The impact of Super Typhoon Nuri (2014) on the structure and strength of the stratospheric polar vortex

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Cyclone Workshop

Pacific Grove, CA

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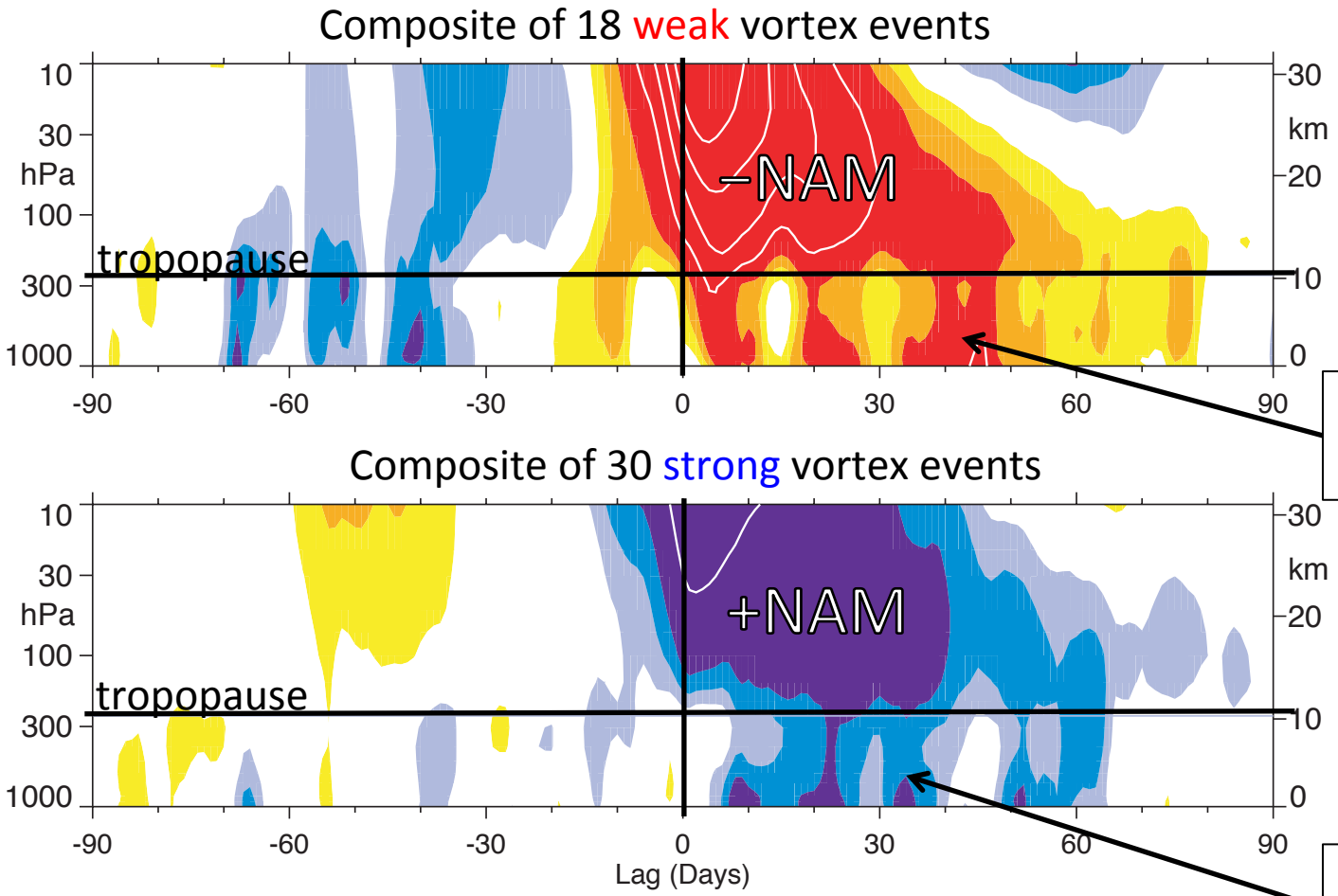
Background

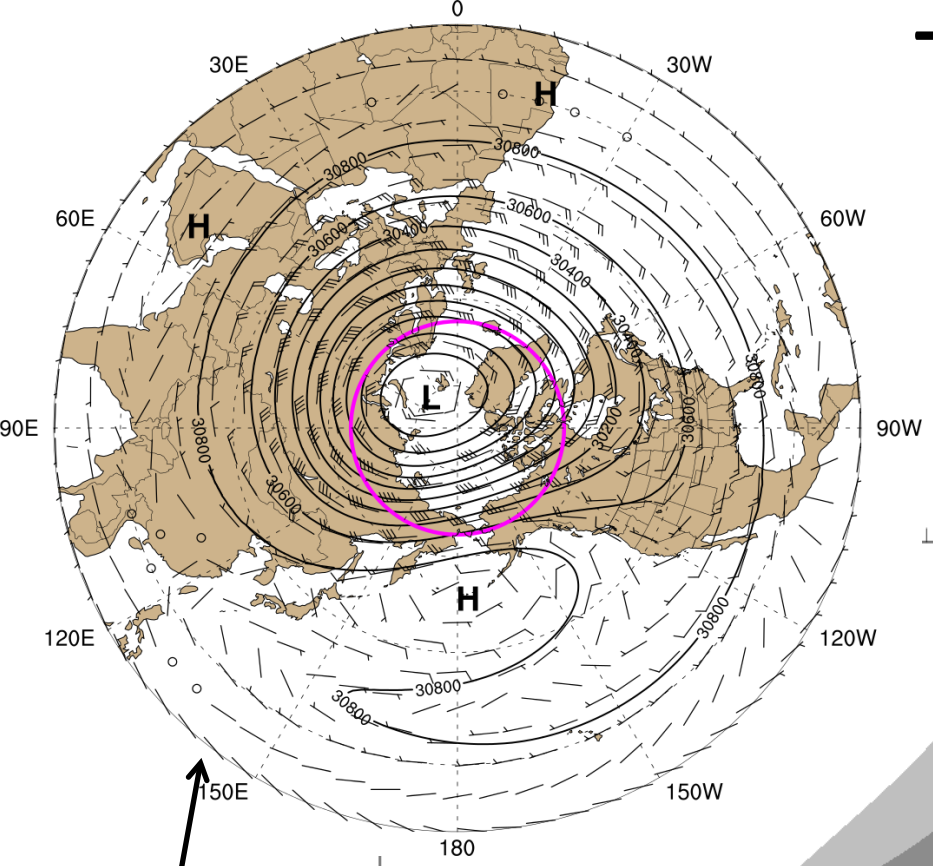


−AO at the surface

+AO at the surface

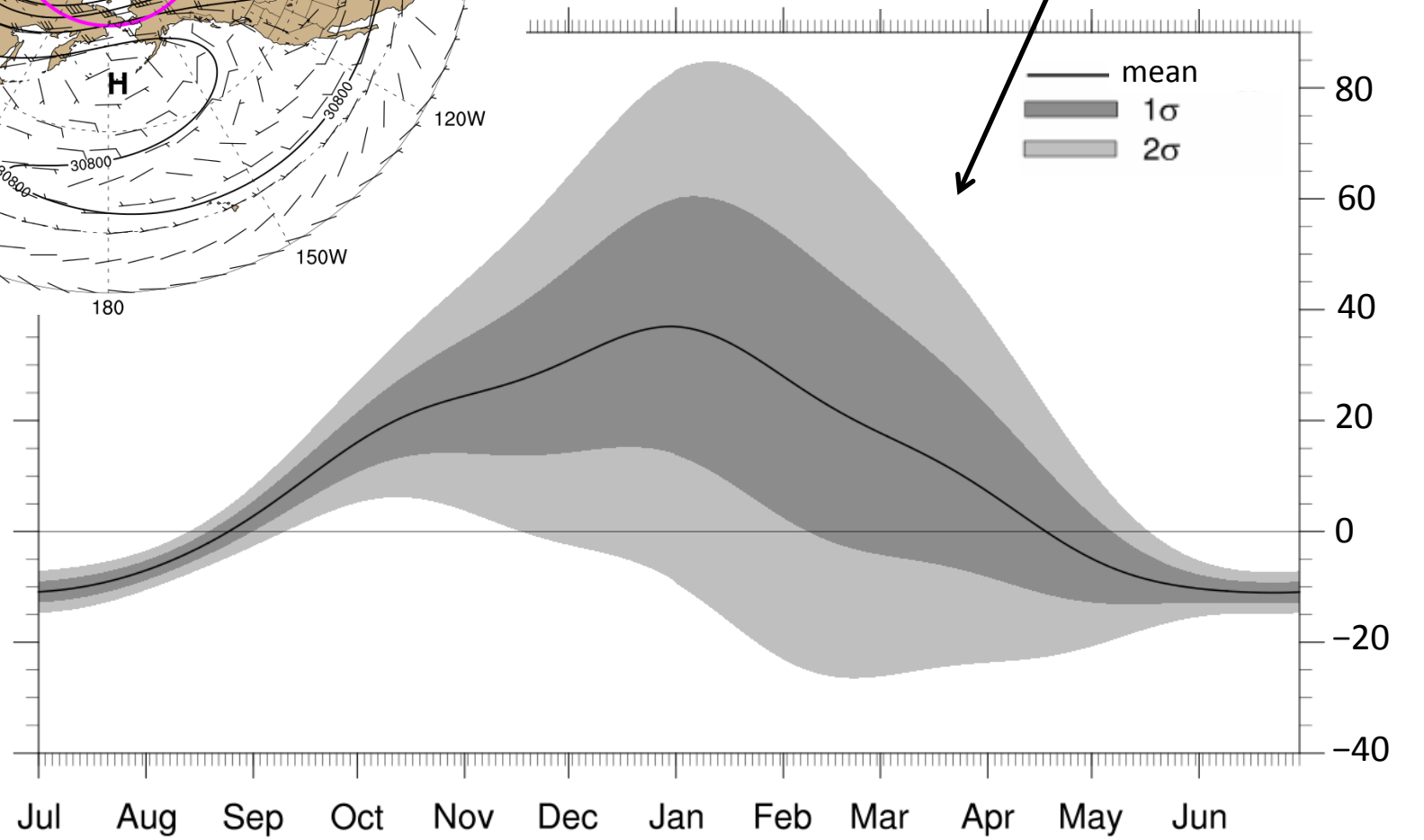
Baldwin and Dunkerton 2001

The stratospheric polar vortex

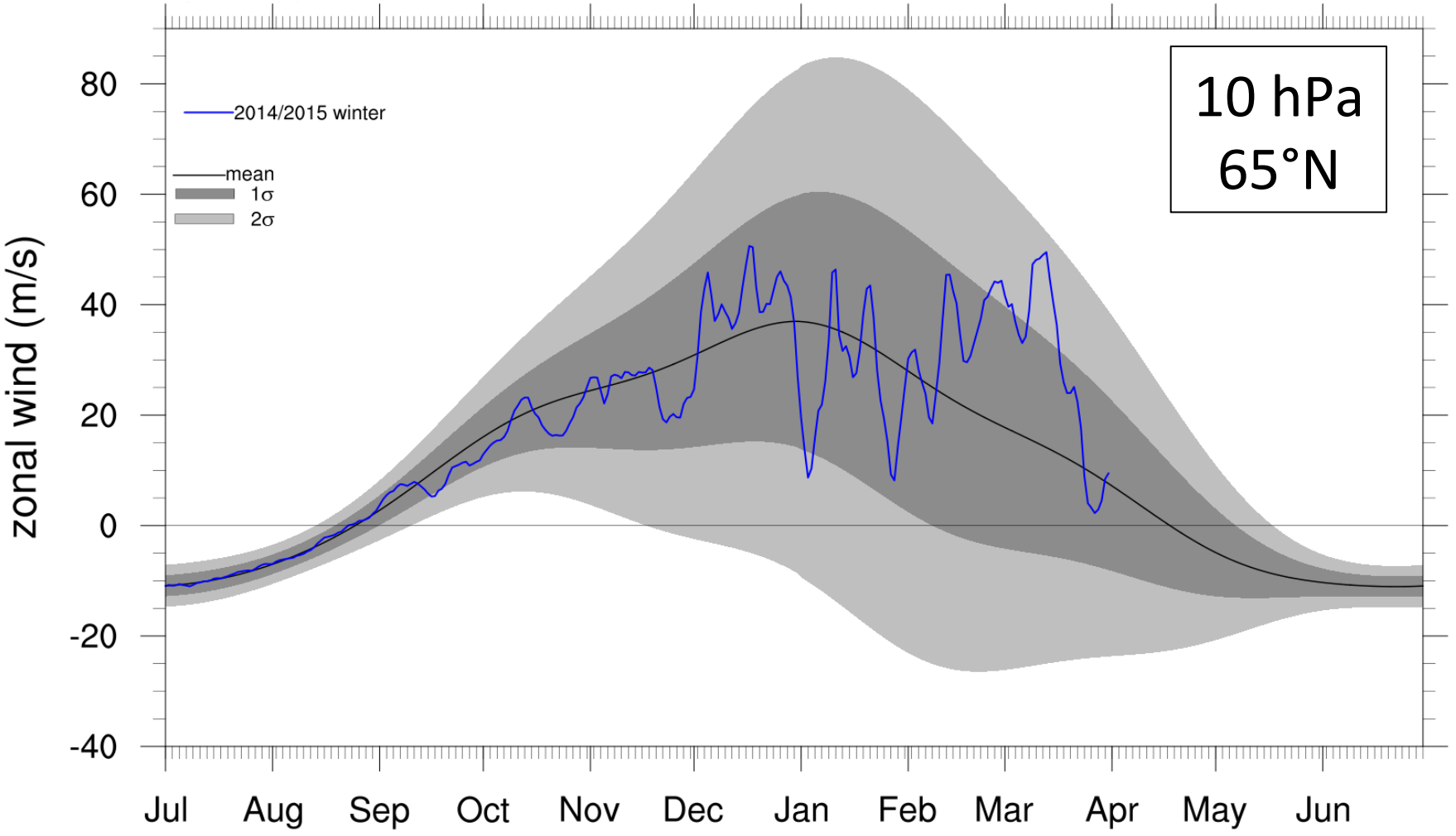


Winter (Nov-Feb) 10 hPa height (m) and wind (m s^{-1})

