“State of the art” of satellite rainfall estimation

3-year comparison over South America using gauge data, and estimates from IR, TRMM radar and passive microwave

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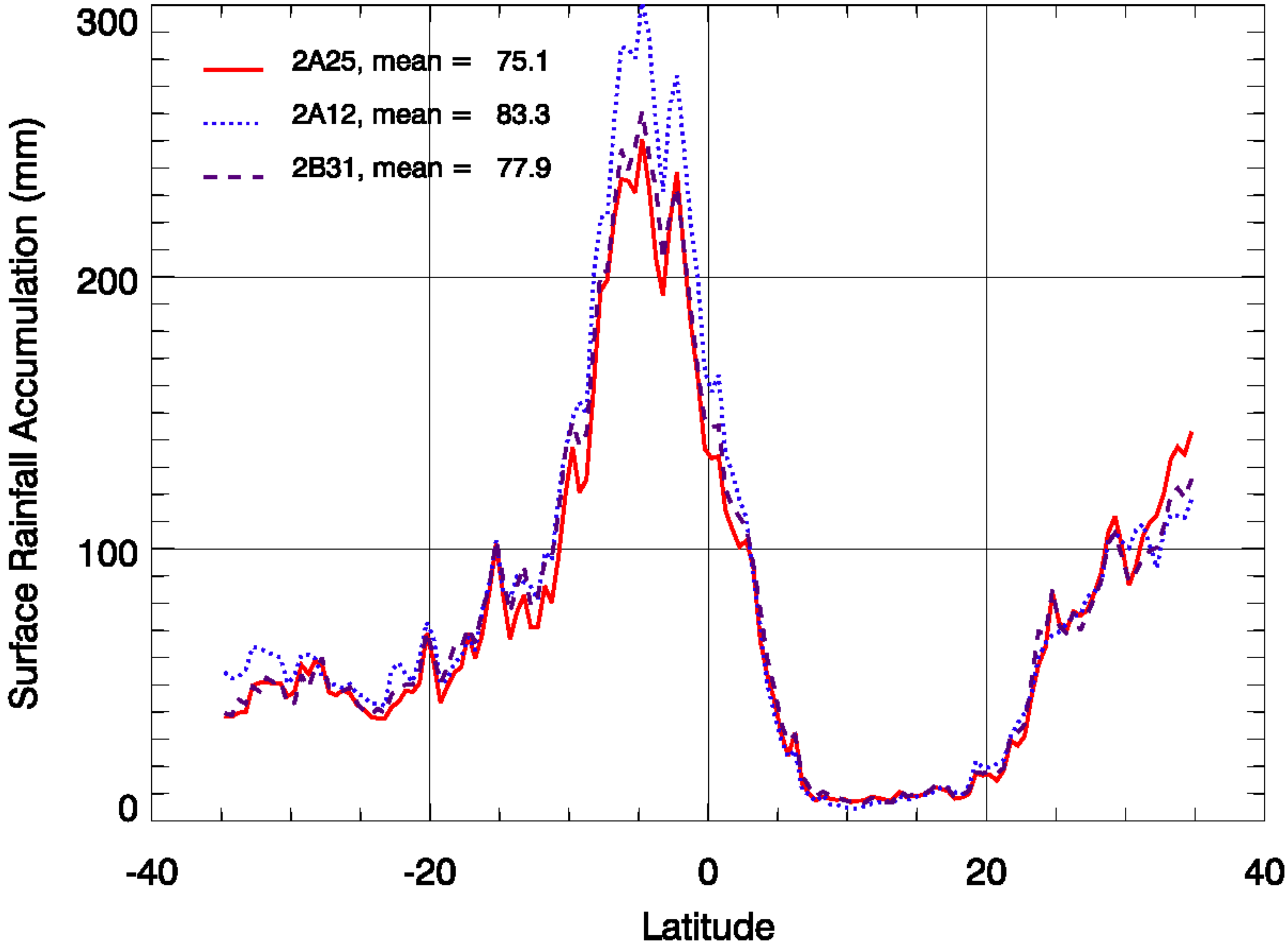
With acknowledgments to Galdino Viana Mota, Stephen Nesbitt, Chris Kummerow, Wesley Berg, and the entire TRMM science team

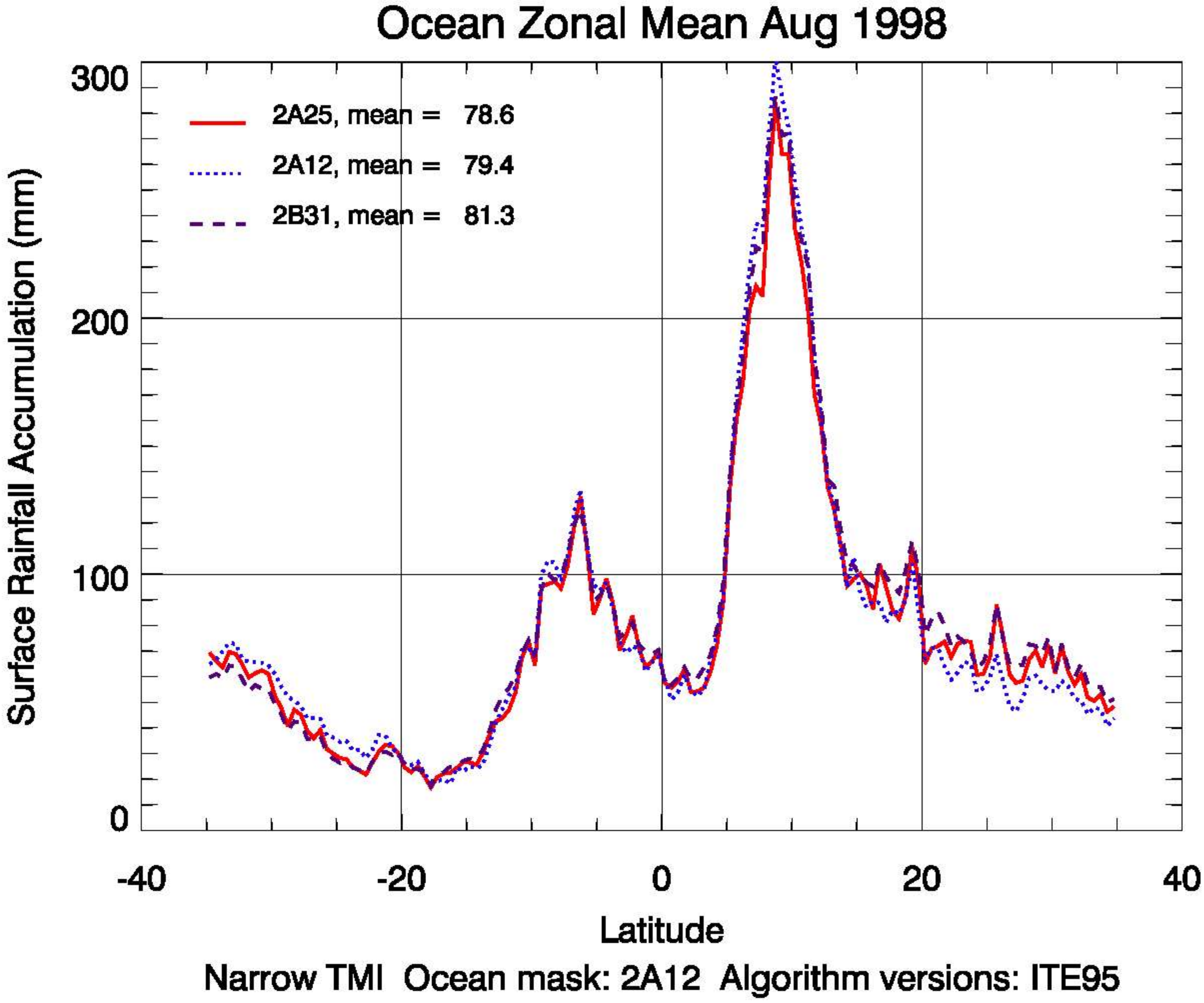
If you believe that IR estimates are OK, you may take a coffee break now.

(Actually, many rainfall estimates are quite accurate if one averages over a sufficiently large space-time domain)

Ocean Zonal Mean Feb 1998



Narrow TMI Ocean mask: 2A12 Algorithm versions: ITE95



Ocean Zonal Mean Aug 1998
2A25, mean = 78.6
2A12, mean = 79.4
2B31, mean = 81.3
Surface Rainfall Accumulation (mm)
300
200
100
0
-40
-20
0
20
40
Latitude
Narrow TMI Ocean mask: 2A12 Algorithm versions: ITE95

Outline of talk

• Compare different algorithms over South America
for the 3-year period Dec 1997 - Nov 2000

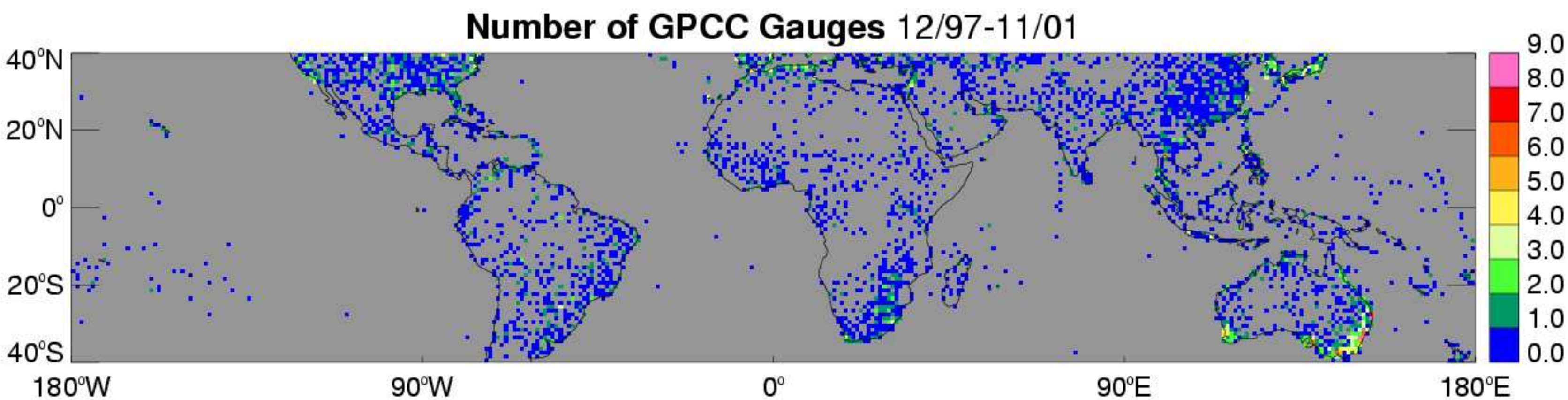
• Demonstrate that some of the differences are functions of type of precipitation system and type of meteorological regime

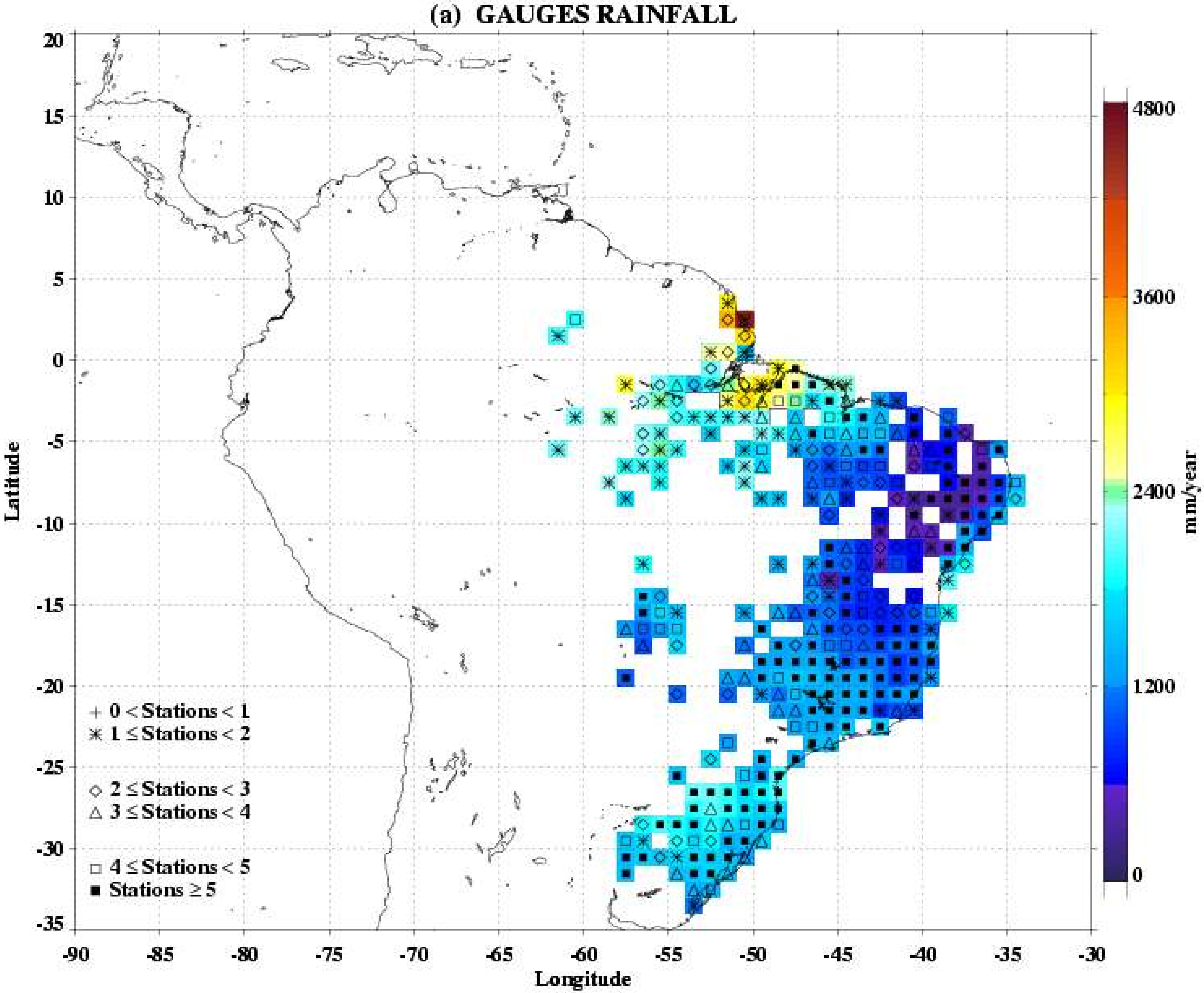
• Summarize a few findings for South America

