An Explicit Representation of Vertical Momentum Transport in an Multiscale Modeling Framework Model through its 2D Cloud-Resolving Model

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Introduction

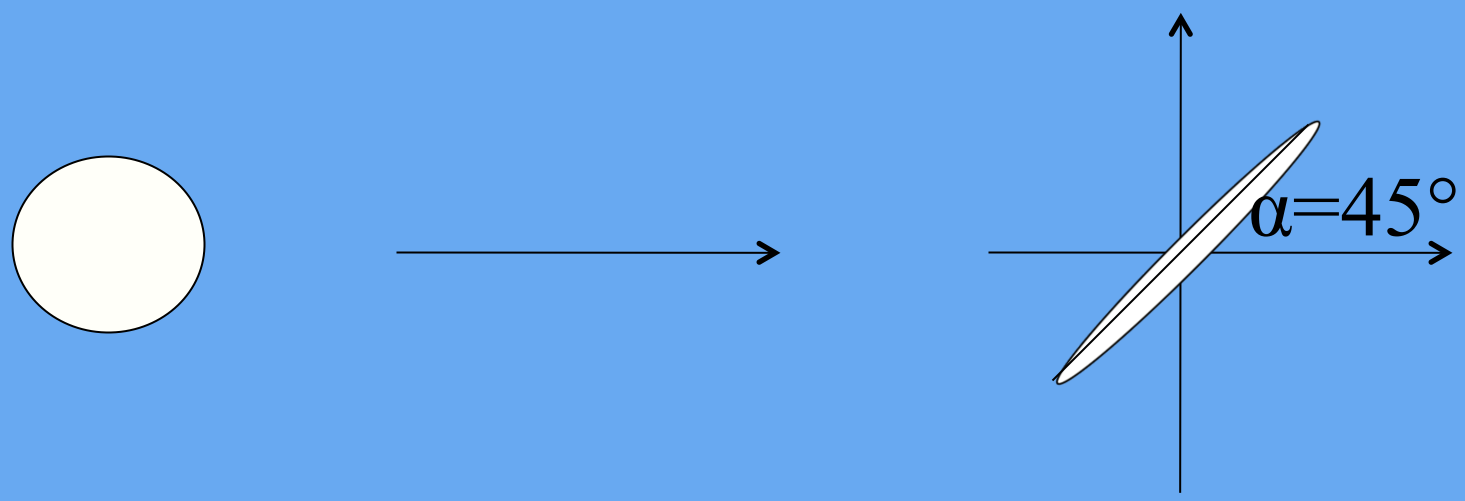
- Transport of momentum by mesoscale convective system (MCS) is an important process impacting climate modeling.
- Multiscale modeling framework (MMF), however, neglects the GCM subgrid-scale momentum transport unless 3D CRMs are embedded.
- The GCM subgrid-scale momentum transport by all clouds, including MCSs, is parameterized and feedbacks to the host GCM in this study.
- The proposed parameterization also alleviates the impact of the cyclical boundary condition of 2D CRM

The Orientation of 2D CRM in a GCM box (1)

- The default 2D CRM/MCS in MMF is fixed in east-west direction and no GCM subgrid-scale momentum feedbacks
- In this study, the orientation of the 2D CRM is determined according to Cheng (2005).
- Its orientation changes continuously every GCM time step (15 minutes) dependent on the vertical shear of the horizontal wind (the vertical wind shear thereafter), and the stability of the atmospheric stratification.
- Three distinct types of MCSs and the associated CRM orientations are explained in the following slides.

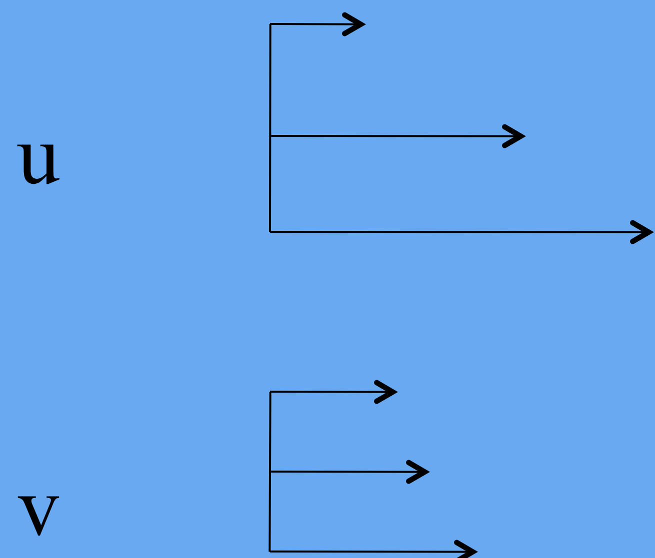
The Orientation of 2D CRM in a GCM box (2)

