A modeling analysis of rainfall and water cycle by the cloud-resolving WRF model over western North Pacific

Wenhua Gao[1] and Chung-Hsiung Sui[2]

[1]National Satellite Meteorological Center, CMA, Beijing
[2]Department of Atmospheric Sciences, NTU, Taipei

Jan. 8, 2013

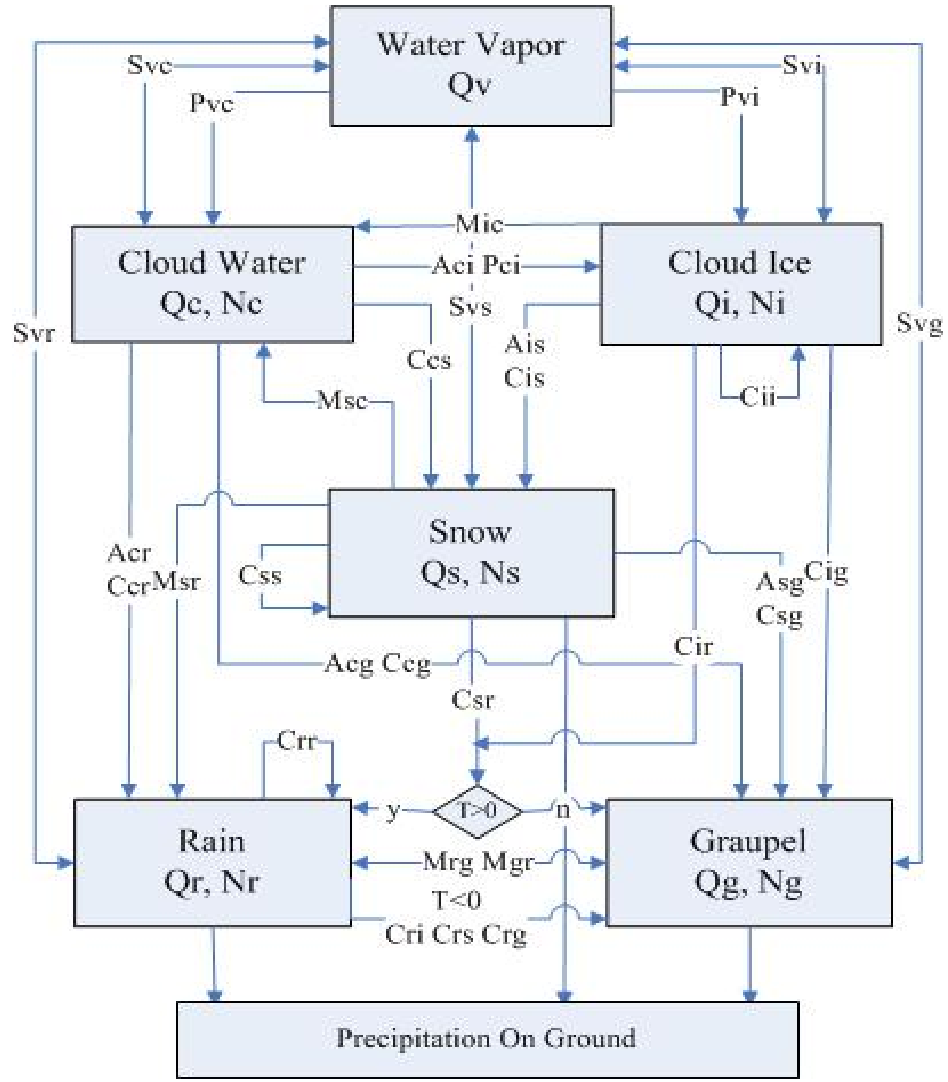
Motivation

- Precipitation is an essential variable describing the monsoon climate, which is also a key component of the earth's hydrological cycle system. Precipitation simulated in most climate models differ significantly from observations due to limitations in spatial resolutions and simple treatments of cloud processes.
- This study investigates the characteristics of precipitation, especially the extreme precipitation and water budget over the western North Pacific using the high-resolution (4-km) dynamic downscaling method based on WRF v3.2.1.

Five hydrometeors (cloud water, rain, ice, snow, graupel) are included in the Chinese Academy of Meteorological Sciences (CAMS) two-moment microphysics scheme. Both mixing ratio and number concentrations of each hydrometeor species are predicted. Total 34 cloud microphysical processes are presented in the scheme.