• Summarize the (unsatisfactory) state of the art

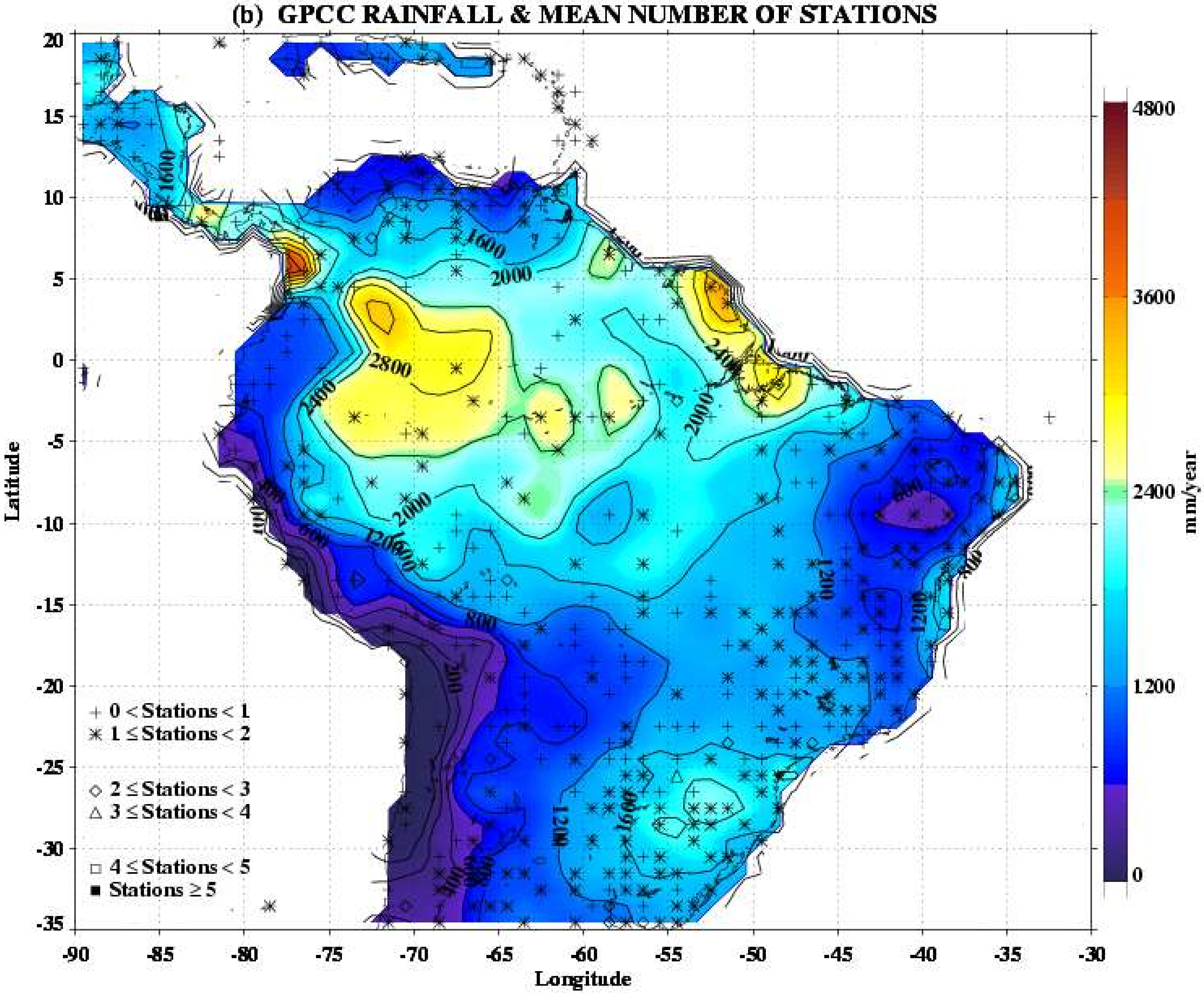
Rain Estimation Issues

- Global gauge coverage is sparse, especially in the deep tropics

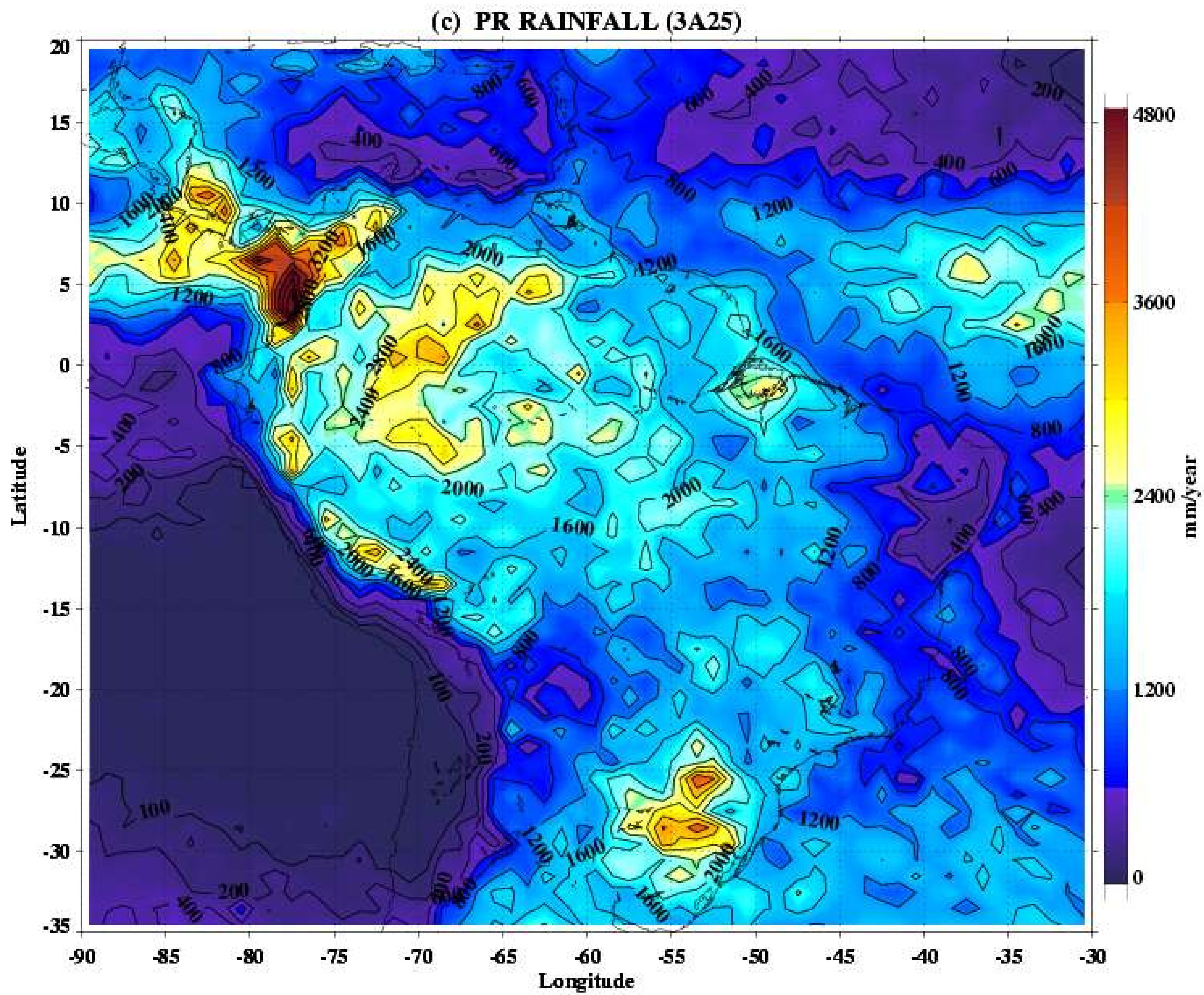




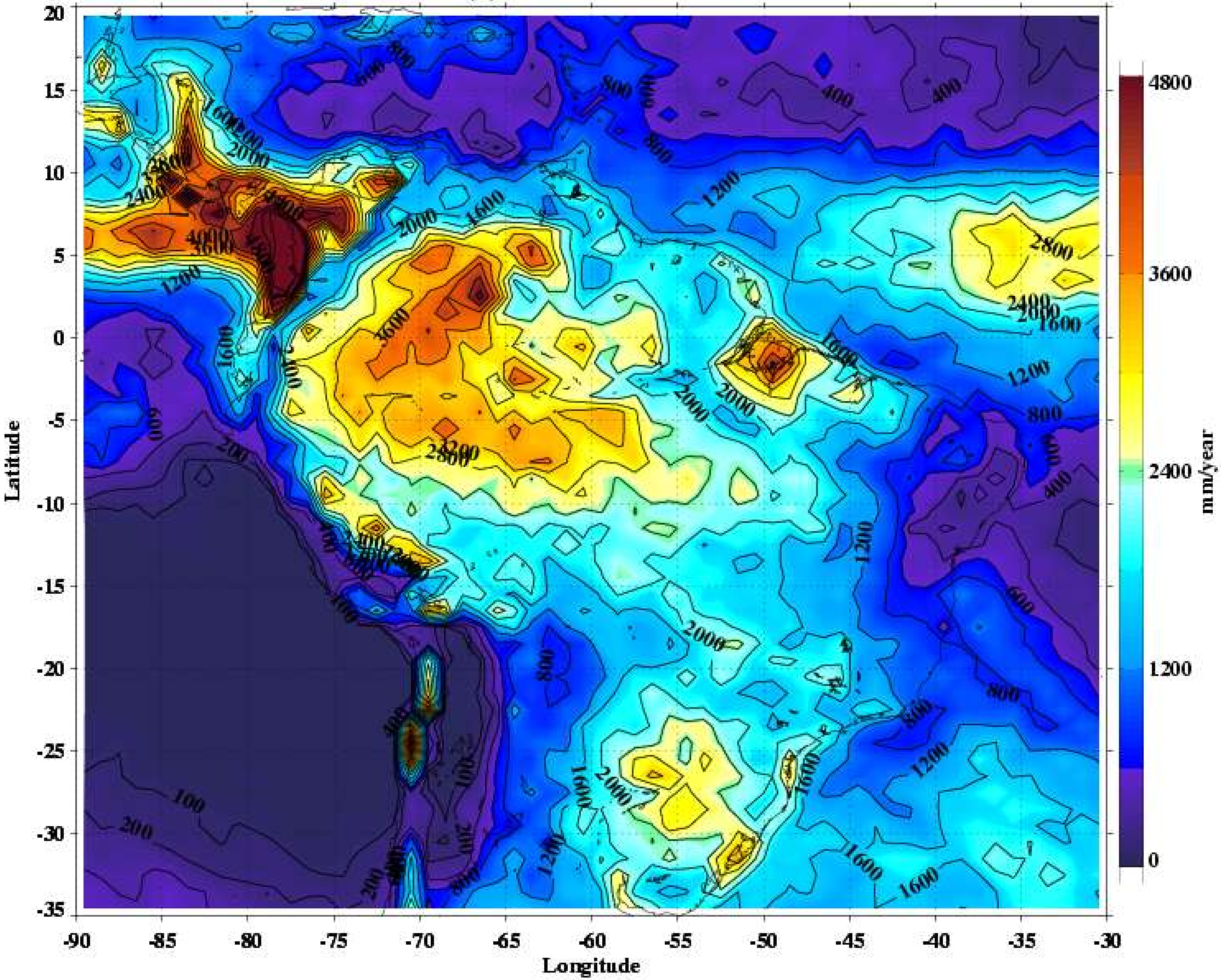
(a) GAUGES RAINFALL
Latitude
Longitude
mm/year
4800
3600
2400
1200
0
+ 0 < Stations < 1
✳ 1 ≤ Stations < 2
◇ 2 ≤ Stations < 3
△ 3 ≤ Stations < 4
□ 4 ≤ Stations < 5
■ Stations ≥ 5

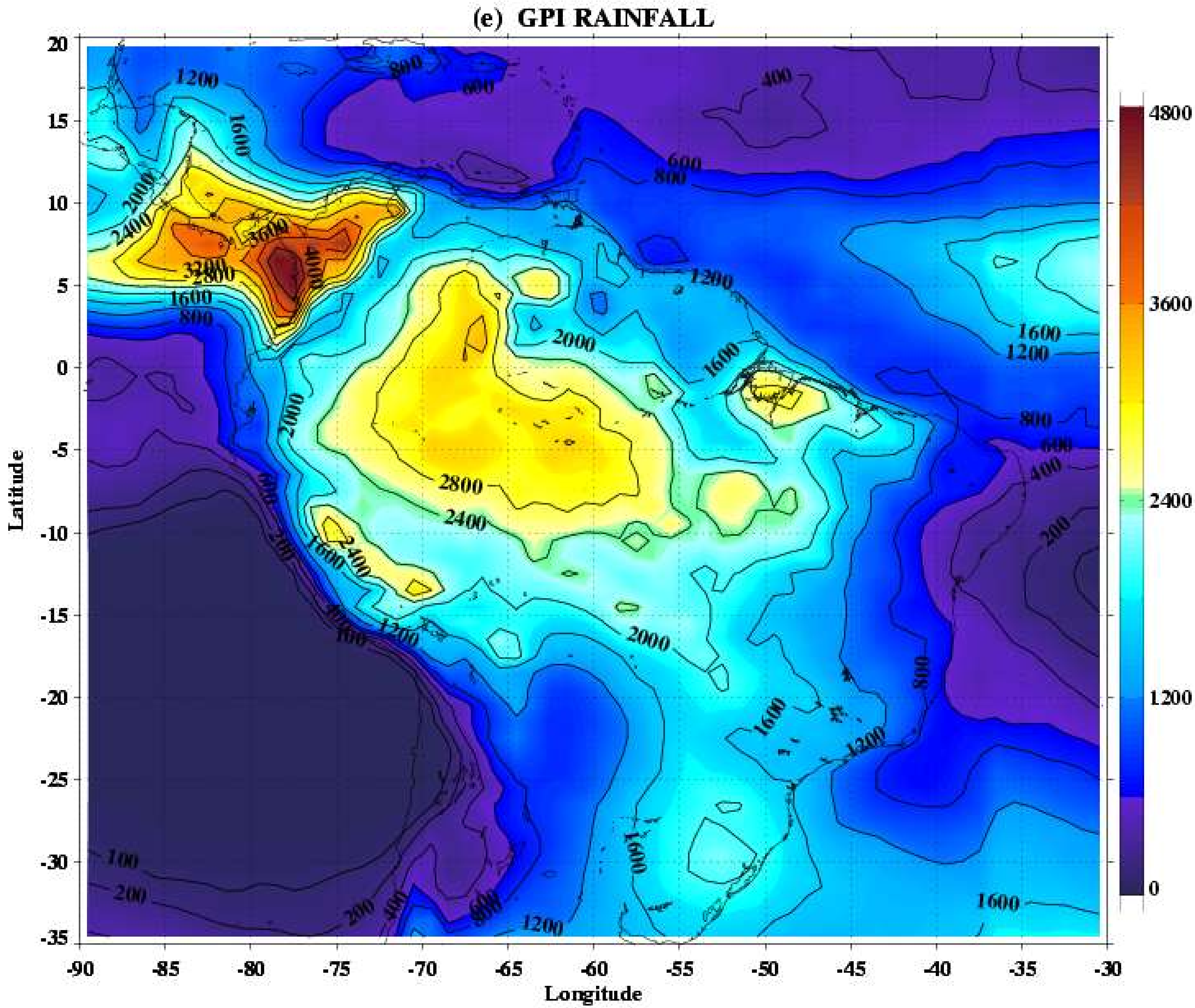


(b) GPCC RAINFALL & MEAN NUMBER OF STATIONS
Latitude
Longitude
mm/year
0 < Stations < 1
1 ≤ Stations < 2
2 ≤ Stations < 3
3 ≤ Stations < 4
4 ≤ Stations < 5
Stations ≥ 5

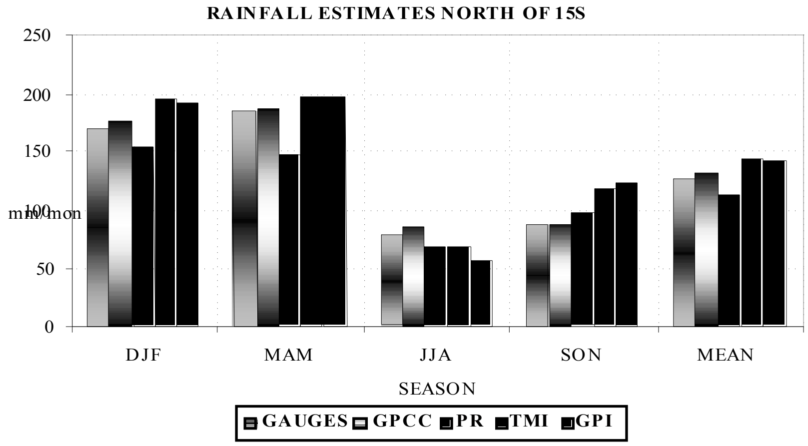

(c) PR RAINFALL (3A25)
Latitude
Longitude
mm/year
4800
3600
2400
1200
0

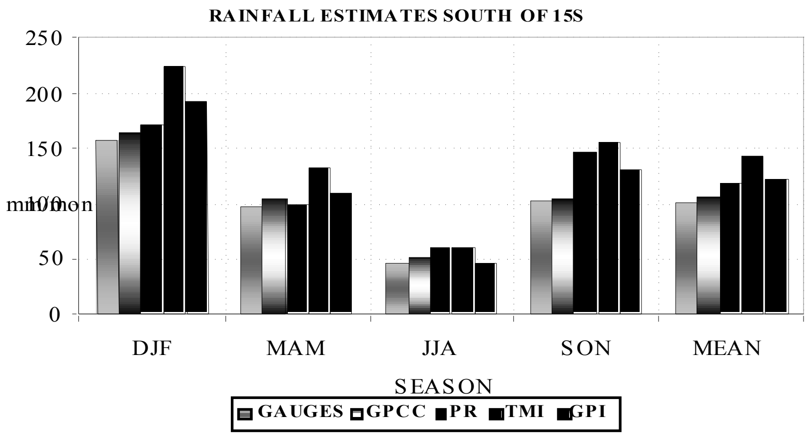
(d) TMI RAINFALL




(e) GPI RAINFALL
Latitude
Longitude
mm/year
4800
3600
2400
1200
0

REGIONAL COMPARISONS FOR S.A. (G.V. Mota, 2003)





