

Studying tropical MCS using high-resolution satellite observations, numerical model, and data assimilation

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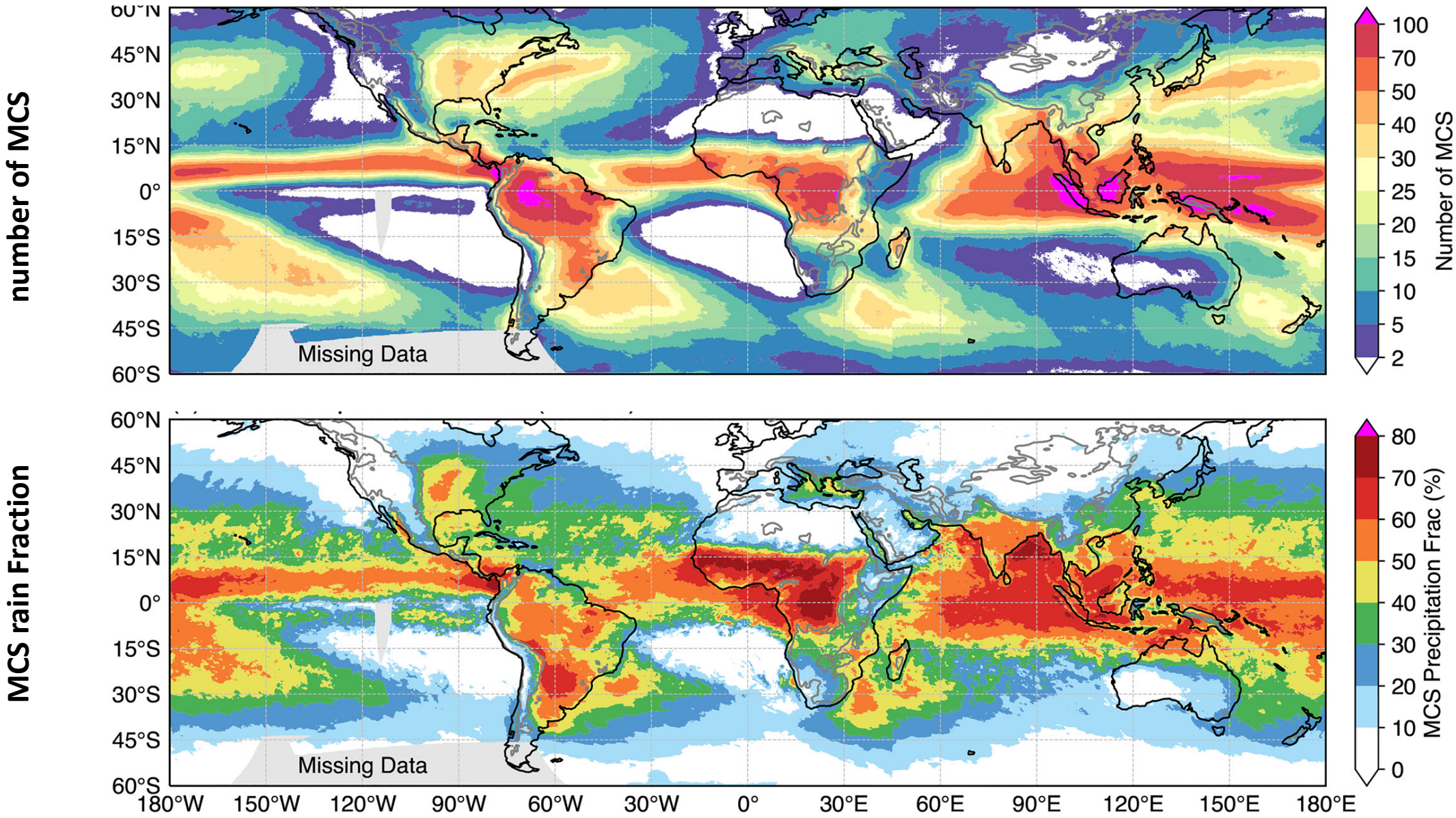
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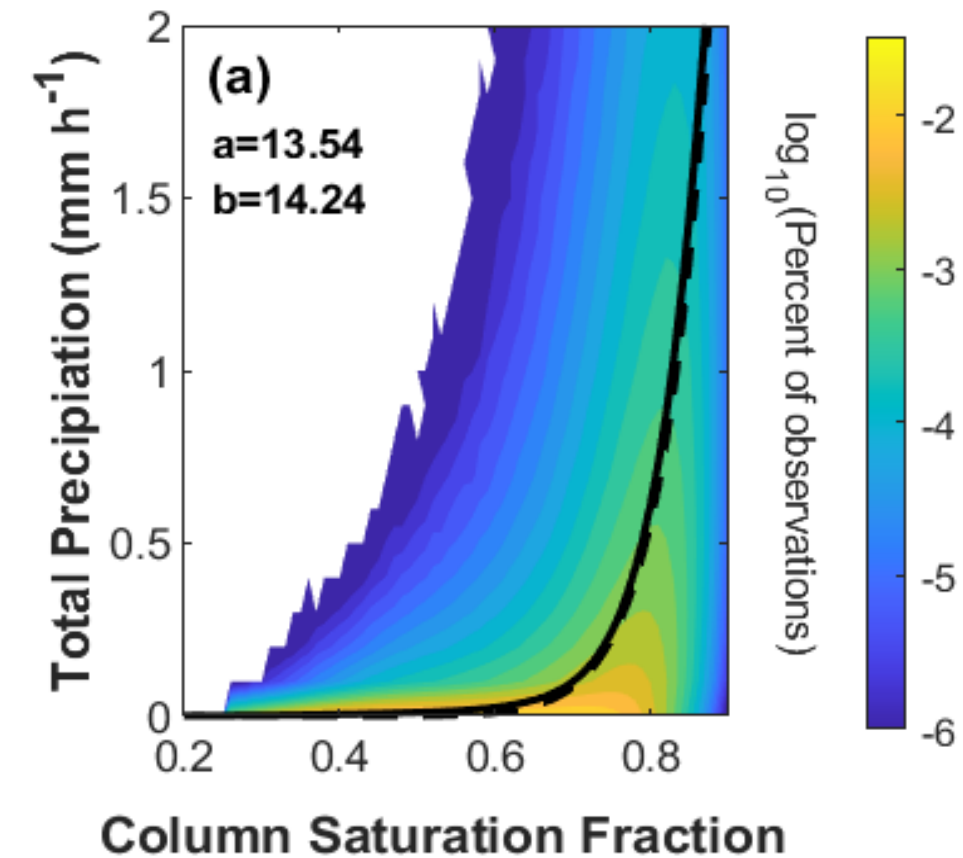
Outline

