Added Value of a Convection Permitting Model in Simulating Atmospheric Water Cycle over the Tibetan Plateau

Yin Zhao[1] , Tianjun Zhou[2] , Puxi Li[1], Kalli Furtado[3], Liwei Zou[2]

[1] Chinese Academy of Meteorological Sciences, China Meteorological Administration
[2] Institute of Atmospheric Physics, Chinese Academy of Science
[3] Met Office

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Introduction

✓ Precipitation over the Tibetan Plateau (TP) has important influence on local and downstream ecosystem, as well as atmospheric circulation.

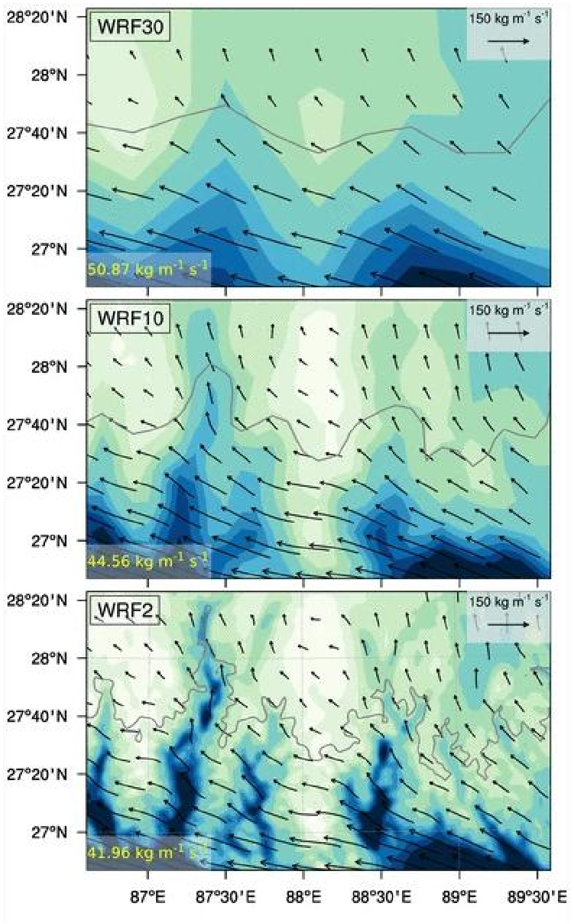
☐ How to improve the simulation of the precipitation over the TP is a facing task of the climate modeling community.

➢ Efforts have been devoted to improving the simulation of water vapor transport over the TP, which is related to precipitation.

- dynamic transport schemes (Yu et al., 2015)
- resolution of and topography used in the model
  (Lin et al., 2018; Wang et al., 2020; Zhou et al., 2019)
- etc.

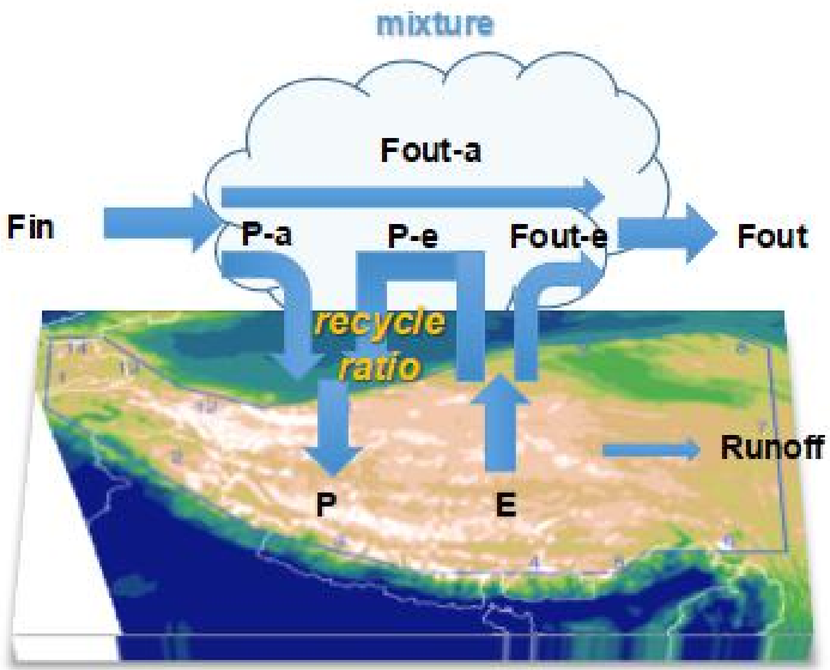
What happens after the transport of moisture?