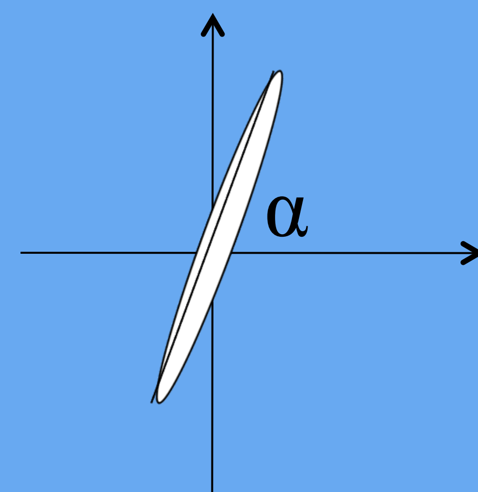
The MCS is a mesoscale convective complex with no preferred orientation and a round shape. The wind shear is weak.



The Orientation of 2D CRM in a GCM box (3)

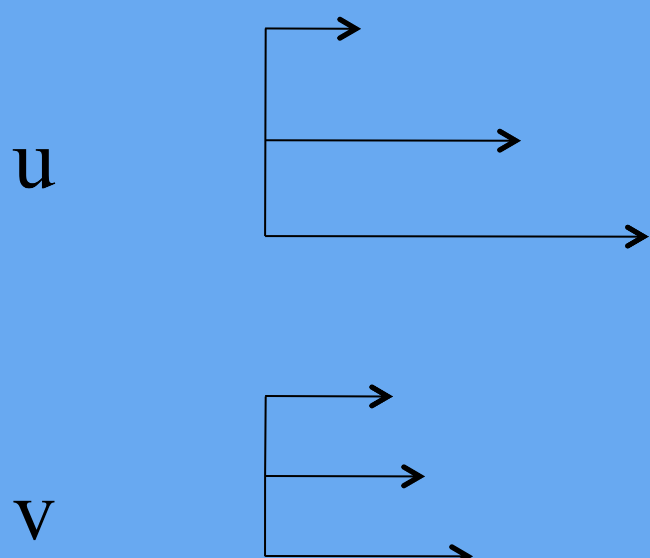
The MCS is perpendicular to the wind shear. The wind shear is strong and the stratification is very unstable.

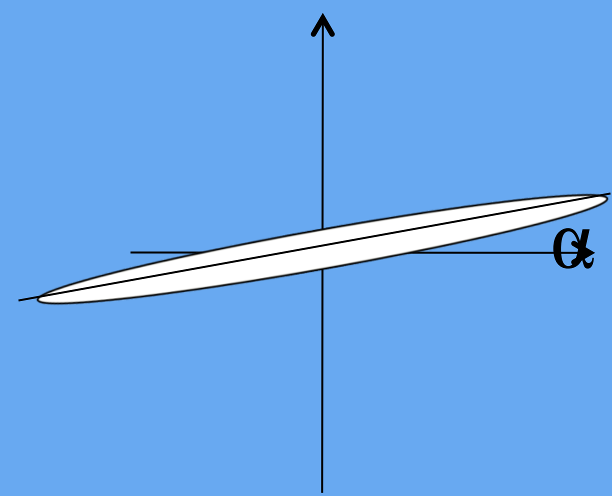




The Orientation of 2D CRM in a GCM box (4)

The MCS is parallel to the wind shear. The wind shear is strong and the stratification is less unstable.





Coupling between CRM and GCM

- CRM updated by

$$\frac{u_c^{m+1} - u_c^m}{\Delta t_C} = B_c + \frac{u_G^{n+1}\cos\alpha + v_G^{n+1}\sin\alpha - \langle u_c \rangle^n}{\Delta t_G}$$

