Possible feedback of tropical cyclone to climate variability

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1. Introduction

It has been know for a long time that the interannual and intraseasonal variation in the large-scale circulation can modulate the genesis and track of tropical cyclone. On the other hand, the possible feedback of tropical cyclone to climate variability has been hardly explored. In reality, the interaction among different spatial and temporal scales makes it difficult to quantify the exact modulation of the low-frequency, large-scale circulation on tropical cyclone, and the exact feedback of tropical cyclone to the large-scale circulation. However, certain approaches can be taken to gain a rough idea on the mutual feedback. In this study, we remove the features associated with tropical cyclones in the western North Pacific from the ERA40 to assess the potential feedback of tropical cyclone to climate variability.

2. Methodology

A removal of the tropical cyclone from the analysis data has been a common practice in the typhoon and hurricane simulation (e.g., Kurihara et al. 1995, Wu et al. 2002). The 850-hPa vortex associated with each tropical cyclone was subtracted, following the procedure proposed by Wu et al. (2002), from the 850 hPa vorticity field for the June-October period from 1958-2001. The subtracted vorticity was filled in by linear interpolation from neighboring grid points. Through this procedure, we obtained two data sets, namely the original and TC-removed fields. The latter represents the large-scale background flow for tropical cyclones. The variances for the intraseasonal and interannual time scale were then computed for the original and TC-removed vorticity fields.

Although the procedure described above may seem unrealistic, the comparison between the original and TC-removed vorticity yield an estimation of the TC contribution to the intraseasonal and interannual variability.

3. Results

The traditional wisdom usually ignores the possible effect of tropical cyclones to the large-scale circulation, by assuming the long-term average will smooth out the perturbation associated with tropical cyclone. However, the TC vortex is characterized by extremely intense positive vorticity, which is too strong to be compensated by the much weaker negative vorticity associated with an anticyclonic anomaly. When the seasonal means were calculated, the strong TC contribution will leave footprint in the mean field. Figure 1 is an example, showing the mean 850 hPa vorticity in June-October 1979. In the Philippine Sea where TCs were active, the mean vorticity reduce by about 50%, a percentage large enough for great concern. Significant reduction is observed in every typhoon season from 1958-2001 with certain degrees of fluctuation in the reduction amount. Since the TC activity exhibits significant interannual variability, the changes in seasonal means would certainly affect the interannual variability. Figure 2 presents the interannual variability in the original and TC-removed fields. The variance in the Philippine Sea reduces by about 50% in the TC-removed 850 hPa vorticity, again a ratio too large to be ignored.

4. Implication for climate variability, prediction, and change study

This study reveals that tropical cyclones contribute significantly to the long-term mean and variance of 850 hPa vorticity. Similar effect is also observed in the intraseasonal variability. As shown in figure 3, the propagation tendency of the intraseasonal oscillation, which is a well known feature in the western North Pacific during the boreal summer, is less organized and weaker in the TC-removed vorticity field.

This large reduction in both long-term means and variances can be explained as follows. While the low-frequency, large-scale circulation has clustering effect on tropical cyclones, the latter with a large positive vorticity, which tend to occur in the positive vorticity background flow, significantly enhances the total strength of the positive vorticity. Conversely, when tropical cyclone does not exist or when a synoptic anticyclone exists, the contribution to the total vorticity field from the synoptic- and meso-scale disturbances is relatively small. This contrast leads to the enlargement of the mean and variance of vorticity. Similar results are also identified in precipitation and a similar interpretation can also be applied. This effect is seen in both intraseasonal and interannual variability in this study. In reality, the relationship between tropical cyclone and the large-scale circulation is nonlinear. Bearing this in mind, our study took an artificial approach to remove tropical cyclone from the circulation to demonstrate that even a simple arithmetic approach can significantly affect the computed mean and variance. Since the intraseasonal and interannual variability is usually interpreted based on the low-pass filtered data or seasonal means, the TC activity, which is imprinted in these means, can possibly misinterpreted as climate variability.

