主として数値モデル検証ツールとしての

衛星データシミュレータが拓く可能性と課題

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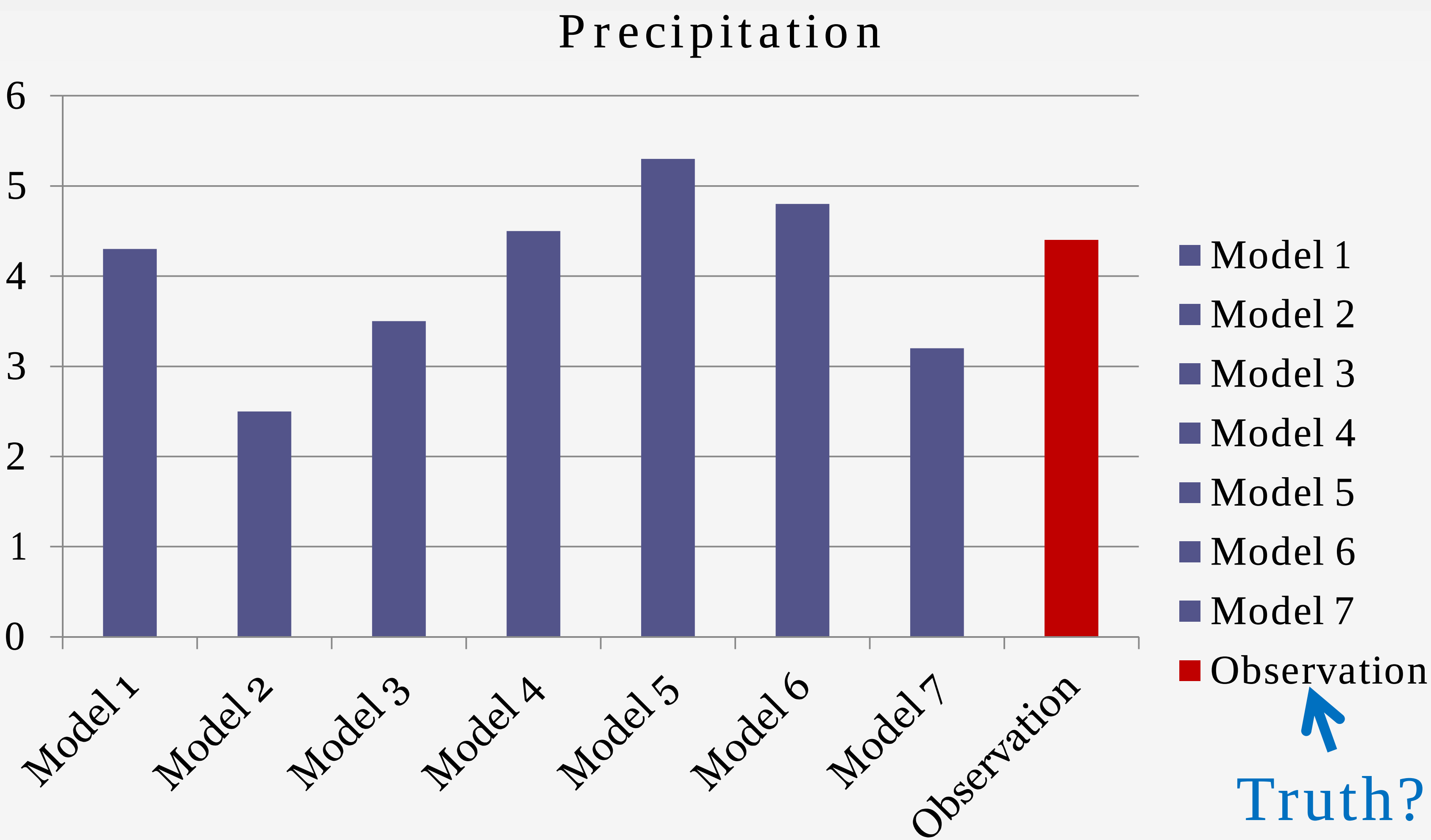
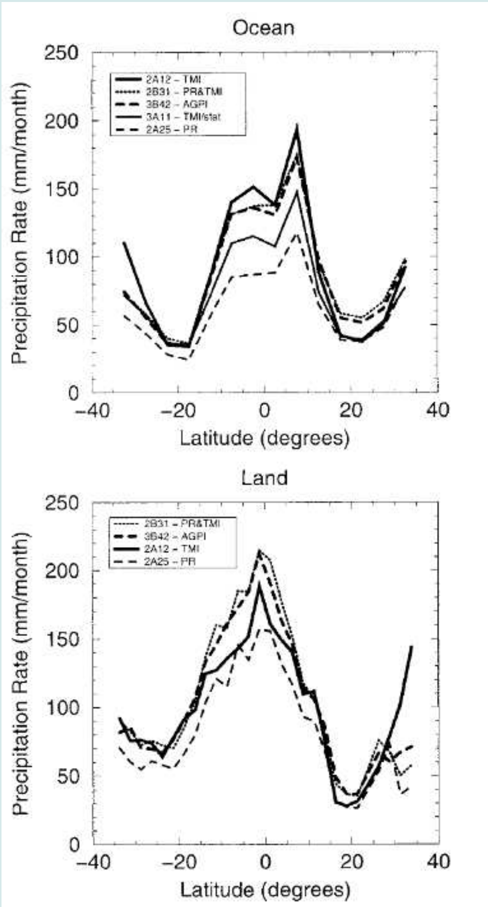
Model comparison with “the” observation

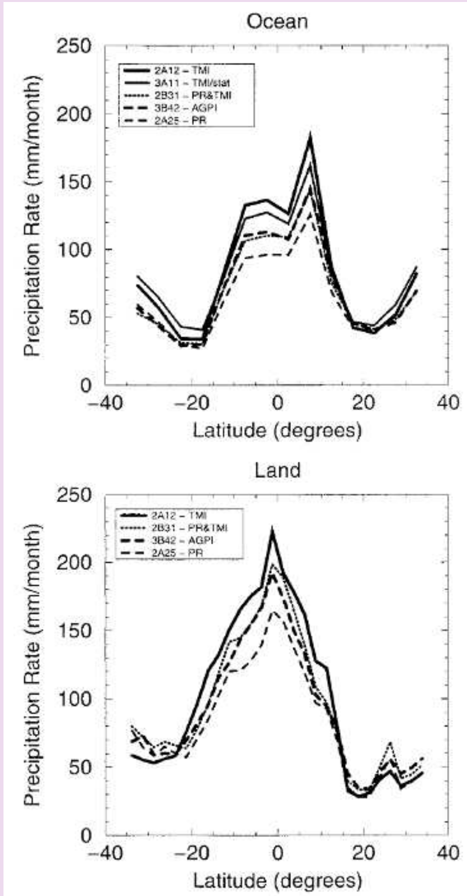


Is there any “truth” that you could rely on?

