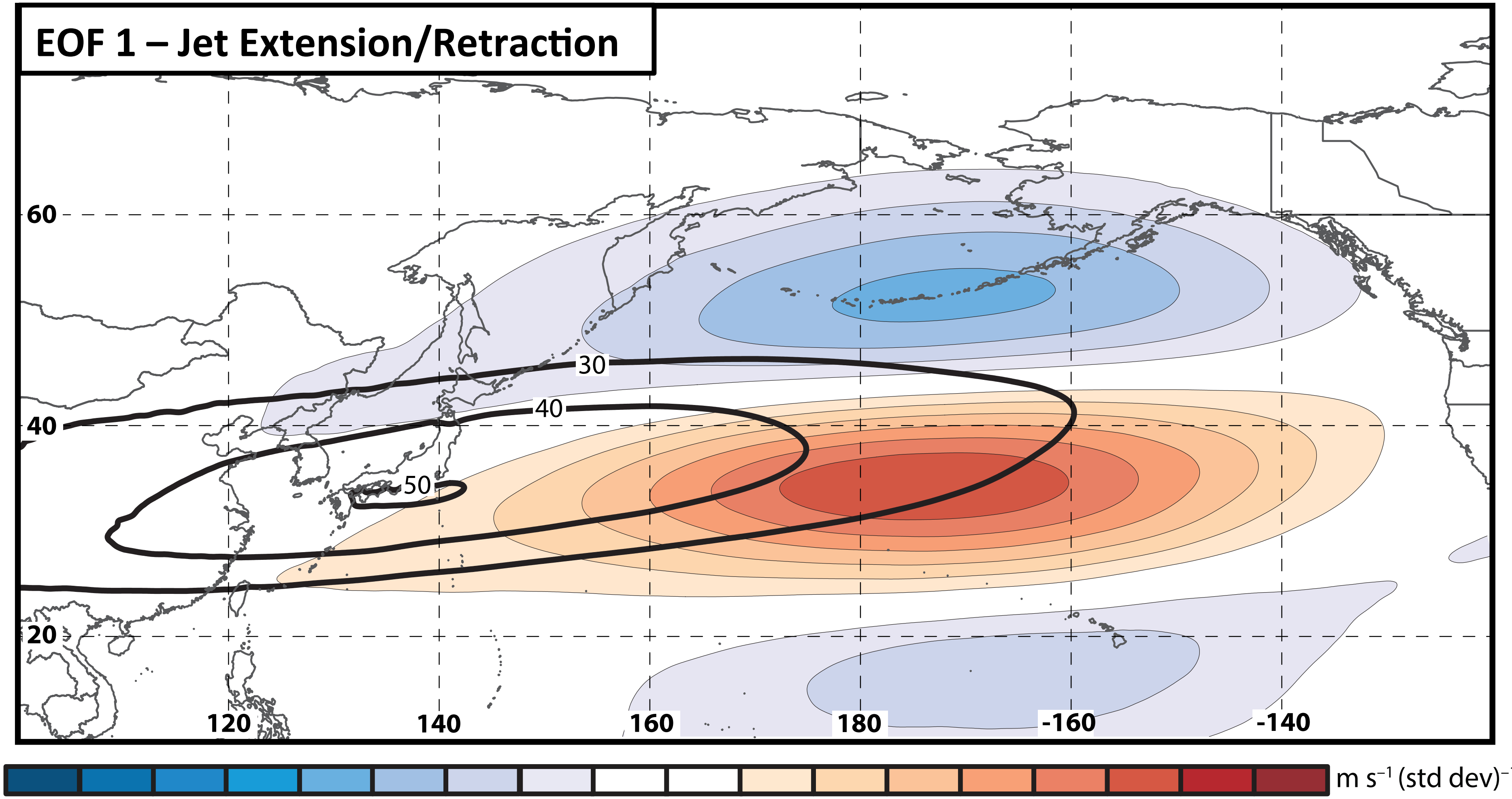
250-hPa North Pacific Zonal Wind Variability

- Removed the mean and the annual and diurnal cycles from 6-hourly, 250-hPa zonal wind data from the CFSR (1979–2014)
- 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 North Pacific Jet:

- Athanasiadis et al. (2010)
- Jaffe et al. (2011)
- Griffin and Martin (2016)

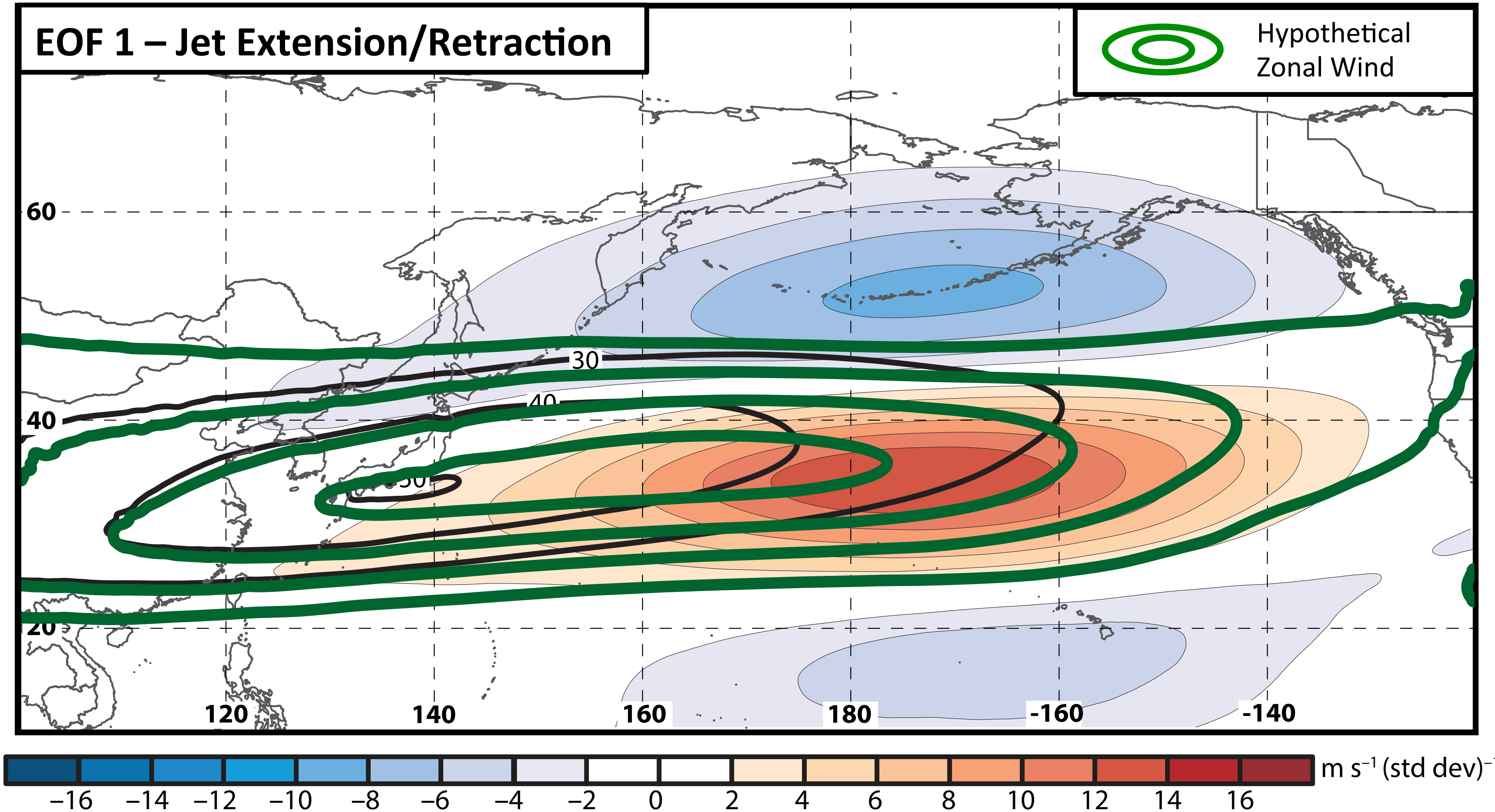
250-hPa North Pacific Zonal Wind Variability



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

250-hPa North Pacific Zonal Wind Variability



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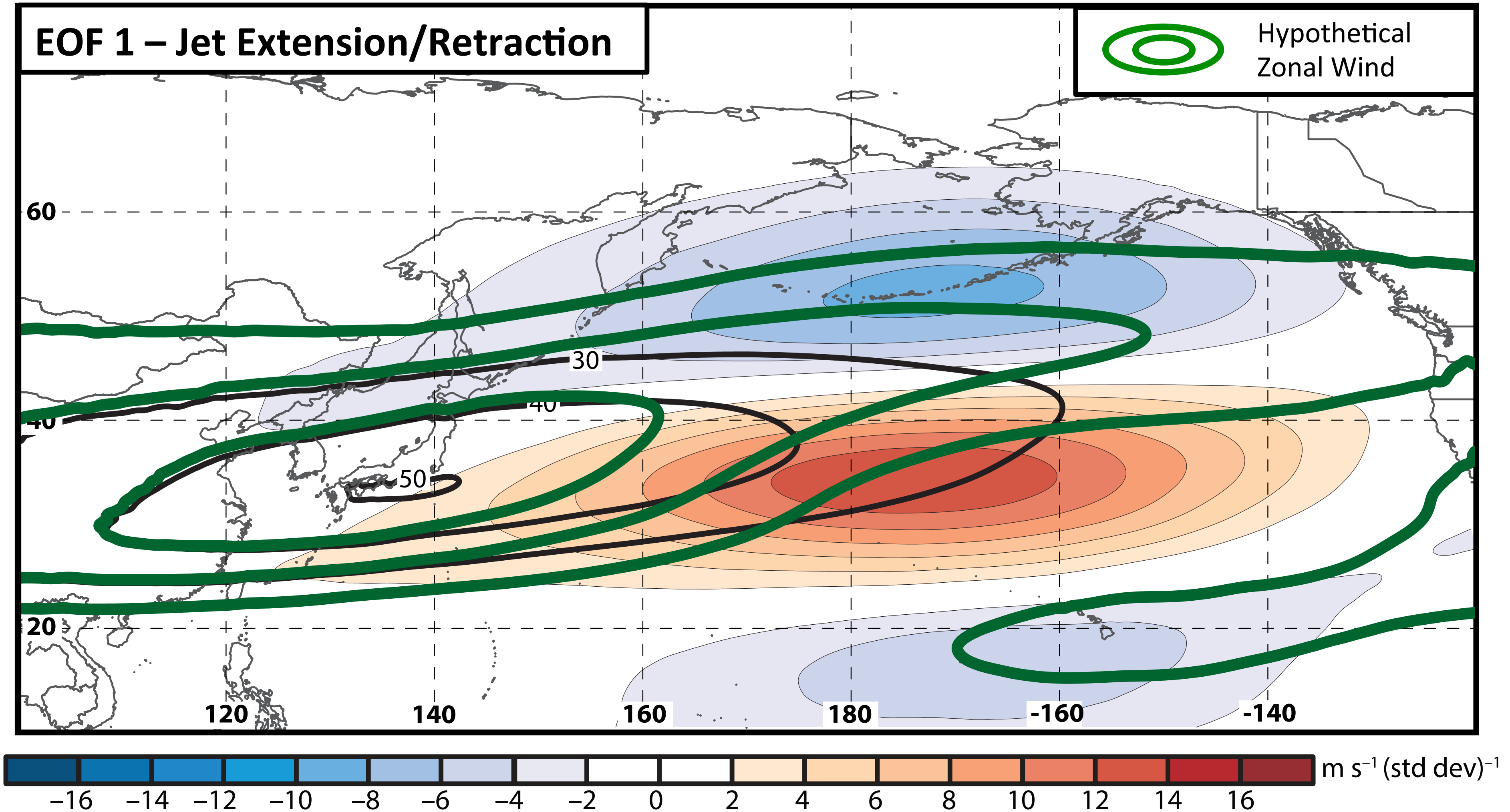

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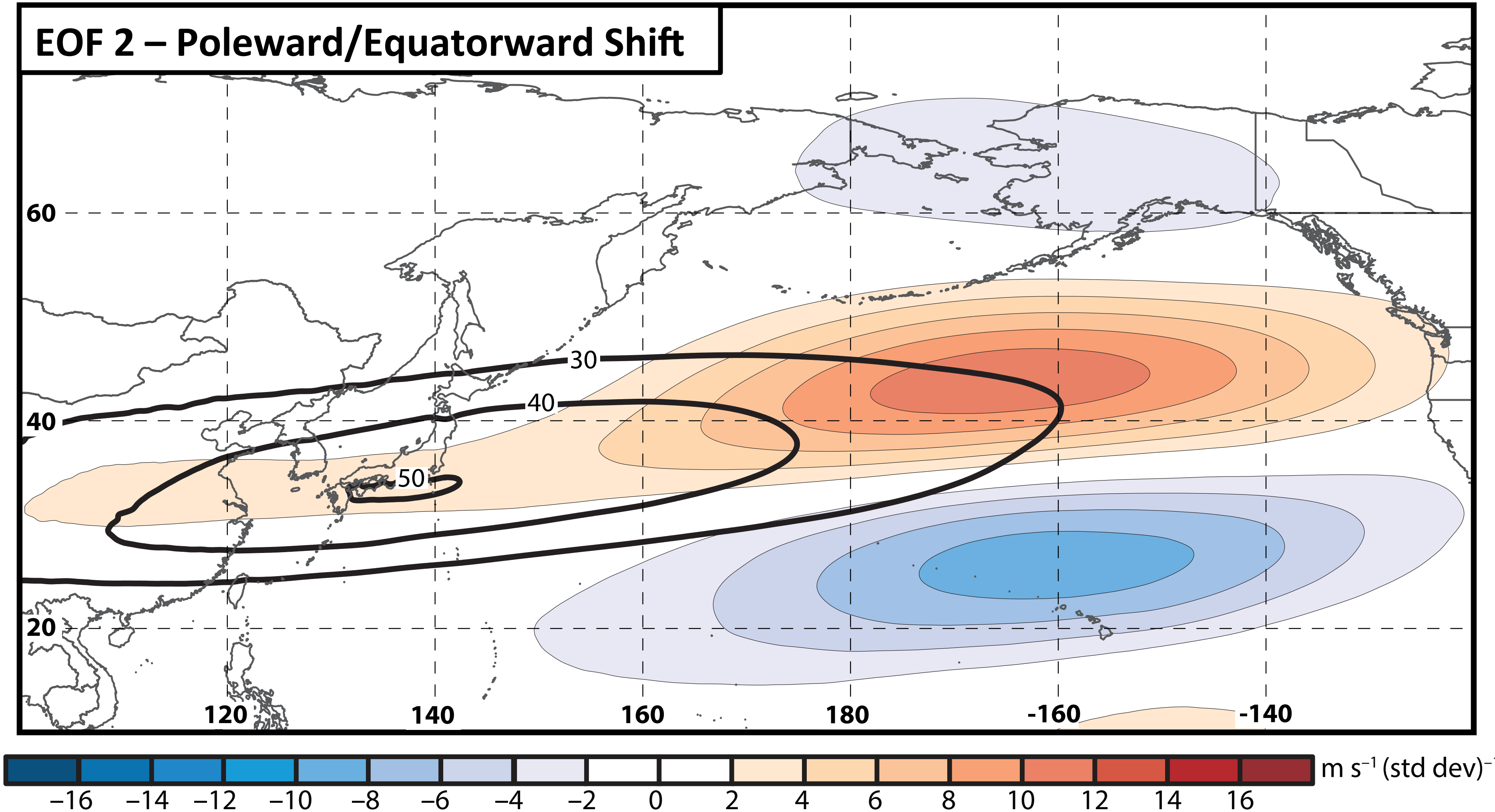
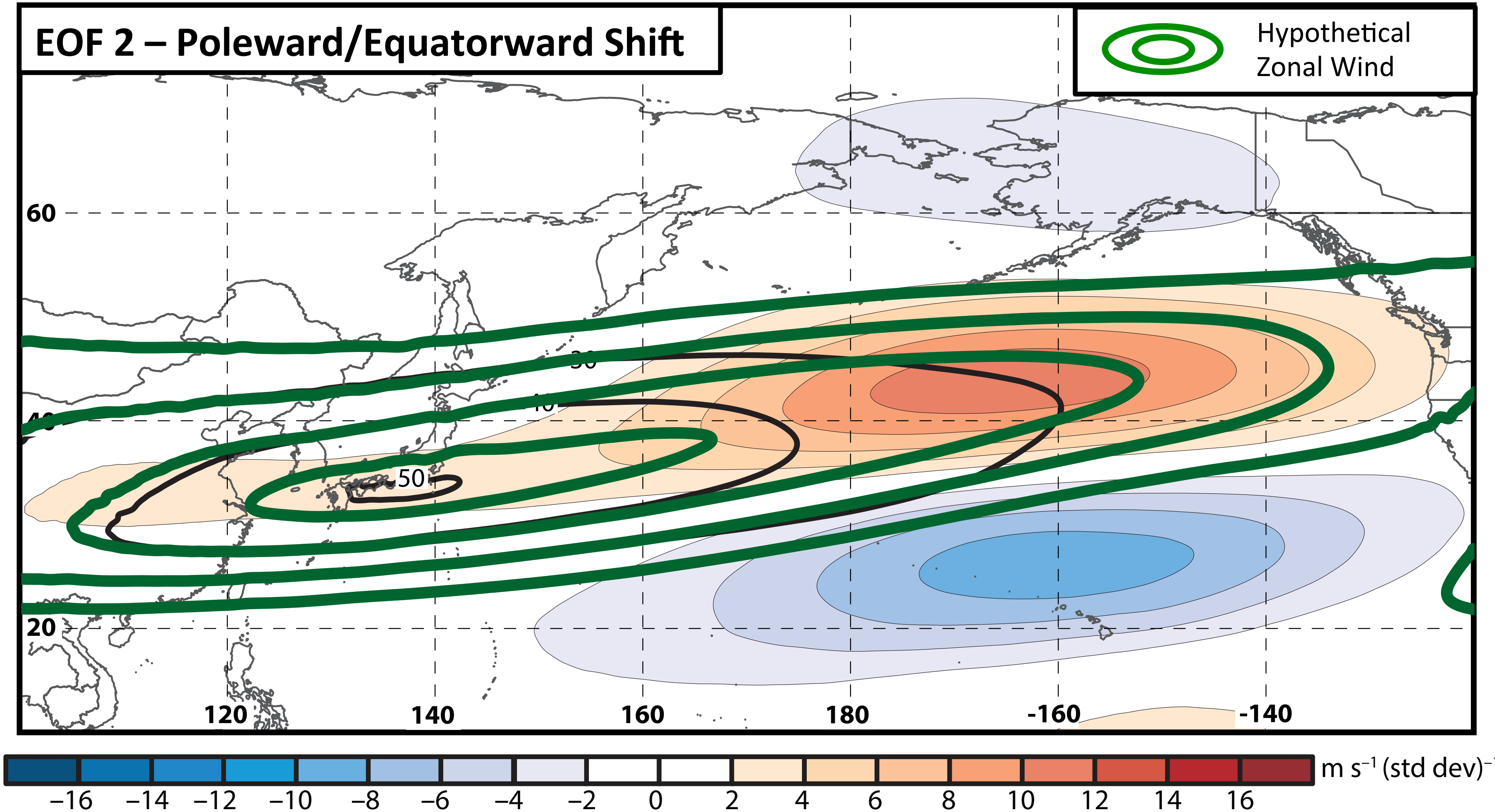
250-hPa North Pacific Zonal Wind Variability



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

250-hPa North Pacific Zonal Wind Variability



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+ EOF 2: Poleward Shift
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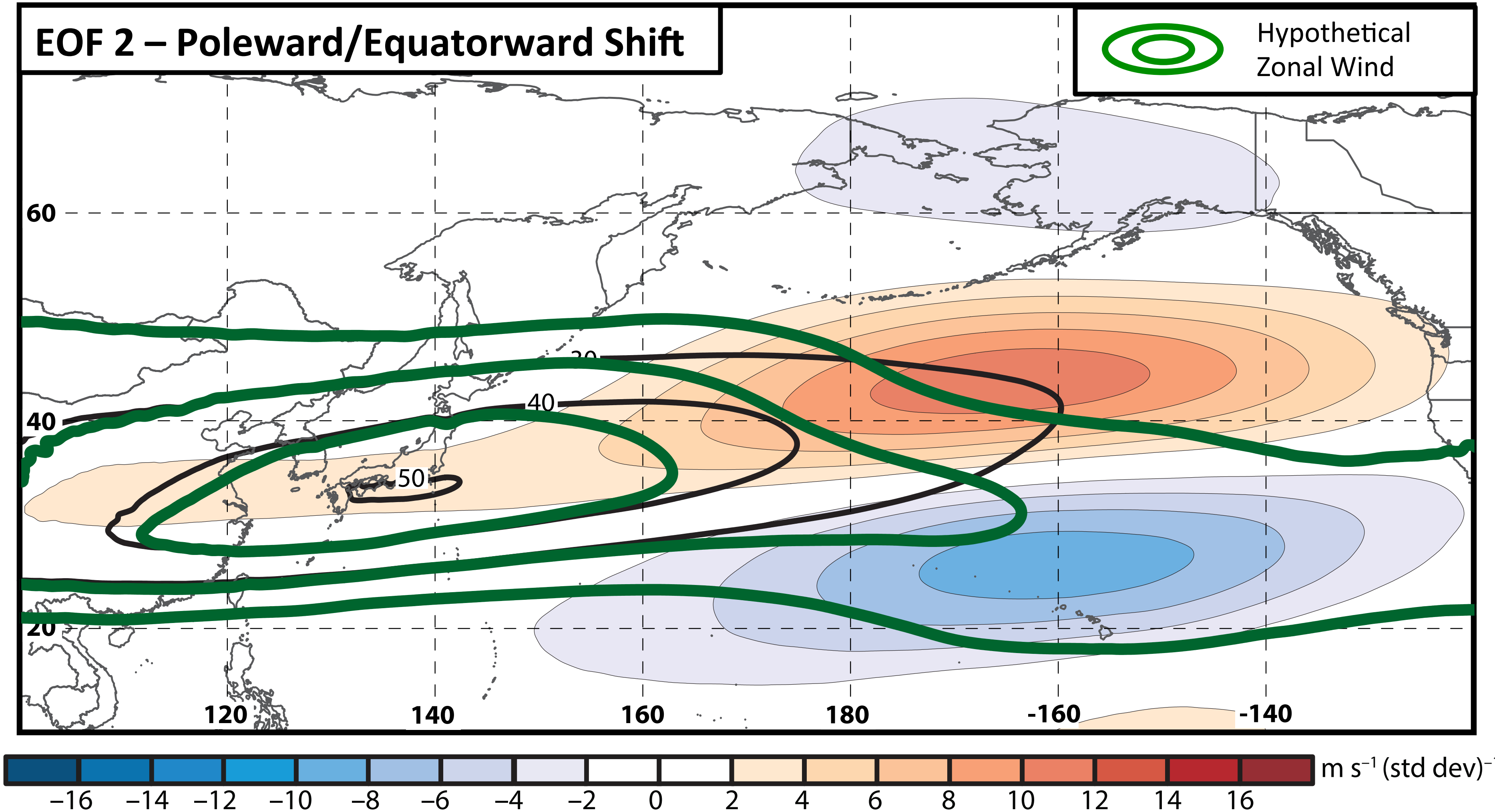
250-hPa North Pacific Zonal Wind Variability



