The SSMI/SSMIS Global Hydrological Gridded Products

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Hydrology training workshop in conjunction with IPWG

11-15 Oct 2010 - University of Hamburg

CENTRO DE PREVISÃO DE TEMPO E ESTUDOS CLIMÁTICOS

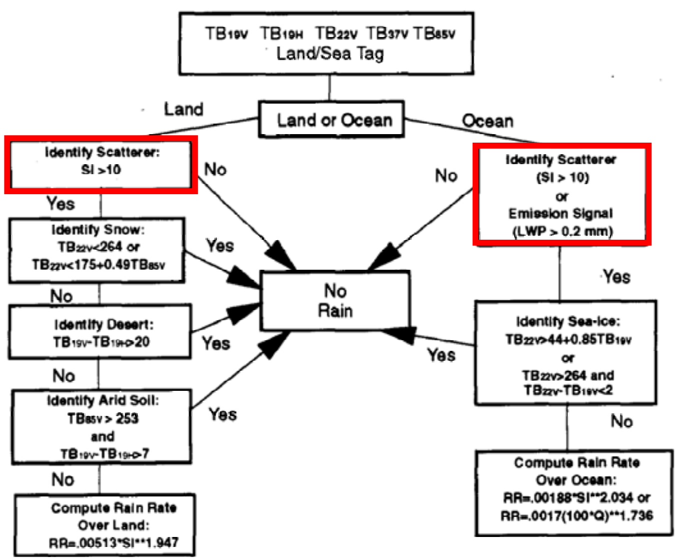
OUTLINES

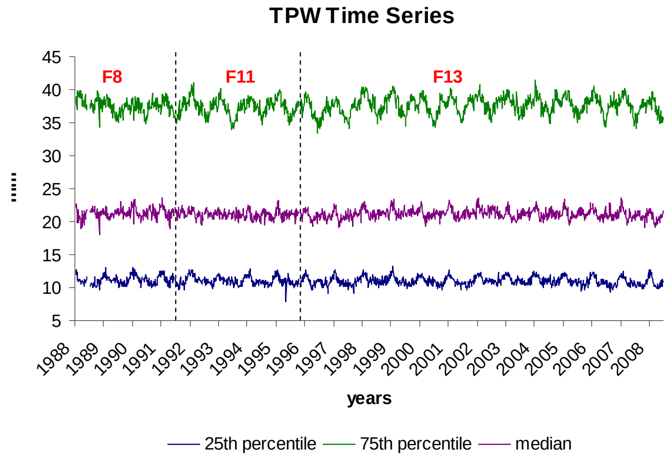
- ***The extension of hydrological products into the SSMI/S era.***
  - ***SSM/I – SSMI/S: similarities and differences***
  - ***The Simultaneous Conical Overpass (SCO) approach***
  - ***Preliminary results***

SSMI-based Monthly Hydrological Products

- Global monthly rainfall estimates (RR) and other hydrological products like integrated Cloud Liquid Water (CLW) and Total Precipitable Water (TPW) have been produced from 1987 to present using measurements from the Defense Meteorological Satellite Program (DMSP) series of Special Sensor Microwave Imager (SSM/I)

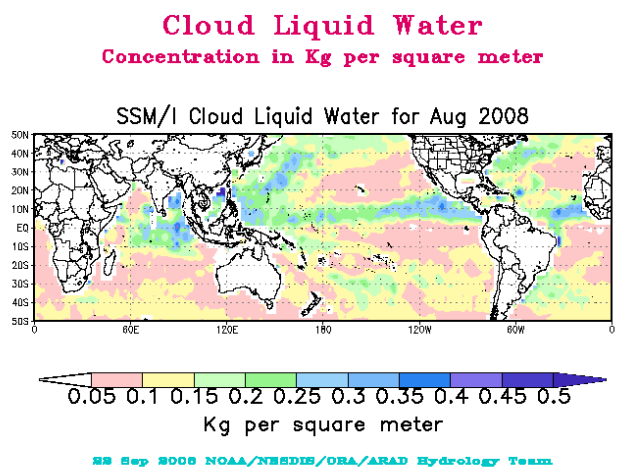
Ferraro, 1997



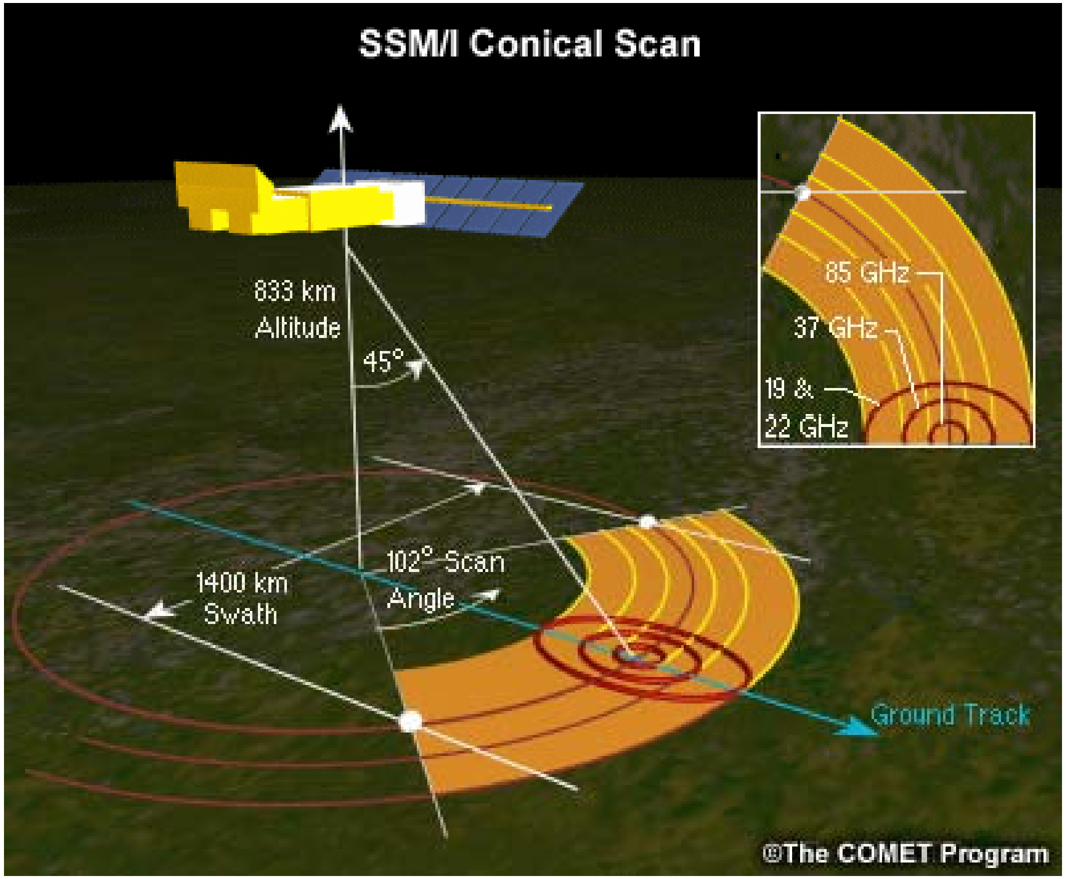


Alihouse et al., 1990

Weng and Grody, 1994



Special Sensor Microwave/Imager (SSM/I)