In the real world, the tropical cyclone, although moving fast, often has a life time longer than 10 days. With a moving large and long-lived energy source like tropical cyclone, the large-scale circulation is likely induced and emanates energy to remote regions. This effect can leave strong footprint on the climate variability. Most of the general circulation models used to simulate past climate suffers from the poor simulation of the climate variability in the western North Pacific during the boreal summer. Our study suggests that the inability to resolve and simulate tropical cyclone may be one of the weaknesses of the GCM leading to this poor simulation. Using this type of coarse-resolution GCM can lead to inaccurate prediction/projection of future climate in intraseasonal, interannual and even climate change time scales.

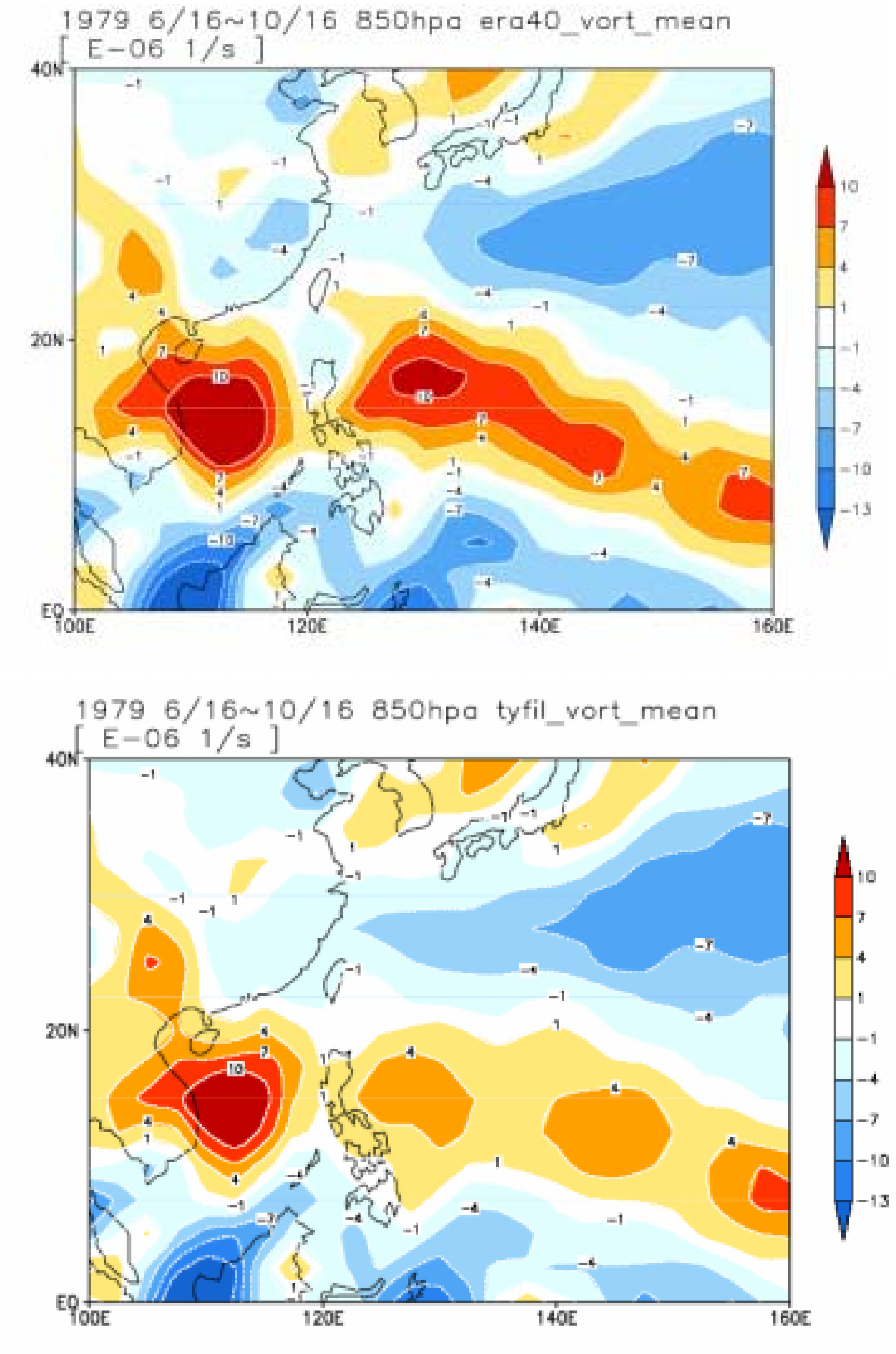

Figure 1. Mean 850 hPa vorticity in June-October 1979: (upper) original and (lower) TC-removed.

