Vertical heating rate profiles associated with MJO in JRA-25

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INTRODUCTION

To study vertical heating rate profiles associated with the Madden-Julian Oscillation (MJO), composite analysis has been made using Japanese 25-year Reanalysis data. The composite of MJO using the empirical orthogonal function (EOF) of the velocity potential at 200hPa was constructed to extract the signal of MJO. The forecasts of the MJO event in late December 2006 have been compared with the JRA-25 and JMA Climate Data Analysis System (JCDAS) data and the TRMM data.

Data and Model

Data used in this study include velocity potential at 200 hPa, zonal wind at 850 hPa and heating rate due to parameterized moist process from JRA-25 and JCDAS (Onogi et al. 2007). The heating rate in the JMA model is parameterized by prognostic Arakawa-Schubert scheme and prognostic cloud water content. To make case study, JMA operational one month forecast model (TL159 with 40 vertical layers) is also used. In the model, the persisted SST anomaly is used as a lower boundary condition. The initial perturbations for model ensemble are obtained by the Breeding of Growing Modes (BGM) method that associated with the tropical intraseasonal oscillation (Chikamoto et al., 2007). TRMM SLH3 Version02 (Shige et al. 2004, 2007) data include monthly averaged $\overline{Q_1} - \overline{Q_R}$ in 0.25 degrees lat/long grid have been compared with JRA-25, JCDAS. The apparent heat source $\overline{Q_1}$ and the radiative cooling/heating rate $\overline{Q_R}$ is defined by following equation:

$$\overline{Q_1} = \frac{\partial \bar{s}}{\partial t} + \overline{\mathbf{V}} \cdot \nabla \bar{s} + \bar{w}\frac{\partial \bar{s}}{\partial z} = -\frac{1}{\bar{\rho}}\frac{\partial \bar{\rho}\,\overline{w's'}}{\partial z} + L(\bar{c} - \bar{e}) + \overline{Q_R}$$

Here *s* is dry static energy, *w* the vertical velocity, *L* the latent heat per unit mass of water vapor, *c* the rate of condensation per unit mass, and *e* the rate of re-evaporation of cloud droplets. The overbar indicates horizontal averages and deviations from the horizontal averages are denoted by primes.

Composite Vertical Heating Rate

This composite analysis is similar to the Maloney and Hartmann(1998)'s method. Daily averaged 6-hourly (1980-2003) JRA-25 data of the velocity potential and heating rate of moist processes were bandpass filtered between 20 and 70 days before compositing. The index is derived from the first two empirical orthogonal functions of the bandpass filtered 5 ºN-5 ºS averaged the velocity potential at 200 hPa. In order to extract the MJO events, the active phase of MJO that the first two principal components have the value exceeds 1.0σ are composited. Here σ is the standard deviation of principal components for the entire period. Figure 1 shows anomaly composite of the velocity potential at 200 hPa and the heating rate (from 1000hPa to 150hPa), averaged between 20 ºS and 20 ºN in DJF. The active phase associated with the MJO is located around 90E and the maximum of heating rates is found between 500 to 400 hPa. Figure 2 shows same as Fig 1, except for JJA. The amplitudes of velocity potential and heating rates are weaker than that of DJF.

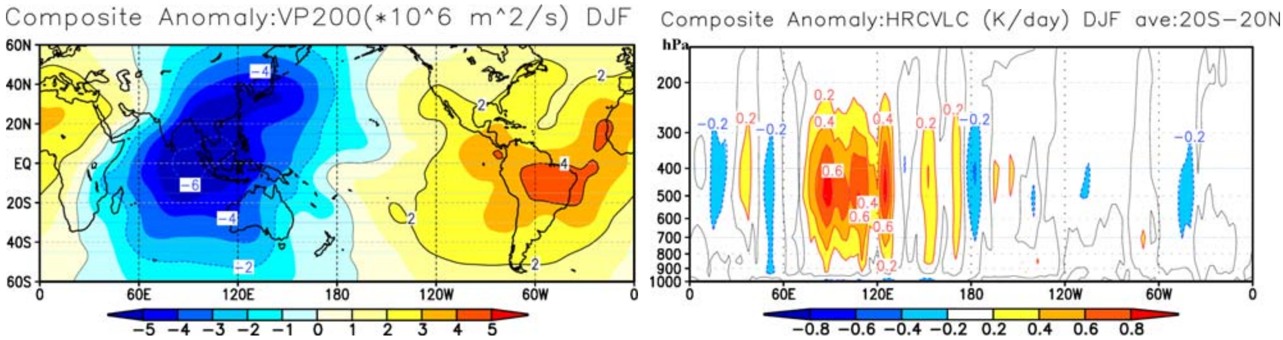

Figure 1: Anomaly composite of the velocity potential at 200 hPa (10^6 m^2/s) and the heating rate (K/day), averaged between 20 ºS and 20 ºN in DJF.