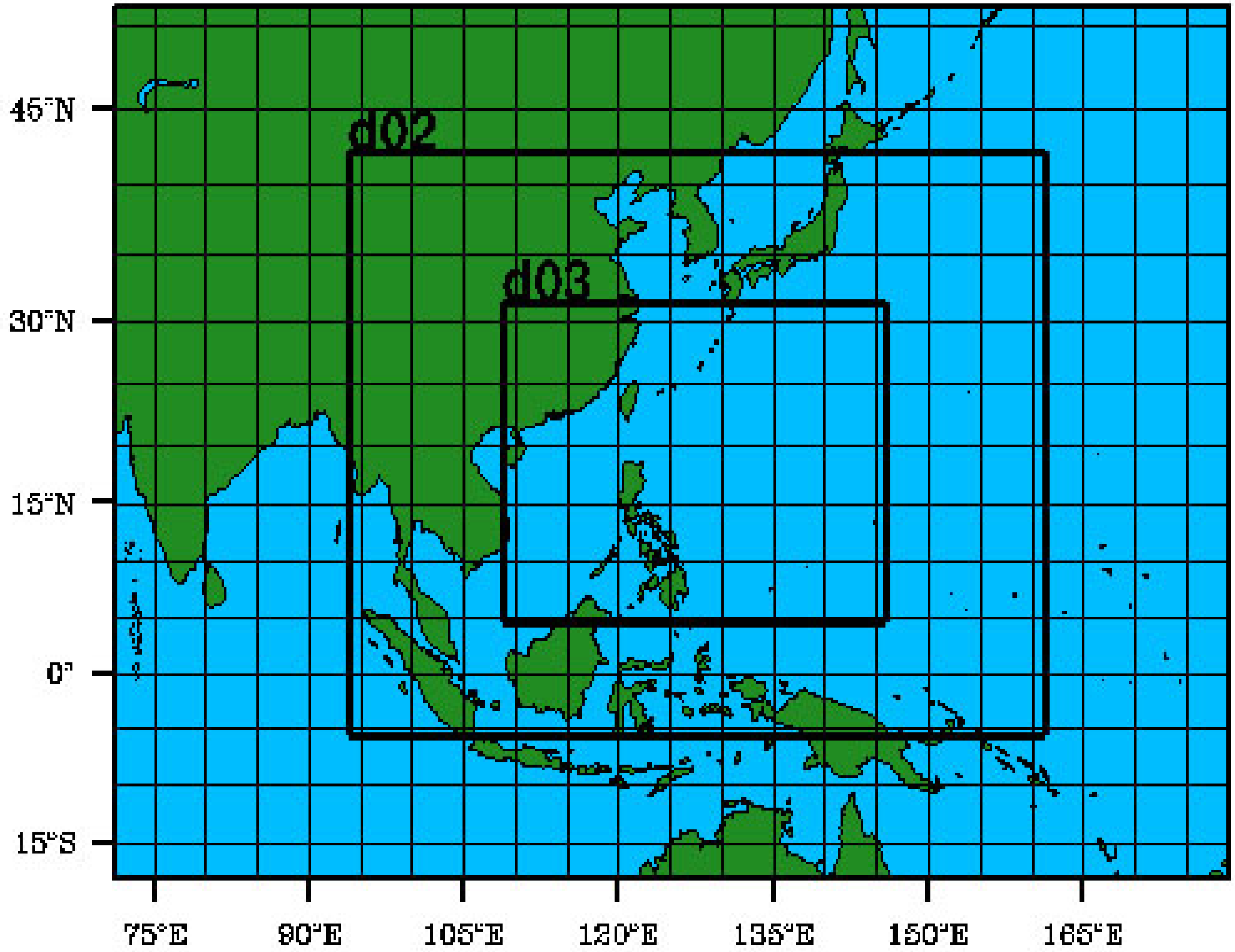
Size Distribution Function:

$$N_x(D) = N_{0x} D^{\alpha_x} e^{-\lambda_x D}$$



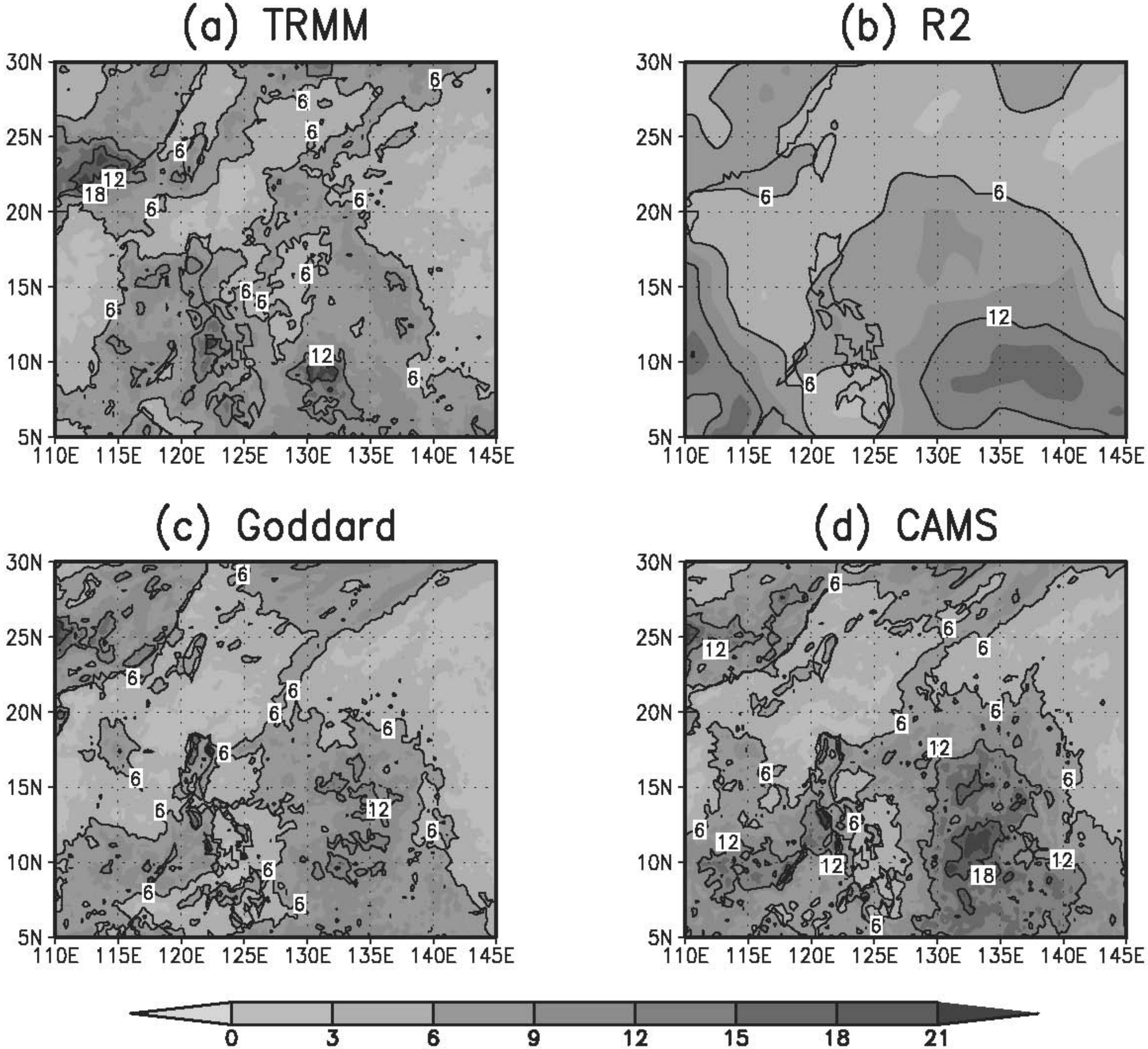
CAMS two-moment microphysics

Cumulus	Grell
Microphysics	CAMS Goddard
Radiation	rrtm Dudhia
Surface layer	M-O
Land surface	Noah
Boundary layer	YSU
I.C B.C	NCEP R2

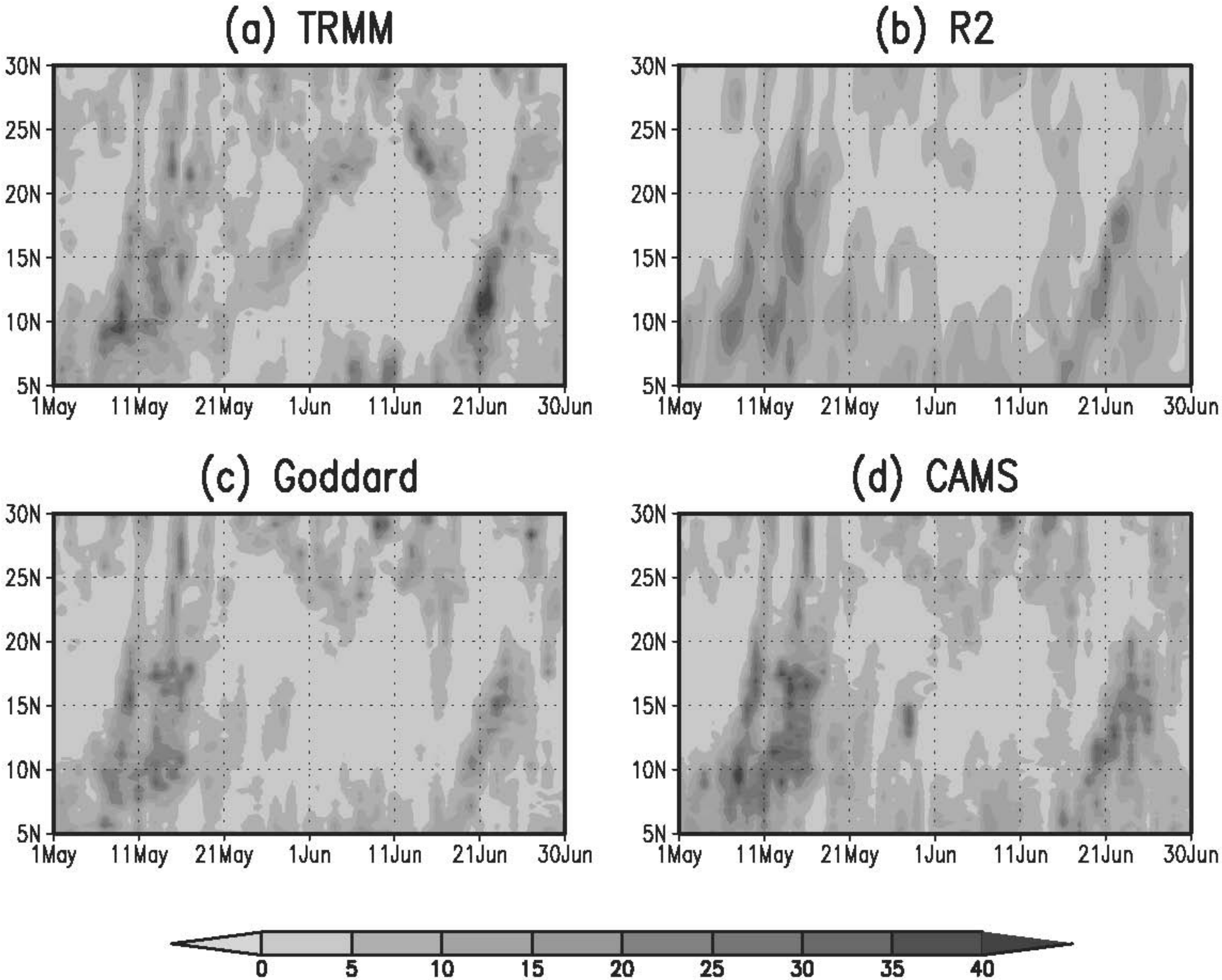


Domains size: (290x210 36-km; 541x421 12-km; 883x691 4-km)

