Potential vorticity budget during the transition from mixed Rossby-gravity waves to Tropical-Depression-type disturbances in a convection-permitting simulation

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Introduction

- In the tropical northwest Pacific, a tropical cyclone usually forms from a preexisting tropical depression (TD)-type disturbance originating from equatorial mixed Rossby-gravity (MRG) waves. Previous studies have revealed the essential role of background flow in the MRG-TD wave conversion process.
- However, moist thermodynamics, including wave-convection interaction, experienced a fundamental transformation during the MRG-TD transition, which was not fully explained by traditional wave-flow interaction mechanisms.
- This study investigates the role of latent heating during the MRG-TD wave transition through potential vorticity (PV) diagnostic analysis and numerical experiments, improving physical understanding of the moist thermodynamics of these convectively-coupled equatorial waves.

Data and Methodology

Potential vorticity (PV) budget

$$\frac{\partial P}{\partial t} = -V \cdot \nabla P - \omega \frac{\partial P}{\partial p} - g\eta \cdot \nabla Q - g\nabla\theta \cdot \nabla \times F$$

Dataset

- European Center for Medium-Range Weather Forecasts reanalysis dataset
  - Horizontal resolution：0.5° × 0.5° (4 × daily)
- Global Precipitation Climatology Project dataset
  - Horizontal resolution： 1° × 1° (daily)
- Global Precipitation Measurement dataset
  - Horizontal resolution： 0.1° × 0.1° (daily)
- period：2004.05.1-2004.07.31

Numerical Simulation

- Weather Research and Forecasting (WRF) model
  - Nesting Resolution： 12km、4km
  - Simulation period： 2004.6.21 00-2004.06.30 18
  - Microphysics： Thompson graupel scheme
  - Boundary layer： Shin-Hong
  - Radiation： RRTMG