Moisture transport over the TP
in WRF simulations with different resolutions



Lin et al. 2018 CD

Introduction



Atmospheric water cycle process

- The external water vapor **transport**
- -> Fin & Fout

- Ratios of atmospheric moisture **converting** into precipitation
- -> P-a & P-e

Objective:

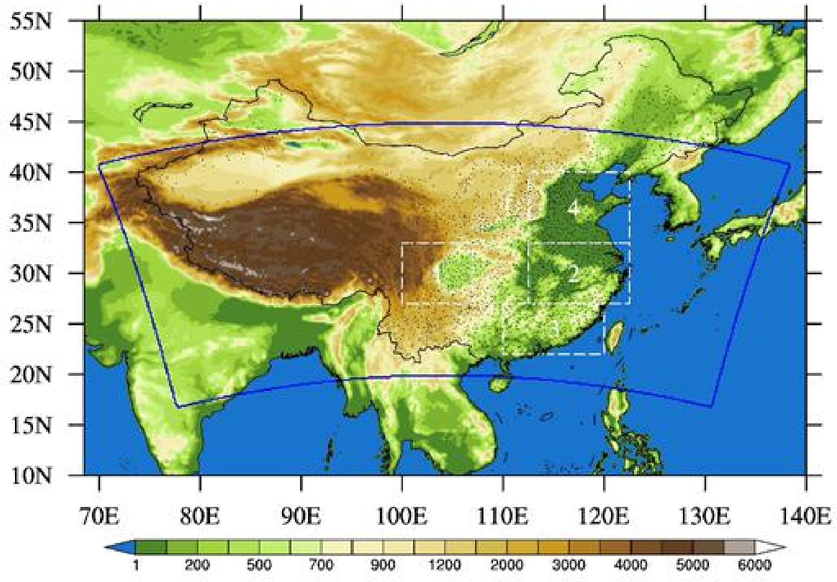
- Difference between the convection permitting and parameterized models in simulating the atmospheric water cycle over the TP?
- Inspiration for the climate modeling community?

Model and observation data

Met Office Unified Model

LSM - large scale model
horizontal resolution of 13.2km
deep convection parameterized:
the Gregory-Rowntree scheme (1990)

CPM - convection permitting model
horizontal resolution of 4.4km
convection permitting:
with no deep convection scheme