SOME LONG-TERM & REGIONAL COMPARISONS

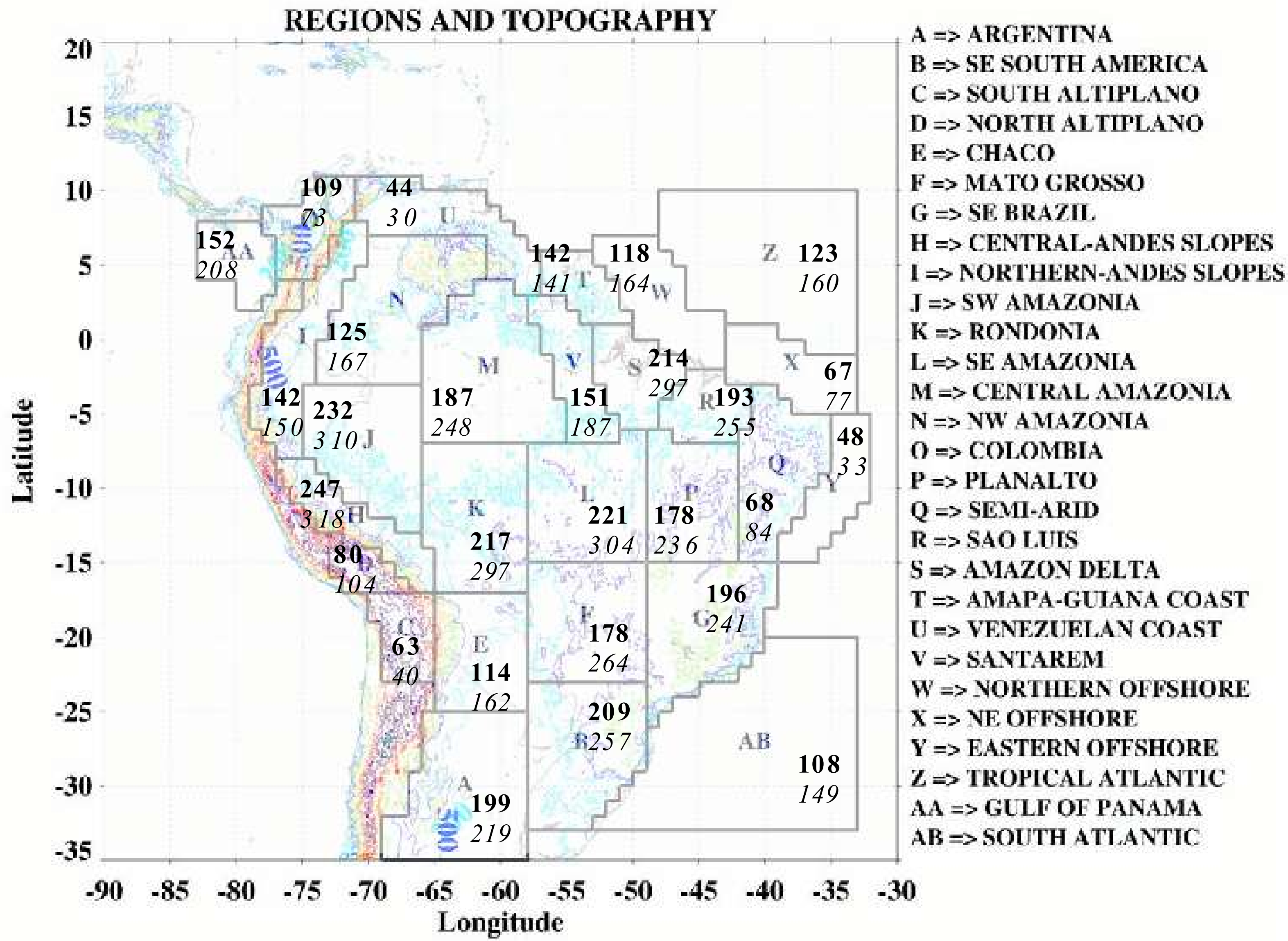
- TMI and GPI are the highest in the regions of maximum rainfall (higher than the PR and the gauges)

- GPCC misrepresents rainfall maximum (comparing with the climatologies) in the regions with lack of stations.

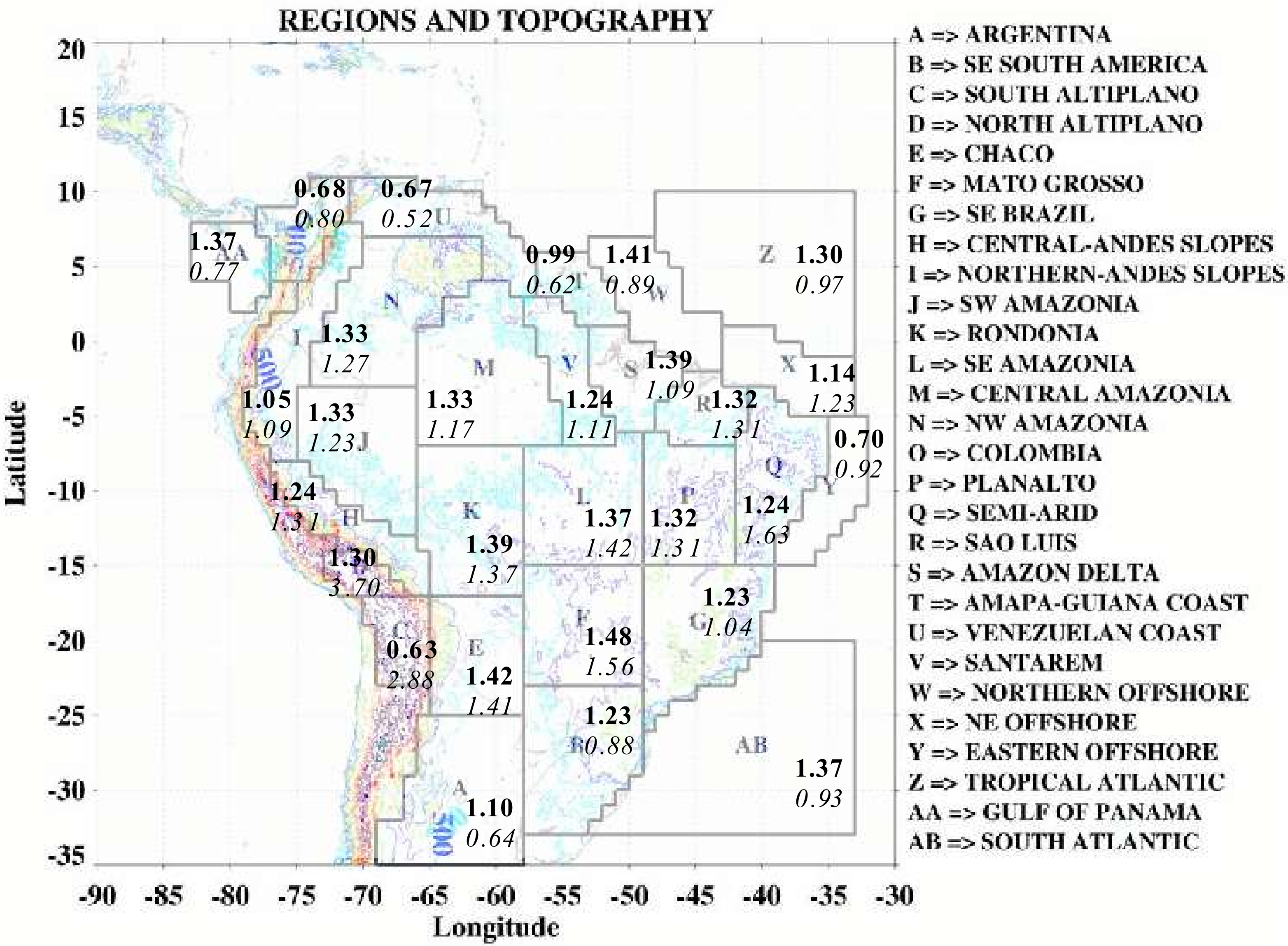
- Good qualitative agreement is found between PR and the Climatologies showing the position of rainfall maxima.

- PR estimates are a little lower than gauges in the tropics and a little higher than gauges in the subtropics.

DJF 3-YR Average Monthly Rain (mm) $\frac{\textbf{PR}}{\textit{TMI}}$



DJF 3-YR Average $\frac{\textbf{TMI / PR}}{GPI\ /\ PR}$



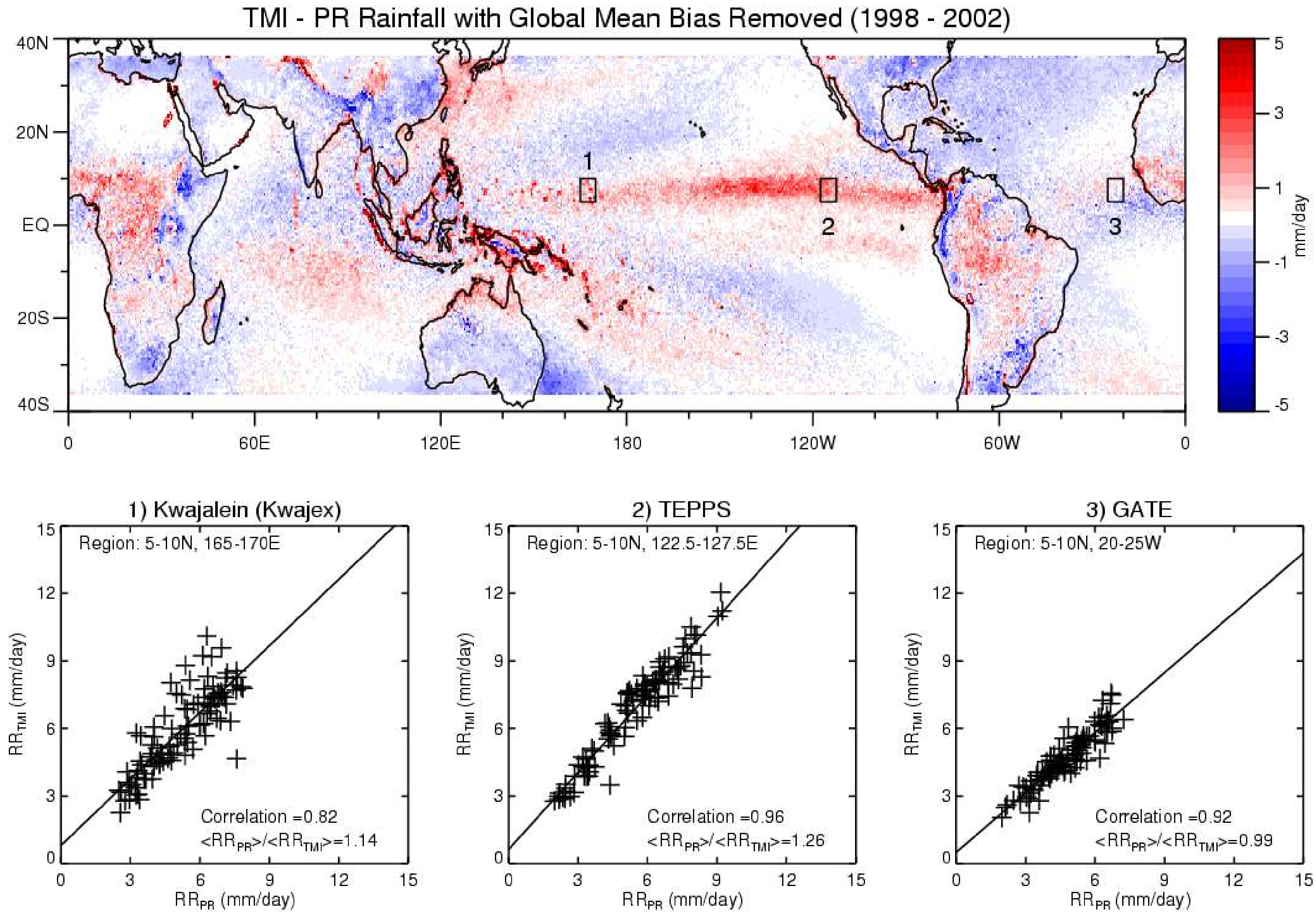
• There is every reason to believe that the biases between estimation methods are strong functions of the meteorological regime.

• Therefore, we have chosen to subdivide the precipitation into specific features (PFs), and to classify them according to their properties

• First step: analyze mesoscale convective systems (MCSs) and compare their properties with smaller
and less organized systems

PR/TMI Global Difference Map
(1998 – 2002 from 3G68 Dataset)

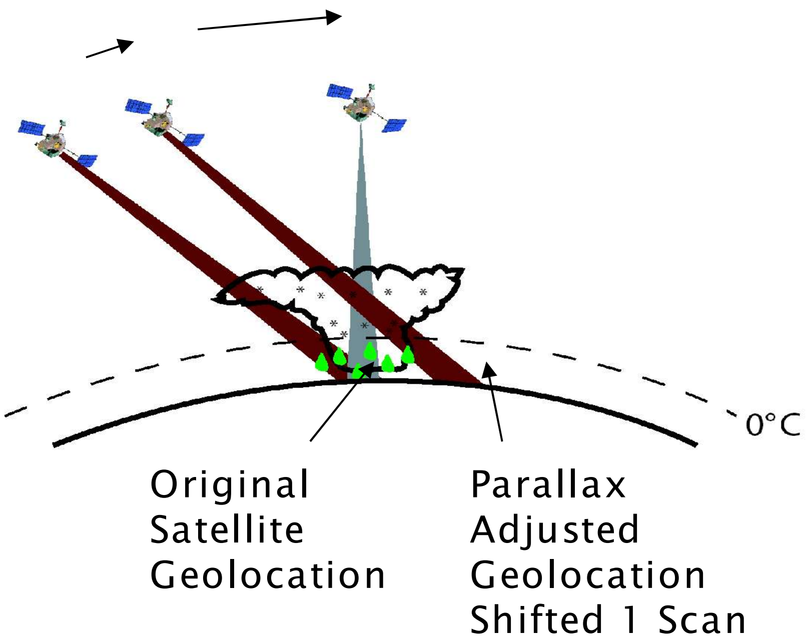
(courtesy Wesley Berg)



The Precipitation Feature Algorithm

- The PF algorithm was originally designed to synergize the TRMM PR, TMI, and LIS data to identify and classify storms by their size and intensity within the PR swath (Nesbitt et al. 2000)
- PR and TMI pixels are matched using a nearest neighbor technique, adjusting for parallax

The Parallax Problem



Precipitation Features

What is a precipitation feature?

Contiguous area at least 4 pixels in size (75 km^2) with:

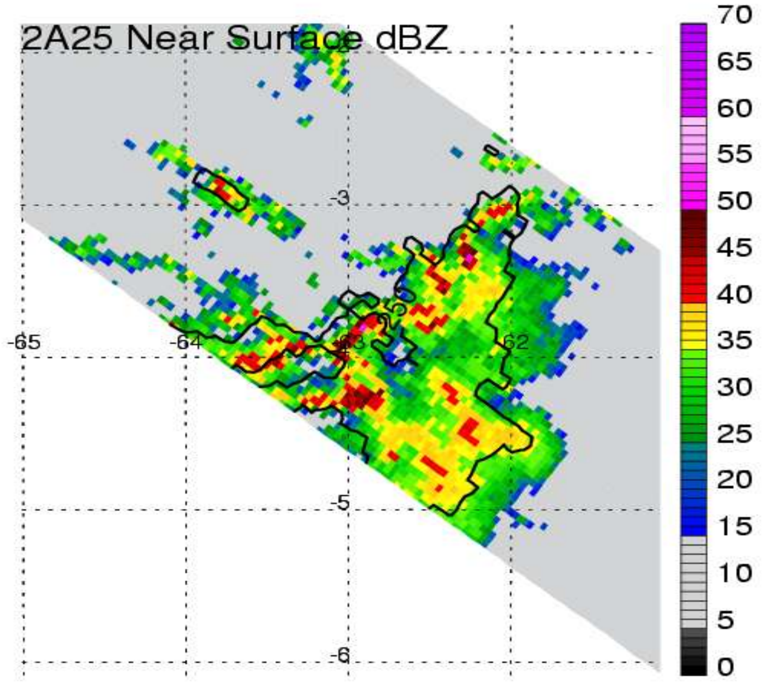
PR "near surface" reflectivity ≥ 20 dBZ

(identify near surface rain)

or

TMI 85 GHz PCT ≤ 250 K

(identify anvils and be consistent with previous work using the SSM/I, e.g. Mohr and Zipser 1996)



Classification of Precipitation Features (PFs)

PF without Ice Scattering (NI)

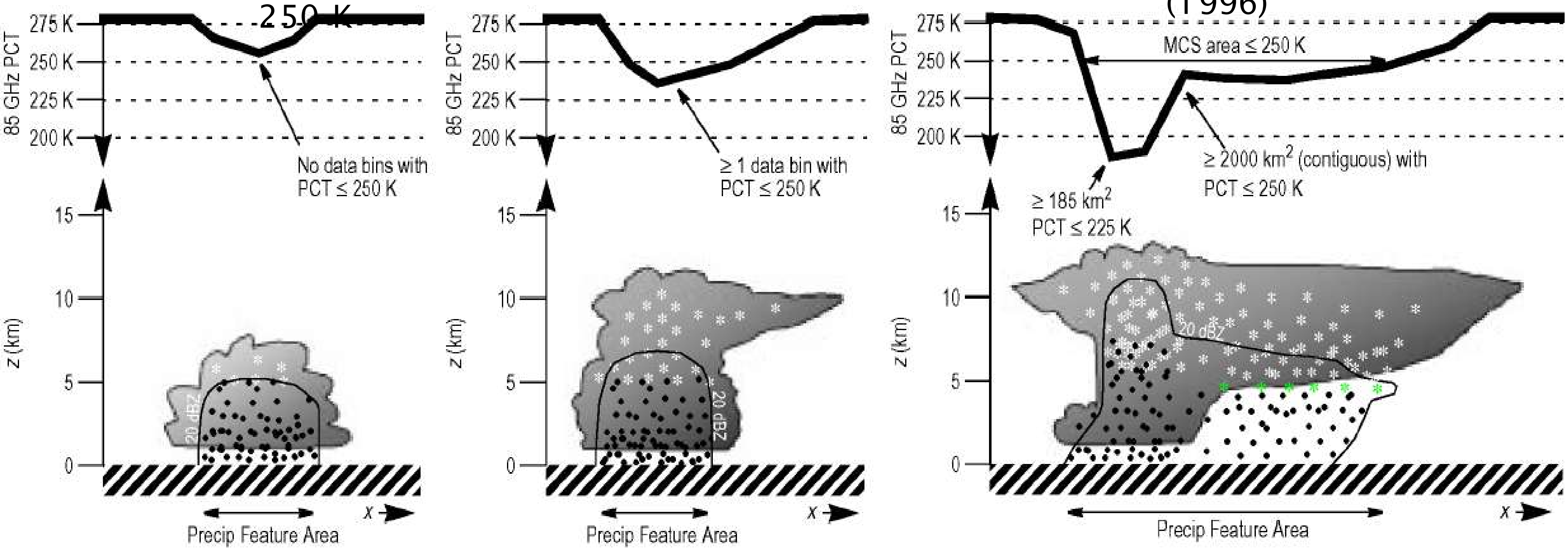
- No pixels with 85 PCT ≤ 250 K

PF with Ice Scattering (WI)