Channels	**1,2**	**3**	**4,5**	**6,7**
Central Frequency Pol. (GHz)	19.35	22.24	37.0	85.5
Radiometric Pol. (V/H) **(*)**	V ,H	V	V ,H	V, H
Thermal **resolution** (K)	0.8	0.8	0.6	1.1
Integrated FOV (Km)	70 x 45	60 x 40	38 x 30	16 x 14
Spatial sampling (Km)	25	25	25	12.5
Scan angle			102.4 °	
Sweep periodicity			1.9s	
Ground incidence			53.1°	
Swath width			1394 Km	
Antenna diameter			65 cm	
Weight			120 Kg	
Power			70 W	

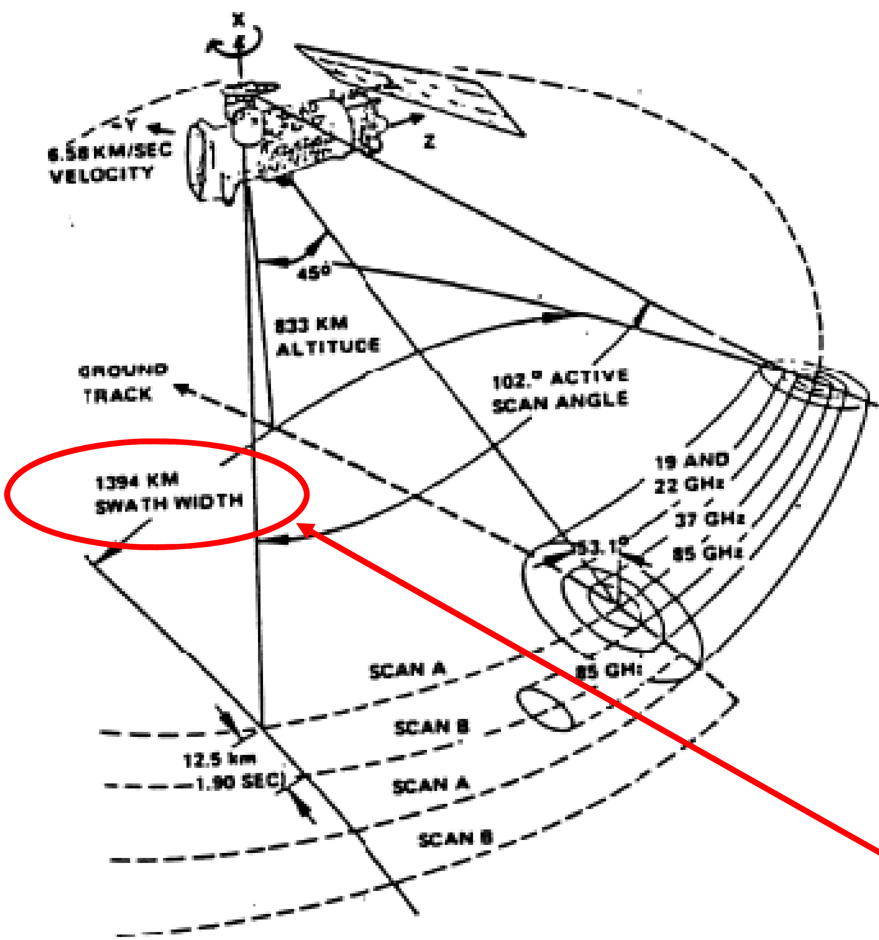
SSMI

180 samples/scan (91, 150, 183 GHz)

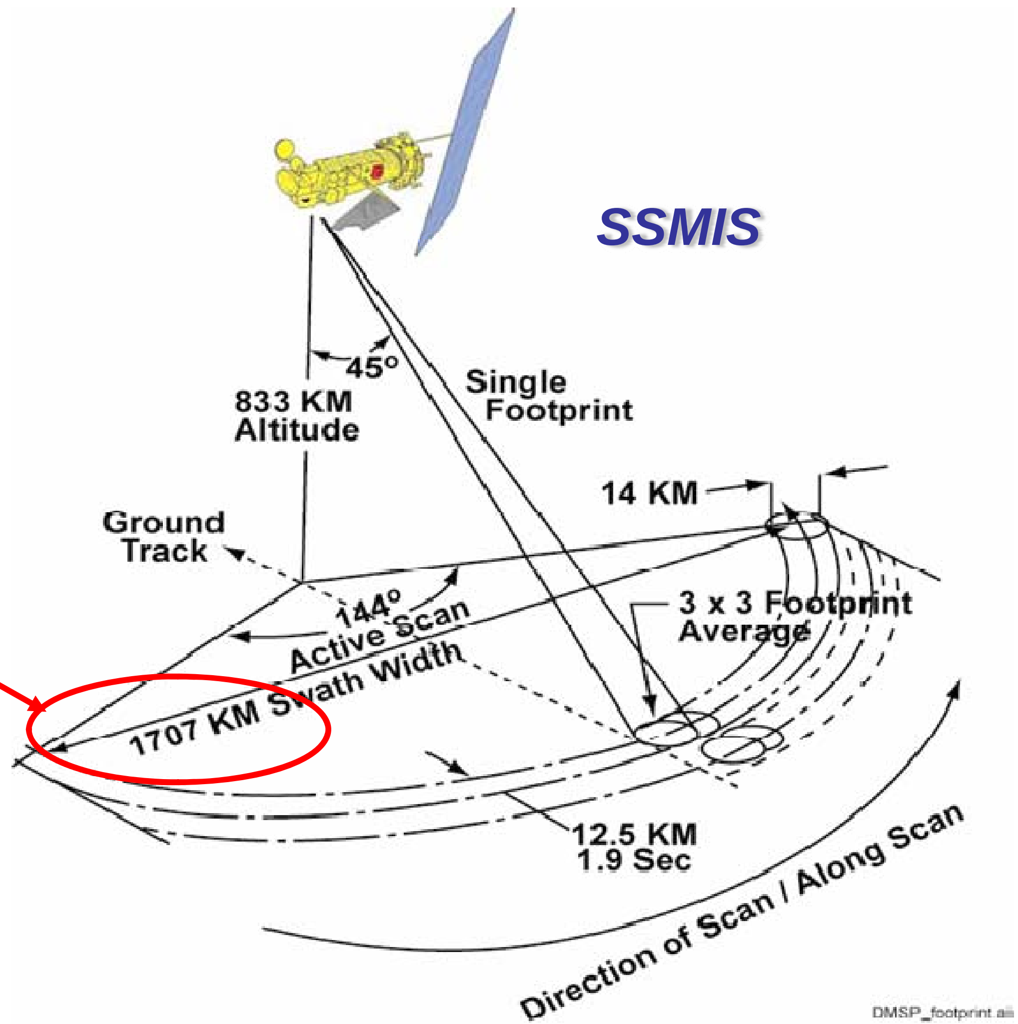
90 samples/scan (19-37 GHz)

