An Investigation of the Skill of Week Two Extreme Temperature and Precipitation Forecasts at the NCEP-WPC

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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.

Project Goal

- Improve extreme temperature and precipitation forecasts on the 8–10 day time range at the WPC in collaboration with WPC personnel.

Project Summary

1. Performed illustrative case studies of individual extreme temperature and precipitation events and conducted verification studies of GFS operational and ensemble forecasts, and associated human forecasts for the illustrative case studies.

Project Summary

Considered four recent EWEs:

1) 22–23 Dec 2013 Northeast ice storm
2) Nov 2014 record U.S. cold that followed the ET of STY Nuri in the western North Pacific
3) 25–27 January 2015 East Coast blizzard
4) 22–24 January 2016 mid-Atlantic blizzard

Forecasts for the four recent EWEs were strongly influenced by precursor events that perturbed the North Pacific Jet and amplified the upper-tropospheric flow pattern.

Presentations accessible via:
http://www.atmos.albany.edu/facstaff/awinters/mayreport

Project Summary

Identified "events of opportunity" during the tenure of the project:

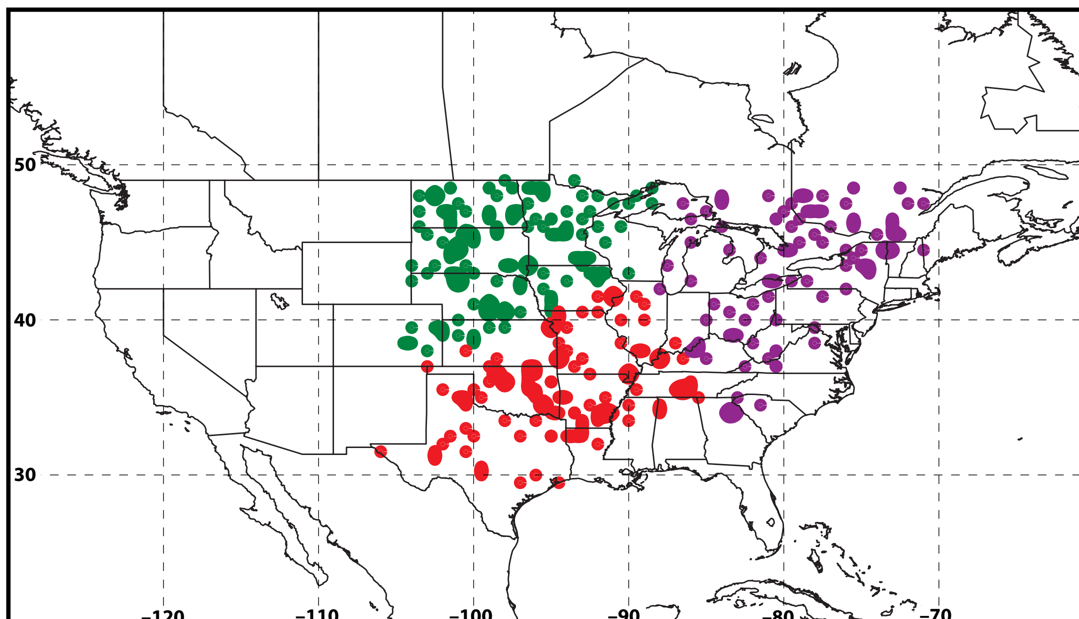
1) Mid-February 2016 sequential mid-Atlantic cyclones
2) 20–21 March 2016 potential for a Nor'easter
3) 23–24 March 2016 Colorado Front Range snowstorm
4) 3–4 April 2016 extreme cold in the Northeast U.S.
5) 16 April 2016 High Plains extreme precipitation event
6) 26 April 2016 Central Plains severe weather outbreak
7) June 2016 extreme heat in the Southwest U.S.

Project Summary

2. Developed a methodology for identifying extreme temperature and precipitation events over the CONUS for all seasons during 1979–2014.

3. Performed composite analyses of characteristic event types in order to determine the multiscale evolution of the governing atmospheric flow patterns that culminate in these event types.

Objectively identified extreme warm event centroids east of the Rockies (n = 304)



Northern Plains Cluster (n=116)
Southern Plains Cluster (n=102)
Eastern U.S. Cluster (n=86)

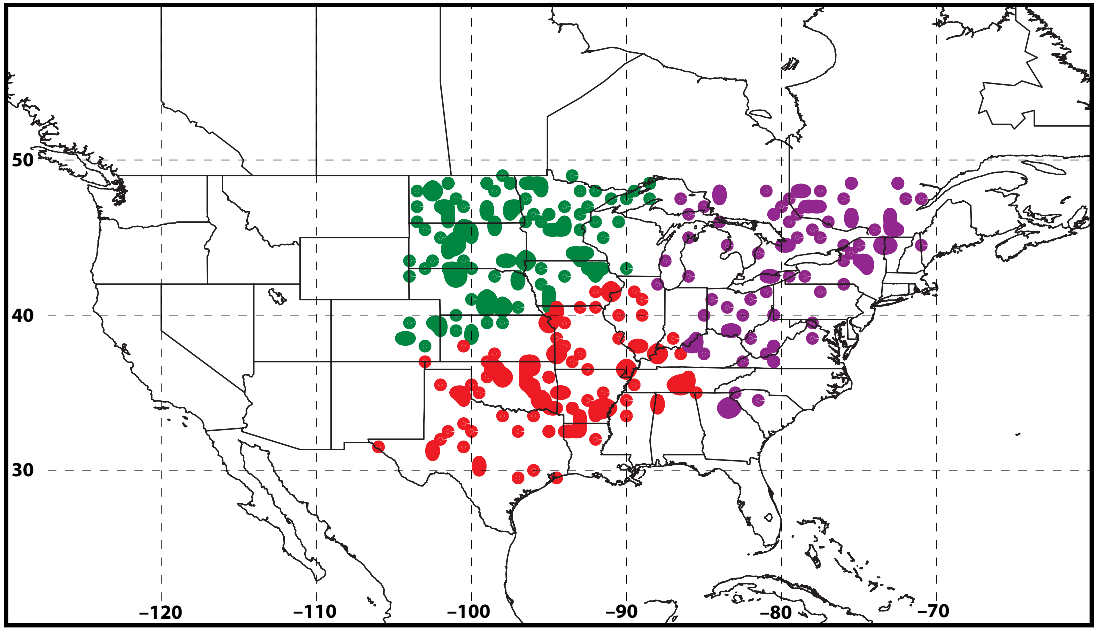
Project Summary

2. Developed a methodology for identifying extreme temperature and precipitation events over the CONUS for all seasons during 1979–2014.

3. Performed composite analyses of characteristic event types in order to determine the multiscale evolution of the governing atmospheric flow patterns that culminate in these event types.

Considerable North Pacific Jet variability characterizes the antecedent environments associated with events in each geographic cluster

Northern Plains Cluster (n=116)
Southern Plains Cluster (n=102)
Eastern U.S. Cluster (n=86)

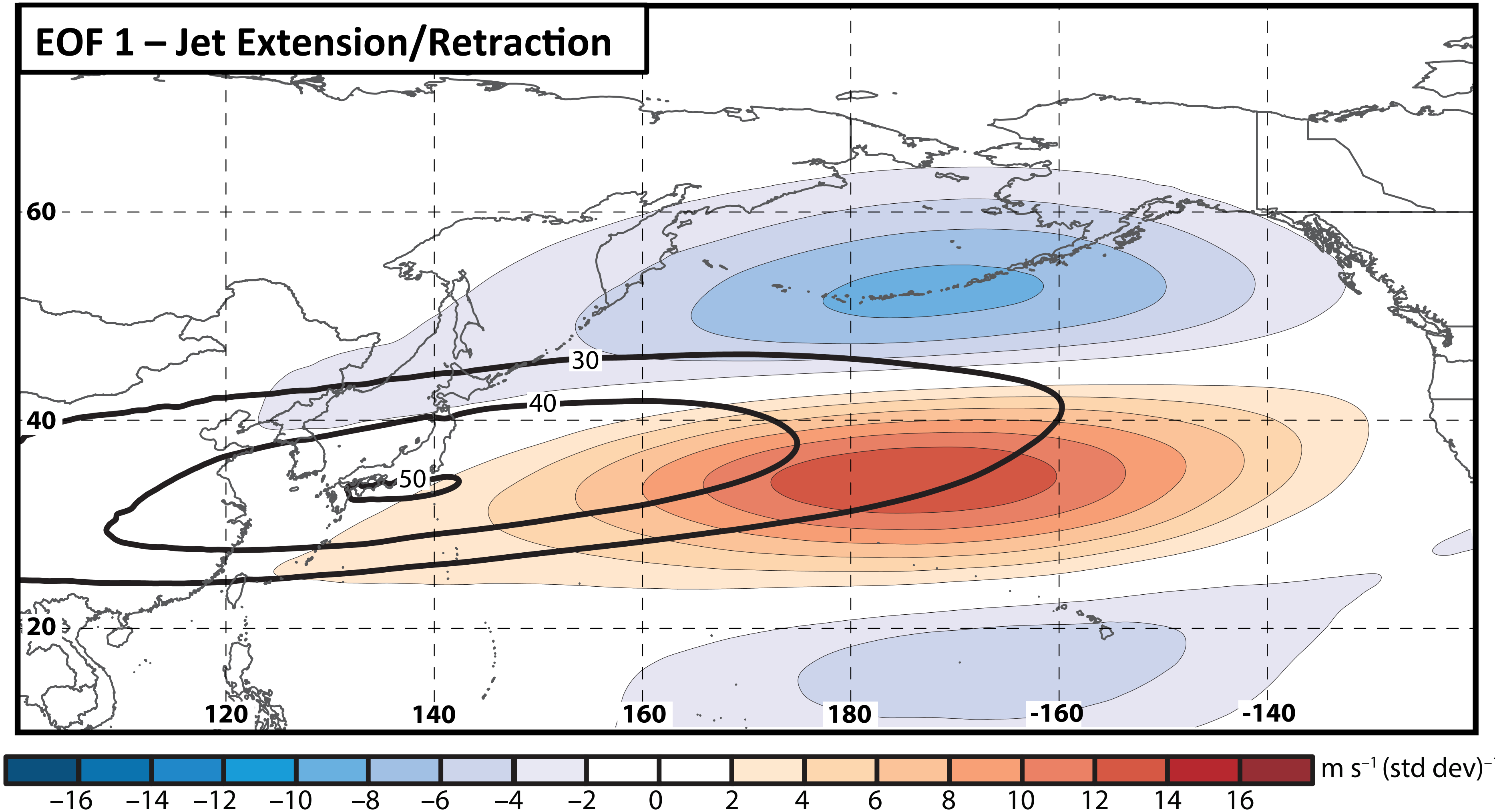


Antecedent Environments Associated with Cool-Season (Sept.–May) EWEs in the Context of North Pacific Jet Variability

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)
- Isolated only data during the cool season (September – May)
- Performed an EOF analysis on the zonal wind anomalies within the domain: 10–80°N ; 100°E–120°W

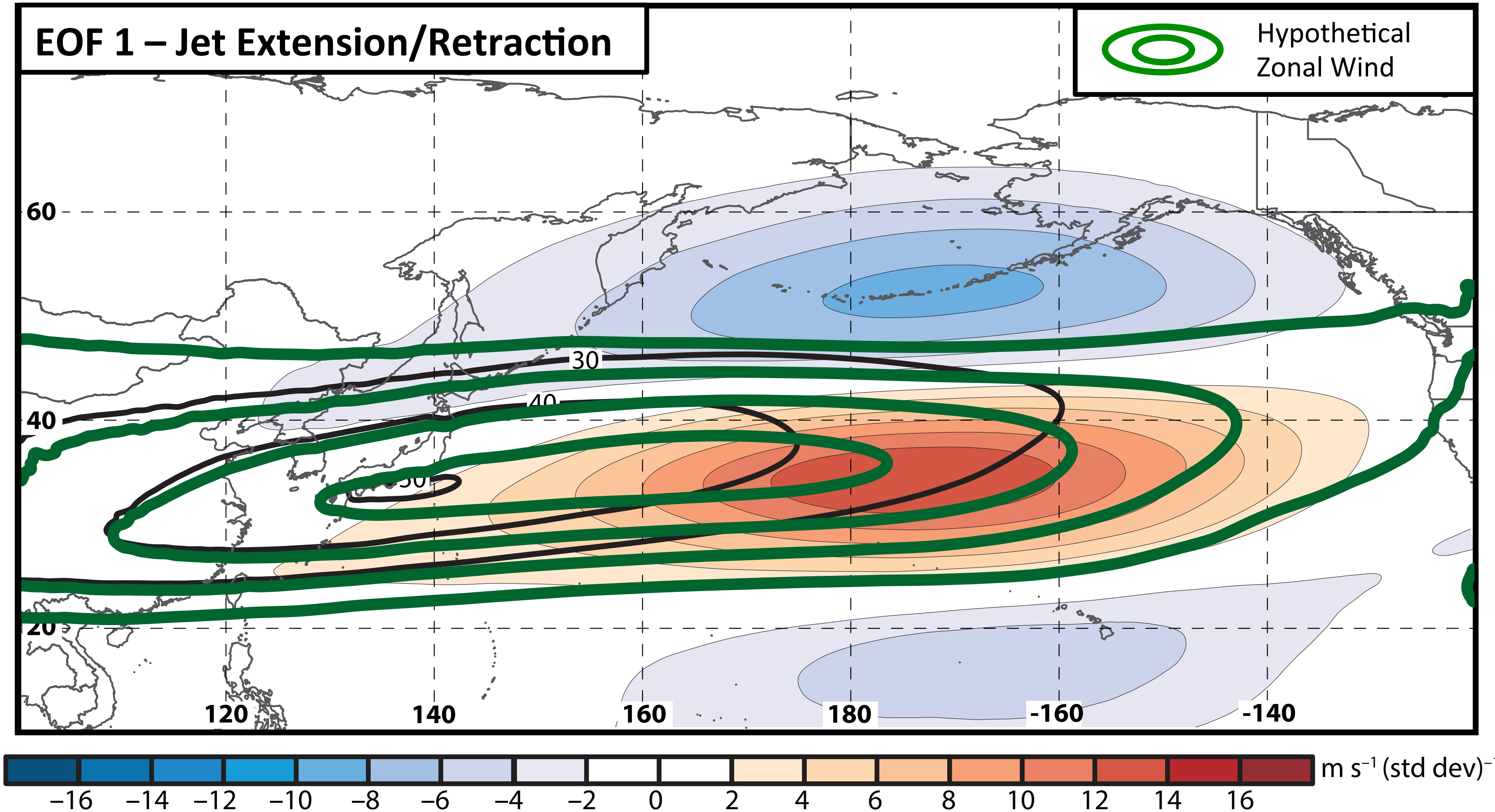
250-hPa North Pacific Zonal Wind Variability



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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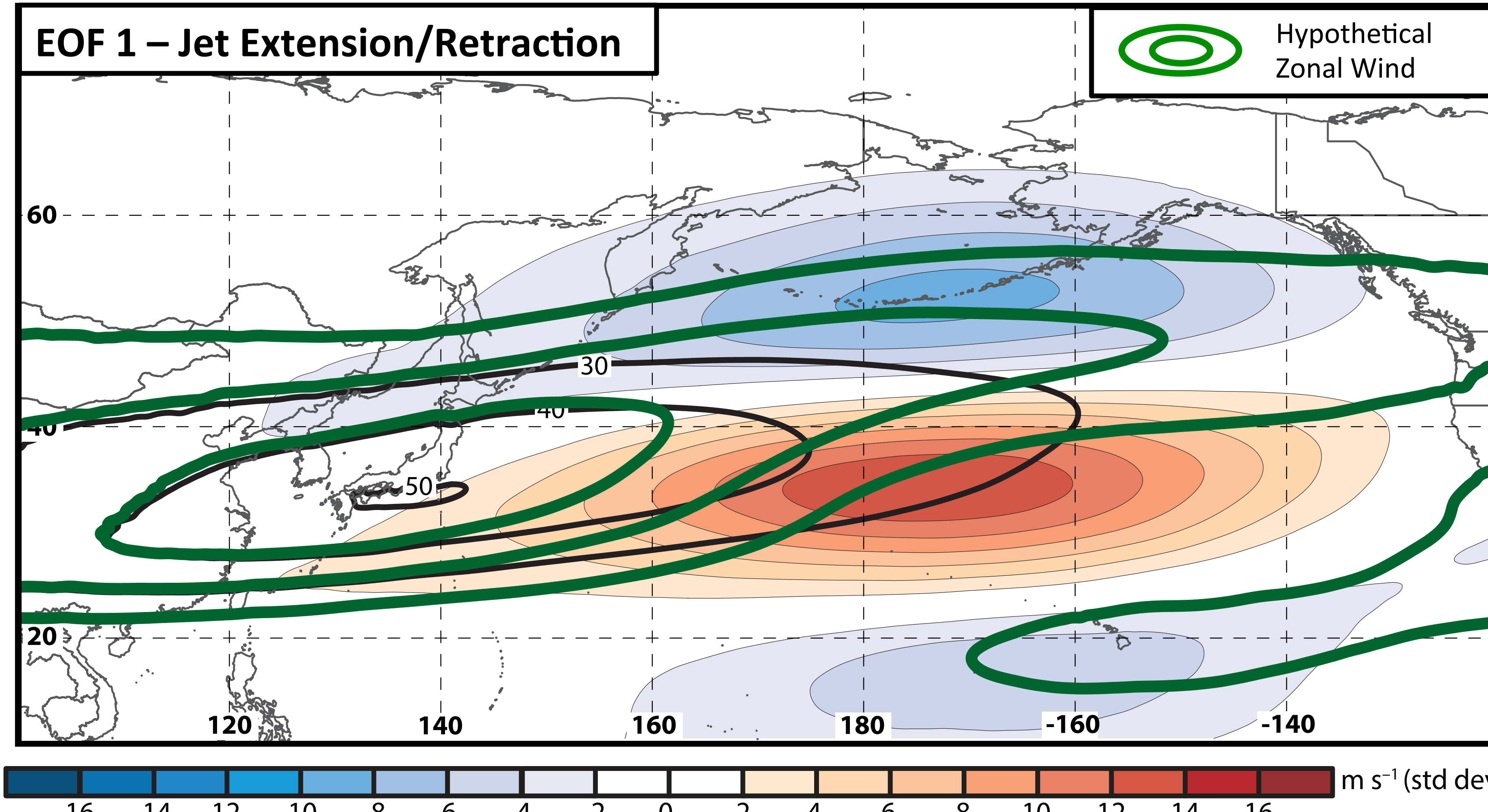

