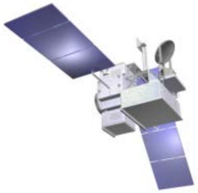


全球降水観測計画（GPM）における二周波降水レーダ観測への期待（TRMMからGPMへ）

井口俊夫
（情報通信研究機構、電磁波計測研究所）

with help of many TRMM and GPM scientists, in particular,
Christian Kummerow (Colorado State U.)
Yukari Takayabu (U of Tokyo)
Takuji Kubota (JAXA)

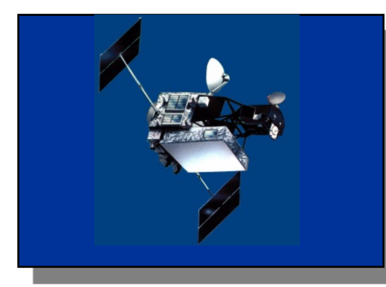
安全安心ICTフォーラム
October 24, 2014
Fukuoka University, Fukuoka, Japan

Rainfall Measurement and Our Life

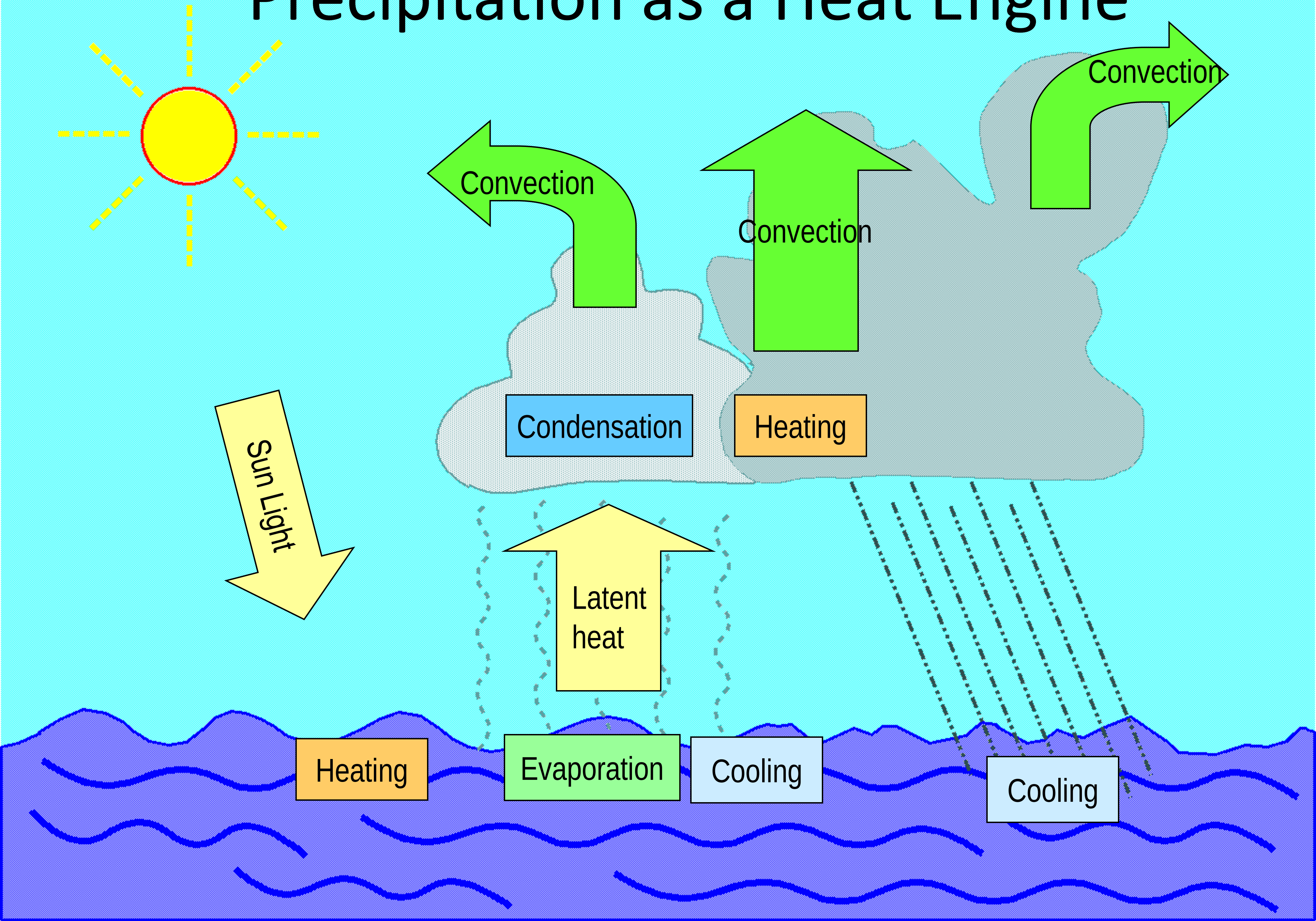
- Rain affects most everyone's life & work
  - **Food production**
  - **Flood, drought**
- Rain is a key variable in
  - **Weather prediction models**
  - **Climate models**
  - **Air-sea interaction models, etc.**
- Rain is one of hardest meteorological parameters to measure, because of its large spatial and temporal variability.
  - **Contribution by rainfall measuring satellites**

→TRMM (Tropical Rainfall Measuring Mission)

→GPM (Global Precipitation Measurement)

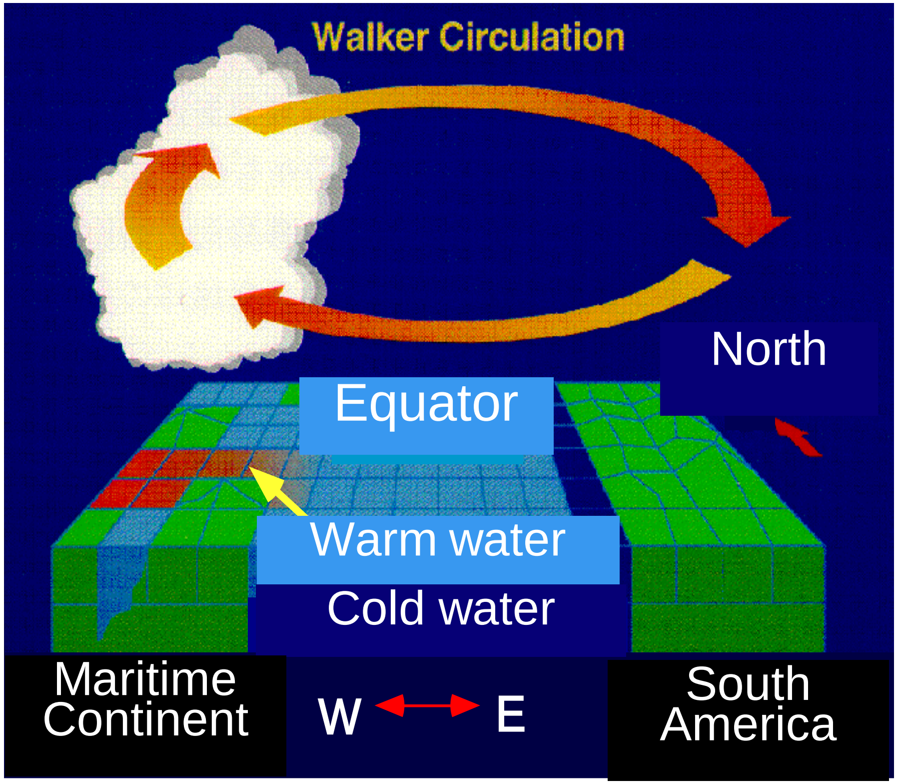


Precipitation as a Heat Engine

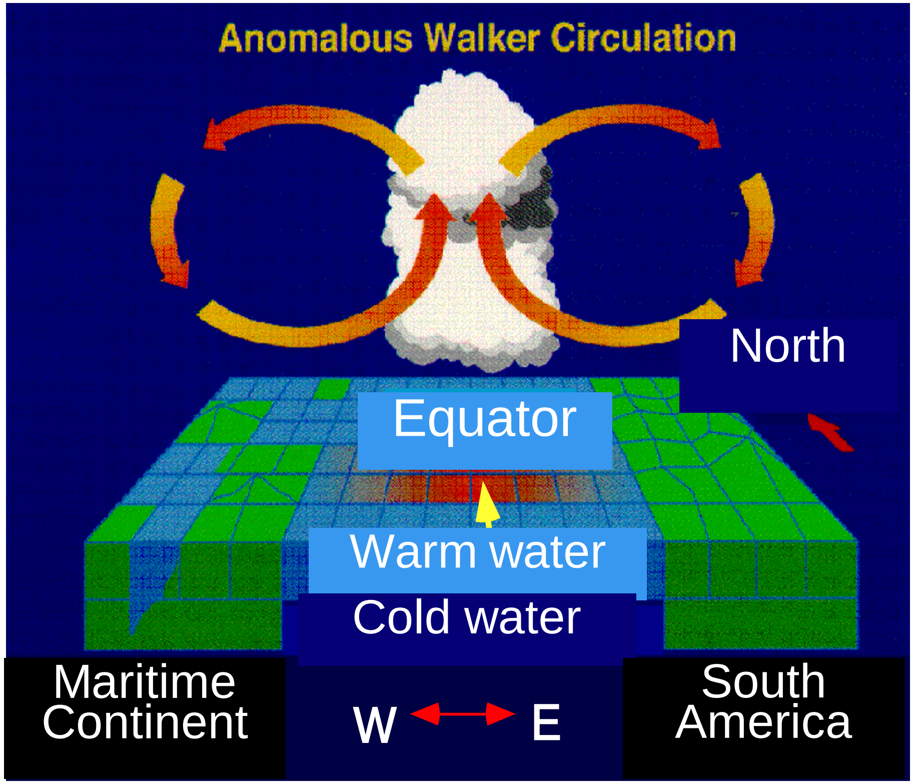


Atmospheric Circulation and Tropical Rainfall

Normal Condition



El Nino Condition

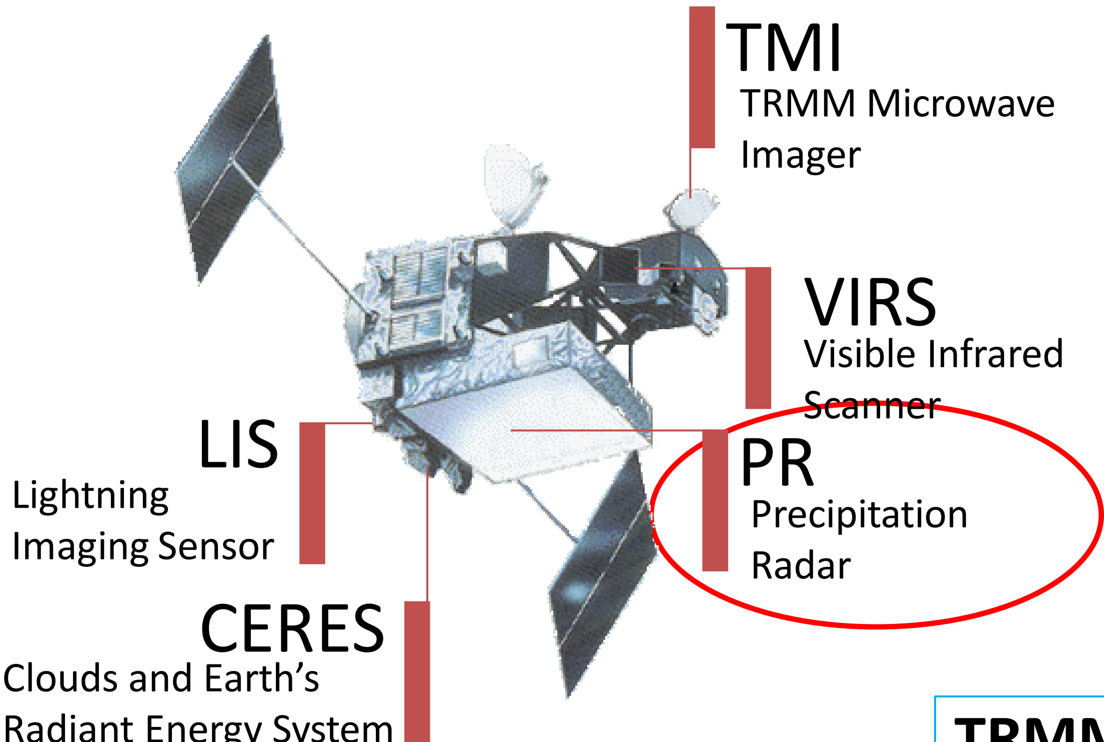


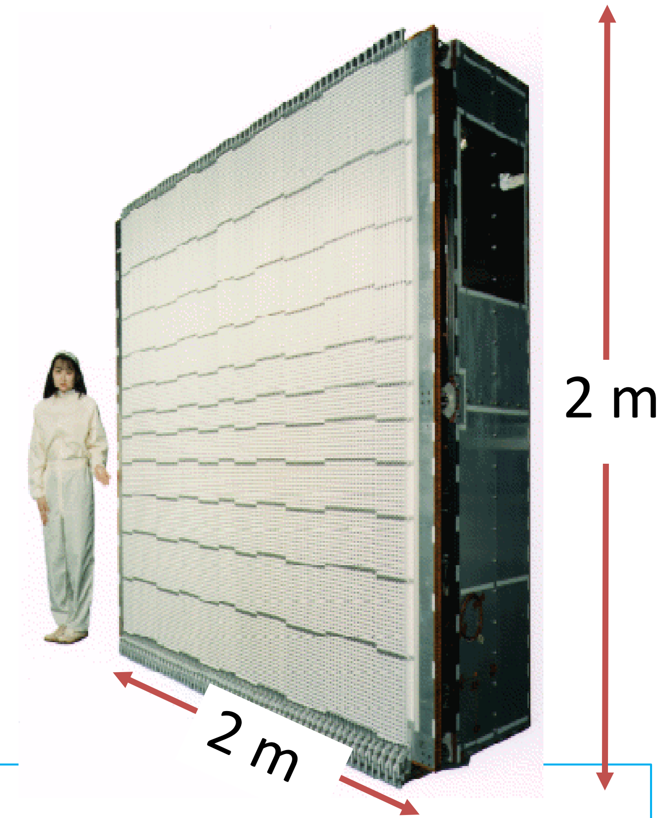
- Tropical Rainfall as a "Heat Engine" of global circulation