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

+ EOF 2: Poleward Shift
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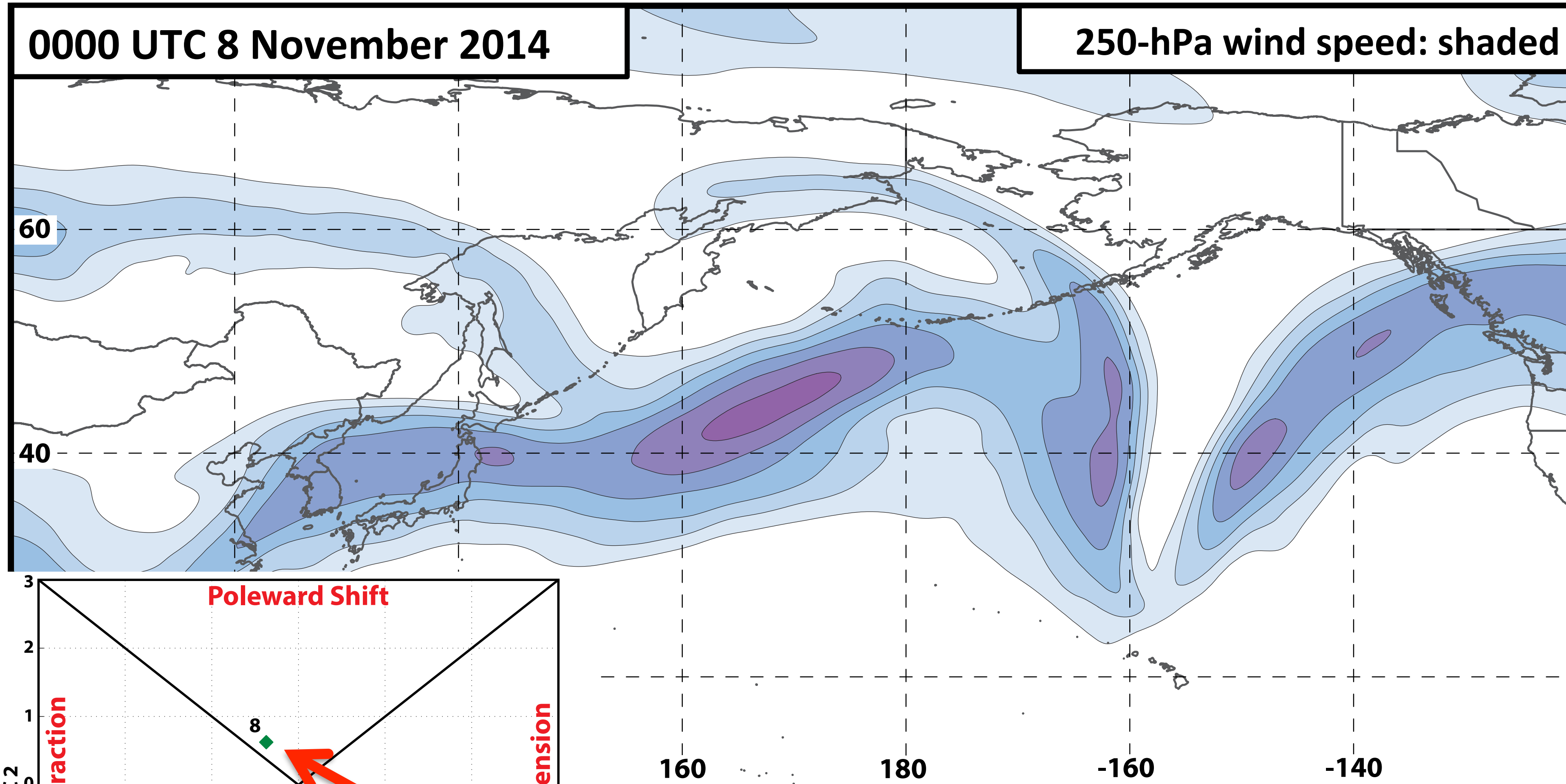
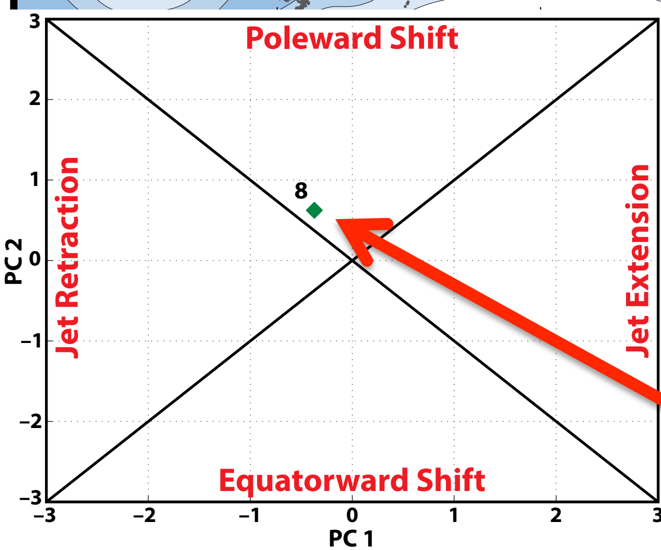
250-hPa North Pacific Zonal Wind Variability

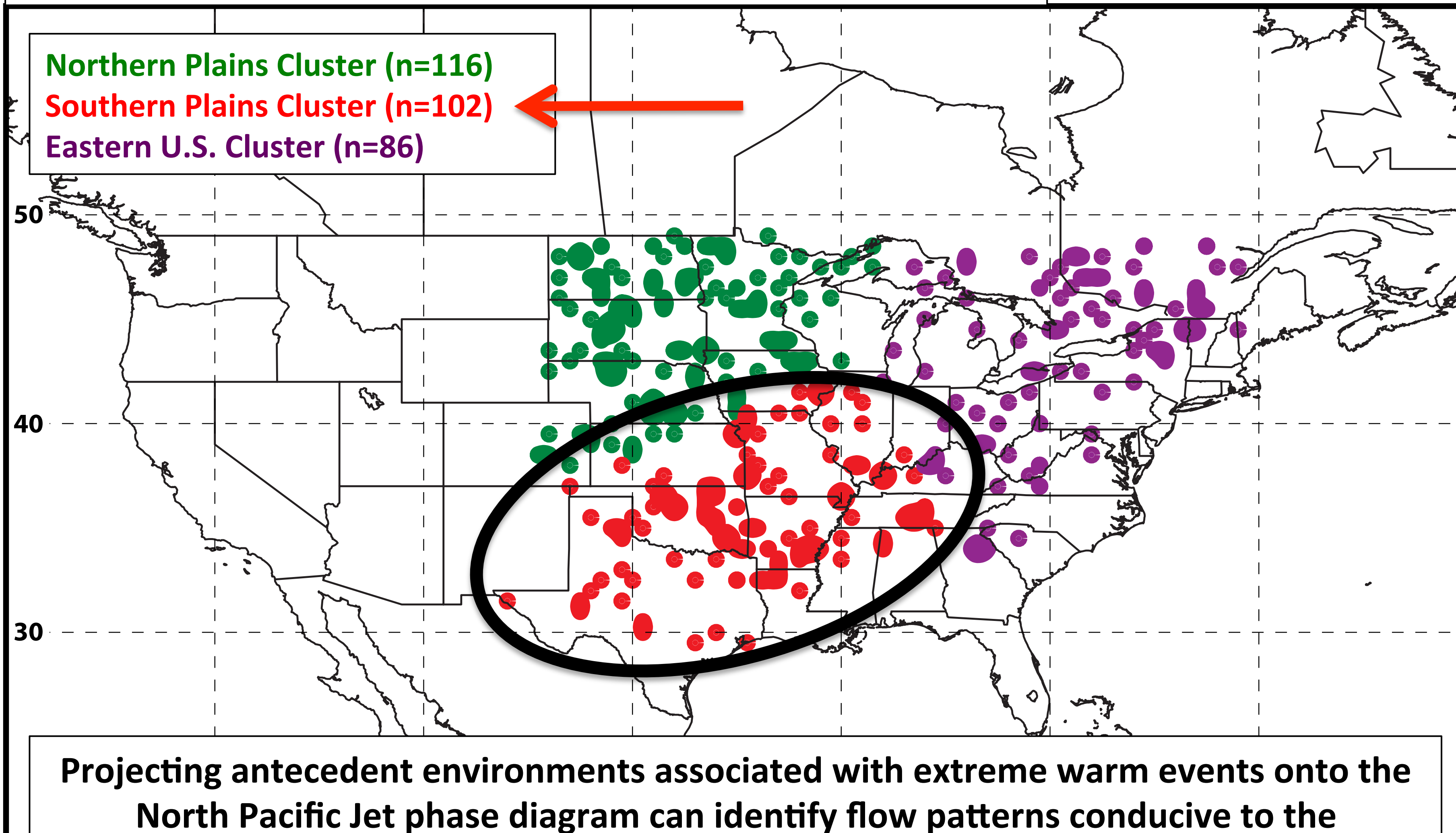




Instantaneous 250-hPa zonal wind anomalies can be projected onto EOF 1 and EOF 2, resulting in a point on a North Pacific Jet phase diagram

250-hPa North Pacific Zonal Wind Variability

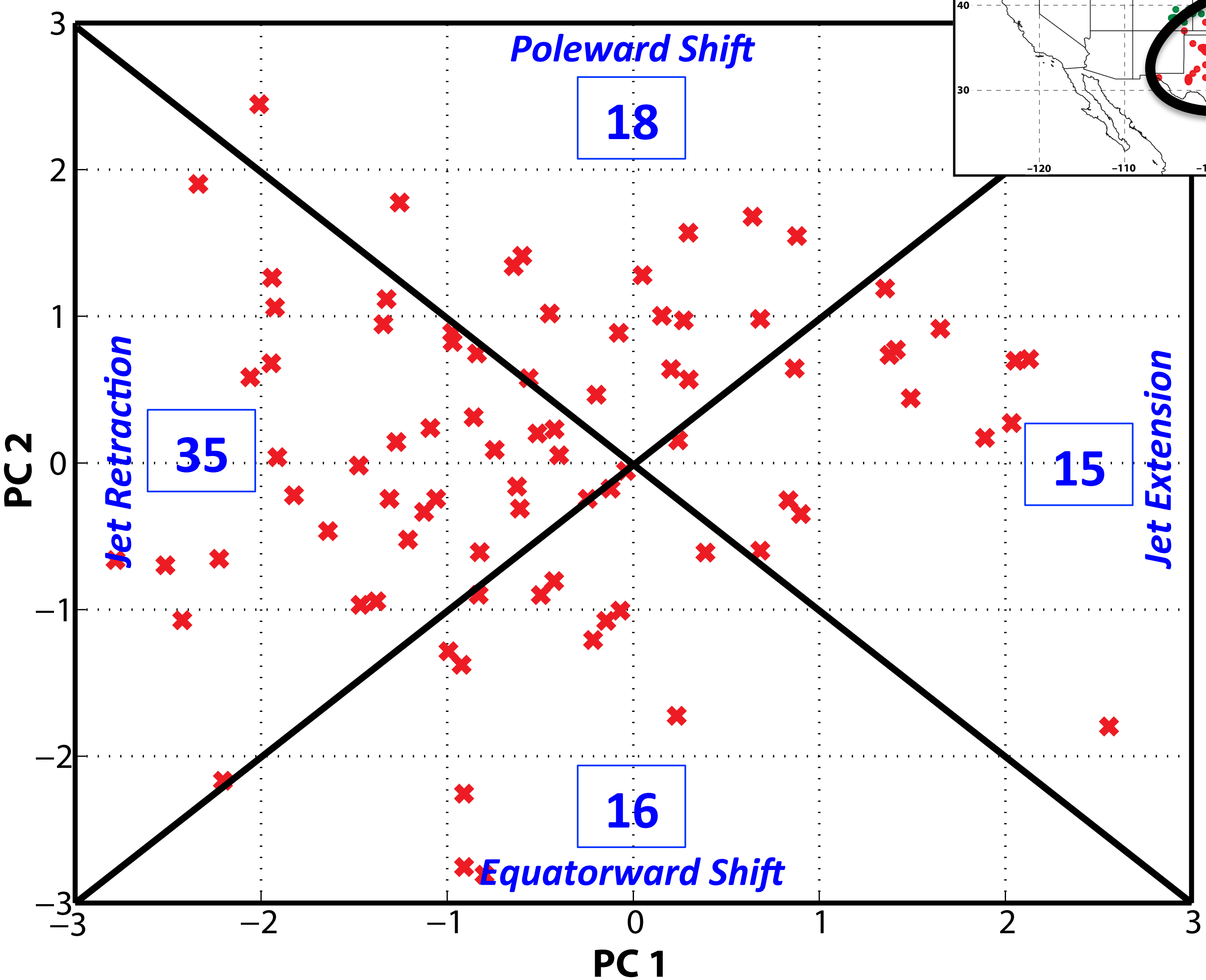
Extreme Warm Event Centroids: Eastern U.S. Domain (n = 304)

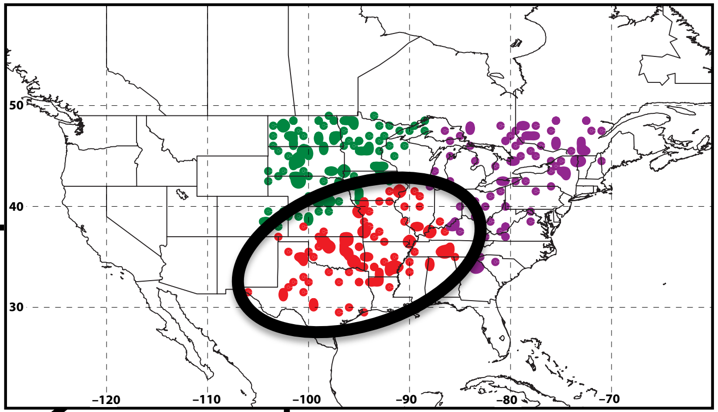


Projecting antecedent environments associated with extreme warm events onto the North Pacific Jet phase diagram can identify flow patterns conducive to the development of these events

Eastern U.S. – S. Plains Cluster

WARM EVENTS (n = 84)



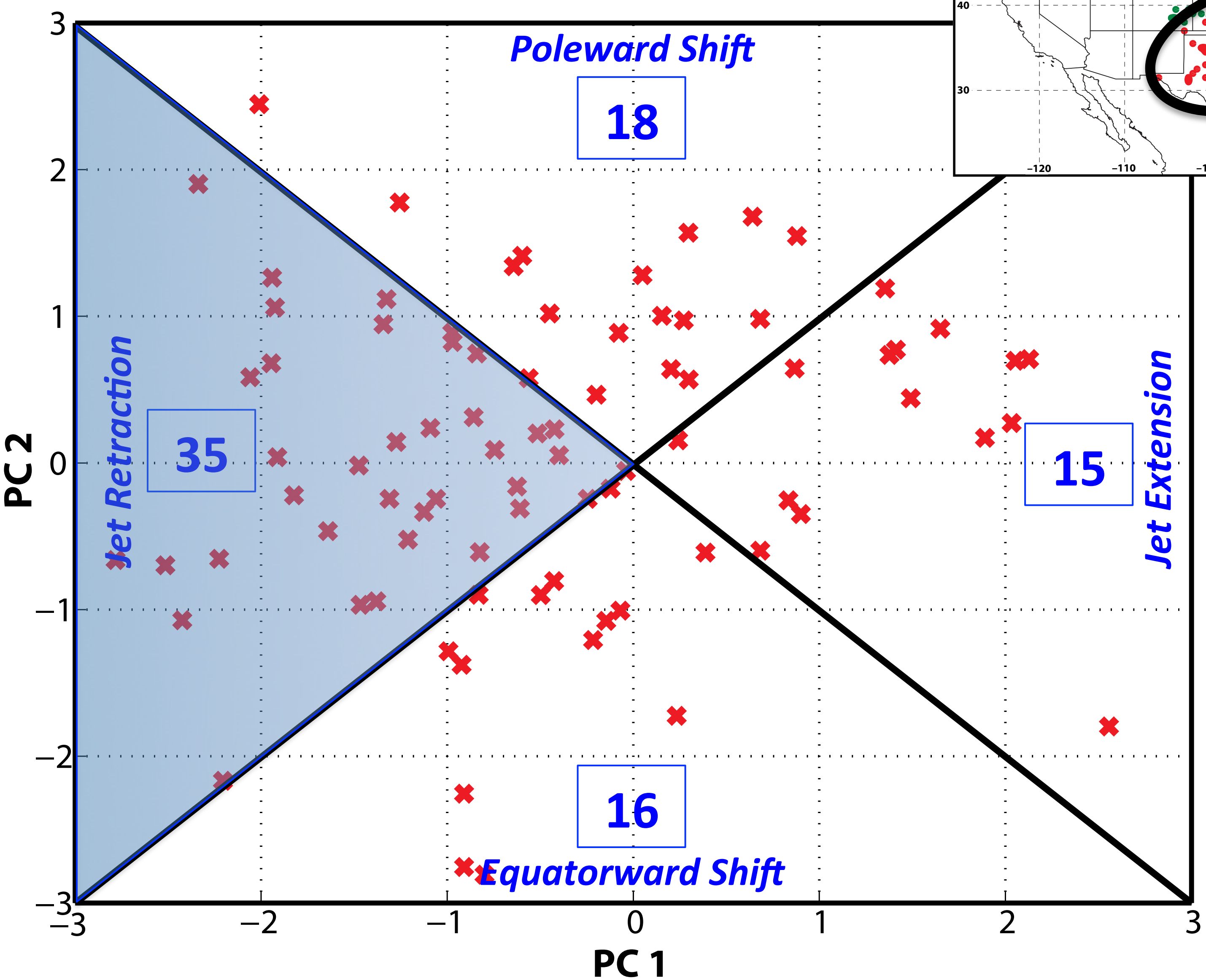


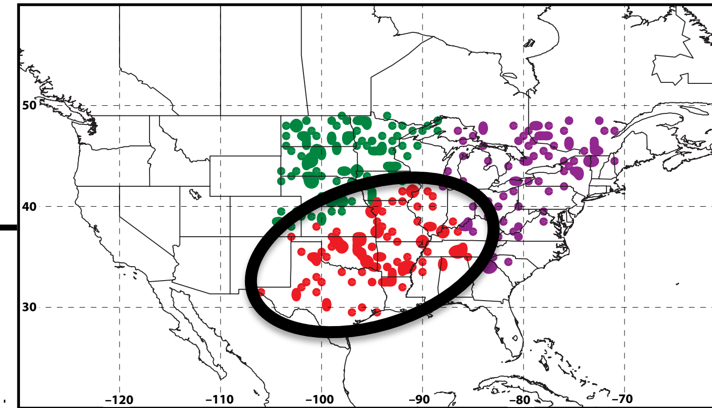
Events during Sept. – May projected onto phase diagram

Each point is an average of the PCs for 3–7 days prior to the event

Eastern U.S. – S. Plains Cluster

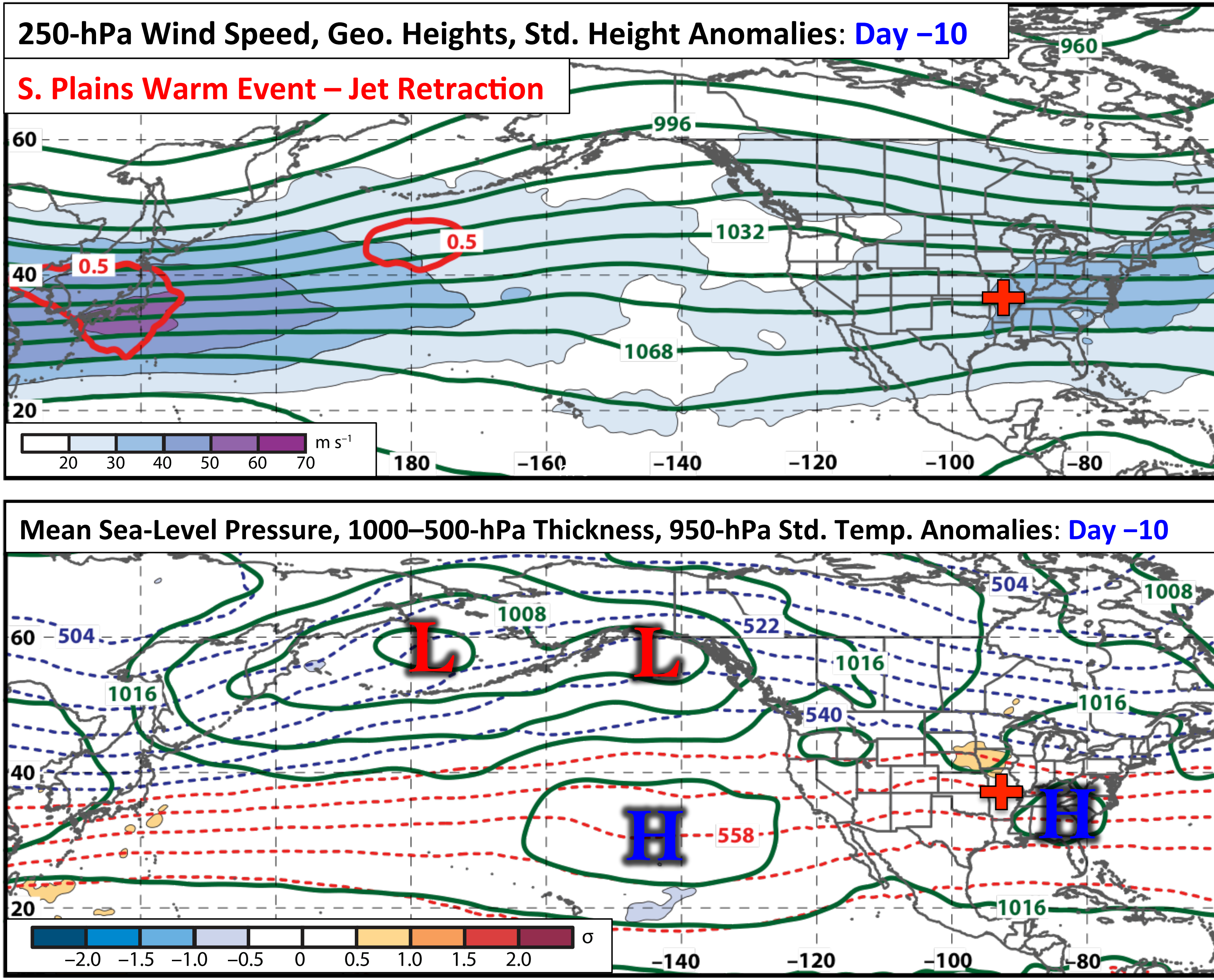
WARM EVENTS (n = 84)

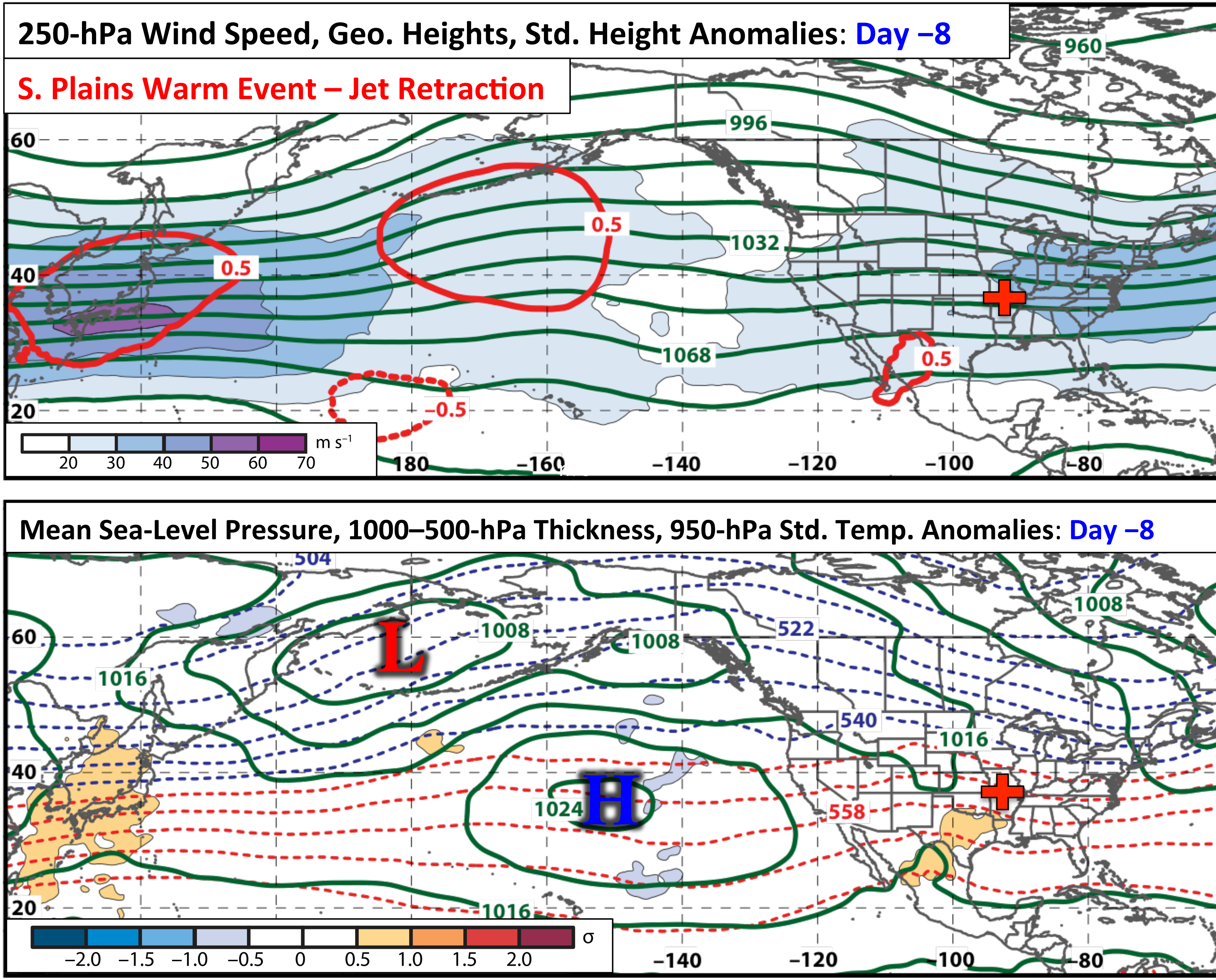




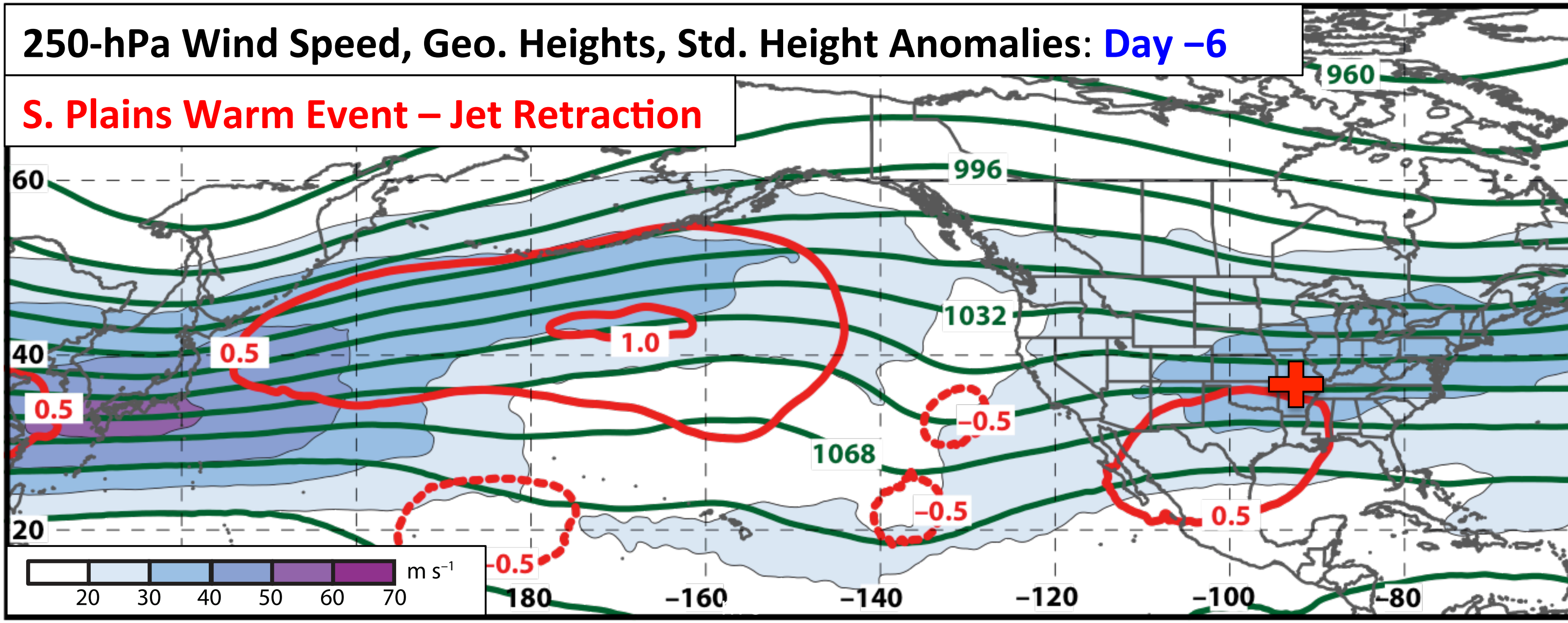
Events during Sept. – May projected onto phase diagram

