A Momentum Transport Parameterization for MMF and Preliminary Results

Anning Cheng[1] and Kuan-Man Xu[2]

1. Science Systems and Applications, Inc.
2. Science Directorate, NASA Langley Research Center

Introduction

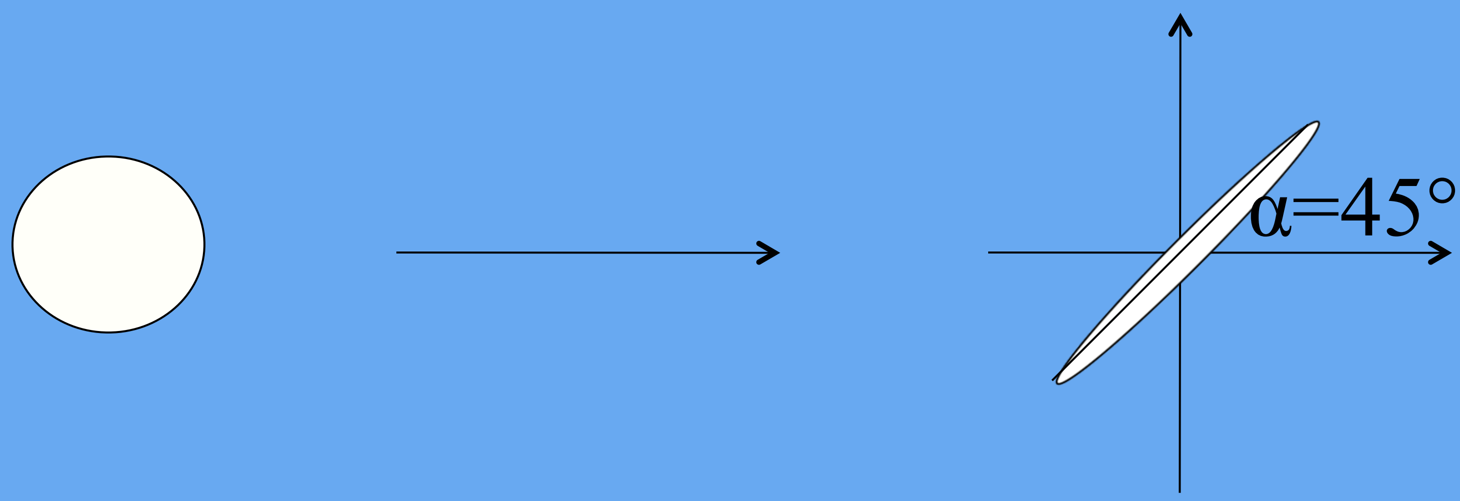
- Transport of momentum by mesoscale convective system (MCS) is an important process impacting climate modeling.
- Multiscale modeling framework (MMF), however, neglects the GCM subgrid-scale momentum transport.
- The GCM subgrid-scale momentum transport by all clouds, including MCSs, is parameterized and feedbacks 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 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.

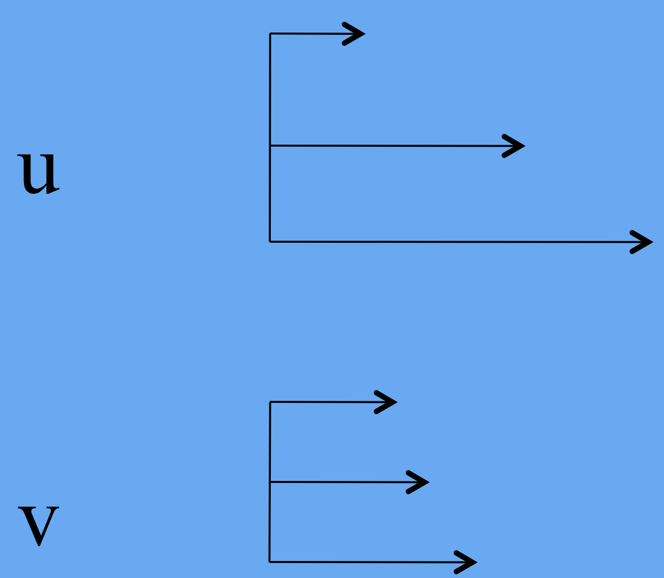
The Orientation of 2D CRM in a GCM box (II)