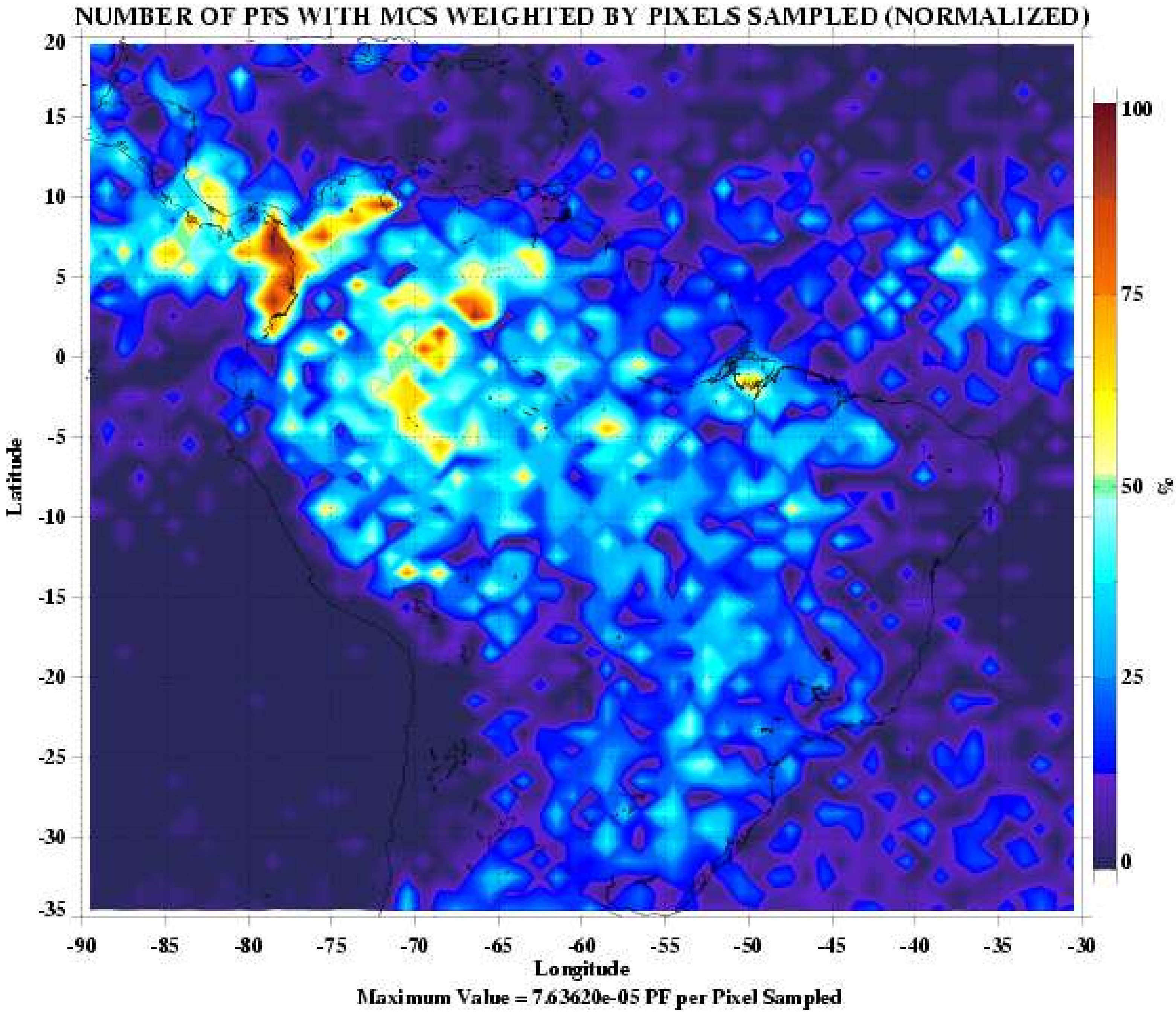
- At least 1 pixel with 85 PCT ≤ 250 K

PF with a Mesoscale Convective System (MCS)

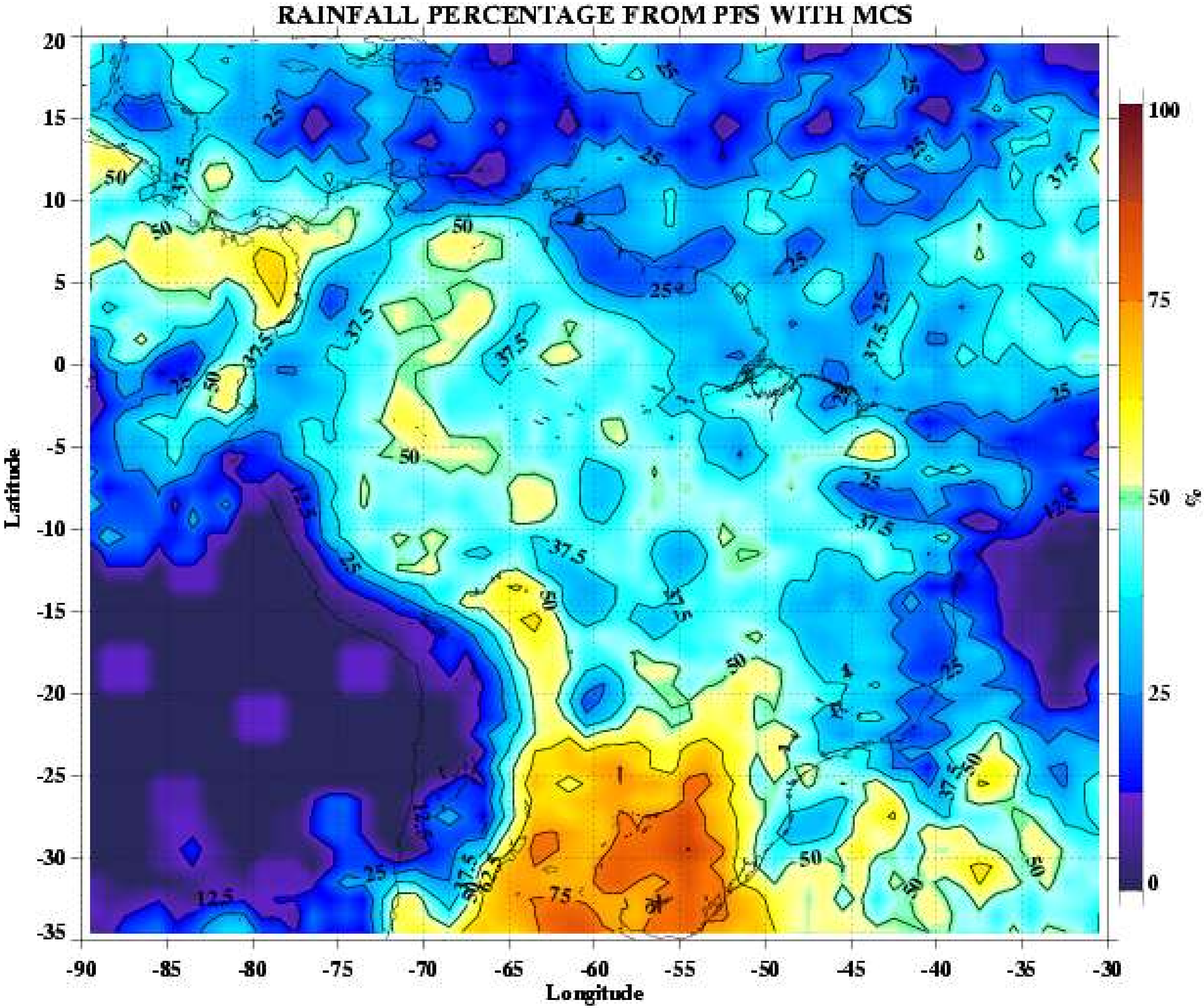
- Meets ice scattering area and intensity criteria of Mohr and Zipser (1996)



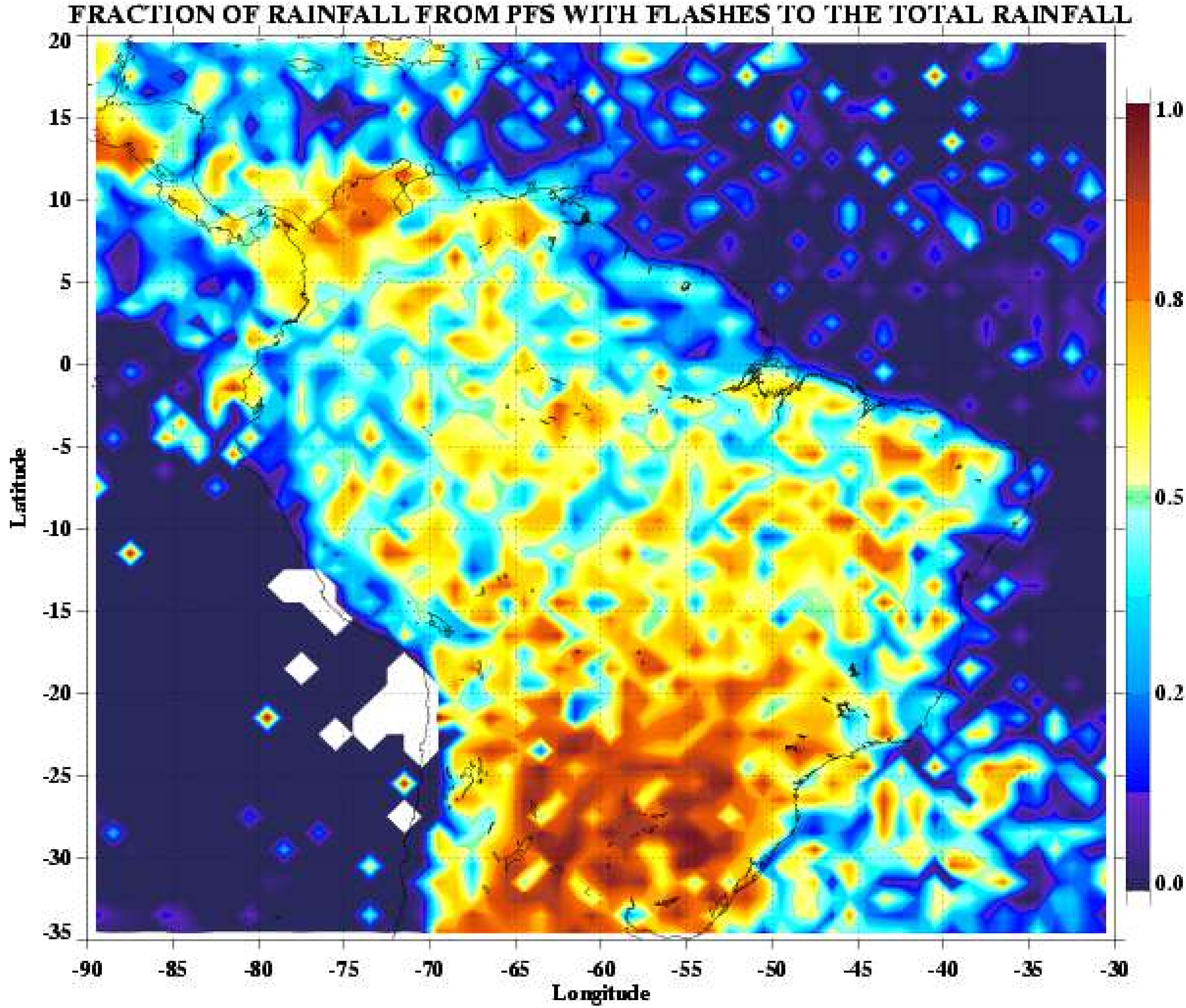
Adapted from Nesbitt et al. (2000)



NUMBER OF PFS WITH MCS WEIGHTED BY PIXELS SAMPLED (NORMALIZED)
Latitude
Longitude
%
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-90
-85
-80
-75
-70
-65
-60
-55
-50
-45
-40
-35
-30
100
75
50
25
0
Maximum Value = 7.63620e-05 PF per Pixel Sampled

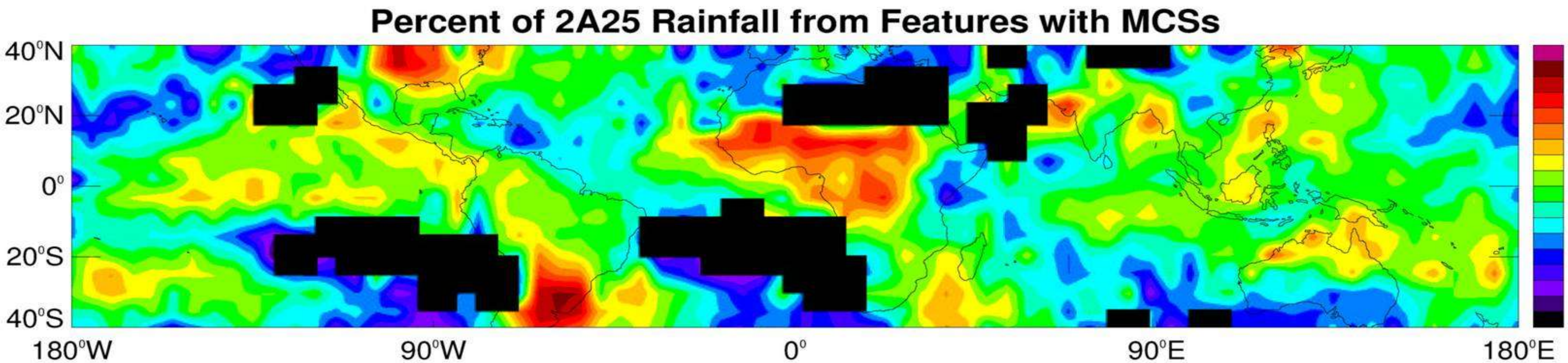


RAINFALL PERCENTAGE FROM PFS WITH MCS
Latitude
Longitude
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-90
-85
-80
-75
-70
-65
-60
-55
-50
-45
-40
-35
-30
100
75
50
25
0
%

