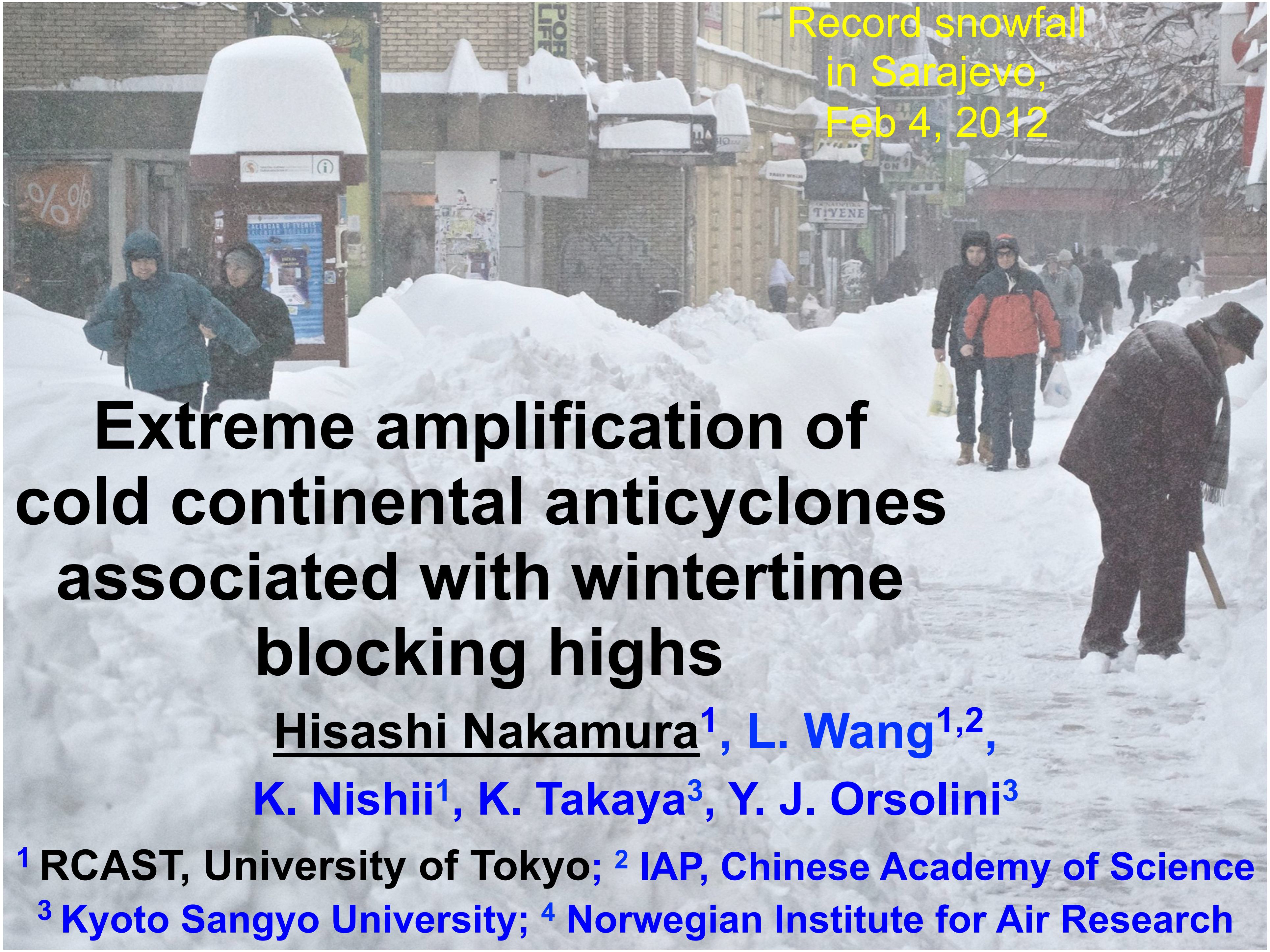


Record snowfall in Sarajevo, Feb 4, 2012

Extreme amplification of cold continental anticyclones associated with wintertime blocking highs

Hisashi Nakamura[1], **L. Wang**[1,2], **K. Nishii**[1], **K. Takaya**[3], **Y. J. Orsolini**[3]

[1] RCAST, University of Tokyo; [2] IAP, Chinese Academy of Science
[3] Kyoto Sangyo University; [4] Norwegian Institute for Air Research

Extreme amplification of the Siberian High

Related review papers:

- Nakamura H. et al. (2010): Chapter 6, AGU Monogr., 189, 149-179.
- Nakamura H. et al. (2015): Chapter 4-21 of ICDM book “Dynamics and Predictability of Large-Scale High-Impact Weather and Climate Events”, Cambridge Univ. Press.

03 Feb, 2012 @Ojiya (Japan) (38°N, 139°E)

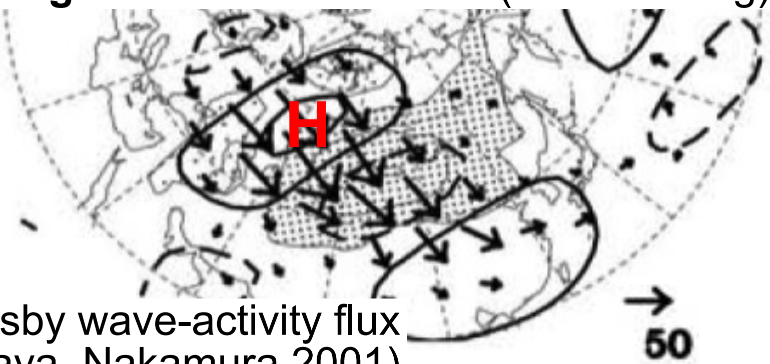
30 Jan, 2012 @ Inner-Mongolia (China); –44.9°C

Typical extreme amplification of the Siberian High

Takaya, Nakamura (2005a JAS); Nakamura et al. (2010, AGU Monogr.)

