Cooling of the wintertime Arctic stratosphere induced by the Western Pacific teleconnection pattern

Kazuaki Nishii (1), Hisashi Nakamura (1), Yvan J. Orsolini (2)

1) Graduate School of Science, The University of Tokyo, 2) Norwegian Institute for Air Research (NILU), Norway (orsolini@nilu.no)

Western Pacific (WP) pattern

- Dominant teleconnection pattern in the wintertime troposphere, with substantial impact on weather and climatic conditions over the Far East and North Pacific, including storm-track activity and cold-air outbreaks [*Nakamura et al.*, 1987]
- Meridional dipole of anomalies over the Far East and North Pacific
- In positive phase, a blocking-flow configuration tends to occur more frequently over the North Pacific

Stratospheric influence of the WP pattern

- *Orsolini et al.* [2009] revealed that an extremely cold Arctic stratosphere (and elevated Polar Stratospheric Clouds volume) tends to follow a tropospheric event of the positive WP pattern that occurs about one month earlier.
- This occurs in correlation with the reduction of upward injection of planetary-wave activity into the stratosphere
- The aim of this study is to present typical daily evolution of the positive WP pattern and the subsequent cooling in the Arctic stratosphere through composite analysis. We also perform a case study for the 1995/96 winter.
- A mechanism is proposed from a viewpoint of interactions between the climatological-mean planetary waves and an anomalous Rossby wave packet.

Method and data

- The Japanese 25-year Reanalysis (JRA-25) [*Onogi et al.*, 2007] from 1979 through 2008.
- Anomalies are departures of the 8-day low-pass-filtered daily fields from the daily climatology.
- WP pattern is leading sectorial (20°N-70°N, 120°E-180°) EOF of monthly anomaly fields at 500-hPa (NDJFM) from 1979/1980 through 2007/2008.
- On the basis of the daily index, the 18 strongest positive events (> 3 std dev) have been selected.
- We estimated the heat flux anomaly ($[V^*T^*]_a$) from the low-pass-filtered fields of meridional wind velocity (V) and temperature (T) with a subscript a for anomaly. An asterisk signifies the eddy component and square bracket the zonal averaging.

