From Radiative Transfer to NASA Missions and NOAA Cooperative Institutes

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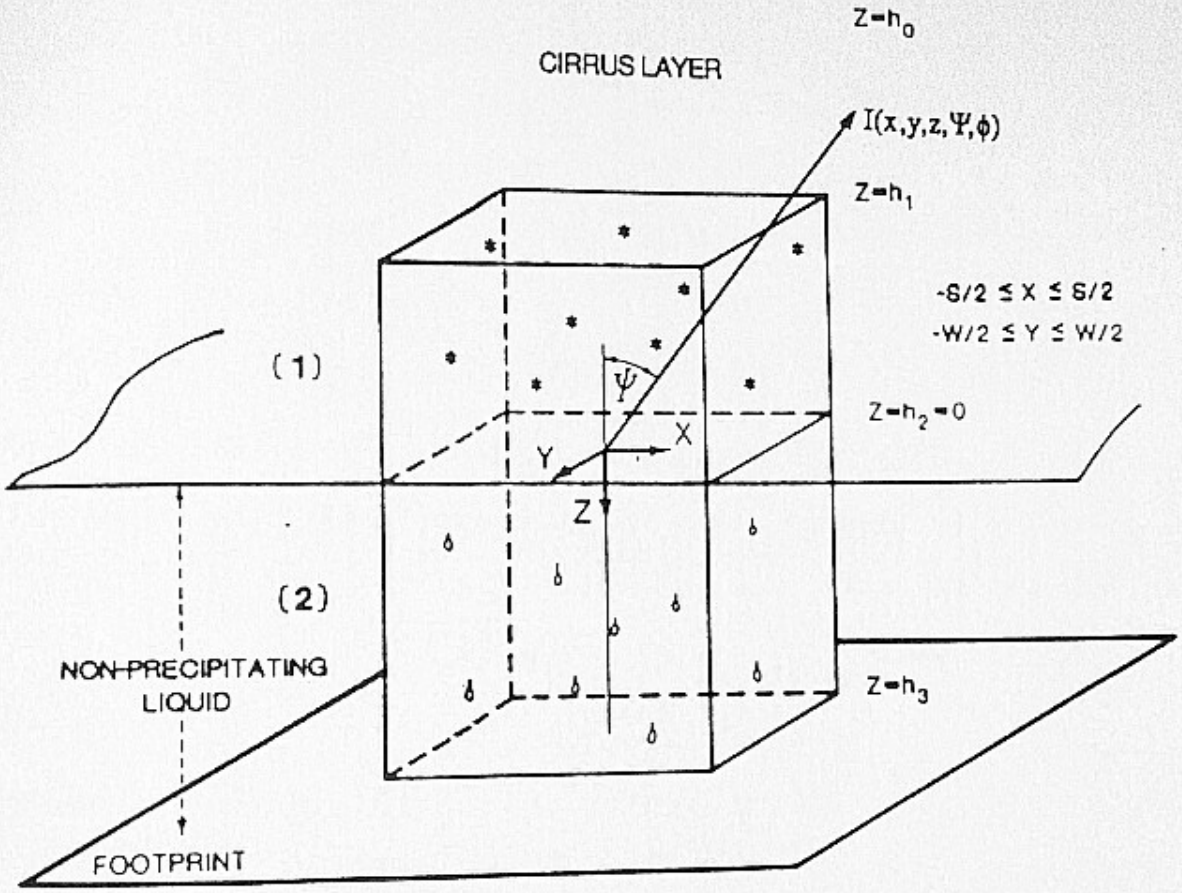
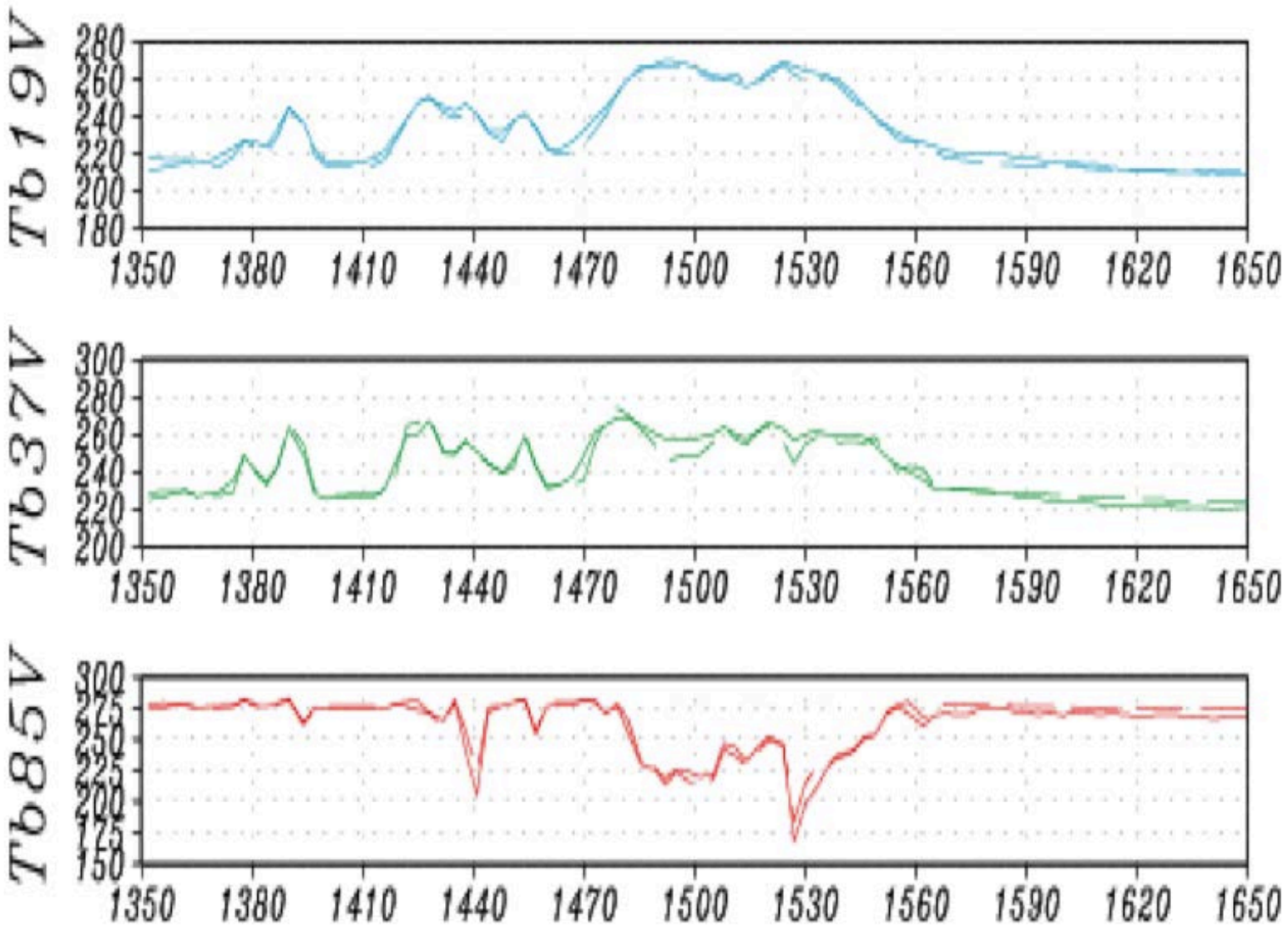
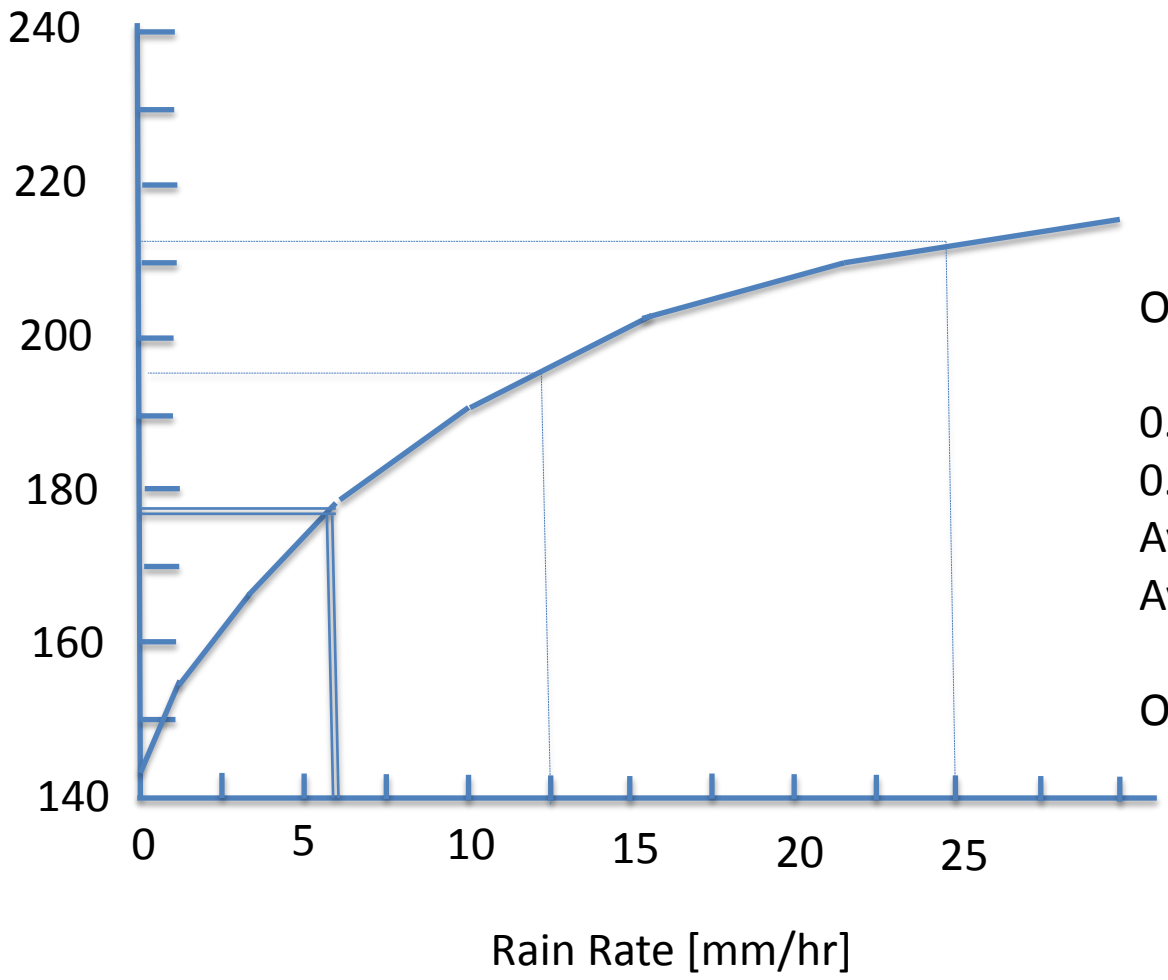
Colorado State University