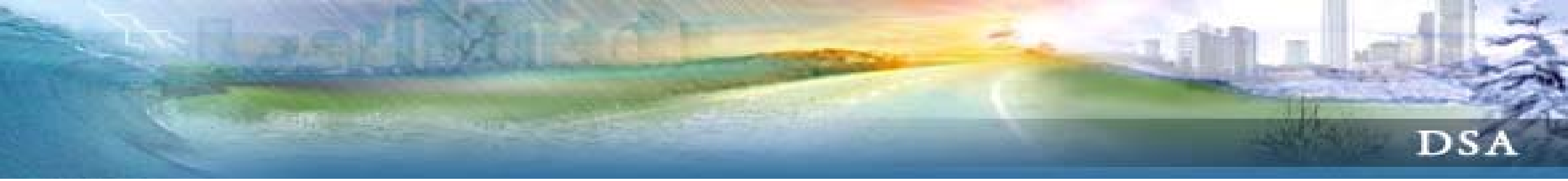
60 samples/scan (lower sounding)

30 samples/scan (upper sounding)

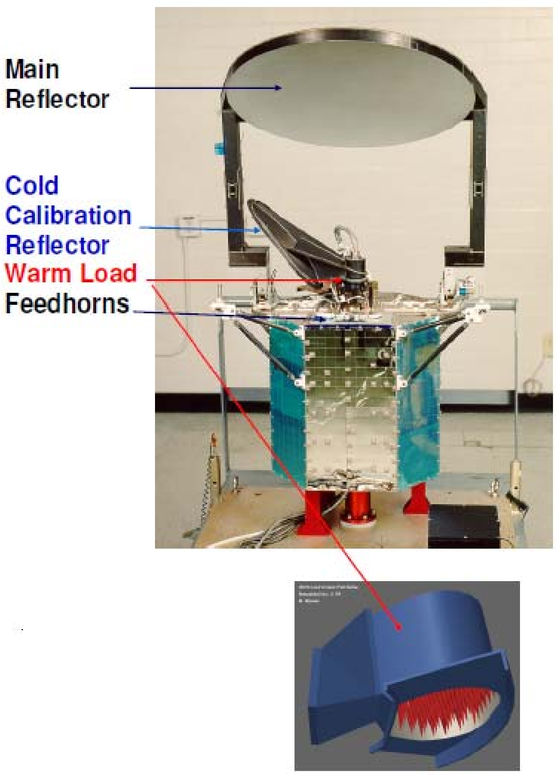


SSMIS





SSMI/T/T2		SSMI/S	
Freq. (Ghz) / Polarization	Footprint (km)	Freq. (GHz) / Polarization	Footprint (km)
19.350 / H & V	43 x 69	19.350 / H & V	73 x 47
22.235 / V	40 x 60	22.235 / V	73 x 47
37.000 / H & V	28 x 37	37.000 / H & V	41 x 31
85.500 / H & V	13 x 15	91.655 / H &V	14 x 13 (imager)



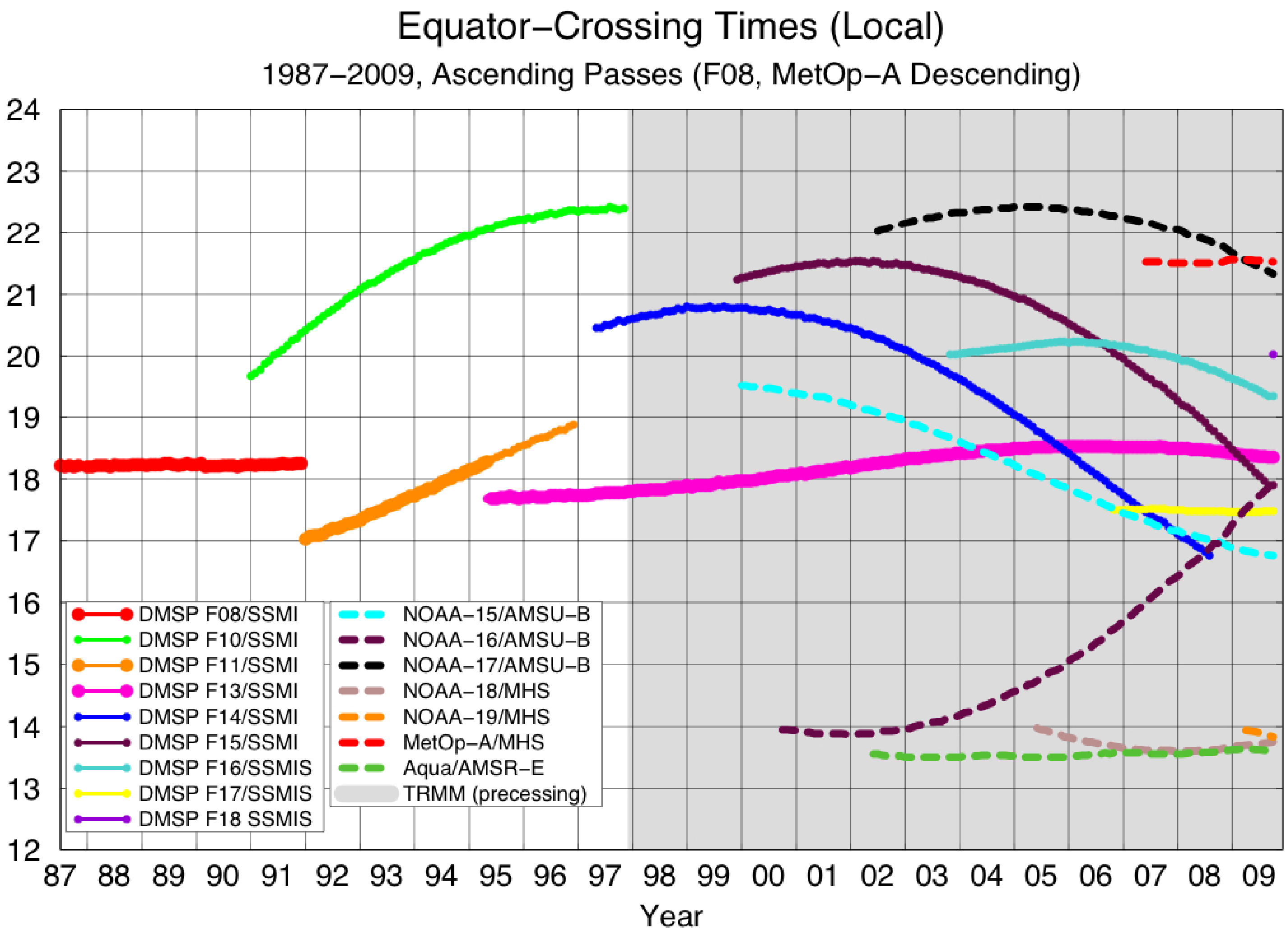
SSMIS Instrument Aboard DMSP16

(Special Sensor MicrowaveImager/Sounder)