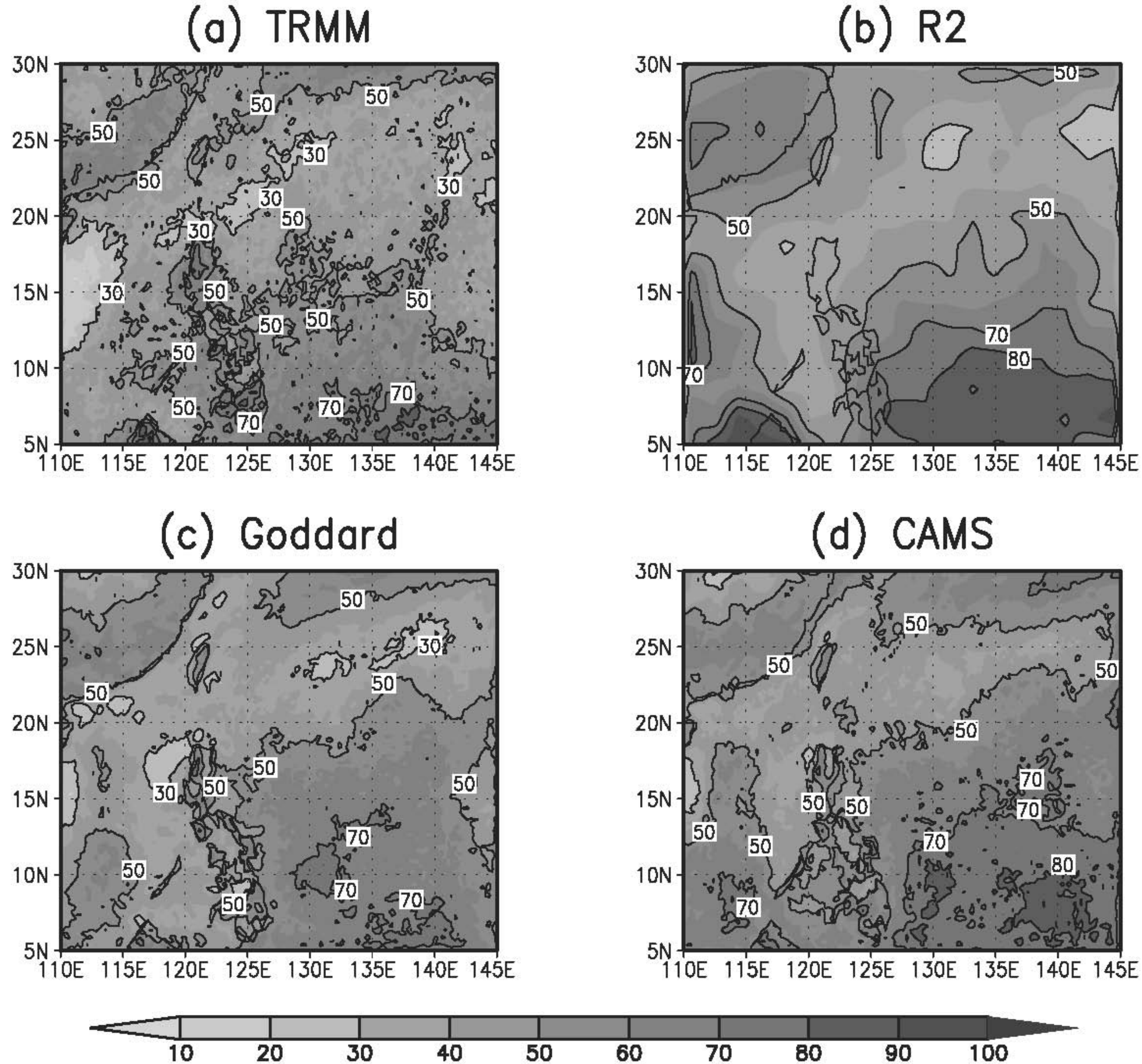
The model is re-initialized every 2 days, and each re-initialization runs for 60 h (12 h is for spinning up time) whose total integration time spans two month.



Spatial distribution of the daily mean precipitation (mm day^{-1}) during May to June 2008 from (a) TRMM, (b) R2 reanalysis, and (c), (d) WRF simulations.



