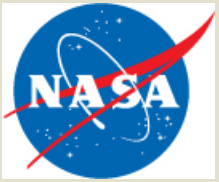


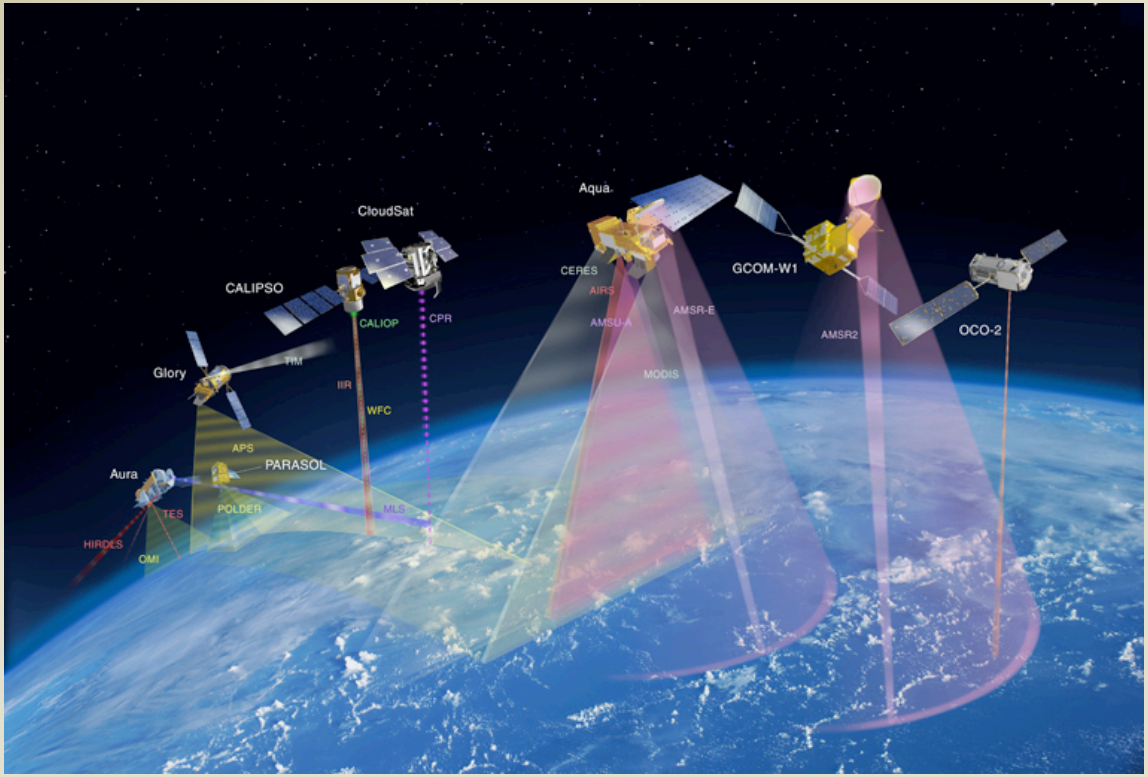
Using CloudSat and the A-Train for Model Validation

Matt Lebsock

Contributors: Kenta Suzuki, Graeme Stephens

Jet Propulsion Laboratory:
California Institute of Technology

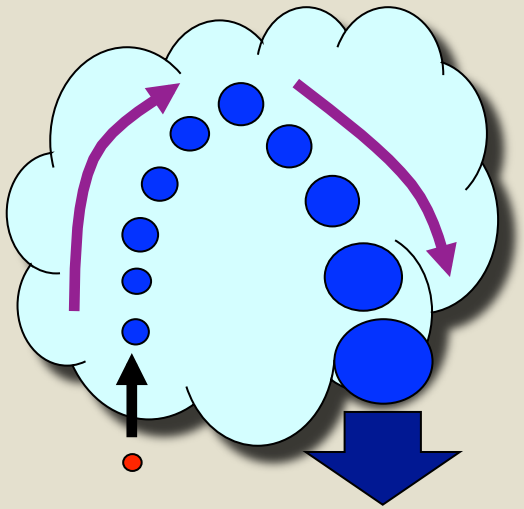
A-Train Satellite Constellation



- ✓ Simultaneous measurement of cloud and precipitation
- ✓ How can we use satellite observations for:
  1. process understanding
  2. model evaluation
  3. parameterization development

Scope of this Talk

- Focus on warm rain precipitation processes
  - Autoconversion
  - Accretion

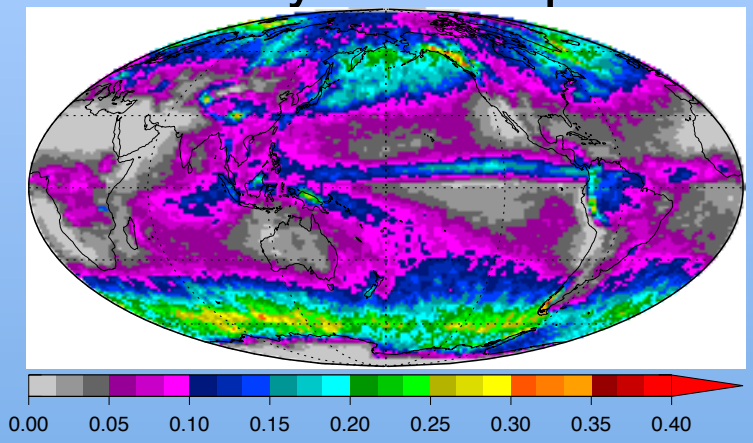


- Emphasis: using the observations to evaluate and constrain the representation of specific processes