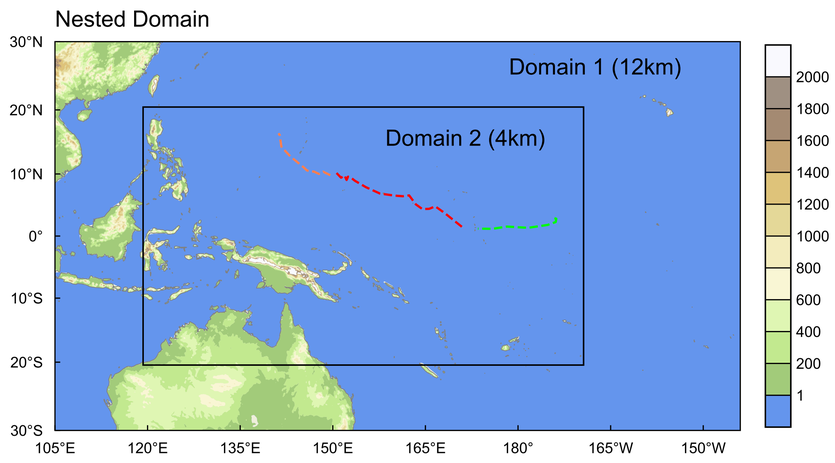


Fig.1. WRF model domain

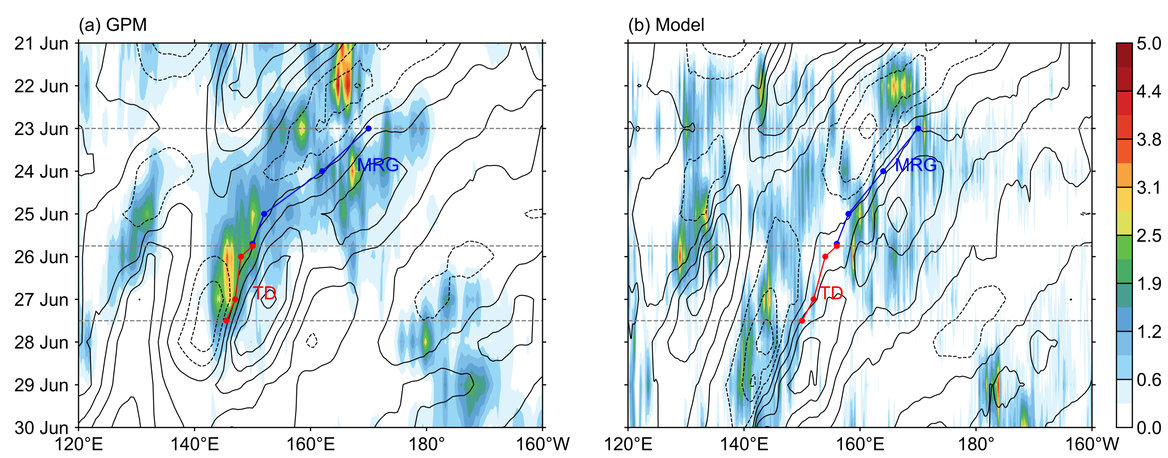


Fig.2. Hovmöller diagram of meridional winds and precipitation. Left: GPM; Right: WRF.

Results

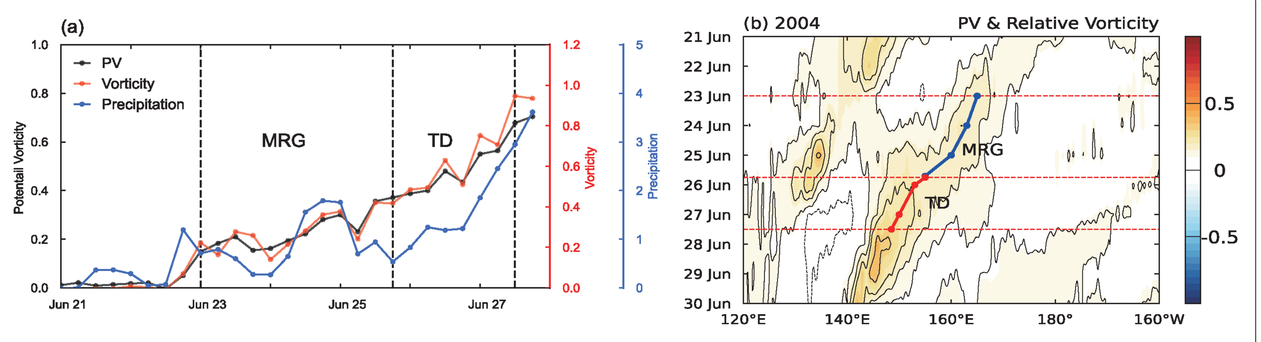


Fig.3. Change of total potential vorticity (PV), relative vorticity, and precipitation following the track of the disturbance.

✓In an MRG disturbance, PV, relative vorticity, and precipitation exhibit steady and erratic growth. When the wave transition began, PV increased rapidly with the growth of precipitation and relative vorticity.

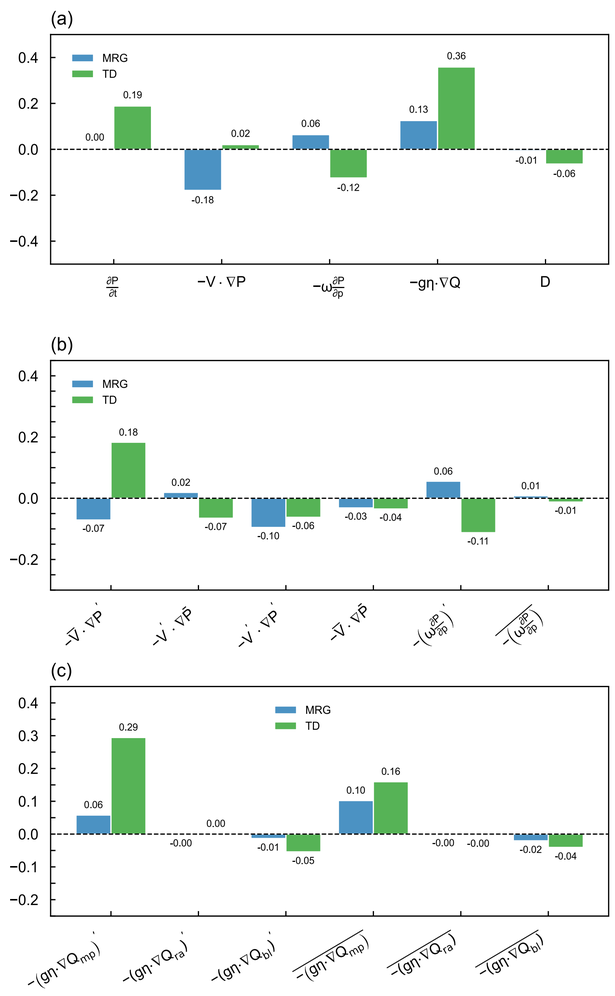


Fig.4. PV source terms.