Channel No.	Frequency (GHz) / Polarization	Resolution (km)	Scan positions	Channel Type
1	50.3 V	37.5	60	Lower Atmosphere Sounder
2	52.8 V	37.5	60	Lower Atmosphere Sounder
3	53.956 V	37.5	60	Lower Atmosphere Sounder
4	54.4 V	37.5	60	Lower Atmosphere Sounder
5	55.5 V	37.5	60	Lower Atmosphere Sounder
6	57.29 V	37.5	60	Lower Atmosphere Sounder
7	59.4 V	37.5	60	Lower Atmosphere Sounder
8	150.0 H	37.5	180	Imager
9	183.31 H (7)	37.5	180	Imager
10	183.31 H (3)	37.5	180	Imager
11	183.31 H (1)	37.5	180	Imager
12	19.35 H	25	90	Environmental
13	19.35 V	25	90	Environmental
14	22.235 V	25	90	Environmental
15	37.0 H	25	90	Environmental
16	37.0 V	25	90	Environmental
17	91.655 V	12.5	180	Imager
18	91.655 H	12.5	180	Imager
19	62.283 H+V	75	30	Upper Atmosphere Sounder
20	60.792 H+V	75	30	Upper Atmosphere Sounder
21	60.792 H+V	75	30	Upper Atmosphere Sounder
22	60.792 H+V	75	30	Upper Atmosphere Sounder
23	60.792 H+V	75	30	Upper Atmosphere Sounder
24	60.792 H+V	37.5	60	Lower Atmosphere Sounder

Notes:

nadir viewing angle of 45 deg	EIA of 53.2 deg
orbit altitude = 833 km	arcs are 144 degrees
rotation period = 1.9s	swath width = 1707 km

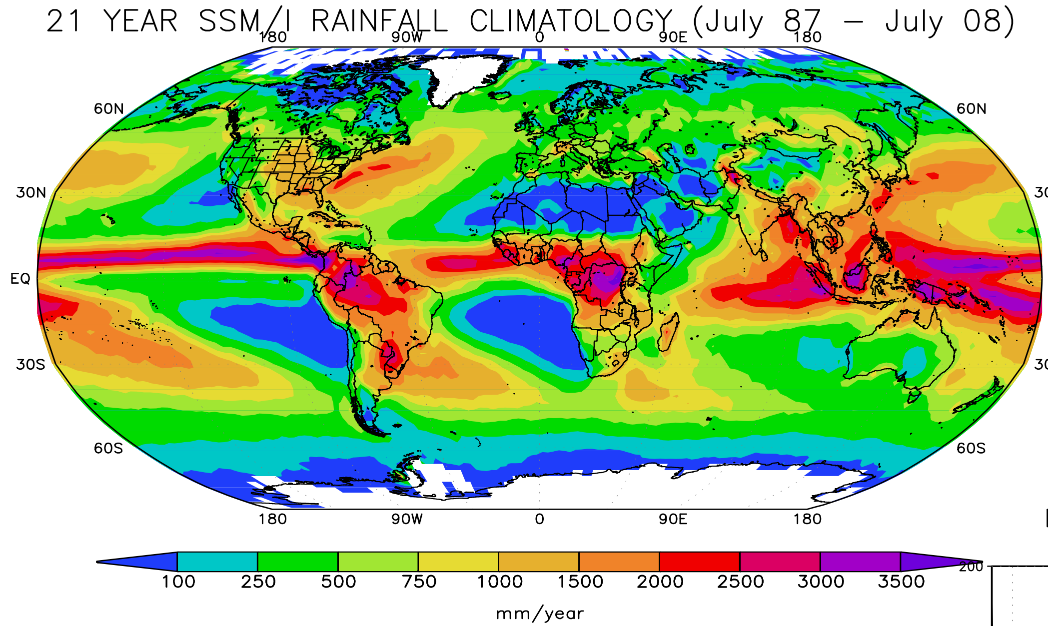


F17 – Replacement for F13

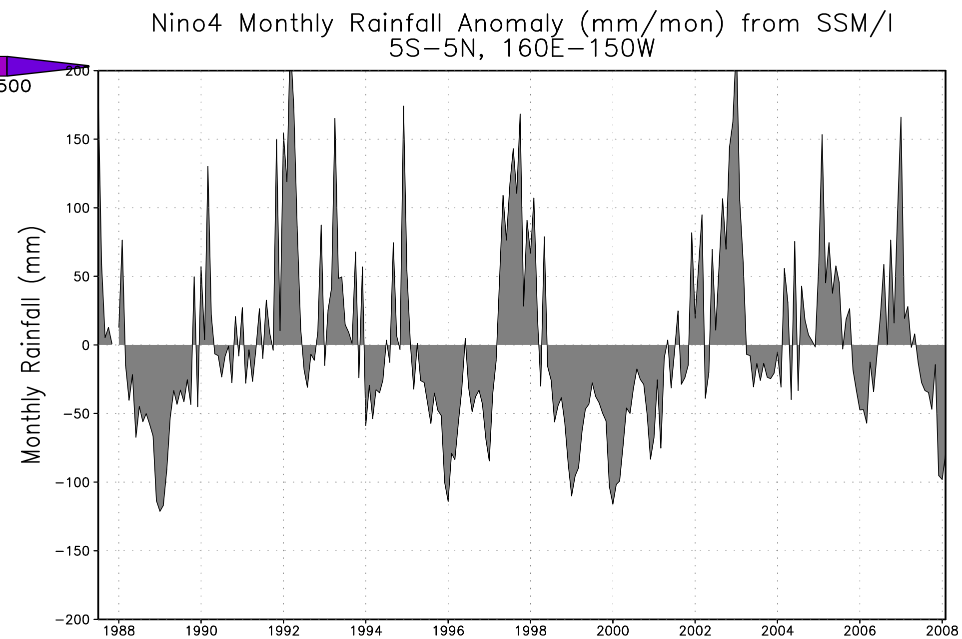
F16 – Replacement for F14/F15

Thickest lines denote GPCP calibrator.

Image by Eric Nelkin (SSAI), 23 October 2009, NASA/Goddard Space Flight Center, Greenbelt, MD.

