

Cloud-Resolving Simulations of Convection during DYNAMO

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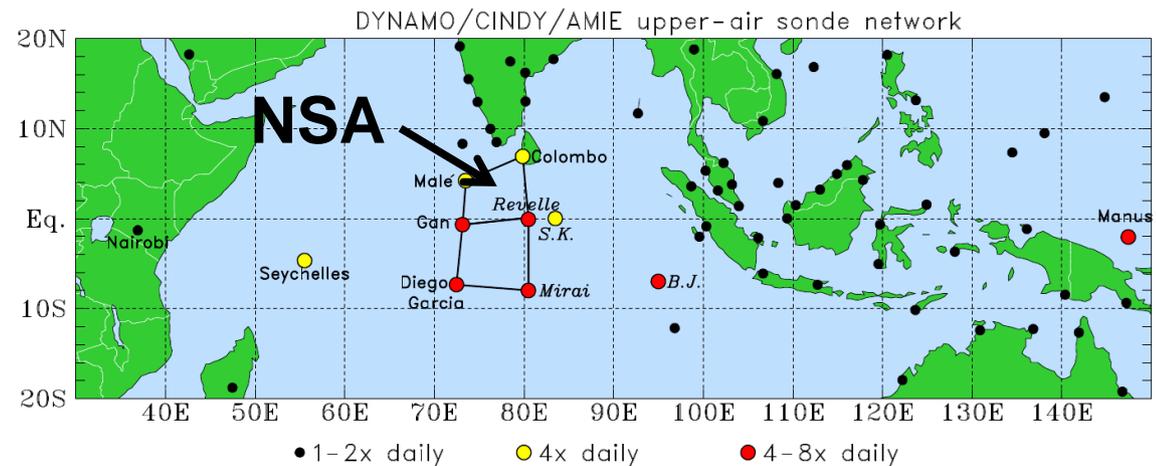
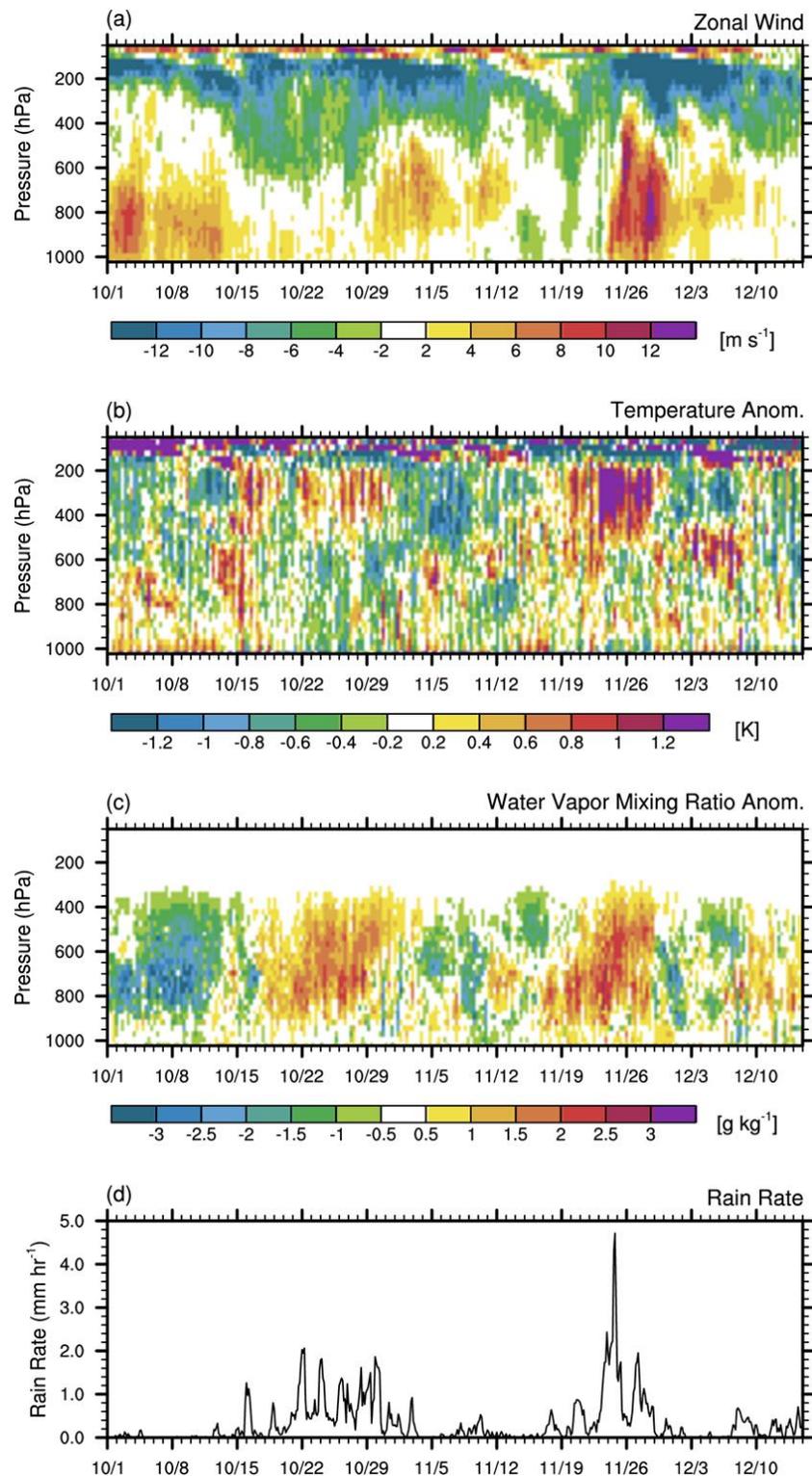
2013 Fall ASR Workshop

Outline

- Overview of observations.
- Methodology.
- Simulation results.
 - Differences between observations and model.
 - Rain statistics and system sizes.
 - Vertical distribution of hydrometeors and clouds.
 - Role of free-tropospheric moisture.
- Summary and conclusions.
- Future work.

Overview of Observed Conditions

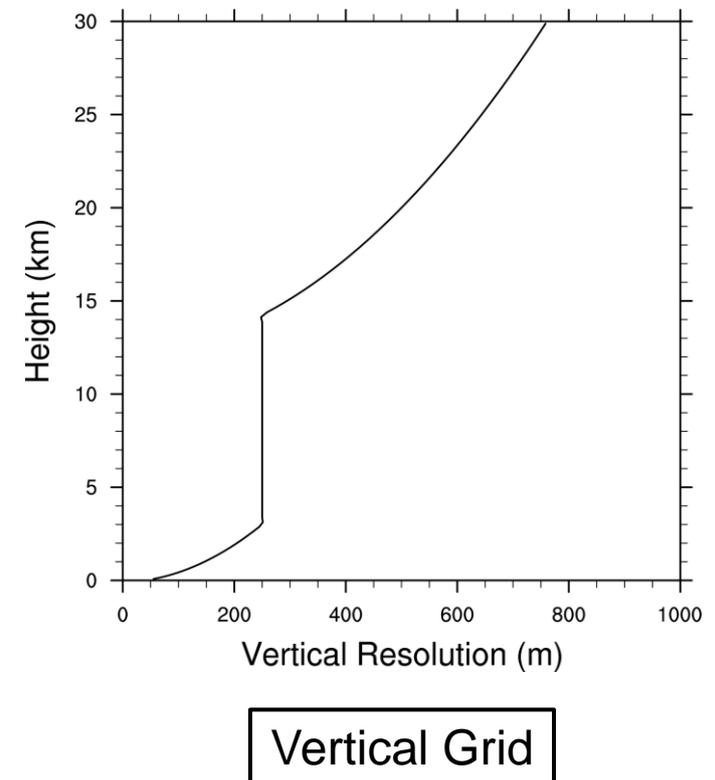
- Two periods of active convection were observed over the northern sounding array (NSA) array.
- Both were accompanied by increased free-tropospheric moisture.