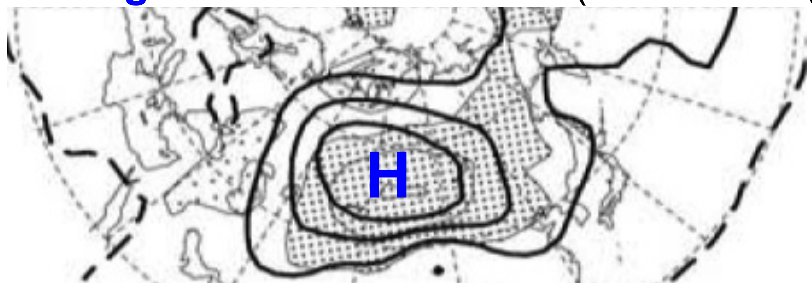
- Extreme amplification of the surface Siberian High occurs typically with a stationary Rossby wave train propagating from the N. Atlantic.
- **Cold advection with anomalous surface northeasterlies induced by the blocking ridge acts to amplify the cold anticyclonic anomaly.**

Anticyclonic Z250 anomalies (solid lines) and **negative SAT anomalies** (dark shading)



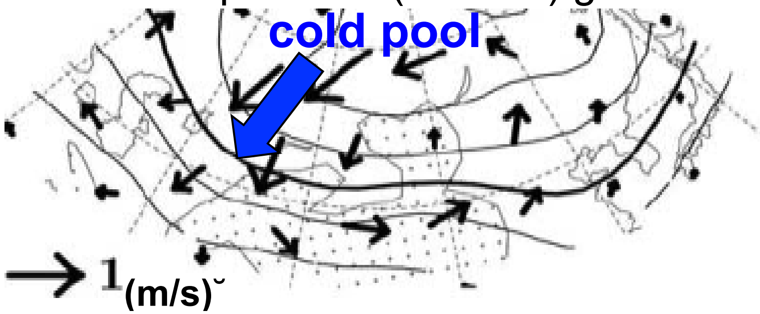
→ Rossby wave-activity flux (Takaya, Nakamura 2001)

Anticyclonic SLP anomalies (solid lines) and **negative SAT anomalies** (dark shading)

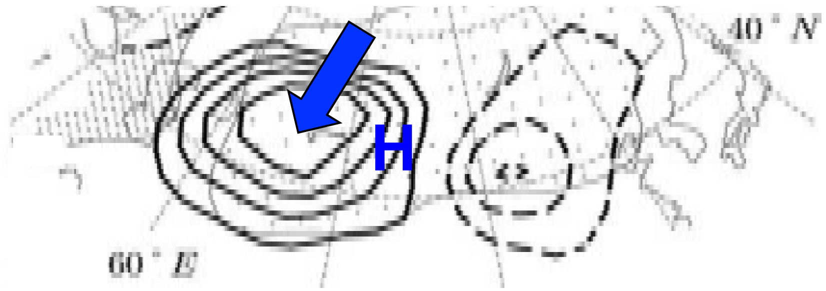


cold, anticyclonic anomaly at the surface slightly downstream of a blocking ridge

1000mb anomalous wind induced by 300mb PV anomalies (→) acting on 1000mb temperature (contour) gradient



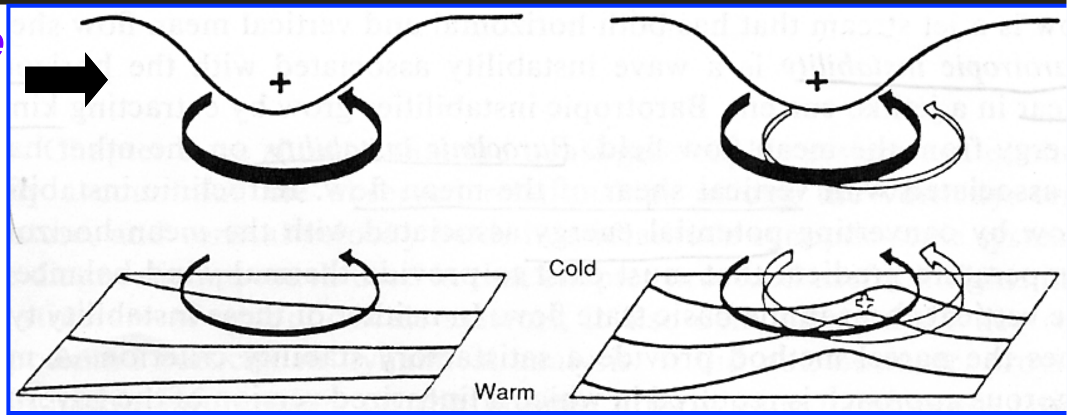
Negative 1000-mb temperature tendency (solid lines) **induced by 300mb PV anomalies**

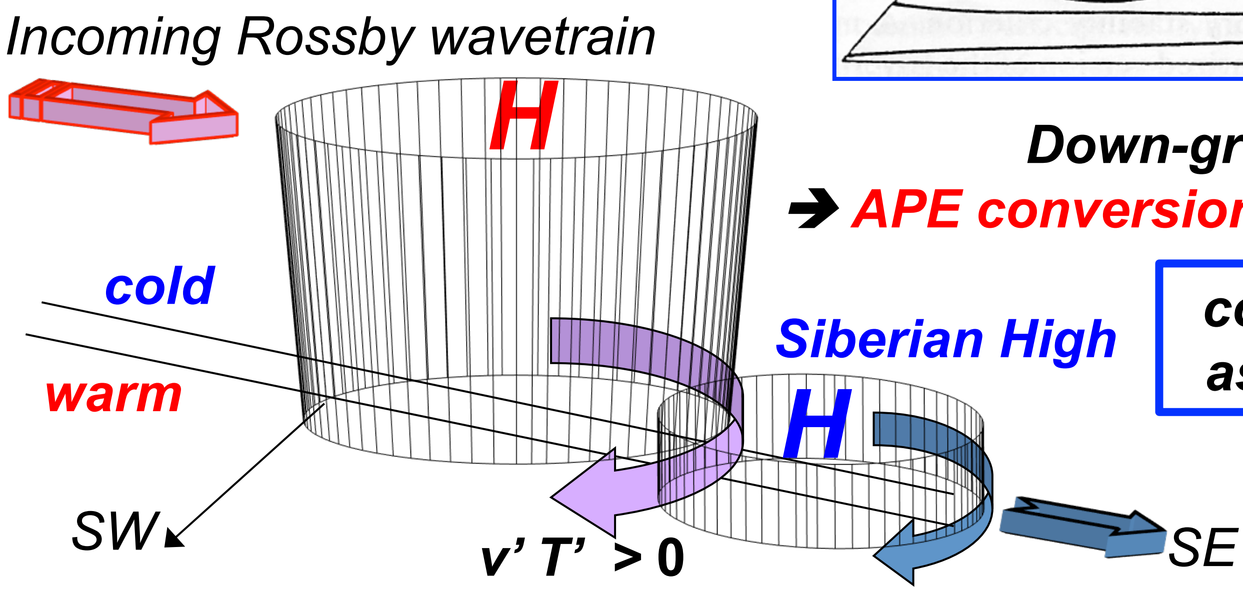


Interaction of a stationary Rossby wave train with surface baroclinicity for the Siberian High intensification

Takaya, Nakamura (2005a, JAS), Nakamura et al. (2010, AGU Monogr.)