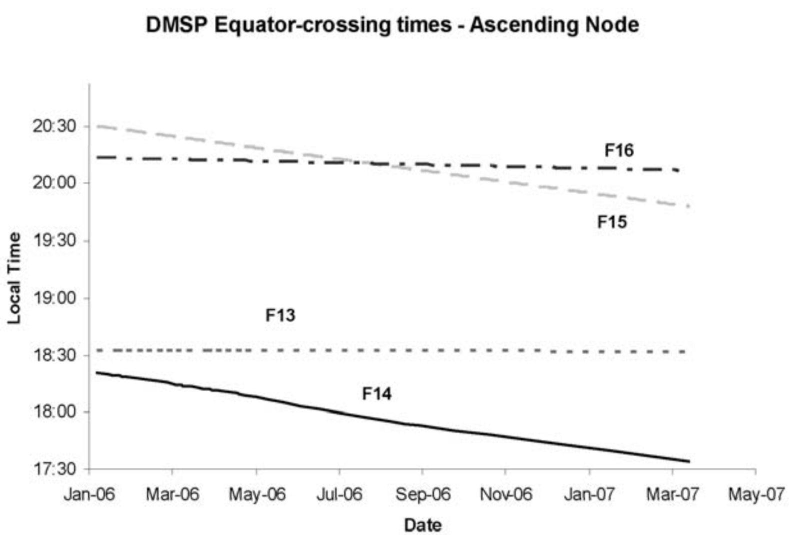


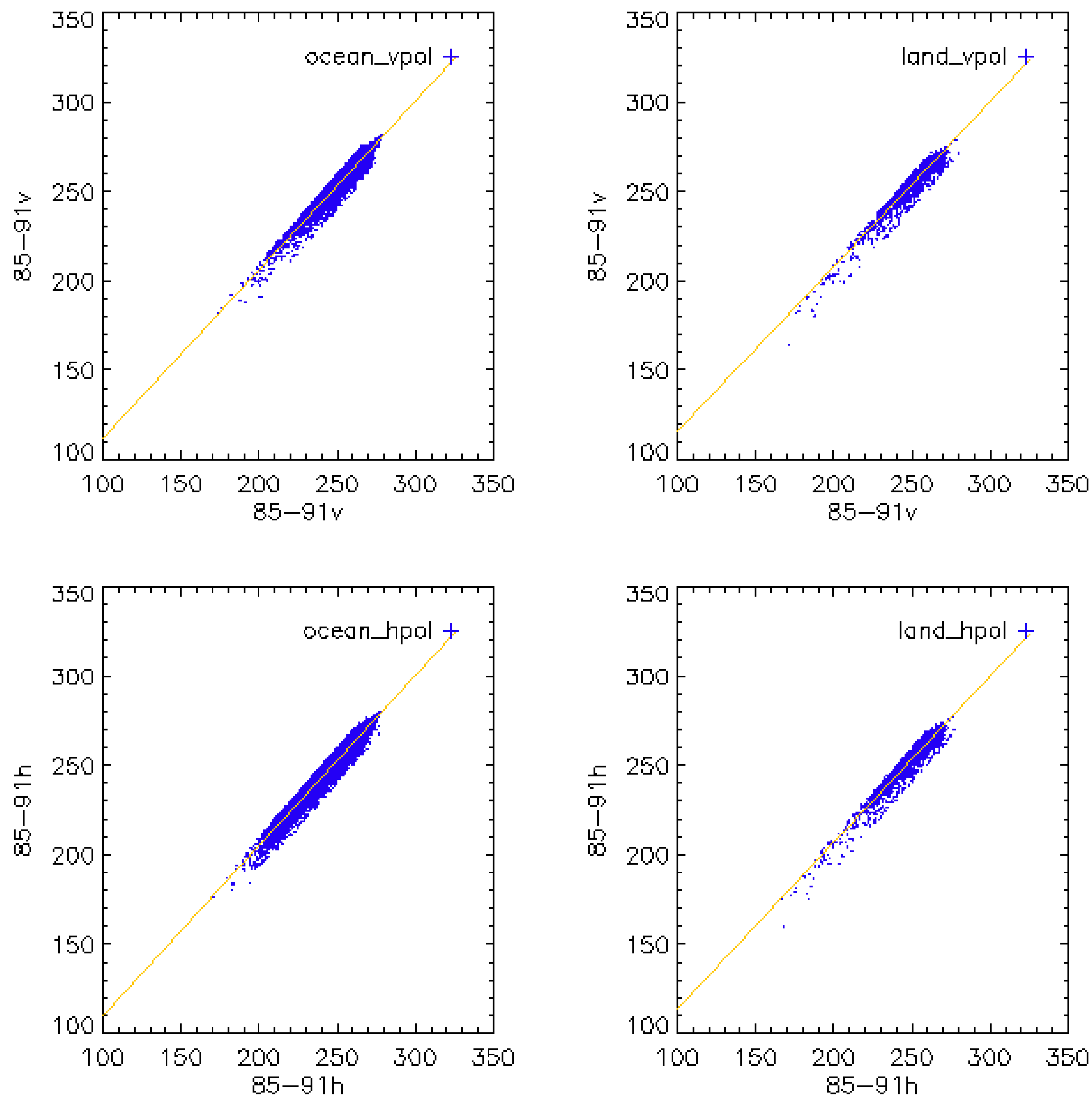
How to continue with the Climate Data Records?



SSMI-SSMIS Transition

A Simultaneous Conical Overpass (SCO) is defined as the data pair generated when two polar-orbiting satellites (SSM/I F15 and SSMI/S F16 cross the same area at similar local times (t < 2 minutes).

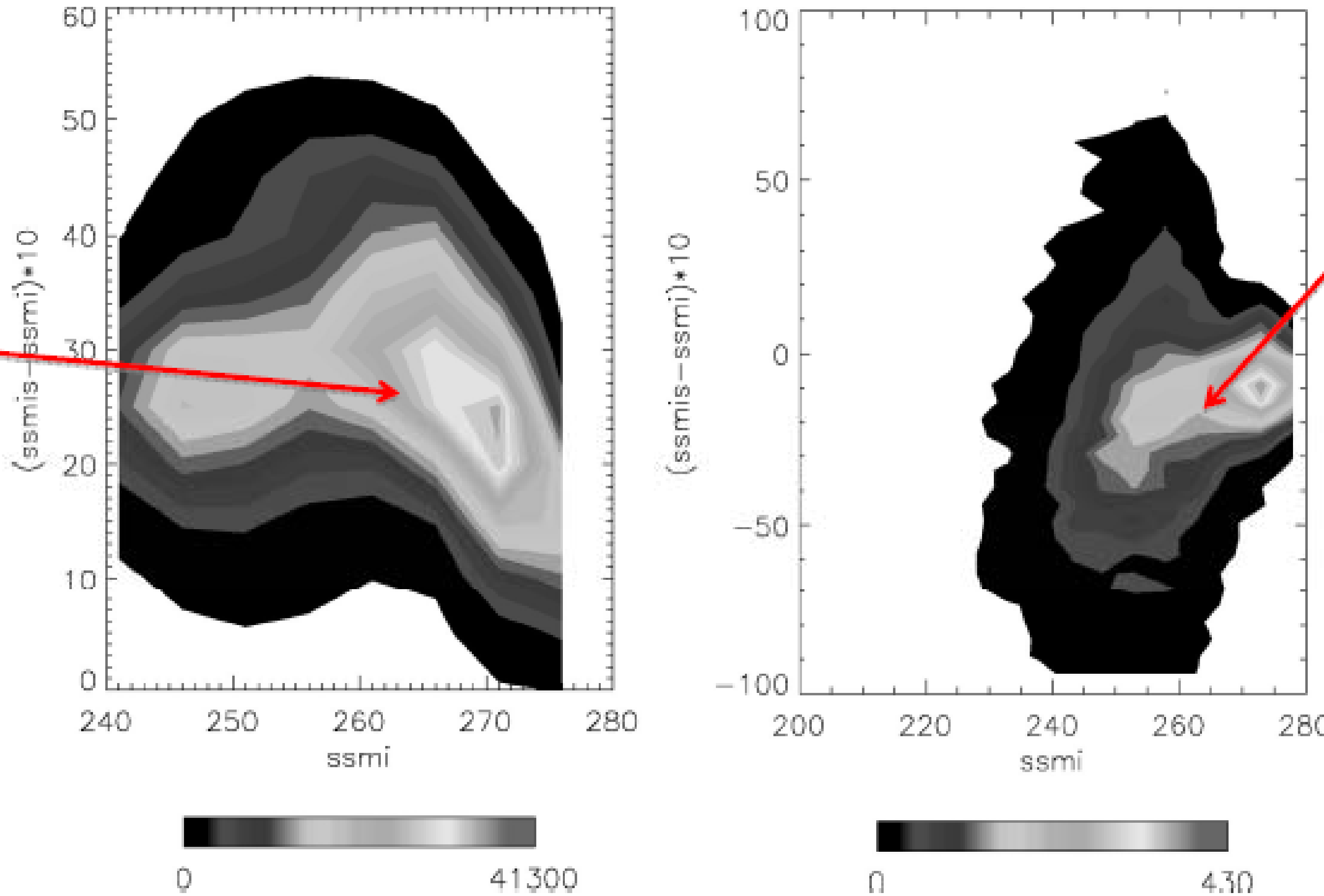




SSMI-SSMIS Transition

Clear Scenes Over-Ocean | **Rainy Scenes Over Ocean**

91 > 85 due to increased thermal emission



91 < 85 for heavier rain events due to higher ice albedo

2-D histogram for SSMIS 91.6 GHz V T_B and SSMI 85.5 GHz T_B difference as a function of SSMI 85.5 GHz V T_B