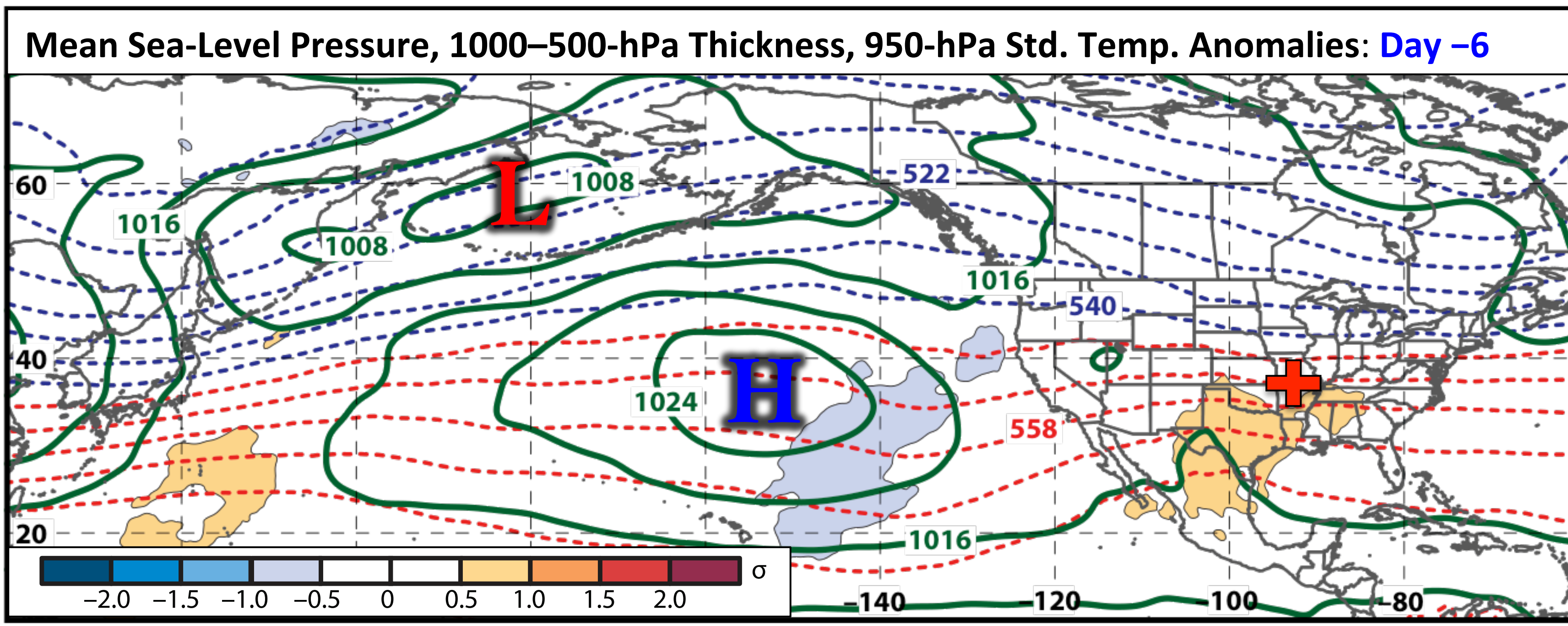
Each point is an average of the PCs for 3–7 days prior to the event

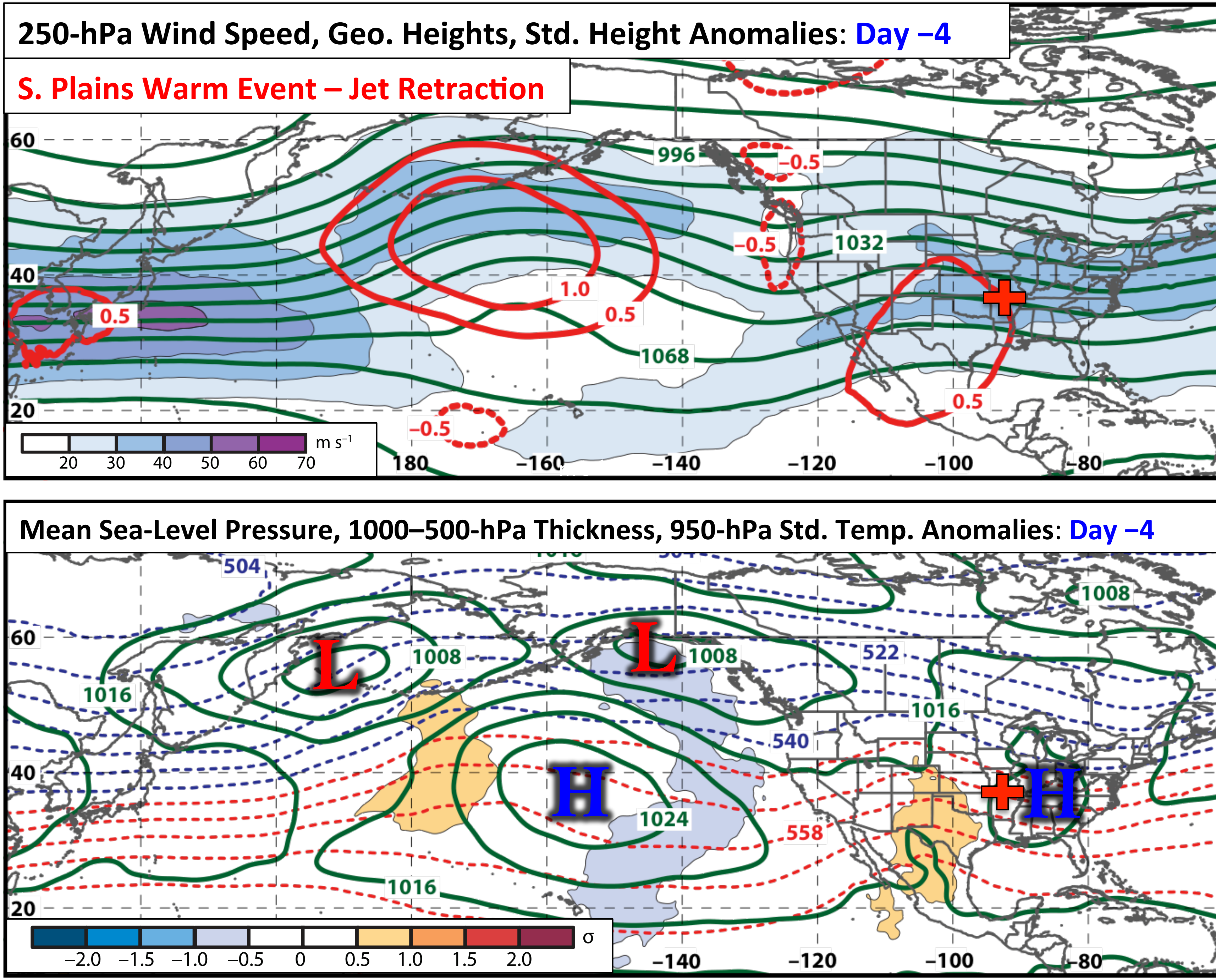

250-hPa Wind Speed, Geo. Heights, Std. Height Anomalies: Day −10
S. Plains Warm Event – Jet Retraction
960
996
1032
1068
0.5
0.5
60
40
20
m s⁻¹
20 30 40 50 60 70
180 −160 −140 −120 −100 −80
Mean Sea-Level Pressure, 1000–500-hPa Thickness, 950-hPa Std. Temp. Anomalies: Day −10
504
504
1008
1008
522
1016
1016
1016
1016
540
558
L
L
H
H
60
40
20
σ
−2.0 −1.5 −1.0 −0.5 0 0.5 1.0 1.5 2.0
−140 −120 −100 −80



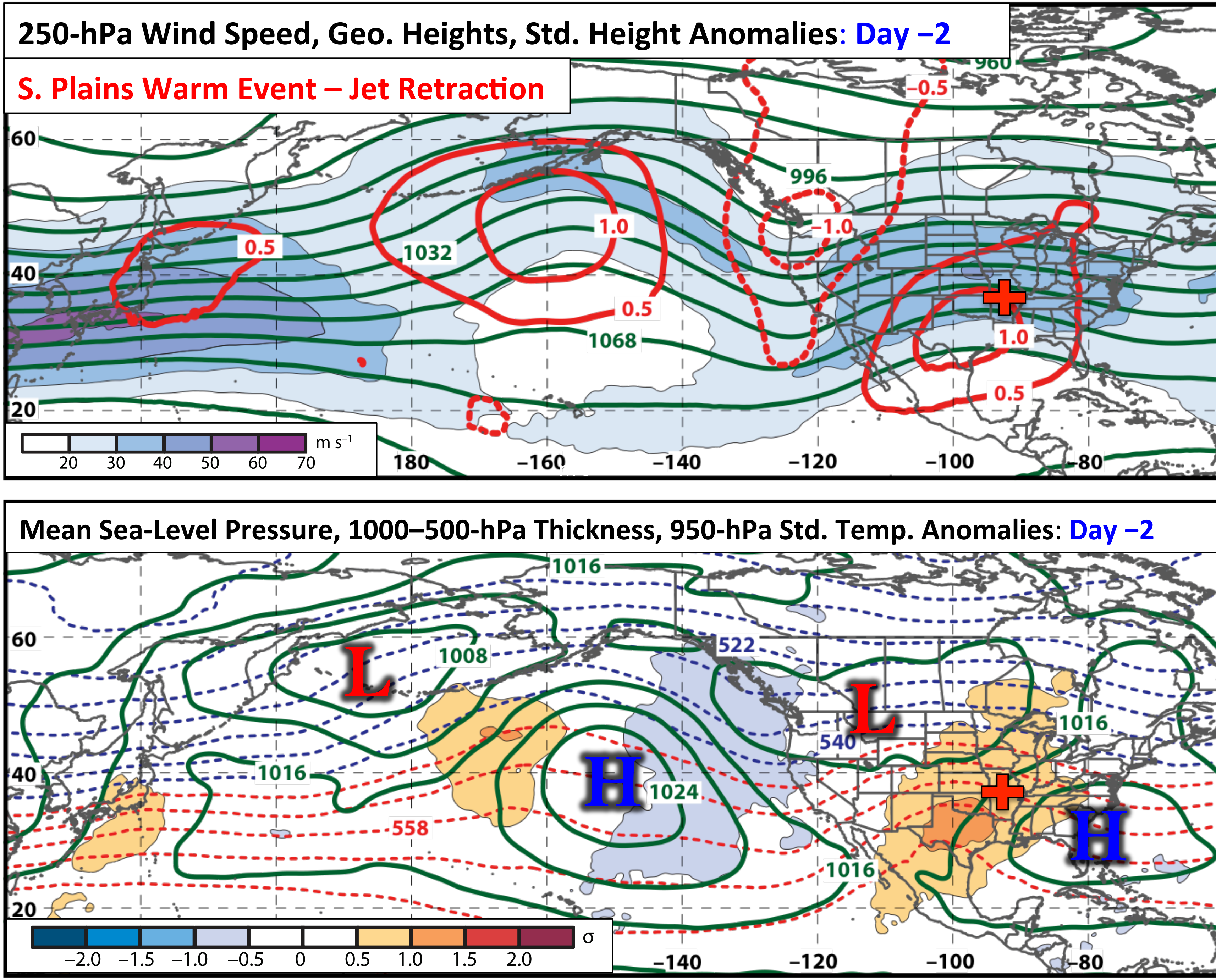
250-hPa Wind Speed, Geo. Heights, Std. Height Anomalies: Day −8
S. Plains Warm Event – Jet Retraction
960
996
1032
1068
0.5
0.5
0.5
−0.5
60
40
20
180
−160
−140
−120
−100
−80
m s−1
20 30 40 50 60 70
Mean Sea-Level Pressure, 1000–500-hPa Thickness, 950-hPa Std. Temp. Anomalies: Day −8
504
522
540
558
1008
1008
1008
1016
1016
1016
1024
L
H
60
40
20
−140
−120
−100
−80
σ
−2.0 −1.5 −1.0 −0.5 0 0.5 1.0 1.5 2.0


250-hPa Wind Speed, Geo. Heights, Std. Height Anomalies: Day −6
S. Plains Warm Event – Jet Retraction
960
996
1032
1068
0.5
1.0
−0.5
60
40
20
m s⁻¹
20 30 40 50 60 70
180 −160 −140 −120 −100 −80

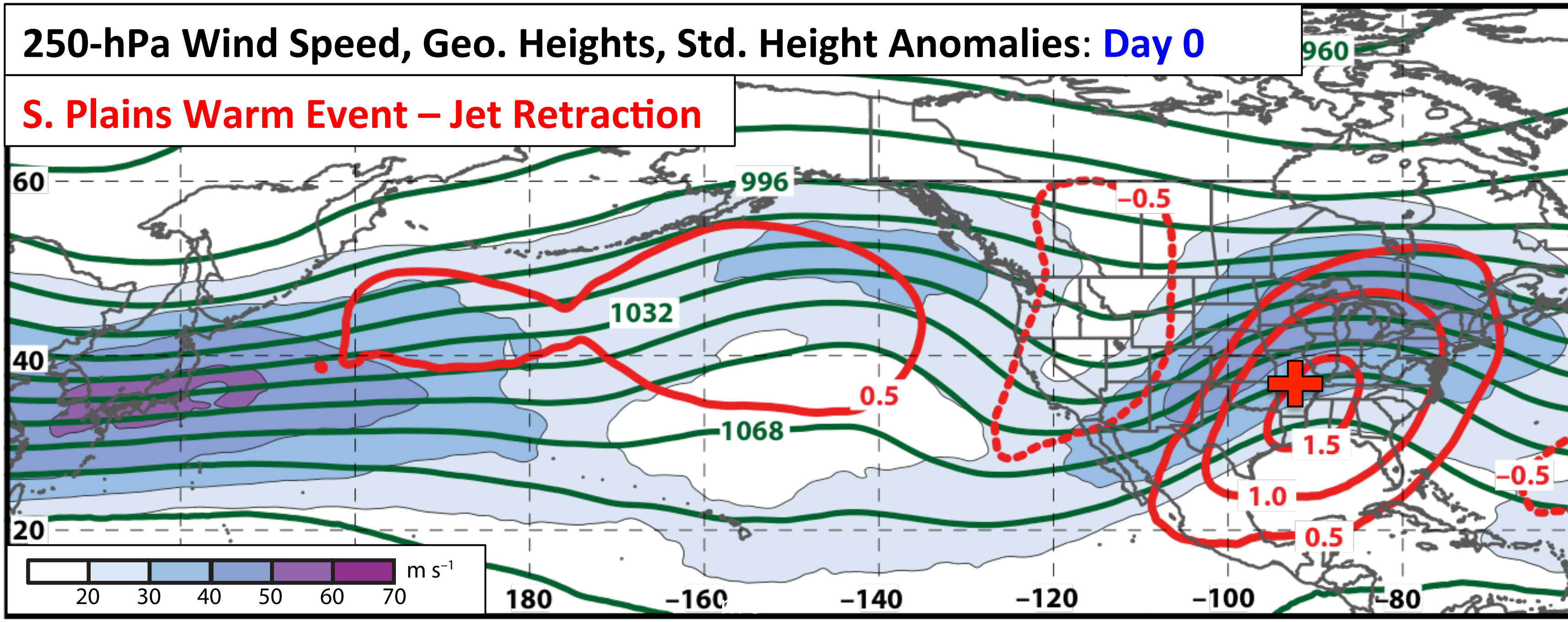

Mean Sea-Level Pressure, 1000–500-hPa Thickness, 950-hPa Std. Temp. Anomalies: Day −6
L
H
1008
1016
1024
522
540
558
60
40
20
σ
−2.0 −1.5 −1.0 −0.5 0 0.5 1.0 1.5 2.0
−140 −120 −100 −80

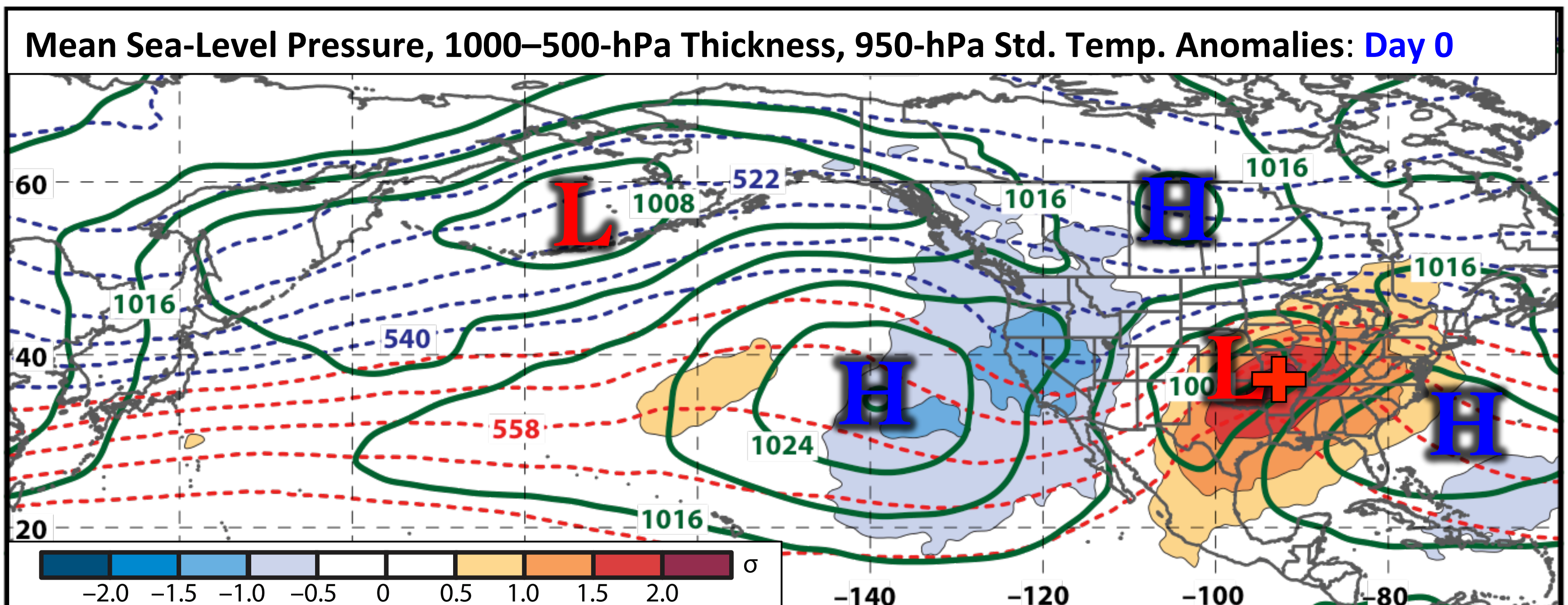


250-hPa Wind Speed, Geo. Heights, Std. Height Anomalies: Day −4
S. Plains Warm Event – Jet Retraction
60
40
20
996
1032
1068
0.5
1.0
−0.5
m s⁻¹
20 30 40 50 60 70
180 −160 −140 −120 −100 −80
Mean Sea-Level Pressure, 1000–500-hPa Thickness, 950-hPa Std. Temp. Anomalies: Day −4
504
522
540
558
1008
1016
1024
L
H
σ
−2.0 −1.5 −1.0 −0.5 0 0.5 1.0 1.5 2.0
−140 −120 −100 −80



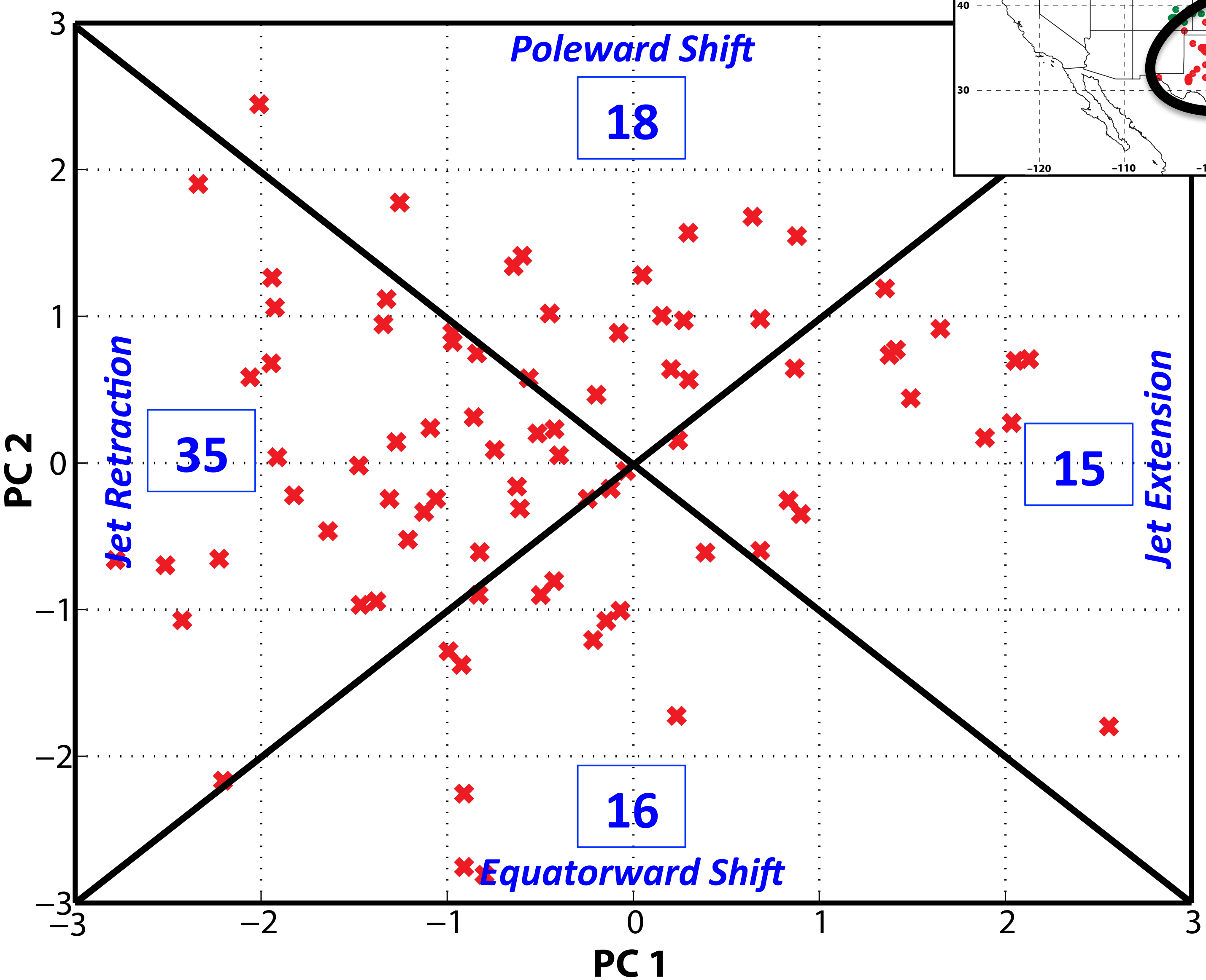
250-hPa Wind Speed, Geo. Heights, Std. Height Anomalies: Day −2
S. Plains Warm Event – Jet Retraction
960
−0.5
996
−1.0
1.0
0.5
1032
1068
60
40
20
180
−160
−140
−120
−100
−80
m s⁻¹
20
30
40
50
60
70
Mean Sea-Level Pressure, 1000–500-hPa Thickness, 950-hPa Std. Temp. Anomalies: Day −2
1016
1008
522
540
558
1024
L
H
σ
−2.0
−1.5
−1.0
−0.5
0
0.5
1.0
1.5
2.0

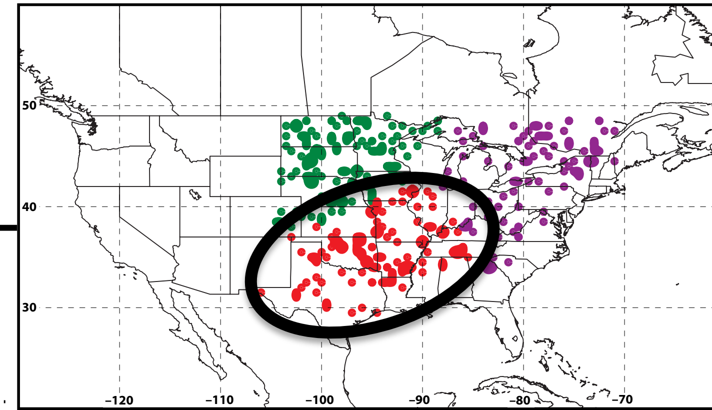

250-hPa Wind Speed, Geo. Heights, Std. Height Anomalies: Day 0
S. Plains Warm Event – Jet Retraction
960
996
1032
1068
–0.5
0.5
1.5
1.0
0.5
–0.5
60
40
20
m s–1
20 30 40 50 60 70
180
–160
–140
–120
–100
–80


