



# **Extraordinary features of the planetary wave propagation during the boreal winter 2013/2014 and the zonal wavenumber two predominance**

---

Yayoi Harada<sup>1</sup>, Toshihiko Hirooka<sup>2</sup>

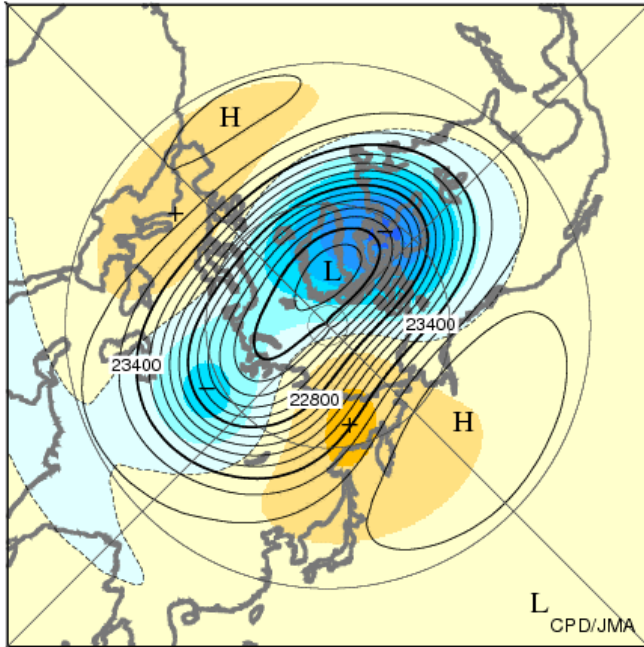
1. Climate Research Department, Meteorological Research Institute, Tsukuba, Japan
2. Department of Earth and Planetary Sciences, Kyushu University, Fukuoka, Japan

# Features of planetary wave propagation during the winter 2013/2014



anomalies (m)

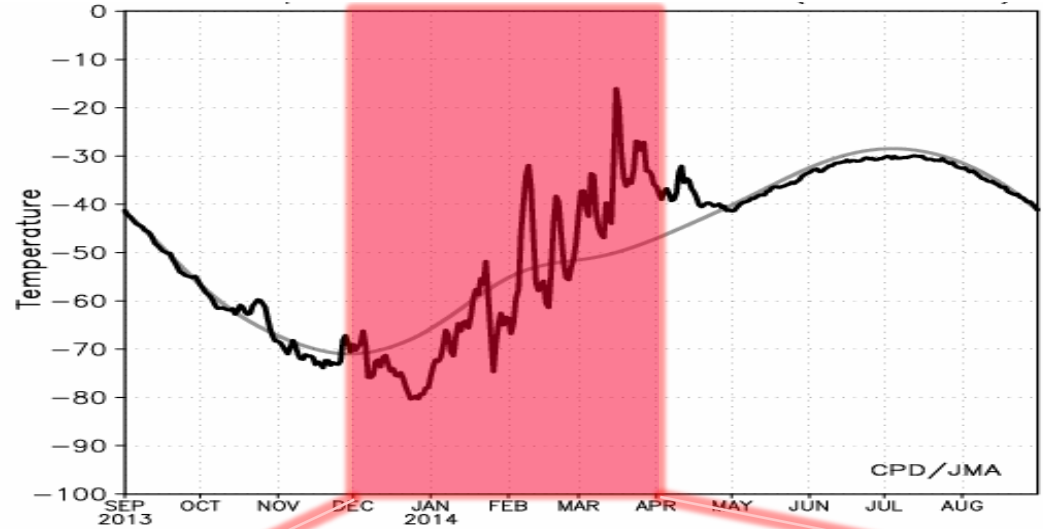
-720 -600 -480 -360 -240 -120 0 120 240 360 480 600 720



**GPH 30hPa DJF mean**

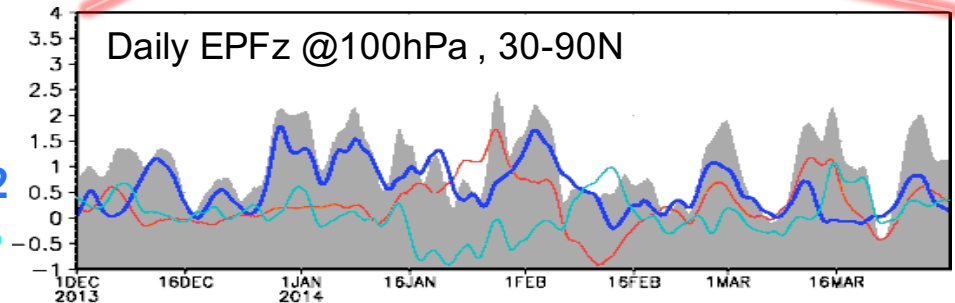
Shading shows anomalies from climatological mean for years 1981-2010

10 hPa Temperature [K] over the North Pole (Sep.2013 – Aug.2014)



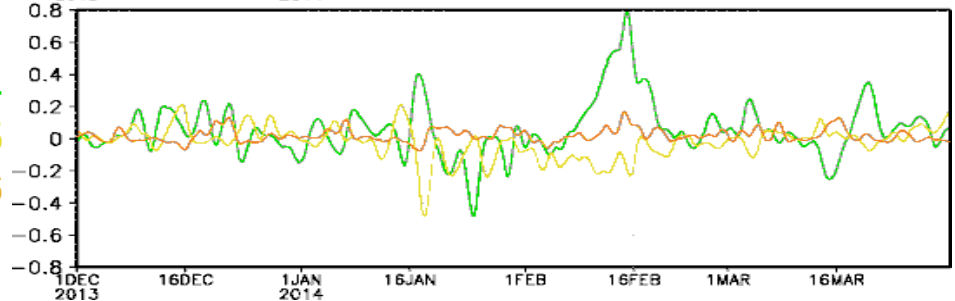
Upper:

- wave 1
- wave 2
- wave 3



Lower:

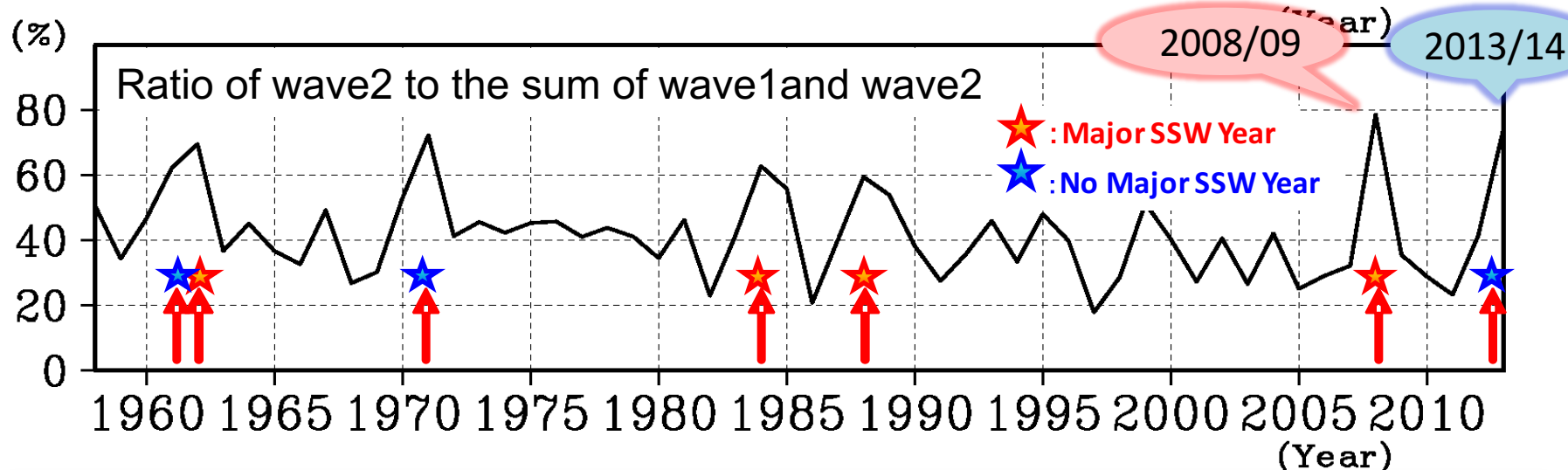
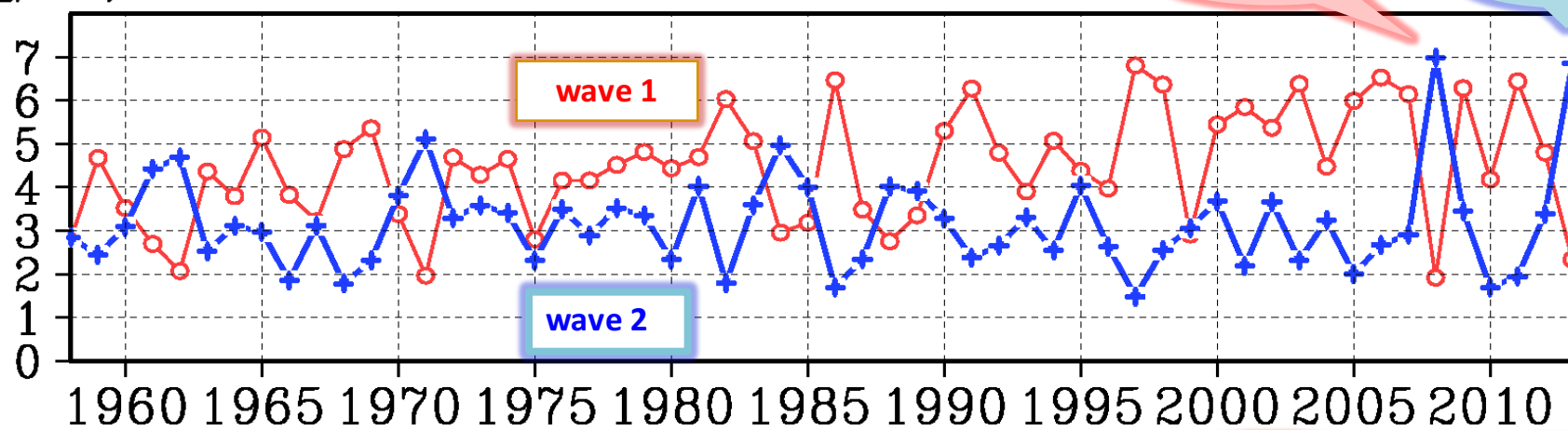
- wave 4
- wave 5
- wave 6



# Interannual variation of planetary wave propagation



( $10^4 \text{ kg/s}^2$ ) EPFz@100hPa, 30-90N, DJF mean



The ratio of the wave 2 contribution to the sum of wave 1 and wave 2 largely surpasses 75% in only these two winters

# Purpose, Data and Analysis Methods



**Purpose:** to examine features and plausible mechanisms of the continuous predominance of wave 2 which could not cause major warmings

- **Data**

- Reanalyses (JRA-55, ERA-Interim, MERRA)
- Retrieved level 2 temperature from Aura-MLS observation (version 4)

- **Analysis Methods**

For JRA-55,

- EP flux (Andrews et al. 1987)
- Wave Activity Flux (WAF) (Plumb 1985)
- Lanczos filtering for temporal filtering and wavenumber decomposition (Duchon 1979)

For intercomparison,

2.5x2.5 degree grid box mean for Aura-MLS and three reanalyses only when corresponding box-mean value from Aura MLS is present



# **Plausible mechanisms related to the features in the winter 2013/2014**

---

# Mechanism #1



## Preferred conditions related to the excitation of wave 2 in the troposphere?

Pacific blocking frequency is significantly increased before La Niña period SSWs

The WARM run favors wave-1 SSWs, while wave-2 events occur more frequently for the COLD run.

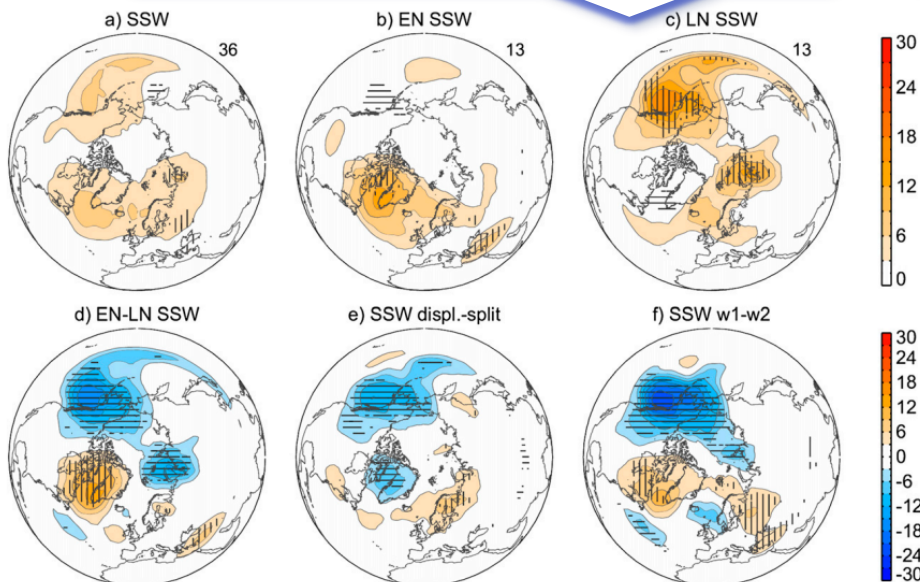


FIG. 1. Composites of blocking precursors of SSWs for (a) all, (b) EN, (c) LN winters, and the composite difference of the blocking precursors for (d) EN minus LN SSWs, (e) displacement minus splitting SSWs, and (f) wave-1 minus wave-2 SSWs. Blocking precursors are identified from the blocking frequency for the  $[-10, 0]$ -day period before the central date of SSWs. The blocking frequency is expressed as the percentage of time (over the 11-day period) during which a blocking was detected at each grid point. The number of SSWs entering into the composites is shown in the top-right corner of each panel. Vertical (horizontal) hatched areas indicate regions with blocking activity significantly above (below) climatology at the 95% confidence level as derived from a 1000-trial Monte Carlo test. Note that the detection of a significantly low blocking frequency ( $p < 5\%$ ) in (a)–(c) is hampered in regions where the climatological blocking activity is low.