- 1. Crucial roles of MCS in tropical weather and climate**
- 2. Challenges of simulating MCS in the current-generation global models**
- 3. Study tropical MCS using high-resolution satellite observations and ensemble-based data assimilation**

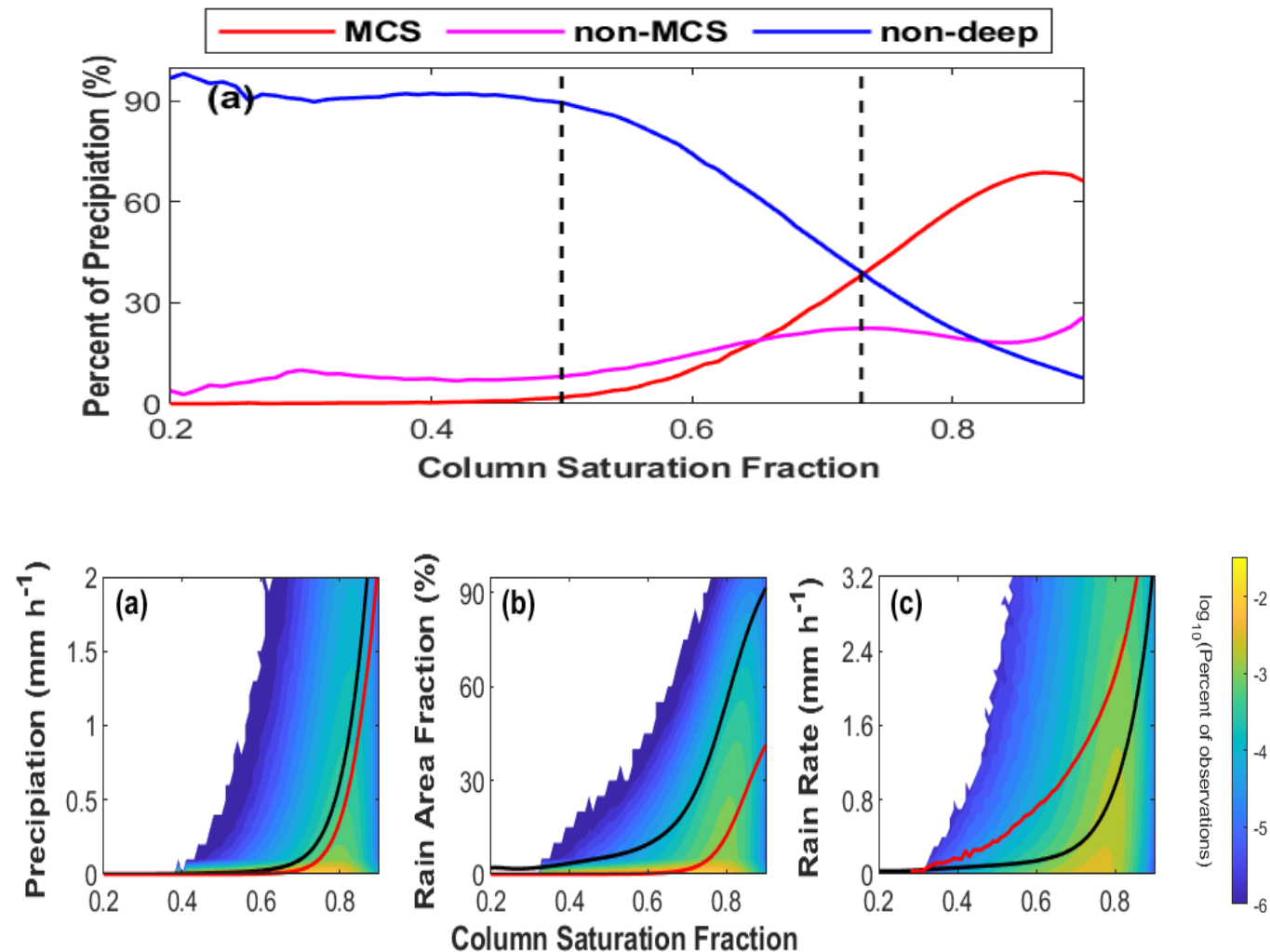
MCS greatly contribute to the total precipitation over the tropics