Zonal mean zonal wind (m s^{-1}) at 10 hPa and 65°N



The winter of 2014/2015 zonal mean zonal wind



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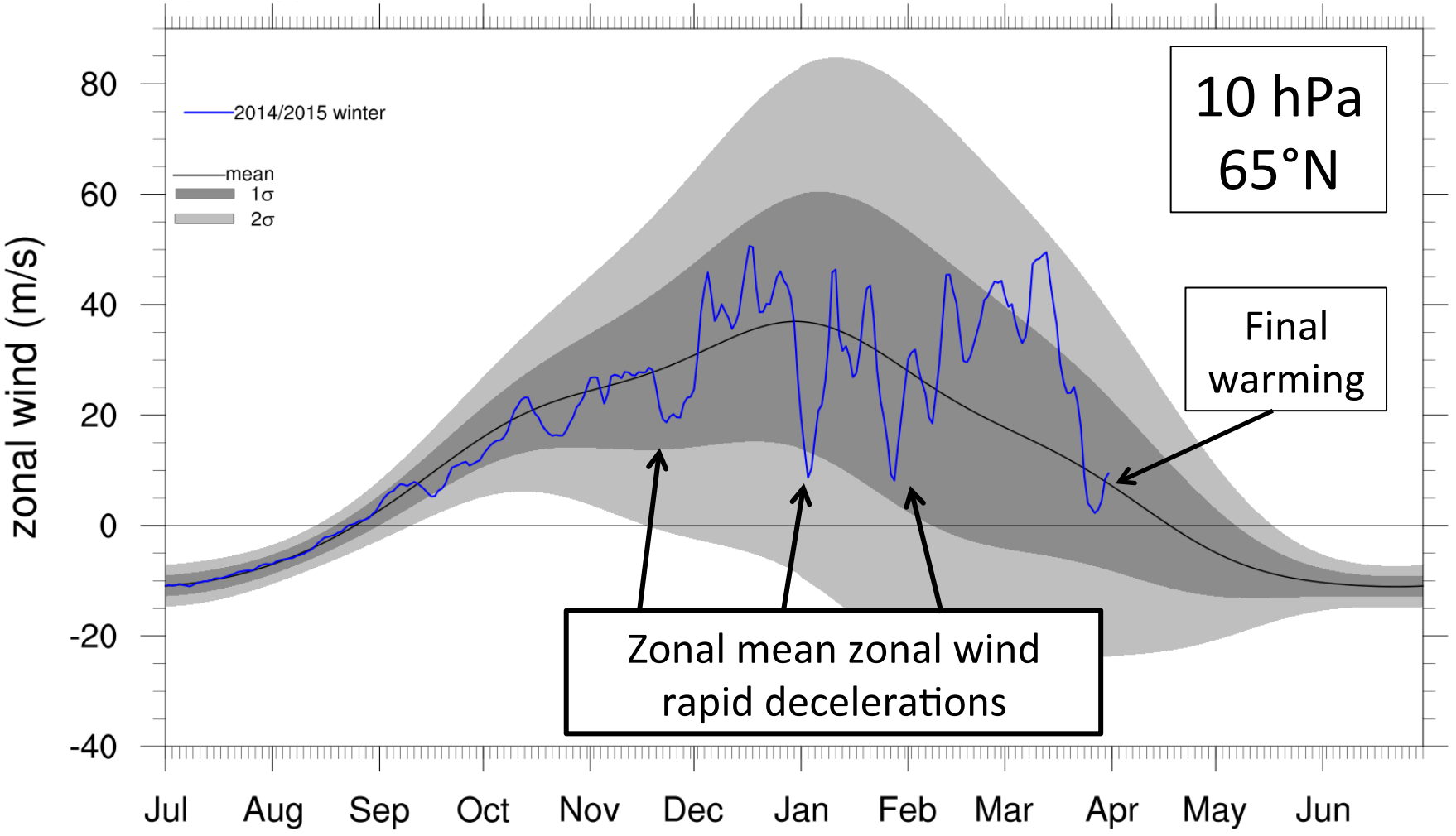
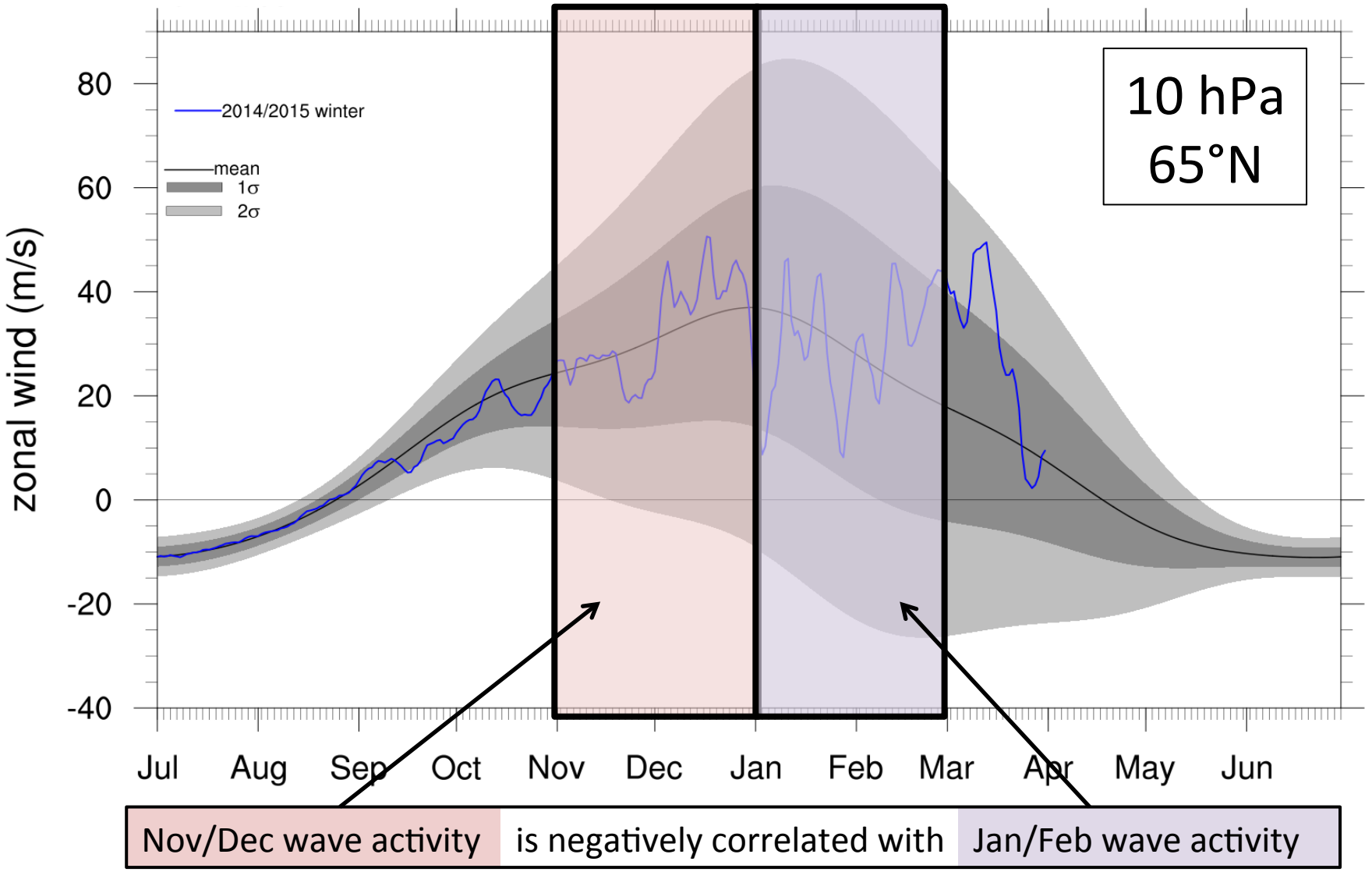


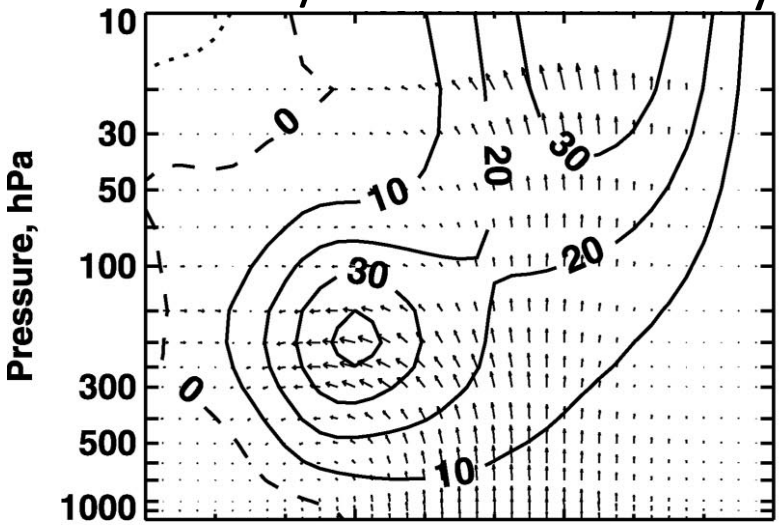
The winter of 2014/2015 zonal mean zonal wind

Karpetcko and Nikulin (2004)

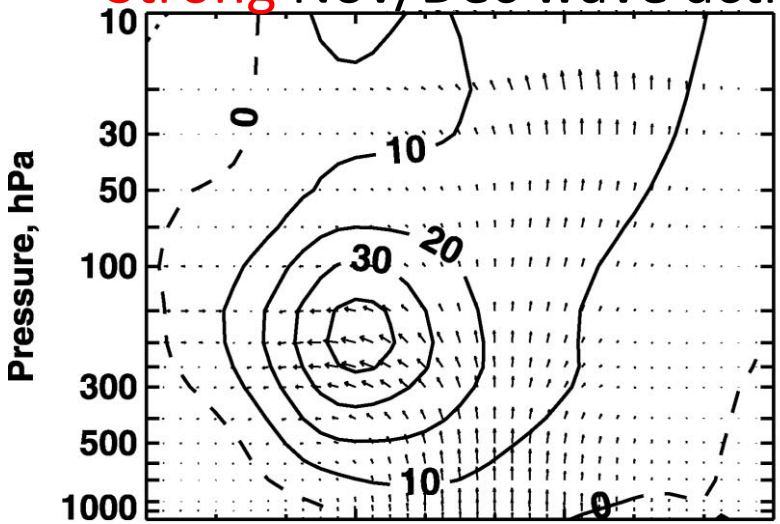


Background
Jan/Feb zonal mean zonal wind

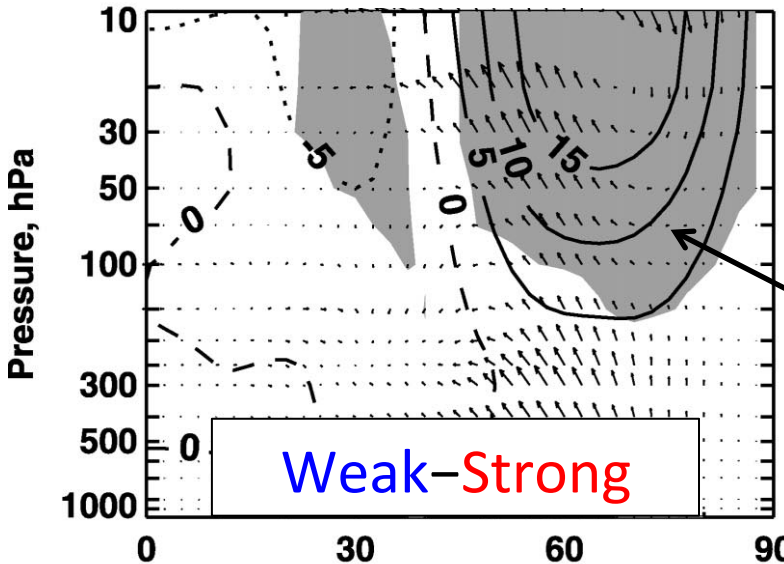
Weak Nov/Dec wave activity



Strong Nov/Dec wave activity



January/ February zonal mean zonal wind



99% confidence level

Karpetchko and Nikulin 2004

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Jan/Feb zonal mean zonal wind

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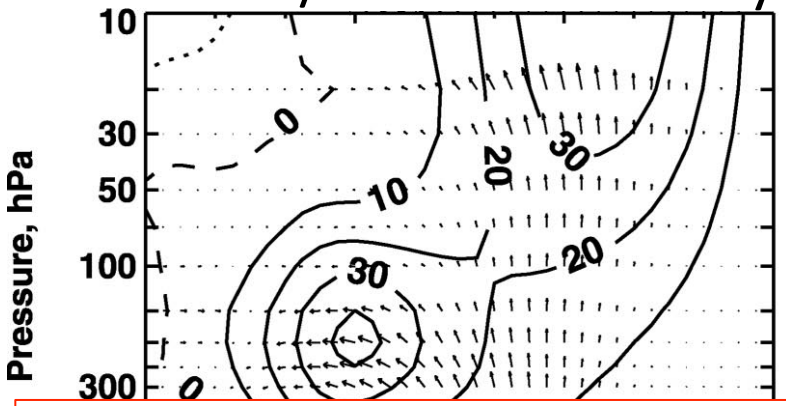
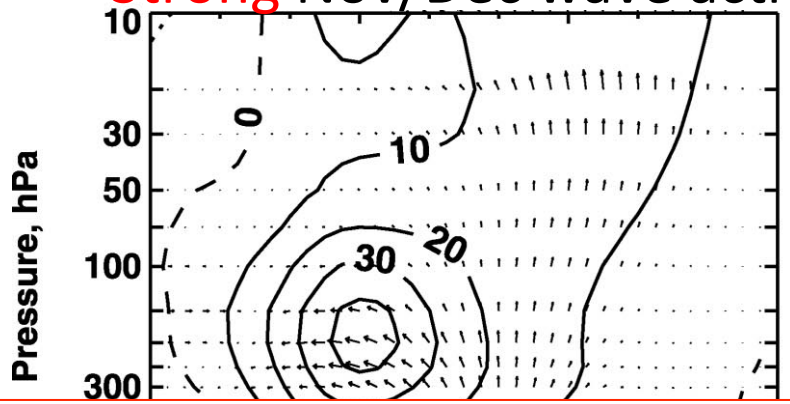


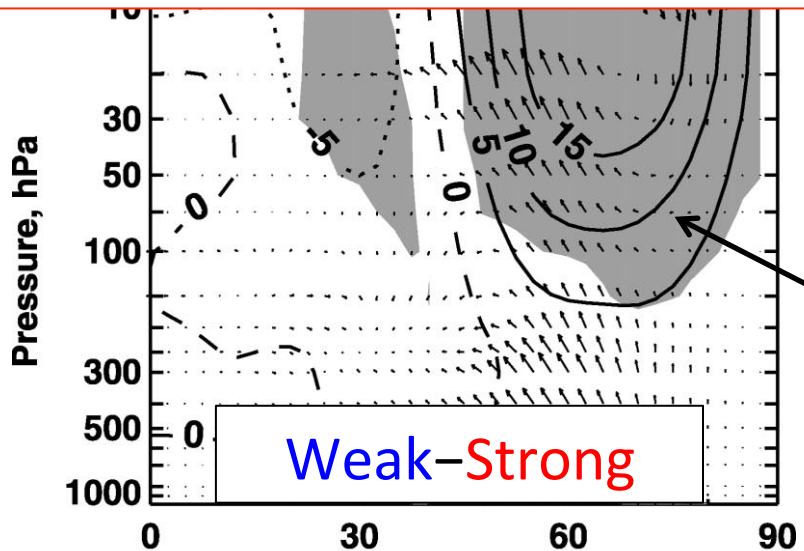
Strong Nov/Dec wave activity



How do we determine if there is wave activity?

- Planetary scale EP flux

January/ February zonal mean zonal wind



99% confidence level

Karpetchko and Nikulin 2004

Why EP flux?

Change in the mean zonal wind with time

$$\vec{\nabla} \bullet \vec{F} \approx \frac{d\bar{u}}{dt}$$

(-) ⟹ (-)

convergence ⟹ decrease

EP Flux Divergence

Zonal-mean eddy heat flux

$$F_z = p_s a f R \cos\phi \frac{\overline{v'T'}}{HN^2}$$

Vertical component of **EP flux**

Why EP flux?

Change in the mean zonal wind with time

$$\vec{\nabla} \bullet \vec{F} \approx \frac{d\bar{u}}{dt}$$

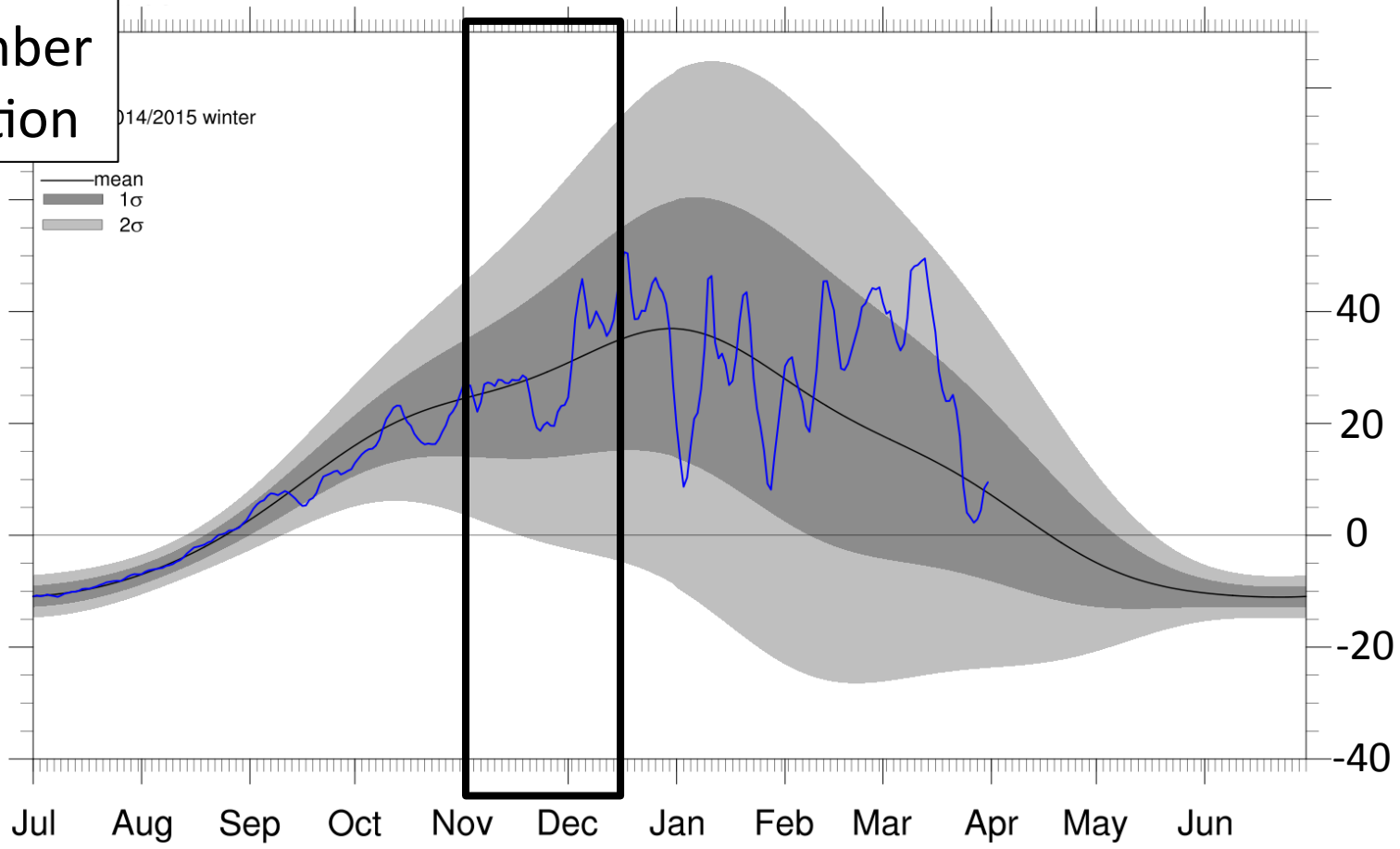
The 100 hPa **zonal-mean eddy heat flux** describes the vertical component of **EP flux** and describes *vertical wave activity flux* near the tropopause

