

Observations of Clouds and Precipitation

Towards an Understanding of Regime Dependent Physics

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Classical Approach

Cloud and precipitation products are derived from satellite data and made available.

Satellite products are validated against Ground Measurements (GV).

To the extent that there are glaring biases, satellite community tries to improve. It is difficult to remove regional biases unless the problem is well understood and many known deficiencies persist.

Satellite products are passed to Modeling Community.

To the extent that there are glaring biases in the models, modeling community tried to remove them. Not always successfully due to internal physics/parameterizations. Field Observation (e.g ARM) make more detailed measurements and offer greater insight but many known biases simply persist with the hope that the next generation model will eliminate them.



The new environment of remote sensing

As more satellites go up, we have more and more ways of retrieving the same geophysical parameter.

Unfortunately

results differ - just as models with different physics lead to different climate states, data or retrievals with different physics lead to differences in products.

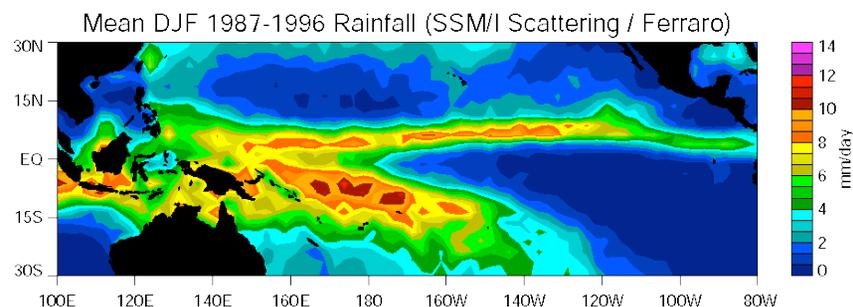
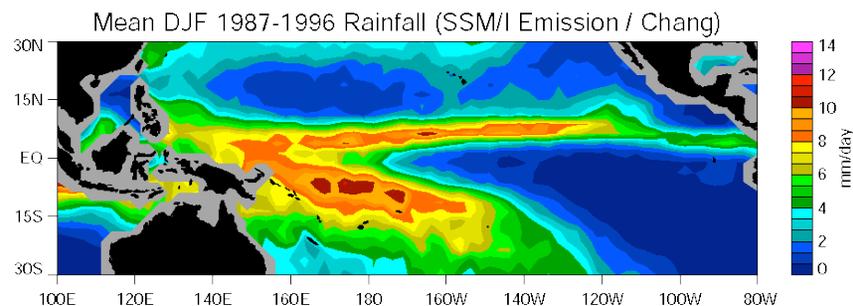
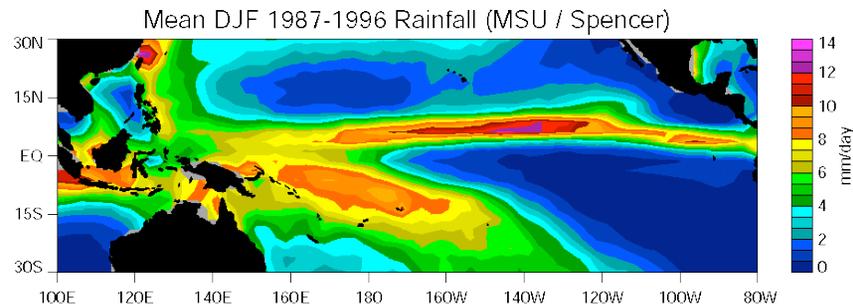
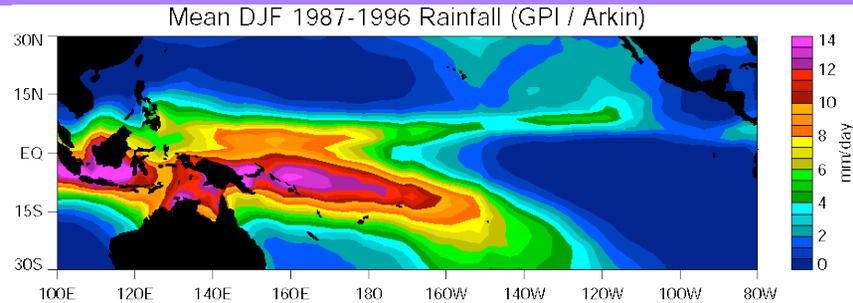
But

because observations are simpler than global models, we may have better luck making inferences about the underlying physical processes and how these might change regionally and temporally.



A comparison between rainfall products

Mean DJF Rainfall (1987 – 1996)



IR - clouds colder than 273K

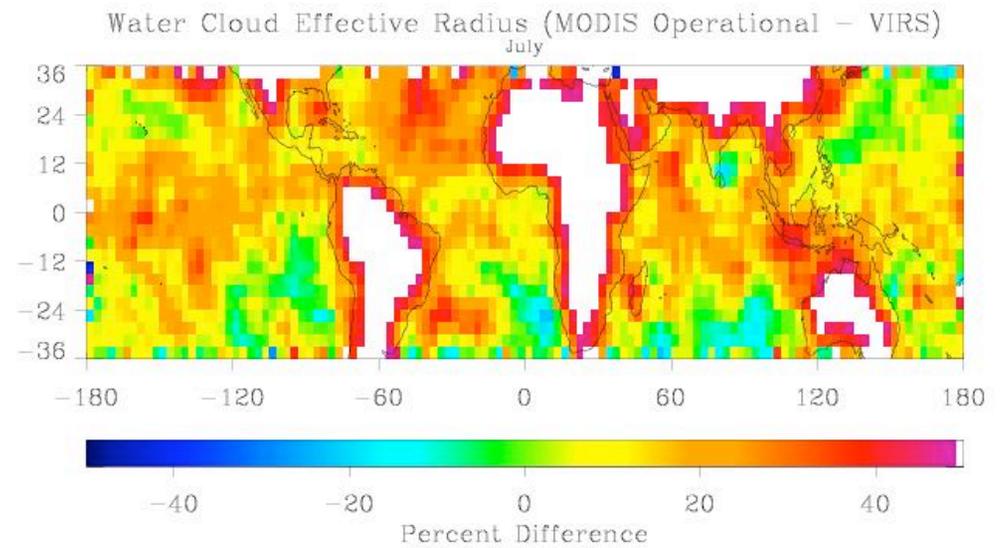
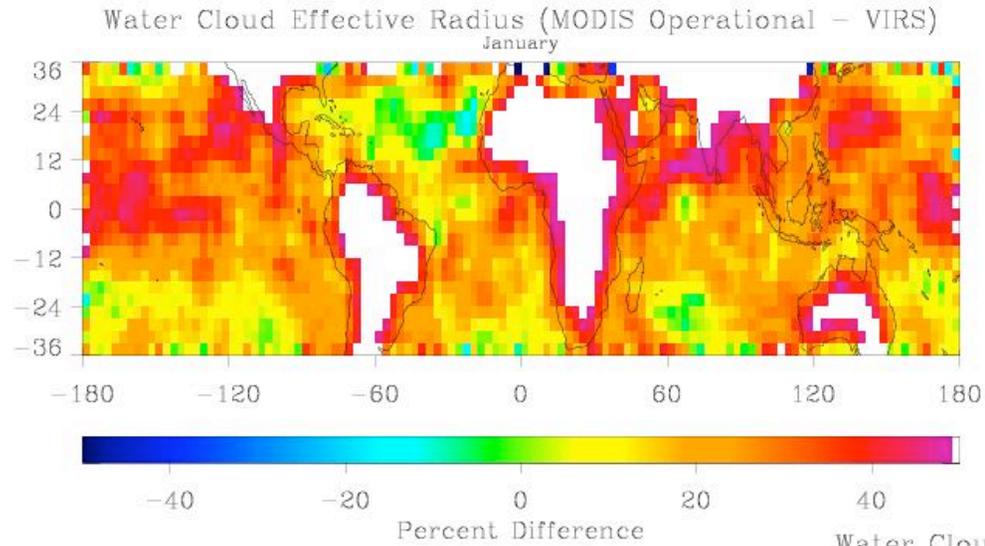
**Microwave sounding channel -
very sensitive to shallow rain
systems (w/o ice scattering).**

