Effects of Orientation of the Mesoscale Convective System on Climate Simulation with a Multiscale Modeling Framework

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Introduction

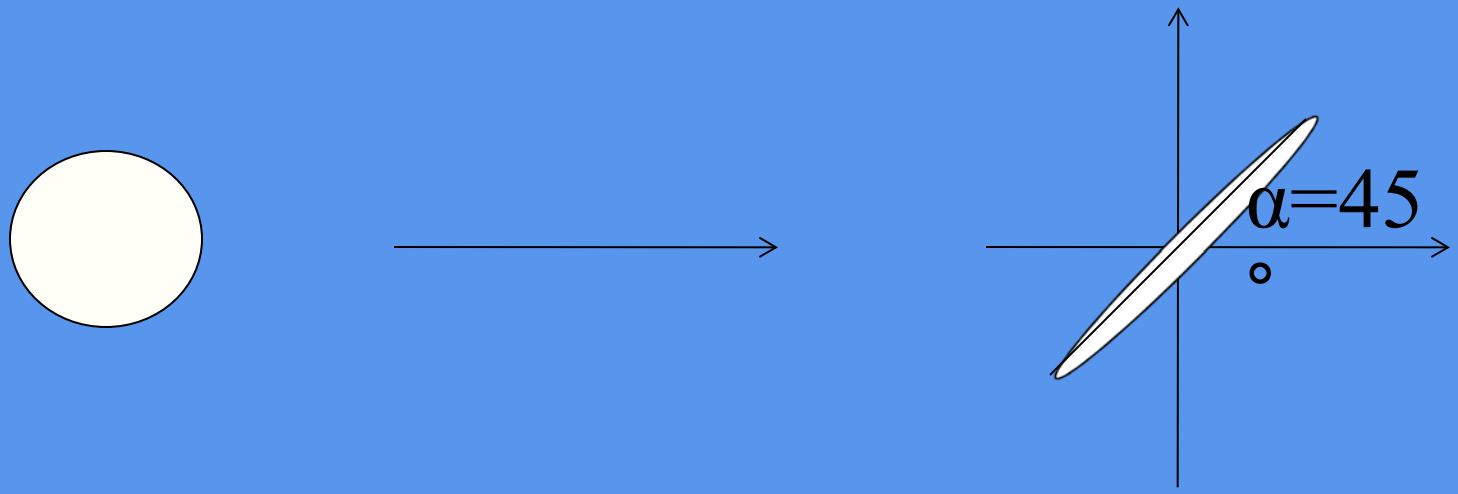
- Organization and the associated transport of momentum by mesoscale convective system (MCS) are important processes impacting climate modeling.
- Multiscale modeling framework (MMF), however, neglects the effects of the orientation of the MCS and the GCM subgrid-scale momentum transport.
- The orientation and the GCM subgrid-scale momentum transport by all clouds, including MCSs, are parameterized and feeds back to the host GCM in this study.

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

- The default 2D CRM/MCS in MMF is fixed in west-east direction, no GCM subgrid-scale momentum feedback.
- 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 (II)

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 (III)

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

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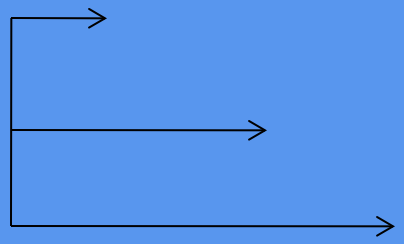

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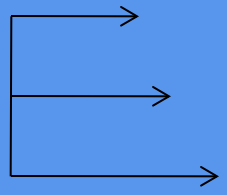

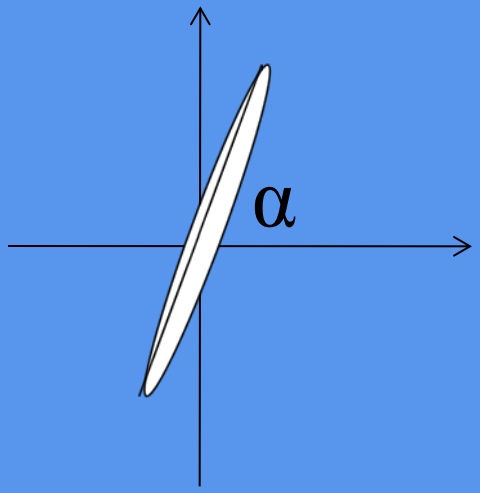

The Orientation of 2D CRM in a GCM box (IV)

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

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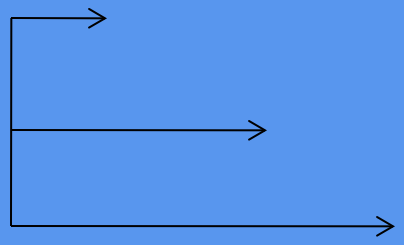