TRMM Rainfall Product Ver. 4

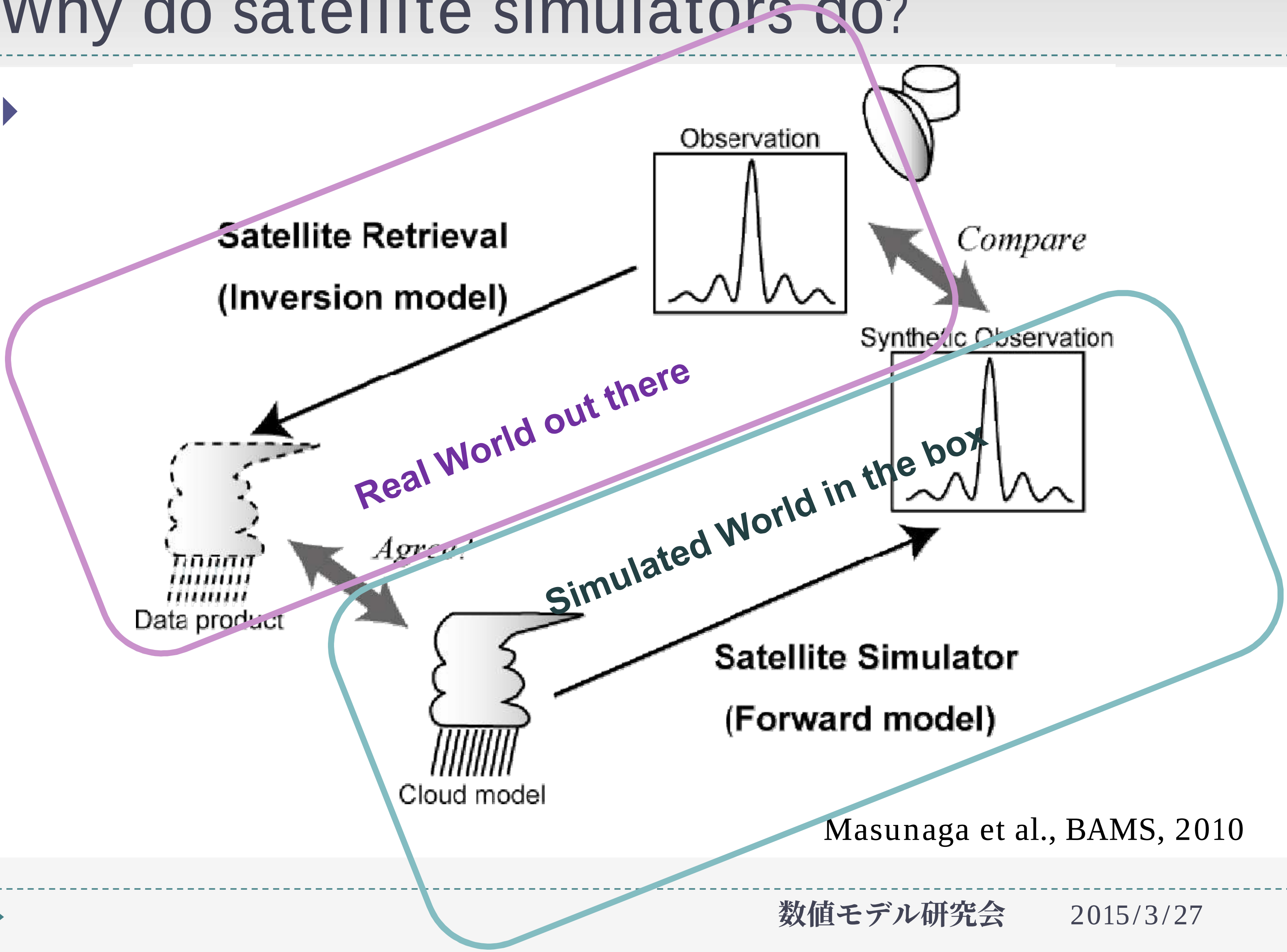


TRMM Rainfall Product Ver. 5



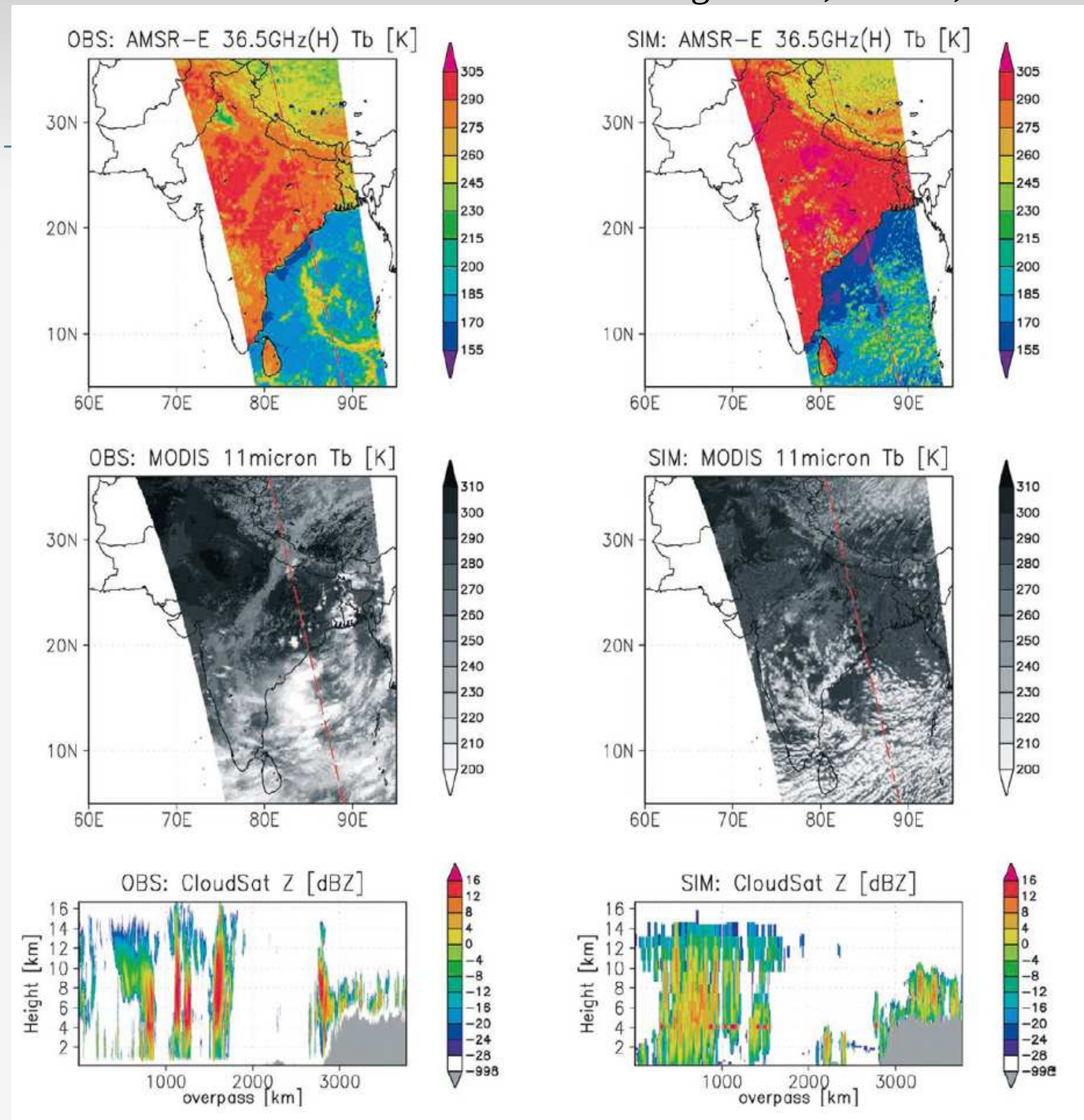
Kummerow et al., *J. App. Meteor.*, 2000

Why do satellite simulators do?



Masunaga et al., BAMS, 2010

Masunaga et al., BAMS, 2010



Observed μ-wave T_b at 37 GHz

Simulated μ-wave T_b at 37 GHz

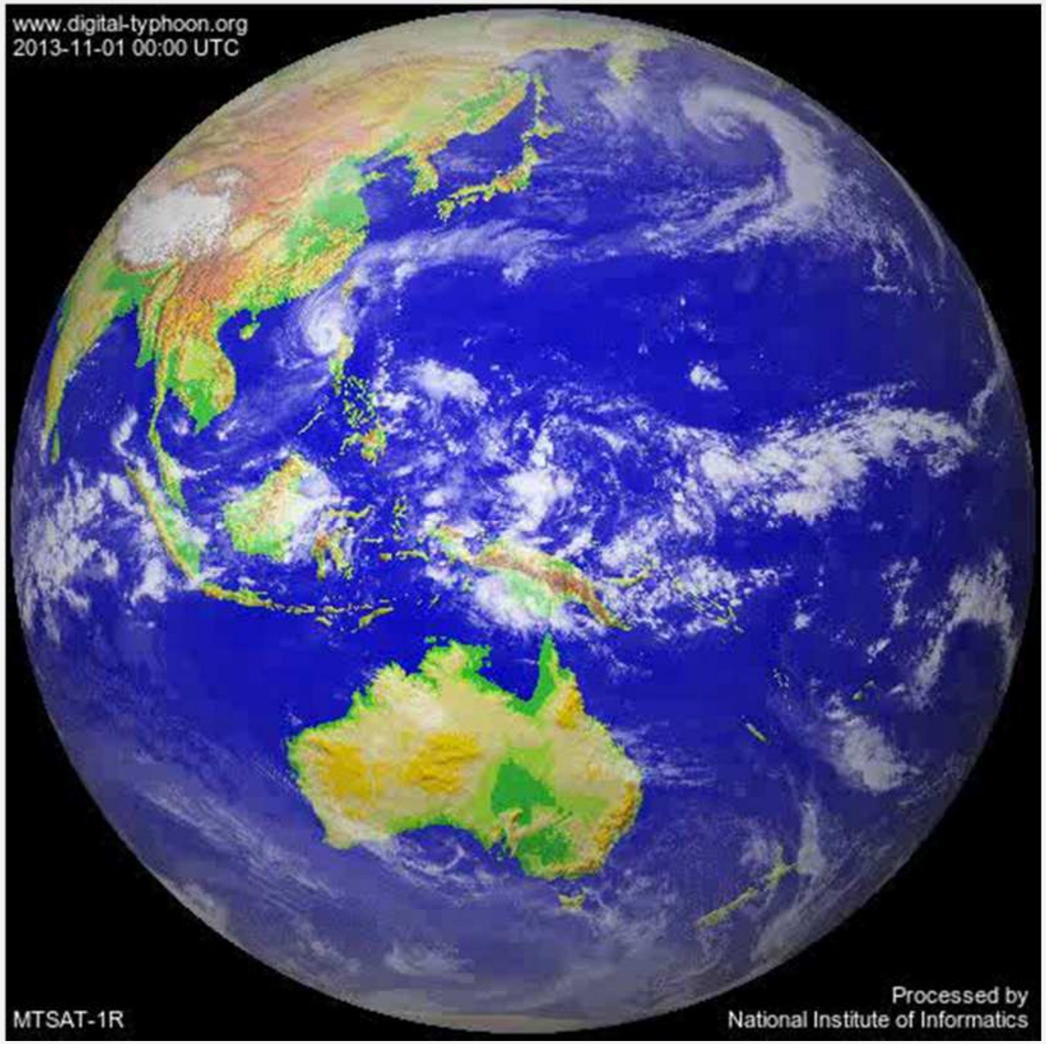
Observed infrared T_b at 11 μm

Simulated infrared T_b at 11 μm

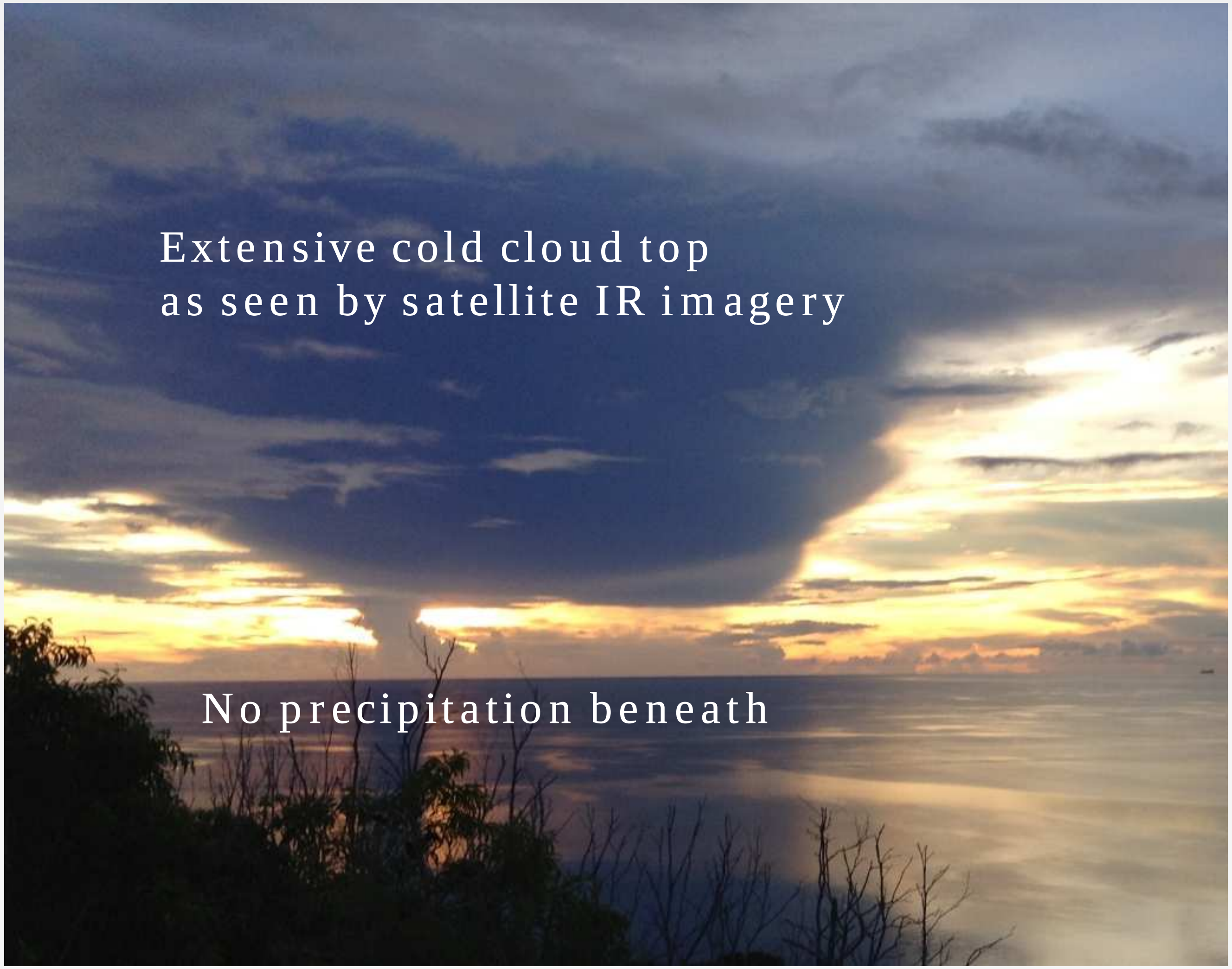
Observed radar dBZ at 95 GHz

Simulated radar dBZ at 95 GHz

Geostationary infrared imagery (Nov. 2013)