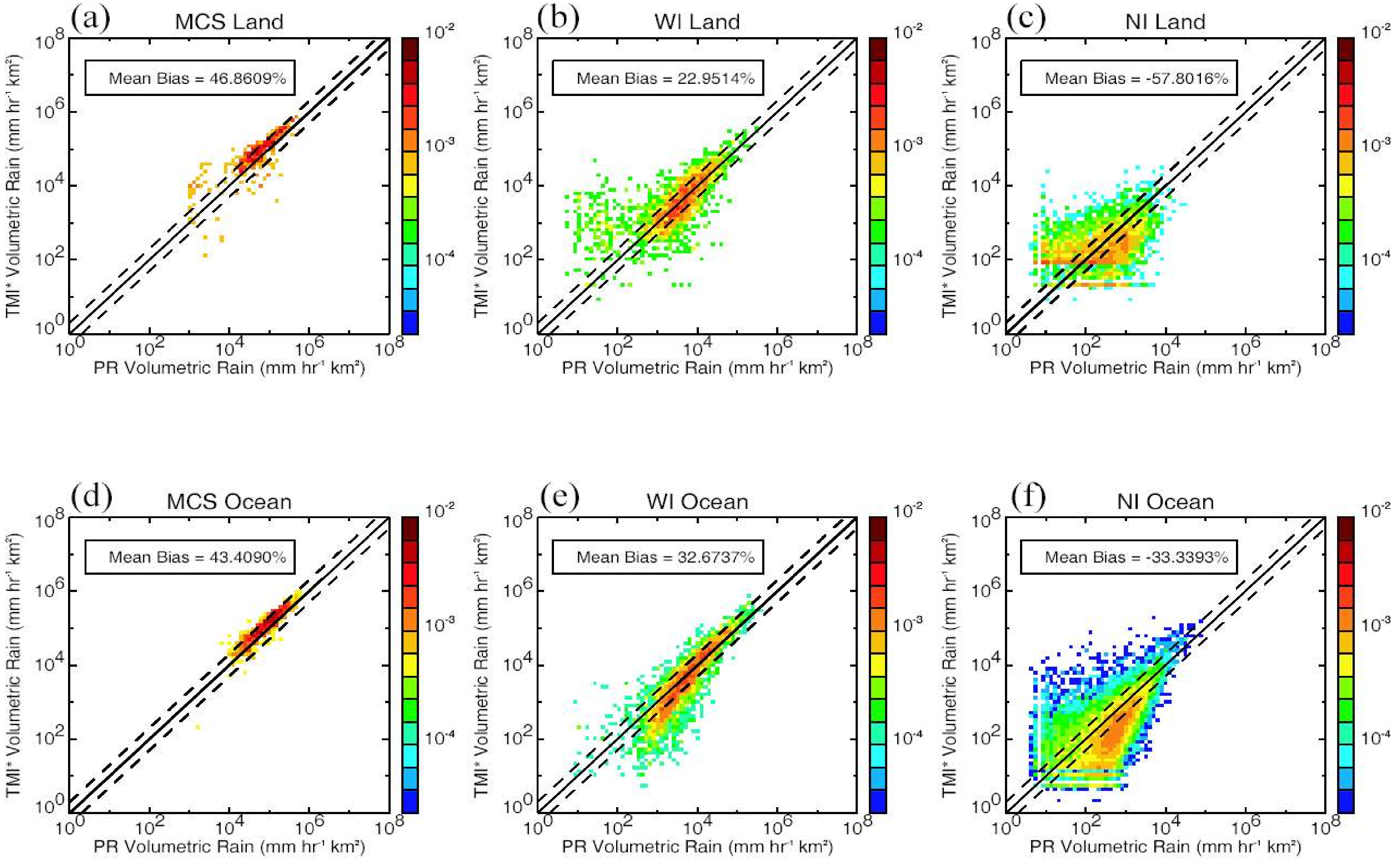


FRACTION OF RAINFALL FROM PFS WITH FLASHES TO THE TOTAL RAINFALL
Latitude
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
Longitude
-90
-85
-80
-75
-70
-65
-60
-55
-50
-45
-40
-35
-30
1.0
0.8
0.5
0.2
0.0

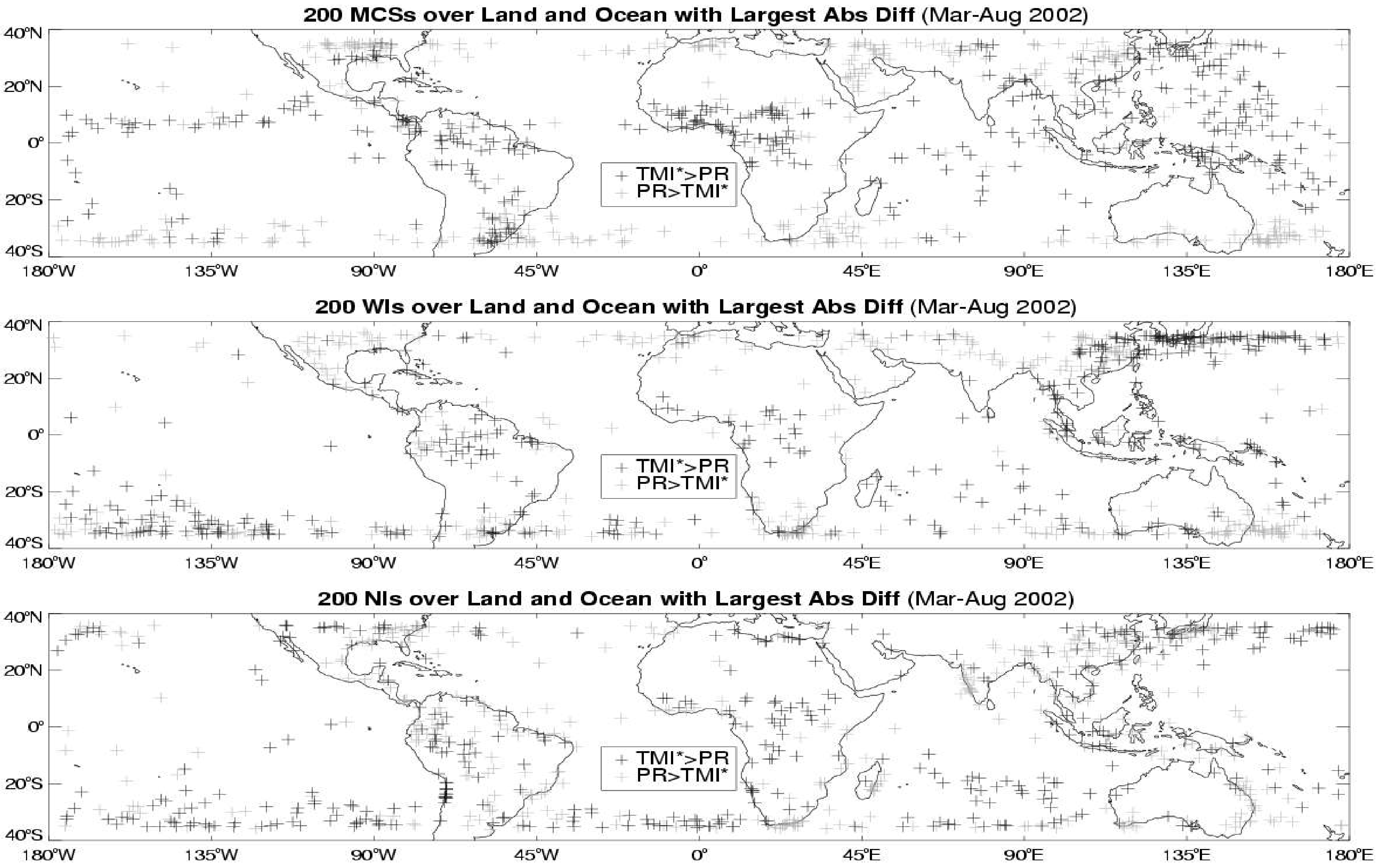
Subtropical South America has the largest fractional contribution of PFs with MCSs to rainfall of anywhere on earth between 36 N and 36 S



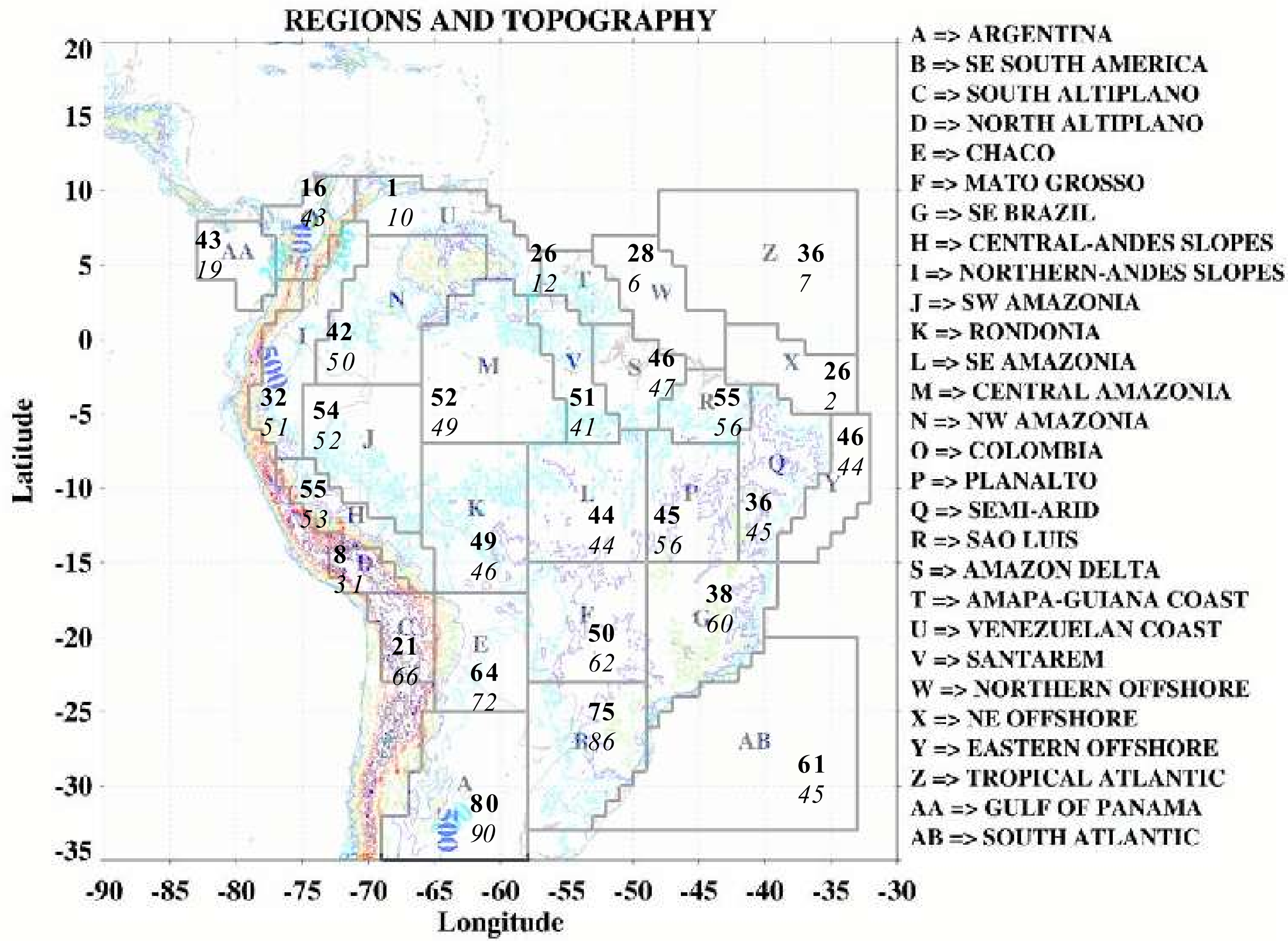
Feature-by-Feature Biases by Feature Type



Location of Features with Largest Absolute Differences



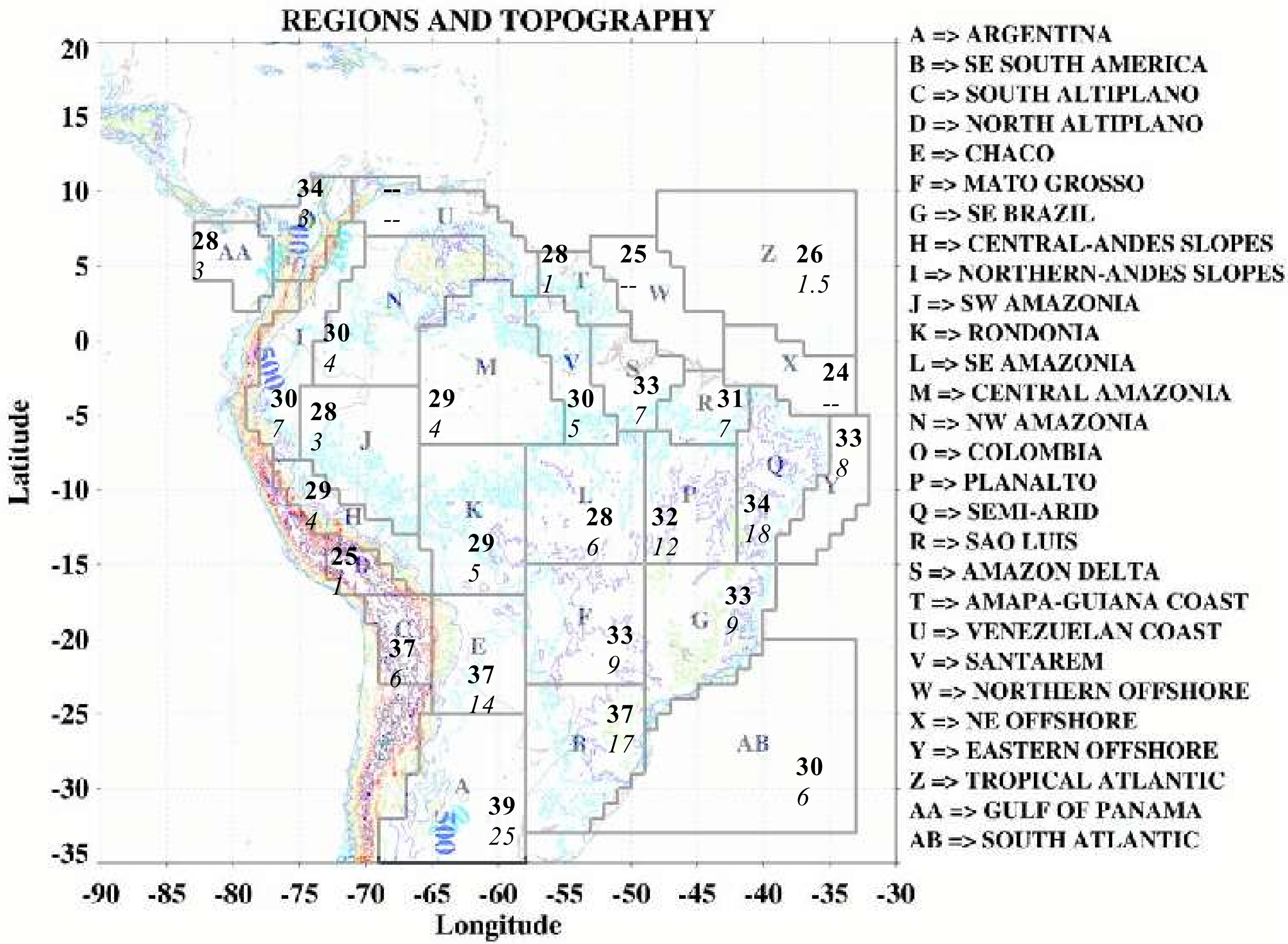
DJF % Rainfall $\frac{\textbf{w/MCS}}{\textit{w/LIS}}$



DJF Median Max dBZ at 9 km & Flash Rate in MCSs

Max dBZ

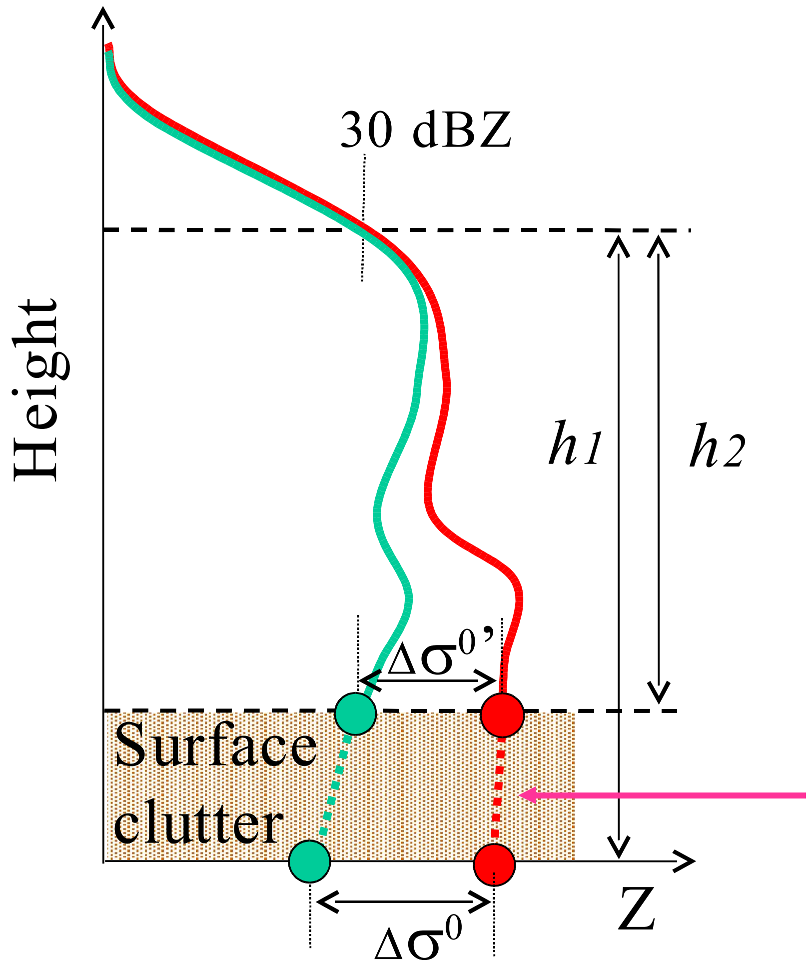
Flash rate



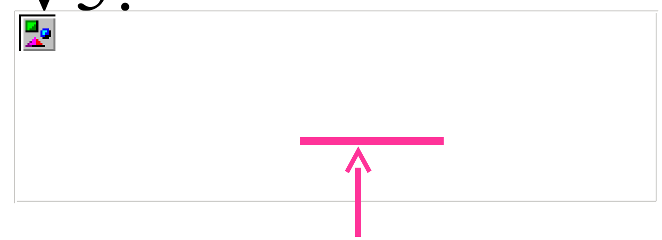
Summary

- Satellite estimates of monthly rainfall are improving, but still have regional uncertainties and biases of ~ 20-30%
- Satellite estimates of rainfall from any specific system may still have uncertainties and biases of ~ factor of 2
- MCSs dominate rainfall in some areas, and they tend to have a consistent bias in various satellite algorithms, but we must do further work to focus on the reasons
- The various TRMM algorithms can be used to learn a great deal more about the structure of precipitation systems. For example, there is an important difference in convective intensity between the rain systems in the SACZ compared with those in the Chaco and Argentina