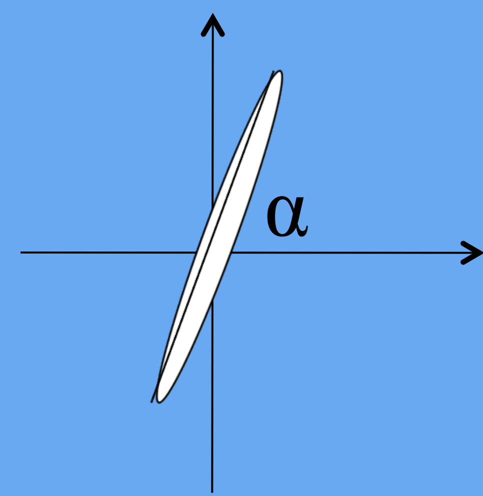
The MCS is a mesoscale convective complex with no preferred orientation and a round shape. The wind shear is weak.



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

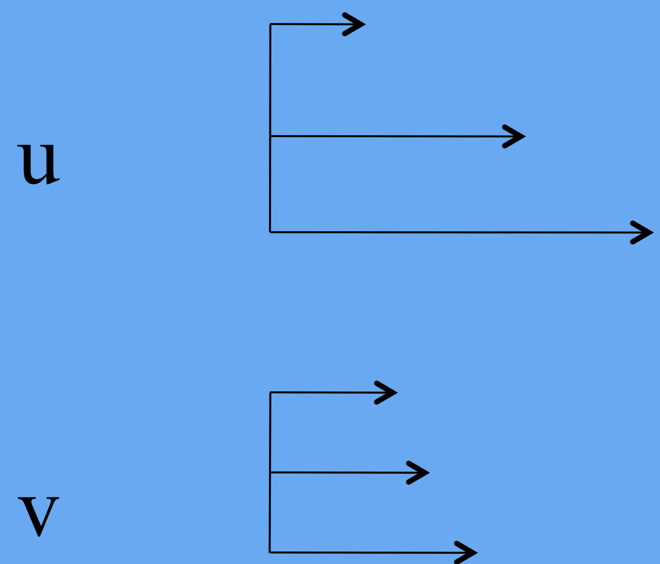
The MCS is perpendicular to the wind shear. The wind shear is strong and the stratification is very unstable.

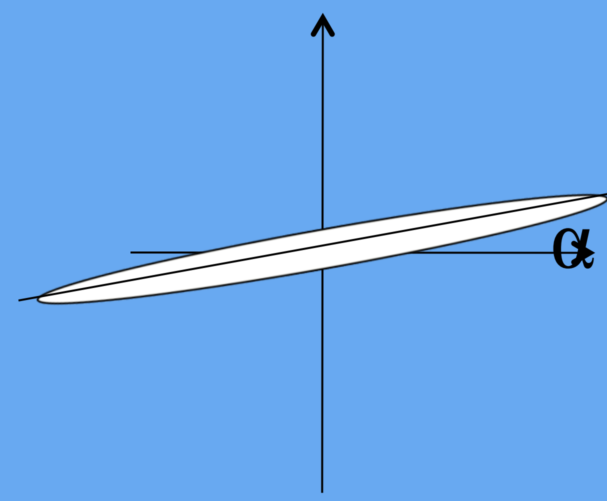




The Orientation of 2D CRM in a GCM box (III)