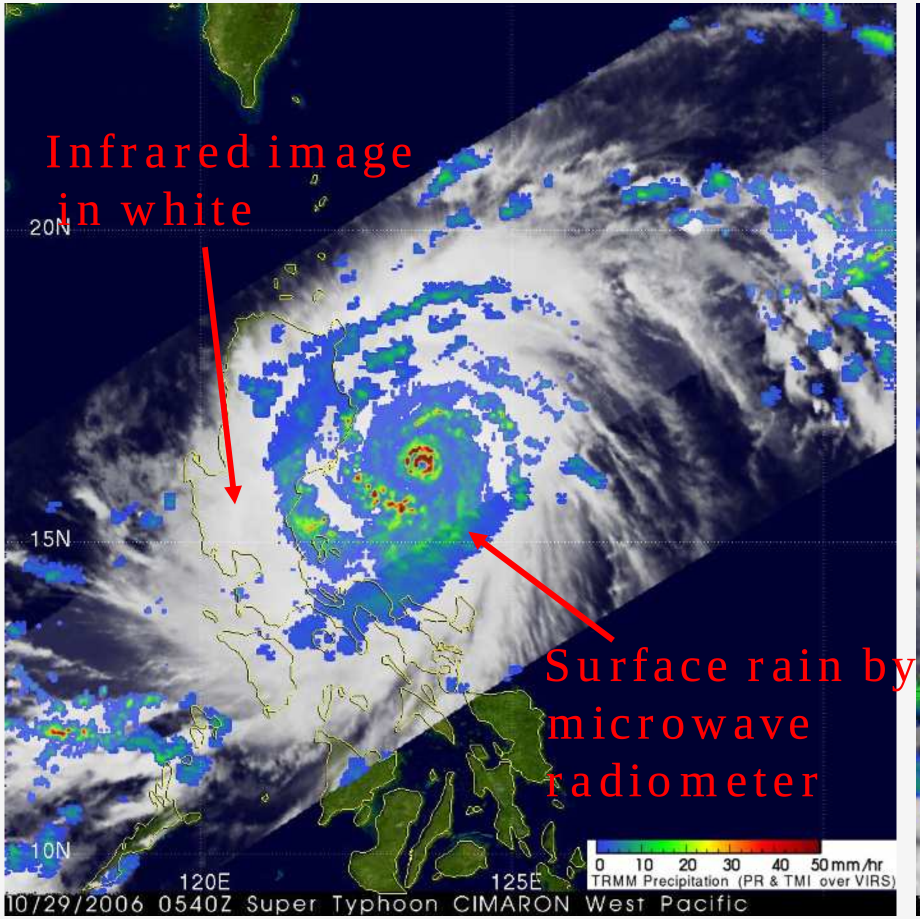


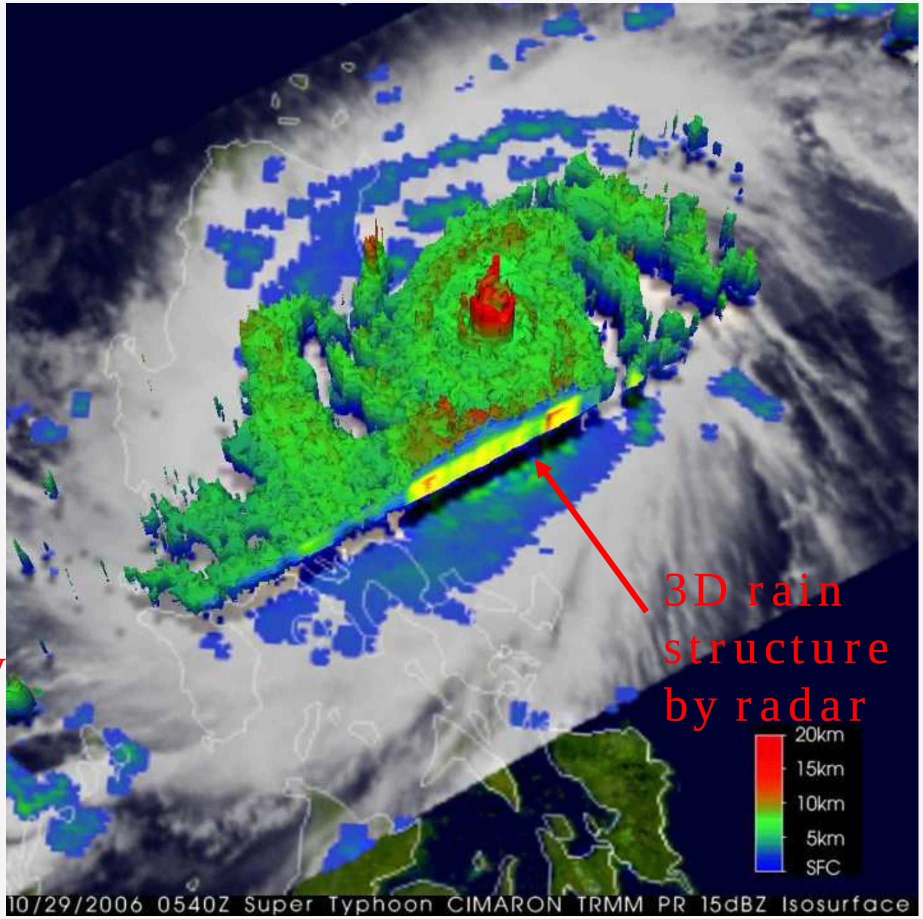
What lies beneath a high cloud?



Infrared versus microwave measurements

Typhoon Cimaron (2006) observed by the Tropical Rainfall Measuring Mission (TRMM) satellite
http://trmm.gsfc.nasa.gov/publications_dir/extreme_events.html





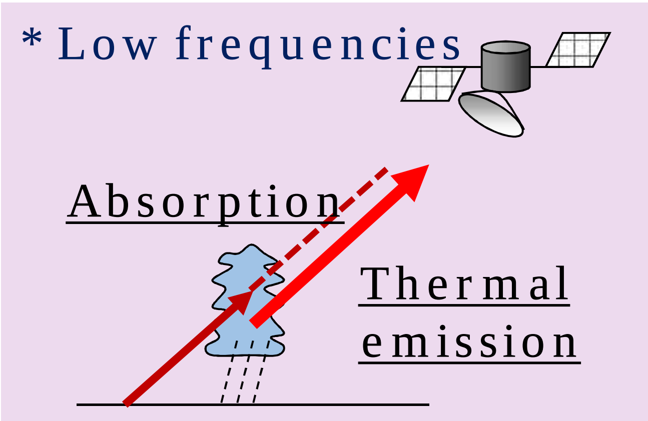
マイクロ波放射計と
衛星シミュレータ（概論）

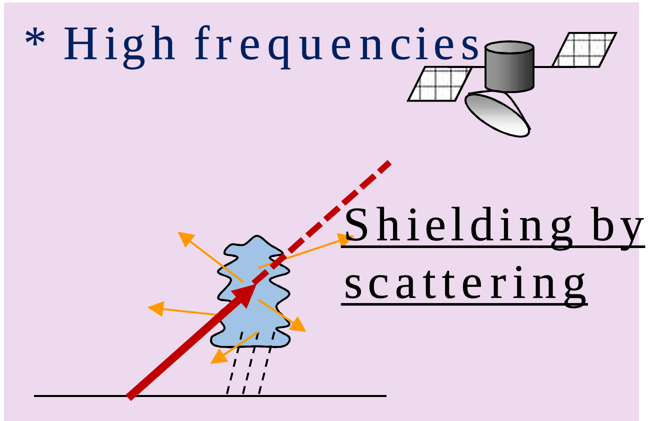
Microwave effects on cloud and precip.

- Microwave radiative transfer equation

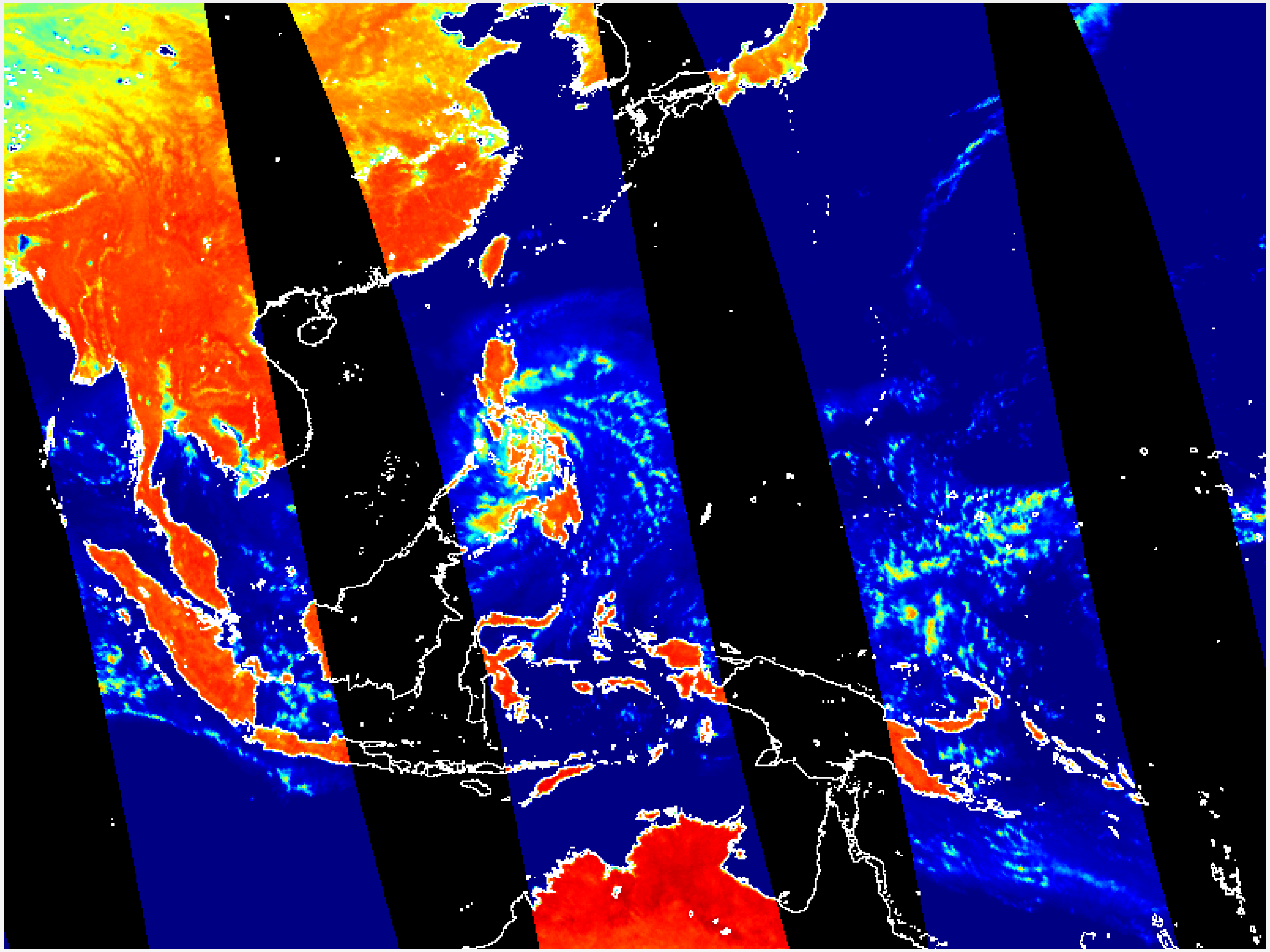
Extinction (Absorption + Shielding by scattering)

$$\frac{dT_b}{d\tau_\nu} = -T_b + \underbrace{(1-\omega_\nu)T}_{\text{Thermal emission}} + \underbrace{\omega_\nu \int P_\nu(\Omega,\Omega')T_b' d\Omega'}_{\text{Confluence by scattering}}$$