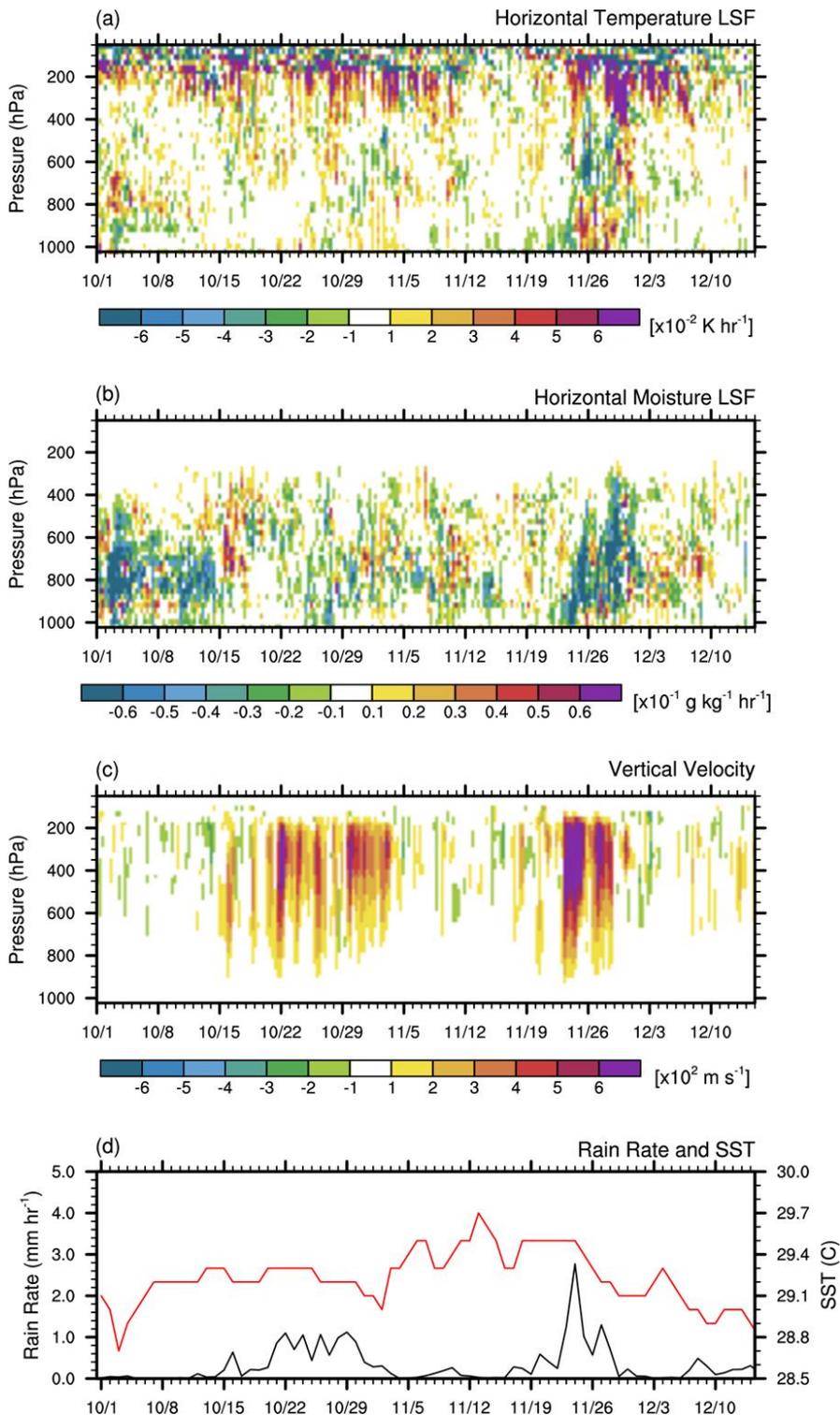
Version 1 of CSU Array-Averaged Analysis Products

Simulation Setup

- **Model** – System for Atmospheric Modeling (SAM) 6.8.2.
- **Domain Grid** – 204.8 x 204.8 km at 800 m grid spacing. Stretched vertical grid with 96 levels up to 30 km and ~250 m grid spacing throughout troposphere.
- **Microphysics** – 2 simulations: **SAM 1-moment** and **Morrison 2-moment**.
- **Radiation** – CAM.
- **Nudging** - Winds nudged at $\tau = 6$ h and no thermodynamic nudging.
- **Damping** – Gravity waves in upper 10 km damped.
- **Forcing** – Convection forced by NSA large-scale forcing (LSF).