Global Energy and Water Exchanges
Project of the World Climate Research Programme


Z=h0
CIRRUS LAYER
I(x,y,z,Ψ,ϕ)
Z=h1
-S/2 ≤ X ≤ S/2
-W/2 ≤ Y ≤ W/2
(1)
Ψ
Z=h2=0
X
Y
Z
(2)
NON-PRECIPITATING
LIQUID
Z=h3
FOOTPRINT


Tb19V
280
260
240
220
200
180
1350
1380
1410
1440
1470
1500
1530
1560
1590
1620
1650
Tb37V
300
280
260
240
220
200
1350
1380
1410
1440
1470
1500
1530
1560
1590
1620
1650
Tb85V
300
250
200
150
1350
1380
1410
1440
1470
1500
1530
1560
1590
1620
1650

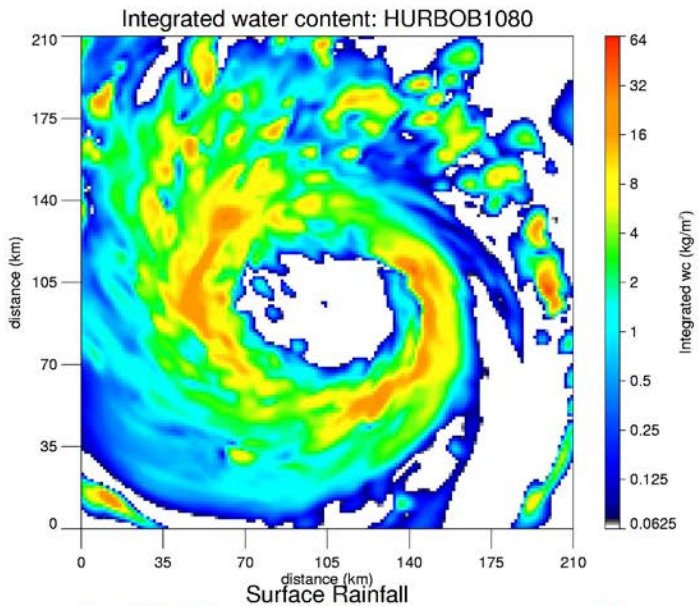
The non-homogeneous footprint dilemma

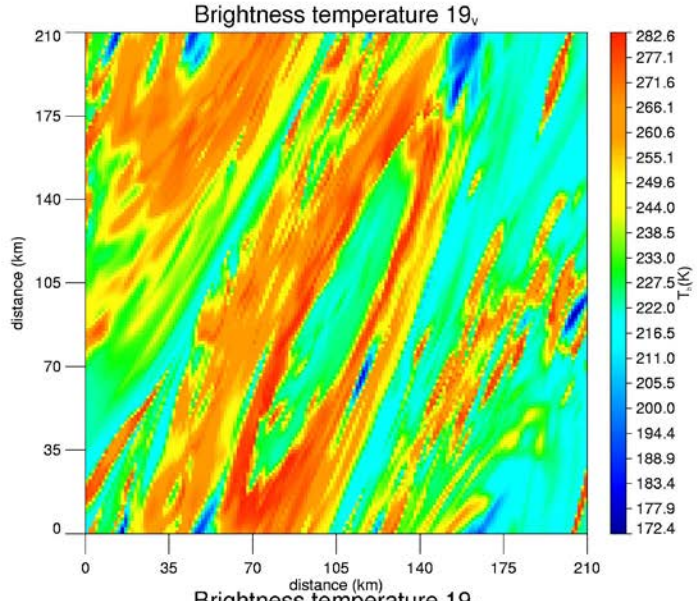


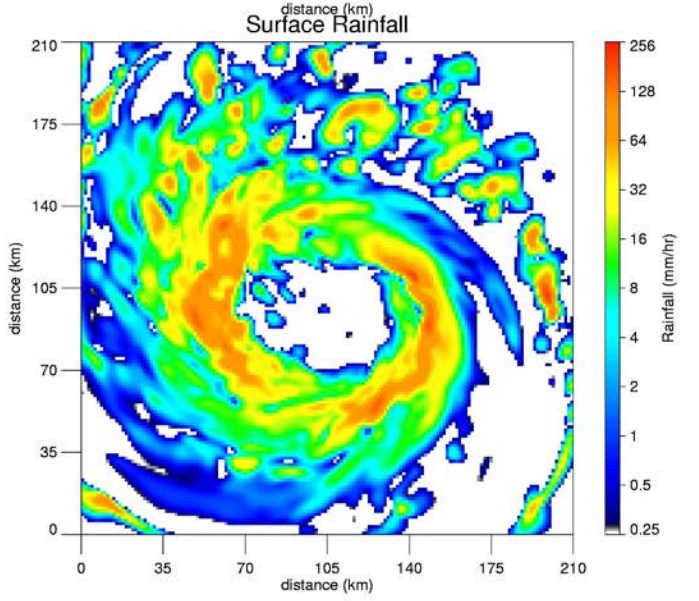
Obs. of 196K = 12.5 mm/hr

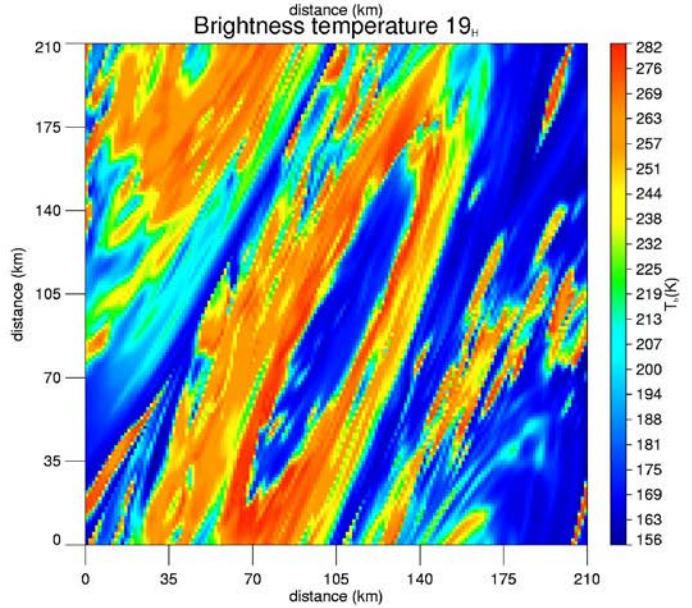
0.5 FOV of 25 mm/hr = 212K
0.5 FOV of 0 mm/hr = 144K
Avg. FOV Tb = 178K
Avg. FOV Rain = 12.5 mm/hr

Obs. of 178K = 7 mm/hr


Integrated water content: HURBOB1080
distance (km)
0
35
70
105
140
175
210
Integrated wc (kg/m²)
64
32
16
8
4
2
1
0.5
0.25
0.125
0.0625


Brightness temperature 19v
distance (km)
0
35
70
105
140
175
210
Tb(K)
282.6
277.1
271.6
266.1
260.6
255.1
249.6
244.0
238.5
233.0
227.5
222.0
216.5
211.0
205.5
200.0
194.4
188.9
183.4
177.9
172.4


Surface Rainfall
distance (km)
0
35
70
105
140
175
210
Rainfall (mm/hr)
256
128
64
32
16
8
4
2
1
0.5
0.25


Brightness temperature 19H
distance (km)
0
35
70
105
140
175
210
Tb(K)
282
276
269
263
257
251
244
238
232
225
219
213
207
200
194
188
181
175
169
163
156