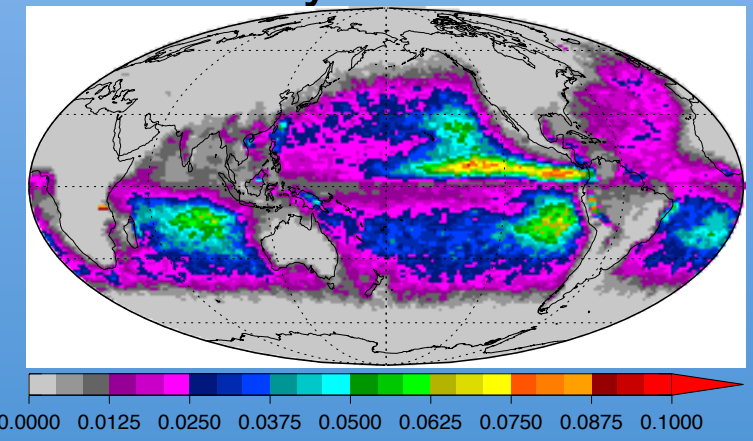
Light Precipitation from CloudSat

Detection

Probability of Precipitation

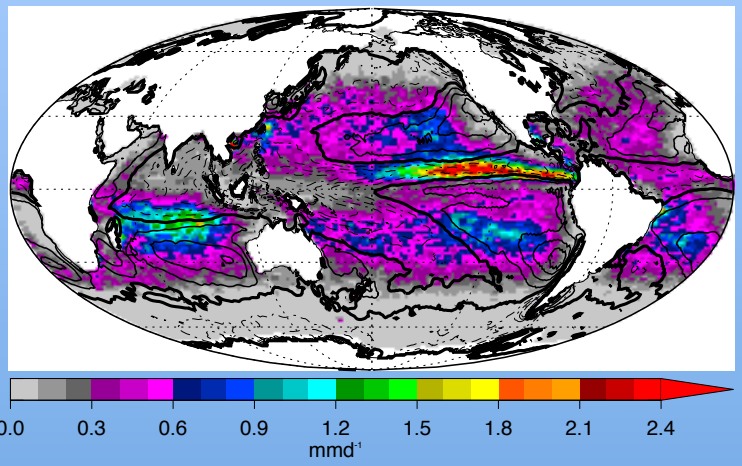


Probability of Warm Rain

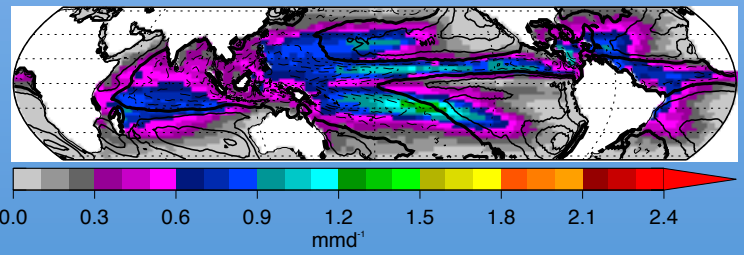


Quantification

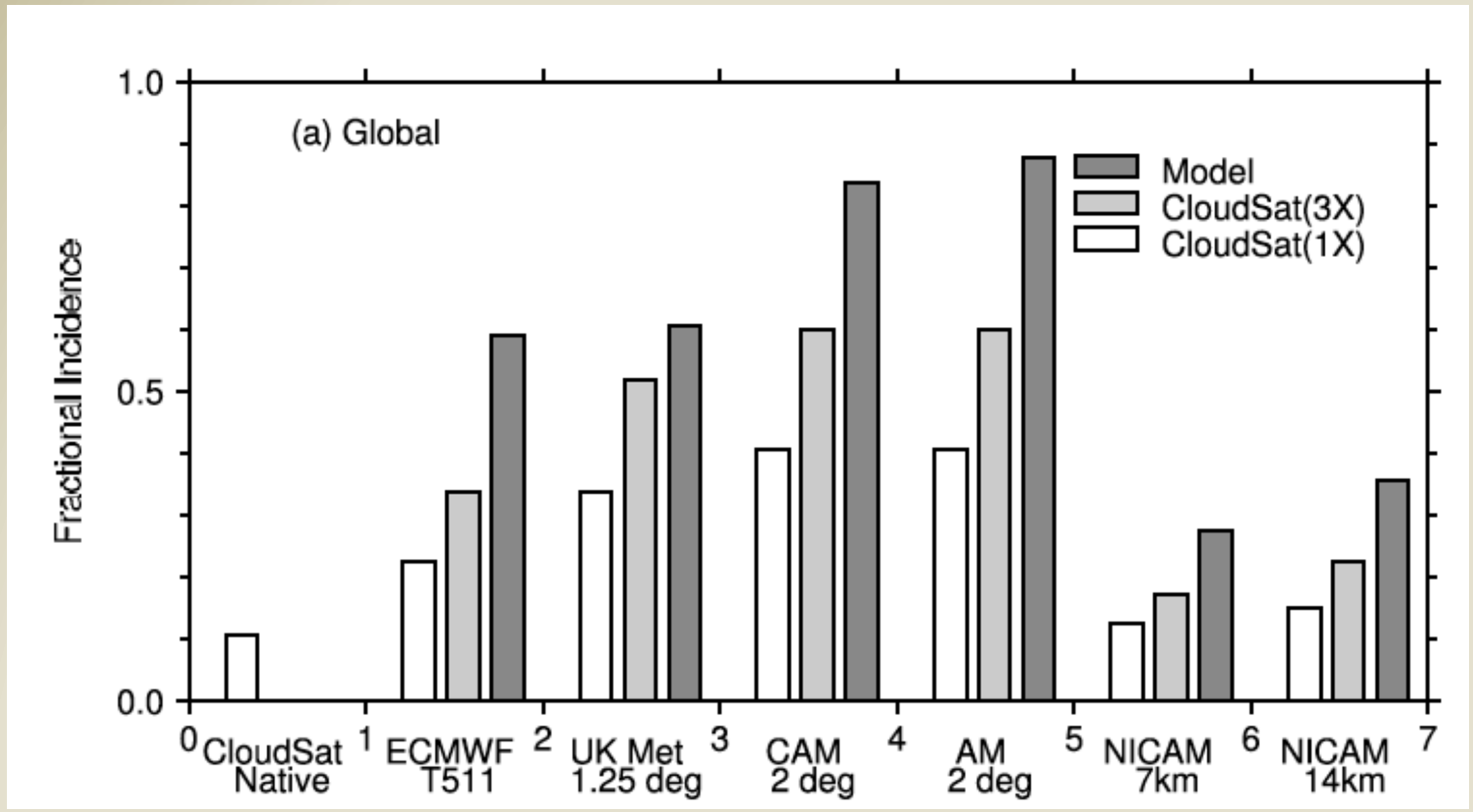
Warm Rainfall



PR Warm Rainfall



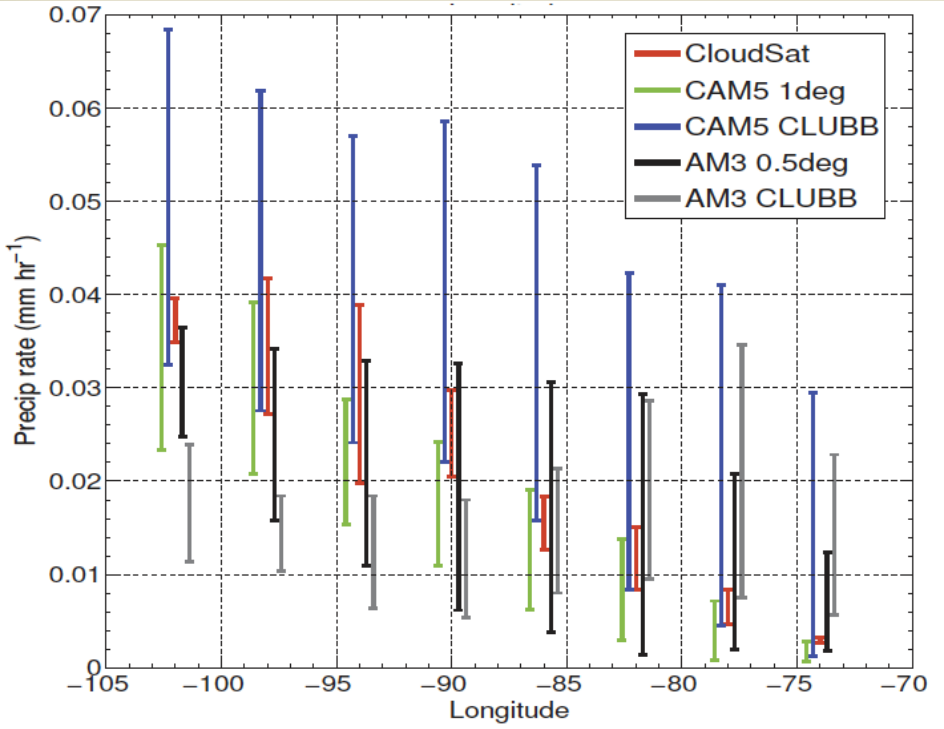
Total Precipitation Occurrence



- Models produce precipitation that occurs too frequently

Stephens et al. (2012)