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

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

- GCM updated by

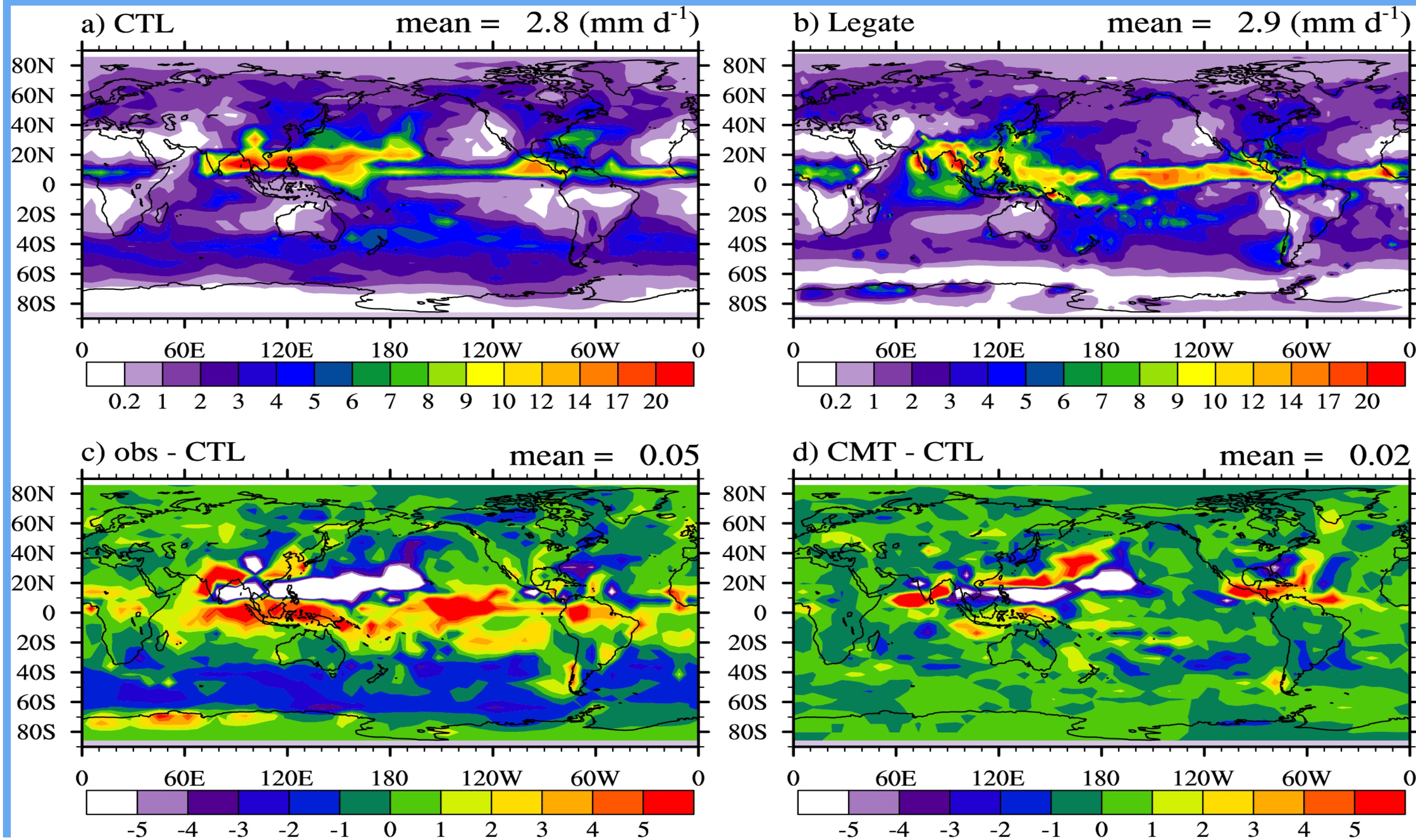
$$\frac{u_G^{n+1} - u_G^n}{\Delta t_G} = \frac{\left(\left\langle u_c \right\rangle^{n+1} - u_G^n\right)\cos\alpha}{\Delta t_G}$$

$$\frac{v_G^{n+1} - v_G^n}{\Delta t_G} = \frac{\left(\left\langle u_c \right\rangle^{n+1} - v_G^n\right)\sin\alpha}{\Delta t_G}$$

