Rainfall Monitoring

Prospects for a synergistic approach between models and observations

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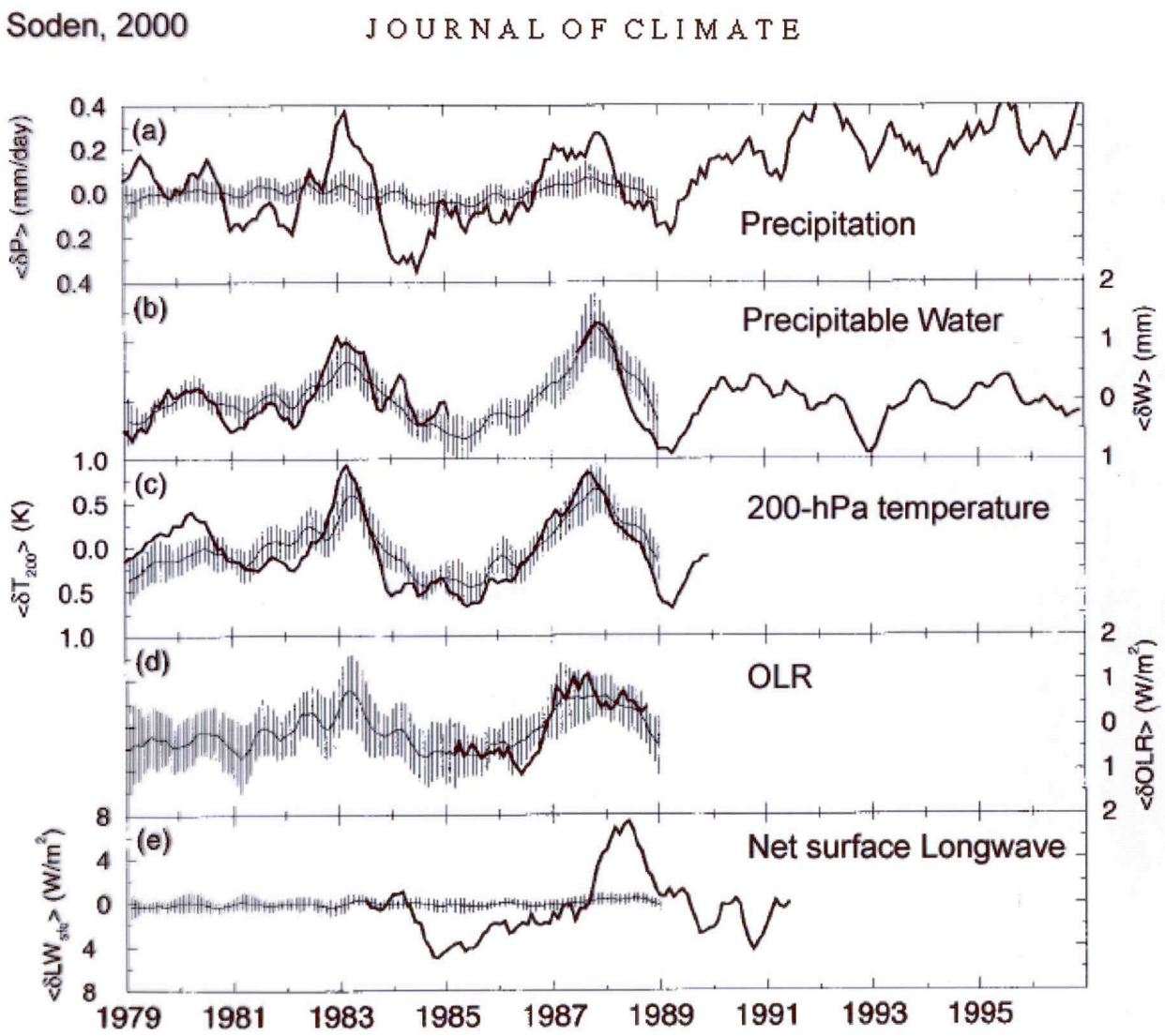
Workshop on the Future of Cloud Parameterizations, Princeville, Kauai. May 9, 2003.

Climate Models



The Problem(s)

- Rainfall Measurements - how accurate are they ?

  It is hard to find decent validation data to compare to

  When we find data, it is hard to do intelligent comparisons

  When we do the intelligent comparisons, we still can't get uncertainties

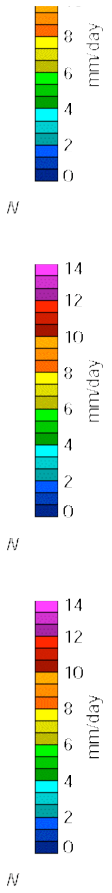
- Cloud Resolving Models

  It is hard to find decent validation data to compare to

  When we find data, it is hard to do intelligent comparisons

  When we do the intelligent comparisons, it is not clear what we do with the results except to tell the model developers about the differences. They ignore us because of (a) & (b) and because the differences may not be systemic but merely an issue with the realization,and besides, they have plenty to do.