Analogous to B-type cyclogenesis:





Down-gradient heat flux

➔ ***APE conversion from mean baroclinicity***

cold-air accumulation as a key precondition

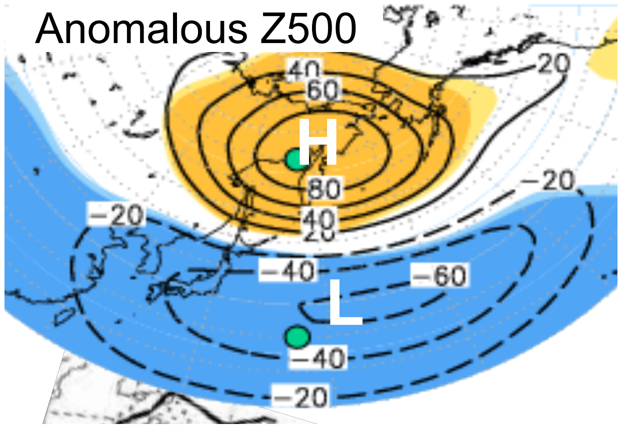
Cold advection induced by upper-level blocking ridge prevents the surface cold high from migrating, acting to retain the vertical phase tilt and thereby APE conversion.

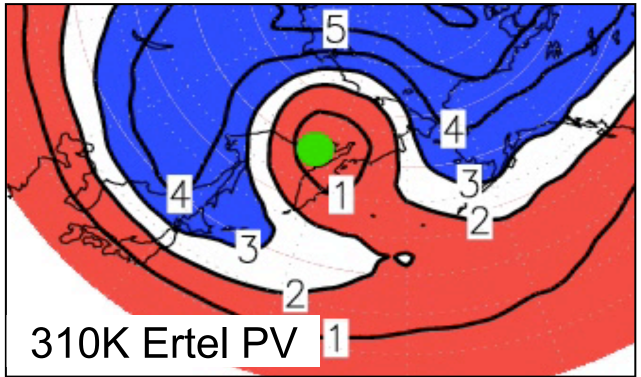
Cold advection with surface northerlies induces southeastward phase propagation as "thermal Rossby waves".

Extreme amplification of Siberian High: Western Pacific (WP) type

Takaya, Nakamura (2005a, JAS); Nishii, Nakamura, Orsolini (2010, GRL)

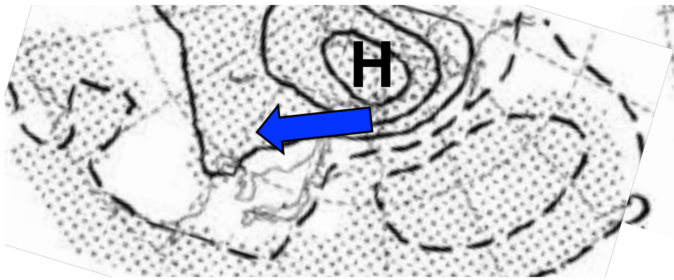
- **WP pattern** is characterized by **a meridional dipole of pressure anomalies over the western N. Pacific** (Wallace, Gutzler 1981).
- Its positive phase corresponds to **blocking formation associated with cyclonic breaking of the planetary-wave trough** over the Far East.



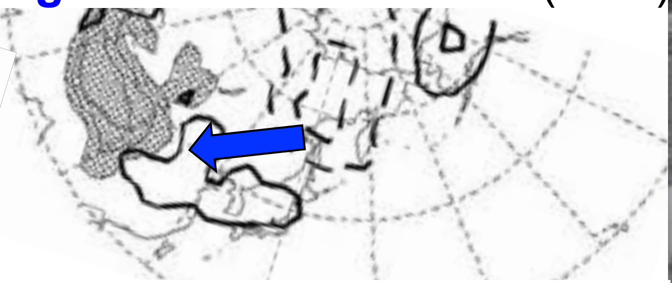


03 Feb, 2012
@Ojiya, Japan (38°N, 139°E)

SLP anomalies



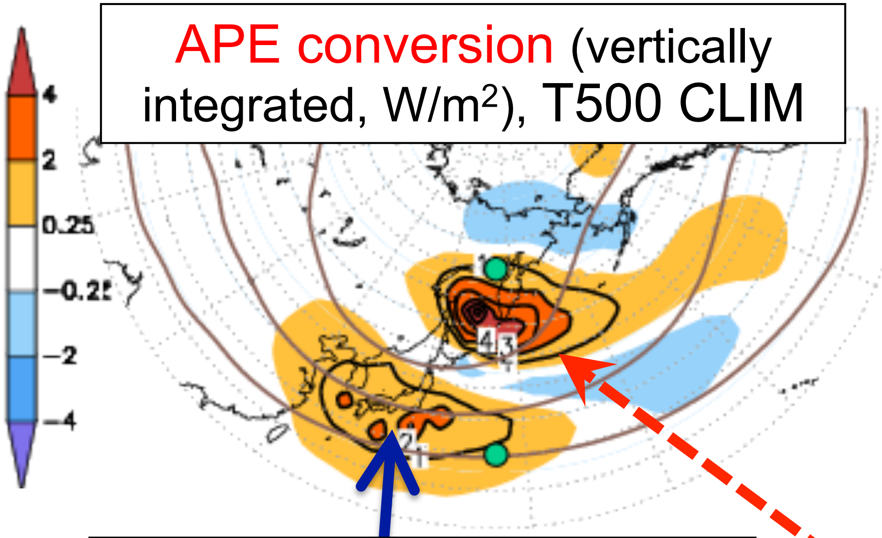
negative SAT anomalies (solid)



- **Cold advection with anomalous surface easterlies induced by the blocking ridge yields a cold surge into midlatitudes.**

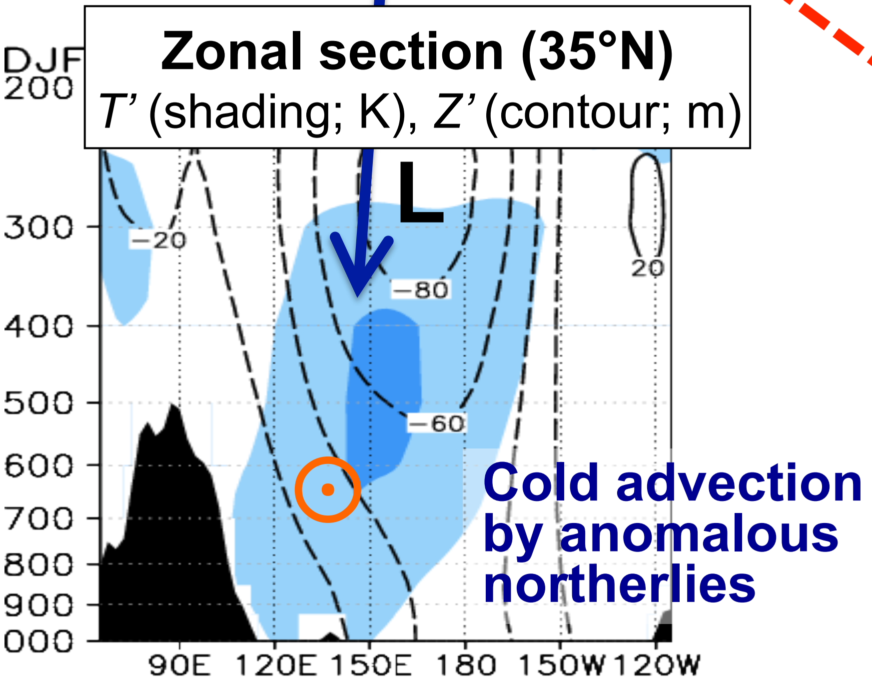
Baroclinic APE conversion for the WP pattern for its strong anticyclonic monthly events based on composites