Blue box indicates the simulation domain

Li et al. 2020 CD

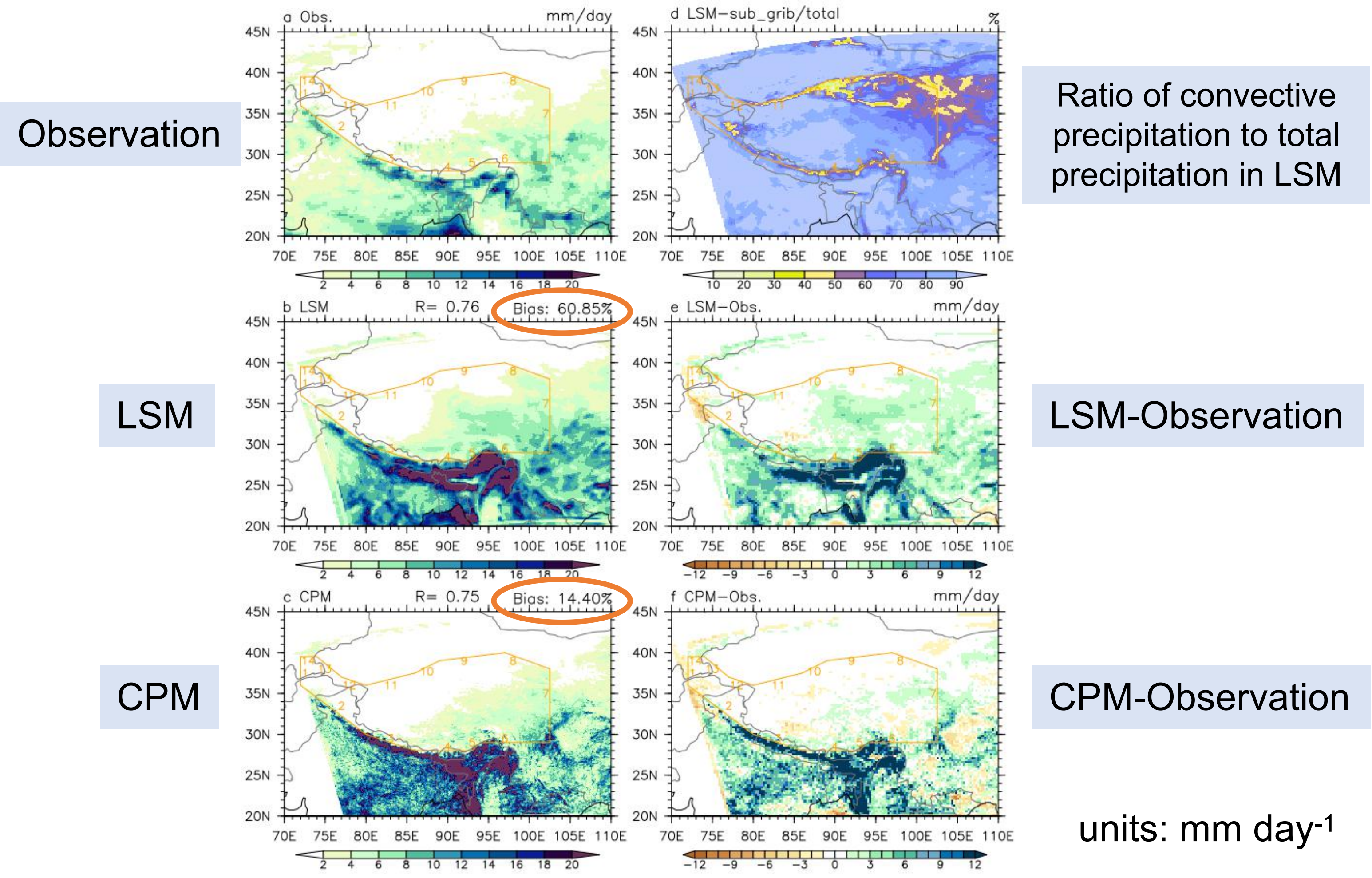
Simulation period April to September in 2009

Precipitation observation data

China Gauge-based Daily Precipitation Analysis (CGDPA; daily, 0.25°)