Warm Rain Accumulation

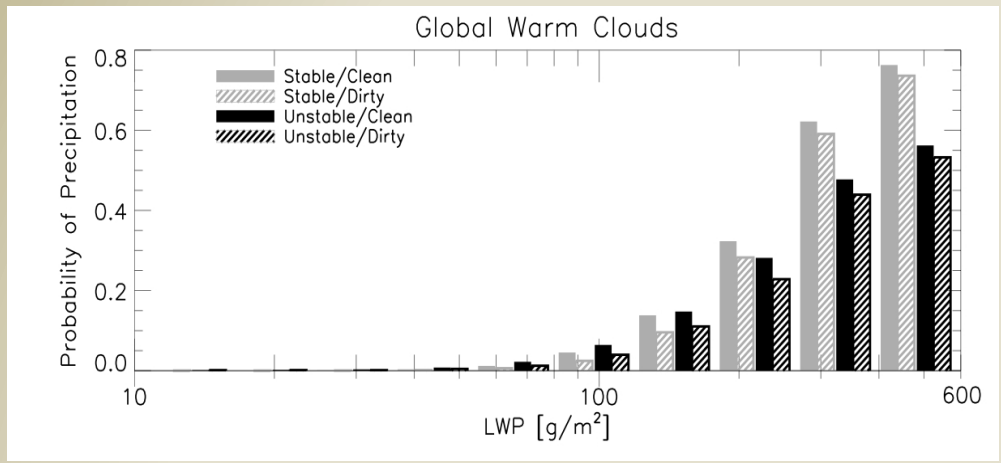


- Models and CloudSat agree on rain rate

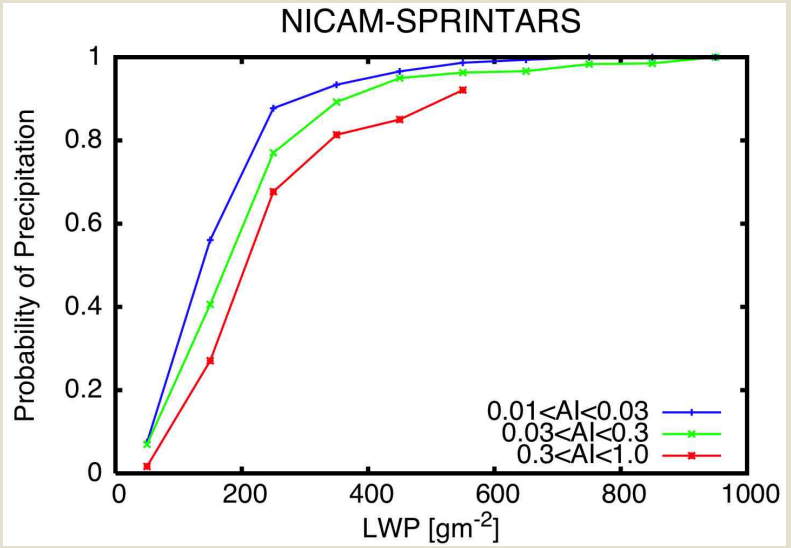
Grovesner et al. (in prep)

Probability of Precipitation and Cloud Water

A-Train: CloudSat+AMSR-E+MODIS



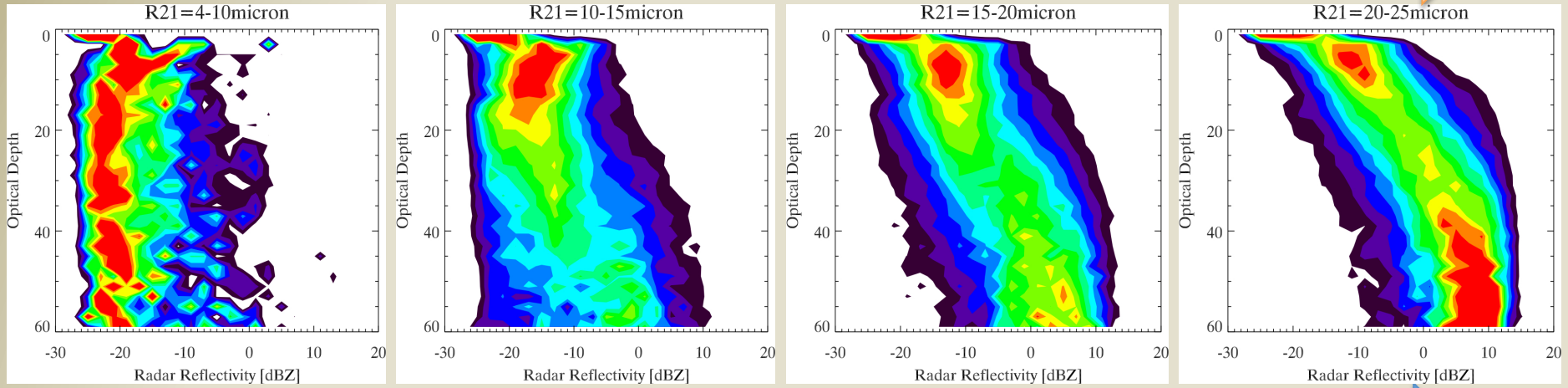
NICAM-SPRINTARS



- ✓ Increase in POP with LWP
- ✓ Aerosol suppression of Precipitation
- ✓ Faster water conversion in NICAM