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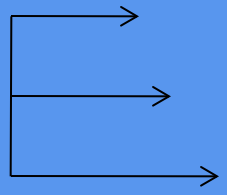
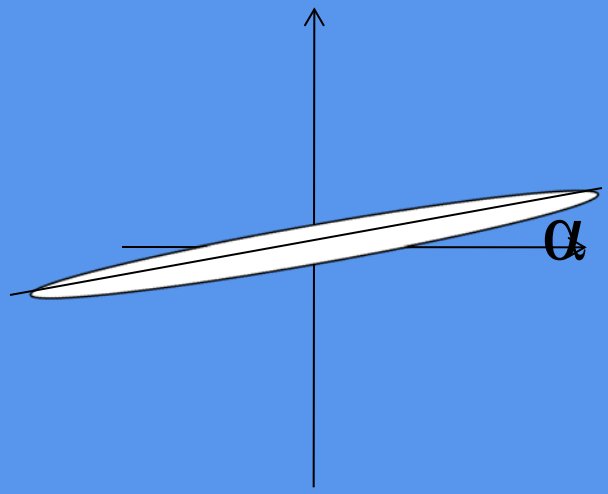




Coupling between CRM and GCM

- 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

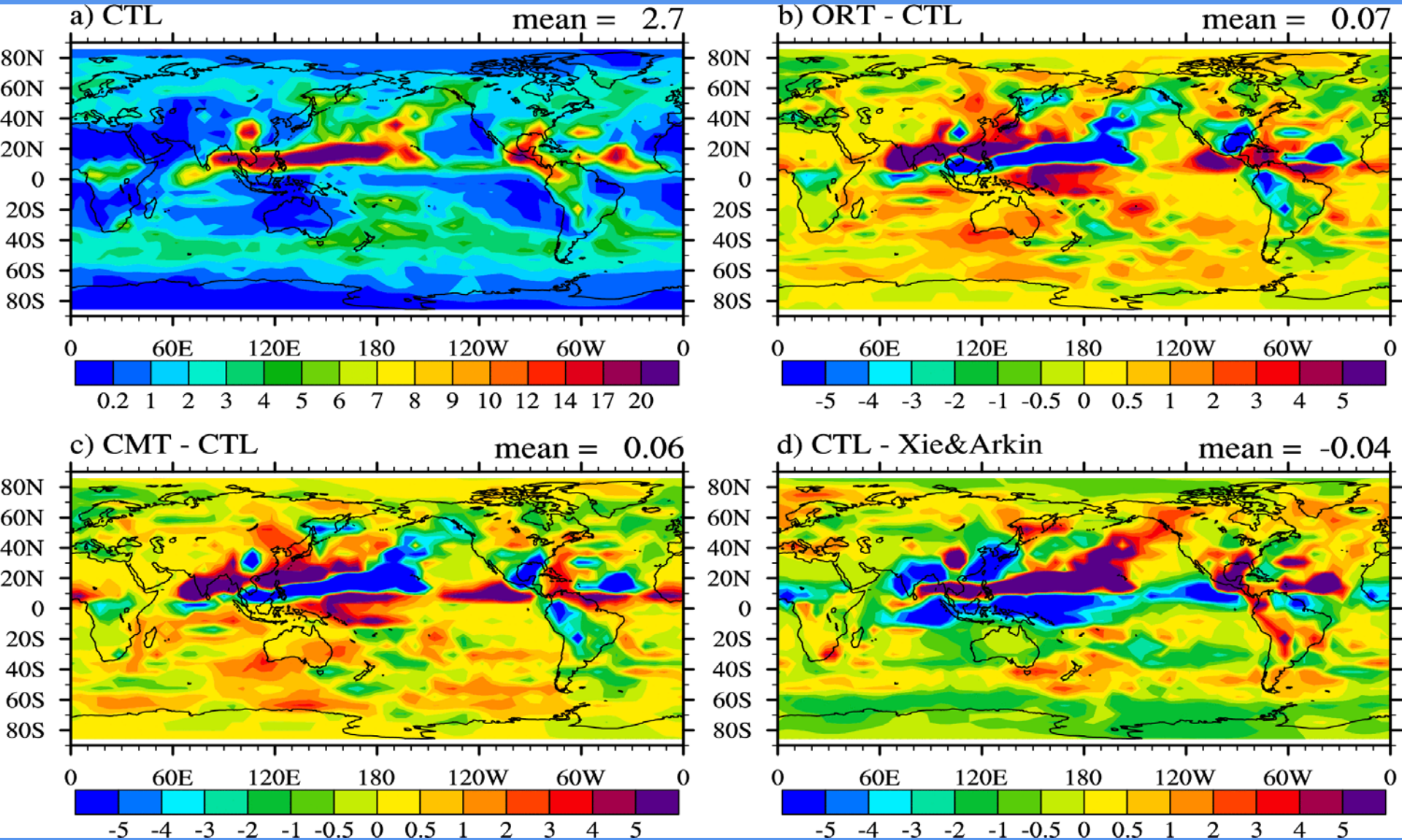
$$\frac{u_G^{n+1}-u_G^n}{\Delta t_G}=\frac{\langle u_c\rangle^{n+1}\cos\alpha-\langle v_c\rangle^{n+1}\sin\alpha-u_G^n}{\Delta t_G}$$