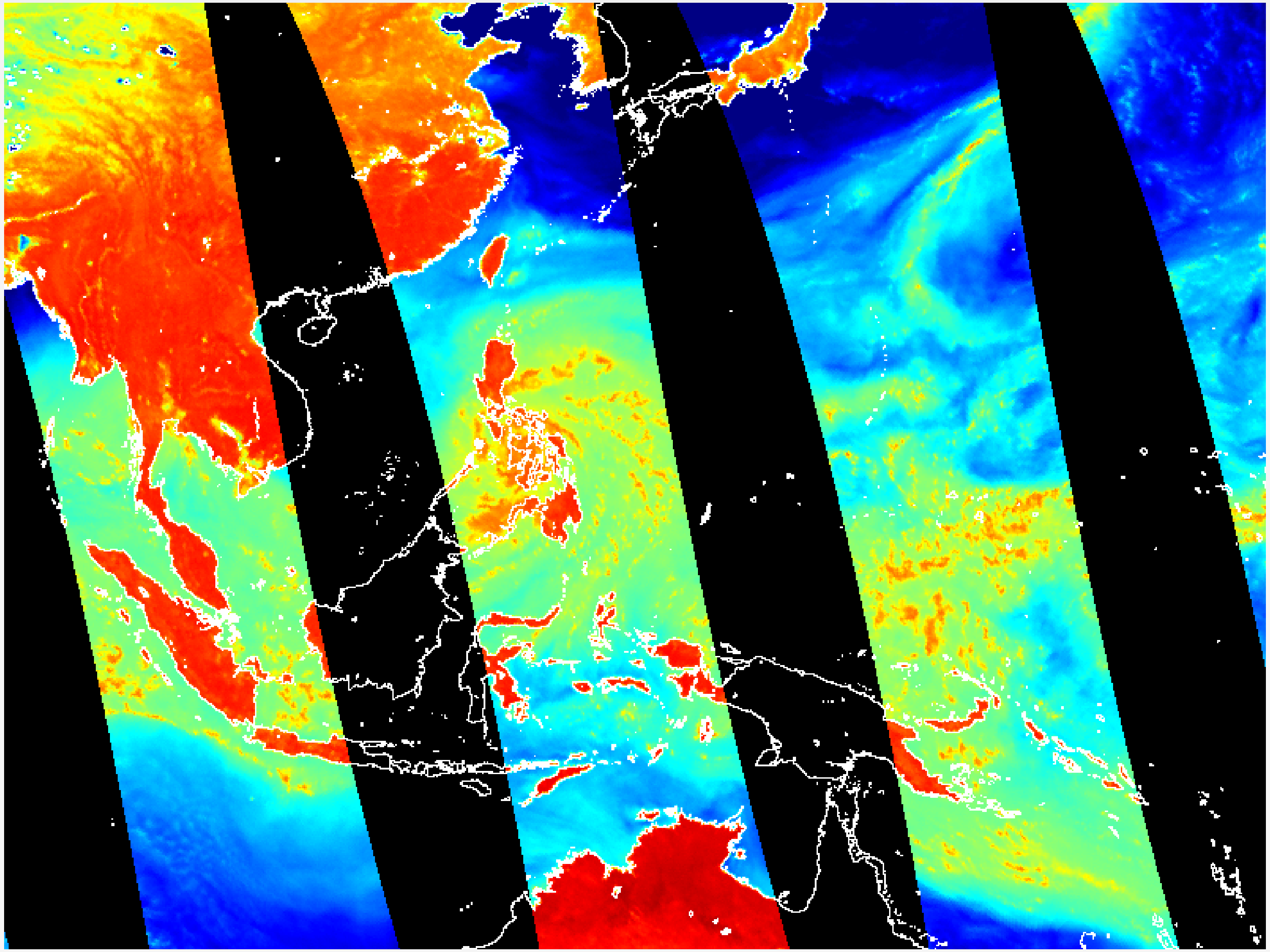




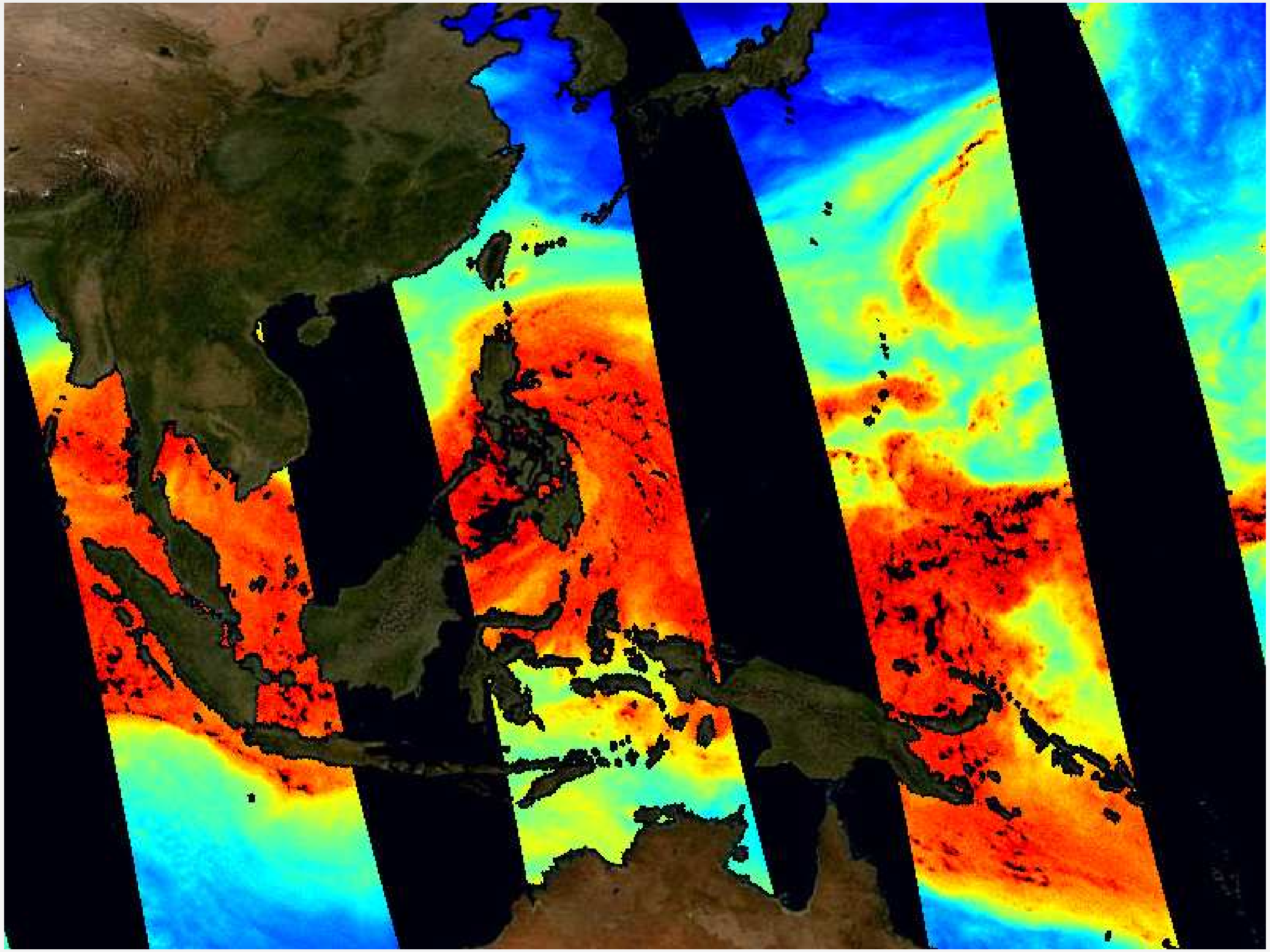
18GHz Brightness Temperature



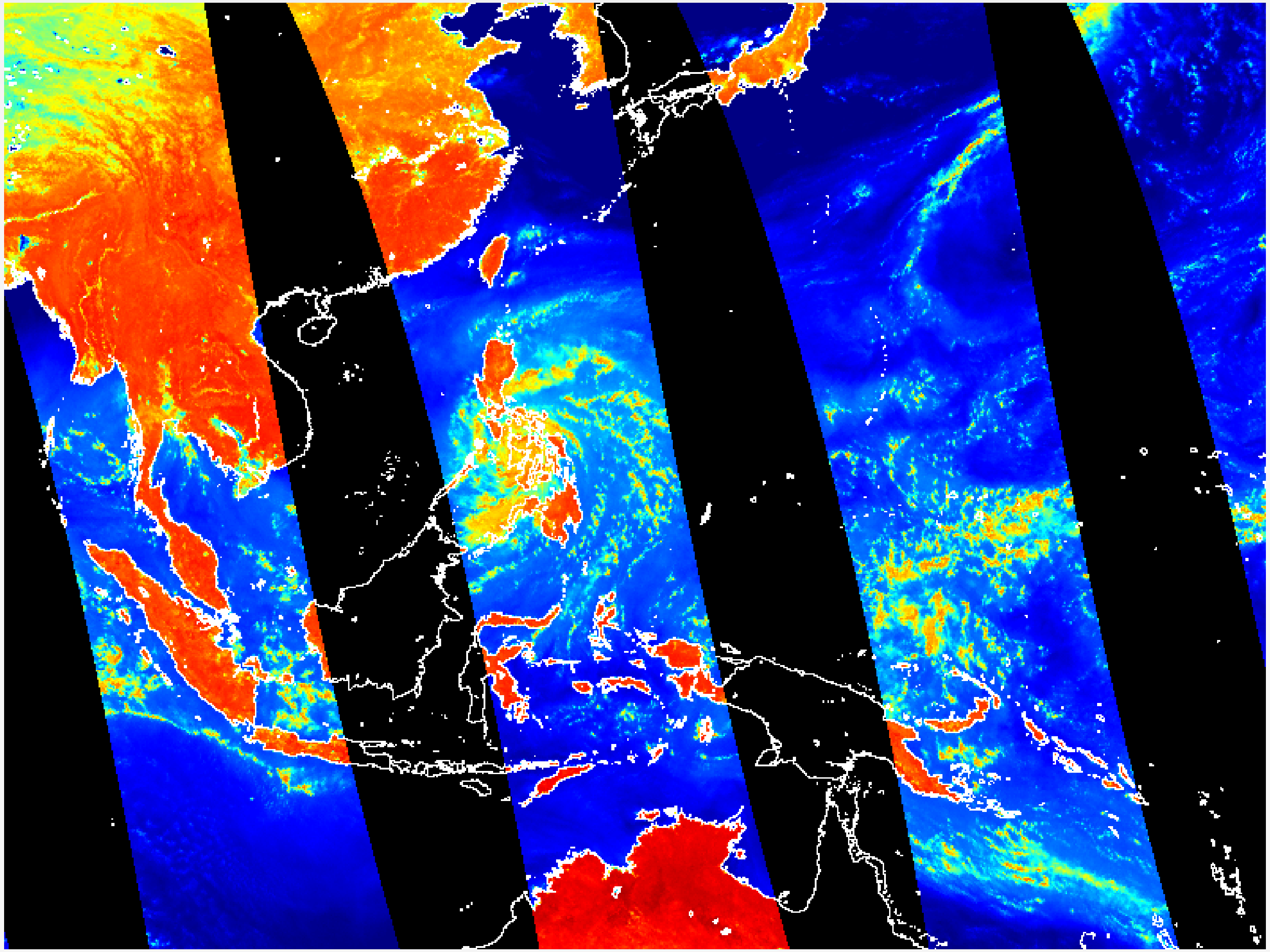
23GHz Brightness Temperature



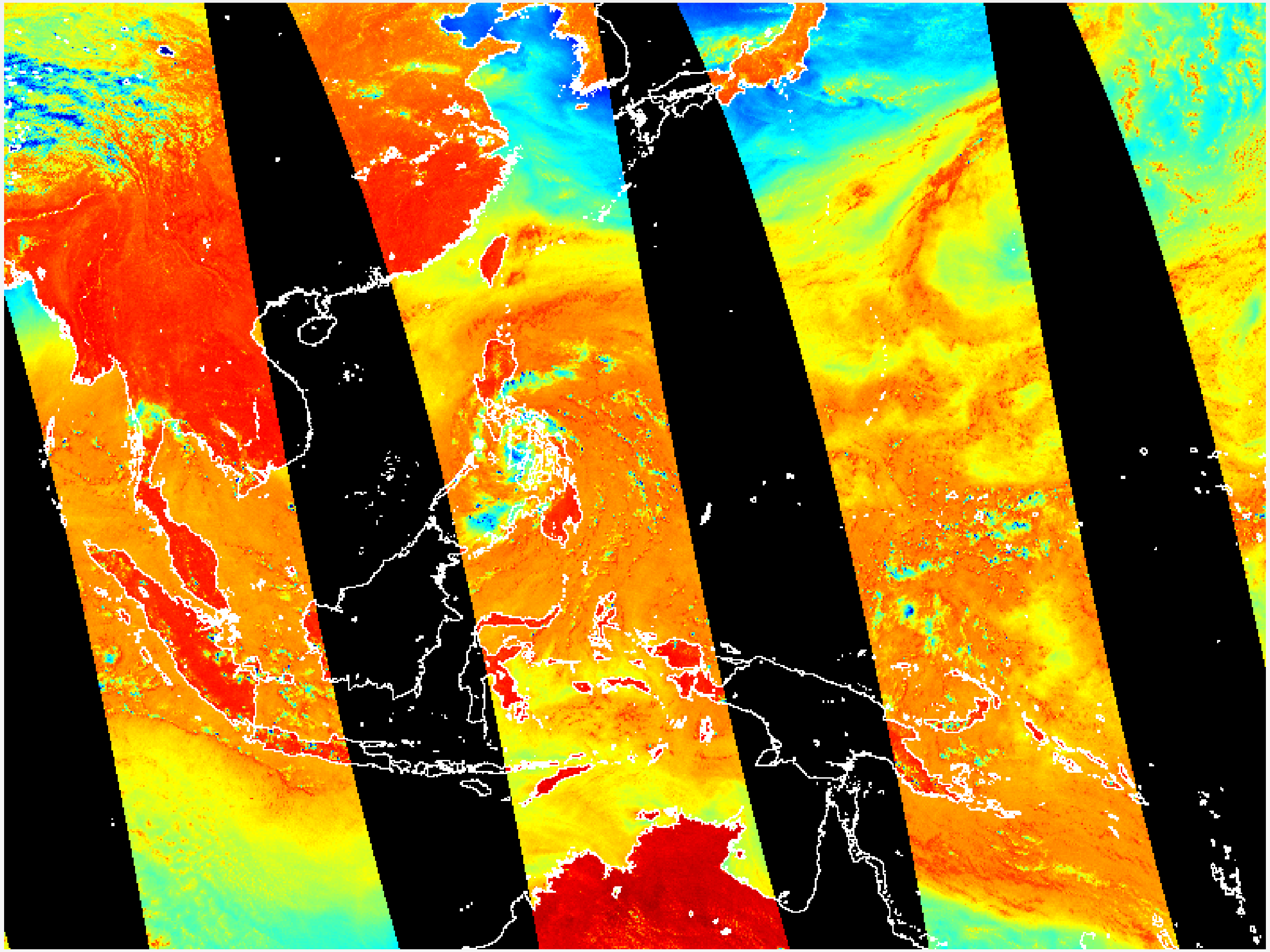
Precipitable Water (Column Water Vapor)