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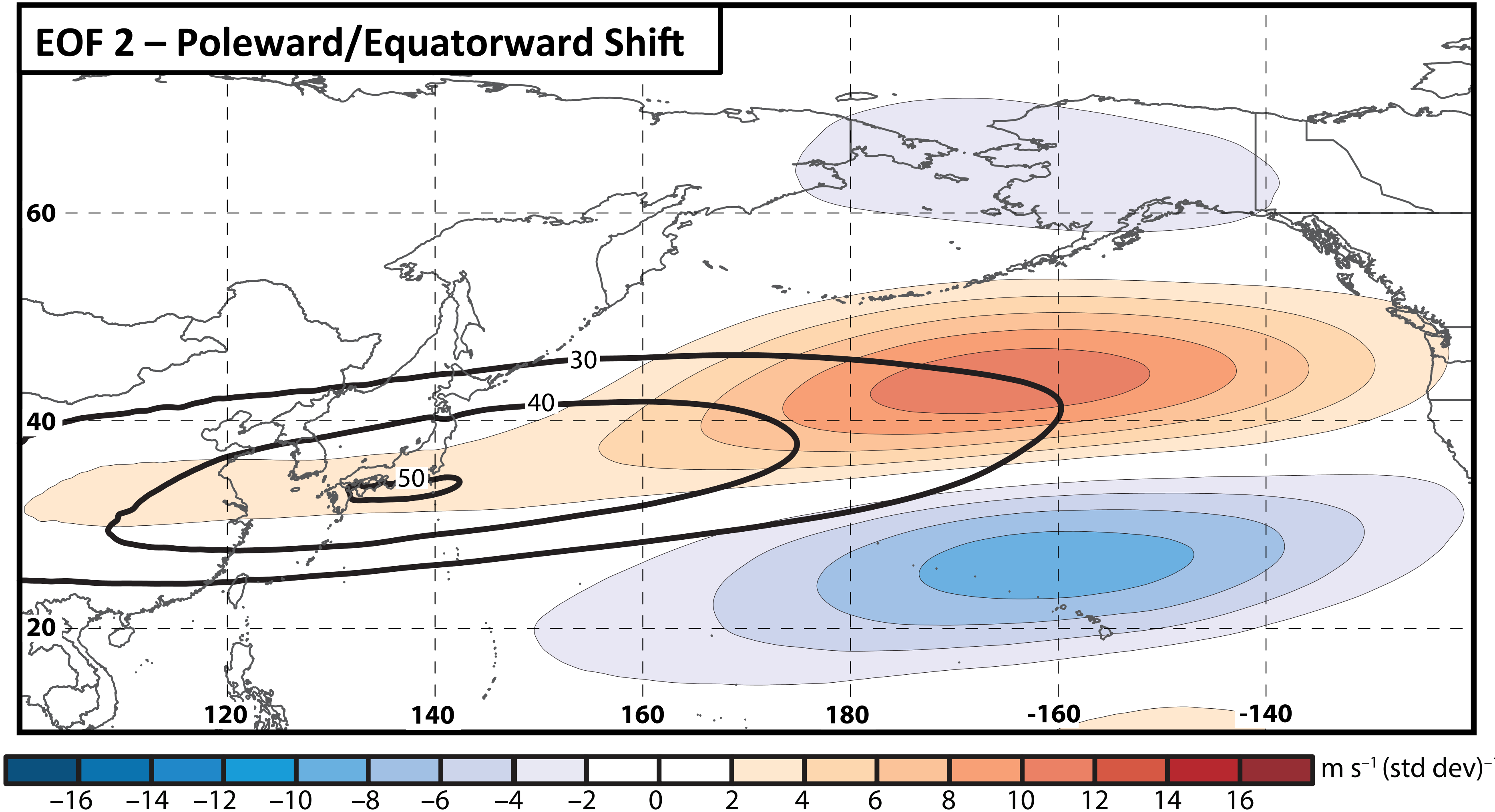
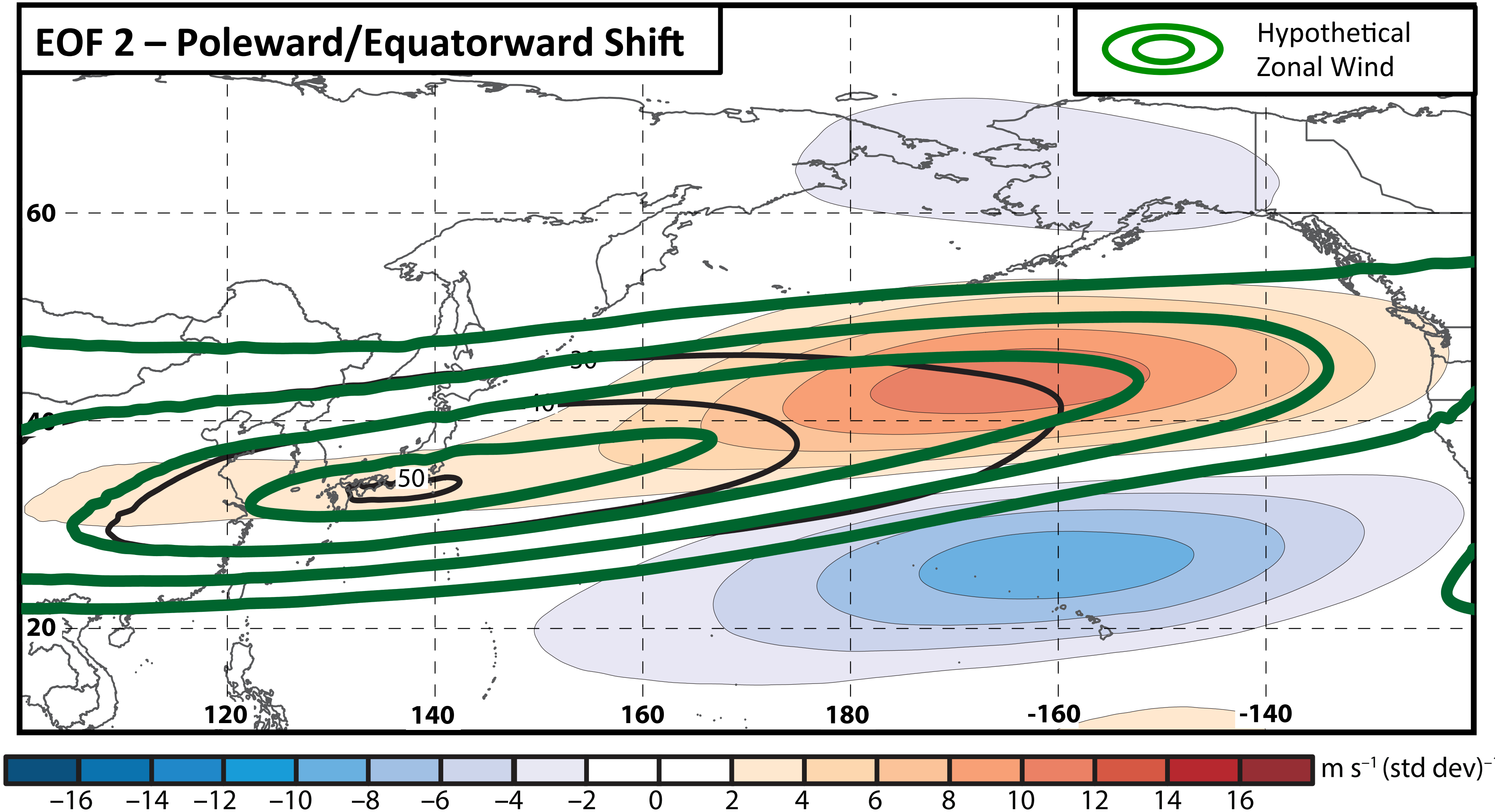


Sept.–May mean 250-hPa zonal wind: black contours
Sept.–May 250-hPa zonal wind EOF 1 pattern: shading

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

250-hPa North Pacific Zonal Wind Variability



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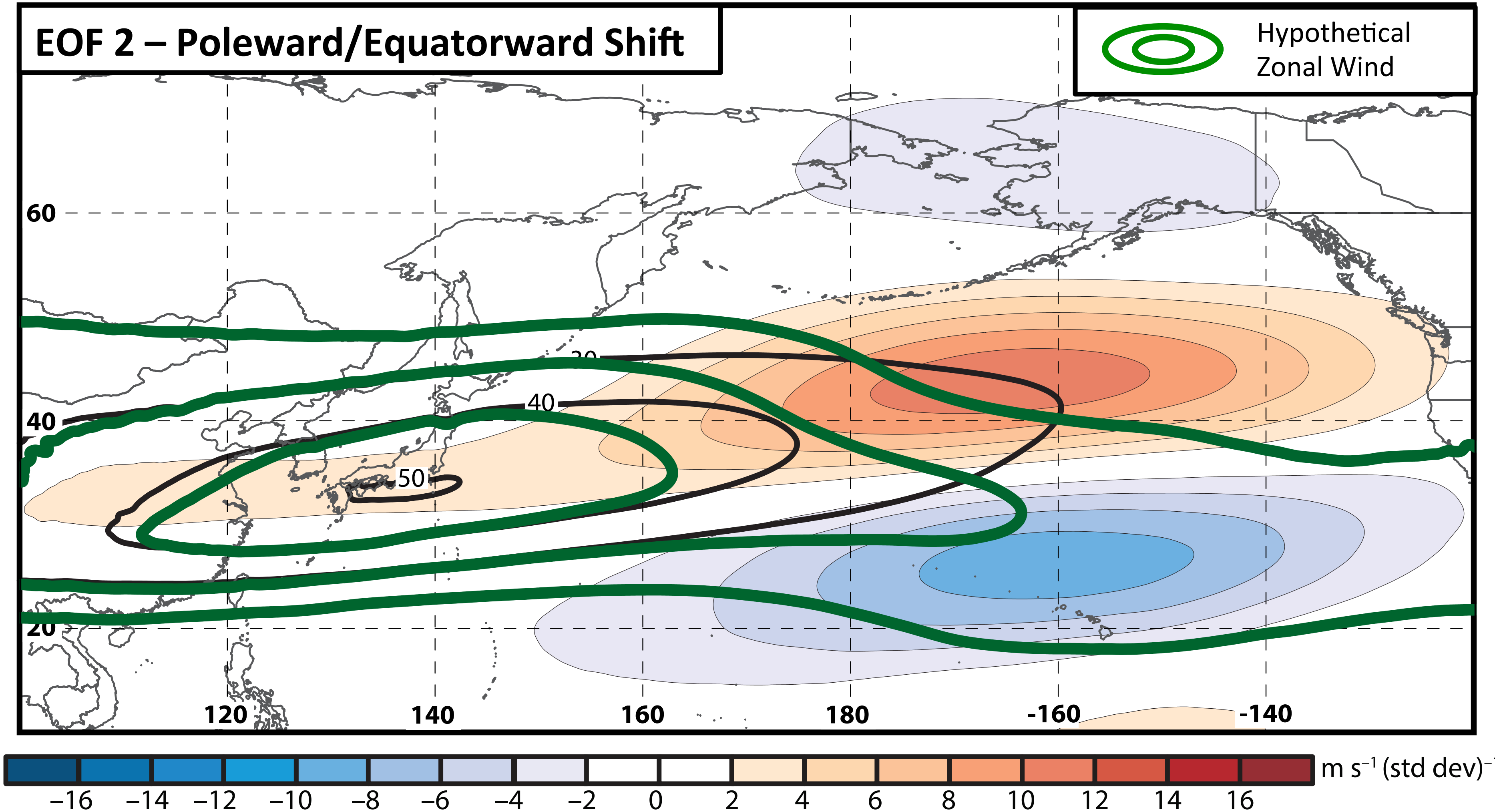

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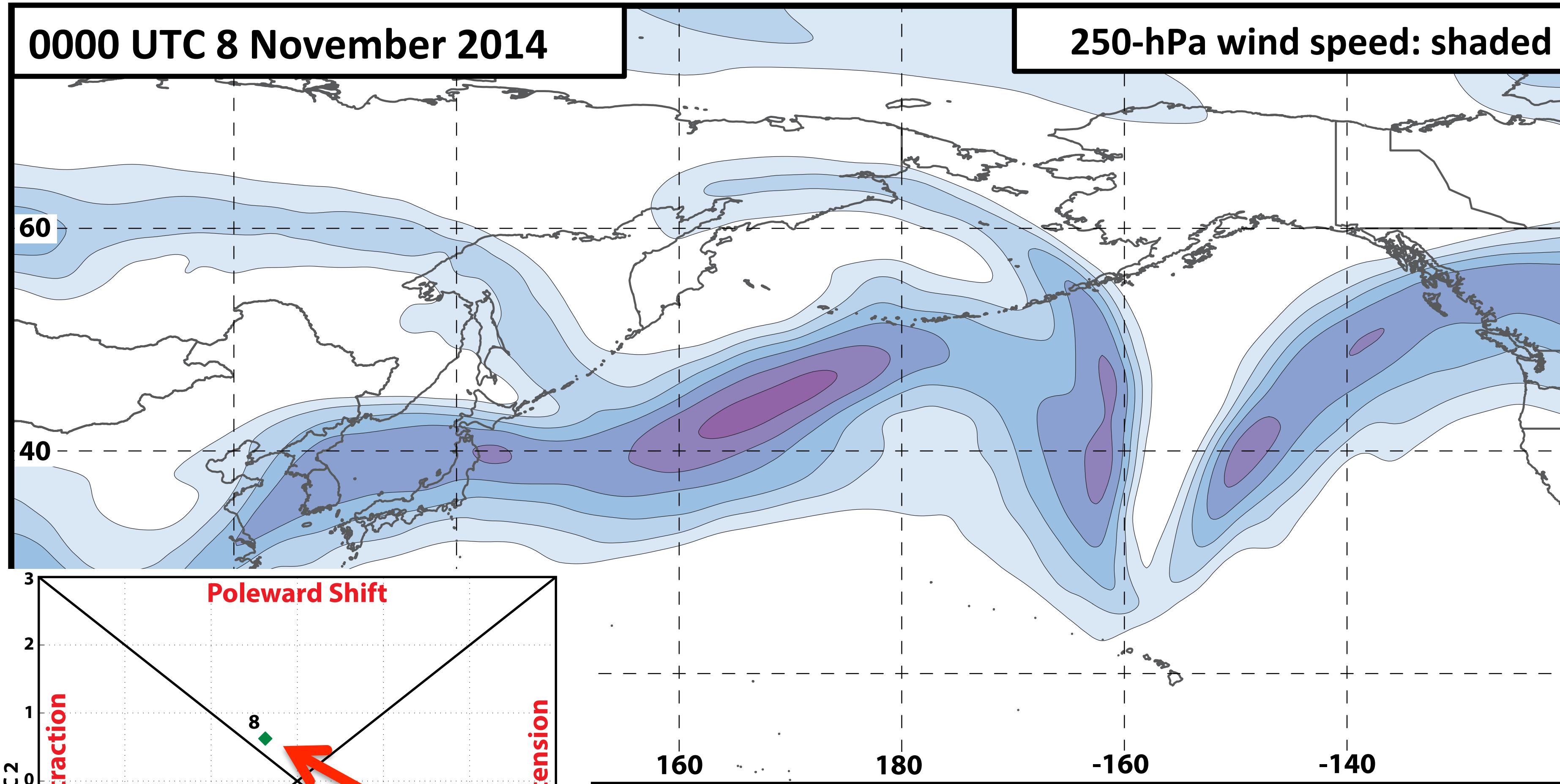
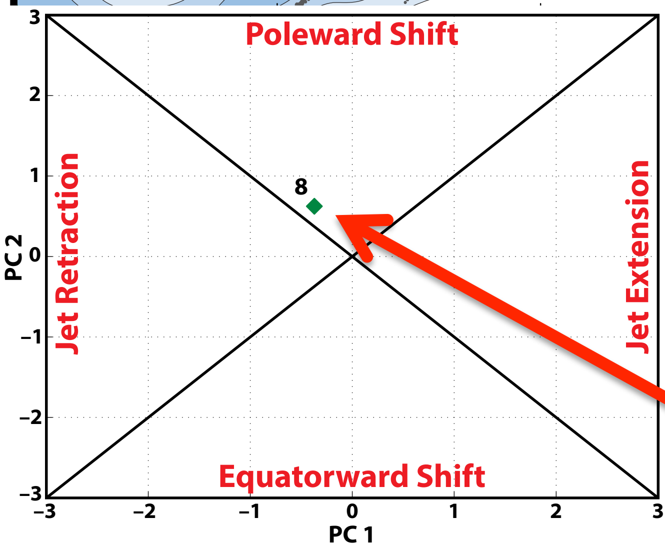
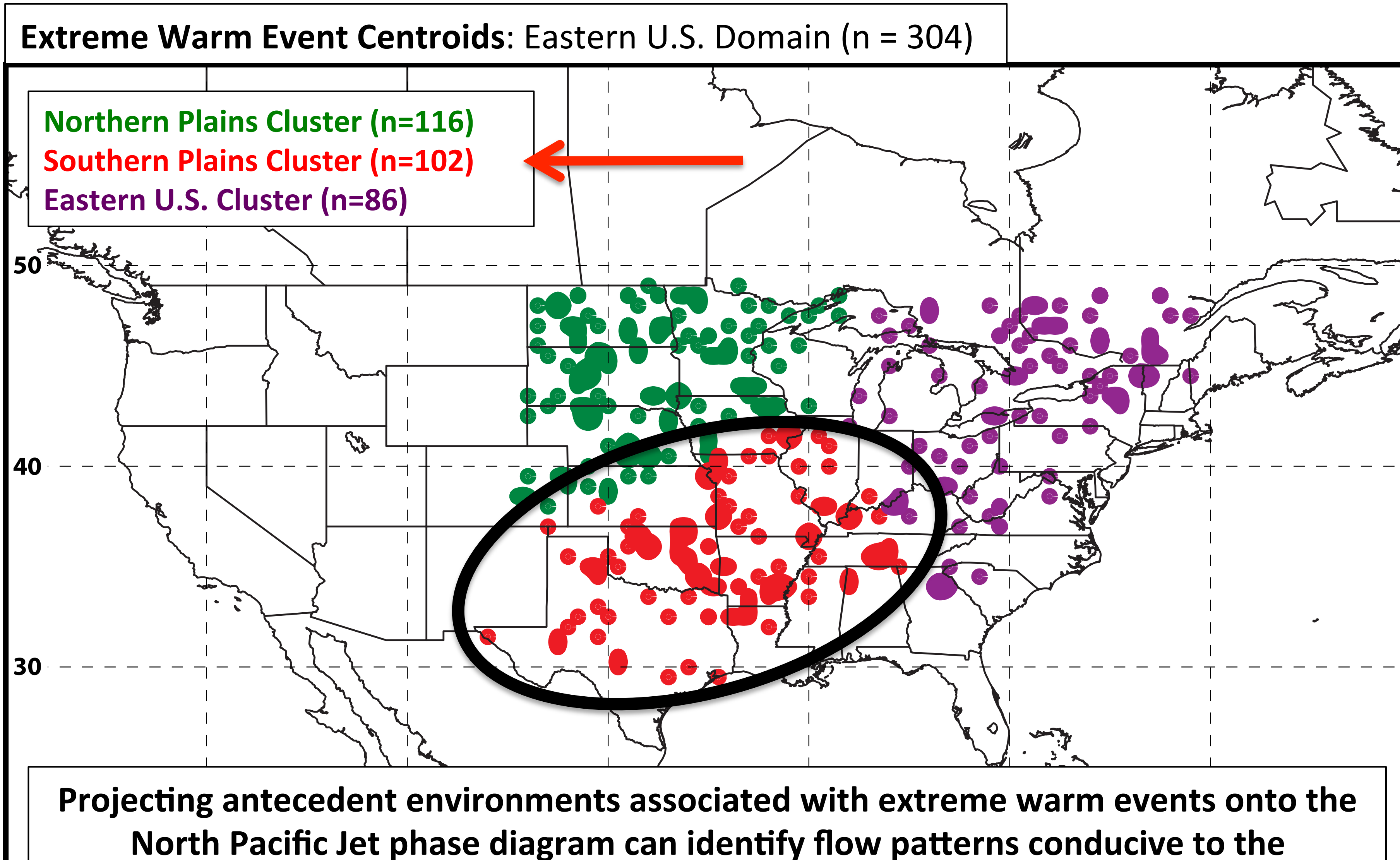




Instantaneous 250-hPa zonal wind anomalies can be projected onto EOF 1 and EOF 2, resulting in a point on a North Pacific Jet phase diagram