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

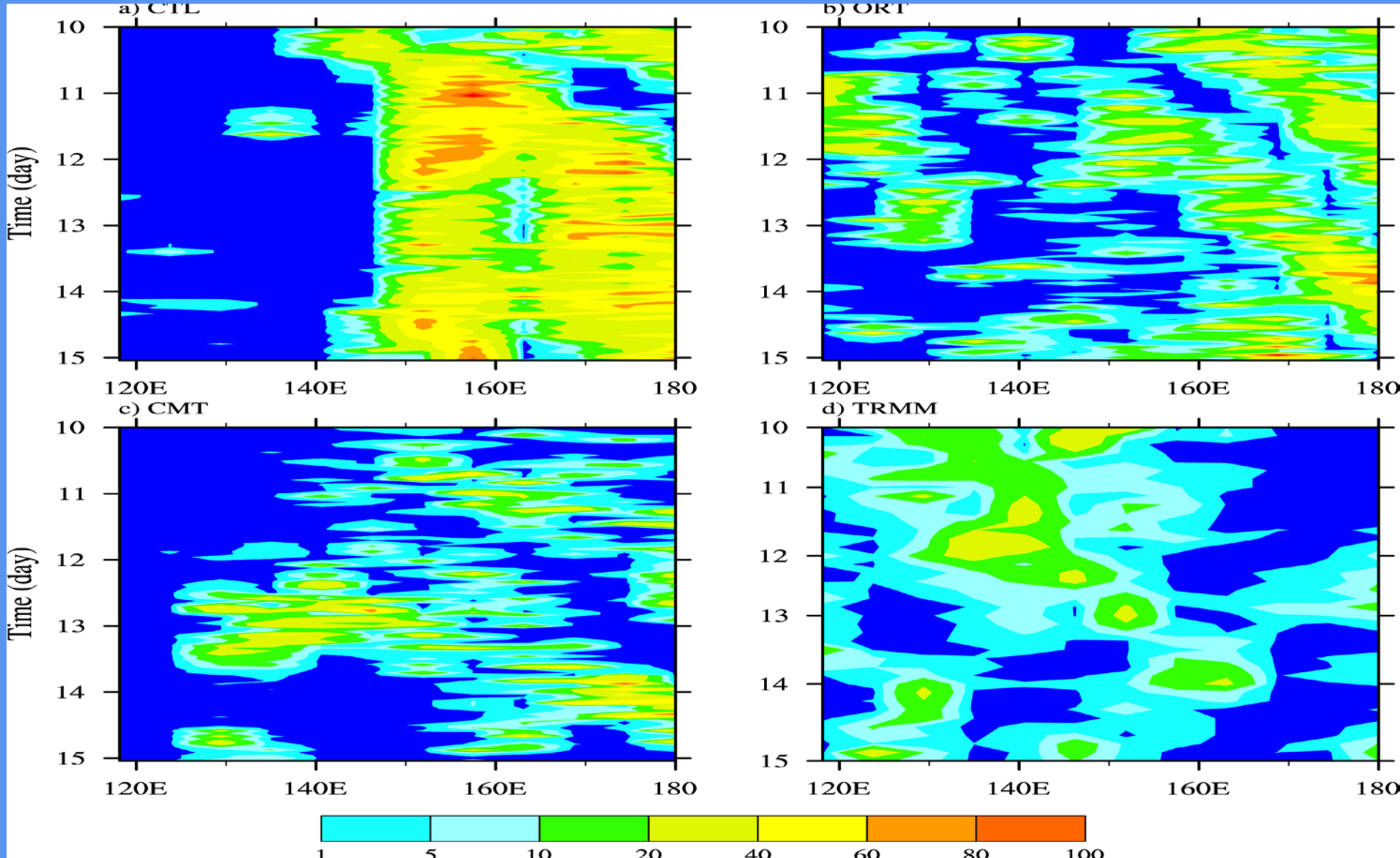
Experiment Design

- 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 feedback.
- 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 dynamic 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 in the study.