$$F_z = p_s a f R \cos\phi \frac{\overline{v'T'}}{HN^2}$$

Vertical component of **EP flux**

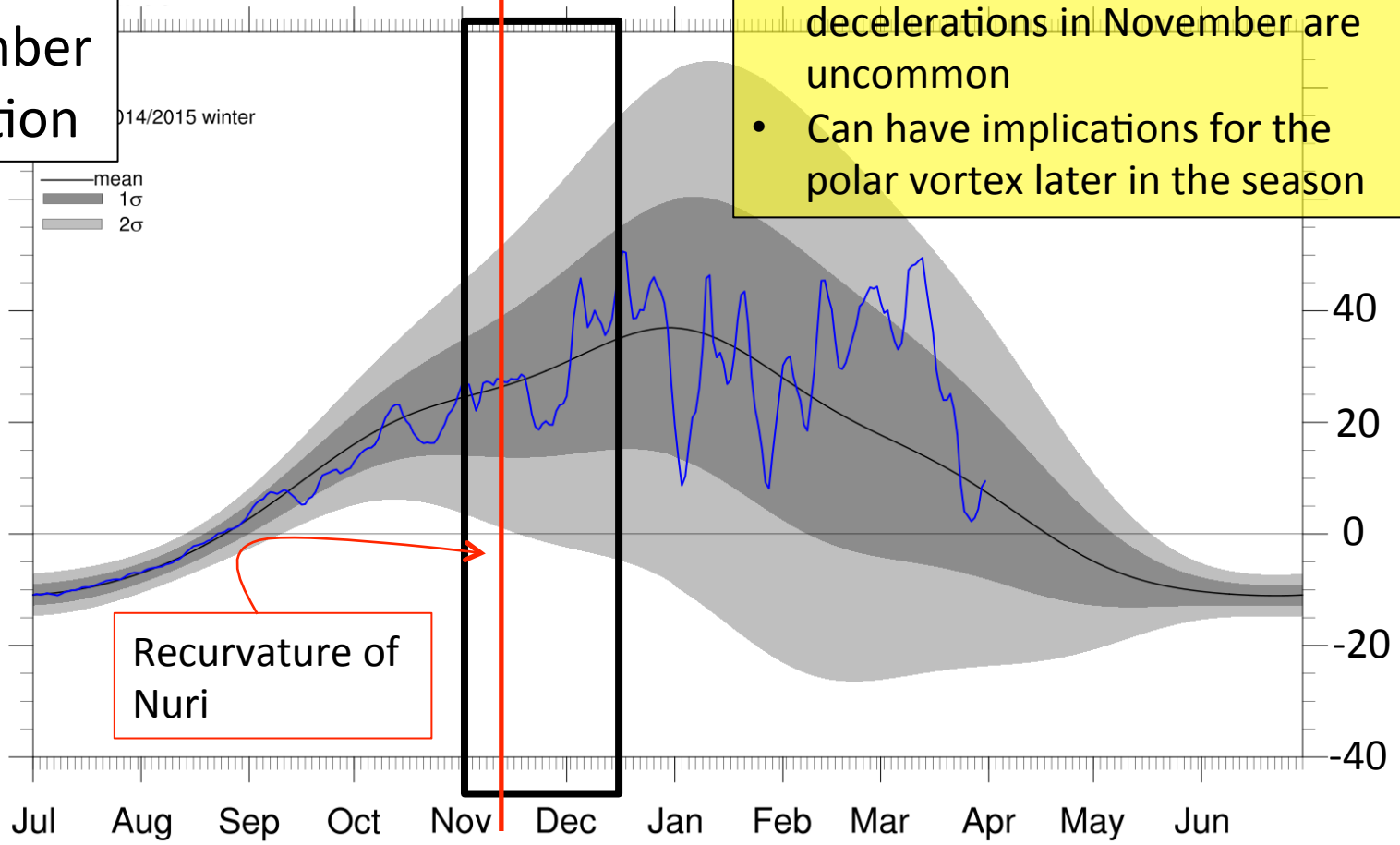
The winter of 2014/2015

Let's explore the 23 November deceleration



The winter of 2014/2015

Let's explore the 23 November deceleration



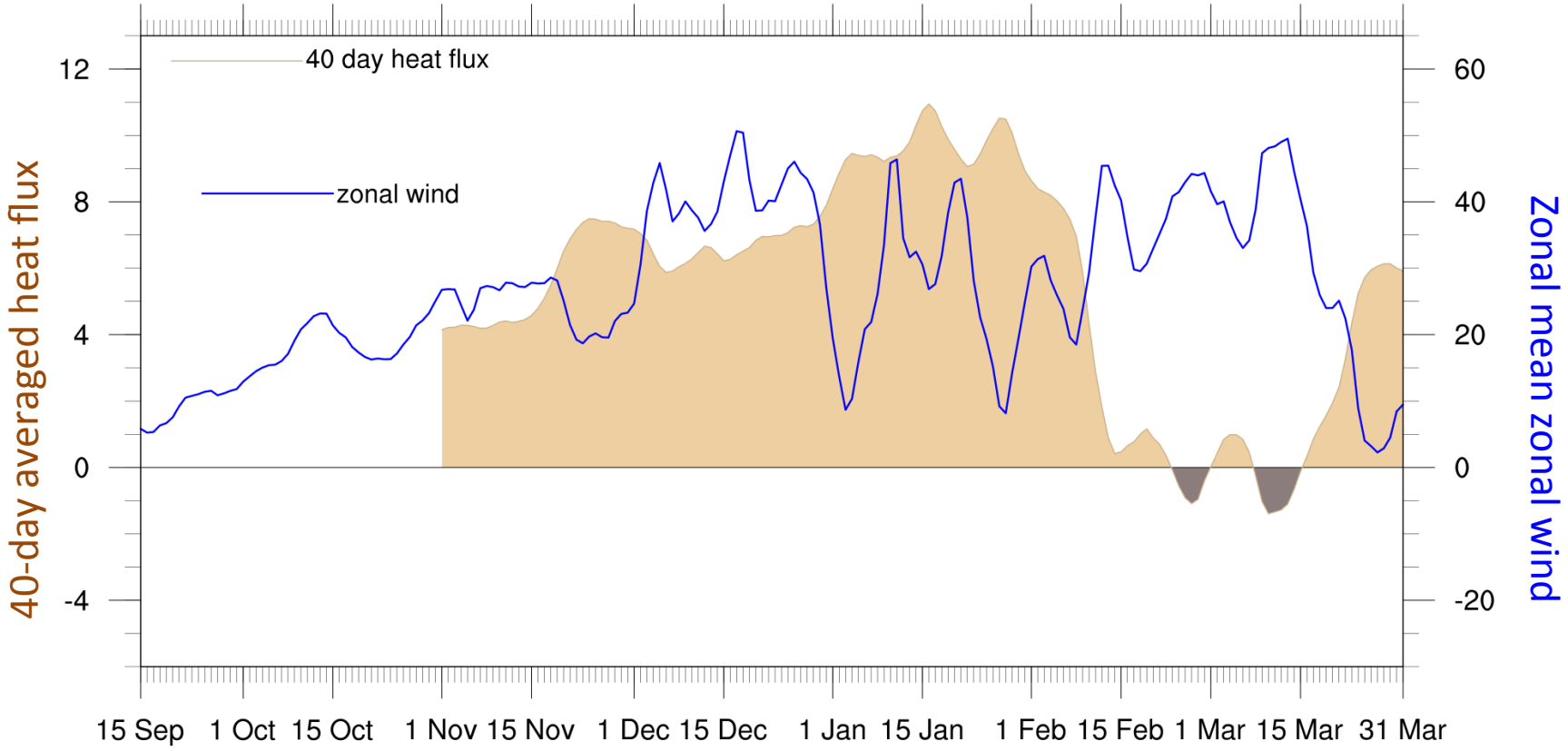
Why the November deceleration?

- Rapid zonal mean zonal wind decelerations in November are uncommon
- Can have implications for the polar vortex later in the season

Data and Methods

- ERA-Interim data
  - ~80 km horizontal resolution
  - 60 vertical levels from 1000 hPa to 0.1 hPa
  - 6-hourly data available from 1000 hPa to 1 hPa
- 31-year climatology from 1979—2010
- Heat flux:
  - Zonal mean ($\overline{v'T'}$)
    - Anomalies with respect to climatology (e.g., Polvani & Waugh 2004)
    - Full heat flux (not anomaly)
  - Longitudinal distribution (v'T')
  - Averaged from 45°-75°N, weighted by the cosine of latitude

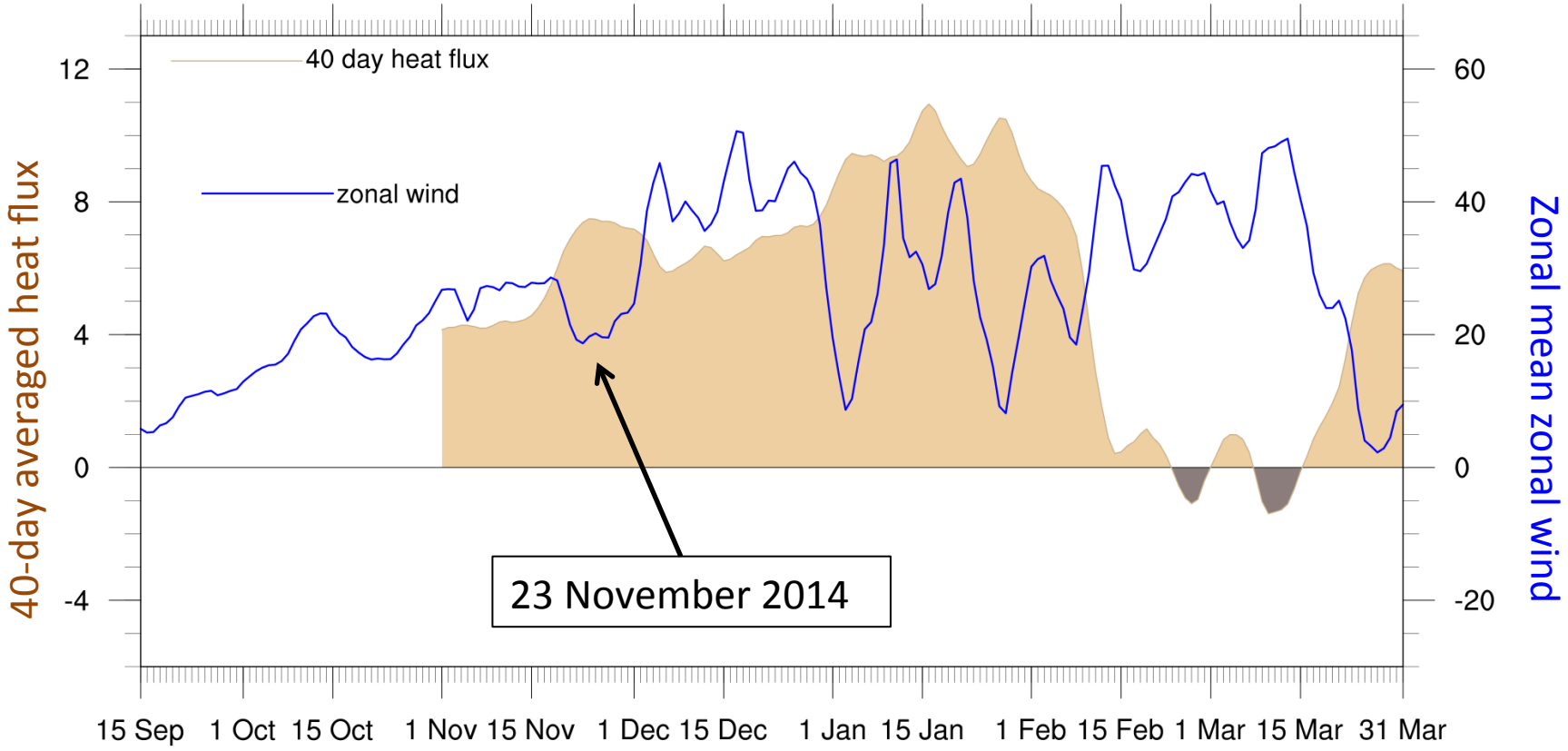
100 hPa heat flux anomaly & 10 hPa zonal mean zonal wind



100 hPa 45—75°N
Heat flux anomaly averaged over the previous 40 days

10 hPa 65°N
Zonal mean zonal wind

100 hPa heat flux anomaly & 10 hPa zonal mean zonal wind



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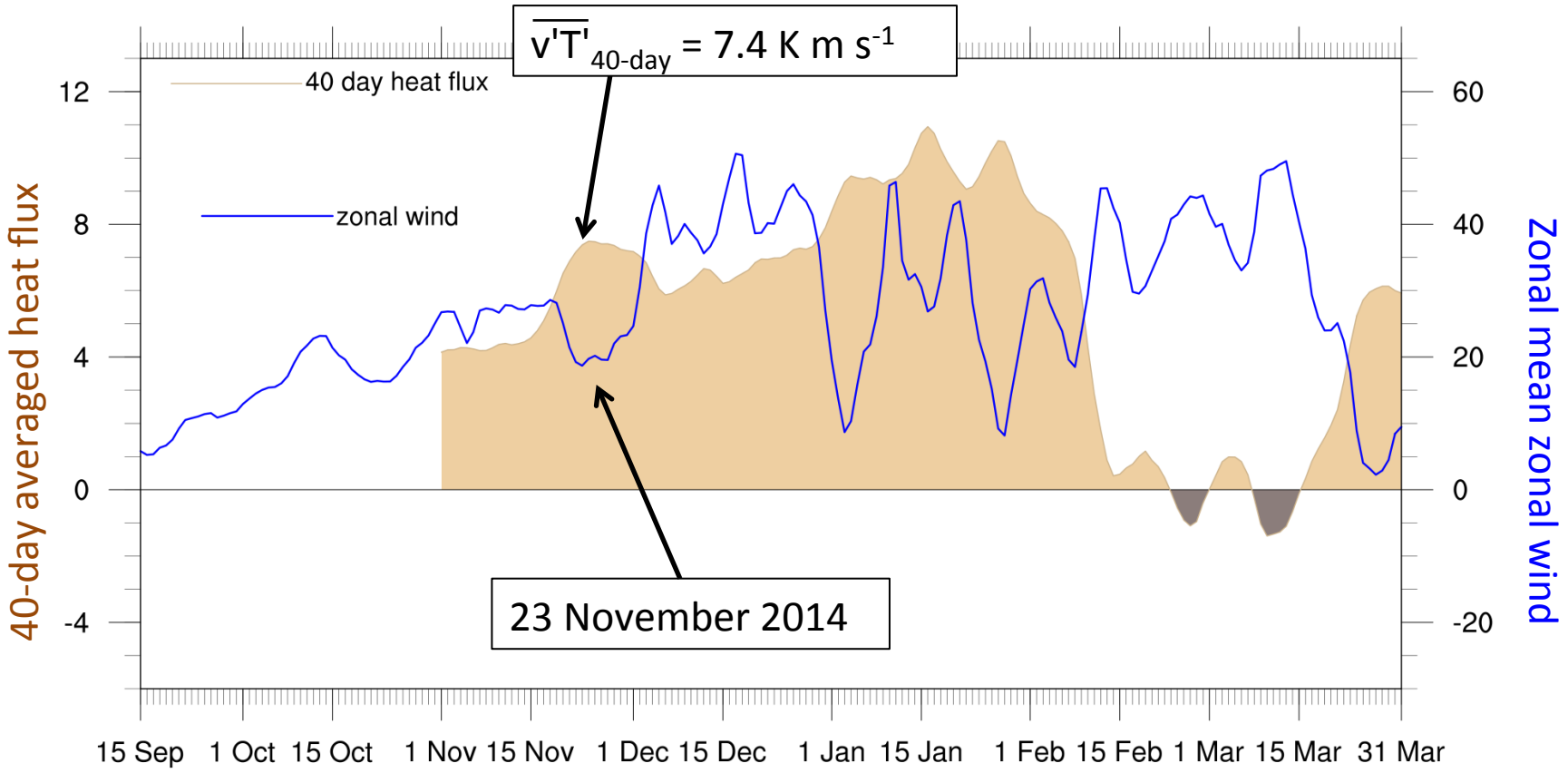

