2015/16 Winter Monsoon in East Asia

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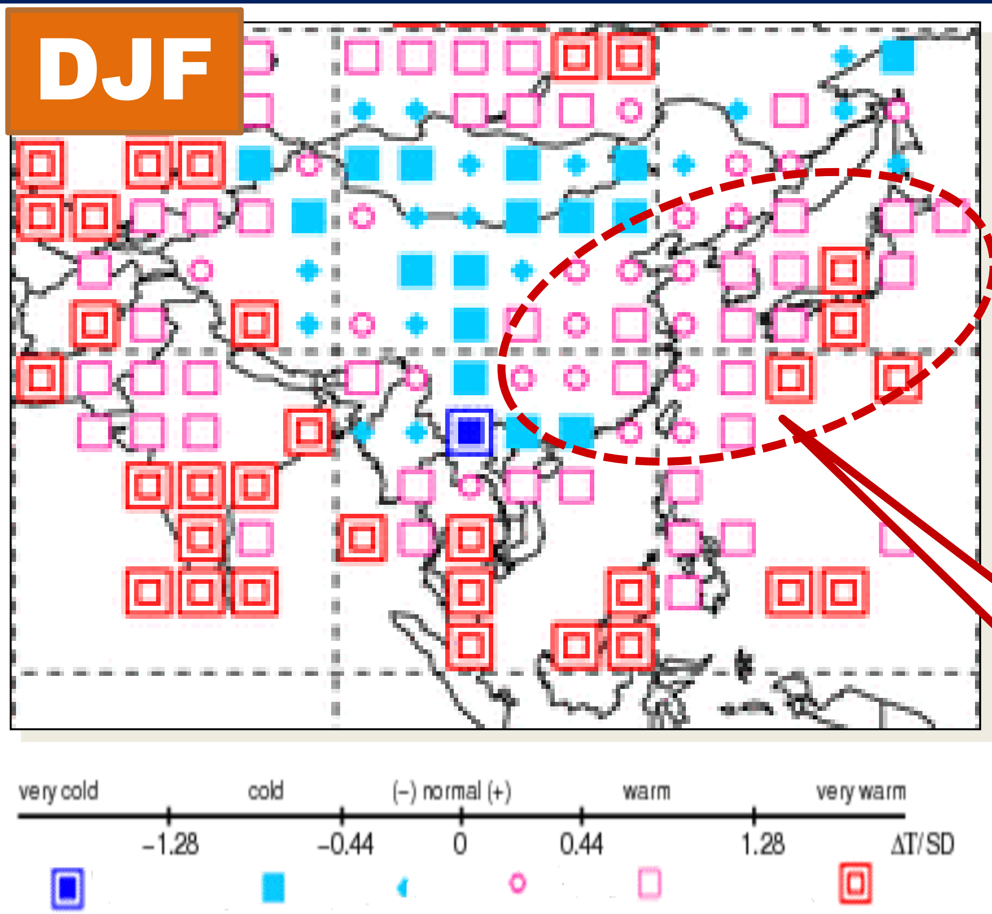
Outline

1. Overview of 2015/16 winter monsoon in East Asia

2. Weak monsoon: The first half of this winter

3. A cold surge in late January 2016

Overview of temperature anomalies in 2015/16 winter



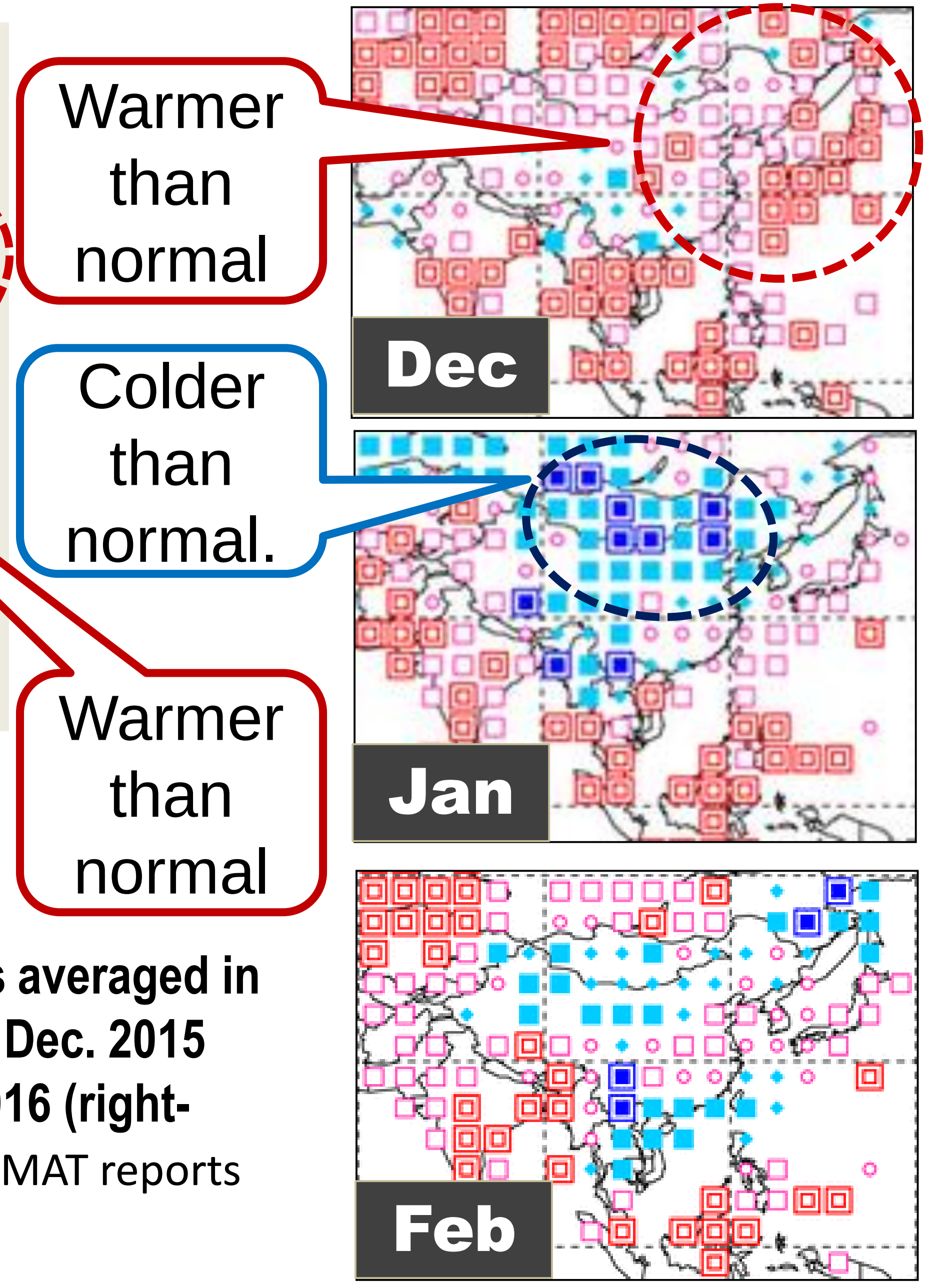


Fig.1 Normalized mean temperature anomalies averaged in 5°x5° grid boxes for 2015/16 winter (DJF) (left), Dec. 2015 (right-top), Jan. 2016 (right-middle) and Feb. 2016 (right-bottom).