Observed "fingerprint" of Microphysical Processes

Increasing radius

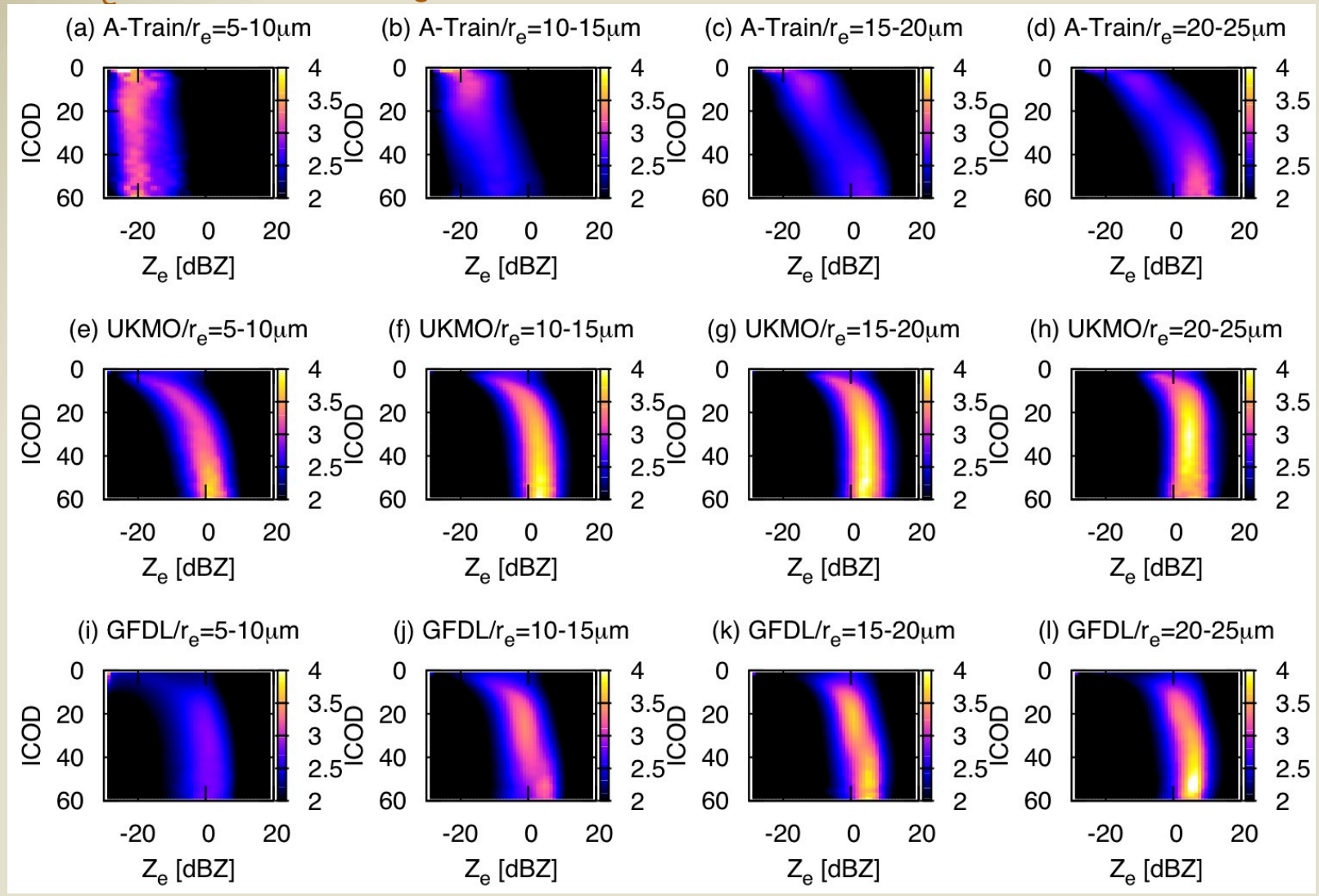


Non-Precipitating → Precipitating

Contoured
Frequency by
Optical
Depth
Diagram

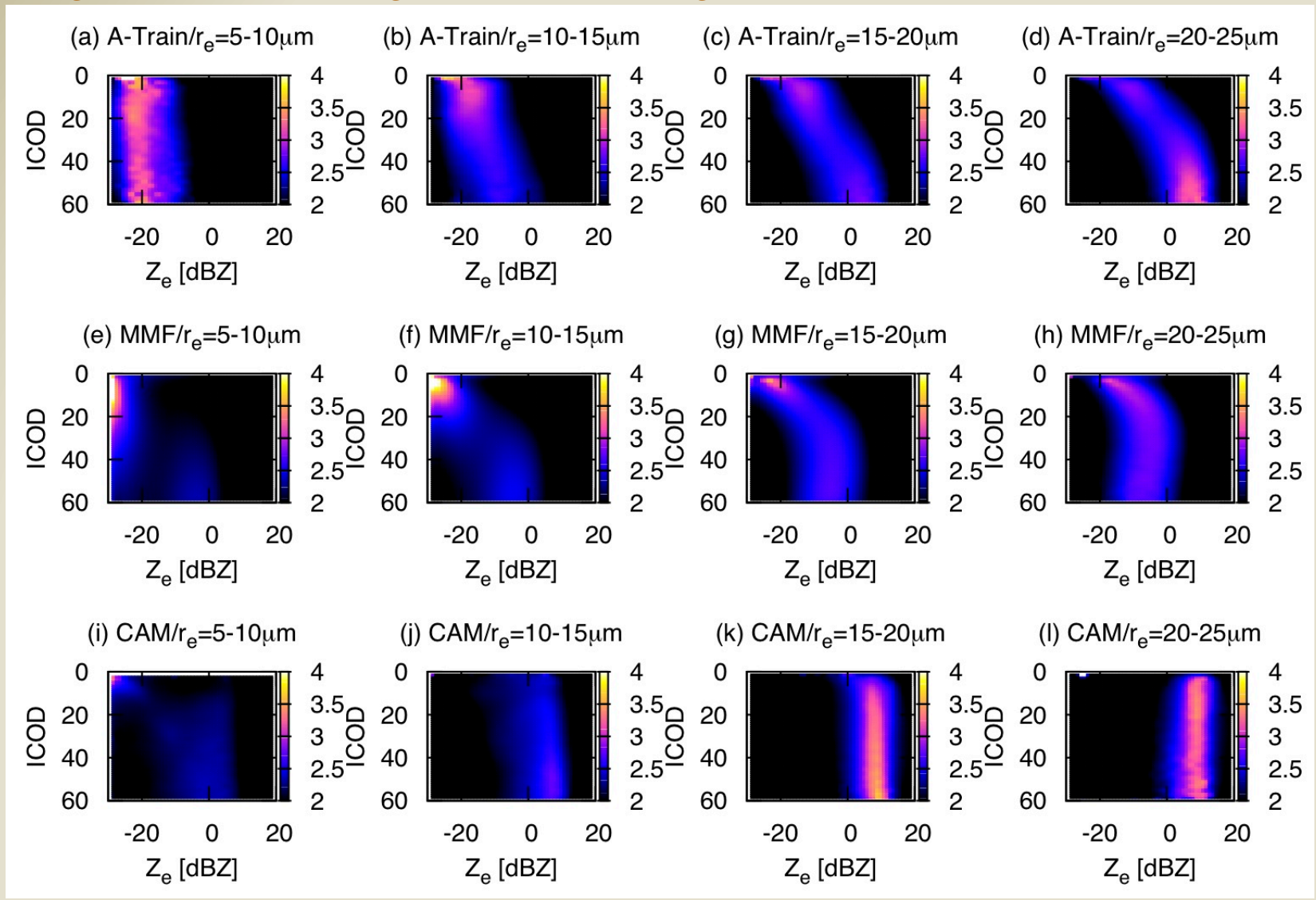
Suzuki et al. (JAS'10)

Evaluation of Climate Models w/ COSP



Suzuki et al. (in prep)

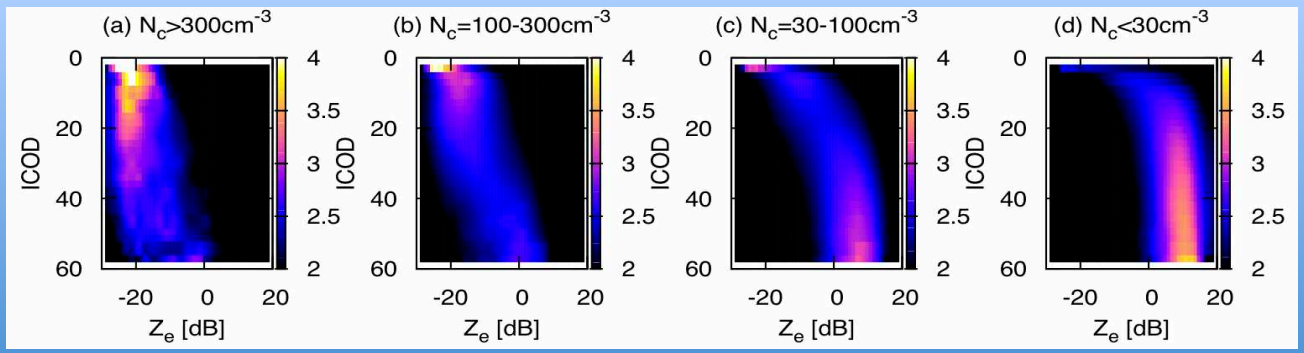
Evaluation of Climate Models w/ COSP (cont'd)



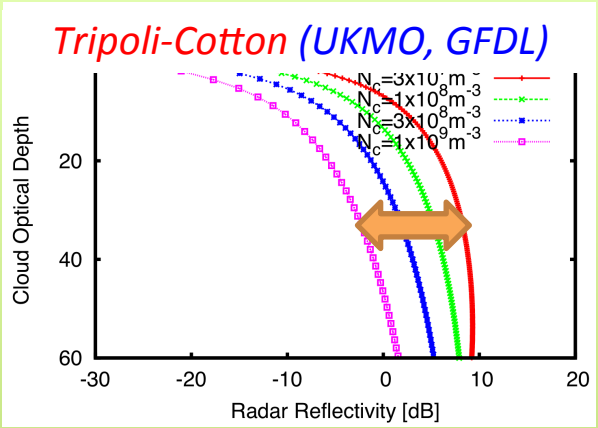
Suzuki et al. (in prep)