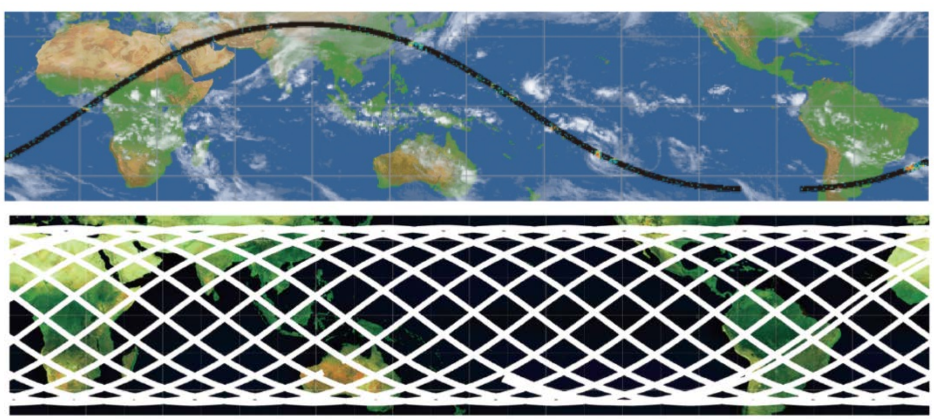
TRMM Objectives - Metrics

- To obtain and study multi-year science data sets of tropical and subtropical rainfall measurements:
  - Launch and successfully operate satellite and data system for 3 years.
- To understand how interactions between the sea, air, and land masses produce changes in global rainfall and climate:
  - Produce accurate maps (10%) of global precipitation at 5°x5° monthly resolution for at least 3 years. Calibrate previous rainfall estimates to extend time series.
- To help improve modeling of tropical rainfall processes and their influence on global circulation in order to predict rainfall and variability at various time scale intervals:
  - Derive Latent Heating products in the tropics; Map Diurnal Cycle of Precipitation; Make data available to modeling community;
- To test, evaluate, and improve the performance of satellite rainfall estimate measurements and techniques:
  - Operate a quantitative validation program and reprocess data as warranted.

TRMM and Precipitation Radar







TRMM PR

- First spaceborne precipitation radar
- Developed by NICT and JAXA, JAPAN
- Ku-band radar 13.8GHz: moderate to heavy rain

TRMM Orbit

35N-35S, non-sunsynchronized

Concept of TRMM Rain Observation

PR: Precipitation Radar

TMI: TRMM Microwave Imager

VIRS: Visible/IR Scanner

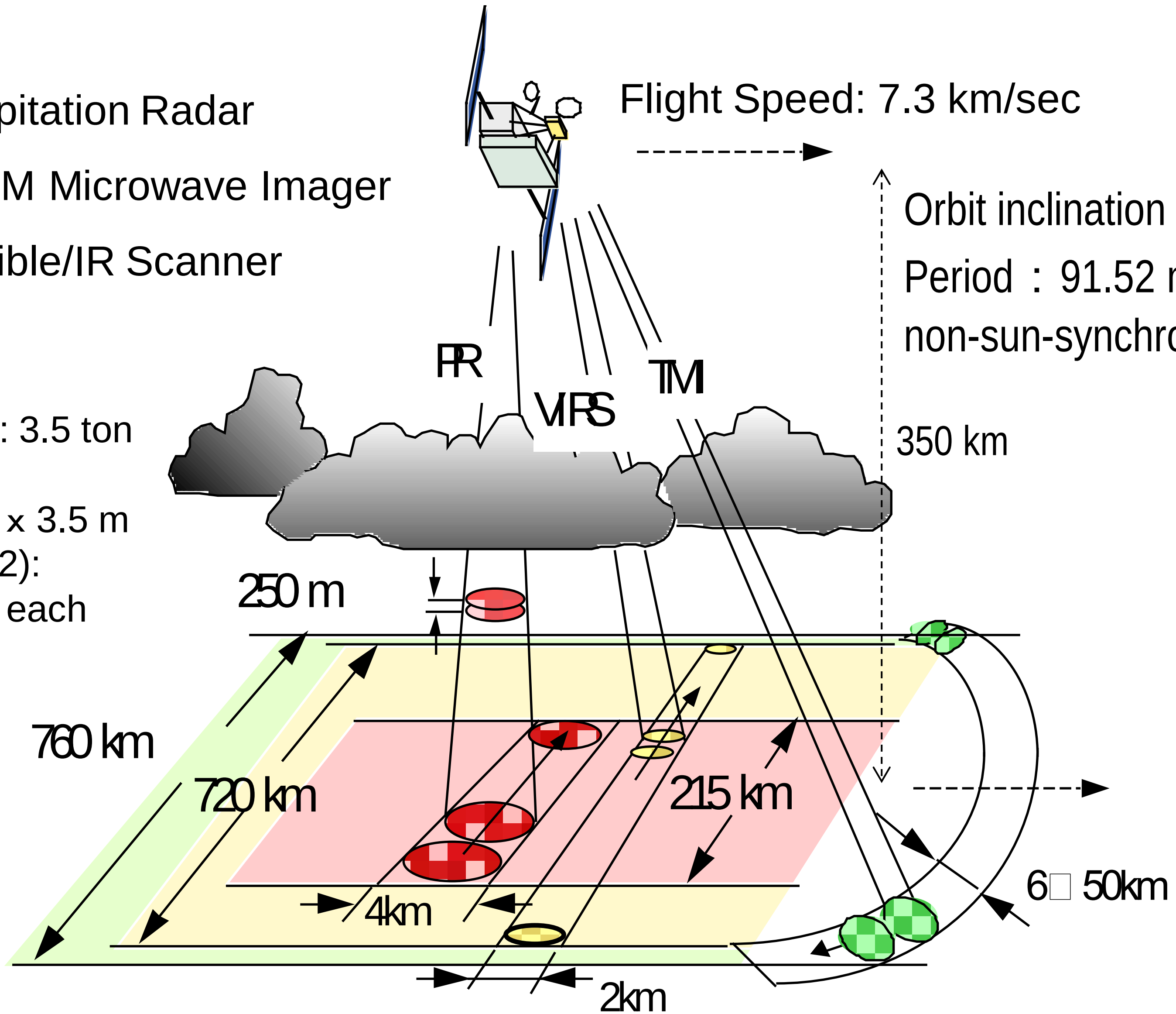
Mass at launch: 3.5 ton
Dimensions:
5.1 m x 3.0 m x 3.5 m
Solar paddles (2):
2.1 m x 4.3 m each

Flight Speed: 7.3 km/sec

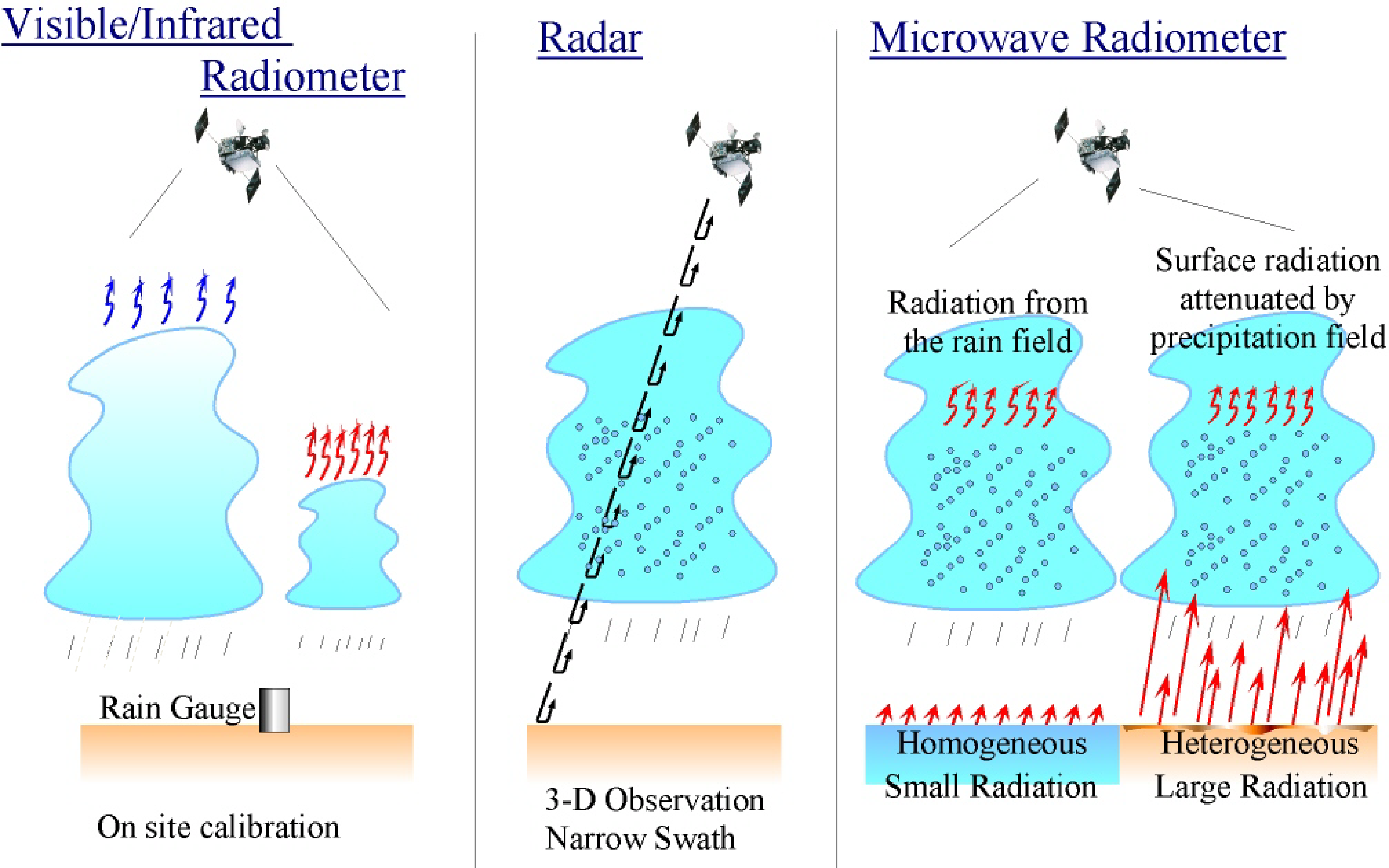
Orbit inclination ： 35 deg.

Period ： 91.52 min

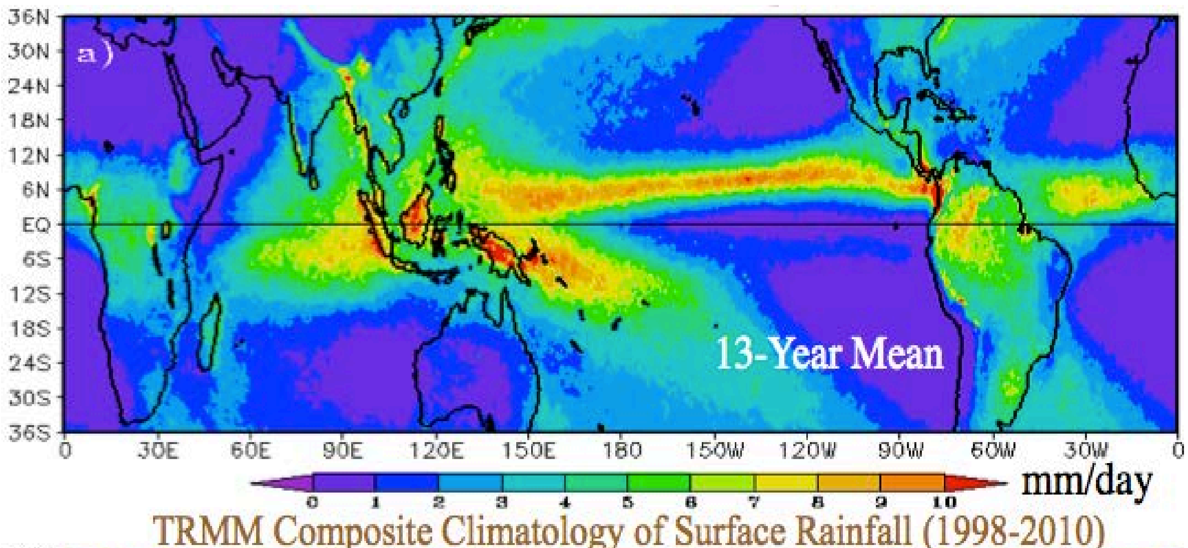
non-sun-synchronous orbit



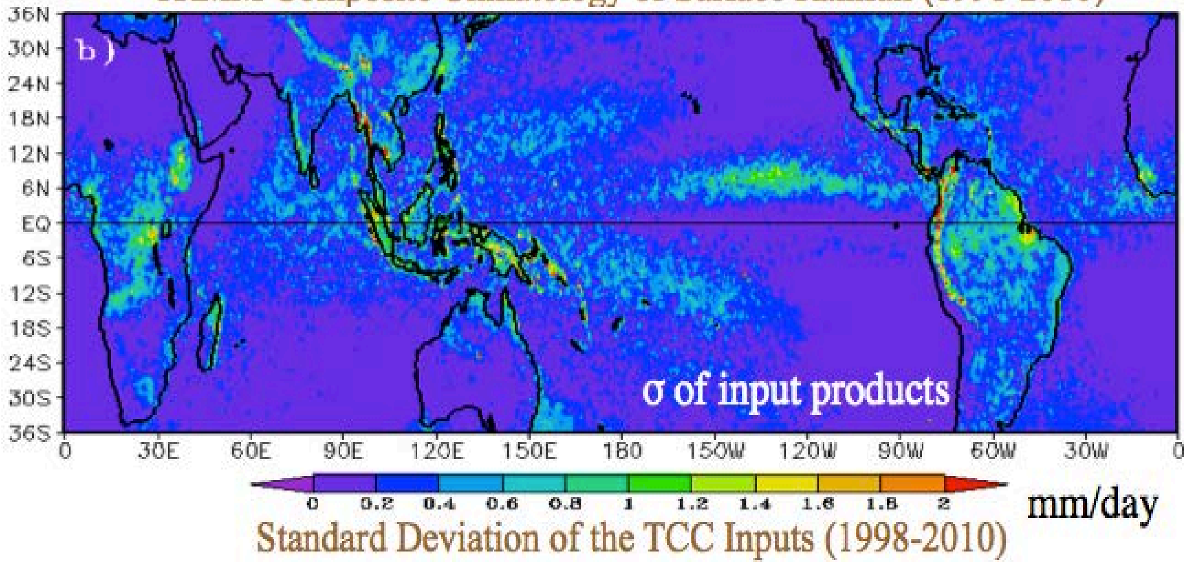
Principles of Precipitation Measurement with Satellite-borne Sensors
衛星搭載センサによる降水測定の原理