- GCM updated by

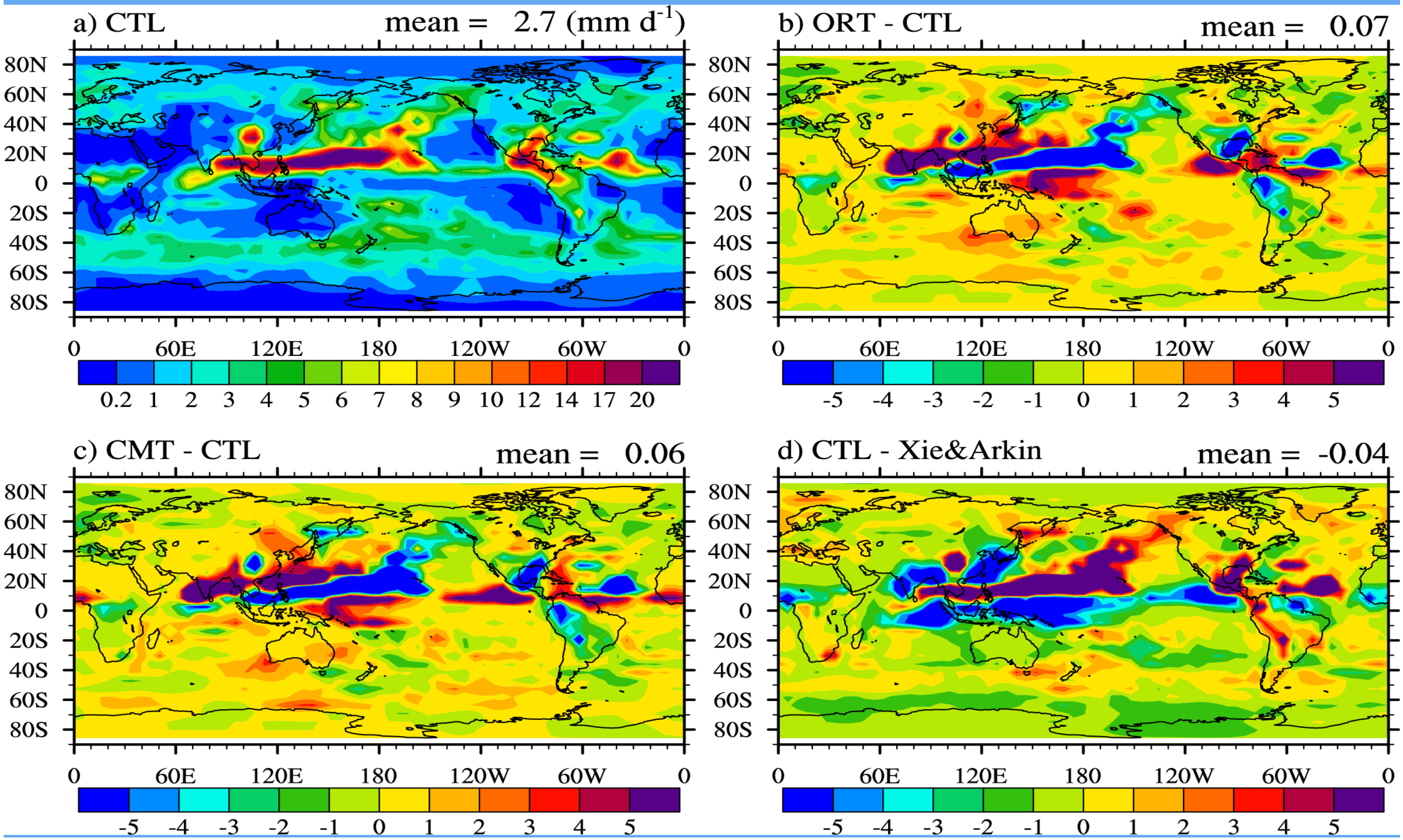
$$\frac{u_G^{n+1} - u_G^n}{\Delta t_G} = \frac{\langle u_c \rangle^{n+1}\cos\alpha - \langle v_c \rangle^{n+1}\sin\alpha - u_G^n}{\Delta t_G}$$

$$\frac{v_G^{n+1} - v_G^n}{\Delta t_G} = \frac{\langle u_c \rangle^{n+1}\sin\alpha - \langle v_c \rangle^{n+1}\cos\alpha - v_G^n}{\Delta t_G}$$