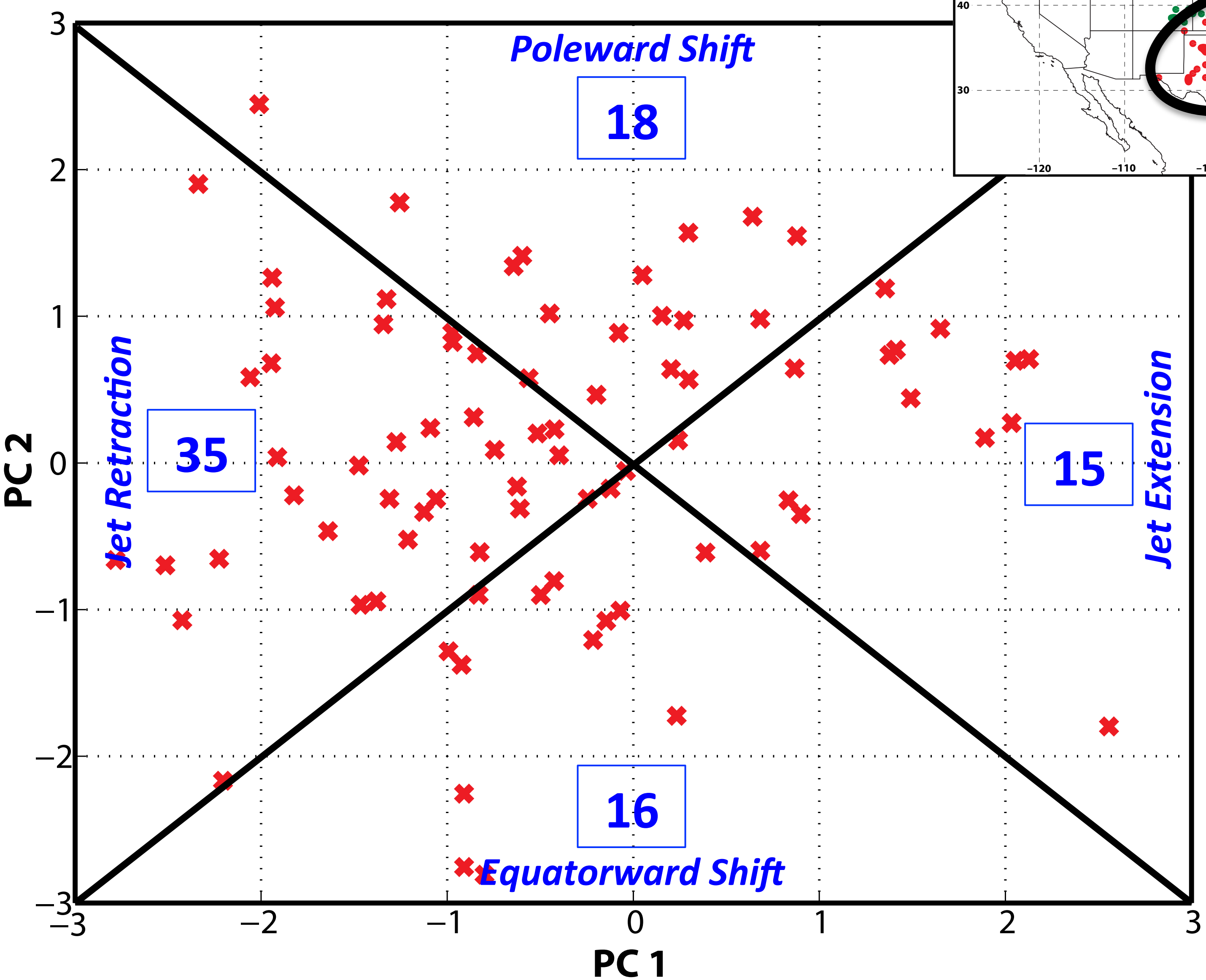
250-hPa North Pacific Zonal Wind Variability

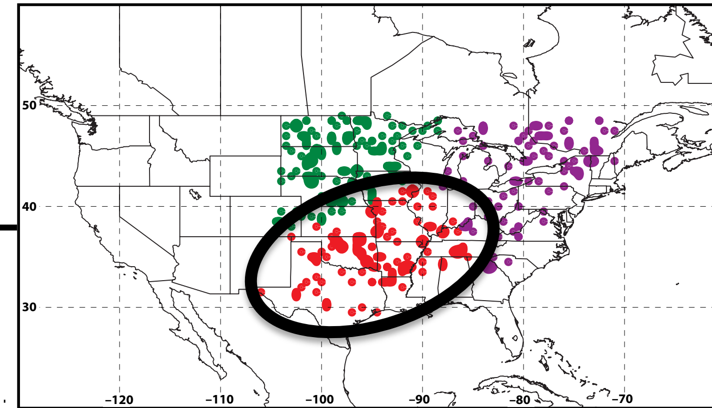


Projecting antecedent environments associated with extreme warm events onto the North Pacific Jet phase diagram can identify flow patterns conducive to the development of these events

E. Rockies – 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

E. Rockies – S. Plains Cluster

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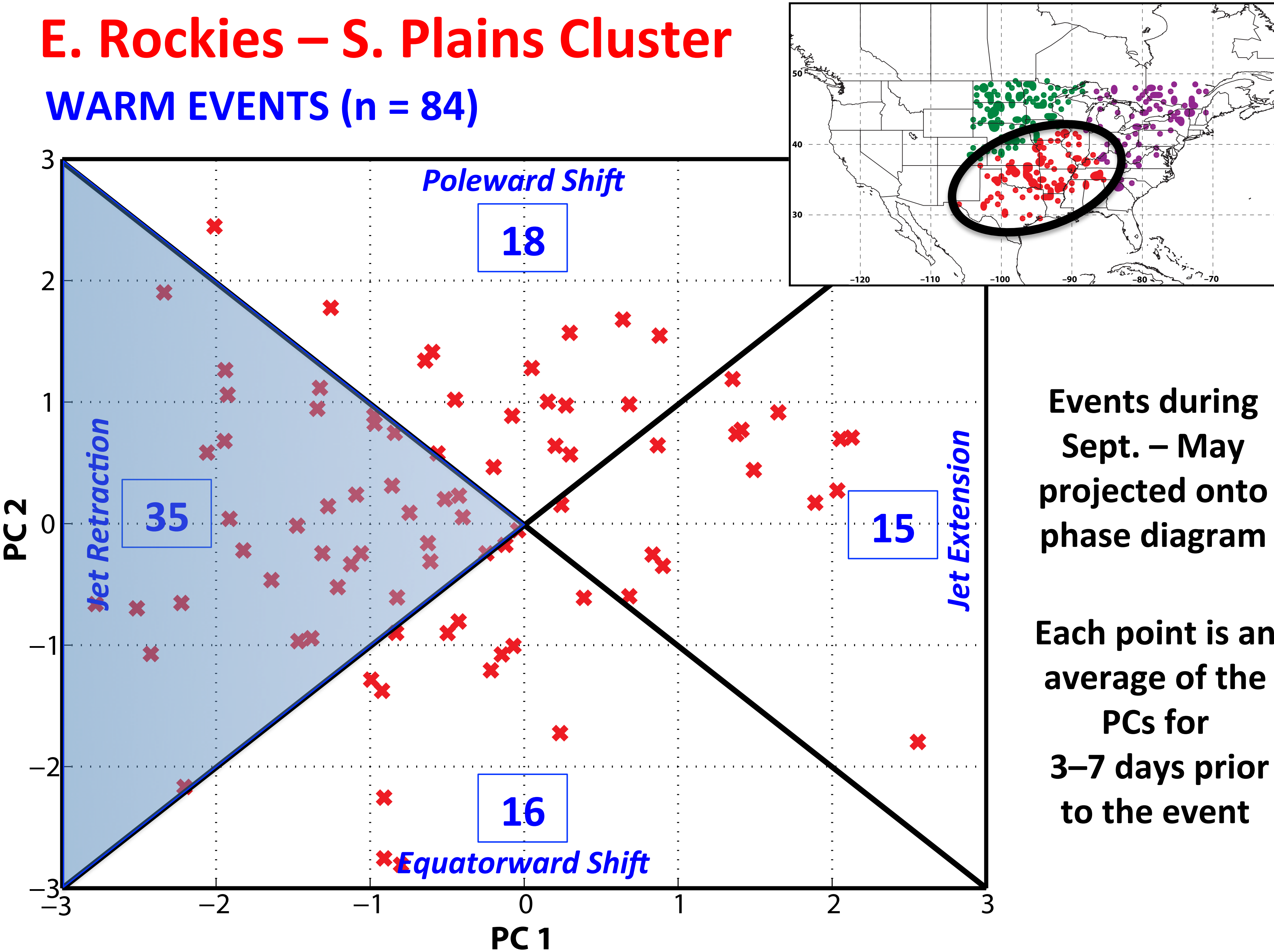

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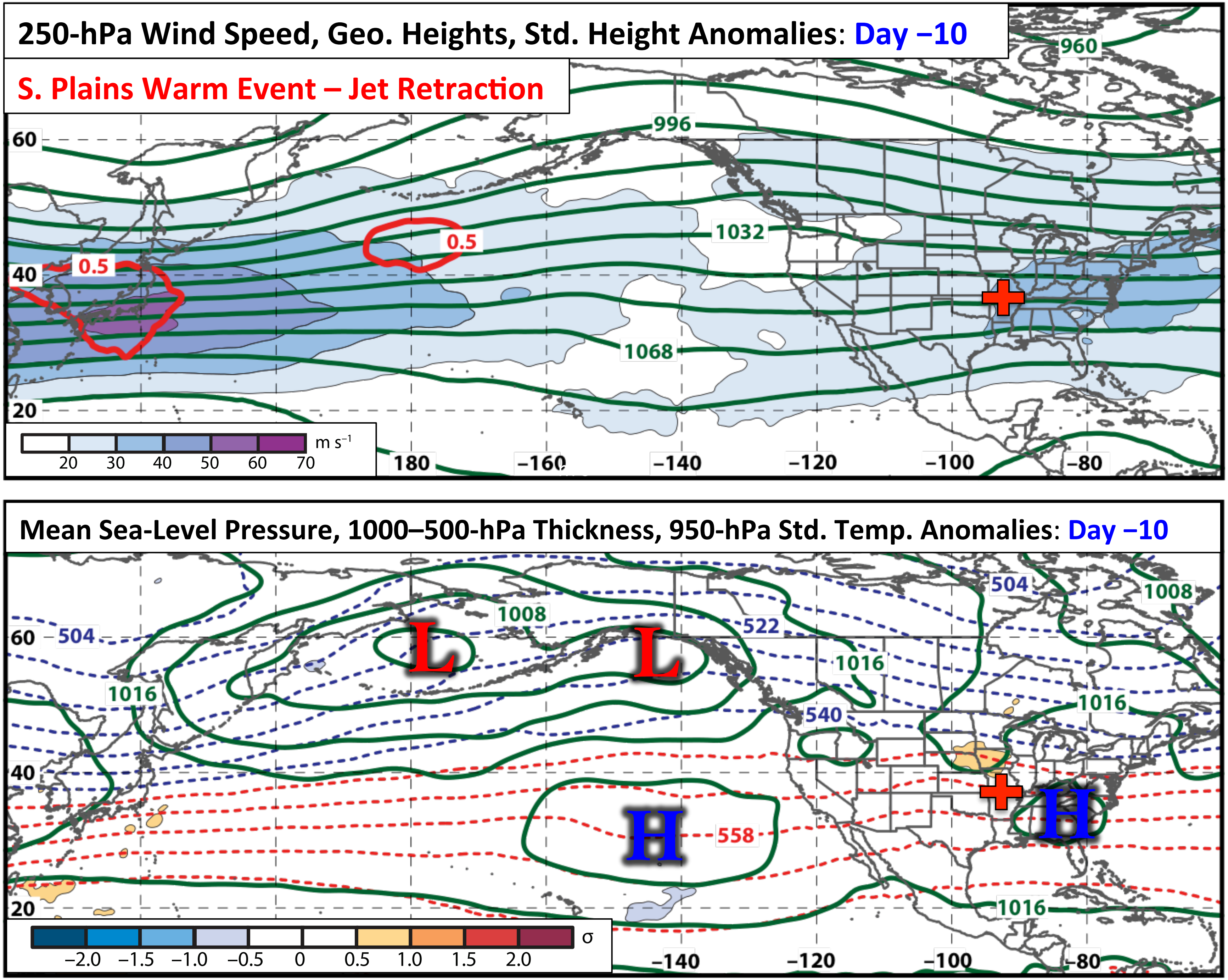
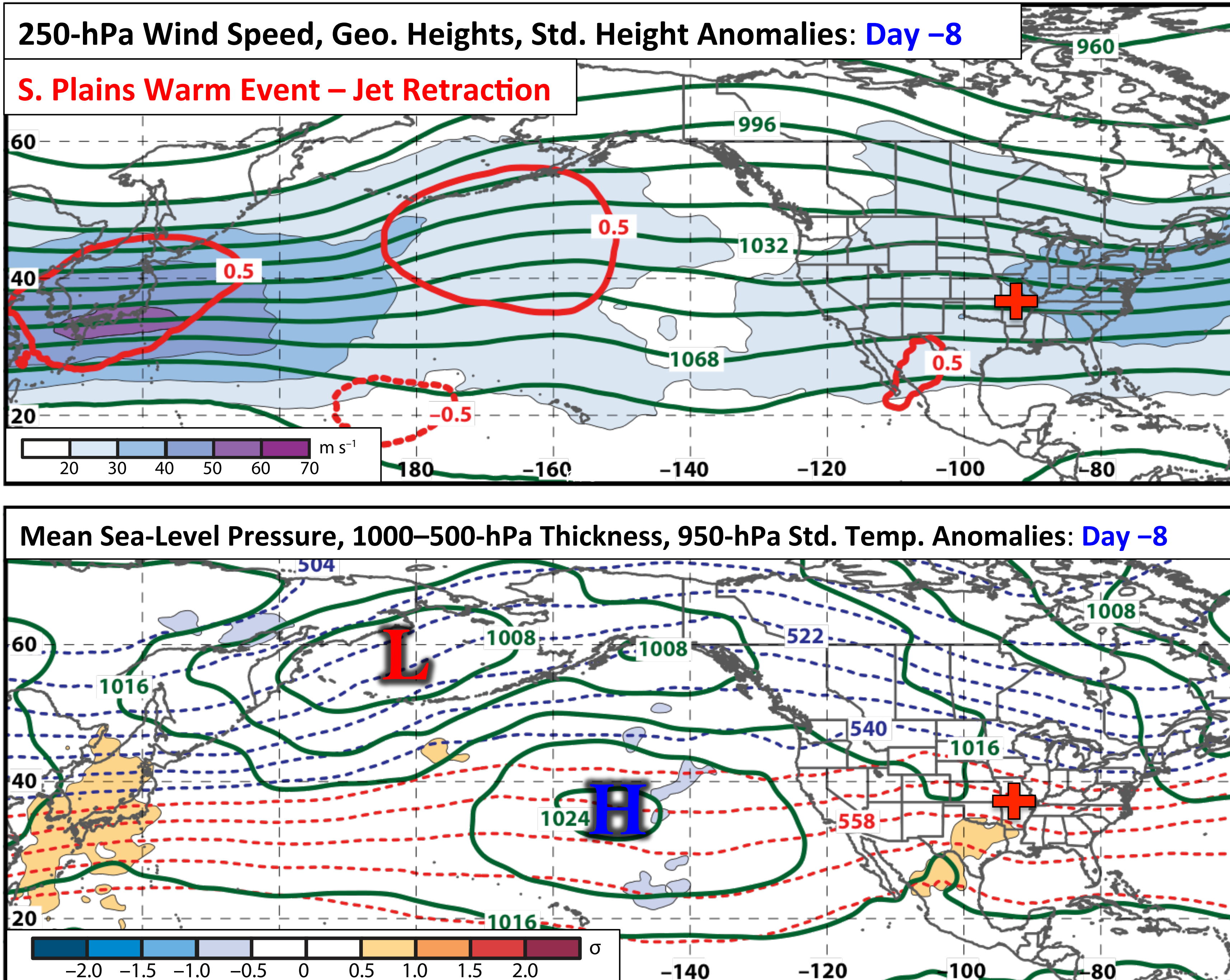


250-hPa Wind Speed, Geo. Heights, Std. Height Anomalies: Day −10
S. Plains Warm Event – Jet Retraction
960
996
1032
1068
0.5
0.5
60
40
20
m s⁻¹
20 30 40 50 60 70
180 −160 −140 −120 −100 −80
Mean Sea-Level Pressure, 1000–500-hPa Thickness, 950-hPa Std. Temp. Anomalies: Day −10
L
L
H
H
504
504
522
540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