Thirteen-year (1998-2010) TRMM Composite Climatology (TCC)

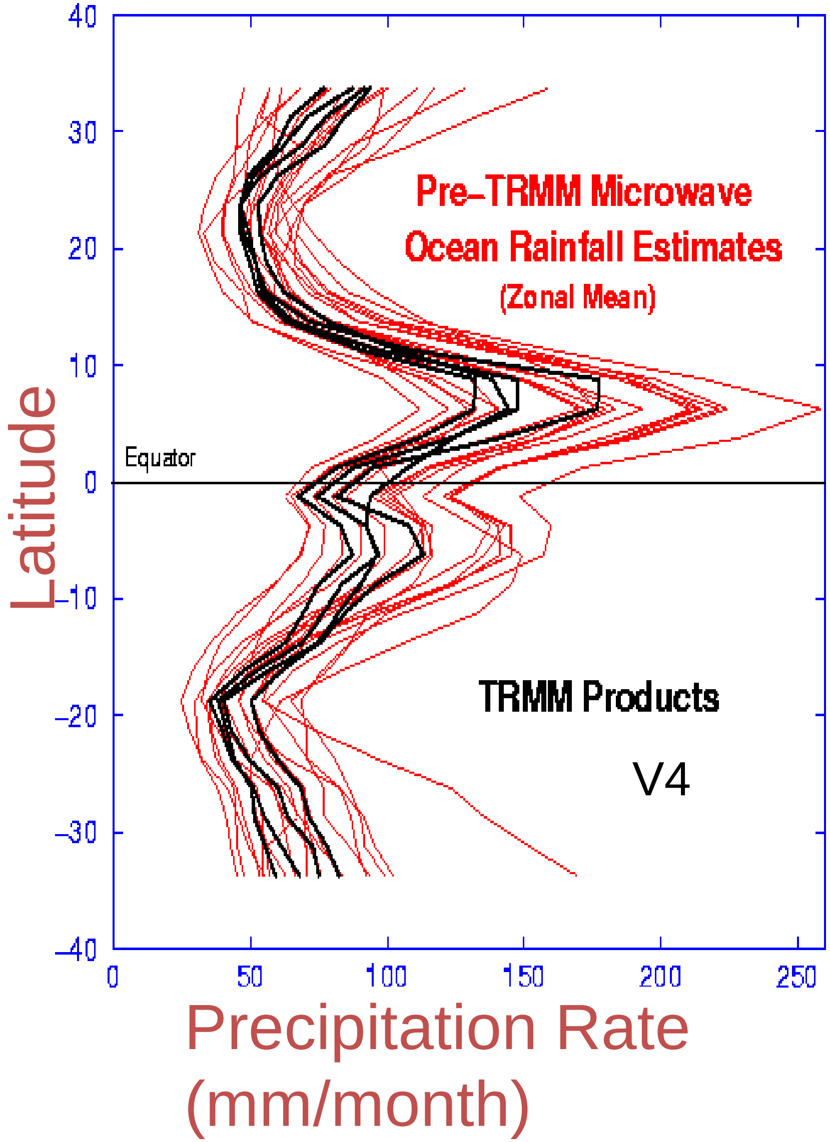


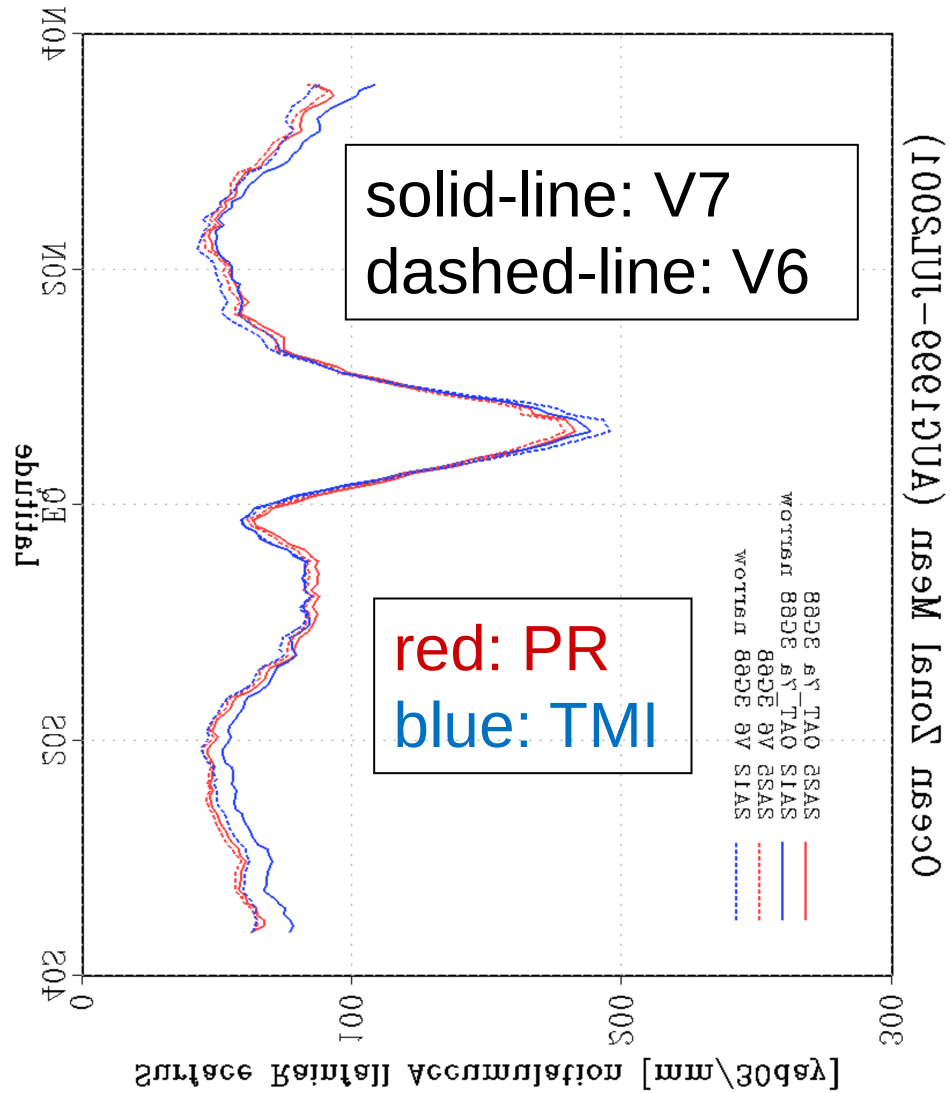
Climatological value is mean of three input products at each 0.5 lat./long. grid from Adler/Wang



Standard deviation (σ) among the three products is an estimate of error—note E. Pac. peak values (σ/mean= 1.3/9 = 14%)

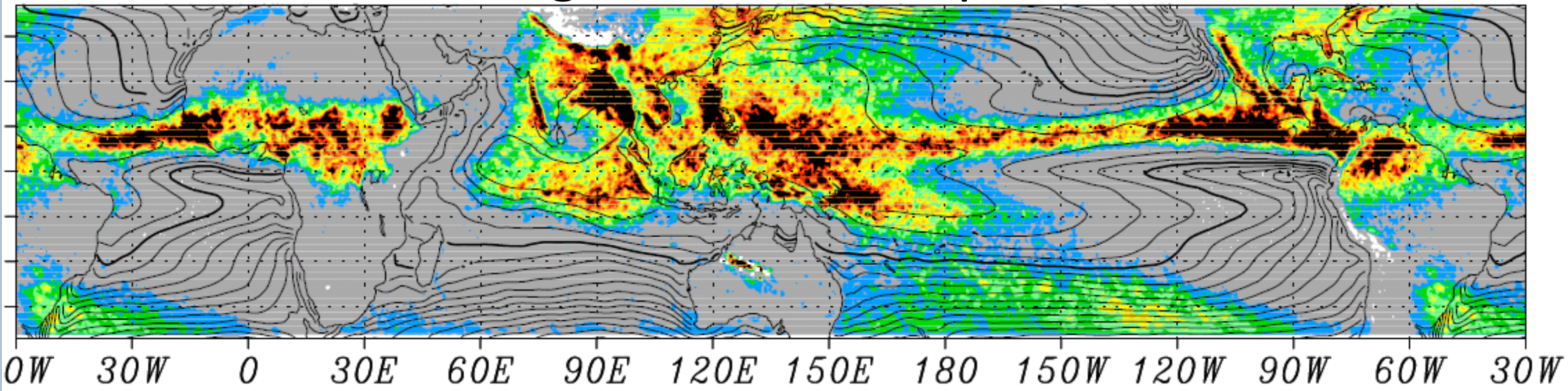
Agreement between PR and TMI Rain Estimates