Attenuation in Surface Clutter



V5:



PIA estimate from SRT

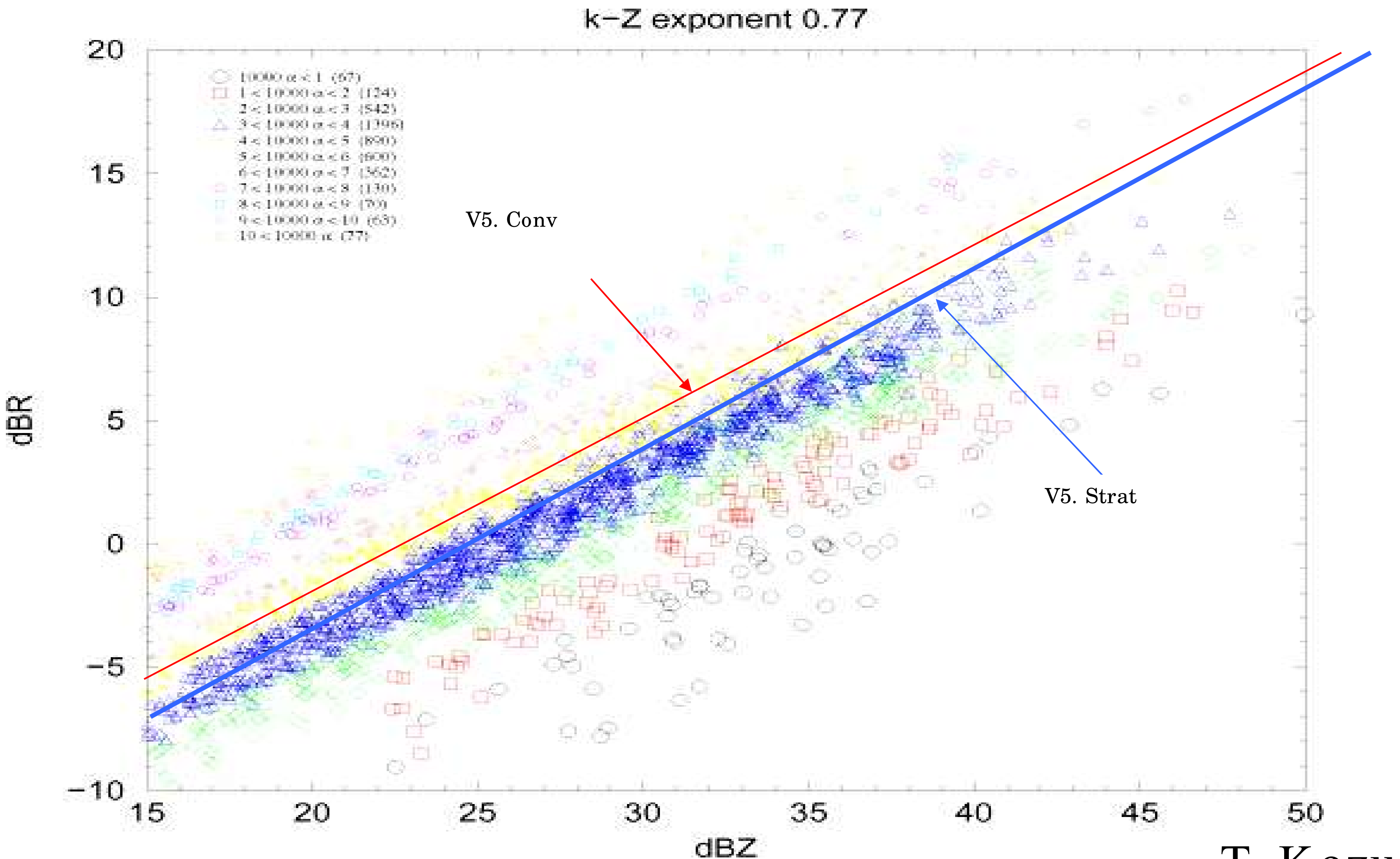
V6:

Constant slope of *Z* after correction

Stratiform: -0.25 dB/km

Convective: 0 dB/km

Z-R relations (DSD) used in V5 and V6

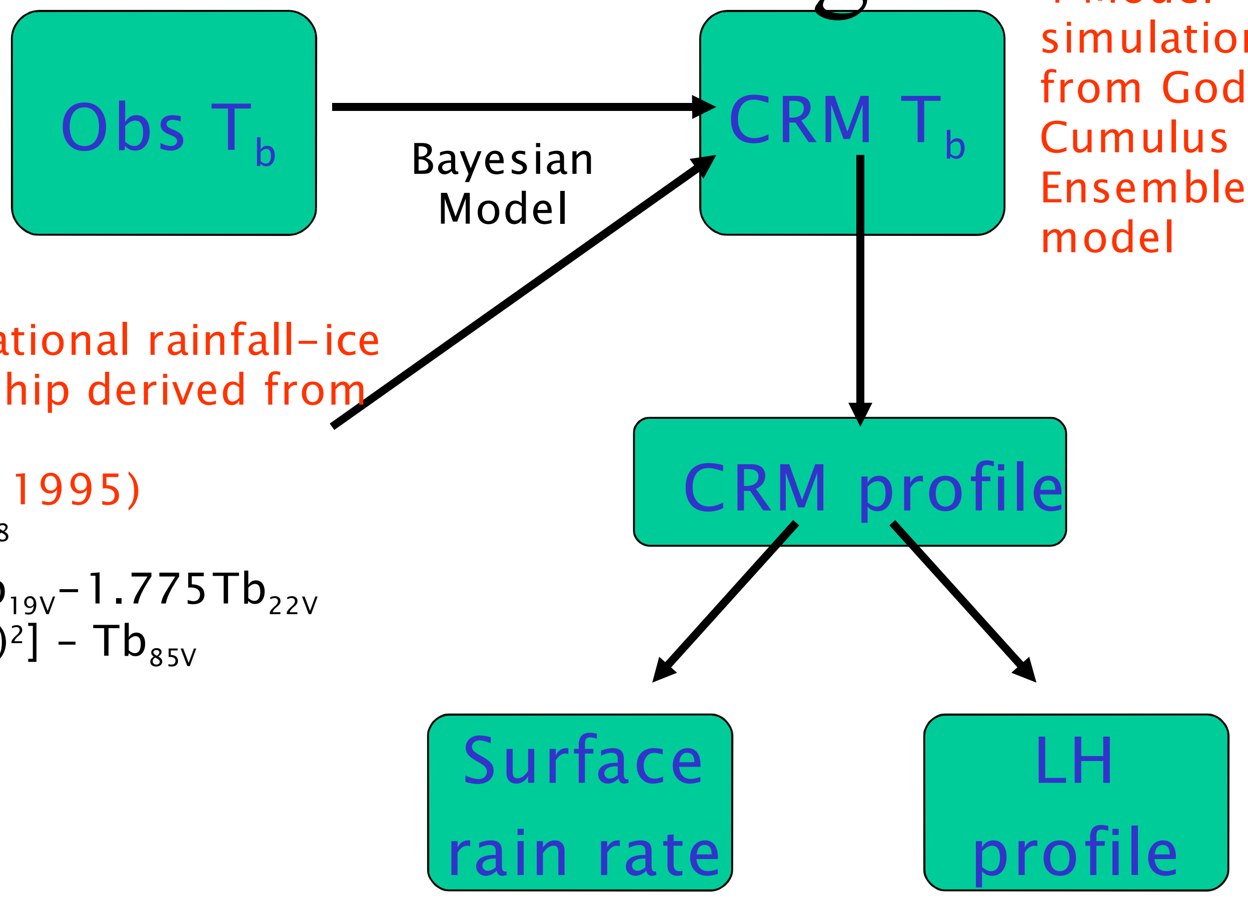


T. Kozu

TMI 2A12 Ver. 5 Algorithm

TMI Tb's

Ocean: 9 channels / c-s classification



4 Model simulations from Goddard Cumulus Ensemble model

Land: NESDIS Operational rainfall-ice scattering relationship derived from radar
(Ferraro and Marks 1995)

$RR = 0.00513(SI)^{1.9468}$

$SI = [451.9 - 0.044Tb_{19V} - 1.775Tb_{22V} + 0.00575(Tb_{22v})^2] - Tb_{85V}$

from Kummerow et al. (2001, JAM)

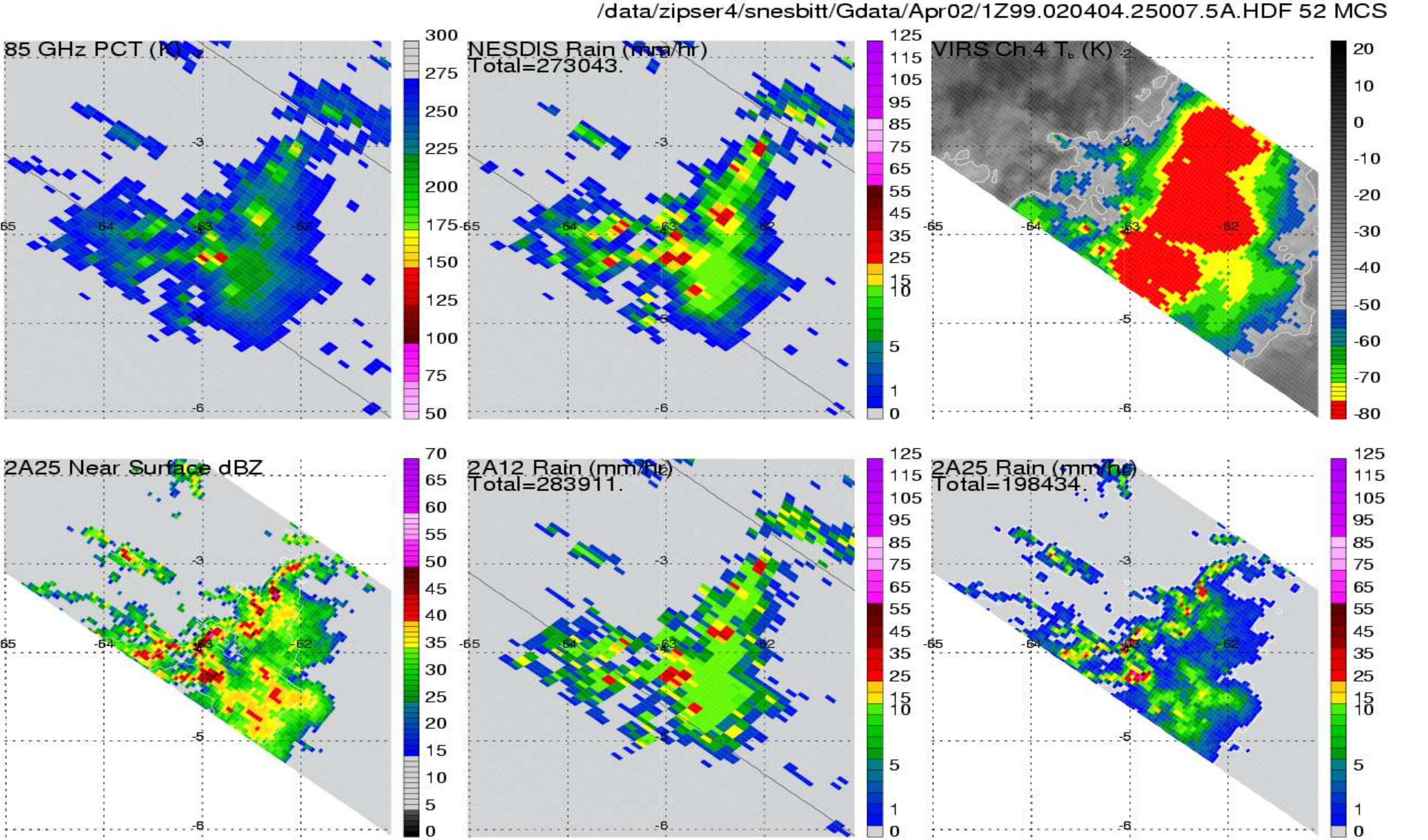
The 3-Year PF Database

- The Ver. 5 database extends from Dec. 1997-Nov. 2000; Ver. 5A database extends from Mar-Aug 2002

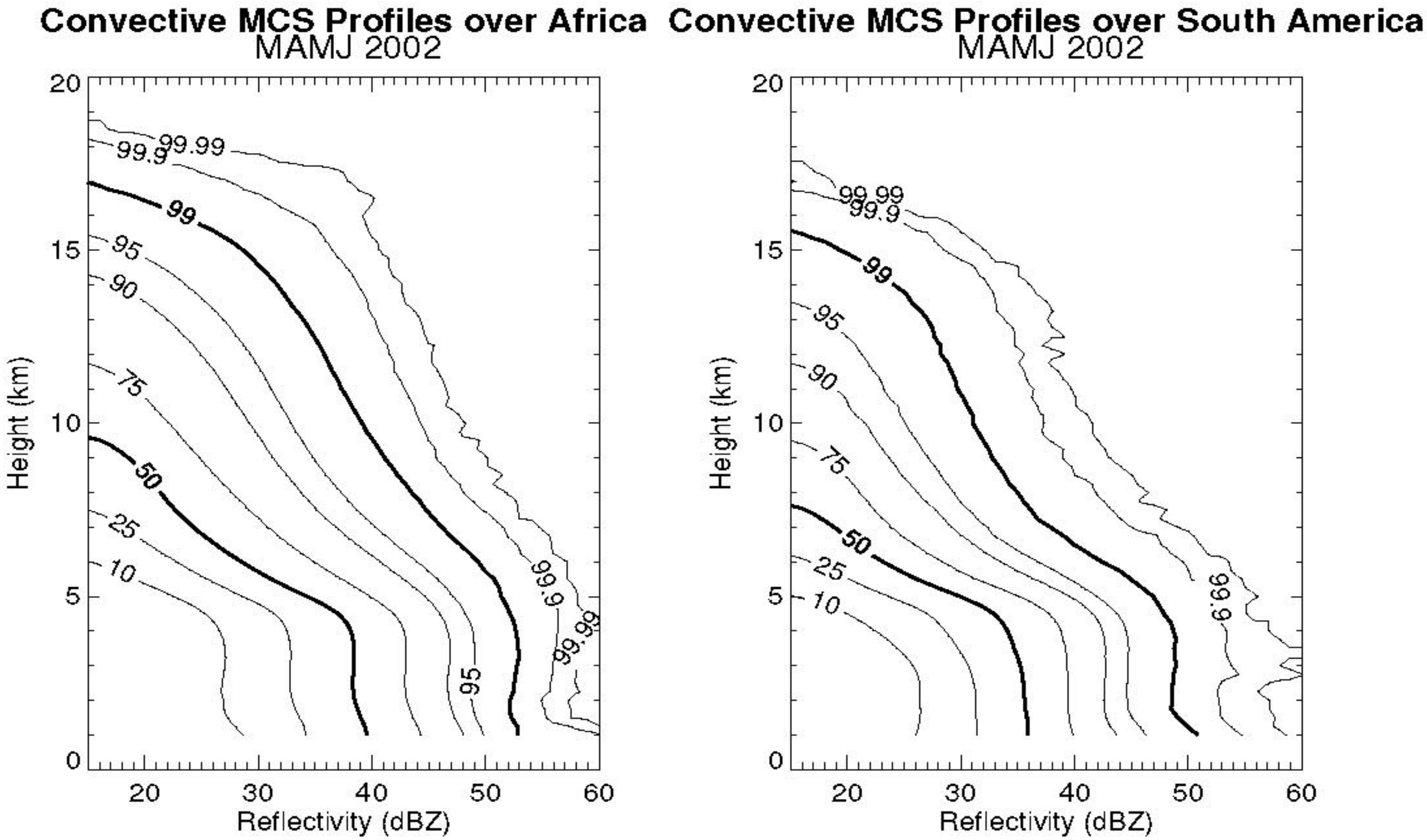
Season	Total	w/MCS	w/ice scattering	w/o ice scattering
DJF	1351309	12978	161088	1177243
MAM	1475053	15065	185857	1274131
JJA	1563772	14617	196853	1352302
SON	1398885	12547	172919	1213419
Total	**5789019**	**55207**	**716717**	**5017095**

Stored for each PF are ~30 characteristics:
i.e. min 85 GHz PCT, max 30 dBZ height, time of occurrence, area, total volumetric rainfall, etc.