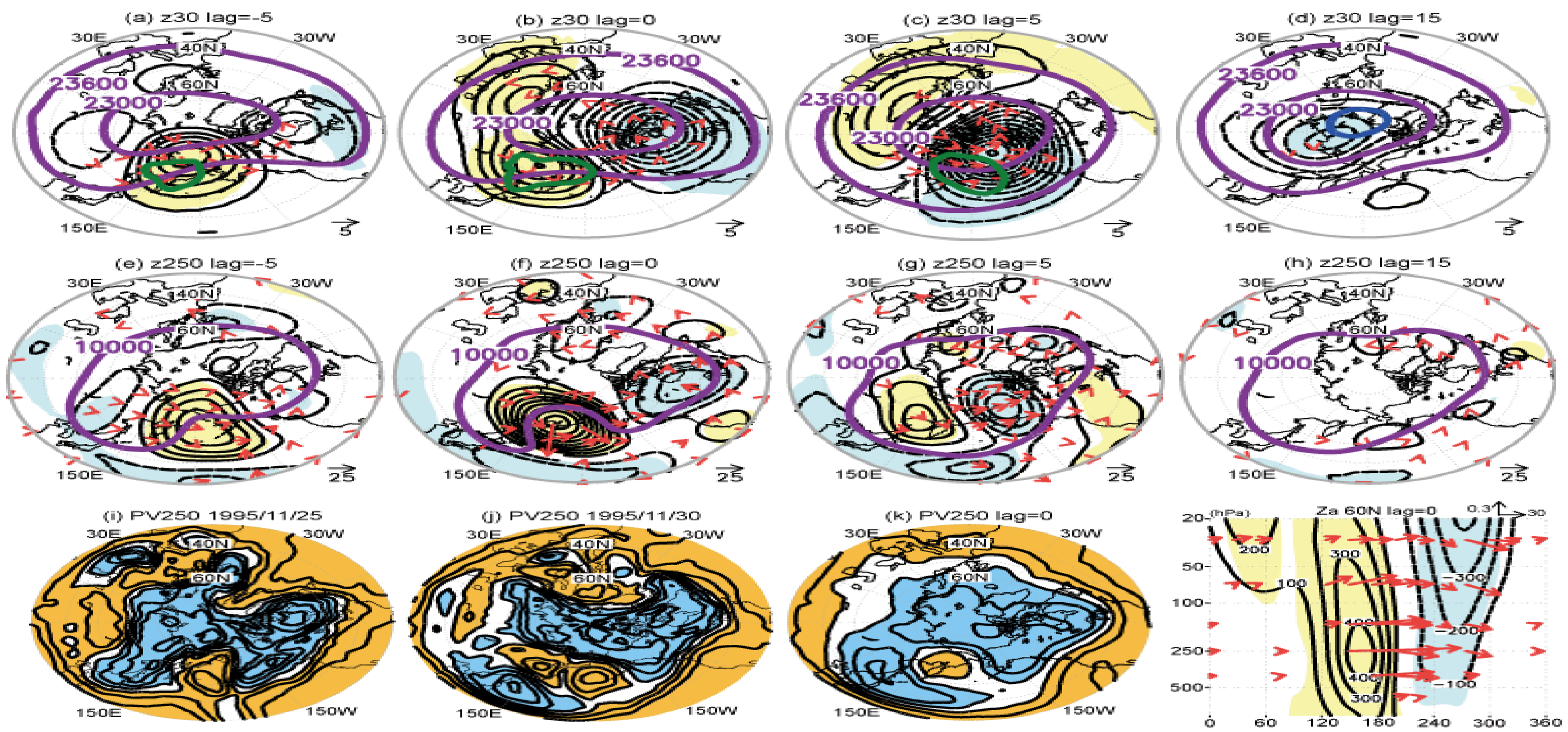

Figure 2. (a-d) Maps (poleward of 30°N) of 30-hPa height anomalies composited for the positive events of the WP pattern events (black lines) with lags of (a) -5, (b) 0, (c) +5 and (d) +15 days relative to the peak time. Contour interval is 50 m (dashed for negative). Yellow and blue shading denotes positive and negative anomalies. The composited 30-hPa height of 23000 and 23600m (purple lines) represent the total field. Arrows represent the 30-hPa horizontal component of Rossby wave-activity flux (unit; m²s⁻²), and its 100-hPa upward component exceeds 0.005 m²s⁻² within the areas encircled by green contours. In the area encircled by the blue contour in (d), 50-hPa temperature composited for the 8 events of the positive WP pattern observed in the October-January period is below 195 K. (e-h) As in (a-d), but for the 250-hPa height anomalies. Purple contours represent composited 250-hPa height of 10000m. (i) Ertel's potential vorticity observed at the 250-hPa level on November 30, 1995 (black; contour interval is 1 PVU) with blue shading for 4 PVU or higher and yellow shading for 3PVU or lower. (h) As in (i), but for PV composited for the peak times of the 18 positive WP events. (j) A zonal height cross-section of height anomalies composited for the peak times of the positive WP events along 60°N.

References:

Martius, O., L. M. Polvani, and H. C. Davies (2009, *Geophys. Res. Lett.*, *36*, L14806, doi:10.1029/2009GL038776.

Nakamura, H., M. Tanaka, and J. M. Wallace (1987), *J. Atmos. Sci.*, *44*, 3377-3391.

Nishii, K., H. Nakamura, and T. Miyasaka (2009), *Q. J. R. Meteorol. Soc.*, *135*, 39-52.

Orsolini, Y. J., A. Y. Karpechko, and G. Nikulin (2009),*Q. J. R. Meteorol. Soc.*, *135*, 1020-1029.