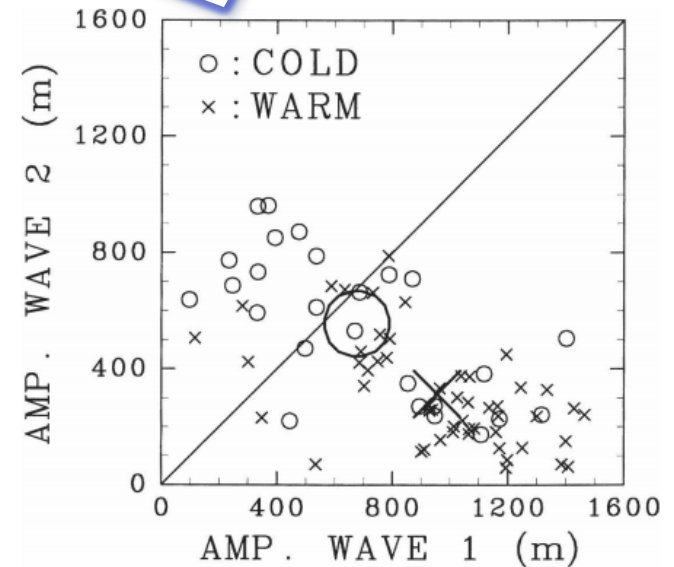
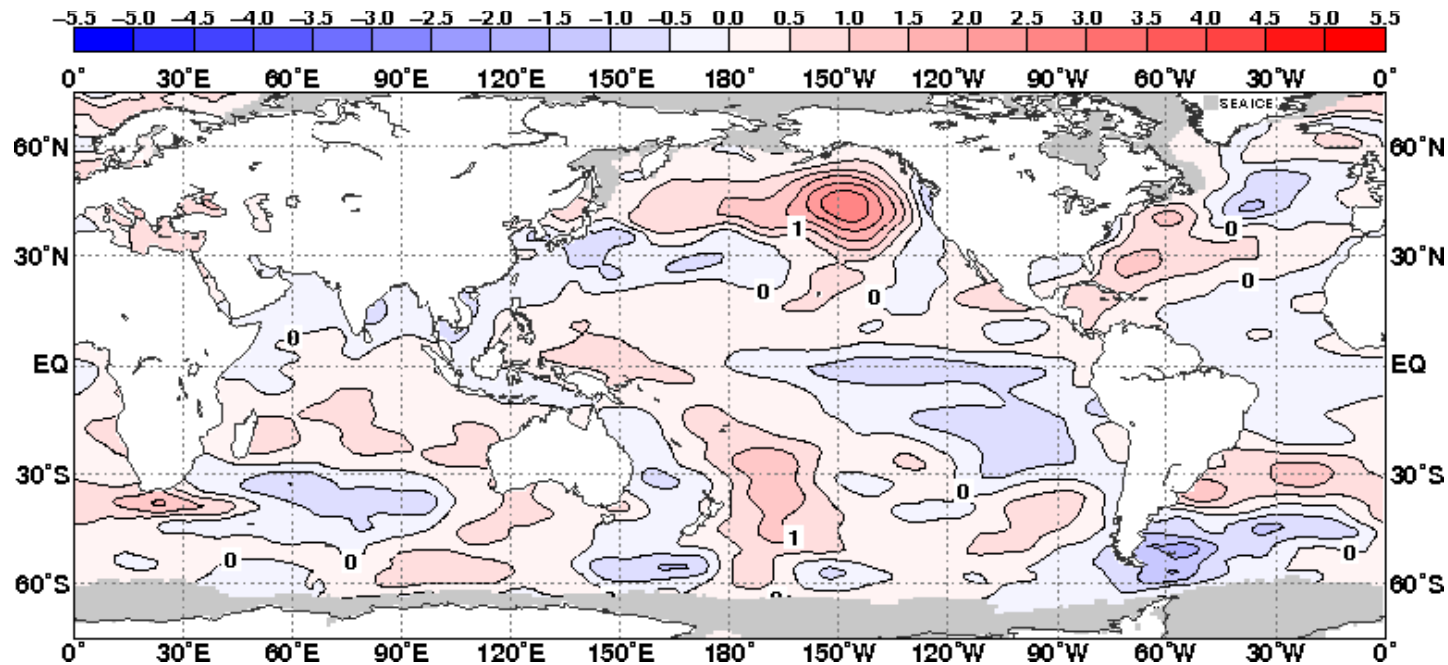


FIG. 8. Scatterplot between amplitude of waves 1 and 2 of geopotential height at  $60^\circ\text{N}$  and 11 hPa for a mature stage of 26 and 52 SSWs in the runs COLD (dots) and WARM (crosses), respectively. Average is denoted by the big symbol for each run.

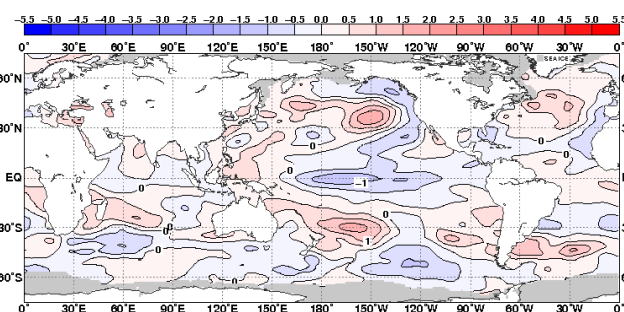
# DJF mean SST anomalies from climatological mean (1981 – 2010)



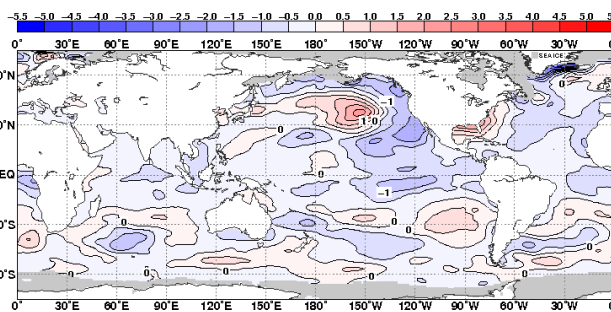
**2013/2014**



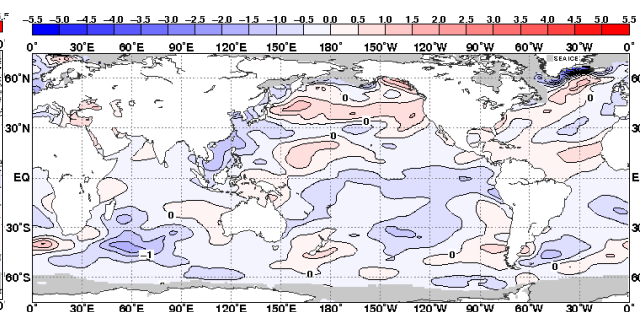
**2008/2009**



**1971/1972**



**1962/1963**



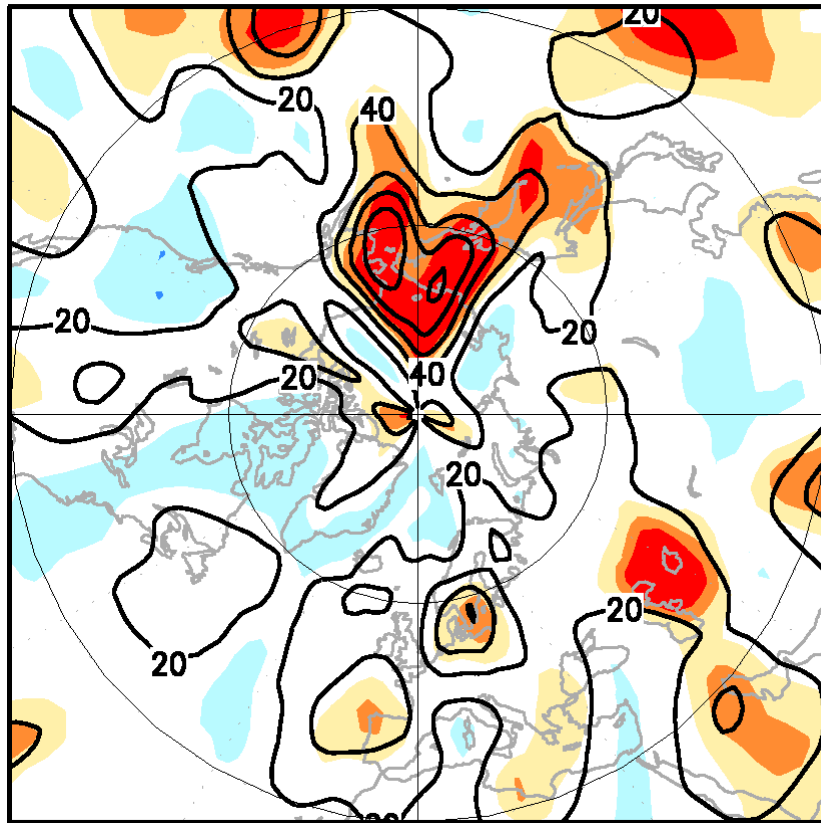


# Activity of lower frequency eddies [ $\text{m}^2/\text{s}^2$ ]

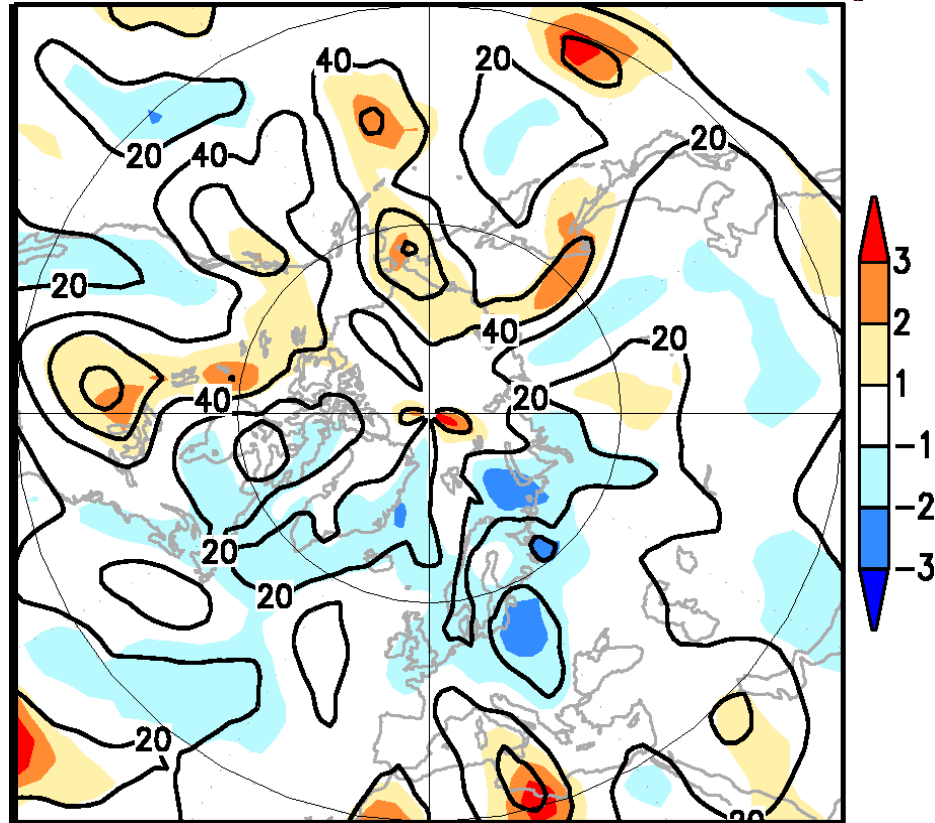


Variance of time filtered meridional wind at 300 hPa during the winter 2013/2014

(20-100 days filtered  $V$ )<sup>2</sup>



(8-30 days filtered  $V$ )<sup>2</sup>



Contour:  $V^2$  [ $\text{m}^2/\text{s}^2$ ]  
Shading:  $V^2$  normalized anomaly

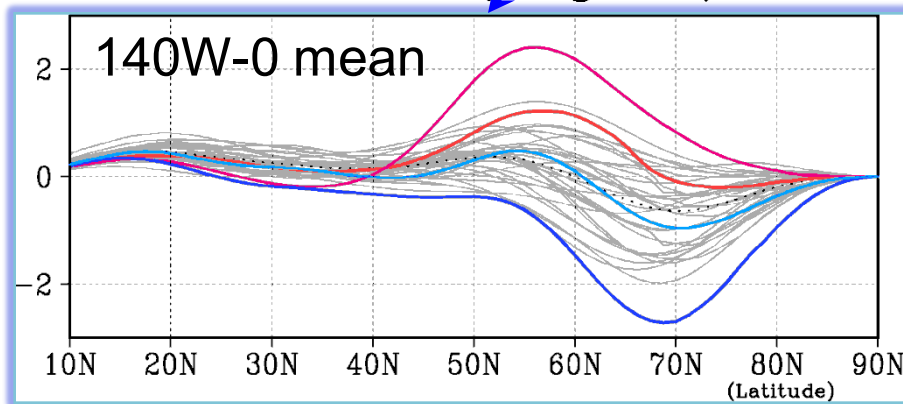
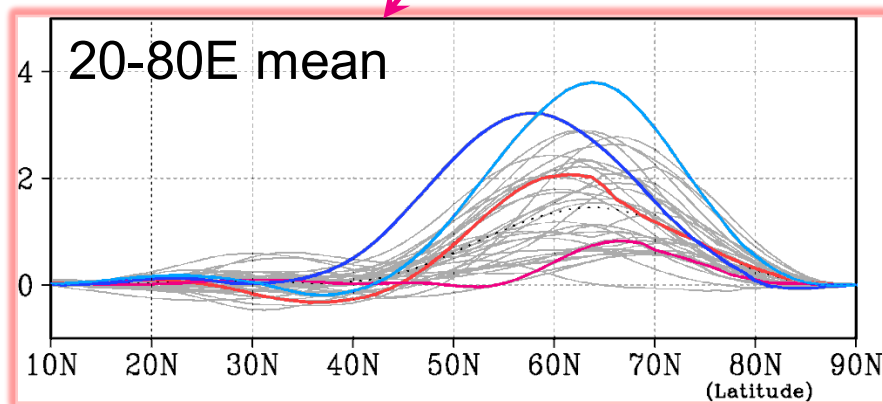
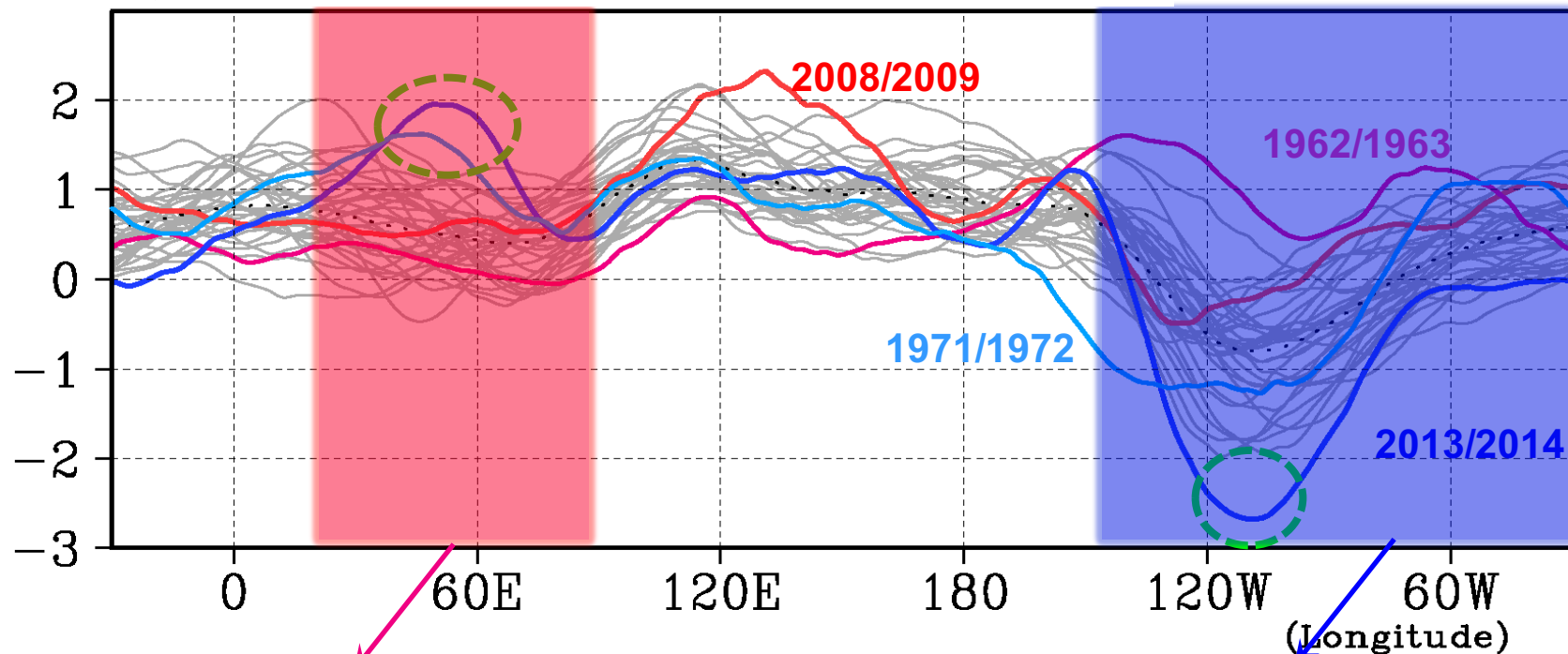
20-100 days period eddy's activity is remarkable and exceeds 3 sigma in the North Pacific basin.