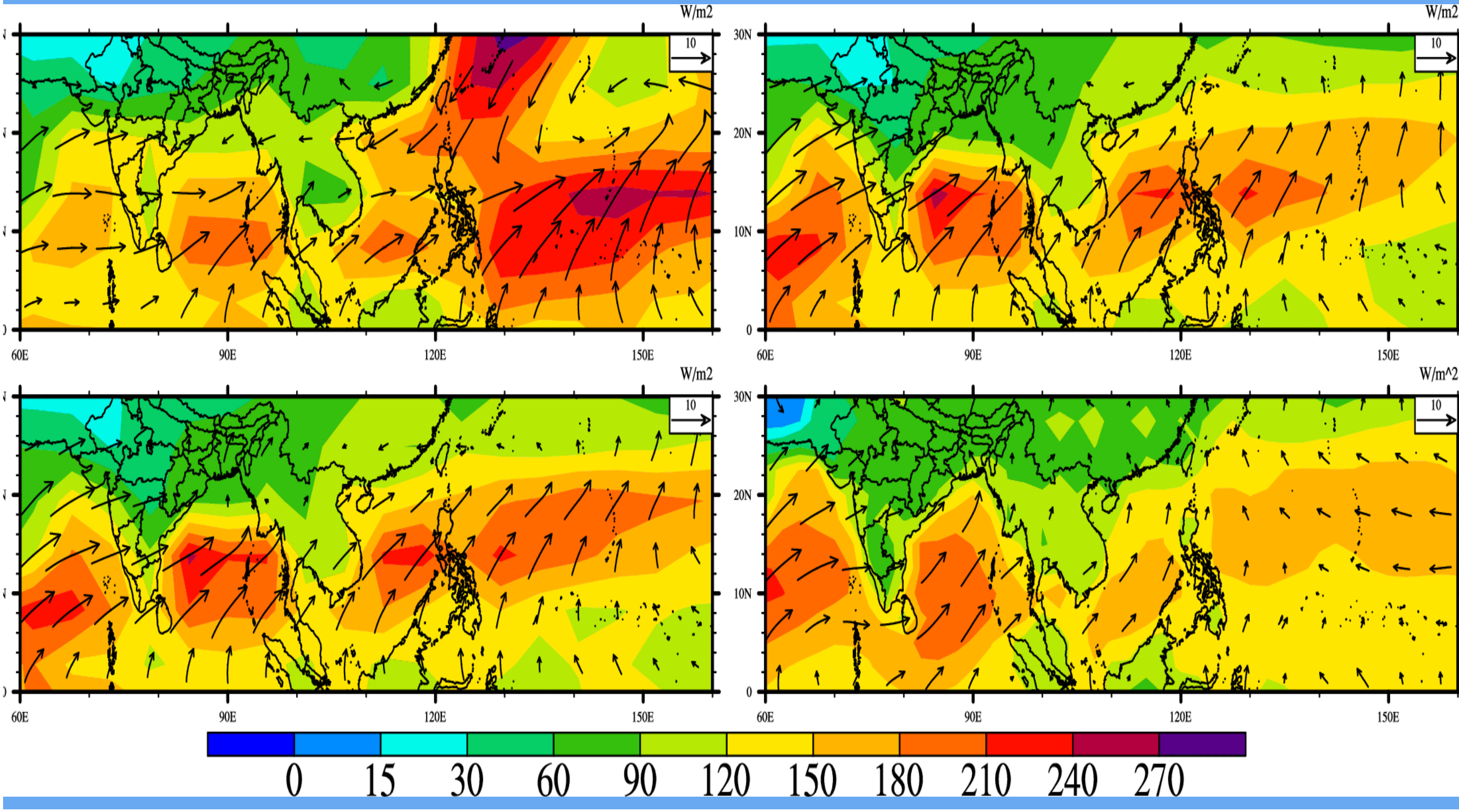
Experiment Design

- Control experiment: standard Community Atmosphere Model (CAM3.5) with a 2D System for Atmospheric Modeling (SAM) embedded; T21 with 26 levels in vertical direction for CAM3.5; same vertical levels and 32 Columns in horizontal with 4 km grid-size for SAM; no momentum transport feedbacks.
- Sensitivity experiment ORT: CRM changing its orientation but without momentum transport feedback to the host GCM.
- Sensitivity experiment CMT: with momentum transport coupled between CRM and GCM dynamical core.
- All experiments were integrated for two years and three months under the climatological-mean conditions. The results from the last two years are analyzed.