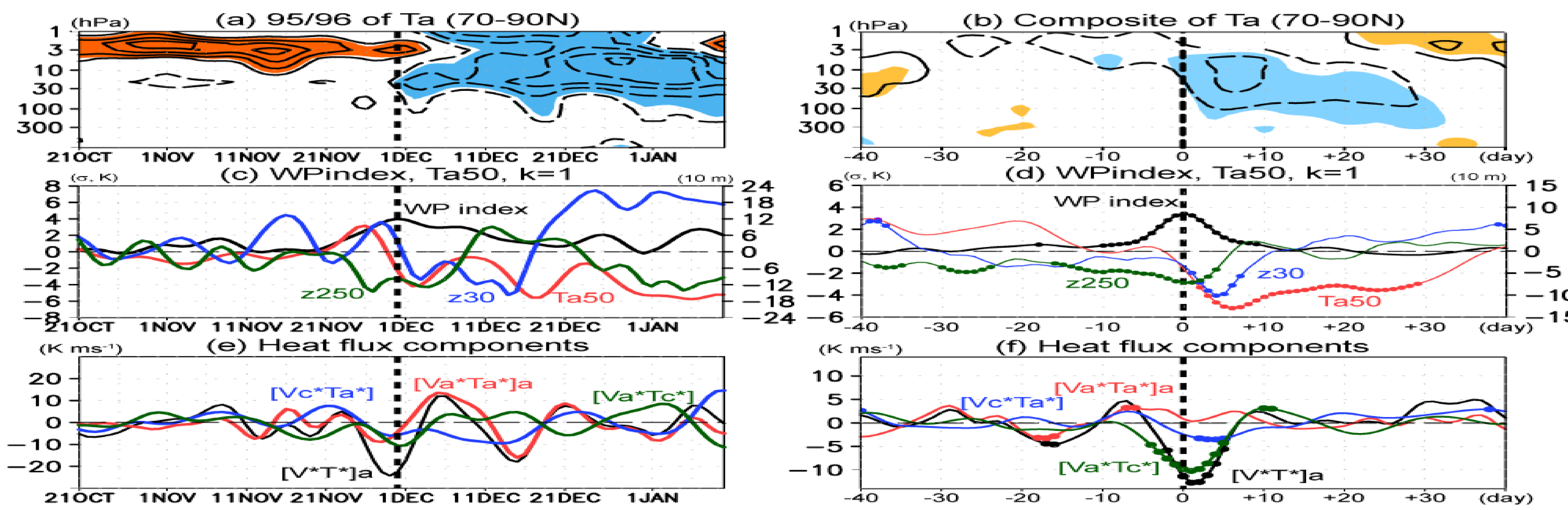

Figure 1. (a) Height-time section of temperature anomaly averaged over the Arctic (poleward of 70°N) from October 20, 1995 through January 10, 1996. Orange and blue shading exceed 4 K.(b) As in (a), but for the composite for the 18 positive WP pattern events. (c) Daily time series of the WP pattern index (black; left axis), 50-hPa temperature anomaly averaged over the Arctic (red; left axis), anomalous amplitude of the *k*=1 component in the 250-hPa height (green; right axis) and 30-hPa height (blue; right axis) along 50°N in the 1995/96 winter. (d) As in (c), but for the corresponding daily time series based on the composite for the positive WP pattern events. (e) Daily time series of 100-hPa eddy heat flux $[V^*T^*]$ (black), $[V_a^*T_c^*]$ (green), $[V_c^*T_a^*]$ (blue) and $[V_a^*T_a^*]_a$ (red) averaged poleward of 45°N (Kms⁻¹) for the 1995/96 winter. (f) As in (e), but for the corresponding time series based on the composite for the positive WP

Composite of strong events and a case study for the 1995/96 winter

- Compositing relative to the peak times of the individual events shows a height-time section of polar temperature anomalies similar to the corresponding evolution in the 1995/96 winter. This cold stratospheric anomaly persists for about one month
- In the composite evolution, the rapid stratospheric cooling occurs concurrently with a significant reduction in the upward flux of planetary wave activity at the 100-hPa level
- In the troposphere, the positive WP pattern accompanies a dipolar height anomaly pattern with an anticyclonic blocking ridge that evolves westward. This evolution corresponds to cyclonic breaking of the planetary-wave trough over the North Pacific, most striking in the PV maps.
- The high in the total planetary wave field is initially recognized as a poleward meander of geopotential height contours (purple). For the next five days, the high in the total field breaks down through its destructive interference with the westward-developing cyclonic *anomaly*. Although the stratospheric anomaly field is dominated by the *k*=1 component, its zonal phase is such that it weakens the total planetary wave field. The polar vortex thus becomes remarkably zonally symmetric under suppressed planetary-wave forcing, and correspondingly a cool anomaly develops rapidly in the Arctic stratosphere and persist for 1 month.