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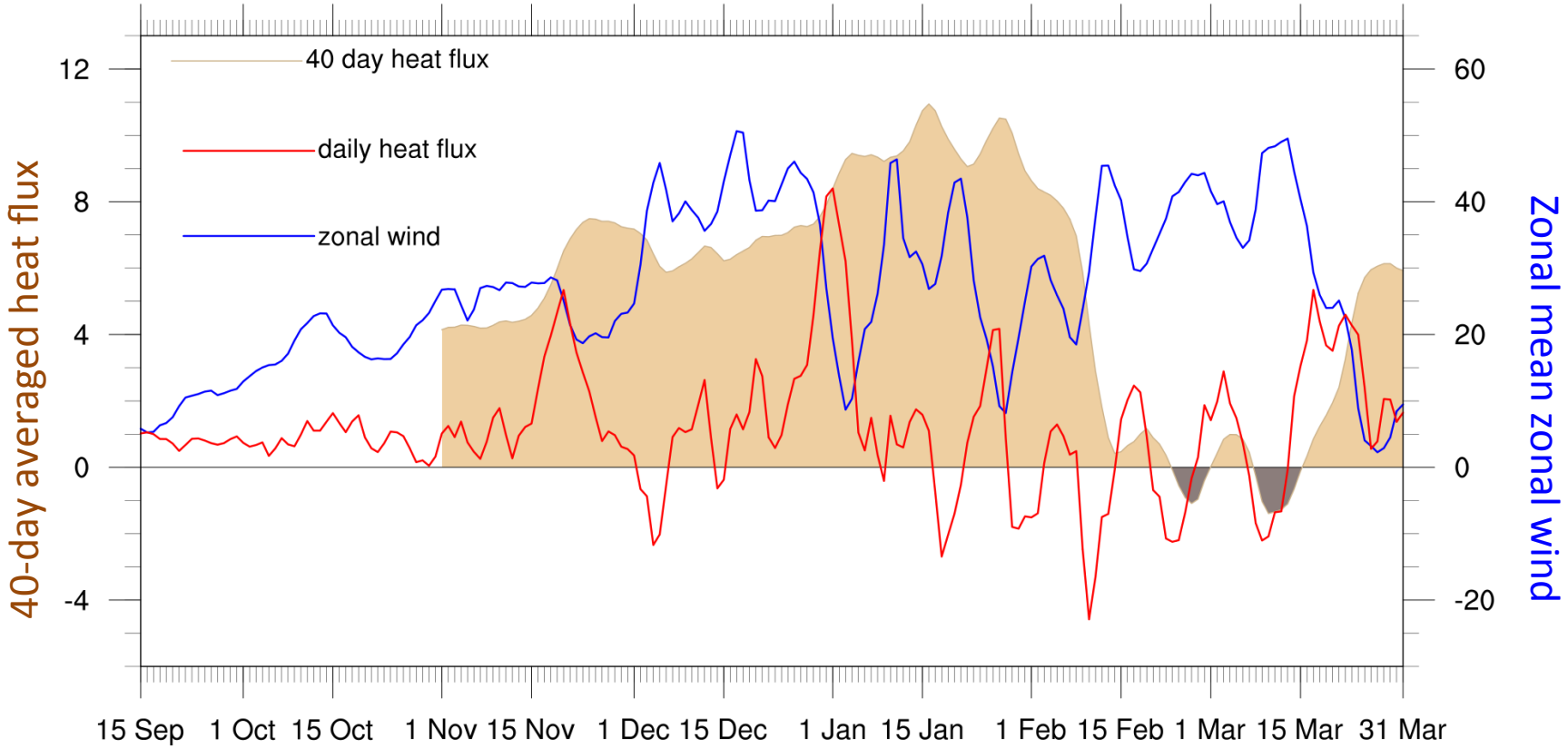
100 hPa heat flux anomaly & 10 hPa zonal mean zonal wind



100 hPa 45—75°N
Heat flux anomaly
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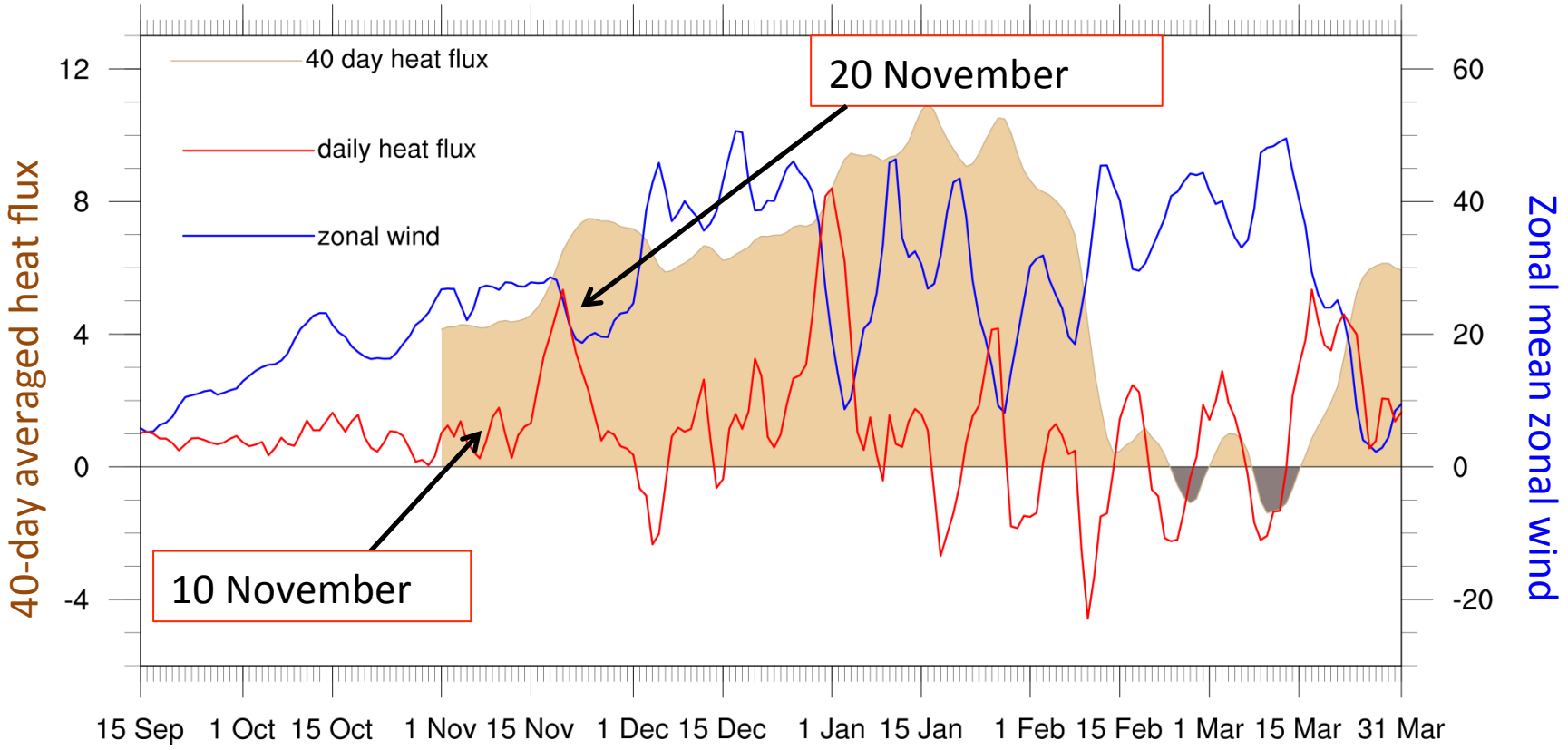
100 hPa 45—75°N
Daily heat flux
anomaly

10 hPa 65°N
Zonal mean
zonal wind

100 hPa heat flux anomaly & 10 hPa zonal mean zonal wind



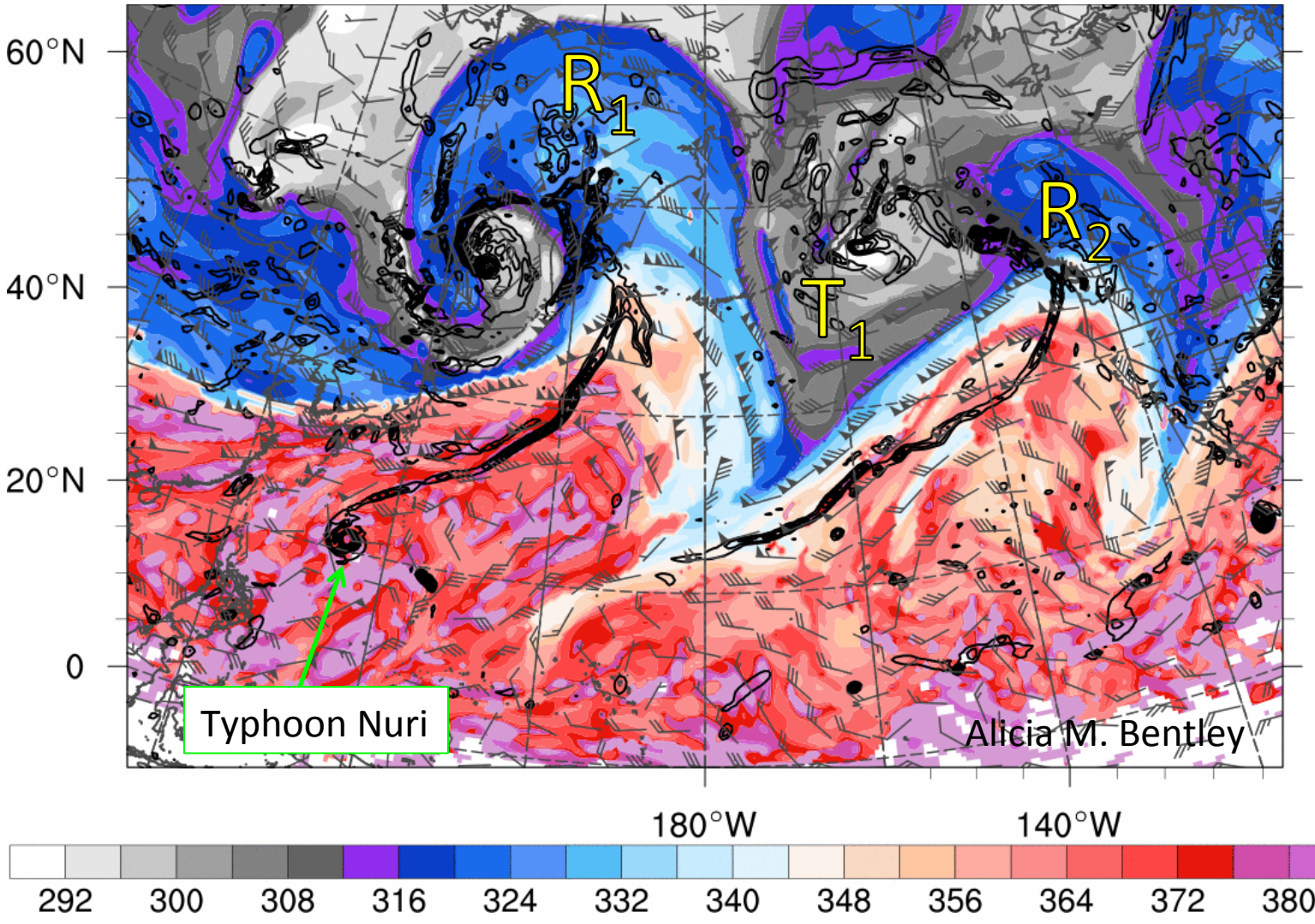
100 hPa 45—75°N Heat flux anomaly averaged over the previous 40 days

100 hPa 45—75°N Daily heat flux anomaly

10 hPa 65°N Zonal mean zonal wind

The tropospheric synoptic evolution

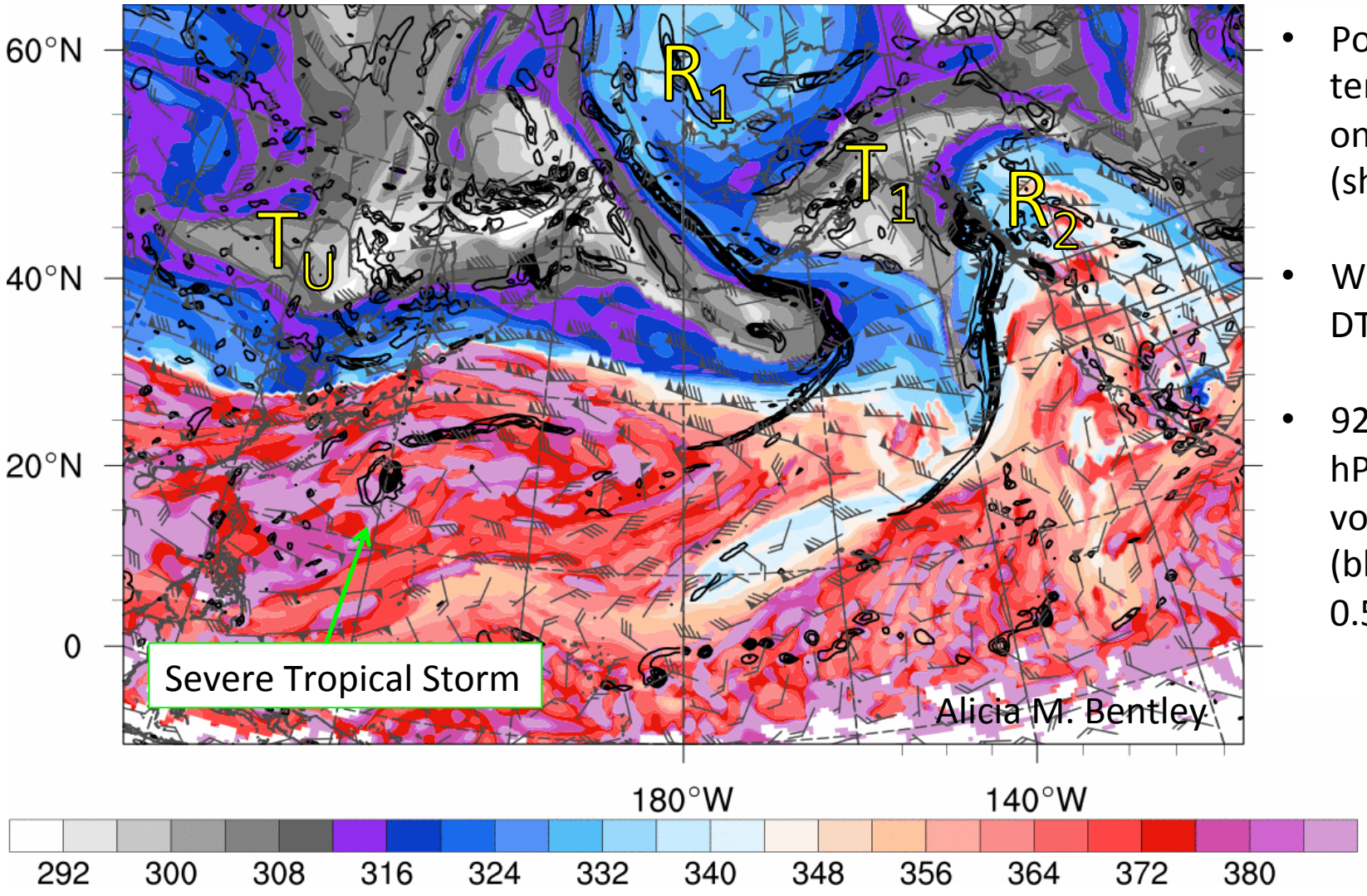
North Pacific
0000 UTC 4 November 2014



- Potential temperature on the DT (shaded)
- Wind on the DT (barbs)
- 925—850 hPa relative vorticity (black) every 0.5×10^{-4} s^{-1}