**Microwave window channel -
emission only**

**Microwave window channel -
scattering only**



Cloud Effective Radius Retrievals (MODIS - VIRS)



From Kyle Leesman's thesis, CSU, 2005



Tropical Rainfall Measuring Mission (TRMM)

NASDA
NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

TRMM Sensors

Precipitation radar (PR):

- 13.8 GHz
- 4.3 km footprint
- 0.25 km vertical res.
- 215 km swath

Microwave radiometer (TMI):

- 10.7, 19.3, 21.3, 37.0
- 85.5 GHz (dual polarized except for 21.3 V-only)
- 10x7 km FOV at 37 GHz
- 760 km swath

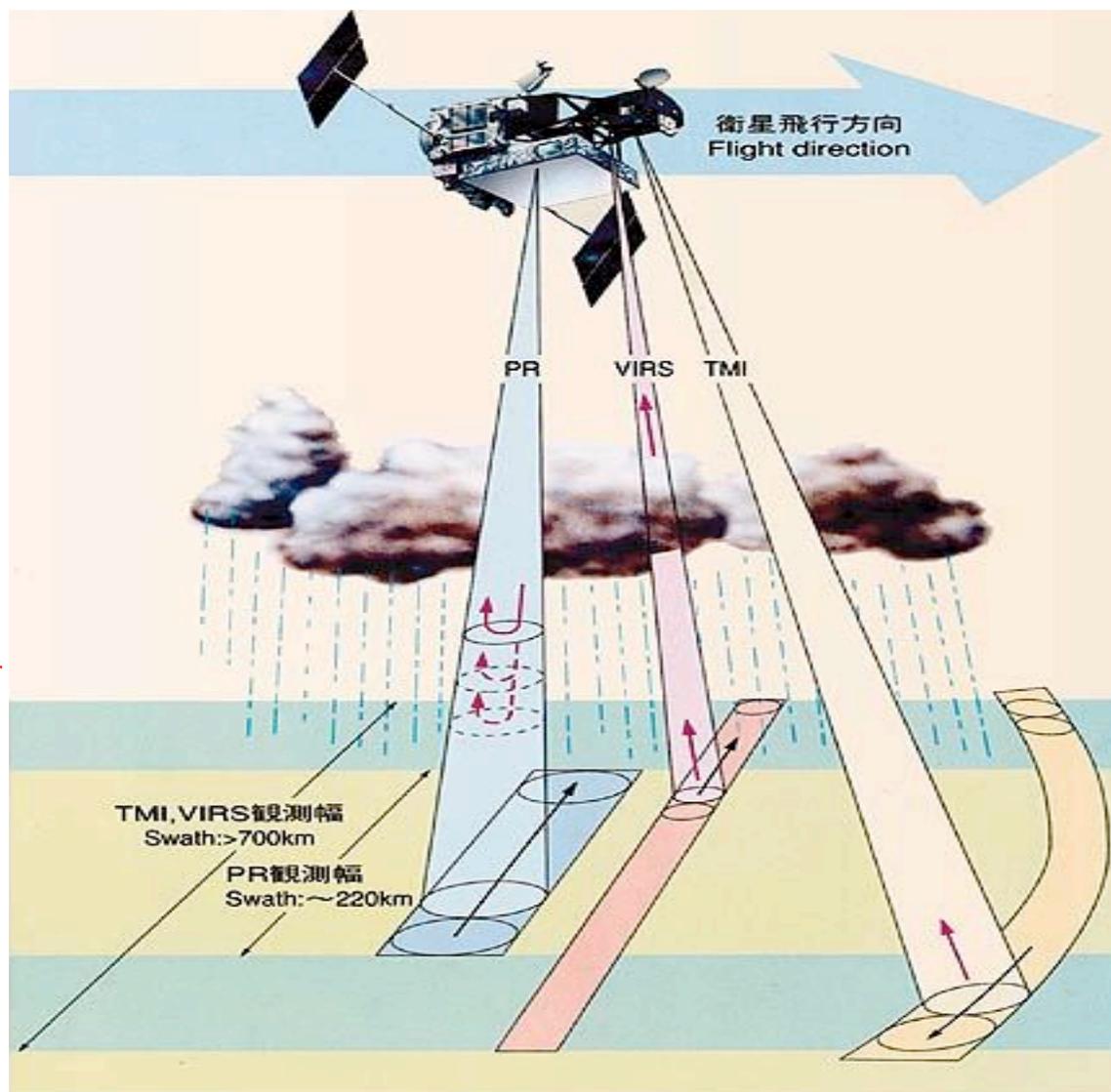
Visible/infrared radiometer (VIRS):

- 0.63, 1.61, 3.75, 10.8, and 12 μm
- at 2.2 km resolution

Lightning Imaging Sensor (LIS)

Cloud & Earth Radiant Energy System (CERES)

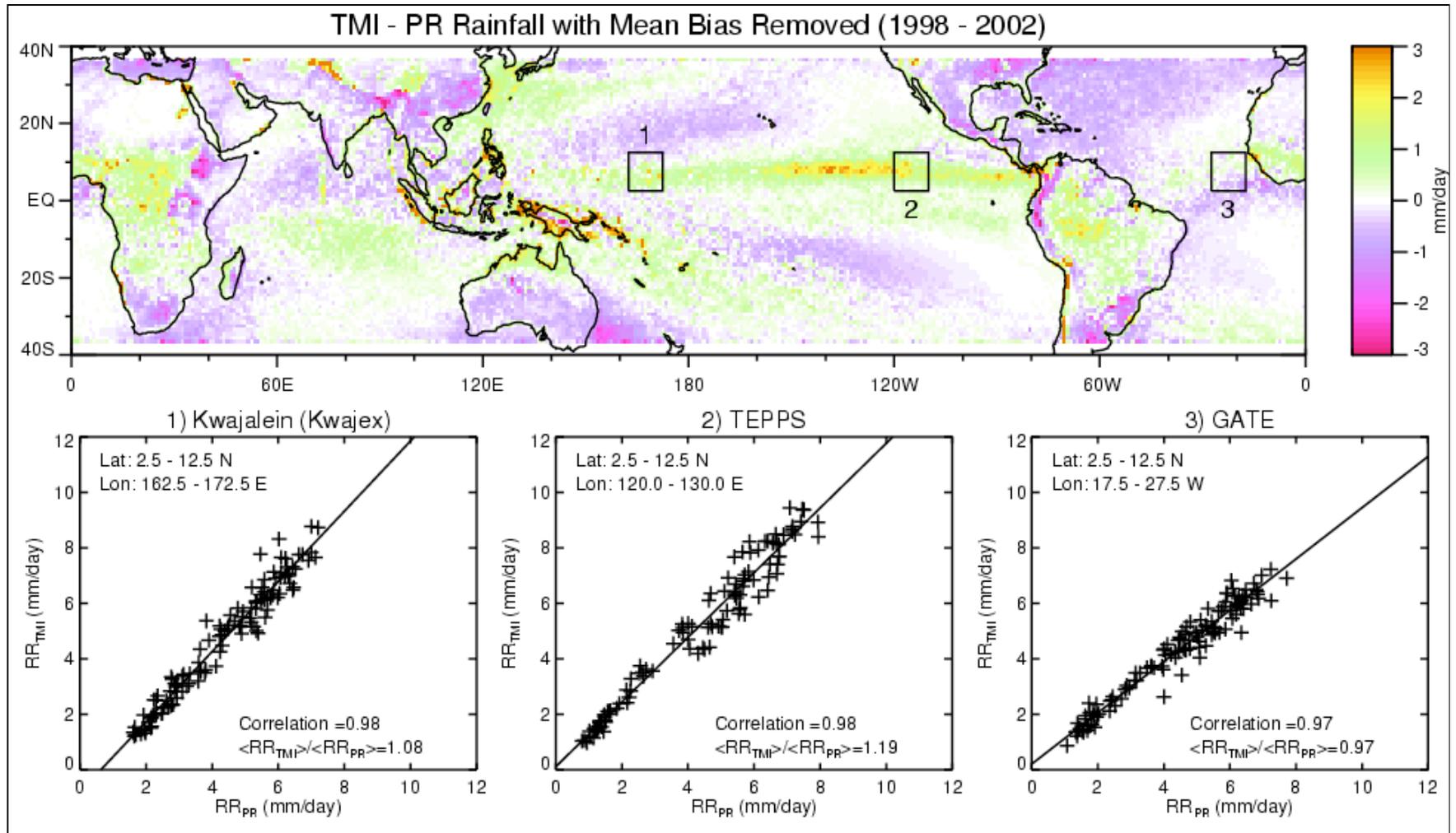
Nov. 1997 launch, 35° inclination; 350 km