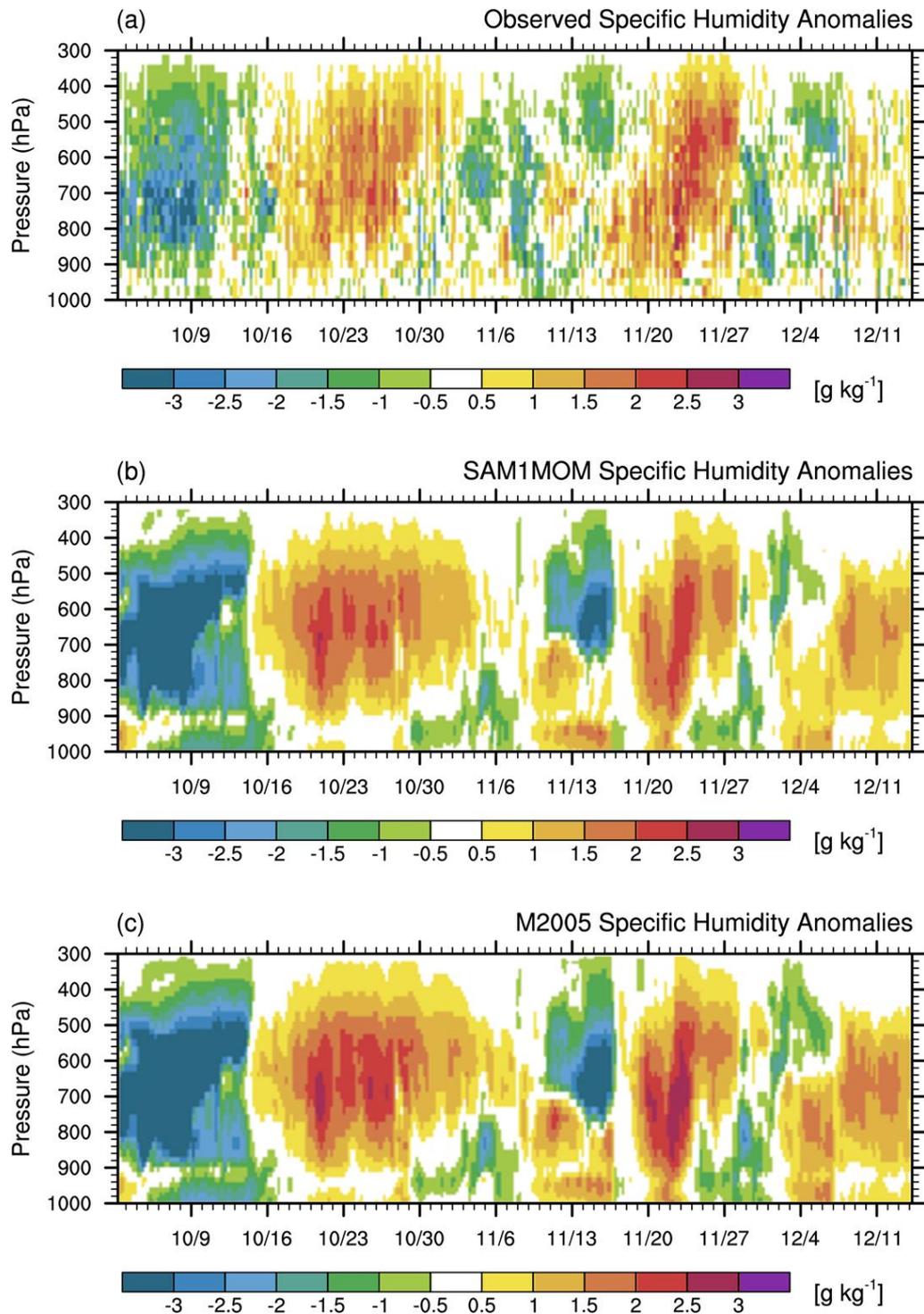


Large-Scale Forcing

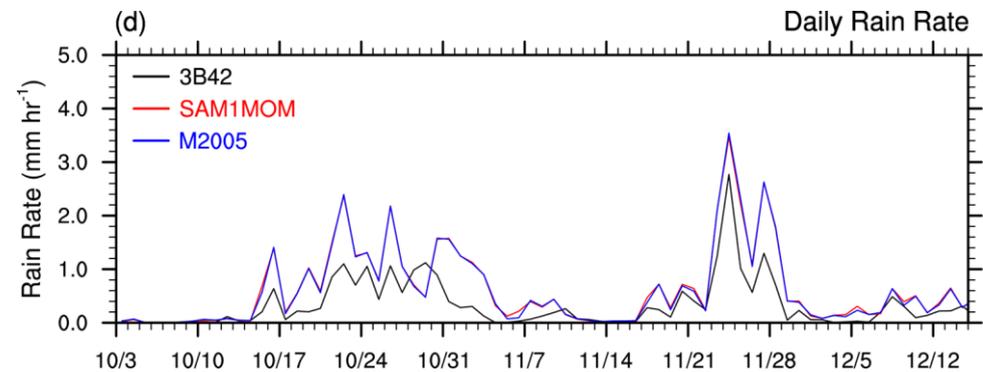


- Simulation covers 10/1 to 12/15, 2011.
- Large-scale horizontal temperature and moisture tendencies, vertical velocities, and time-varying SSTs were prescribed to force the development of convection.
- Vertical velocity is the most important of the forcings.

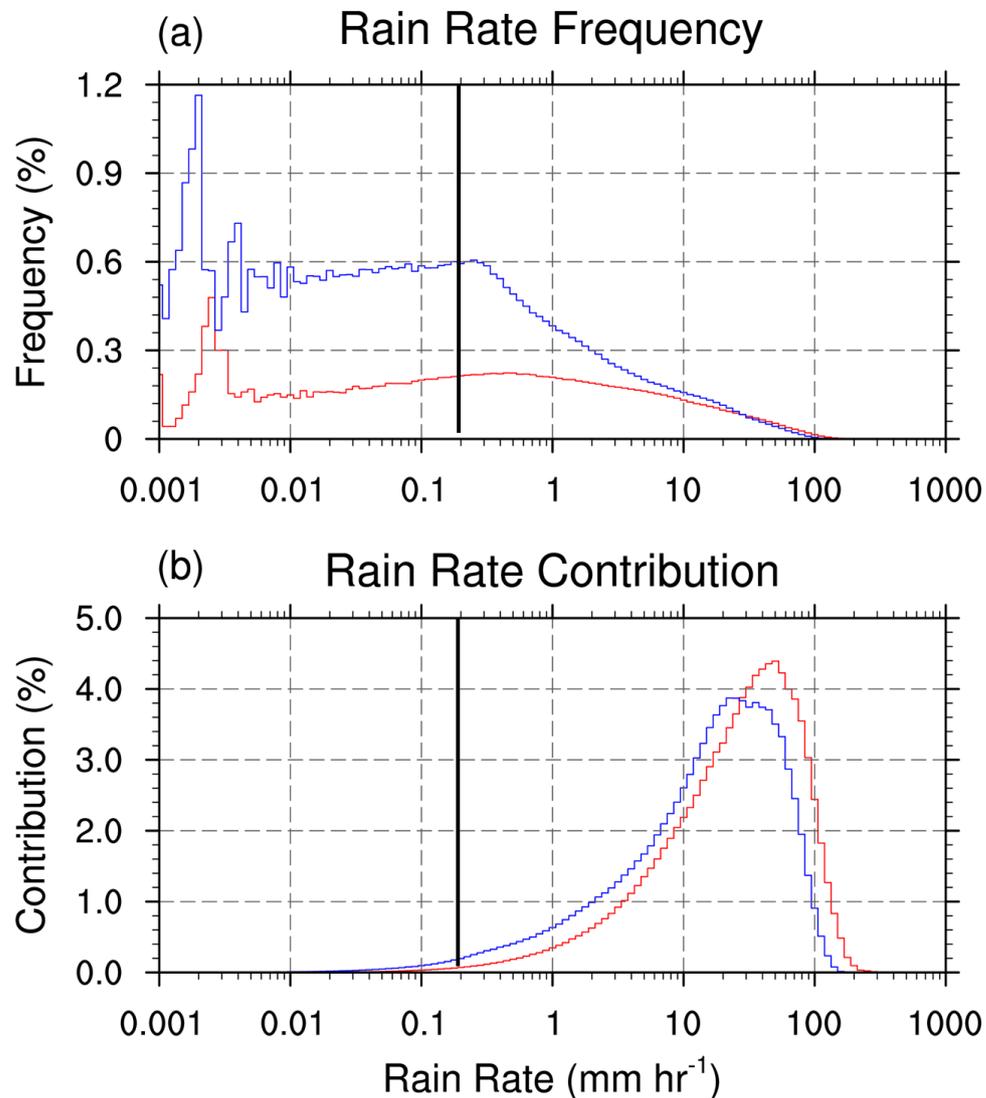
Overview of Model vs. Obs.



- The general pattern of rainfall is reproduced in the simulations. However, dry and moist periods are overdone.
- Discrepancies between model and observed rain rate should be smaller with the variational analysis.