The tropospheric synoptic evolution

North Pacific
0000 UTC 6 November 2014



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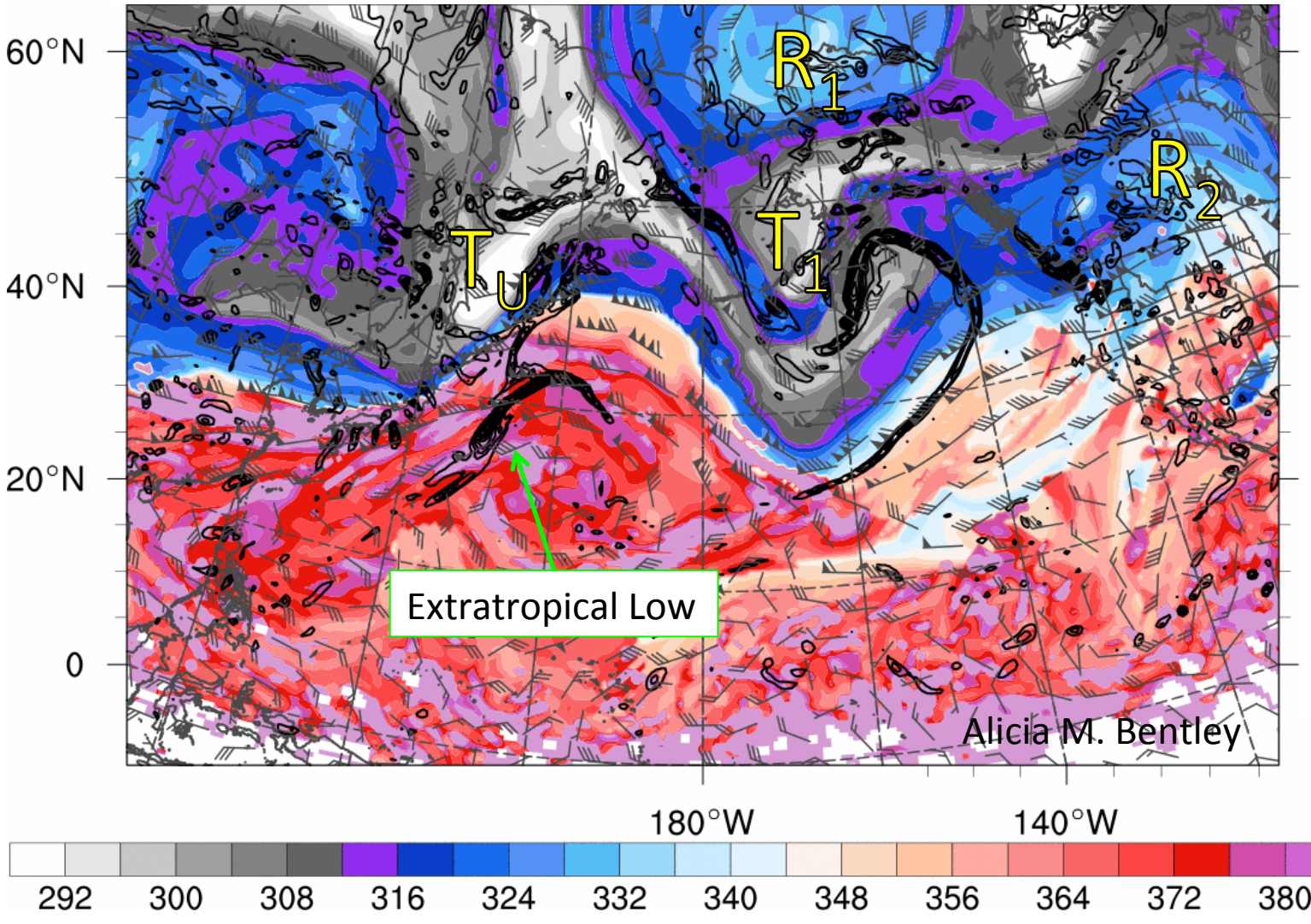
The tropospheric synoptic evolution

North Pacific
0000 UTC 7 November 2014



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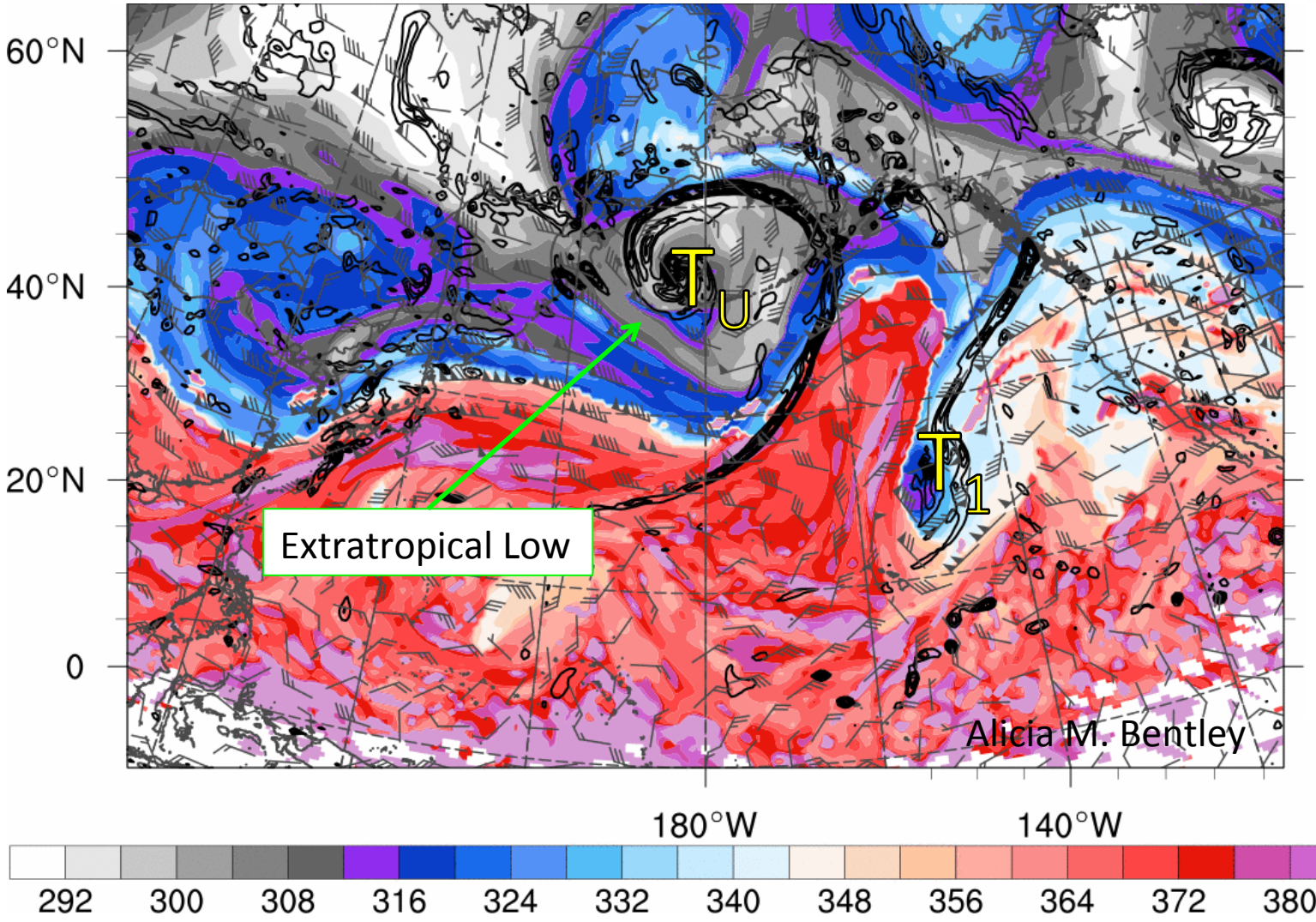
The tropospheric synoptic evolution

North Pacific
0000 UTC 9 November 2014



- Potential temperature on the DT (shaded)
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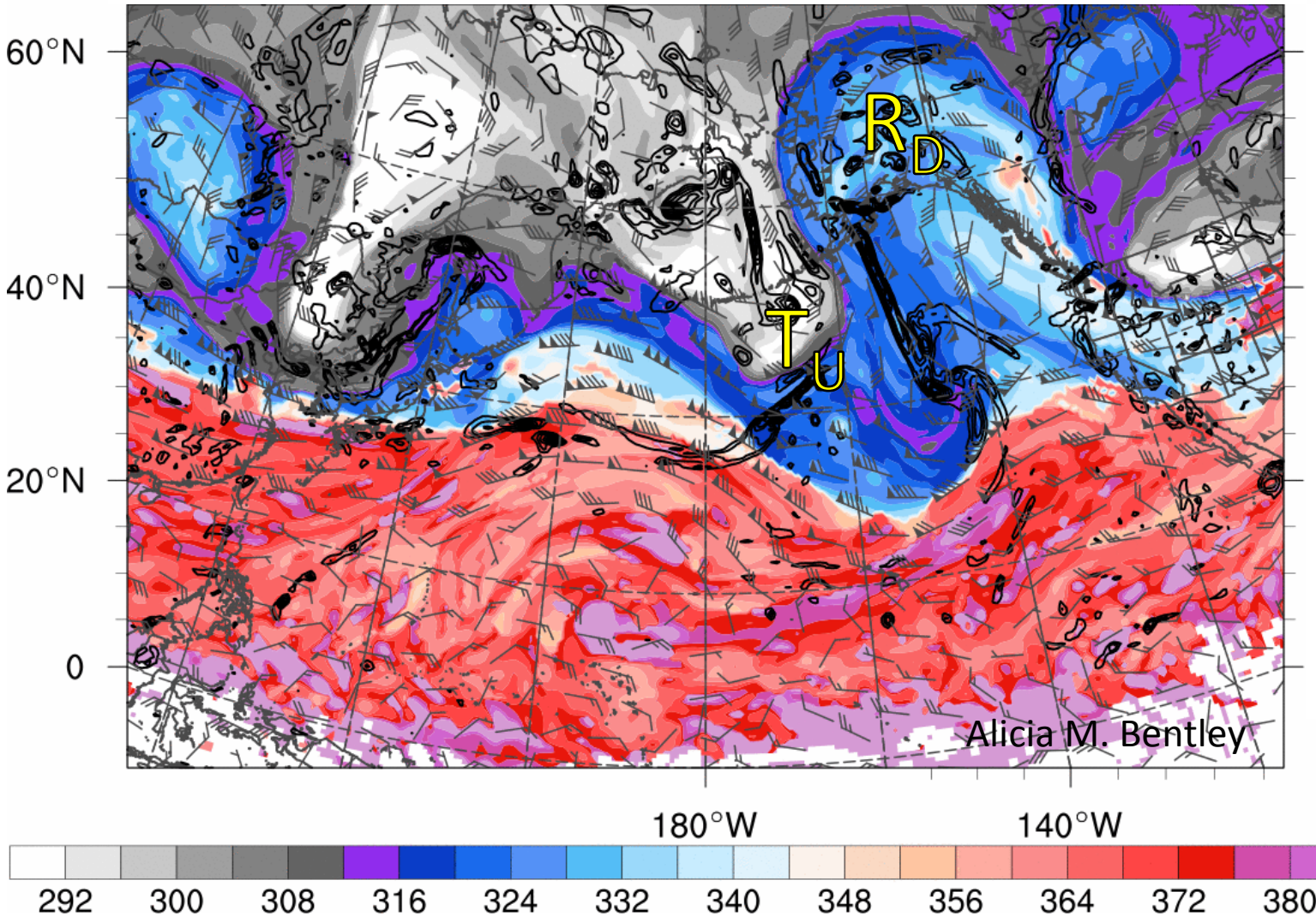
The tropospheric synoptic evolution

North Pacific
0000 UTC 12 November 2014



- Potential temperature on the DT (shaded)
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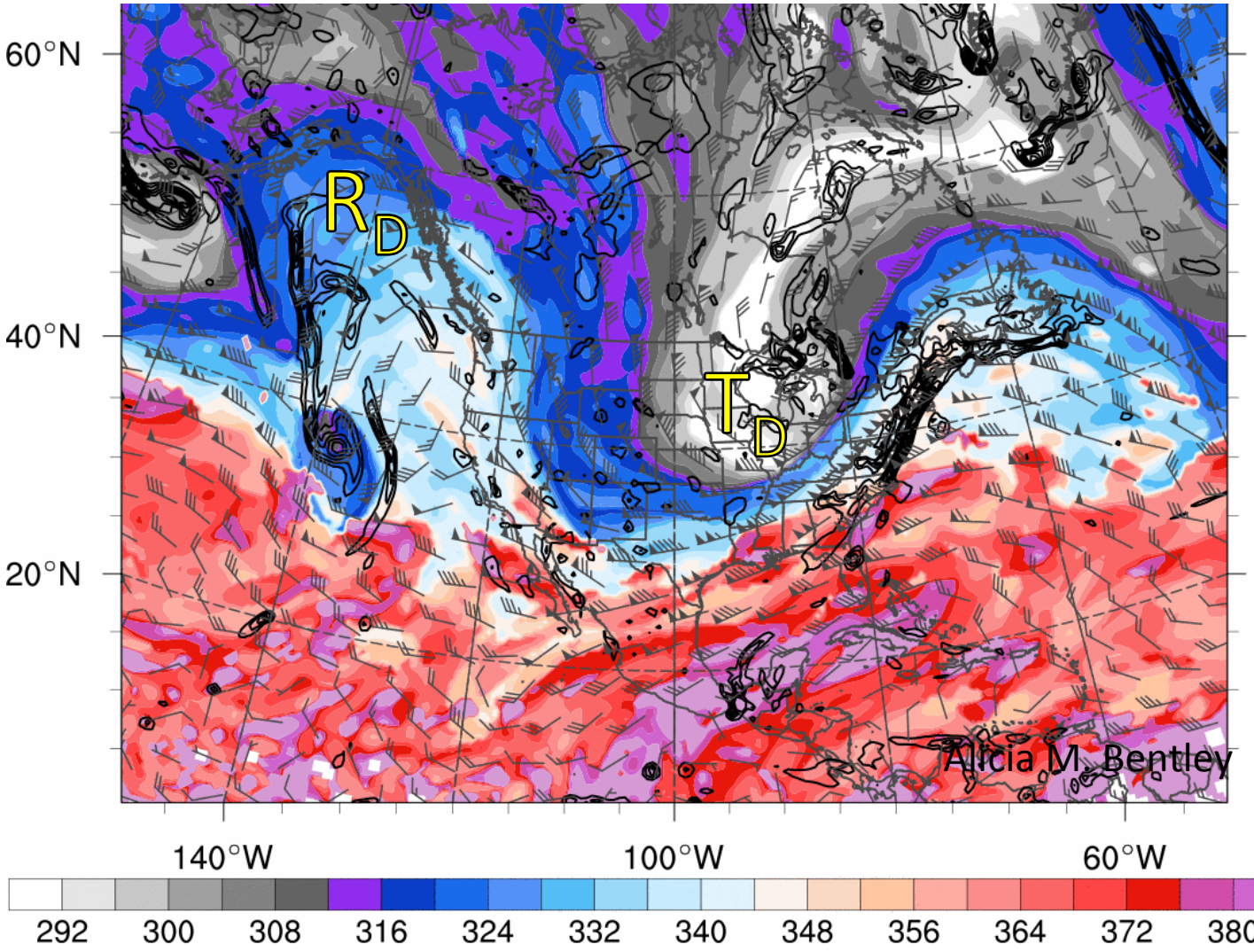
The tropospheric synoptic evolution

North America
0000 UTC 18 November 2014



- Potential temperature on the DT (shaded)
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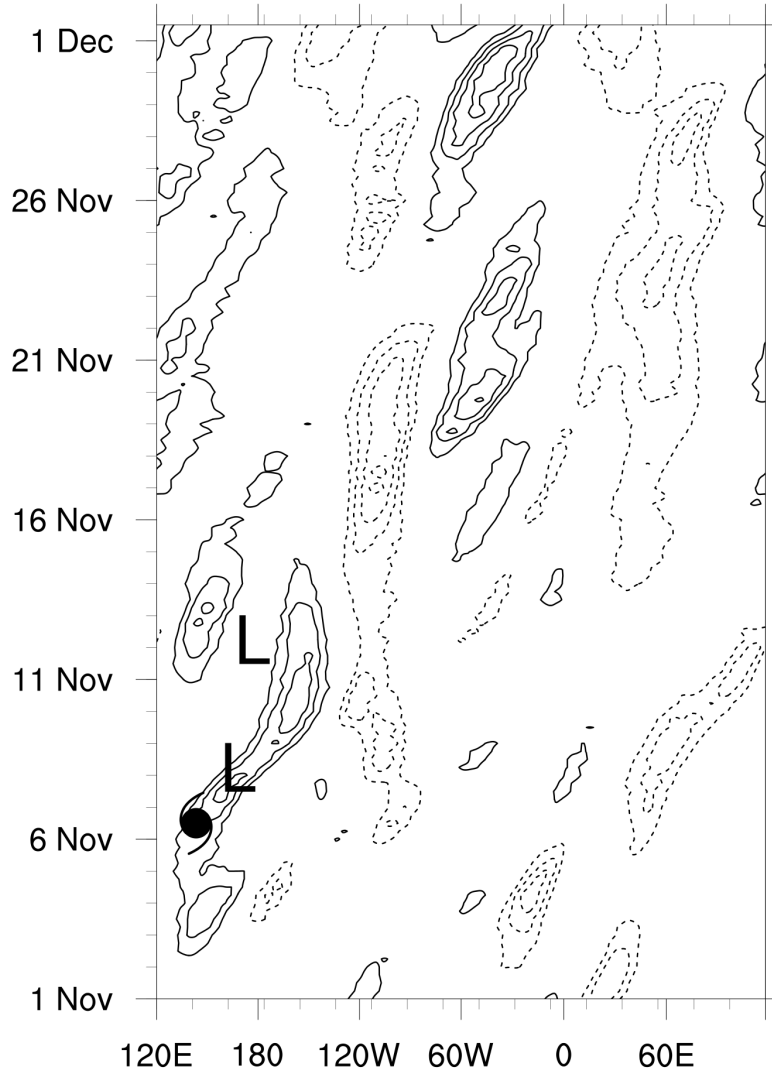
100 hPa Hovmoller
45°—75°N