PR/TMI Rainfall Differences

5-year mean Radar (2A25) - Radiometer (2A12)





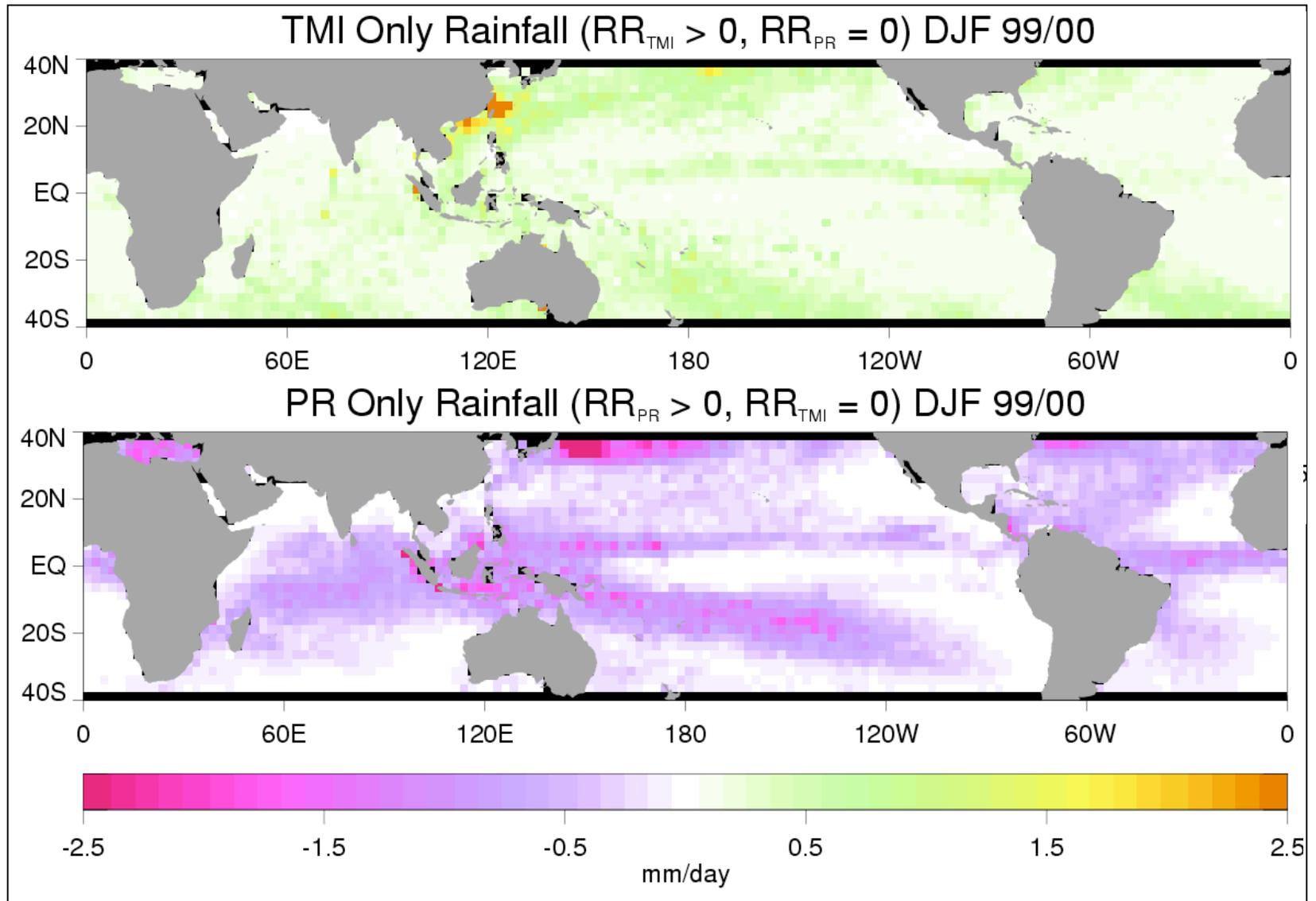
Rainfall Detection vs. Intensity

Breaking it into 3 Problems

- Rainfall Detection
 1. TMI Only ($RR_{TMI} > 0, RR_{PR} = 0$)
 2. PR Only ($RR_{PR} > 0, RR_{TMI} = 0$)
- Rainfall Intensity
 3. Differences in rain amount ($RR_{TMI} > 0, RR_{PR} > 0$)