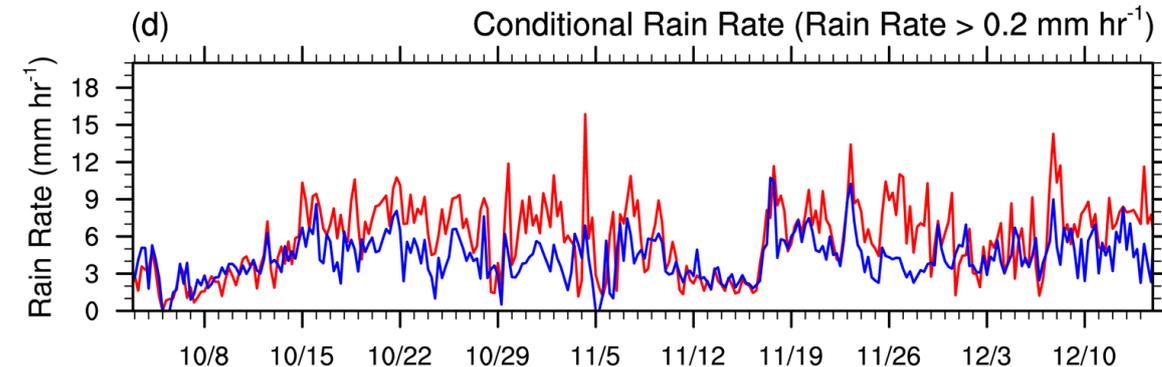
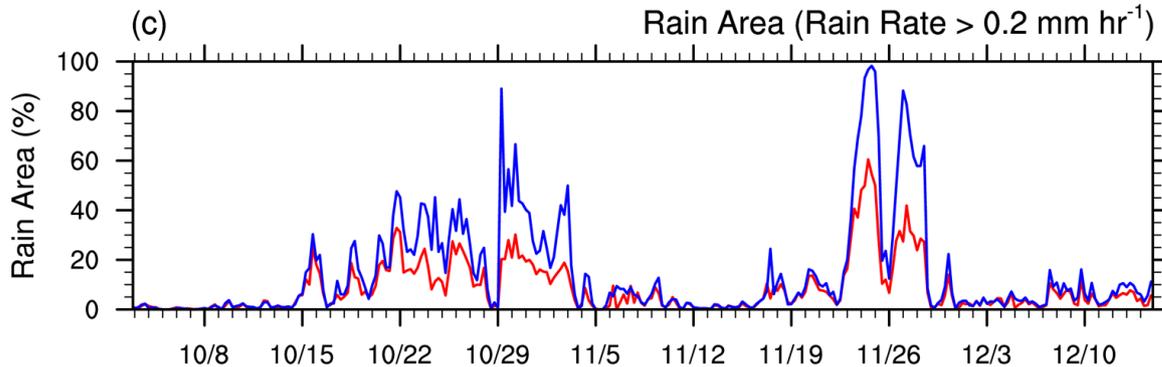
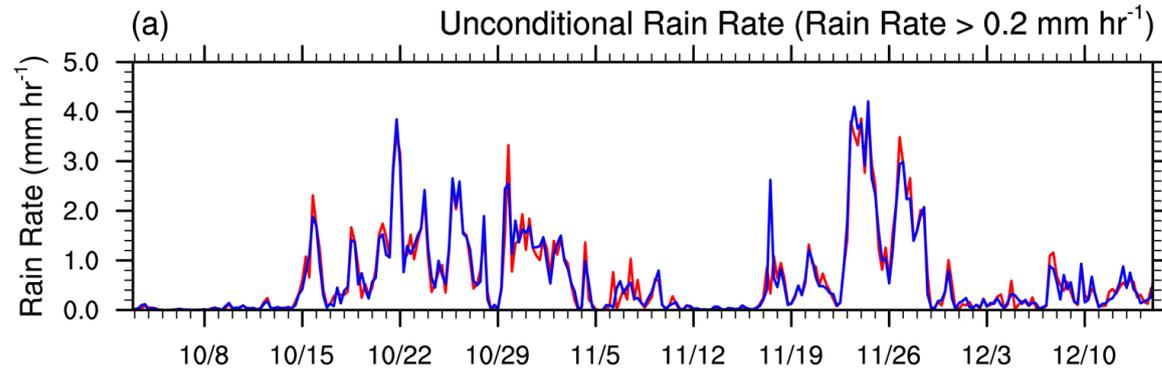


Rain Rate PDFs



- Much of the extra light rain (< 2 mm/hr) in **M2005** is probably stratiform.
- Rain rates < 0.2 mm/hr excluded from subsequent rain statistics.
- **SAM1MOM**
 - Rain Rate = 0.60 mm/hr
 - Rain Freq. = 8.06% (of total area)
 - Cond. RR = 5.71 mm/hr
- **M2005**
 - Rain Rate = 0.60 mm/hr
 - Rain Freq. = 13.80% (of total area)
 - Cond. RR = 4.26 mm/hr

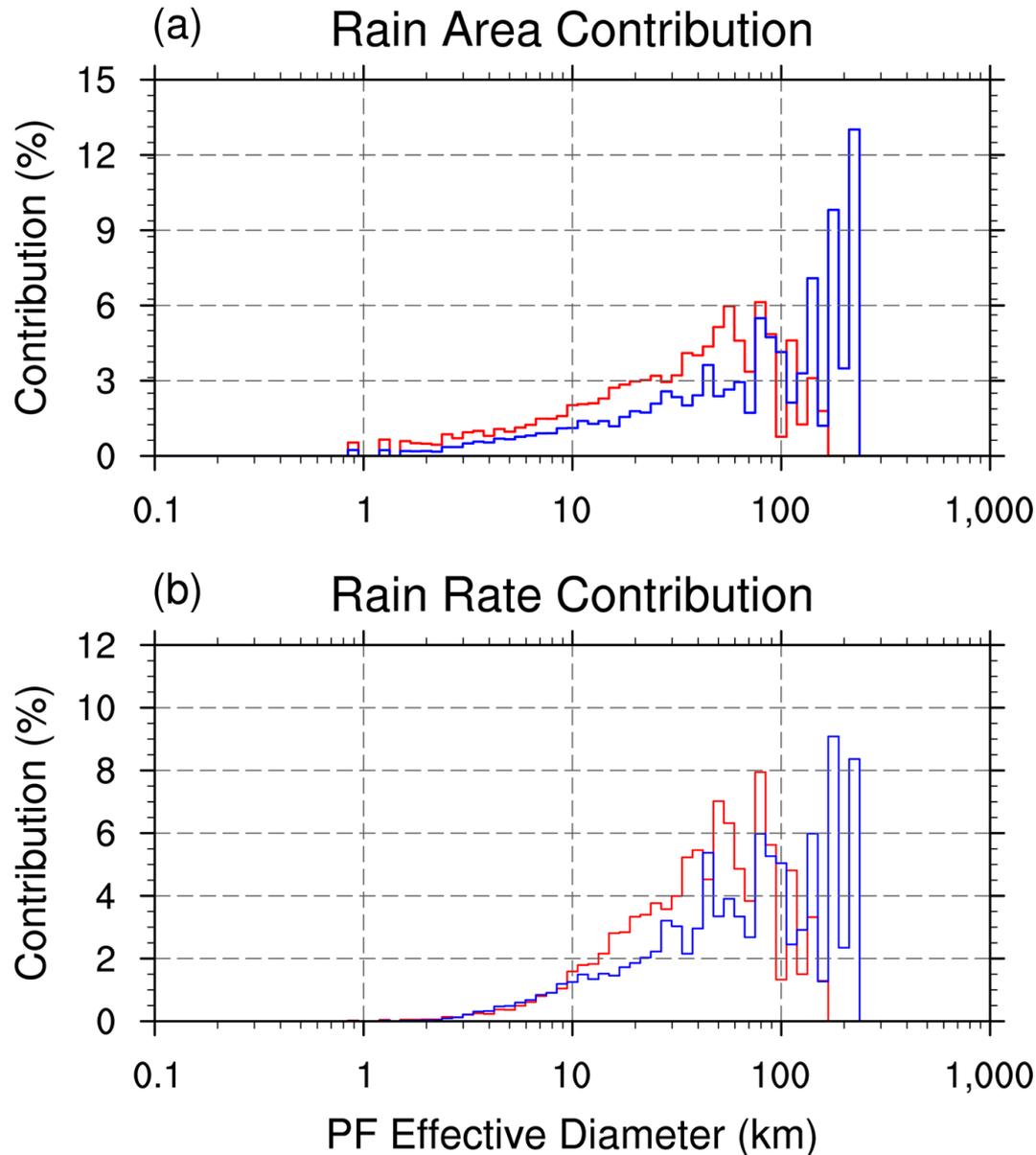
Time Series of Rain Statistics



- **Only rain rates $> 0.2 \text{ mm/hr}$ used.**
- The unconditional rain rates match very well.
- Rain area and conditional rain rates show less agreement.
- The unconditional rain rate is controlled by the rain area more than the rain intensity.