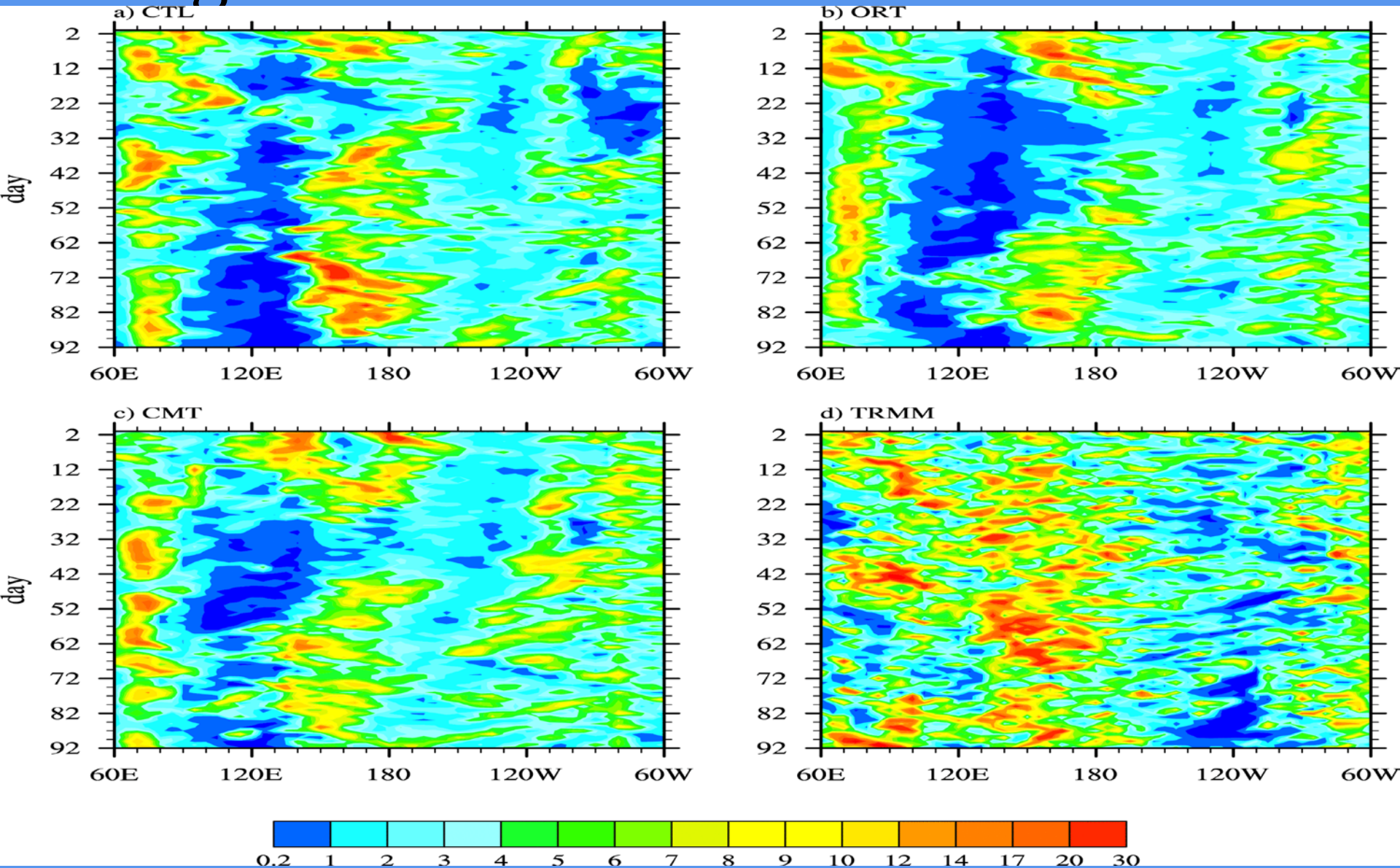
Global Distribution of JJA-mean Surface Precipitation