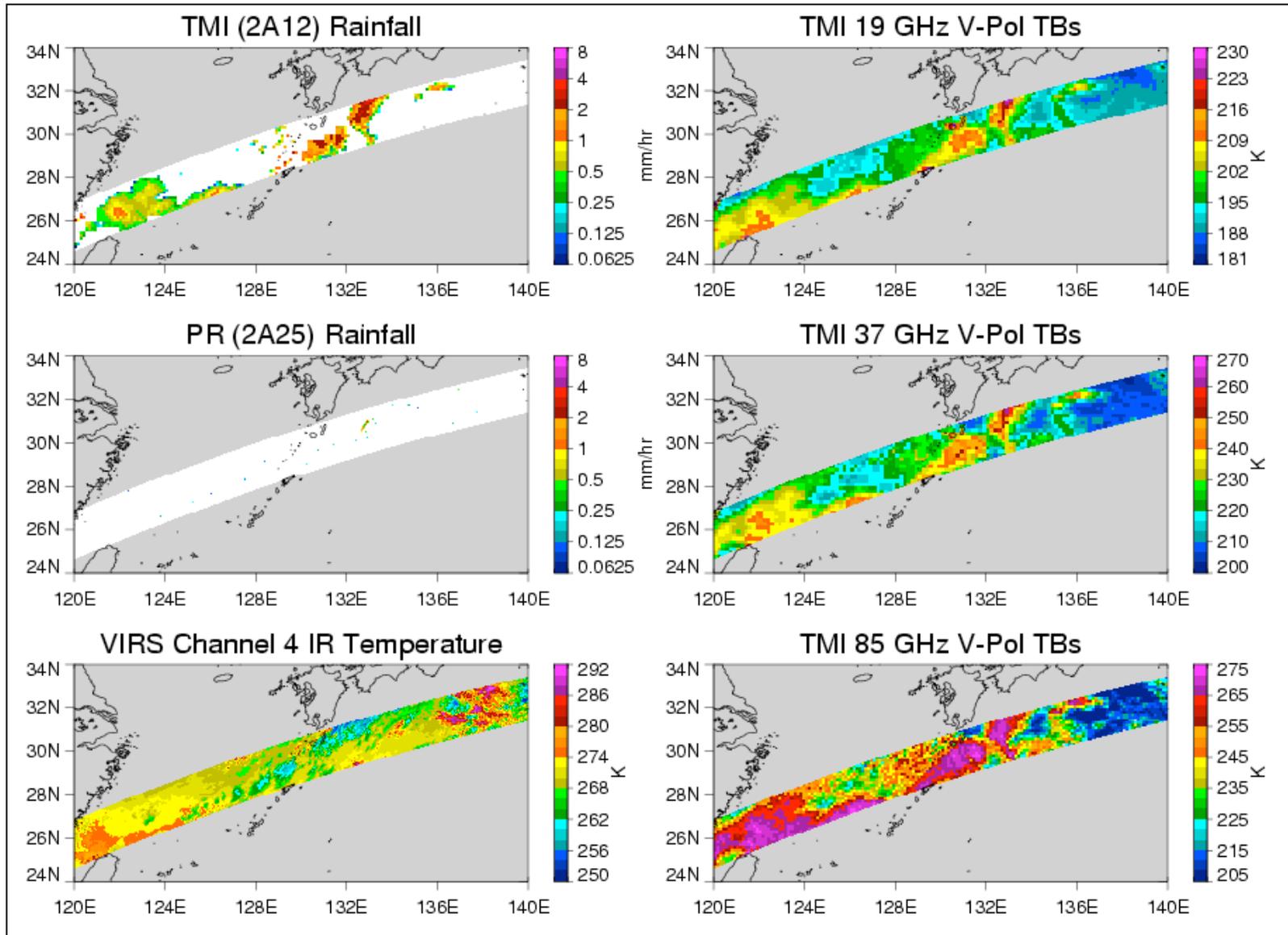
Rainfall Detection Errors





Rainfall Detection Error

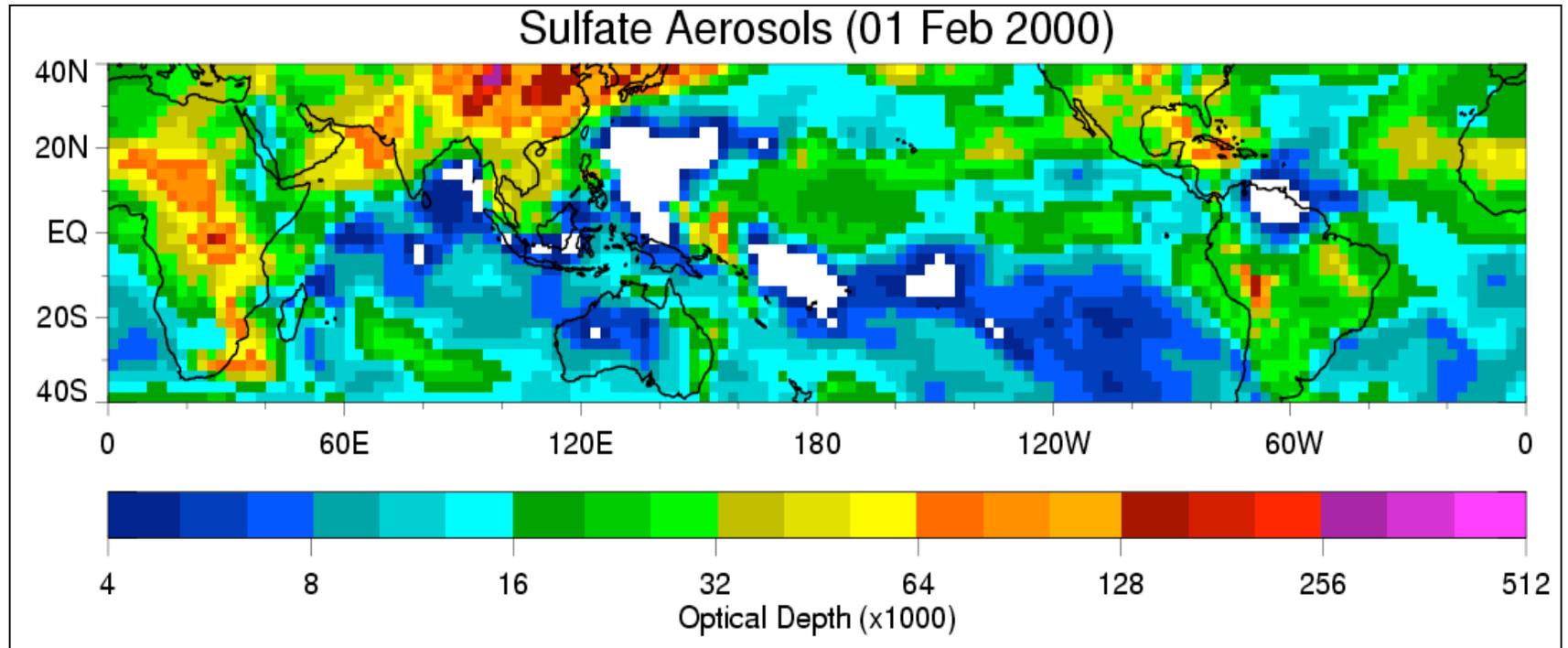
February 1, 2000





Role of Aerosols?