† Data based on CLIMAT reports

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Atmospheric circulation in the N.H. (1st Dec – 10th Jan)

- Rossby wave propagation over the southern Eurasian continent
  → A ridge centered at the east of Japan.

Z500

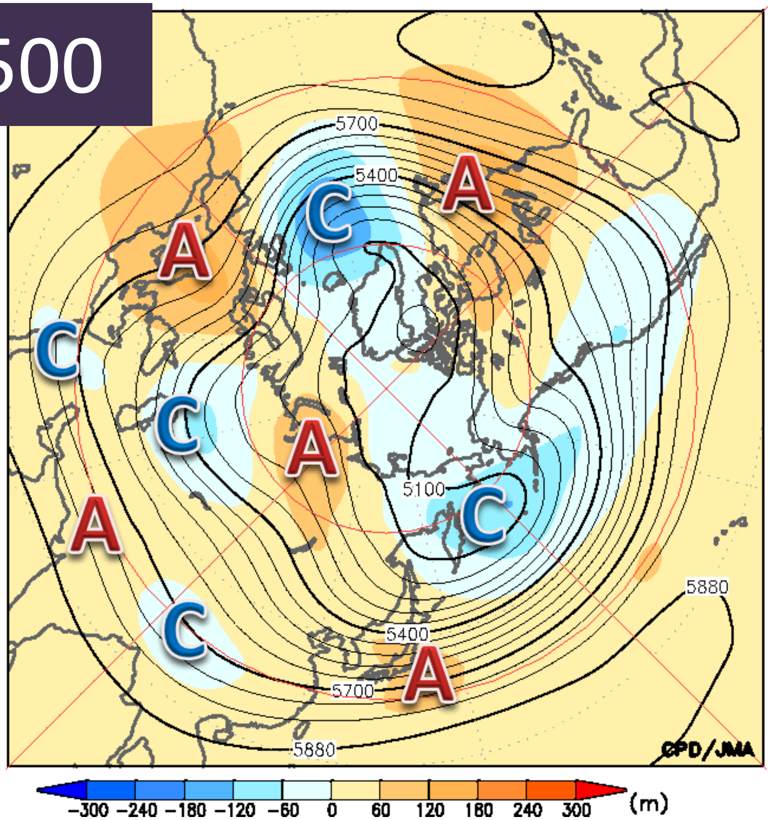


Fig.2 41-days mean 500 hPa level geopotential height (contour) and anomalies (color) for 1st Dec. – 10th Jan.

ψ300

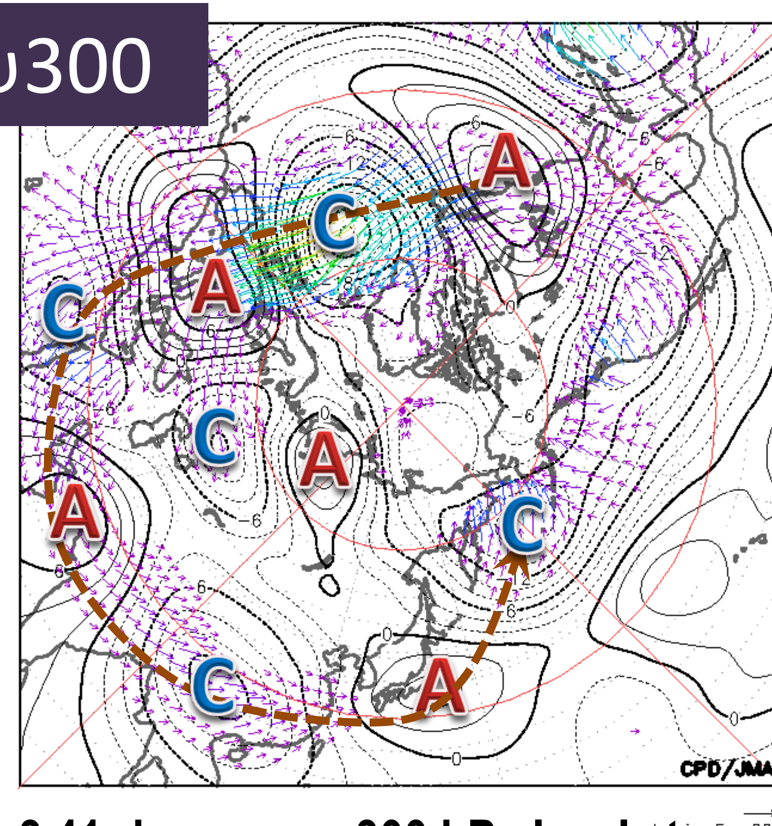


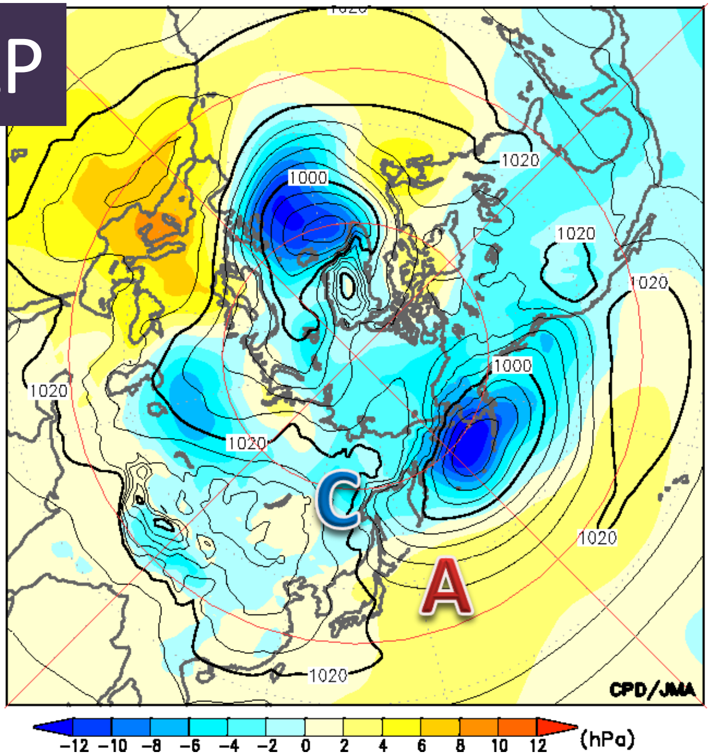
Fig.3 41-days mean 300 hPa level stream function anomalies (contour) and wave activity flux (Takaya and Nakamura 2001) (vector) for 1st Dec. – 10th Jan.

† Data used for this investigation is JRA-55, OLR(provided by NOAA) and COBE-SST.

Atmospheric circulation in the N.H. (1st Dec – 10th Jan)

- Weak Siberian High and high pressure anomalies to the east of Japan. Warmer situation over Siberia. → ***Weak winter monsoon***
- AO index was generally positive during December.