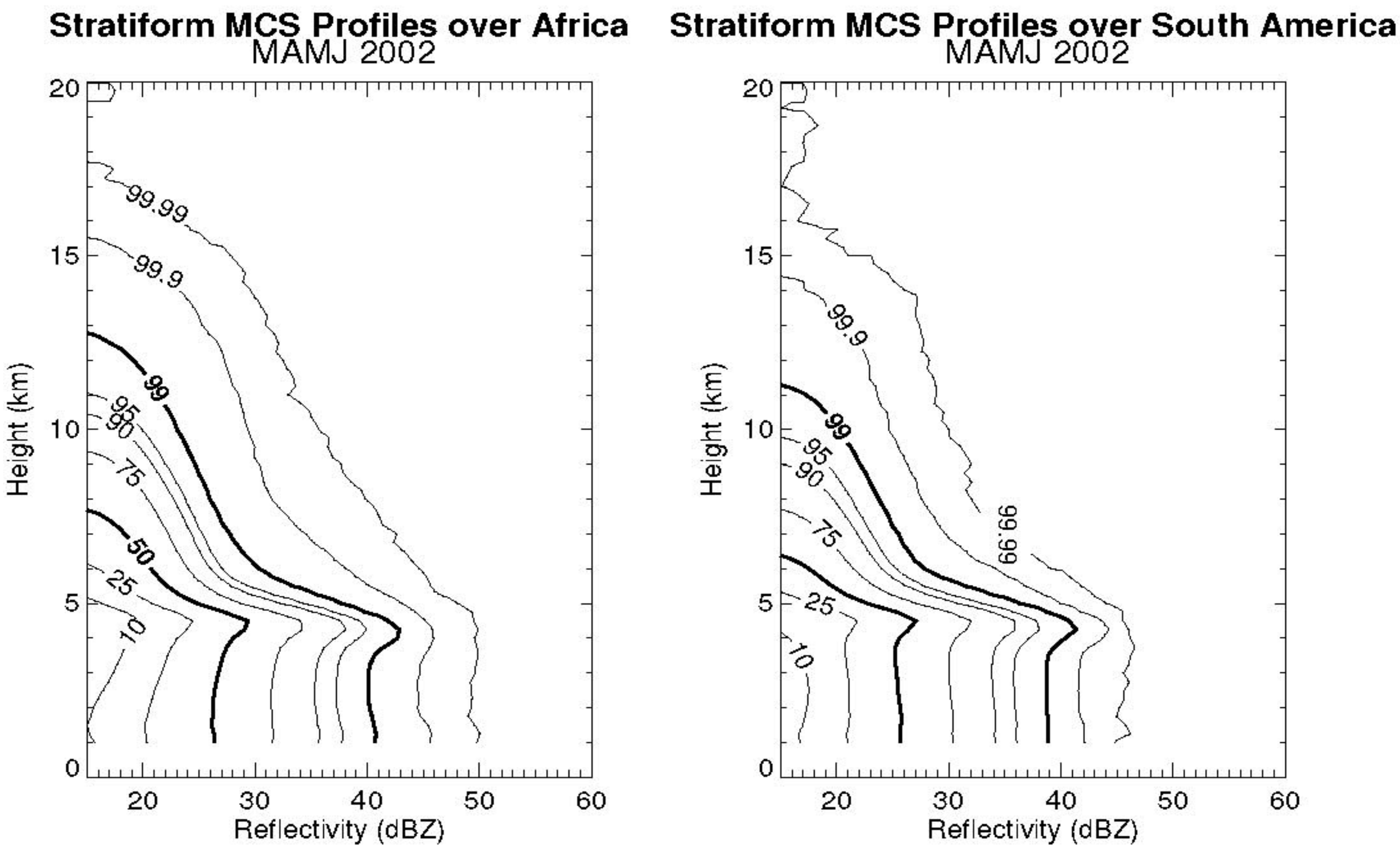
"Typical" MCS over Amazonia for which TMI and IR estimate ~40% more rain than TRMM radar (PR)



Convective MCS Profiles over Africa and South America

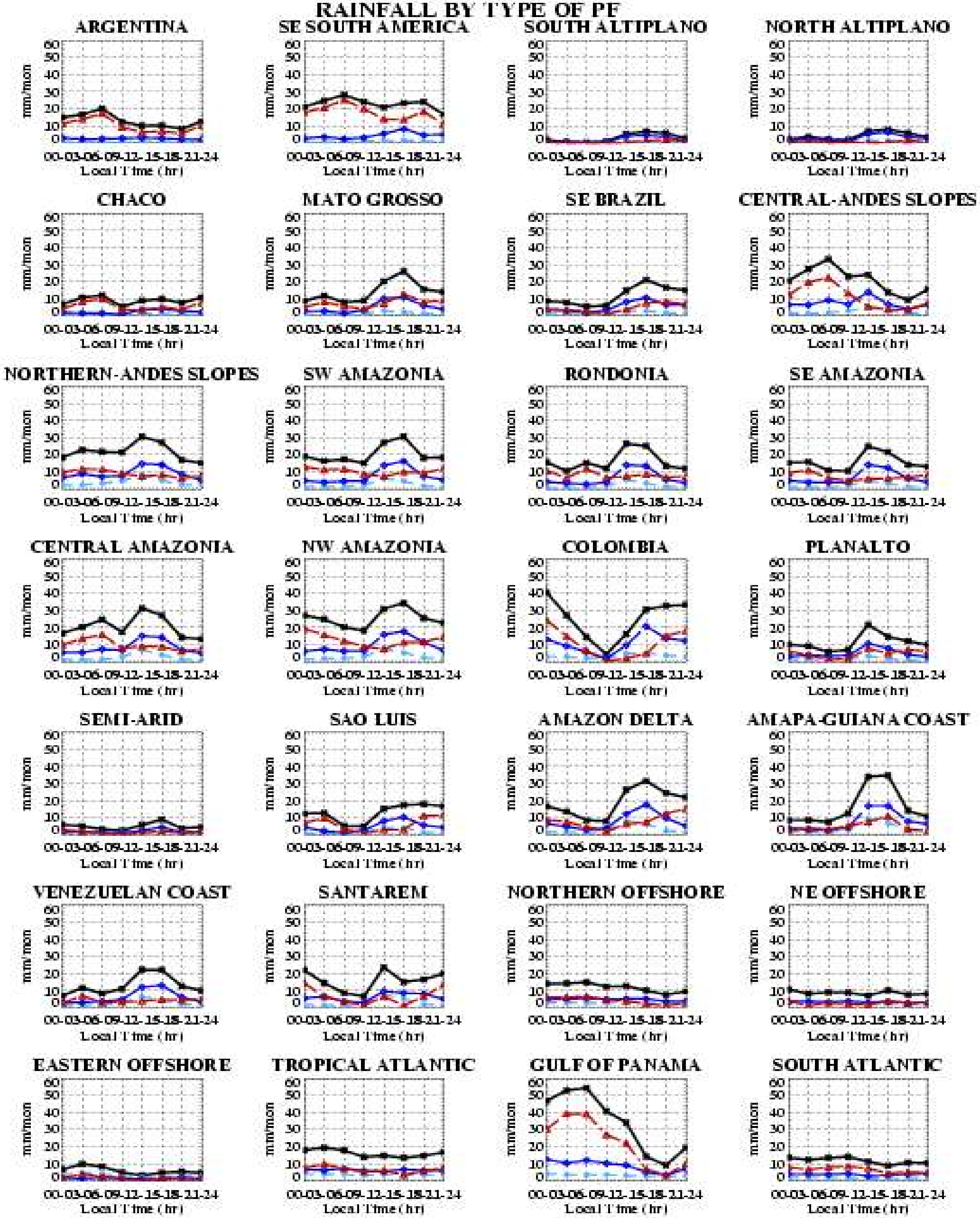


Stratiform MCS Profiles over Africa and South America

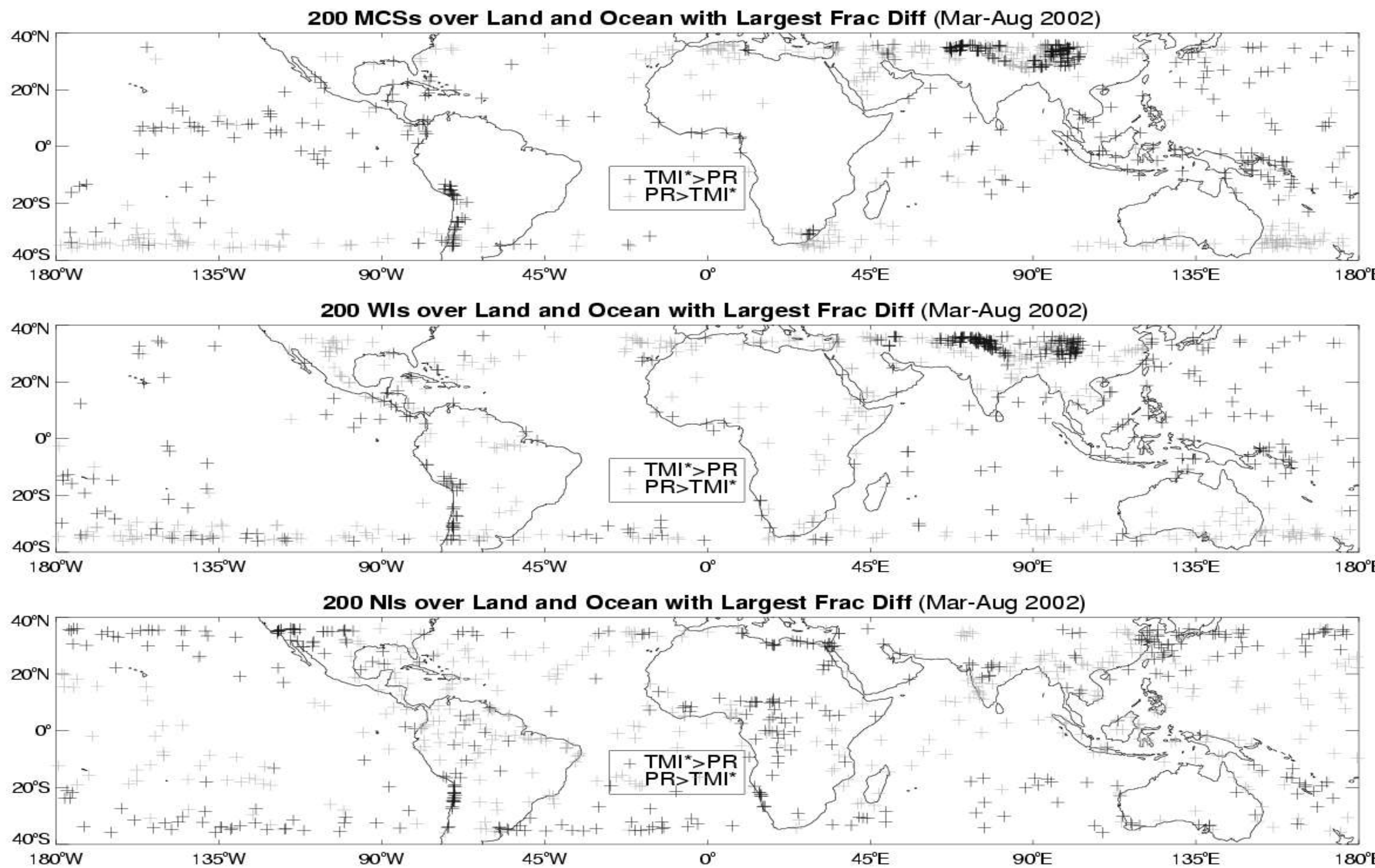


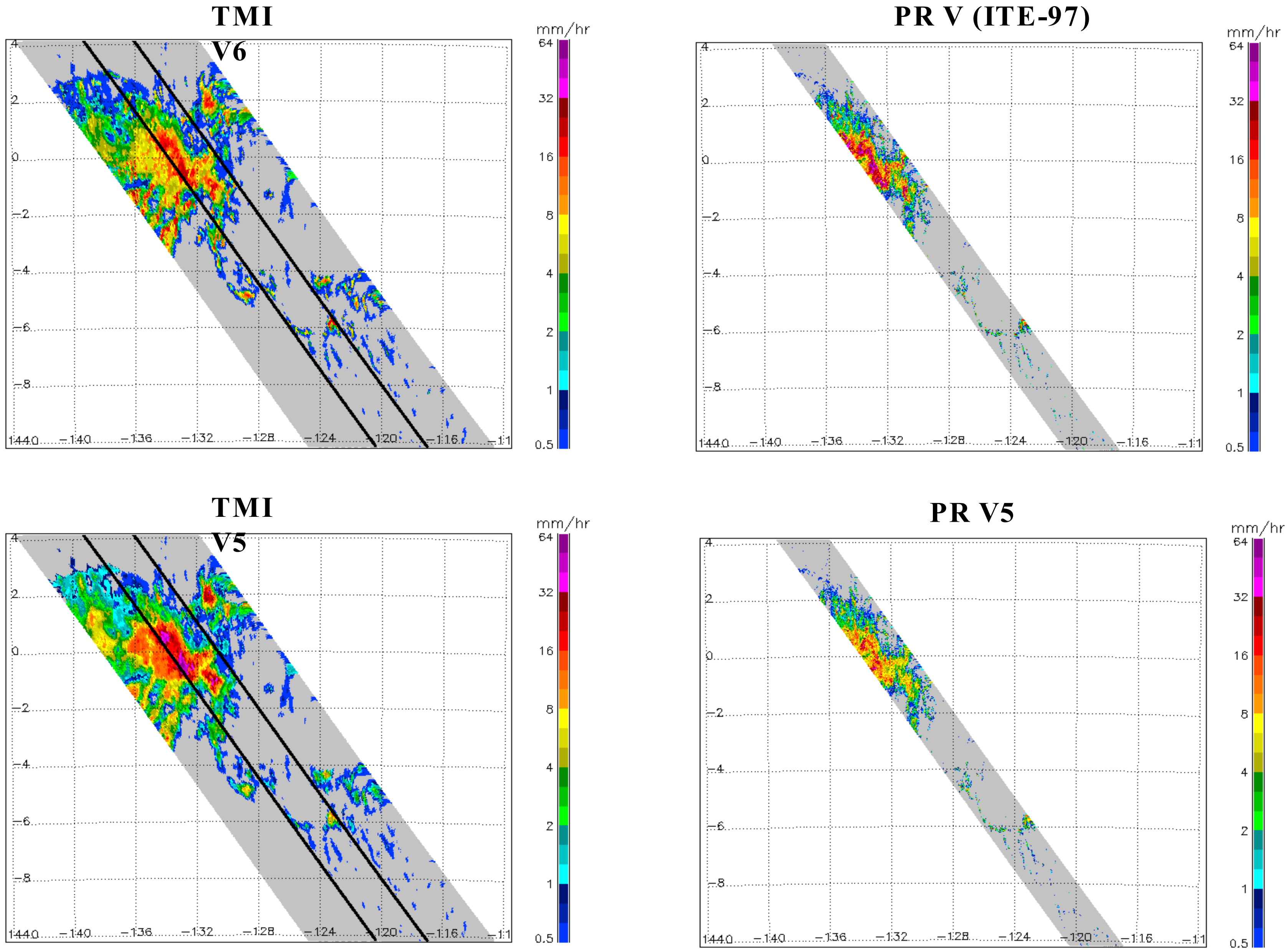
INTRODUCTION: CLIMATOLOGY

- Rain Gauges => conventional and field experiments
  - Lack and/or sparseness of rain gauges are obstacles
- Distribution and characteristics of indirectly estimated precipitation
  - Outgoing Longwave Radiation (OLR) and/or meteorological analysis to describe large-scale distribution and variability of:
    - convection,
    - rainfall, and
    - MCCs
- It is well known that the cloud-top temperatures measured remotely by IR do not describe directly the physical processes occurring in clouds and their consequent precipitation.