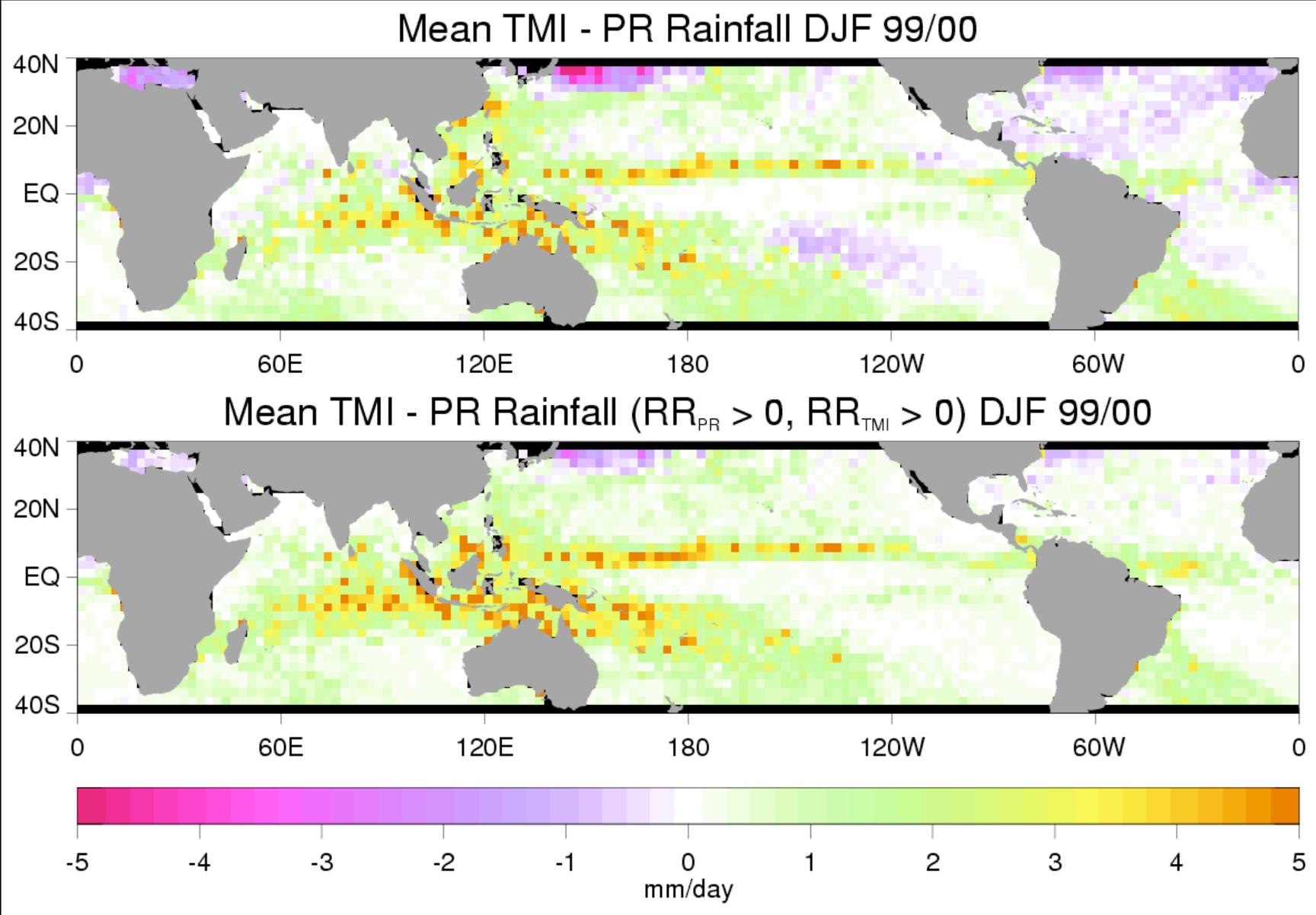
Impact on Drop Size





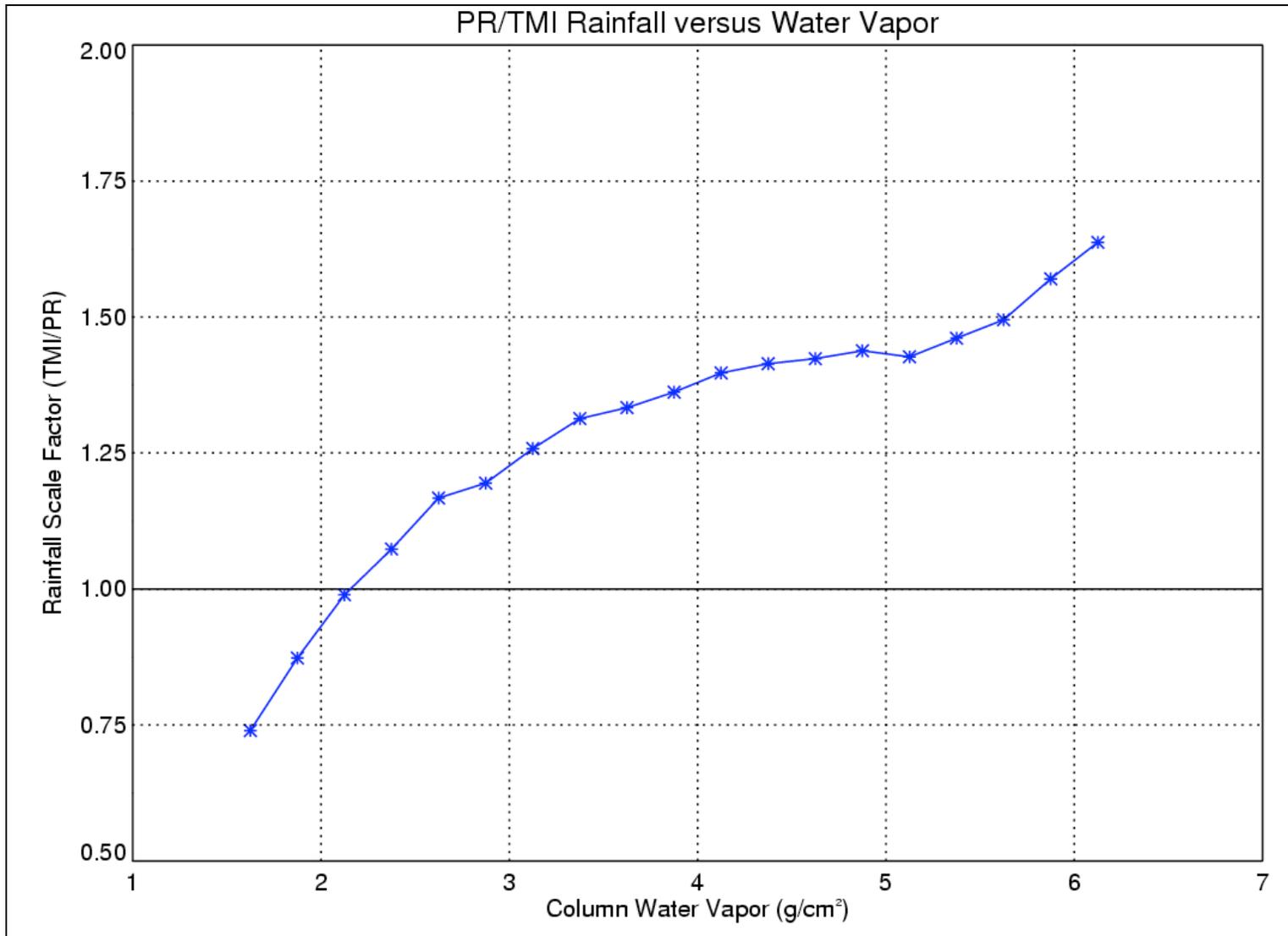
Rainfall Detection Errors

Impact on TMI/PR Differences





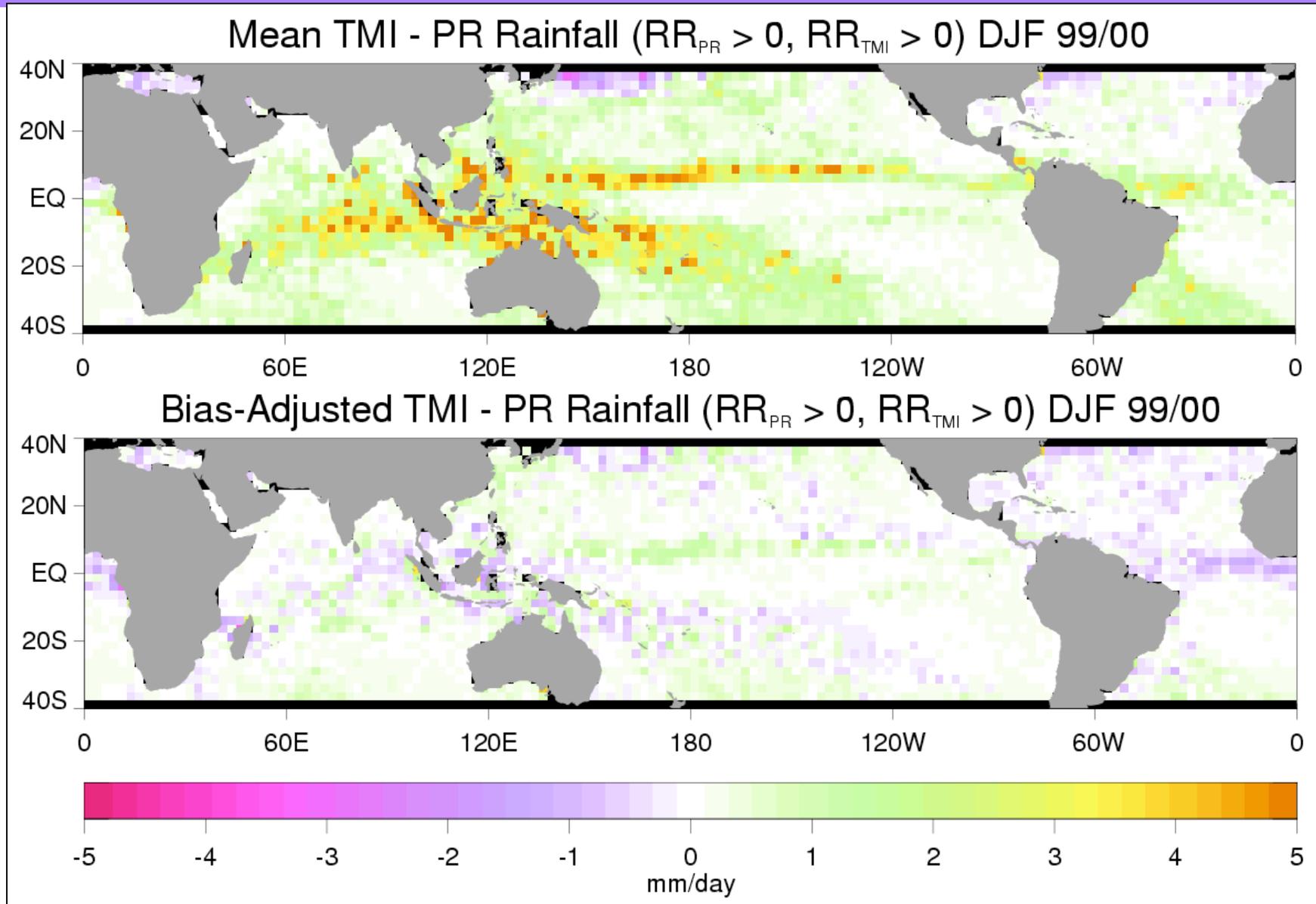
PR/TMI Bias vs. Column Water Vapor





Rainfall Bias Removal

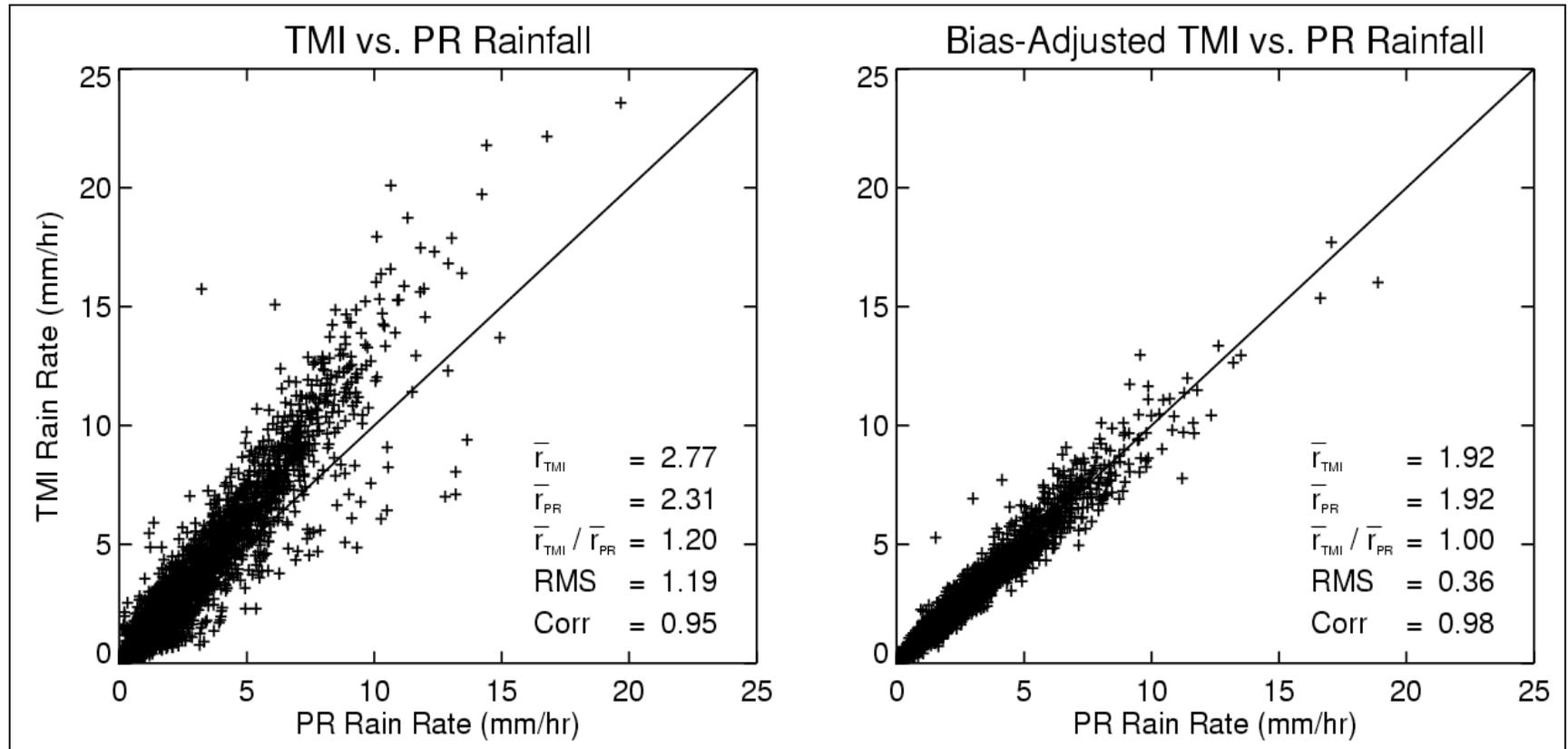
Based on Column Water Vapor





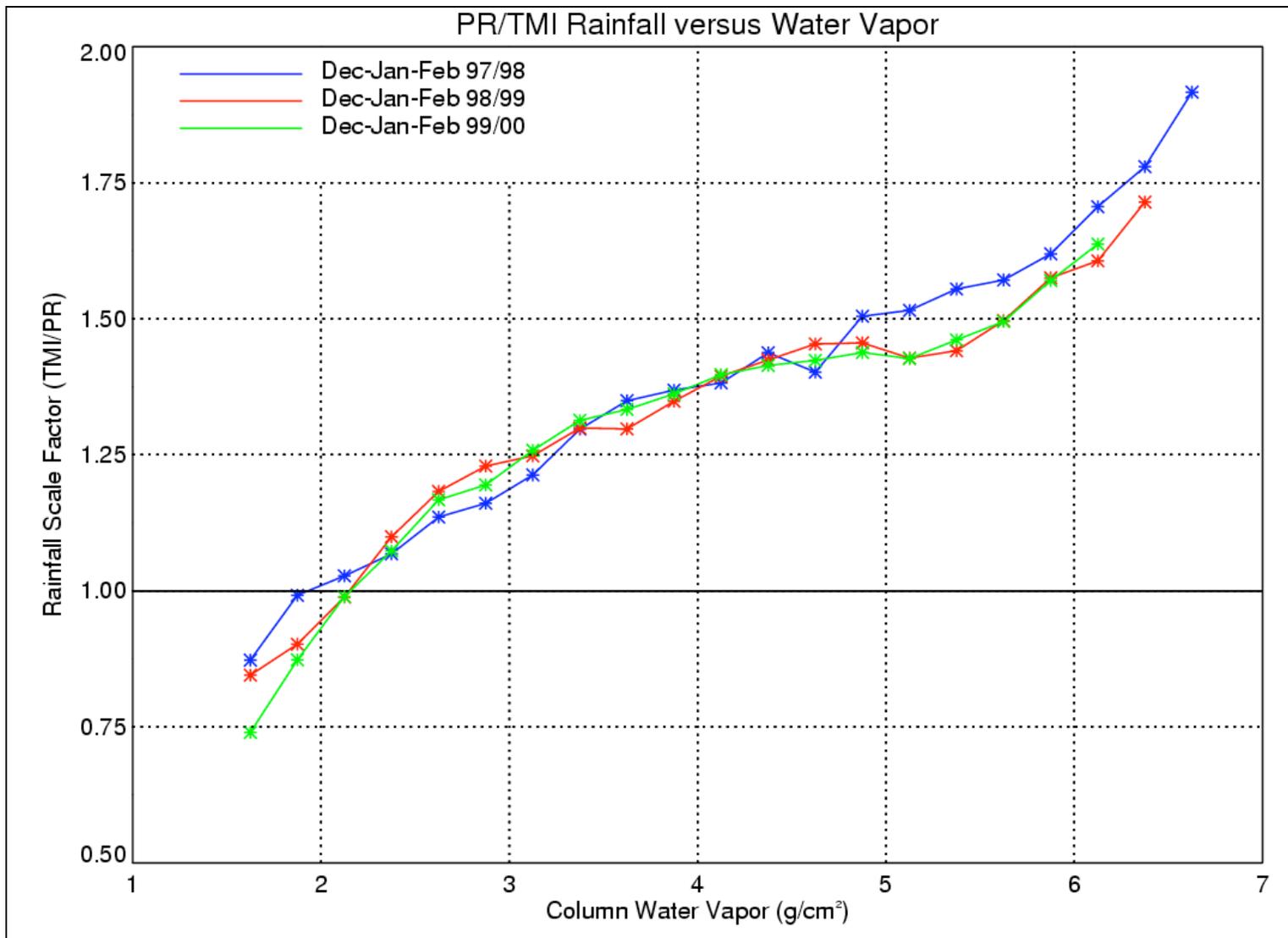
PR/TMI Rainfall Differences

Impact of Column Water Vapor Bias Adjustment





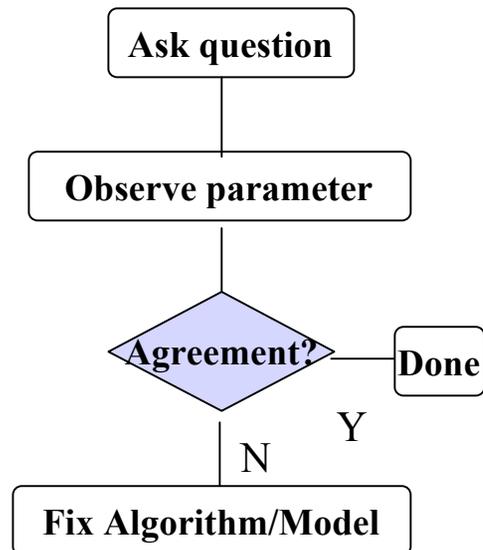
PR/TMI Rainfall Differences as a Function of Column Water Vapor



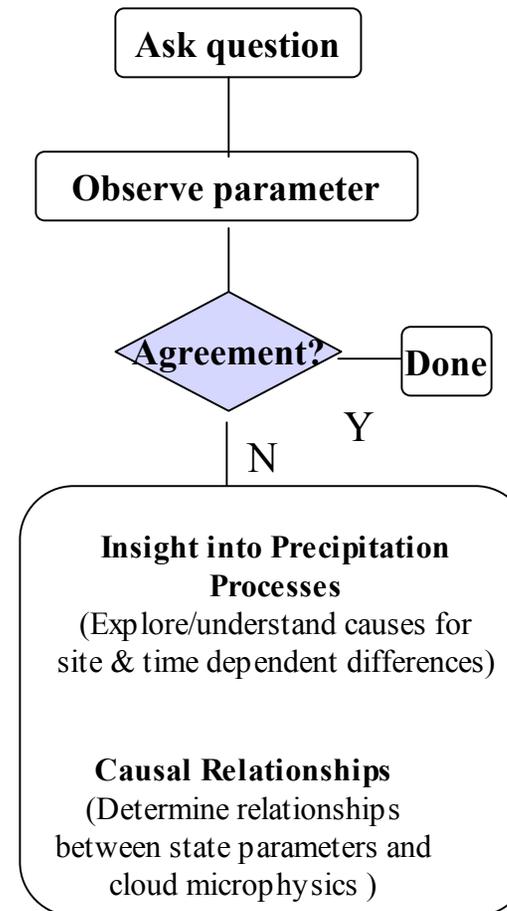


From Ground Validation to Process Guidance