CPM improves the simulation of TP precipitation

Precipitation

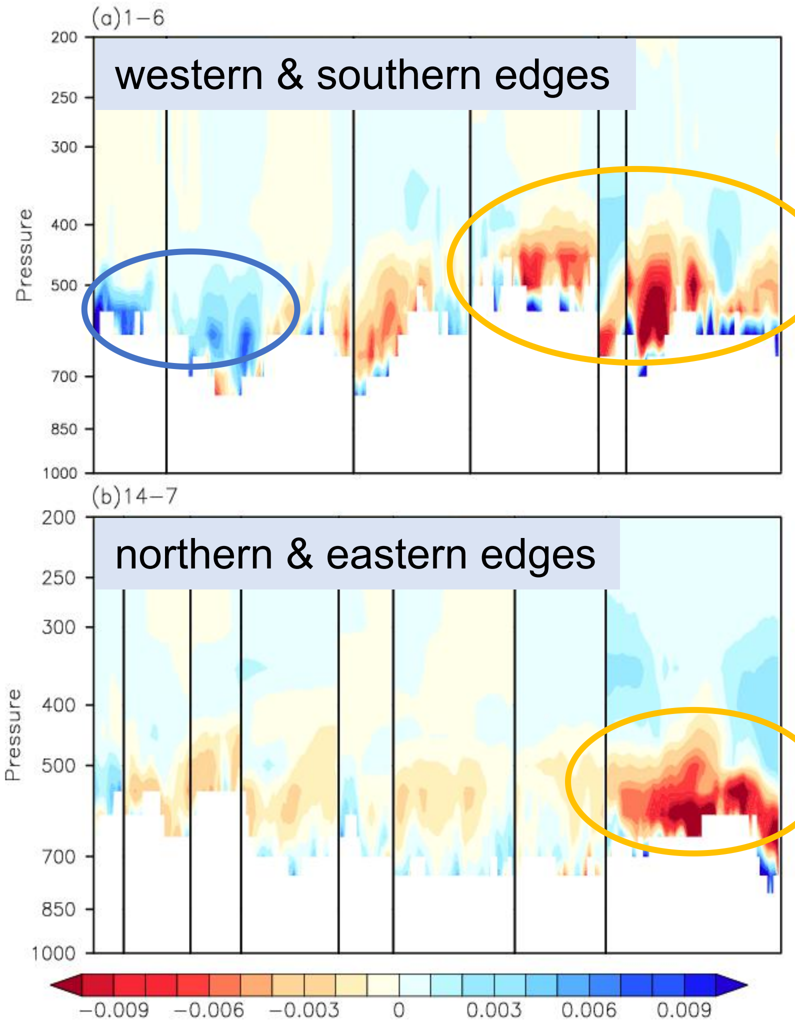


units: mm day^{-1}

- Both LSM and CPM can reproduce the spatial characters of the summer precipitation over the TP.
- The summer precipitation over TP is greatly overestimated in LSM by 61% compared with the observation, dominated by convections.
- With explicitly resolved deep convection, the overestimation of the TP precipitation is improved in CPM, with the bias decreased to only 14% of the observation.

CPM simulates stronger eastward moisture transport

Profiles of Water Vapor Transport



blue represents inflow red represents outflow units: kg kg^{-1} m s^{-1}

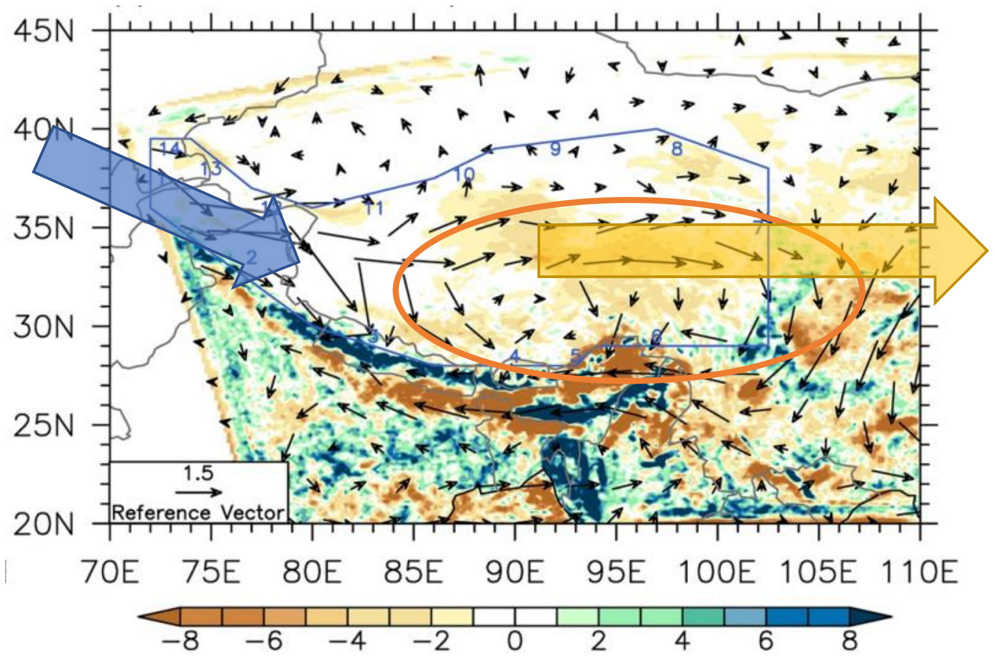
Difference between CPM and LSM

- The moisture transport through the southeastern edges of the TP is reduced in CPM due to the finer terrain.
- However, the inflow through western edges and the outflow through the eastern edge are even stronger (above 600hPa) in the CPM simulation, in spite of the finer topography.