Tropical Rainfall Measuring Mission (TRMM)

NASDA
NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

TRMM Sensors

Nov. 1997 launch, 35° inclination; 402 km

Precipitation radar (PR):

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

Microwave radiometer (TMI):

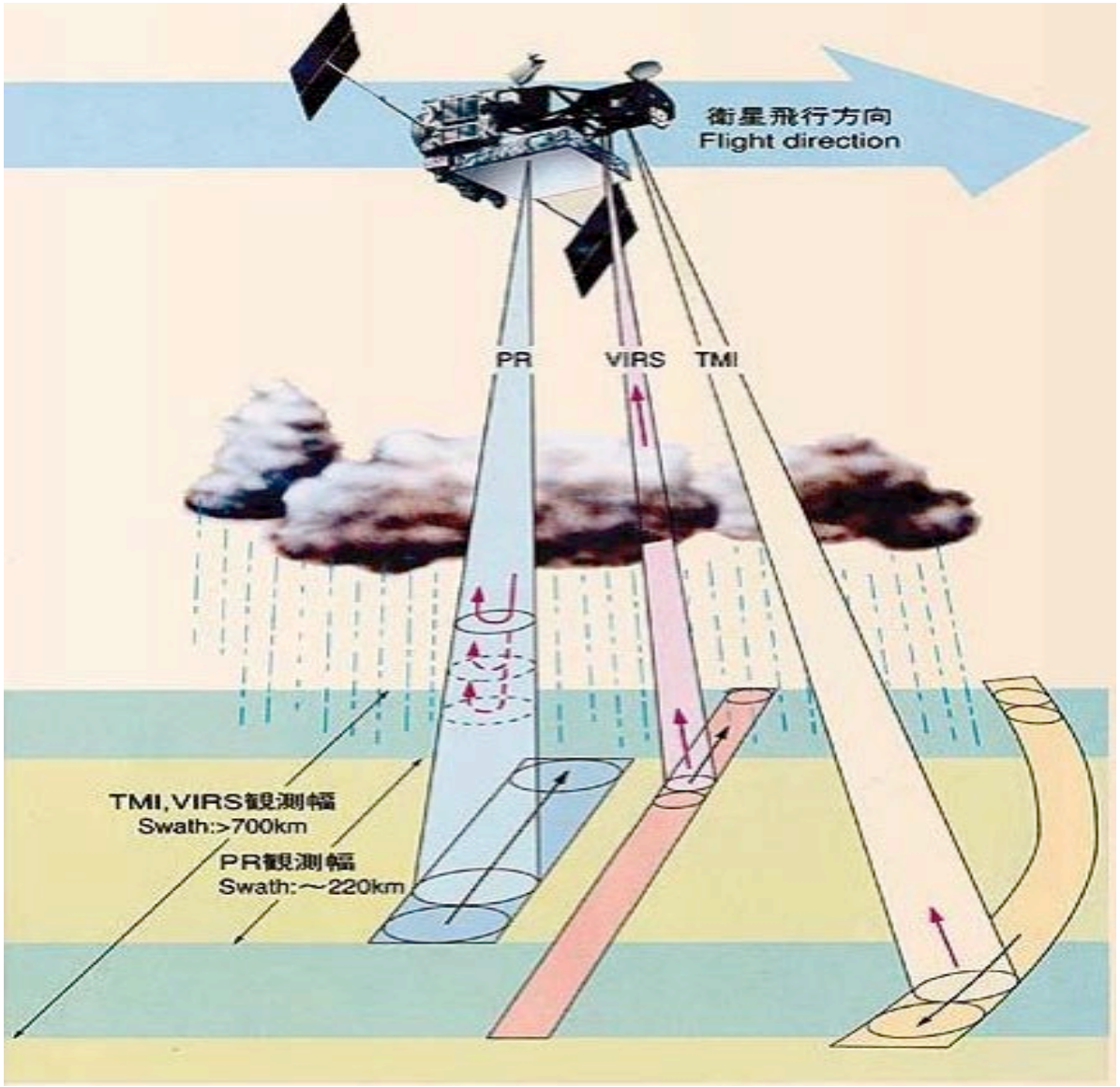
- 10.7, 19.3, 21.3, 37.0
- 85.5 GHz (dual polarized
- except for 21.3 V-only)
- 10x7 km FOV at 37 GHz
- 760 km swath

