Workshop on Modelling Monsoon Intraseasonal Variability, First meeting of the YOTC Task Force on the Madden Julian Oscillation, And 10th Session of the Asian-Australian Monsoon Panel (AAMP10)

Intraseasonal Oscillation in the Western North Pacific – An Inseparable Component of the Multiscale System

Huang-Hsiung Hsu

Department of Atmospheric Sciences, National Taiwan University, Taipei, Taiwan

Abstract

Intraseasonal oscillation in the western North Pacific (WNP ISO), which is most active during the boreal summer, is characterized by northwestward propagation from the tropical Philippine Sea to toward East Asian coast. The WNP ISO is intertwined with the fluctuation of monsoon trough and subtropical anticyclonic ridge in the region. Our recent studies identified a submonthly wave pattern, which usually couples with recurving tropical cyclone and moves northwestward toward Taiwan and Japan in the Philippine Sea. Such a TC/submonthly wave pattern is much more active during the westerly (convective) phase of the WNP ISO while poorly organized and inactive during the easterly phase. The devastating Typhoon Morakot, which produced record-breaking rainfall in Taiwan in early August 2009, developed in such an environment. While the WNP ISO has a strong clustering effect on the genesis and development of tropical cyclone, the clustered tropical cyclone in turn contributes significantly to the intraseasonal variability. One of our studies demonstrated that tropical cyclone contributes 40-50 percent of intraseasonal variance. Our calculation also indicates that tropical cyclone contributes positively and significantly to the kinetic energy conversion between the ISO and synoptic-scale disturbances. Our studies indicate that the ISO is an inseparable component of the multiscale system in the Western North Pacific. Further understanding and improvement of the WNP ISO needs to consider the interaction between different scales ranging from TC to ISO.

1. Multiscale system – ISO, submonthly wave, and TC

The multiscale features include intraseasonal oscillations (ISO), northwestward-propagating submonthly wave patterns, and recurving tropical cyclones (TCs). A 7-30-day wave-like pattern that propagates north-northwestward from the northeast of Papua New Guinea, to the East China Sea was identified by Ko and Hsu (2006). For more than 70% of cases which reveal the wave-like fluctuation, recurving tropical cyclones are found to occur concurrently with the wave-like pattern. These recurving tropical cyclones are likely part of the wave-like pattern, and may not be regarded as isolated vortices (Figure 1).

Fig. 1

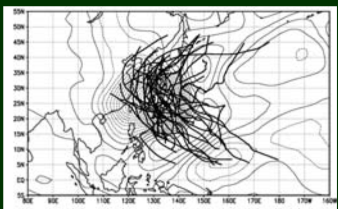

Figure 1 850 hPa composite filtered stream function (TC cases) at Day0 for July–August over 11 summers (1991–2001).

In the ISO westerly phase, the wave pattern was better organized and the TCs were clustered near the cyclonic circulation of the wave pattern during the genesis, development, and propagation (Figure 2). On the other hand, the wave pattern and TCs were weak and poorly organized in the ISO easterly phase. The distinct characteristics between the westerly and easterly phases could be attributed to the ISO modulation on the monsoon trough and the subtropical anticyclonic ridge. The ISO in the westerly phase provided a favorable background (e.g., enhanced monsoon trough and moisture confluent zone) for the wave–TC pattern development, while the ISO in the easterly phase provided a less favorable environment (Ko and Hsu 2009).

Fig. 2

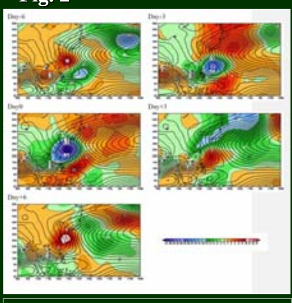

Figure 2. Composite maps of 7–30-day filtered 850-hPa streamfunction and the 30–80-day filtered streamfunction in the ISO westerly phase.

Fig. 3

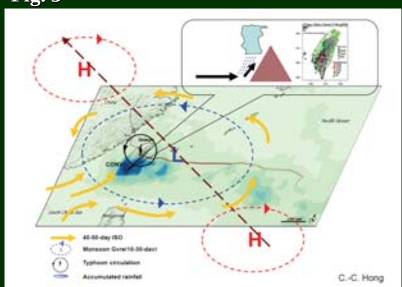

Figure 3. Schematic diagram showing the multiscale system that affected Typhoon Morakot.