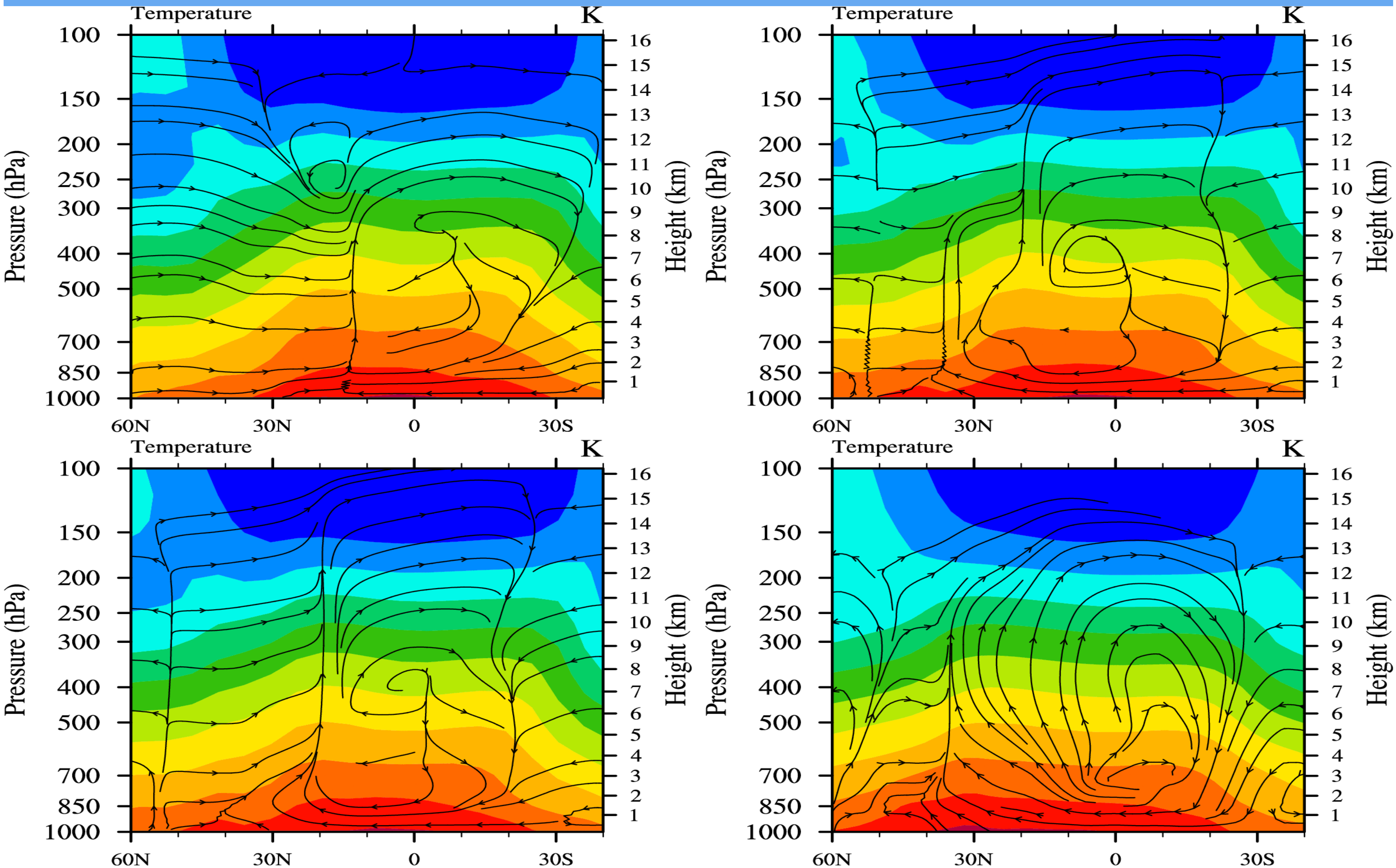
Global Distribution of JJASurface Precipitation