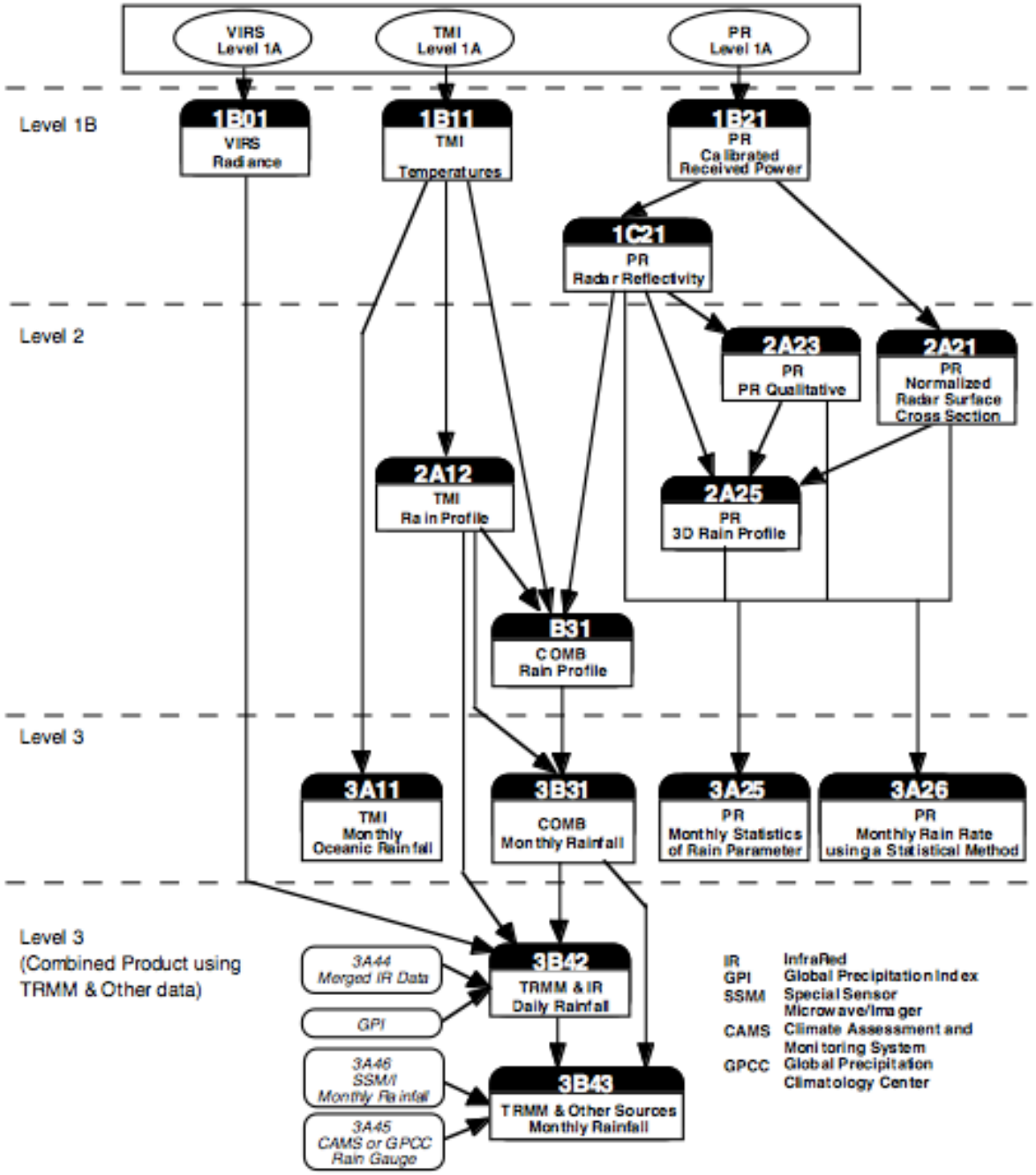
Visible/infrared radiometer (VIRS):

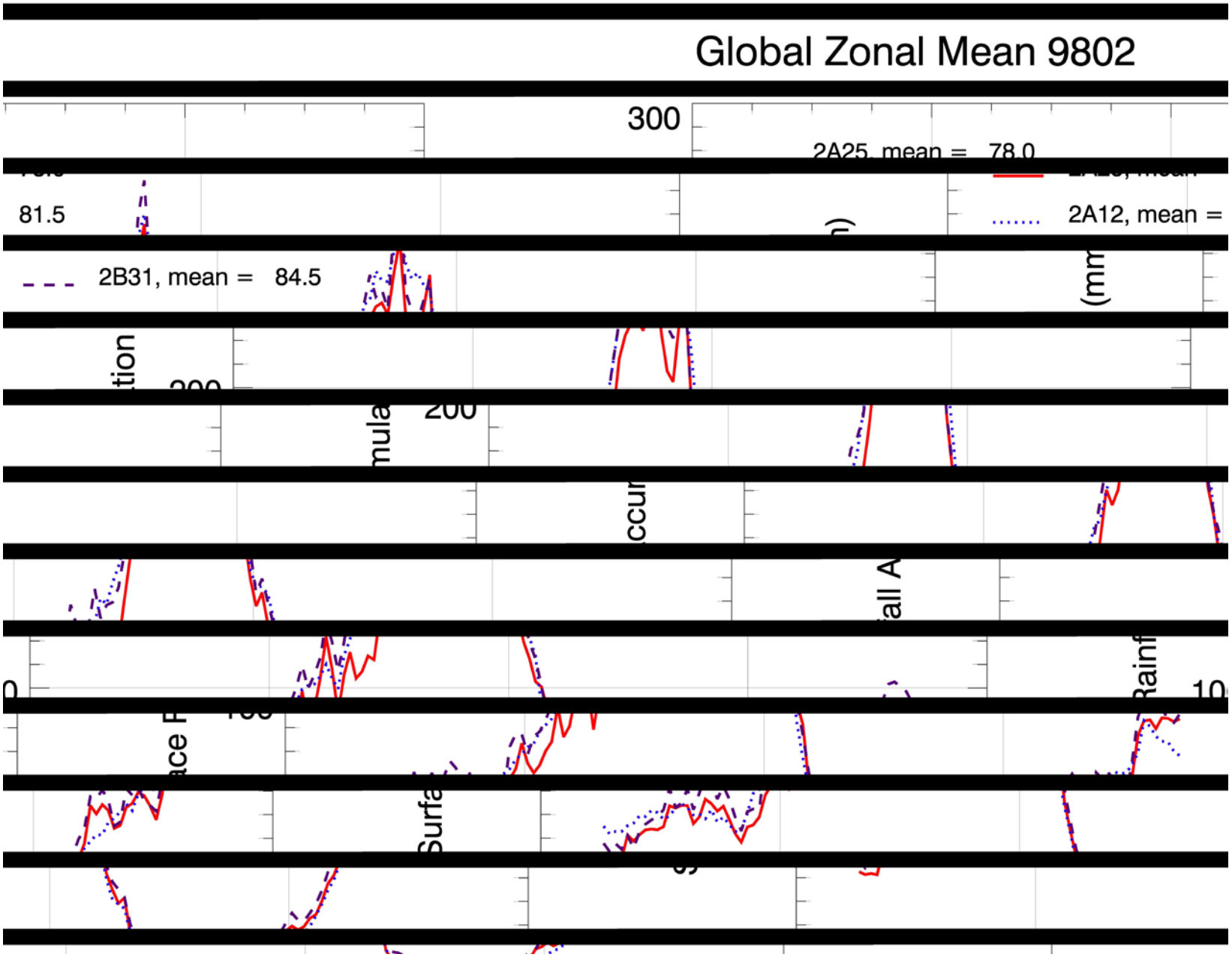
- 0.63, 1.61, 3.75, 10.8, and 12 :m
- at 2.2 km resolution

Lightning Imaging Sensor (LIS)