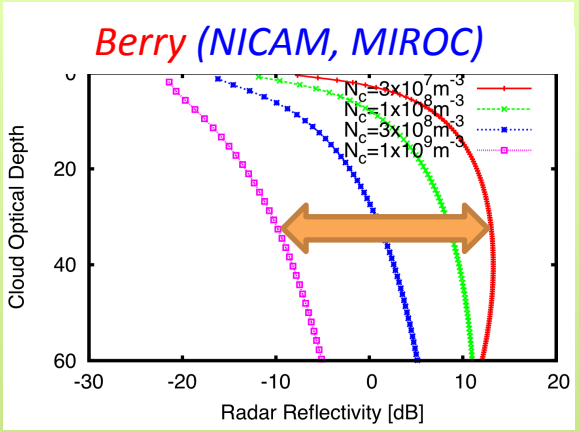
Autoconversion Parameterizations in a Single Column Model

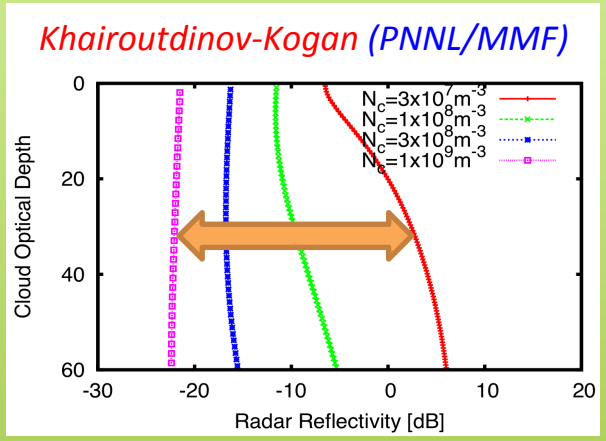
A-Train

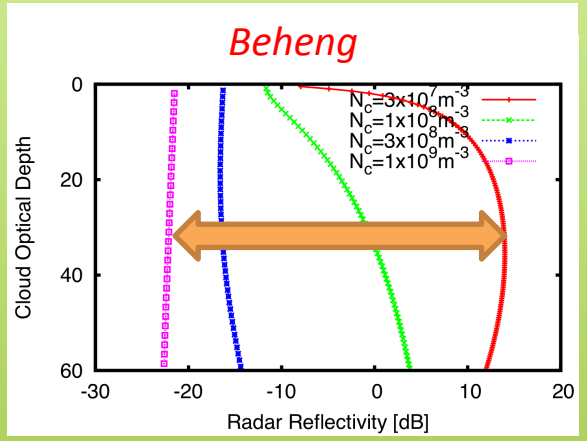


SCM









Suzuki et al. (2012)

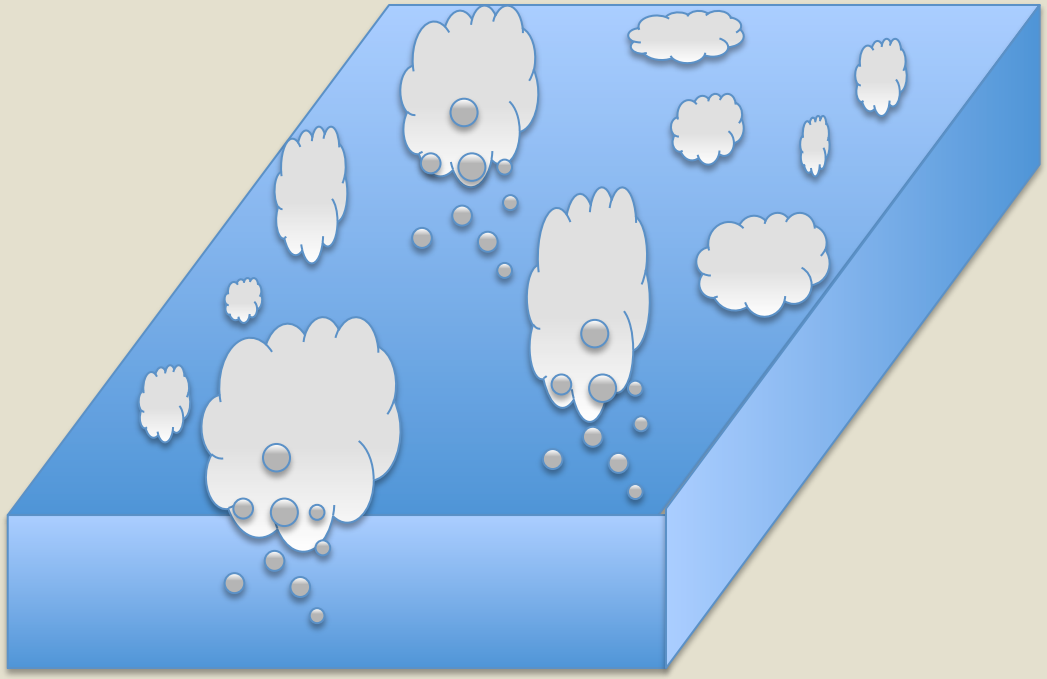
Sub-grid Variability of Microphysics

- The model provides grid mean:

$$\overline{q}_c, \overline{N}_c, \overline{q}_r, \overline{N}_r$$

- Microphysical processes are non-linear and occur at local scales. One cannot use the grid means to calculate their rates without incurring a non-linear averaging bias.

- Focus on two processes
  - Autoconversion: Direct conversion of cloud water to rain water
  - Accretion: Collection of cloud water by falling rain



Process Rate Formulation

- Assume the Khairoutdinov and Kogan, [2000] formulations

Autoconversion

$$M_{auto} = a_{auto} \frac{q_c^{b_{auto}}}{N_c^{c_{auto}}}$$

Accretion

$$M_{acc} = a_{accr} \left(q_r q_c \right)^{b_{accr}}$$

Khairoutdinov and Kogan, 2000

	Autoconversion			Accretion	
parameter	a_{auto}	b_{auto}	c_{auto}	a_{accr}	b_{accr}
value	1350	**2.47**	1.79	67	**1.15**

- Autoconversion is much more non-linear than accretion.
- Is subgrid influence on accretion negligible?

Framework

- Assume Bi-variate lognormal distribution

$$P(x_1,x_2)=\frac{1}{\sqrt{2\pi}\sigma_{\ln,1}\sigma_{\ln,1}x_1x_2\sqrt{1-\rho^2}}\exp\left(\frac{\left(\ln(x_1)-\mu_1\right)^2}{2\left(1-\rho^2\right)\sigma_{\ln,1}}\right)\exp\left(\frac{\left(\ln(x_2)-\mu_2\right)^2}{2\left(1-\rho^2\right)\sigma_{\ln,2}}\right)\exp\left(\frac{\rho(x_1-\mu_1)(x_2-\mu_2)}{\left(1-\rho^2\right)\sigma_{\ln,1}\sigma_{\ln,1}}\right)$$