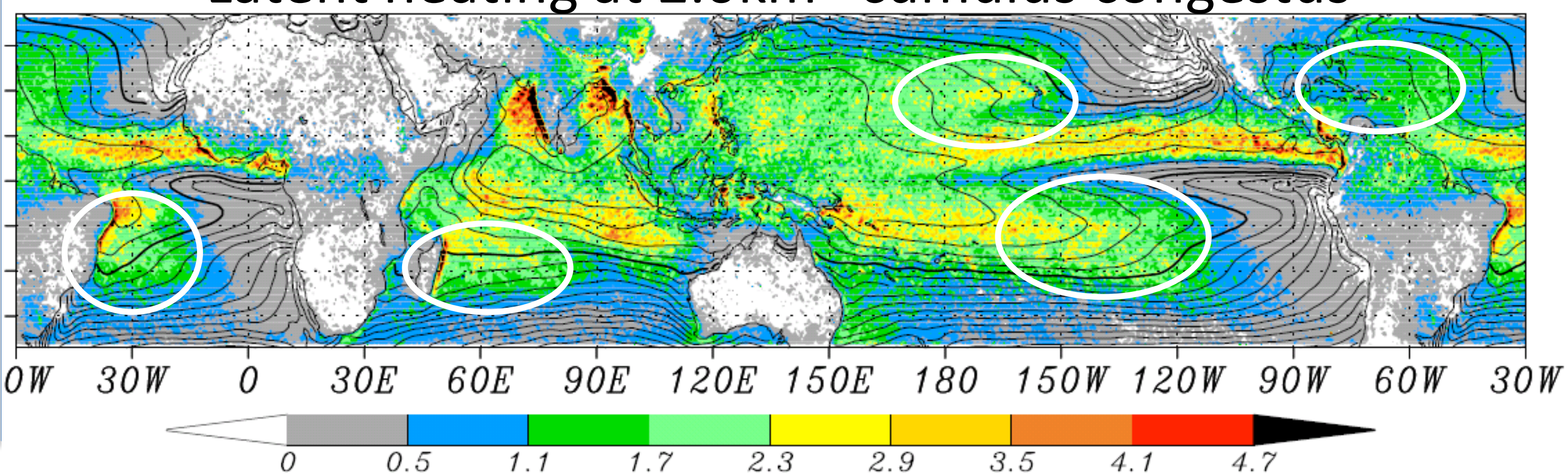


Latent Heating by Convection, 98-07 June-Aug

Latent heating at 7.5km deep convection

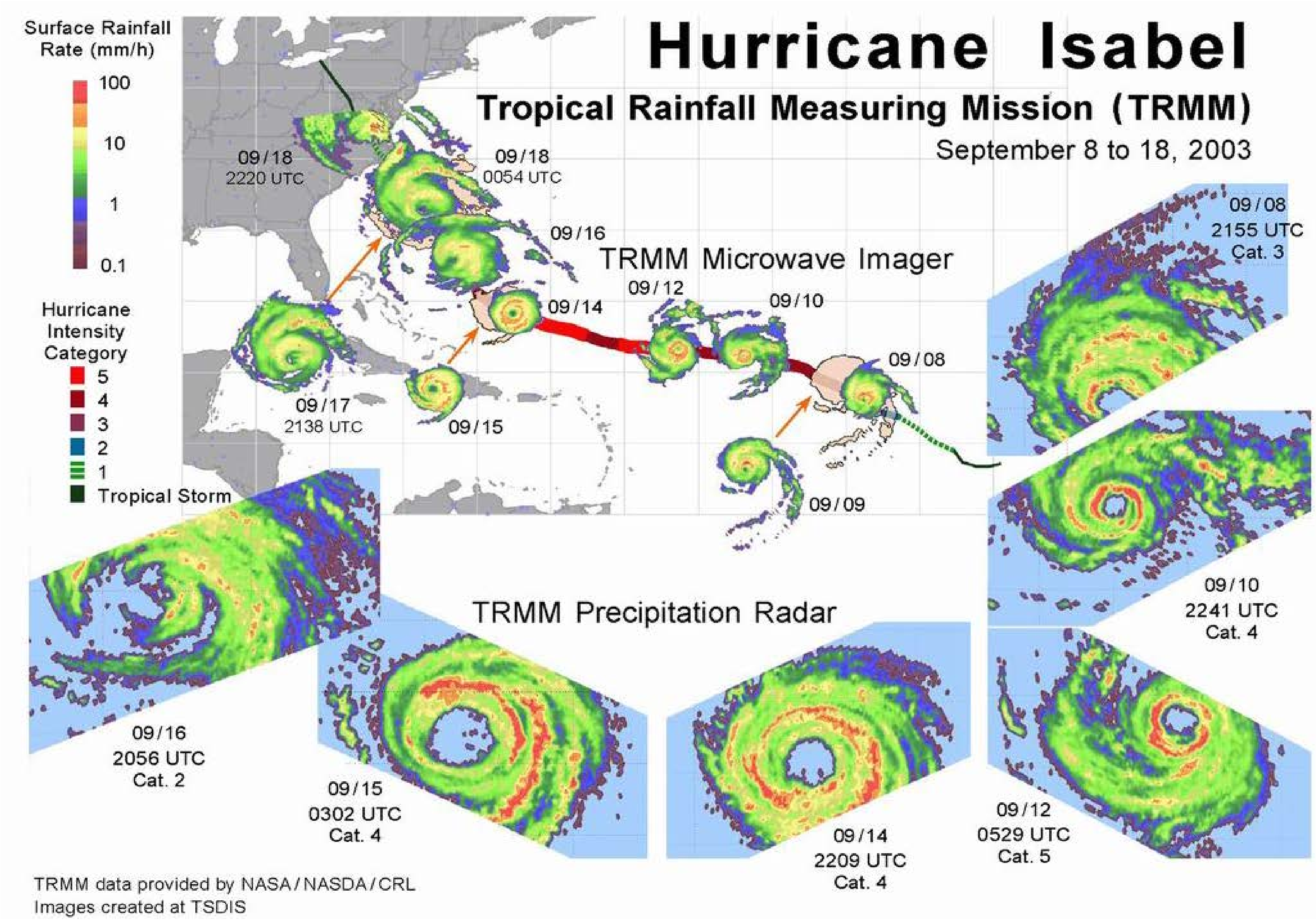


Latent heating at 2.0km cumulus congestus

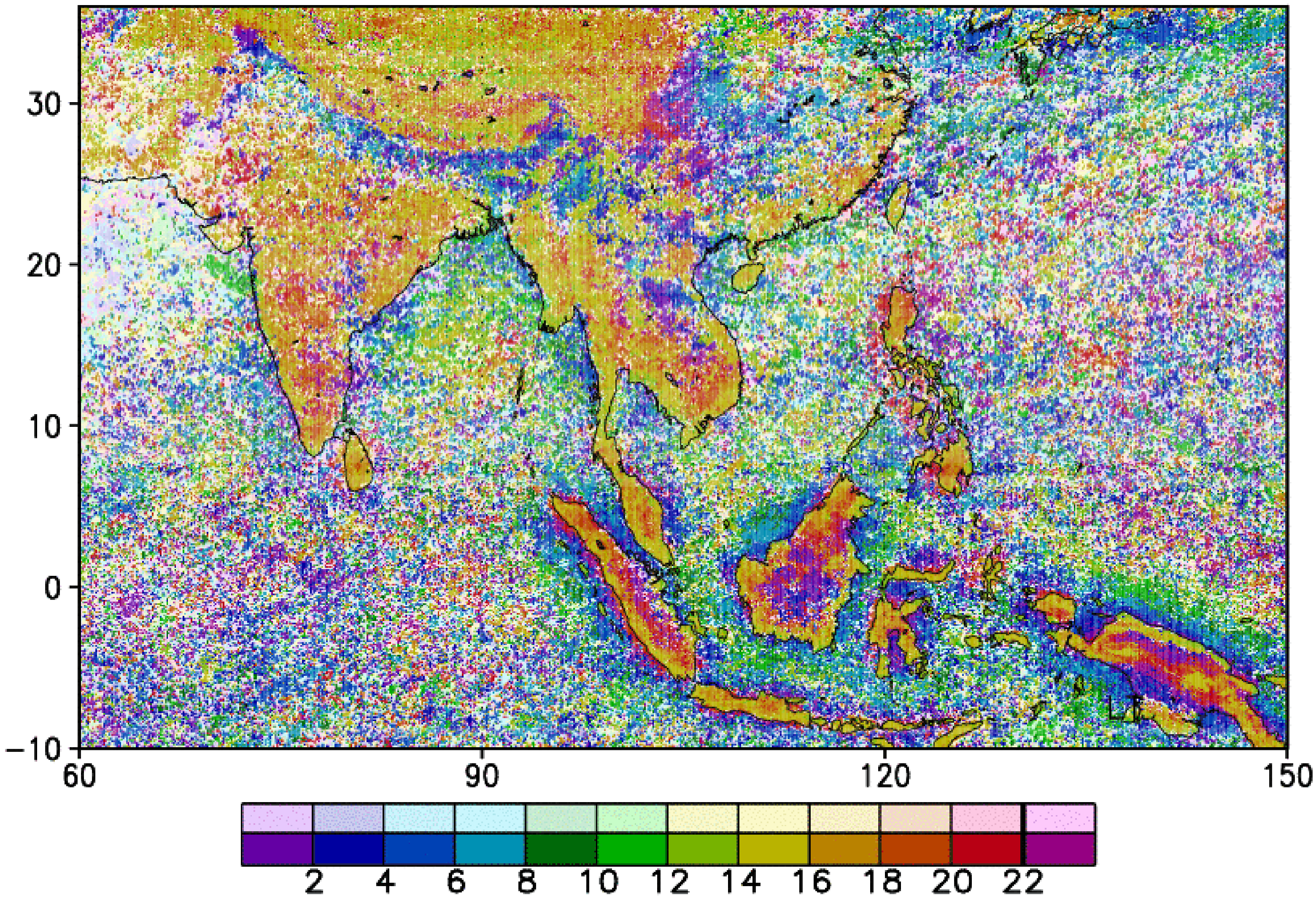


Latent heating by convection is estimated utilizing TRMM PR (Shige et al. 2004). Significant distribution of cumulus congestus regime emerged out over moderately warm water with large-scale atmospheric subsidence. (Takayabu et al. 2010)

Hurricane Structure and Variations Studied with TRMM



Diurnal Variation of Rainfall (Local Time of Max. Rainfall)



0.1 degree 1998-2010

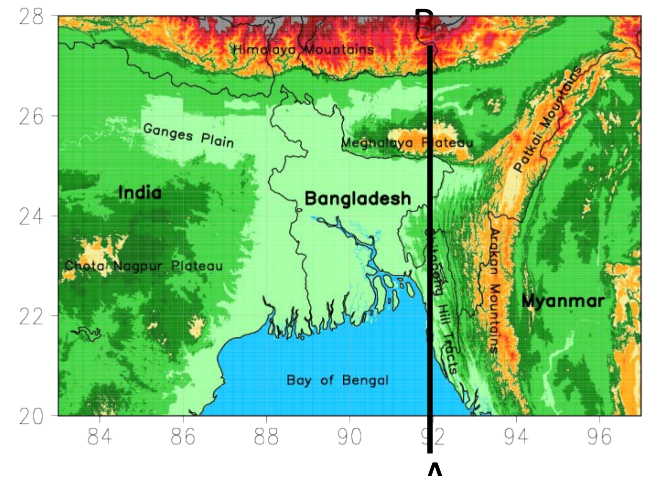
Courtesy of Masafumi Hirose

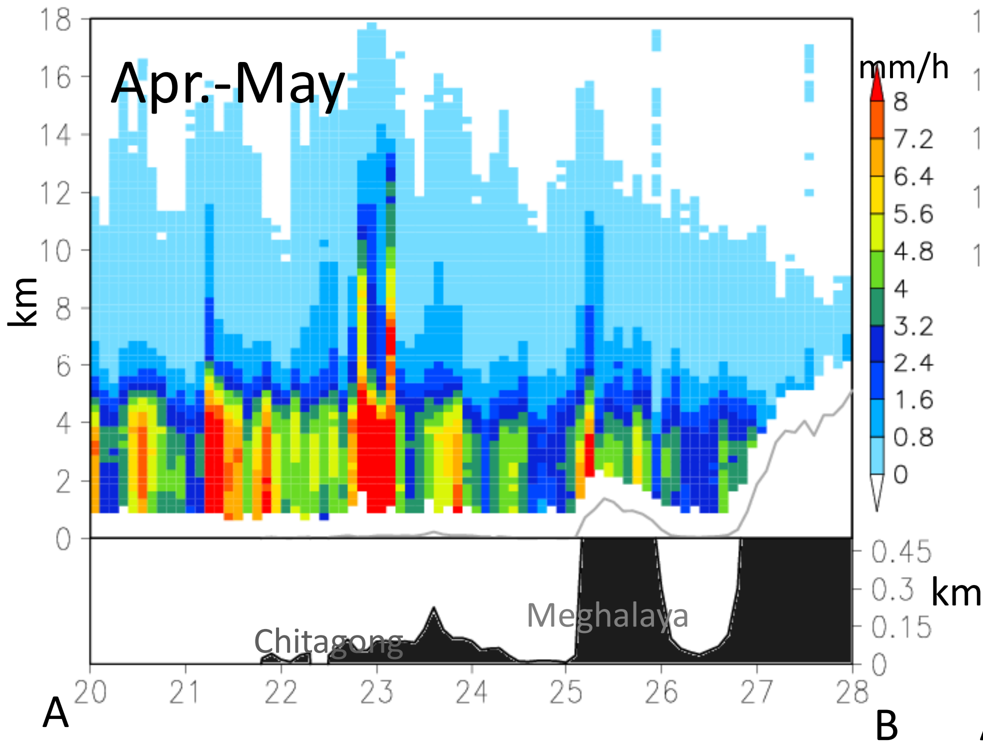
Rainfall Profiles in Bangladesh

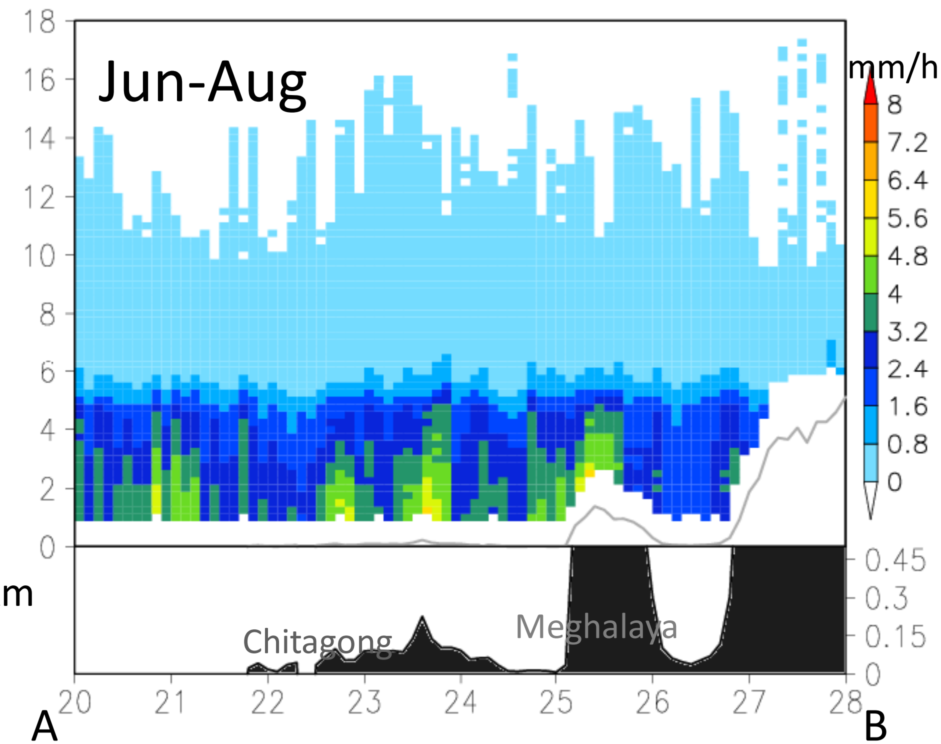
Kenji Nakamura

10-year mean (92° E)

- Apr-May: Pre-Monsoon
  Deep and Intense Rainfall
  Large effects of small topography
- Jun-Aug: Monsoon Rainy Season
  Moderate and Uniform Rainfall