# Longitudinal distribution of WAFz



$[10^{-2} \times \text{m}^2 \text{s}^{-2}]$  WAFz @100 hPa, 30-90N mean, DJF mean



Thin gray lines show each DJF mean for years of 1981/1982 to 2012/2013, thick black dot lines show climatological mean.

# Mechanism #2

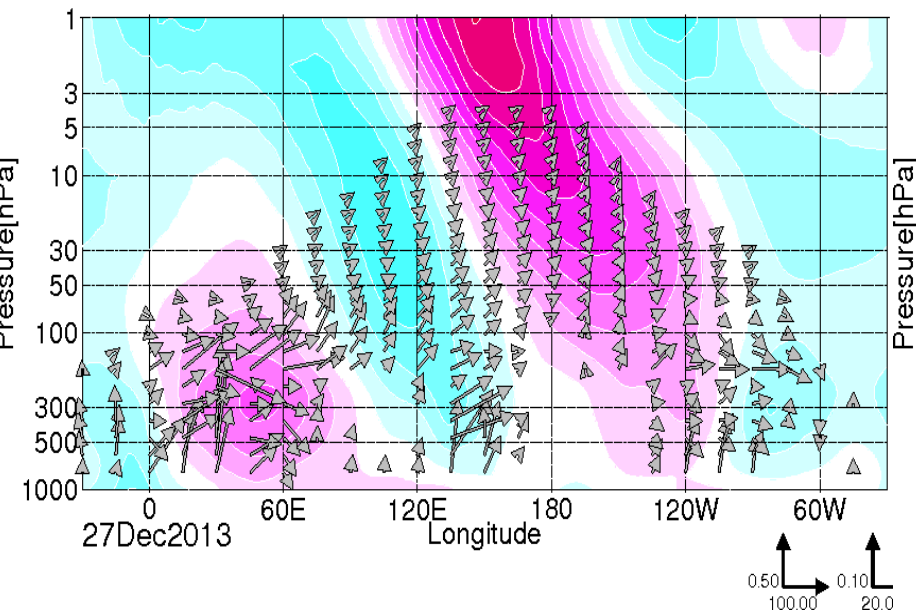


Effects of the southward shift of the upward wave packet propagations over western Russia on the stratosphere ?

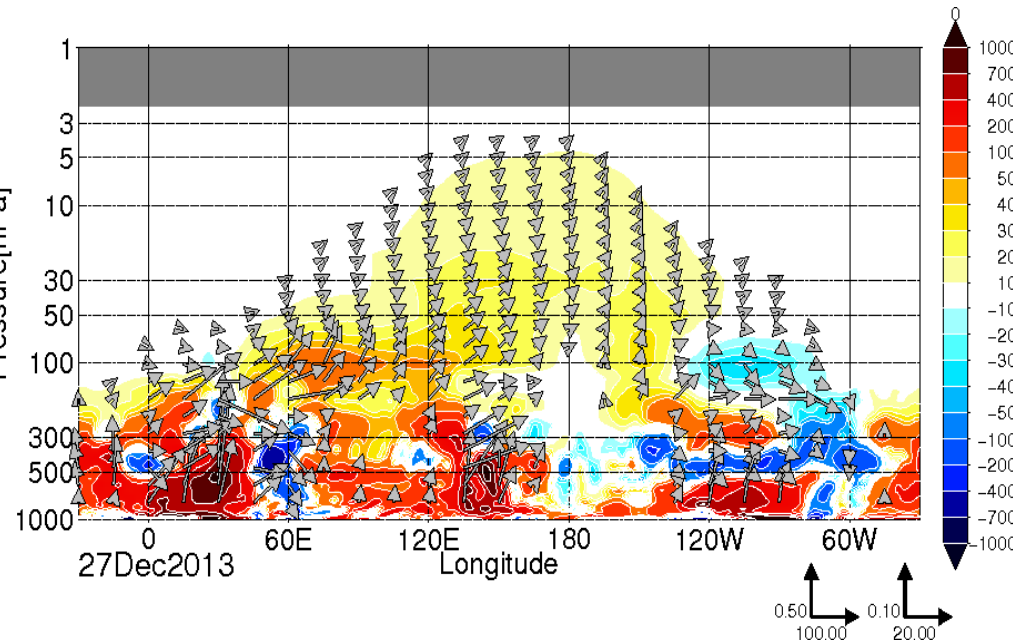
→ Strengthening of the Aleutian High

**Longitude-height cross section of daily WAF (55-59N mean)**

WAF (vector) & GPH (shading)



WAF (vector) & WAFZ (shading)

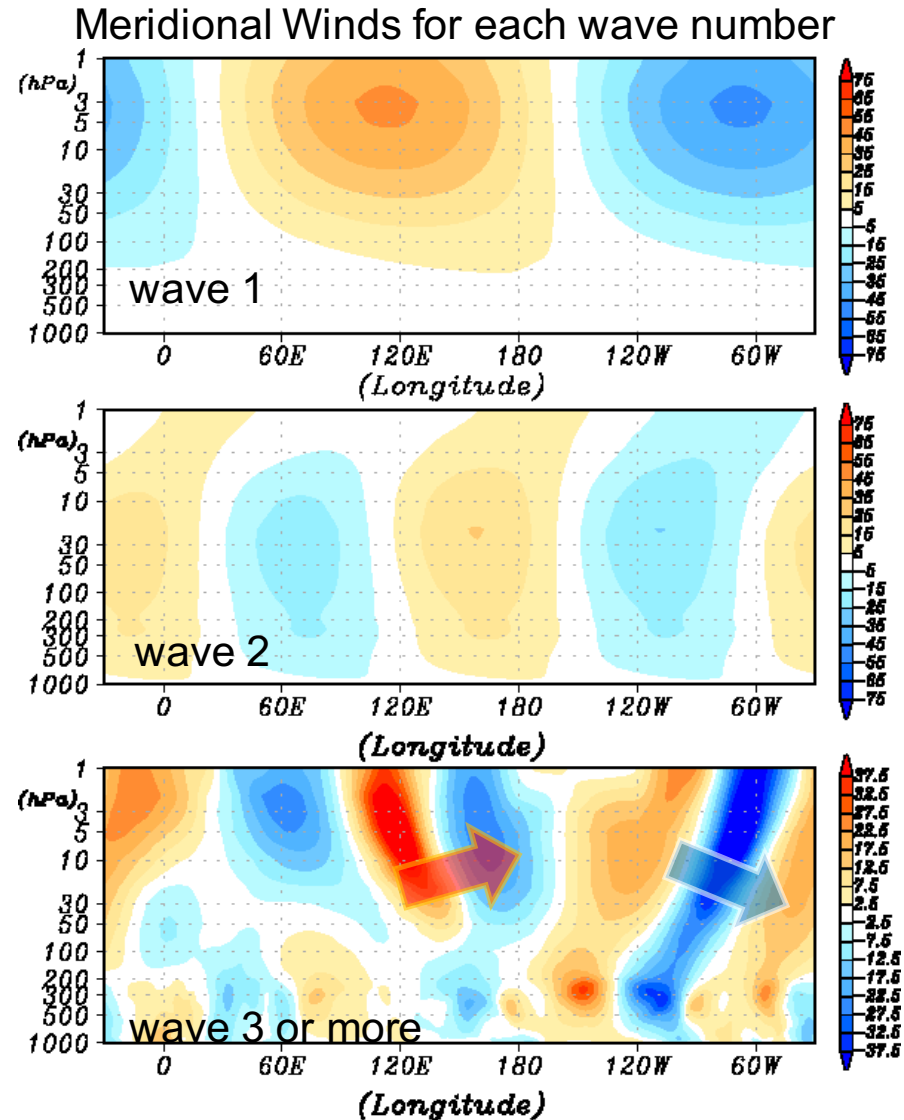
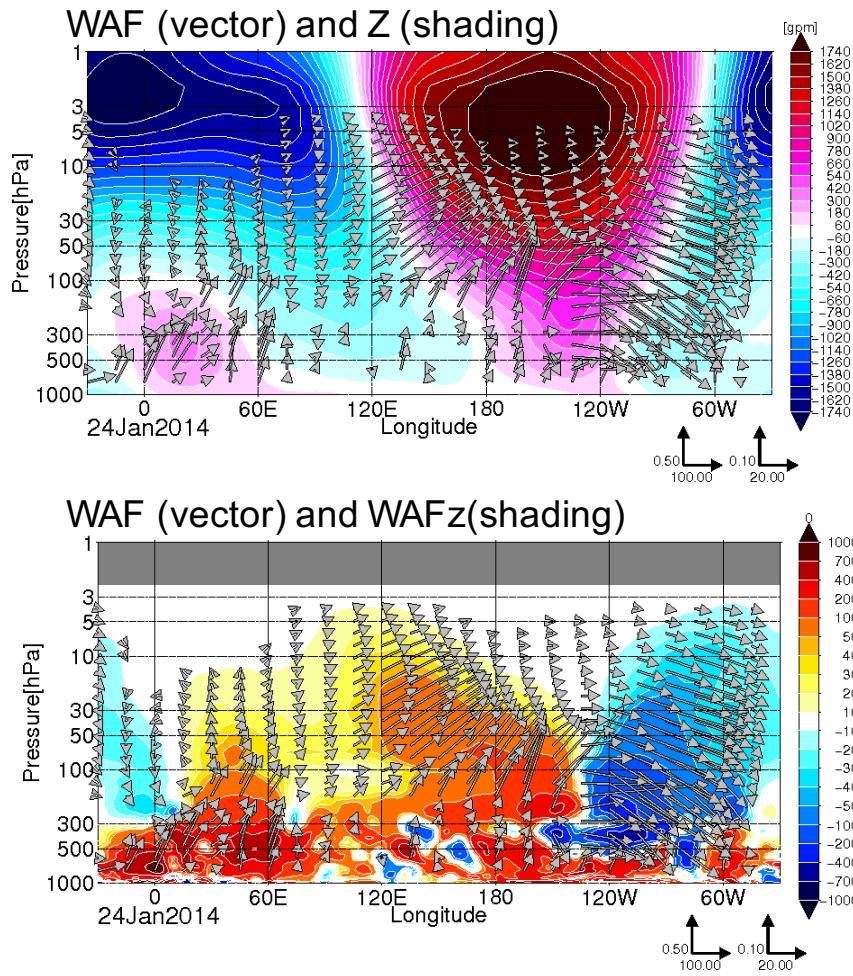


# Phase structure of the planetary waves during the remarkable downward propagation (24Jan.2014)



Longitude-height cross sections (65-69N mean)

24 Jan. 2014

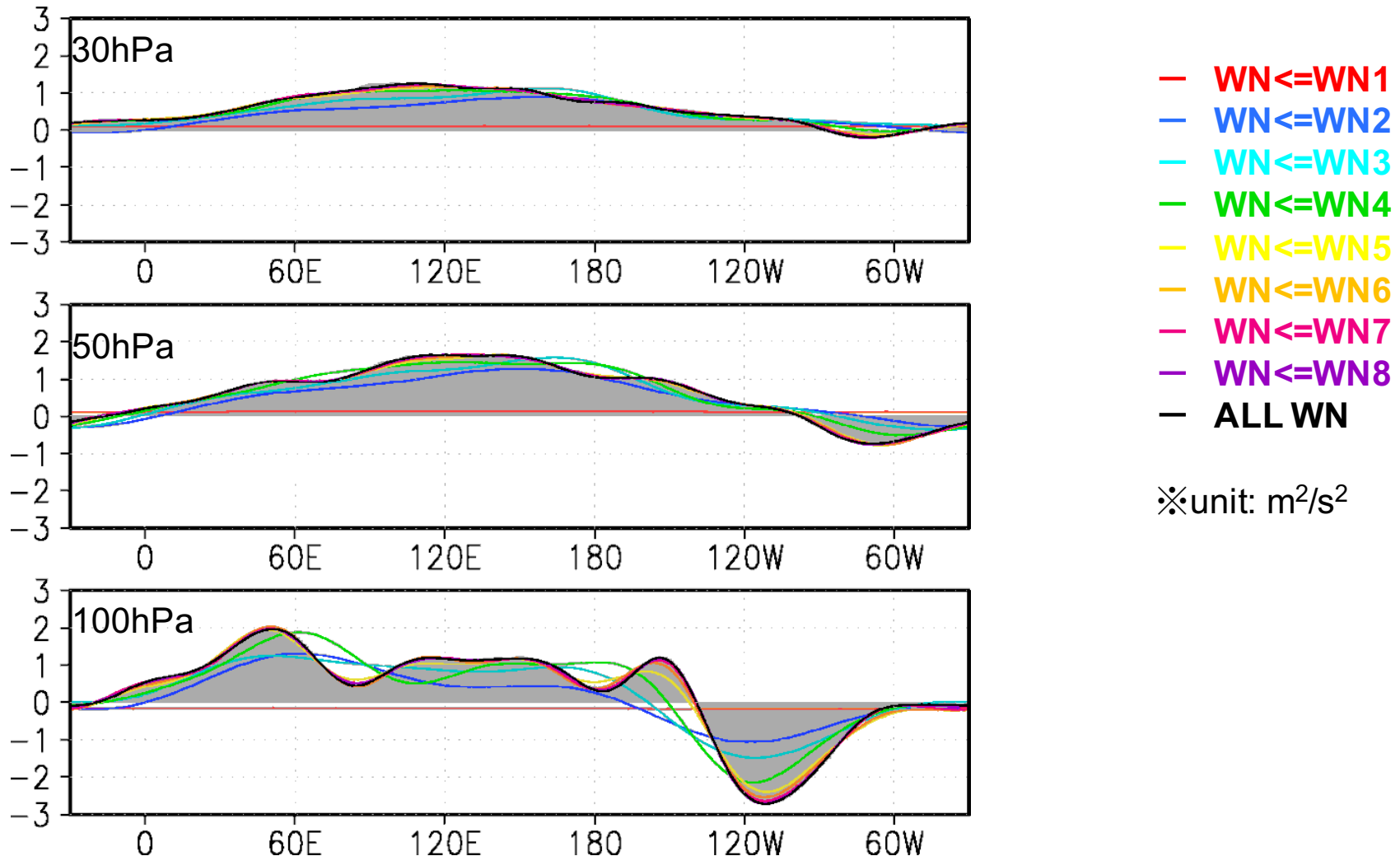


Phase tilts of wave1 and wave2 are not clear.  
Phase tilt of wave3 or more is clear and corresponds to the upward and downward wave packet propagations.