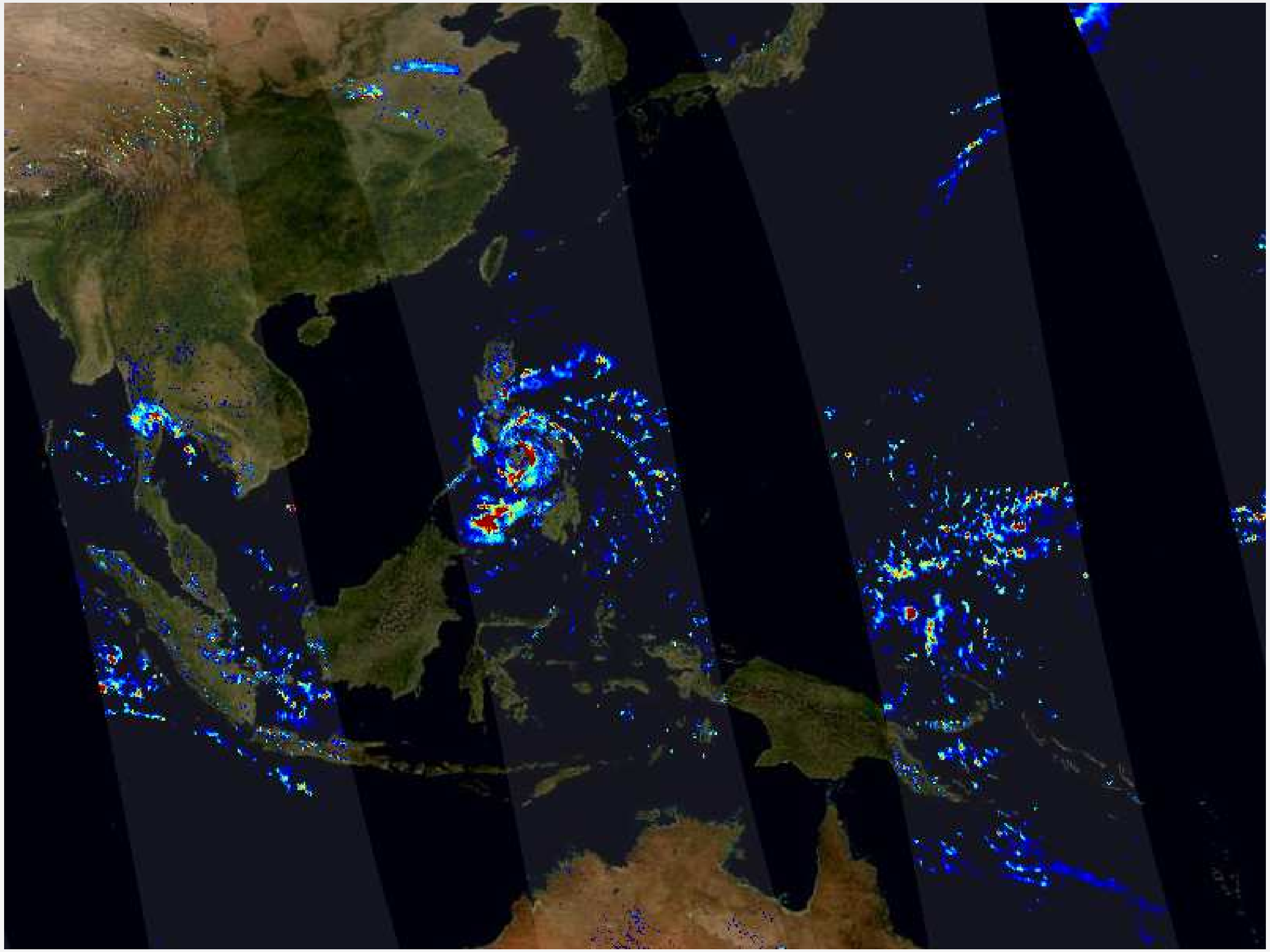
36GHz Brightness Temperature



89GHz Brightness Temperature



Surface Precipitation

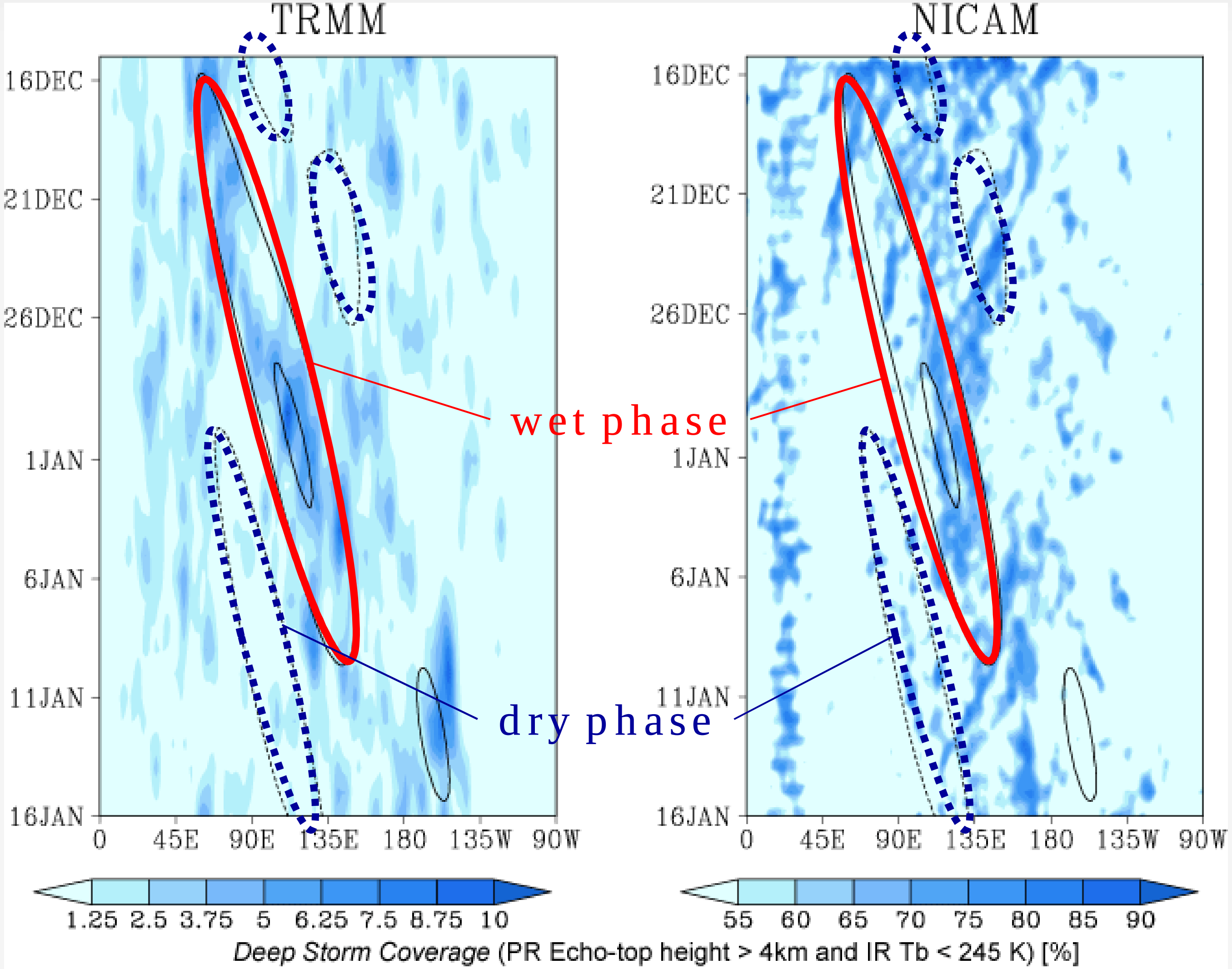


雲・降水レーダと
衛星シミュレータ（研究例）

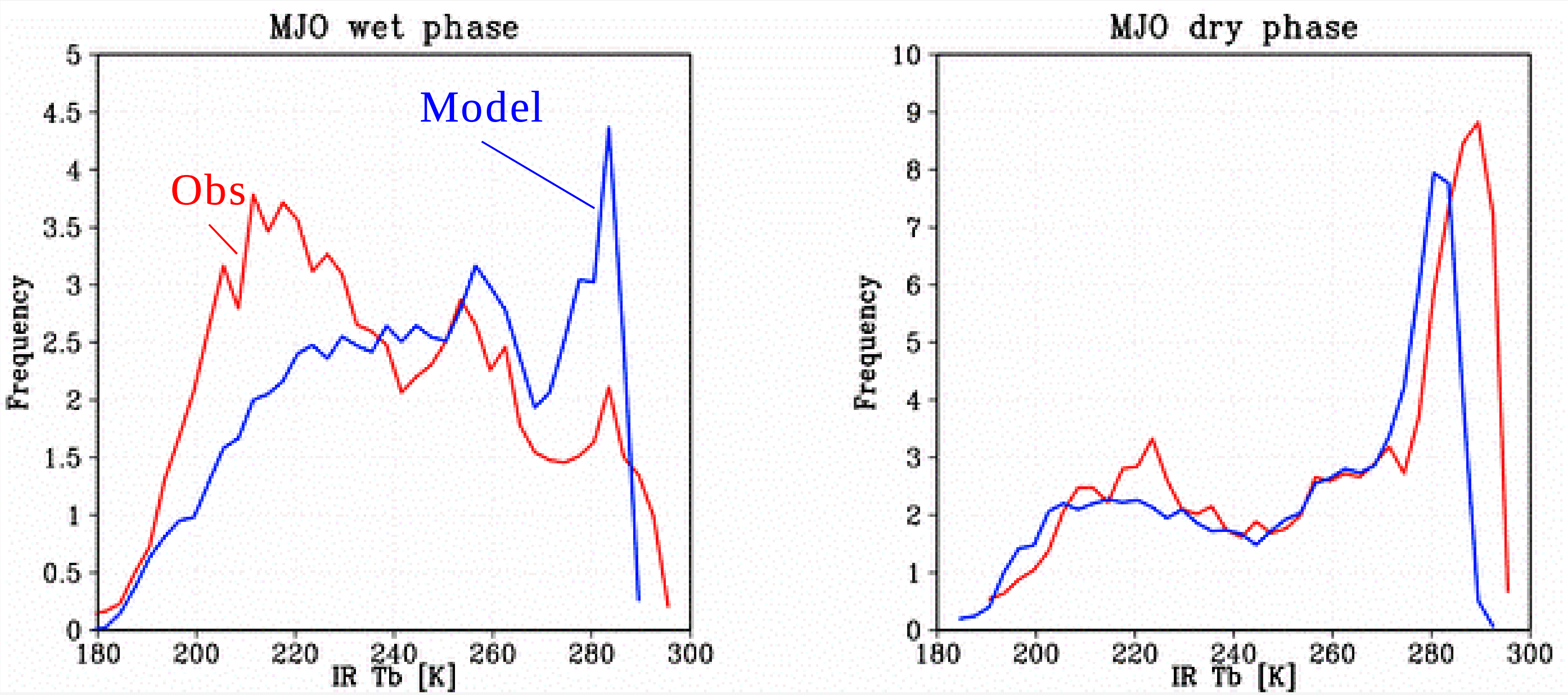
Masunaga, Satoh, and Miura, *JGR* (2008)

TRMM/NICAM MJO in the Hovmöller diagram

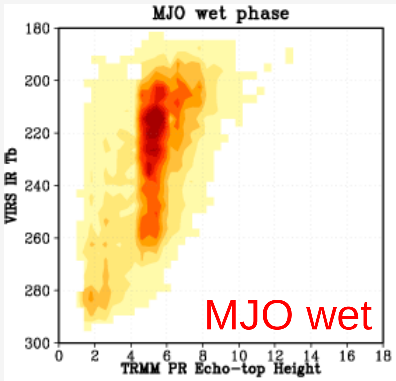
The MJO is filtered by 20-80 day and k=1-7



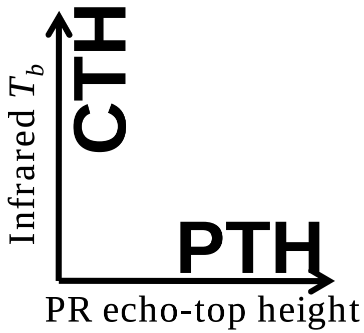
Infrared histogram: model vs. satellite

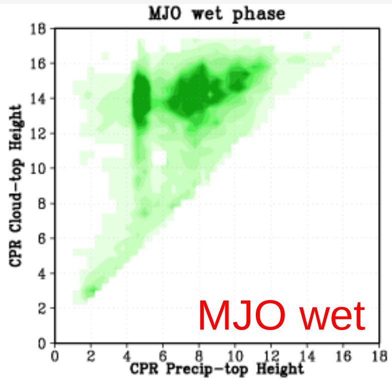


Cloud and Precip Top Heights (CTH and PTH)