- Calculate Process Rates

$M = ax_1^{b1}x_2^{b2}$

Local

Integrate

$$\bar{M}=\iint ax_1^{b_1}x_2^{b_2}P(x_1,x_2)\,dx_1\,dx_2$$

$$\bar{M}=E\,a\bar{x}_1^{b_1}\bar{x}_2^{b_2}$$

Grid-Mean

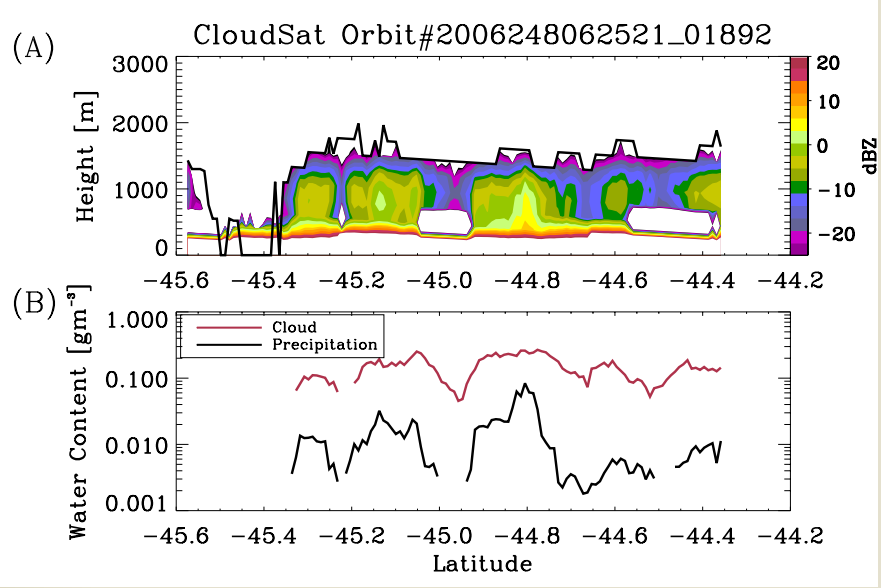
- Enhancement factor

$$E[\nu_1,\nu_2,b_1,b_2,\rho]=\left(1+\frac{1}{\nu_1}\right)^{\frac{b_1^2-b_1}{2}}\left(1+\frac{1}{\nu_2}\right)^{\frac{b_2^2-b_2}{2}}\exp\left(\rho b_1b_2\sqrt{\ln\left(1+\frac{1}{\nu_1}\right)\ln\left(1+\frac{1}{\nu_2}\right)}\right)$$

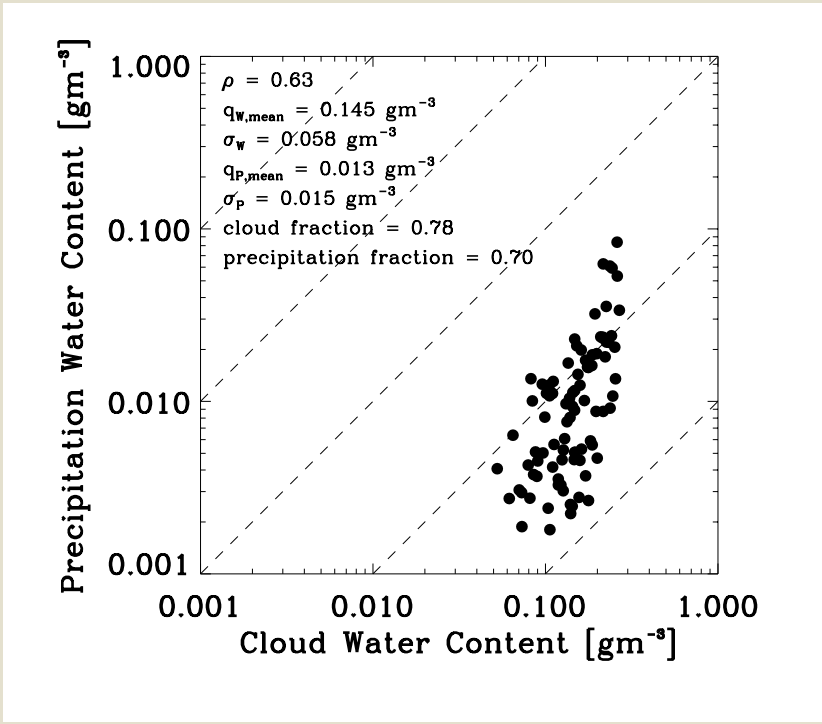
  - Parameters
    1. Normalized Cloud Water Variance
    2. Normalized Precipitation Water Variance
    3. Cloud/Precipitation Correlation
    4. Microphysical coefficients
  - The grid mean process rate can be calculated using the **original** microphysical coefficients modified by an enhancement factor (*E)* related to the sub-grid variability

CloudSat & MODIS Data

- CloudSat: sensitive to Precipitation
- MODIS: sensitive to cloud

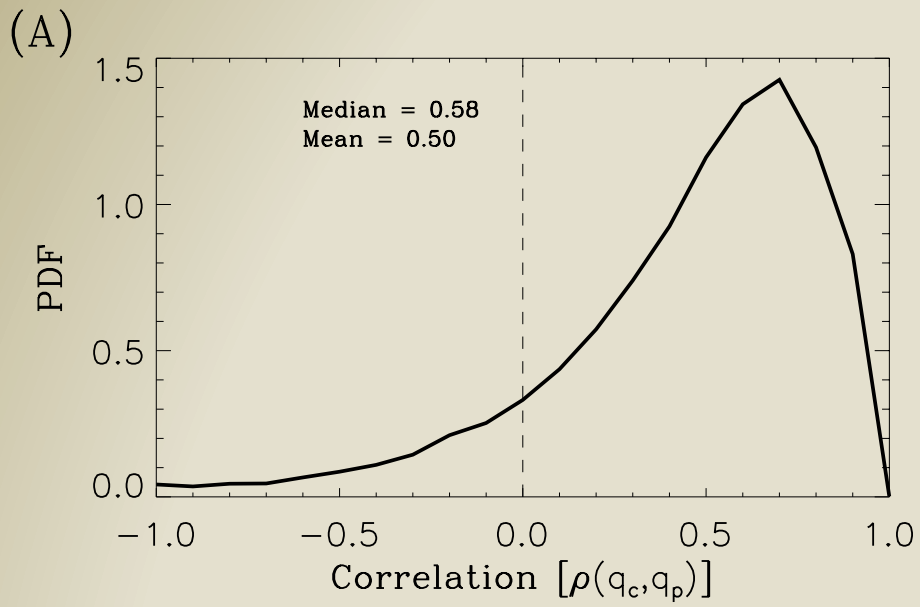


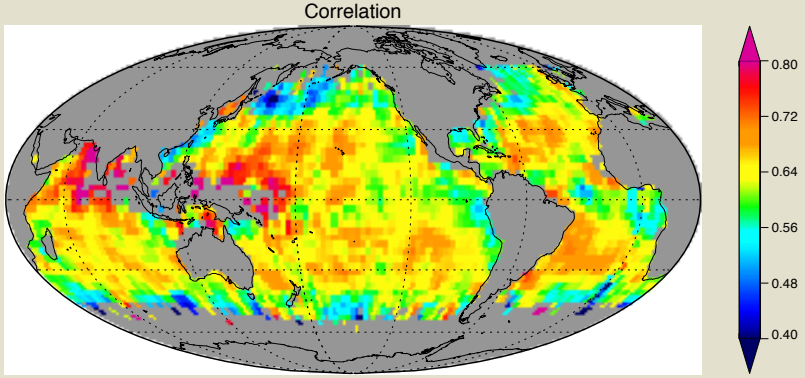
141 km



- Calculate (linear & log) statistics
  - Correlation
  - Cloud variance/mean
  - Precip variance/mean