# Localized wave propagation



30-90N mean Plumb's WAFz during the winter 2013/2014



It is necessary to include smaller scale waves for the presentation of the wave packet propagation even in the stratosphere.



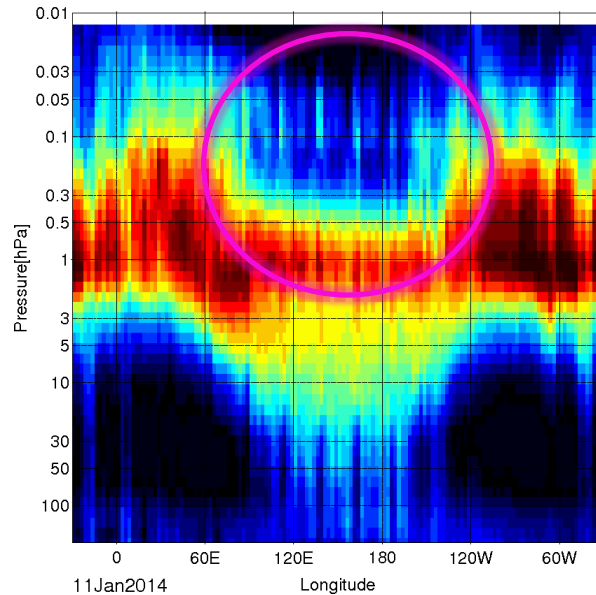
## **Comparison of three reanalyses with Aura-MLS**

---

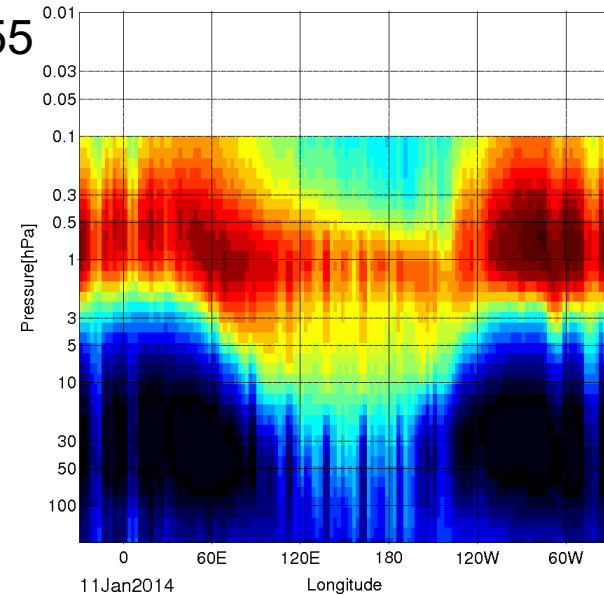
# Comparison of longitudinal distribution of temperature averaged 60-80N, 100-0.1 hPa



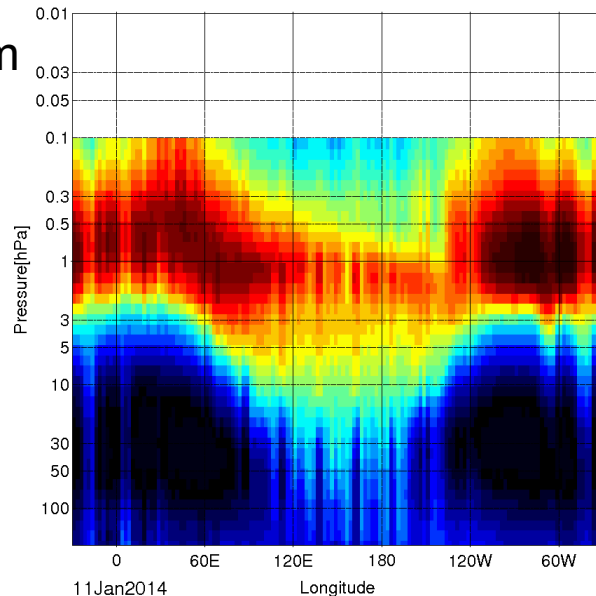
Aura-MLS



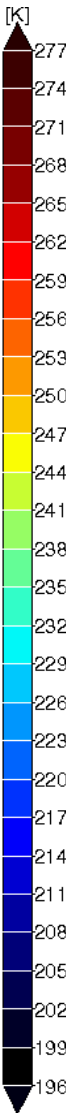
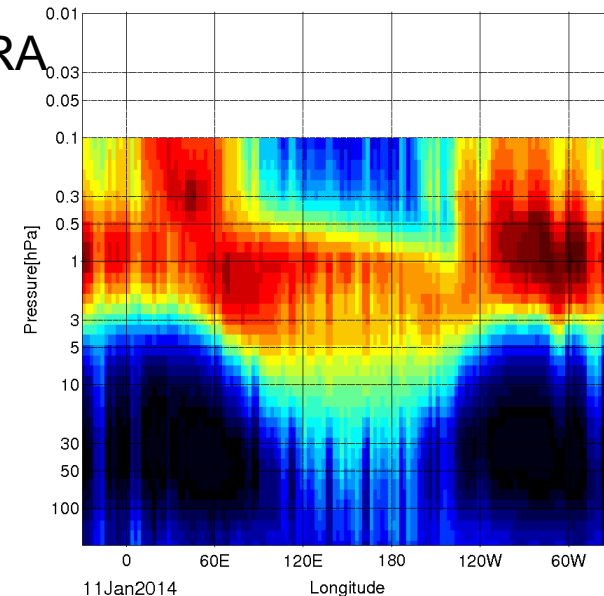
JRA-55



ERA-Interim



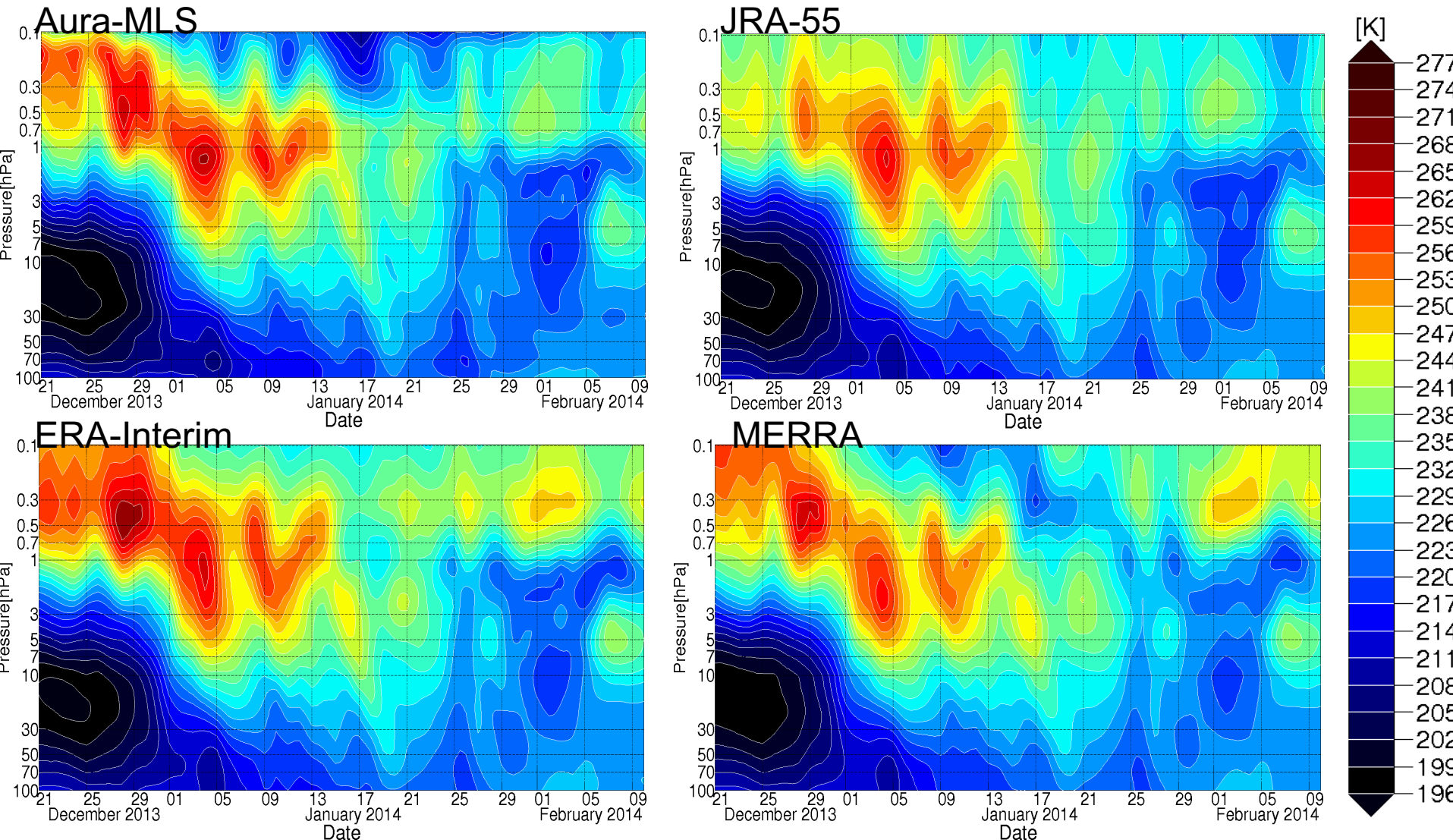
MERRA



Aura-MLS clearly shows cooling at around 0.2hPa in Aura-MLS, while JRA-55 and ERA-Interim are warmer.



# Time series of temperature averaged over 60-80N, 120E-120W



Aura-MLS shows cooling and warming above 0.5 hPa level, but no reanalysis represents correctly this fluctuation.

# Summary

---



The mechanisms related to the features in the winter 2013/2014 and the early results of comparison with Aura-MLS are summarized as follows:

1. The remarkable blocking activity in the North Pacific basin modulated by La Niña like SST condition excited wave 2 in the upper troposphere.
2. The upward wave packet propagations over western Russia influenced the expansion and continuation of the Aleutian High, which might be related to the strong downward propagation over northern Canada and no major SSW occurrence in the winter.
3. Temperature distribution around the Aleutian High is generally well represented and consistent among three reanalyses. On the other hand, uncertainty in reanalyses becomes relatively large above the upper stratosphere.