GPI/MSU/SSM/I


14
12
10
8
6
4
2
0
mm/day
N
14
12
10
8
6
4
2
0
mm/day
N
14
12
10
8
6
4
2
0
mm/day
N

Tropical Rainfall Measuring Mission (TRMM)

Nov. 1997 launch, 35° inclination; 402 km

TRMM Sensors

Precipitation radar (PR):

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

Microwave radiometer (TMI):

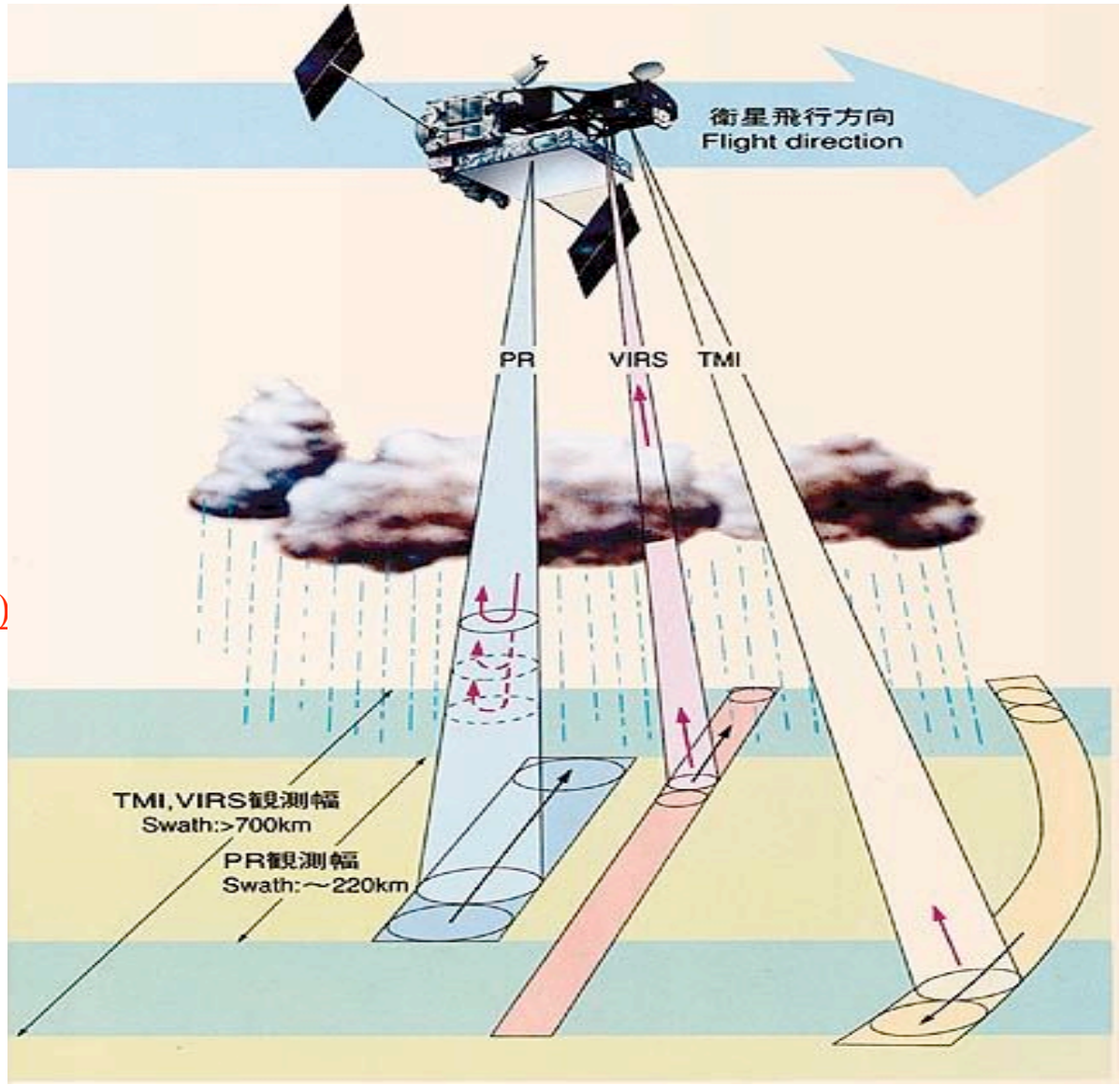
- 10.7, 19.3, 21.3, 37.0
- 85.5 GHz (dual polarized
- except for 21.3 V-only)
- 10x7 km FOV at 37 GHz
- 760 km swath

Visible/infrared radiometer (VIRS)