v': every 5 (−5) m/s starting at 10 (−10) m/s

100 hPa Hovmoller
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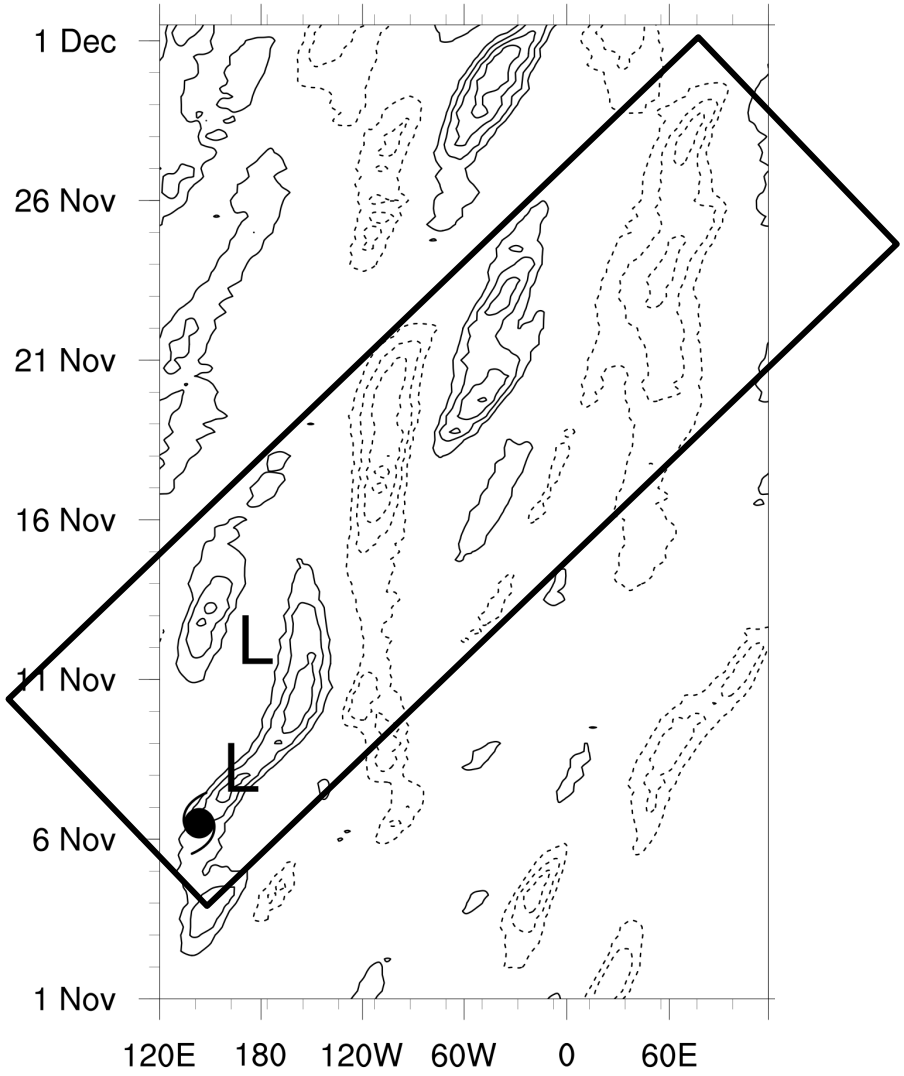

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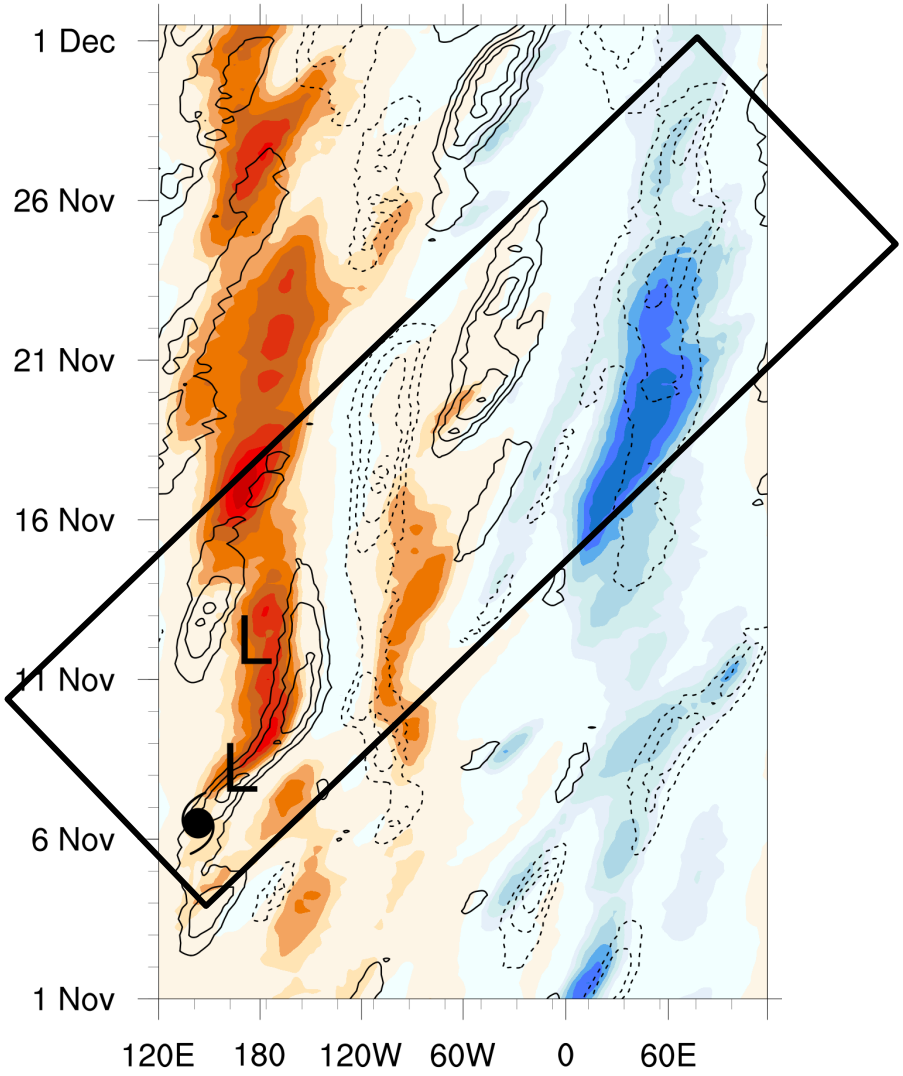

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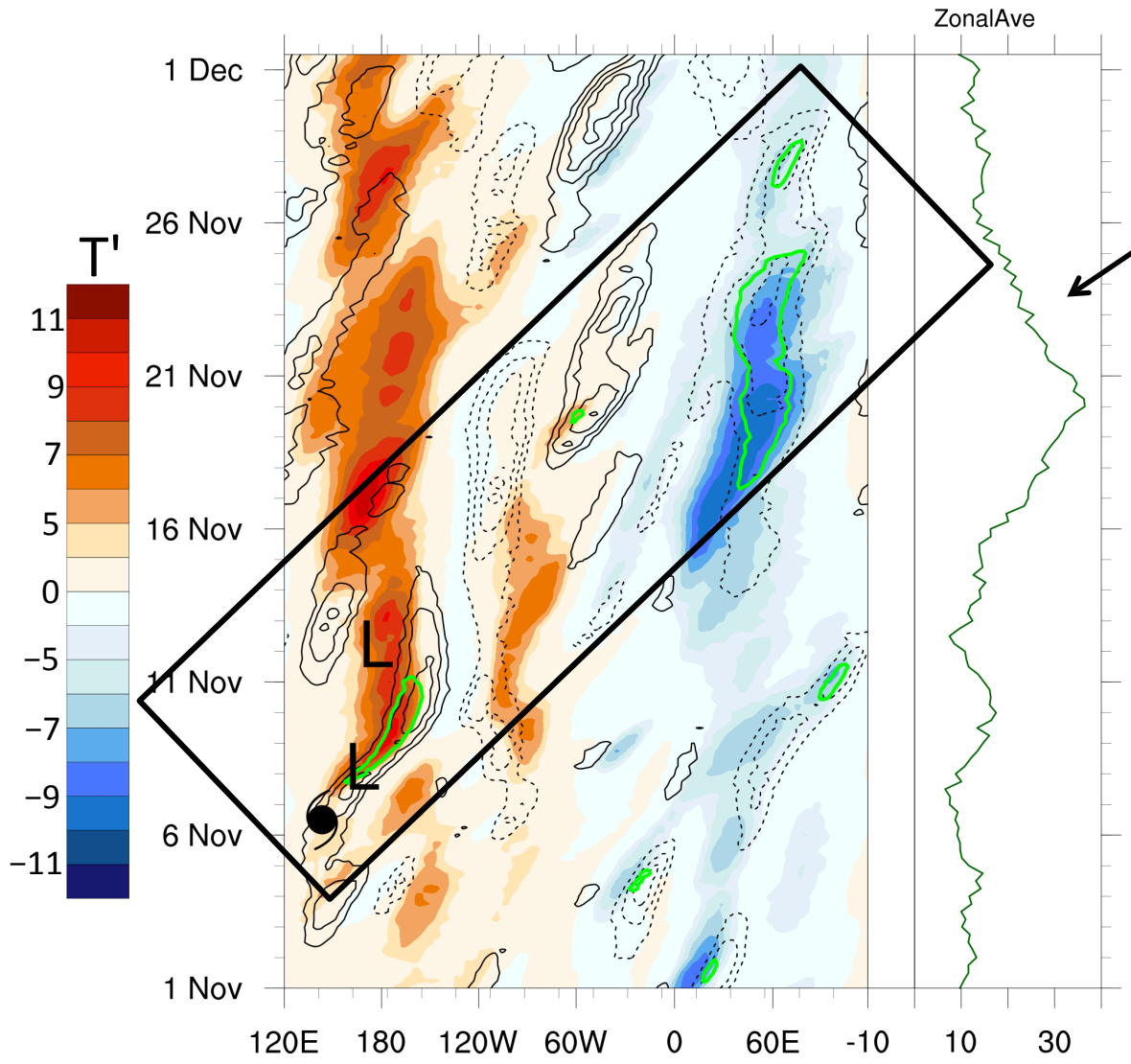
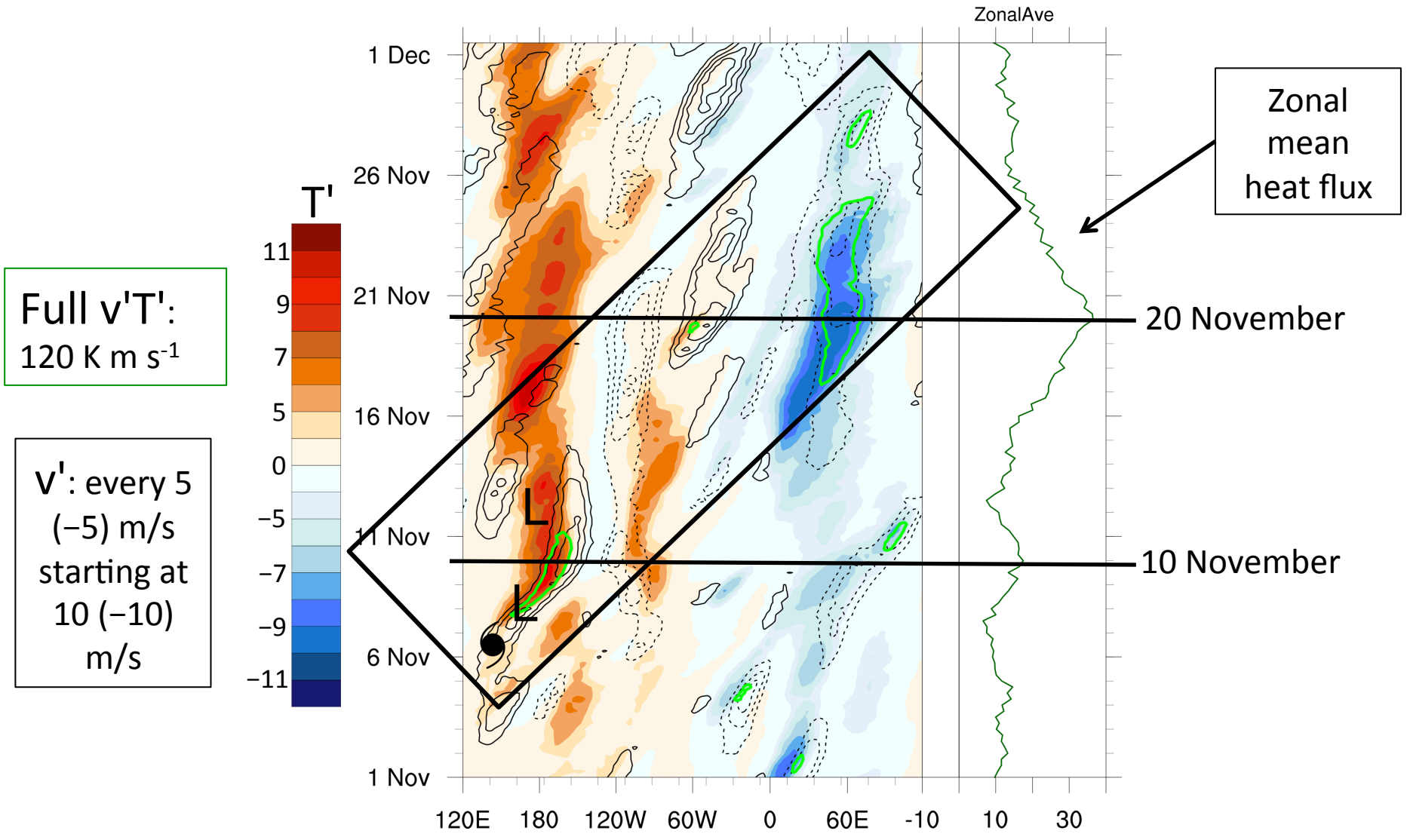