SLP



T850

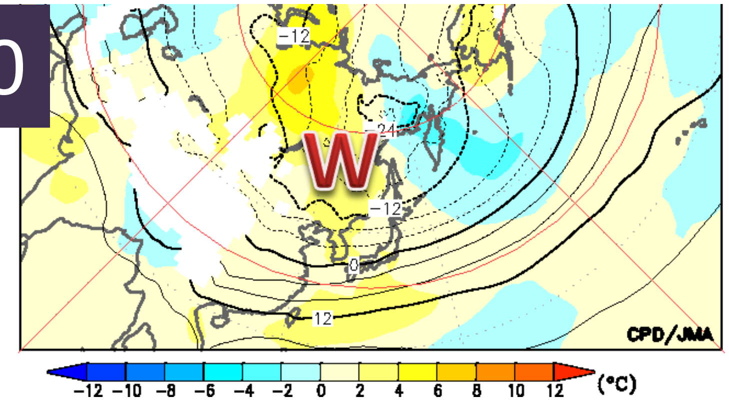


Fig.4 41-days mean (contour) and anomalies (shade) for 1st Dec. – 10th Jan. Left: Sea level pressure, Top-right: Temp. at 850 hPa level.

AO index

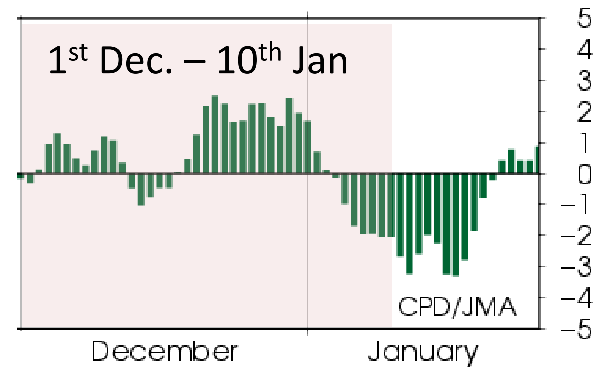


Fig.5 The time series of AO index, where the AO pattern is defined as the leading mode of EOF analysis of SLP over the Northern Hemisphere.

Impacts of El Niño event (Dec)

- Upper-level circulation pattern in December 2015, when the ongoing El Niño event matured, was similar to that of El Niño composite.

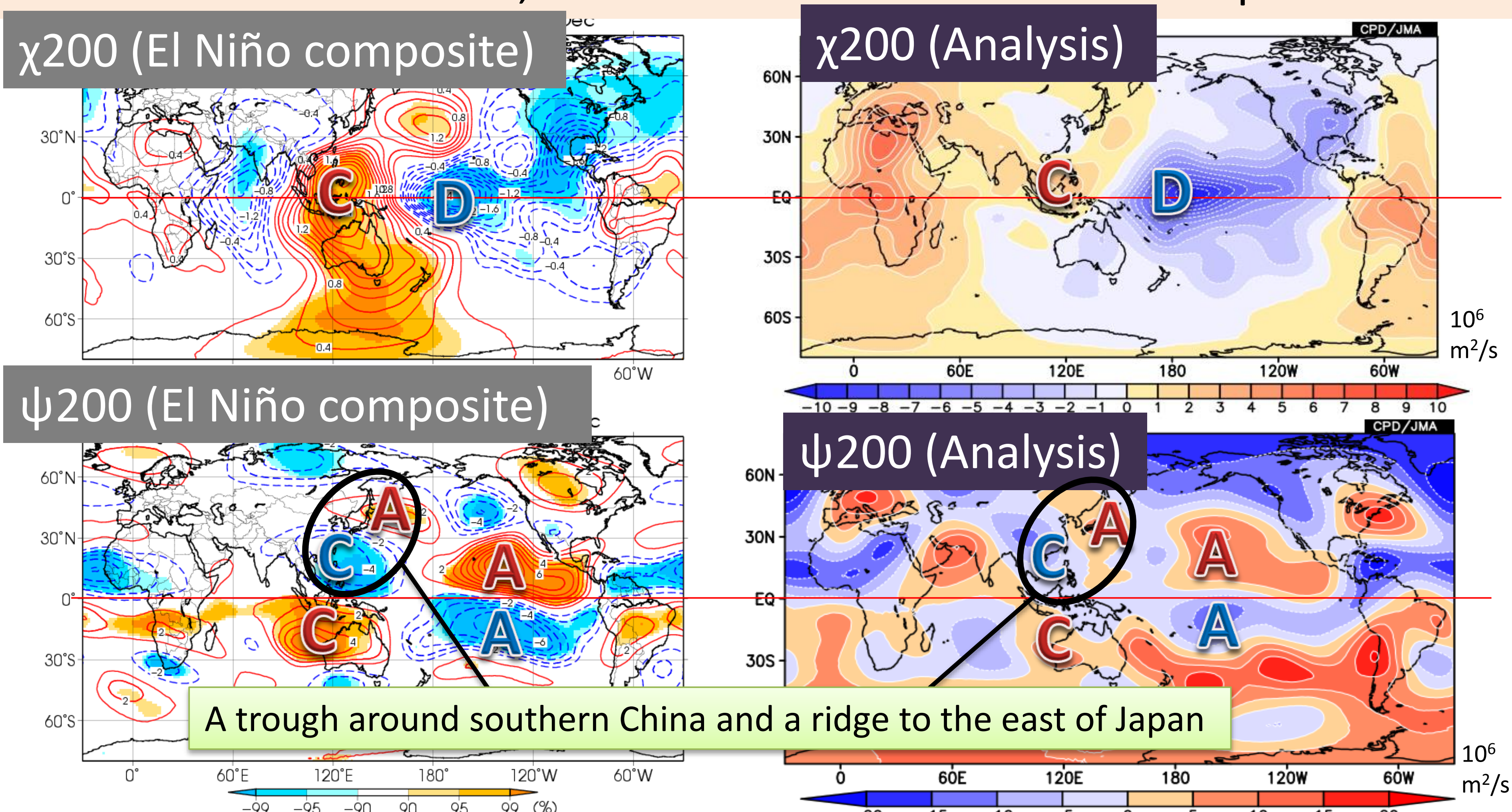


Fig.6 El Niño composites for December (Top left: χ200, Bottom left: ψ200) and anomalies in December 2015 (Top Right: χ200, Bottom Right: ψ200).