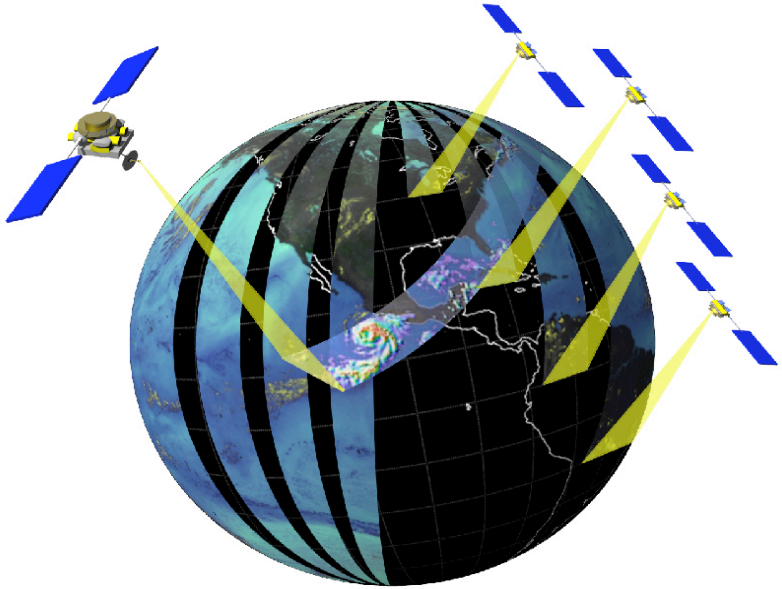
- 0.63, 1.61, 3.75, 10.8, and 12 :m
- at 2.2 km resolution

Lightning Imaging Sensor (LIS)

Cloud & Earth Radiant Energy System (CERES)



The Global Precipitation Mission (~2008)



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

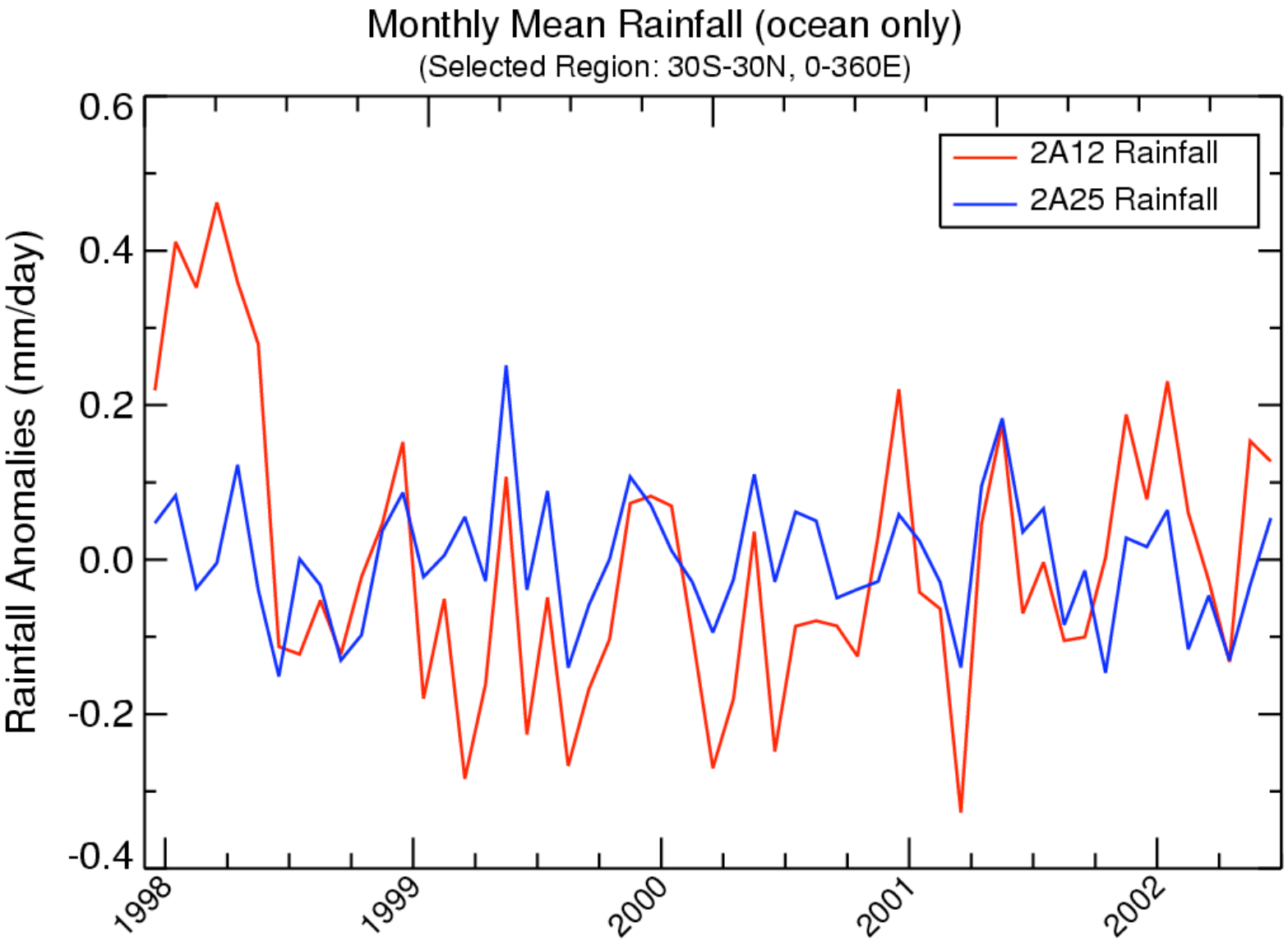
- 8 small satellites with microwave radiometer only*
- 3 hr revisit time
- Sun-synchronous polar orbit
- ~ 600 km altitude

*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.