— SAM1MOM
— M2005

Precipitation Feature (PF) Size PDFs

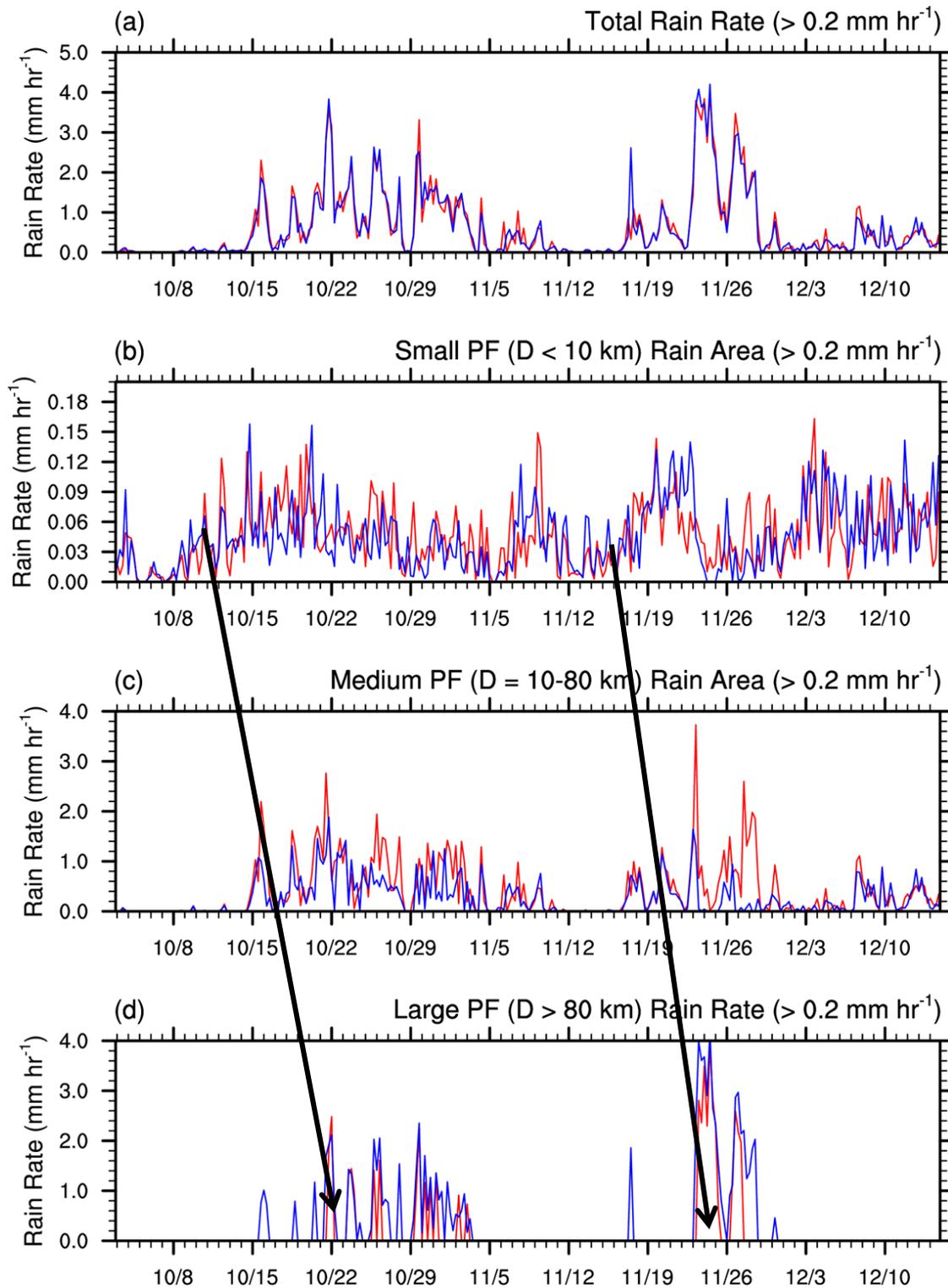


Effective Diameter (D) Statistics

- Small = $D < 10$ km.
 - 18.6% of Area, 7.4% of rain.
 - 10.5% of area, 7.7% of rain.
- Medium = $D = 10$ -80 km.
 - 58.9% of area, 66.7% of rain.
 - 35.1% of area, 43.6% of rain.
- Large = $D > 80$ km.
 - 22.5% of area, 25.8% of rain.
 - 54.4% of area, 48.7% of rain.