Product paradigm



Process paradigm





The new environment of remote sensing

To the extent that the signature of cloud/precipitation physics is contained in the product discrepancies, it should be possible to gain some understanding of the processes on a global scale offered by the satellites.

Satellites themselves often lack the complete data set to unravel the physical causes.

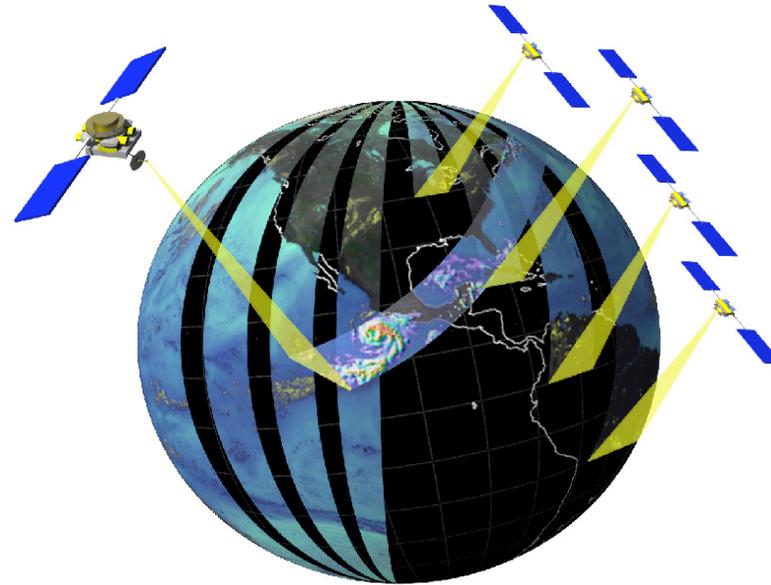
Must rely on cloud resolving models to guide the hypotheses

Must rely of Ground Measurements to confirm.

From the climate forecasting perspective, the processes are more important than the products themselves.