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
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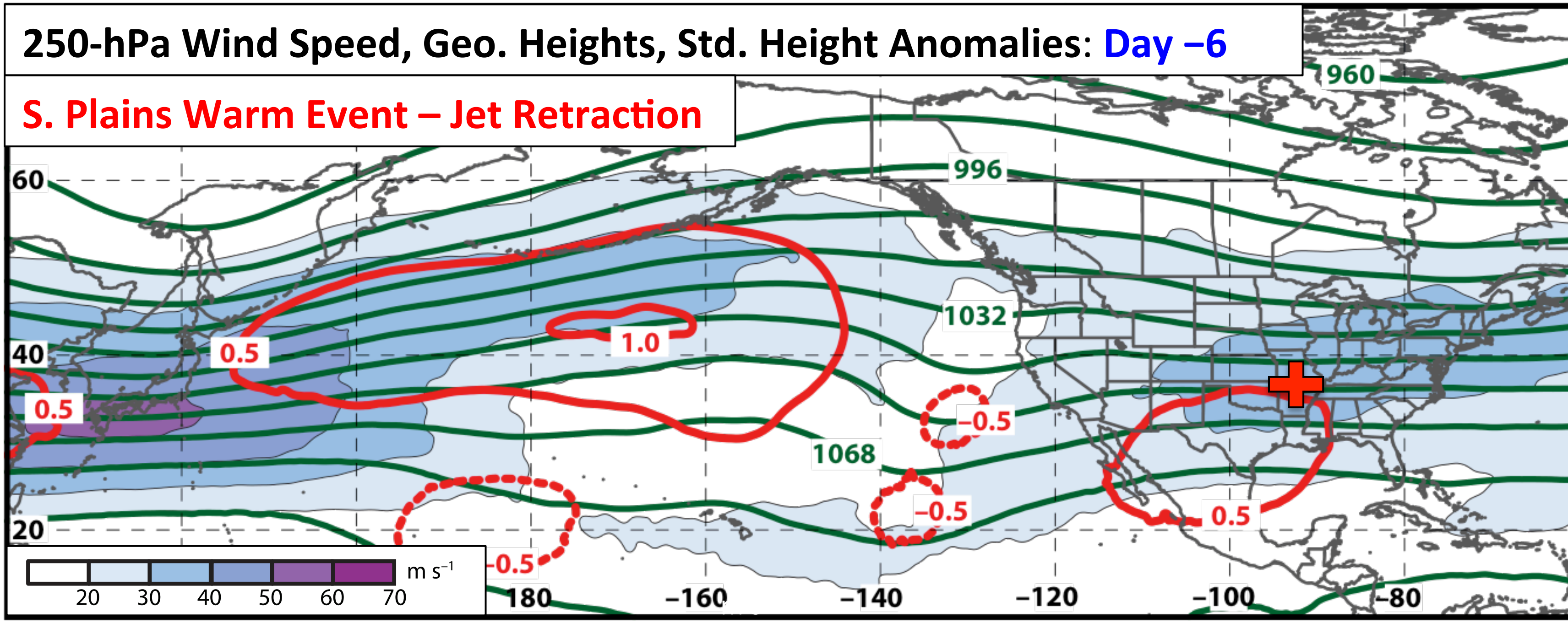
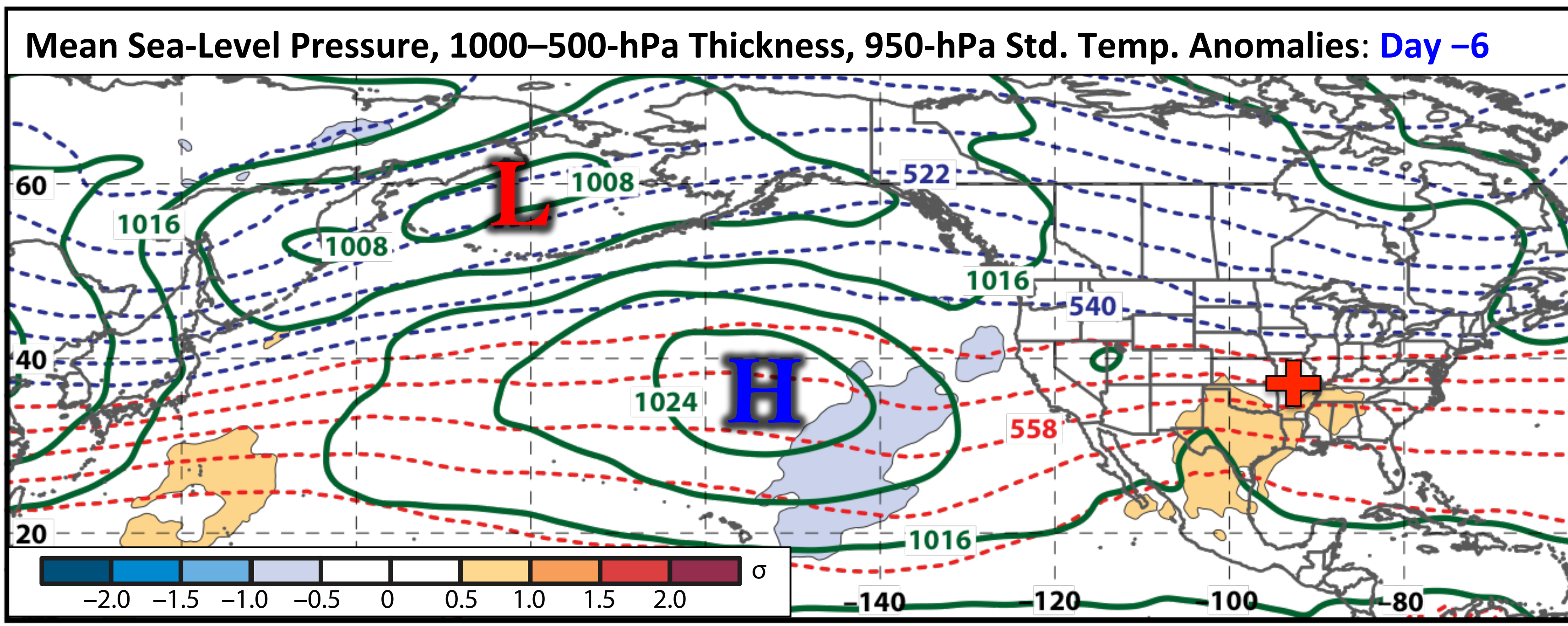
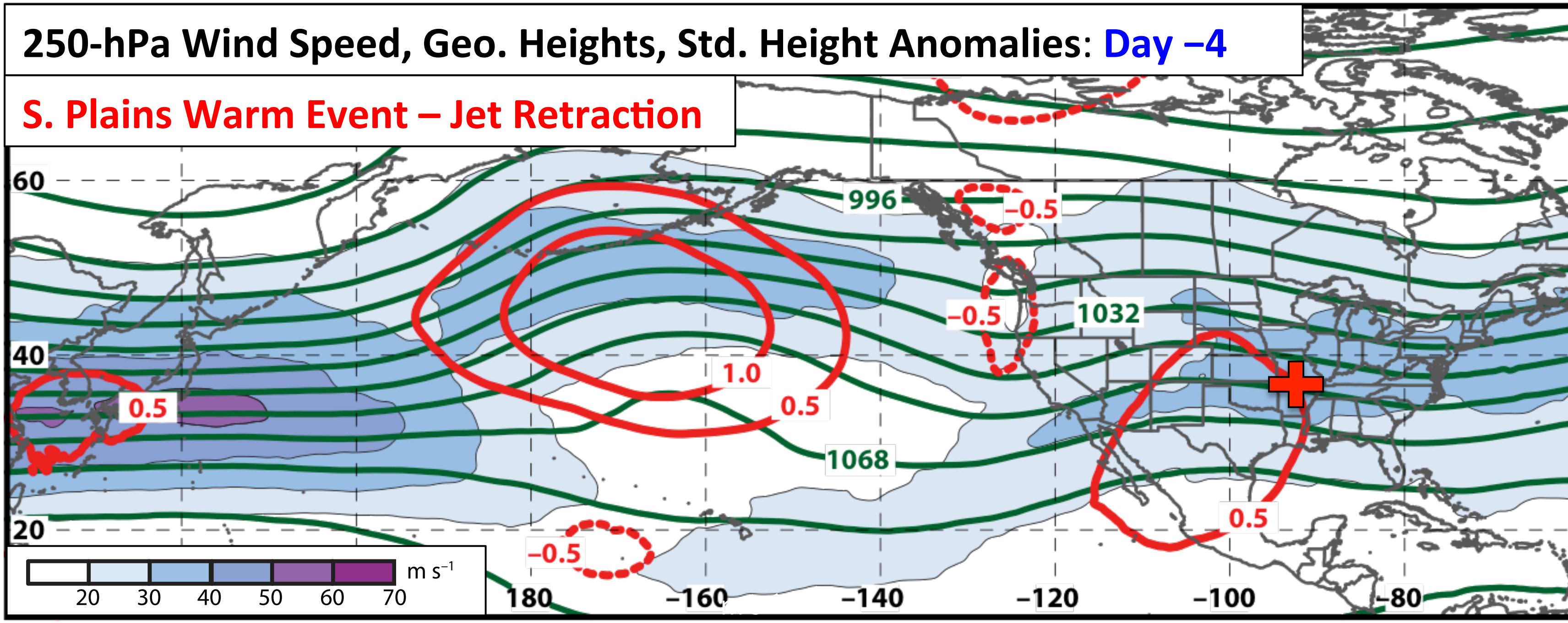
20
−140
−120
−100
−80
σ
−2.0 −1.5 −1.0 −0.5 0 0.5 1.0 1.5 2.0

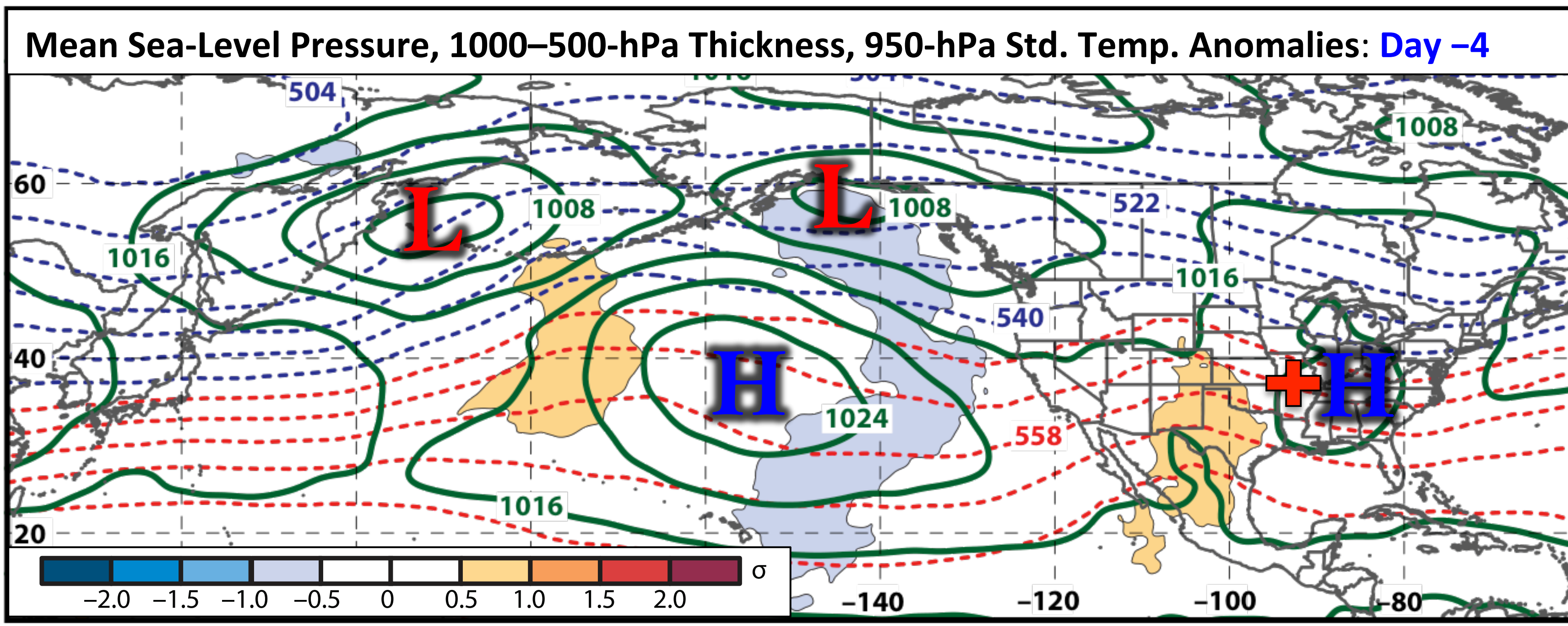


250-hPa Wind Speed, Geo. Heights, Std. Height Anomalies: Day −6
S. Plains Warm Event – Jet Retraction
960
996
1032
1068
0.5
1.0
−0.5
60
40
20
180
−160
−140
−120
−100
−80
20 30 40 50 60 70
m s−1



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
−140
−120
−100
−80
−2.0 −1.5 −1.0 −0.5 0 0.5 1.0 1.5 2.0
σ


250-hPa Wind Speed, Geo. Heights, Std. Height Anomalies: Day −4
S. Plains Warm Event – Jet Retraction
996
−0.5
−0.5
1032
1.0
0.5
0.5
1068
0.5
−0.5
0.5
60
40
20
20 30 40 50 60 70
m s⁻¹
180
−160
−140
−120
−100
−80


Mean Sea-Level Pressure, 1000–500-hPa Thickness, 950-hPa Std. Temp. Anomalies: Day −4
504
L
L
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1008
1008
522
1016
1016
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H
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1024
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1016
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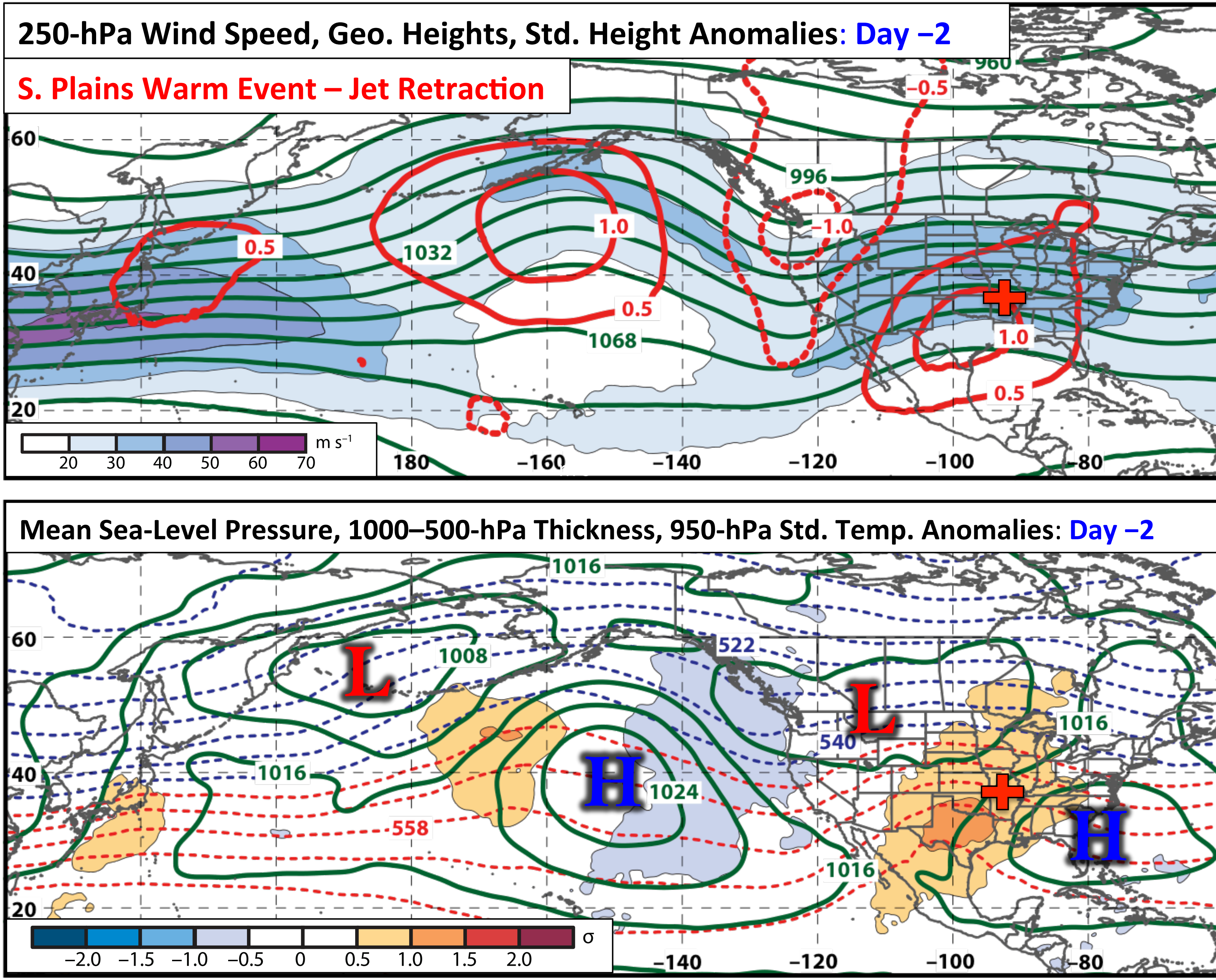
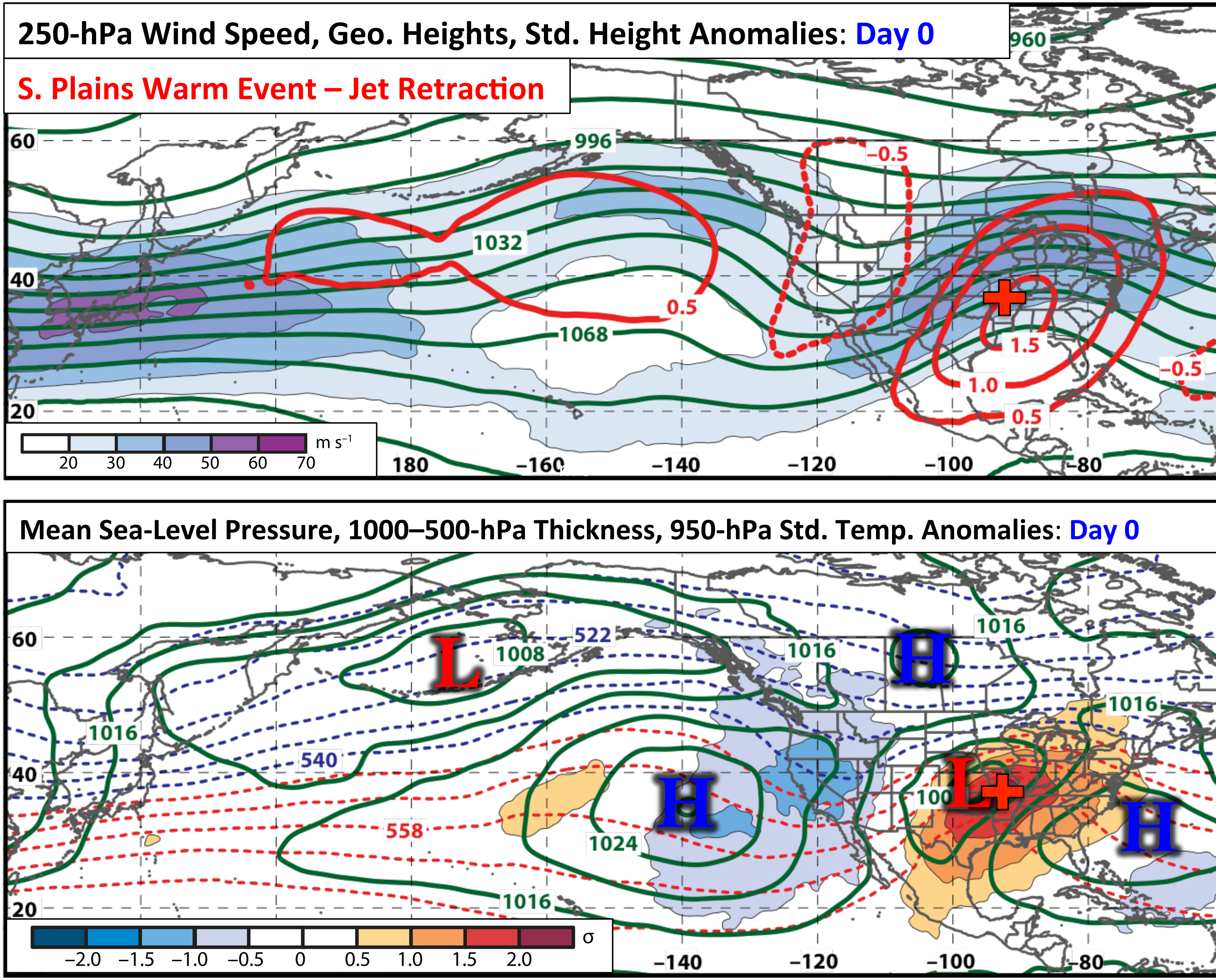
−2.0 −1.5 −1.0 −0.5 0 0.5 1.0 1.5 2.0
σ
−140
−120
−100
−80



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
0.5
1.0
0.5
60
40
20
20 30 40 50 60 70
m s−1
180
−160
−140
−120
−100
−80
Mean Sea-Level Pressure, 1000–500-hPa Thickness, 950-hPa Std. Temp. Anomalies: Day −2
1016
1008
522
L
L
540
1016
1016
H
1024
558
H
1016
60
40
20
−2.0 −1.5 −1.0 −0.5 0 0.5 1.0 1.5 2.0
σ
−140
−120
−100
−80


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
540
H
1024
558
1016
100
L
H
60
40
20
σ
–2.0
–1.5
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–120
–100
–80