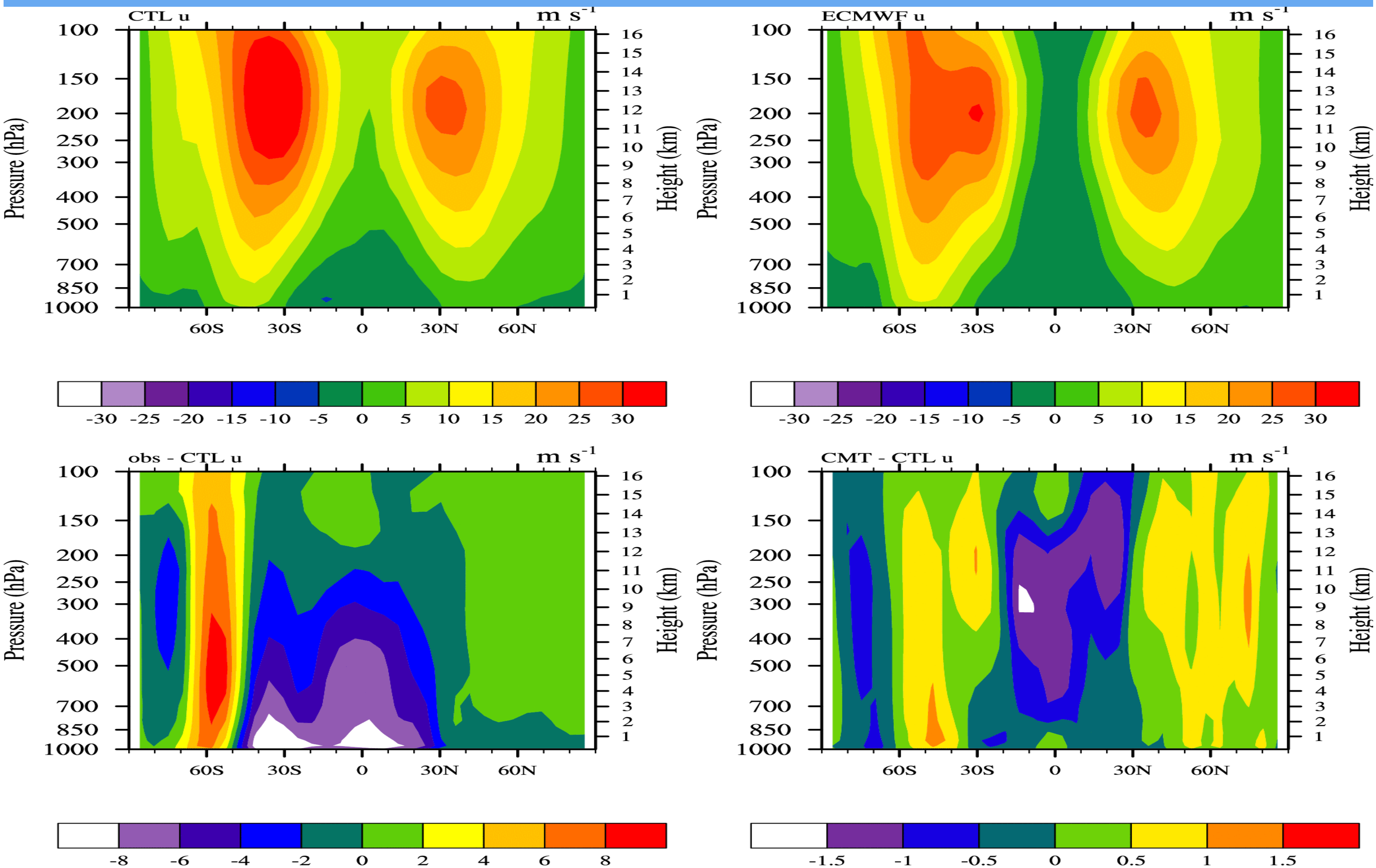
Experiment Design

- 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 CMT: with momentum transport coupled between CRM and GCM dynamic core.