Schematic –Weak winter monsoon in the first half of 2015/16 winter-

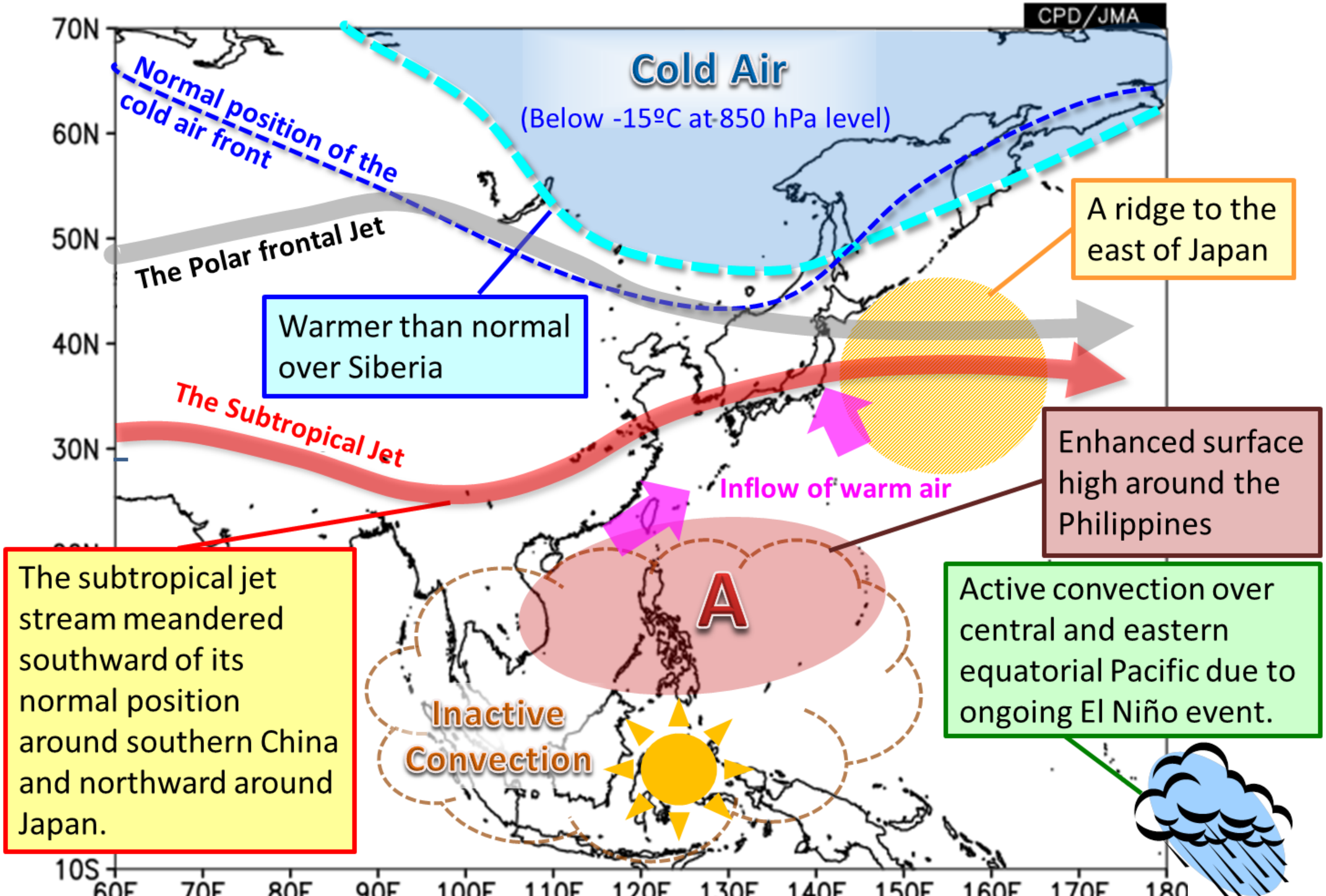


Fig.7 Schematic illustrating primary factors contributing weak winter monsoon in East Asia in the first half of 2015/16 winter.

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A cold surge event in late January 2016

Surface temp. anomalies 21st – 31st Jan 2016

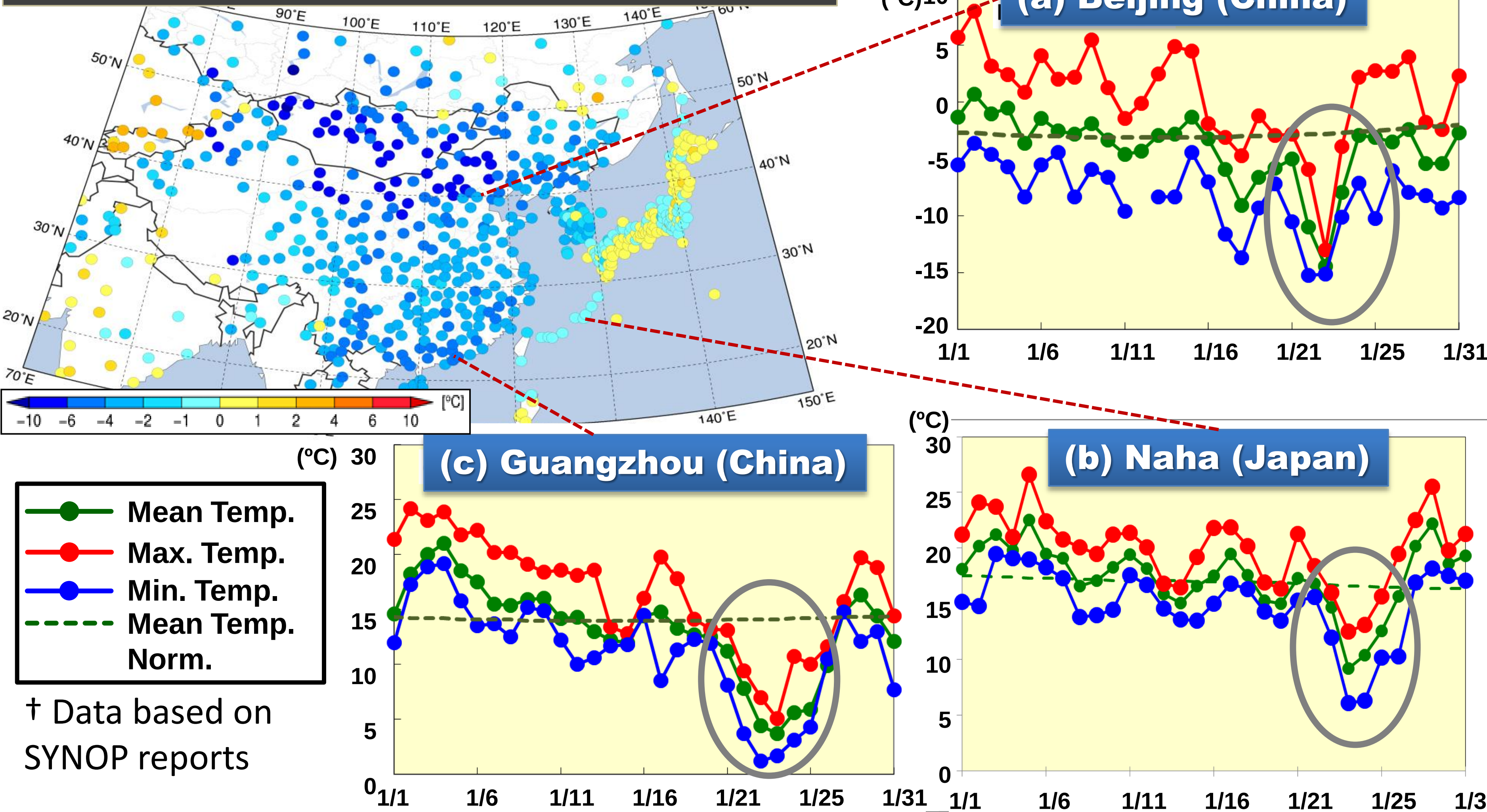


Fig.8 11-days mean temperature anomalies for 21 - 31 January 2016 (Top left). Time series of daily mean (green), maximum (red) and minimum (blue) temperature at (a) Beijing, (b) Naha and (c) Guangzhou. Green dashed lines are daily mean temperature normals.

Isentropic Analysis of Polar Cold Air Mass Stream

- Here, we define cold air mass as air between ground and ϑ=280K isentropic surface based on Iwasaki *et al.* (2014).

$$Cold\ air\ mass\ amount\ [hPa] = p(surface) - p(\theta = 280\mathrm{K})$$

The calculation program for the isentropic analysis was by courtesy of Prof. Iwasaki (Tohoku University).