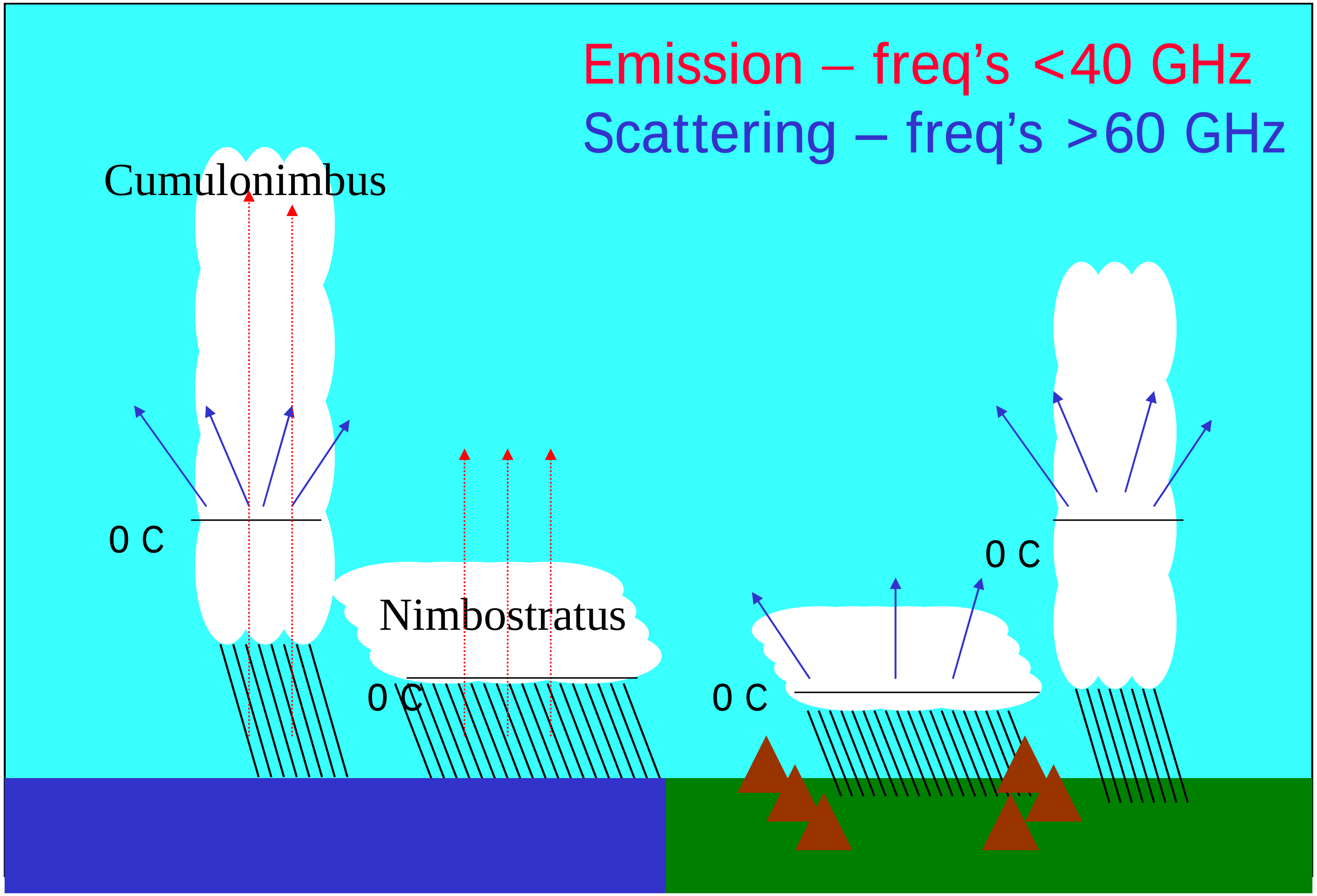
- Develop empirical fits between SSM/I F15 and SSMI/S F16 during period of close overpass times (3/06 – 2/07)
  - All channels
  - Stratify via land/ocean; rain/no-rain
  - RADCAL correction applied to F15 8/06 and forward
- Improves
  - Rain/No-Rain threshold
  - Rain rate PDF's
  - Other products (e.g., TPW, CLW, etc.)

$$TA_{SSMI} = \alpha_{chan,sfctype,rain} + \beta_{chan,sfctype,rain} * TA_{SSMI/S}$$