Cloud-Precipitation Correlation

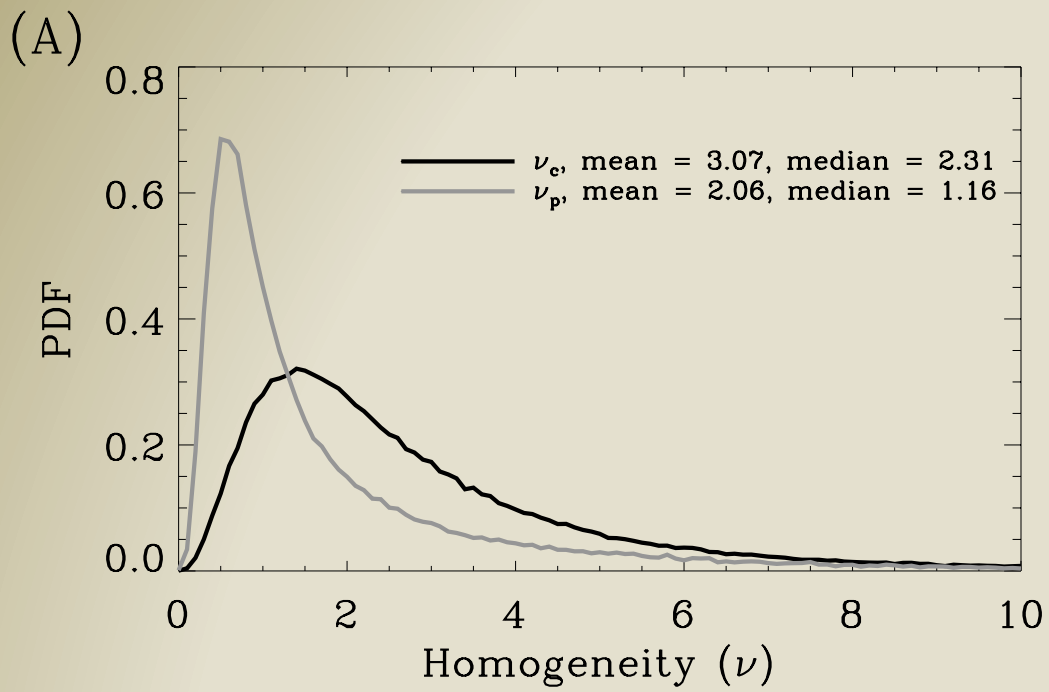


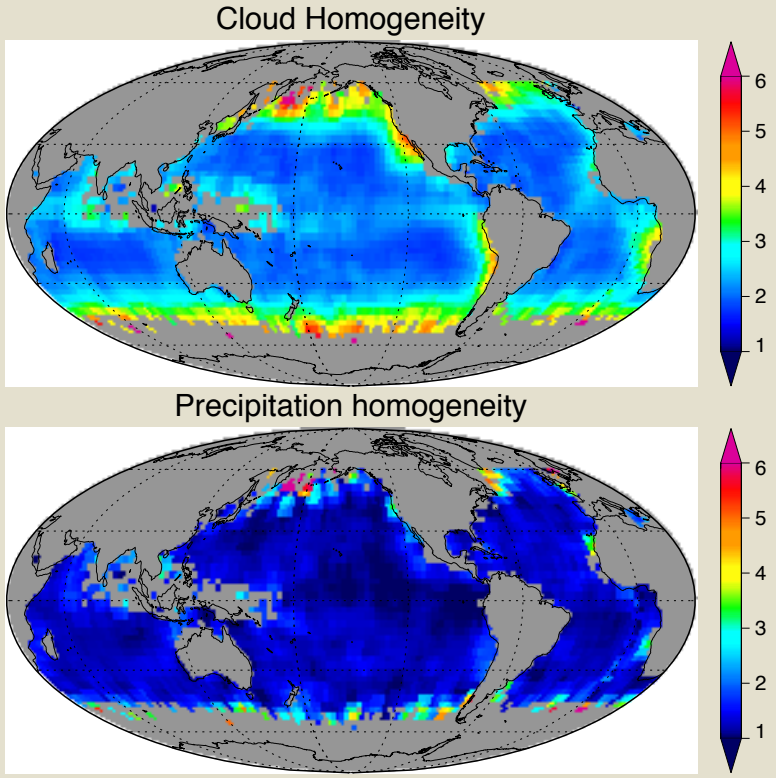


- Satellite correlation is large
  - LES ~0.24 [*Larson and Griffin*]
  - Aircraft ~0.13 [*Boutle et al., in press*]

Spatial scale of observations?