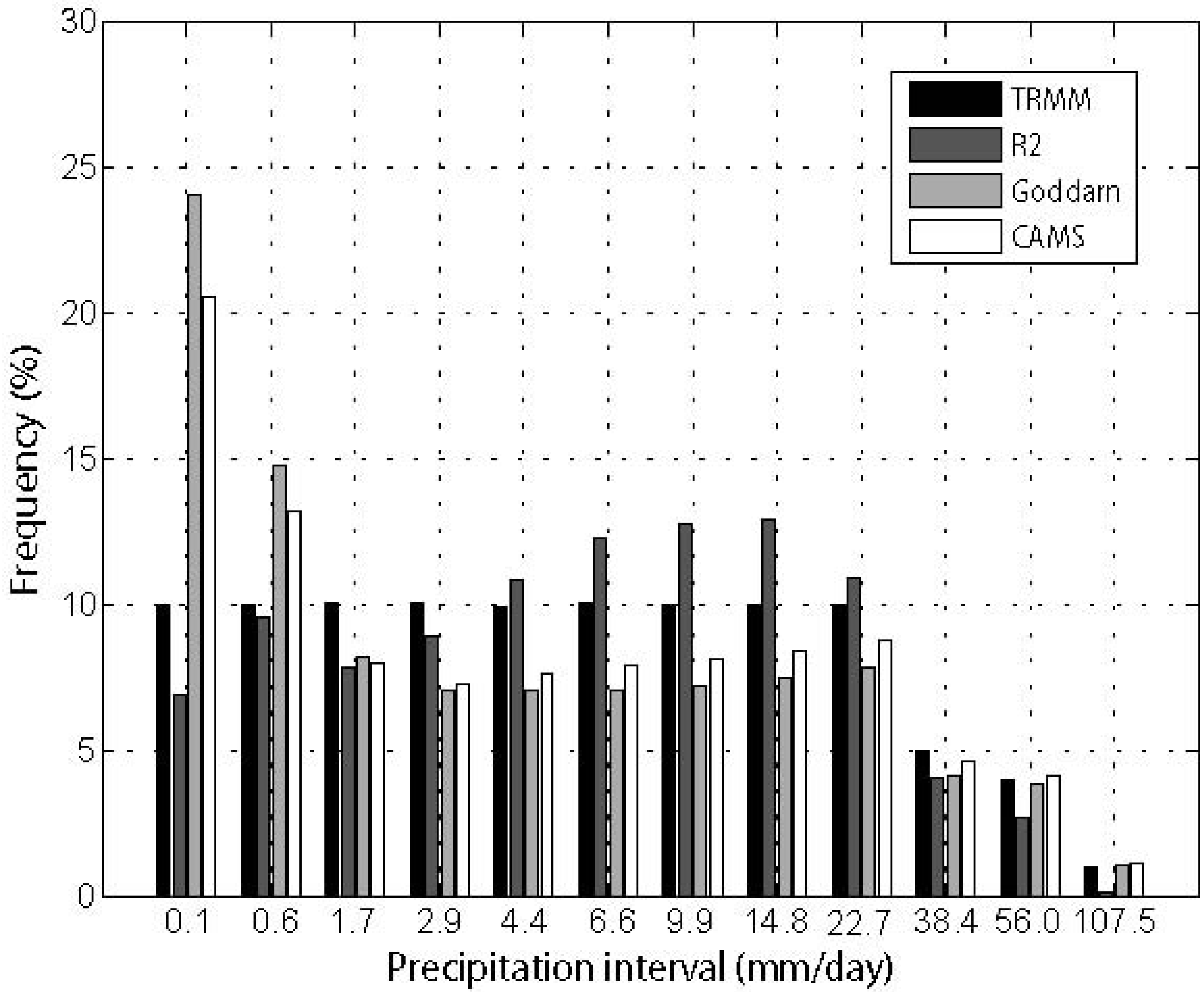
Precipitation (mm day^{-1}) as a function of time and latitude averaged over 110-145° E from (a) TRMM, (b) R2, and (c), (d) WRF simulations.