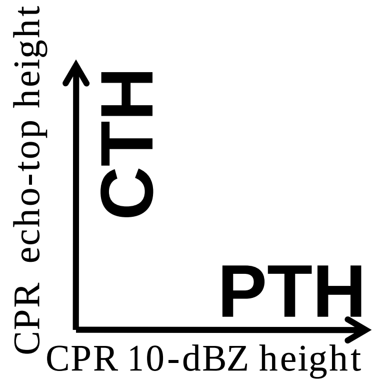


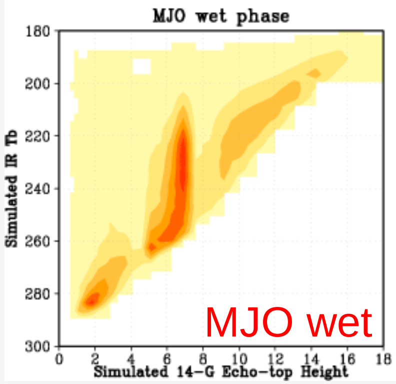
← TRMM PR&VIRS



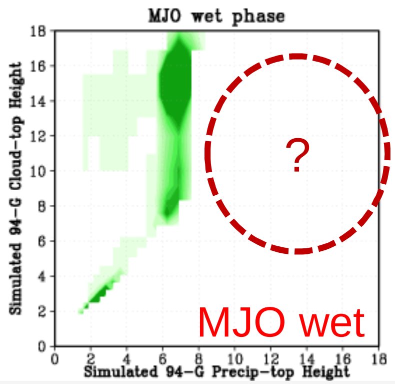


← CloudSat CPR



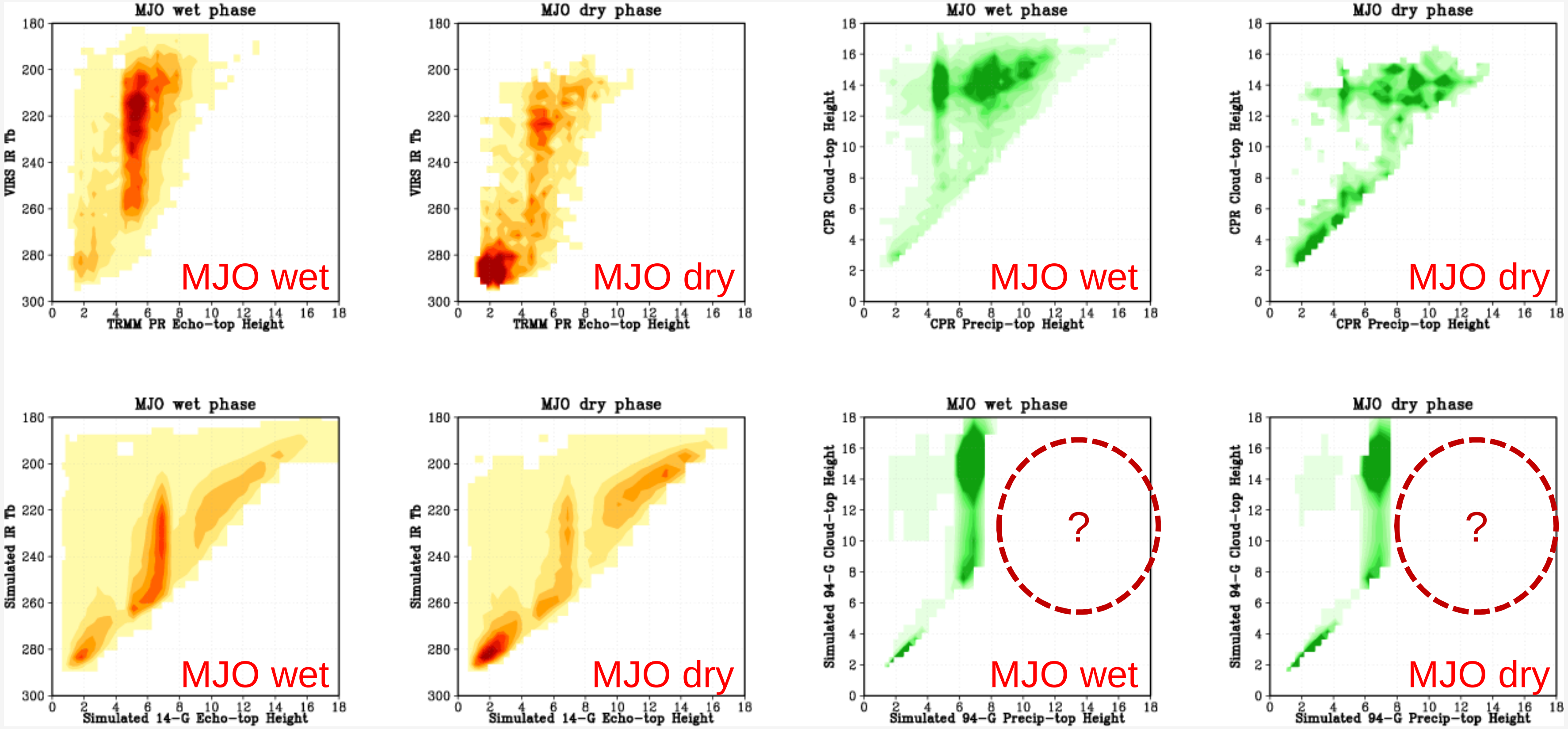


← NICAM+SDSU



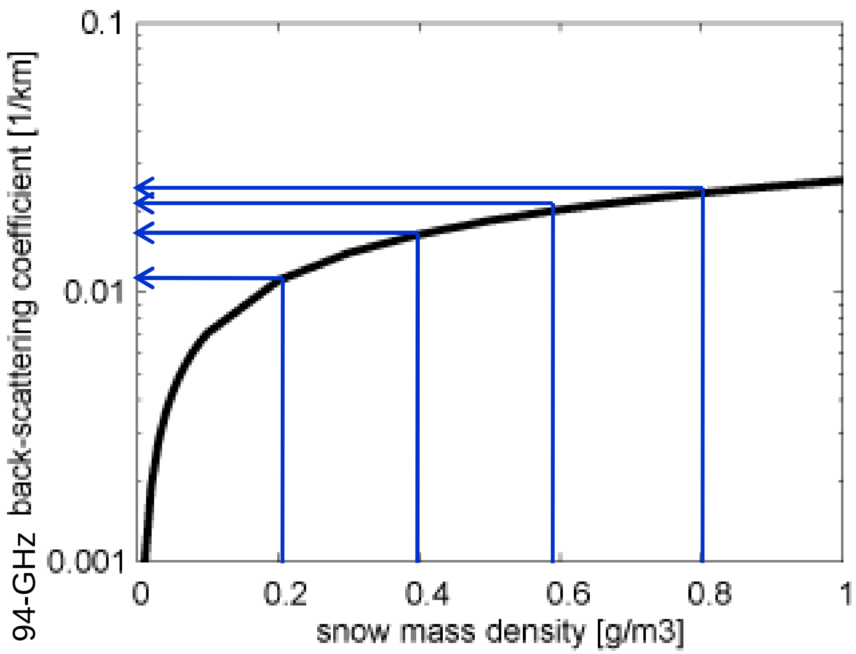
← NICAM+SDSU

Cloud and Precip Top Heights (CTH and PTH)



Missing 94-GHz Echoes above 8 km

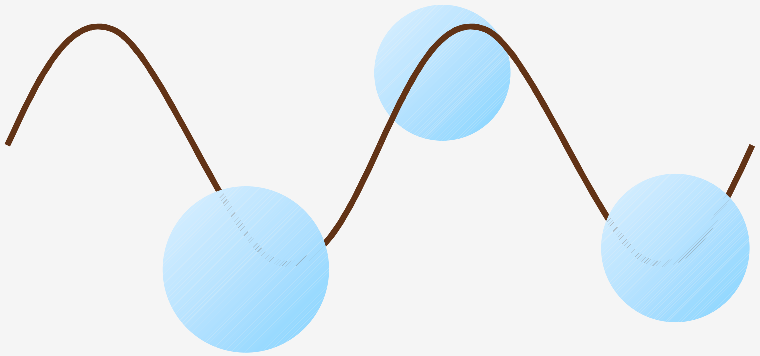
The 94-GHz back-scattering coefficient begins to be saturated due to non-Rayleigh scattering as snow content increases.



$$W = \frac{4}{3}\pi\rho N r^3 \quad \Rightarrow \quad r = \left(\frac{3W}{4\pi\rho N}\right)^{1/3}$$