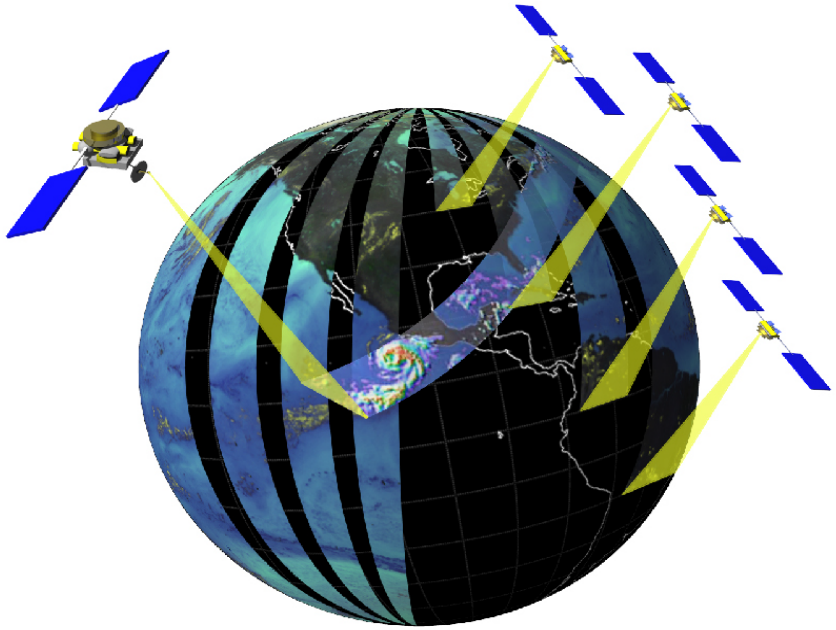
Cloud & Earth Radiant Energy System (CERES)




VIRS Level 1A
TMI Level 1A
PR Level 1A
Level 1B
1B01 VIRS Radiance
1B11 TMI Temperatures
1B21 PR Calibrated Received Power
1C21 PR Radar Reflectivity
Level 2
2A23 PR PR Qualitative
2A21 PR Normalized Radar Surface Cross Section
2A12 TMI Rain Profile
2A25 PR 3D Rain Profile
2B31 COMB Rain Profile
Level 3
3A11 TMI Monthly Oceanic Rainfall
3B31 COMB Monthly Rainfall
3A25 PR Monthly Statistics of Rain Parameter
3A26 PR Monthly Rain Rate using a Statistical Method
Level 3 (Combined Product using TRMM & Other data)
3A44 Merged IR Data
GPI
3A46 SSM/I Monthly Rainfall
3A45 CAMS or GPCC Rain Gauge
3B42 TRMM & IR Daily Rainfall
3B43 TRMM & Other Sources Monthly Rainfall
IR InfraRed
GPI Global Precipitation Index
SSMI Special Sensor Microwave/Imager
CAMS Climate Assessment and Monitoring System
GPCC Global Precipitation Climatology Center


Global Zonal Mean 9802
300
2A25, mean = 78.0
2A12, mean =
81.5
2B31, mean = 84.5
200

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

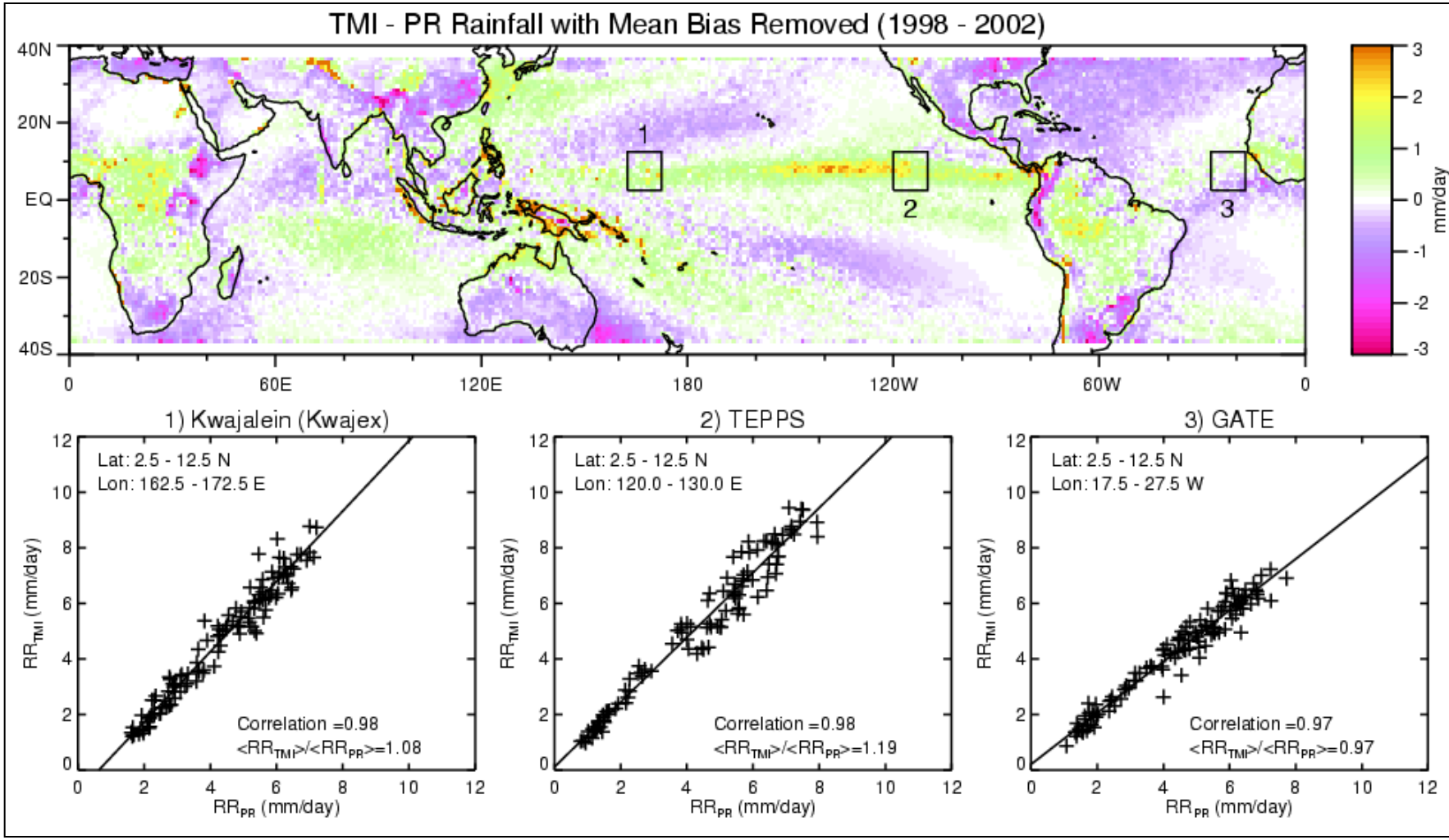
- 8 small satellites with microwave radiometer only*
- 3 hr revisit time
- Sun-synchronous polar orbit
- ~ 600 km altitude