Why does CPM simulate **stronger eastward moisture transport**?

Upscale effect of diabatic process on moisture transport

Difference in large-scale circulation between CPM and LSM

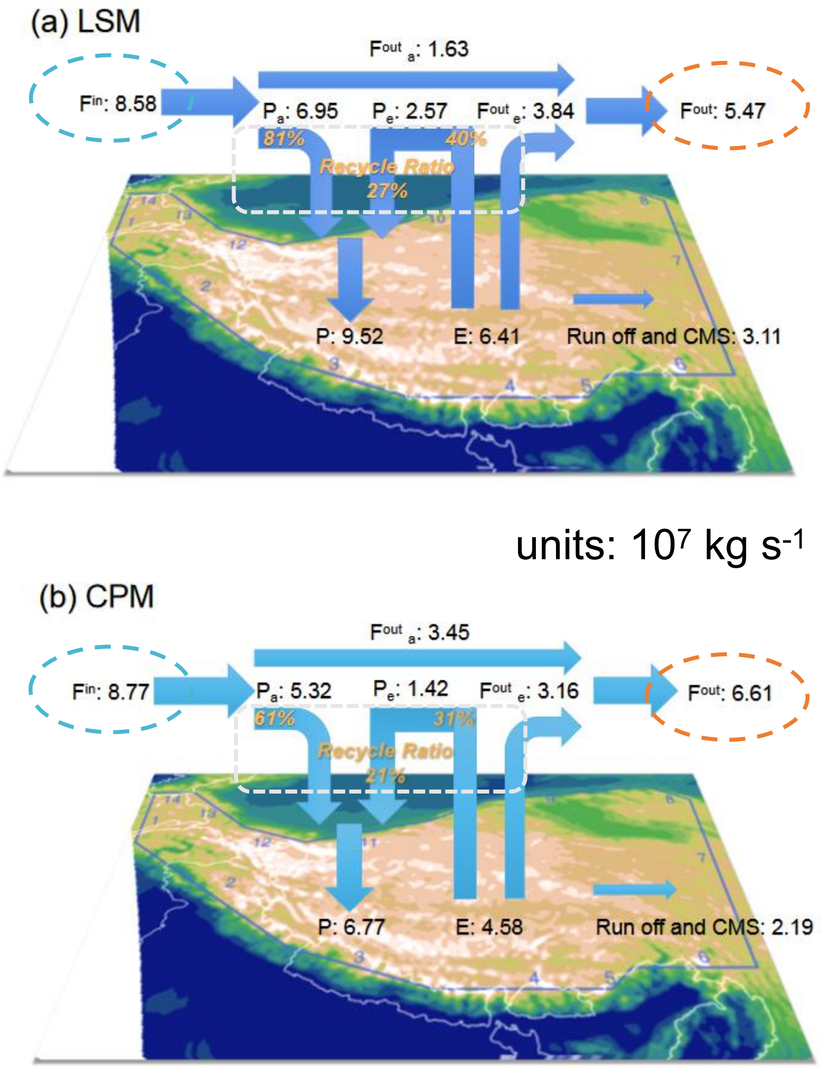


shading: precipitation, mm day^{-1}
vector: horizontal winds at 500hPa, m s^{-1}

- **The stronger eastward transport of water vapor is related to the anticyclonic anomalies over the TP in the CPM** simulation compared with the LSM.
- Since the boundary conditions are identical between the LSM and the CPM, the anomalous anticyclone should be the **feedback of the local diabatic process to the large-scale circulation**.
- The CPM simulation generates less precipitation over the TP, therefore there is an anticyclonic response of the circulation and the related moisture transport.
- The upscale effect of the moist convection has been found to play an important role in the West African monsoon and South Asian summer monsoon. (Birch et al., 2014; Willetts et al., 2017)