Mean Sea-Level Pressure, 1000–500-hPa Thickness, 950-hPa Std. Temp. Anomalies: Day 0
L
1008
522
1016
H
1016
1016
1016
540
H
558
1024
100
L
H
1016
60
40
20
σ
–2.0 –1.5 –1.0 –0.5 0 0.5 1.0 1.5 2.0
–140
–120
–100
–80

Eastern U.S. – S. Plains Cluster

WARM EVENTS (n = 84)



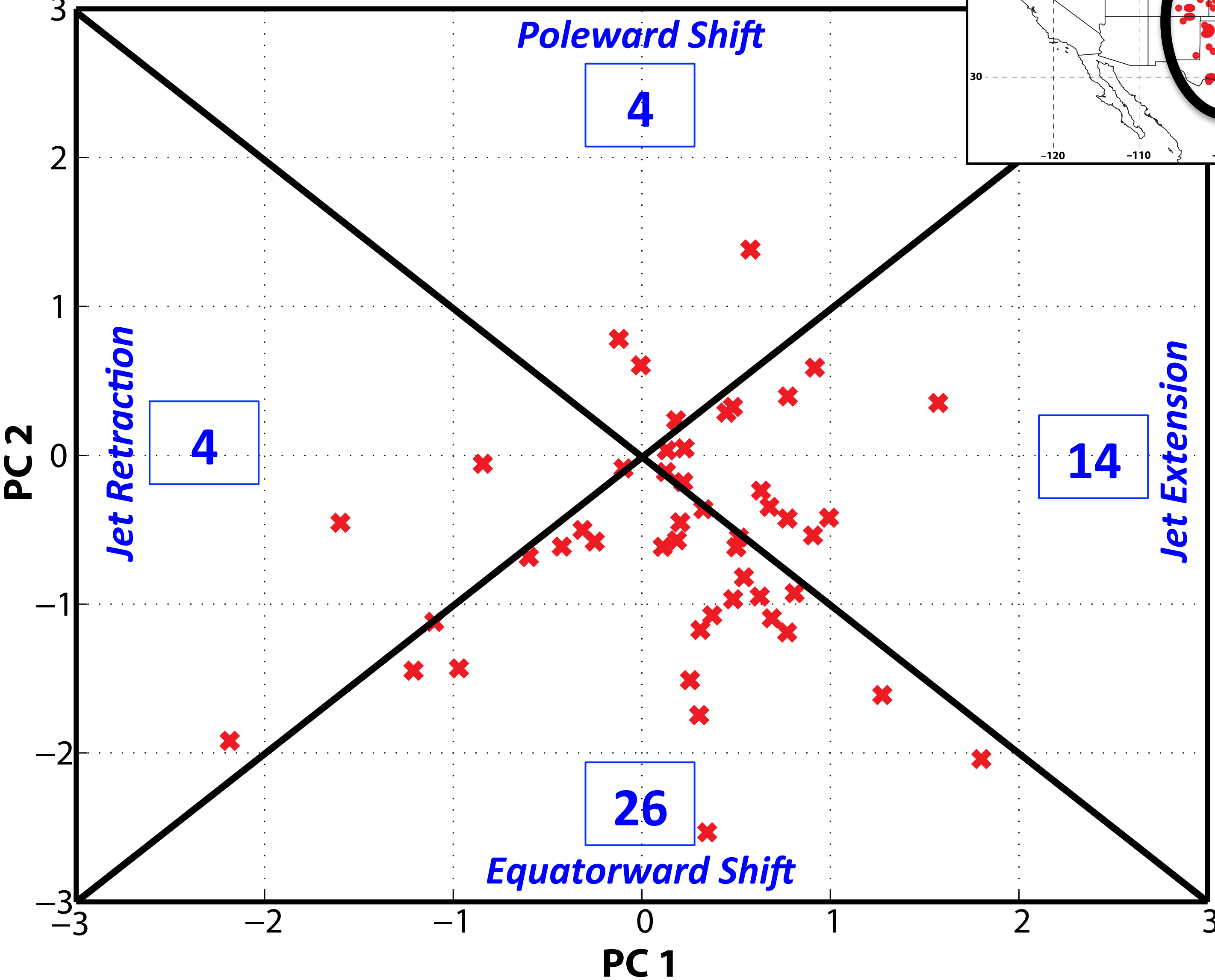


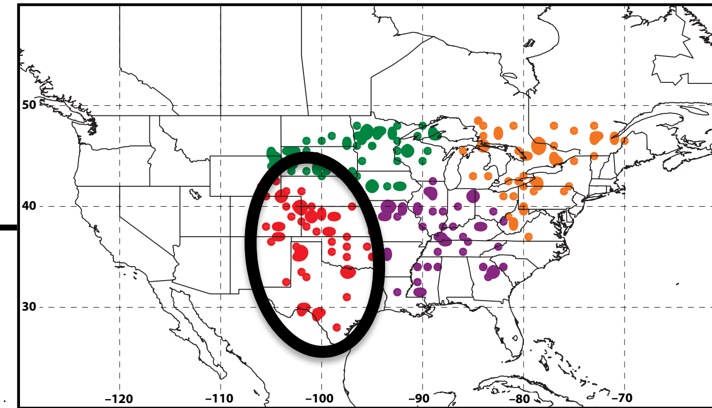
Events during Sept. – May projected onto phase diagram

Each point is an average of the PCs for 3–7 days prior to the event

Eastern U.S. – S. Plains Cluster

COLD EVENTS (n = 48)



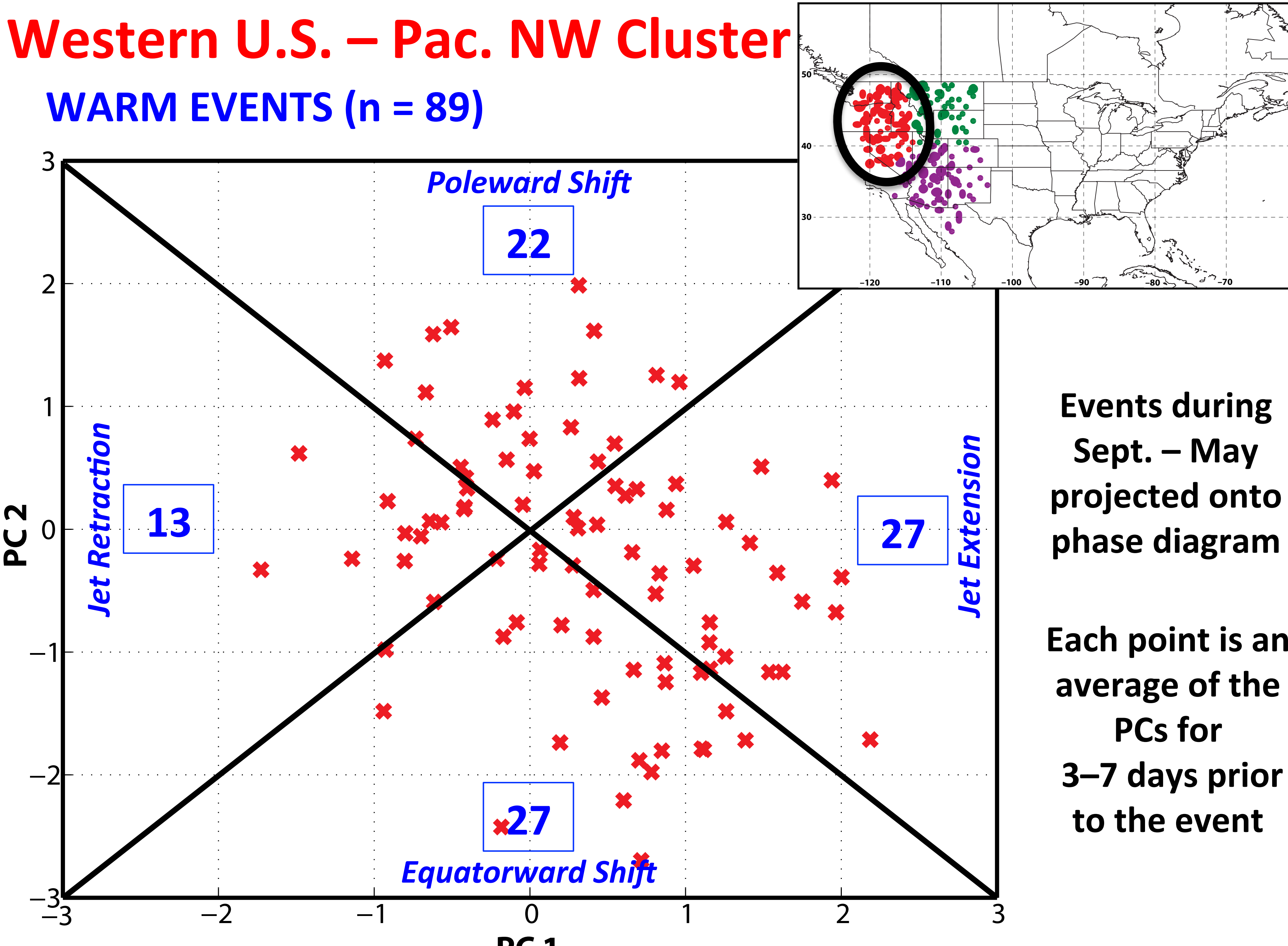


Events during Sept. – May projected onto phase diagram

Each point is an average of the PCs for 3–7 days prior to the event

Western U.S. – Pac. NW Cluster

WARM EVENTS (n = 89)

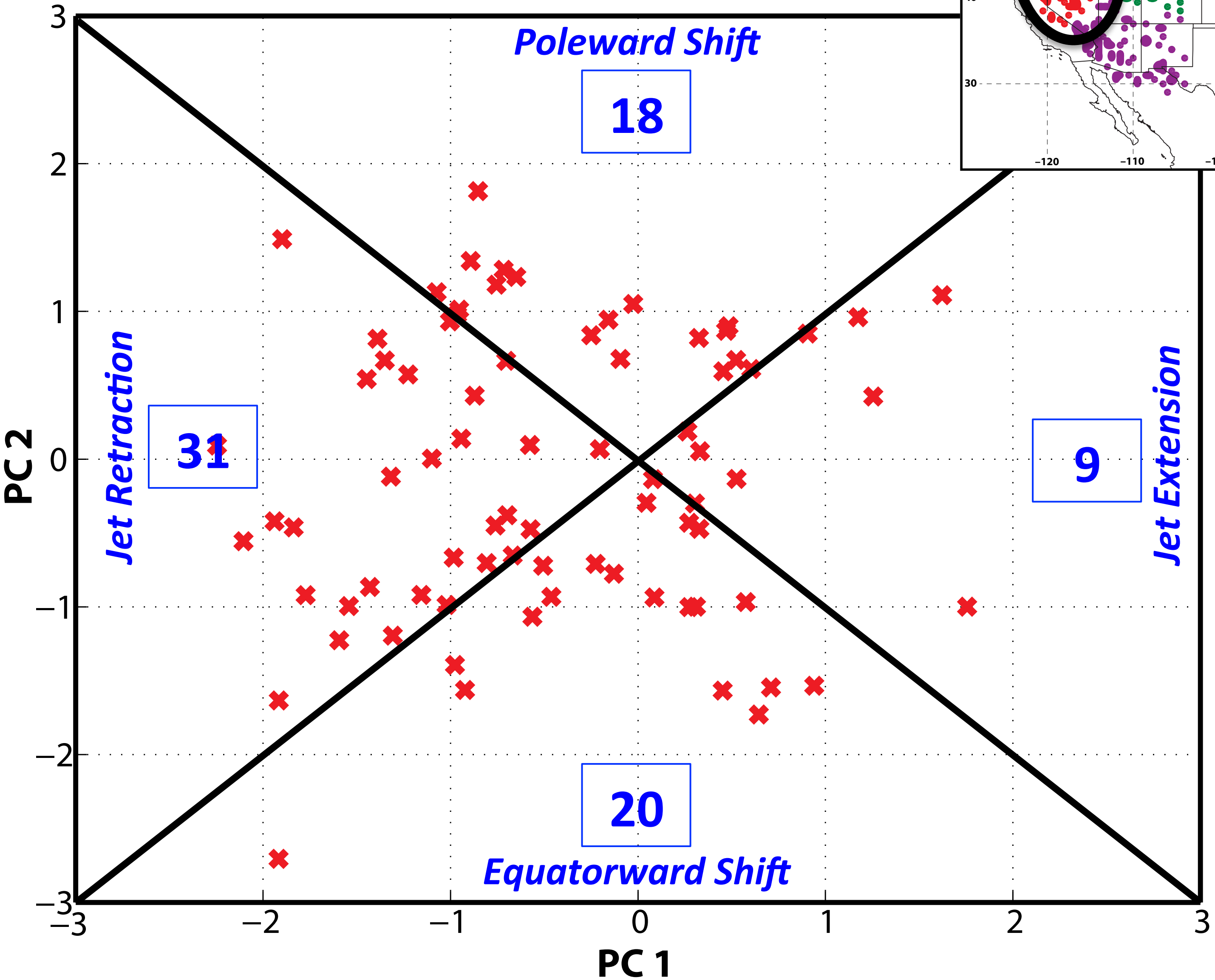


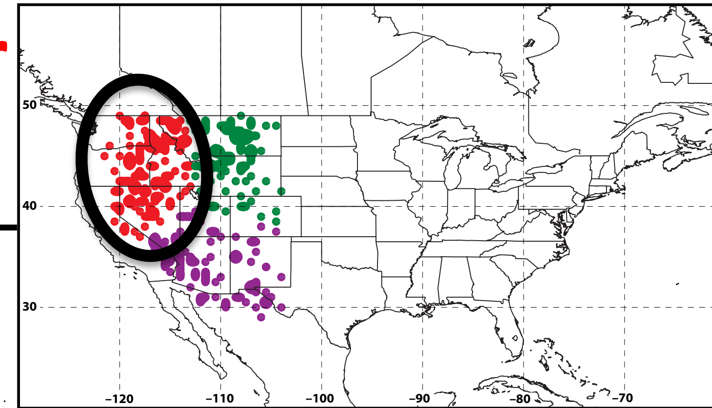
Events during Sept. – May projected onto phase diagram

Each point is an average of the PCs for 3–7 days prior to the event

Western U.S. – Pac. NW Cluster

COLD EVENTS (n = 78)





Events during Sept. – May projected onto phase diagram

Each point is an average of the PCs for 3–7 days prior to the event

Next Steps

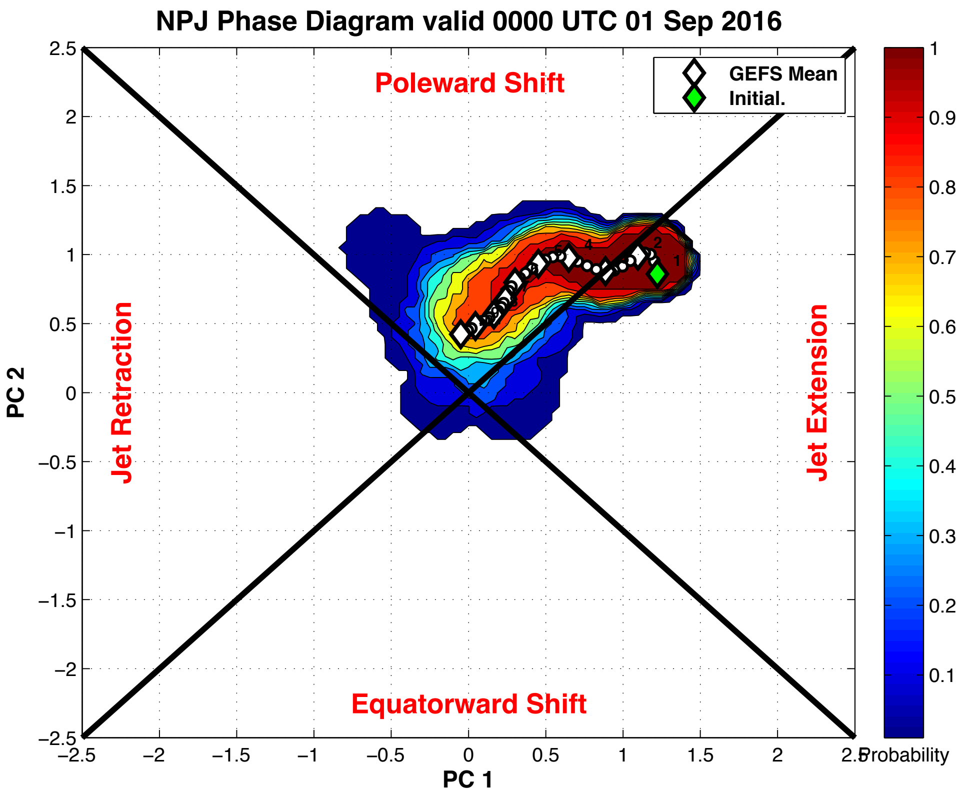
- Demonstrate further the potential of the North Pacific Jet phase diagram to **indicate antecedent environments** favorable for the development of EWEs over the continental U.S.
- Differentiate between antecedent environments conducive to the development of **extreme and non-extreme events**.
- Evaluate the **skill of NCEP GFS and GEFS forecasts** for the identified EWEs and for non-extreme events in the context of the North Pacific Jet phase diagram.
- Develop a **real-time North Pacific Jet phase diagram** and test it during the HMT Medium Range Experiments at WPC this winter.

Next Steps

Real-time North Pacific Jet phase diagram:

- Probabilistic, GFS deterministic, and GEFS ensemble forecasts
- Complementary analysis/forecasts of 250-hPa wind speed/geo. heights over the North Pacific
- Complementary analysis/forecasts of corresponding synoptic flow pattern over North America

URL: www.atmos.albany.edu/facstaff/awinters/realtime



9-day probabilistic forecast trajectory within the North Pacific Jet phase diagram

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.

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.

Extreme Event Identification

Extreme Precip. Events:

- Employed CPC Unified Gauge-Based Analysis of Daily Precipitation over CONUS during 1979–2014 (0.25°× 0.25°)
- Compiled data within 21-day windows centered on each time for all 36 years
  - Each grid point has (21 × 36) 756 data points for a given time
- Determined the precipitation values that correspond to the 99th percentile for each grid point at a given time (only for days precipitation was observed)
- Identified times that rank in the **top 5%** in terms of the number of grid points > 99th percentile within each domain as **extreme precipitation events**

Extreme Event Identification

Temperature

Eastern U.S. (**1st % Cold**):
- Threshold: 221 grid points ~7.0°×7.0° box
- After QC: 226 events

Eastern U.S. (**99th % Warm**):
- Threshold: 224 grid points ~7.0°×7.0° box
- After QC: 304 events

Western U.S. (**1st % Cold**):
- Threshold: 125 grid points ~5.0°×5.0° box
- After QC: 271 events

Western U.S. (**99th % Warm**):
- Threshold: 144 grid points ~5.5°×5.5° box
- After QC: 264 events

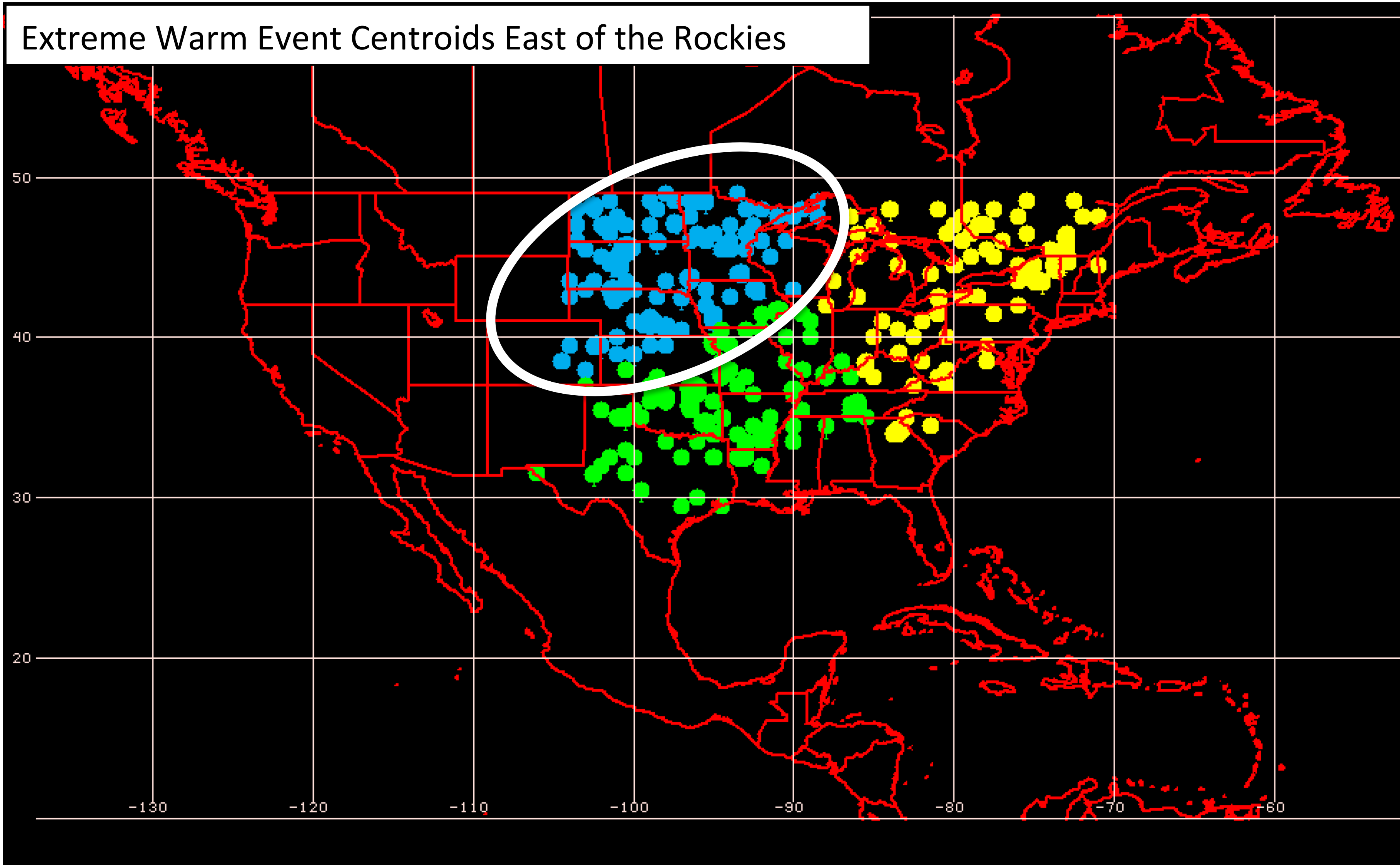
Precipitation

Eastern U.S. (**99th %**):
- Threshold: 211 grid points ~3.5°×3.5° box
- After QC: 351 events

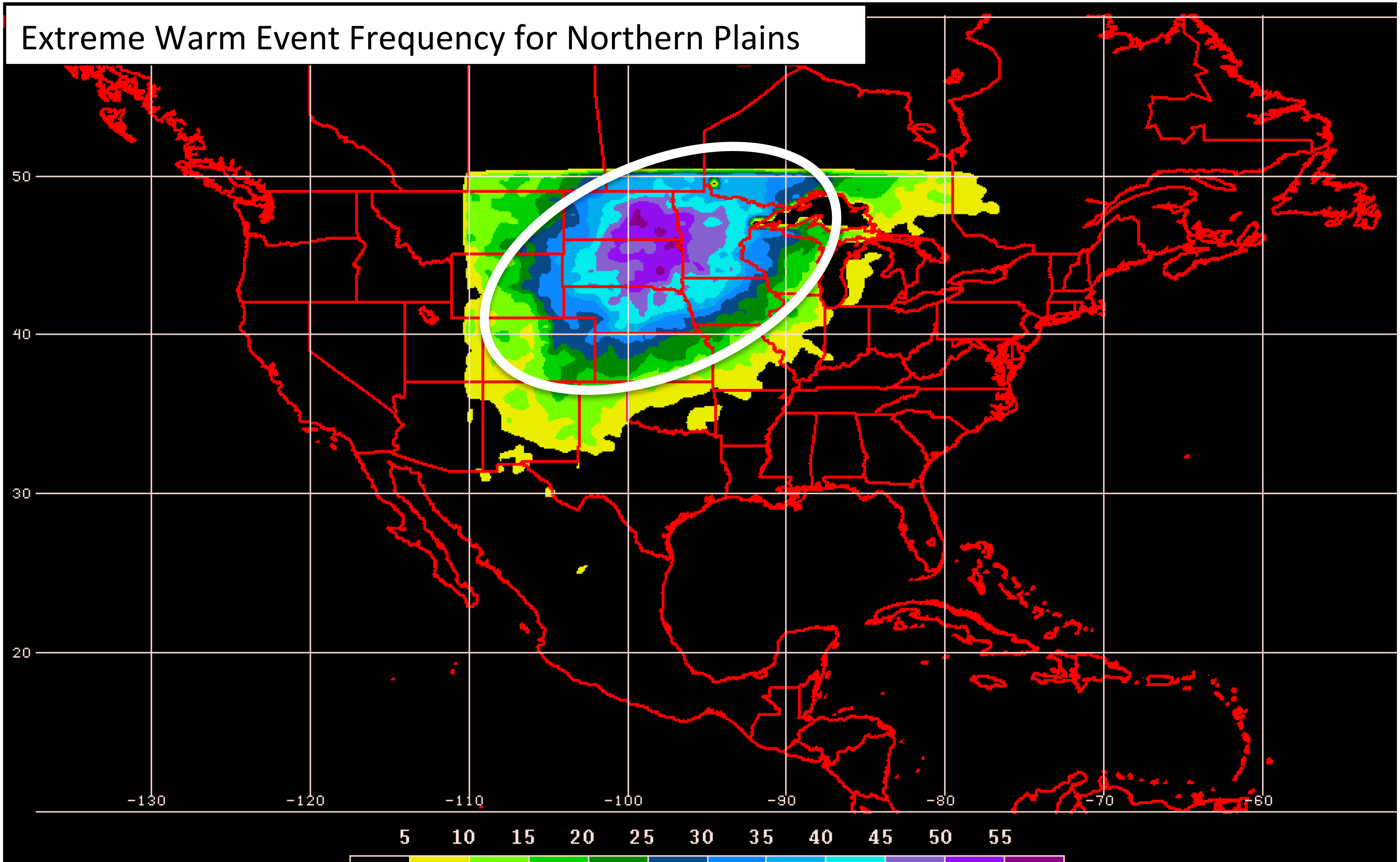
Western U.S. (**99th %**):
- Threshold: 141 grid points ~2.75°×2.75° box
- After QC: 333 events

Quality control: Events within 24-h of another event were considered to be the same event.