# **Merci pour votre attention!**

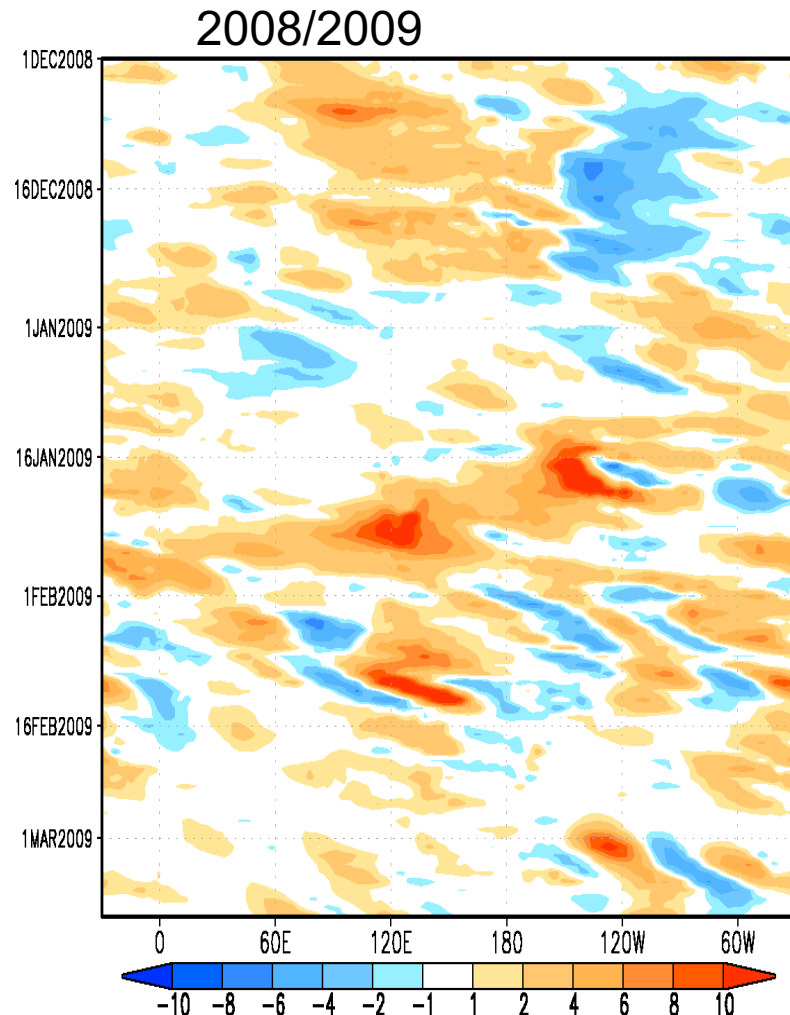
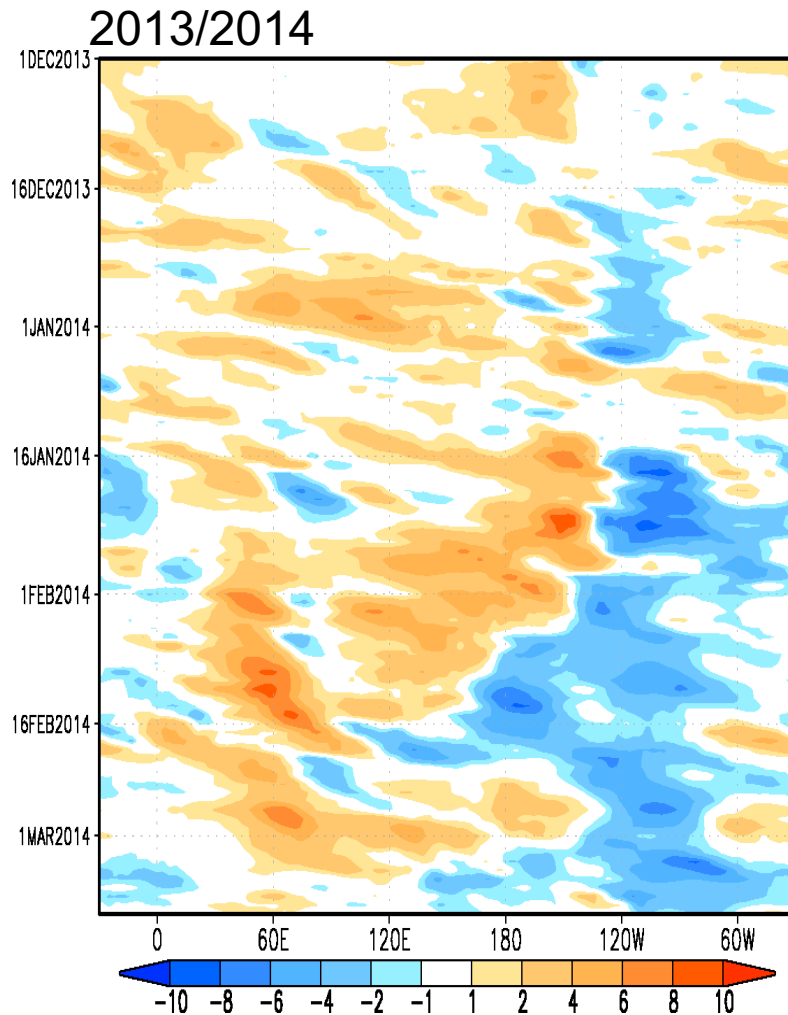
---



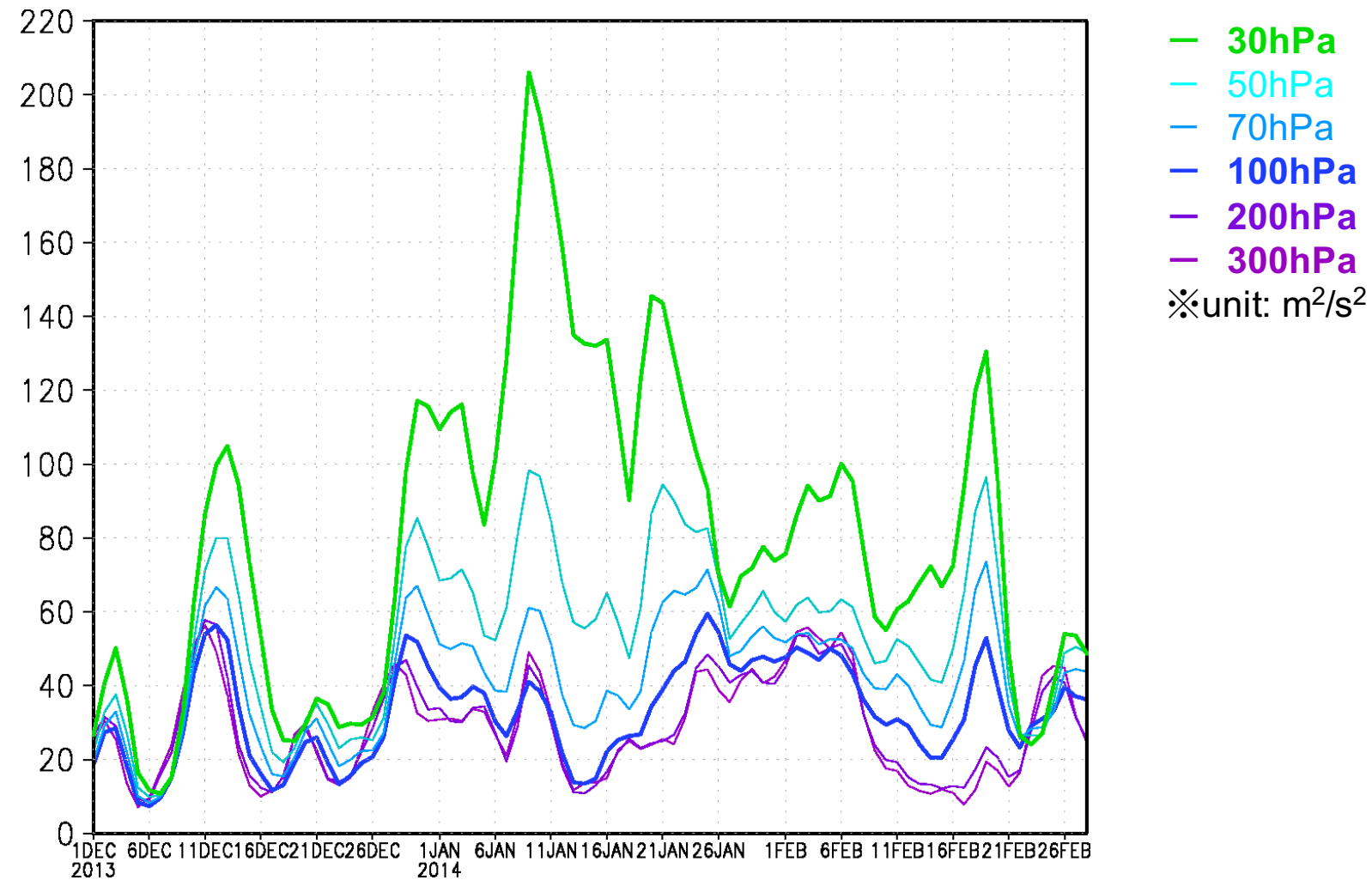
# Backup slide

---

# Plumb's WAFz at 100 hPa, 30-90N mean



# Daily amplitudes of WN2 (variance of meridional wind [ $\text{m}^2/\text{s}^2$ ])

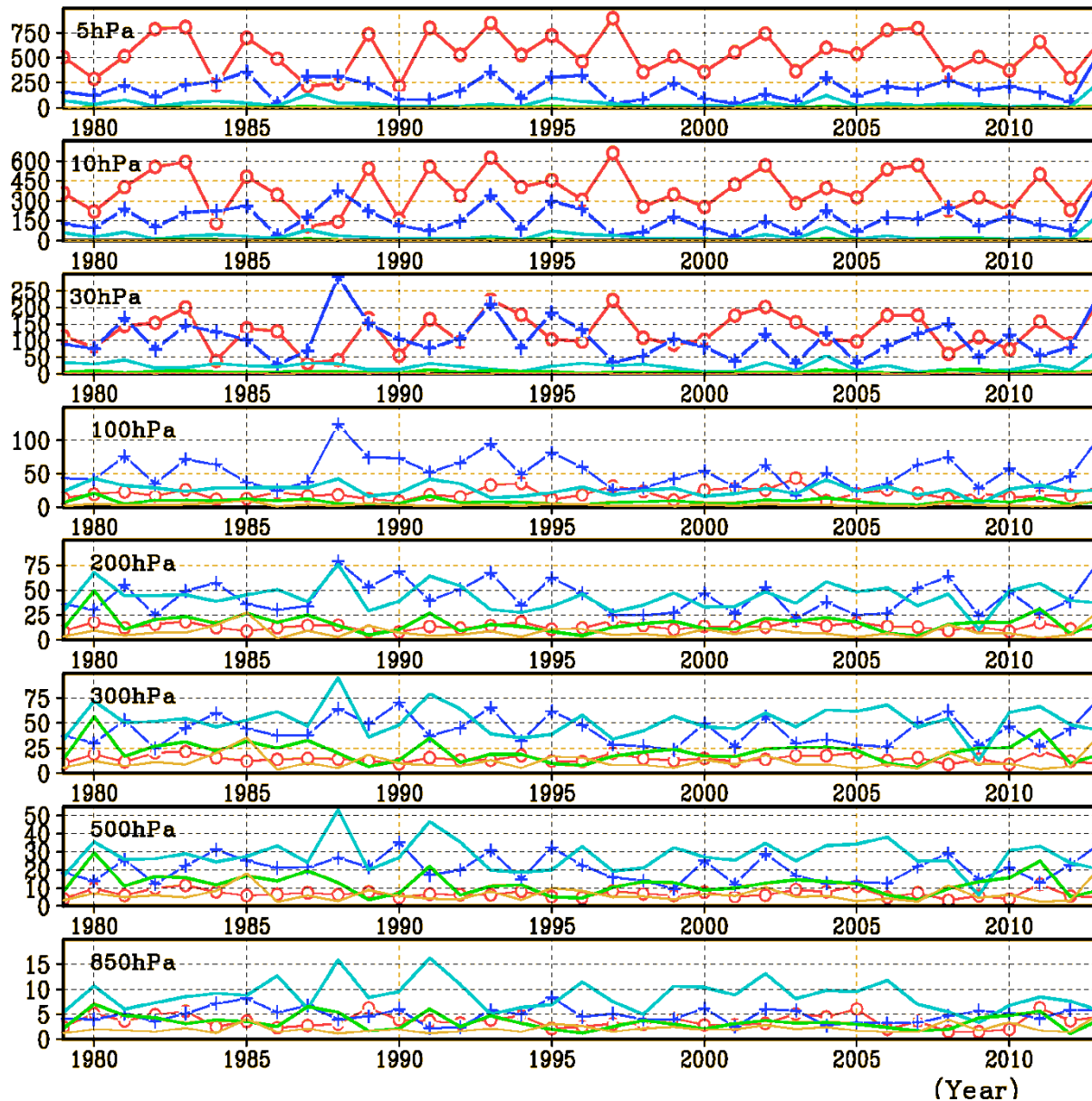




# Amplitudes for each WN ( $v^2[m^2/s^2]$ )



( $1m^2/s^2$ )



— WN1

— WN2

— WN3

— WN4

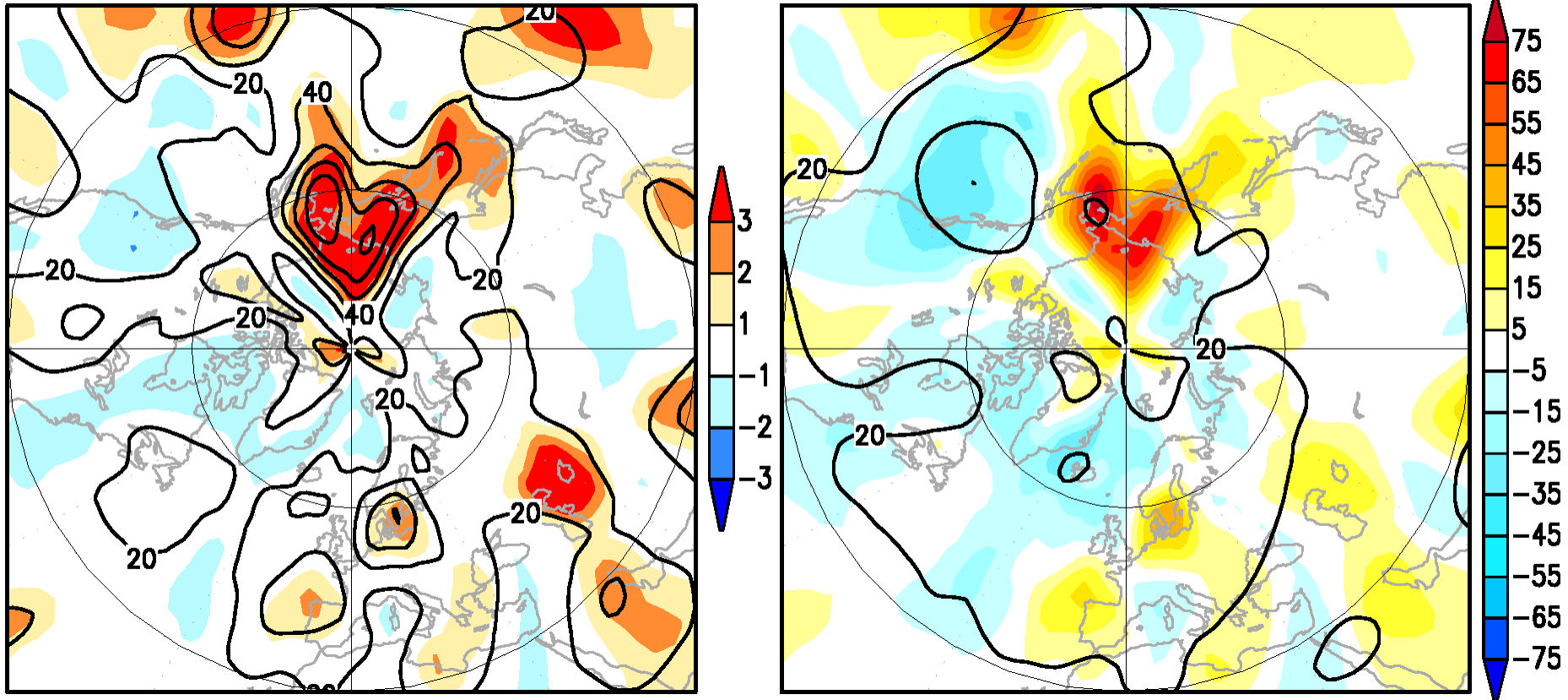
— WN5

※unit:  $m^2/s^2$

# Activity of low frequency eddies [ $\text{m}^2/\text{s}^2$ ]



Variance of 20-100 day filtered meridional wind at 300 hPa during the winter 2013/2014