MCS dominates the rain-moisture interactions over tropical oceans

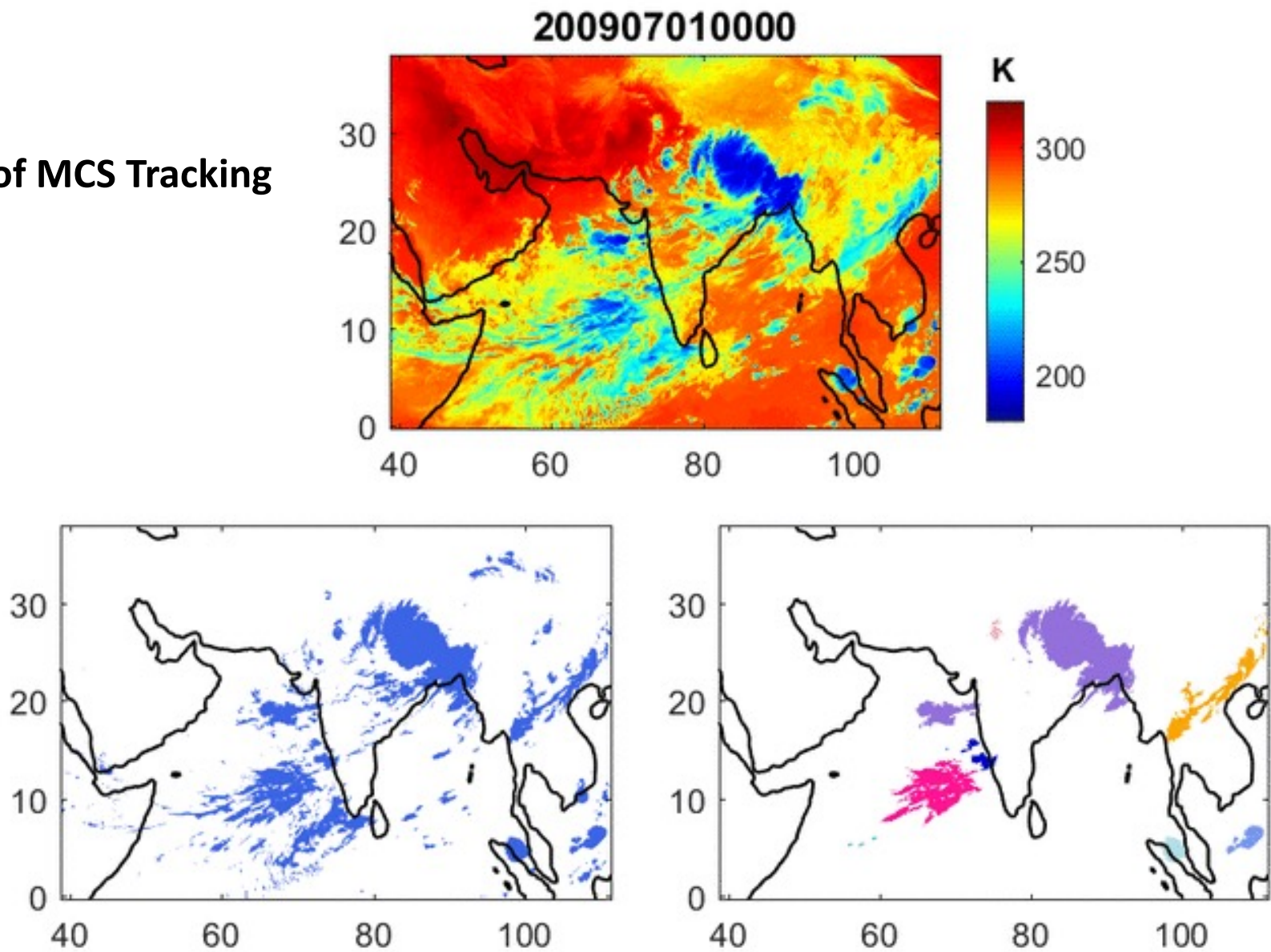


Solid line: CSF-binned mean precipitation rate.
Dashed line: power-law fit



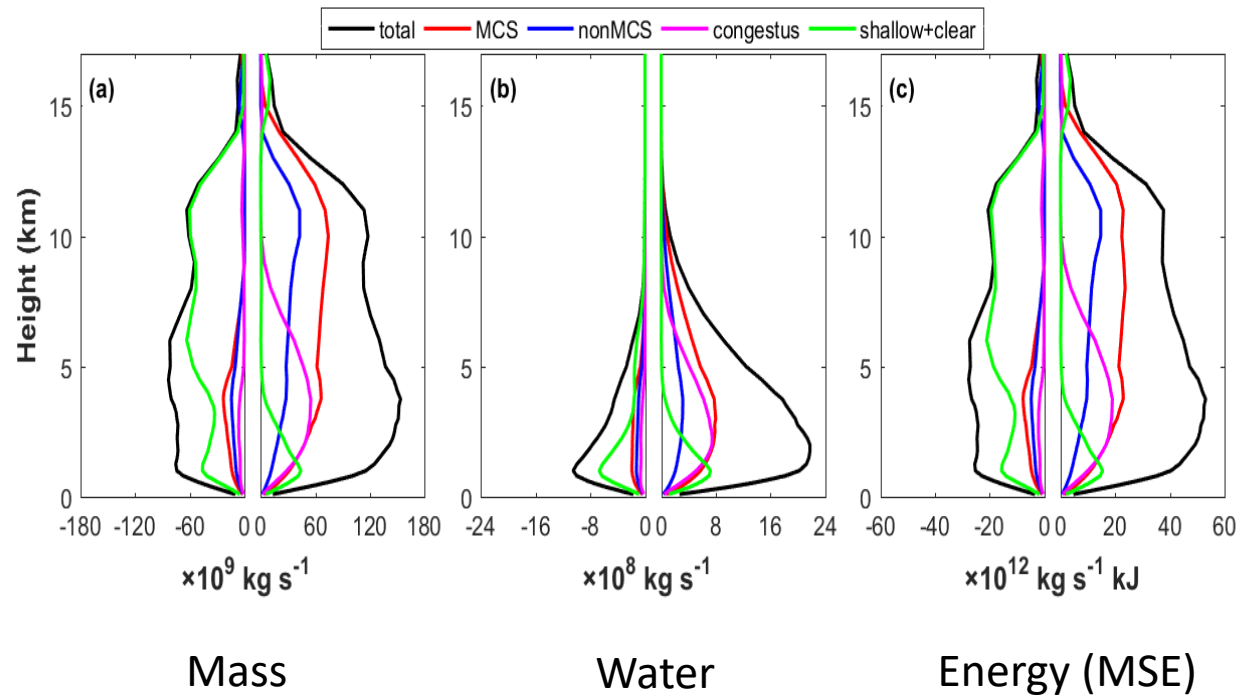
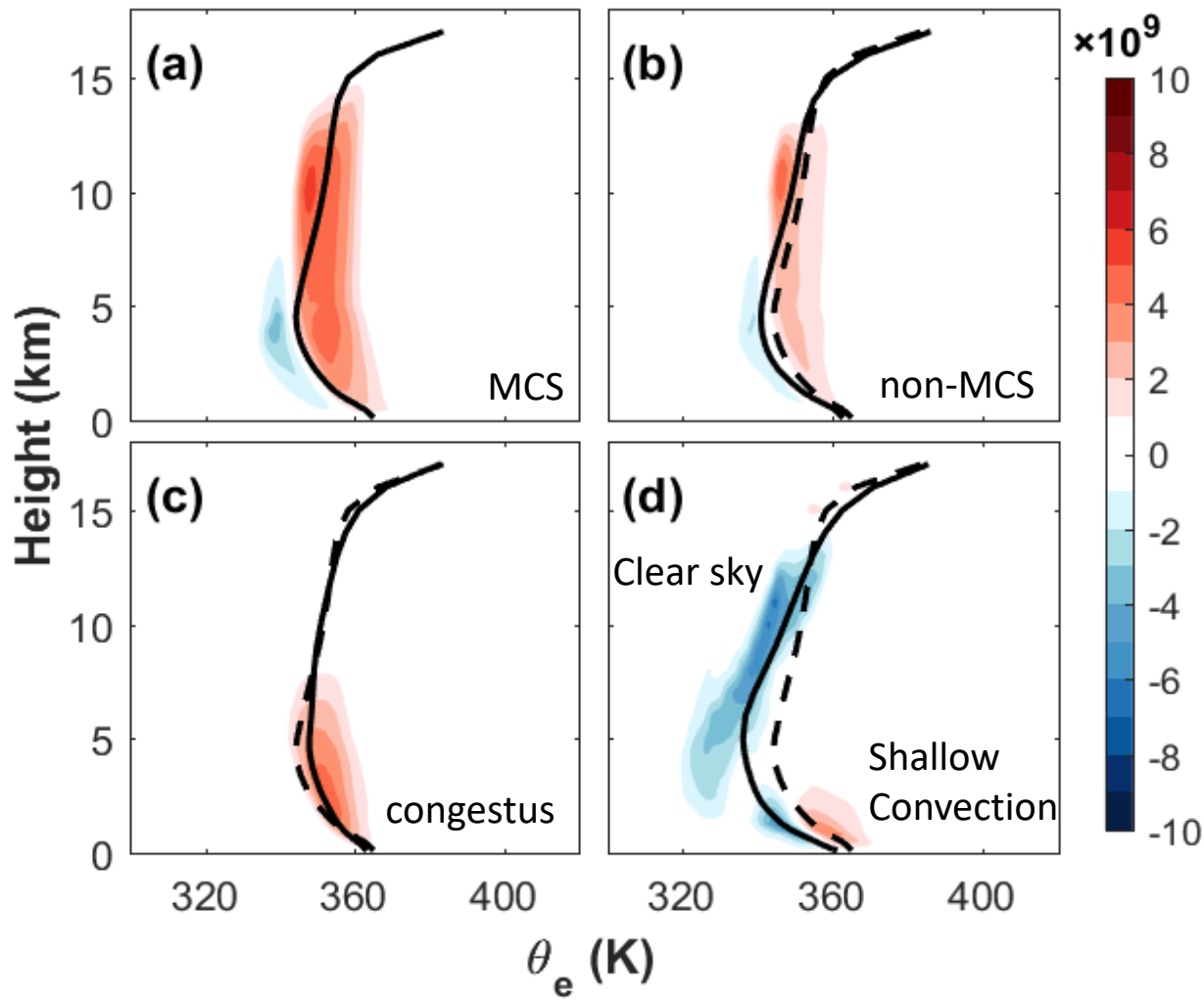
Crucial role of MCS in the vertical mass, water and energy transports in the tropics