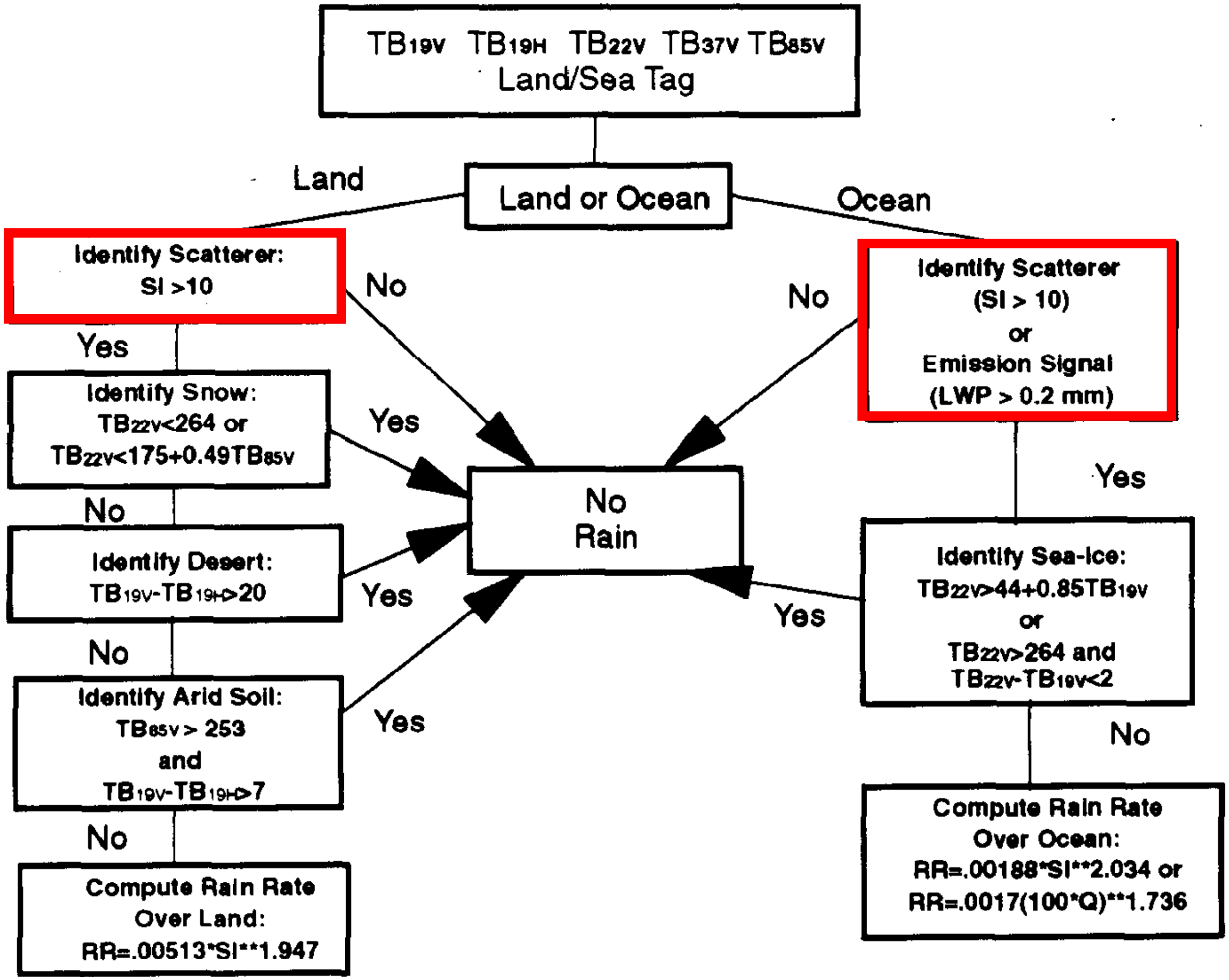
Frequency (GHz)		rain		clear sky	
		α	β	α	β
19.35 (V)	ocean	-4.3056	1.0154	-3.7588	1.0081
19.35 (H)		-0.1004	1.0000	-0.5628	0.9941
19.35 (V)	land	-2.5415	1.0116	-3.0527	1.0139
19.35 (H)		1.2867	1.0001	1.3982	1.0000
22.235 (V)	ocean	-4.7092	1.0064	-5.6801	1.0069
22.235 (V)	land	1.0261	0.9879	0.0261	0.9879
37.0 (V)	ocean	15.9657	0.9279	-2.5349	0.9950
37.0 (H)		18.9355	0.9165	0.4925	0.9900
37.0 (V)	land	2.3171	0.9825	-8.1856	1.0206
37.0 (H)		1.6337	0.9875	1.0819	0.9905
91.655 (V) - 85.5 (V)	ocean	30.1409	0.8985	-9.1453	1.0463
91.655 (H) - 85.5 (H)		30.8093	0.8947	-3.2688	1.0066
91.655 (V) - 85.5 (V)	land	29.9904	0.8980	1.0681	1.0090
91.655 (H) - 85.5 (H)		28.0057	0.9067	0.8296	1.0111

Rainfall retrieval using PMW Techniques

- Microwave energy can penetrate clouds, in particular, cirrus clouds, and its signal has a strong interaction with precipitation-size drops and ice particles.
- Below 20 GHz, emission by precipitation-size drops dominates and ice particles above the rain layer are nearly transparent. Above 60 GHz, ice scattering dominates and the radiometers cannot sense the rain drops below the freezing layer.



FERRARO ALGORITHM (1997)



FERRARO ALGORITHM (1997)

Scattering Index Computation

scattering materials: $T_v(22) > T_v(85)$

precipitation, dry snow, aged sea ice, glacial ice, deserts

absorbing materials: $T_v(22) < T_v(85)$

clouds, melting snow, new sea ice, vegetation, wet soil

Oceanic:

SI85= (-174.4 + 0.715*TB19v + 2.439*TB22v - 0.00504*TB22v*TB22v) - TB85v

Land:

SI85= (451.9 - 0.44*TB19v - 1.775*TB22v + 0.00574*TB22v*TB22v) - TB85v

Estimation of the non-scattering contribution of the 85 GHz measurements

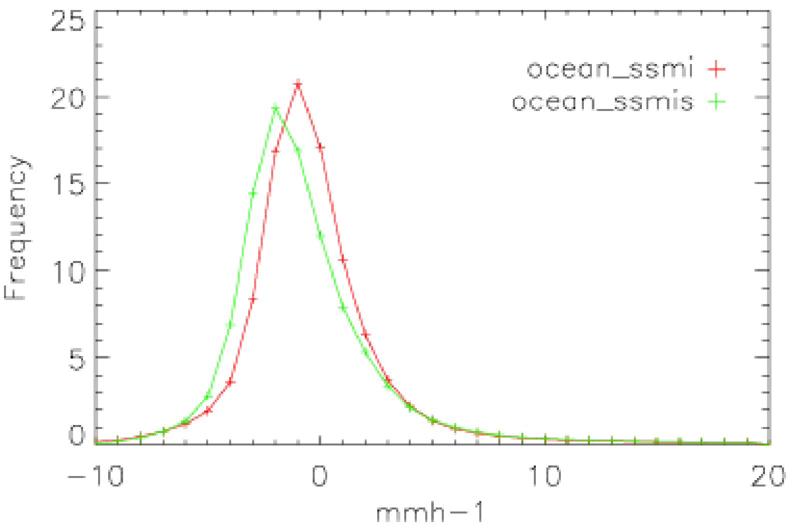
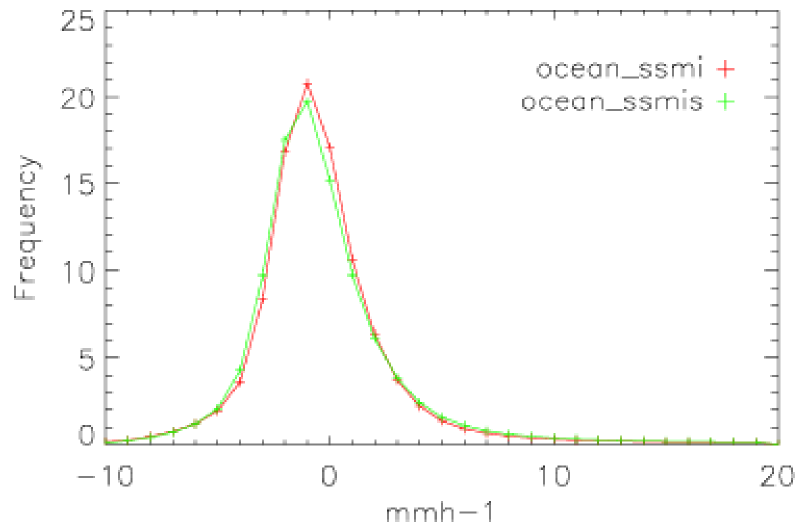
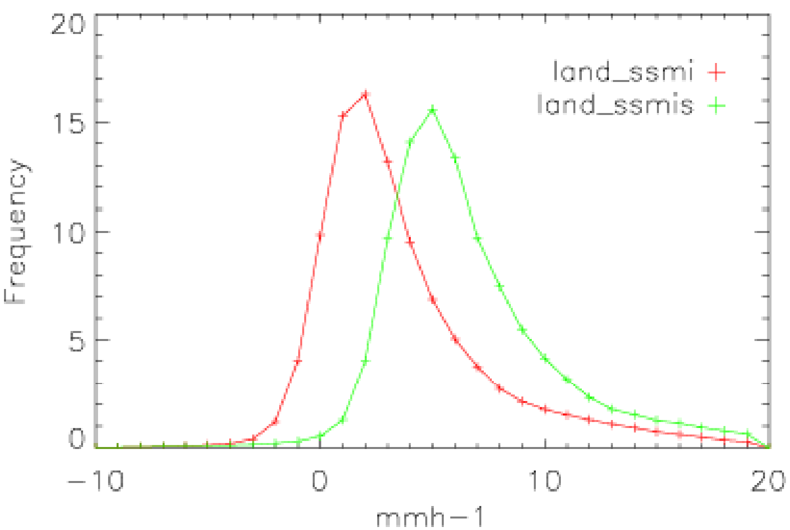
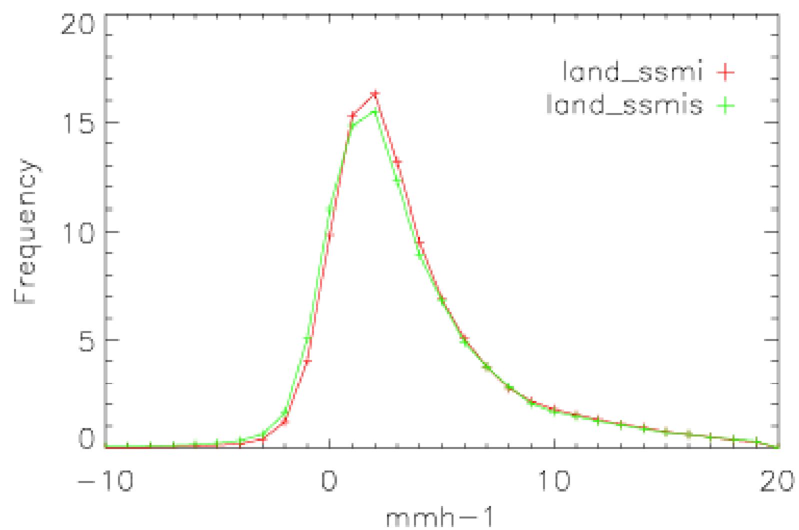
If SI85 > 10 then Rain ~ log(SI85)
(after screens for ice, deserts, etc using polarization checks)