RAINFALL BY TYPE OF PF
ARGENTINA
SE SOUTH AMERICA
SOUTH ALTIPLANO
NORTH ALTIPLANO
CHACO
MATO GROSSO
SE BRAZIL
CENTRAL-ANDES SLOPES
NORTHERN-ANDES SLOPES
SW AMAZONIA
RONDONIA
SE AMAZONIA
CENTRAL AMAZONIA
NW AMAZONIA
COLOMBIA
PLANALTO
SEMI-ARID
SAO LUIS
AMAZON DELTA
AMAPA-GUIANA COAST
VENEZUELAN COAST
SANTAREM
NORTHERN OFFSHORE
NE OFFSHORE
EASTERN OFFSHORE
TROPICAL ATLANTIC
GULF OF PANAMA
SOUTH ATLANTIC
mm/mon
0 10 20 30 40 50 60
00-03-06-09-12-15-18-21-24
Local Time (hr)

Location of Features with Largest Fractional Differences



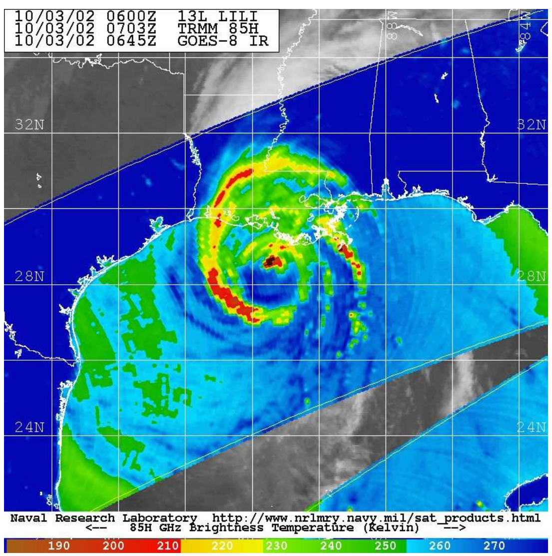

TMI
V6
PR V (ITE-97)
TMI
V5
PR V5
mm/hr
64
32
16
8
4
2
1
0.5

Polarization Corrected Temperature

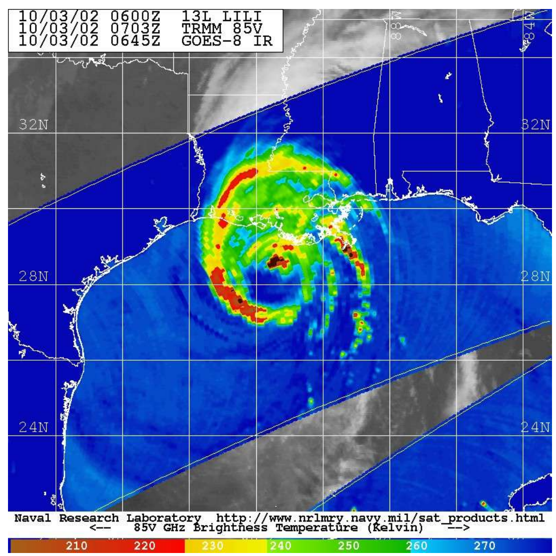
- To remove non-uniform surface emissivity effects, a Polarization Corrected Temperature is calculated from the 85 GHz horizontally and vertically polarized T_bs (Spencer et al. 1989):

$$PCT = \frac{\beta T_{b_H} - T_{b_V}}{\beta - 1} \qquad \beta \text{ is } 0.45 \text{ at } 85 \text{ GHz}$$

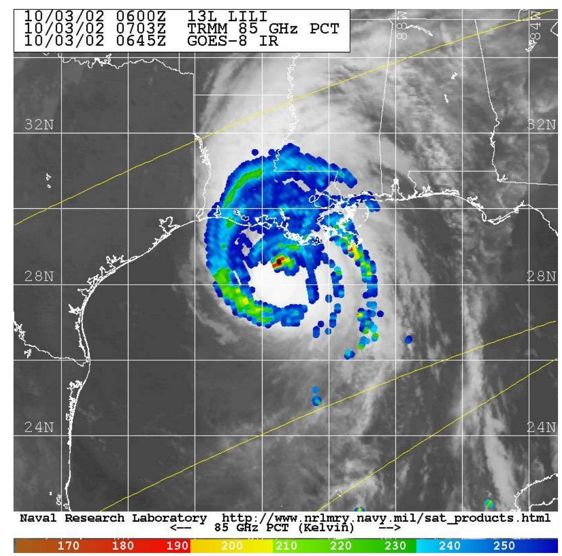
85 H



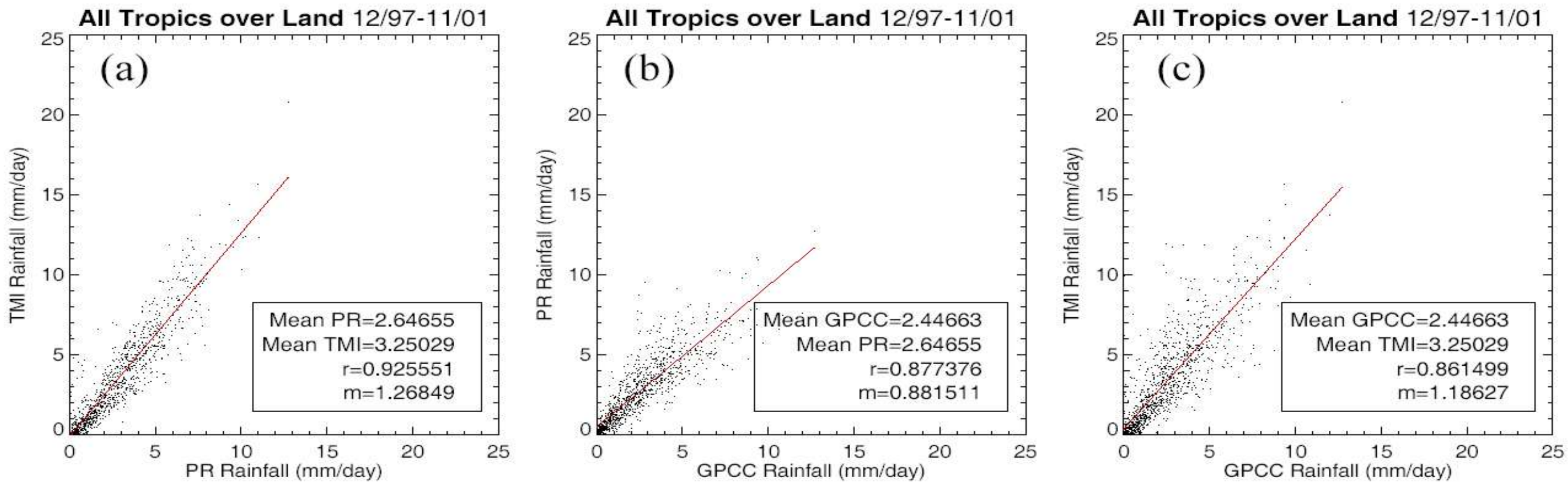
85 V



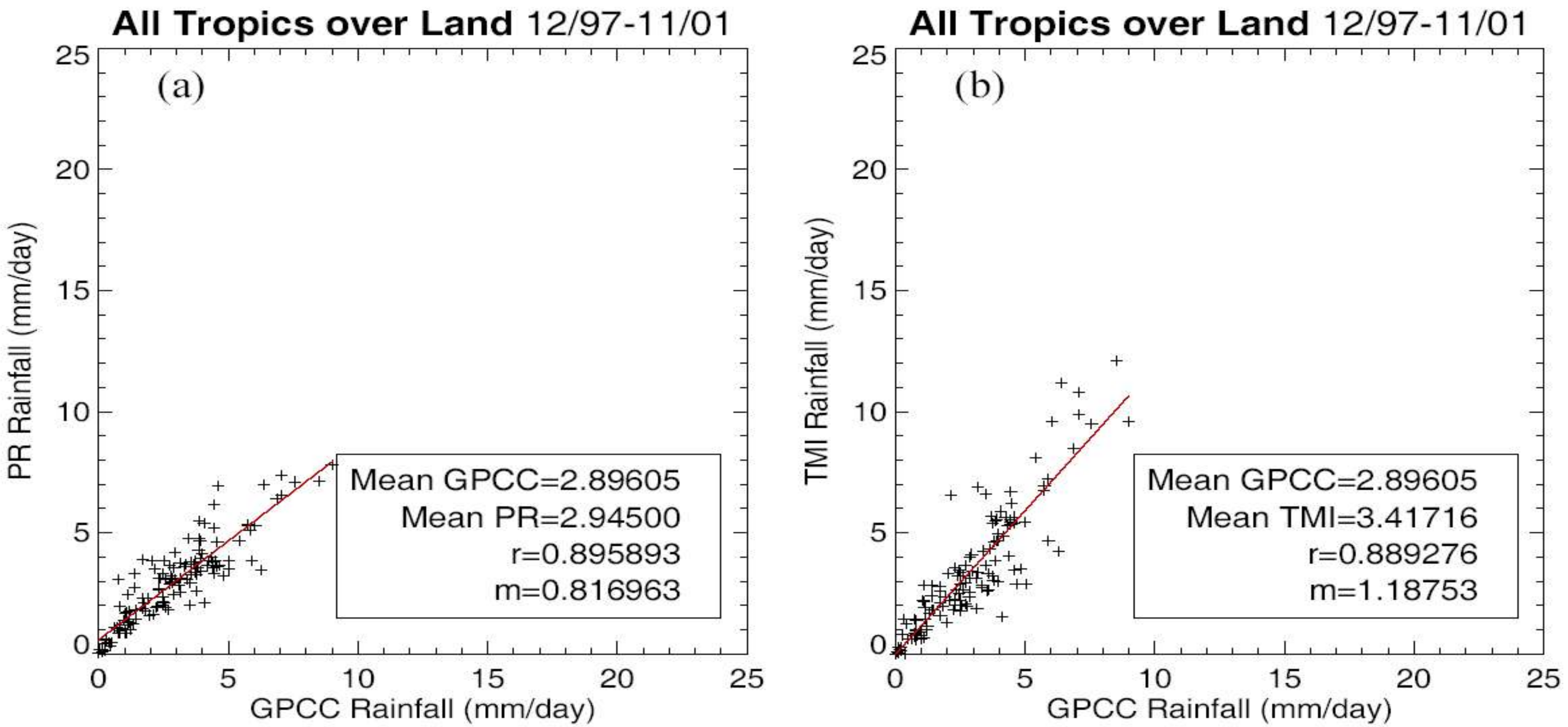
85 PCT



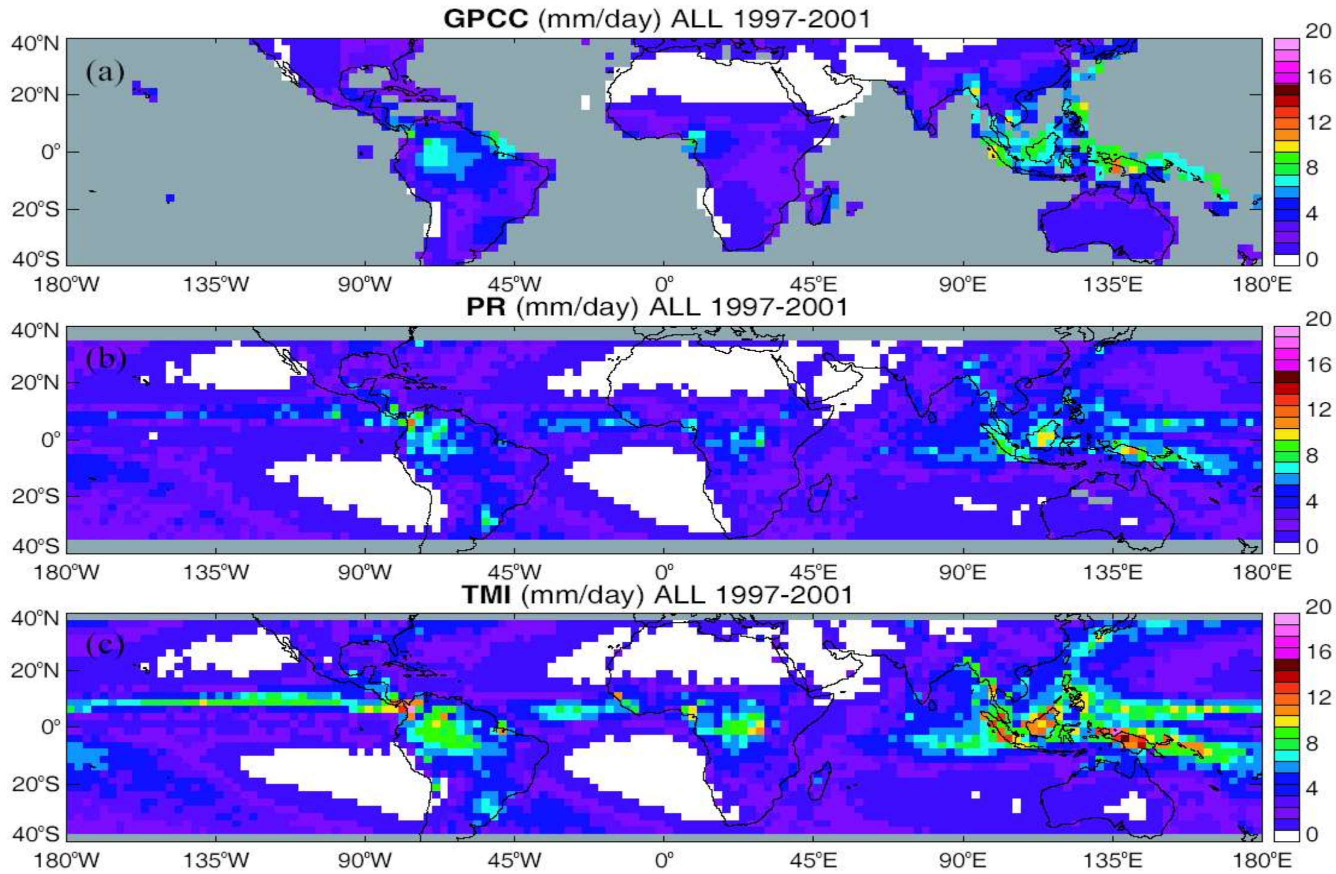
2.5° Estimates

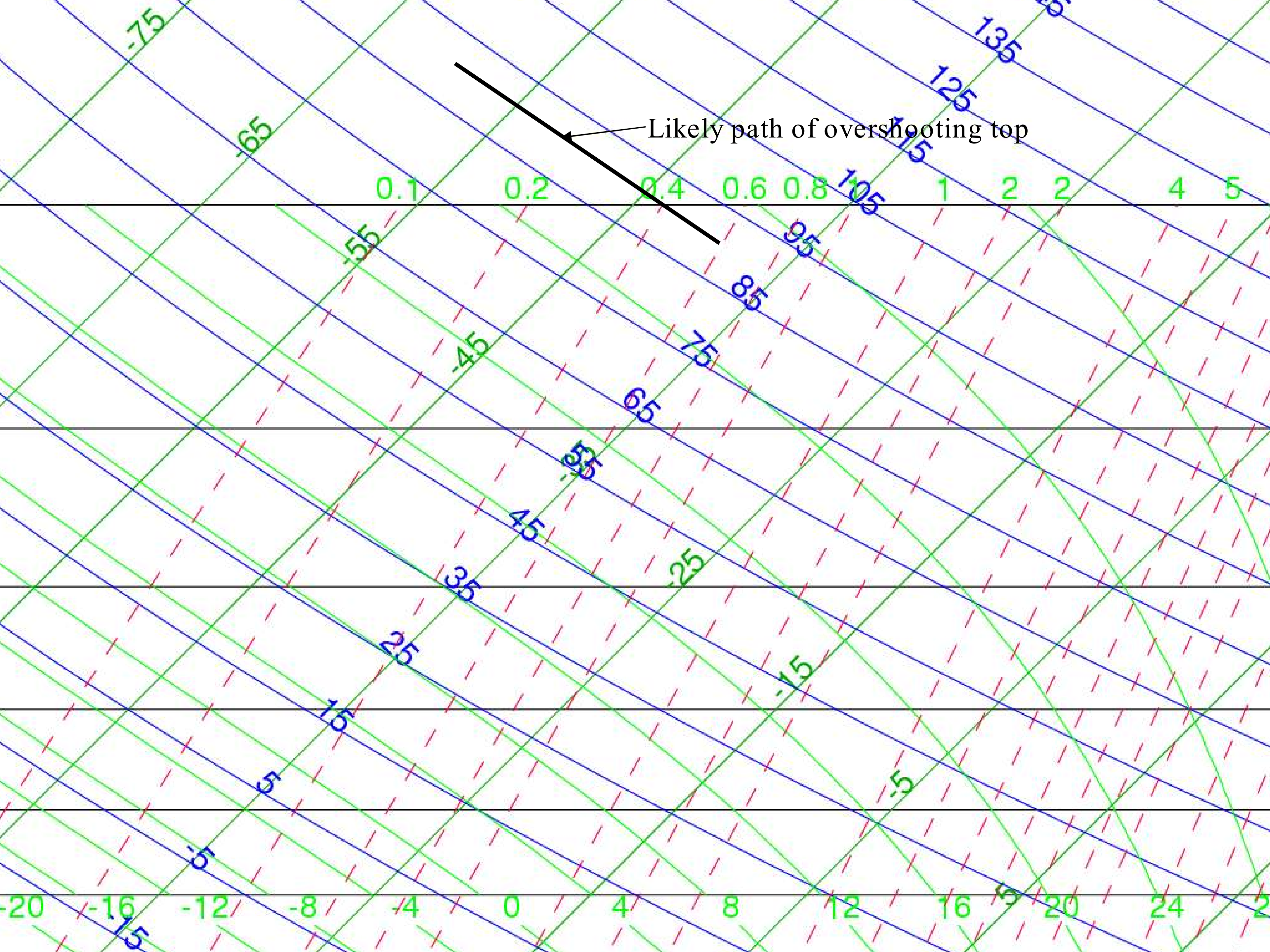


2.5° Estimates where Gauges Exist



All Season Rainfall Estimates




Likely path of overshooting top
0.1
0.2
0.4
0.6
0.8
1
2
2
4
5
-75
-65
-55
-45
-25
-15
-5
135
125
105
95
85
75
65
45
35
25
15
5
-5
-20
-16
-12
-8
-4
0
4
8
12
16
20
24