Schematic of MCS Tracking



Crucial role of MCS in the vertical mass, water and energy transports in the tropics

Isentropic analysis
on a 4.5-km WRF simulation



MCSs and congestus contribute comparably to the vertical transports below the melting level, and MCSs dominate above that.

Simulating MCS in current-generation global models is challenging!

Most current-generation global models cannot explicitly resolve convection due to their coarse grid spacings.

As a result, convective parameterizations are used in global models to represent the dependence of the statistical characteristics of convection on large-scale environments.

Convective parameterizations assume there is a gap between the cumulus scale and the large-scale motion.

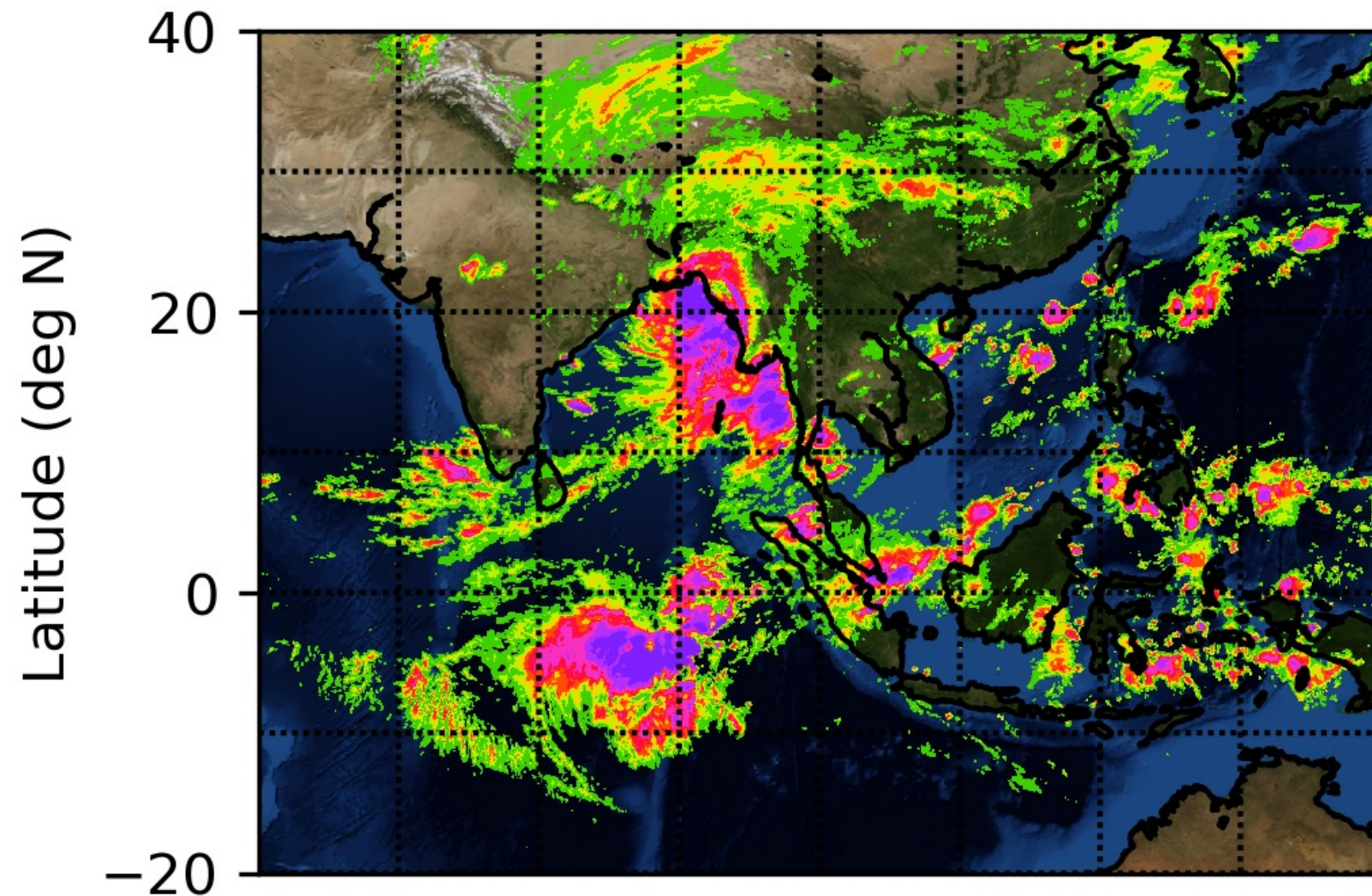
However, MCS is at a similar scale as the global models' grid spacing: MCS being neither parameterized nor resolved in the current-generation global models.