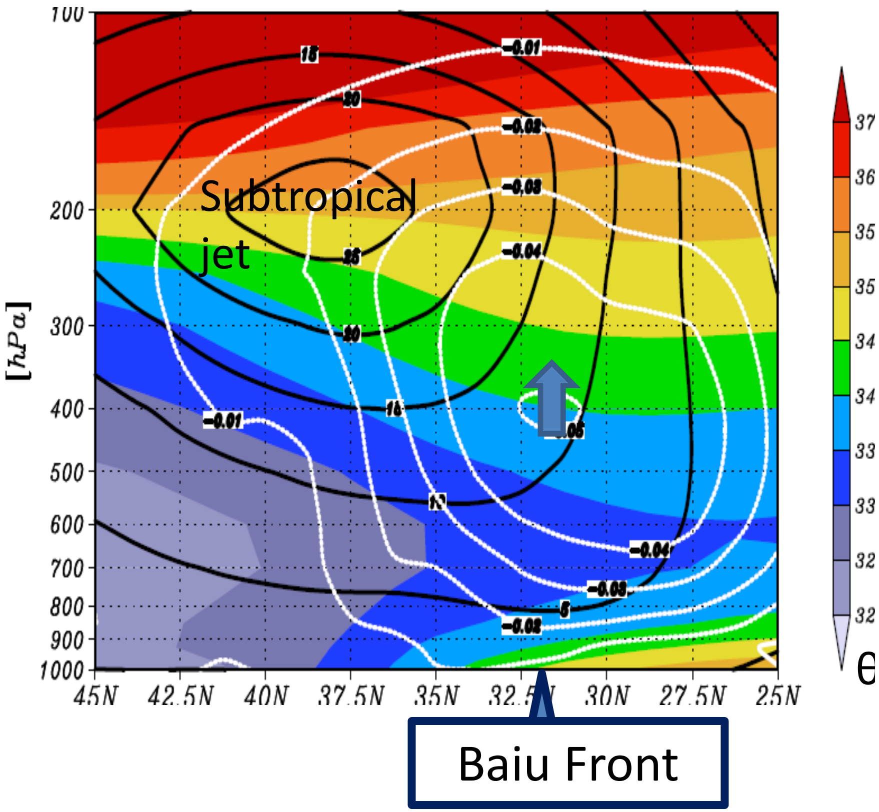


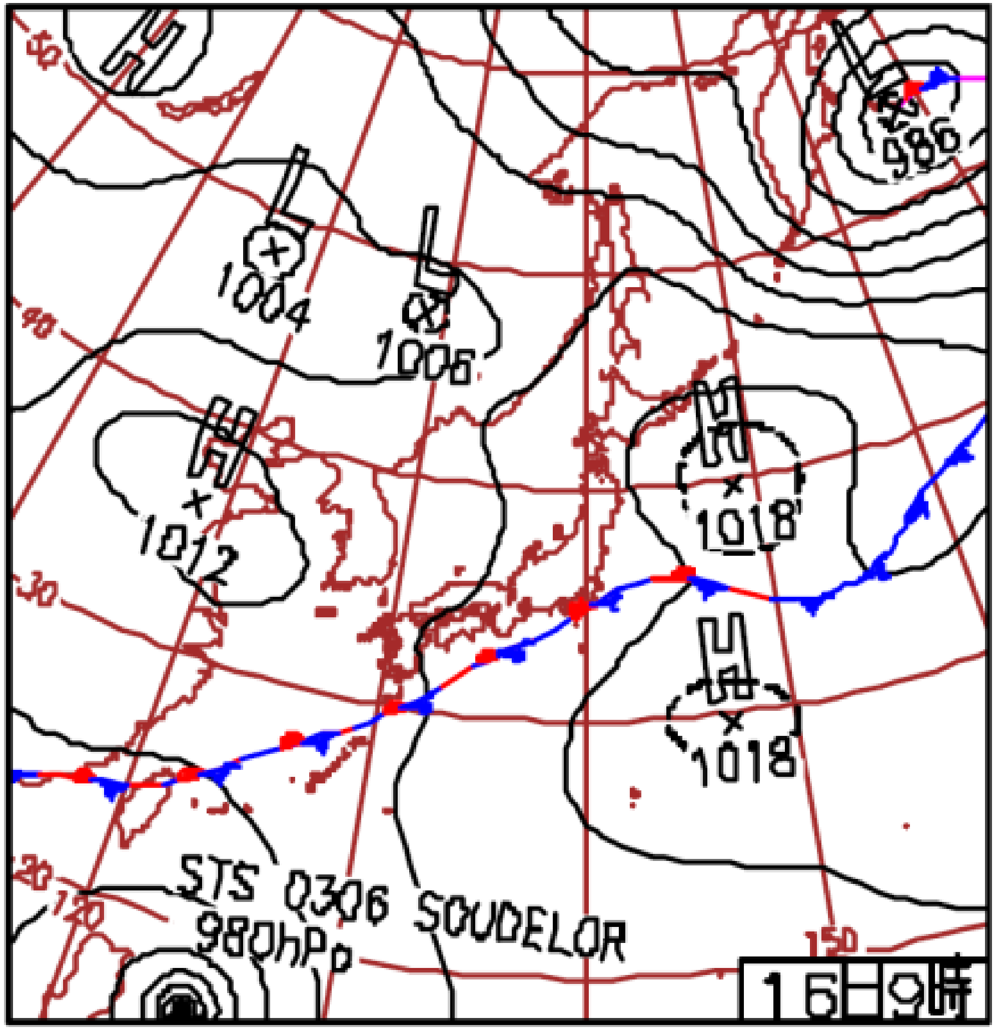




A Contrast in Precipitation Across the Baiu Front

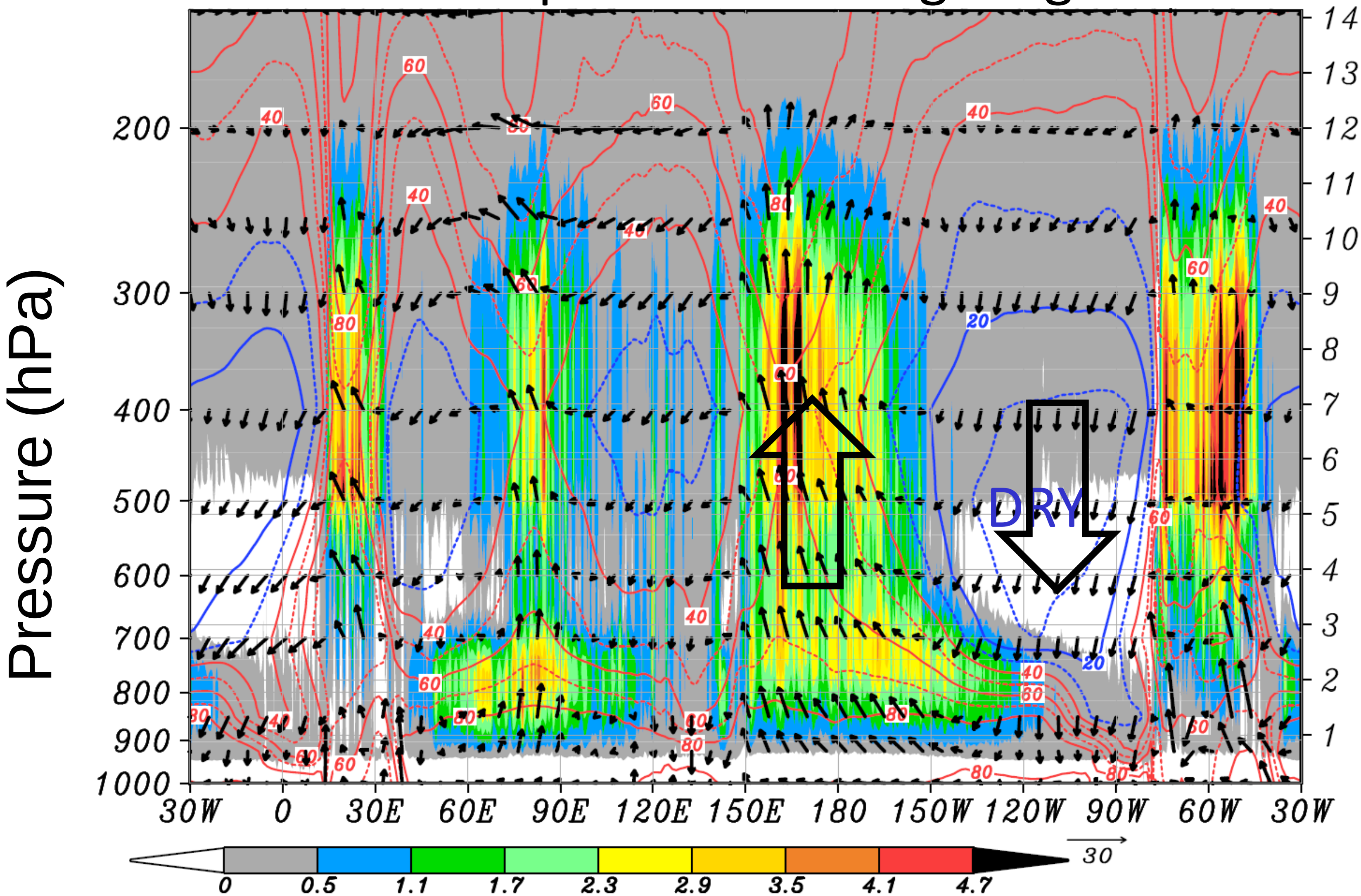
Meridional-vertical structure (122-145E)
June-July, 1998-2011
Color : Moist static energy CpT+gz+Lq





Yokoyama et al. 2013, submitted

TRMM SLH (Q1-QR)
Conv. Diabatic Heating of the Atmosphere
1998-2005 Sep.-Nov. 10S long-height section

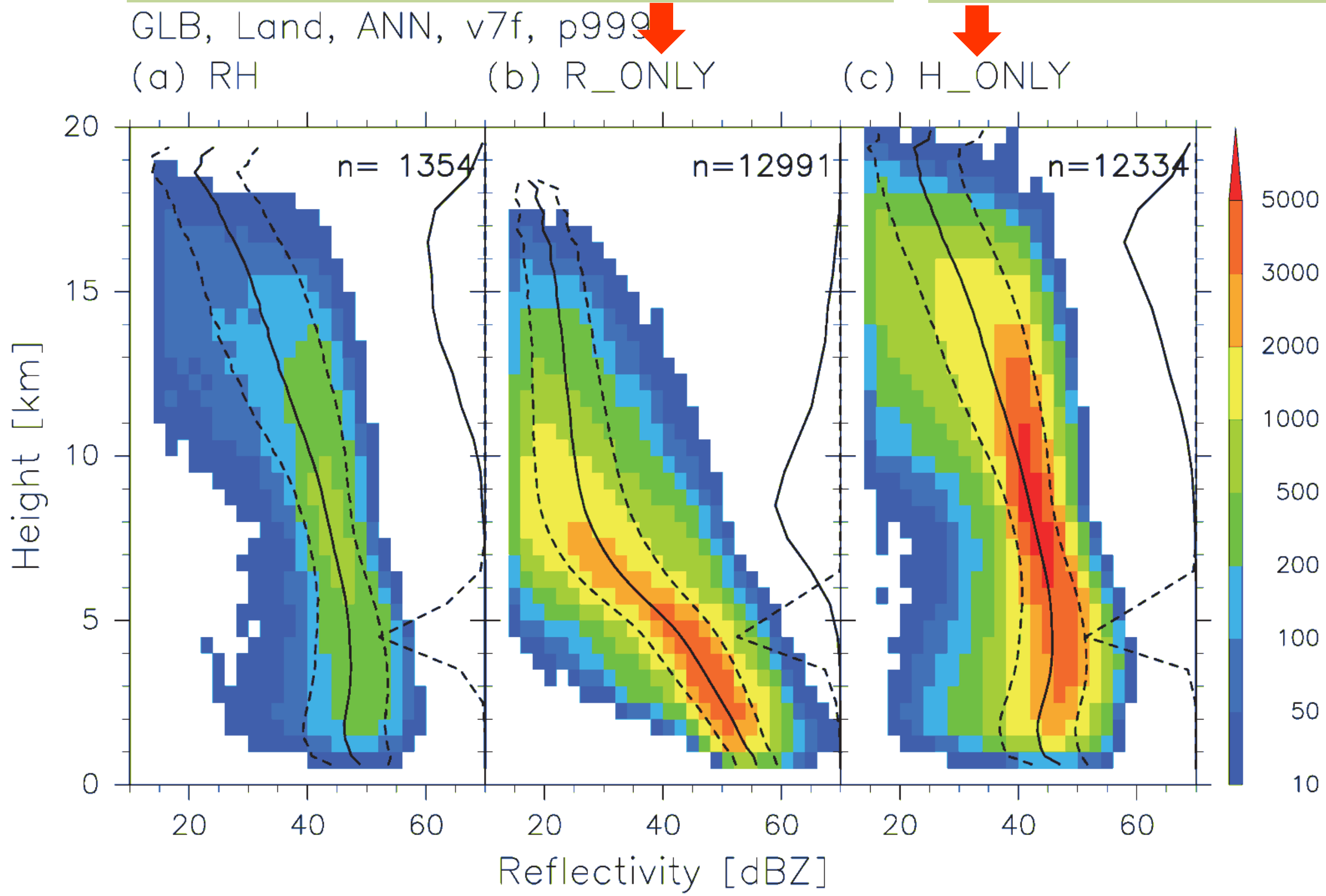


(Takayabu et al. 2010, modified)

Extreme Rainfall vs. Extreme Convection

Top 0.1% in each 2.0 deg x 2.0 deg grid in terms of surface rain rate

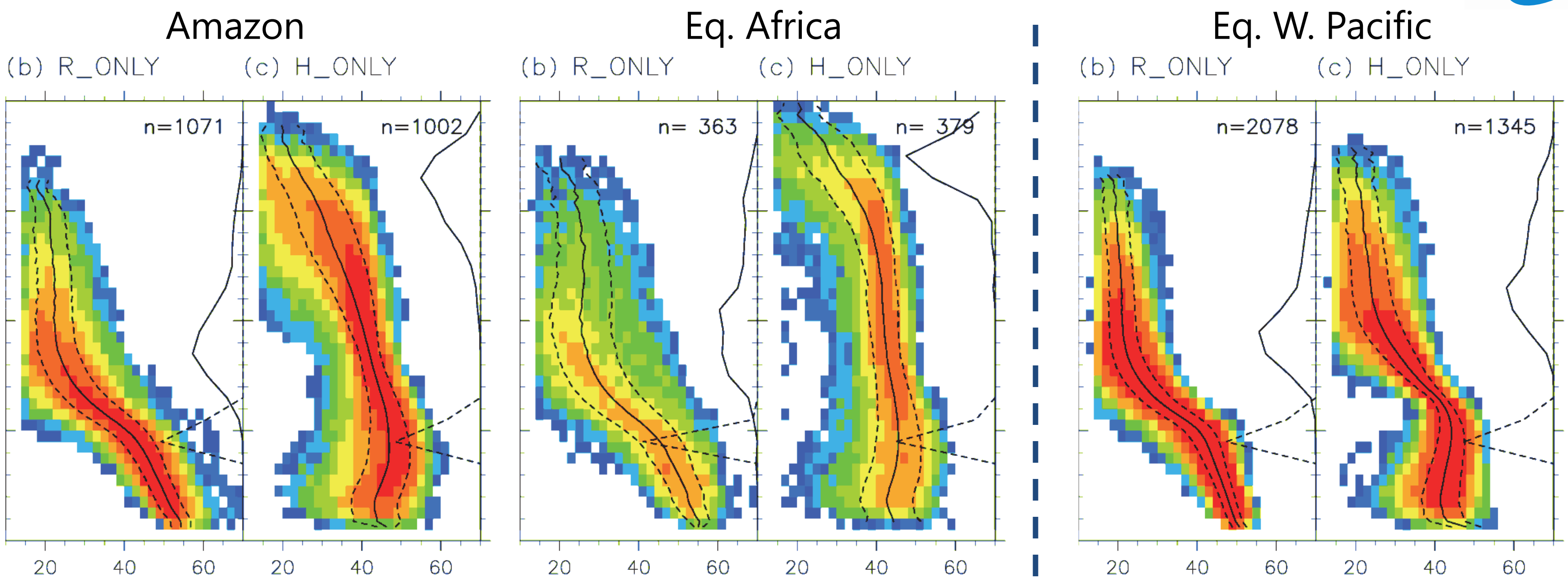
Top 0.1% in terms of 40dBZ echo top height