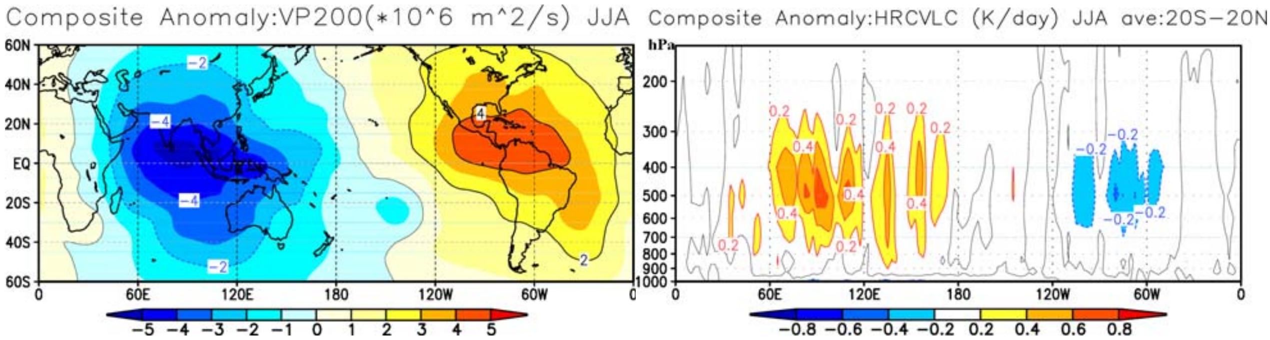

Figure 2: Same as Fig 1, except for JJA.

Case Study

In this section, forecast Experiment of the MJO event in late December 2006 have been compared with reanalysis data and the TRMM data. Figure 3 shows time-longitude sections of the velocity potential at 200 hPa of JCDAS and model prediction, averaged between 5 ºS and 5 ºN. The initial time of model prediction is 12 UTC, December 21 2006. JRA-25/JCDAS reanalysis data (Fig.3-a) represents active MJO propagates eastward from the Indian Ocean to the Date Line. Fig. 3-b shows result of 25 member ensemble mean, Fig. 3-c control run, and Fig. 3-p to # perturbation members. Figure 4 shows zonal wind at 850hPa corresponding to Fig.3. For example, "24m" is one of the perturbation members, westerly and easterly wind anomalies at lower troposphere associated with the MJO are well predicted. Figure 5 shows heating rate profiles over the Maritime Continent (20ºS-20ºN, 95ºE-155ºE). Forecast range is 2nd week. Blue lines indicate JCDAS and red lines indicate ensemble forecasts. Each line shows 7 day running mean, centered at December 29 2006 through January 2 2007. Vertical heating associated with the MJO are also reproduced. The heating rates of model forecasts are weaker than that of the JCDAS data. Figure 6 shows longitude-height sections of the heating rate and anomaly (K/day) averaged between 20ºS and 20ºN in December 2006, from the TRMM SLH3 version02 (Shige et al., 2004, 2007) and JRA-25/JCDAS. The maximum heating rates in the TRMM and JRA-25, JCDAS data are observed at the similar heights, although the magnitudes are different.