Some experimental MCS parameterizations have been developed recently to represent the vertical transport and latent heating effects of MCS in global models (e.g., Moncrieff 2019, Chen et al, 2021)

But we still need a better understanding of the multiscale interactions between tropical MCS and large-scale environments.

A high-resolution reanalysis dataset is badly needed!

An experimental high-resolution regional reanalysis for studying tropical MCS



Reanalysis domain

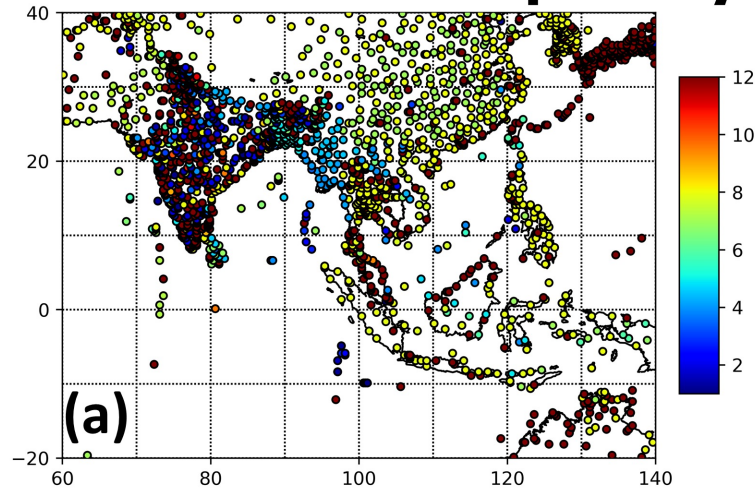
Horizontal grid spacing: 9 km ; Period: May-August 2017

Color shading: satellite observed window-channel IR brightness temperature

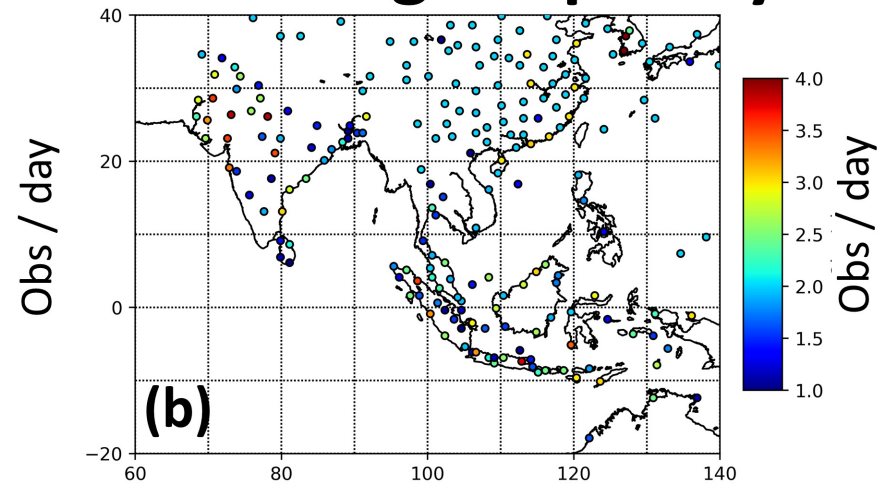
An experimental high-resolution regional reanalysis for studying tropical MCS