The Global Precipitation Mission



CORE SATELLITE

- Dual frequency radar
- Multifrequency radiometer
- Non-sun synchronous orbit
- ~ 70° inclination
- ~ 400 - 500 km altitude
- ~ 4 km horizontal resolution
- 250 m vertical resolution

MISSION: Understand the horizontal and vertical structure of rainfall and its microphysical elements. Provide training for constellation radiometers.

CONSTELLATION SATELLITES

- 8 small satellites with microwave radiometer only*
- 3 hr revisit time
- Sun-synchronous polar orbit
- ~ 600 km altitude

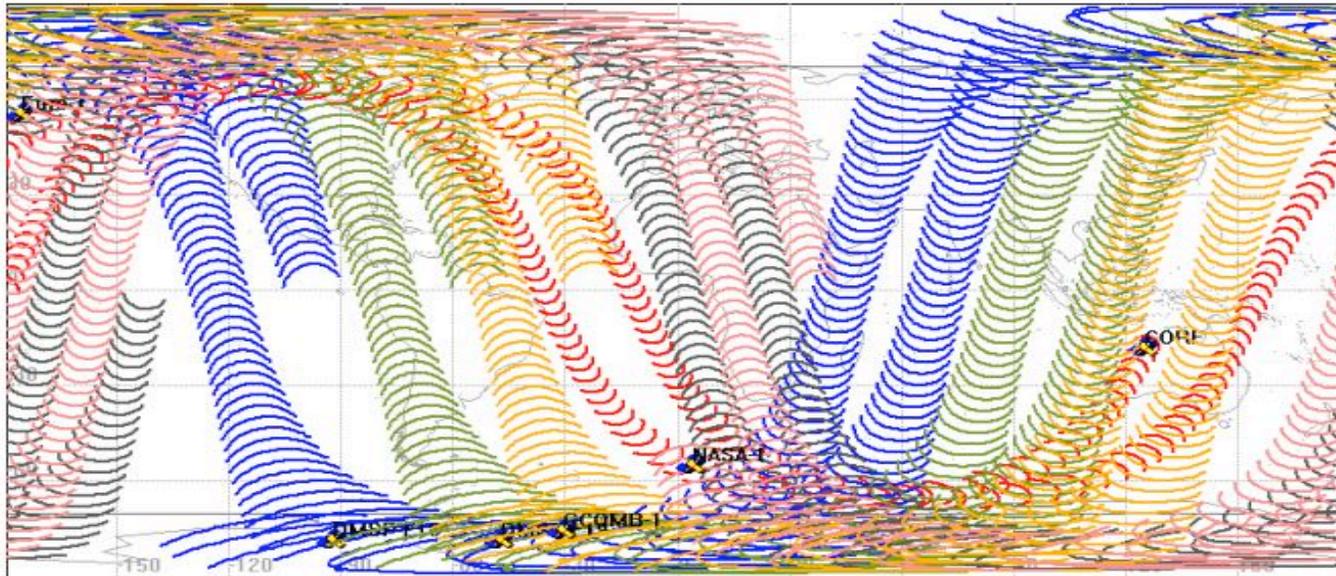
*Some of the 8 small satellites may be replaced by existing radiometers (e.g., SSM/Is, AMSR, etc.)