Zonal mean heat flux

Full v'T': 120 K m s^{-1}

v': every 5 (−5) m/s starting at 10 (−10) m/s

100 hPa Hovmoller
45°—75°N

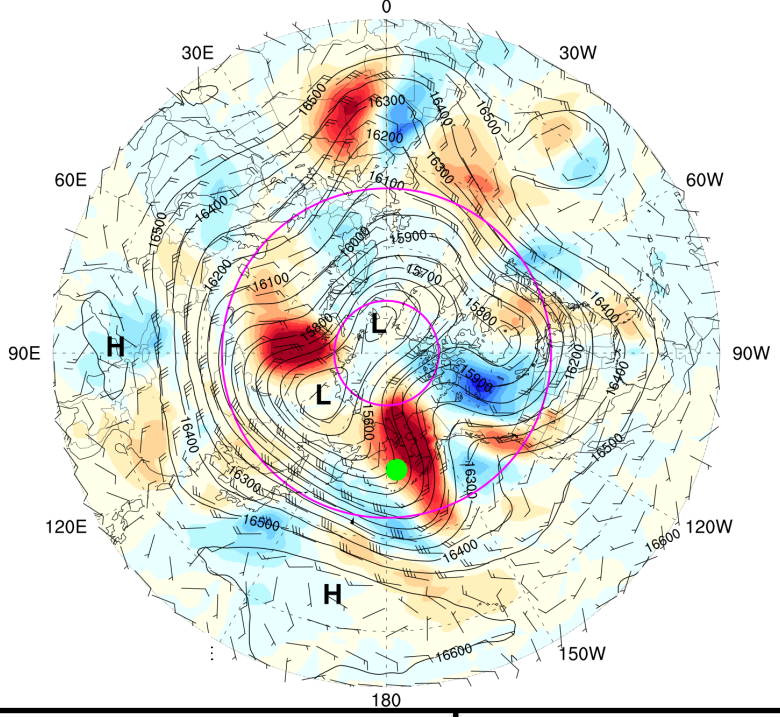


10 November 2014

Geopotential height

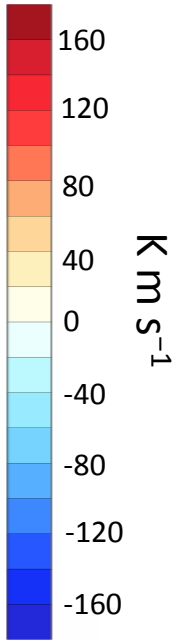
45° and 75° N latitude lines

First zonal mean heat flux maxima

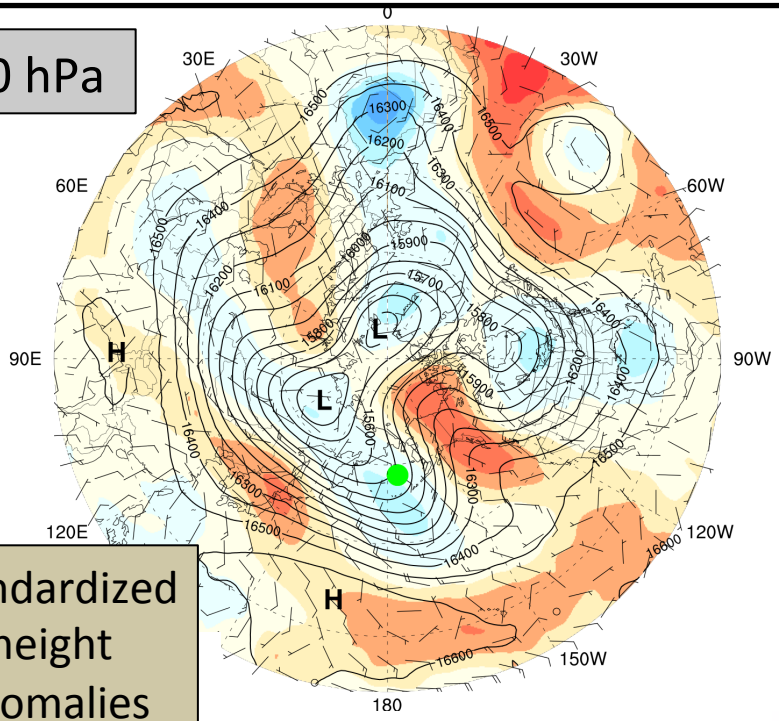


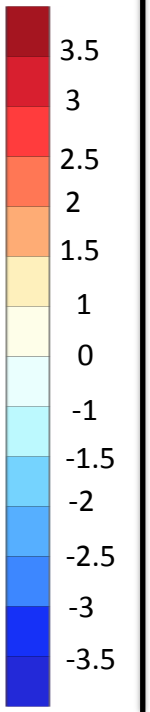
100 hPa

Full heat flux

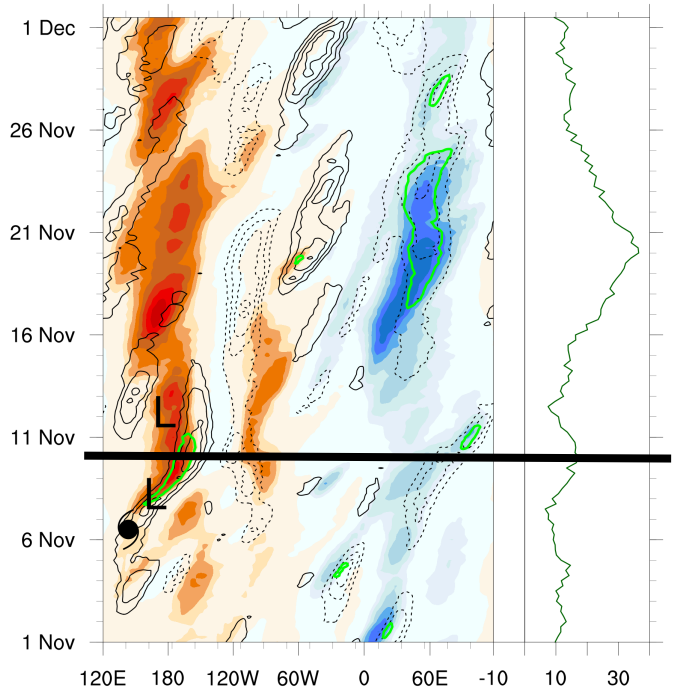


100 hPa





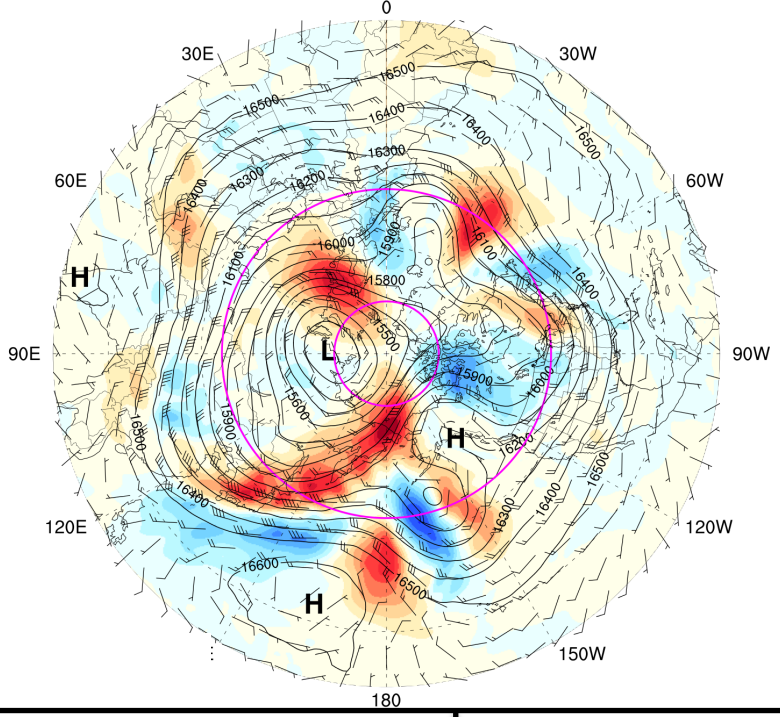
Standardized height anomalies



14 November 2014

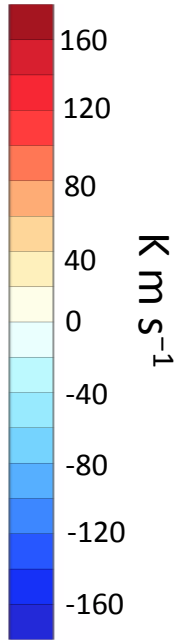
Geopotential height

45° and 75° N latitude lines

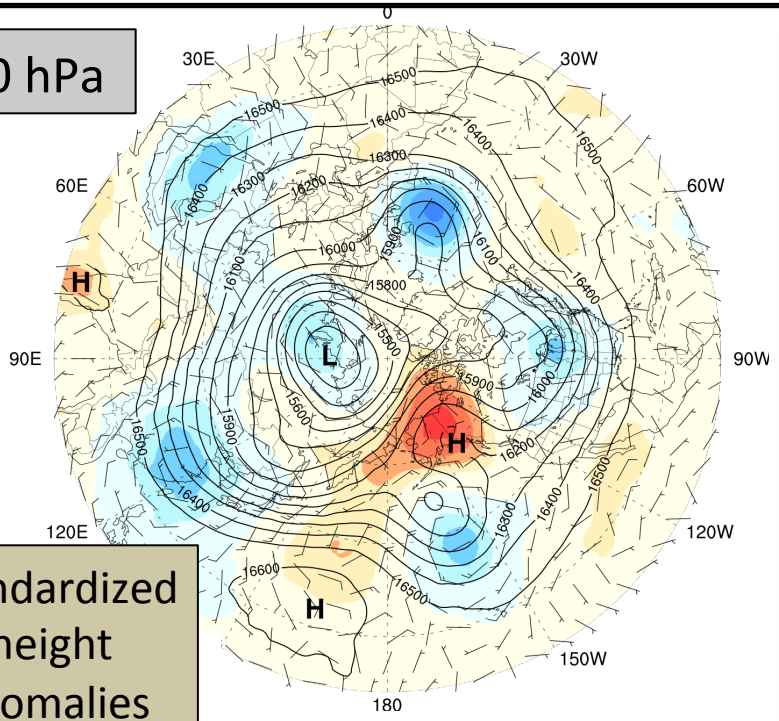


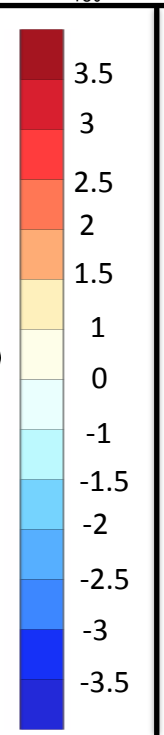
100 hPa

Full heat flux

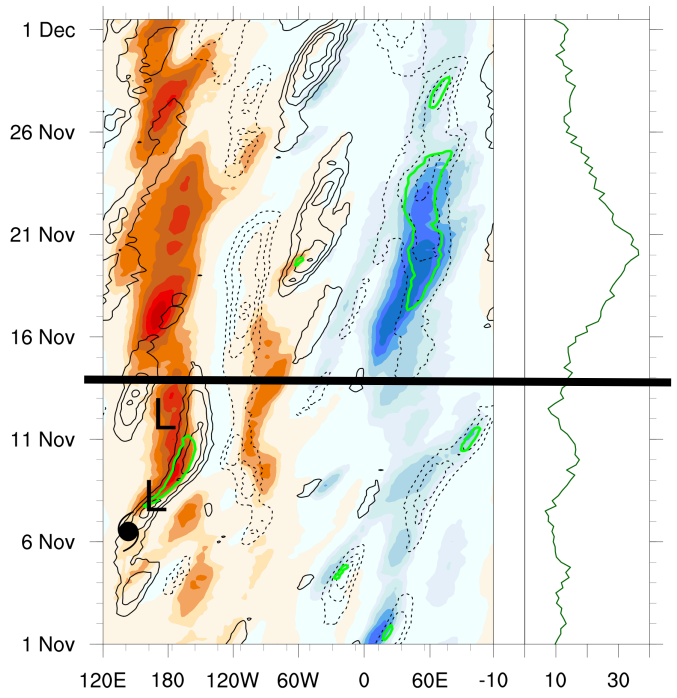


100 hPa





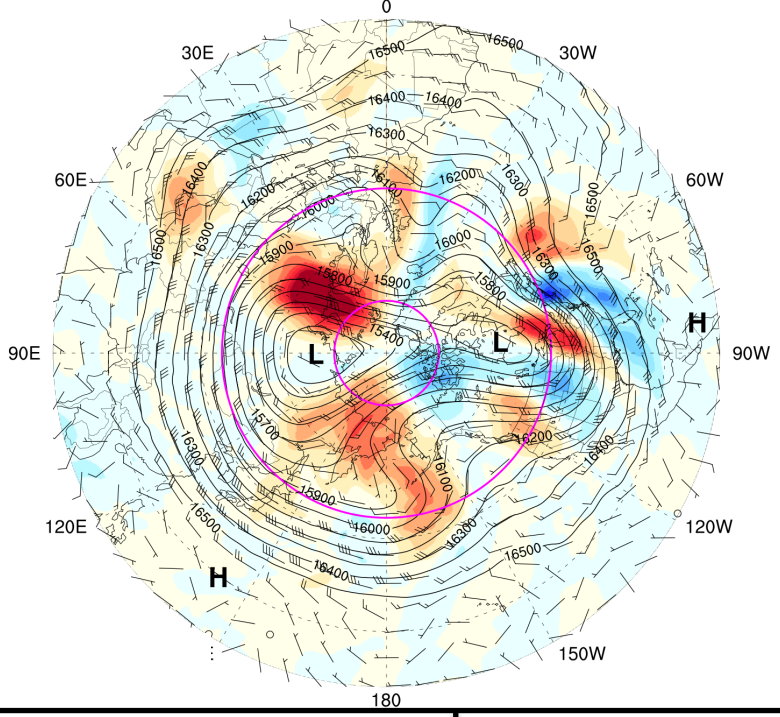
Standardized height anomalies



18 November 2014

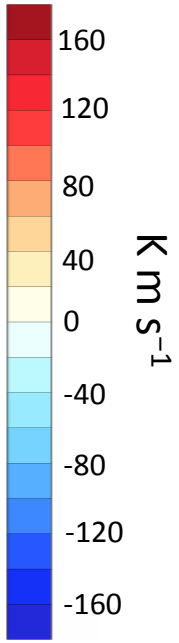
Geopotential height

45° and 75° N latitude lines

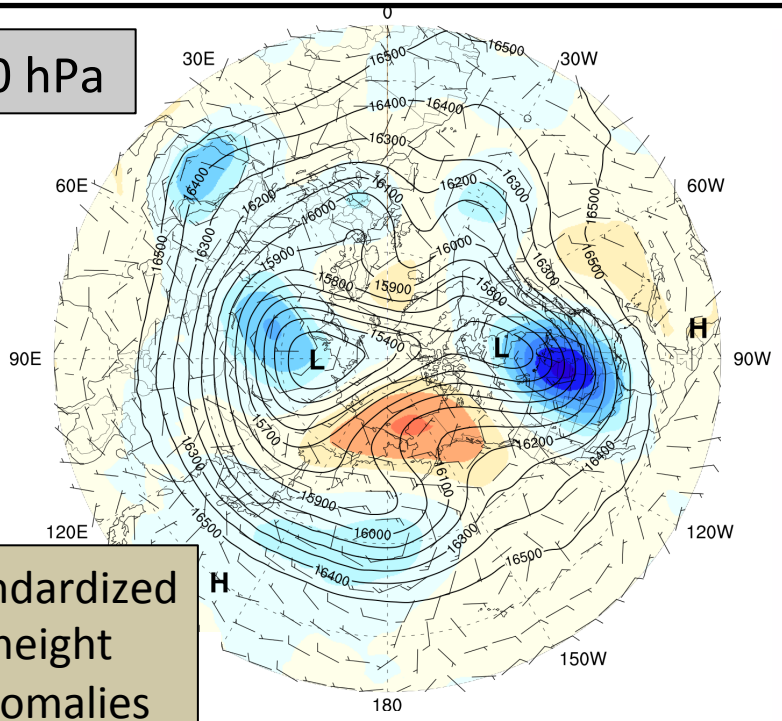


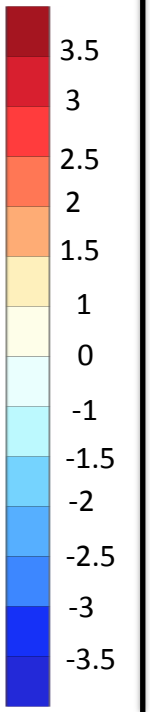
100 hPa

Full heat flux

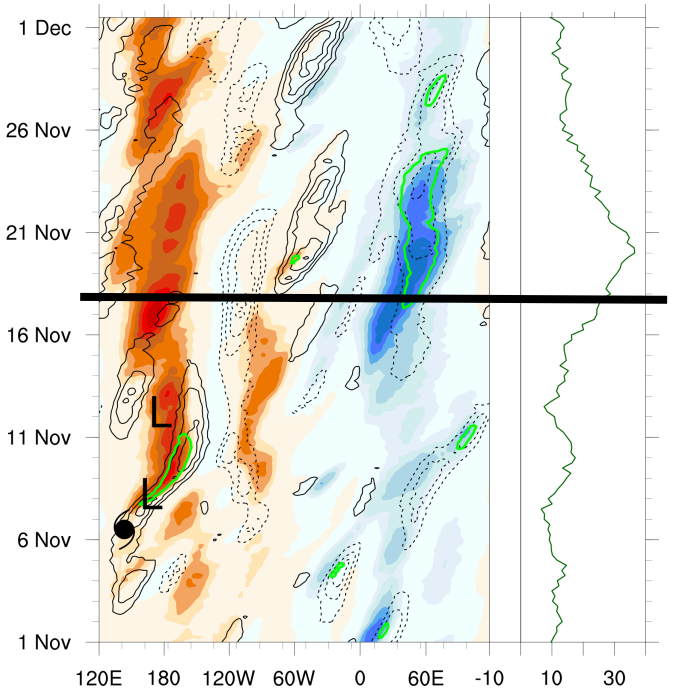


100 hPa





Standardized height anomalies

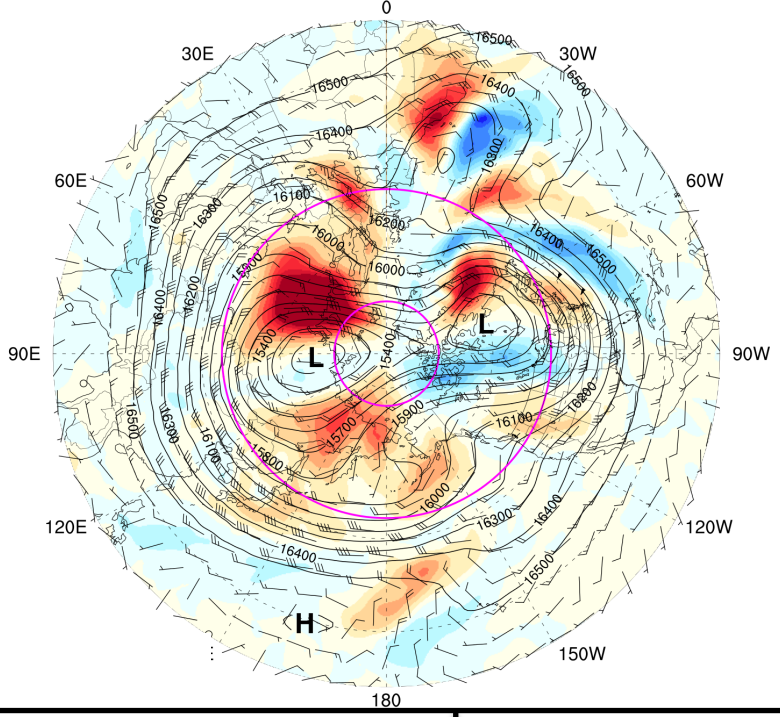


20 November 2014