Conclusions

- A positive event of the WP pattern in winter can be a precursor for the one-month lasting polar stratospheric cooling (up to 6 K)
- It weakens upward propagation of planetary waves into the stratosphere through the destructive interference between the climatological planetary waves and wavy anomalies associated with the WP pattern
- This study confirms the findings in *Orsolini et al.* [2009], that monthly events of the largest PSC volume tend to be observed in the following months of the positive WP pattern.
- The daily evolution of the positive WP pattern is quite similar to the development of a blocking high over the Pacific. It presents a unique case where a blocking high can induce cooling in the polar stratosphere rather than warming. The positive contribution $[V^*_aT^*_a]_a$, which is consistent with a general tendency for blocking anticyclones to act as precursors of stratospheric sudden warming events (*e.g.*, *Martius et al.* [2009]), is here rather weak. As their unique dynamical characteristic, the contribution is overwhelmed by the destructive interference between the blocking anomaly and climatological-mean planetary waves.

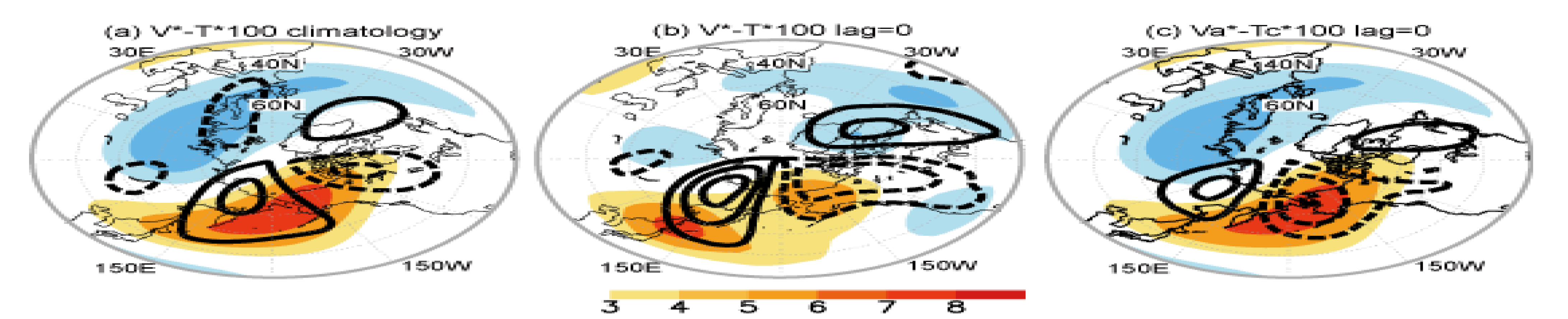

Figure 3. (a) Winter-mean (NDJFM) climatology of eddy components of 100-hPa meridional wind velocity (V_c^*; contoured for every 5 ms⁻¹; dashed for the northerlies) and temperature (T_c^*; shaded as indicated below if warmer and cooler, respectively, than the longitudinal average; interval: 2 K). (b) As in (a), but for the composite fields for the peak times of the 18 positive WP event. (c) As in (b), but for anomalous meridional wind (V_a^*) and climatological-mean temperature (T_c^*) that contribute to $[V_a^*T_c^*]$.

PP NILU 7-2010 YOr

KN and HN have been supported by the Japanese Ministry of Education, Culture, Sports, Science and Technology under the Grant-in-Aid for Scientific Research (A) #18204044 and #22340135 and also by the Global Environment Research Fund (S-5) of the Ministry of Environment.
YO has been supported by the Norwegian Research Council through the Nor-Clim collaboration.