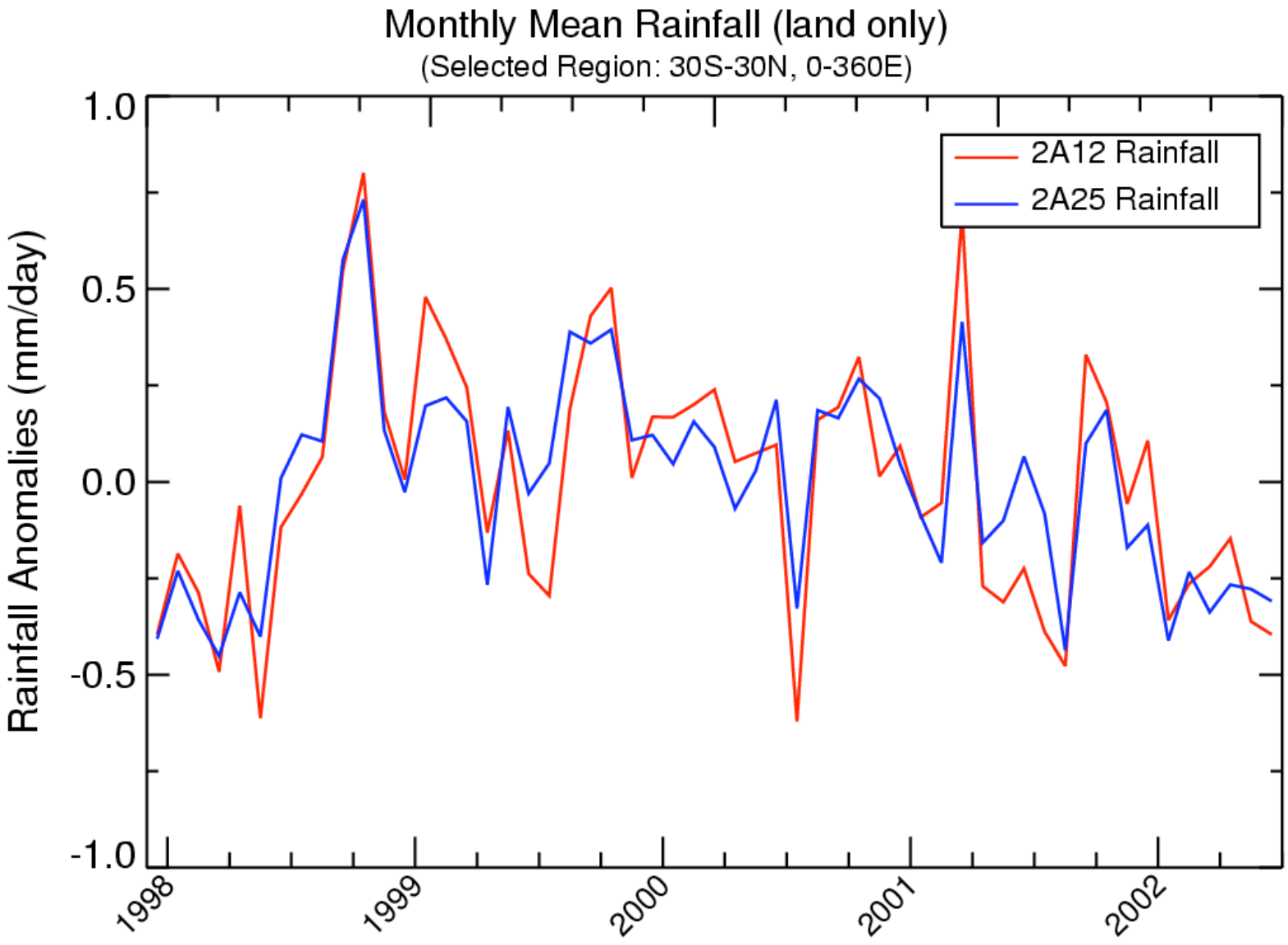
Tropical Rainfall Anomalies

(TRMM Ocean Retrievals)