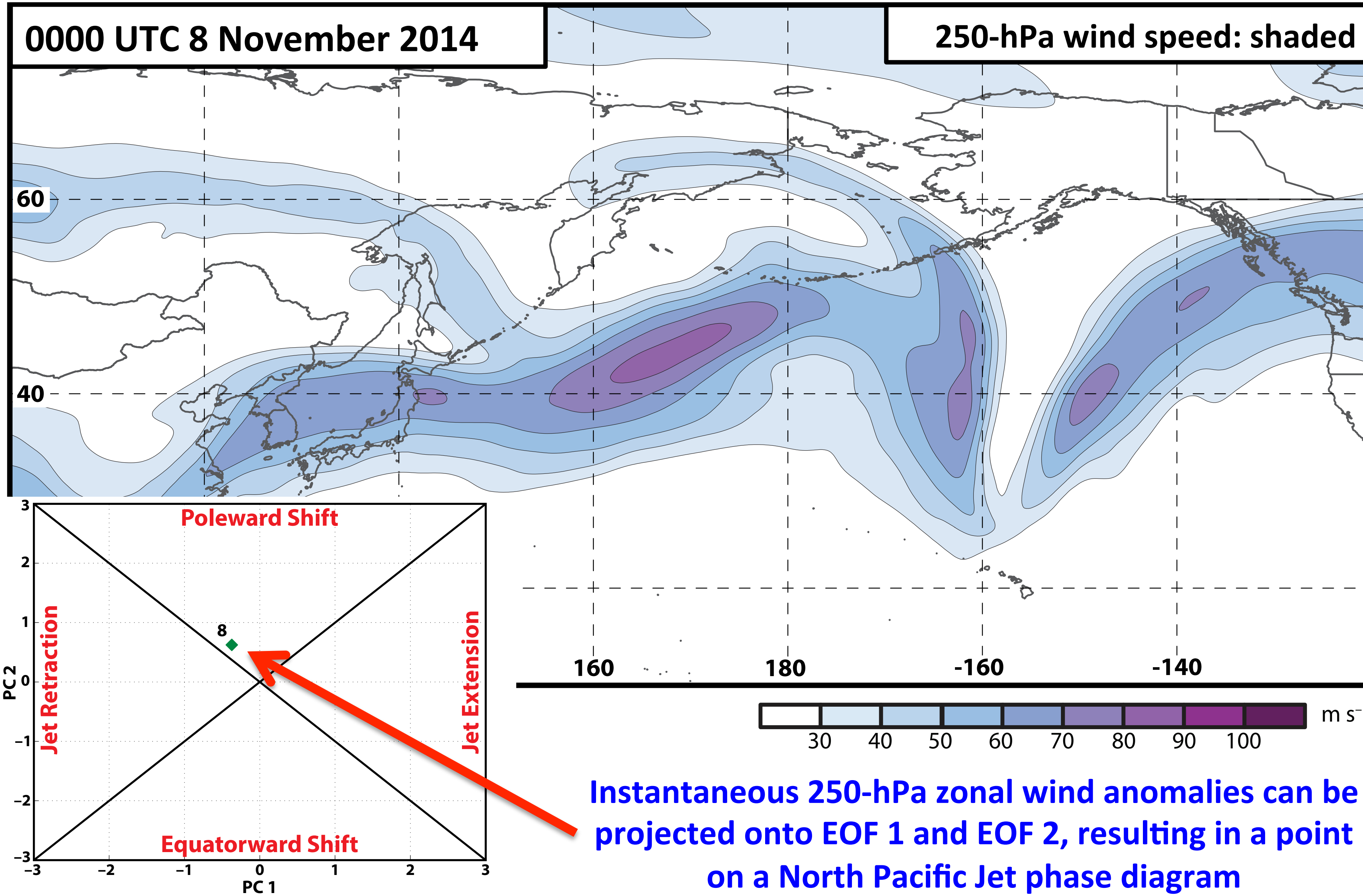
Geographic Event Clusters



Geographic Event Clusters



250-hPa North Pacific Zonal Wind Variability

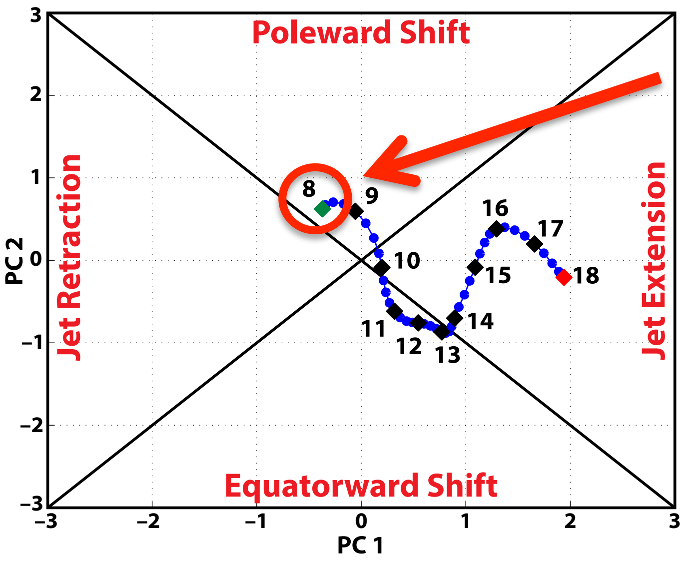


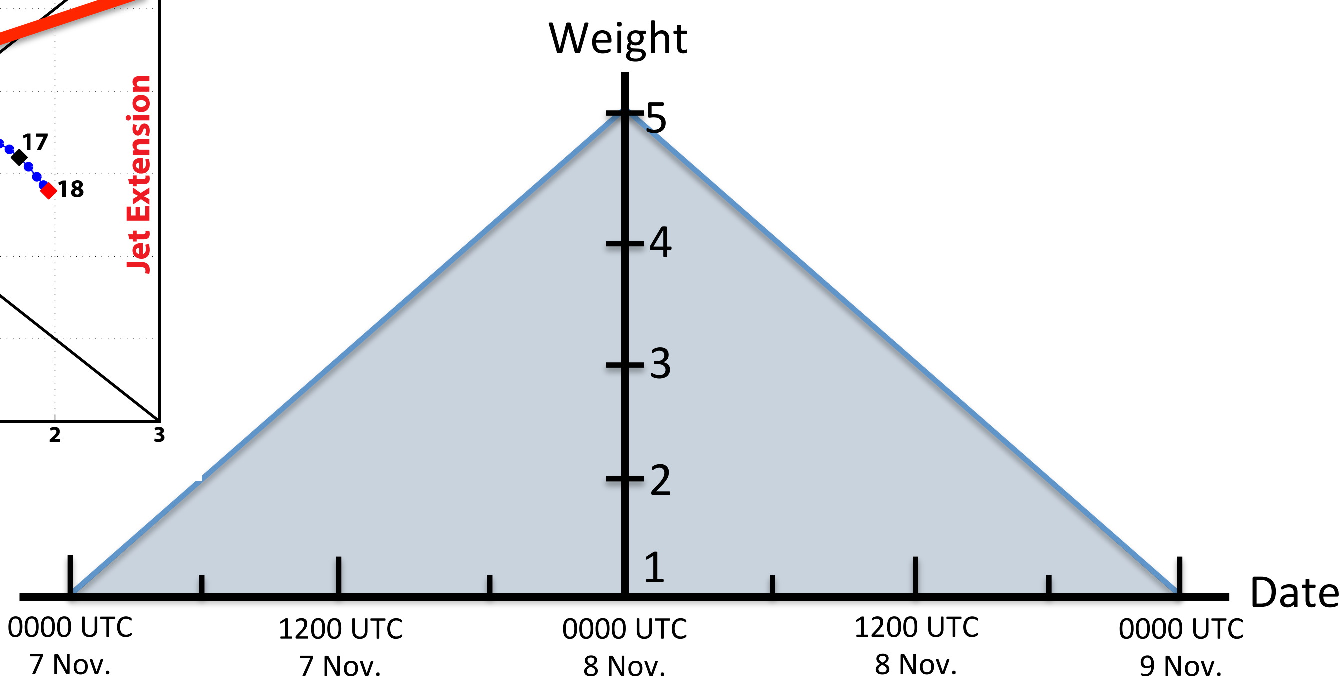
Instantaneous 250-hPa zonal wind anomalies can be projected onto EOF 1 and EOF 2, resulting in a point on a North Pacific Jet phase diagram

Notes on 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

Example: 0000 UTC 8 November 2014





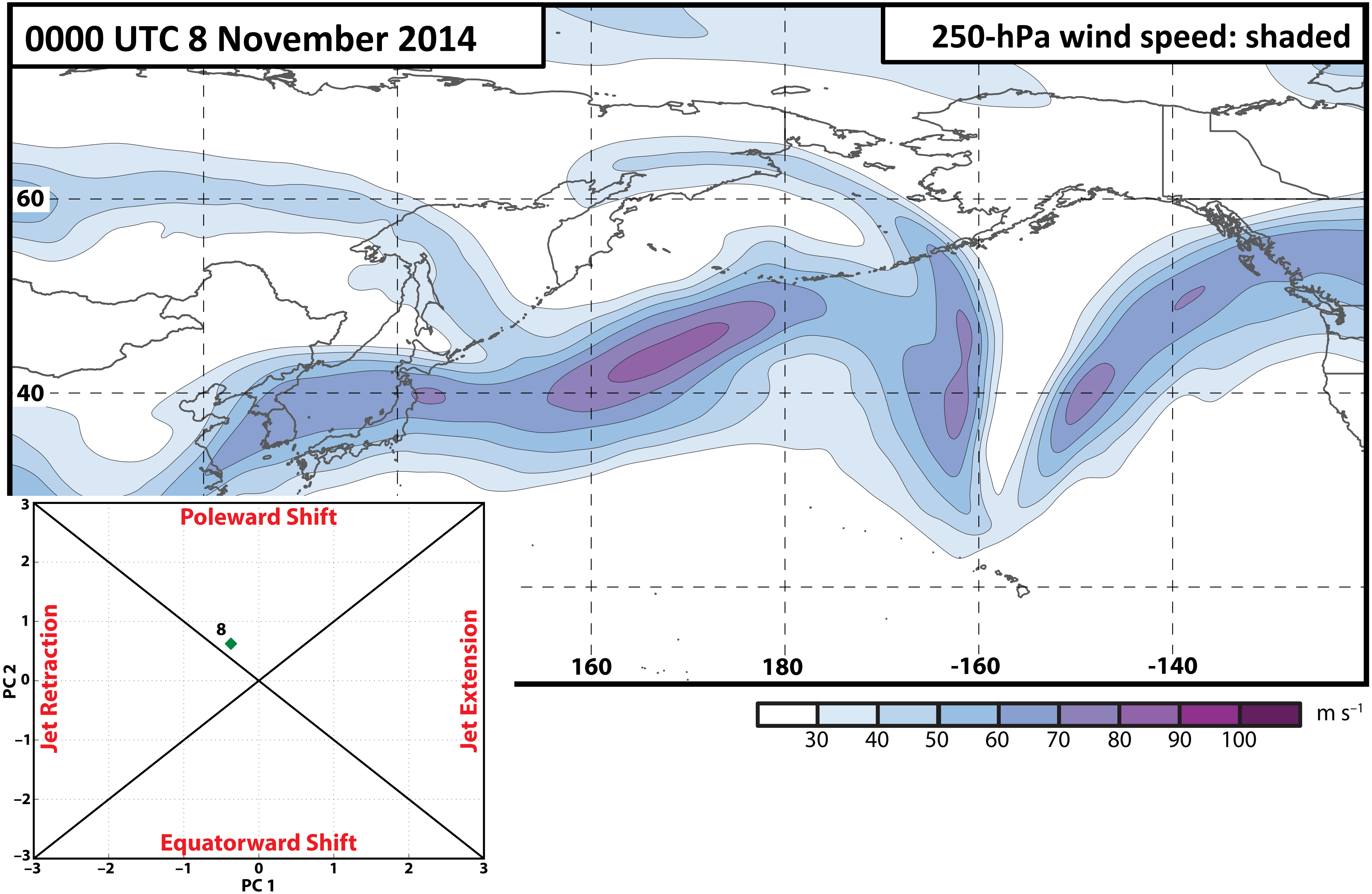
Real-Time North Pacific Jet Phase Diagram

1. Characterizes the past evolution and present state of the upper-tropospheric flow pattern over the North Pacific.

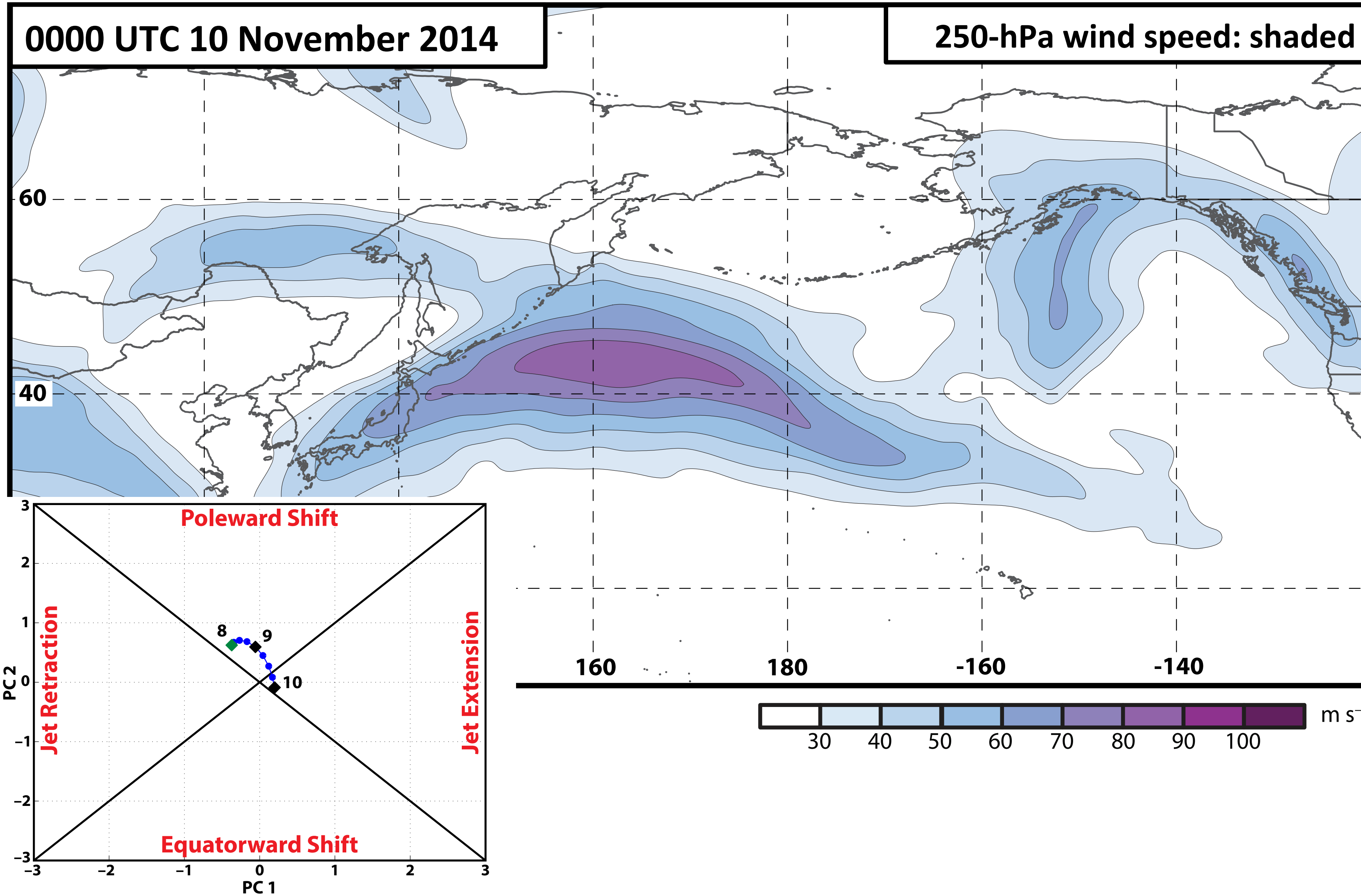
   - Captures regime transitions
   - Identifies flow patterns conducive to the development of EWEs

2. Characterizes the forecasted evolution of the upper-tropospheric flow pattern over the North Pacific.

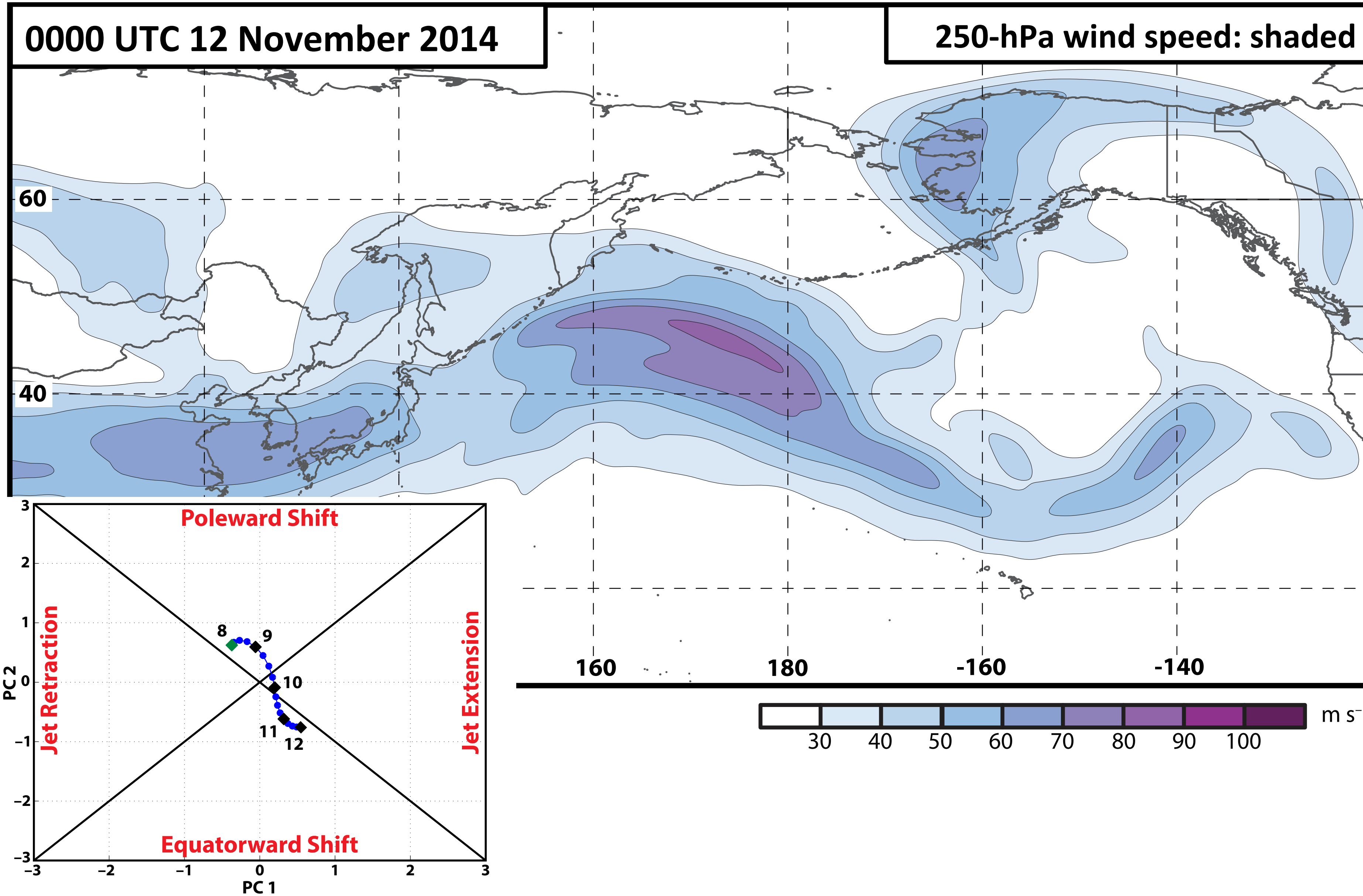
Real-Time North Pacific Jet Phase Diagram



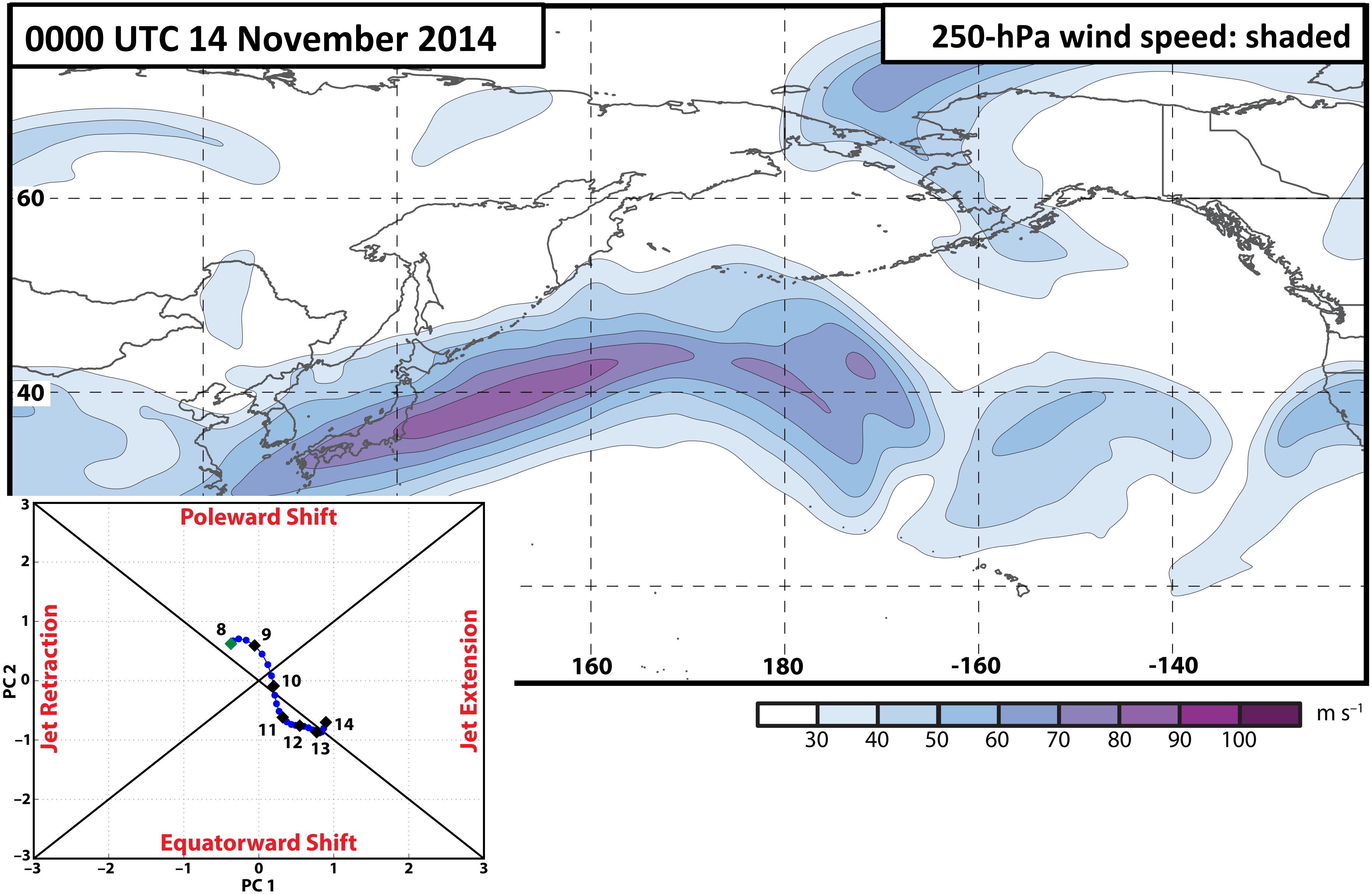
Real-Time North Pacific Jet Phase Diagram