- Both 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.

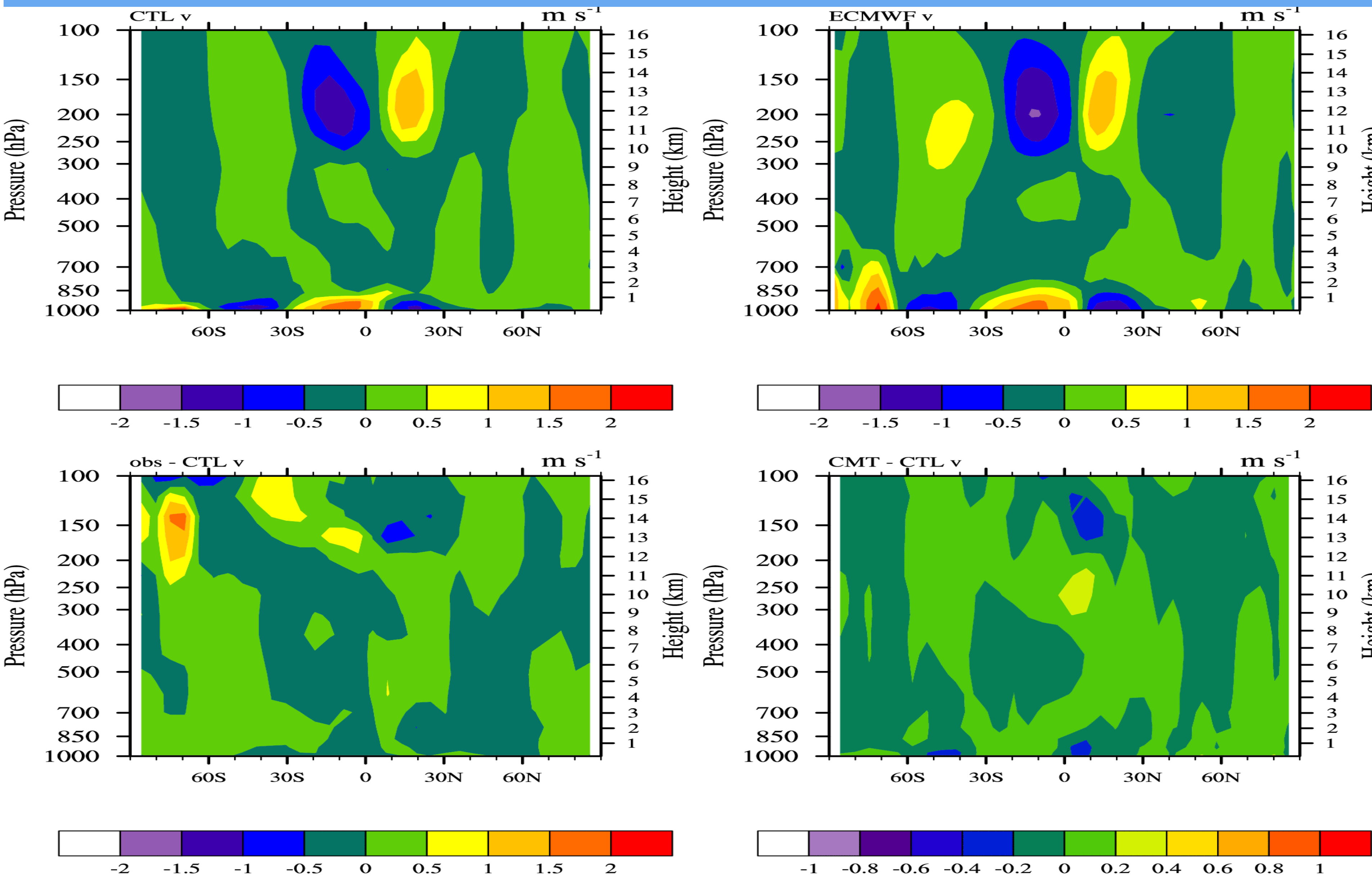
Global Distribution of JJA-mean Surface Precipitation