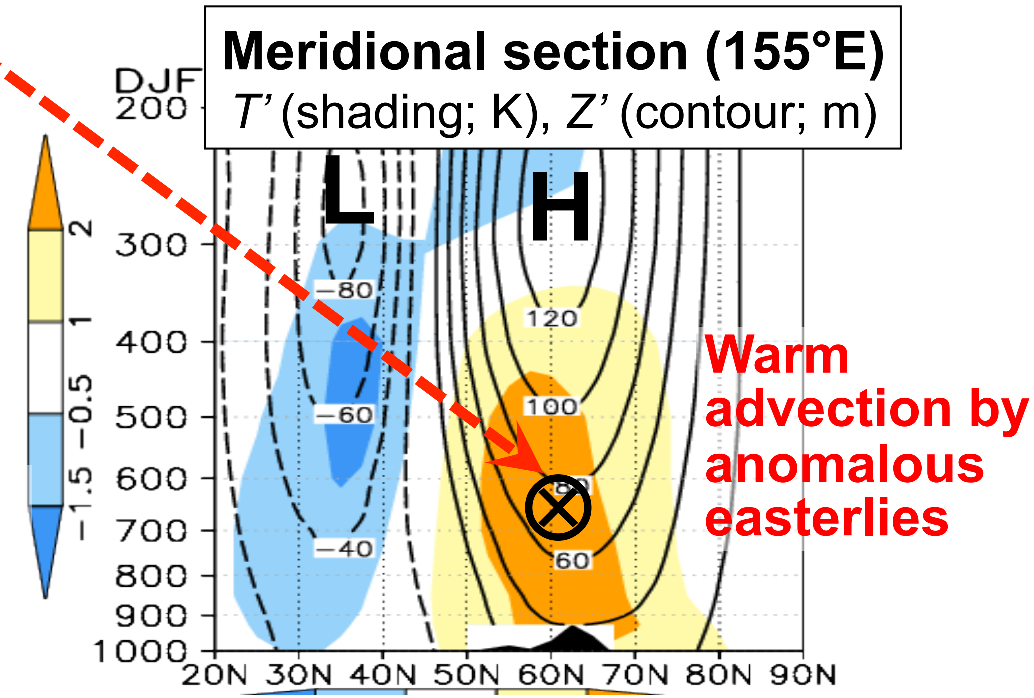
Nishii, Tanaka, Nakamura (2015, submitted to J. Clim.)



- **Westward and southward phase tilts of pressure anomalies allow efficient APE conversion from the background planetary waves** (timescale of ~5 days).

$$CP = \frac{R}{pS_p}\left(\boxed{-T'u'\frac{\partial \overline{T}}{\partial x}}\boxed{-T'v'\frac{\partial \overline{T}}{\partial y}}\right)$$

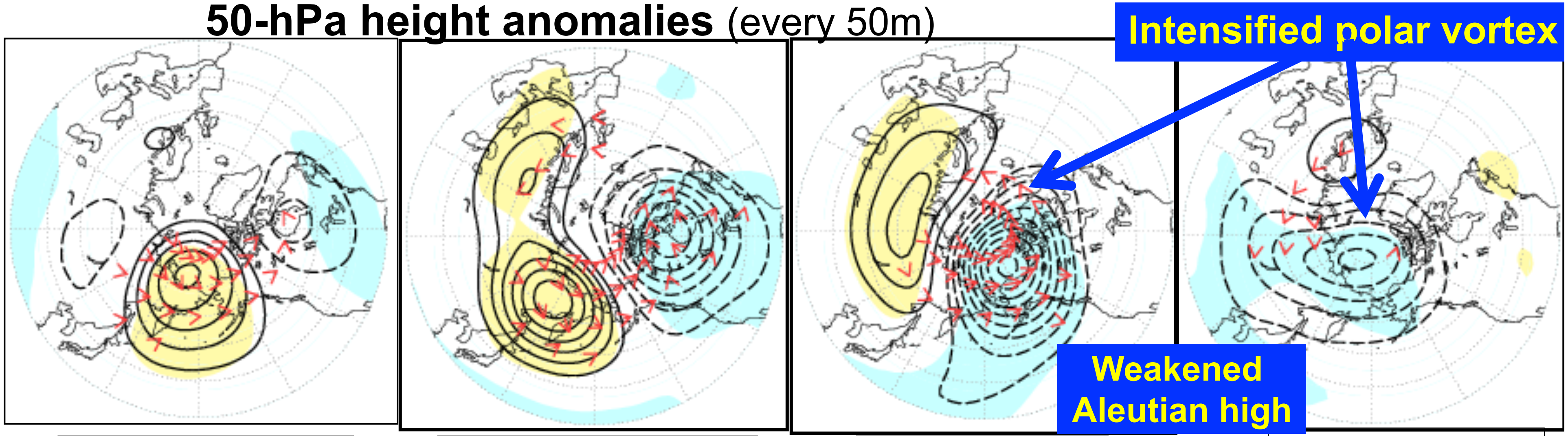




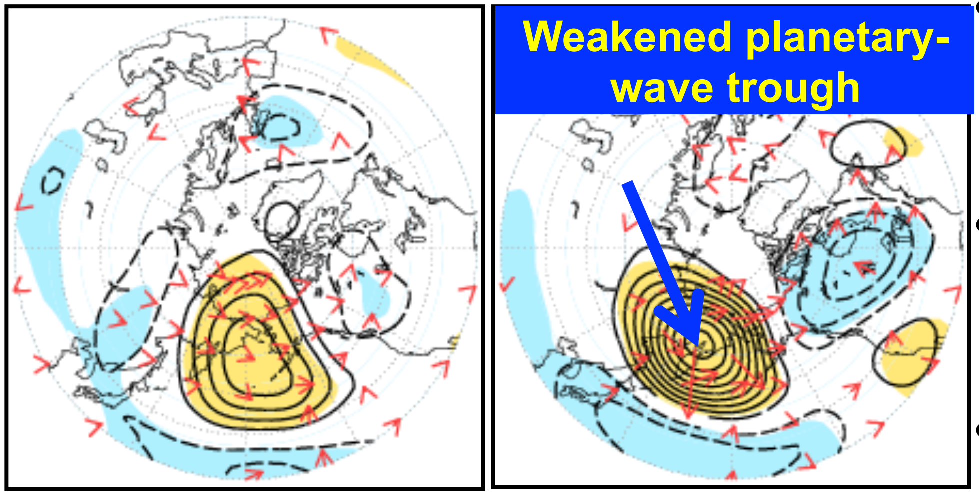
Influence of the WP pattern on the stratosphere as a potential trigger of the annular mode

Nishii, Nakamura, Orsolini (2010 GRL; 2011 J.Clim.)