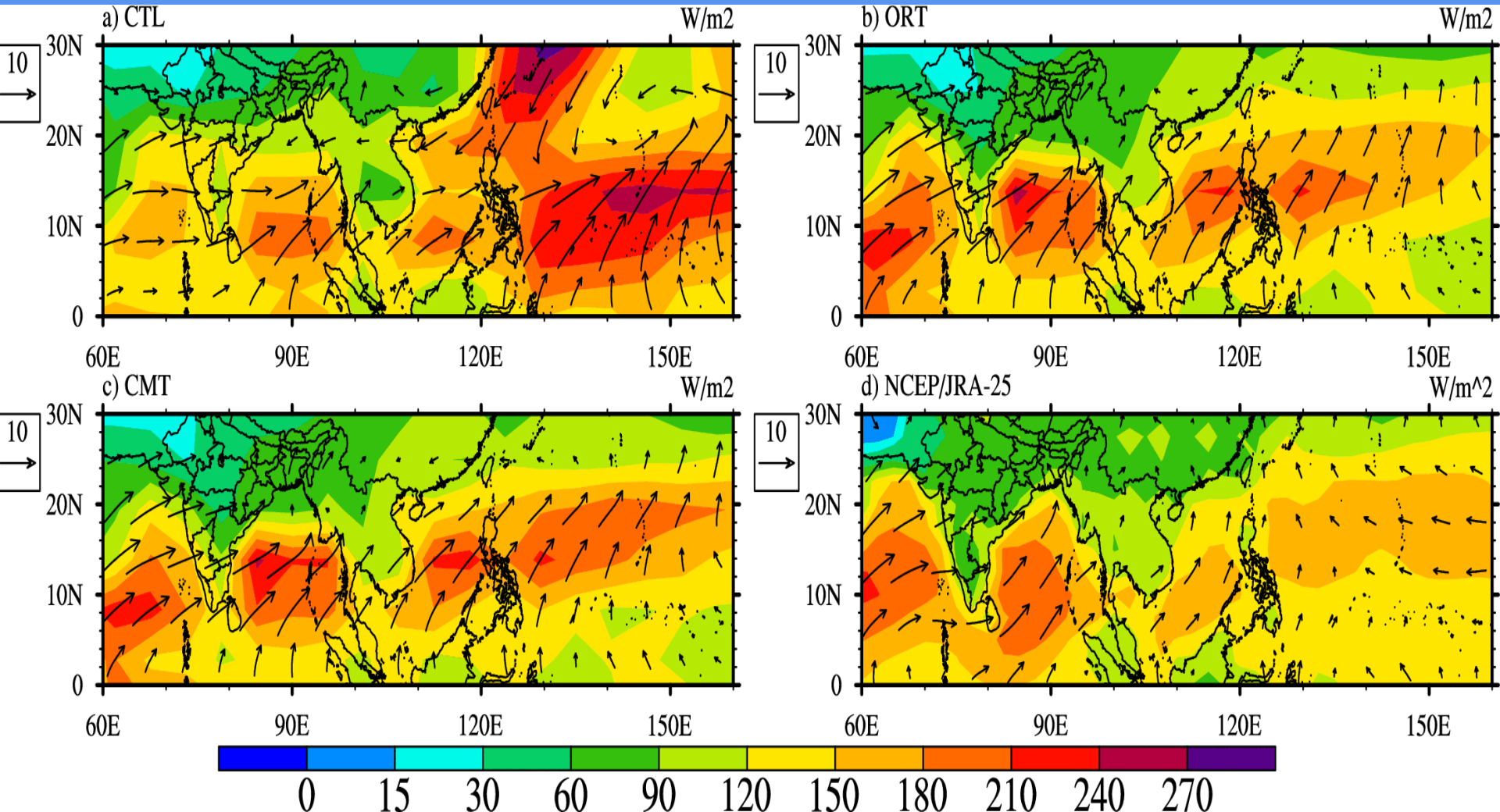
Hovmöller Diagrams of hourly precipitation in August at 15° N