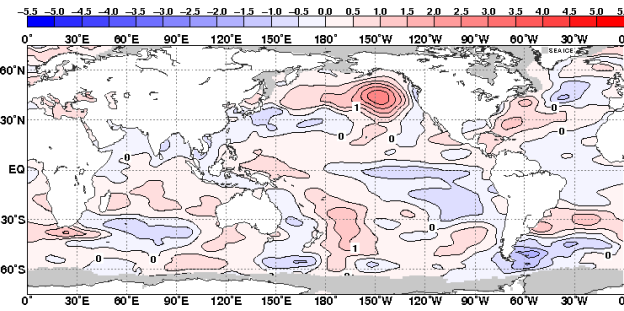
Left panel:  $V^2$  (using 2-8 day filtered  $V$ ) [ $\text{m}^2/\text{s}^2$ ] (contour),  $V^2$  normalized anomaly (shading)

Right panel: climatological mean of  $V^2$  [ $\text{m}^2/\text{s}^2$ ] (contour),  $V^2$  anomaly [ $\text{m}^2/\text{s}^2$ ] (shading)

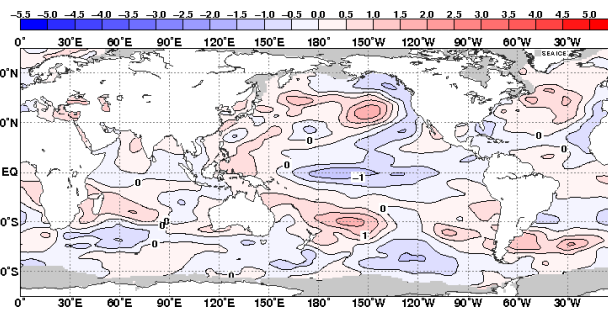
# DJF mean SST anomalies



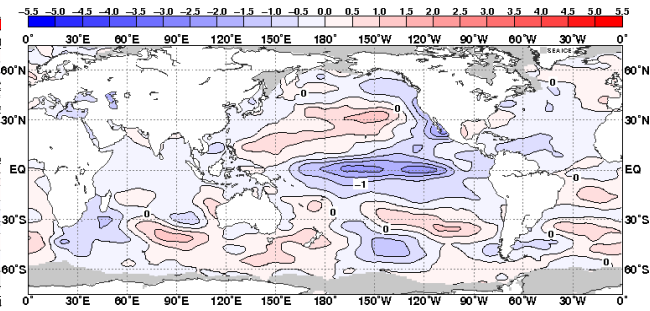
2013/14



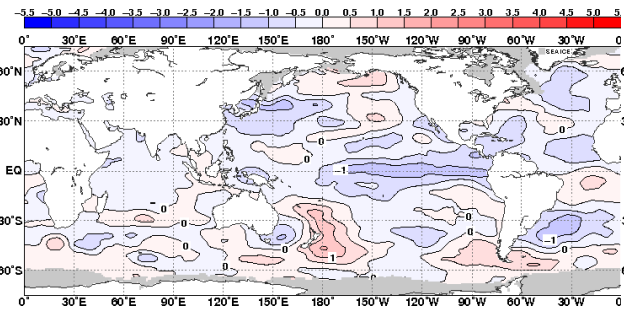
2008/09



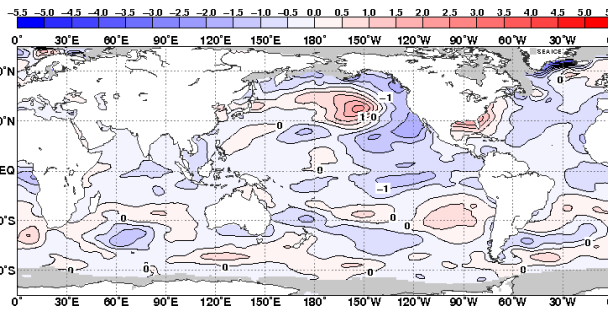
1988/89



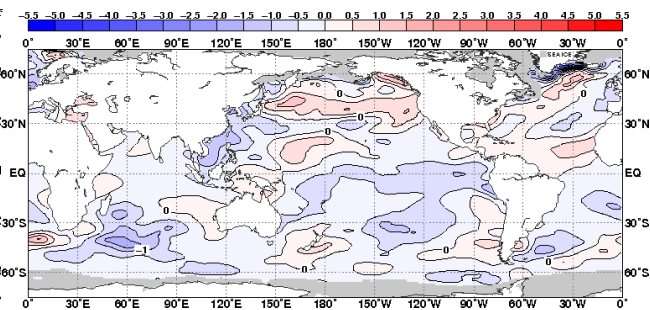
1984/85



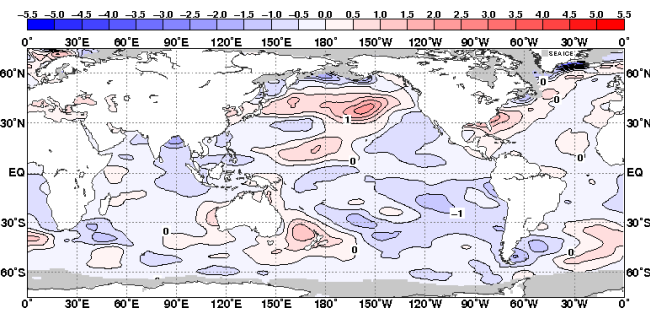
1971/72



1962/63



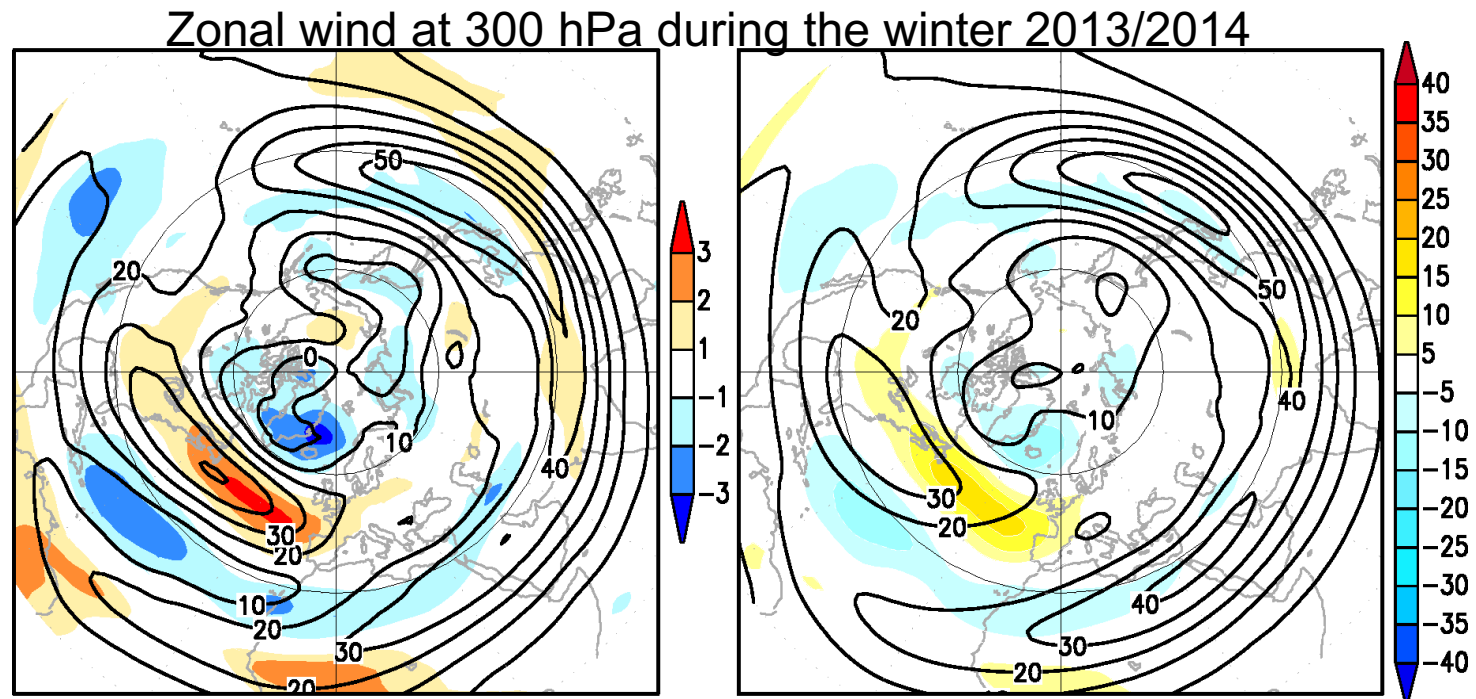
1961/62



# Zonal wind at 300 hPa during winter 2013/2014



- Why did the upward propagation of planetary wave packets over Western Russia become the strongest and extremely shift southward?



Left panel: zonal mean U [m/s] (contour), normalized U anomaly (shading)

Right panel: climatological mean of zonal mean U [m/s] (contour), U anomaly [m/s] (shading)

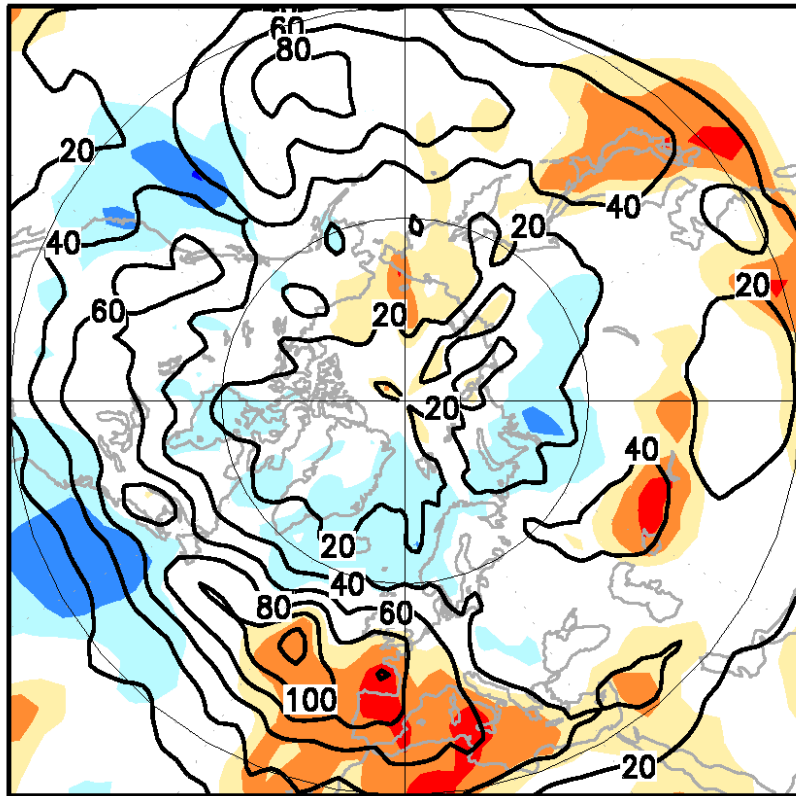
The North Atlantic Polar Front jet stream was extremely strong (over  $3\sigma$ ) and shifted southward in its exit region.

# Activity of sub-monthly scale eddies [ $\text{m}^2/\text{s}^2$ ]

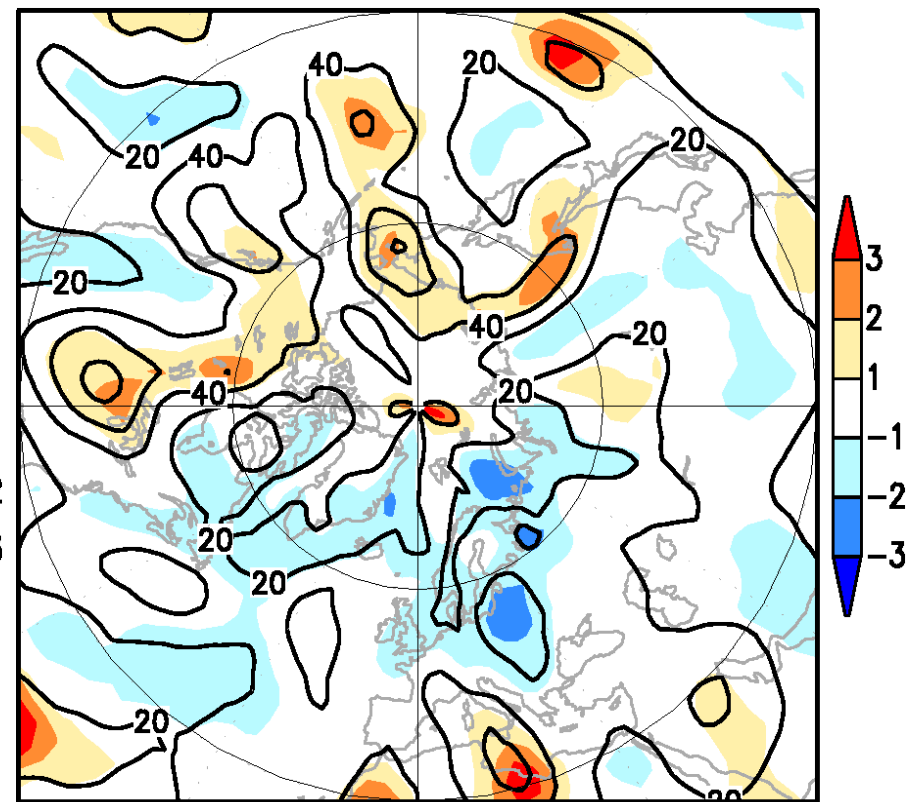


Variance of 2-8 day (left) and 8-30 day (right) filtered meridional wind (right) at 300 hPa and during the winter 2013/2014

(2-8 day filtered  $V^2$ )



(8-30 day filtered  $V^2$ )