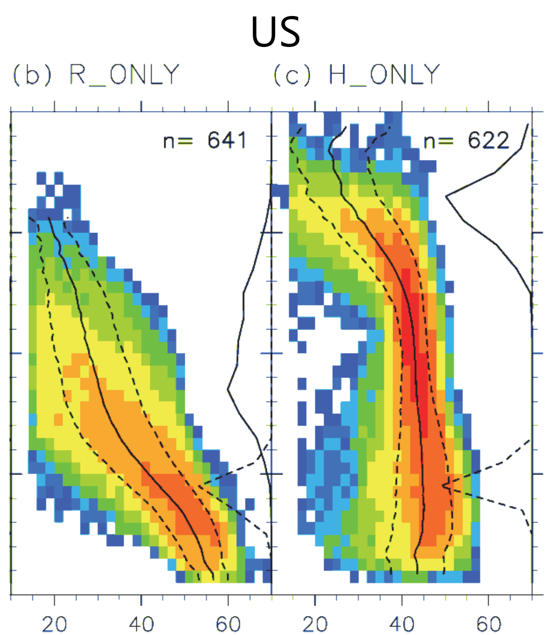
Profiles of extremely intense rainfall and extremely tall convection are very different

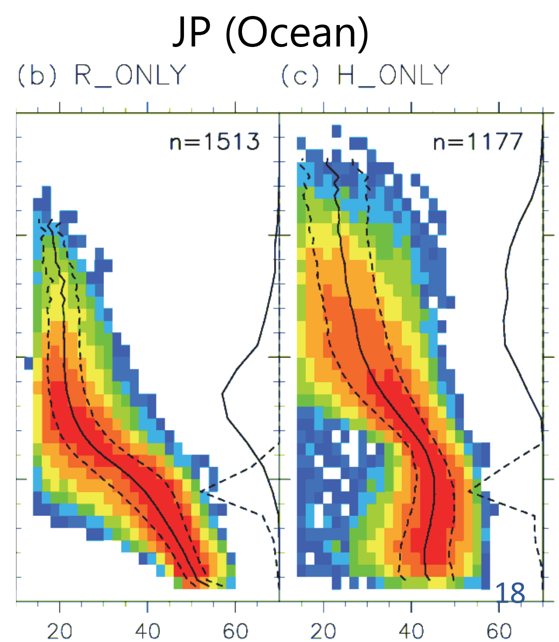
Hamada et al. 2014 in prep.

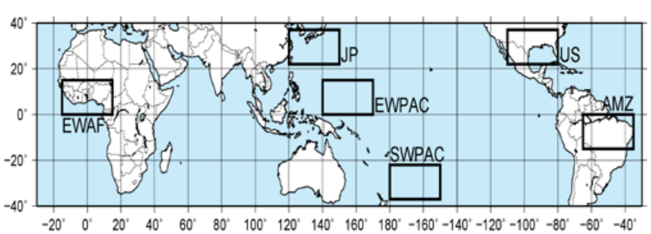
Regional Characteristics of R/H-only Extreme Profiles



- Same irrespective of regions
- Extreme rain rate is mostly associated with moderate systems, even in the regions where severe convective storms are dominant







Impact of Asian Pollution on Rainfall?

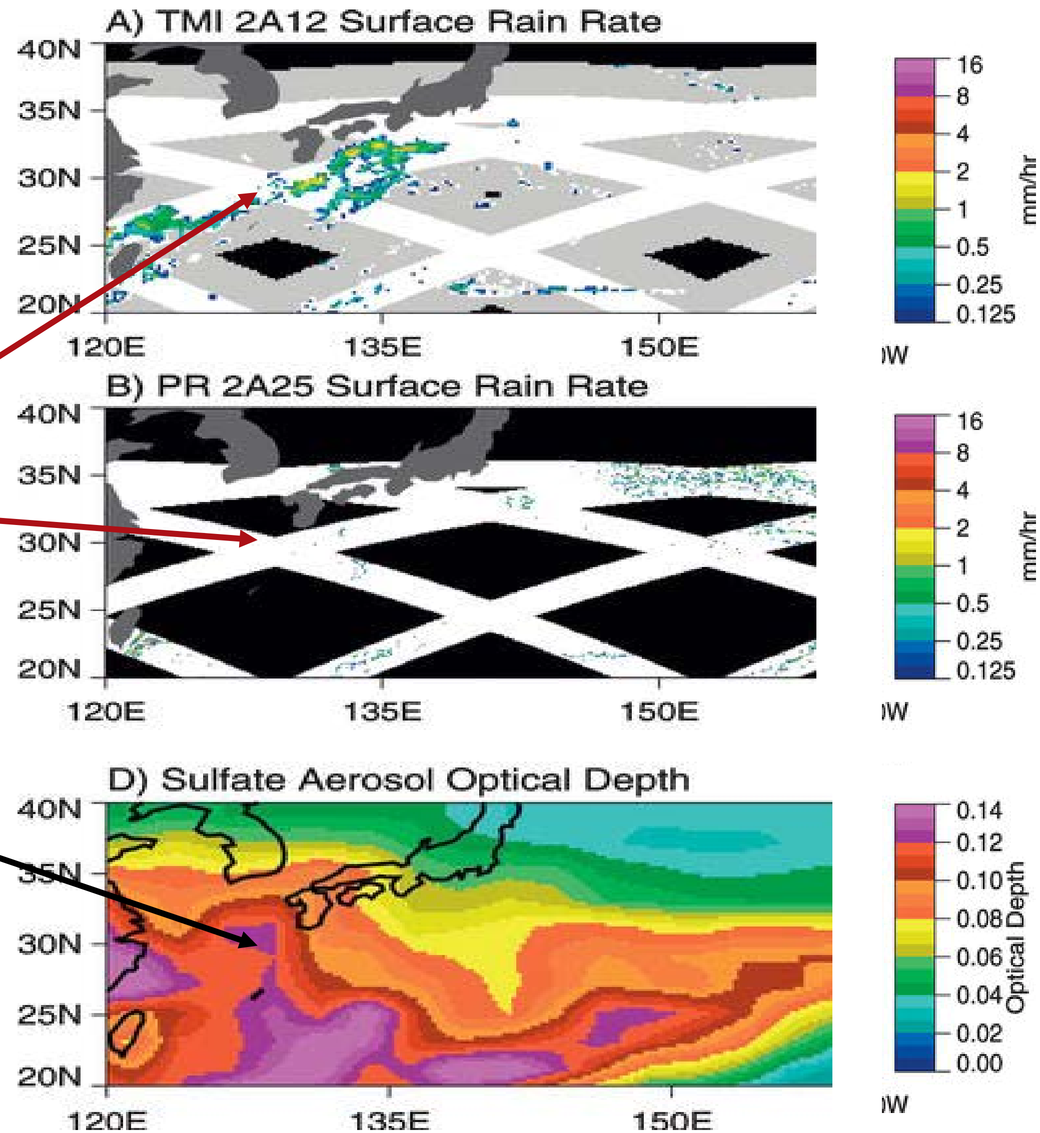
Importance of Radar and Passive Microwave on Same Satellite

Remaining Differences between Passive Microwave and Radar Retrievals --an extreme example

TMI shows significant rain area, but PR shows very little

Result probably due to <u>aerosol effects (pollution)</u> on size distribution of cloud/rainfall droplets

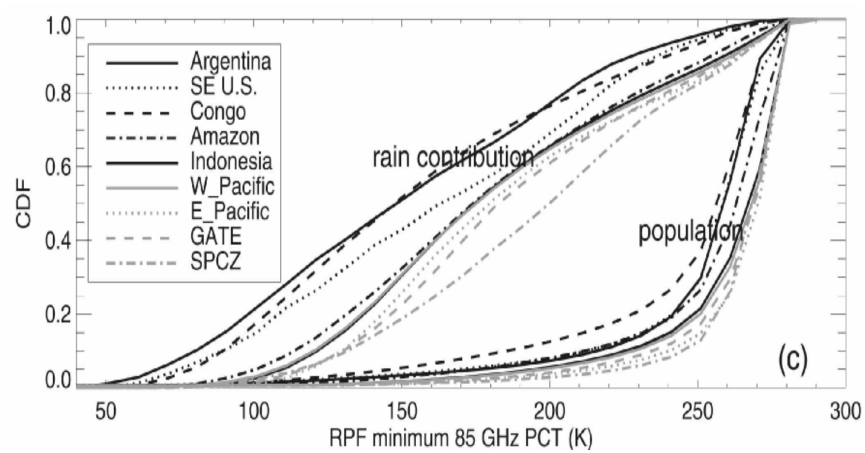
(high cloud liquid water content, but small amount of rain)



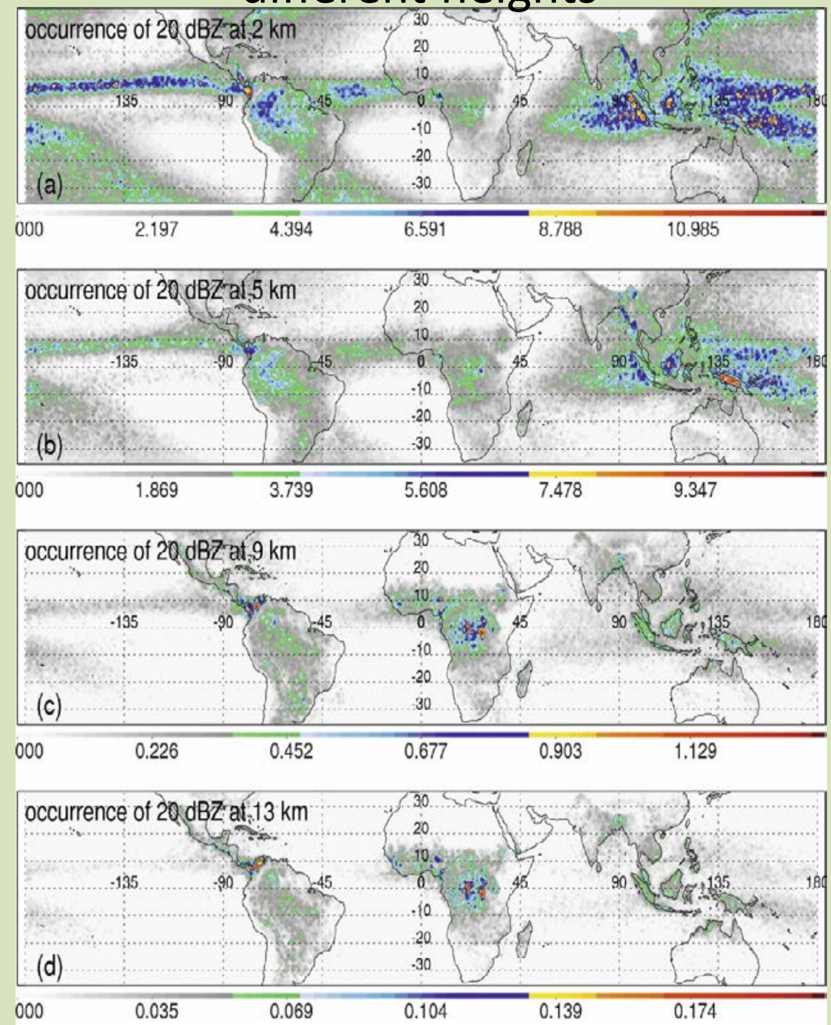
Berg and Kummerow

The TRMM Precipitation Feature Database

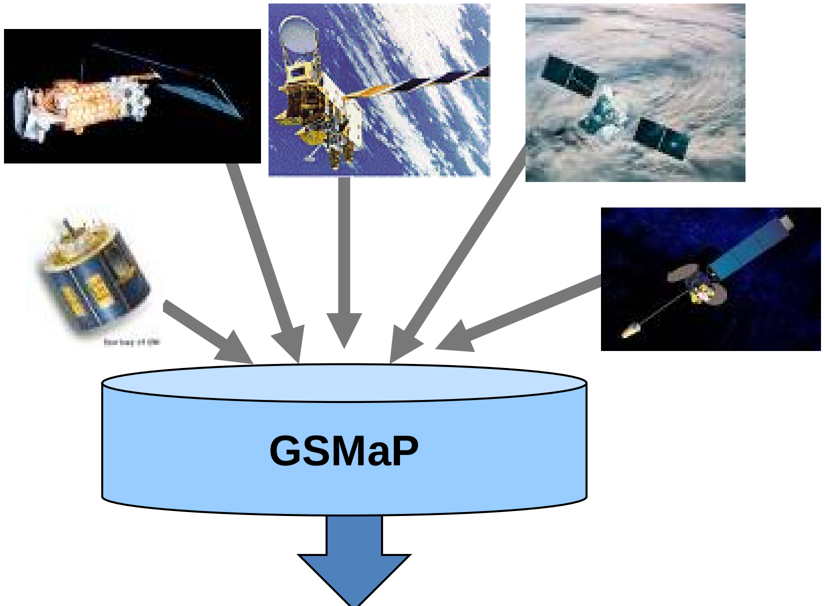
- Continuously updated database of precip. features
- Easy subsetting by location, time, feature size, dBZ, or other parameters
- Identifies occurrences of extremes, rain feature population statistics, vertical structure