50-hPa height anomalies (every 50m)



5 days earlier | Blocking peak | 5 days later | 10 days later

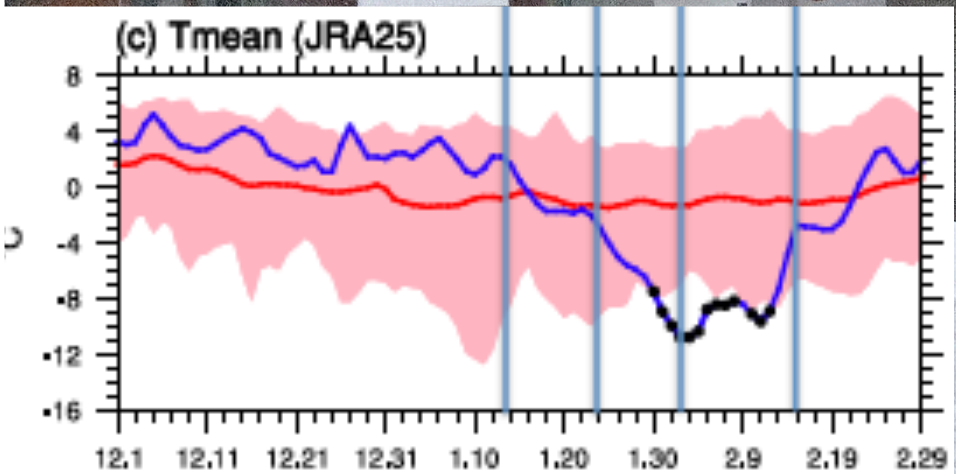


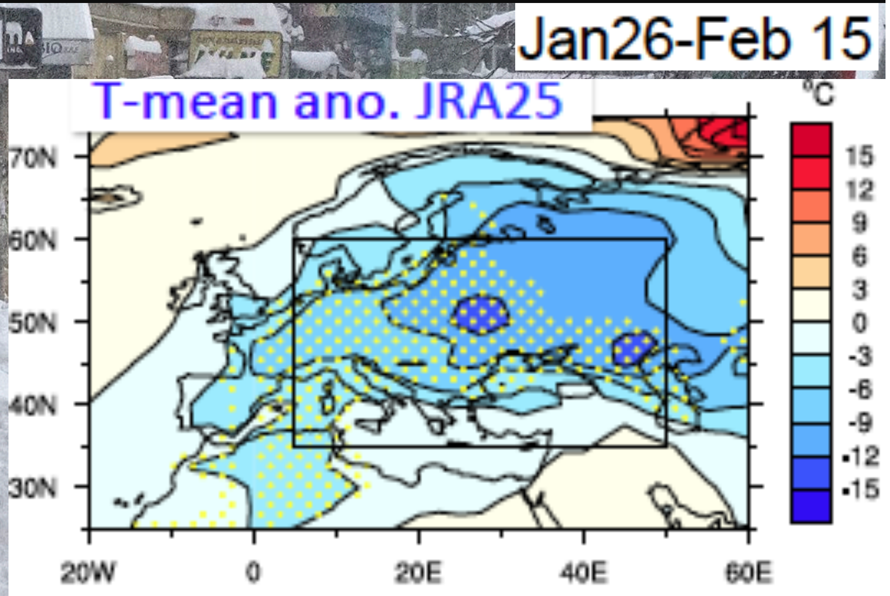
250-hPa height anomalies (every 50m)

- **Tropospheric blocking high amplifies in the N. Pacific, while retrograding slowly into planetary-wave trough.**
- **Then, a stratospheric cyclonic anomaly develops to intensify the the stratospheric polar vortex.**
- **Influence of ENSO or midlatitude SST anomalies can be transferred into the stratosphere via WP pattern.**

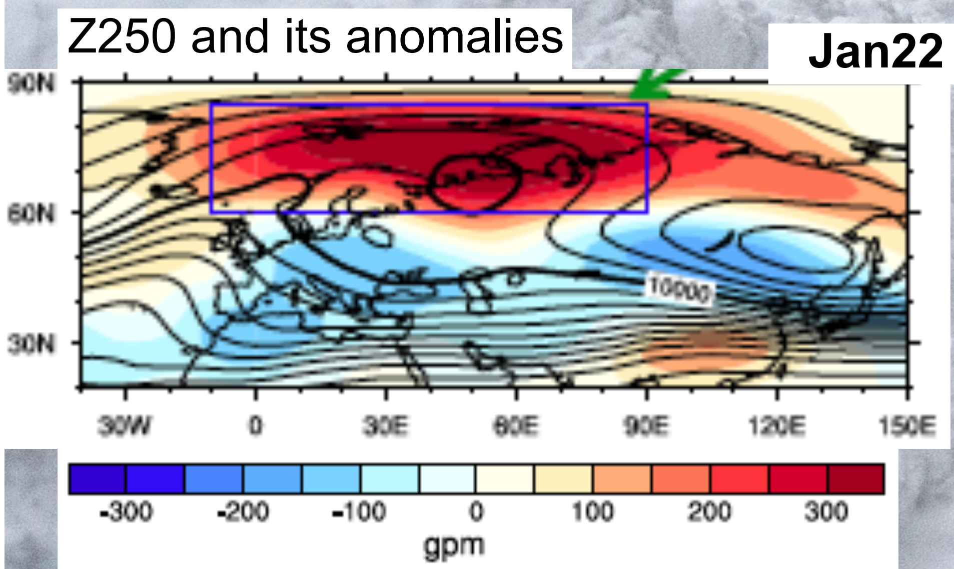
Cold continental high over N. Europe in 2011/12 winter