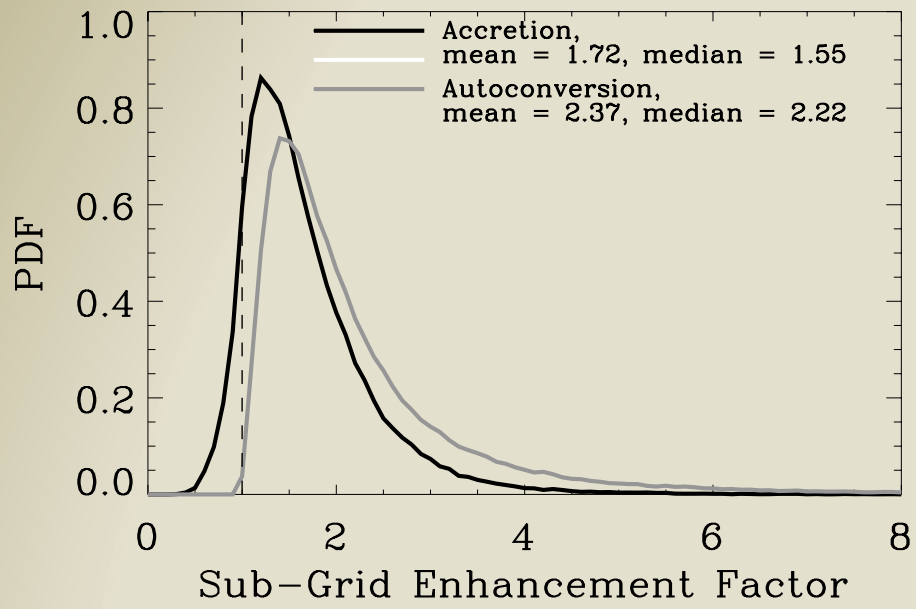
Homogeneity

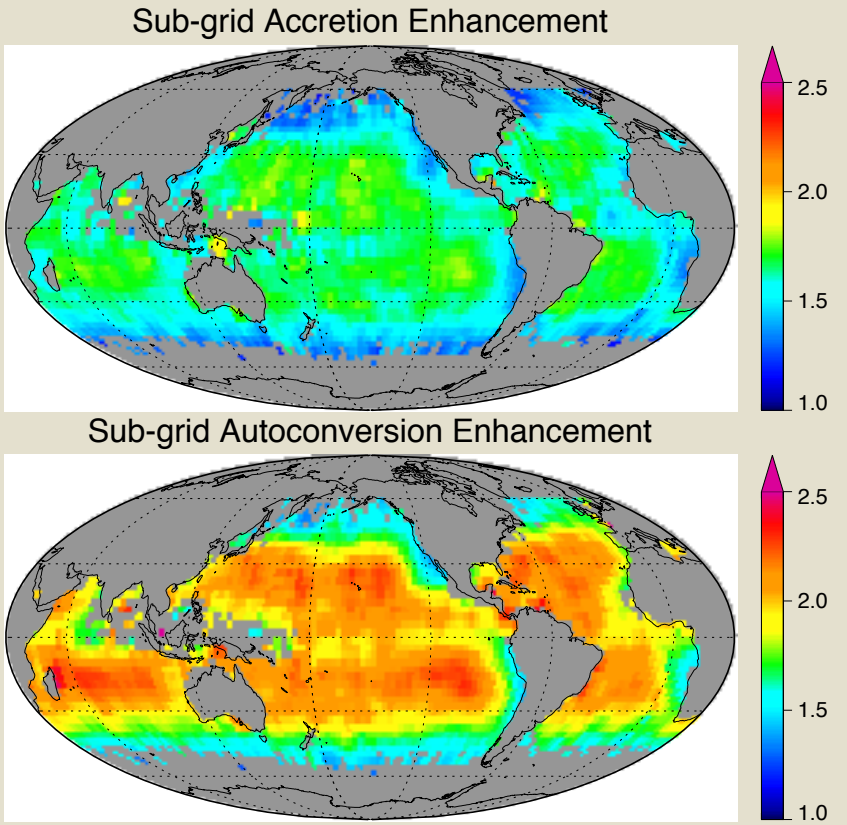




- Precipitation is more variable than cloud
- Well defined geographical patterns

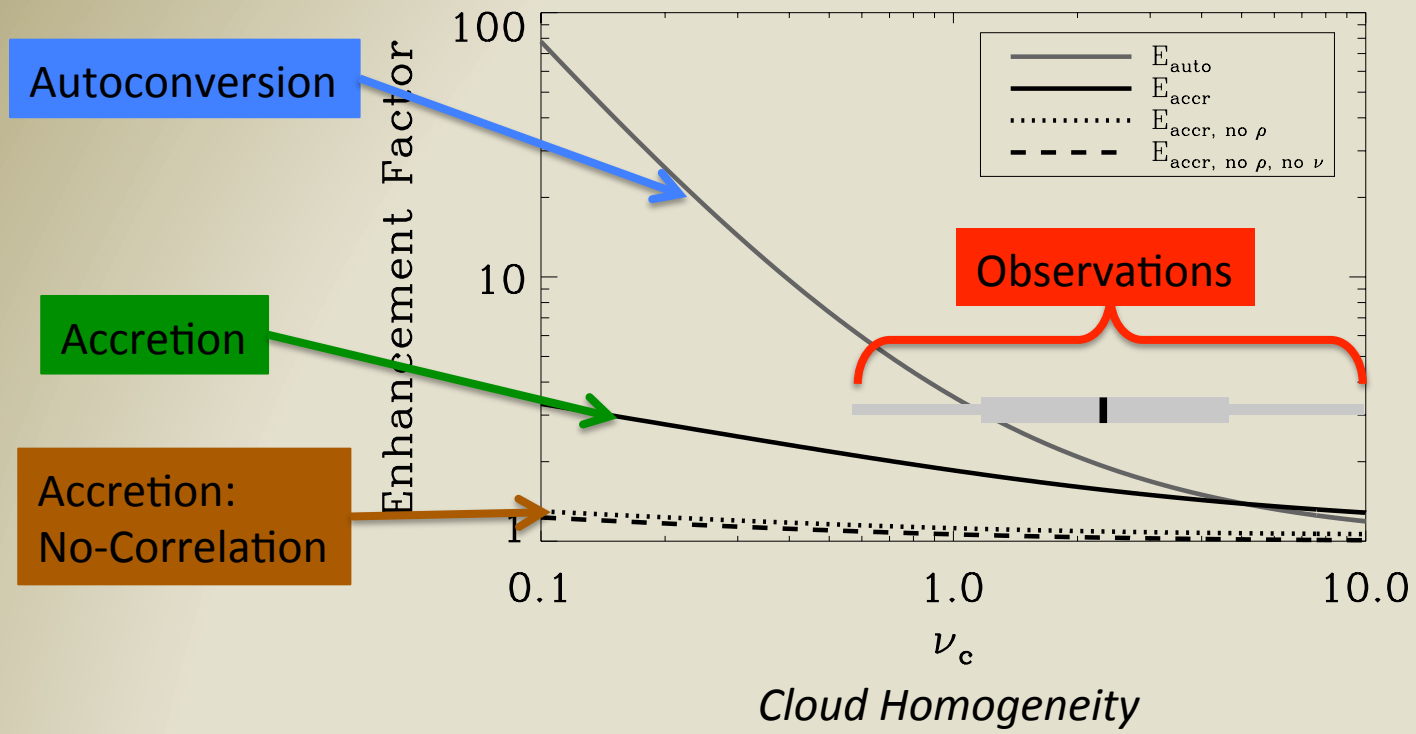
Enhancement Factors





- The geography of the enhancement follows that of the cloud water variance
- Accretion enhancement is comparable to autoconversion enhancement

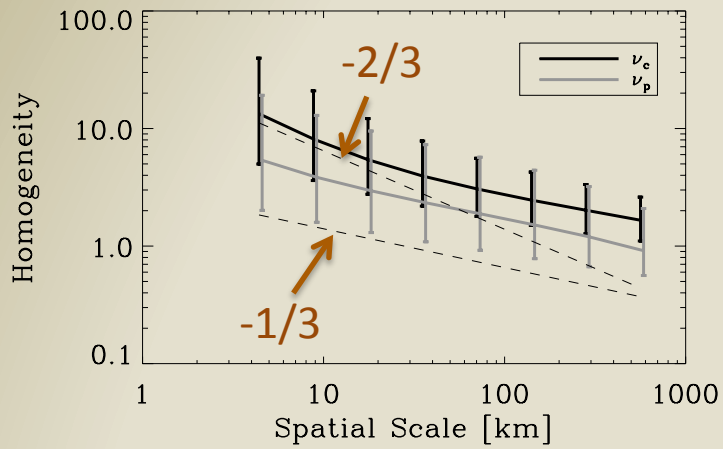
Importance of Including Correlation

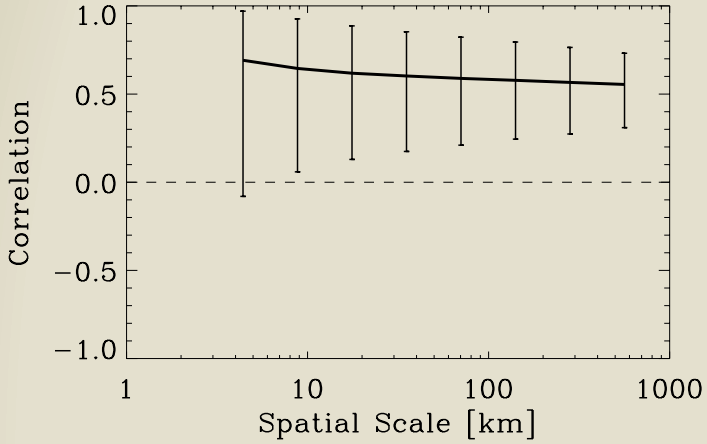


- Is sub-grid influence on accretion negligible?
  - No. Accretion enhancement becomes important when sub-grid variance in both cloud/ precipitation AND their correlation are considered.

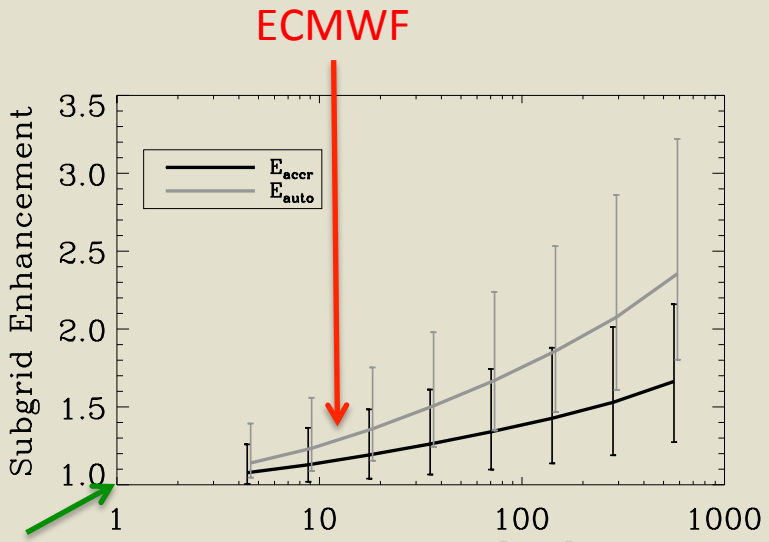
Scale Dependence

Covariance Parameters





Enhancement Factors



No Enhancement

Weather & Climate Models

Summary

- CloudSat offers a unique global view of light precipitation
- A-Train observables can be used to constrain **specific processes**
- Conversion of cloud to rain is too fast in global models
  - KK parameterization seems to perform best
  - Representation of the sub-grid is critical
- Sub-grid influence on accretion rates is non-negligible
  - Requires a representation of cloud/precipitation variability and correlation