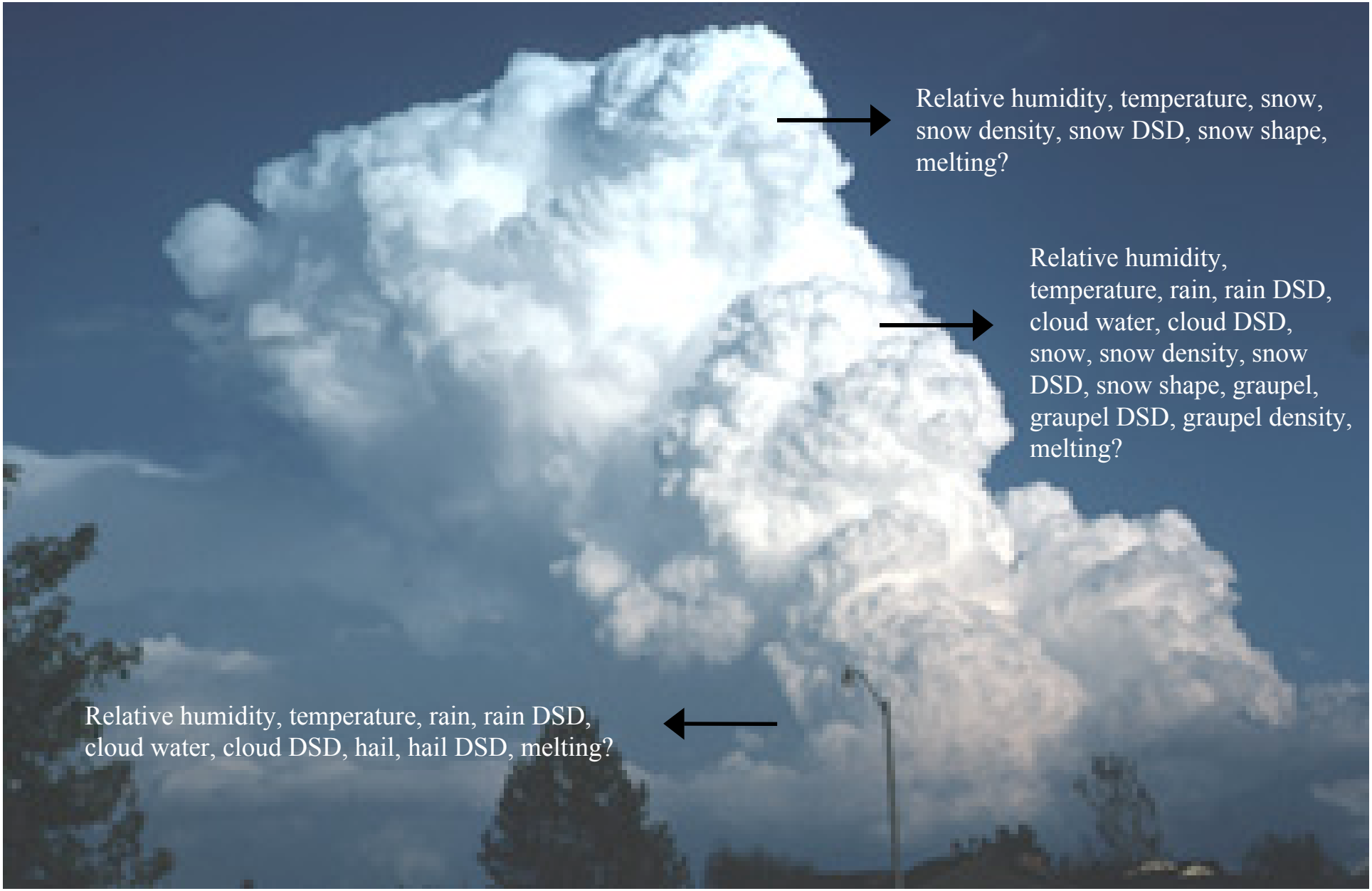


Tropical Rainfall Anomalies

(TRMM Land Retrievals)



Real Clouds are Complicated



Rainfall Retrievals

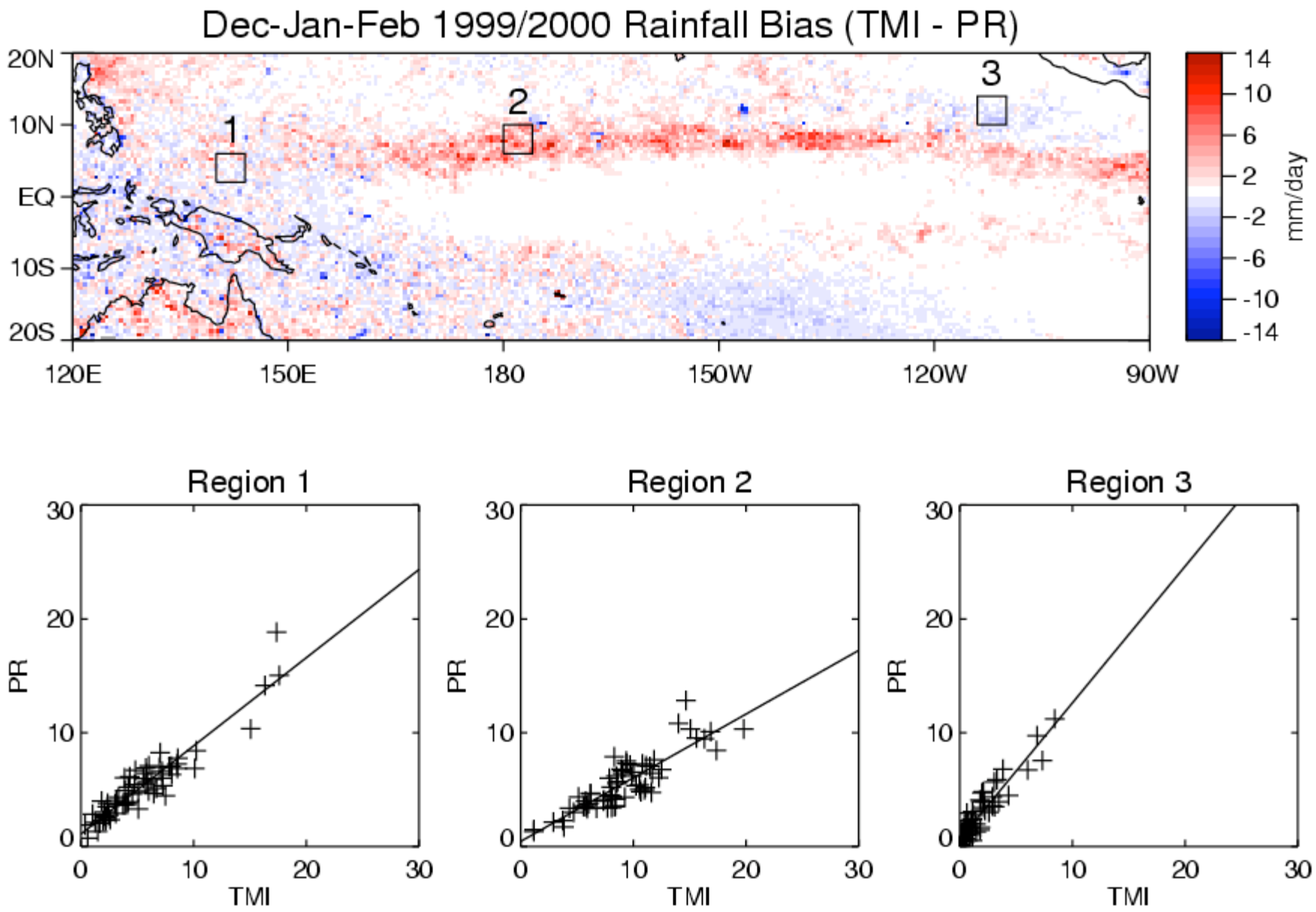
- A cloud resolving model (1.5 km resolution) provides **7840** parameters that affect the upwelling Tb in a typical radiometer FOV (30km).