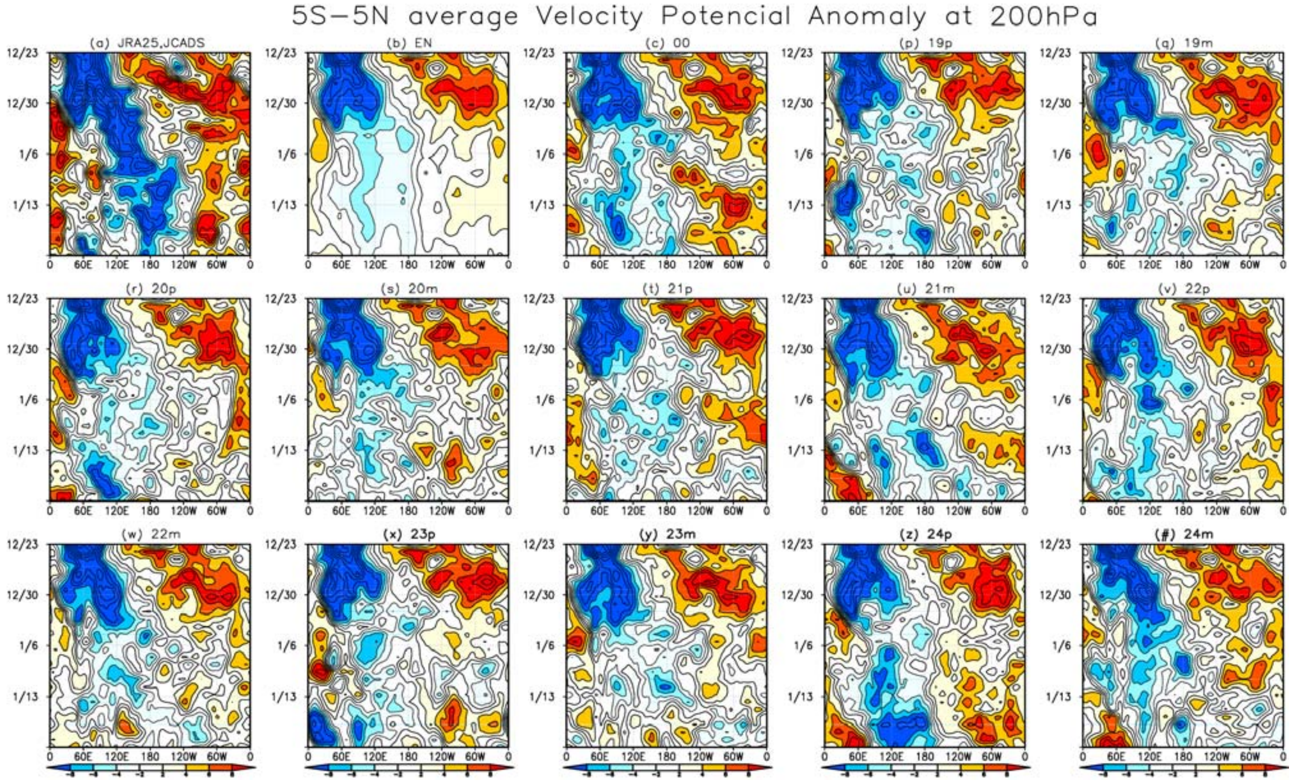

Figure 3: Time-longitude sections of the velocity potential (10^6 m^2/s) at 200 hPa, averaged between 5 ºS and 5 ºN. The initial time is 12 UTC, December 21 2006. (a)JRA-25/JCDAS,(b)25 member ensemble mean, (c)control run, and (p)-(#) perturbation members.

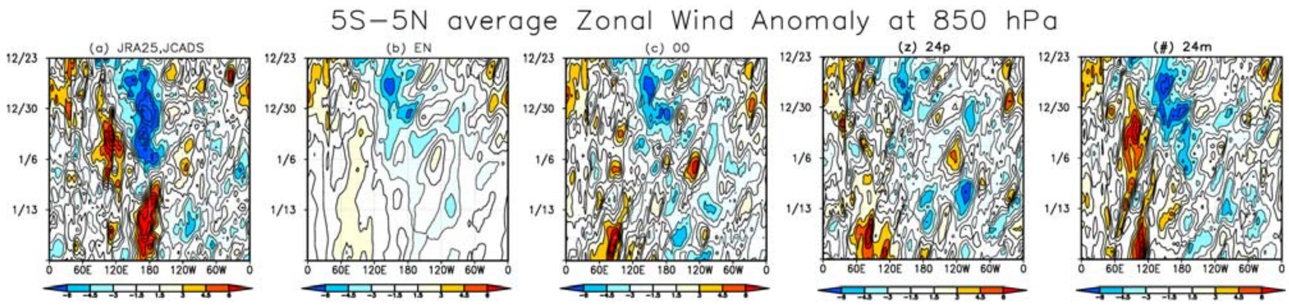

Figure 4: Same as Fig.3, but for zonal wind (m/s) at 850hPa.

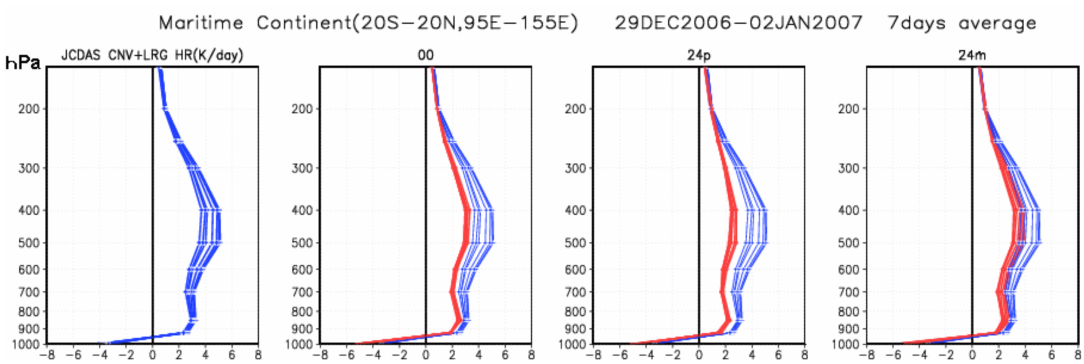

Figure 5: Heating rate profiles over the Maritime Continent. Forecast range is 2nd week. Blue: JCDAS. Red:ensemble forecasts. Each line shows 7 day average , centered at December 29 2006 through January 2 2007.