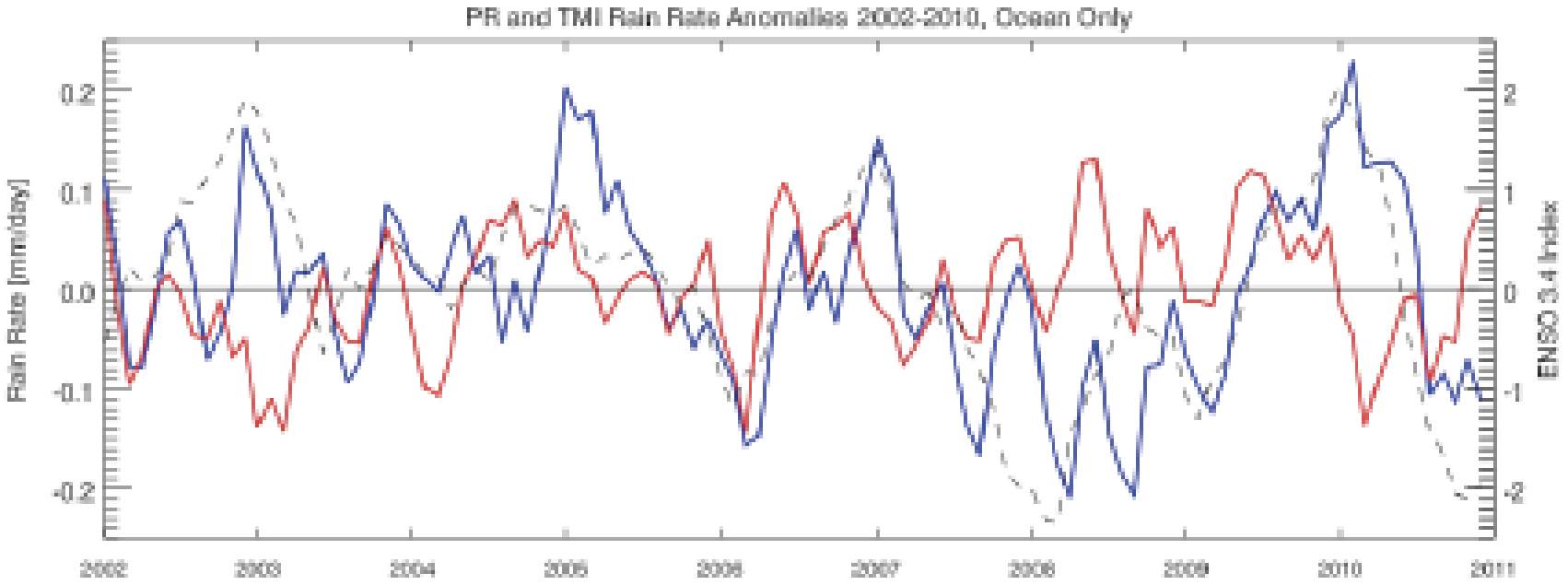
*Some of the 8 small satellites may be replaced by existing radiometers (e.g., SSM/Is, AMSR, etc.)

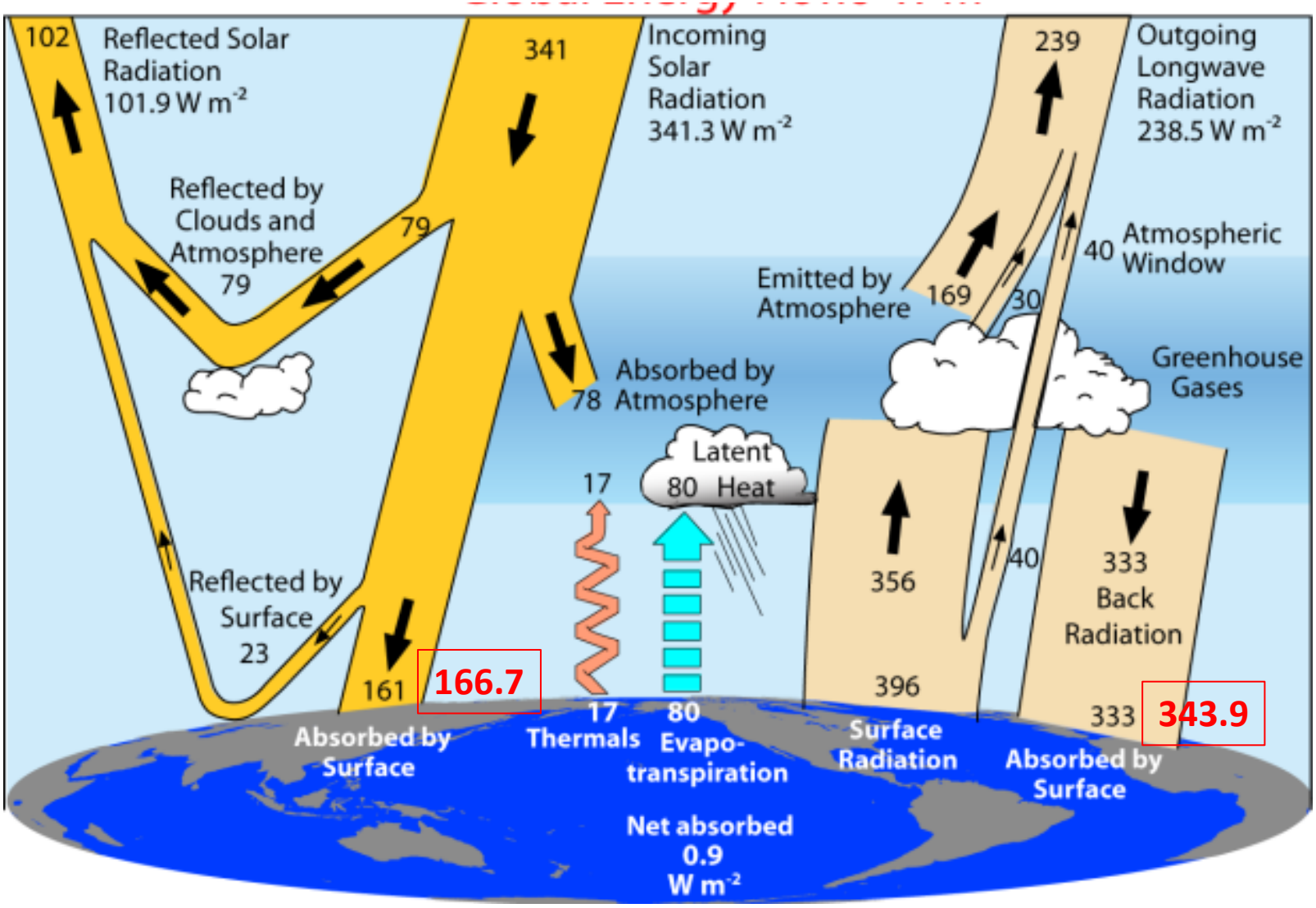
MISSION: Provide enough sampling to reduce uncertainy in short-term rainfall accumulations. Extend scientific and societal applications.