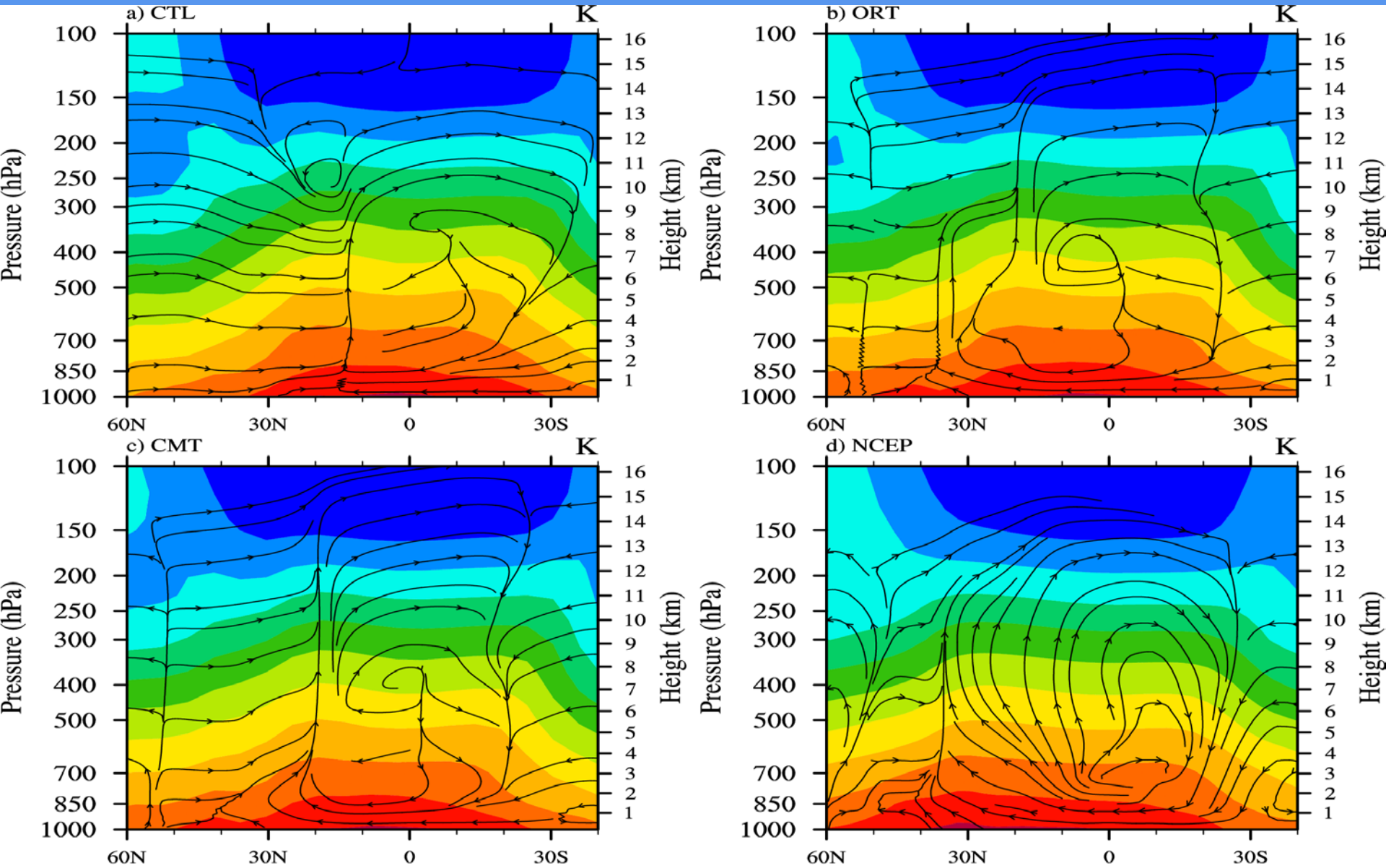
Hovmöller Diagrams of daily precipitation averaged between 10° S and 10° N in JJA



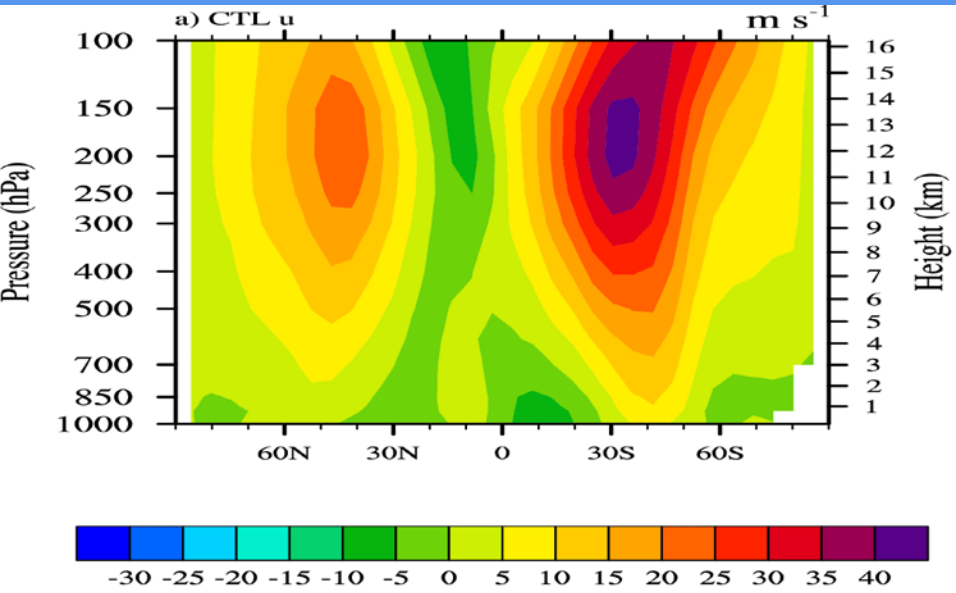
JJA Mean Surface Wind Overlapped with Latent Heat Flux