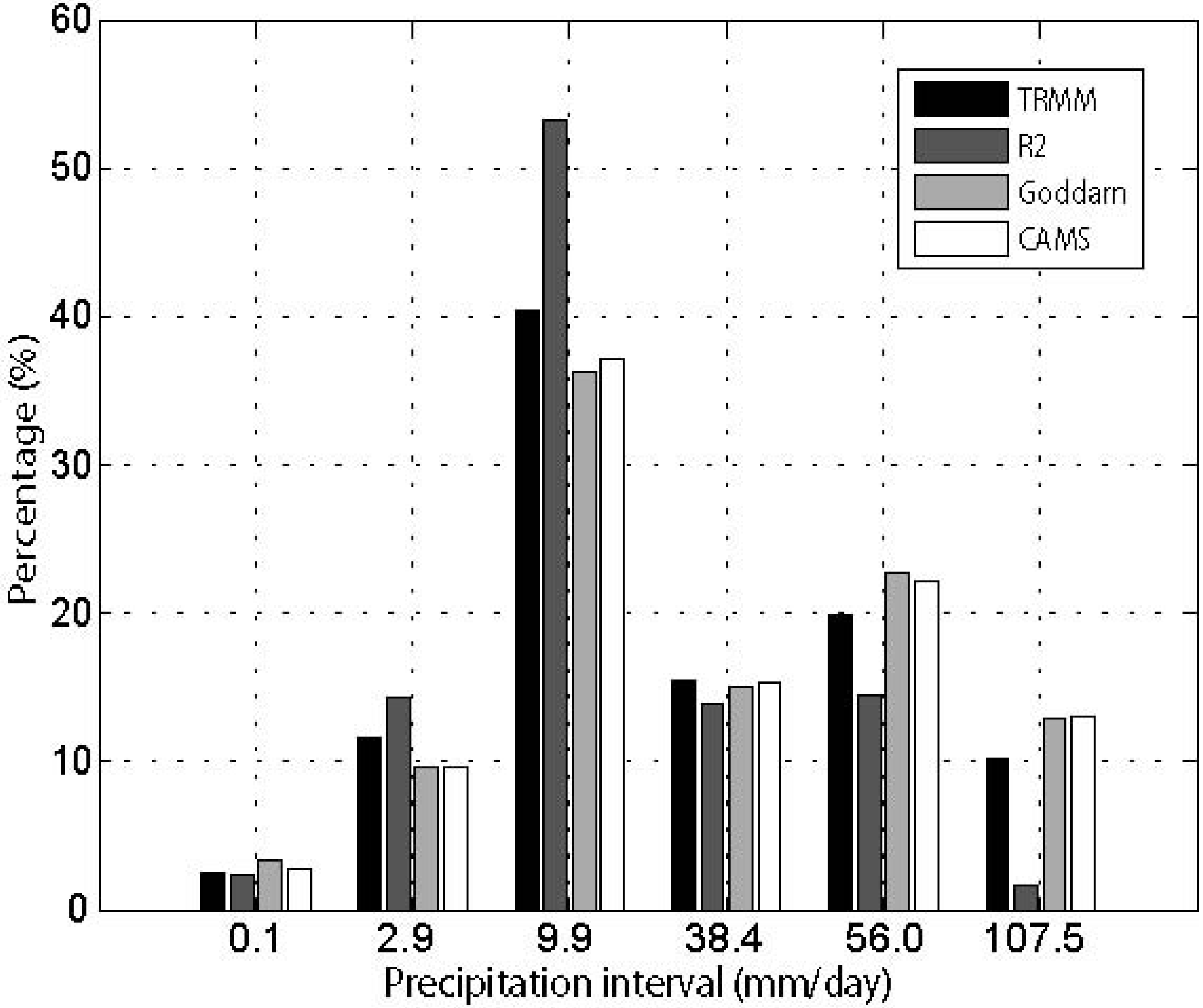
Percentage of days with precipitation rate exceeding 0.1 mm day^{-1} during May to June 2008 from (a) TRMM, (b) R2, and (c), (d) WRF simulations.

Area-averaged daily mean precipitation (mm day^{-1}), pattern RMSE (mm day^{-1}), percentage of rainy days (%) and precipitation intensity (mm day^{-1}).

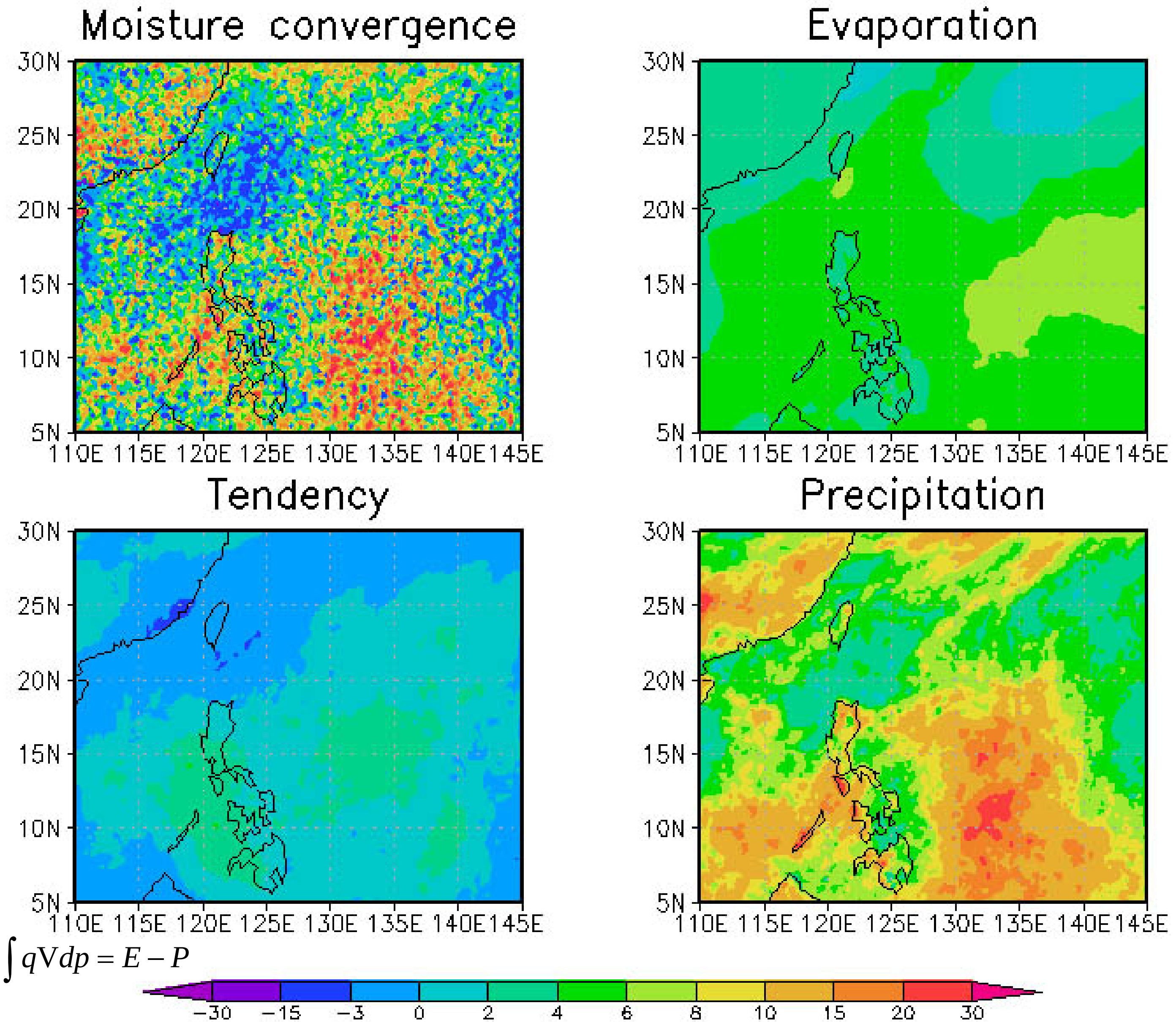
	TRMM	R2	Goddard	CAMS
Mean	7.03	7.38	6.24	8.01
Spatial RMSE	-	4.20	3.26	4.00
Rainy days	47.4	55.6	49.1	57.1
Intensity	14.8	13.3	12.7	14.0



