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

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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 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 $[V_a^*T_c^*]_a$, 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.
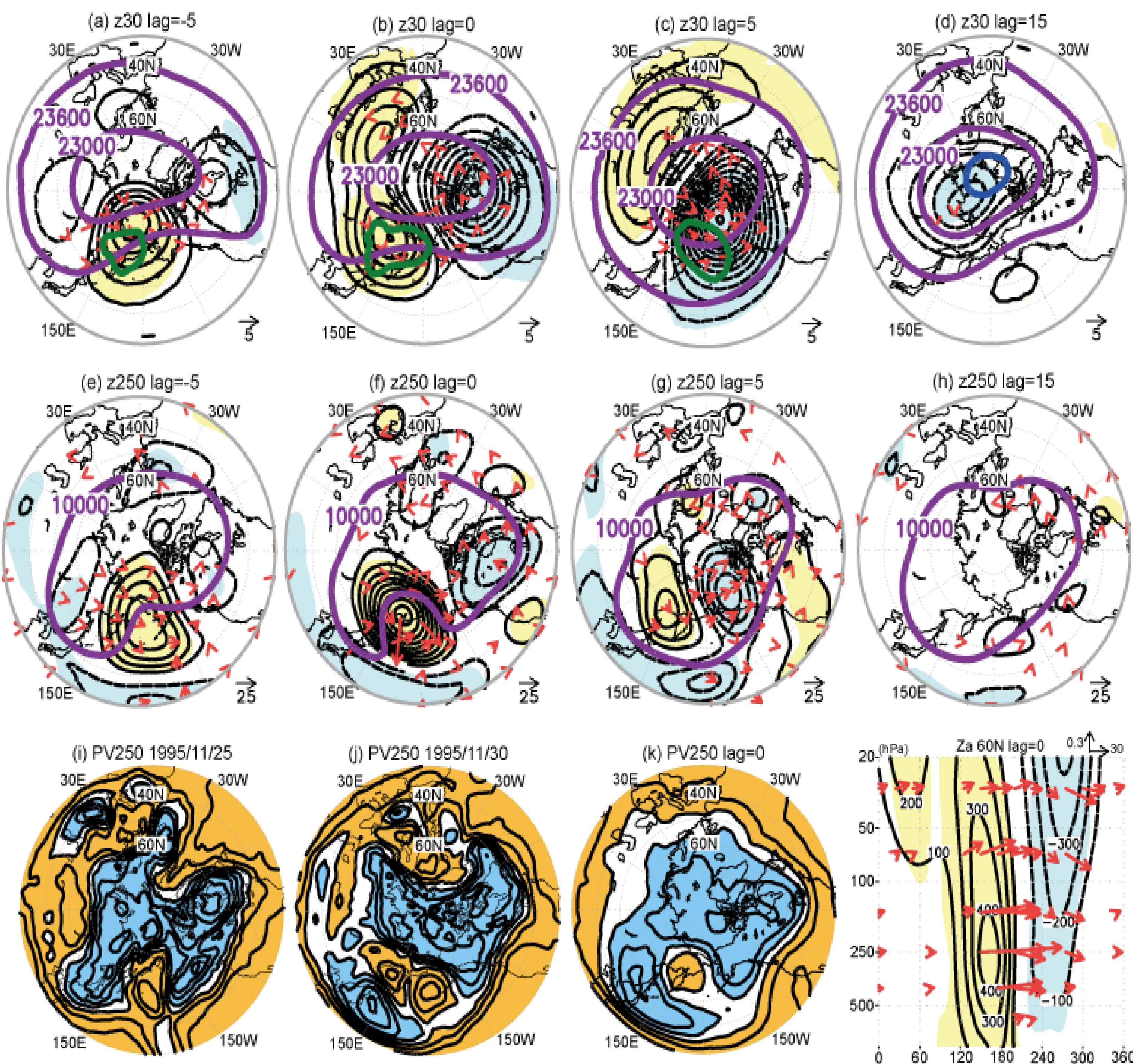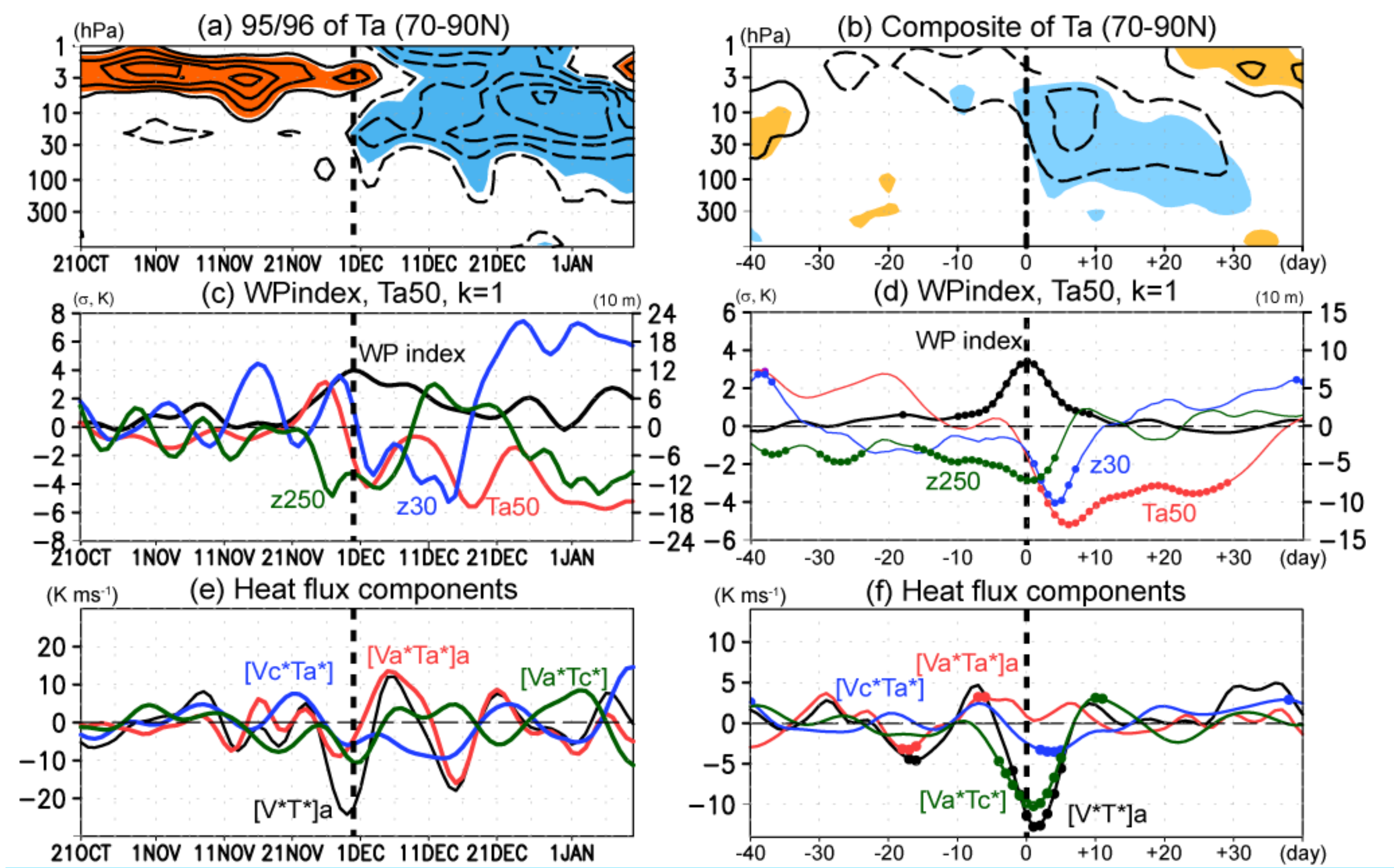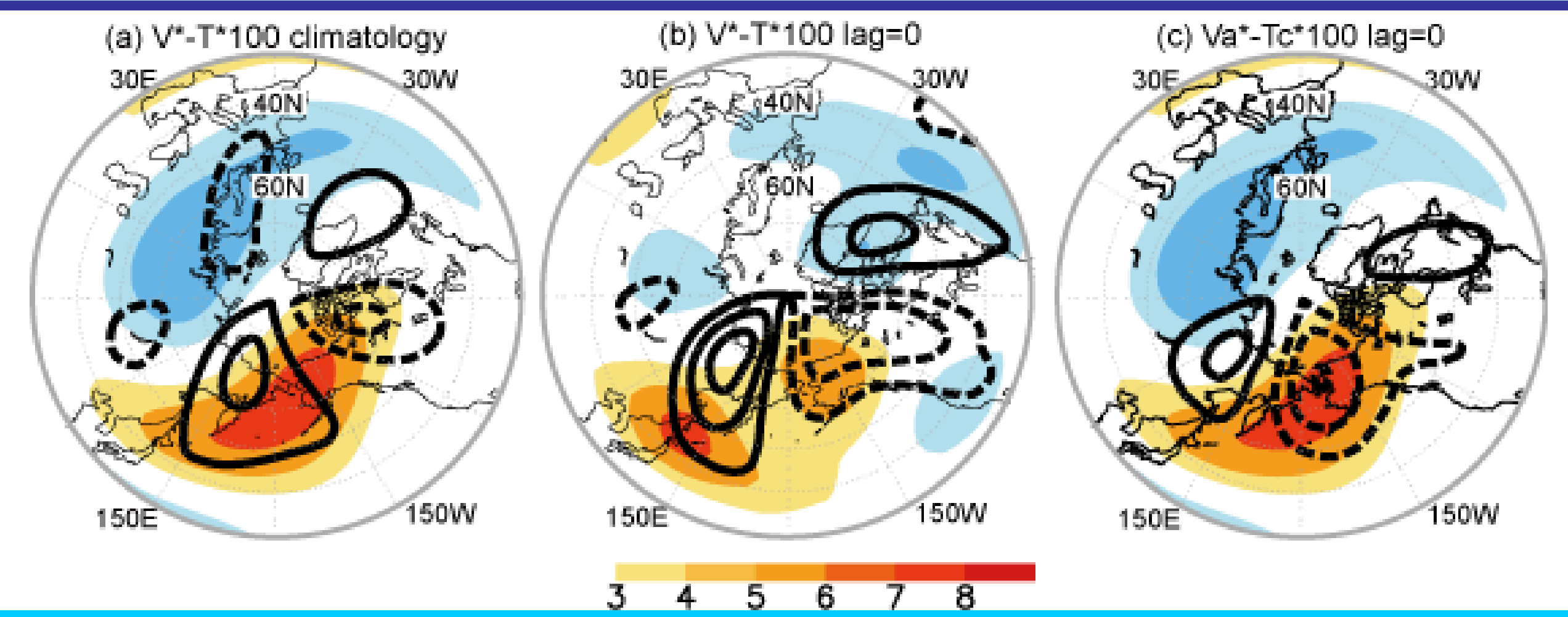

Figure 2. (a-d) Maps (poleward of 30°N) of 30-hPa height anomalies composited for the positive events of the WP pattern events (black lines) with lags of (a) -5, (b) 0, (c) +5 and (d) +15 days relative to the peak time. Contour interval is 50 m (dashed for negative). Yellow and blue shading denotes positive 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.

Figure 3. (a) Winter-mean (NDJFM) climatology of eddy components of the 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 $[V_a^*T_c^*]$.

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