- With this idea, we can diagnose the geographical distribution of cold air stream quantitatively.

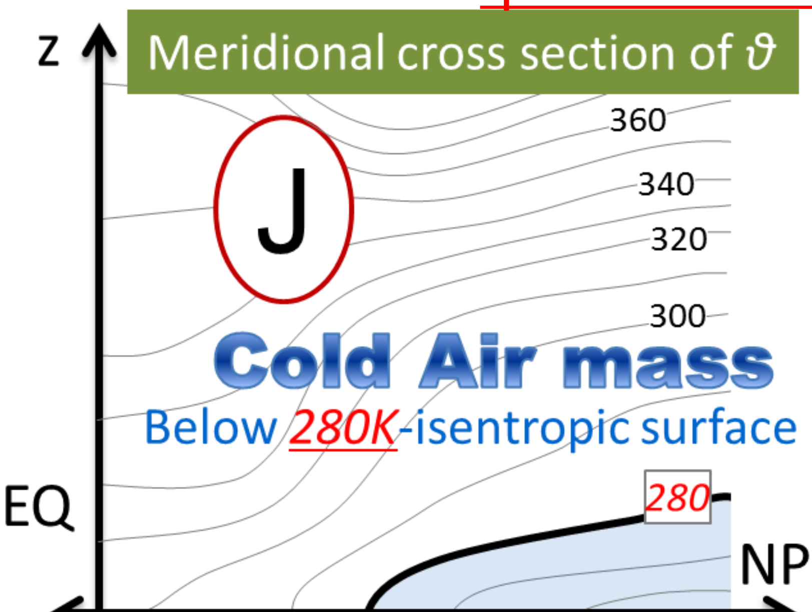


Fig.9 Schematic of meridional cross section of potential temperature.

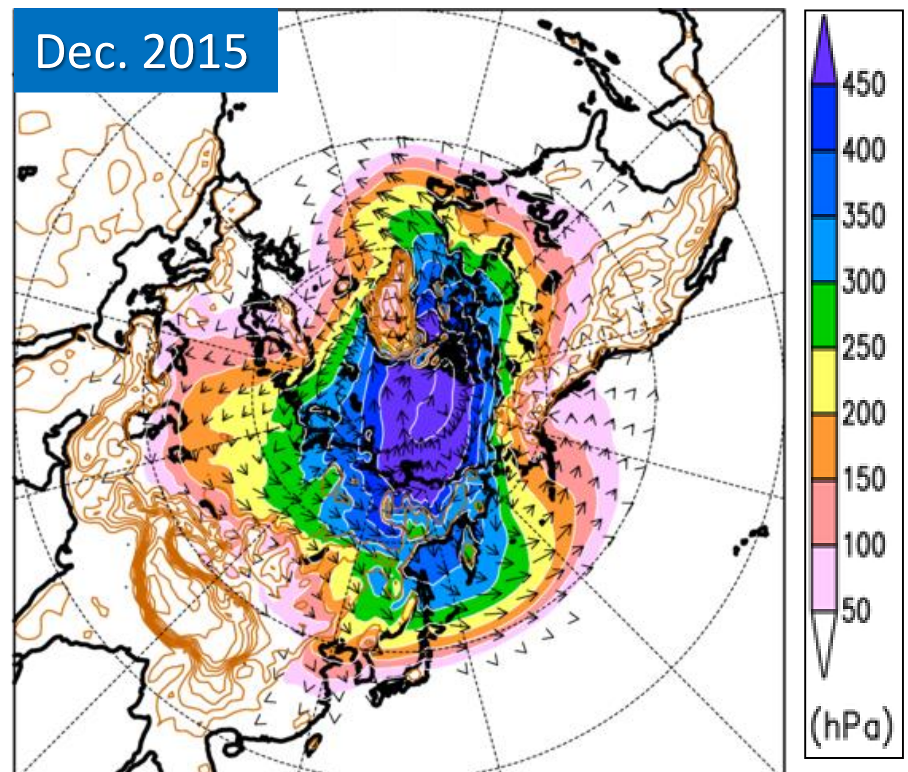


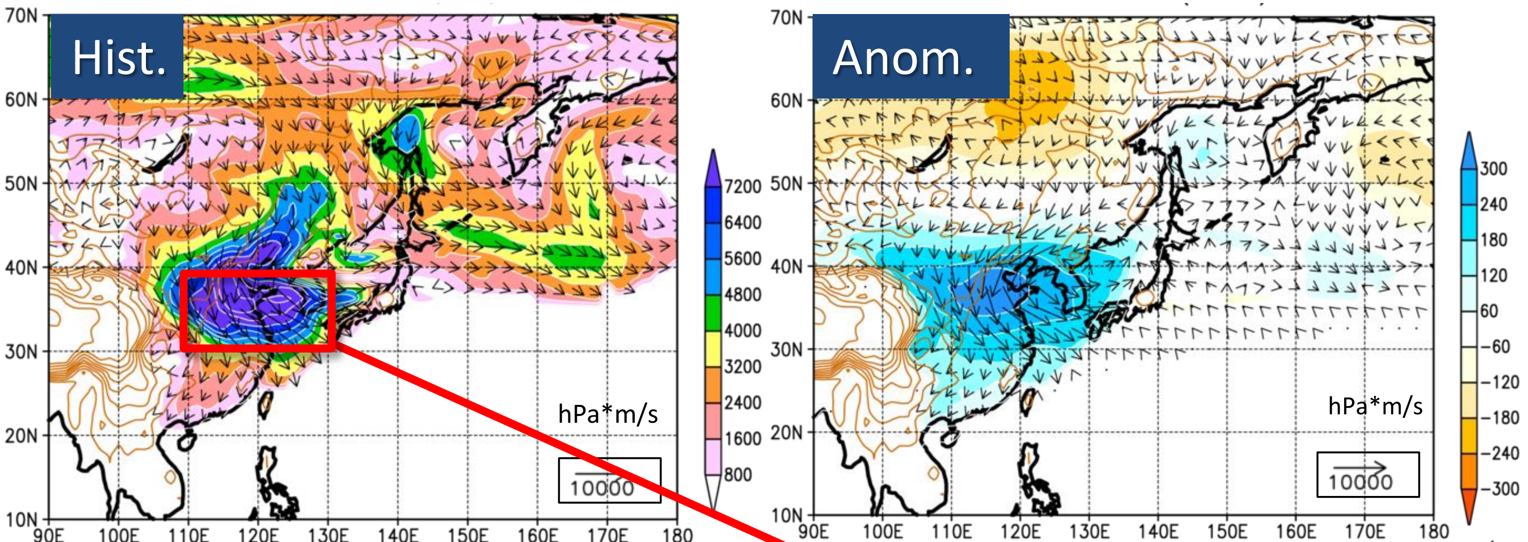
Fig.10 Cold air mass amount [hPa] in December 2015.

Isentropic Analysis of Polar Cold Air Mass Stream

- "Cold air mass flux" defined as mass-weighted wind velocity below ϑ=280K surface.