Probability distribution of observed and simulated daily precipitation at different intervals over domain 3.

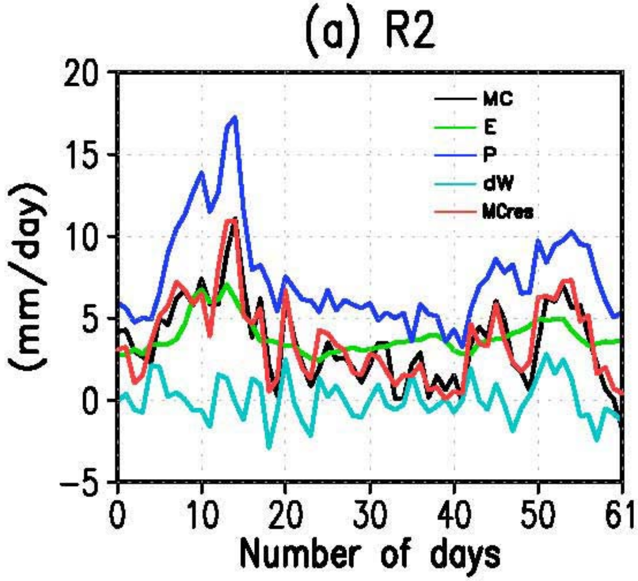


Percentage of observed and simulated precipitation amount as a function of precipitation rate over domain 3.

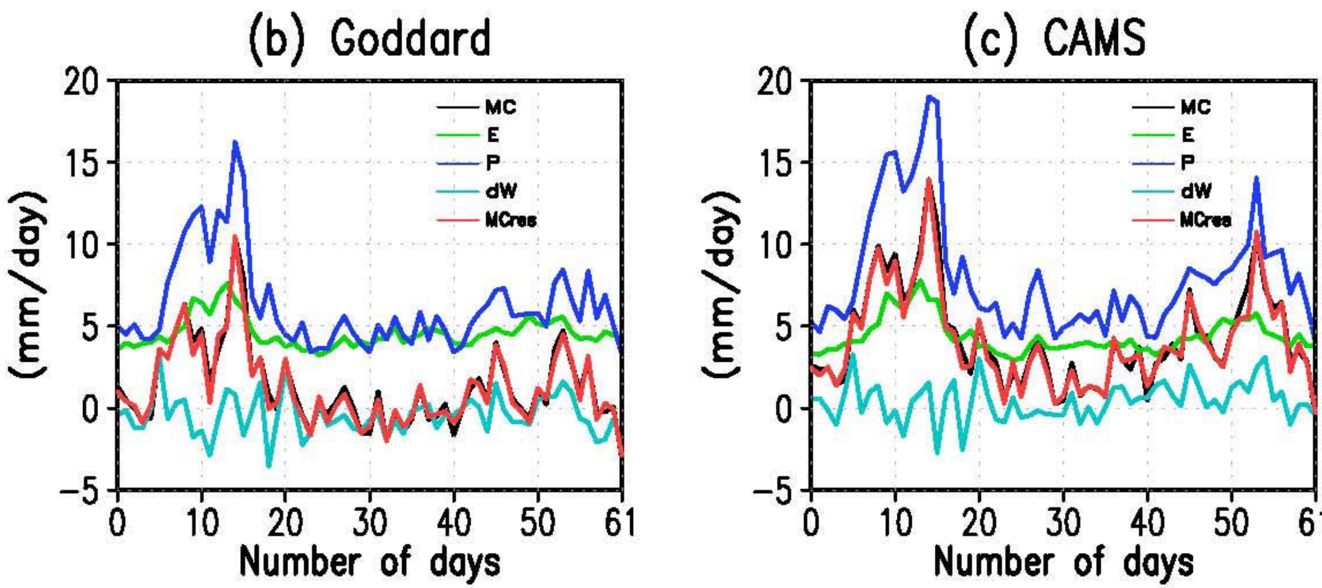


$$\frac{\partial}{\partial t}\frac{1}{g}\int q dp + \nabla \cdot \frac{1}{g}\int q\mathbf{V} dp = E - P$$

Daily mean (a) moisture convergence, (b) evaporation, (c) precipitable water tendency, and (d) precipitation (mm day^{-1}) derived from CAMS microphysics during May to June 2008.