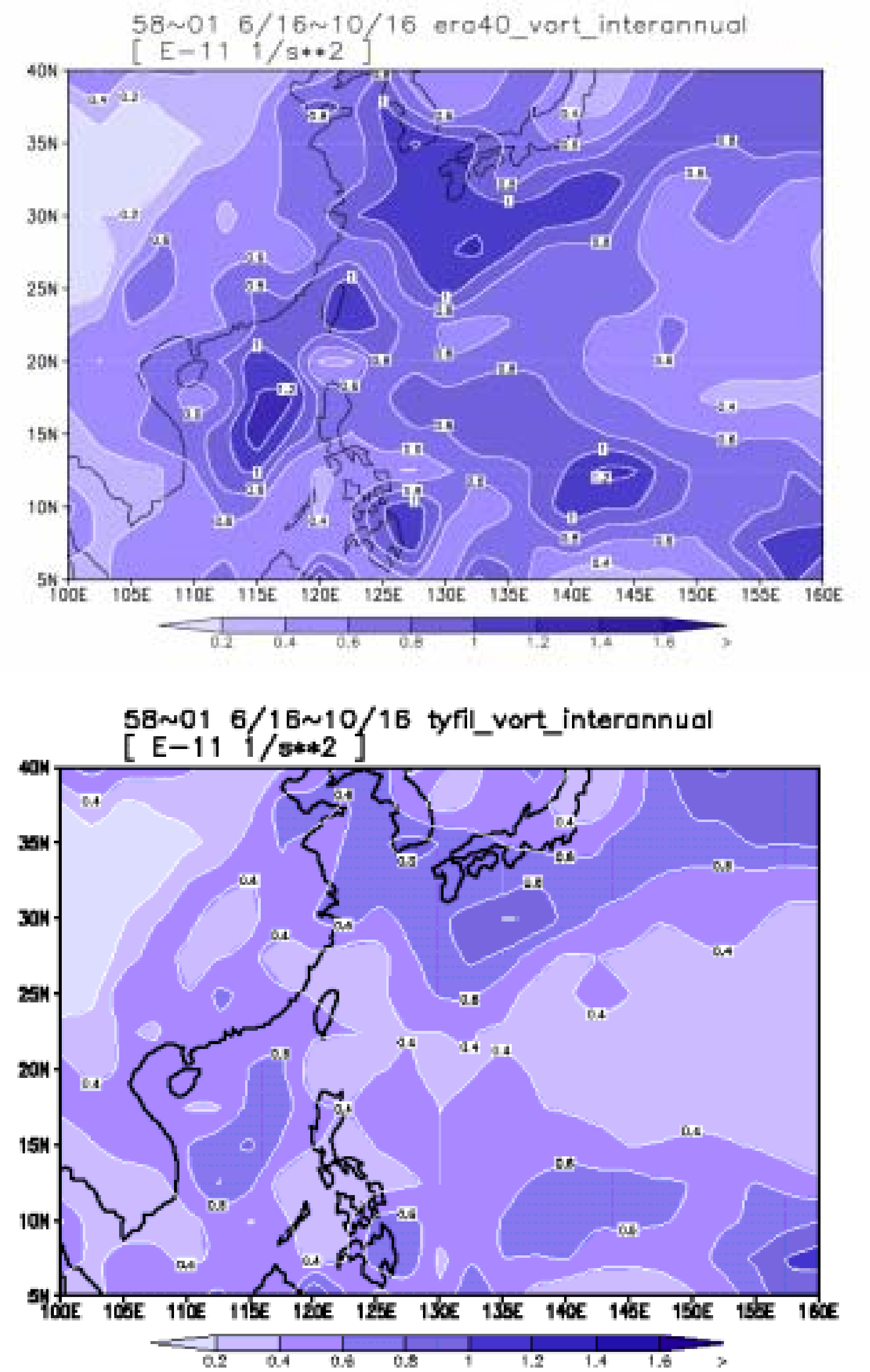

Figure 2. Interannual variance of 850 hPa vorticity of (upper) total and (lower) TC-removed fields, from 1958-2001.