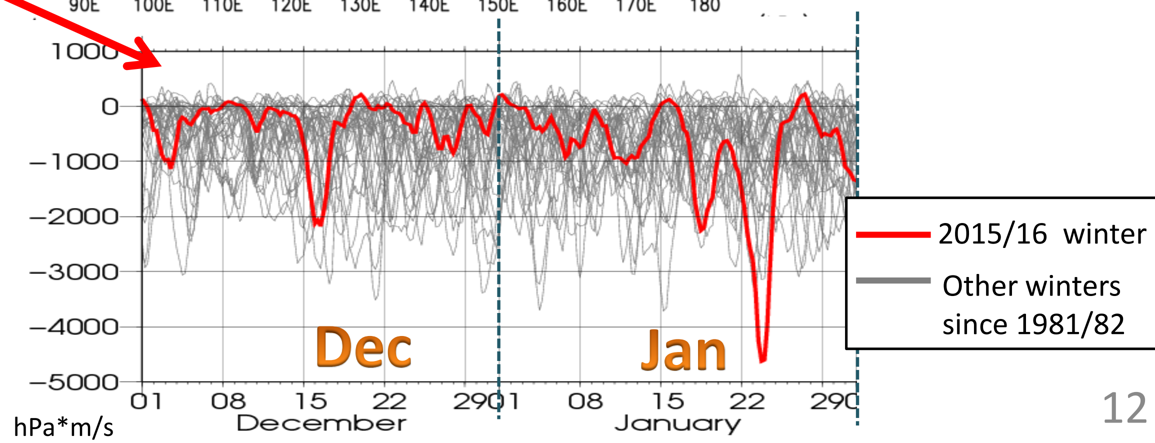
$$Cold\ air\ mass\ flux = \int_{p(\theta=280\mathrm{K})}^{p(surface)} \vec{V}\, dp$$

Cold air mass flux (vector) and its intensity (color) at 12Z 23rd Jan 2016



←Fig.11 Snapshot of cold air mass flux (vector) and intensity (color) at 12Z 23rd Jan 2016 (left) and its anomalies (right).

→Fig.12 The time series of meridional component of cold air mass flux averaged in latitude/longitude box of 30ºN-40ºN by 110ºE-130ºE. Red line indicates 2015/16 and gray lines are for the other winters since 1981/1982.



Isentropic Analysis of Polar Cold Air Mass Stream

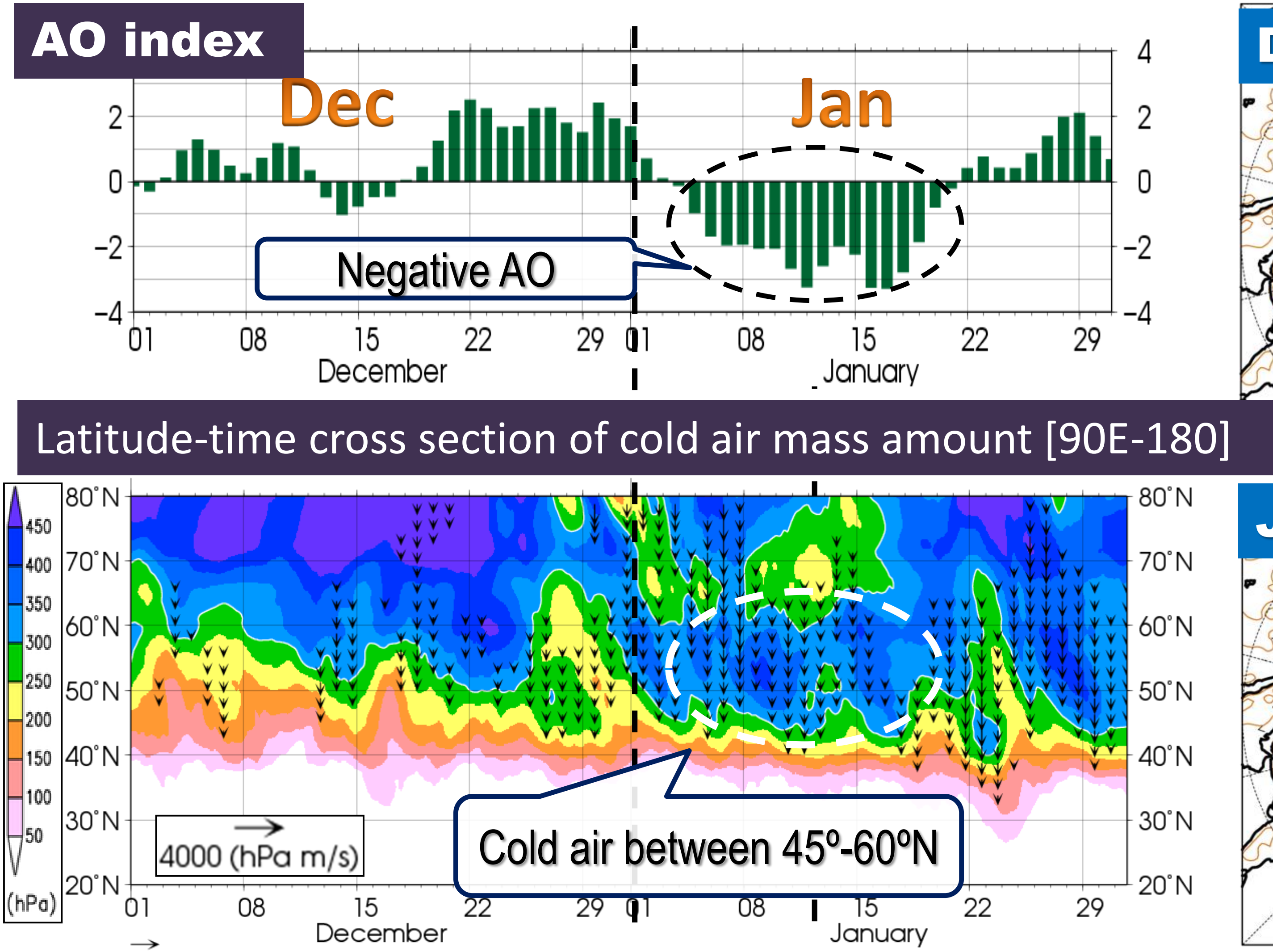


Fig.13 Time series of AO index (top) and time-latitude cross section of cold air mass amount and its meridional flux averaged between 90E and 180 (bottom) .

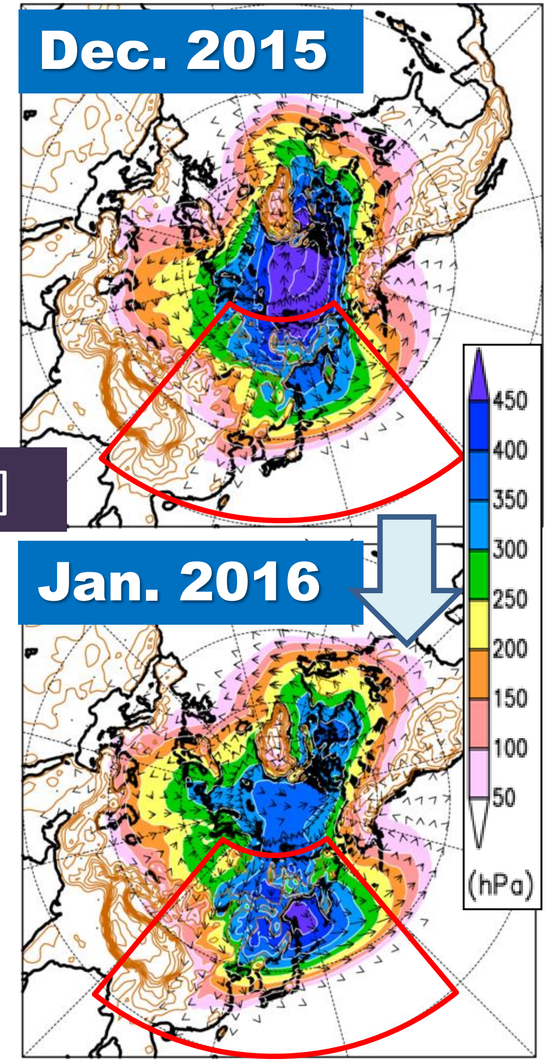


Fig.14 Monthly mean of cold air mass amount [hPa] in December 2015 (top) and January 2016 (bottom).