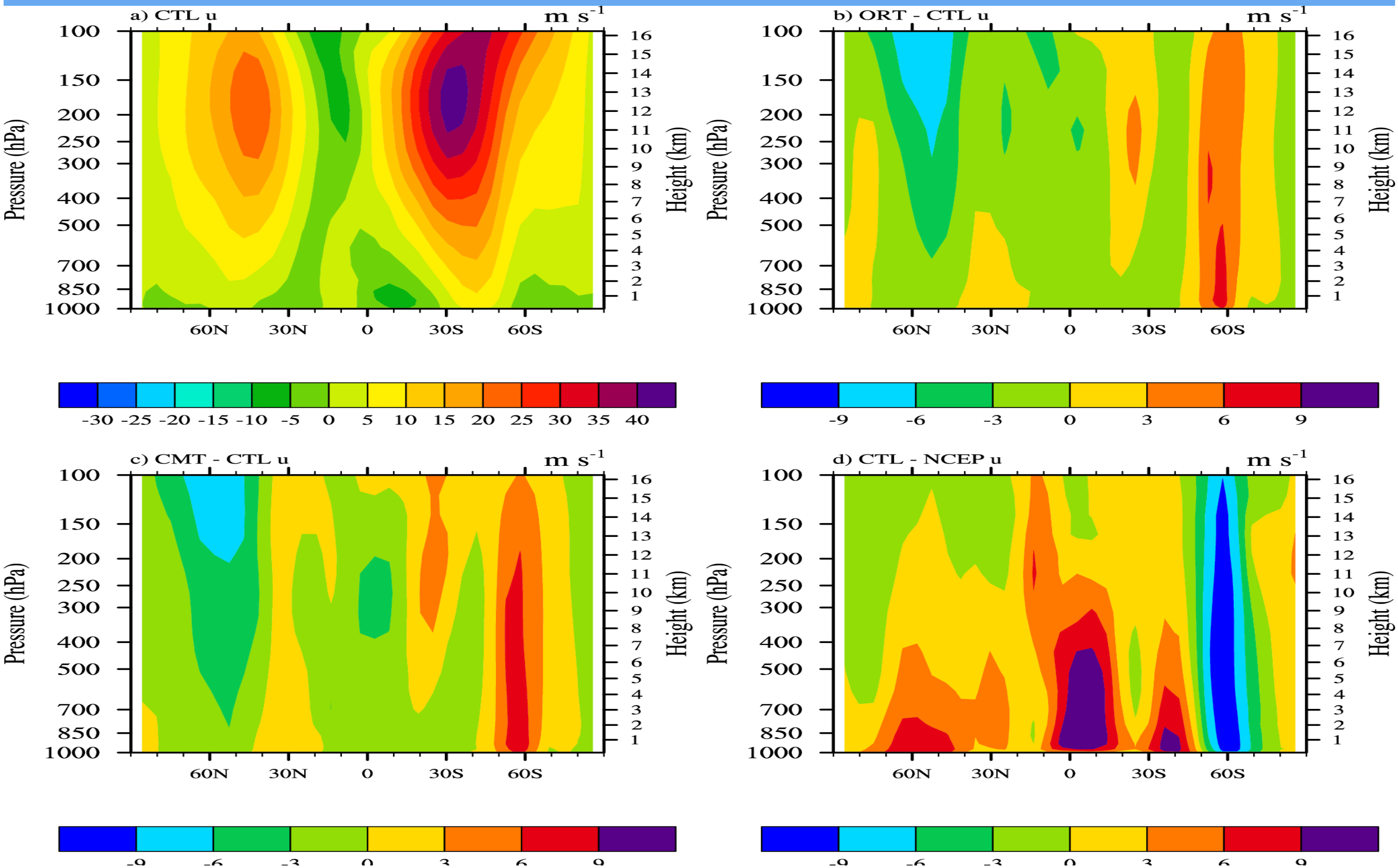
JJA Surface Wind and Latent Heat Flux over Tropical Indian/Western Pacific