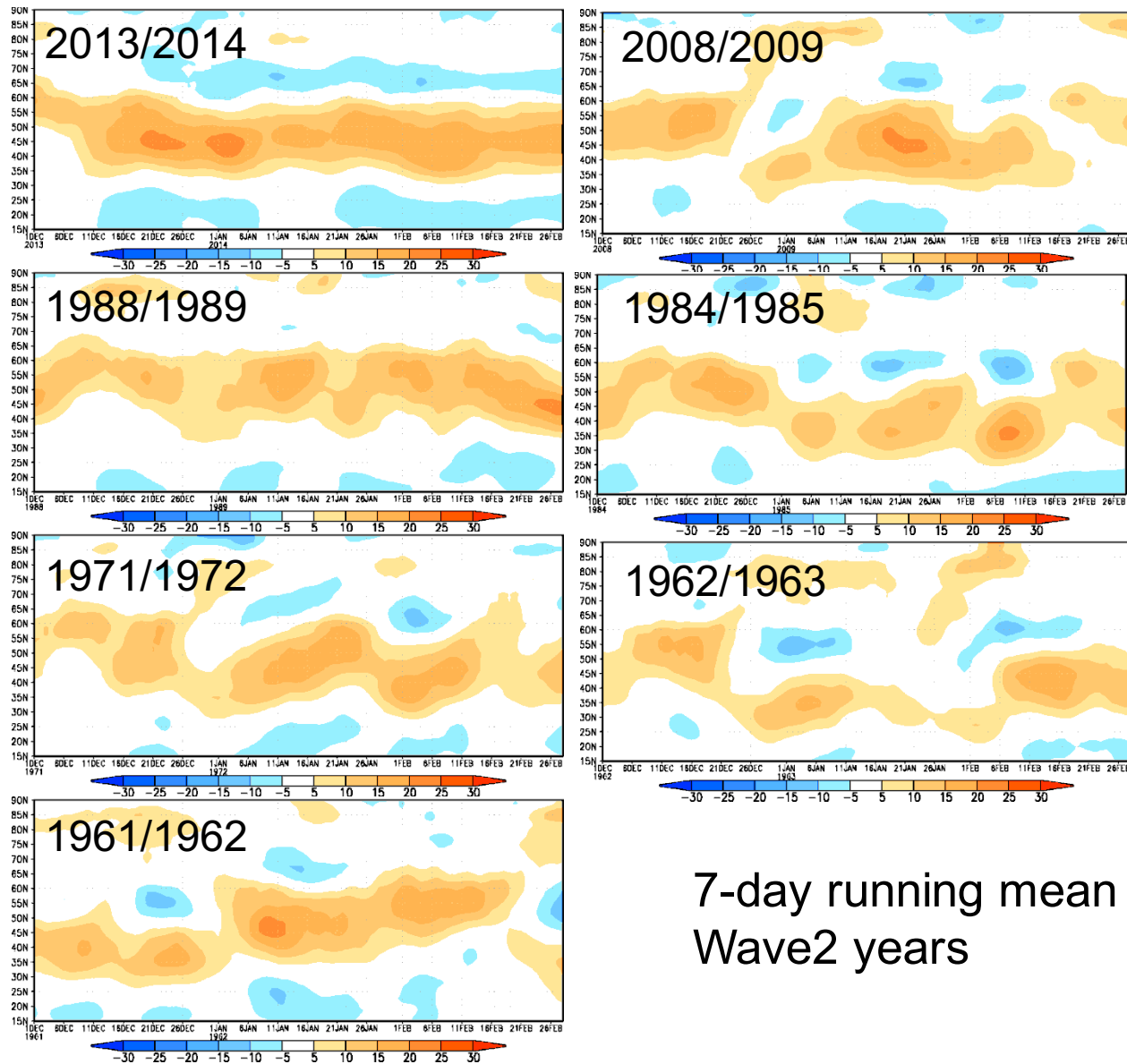
Contour:  $V^2$

Shading:  $V^2$  normalized anomaly

The activity of 2-8 day high frequency eddy is extremely strong (from 2 to  $3\sigma$ ).



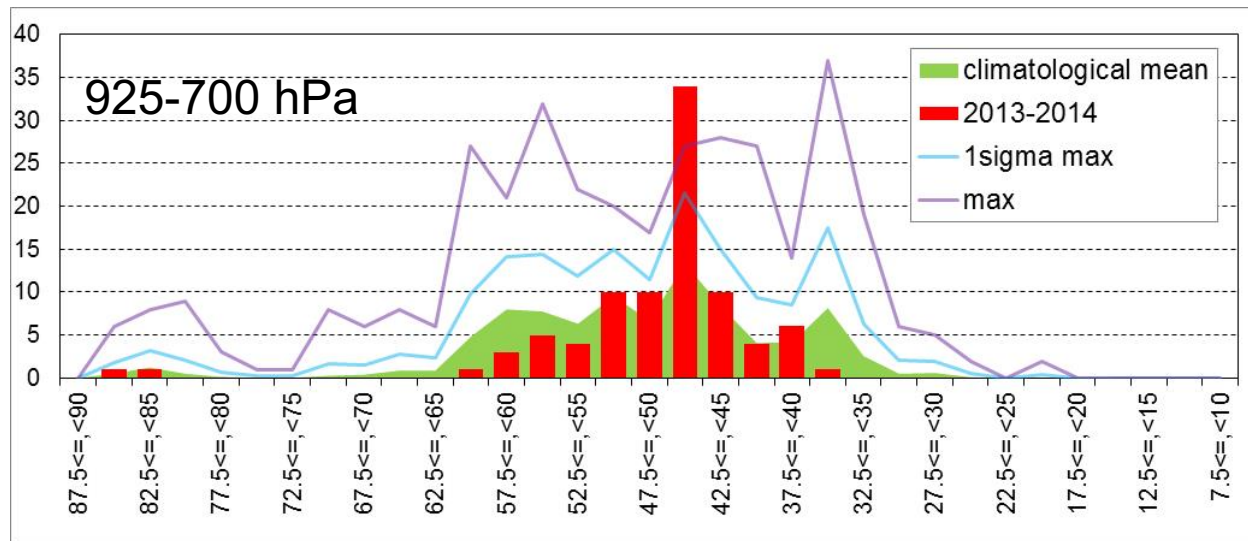
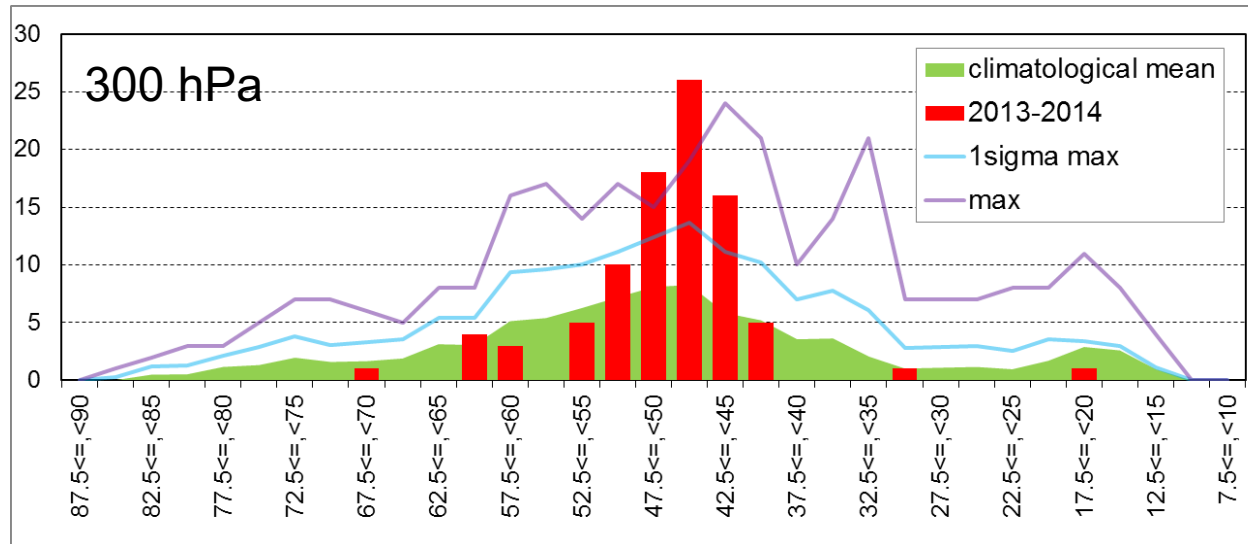
# 0-60W, 925-700hPa mean Zonal Wind [m/s]



7-day running mean  
Wave2 years



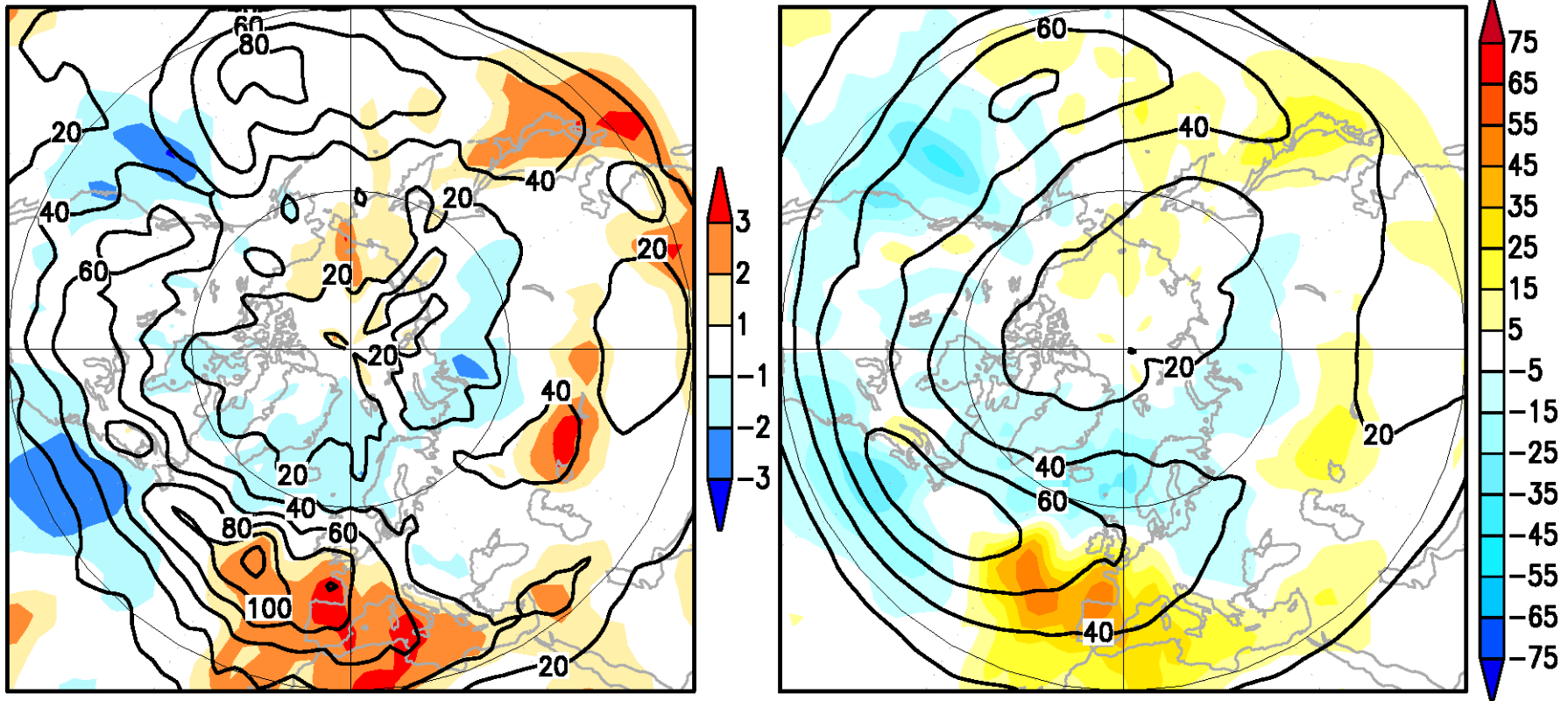
# Frequency of 7-day mean zonal wind maximum during boreal winter



# Activity of high frequency eddies [ $\text{m}^2/\text{s}^2$ ]



Variance of 2-8 day filtered meridional wind at 300 hPa during the winter 2013/2014



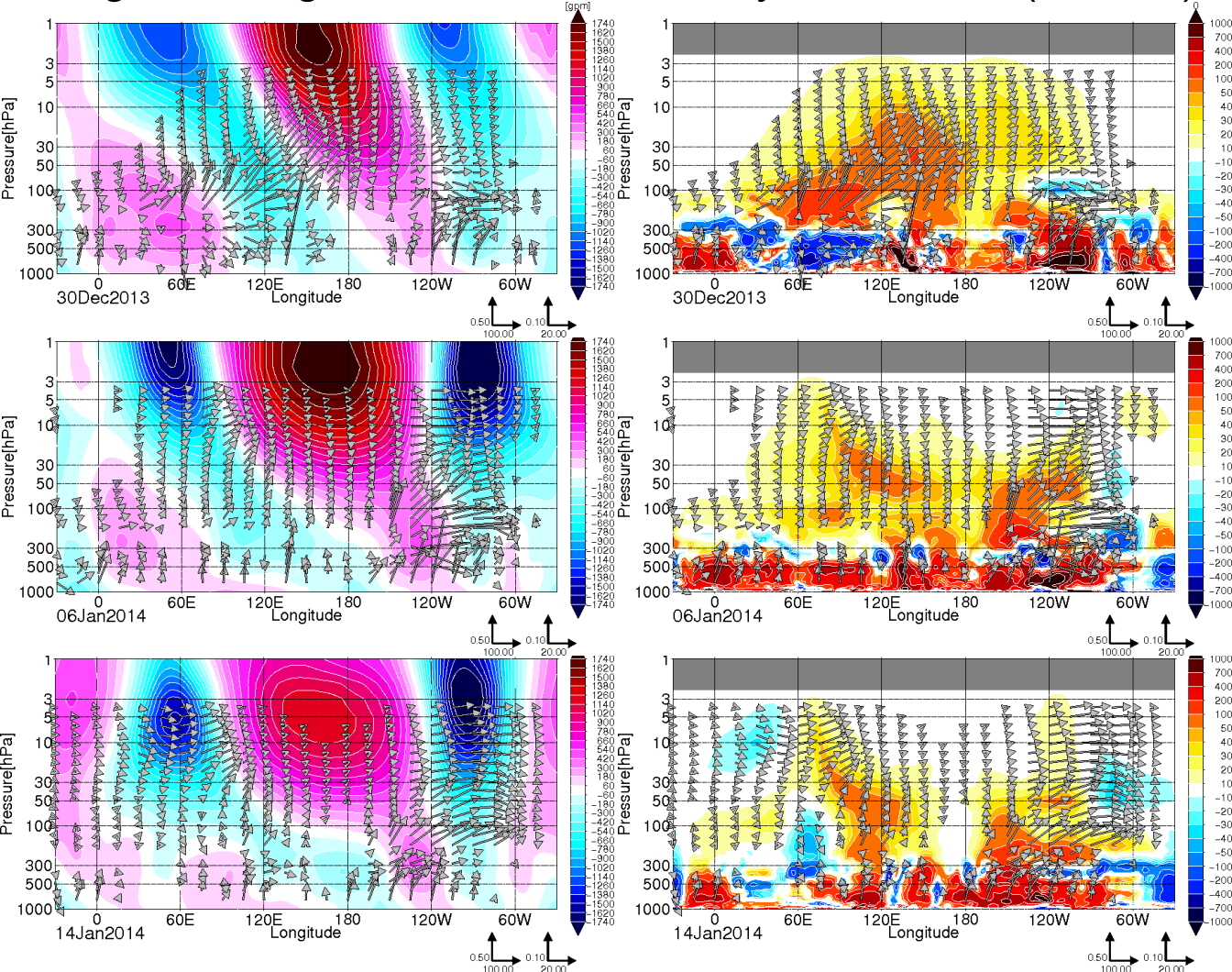
Left panel:  $V^2$  (using 2-8 day filtered  $V$ ) [ $\text{m}^2/\text{s}^2$ ] (contour),  $V^2$  normalized anomaly (shading)