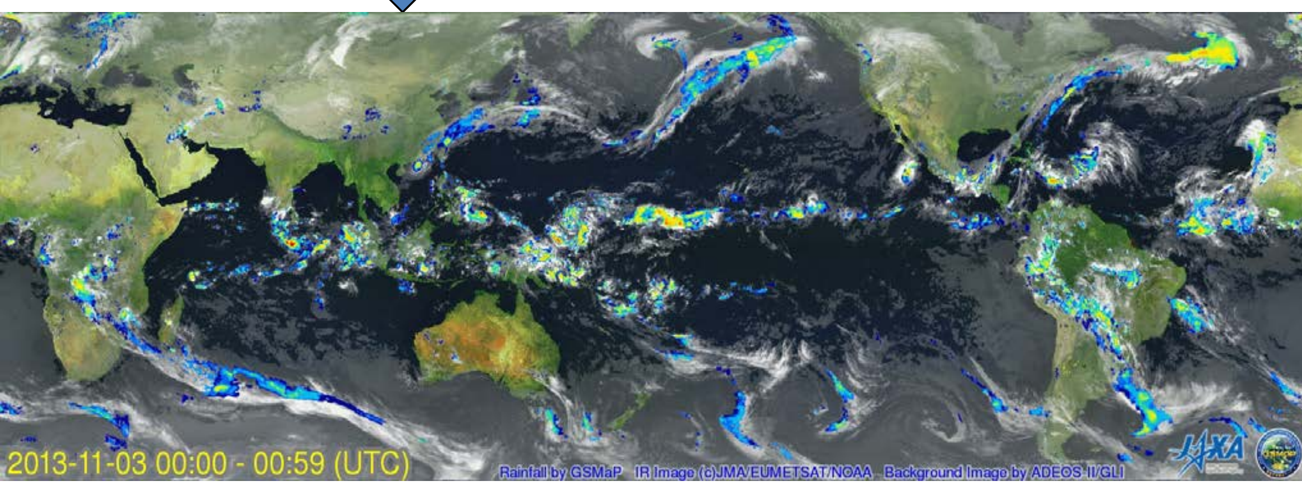
Occurrence of 20 dBZ for different heights

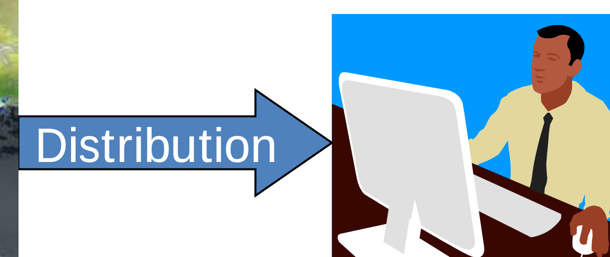


Global Satellite Mapping of Precipitation (GSMaP) : A prototype for GPM



- Merged global rainfall map from TRMM, AMSR2 and other microwave sensors
- Hourly, 0.1-degree lat/lon
- Available 4-hr after observation
- Browse images, 24-hr animation, displaying by Google Earth
- Data are also available via password protected ftp site





http://sharaku.eorc.jaxa.jp/GSMaP

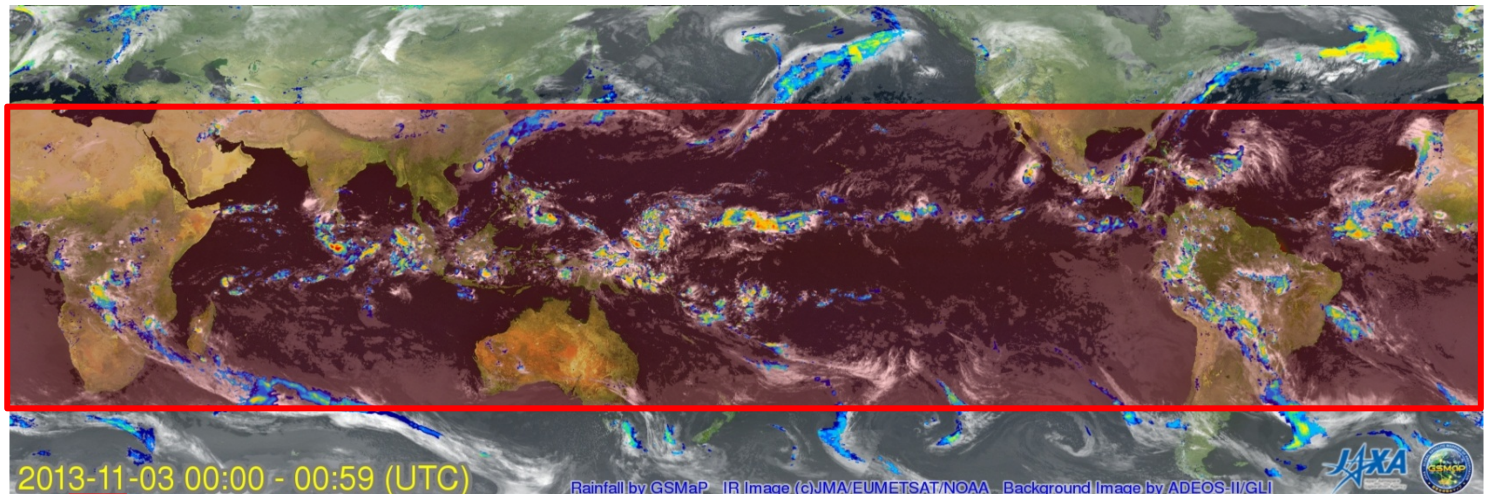
Improvement of GMaP: from TRMM Era to GPM Era

TRMM era

DB from a model

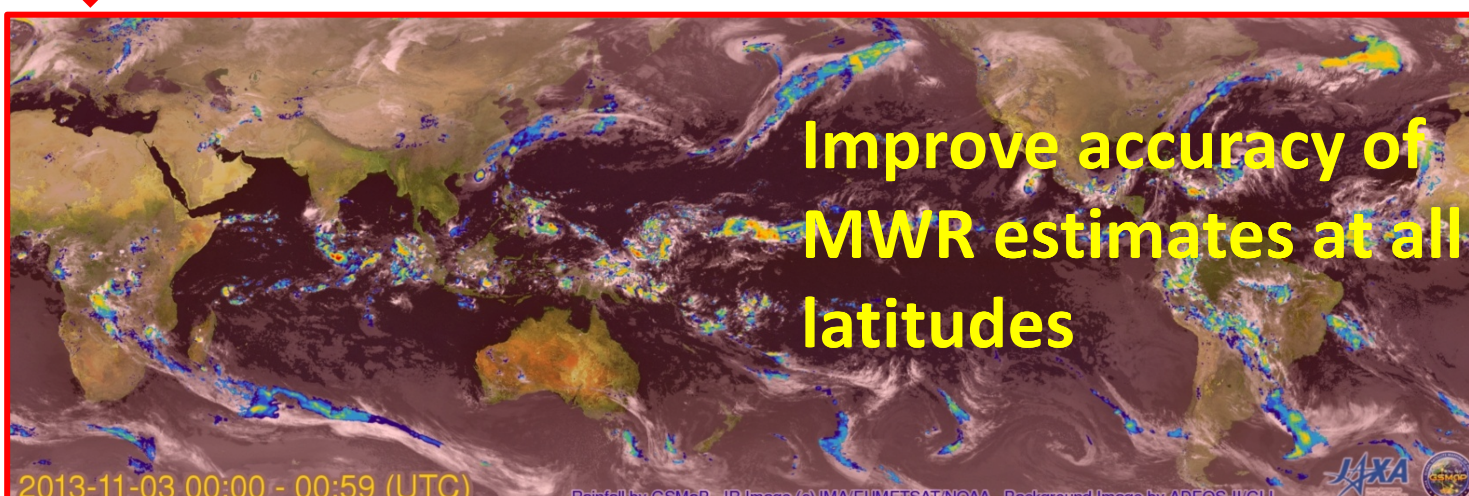
DB from TRMM/PR data

DB from a model



GPM era

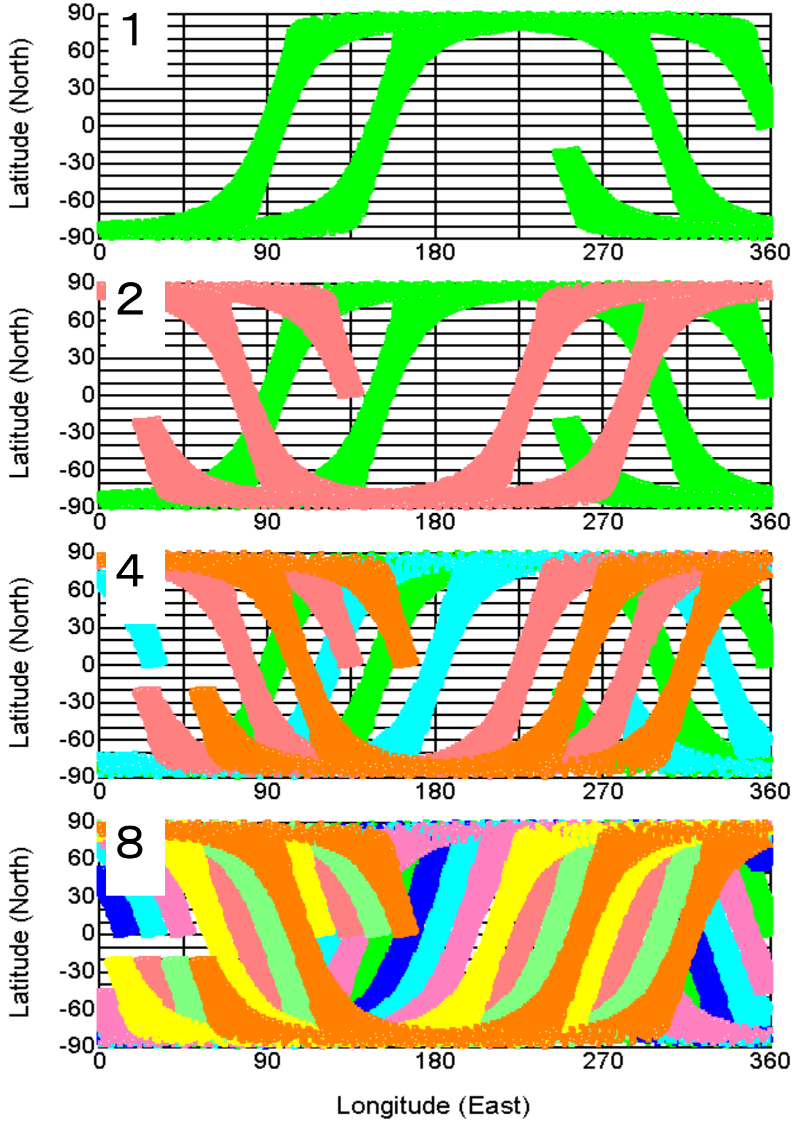
DB from GPM/DPR data



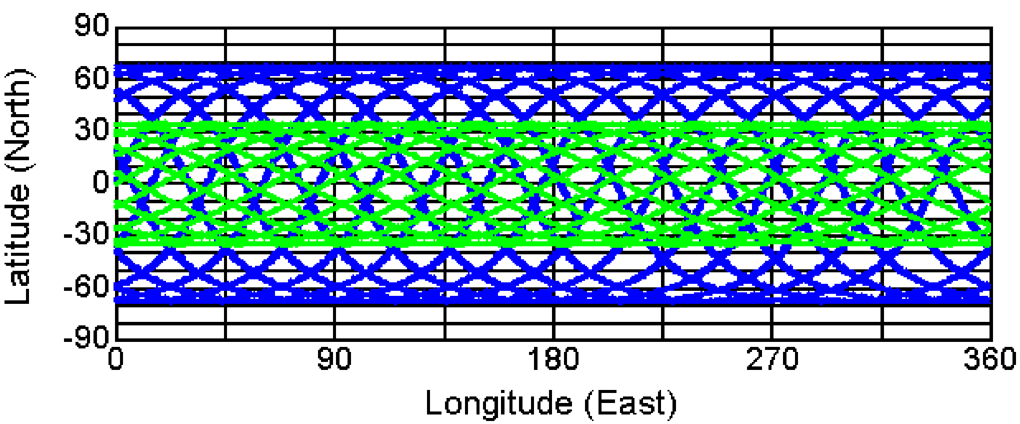
(Plot by M. Kachi)

Observation by a Fleet of Satellites with Microwave Radiometer

Observation area with MWRs in 3 hours
(1, 2, 4 and 8 satellites from top to bottom)