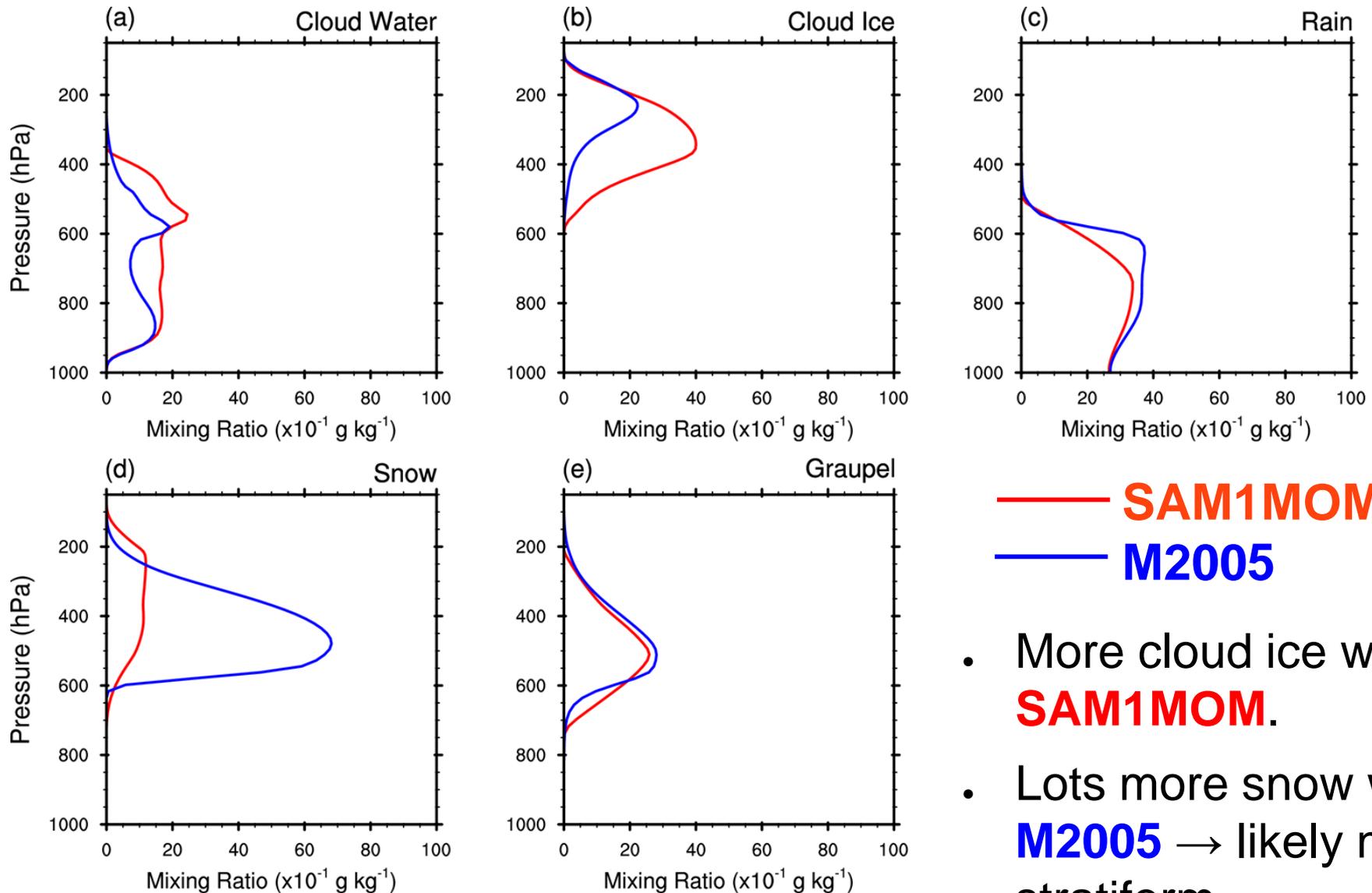
— SAM1MOM
— M2005

Time-Series of Rain Rate by PF Sizes



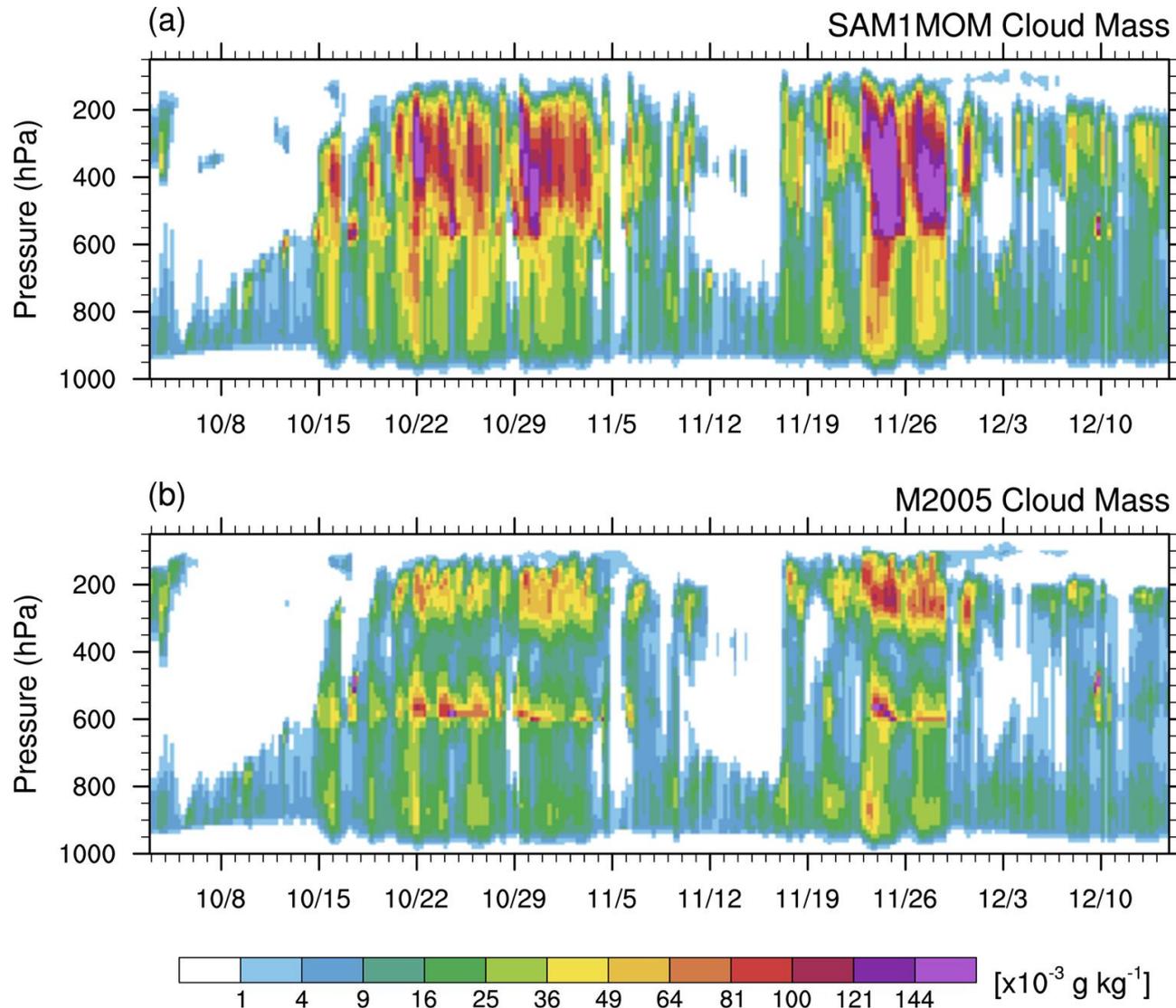
- Small PFs are found at all times while large PFs are concentrated in the active periods.
- There is a suggestion of a transition from small to medium to large PFs.

Vertical Profile of Hydrometeors



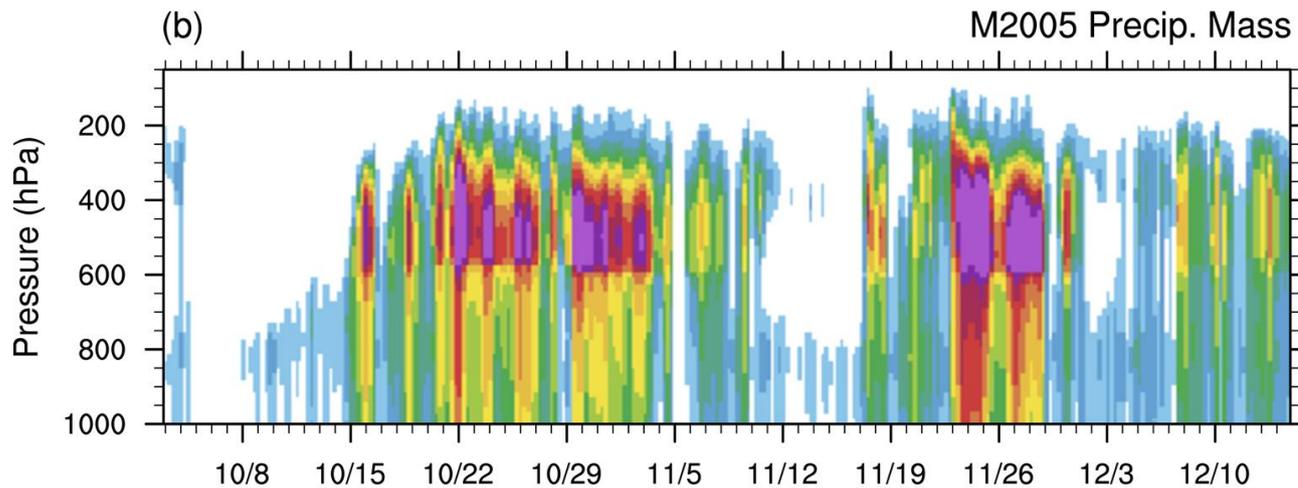
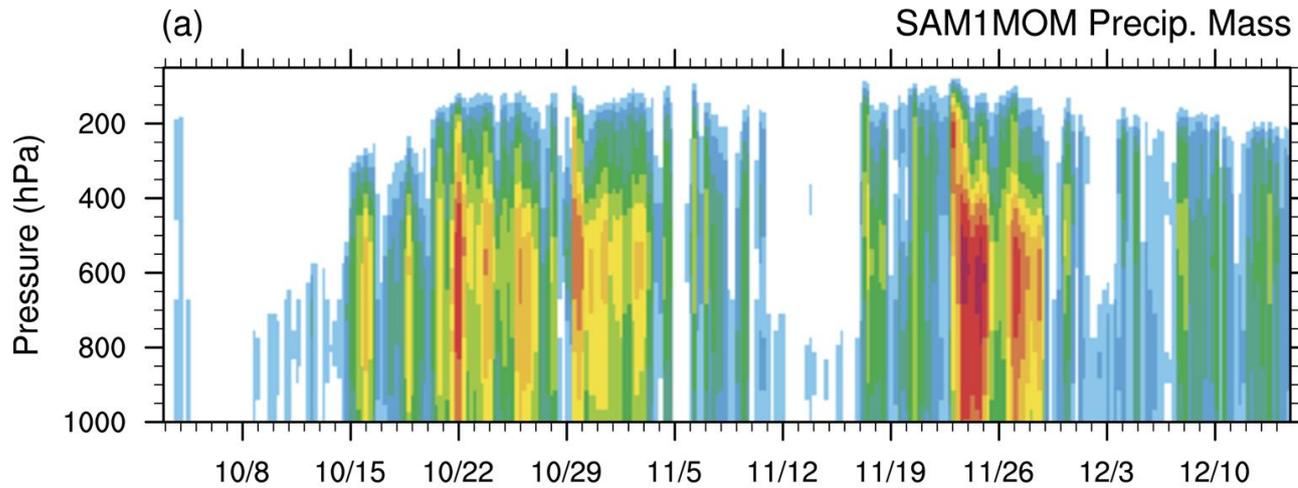
- More cloud ice with **SAM1MOM**.
- Lots more snow with **M2005** → likely more stratiform.