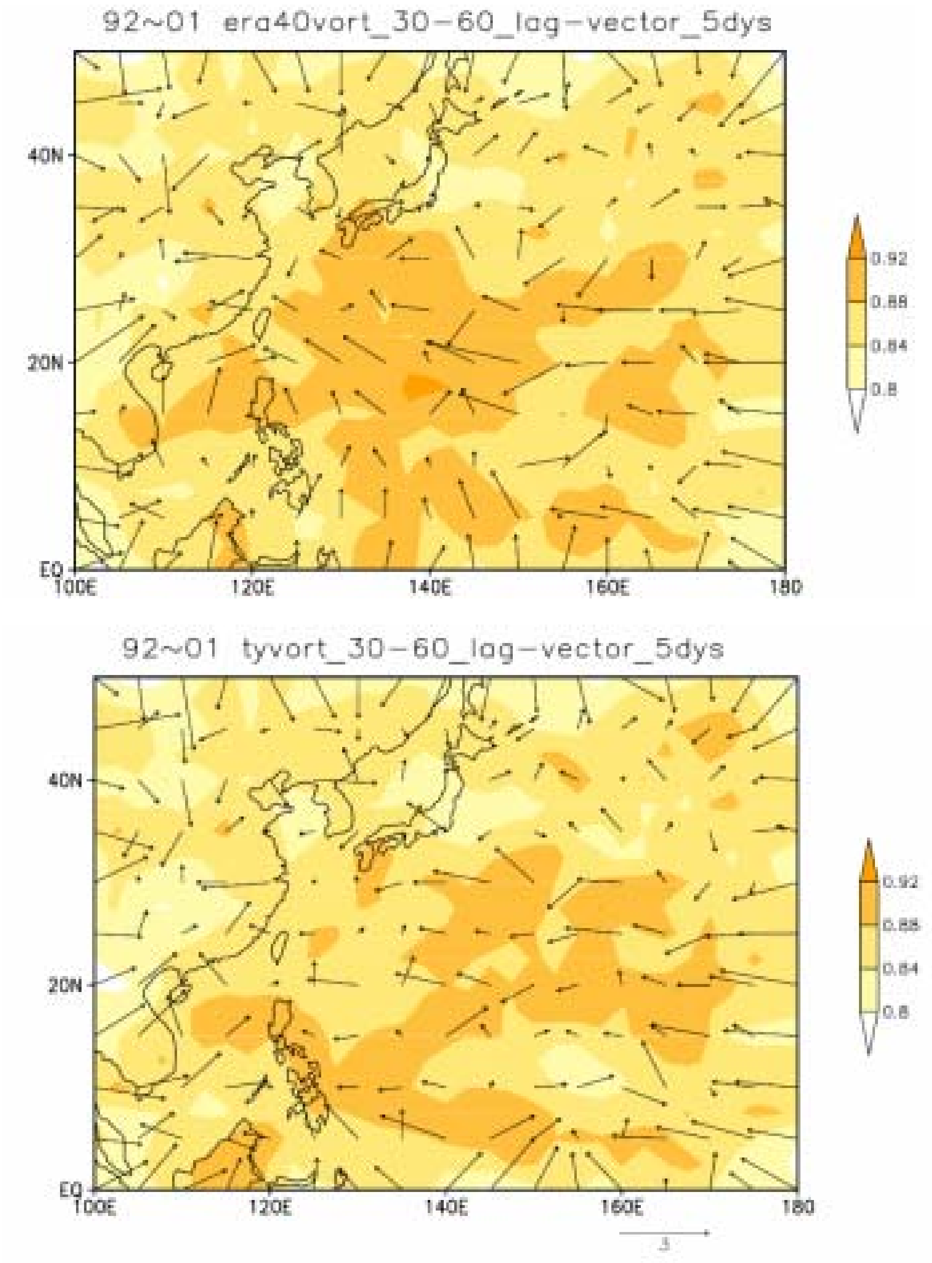

Figure 3. Propagation tendency for the 30-60 day band-pass filtered 850 hPa vorticity, based on the 5-day lagged correlation map at each grid point: (upper) original and (lower) TC-removed.