Midlatitude westward propagating disturbances preceding intraseasonal oscillations of convection over the subtropical western North Pacific during summer

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[1] We start with an analysis of the abruptly enhanced convection over the subtropical western North Pacific (WNP) around late July, the so-called “convection jump,” and indicate that intraseasonal oscillations (ISOs) play a dominant role in this feature. Then, we analyze the extratropical circulation anomalies in association with the convection ISOs over the subtropical WNP, which are more common than the convection jump and thus provide a greater sample size. It is found that prior to convection ISO peaks, a well-defined wave train of alternating cyclonic and anticyclonic perturbations appears and propagates westward in the upper troposphere over the midlatitude North Pacific, and bends southward to the subtropical WNP. The present results imply that midlatitude circulation anomalies in the North Pacific may affect intraseasonal variability of climate in the subtropical WNP and East Asia during summer.


1. Introduction

[2] Ueda et al. [1995] revealed that atmospheric convection is enhanced abruptly over the subtropical western North Pacific (WNP) during late July, a feature that has been named “convection jump” [Ueda and Yasunari, 1996]. Concurring with this abrupt change, the subtropical ridge rapidly moves northward and covers Japan, marking the end of the Baiu rainy season there.

[3] The mechanisms responsible for the convection jump, however, remain as an open question. Ueda and Yasunari [1996] suggested that the interaction between the atmosphere and ocean in the WNP induces the convection jump. On the other hand, Sato et al. [2005] proposed that upper cold lows contribute to the convection jump, based on composite results of three typical convection jump cases.

[4] Intraseasonal oscillations (ISOs), particularly those in the subtropical WNP, may contribute significantly to the convection jump. Actually, ISOs are pronounced over the subtropical, as well as tropical, WNP during summer [Lau and Chan, 1988; Ren and Huang, 2003]. However, previous studies have focused on tropical ISOs over the WNP. Wu and Wang [2001] showed that in the climatology, the multi-stage onset of the summer monsoon over the WNP is related to ISOs. Lu et al. [2005] suggested that the 30–60-day oscillations over the Philippine Sea partly contribute to the interannual variation of the convection jump. Unfortunately, an understanding of the convection ISOs over the tropical WNP may not be essentially helpful for subtropical ISOs, since the northward propagation of convection ISOs is generally confined to the tropics over the WNP, or more exactly, south of 20°N [Lau and Chan, 1986; Hsu and Weng, 2001]. Although tropical ISOs have been extensively studied, their subtropical counterparts have been less well documented.

[5] In this study, we first demonstrate that subtropical ISOs contribute greatly to the convection jump, and then investigate the roles of midlatitude circulation disturbances in the ISOs of convection over the subtropical WNP.

2. Data and Analysis Procedure

[6] We use the daily data of outgoing longwave radiation (OLR) and wind for the 26 years from 1979 to 2004. The OLR data are from the National Oceanic and Atmospheric Administration (NOAA), and the wind data are from the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR) reanalysis dataset.

[7] We focus on OLR variation over the region (15°–25°N, 150°–160°E), which was called a key region by Ueda and Yasunari [1996]. A convection jump is defined when the OLR averaged over the key region during two successive pentads (Pn and Pn+1) first becomes lower than 230 W/m² during summer (June to August) of each year. Here, Pn is defined as the time of the convection jump. Averaging over two successive pentads, which is also similar to Ueda and Yasunari [1996], removes the effects of synoptic disturbances. However, there is a major difference in definition between the present study and that of Ueda and Yasunari [1996]. The time of convection jump is fixed to the 42nd pentad by Ueda and Yasunari [1996], while it is flexible with years in our study. It will be shown in the next section that the convection jump happens at quite different times from year to year.

[8] In this study, we obtain the 10–90-day component for each year by applying a band-pass filter to the annual cycle-removed daily anomalies. The annual cycle for each year is defined by the sum of the annual mean and the first three harmonics at each grid point. We perform a lead-lag
regression analysis by an approach similar to that of Zhou and Chan [2005] to investigate the evolution of ISOs. For this purpose, a reference time series is defined by the normalized time series of the 10–90-day filtered OLR averaged over the region (15°–25°N, 150°–160°E), over a time span from 50 days before to 50 days after the date of the convection jump. The jump date is defined by the first day of the jump pentad, and there are 24 convection jump events in 26 years (see next section). Therefore, the length of the reference time series is 2424 (101 × 24) days. We have performed regression analyses with different lengths of reference time series and found that the results are not sensitive to the length. The 2424 samples are not independent, and they are highly auto-correlated. Thus, the equivalent sample size is used to evaluate the statistical significance [Davis, 1976]. For the present results, equivalent sample sizes range generally from 500 to 900, dependent on grids and elements.

3. Results

[9] Figure 1 shows the time of convection jumps in individual years. A convection jump event happens in each year according to our criterion, except 1987 and 1995. This indicates that the convection jump is a typical phenomenon over the subtropical WNP during summer. The average jump time in the 24 summers analyzed is Pentad 42.1, which is consistent with Ueda and Yasunari [1996], who fixed the jump time to Pentad 42. However, the jump time exhibits a clear interannual variability, ranging from Pentad 34 to Pentad 49, with the standard deviation being 3.7 pentads. Figure 1 also shows that the jump time is earlier than Pentad 43 in all the “typical years” of Ueda and Yasunari [1996], while it is later than Pentad 43 in all the “untypical years,” except 1987 in which no convection jump is identified.