Summary

JMA's one month ensemble forecast model captures the MJO event in December 2006. Vertical heating rate and westerly wind anomaly at lower troposphere associated with the MJO are also reproduced. The predicted heating rate is weaker than that of the JCDAS data. The maximum heating rates in the TRMM and JRA-25, JCDAS data are observed at the similar heights, although the magnitudes are different. By adjusting the profiles of parameterized moist processes to the TRMM and JRA-25 data, it is expected that the model performance is improved in the tropical region.

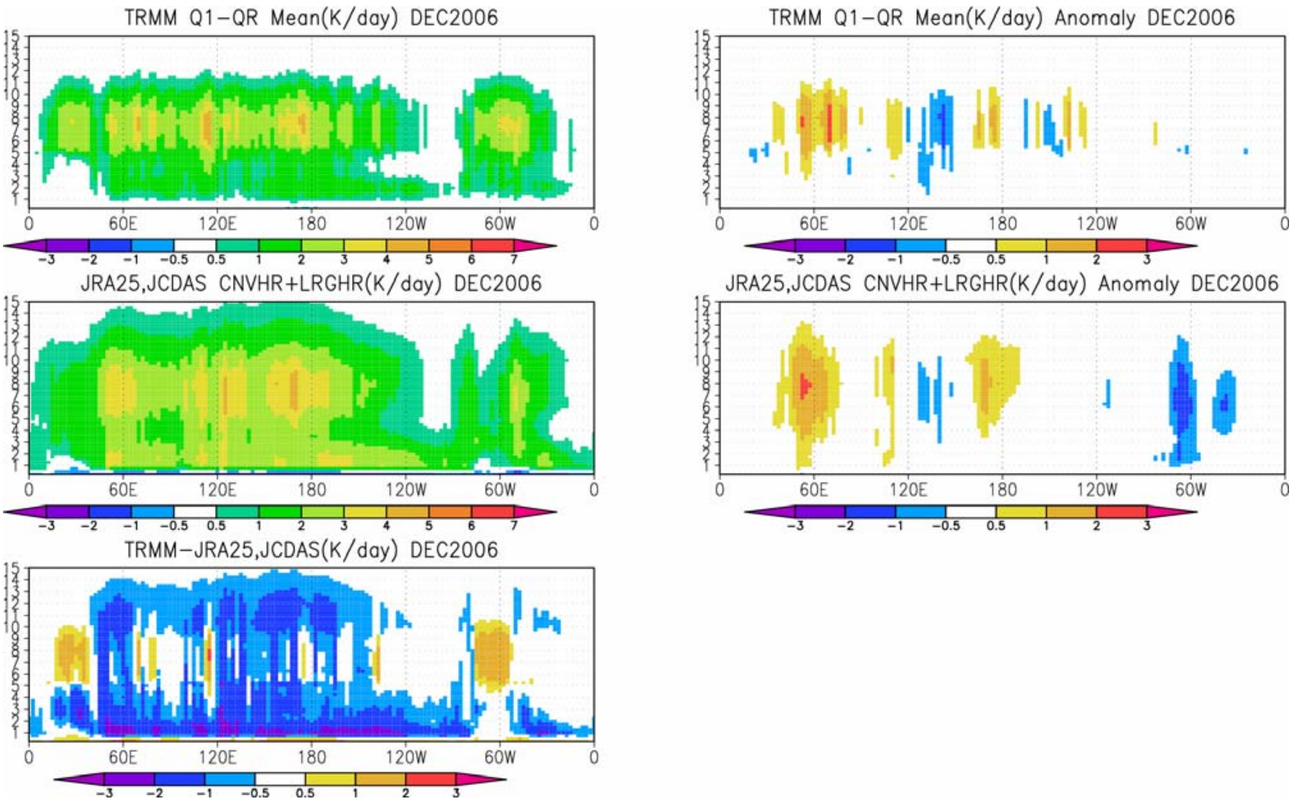

Figure 6: Longitude-Height sections of the heating rate and anomaly (K/day), averaged between 20ºS and 20ºN. Upper figures are for the TRMM SLH3 version02, middle figures for JRA-25/JCADAS, and lower their difference.

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