E. Rockies – S. Plains Cluster

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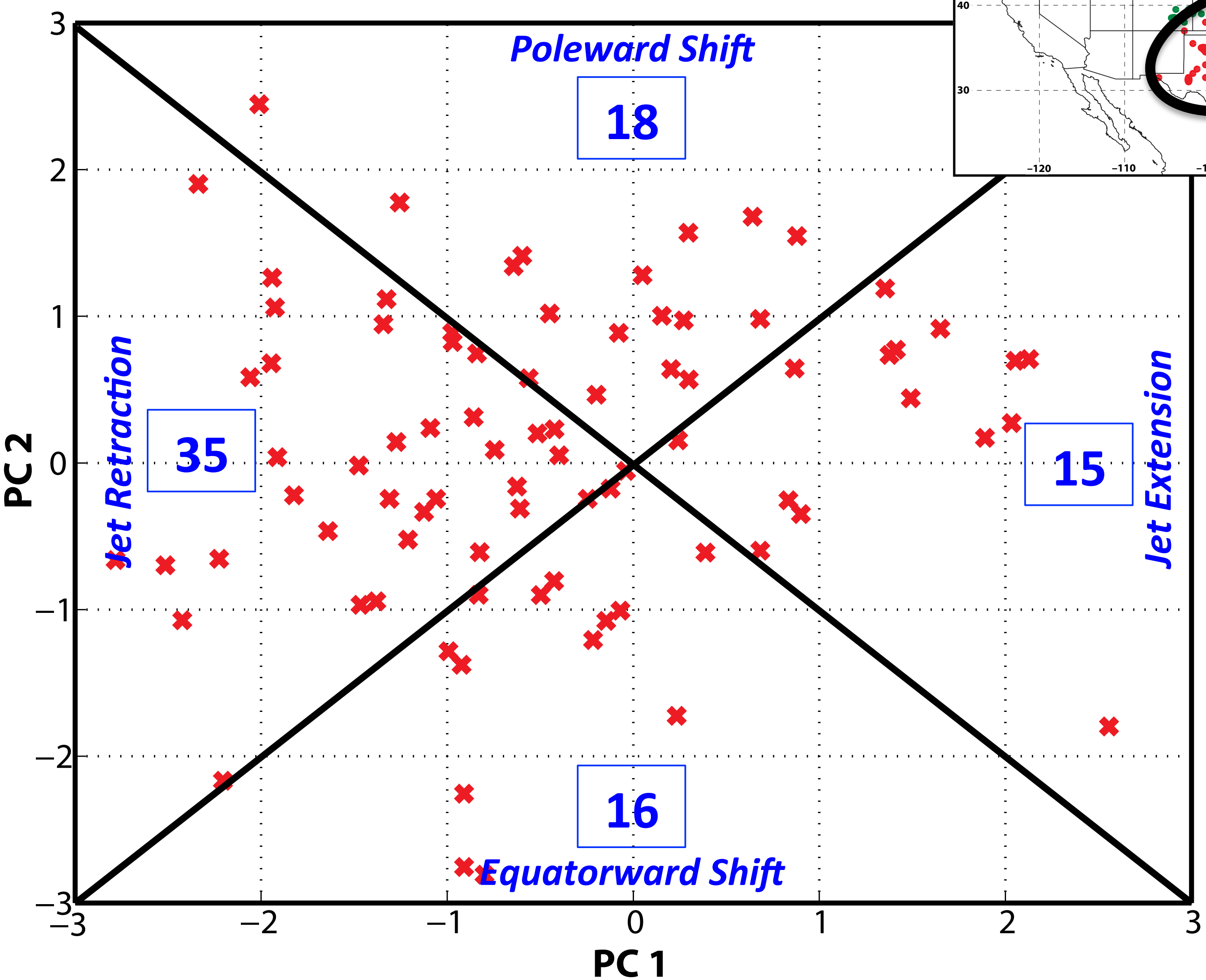
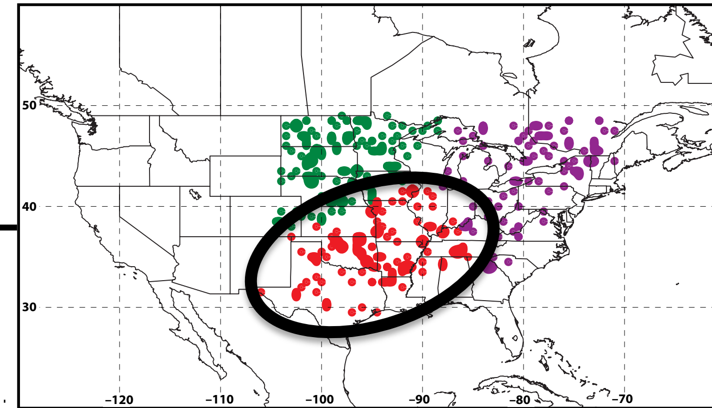


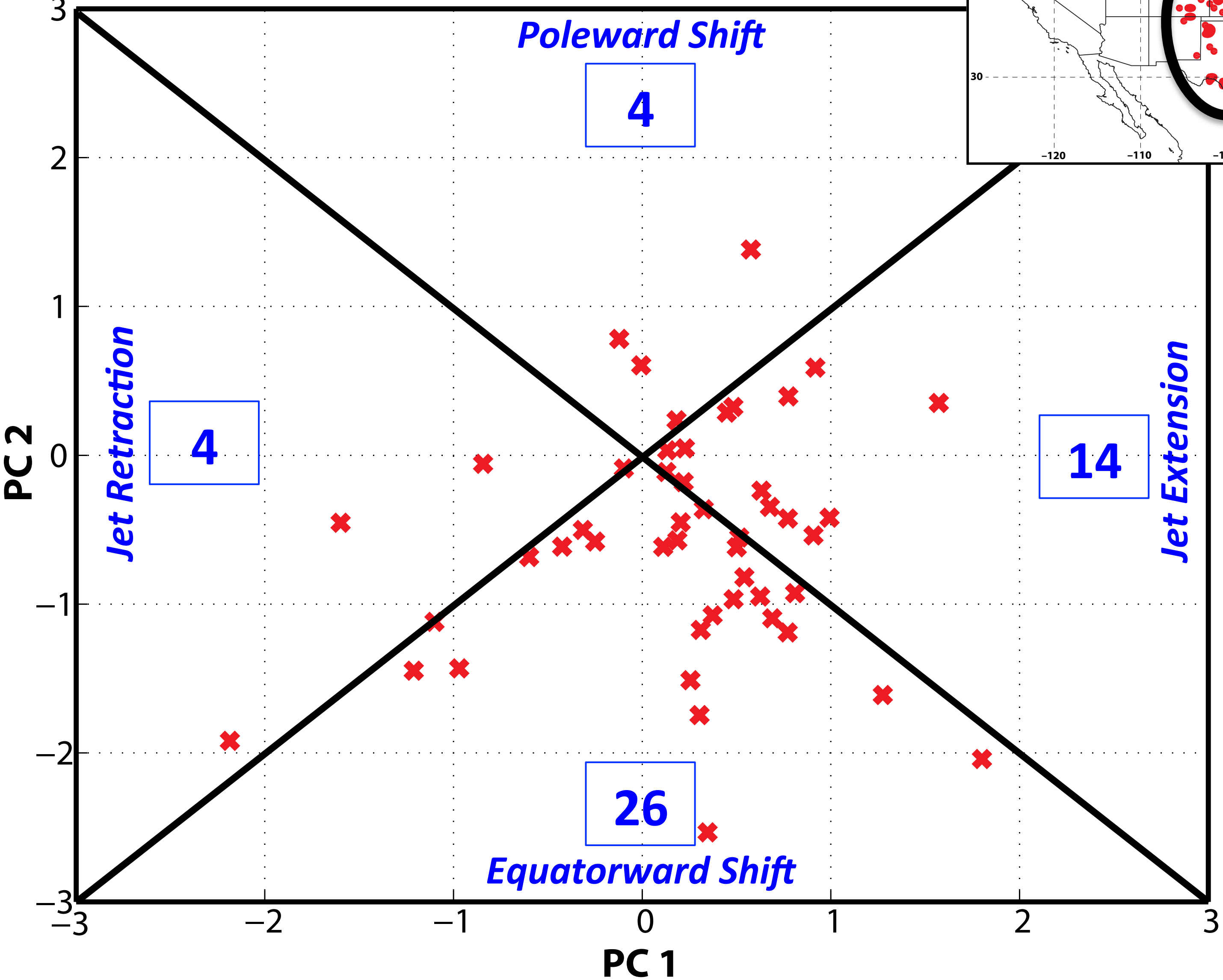


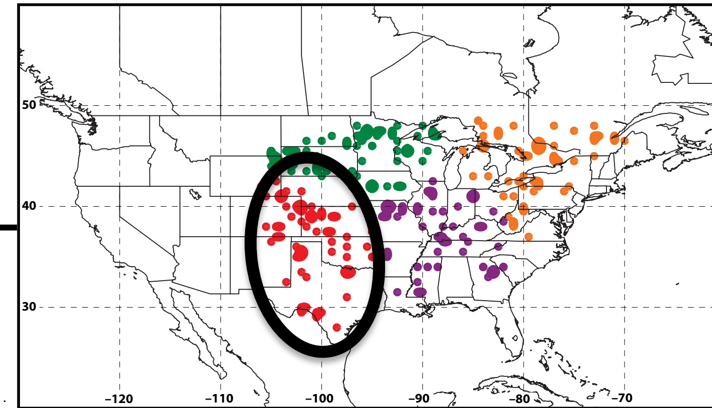
Events during Sept. – May projected onto phase diagram

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

E. Rockies – S. Plains Cluster

COLD EVENTS (n = 48)





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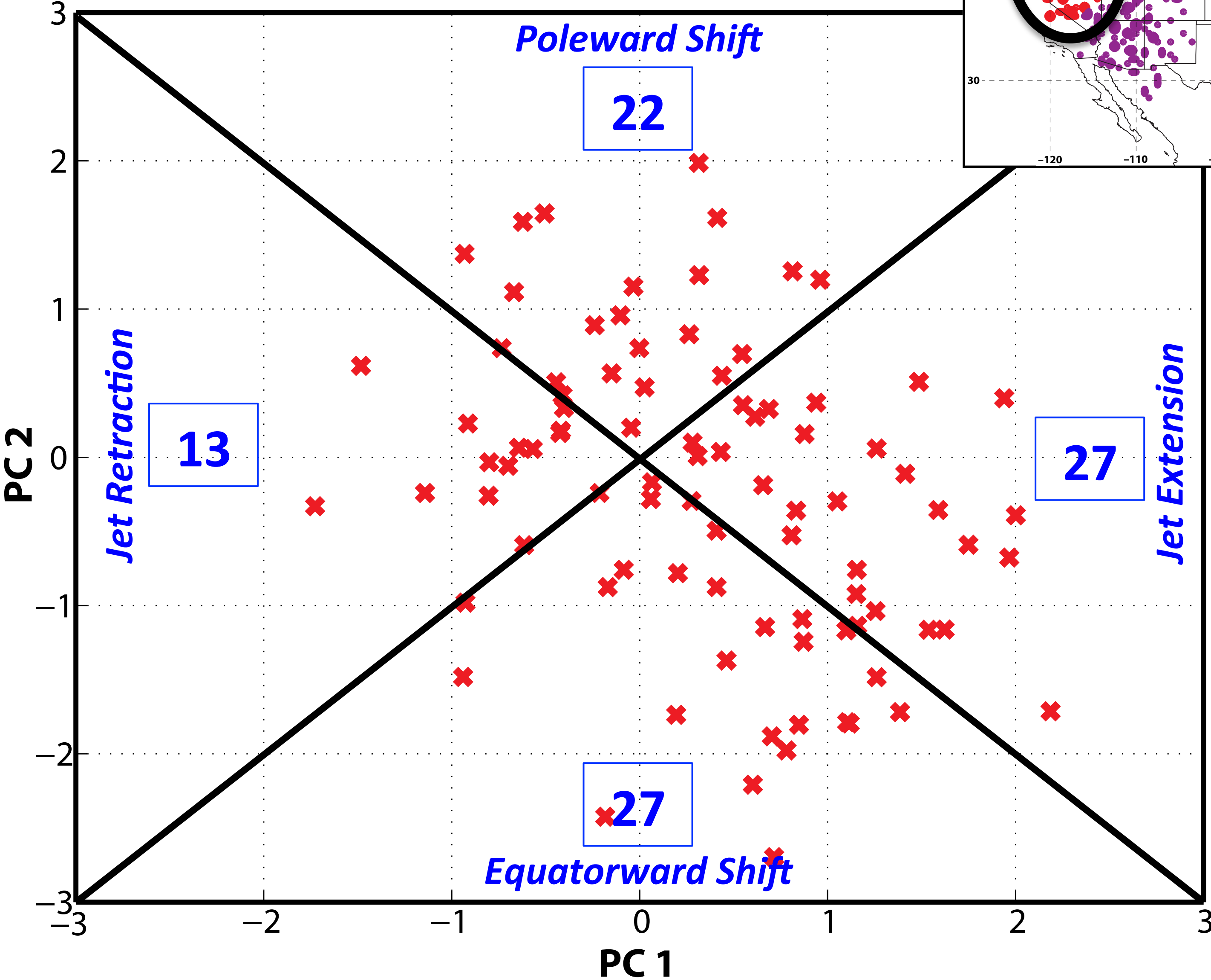
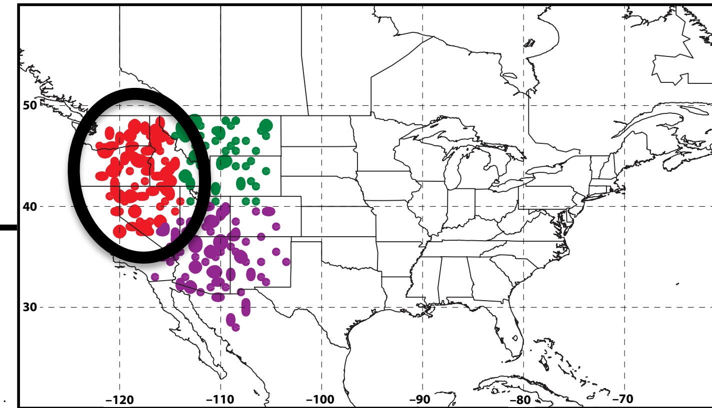
W. Rockies – Pac. NW Cluster

WARM EVENTS (n = 89)





Events during Sept. – May projected onto phase diagram

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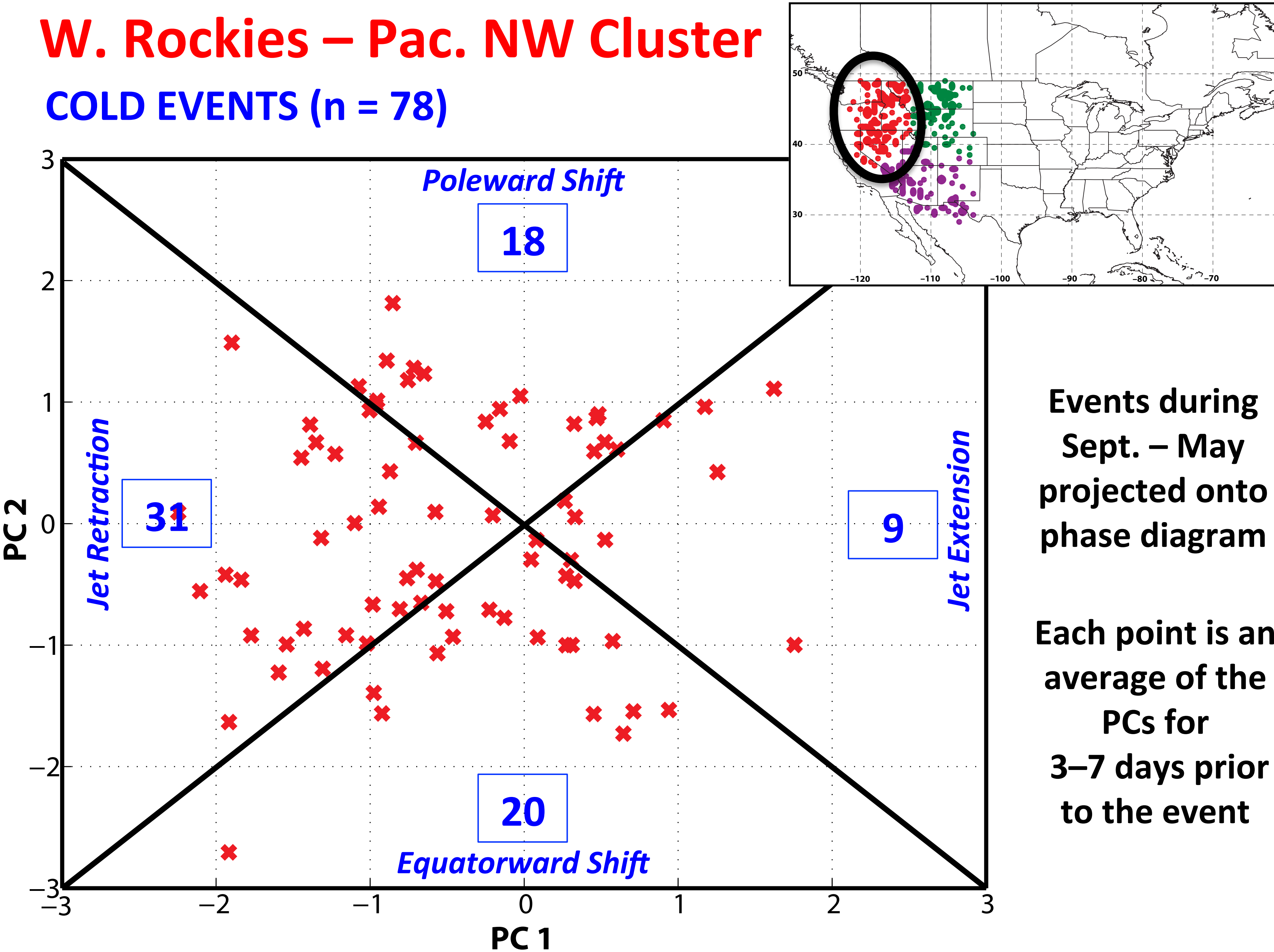
W. Rockies – Pac. NW Cluster

COLD EVENTS (n = 78)



Events during Sept. – May projected onto phase diagram

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Project Summary

4. Perform an evaluation of operational NCEP GFS and GEFS week two forecast skill for the identified extreme temperature and precipitation events over the CONUS during 1979–2014 for the 8–10 day time range.

   - To be investigated during Fall 2016 in the context of the North Pacific Jet phase diagram

5. Test methodology and new forecast formats under development at WPC and incorporate them into forecast operations.

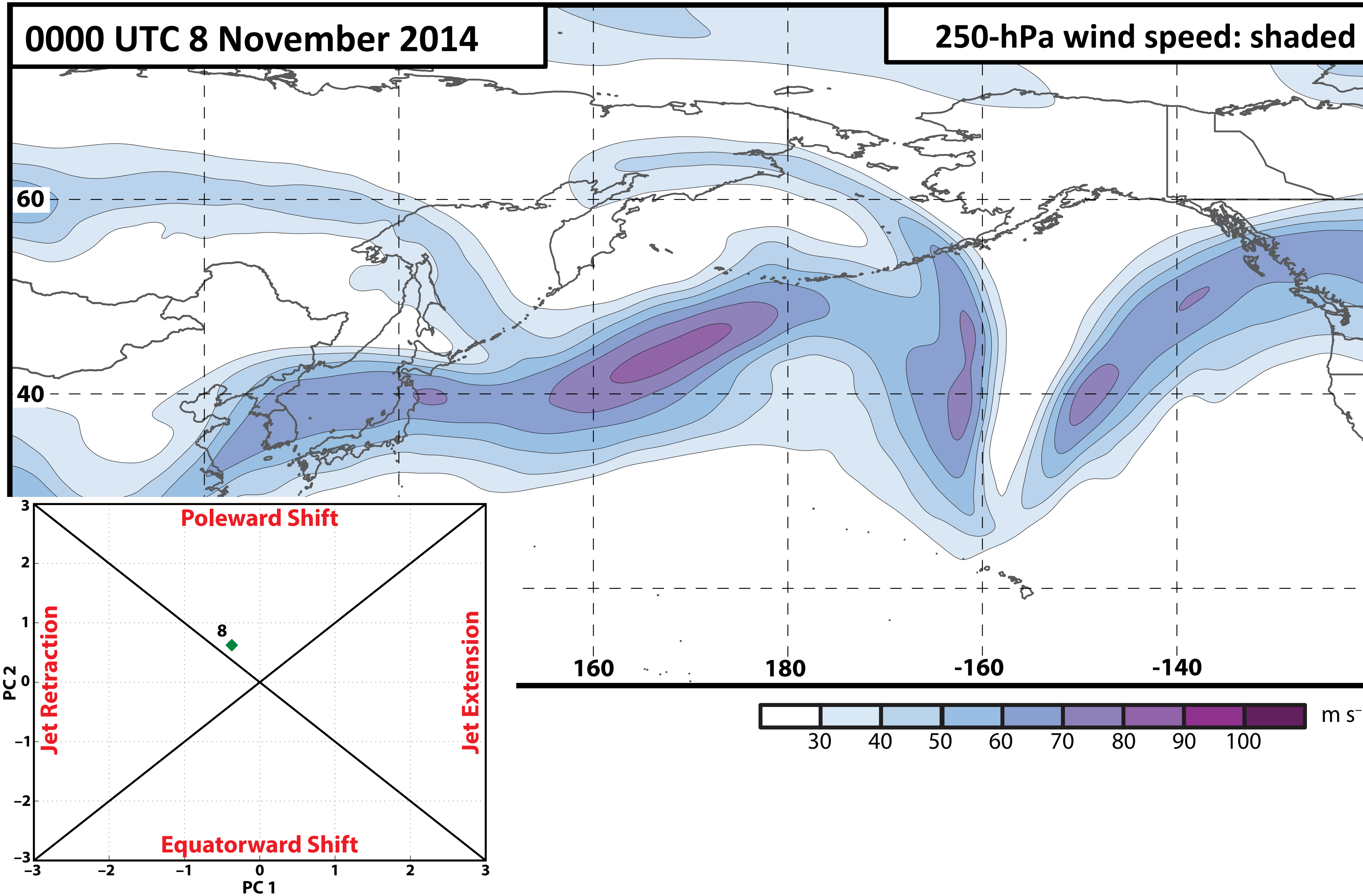
   - Conduct regular teleconferences/visits with WPC personnel
   - Develop real-time North Pacific Jet phase diagram (Sept. 2016)
   - Evaluate and test North Pacific Jet phase diagram as part of the HMT Medium Range Experiments (Jan. 2017)