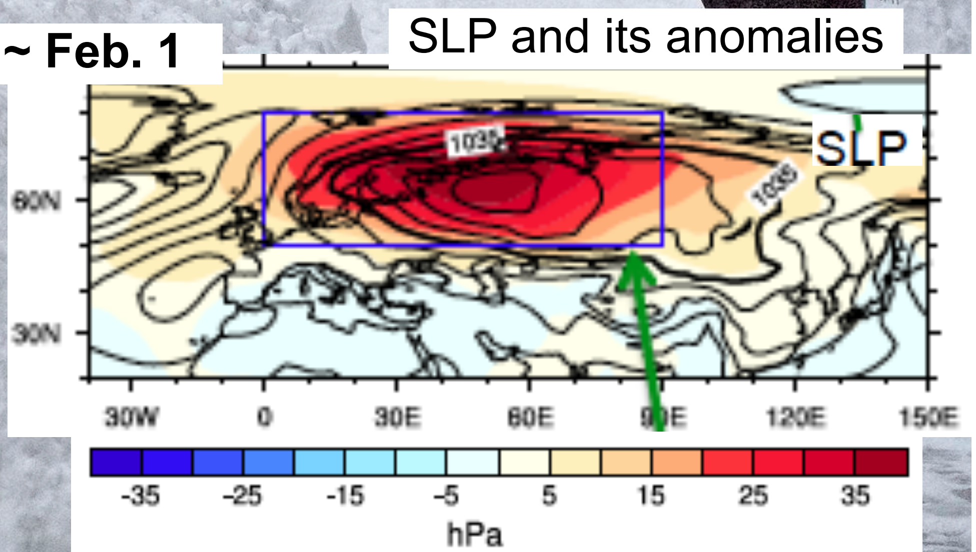
Wang, Nakamura, Nishii (2015, to be submitted to J. Clim.)





Jan22 ~ Feb. 1





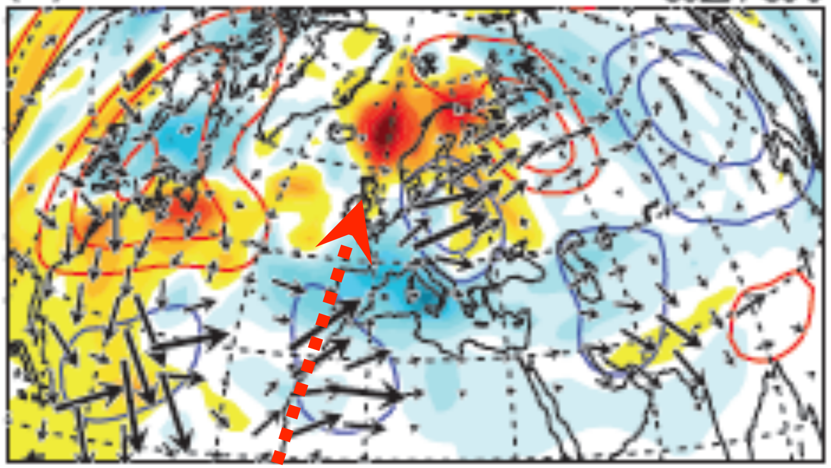
Contributions from transient eddies and Rossby waves to the amplification of the blocking high

Wang, Nakamura, Nishii (2015, submitted to J. Clim.)

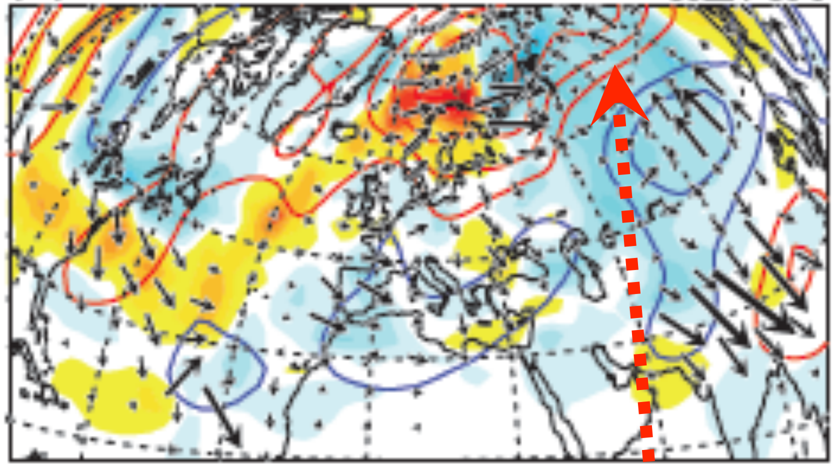
contours: 300hPa height anomalies (LP) ; red: anticyclonic; blue: cyclonic

color: feedback forcing → Rossby wave-activity flux (Takaya, Nakamura 2001)

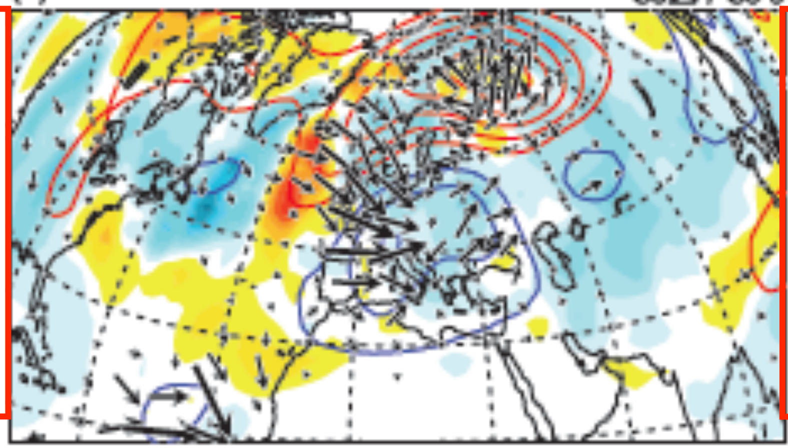
(b) Jan 24 dZ/dt



(d) Jan 28 dZ/dt



(f) Feb 1 dZ/dt



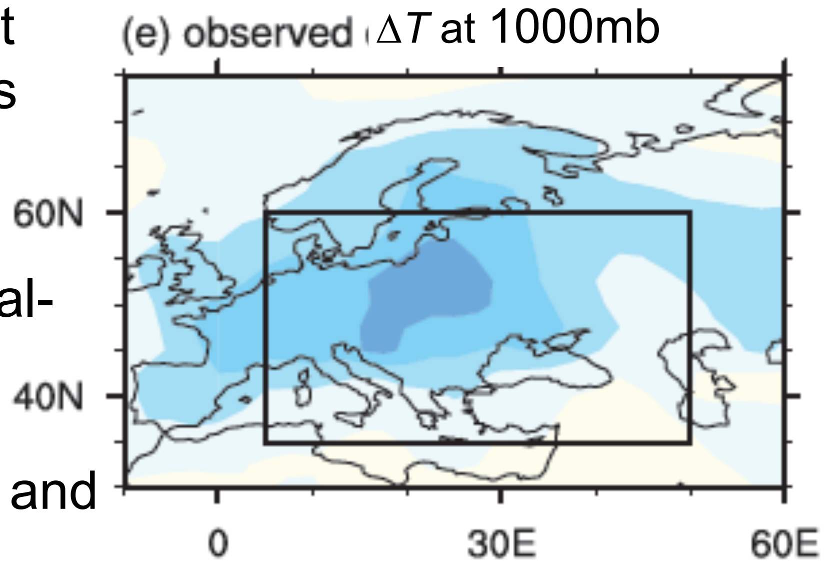
Anticyclonic feedback forcing by migratory synoptic-scale eddies contributed to westward expansion of the blocking high.