Time Evolution of the Siberian High

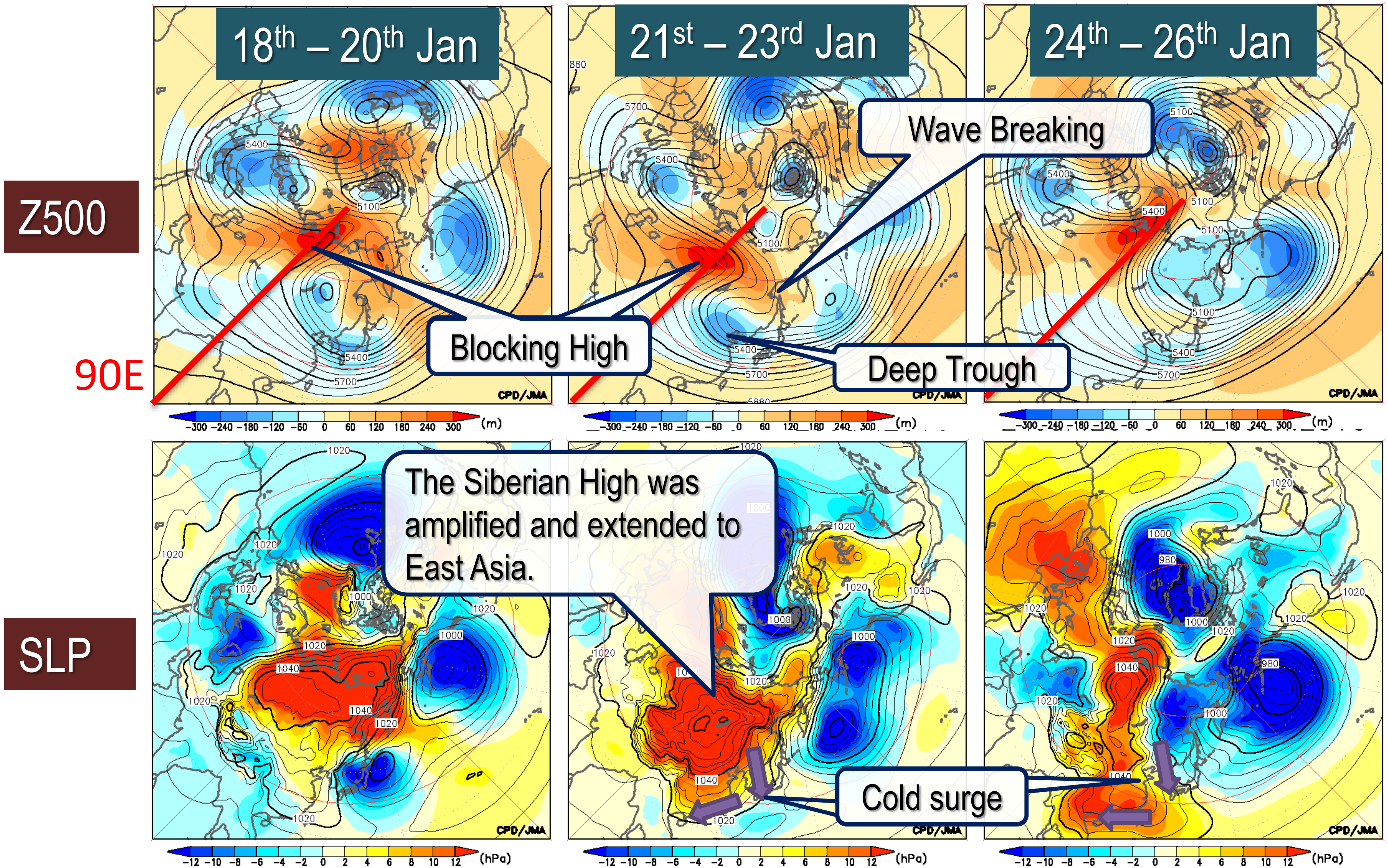
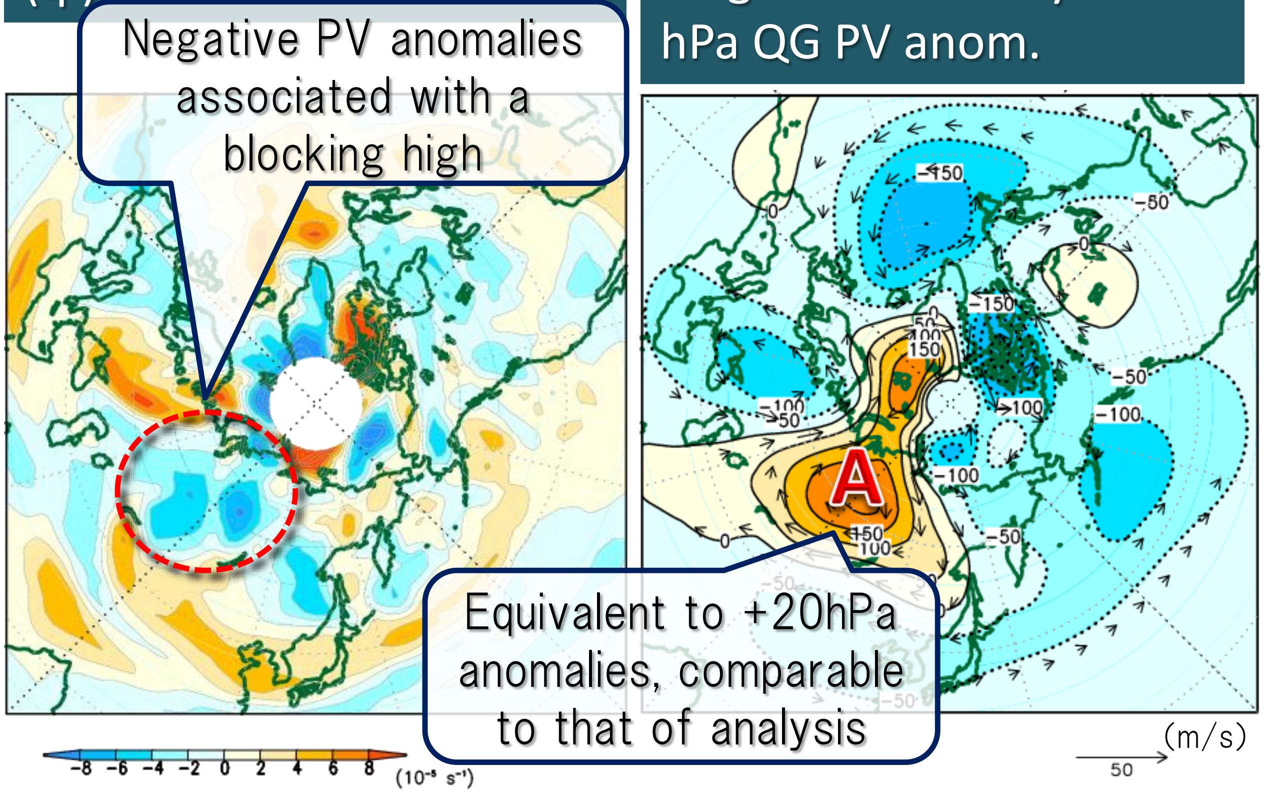


Fig.15 3-day mean of Z500 (upper panels) and SLP (lower panels) in 18th – 20th Jan 2016 (left), 21st – 23rd Jan 2016 (middle) and 24th – 26th Jan 2016 (right).