PR/TMI Rainfall Differences

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




PR and TMI Rain Rate Anomalies 2002-2010, Ocean Only
Rain Rate [mm/day]
0.2
0.1
0.0
-0.1
-0.2
ENSO 3.4 Index
2
1
0
-1
-2
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011


102
Reflected Solar Radiation 101.9 W m-2
341
Incoming Solar Radiation 341.3 W m-2
239
Outgoing Longwave Radiation 238.5 W m-2
Reflected by Clouds and Atmosphere 79
79
40 Atmospheric Window
Emitted by Atmosphere
169
30
Greenhouse Gases
Absorbed by Atmosphere 78
Latent 80 Heat
17
356
40
333 Back Radiation
Reflected by Surface 23
161
166.7
396
333
343.9
Absorbed by Surface
17 Thermals
80 Evapo-transpiration
Surface Radiation
Absorbed by Surface
Net absorbed 0.9 W m-2

GEWEX Integrated Products

Global Energy and Water Exchanges Project

GEWEX WCRP

Common Ancillary Data

ISCCP

Aerocom

GLOBAL PRECIPITATION CLIMATOLOGY CENTRE

+

GPCP

SURFACE RADIATION BUDGET

Validation

BSRN

SEAFLUX

Validation

Buoys/Ships

LandFLUX

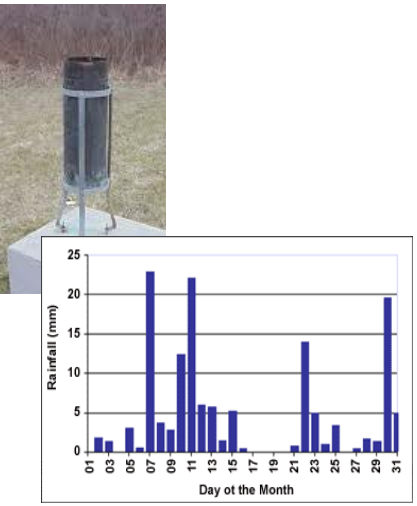
Validation

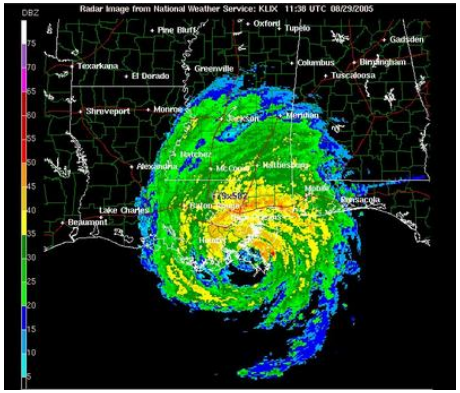
Towers

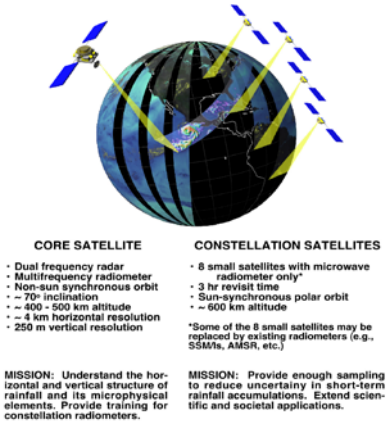
Common Output w. Uncertainty

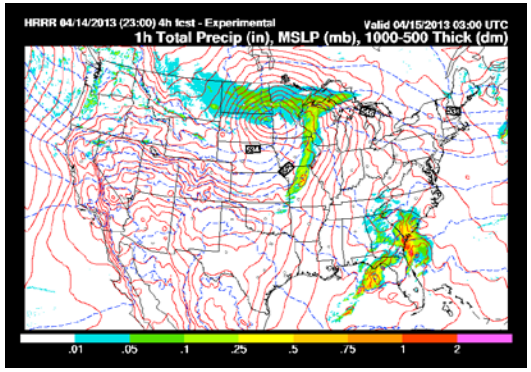
CIRA's effort in Rainfall Data Fusion

Optimal Estimation of Precipitation from Gauges, Radars, Satellites and Models









Gauges

- NOAA operated gauge networks
- Community Cooperative Rain Hail & Snow Network

Radars

- Strong involvement via NOAA Physical Sciences Division (PSD) HMT
- Connection with ATS and ECE

Satellites

- Strong involvement in Mission definition and algorithm development

Models

- Strong involvement in model development at NOAA Global Modeling Division (GMD)

The data fusion effort is one that begins to link the various components into a single estimation framework intended to (a) provide the best possible precipitation for applications as well as (b) diagnosing model processes that will help improve model parameterizations leading to improved forecasts.