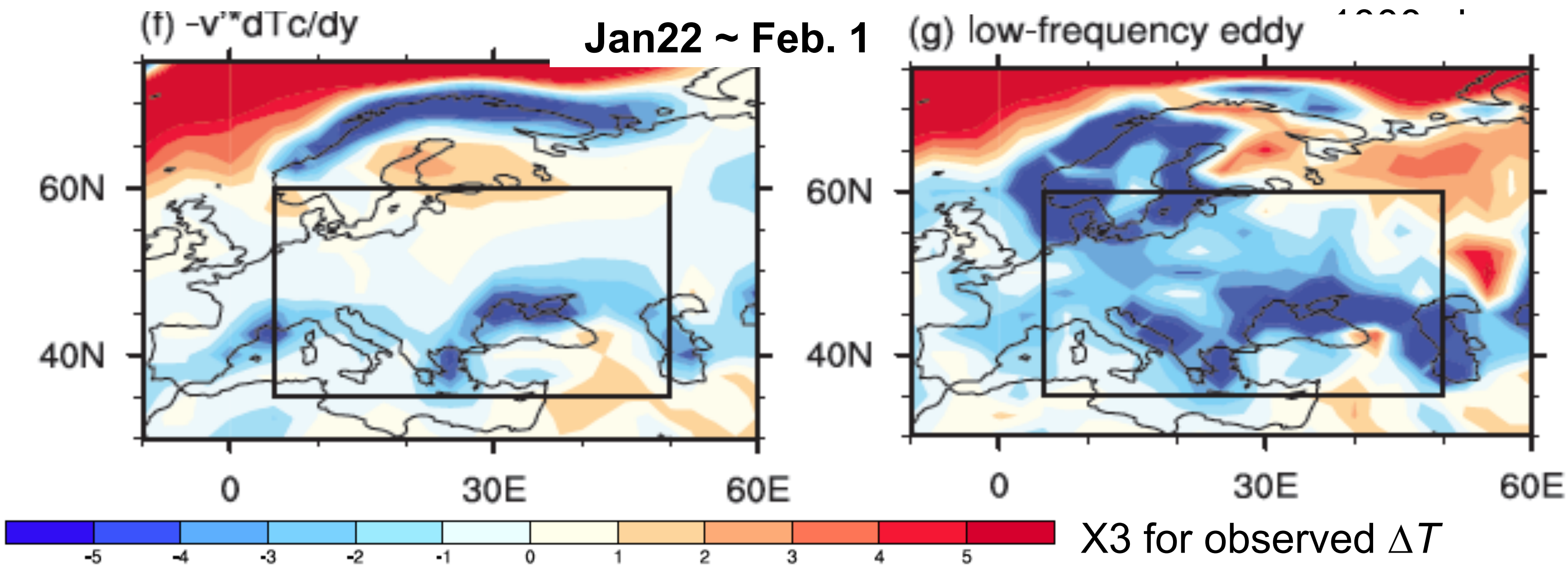
Incoming Rossby waves also contributed to the strengthening of the eastern portion of the high.

Importance of dynamical cooling for the surface cold high

Wang, Nakamura, Nishii (2015, submitted to J. Clim.)

- In late January 2012, the European continent underwent rapid cooling, to which anomalous thermal advection associated with the cold anticyclone make the major contribution.
- Anomalous winds acting on the climatological-mean thermal gradient contributes only in southern Europe, while self associated with the developing anticyclone makes a greater and more wide-spread contribution.

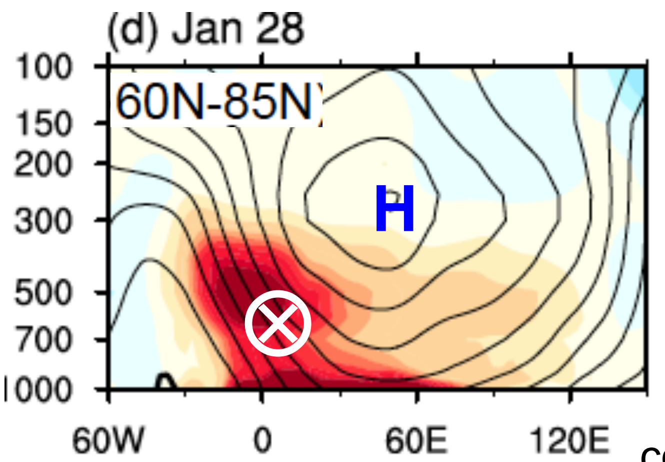


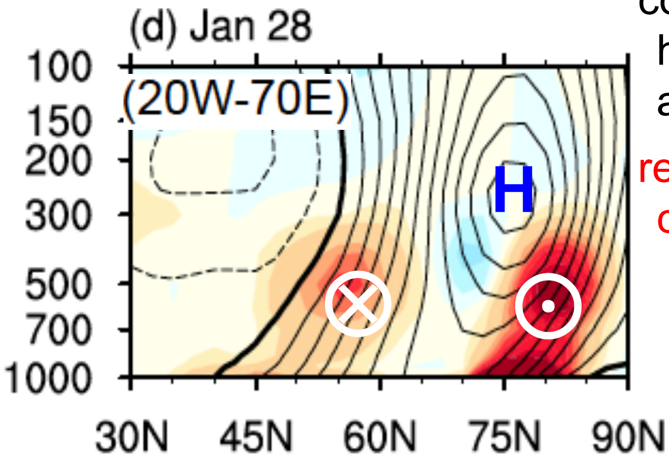


Baroclinic APE conversion for the anticyclonic anomalies

Wang, Nakamura, Nishii (2015, submitted to J. Clim.)

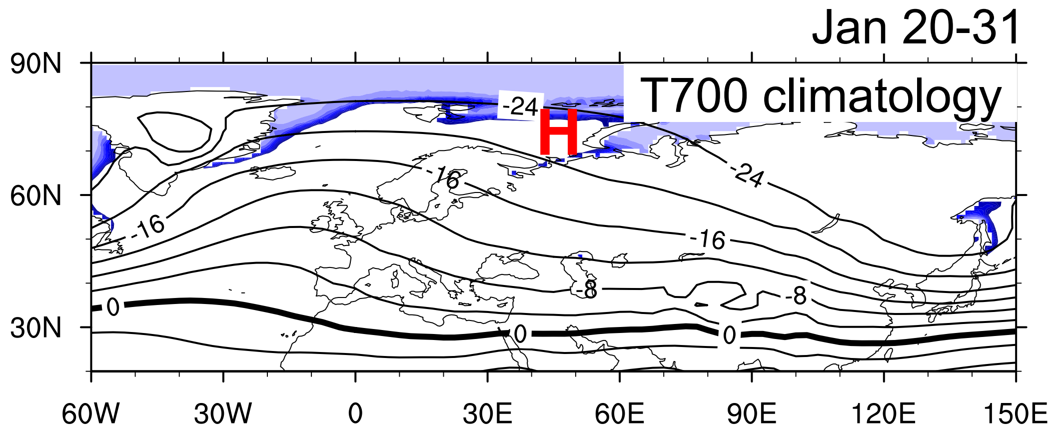
- Similar to the WP pattern, **the anticyclonic anomaly converts APE from the the background planetary waves and land-sea thermal contrasts with its westward and *northward* phase with height**.
- The northward tilt is consistent with the cooler continent to the east.