Conventional observations have been assimilated

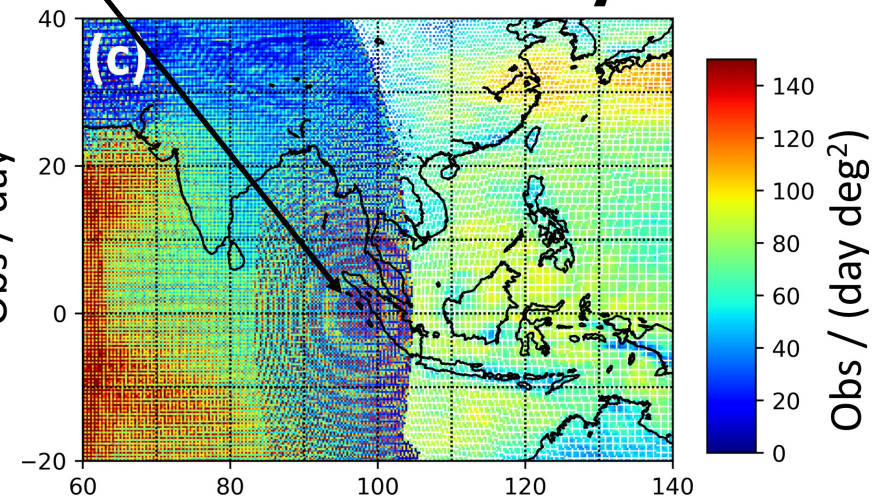
Surface obs frequency



Sounding frequency



AMV density



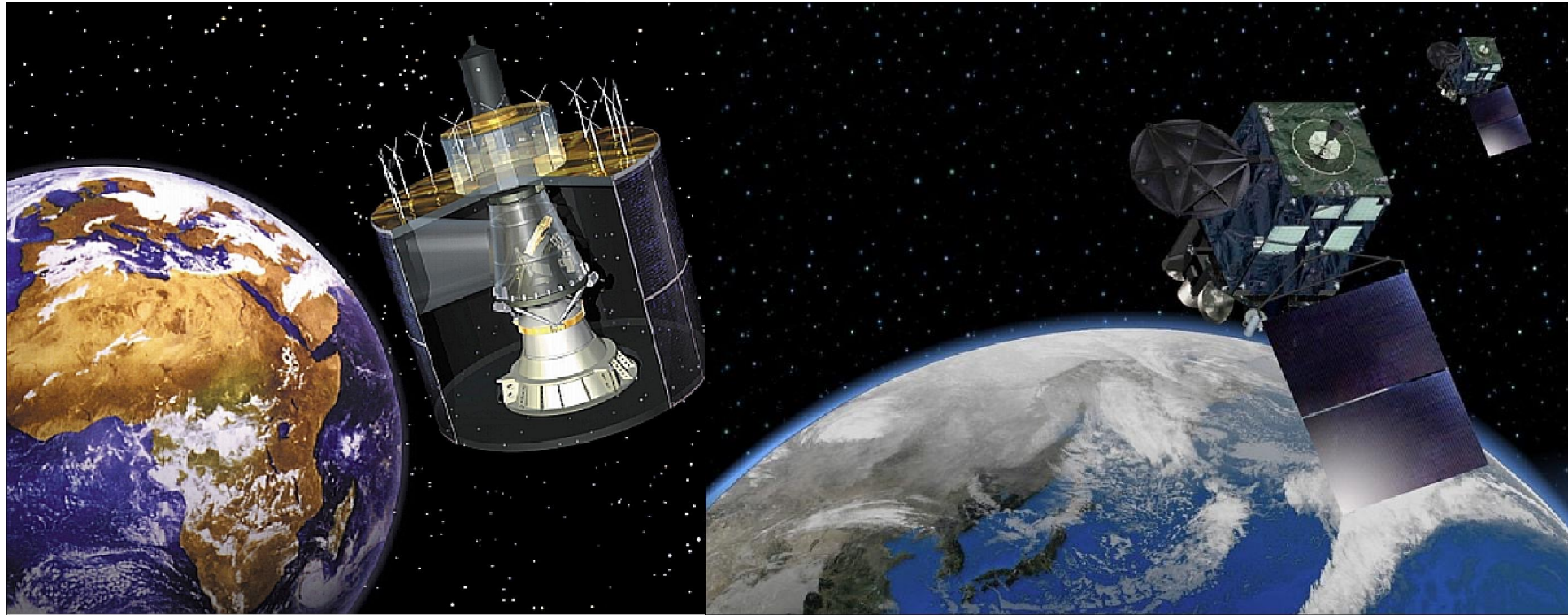
The wave-like pattern is an artifact of the algorithm used to generate Himawari-8 AHI AMVs (Lean et al., 2016).

Most surface and sounding stations are located over the inland region, and their spatial and temporal resolutions are low

Assimilating additional AMV cannot well capture individual MCS systems.

An experimental high-resolution regional reanalysis for studying tropical MCS

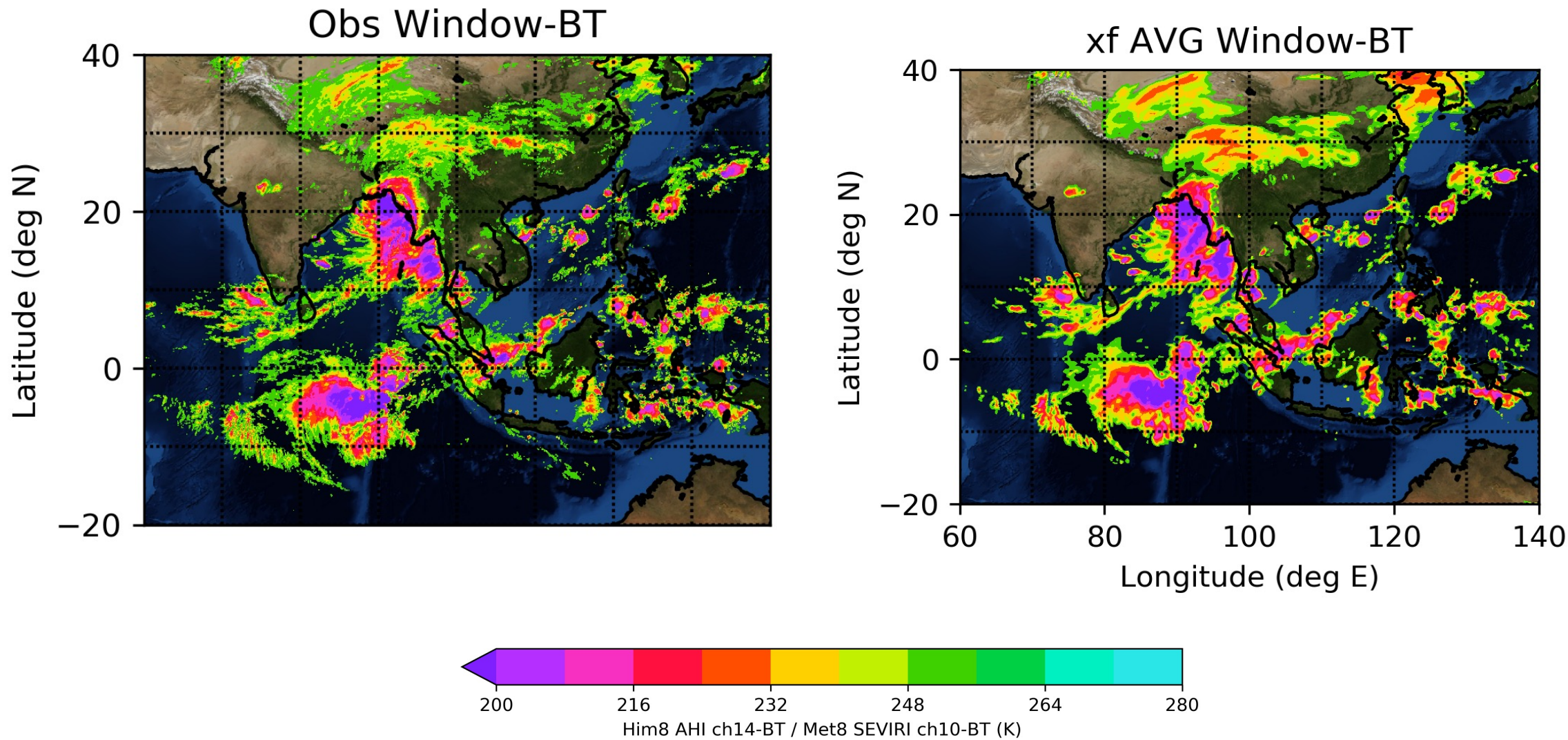
Satellite all-sky infrared radiance assimilation