Real-Time North Pacific Jet Phase Diagram

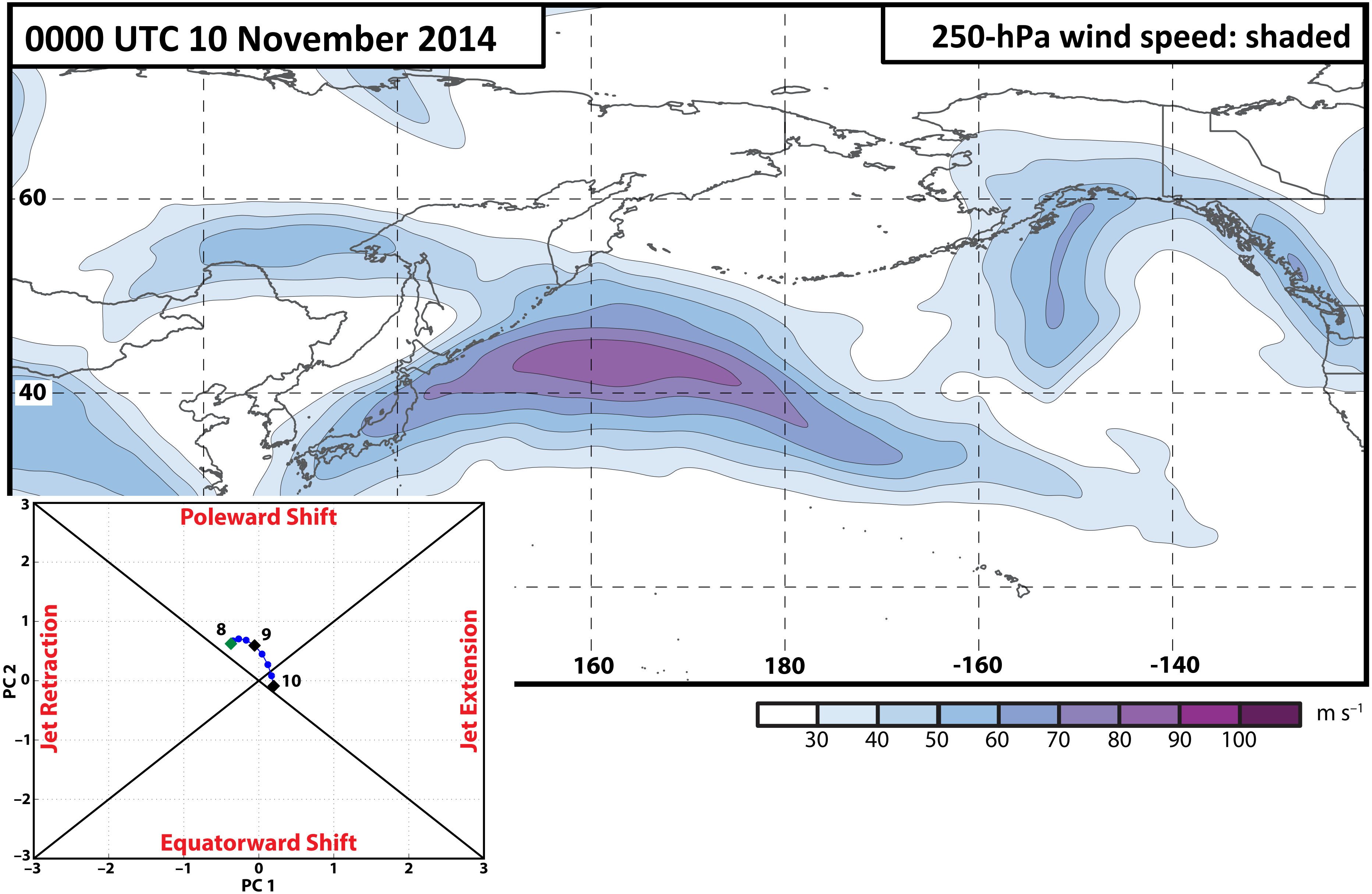
1. Characterizes the past evolution and present state of the upper-tropospheric flow pattern over the North Pacific.

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

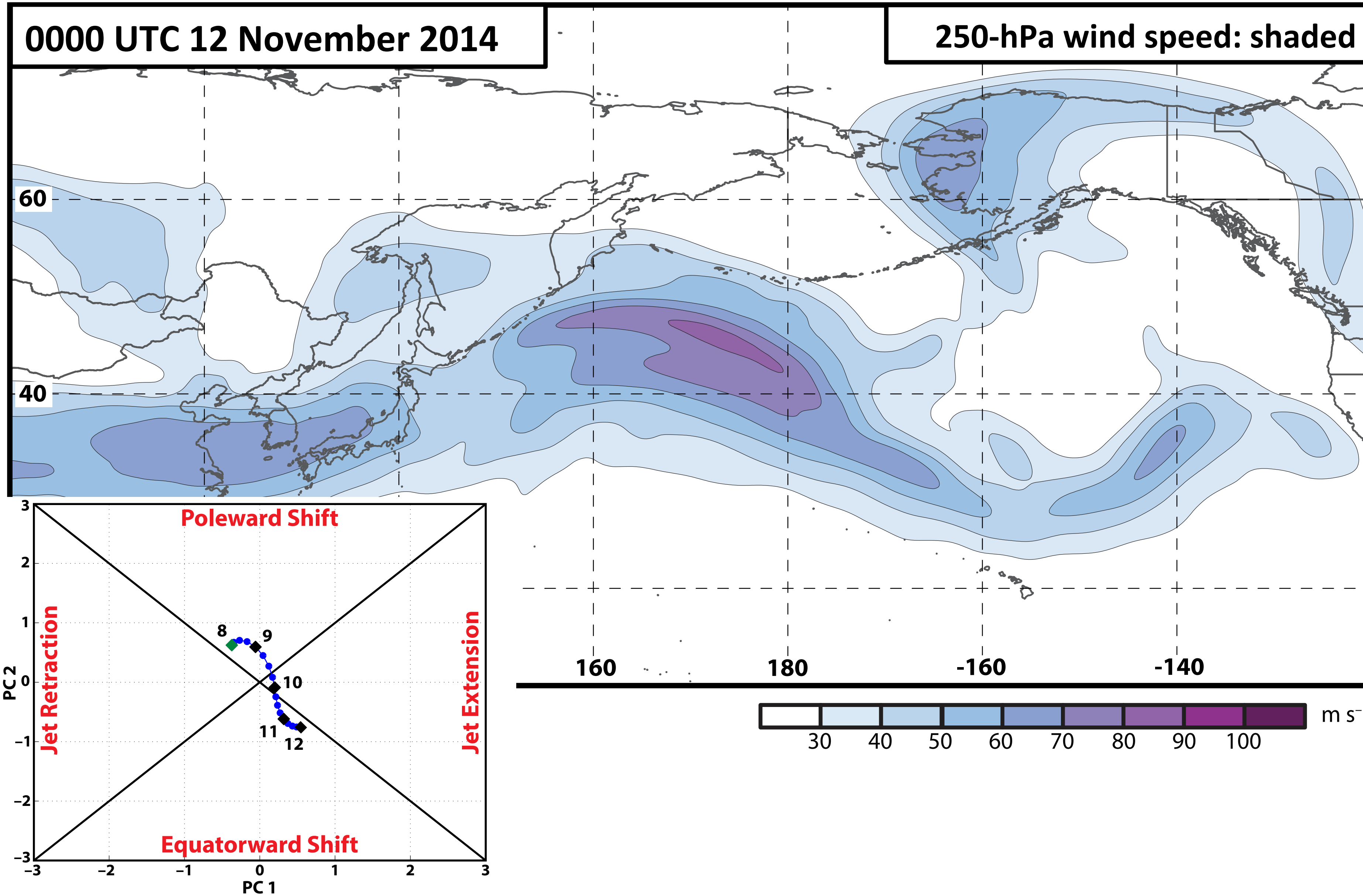
Real-Time North Pacific Jet Phase Diagram



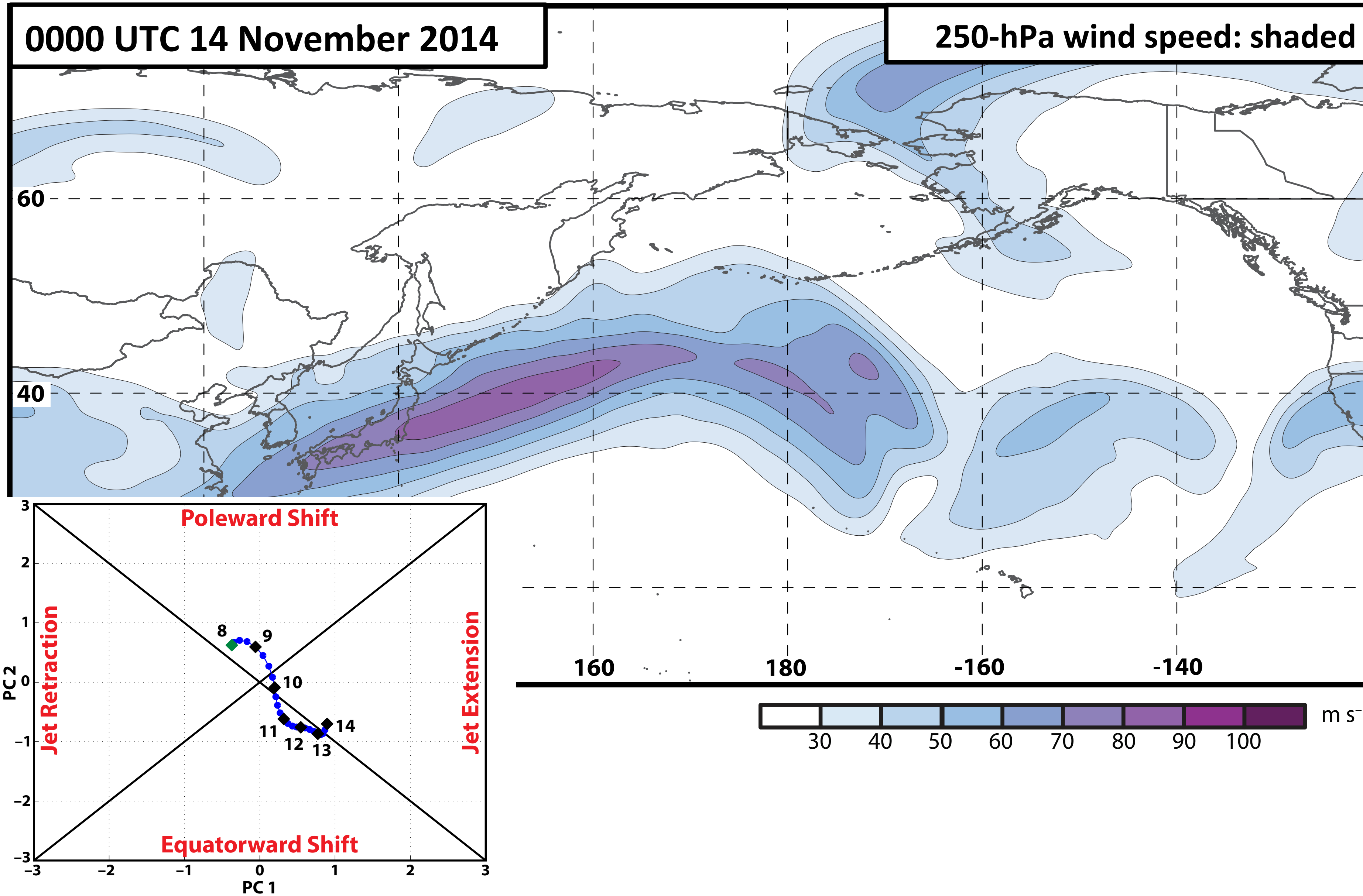
Real-Time North Pacific Jet Phase Diagram



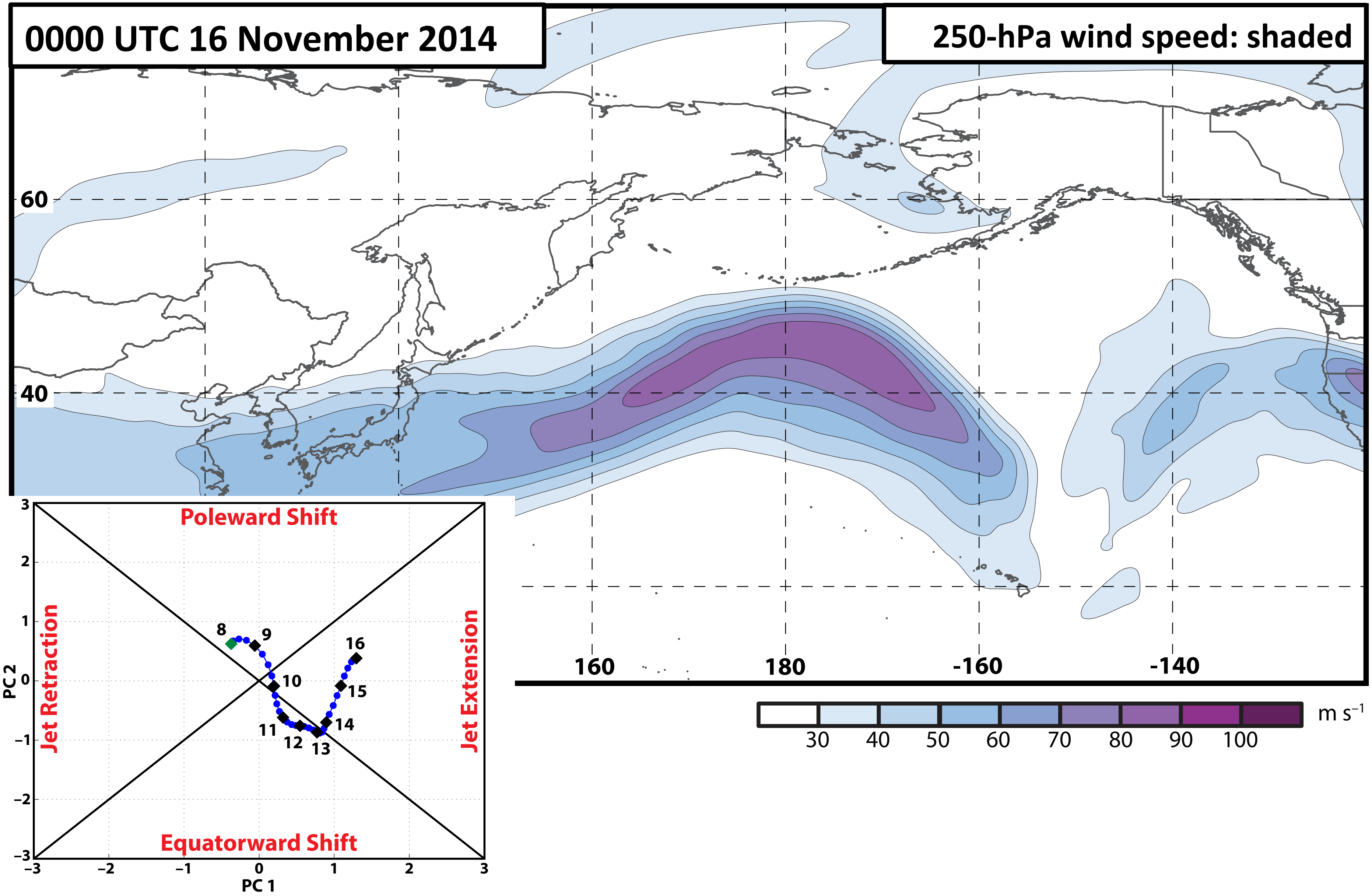
Real-Time North Pacific Jet Phase Diagram



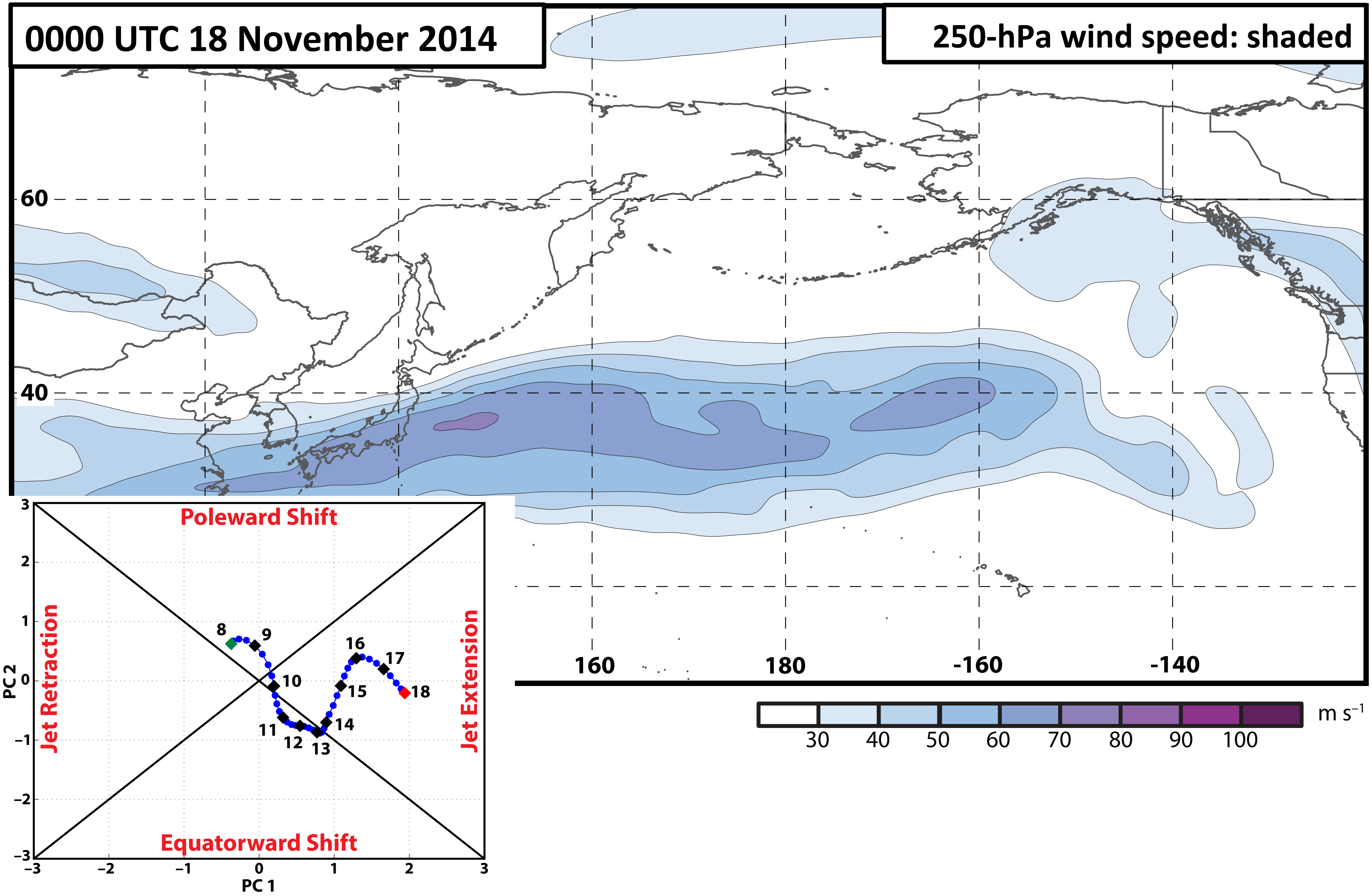
Real-Time North Pacific Jet Phase Diagram