Rayleigh regime

Wavelength >> 2πr

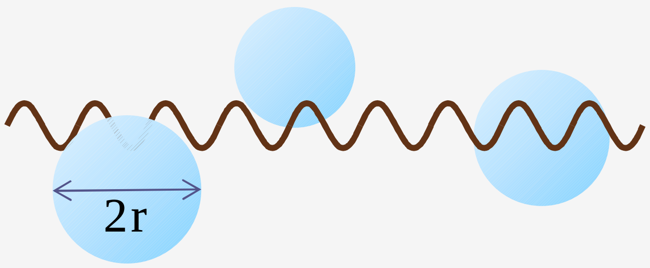


$$\sigma_s \propto N\frac{r^6}{\lambda^4} \propto \frac{W^2}{N\lambda^4}$$

$$\left.\frac{d\sigma_s}{dW}\right|_{N,\lambda} \propto W$$

Geometric optics regime

Wavelength << 2πr

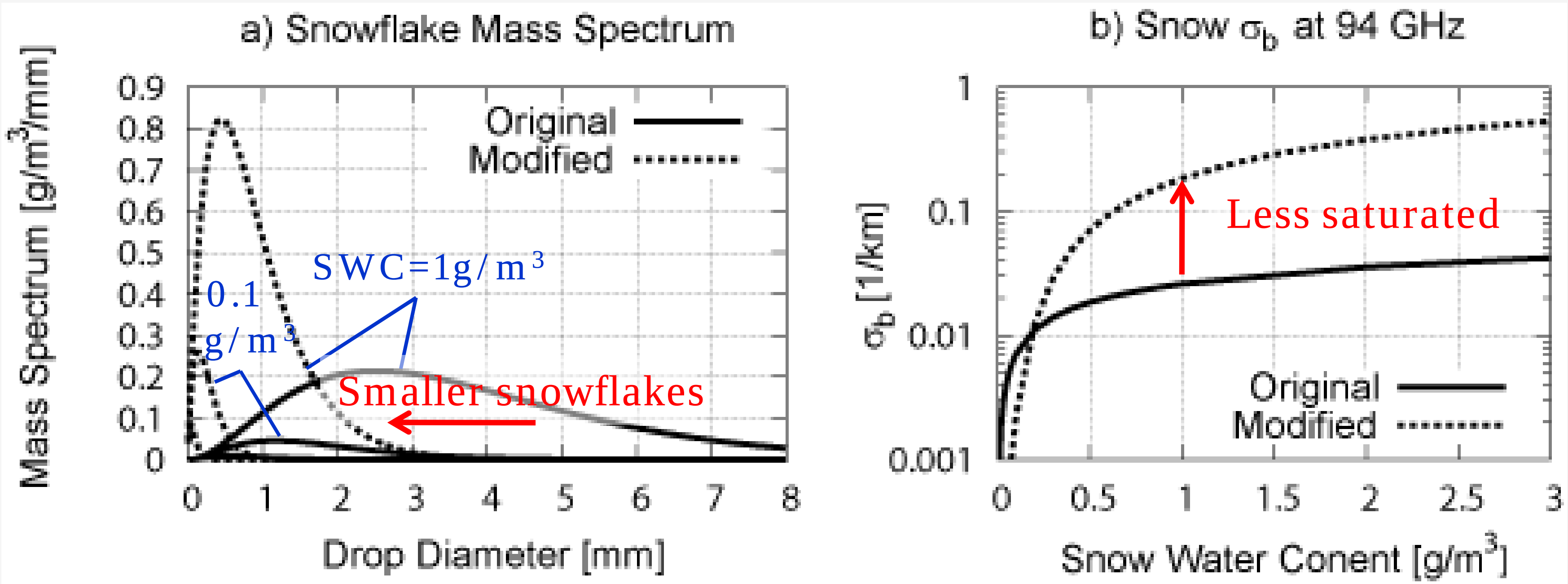


$$\sigma_s \propto Nr^2 \propto (NW^2)^{1/3}$$

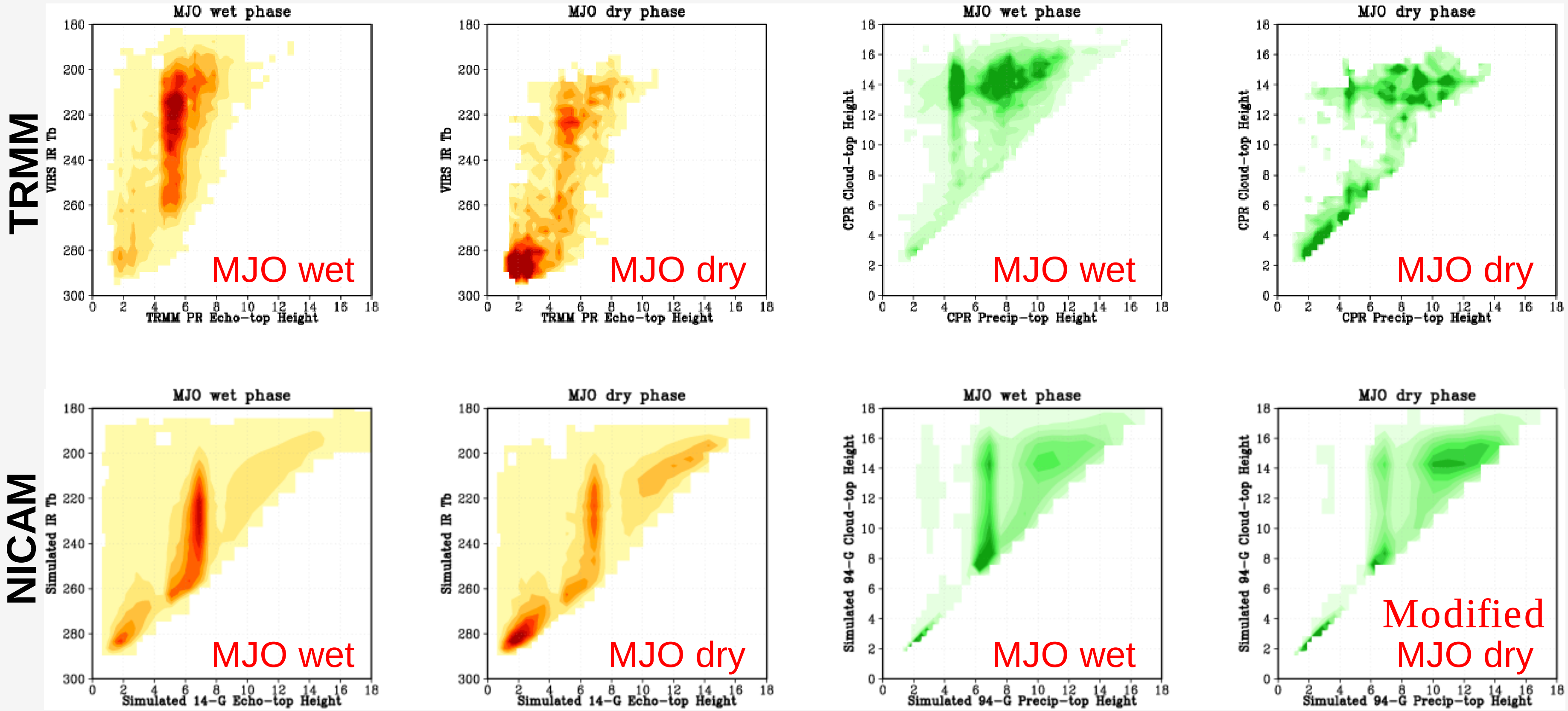
$$\left.\frac{d\sigma_s}{dW}\right|_{N,\lambda} \propto W^{-1/3}$$

A Modification to snow microphysics

Snowflake mass spectrum = $m(D)n(D)=aD^b N_0 \exp(-\lambda D)$
where $a=2.5\text{x}10^{-2}$ kg m^{-2} and b=2 (original=Grabowski, 1998)
$a=5\text{x}10^{-4}$ kg m^{-1} and b=1 (modified)



PSD Impact on the CTH/PTH Histogram



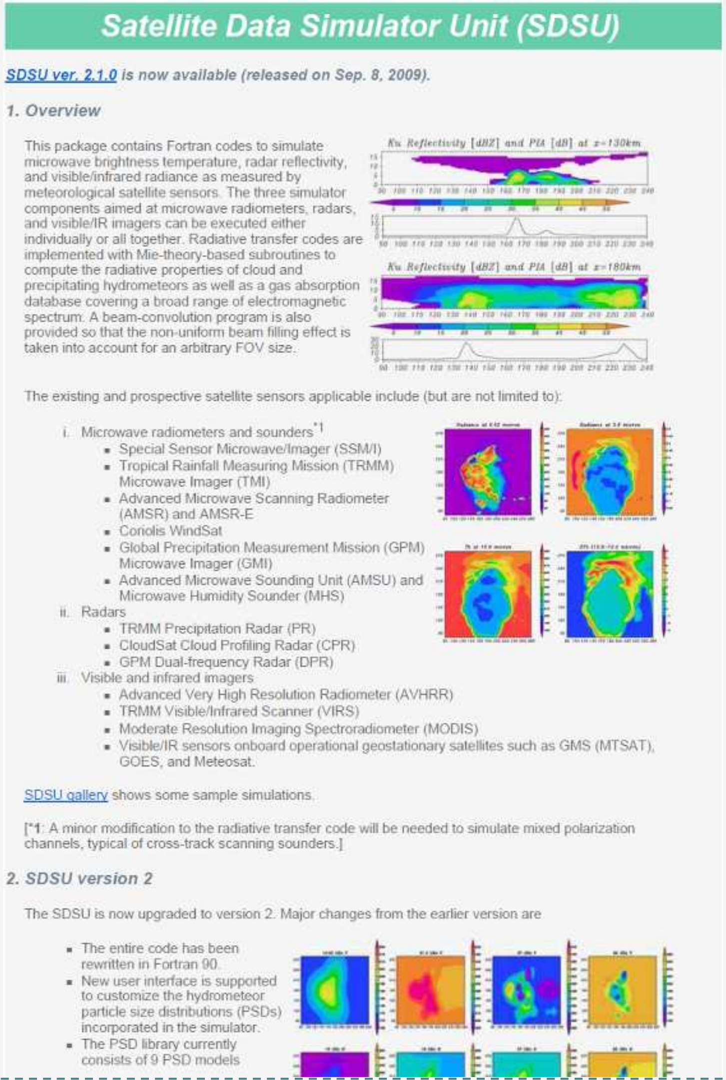
Multi-sensor simulator packages

- COSP: CFMIP Observation Simulator Package
  - CFMIP (http://cfmip.metoffice.com/COSP.html)
- ECSIM: EarthCARE Simulator
  - ESA (Voors et al, 2007)
- J-simulator: Joint Simulator for Satellite Sensors
  - JAXA/U Tokyo (http://www22.atwiki.jp/j-simulator/)
- RTTOV: Radiative Transfer Model for TOVS
  - UK MetOffice/ECMWF (Matricardi et al. 2004; Bauer et al., 2006)
- SDSU: Satellite Data Simulator Unit
  - Nagoya U (http://precip.hyarc.nagoya-u.ac.jp/sdsu/)
- Goddard SDSU