MISSION: Provide enough sampling to reduce uncertainty in short-term rainfall accumulations. Extend scientific and societal applications.



GPM Era Coverage / 3 hours

CORE, DMSP-F18, DMSP-F19, GCOM-B1, NASA-1, Euro-1





Discrepancies between 3 identical SSM/I sensors

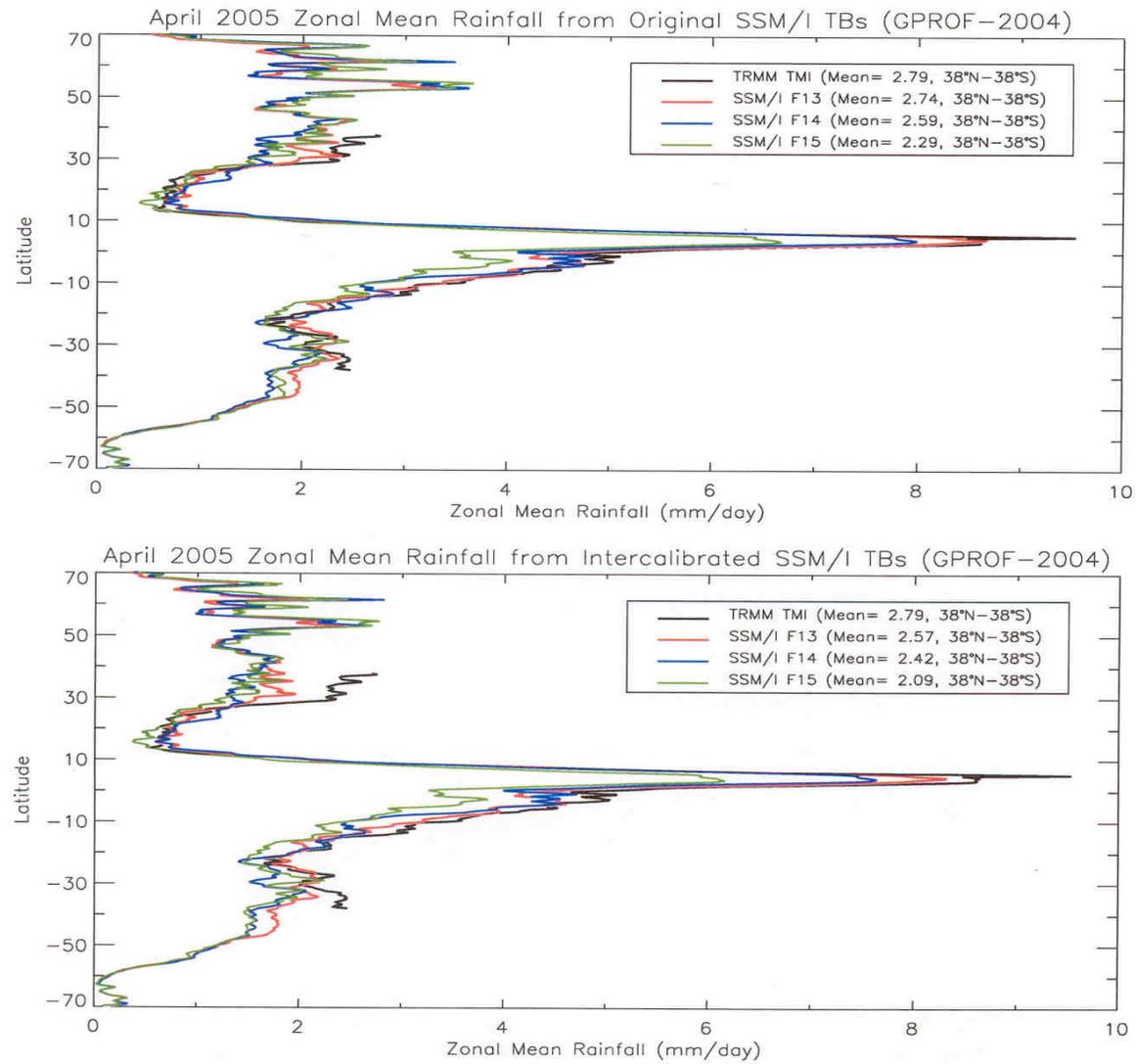
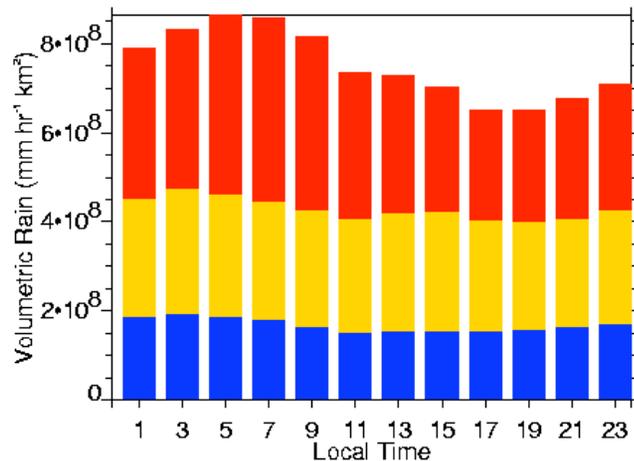


Figure 3: Comparison of zonal mean rainfall from SSM/I F13, F14, and F15 (GPROF-2004) for April 2005 based on a) uncalibrated brightness temperatures, and b) calibrated brightness temperatures.

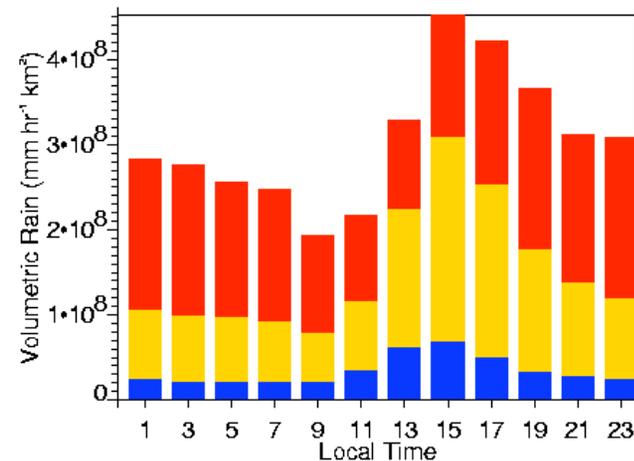


Diurnal Cycle of TRMM Precipitation by System Type

Ocean Areas



Land Areas



- Mesoscale Convective Systems
- Features with Ice Scattering < 250 K at 85 GHz
- Features without Ice Scattering < 250 K at 85 GHz

- Over ocean, all types of precipitation features produce the most rainfall at night around 6 AM, mainly controlled by MCSs
- Over land, the total rainfall peaks in the afternoon when the atmosphere is least stable, however MCS rainfall peaks later at night, around midnight, due to their longer life cycle