Real-Time North Pacific Jet Phase Diagram



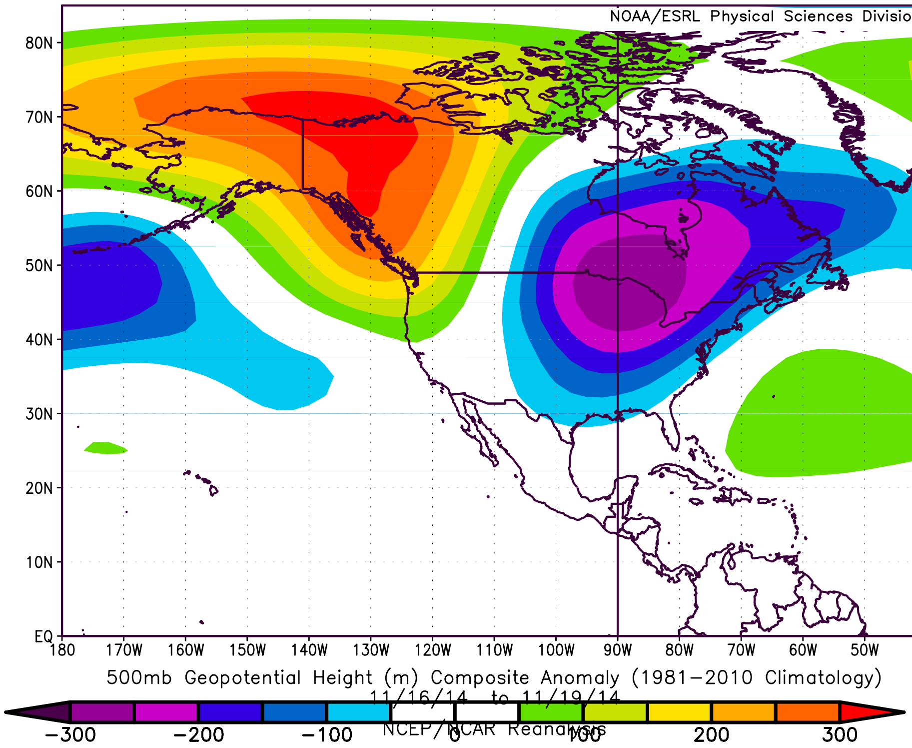
Real-Time North Pacific Jet Phase Diagram



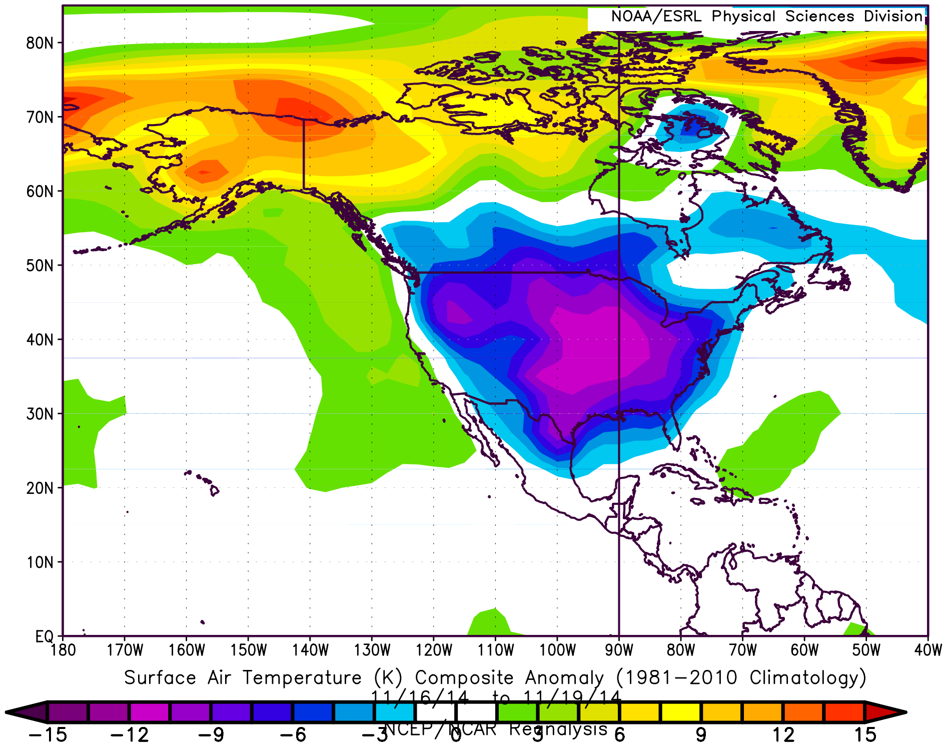
Real-Time North Pacific Jet Phase Diagram

16–19 November 2014 Composite Anomalies

500-hPa Geo. Height (m)

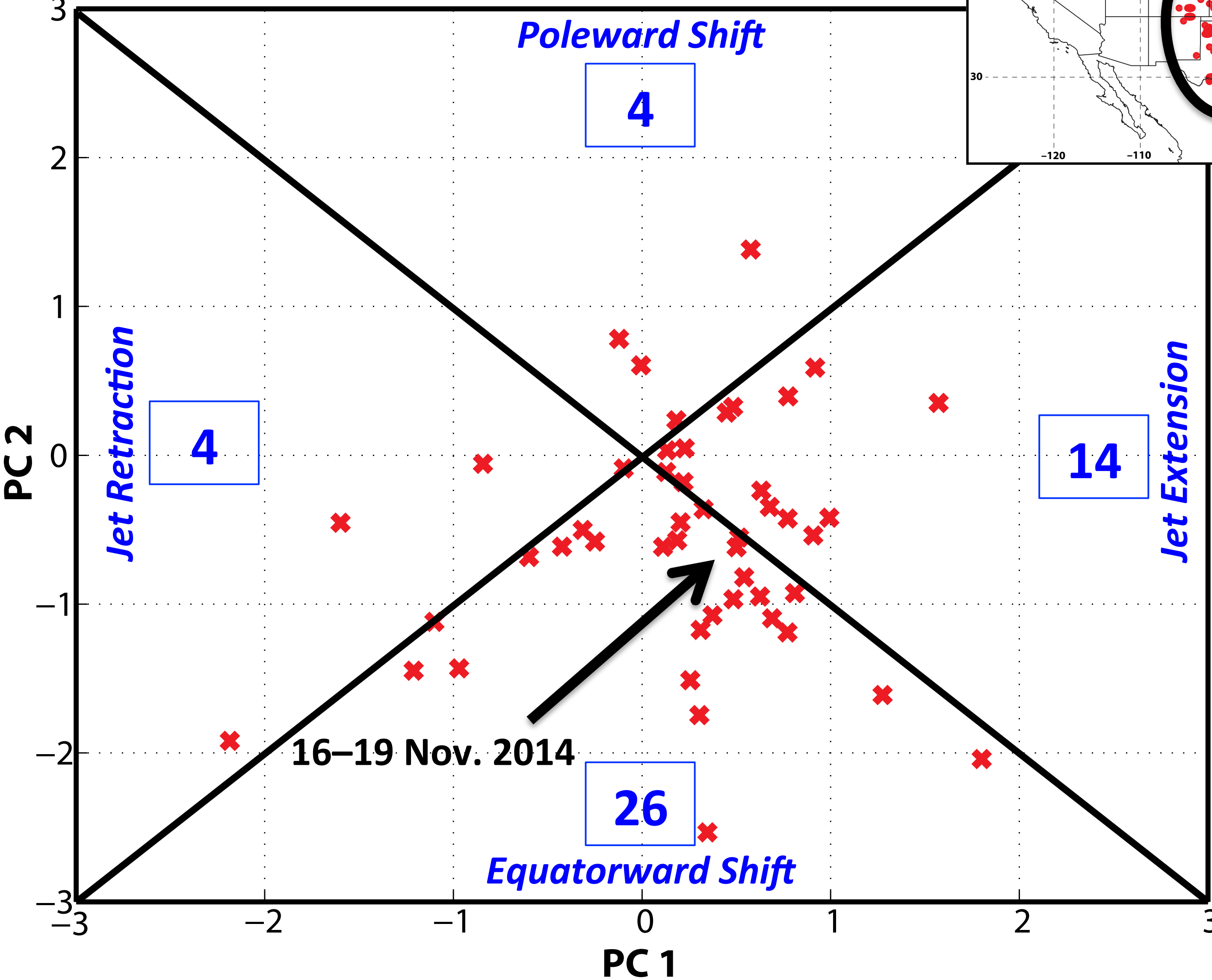


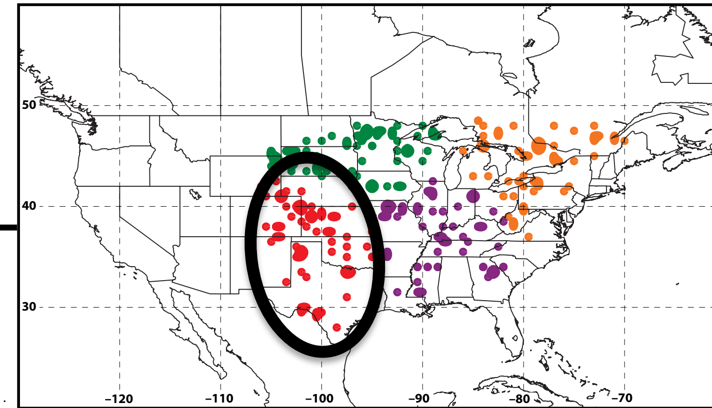
Surface Temperature (°C)



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

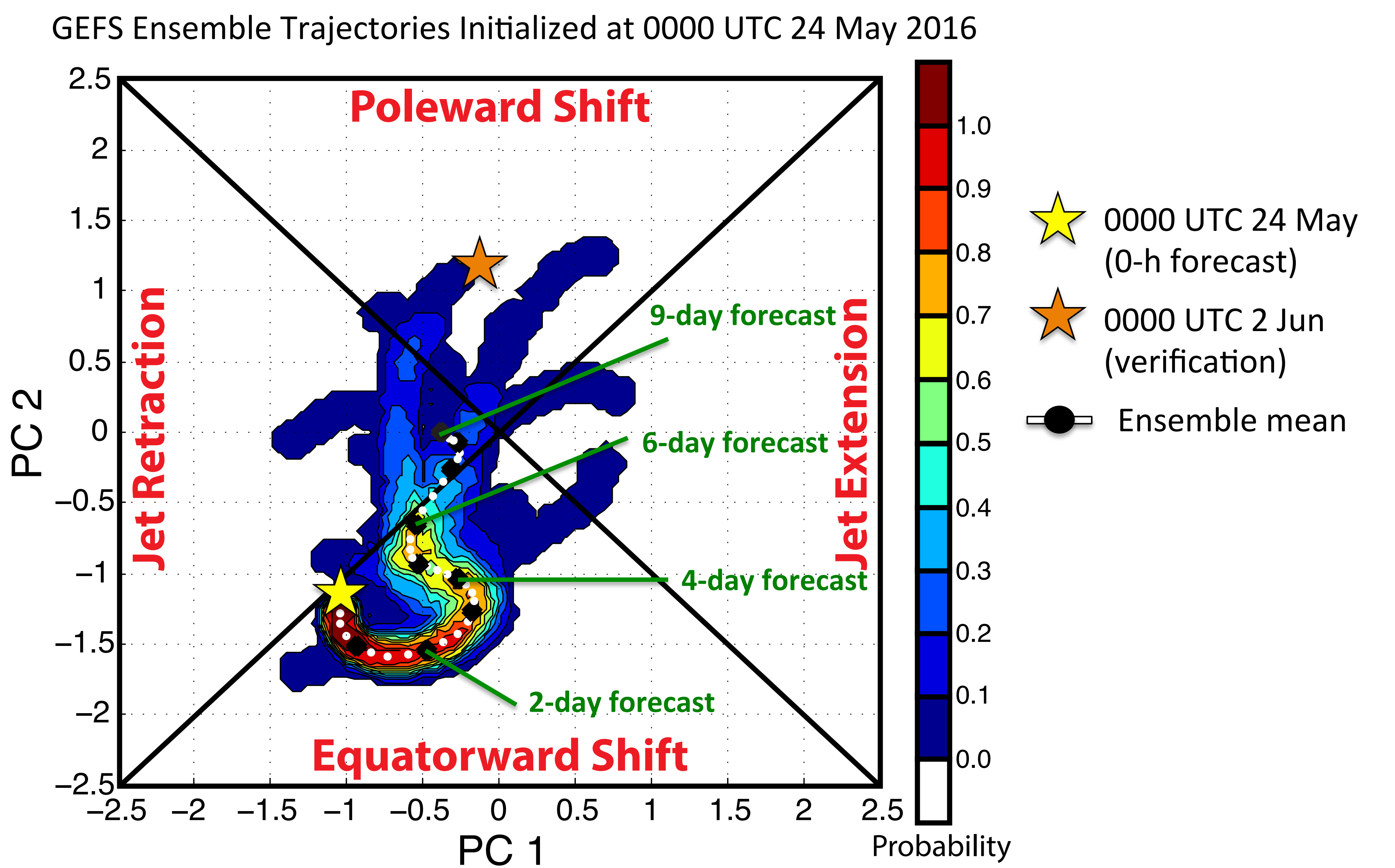
Real-Time North Pacific Jet Phase Diagram

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



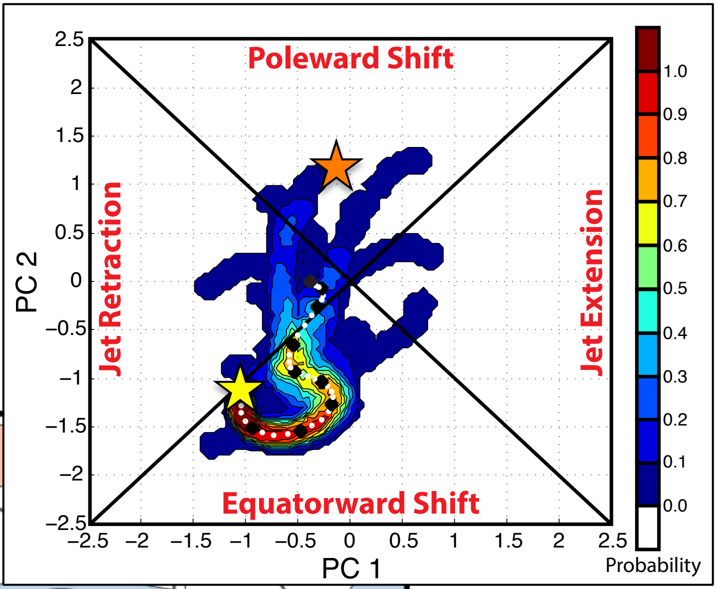
Real-Time North Pacific Jet Phase Diagram

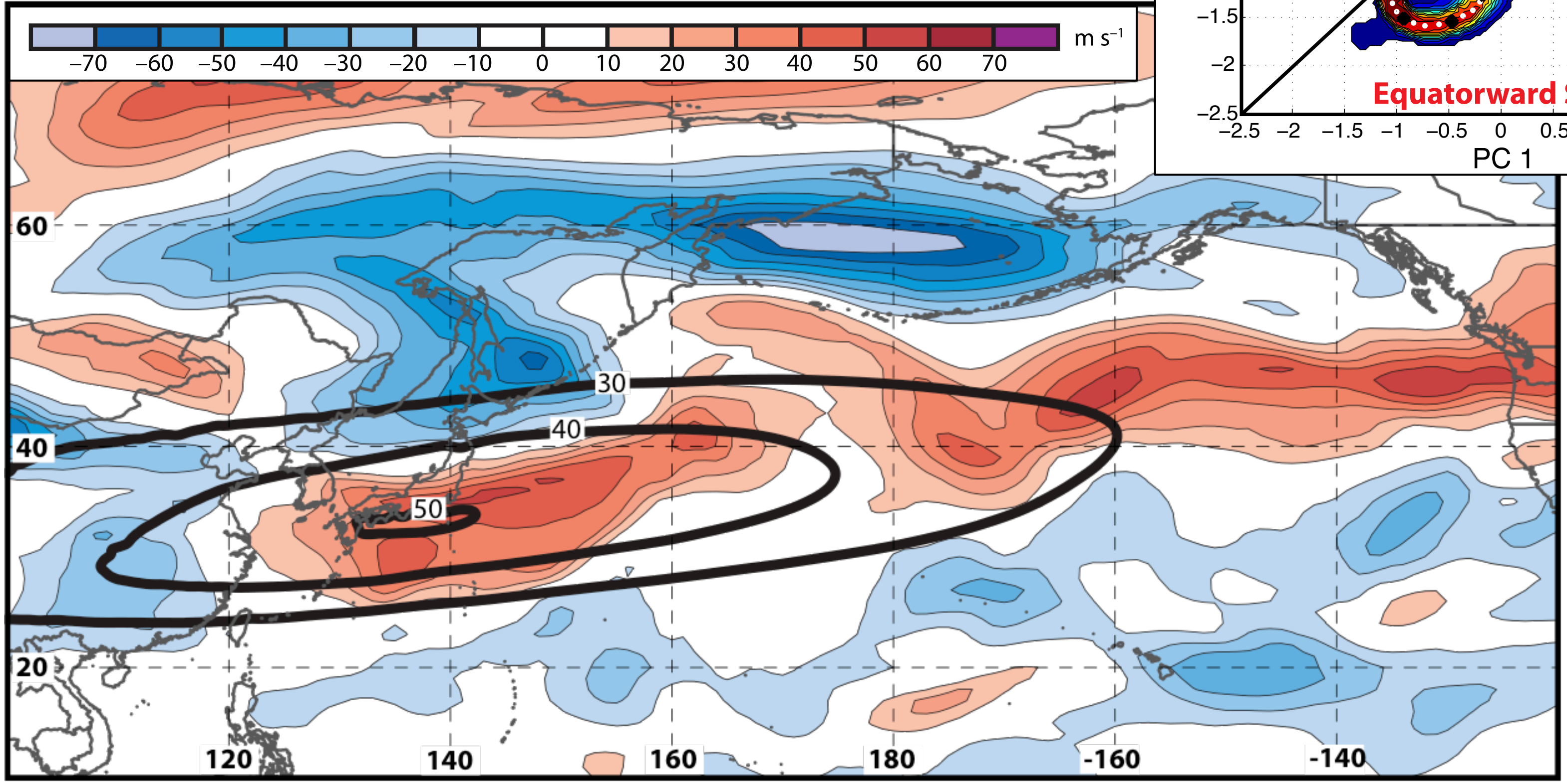
250-hPa zonal wind at 0000 UTC 2 Jun minus 250-hPa zonal wind at 0000 UTC 24 May (shading) in the GFS analyses shows the transition to a poleward-shifted jet regime

0000 UTC 24 May (0-h forecast)

0000 UTC 2 Jun (verification)

Ensemble mean





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

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.