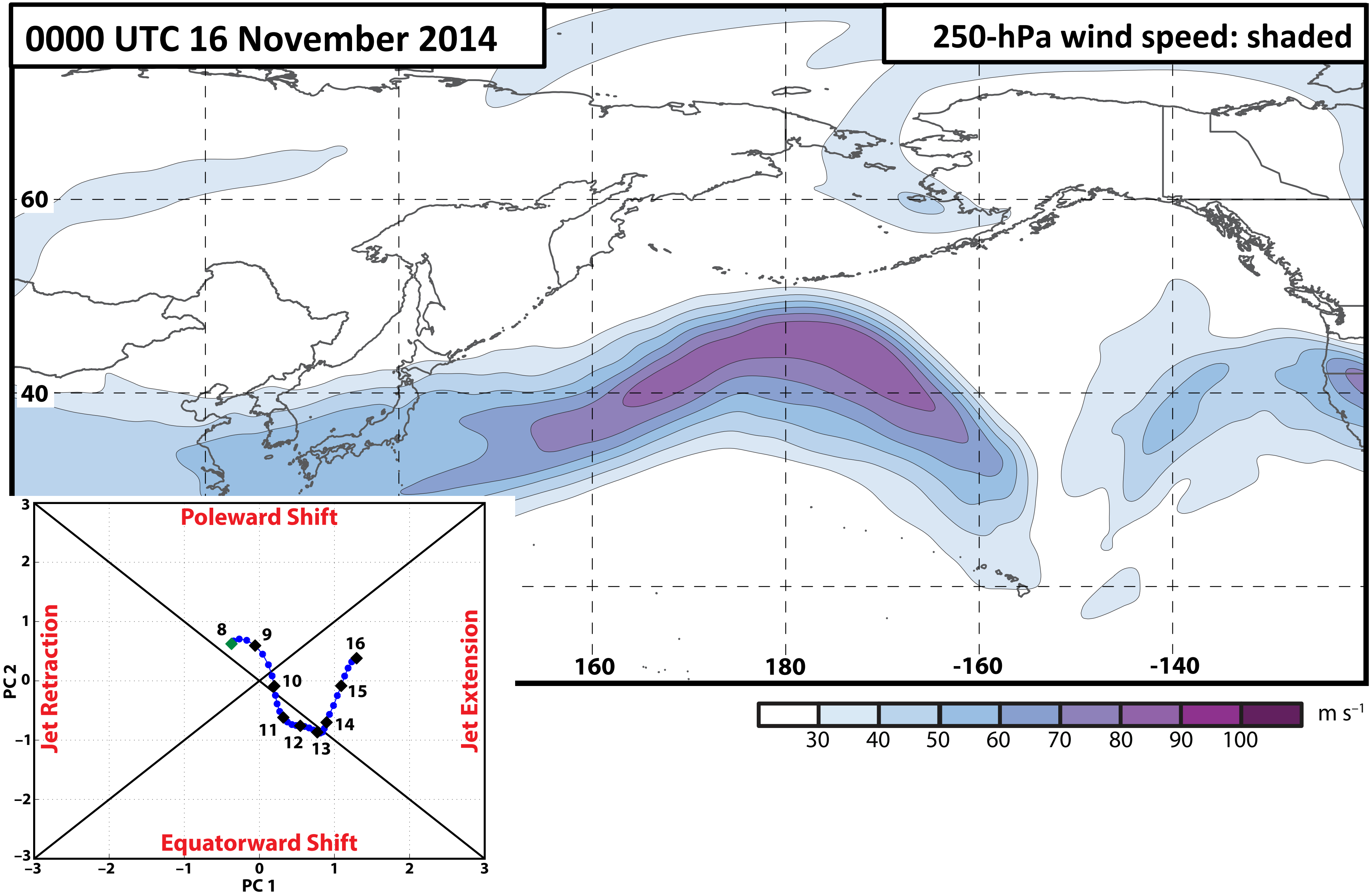
Real-Time North Pacific Jet Phase Diagram



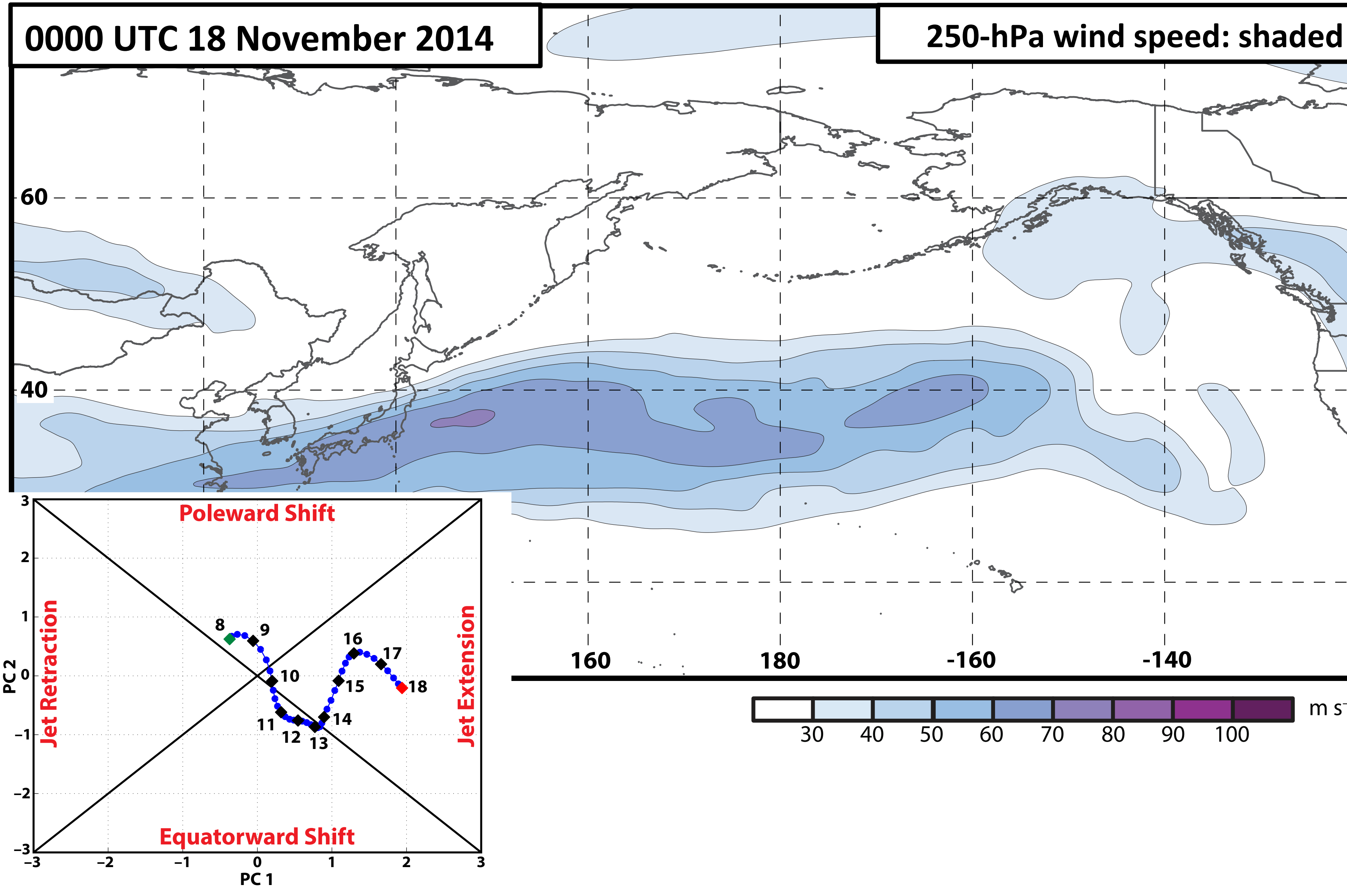
Real-Time North Pacific Jet Phase Diagram



Real-Time North Pacific Jet Phase Diagram



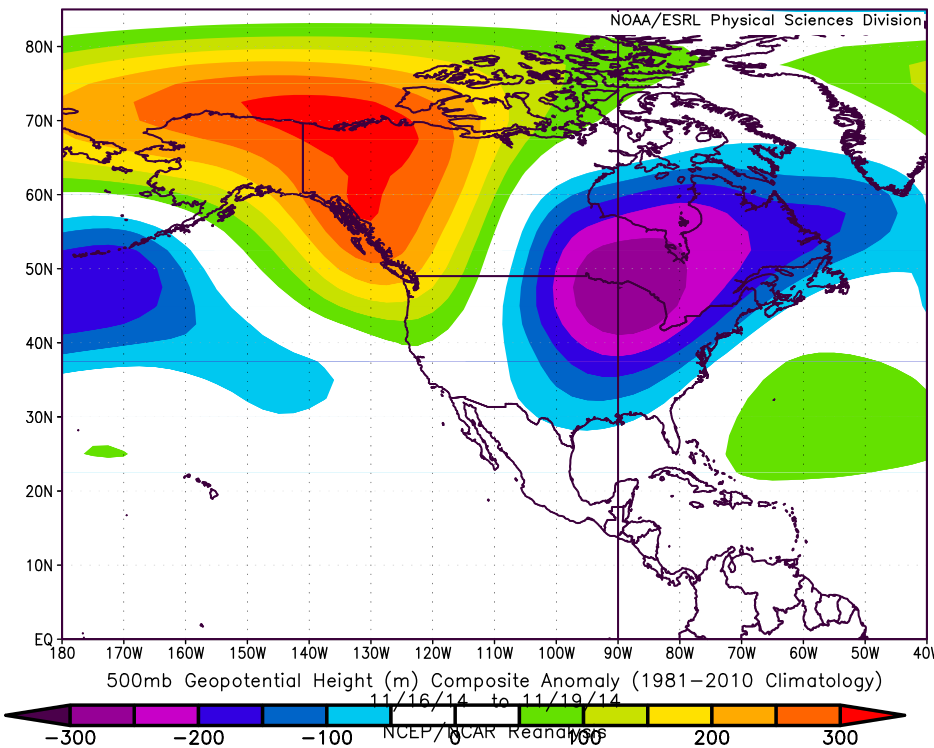
Real-Time North Pacific Jet Phase Diagram



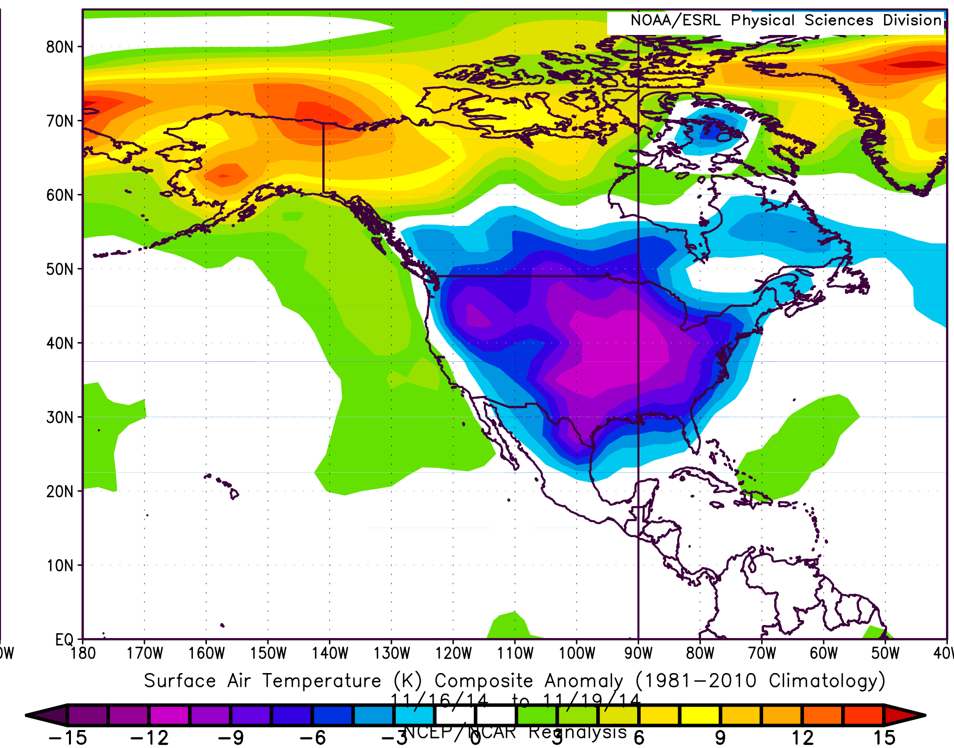
Real-Time North Pacific Jet Phase Diagram

16–19 November 2014 Composite Anomalies

500-hPa Geo. Height (m)

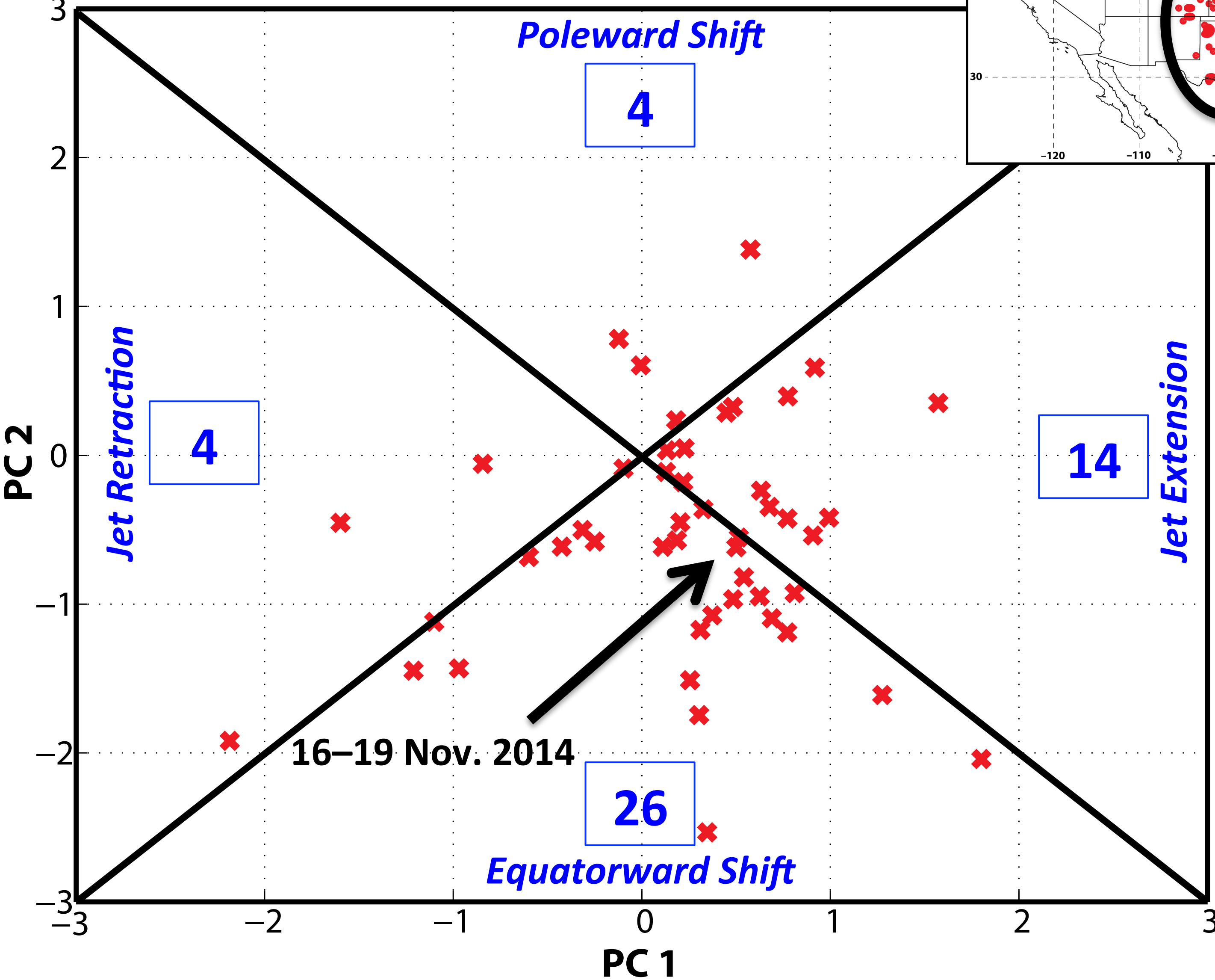


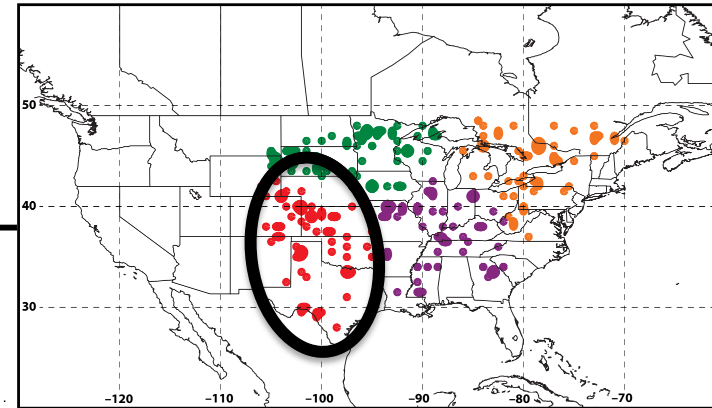
Surface Temperature (°C)



E. Rockies – S. Plains Cluster

COLD EVENTS (n = 48)

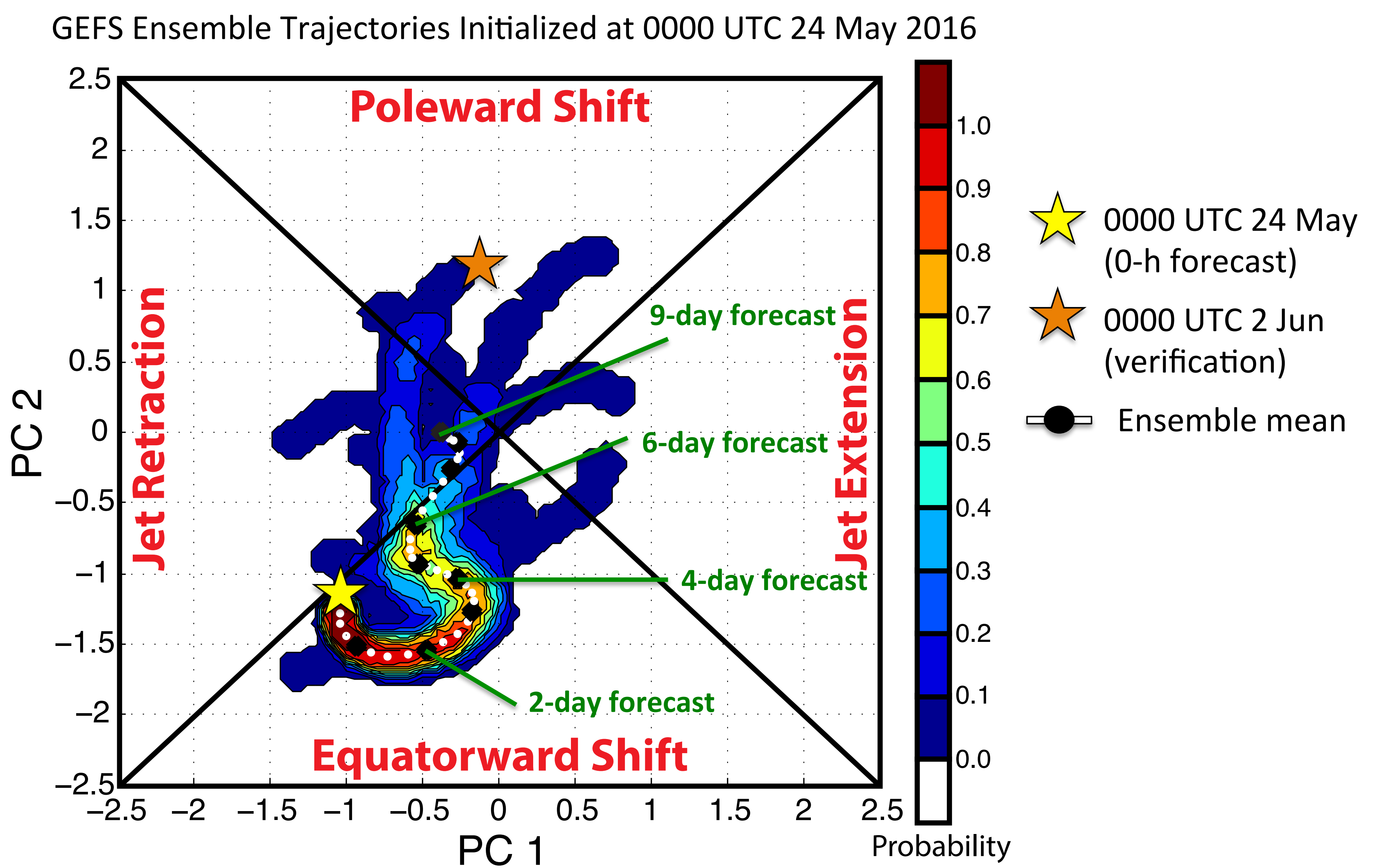




Events during Sept. – May projected onto phase diagram

Each point is an average of the PCs for 3–7 days prior to the event

Real-Time North Pacific Jet Phase Diagram



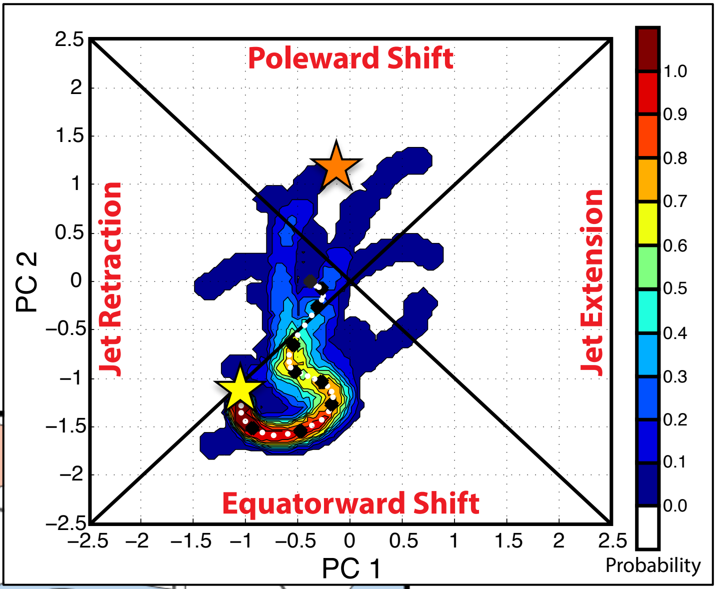
Real-Time North Pacific Jet Phase Diagram

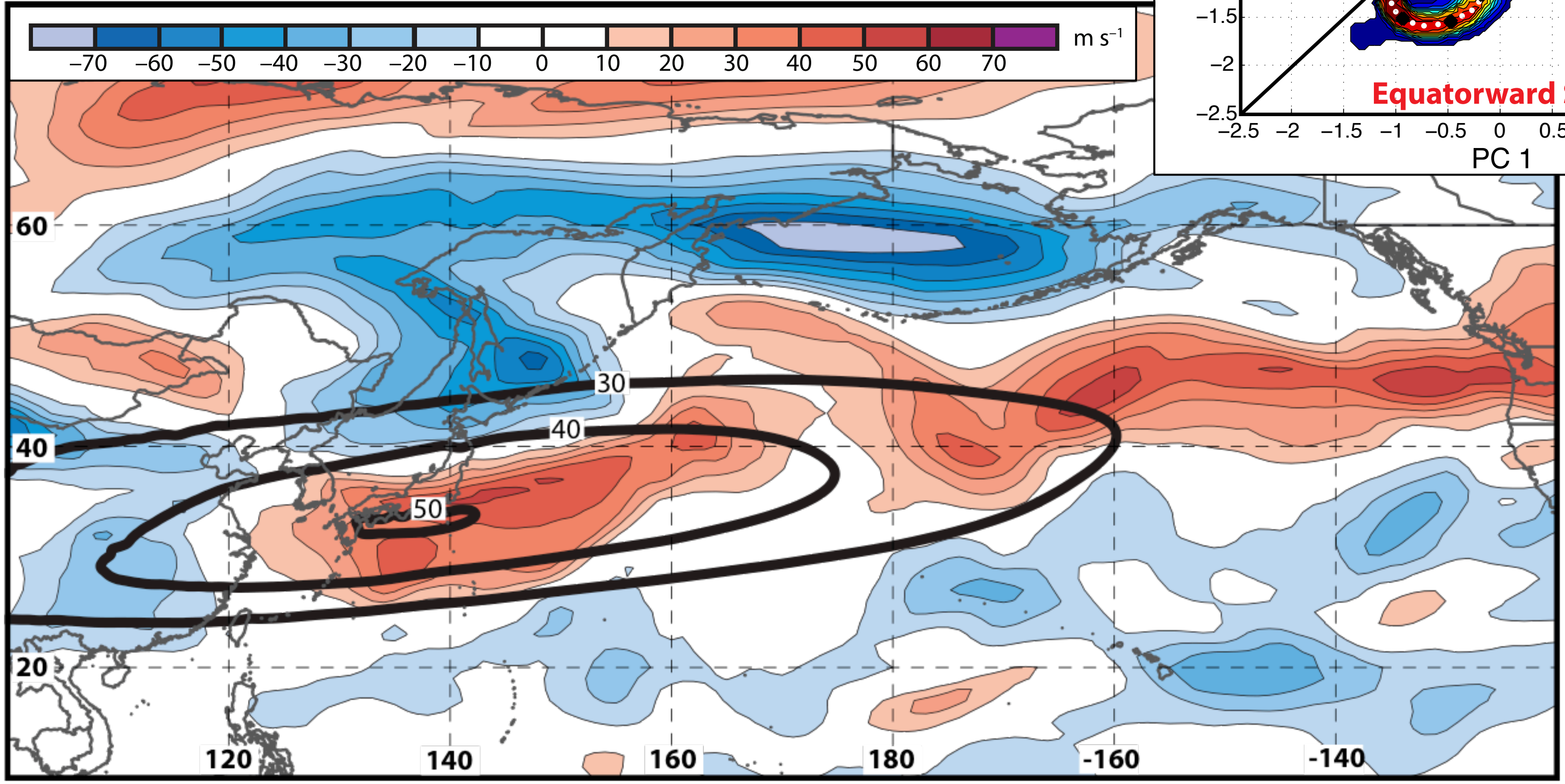
250-hPa zonal wind at 0000 UTC 2 Jun minus 250-hPa zonal wind at 0000 UTC 24 May (shading) in the GFS analyses shows the transition to a poleward-shifted jet regime

★ 0000 UTC 24 May (0-h forecast)