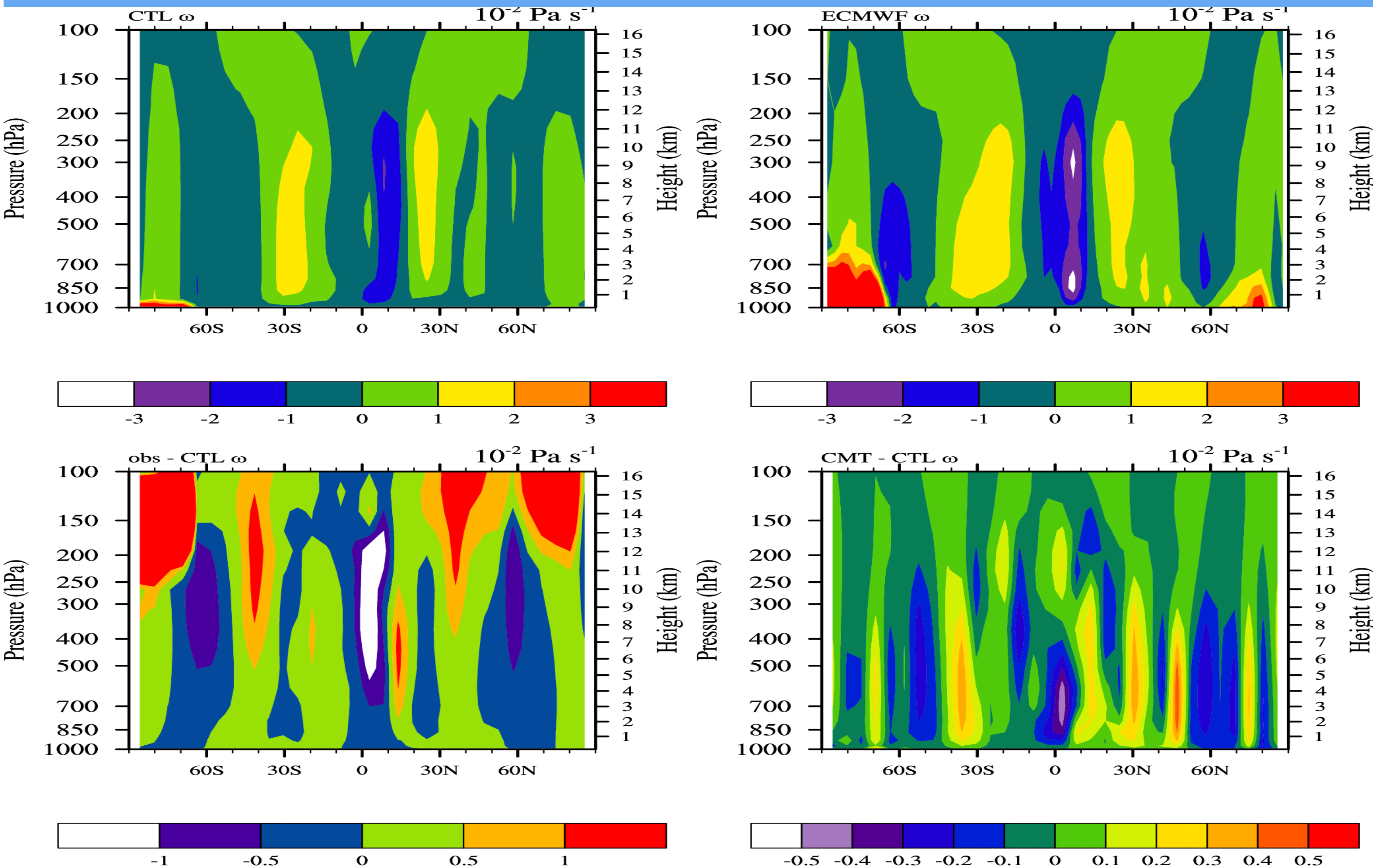
Zonal-annual mean u Wind



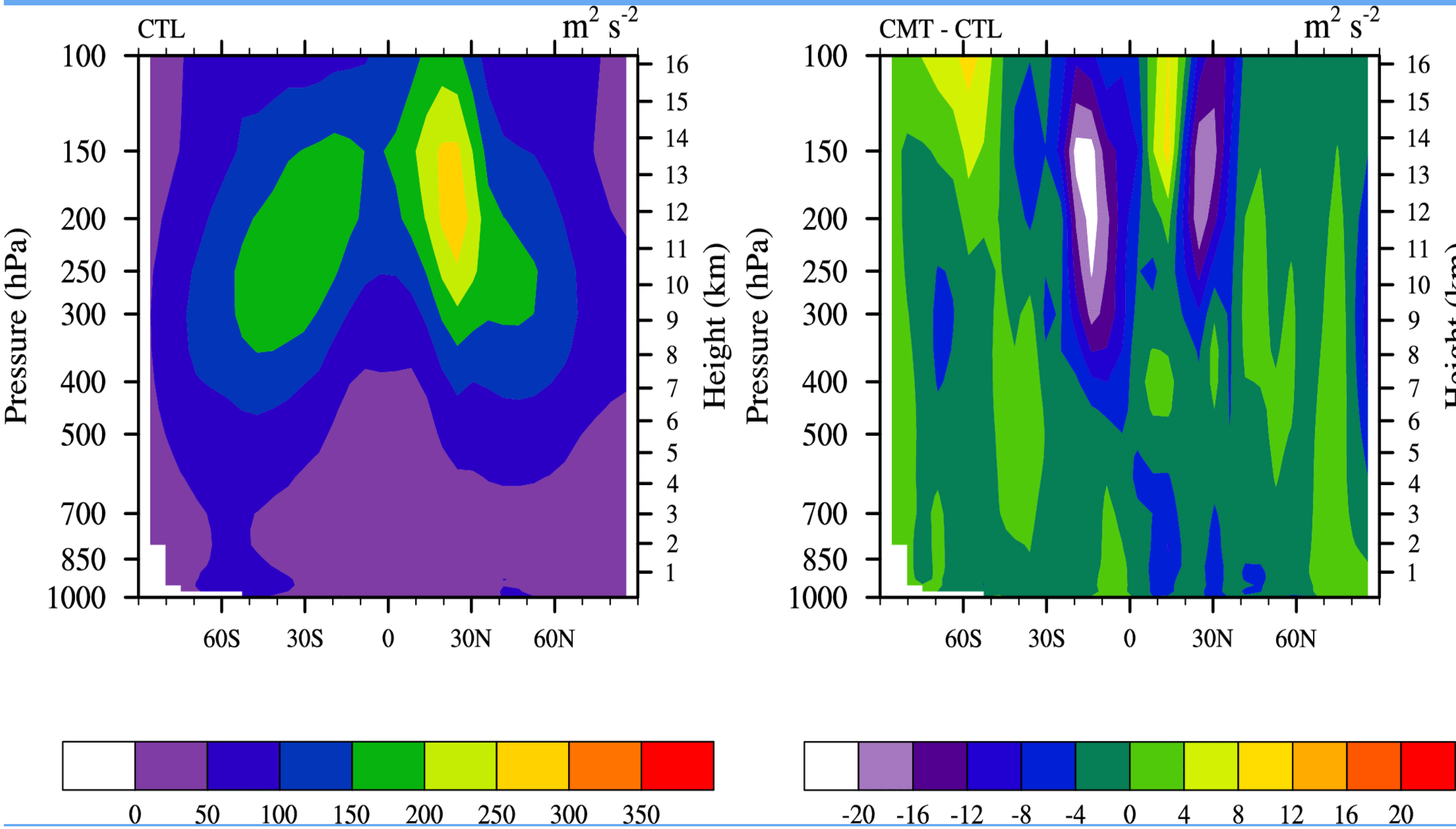
Zonal-annual mean v Wind



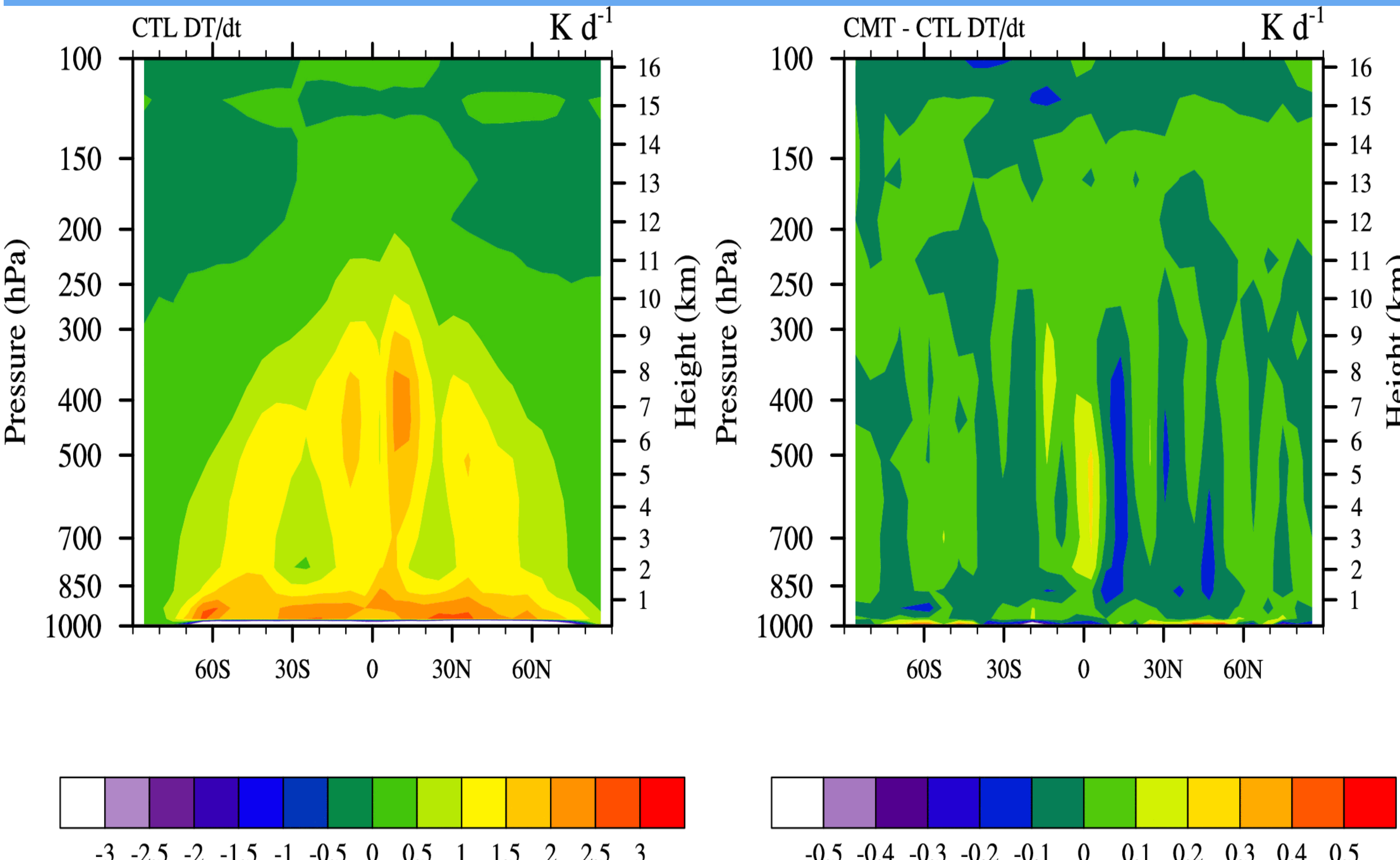
Zonal-annual Mean Vertical Velocity