- Retrievals must make "reasonable" assumptions about some of these parameters, any cross correlations between them, and what sorts of clouds occur in nature. Can use conceptual models or 3-D **C**loud **R**esolving **M**odels. These assumptions can have significant impacts on the retrieved results.

- It has taken the community ~15 years to get these mean assumptions into place such that different sensors (somewhat different assumptions) now agree reasonably well for global scale averages.

- If these mean assumed cloud properties change regionally, or with climate, then the retrievals will differ regionally and over time.

- **Given the significant number of assumptions in the CRMs, one expects them to behave the same way.**


Dec-Jan-Feb 1999/2000 Rainfall Bias (TMI - PR)
20N
10N
EQ
10S
20S
120E
150E
180
150W
120W
90W
1
2
3
14
10
6
2
-2
-6
-10
-14
mm/day
Region 1
Region 2
Region 3
PR
TMI
0
10
20
30

The Validation Problem

- Biases at any one site are fairly meaningless because they represent largely random errors when viewed from a global perspective.
- Aggregate statistics (standard error of the mean and confidence intervals) are treated as independent samples from a population which do not consider the behavior of the "system" as a whole. This causes aggregate statistics to overestimate actual uncertainty at the global (or large regional) scales.

Baroque validation activities have occasionally revealed procedural errors but have been unable to quantify uncertainties needed for climate studies.

CRM validation is currently centered around procedural issues only. Are climate change issues properly accounted for ? (e.g upper level humidity changes the rain efficiency in most CRMs - fact or fiction ?)