Cloud Mass Time-Height



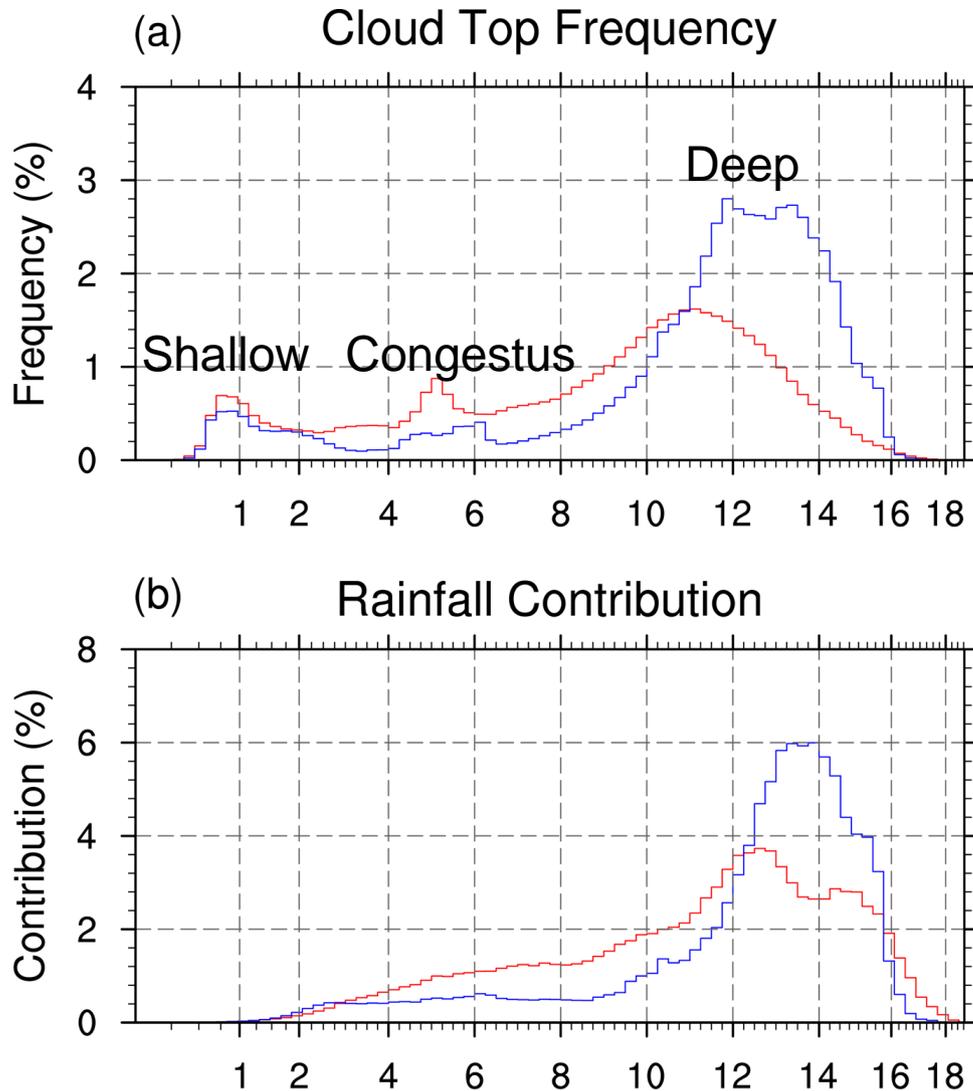
- Cloud mass = cloud water + cloud ice.
- Shallow and congestus clouds are present during suppressed and active periods.
- More anvil cloud mass in **SAM1MOM** than **M2005**.
- Strong peak in cloud mass at 600 hPa in **M2005**.

Precip. Mass Time-Height



- Precip. mass = snow + rain + graupel.
- The abundance of snow in **M2005** really stands out.

Cloud Top PDFs



SAM1MOM

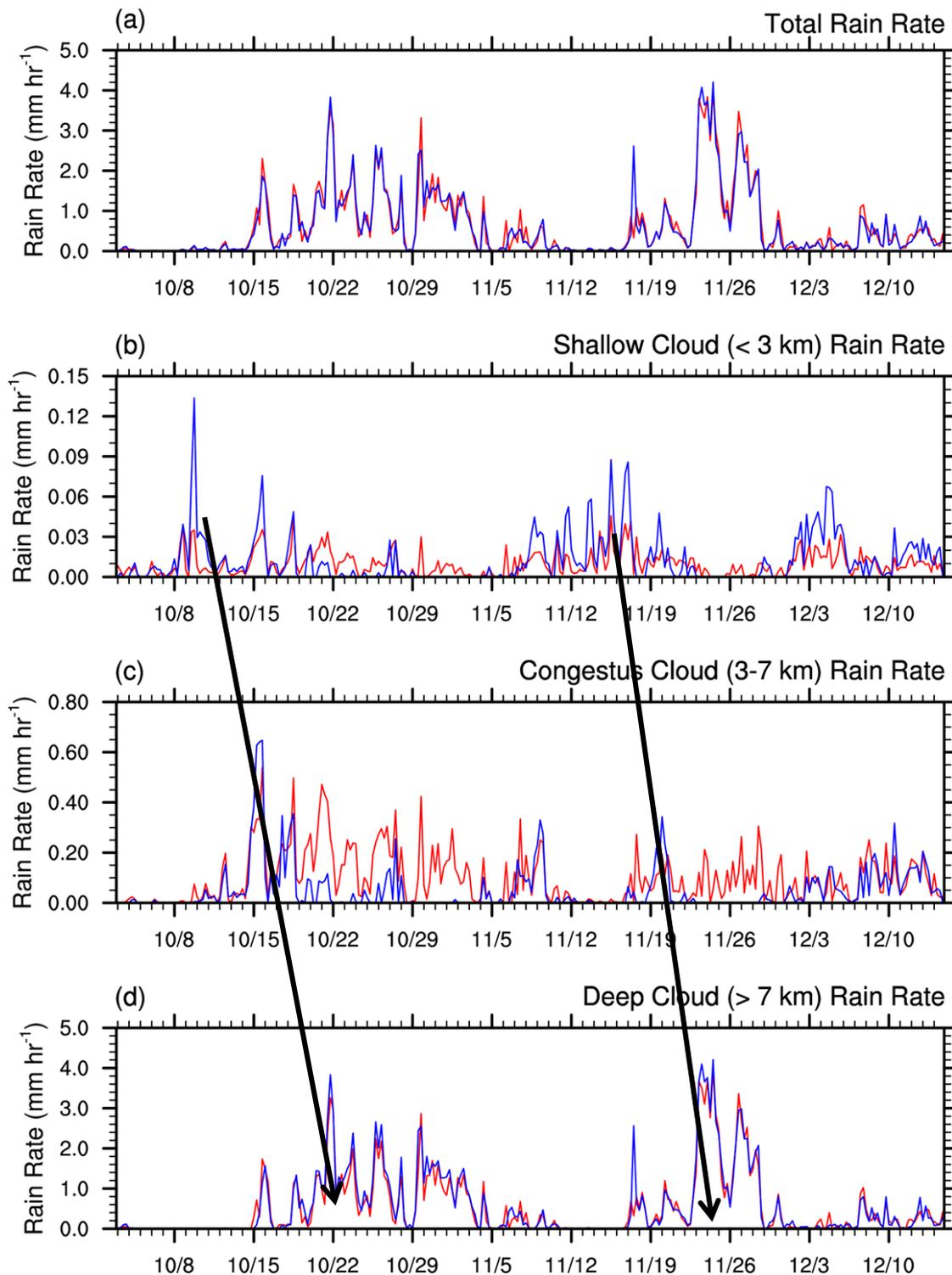
- <3 km = 12.3% of area, 1.7% of rain.
- 3-7 km = 18.6% of area, 15.3% of rain.
- >7 km = 69.0% of area, 82.7% of rain.