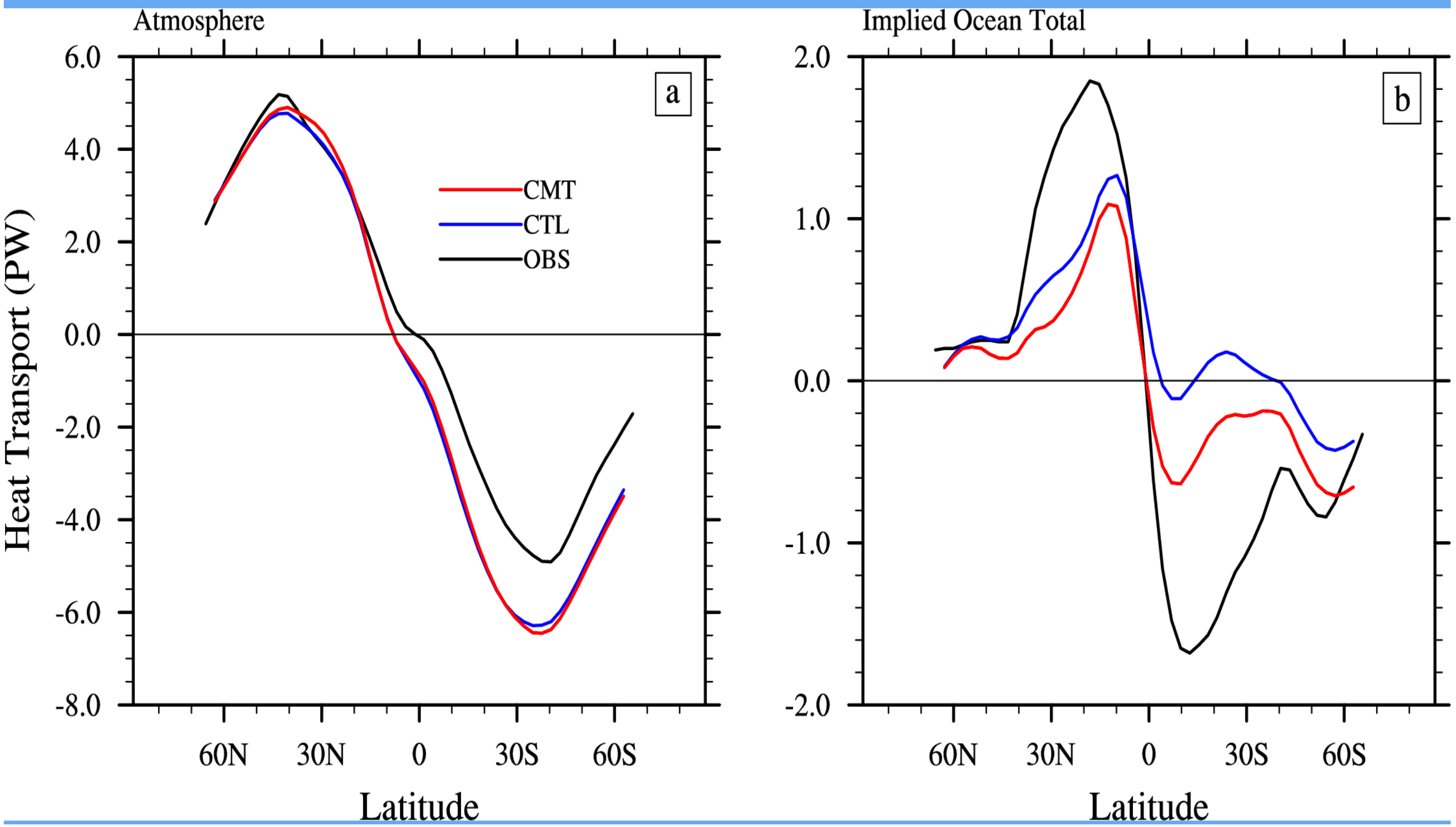
Zonal-annual Mean Kinetic Energy for Transient Eddies



Zonal-annual Mean Cloud Heating



Annual Mean Meridional Heat Transport



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 in the upper troposphere
- Mean meridional circulation becomes stronger due to the convective heating.
- Implied ocean heat transport becomes more reasonable in southern hemisphere due to the realistic surface energy budget.