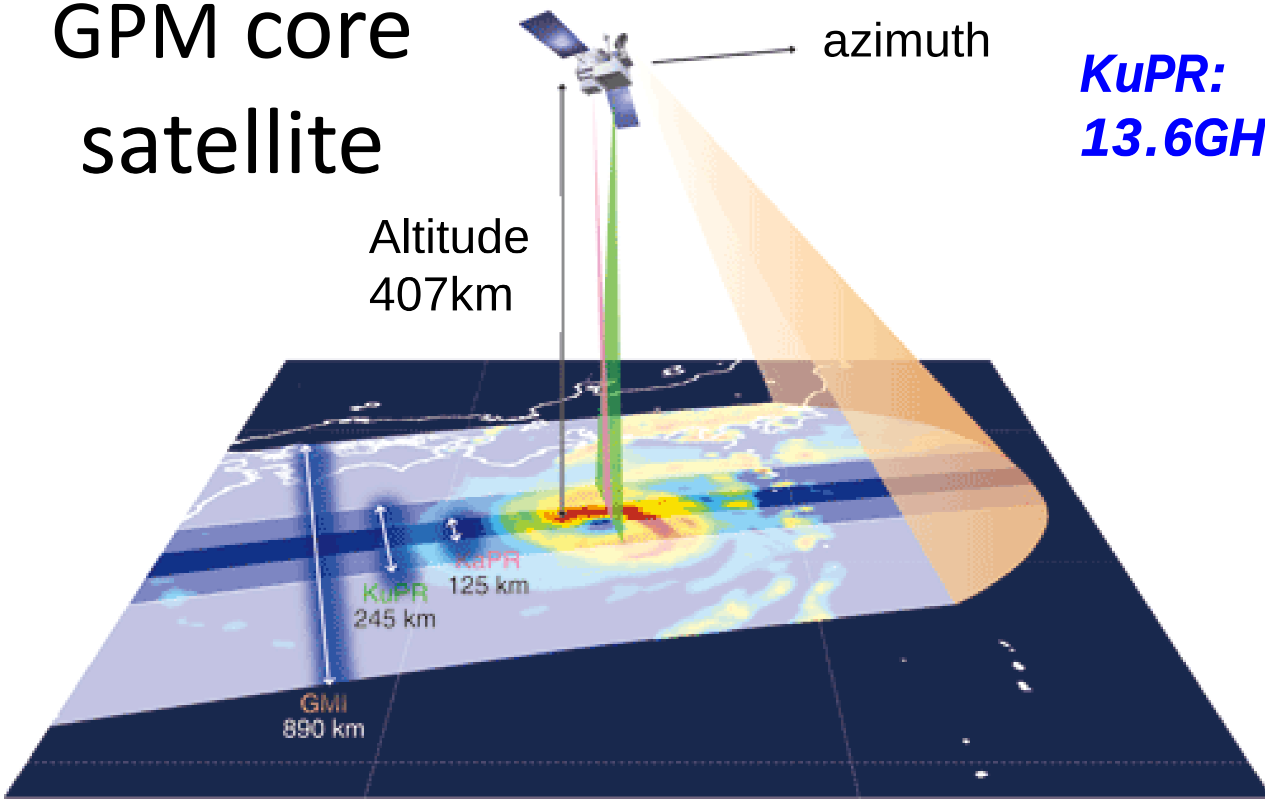
Coverages by **TRMM PR** and **GPM DPR** in a day

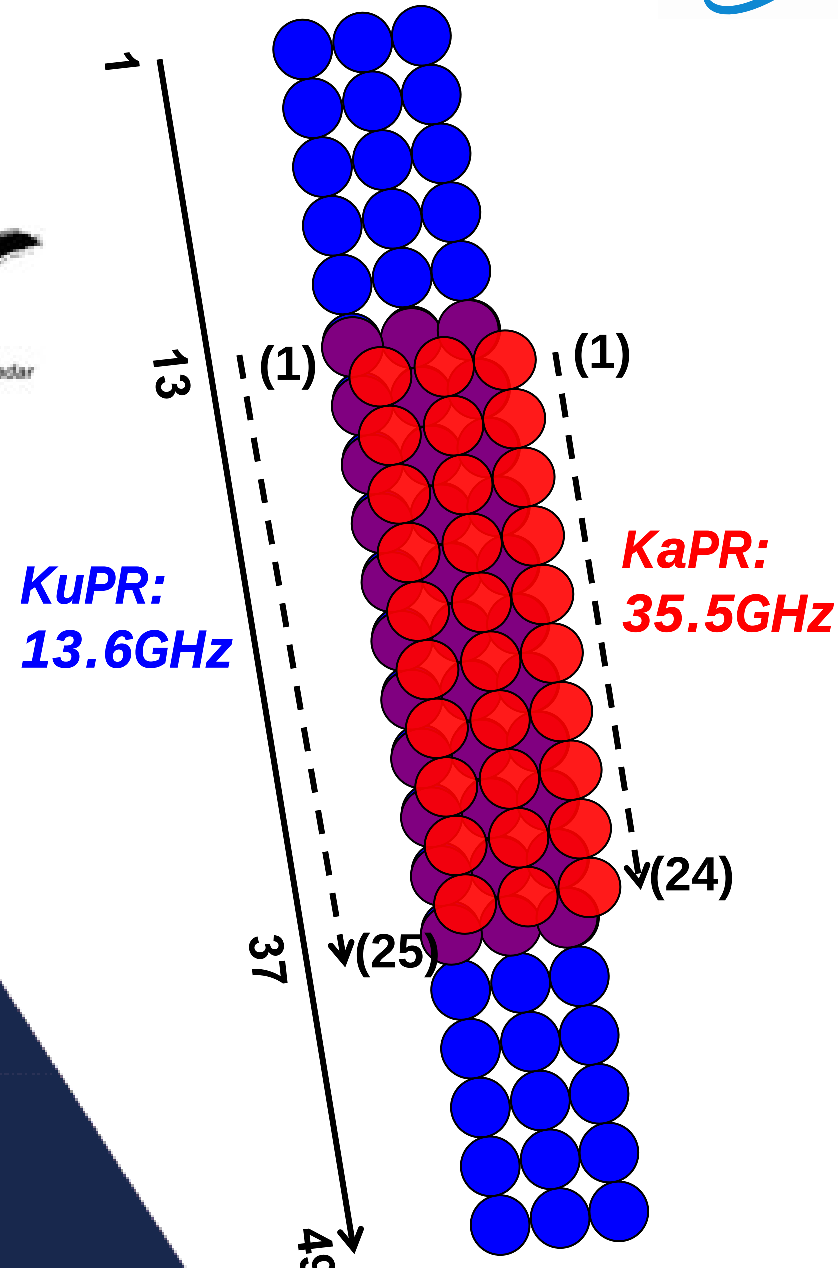


GPM (Global Precipitation Measurement Mission)

DPR (Dual-frequency Precipitation Radar)

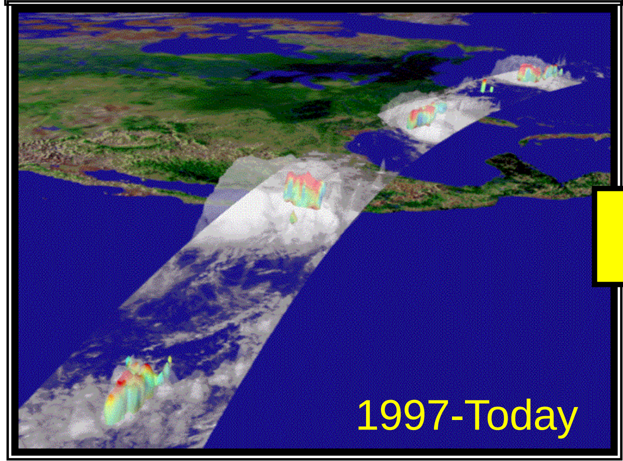
GPM core satellite



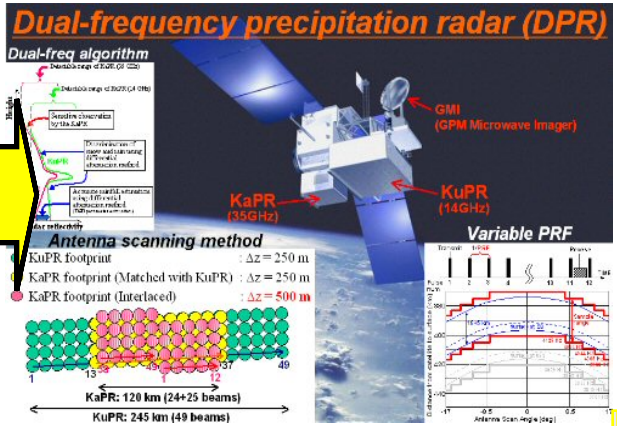


Spaceborne Atmospheric Radars

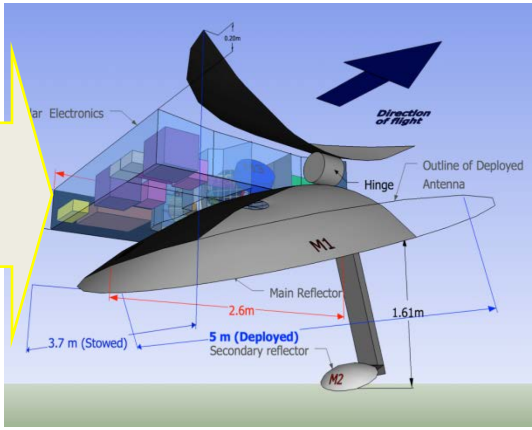
TRMM/PR – NICT/JAXA
Ku, Scanning , Tropical Rain



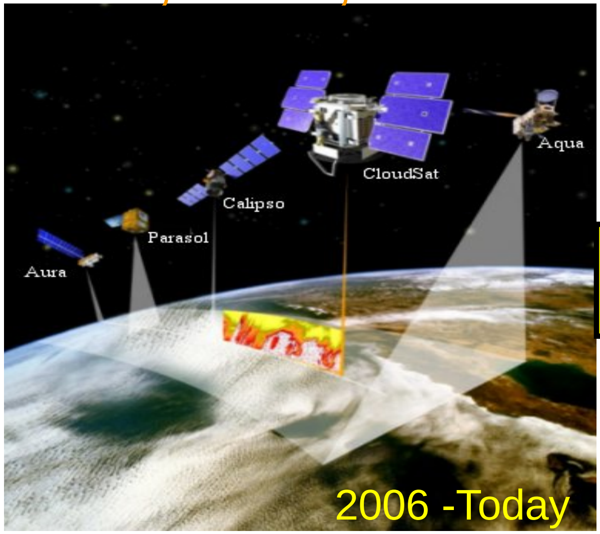
GPM/DPR – NICT/JAXA
Ku/Ka, Scanning, Precipitation



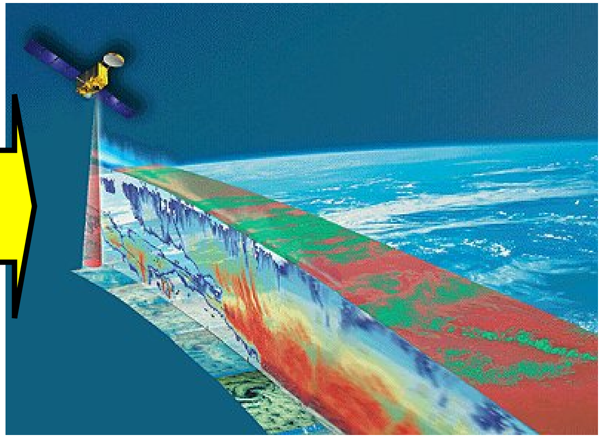
ACE Radar (one concept)
W/Ka, Scanning, Doppler



CloudSat/CPR – JPL/NASA
W, -30dBZ , Clouds



EarthCARE/CPR – NICT/JAXA
W, Doppler, Clouds



TRMM's Achievements

TRMM/PR has opened a new era of accurate precipitation measurement from space.

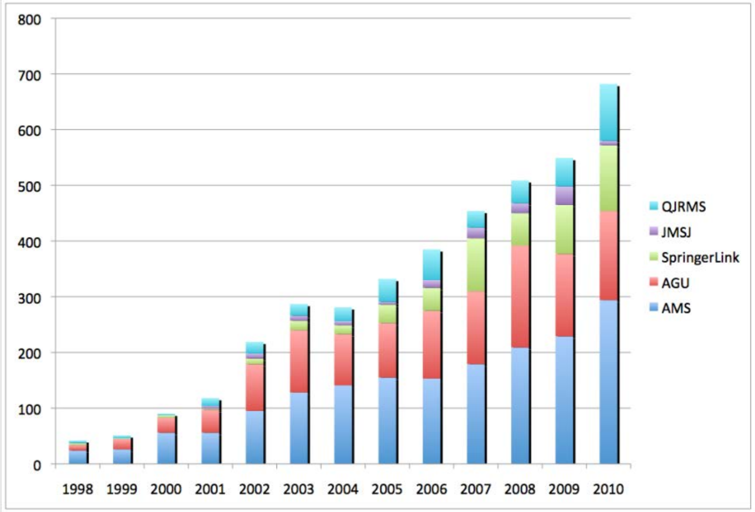
- Demonstrated the world's first space-borne precipitation radar technology
- Improved the accuracy of precipitation estimates from space and made space standard for measuring precipitation
- Improved climatology of tropical rainfall and variations from 16-year accumulation of 3D rainfall data, multi-sensor measurements, diurnal samplings.
- Vertical hydrometeor/heating structure and diurnal signal
- Became a new standard precipitation data set for numerical model evaluations and improved climate and weather modeling
- Multi-satellite (~3-hr) rainfall analyses using TRMM+other satellites (GSMaP)
- Operational use of data by weather agencies with 4-D data assimilation.

Other studies include

- Impact of humans on precipitation
- Hurricane/typhoon structure/evolution
- Flood and agricultural applications

More than 3000 scientific journal articles published using TRMM data

Successful cooperation between US and Japan



Summary

- TRMM started as a science mission.
  - It has achieved the original science objectives and much more.
    - Improved the MWR algorithm significantly.
  - Several practical applications have emerged.
    - Weather forecast, Flood warning, etc.
- GPM inherits TRMM's success.
  - GPM instruments will set a new standard for precipitation measurements from space
  - The GPM mission will help advance our understanding of Earth's water and energy cycles, improve the forecasting of extreme events that cause natural disasters, and extend current capabilities of using satellite precipitation information to directly benefit society.