M2005

- <3 km = 7.7% of area, 2.2% of rain.
- 3-7 km = 6.5% of area, 8.3% of rain.
- >7 km = 85.8% of area, 89.0% of rain.

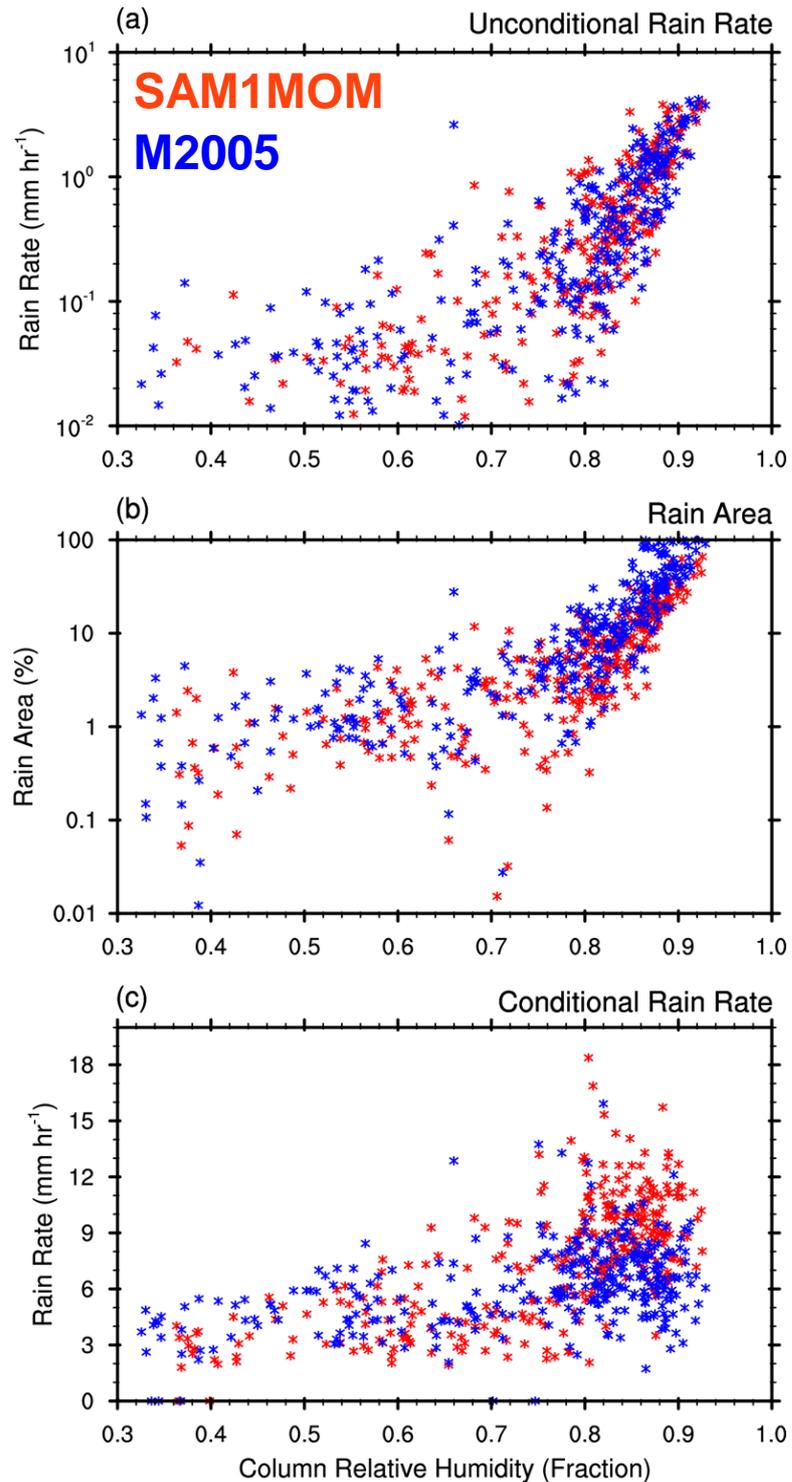
- More medium-top cloud from **SAM1MOM** and more high-top cloud from **M2005**.
- Very little rain from shallow clouds.

Time-Series of Cloud Tops



- The shallow cloud rain rate is increased ahead of the two active periods.
- In the first event this is followed by increased congestus rain.
- Especially in the first event there is a progression of increased shallow, congestus, and deep cloud rainfall.

Rain and CRH



- Unconditional rain rates and rain area vary by a factor of 100.
- Rain intensity (conditional rain rates) varies by less than a factor of 2 or 3.
 - Part of this is the increase in stratiform (weak intensity).

Summary and Conclusions 1: *Microphysics*

- Absence of light rain rates with **SAM1MOM** compared to **M2005** are consistent with comparisons of 1 and 2-moment schemes (e.g., Bryan and Morrison 2012).
 - Smaller drop sizes → more low-level evaporation.
- Abundance of snow in **M2005** is also consistent with past studies (e.g., Varble et al. 2011).
 - Would be associated with more stratiform → abundance of light rain with **M2005**.

Summary and Conclusions 2:

Shallow to Deep Transition

- With both MJO events (especially in the 1st one) there is a progression from small shallow clouds to large deep clouds.
- Small PFs and shallow clouds are not as strongly modulated as large PFs and deep clouds...consistent with some observations (Barnes and Houze 2013, Deng et al. 2013).
- The transitions are dominated by increases in rain area as opposed to rain intensity.
 - Increased free-tropospheric moisture → deep convection → cold pools and more triggering → more convective area.

Future Work

- Simulations using parameterized large-scale dynamics simulations and variational analysis forcing datasets.
- Analysis of convective/stratiform in simulations and comparisons with radar observations.
- More detailed investigation of microphysics schemes.