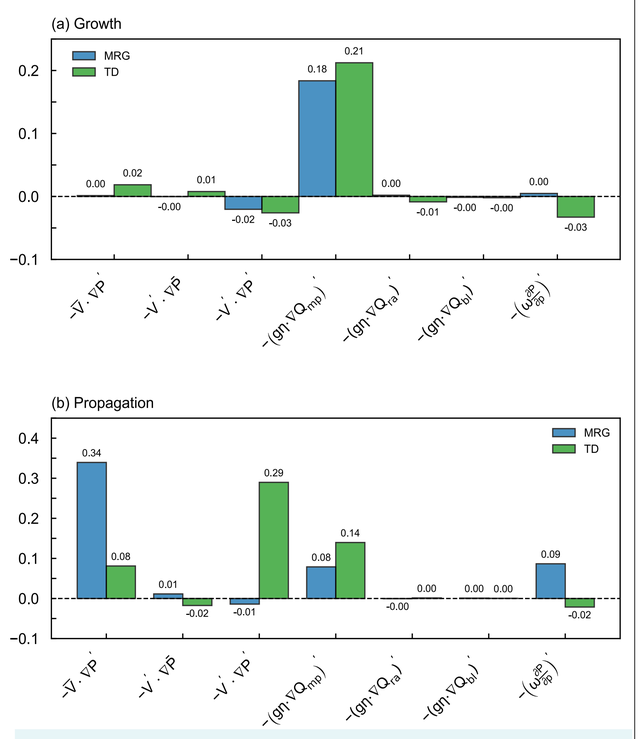
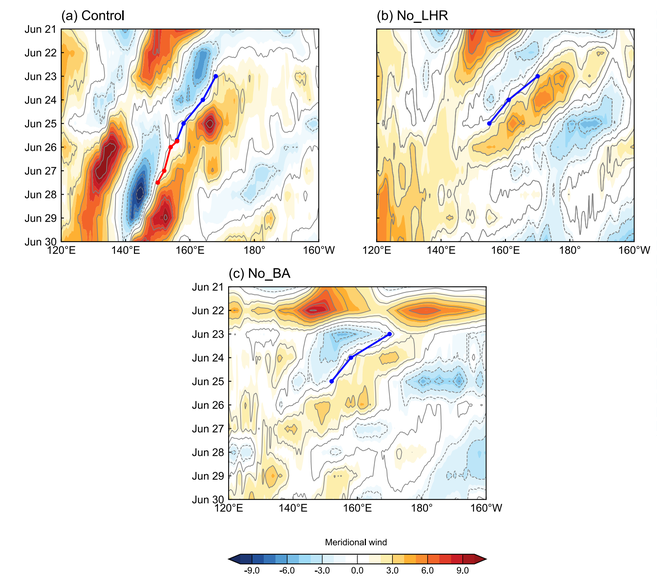


Fig.5. Contributions of PV source terms to growth and propagation.

✓The MRG-TD conversion process is influenced by diabatic heating, which promotes the development of vortices. In the MRG wave stage and the TD-type disturbance stage, the source terms of PV generation differ. Additionally, the leading contributor to the propagation of MRG wave and TD-type disturbance is distinct.



✓ Numerical experiments show that an MRG disturbance cannot transit into a TD-type disturbance without background flow or latent heat release, indicating that the shear of ambient flow and latent heat release are both necessary for the MRG-TD wave transition.

Fig.6. Sensitivity experiments

Conclusions

- ✓ An MRG-TD wave transition event is diagnosed through a PV perspective using a convection-permitting simulation.
- ✓ Latent heat release from cumulus convection, the primary contributor to wave growth, is indispensable in the MRG-TD wave transition.