Rainfall Validation by Climate Regime

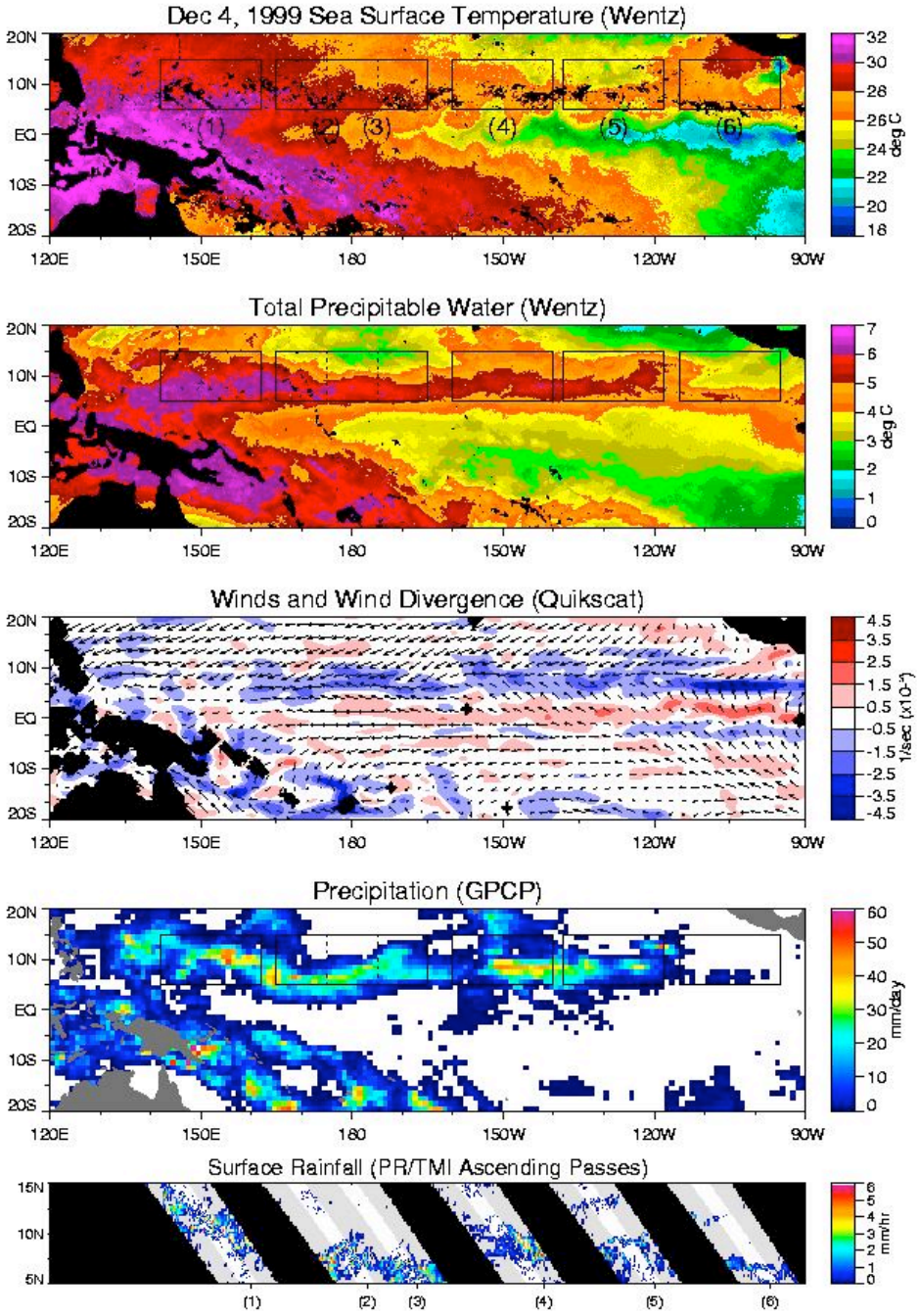
- We have substantial evidence from Field Experiments that cloud structures are consistent within climate regimes

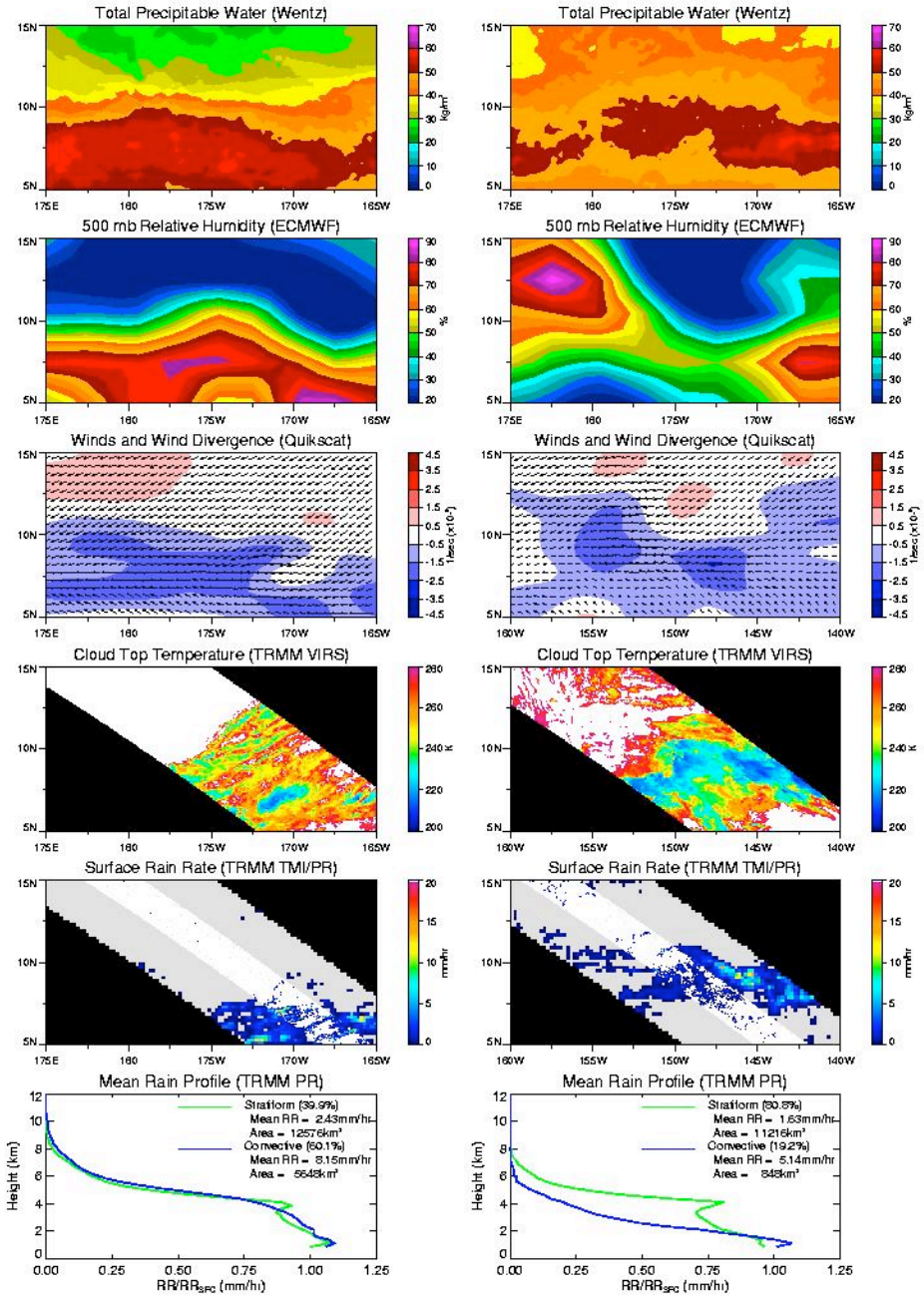
- We have less quantitative but substantial anecdotal evidence that algorithm biases are consistent within climate regimes.