Meteosat-8

Himawari-8

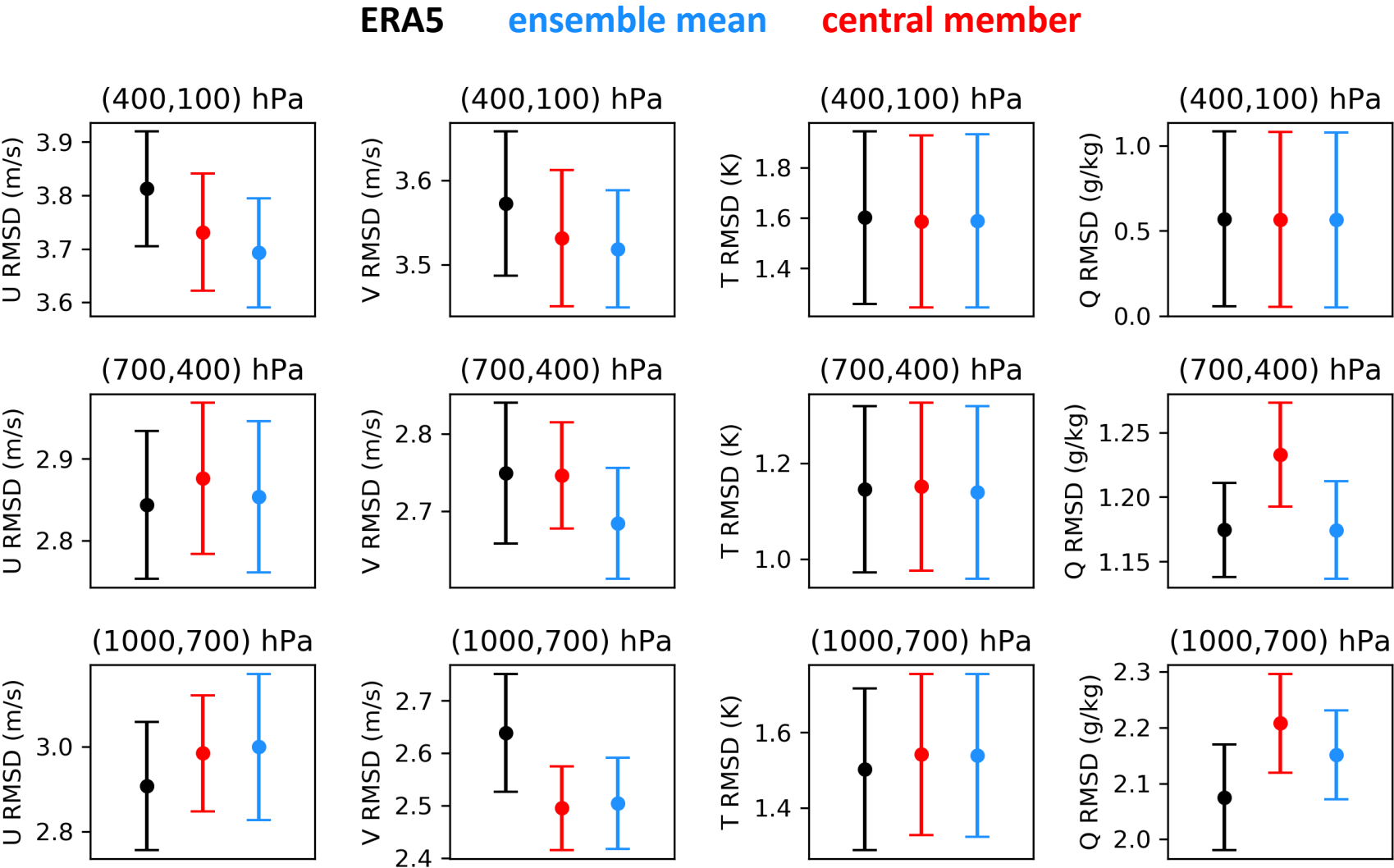
An experimental high-resolution regional reanalysis for studying tropical MCS



An experimental high-resolution regional reanalysis for studying tropical MCS

Compare to independent sounding observations

Deterministic forecast RMSDs at 16 hours forecast lead time.