Geopotential height

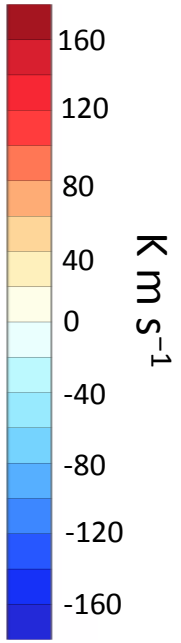
45° and 75° N latitude lines

Second zonal mean heat flux maxima

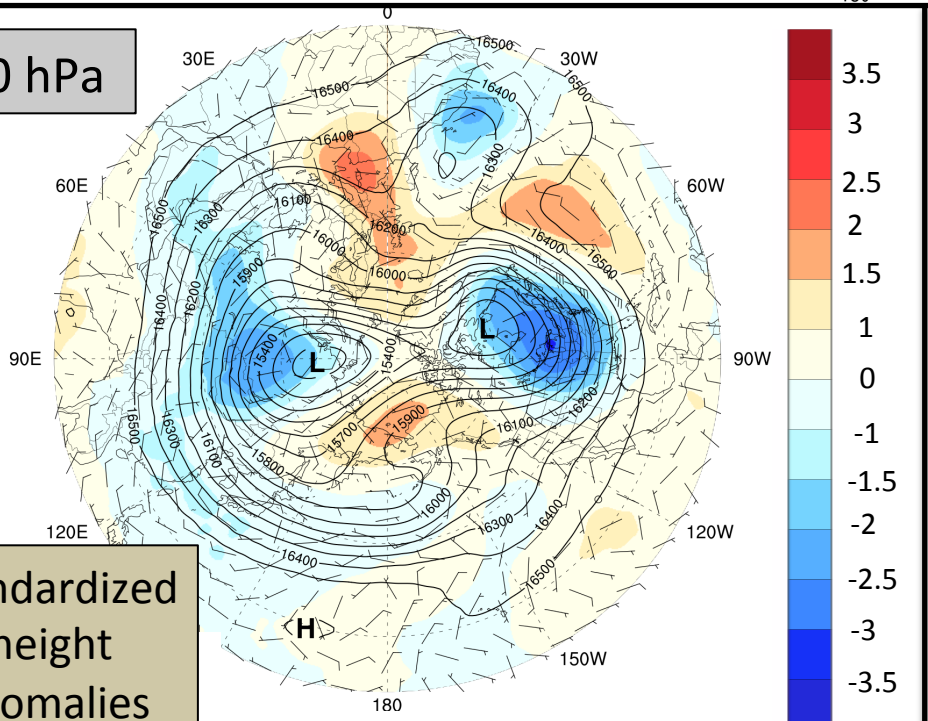


100 hPa

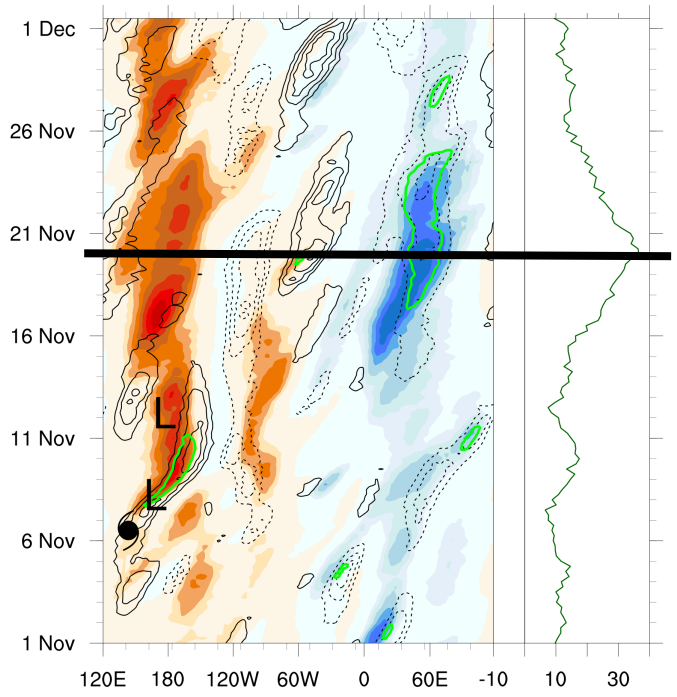
Full heat flux



100 hPa



Standardized height anomalies



Conclusions

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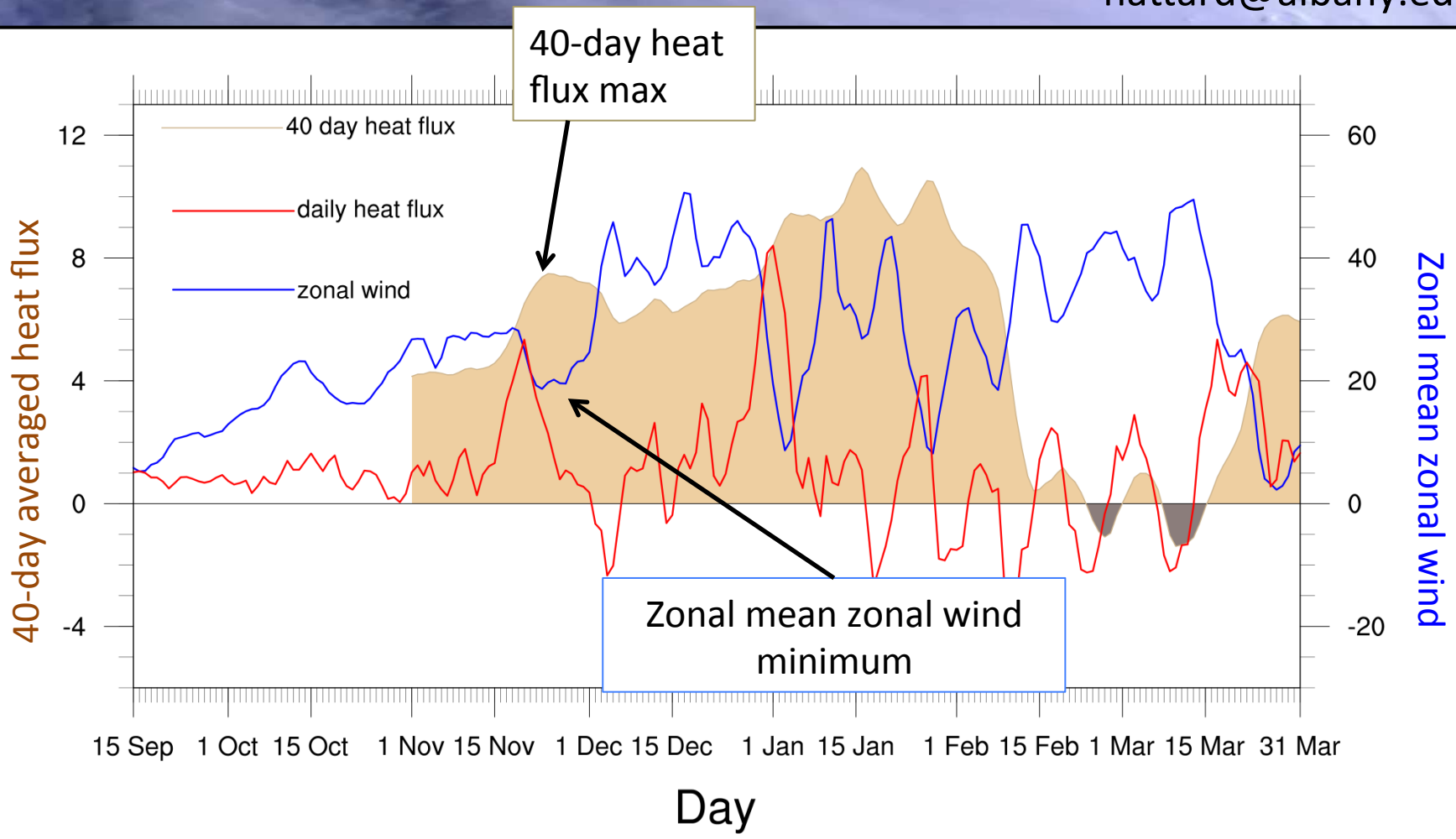

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Conclusions

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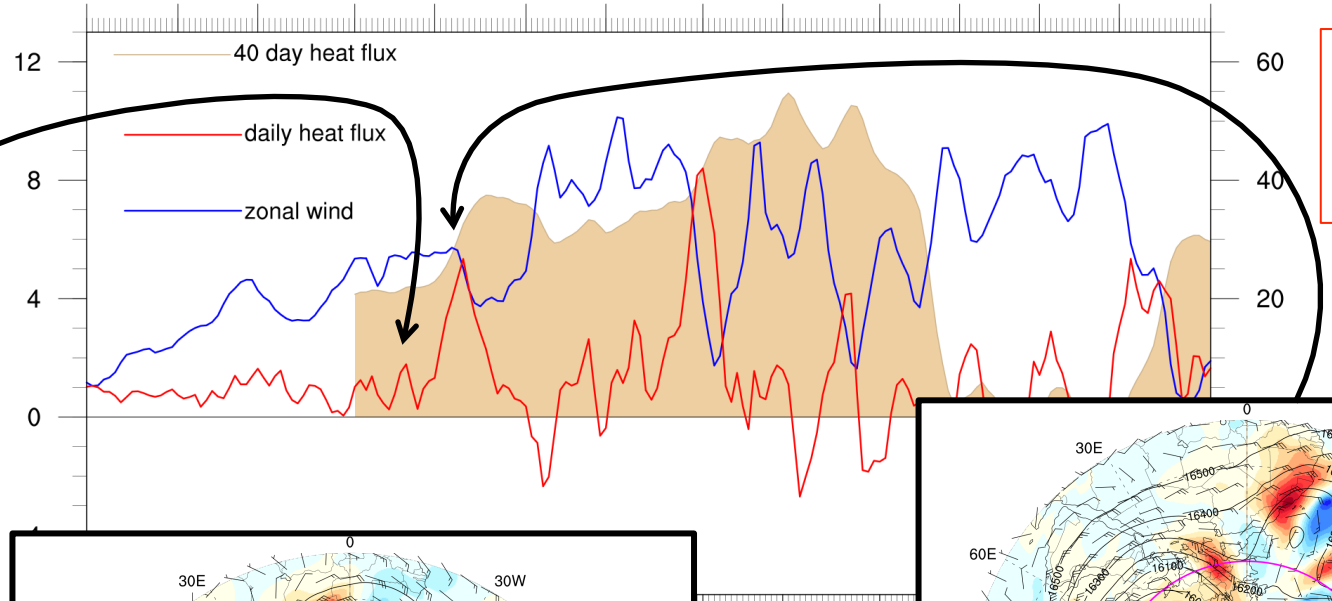
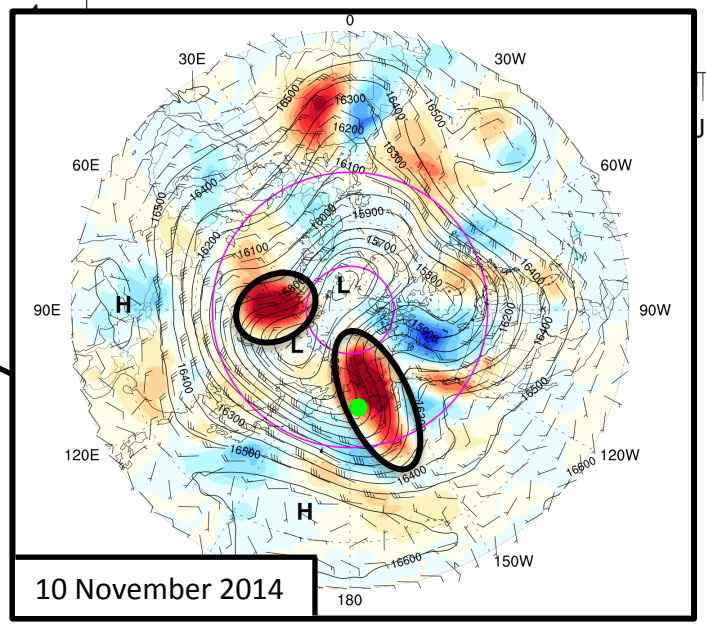
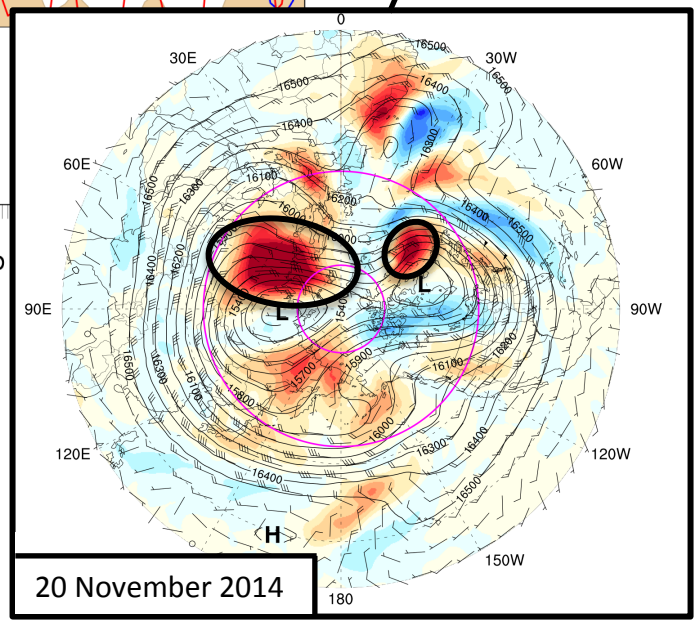


2 daily heat flux maxima within those 40 days





Conclusions

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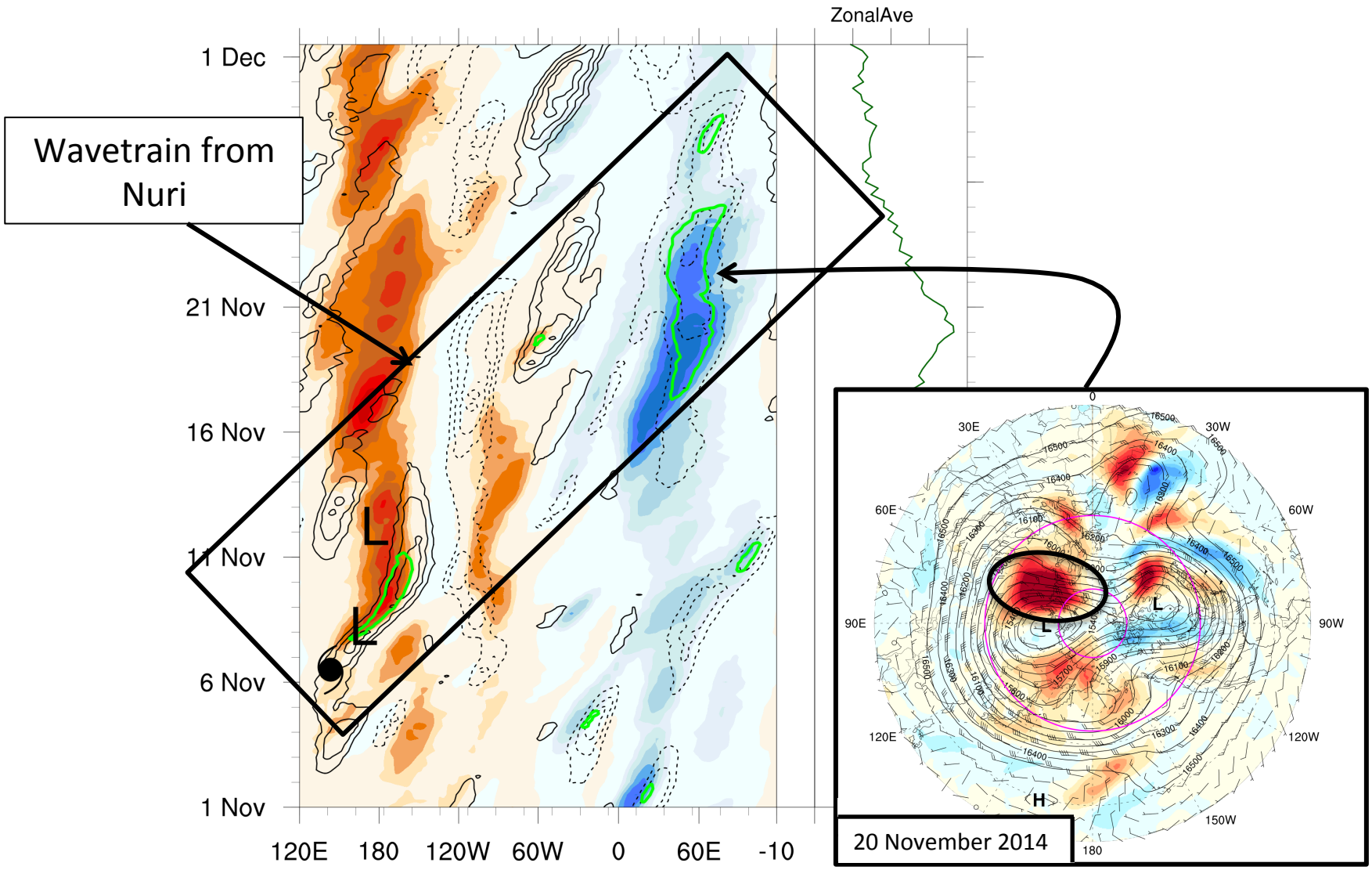

Conclusions

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- 23 November:
  - rapid deceleration of the 10 hPa 65°N zonal mean zonal wind
  - 40-day average 100 hPa heat flux anomaly maximum
- 10 November: Anomalously large and positive 100 hPa heat flux anomaly
  - associated with the ridge just downstream of Nuri
- 20 November: anomalously large and positive 100 hPa heat flux anomaly
  - associated with the downstream wavetrain excited by the recurvature of Nuri