….. but we're not sure how to define these climate regimes.

- By defining climate regimes based upon globally observed atmospheric state parameters, we expect rainfall statistics to show consistent behavior that does not confuse a regional variability with a systematic problem.

….. Quantifying rainfall properties as a function of robust atmospheric state parameters can also lead to the validation of the physical processes of the Cloud Models that do not depend on latitude & longitude.


Dec 4, 1999 Sea Surface Temperature (Wentz)
20N
10N
EQ
10S
20S
120E
150E
180
150W
120W
90W
(1)
(2)
(3)
(4)
(5)
(6)
32
30
28
26
24
22
20
18
deg C
Total Precipitable Water (Wentz)
7
6
5
4
3
2
1
0
deg C
Winds and Wind Divergence (Quikscat)
4.5
3.5
2.5
1.5
0.5
-0.5
-1.5
-2.5
-3.5
-4.5
1/sec (x10-6)
Precipitation (GPCP)
60
50
40
30
20
10
0
mm/day
Surface Rainfall (PR/TMI Ascending Passes)
15N
10N
5N
6
5
4
3
2
1
0
mm/hr


Total Precipitable Water (Wentz)
15N
10N
5N
175E
180
175W
170W
165W
70
60
50
40
30
20
10
0
kg/m²
Total Precipitable Water (Wentz)
15N
10N
5N
175E
180
175W
170W
165W
70
60
50
40
30
20
10
0
kg/m²
500 mb Relative Humidity (ECMWF)
15N
10N
5N
175E
180
175W
170W
165W
90
80
70
60
50
40
30
20
%
500 mb Relative Humidity (ECMWF)
15N
10N
5N
175E
180
175W
170W
165W
90
80
70
60
50
40
30
20
%
Winds and Wind Divergence (Quikscat)
15N
10N
5N
175E
180
175W
170W
165W
4.5
3.5
2.5
1.5
0.5
-0.5
-1.5
-2.5
-3.5
-4.5
1/sec (x10⁻⁵)
Winds and Wind Divergence (Quikscat)
15N
10N
5N
160W
155W
150W
145W
140W
4.5
3.5
2.5
1.5
0.5
-0.5
-1.5
-2.5
-3.5
-4.5
1/sec (x10⁻⁵)
Cloud Top Temperature (TRMM VIRS)
15N
10N
5N
175E
180
175W
170W
165W
280
260
240
220
200
K
Cloud Top Temperature (TRMM VIRS)
15N
10N
5N
160W
155W
150W
145W
140W
280
260
240
220
200
K
Surface Rain Rate (TRMM TMI/PR)
15N
10N
5N
175E
180
175W
170W
165W
20
15
10
5
0
mm/hr
Surface Rain Rate (TRMM TMI/PR)
15N
10N
5N
160W
155W
150W
145W
140W
20
15
10
5
0
mm/hr
Mean Rain Profile (TRMM PR)
Stratiform (39.9%)
Mean RR = 2.43mm/hr
Area = 12576km²
Convective (60.1%)
Mean RR = 8.15mm/hr
Area = 5543km²
Height (km)
12
10
8
6
4
2
0
0.00
0.25
0.50
0.75
1.00
1.25
RR/RR_SFC (mm/hr)
Mean Rain Profile (TRMM PR)
Stratiform (80.8%)
Mean RR = 1.63mm/hr
Area = 11216km²
Convective (19.2%)
Mean RR = 5.14mm/hr
Area = 843km²
Height (km)
12
10
8
6
4
2
0
0.00
0.25
0.50
0.75
1.00
1.25
RR/RR_SFC (mm/hr)

Conclusions

Rainfall to rainfall comparisons by Lat, Lon & Time got us nowhere in validating global satellite rainfall products.

By changing rainfall validation and Cloud Resolving Model assessments to a more physically based parameter space (the atmospheric state parameters) we can make progress on both fronts

A lot of work remains to find what these optimal atmospheric state parameters are.