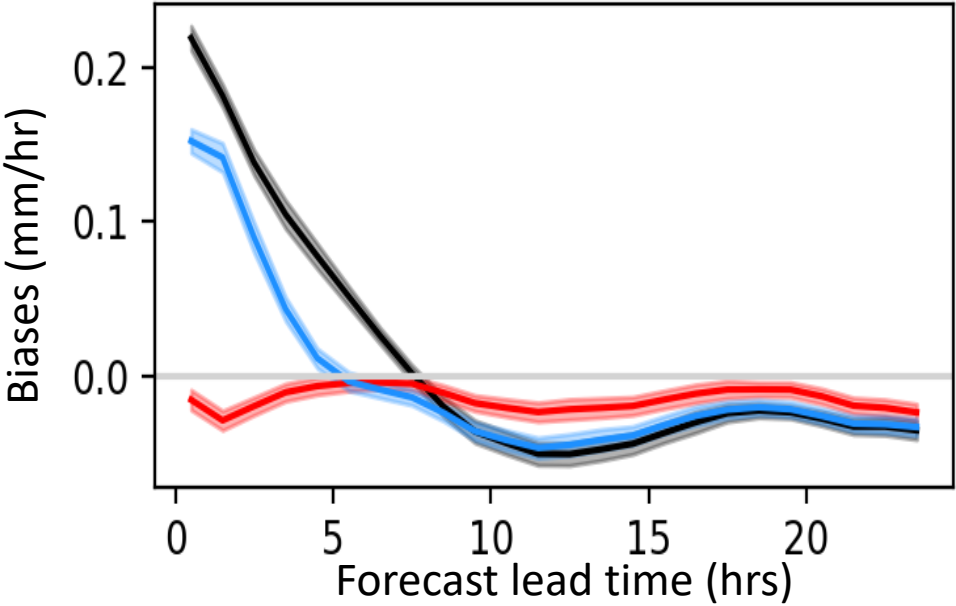


An experimental high-resolution regional reanalysis for studying tropical MCS

Compare to independent IMERG precipitation estimate

ERA5 ensemble mean central member

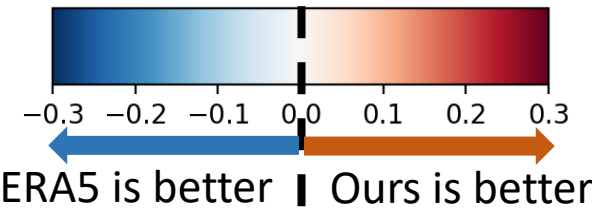
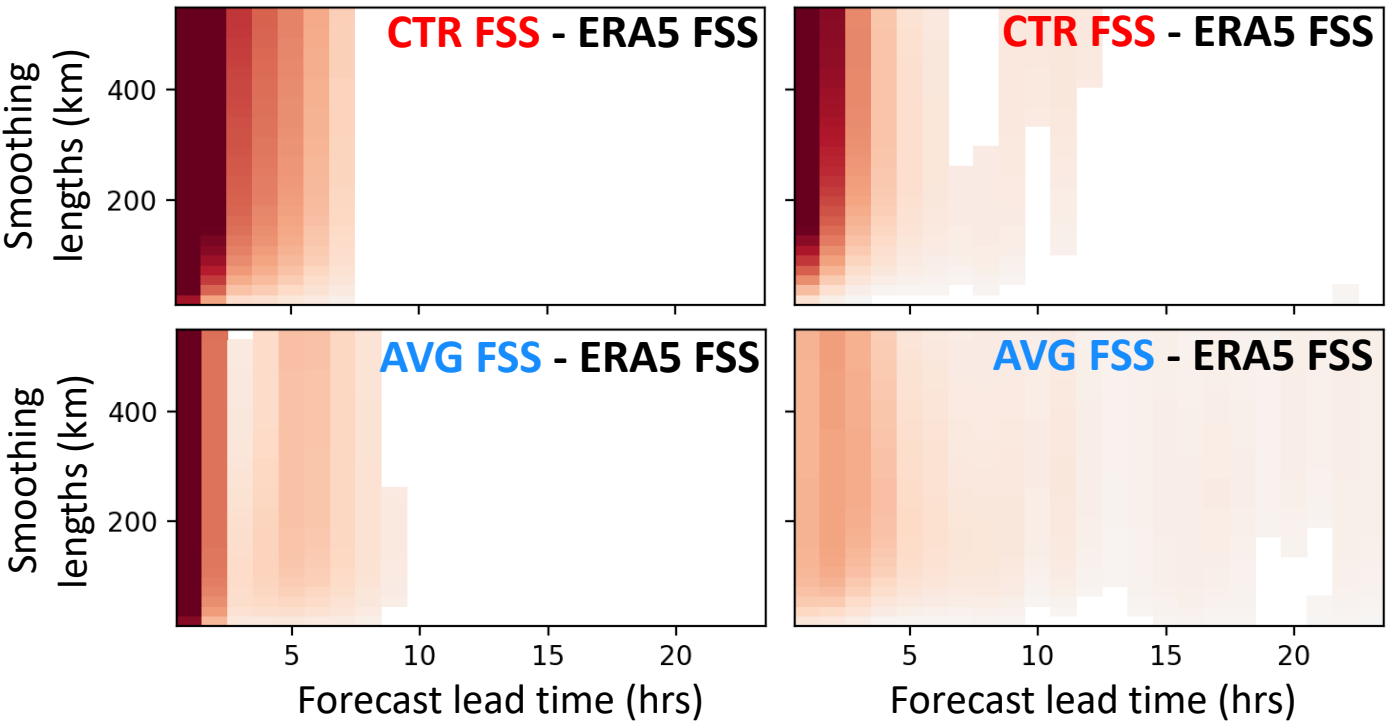
Rainfall biases



Fractions Skill Score

(≥ 0.5 mm/hr)

(≥ 10 mm/hr)



Only showing significant FSS differences
Definition of statistical significance:

$$\left| \frac{\text{avg FSS diff}}{\text{standard error of FSS diff}} \right| > 2$$

Summary

1. MCS plays a curial role in precipitation, moisture-rainfall coupling, and vertical transports over the tropics
2. Simulating MCS in global models is still challenging
3. An experimental high-resolution tropical MCS reanalysis has been generated

Future work

1. Use the high-resolution reanalysis to better understand the multiscale interactions between tropical MCS and large-scale environment
2. Improve the high-resolution reanalysis by increasing model resolution (~ 4 km) and assimilating additional observations (e.g., satellite microwave radiances)
3. Improve the MCS parameterizations in global models

Thank you!