  - NASA GSFC (http://cloud.gsfc.nasa.gov/index.php?section=14)

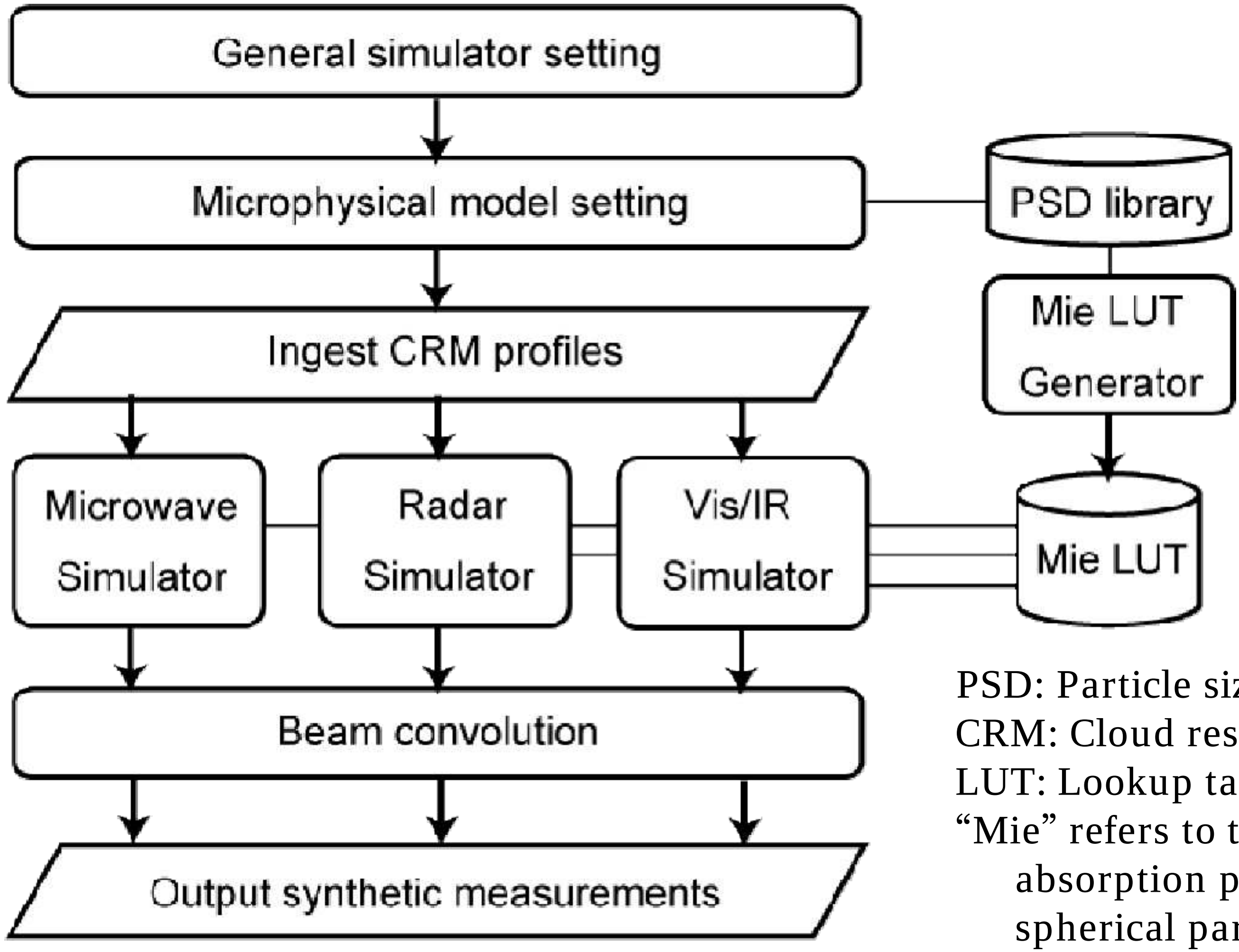
- Visit "Satellite Data Simulator Portal" for quick overview
  - https://sites.google.com/site/satellitesimulators/

The SDSU package

- SDSU WWW site
  - precip.hyarc.nagoya-u.ac.jp/sdsu/
  - User registration
    - only requires your name and email address.
  - Patches (Linux shell scripts)
    - available for existing SDSU-v2 users in case of future upgrades.
  - SDSU v2.1.4 is the latest.



SDSU Structure



PSD: Particle size distribution
CRM: Cloud resolving model
LUT: Lookup table
"Mie" refers to the scattering & absorption properties of spherical particles

Summary: Advantages and challenges

- Advantages
  - Independent of algorithm uncertainties, which are often very difficult to track down.
    - Sensitivity to assumptions can be tested with simulators.
  - Simulators offer a tool to diagnose cloud microphysics.
- Challenges
  - Interpretations of synthetic satellite measurements require a profound knowledge of physical principles in satellite remote sensing.
    - Radiative transfer theory, electromagnetic dynamics, etc.
  - Close communication between scientists in different areas (modeling and satellite experts etc.) would be crucial.