[10] Figure 2 shows the composite OLR ISO evolution associated with the 24 convection jump events. Here, Pentad 0 represents the jump time, and minus and plus numbers at the ordinate indicate the pentads before and after the jump time, respectively. The active convection phase of ISO begins at Pentad 0 and ends at Pentad 3. This active convection phase concurs with the rapid convection enhancement over the key region, which is indicated by the abrupt poleward shift of the composite OLR contour line of 230 W m⁻² from around 10°N to 25°N. In fact, when we define this abrupt change of OLR as the difference between the average for Pentads 0 to 1 and Pentads -2 to -1, 75% of the change is accounted for by the 10–90-day component. This indicates that ISO contributes greatly to the convection jump.

[11] Figure 3 shows the results of a regression analysis on horizontal winds at 200 hPa, by using 10–90-day filtered OLR averaged over the region (15°–25°N, 150°–160°E) as a reference time series. At 9 days before the ISO peaks, there is a well-defined wave train of alternating cyclonic and anticyclonic perturbations in the midlatitude North Pacific (Figure 3a). Subsequently, the wave train propagates westward (Figures 3b–3d) at a phase speed of about 2 degrees per day or 1.8 m s⁻¹. The westward propagating disturbances somewhat resemble the extratropical wintertime westward-traveling patterns identified by previous studies.

Figure 1. Time of convection jump in individual years, shown in pentad numbers. No convection jump event is identified in the summers of 1987 and 1995.

Figure 2. Latitude-time section of composite OLR ISO averaged over 150°–160°E, based on the convection jump cases. Pentad 0 represents the pentad of convection jump. Contour interval is 5 W m⁻², and the contour line of zero is omitted. Solid and dashed lines represent positive and negative contours, respectively. The contour line of 230 W m⁻² for composite pentad mean OLR (thick line) is also given.
Branstator, 1987; Kushnir, 1987; Lau and Nath, 1999]. Lau and Nath [1999] revealed that the behavior of the wintertime westward-traveling patterns is in essence governed by Rossby wave dynamics. The resemblance between summer and winter westward-traveling patterns implies that the summer wave train might also be governed by Rossby wave dynamics. In fact, the wavenumber of the westward-traveling wave train in summer (about 4–5) is smaller than the stationary Rossby wavenumber over the Pacific (6–7), which is in agreement with the nature of Rossby waves.

This wave train bends to the south, when it propagates toward the WNP. The cyclonic disturbance centered east of the central Japan at day −9 shifts southward and westward, and locates south of Japan at days −3 and 0. The shift in a southward direction can be more clearly seen in the time-latitude sections (not shown). When this cyclonic disturbance shifts toward the subtropical WNP, there appears a convection enhancement over the key region (Figures 3c and 3d). This relationship between the cyclonic disturbance and convection enhancement over the subtropical WNP has been found in previous studies [Sakamoto and Takahashi, 2005; Sato et al., 2005]. These previous studies suggested that upper-tropospheric lows induce a convection enhancement southeast of the lows. In Figure 3, the region of convection enhancement also locates southeast of the cyclonic disturbance, consistent with the previous studies. Furthermore, there is a significant 200-hPa divergence anomaly over the key region (Figure 4). This divergence anomaly, together with the plentiful moisture over the subtropical WNP, may facilitate a convection enhancement.

The westward-traveling disturbances shown in the present results are different from the following aspects given by Sato et al. [2005], who showed that an upper cold low, recognized as a large-scale high-potential vorticity (PV) air mass, stretches westward from the eastern Pacific. The disturbances propagate westward in the midlatitude North Pacific in our results but along the subtropical North Pacific in the work of Sato et al. [2005]. Furthermore, these disturbances are related to ISOs in our results, while they are related to seasonal marching in the work of Sato et al. [2005]. The phase speeds of westward propagation are about 2 degrees per day in the present analysis. However, in the work of Sato et al. [2005, Figure 4], the wave-like pattern appears as a stationary wave with westward energy propagation at a speed of about 3 degrees per day.
4. Summary

This study has shown that ISOs play a dominant role in the abrupt convection enhancement over the subtropical WNP during late July, the so-called "convection jump." The jump time exhibits a clear interannual variability, ranging from Pentad 34 to Pentad 49 during 1979–2004, with the standard deviation being 3.7 pentads, which likely results from the year-to-year difference in ISOs [Lu et al., 2005].

Then, we investigated the composite upper- and lower-tropospheric circulation anomalies associated with the ISOs of convection over the subtropical WNP. The convection ISOs are a more common phenomenon, in comparison with the convection jump, and thus can provide a greater equivalent sample size for analysis. Prior to convection ISO peaks, a well-defined wave train of alternating cyclonic and anticyclonic perturbations appears and propagates westward in the upper troposphere over the midlatitude North Pacific, and bends to the south when it propagates toward the WNP. On the other hand, the lower-tropospheric circulation anomalies over the subtropical WNP seem to be a result of the convection ISOs over the key region.

Many questions remain. Are there any differences in dynamical processes between the summertime and winter-time westward-propagating disturbances? Why does the summertime wave train bend to the south over the WNP? Are the westward-propagating disturbances affected by the tropical and subtropical convection over the Pacific? The answers to these questions would be potentially helpful for the forecasting of intraseasonal variability in the East Asian climate during summer.

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References


Figure 5. Same as Figures 3b–3d, except for 850-hPa horizontal winds. The blank boxes indicate the location of centers of corresponding 200-hPa cyclonic/anticyclonic anomalies.
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