2. An example – Typhoon Morakot

Typhoon Morakot struck Taiwan from 7-9 August 2009, causing record breaking rainfall (near 3000mm in three days) in Southern Taiwan and nearly 700 deaths from mudslides. Morakot's landing on Taiwan occurred concurrently with the arrival of a large-scale cyclonic circulation in a submonthly wave pattern (10-30-day) during the cyclonic phase of the 40-50-day ISO (Figure 3, Hong et al. 2010).

3. Upscale feedback of TC

The possible upscale feedback of TC to the intraseasonal variability can be estimated by calculating the differences between the original and TC-removed fields derived from the reanalyses, Hsu et al. (2008a) revealed that TCs contribute significantly (exceeding 50 percents in certain regions) to the intraseasonal variance of the 850 hPa vorticity along the TC tracks in the tropical Western North Pacific (Figure 4). While the intraseasonal large-scale circulation produces a clustering effect on TCs, the latter, which has a large positive vorticity and tends to occur in the positive vorticity background flow, significantly enhances the strength of the positive vorticity. The contribution from TCs, which is not offset by the synoptic systems with weak negative vorticity, can therefore leave marked footprints in the climate signal and variability. This effect is not removed by long-term averaging and low-pass filtering, which are often used to retrieve the climate perturbations. The TC effect has to be taken into account to understand the intraseasonal variability in the tropical Western North Pacific. Subsequently, the ensemble effect of TCs, at least in the statistical sense, has to be resolved in the climate model to obtain a better simulation of the climate variability in the TC-prone region, such as the tropical Western North Pacific.

Fig. 4

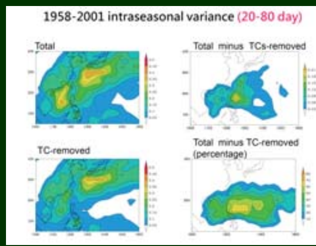

Figure 4. Intraseasonal (20-80 days) variance of 850-hPa vorticity in 1980-2001: (a) total, (b) TC-removed, (c) TC, and (d) TC contribution in percentage.

4. 2004 – A summer of active ISO-TC coupling

One of the strongest ISO-TC coupling events occurred in 2004. The repeated appearance of the ISO during JJASO resulted in the fluctuation of the EA monsoon trough and the Pacific anticyclone, which in turn modulated the TC activity and led to the spatial and temporal clustering of TC, and resulted in record-breaking 10 landfalls in Japan (Figure 5). While TC occurred in groups during the cyclonic phase of ISO, the clustering of these strong TC vortices significantly increases the overall amplitude of positive vorticity during the cyclonic phase of ISO and therefore increase variance by about 50 percents (Hsu et al 2008b). A comparison of barotropic energy conversion between original and TC-removed data indicates that the energy conversion from synoptic-scale perturbation in the tropical WNP was enhanced (little difference) during the cyclonic (anticyclonic) ISO phase (Figure 6).

Fig. 5

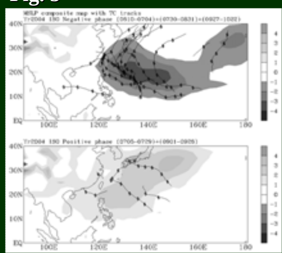

Figure 5. Composites of MSLP for (upper) three cyclonic phases and (lower) two anticyclonic ISO phases in JJAS 2004.

Fig. 6

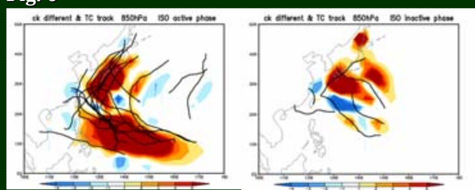

Figure 6. Difference of eddy-mean flow kinetic energy conversion between original and TC-removed 850 hPa fields during cyclonic (left) and anticyclonic (right) phase of ISO.

5. Conclusion

Our studies indicate that the ISO is an inseparable component of the multiscale system in the WNP. Further understanding and improvement of the WNP ISO needs to consider the interaction between different scales ranging from TC to ISO.

6. Reference

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