Difference in atmospheric water cycle between CPM and LSM

Atmospheric water cycle process



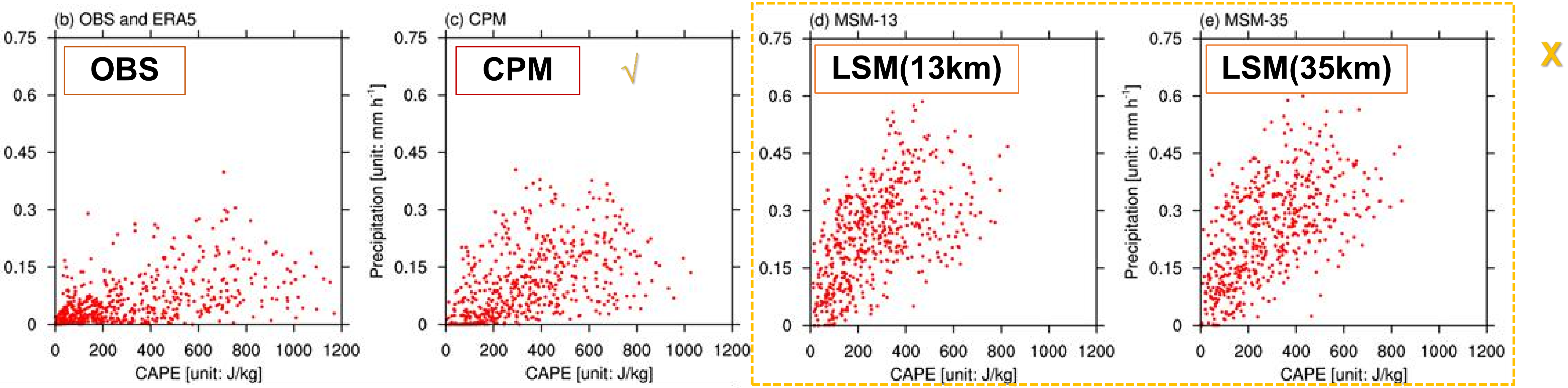
- For water vapor transport:
- Due to the stronger inflow though western edges, the total moisture inflow is even larger in the CPM.
- Net moisture transport is less in CPM, which is dominated by the stronger outflow through the eastern edge.

- For ratios of atmospheric moisture converting to precipitation:
- In addition to the larger convergence of water vapor, the wet bias in the LSM is also caused by a stronger atmospheric water cycle.

Why does **LSM overestimate the strength of atmospheric water cycle**?

Possible explanation on the overestimation of precipitation in the LSM

CAPE .vs. Precipitation



- **The deep convection scheme used in LSM** is based on the Gregory-Rowntree (1990) scheme with a stability-dependent closure.
- The G-R scheme **is extensively sensitive to local convective available potential energy** (CAPE) and results in the overestimation of precipitation in LSM.

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Summary

- The traditional convection-parameterized models have overestimated the strength of the atmospheric water cycle, and therefore lead to the overestimation of the precipitation.
- The explicit deep convection in CPM significantly improves the simulation of precipitation and moisture transport over the TP.
- The response of large-scale circulation to the local diabatic process further reduces the wet bias.
- In addition to resolution, terrain, schemes of parameterization or dynamics in models, the upscale effect of local diabatic process is also important to a reasonable simulation of precipitation.

THANKS FOR YOUR ATTENTION

zhaoyin@lasg.iap.ac.cn

Zhao, Y., Zhou, T., Li, P., Furtado, K., Zou, L. (2021). Added value of a convection permitting model in simulating atmospheric water cycle over the Asian Water Tower. Journal of Geophysical Research: Atmospheres, 126, e2021JD034788.

Puxi Li, Kalli Furtado, Tianjun Zhou, Haoming Chen, Jian Li. (2021) Convection-permitting modelling improves simulated precipitation over the central and eastern Tibetan Plateau. Quarterly Journal of the Royal Meteorological Society, 147(734): 341-362.