Right panel: climatological mean of  $V^2$  [ $\text{m}^2/\text{s}^2$ ] (contour),  $V^2$  anomaly [ $\text{m}^2/\text{s}^2$ ] (shading)

# Effect of the southward shift of the wave propagation on the stratosphere



Longitude-height cross section of daily WAF and Z (55-59N)

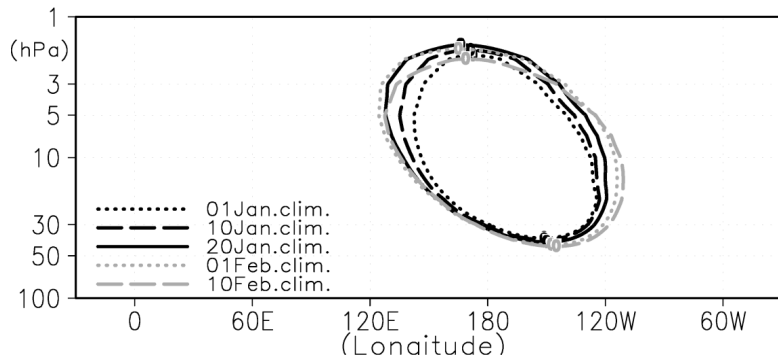
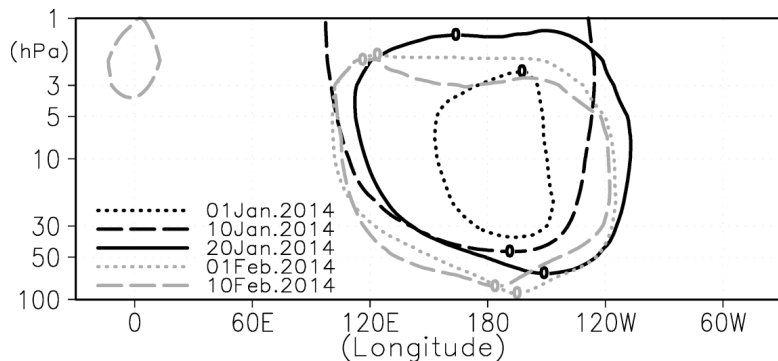


Left panel: Plumb's WAF [ $\text{m}^2/\text{s}^2$ ] (vector), GPH anomaly from its zonal mean (shading)

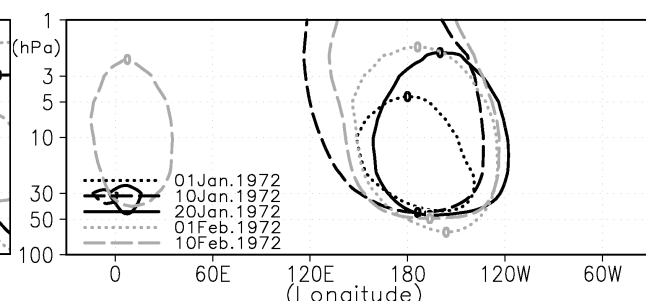
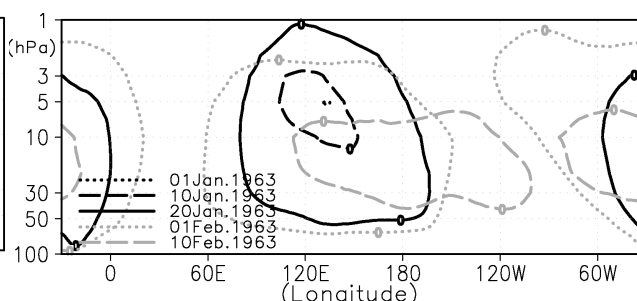
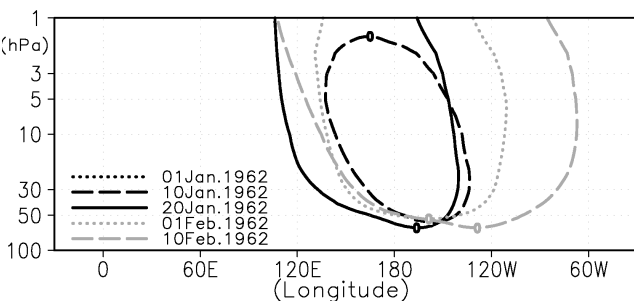
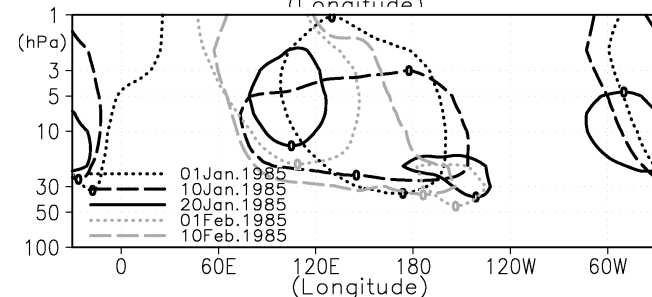
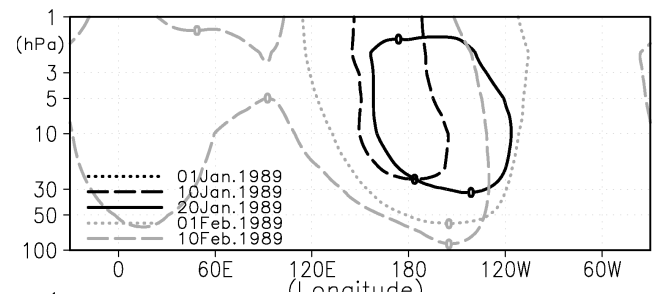
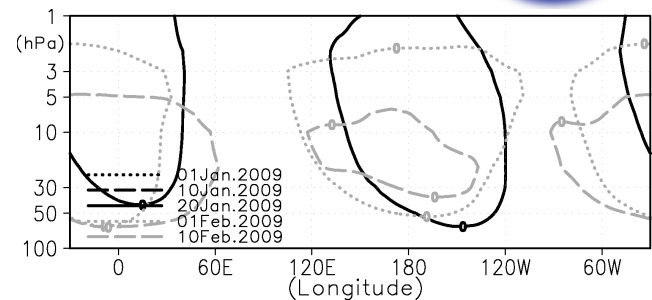
Right panel: Plumb's WAF [ $\text{m}^2/\text{s}^2$ ] (vector), Plumb's WAFZ [ $\text{m}^2/\text{s}^2$ ] (shading)

Wave packets emanated from Western Eurasia converged at the western edge of the Aleutian High, and contributed the expansion and maintenance of easterly region to accompany the Aleutian High.

# Seasonal progression of the easterly area over the date line (40–50N mean)



The expansion and preservation of the easterly area over the date line in the winter of 2013/2014 is extraordinary, comparing with other wave 2 years.



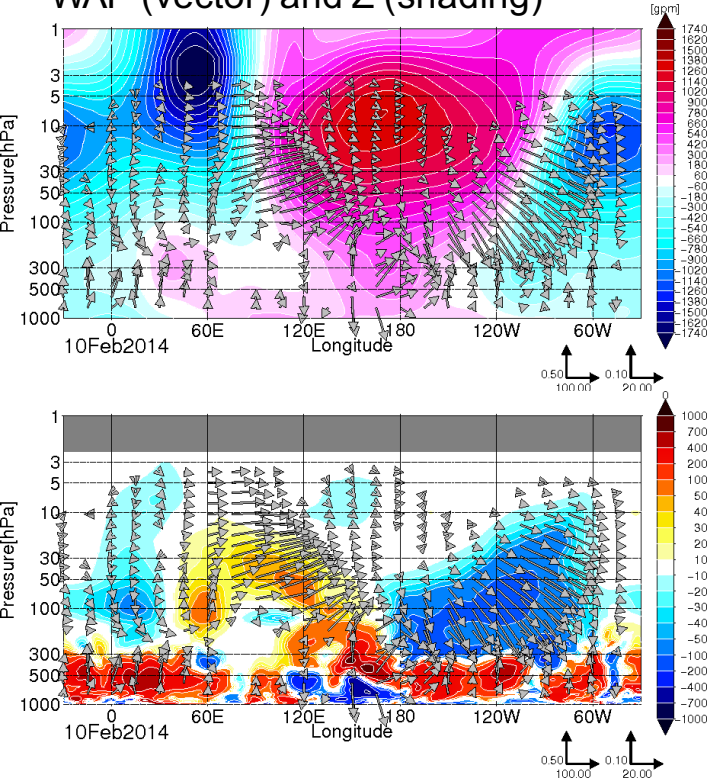


# Phase structure of the planetary waves during the remarkable downward propagation (10Feb.2014)

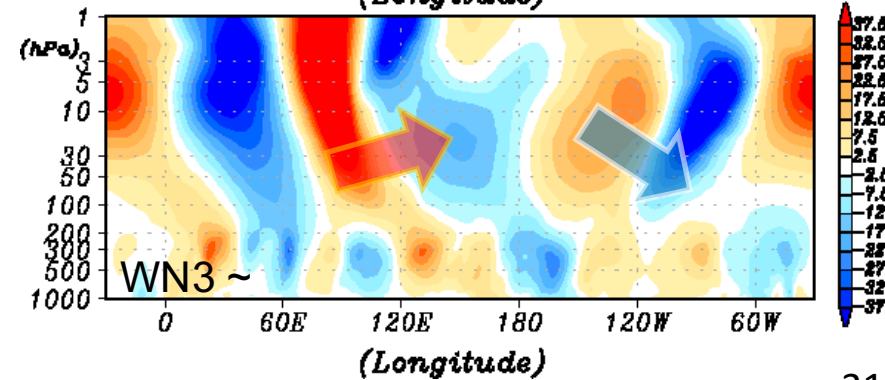
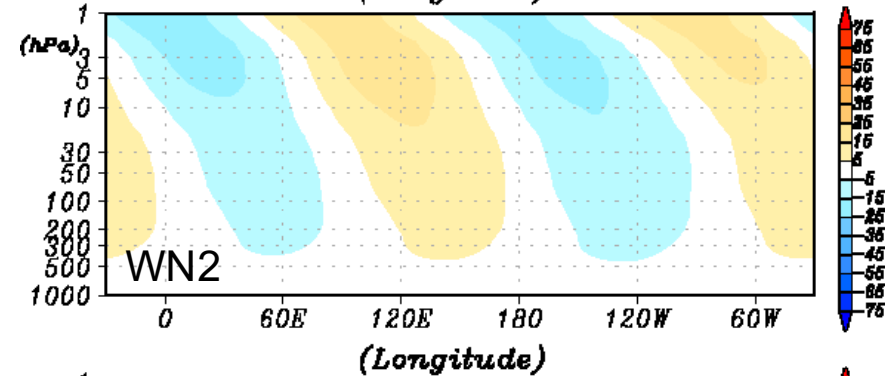
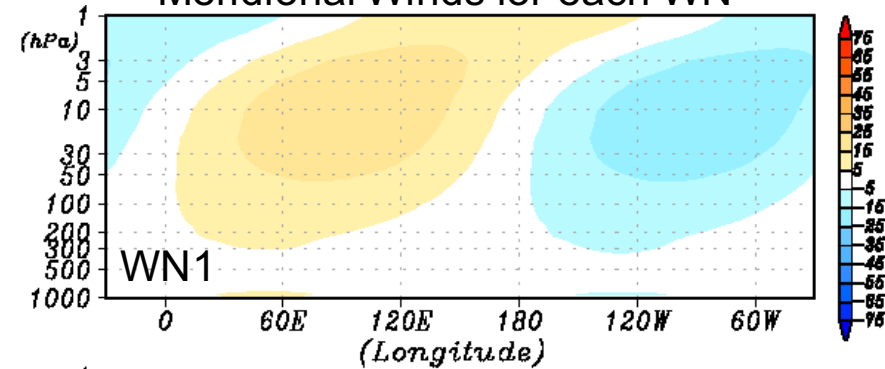


Longitude-height cross sections (65-69N)

WAF (vector) and Z (shading)



Meridional Winds for each WN



# Data sources of long-lived greenhouse gases.



| Molecule         | Period    | Source   |
|------------------|-----------|--|
| CO <sub>2</sub>  | 1958      | Law Dome ice core data (Etheridge et al. 2008)                               |
|                  | 1959–1982 | Keeling Mauna Loa observations   |
|                  | 1983–2010 | WDCGG (WMO 2012)   |
|                  | 2011–     | RCP4.5 (Clarke et al. 2007; Smith and Wigley 2006; Wise et al. 2009)         |
| CH <sub>4</sub>  | –1983     | 20C3M (Meinshausen et al. 2011)  |
|                  | 1984–2010 | WDCGG (WDCGG 2012)   |
|                  | 2011–     | Constant at the value in 2010  |
| N <sub>2</sub> O | –1979     | 20C3M (Meinshausen et al. 2011)  |
|                  | 1980–2010 | WDCGG (WDCGG 2012)   |
|                  | 2011–     | RCP4.5 (Clarke et al. 2007; Smith and Wigley 2006; Wise et al. 2009)         |
| CFC-11,          | –2005     | 20C3M (Meinshausen et al. 2011)  |
| CFC-12,          | 2006–     | A1 scenario of the Scientific Assessment of Ozone depletion: 2010 (WMO 2010) |
| HCFC-22          |           |  |



# References

---



- **S. Kobayashi et al. (2015)**
  - Shinya Kobayashi, Y.Ota, Y.Harada, A.Ebita, M.Moriya, H.Onoda, K.Onogi, H.Kamahori, C.Kobayashi, H.Endo, K.Miyaoka, and K.Takahashi
  - “ The **JRA-55** Reanalysis: General Specifications and Basic Characteristics ”
  - Submitted to JMSJ. It is likely to be accepted. **Coming soon.**
  - Ebita et al. (2011) “The Japanese 55-year Reanalysis “JRA-55”: An Interim Report” will be replaced with S. Kobayashi et al. (2014).
- Harada et al. (to be issued in 2015)
  - A comprehensive evaluation report of JRA-55 (in preparation)
- **C. Kobayashi et al. (2014)**
  - Chiaki Kobayashi, H.Endo, Y.Ota, S.Kobayashi, H.Onoda, Y.Harada, K.Onogi and H.Kamahori
  - “**Preliminary** Results of the **JRA-55C**, an Atmospheric Reanalysis Assimilating Conventional Observations Only”
    - SOLA, 2014, Vol.10, 78-82, doi:10.2151/sola.2014-016
    - [https://www.jstage.jst.go.jp/article/sola/10/0/10\\_2014-016/\\_article](https://www.jstage.jst.go.jp/article/sola/10/0/10_2014-016/_article)