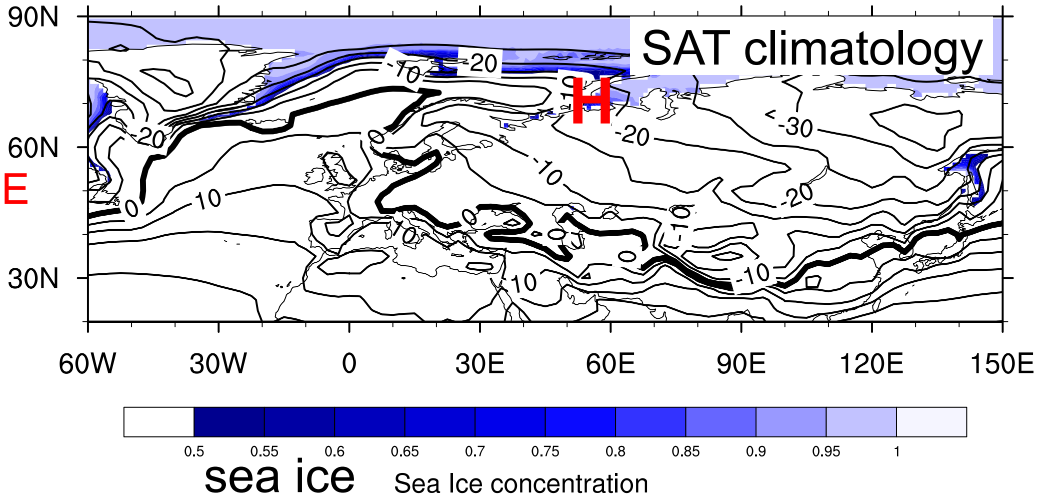




contours: height anomalies;

red: pos. APE conversion





Summary and implications

- Extreme amplification of a cold continental high tends to occur in conjunction with the development of a blocking ridge aloft, which can form as a component of a stationary Rossby wave train and/or under the feedback forcing from the nearby stormtrack.
- Wind anomalies induced by the upper-level blocking high generate anomalous cold advection to amplify the cold surface high.
- The anomalies are, by nature, baroclinic and efficient for APE conversion from the background state, thereby to amplify/maintain themselves against damping/dissipative processes with the potential for a prolonged cold surge.
- The anomalies exhibit a westward phase tilt under the background meridional temperature gradient, while their meridional tilt depends on zonal temperature gradient, including land-sea thermal contrast.
- The baroclinic nature of the anomalies may also be important for the response to sea-ice anomalies.

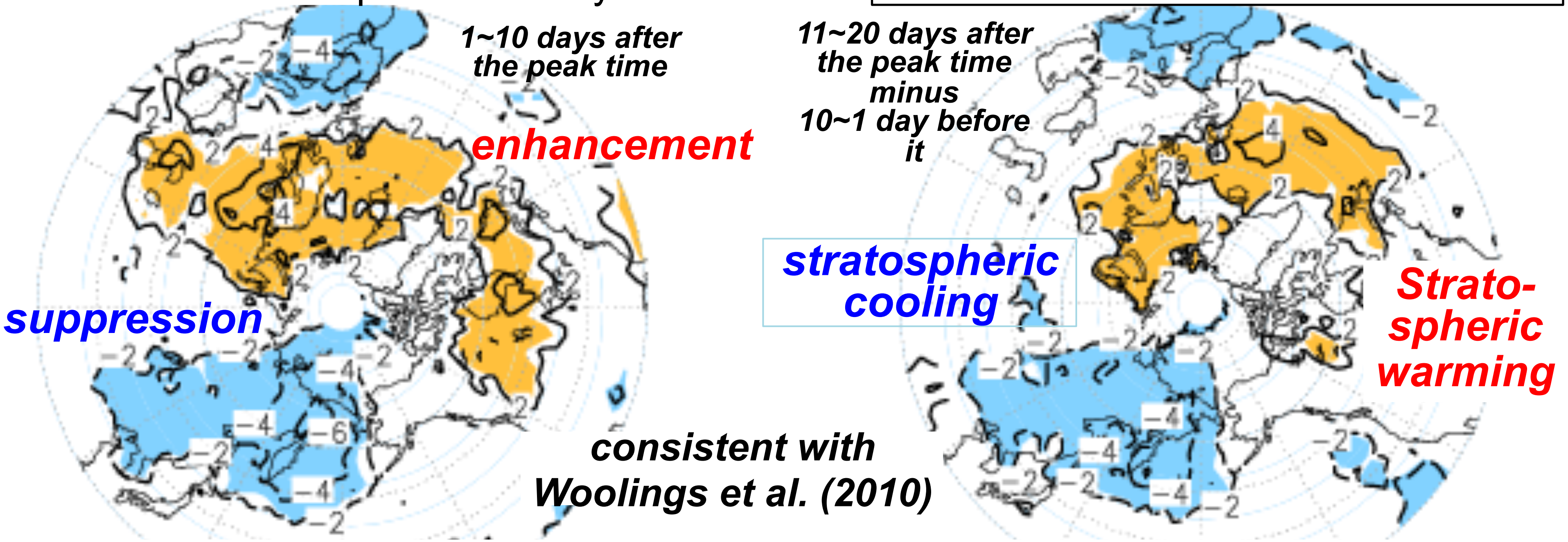
Blocking high influence on the stratosphere: Determining the sign of the stratospheric annular mode

Nishii, Nakamura, Orsolini (2011 J.Clim.)

Based on composite for 20 strongest anticyclonic anomaly events at each point

Planetary-wave activity into the stratosphere measured as
100hPa anomalous poleward eddy heat flux

Anomalous tendency in 50hPa temperature poleward of 70°N
induced by blocking



- **Blocking highs over N. America, N. Atlantic and Europe enhance upward planetary-wave propagation and thereby warm the polar stratosphere.**
- **Blocking highs over the W. Pacific and Far East suppress upward planetary-wave propagation and thereby cool the polar stratosphere.**