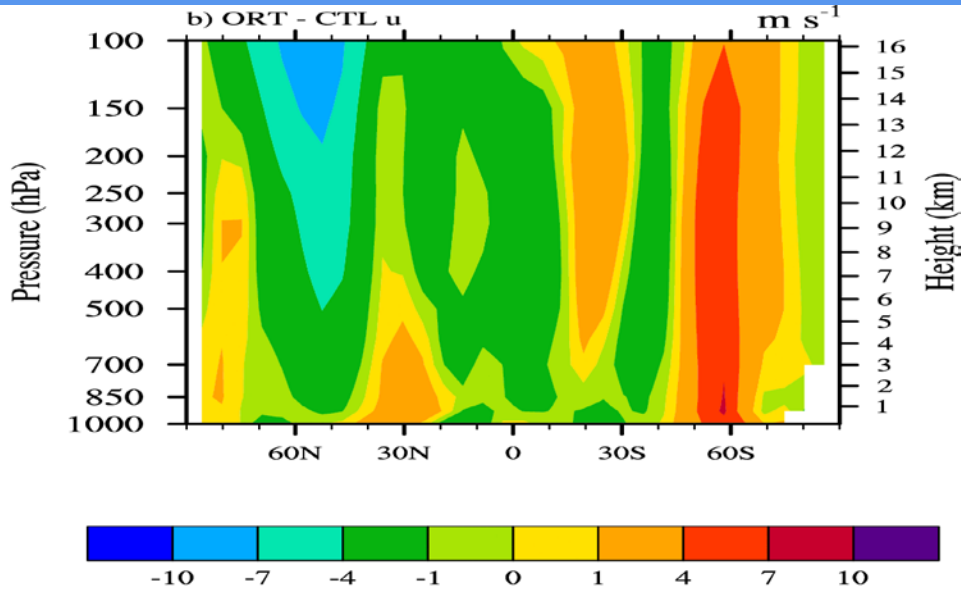


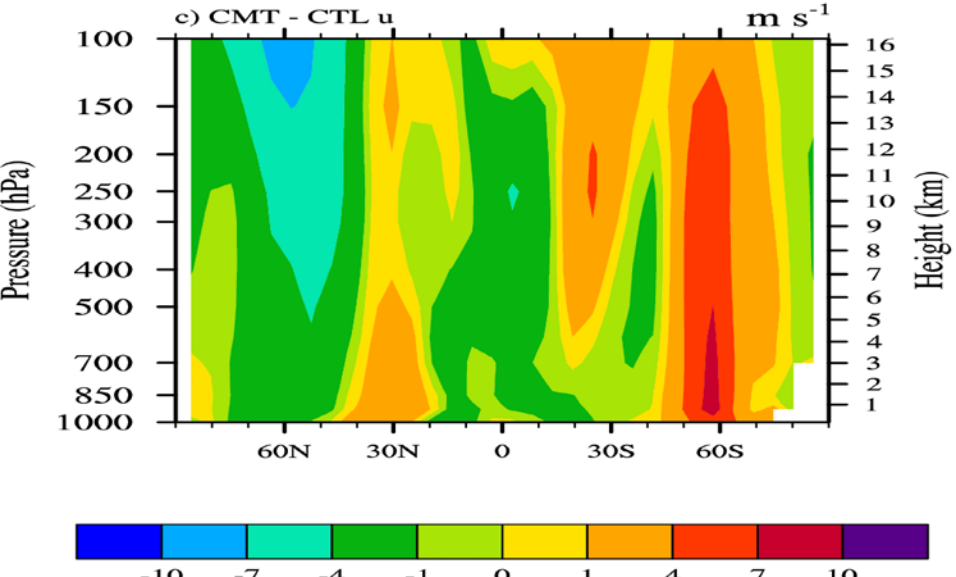
JJA Monsoon Circulation

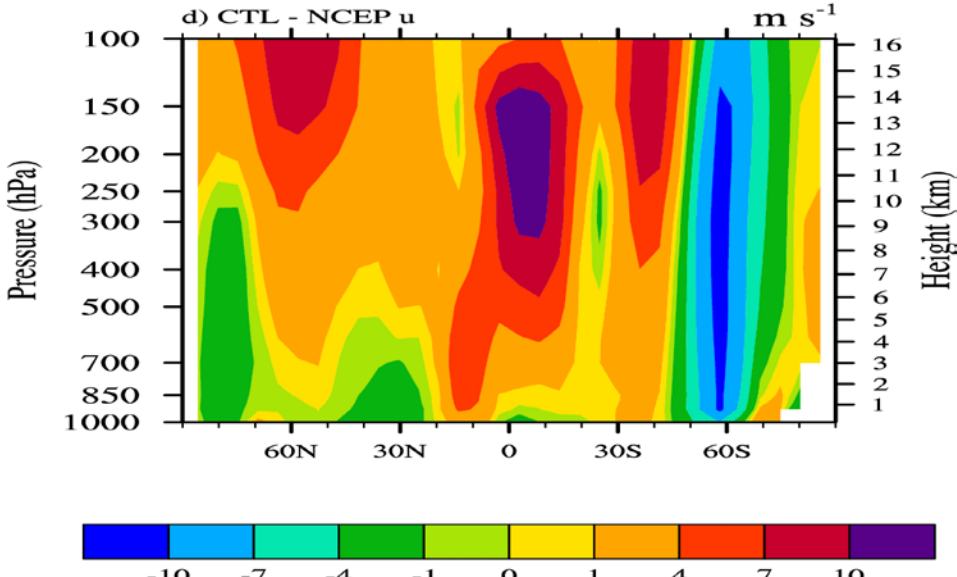


Zonal-annual mean u Wind

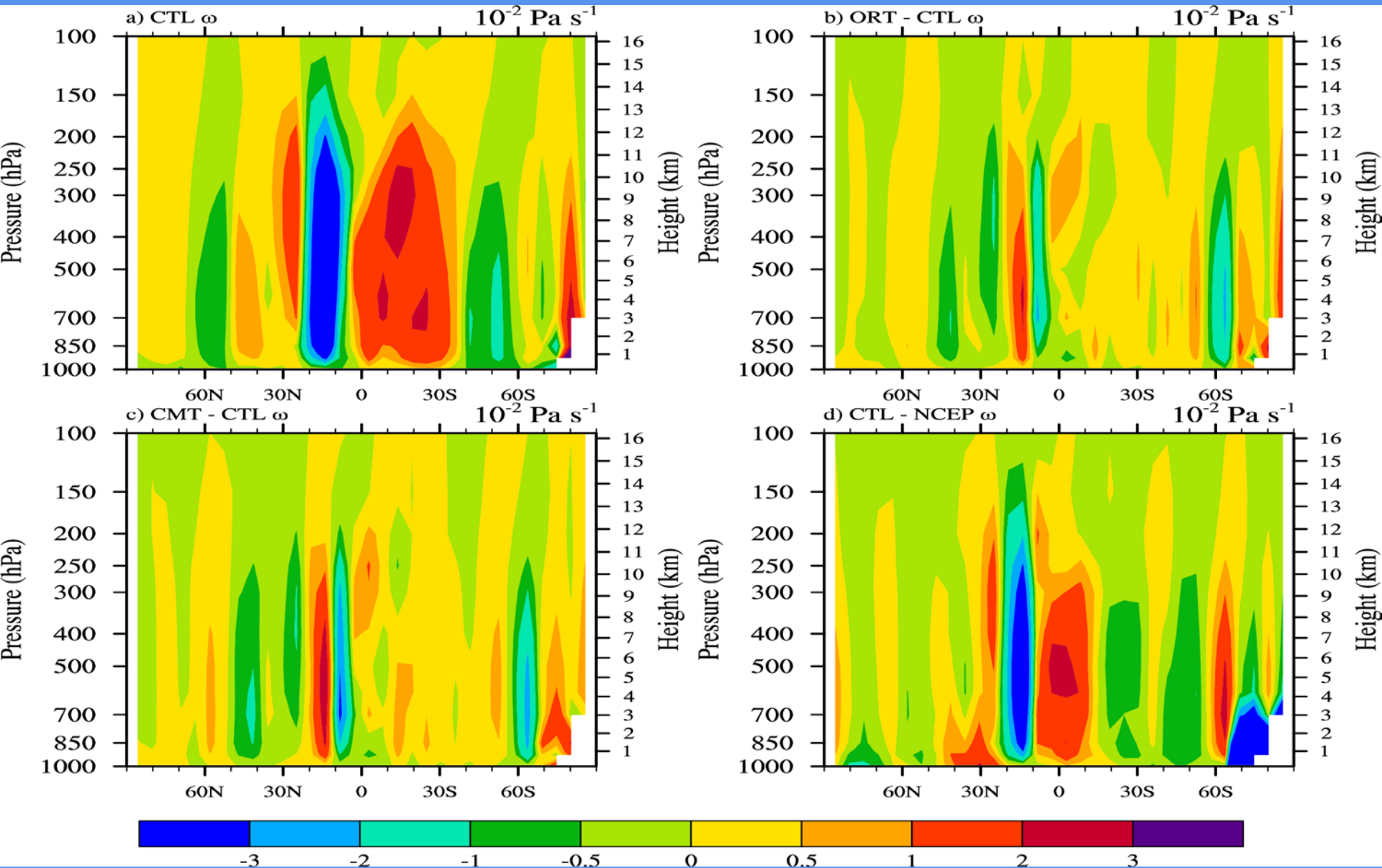








Zonal-annual Mean Vertical Velocity



Summary

- The orientation of the MCS and the associated momentum transport parameterization have 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 moistening are consistent with the u and v fields, implying a weak Hadley cell in summer.