QG PV inversion (21st - 25th Jan. 2016)

(a) 300-hPa QG PV anom. (q’)

(b) Anomalous 1000-hPa height induced by 300-hPa QG PV anom.



General concept†

QGPV anom. ψ anom.

$$\boxed{q' = L_g(\psi')}$$

Laplacian-like operator

$$L_g \equiv \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{f_0^2}{\rho_0}\frac{\partial}{\partial z}\left[\frac{\rho_0}{N^2}\frac{\partial}{\partial z}\right]$$

Inversion

Log-P coordinate

$$z = -H \ln\left(p[\mathrm{hPa}]/1000\right)$$

H: a constant scale height

$$\boxed{\psi' = L_g^{-1}(q')}$$

Fig.16 (a) 5-day mean anomalies in 300-hPa QG PV (Quasi-geostrophic potential vorticity) anomalies for 21st - 25th January 2016 (left), (b) anomalous 1000-hPa geopotential height induced by 300-hPa QG PV anomalies (middle). Color indicates anomalies in each panel and vectors in (b) are 1000-hPa wind anomalies.

† See Takaya and Nakamura (2005) for details of the PV inversion technique and the mechanism of amplification of the Siberian High.

The calculation program was by courtesy of Prof. Nakamura (RCAST, The University of Tokyo).

Concluding Remarks

- The first half of this winter: Weak monsoon
  - Matured El Niño event contributed to the meandering of the subtropical jet stream which weaken winter monsoon.
  - Rossby wave propagation along with the subtropical jet stream enhanced that meandering.
  - Cold air tended to be trapped within the polar region associated with the positive AO.
- January 2016: A cold surge in late of the month
  - Cold air broke out of the polar region associated with the negative AO.
  - The Siberian High was amplified associated with an upper-level blocking high over Central Siberia to bring a cold surge in East Asia.

References

- Iwasaki, T., T. Shoji, Y. Kanno, M. Sawada, M. Ujiie, and K. Takaya, 2014: Isentropic analysis of cold air mass stream in the Northern Hemispheric winter. *J. Atmos. Sci.*, **71,** 2230-2243, doi:10.1175/JAS-D-13-058.1.
- Takaya, K., and H. Nakamura, 2005: Mechanisms of intraseasonal amplification of the cold Siberian high. *J. Atmos. Sci.*, **62,** 4423-4440, doi:10.1175/JAS3629.1.

Schematic –Cold surge event in late January-

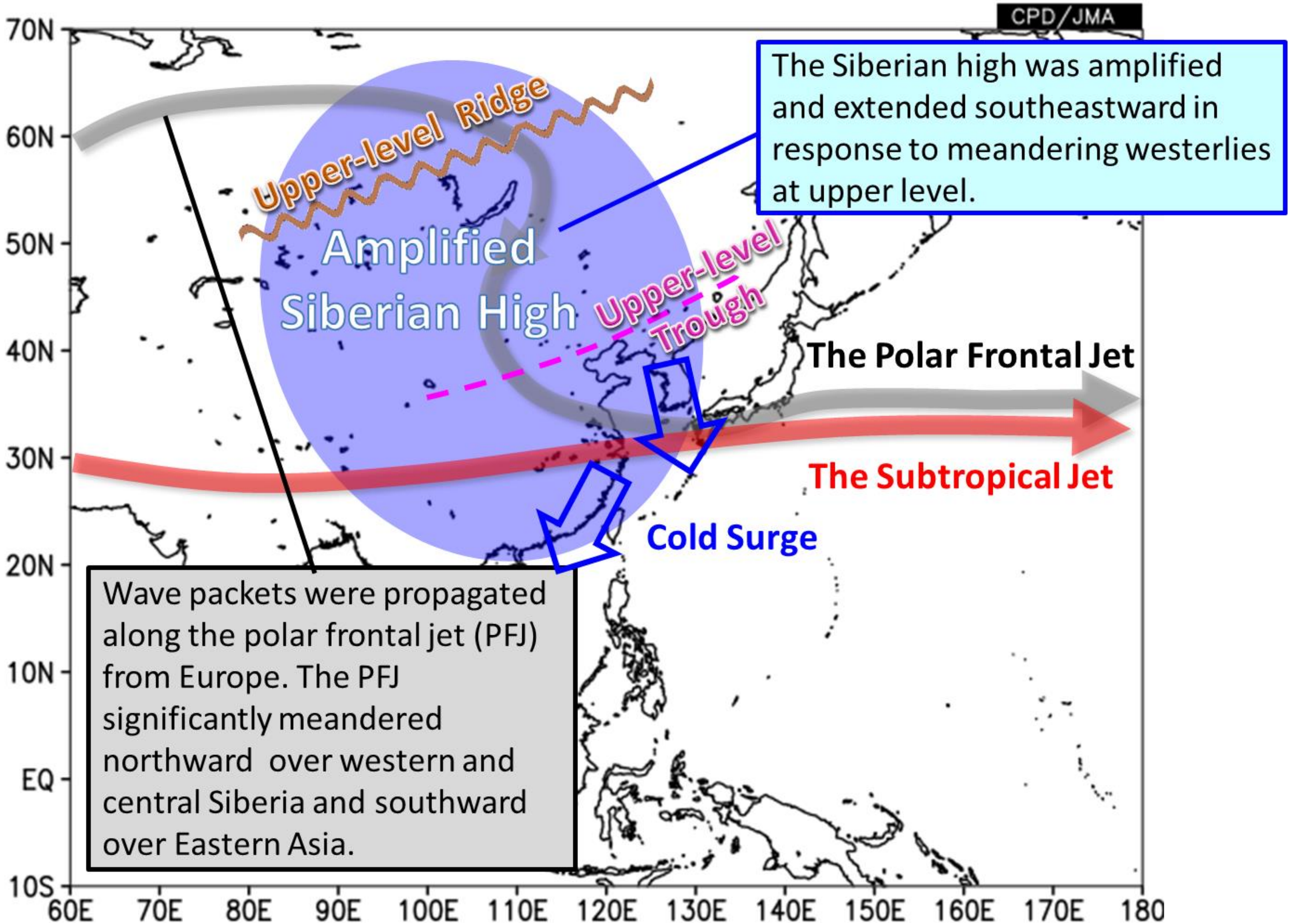


Fig.X Schematic illustrating primary factors contributing a cold surge in East Asia in late January 2016.