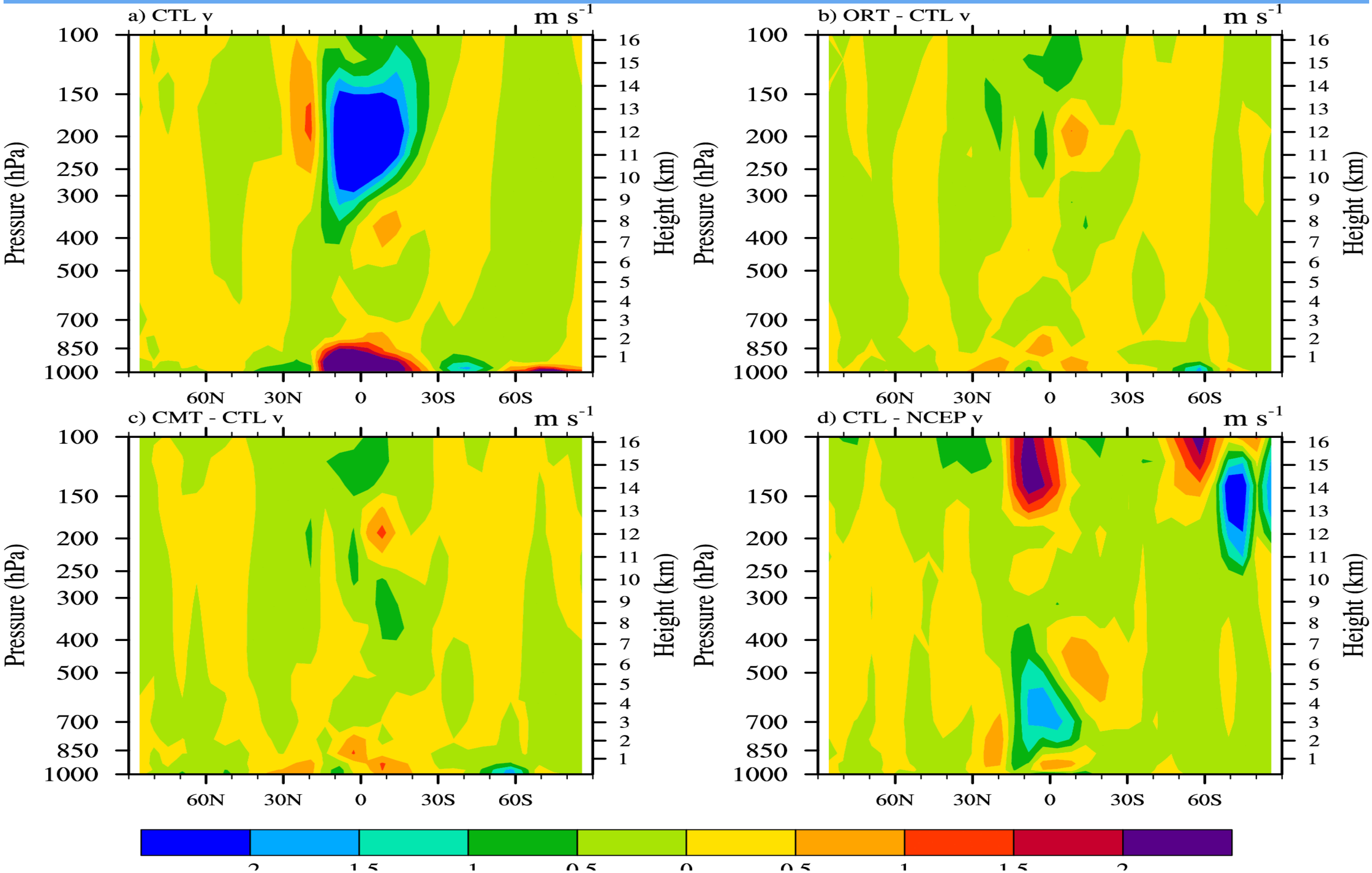
JJA Monsoon Circulation



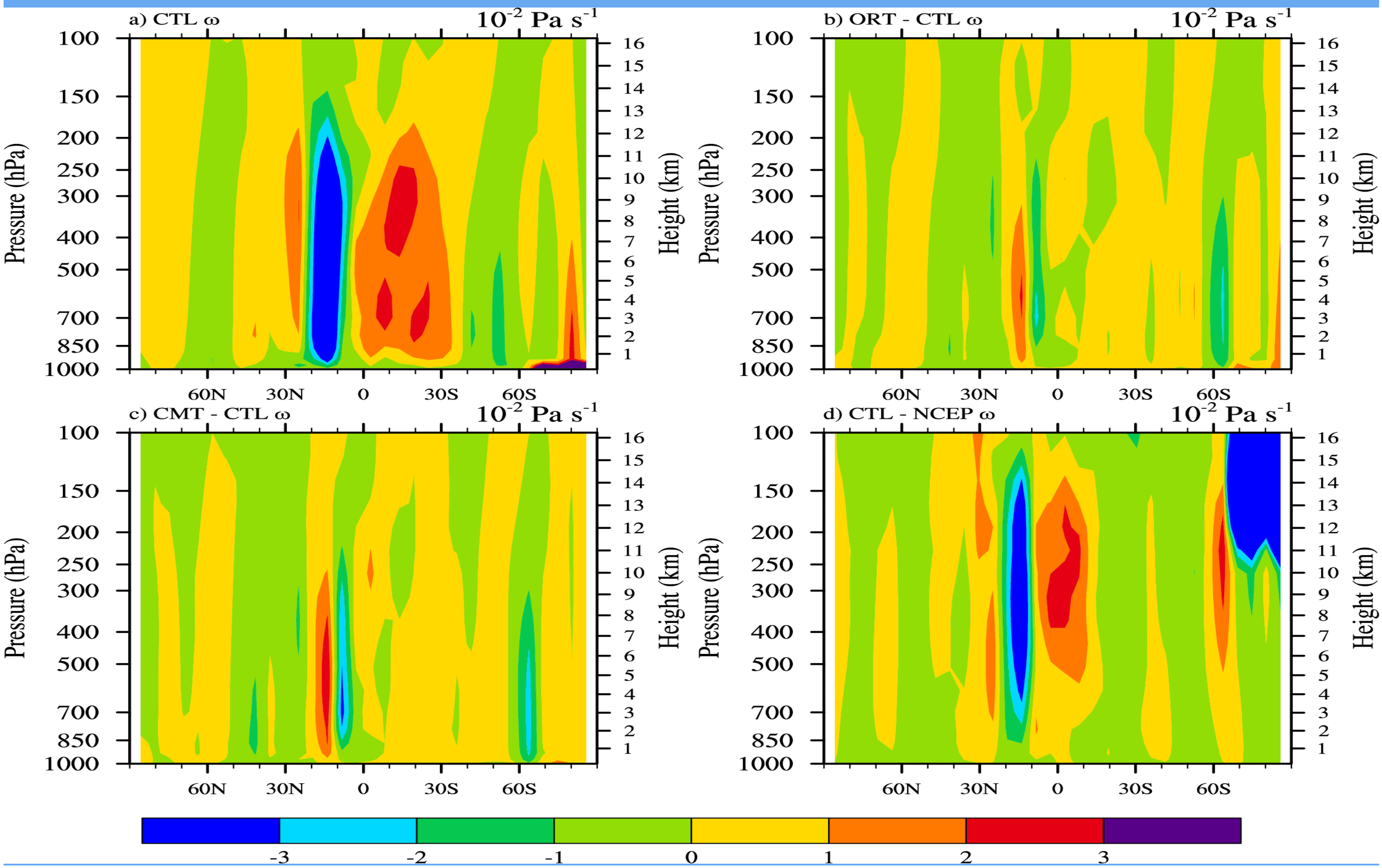
Zonal-annual Mean u Wind



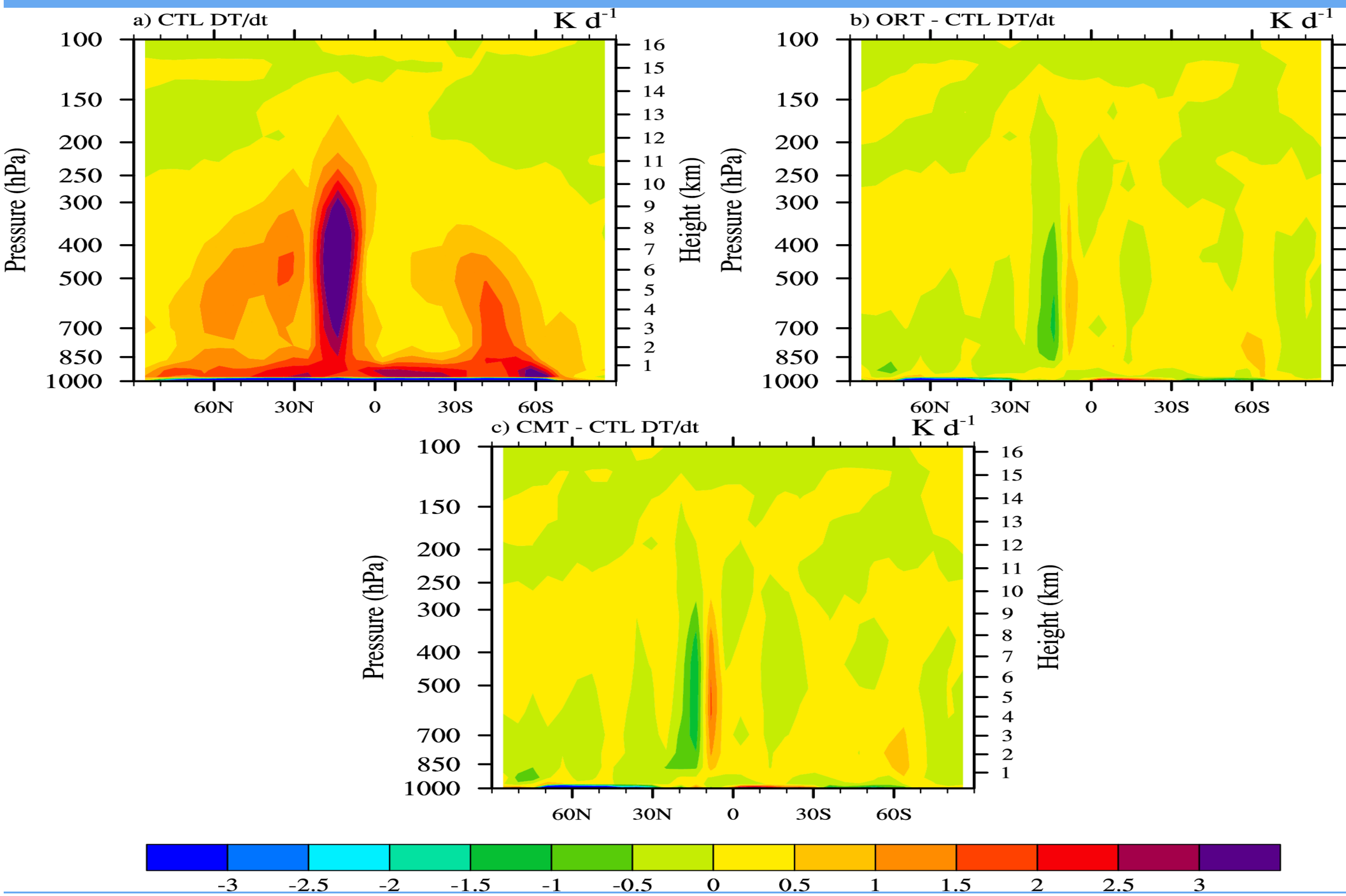
Zonal-annual Mean v Wind



Zonal-annual Mean Vertical Velocity



Zonal-annual Mean Heating



Summary

- A momentum transport parameterization by clouds in CRM has been implemented and tested in an SPCAM.
- The excessive precipitation in the warm pool region decreases more than 5 mm per day because three types of MCSs have been considered in the 2D CRM, which may prevent the great red spot to occur.
- Biases of u and v winds decrease.
- More reasonable summer monsoon circulation is produced.
- Heating and drying are consistent with the u and v fields, implying for a weak Hadley cell in summer.