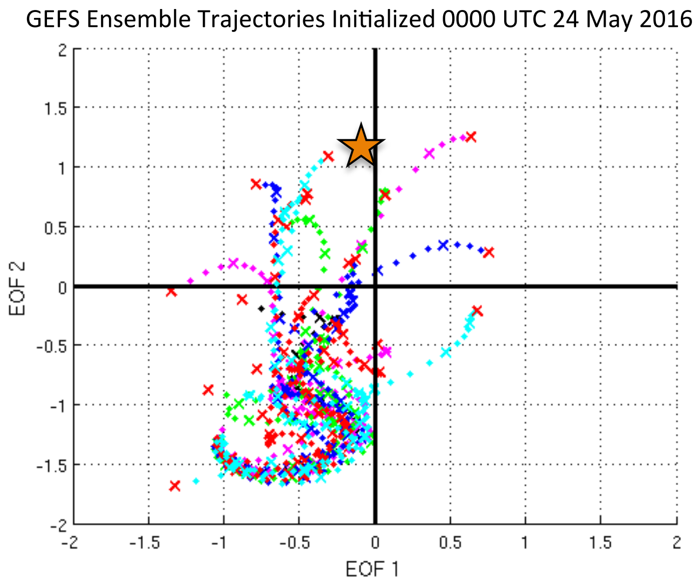
★ 0000 UTC 2 Jun (verification)

Ensemble mean

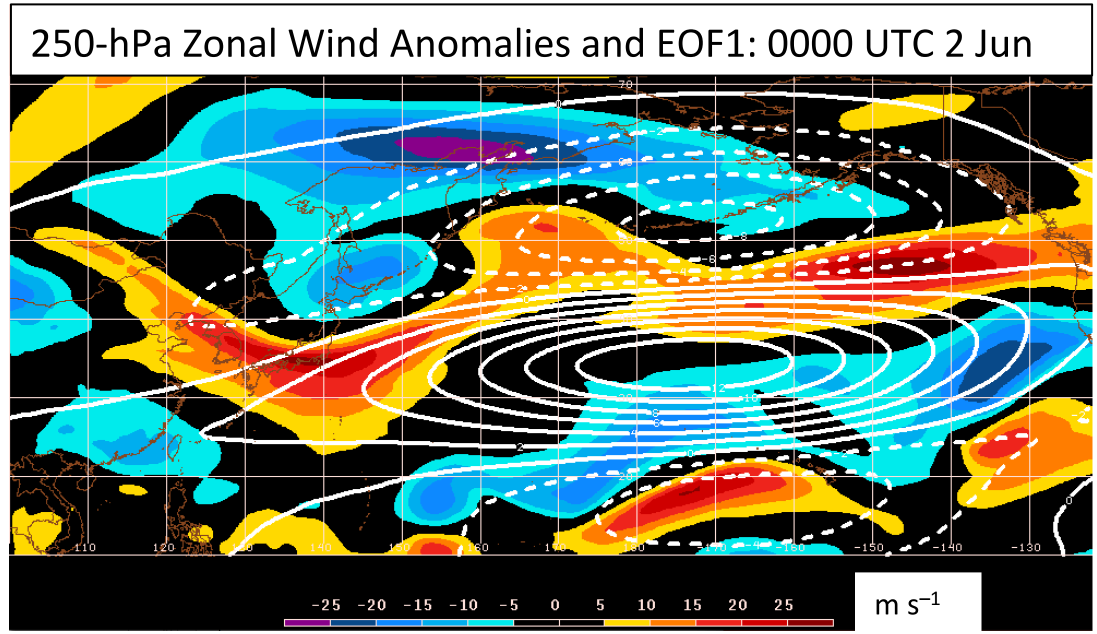




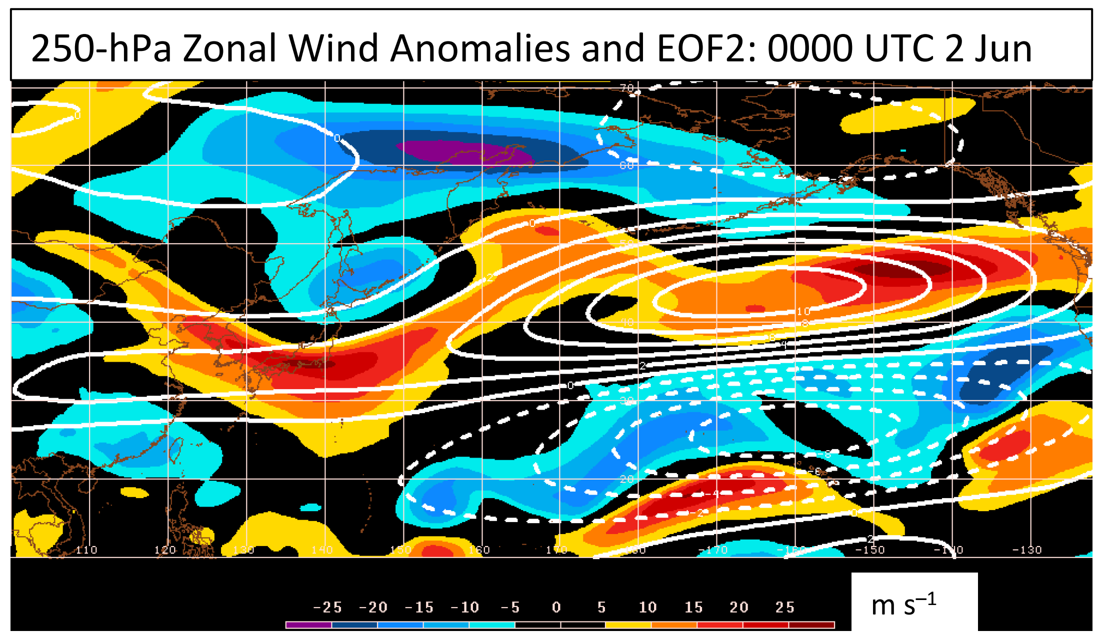
Sept.–May mean 250-hPa zonal wind: black contours



0000 UTC 2 Jun (verification)

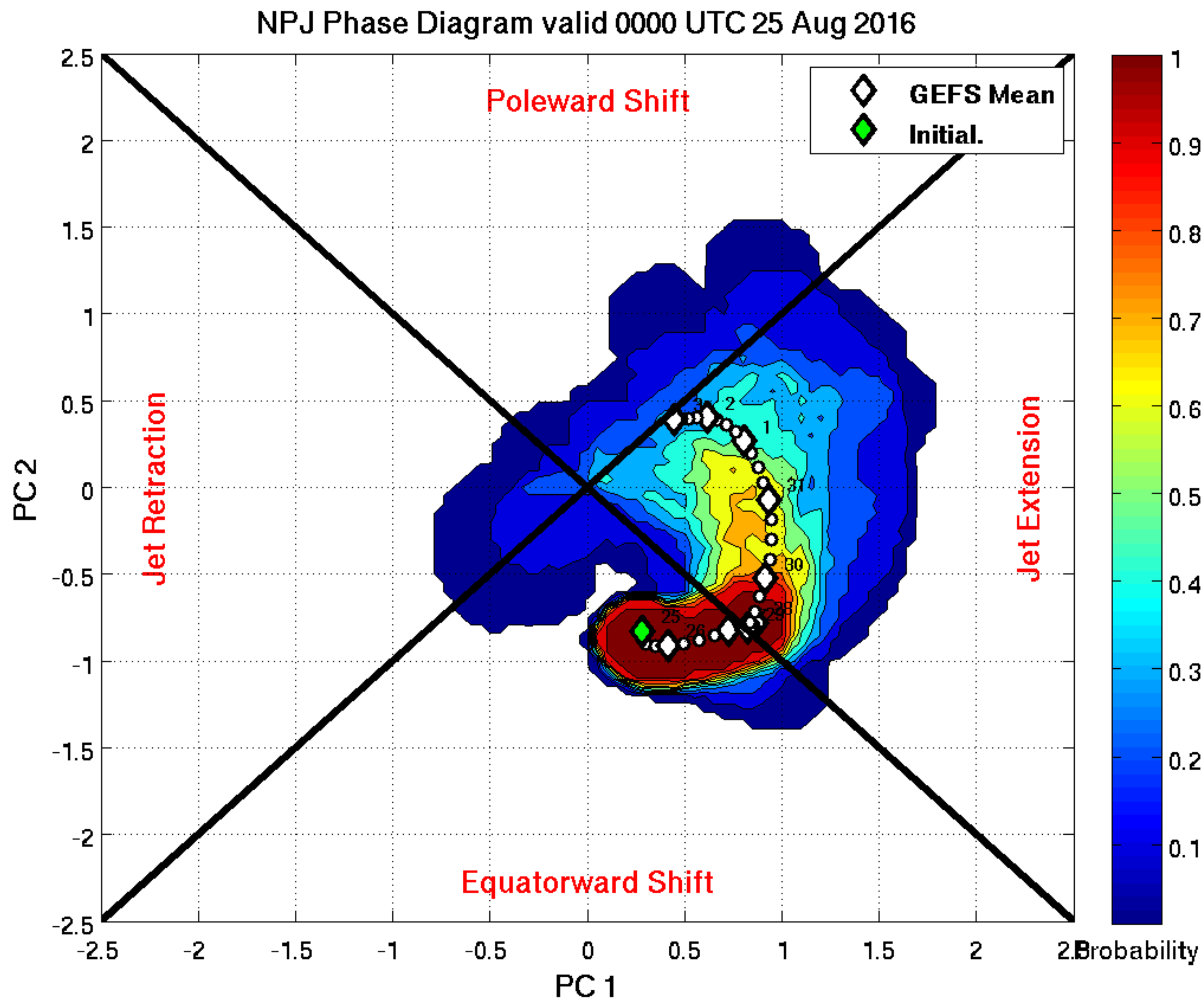


250-hPa zonal wind anomalies at 0000 UTC 2 Jun project strongly onto EOF2 > 0



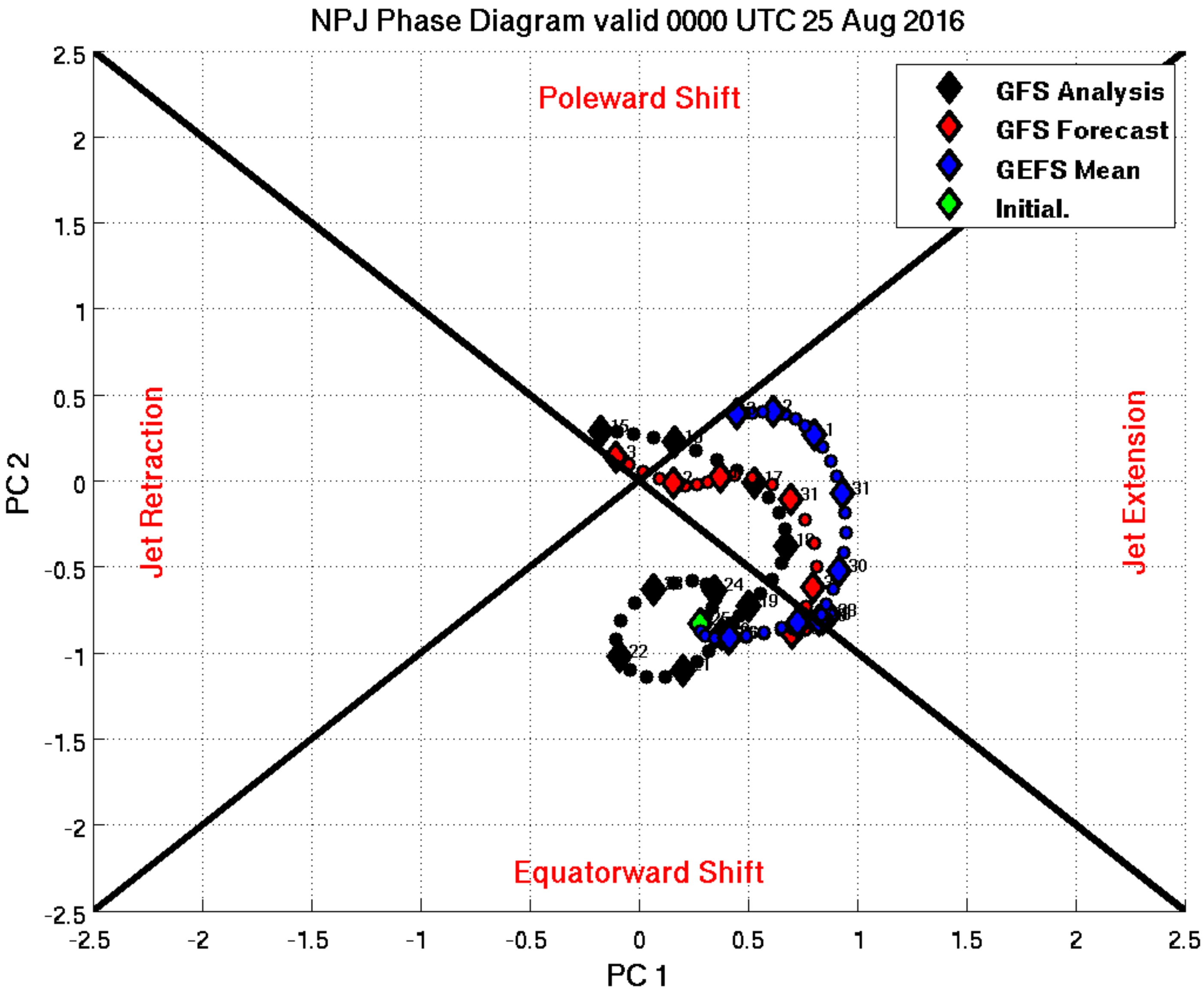
Real-time NPJ Phase Diagram Products

GEFS forecast probability of the verifying analysis occurring within a radius of 0.25 of a point during the upcoming 9-day period.



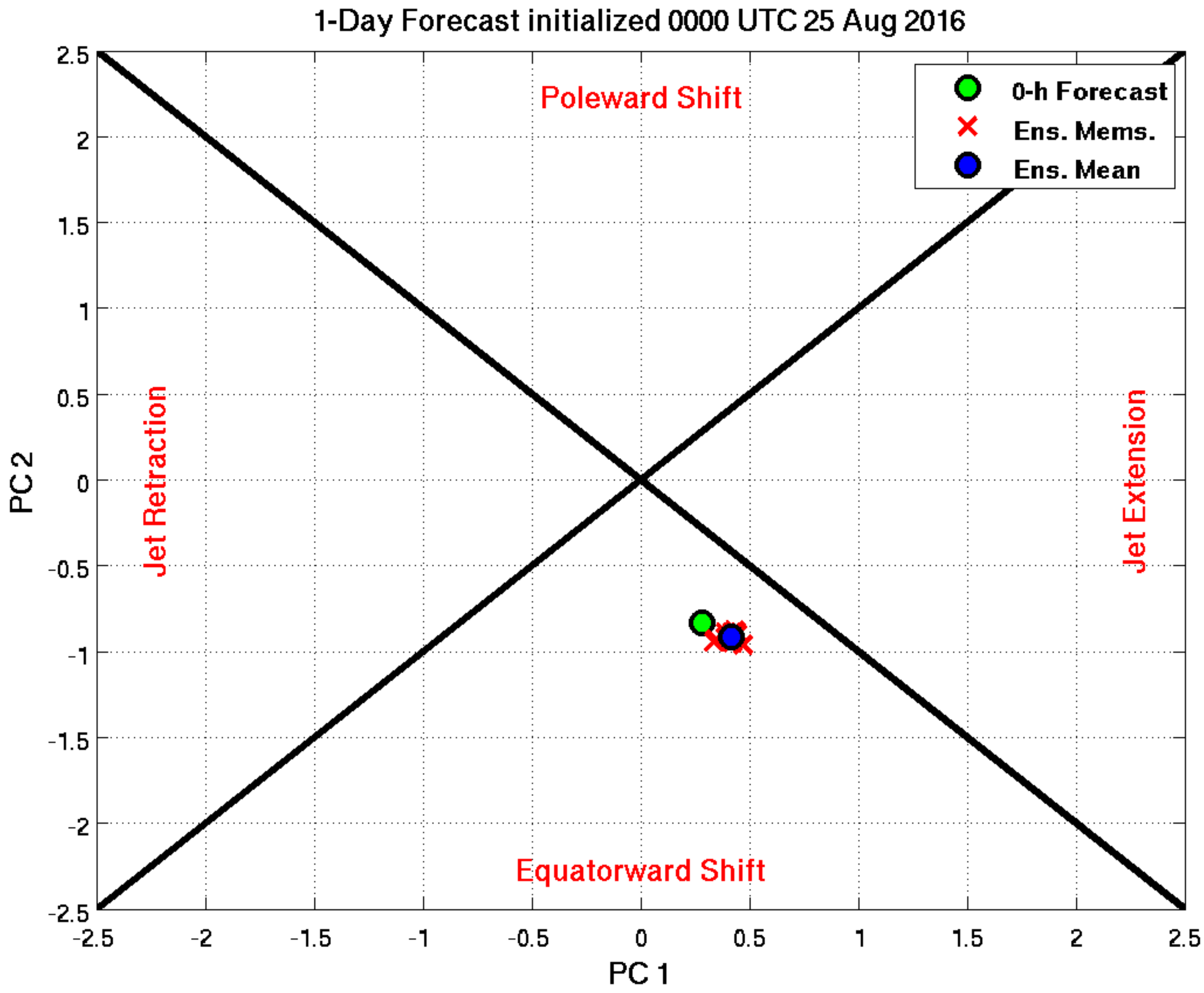
Real-time NPJ Phase Diagram Products

GFS deterministic and GEFS ensemble mean forecast trajectories with the GFS analysis over the previous 10-day period.