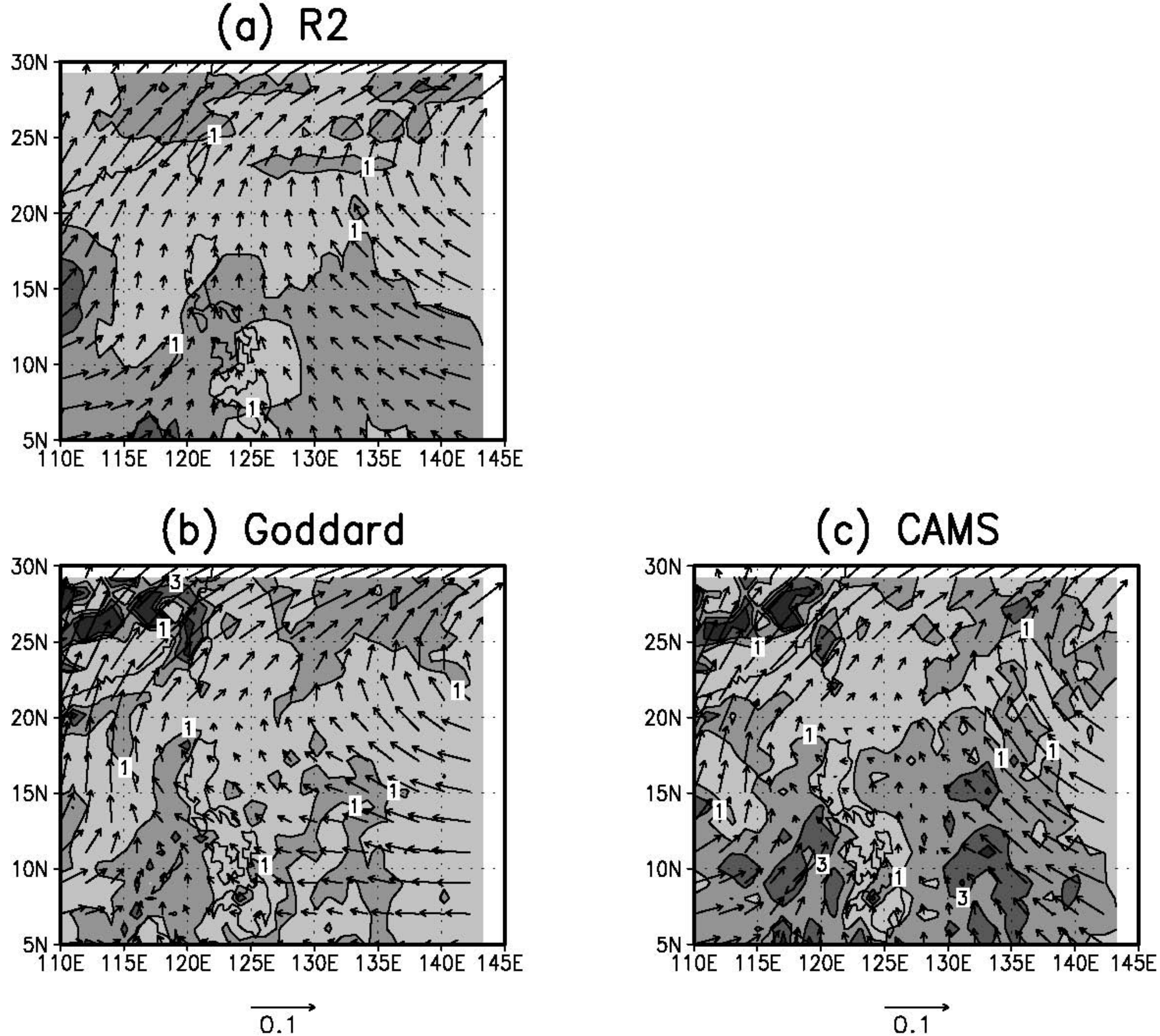
$$\frac{\partial}{\partial t}\frac{1}{g}\int q dp + \nabla \cdot \frac{1}{g}\int q\mathrm{V} dp = E - P$$



Time evolution of the daily mean moisture budget averaged over domain 3 from (a) R2 reanalysis, (b) Goddard, and (c) CAMS simulations.

The daily mean hydrologic budget terms averaged over domain 3 during May to June 2008.

	Moisture Convergence	Evaporation	Precipitation	Tendency
R2	3.03	3.86	7.38	0.05
Goddard	1.31	4.58	6.26	-0.45
CAMS	4.26	4.38	8.01	0.42



Mean 850 hPa moisture flux vector (m kg s^{-1} kg^{-1}) with associated moisture convergence fields (mm day^{-1}) averaged over May and June 2008 from (a) R2 reanalysis, (b) Goddard, and (c) CAMS simulations.

Conclusions

- The WRF simulations reproduce the spatial distributions of time mean precipitation amount. The simulated frequency distributions of rainy days show overestimated light precipitation, underestimated moderate to heavy precipitation, and well simulated extreme precipitation.
- The vapor budget analysis shows that the heavy precipitation is contributed mostly by the stronger moisture convergence. However, in less convective periods, the precipitation is more influenced by the surface evaporation.

Conclusions

- The vapor budget is sensitive to the cloud microphysics scheme that affects the location and strength of atmospheric latent heating and then the large-scale circulation.

Thanks !