Supplementary Slides

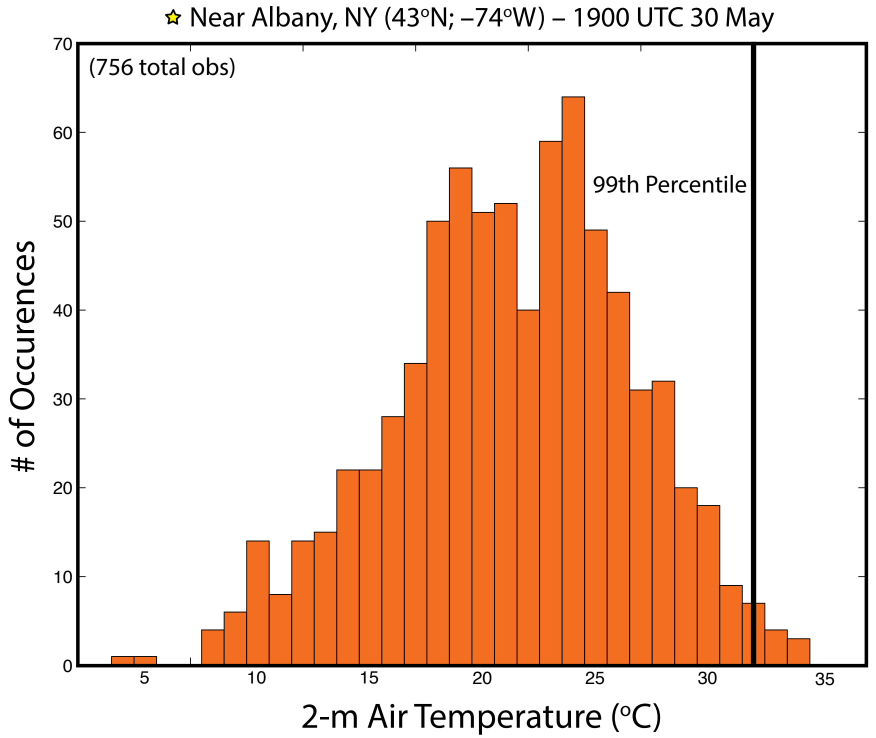
Extreme Event Identification

Extreme Warm Events:

- Employed 1-h forecasts of **2-m temperature** from the CFSR (0.5°× 0.5°) at 6-h intervals

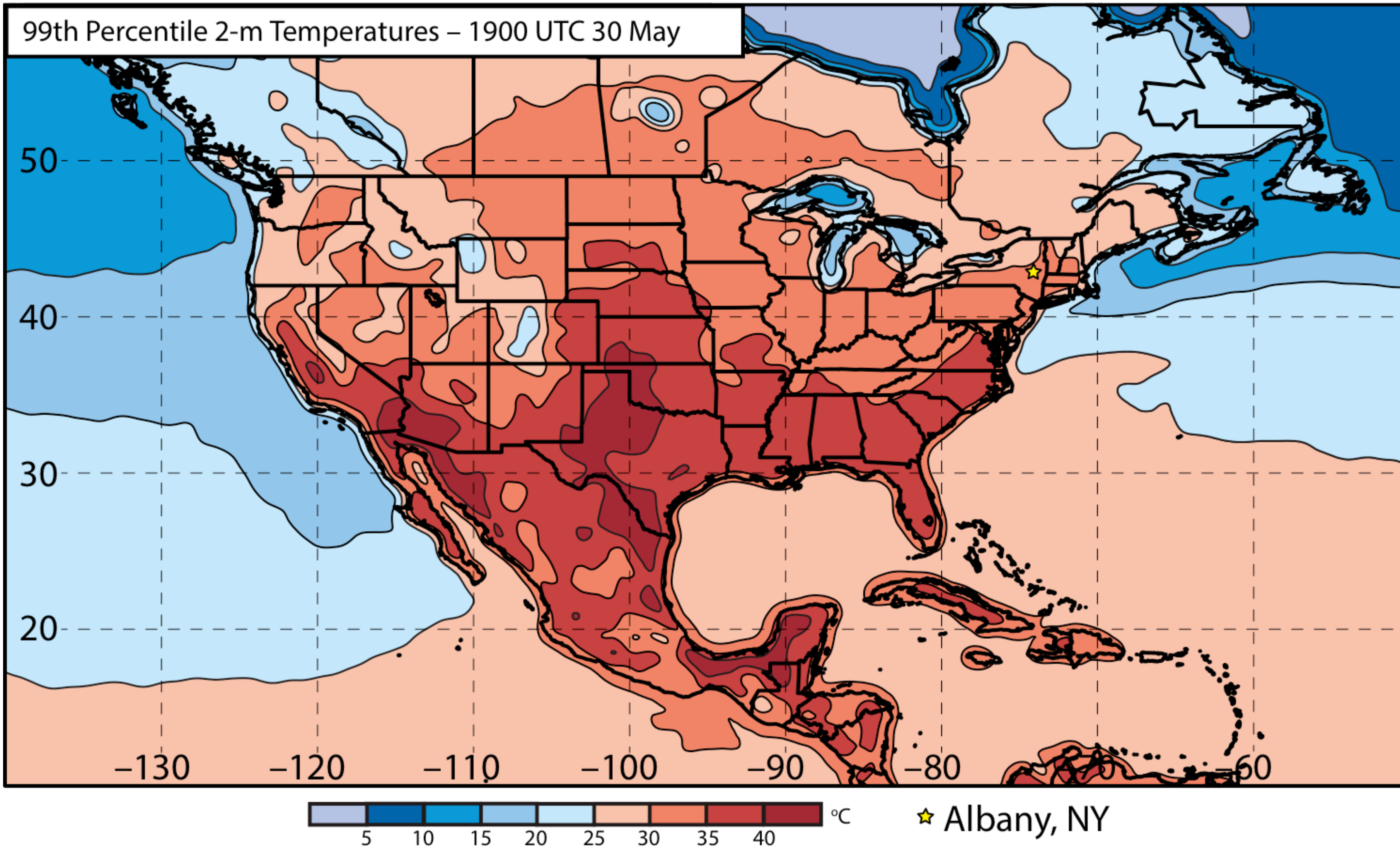
- Compiled data **for each grid point** within 21-day windows centered on each analysis time for 36 years, 1979–2014
  - Each grid point has 756 data points for each analysis time

- Determined the temperature value that corresponds to the **99th percentile** for each grid point at a given analysis time

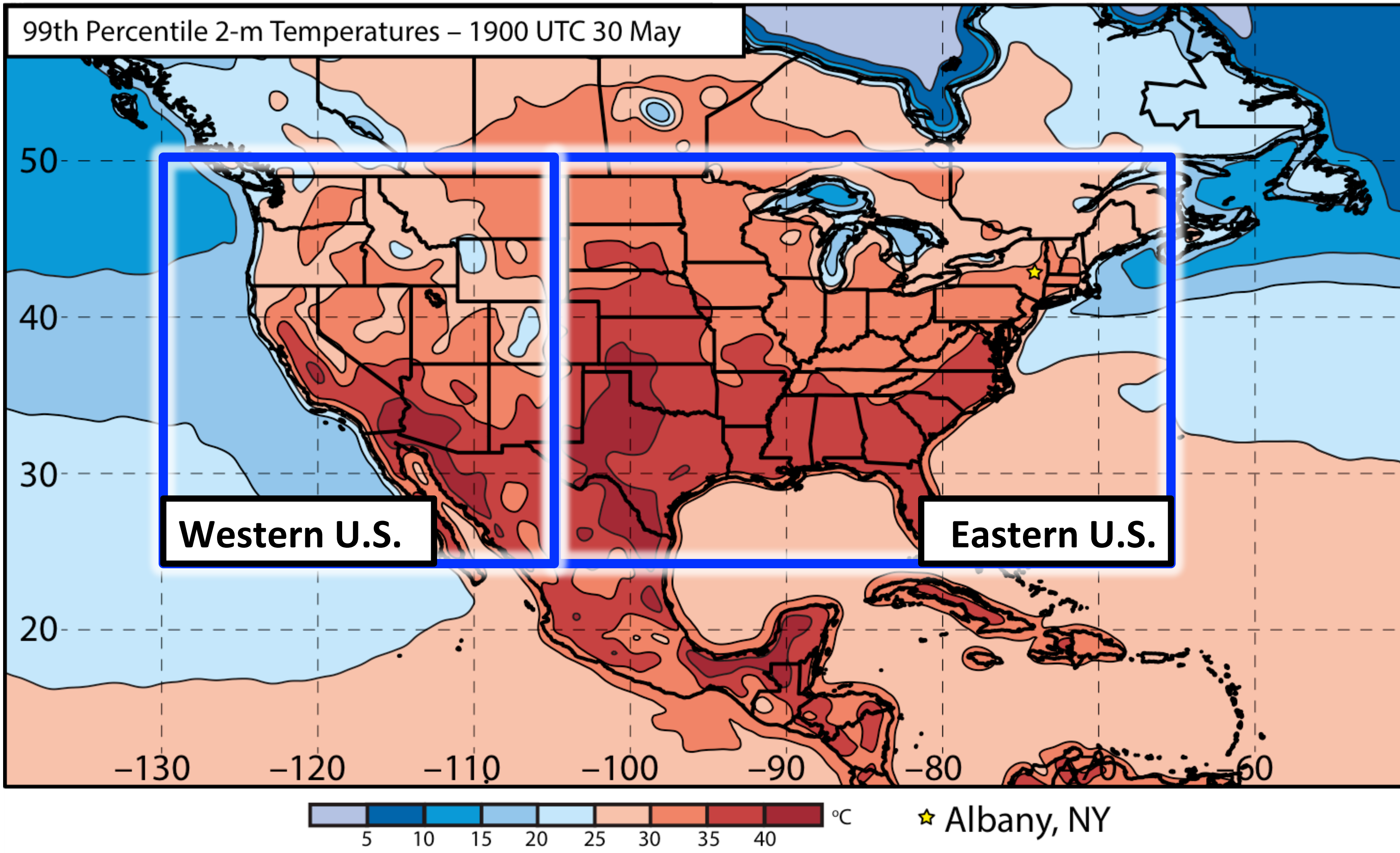


2-m temperature frequency distribution at 1900 UTC 30 May for a grid point near Albany, NY

Extreme Event Identification



Extreme Event Identification



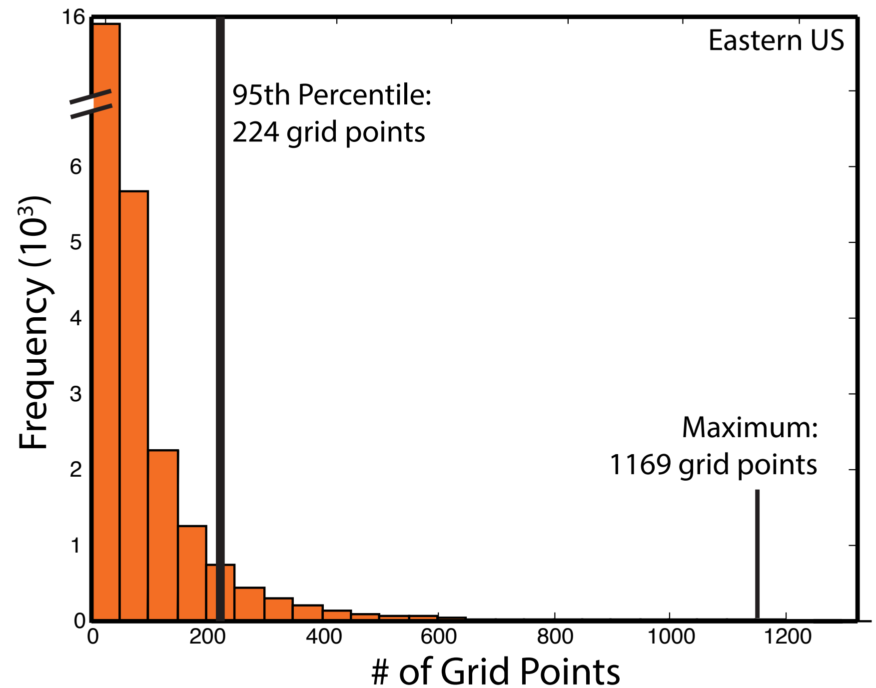
Extreme Event Identification

Extreme Warm Events:

- Cataloged the 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 Precip. Events:

- Employed CPC Unified Gauge-Based Analysis of Daily Precipitation over CONUS (0.25°× 0.25°)
- Compiled data within 21-day windows centered on each time for all 36 years
  - Each grid point has 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

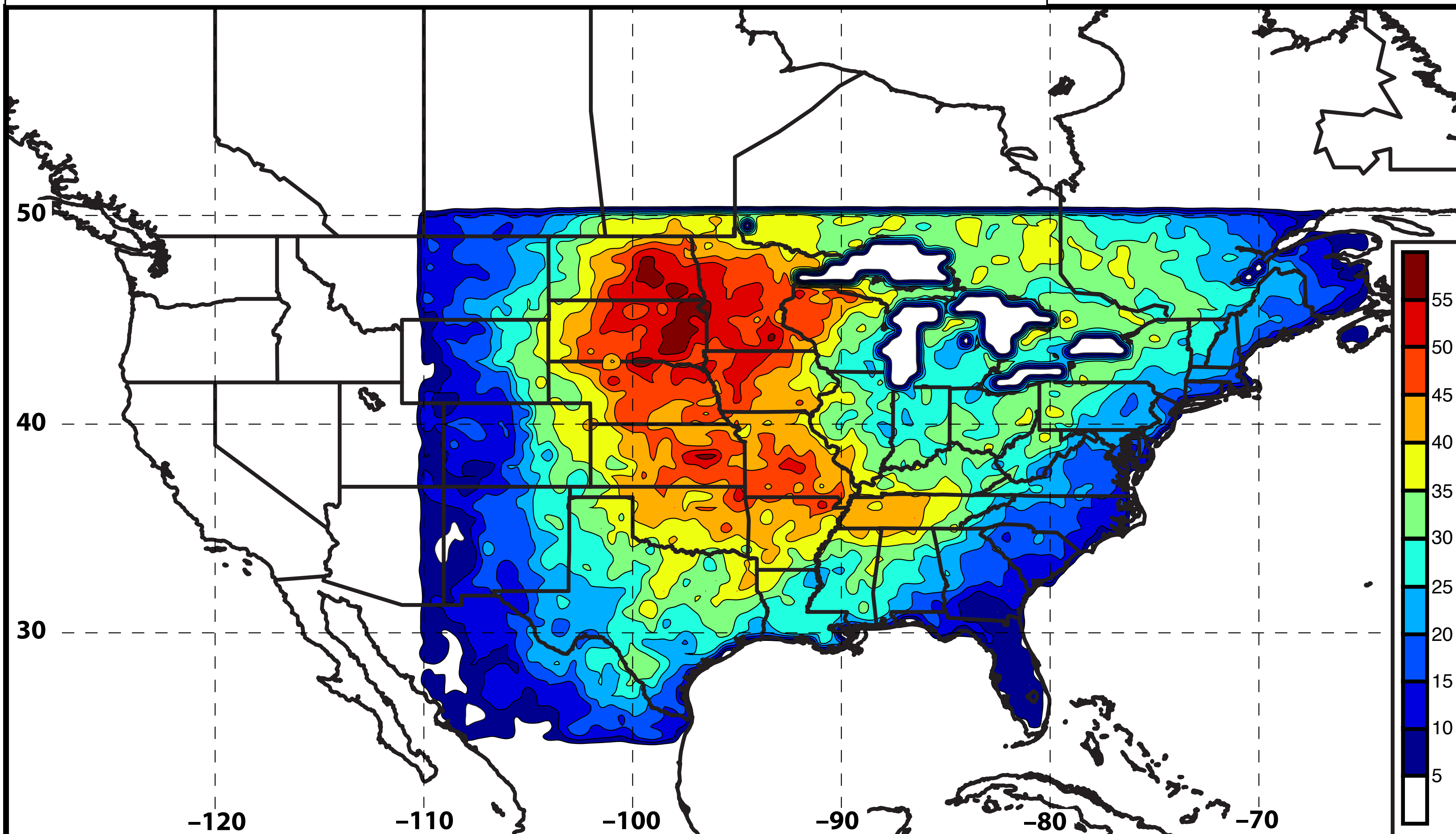
Eastern U.S. (**99th %**):
- Threshold: 211 grid points ~3.5°×3.5° box
- After QC: 351 events

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

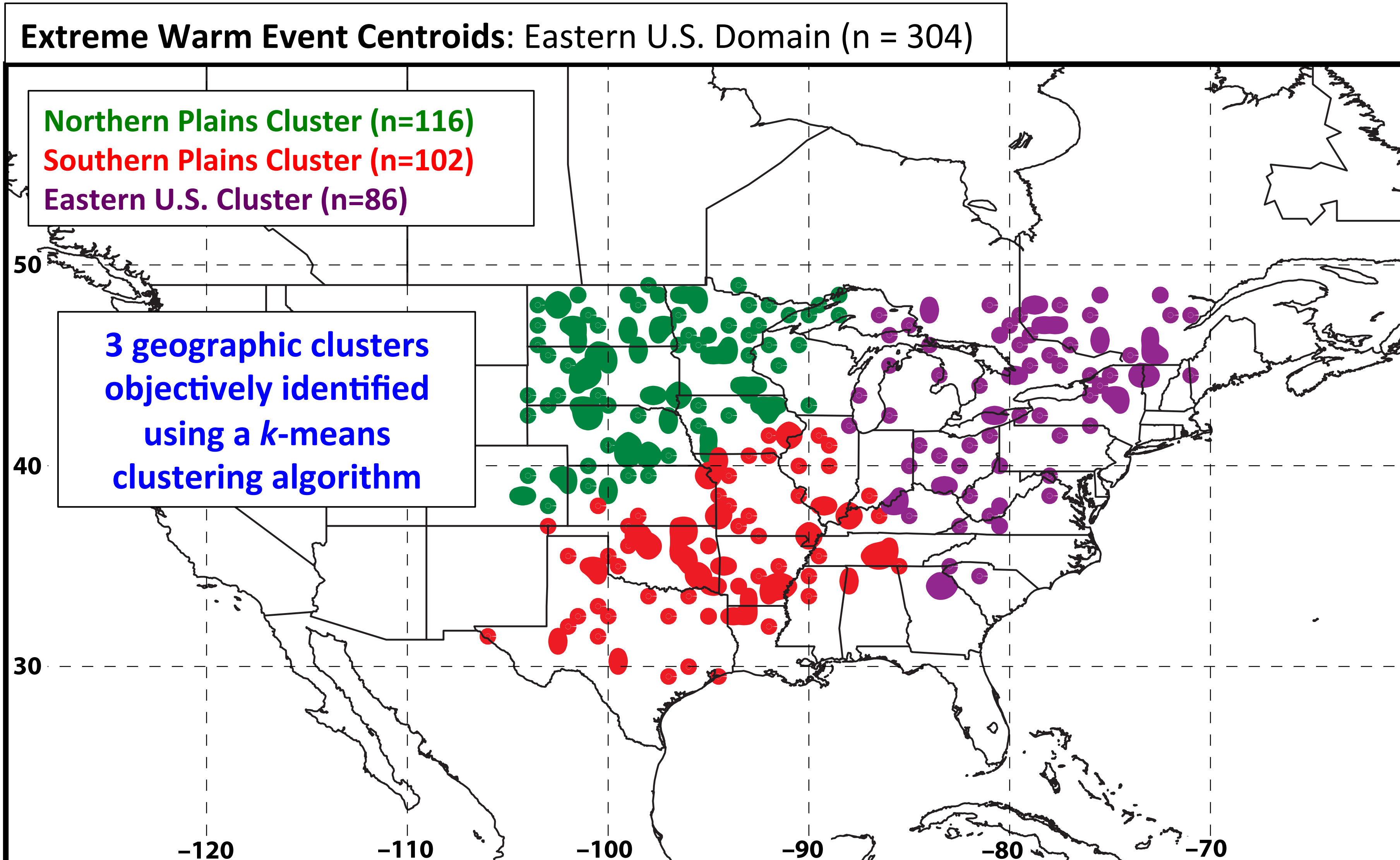
Quality control: Events within 24-h of another event were considered to be the same event.

Extreme Event Identification

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



Extreme Event Identification



EOF Calculations

- Removed the mean and the annual and diurnal cycles from 6-hourly, 250-hPa zonal wind data from the CFSR (1979–2014)
- Isolated data for September – May only
- Performed an EOF analysis within the domain: 10–80°N ; 100°E–120°W

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

<u>Example</u>: 0000 UTC 15 November 2014