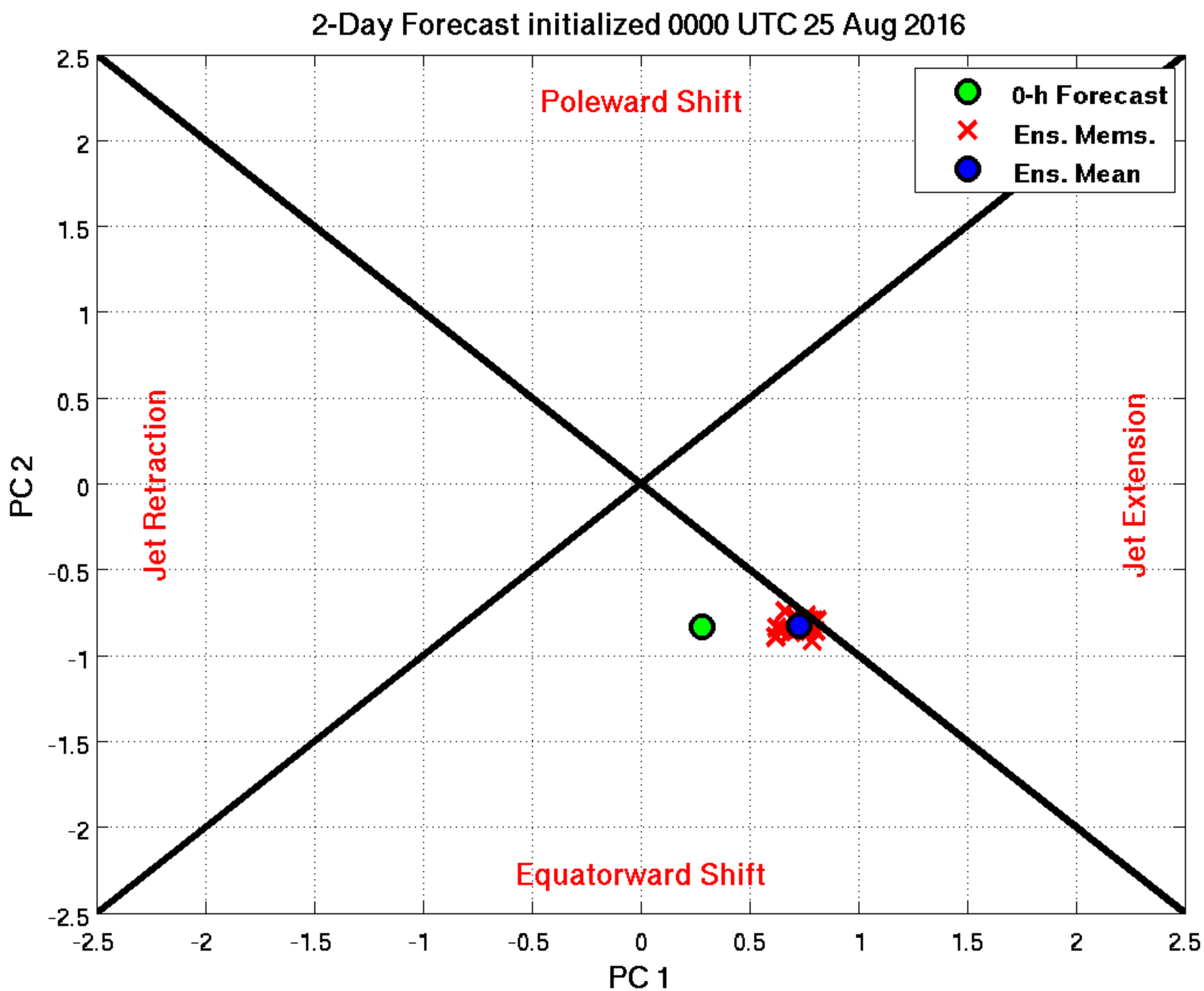
Real-time NPJ Phase Diagram Products

1-day forecast of GEFS ensemble members, GEFS ensemble mean, and 0-h forecast



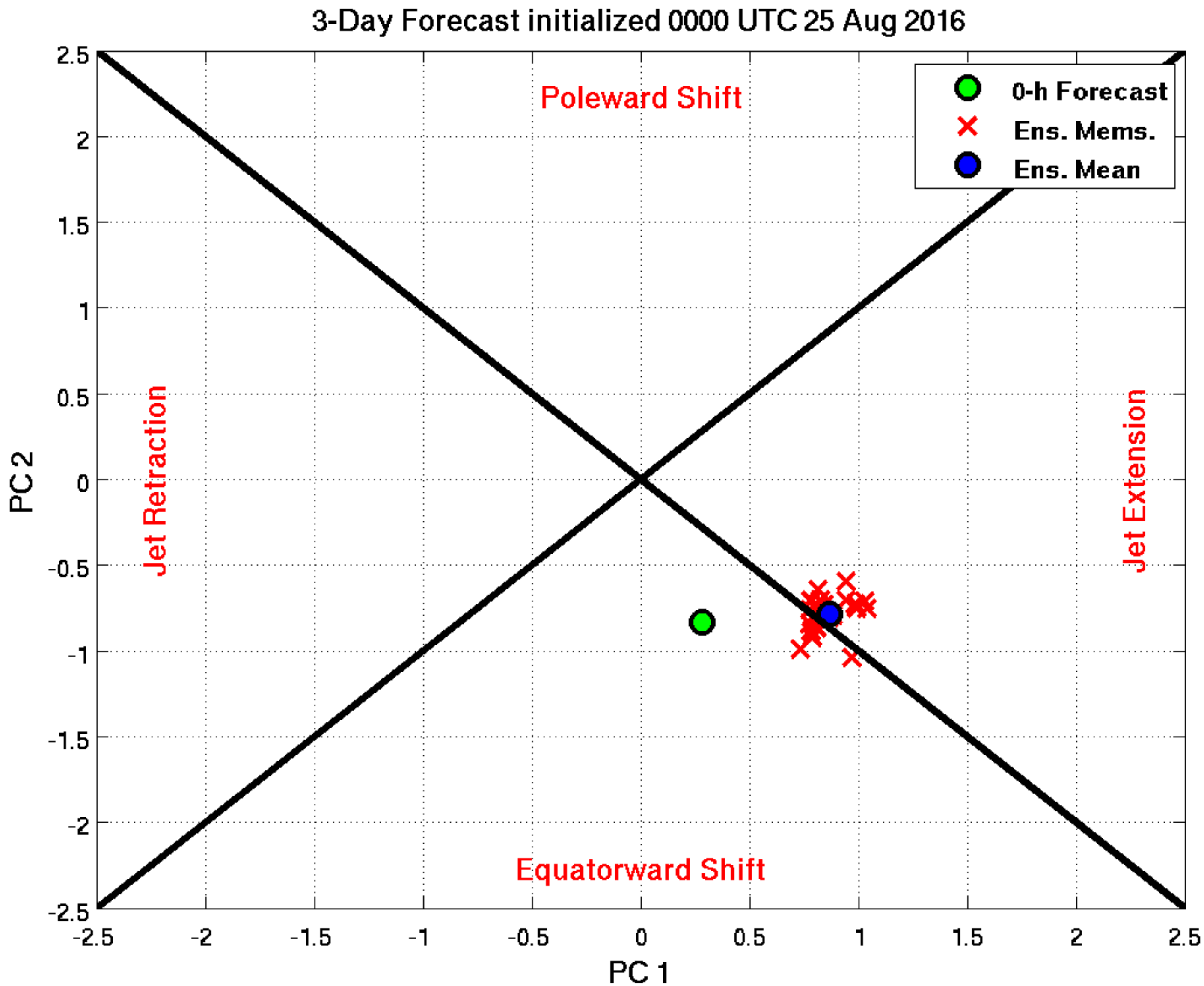
Real-time NPJ Phase Diagram Products

2-day forecast of GEFS ensemble members, GEFS ensemble mean, and 0-h forecast



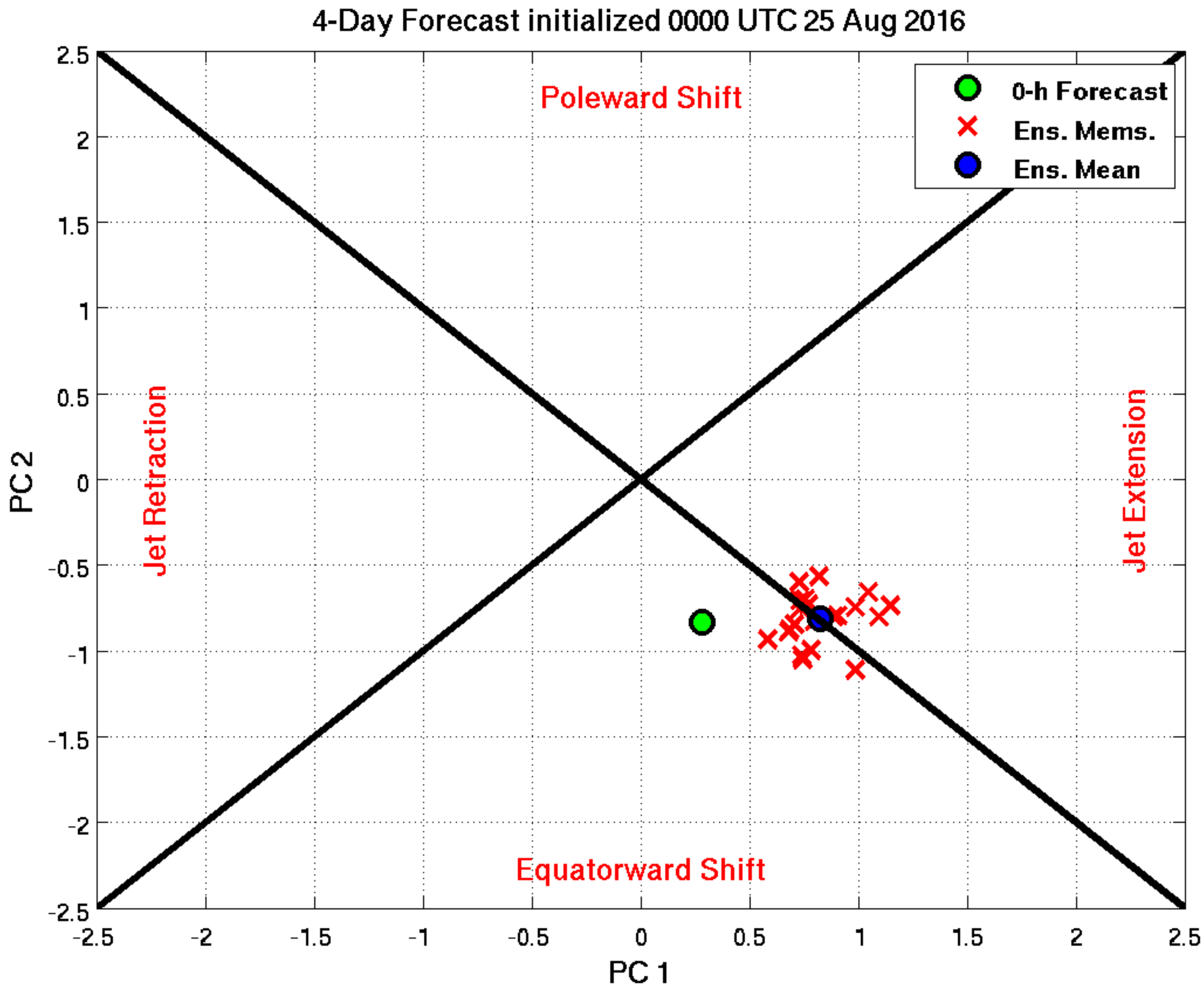
Real-time NPJ Phase Diagram Products

3-day forecast of GEFS ensemble members, GEFS ensemble mean, and 0-h forecast



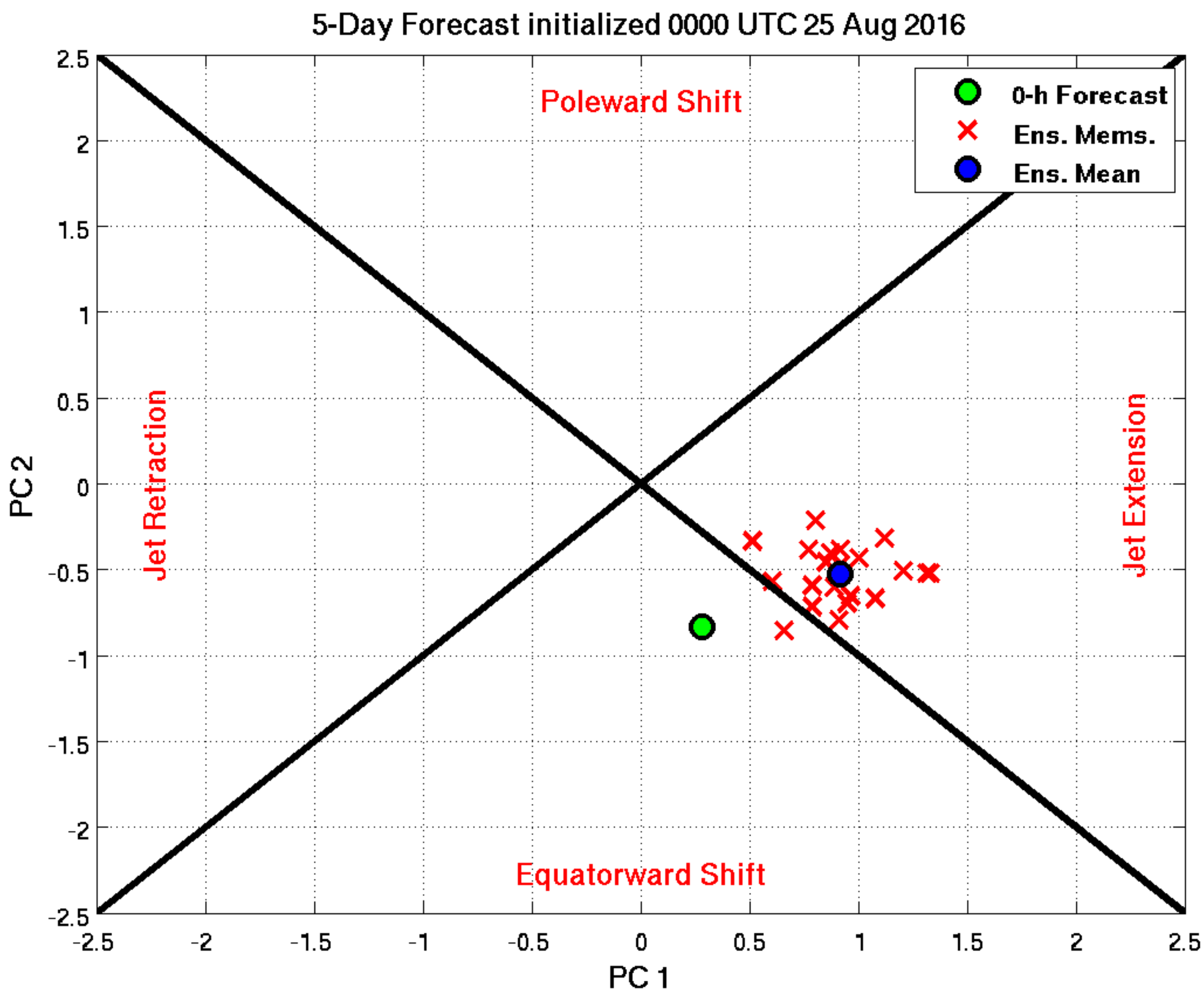
Real-time NPJ Phase Diagram Products

4-day forecast of GEFS ensemble members, GEFS ensemble mean, and 0-h forecast



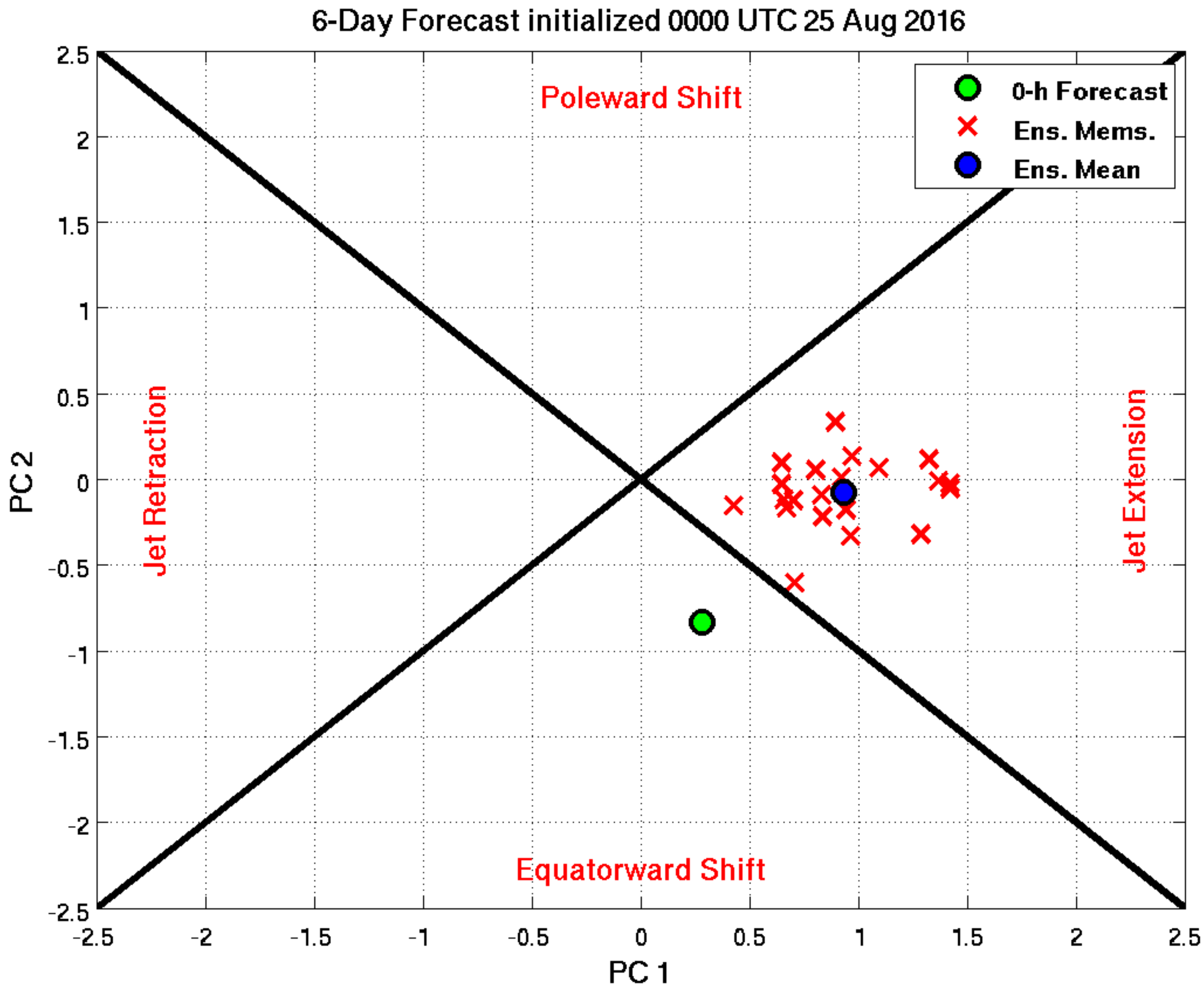
Real-time NPJ Phase Diagram Products

5-day forecast of GEFS ensemble members, GEFS ensemble mean, and 0-h forecast



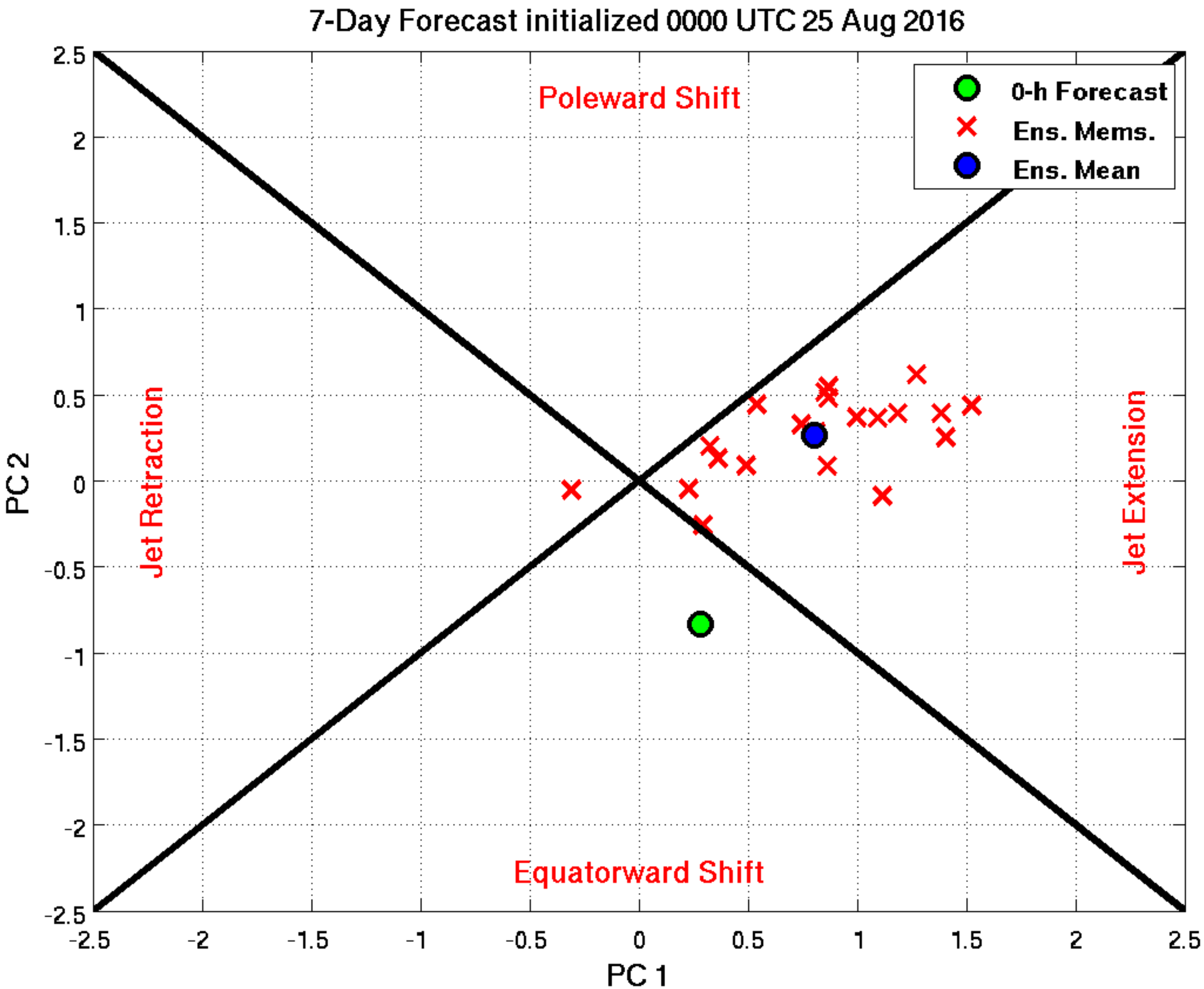
Real-time NPJ Phase Diagram Products

6-day forecast of GEFS ensemble members, GEFS ensemble mean, and 0-h forecast



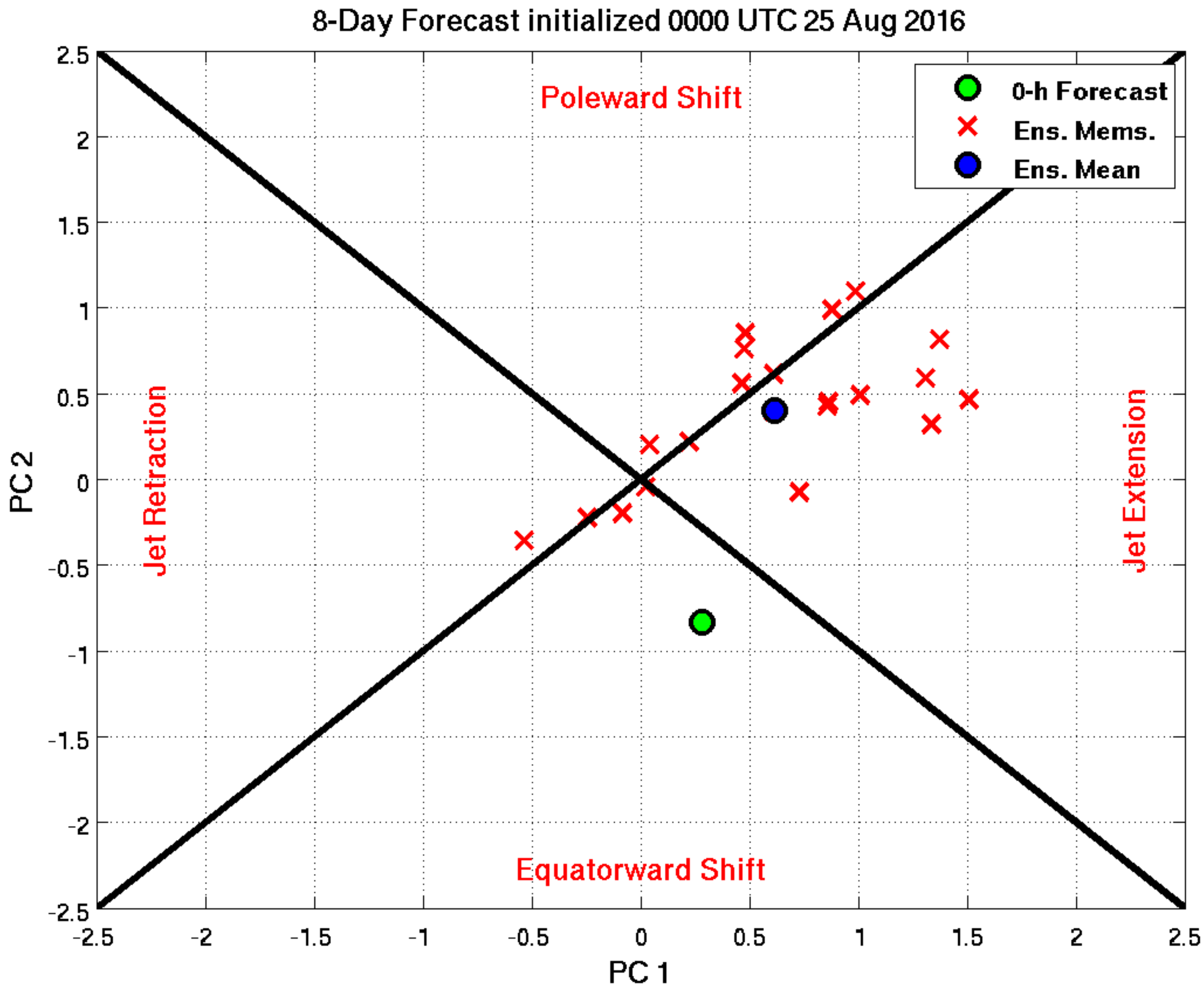
Real-time NPJ Phase Diagram Products

7-day forecast of GEFS ensemble members, GEFS ensemble mean, and 0-h forecast



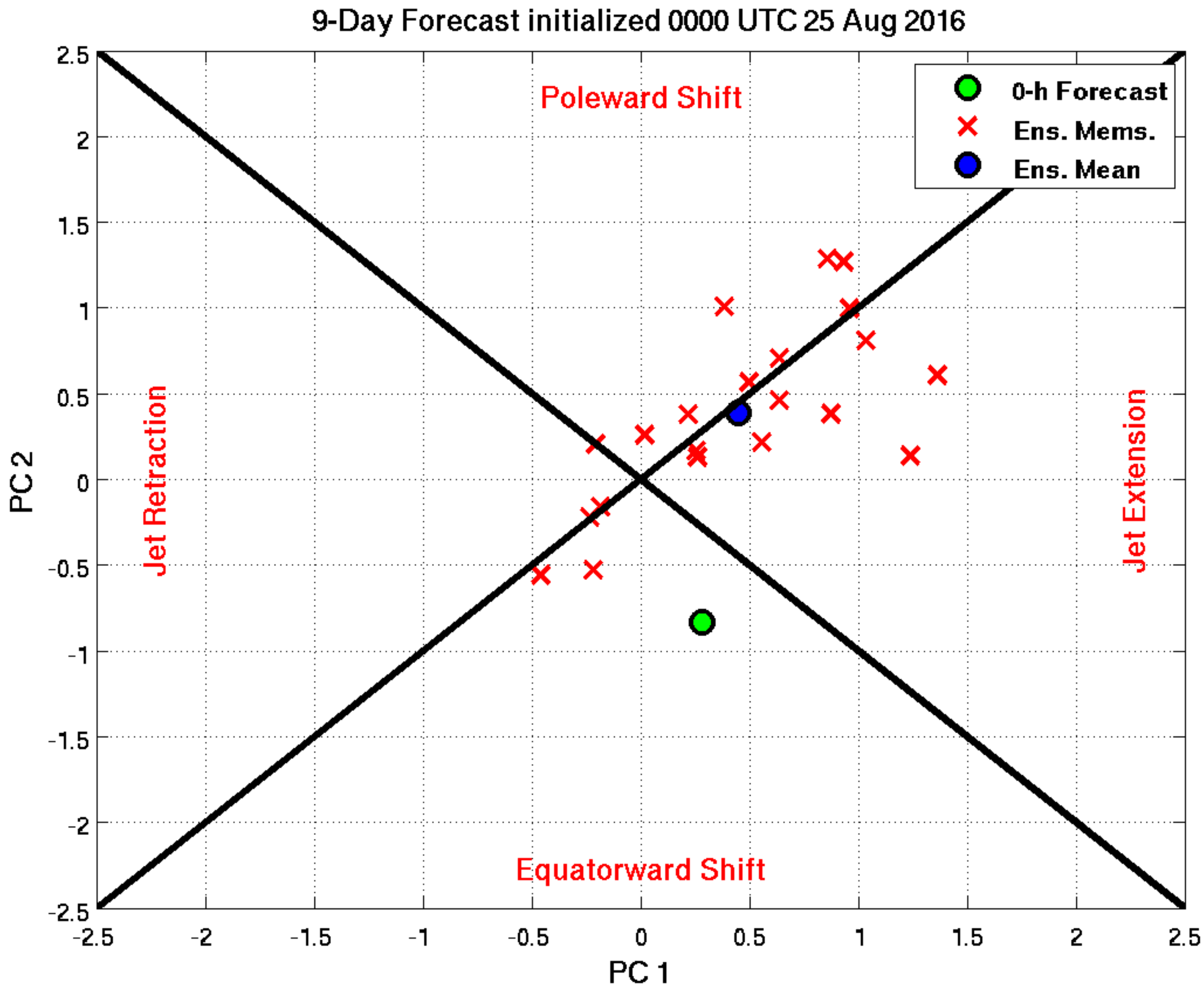
Real-time NPJ Phase Diagram Products

8-day forecast of GEFS ensemble members, GEFS ensemble mean, and 0-h forecast



Real-time NPJ Phase Diagram Products

9-day forecast of GEFS ensemble members, GEFS ensemble mean, and 0-h forecast

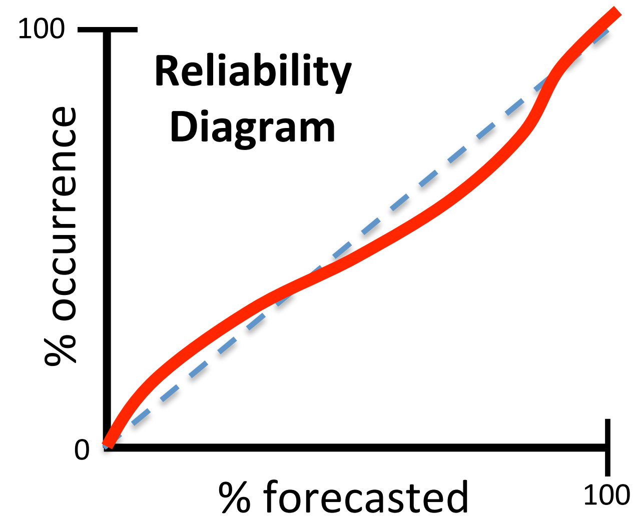


Candidate Verification Metrics

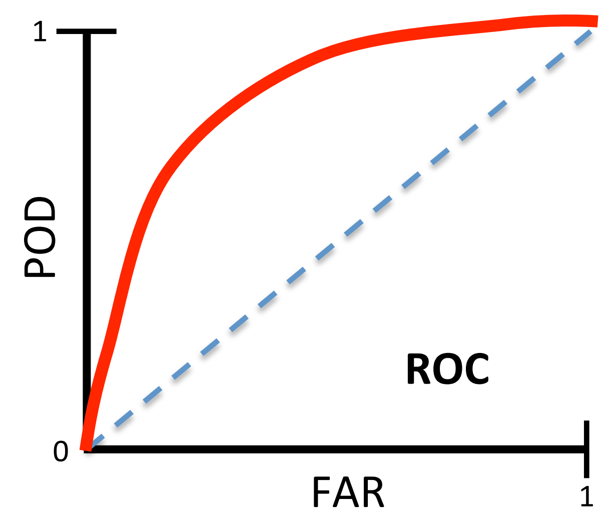
- **Forecast Error**
  - Distance between GFS deterministic forecast and the analysis at each forecast hour
  - Distance between the GEFS ensemble mean forecast and the analysis at each forecast hour
  - Average distance between ensemble members and the analysis at each forecast hour
- **Probability of Detection**
  - Did the analysis fall within the ensemble envelope at each forecast hour?

Candidate Verification Metrics

- **Reliability Diagram**
  - Could a reliability diagram be used to evaluate the performance of GEFS ensemble forecasts with respect to the NPJ Phase Diagram?



- **ROC**
  - Could a ROC be an alternative metric to evaluate the performance of GEFS ensemble forecasts with respect to the NPJ Phase Diagram?



Next Steps

- **EWE Predictability**
  - What is the predictability of EWEs in the GEFS reforecast dataset with respect to the NPJ Phase Diagram?
- **General Predictability**
  - What is the predictability of all GEFS ensemble reforecasts with respect to the NPJ Phase Diagram?

Project Outcomes

- Provide forecasters with a **"first alert"** to the possibility of the occurrence of extreme temperature and precipitation events during week two on the basis of current conditions and model forecasts.

- Provide forecasters with an indication of the **character and flavor** of possible extreme events as inferred from where the events lie in the frequency distributions of the anticipated event types.

- Provide forecasters with knowledge that allows them to make **science-based adjustments** to model guidance and add value to week two forecasts of temperature and precipitation.