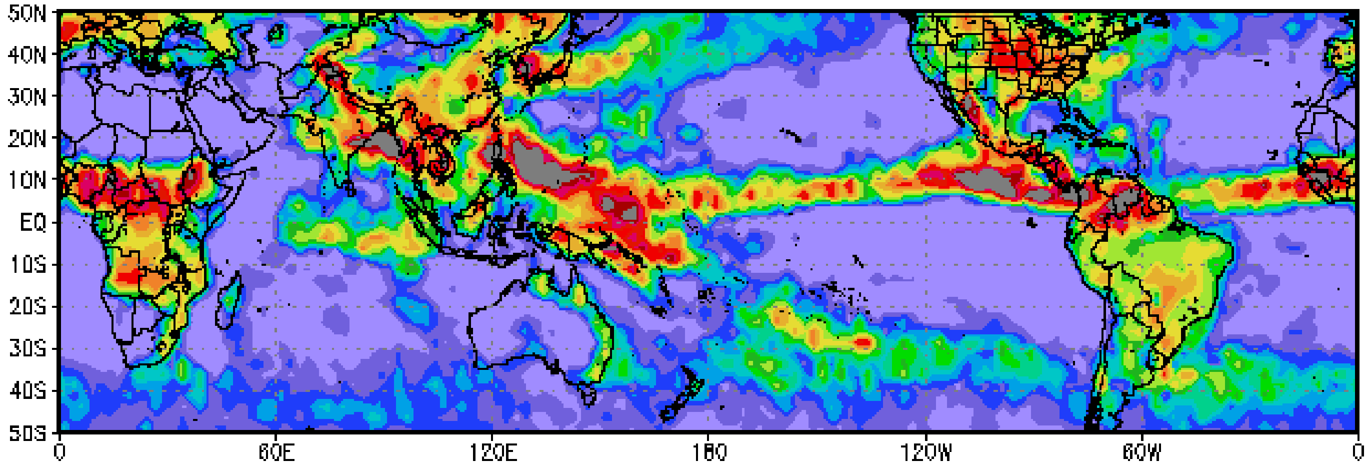
SSMIS vs. SSMI:

For scattering materials, 91 GHz scatters a bit more than 85 GHz

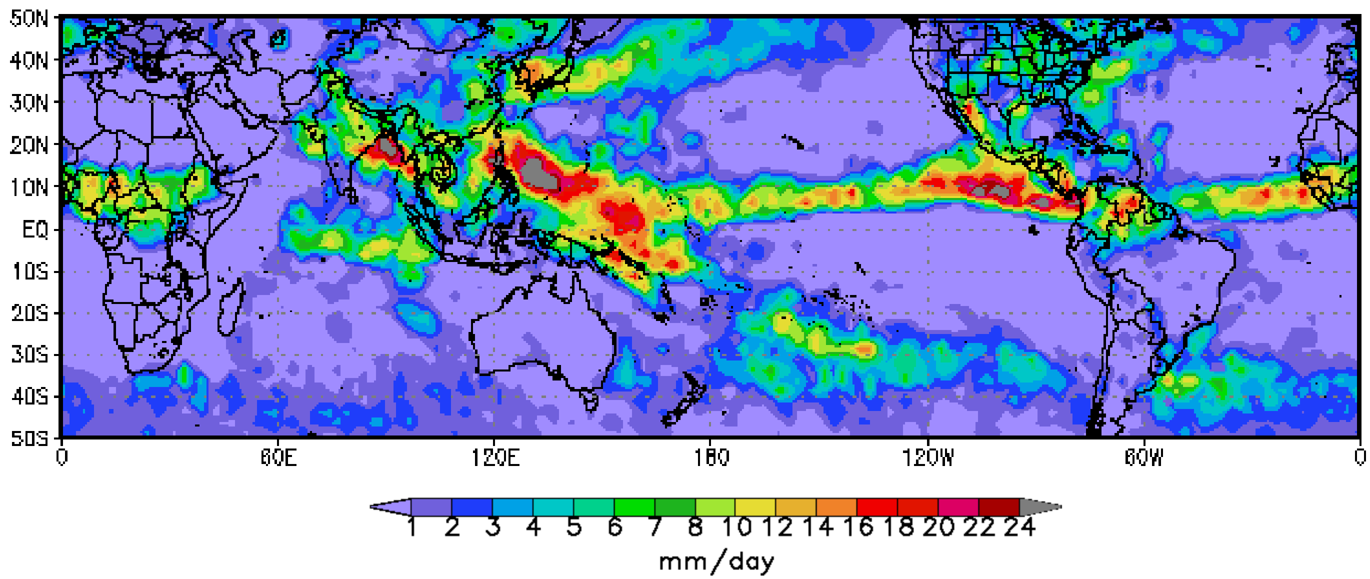
For absorbing materials, 91 GHz emits (absorbs) more than at 85 GHz

SCATTERING INDEX

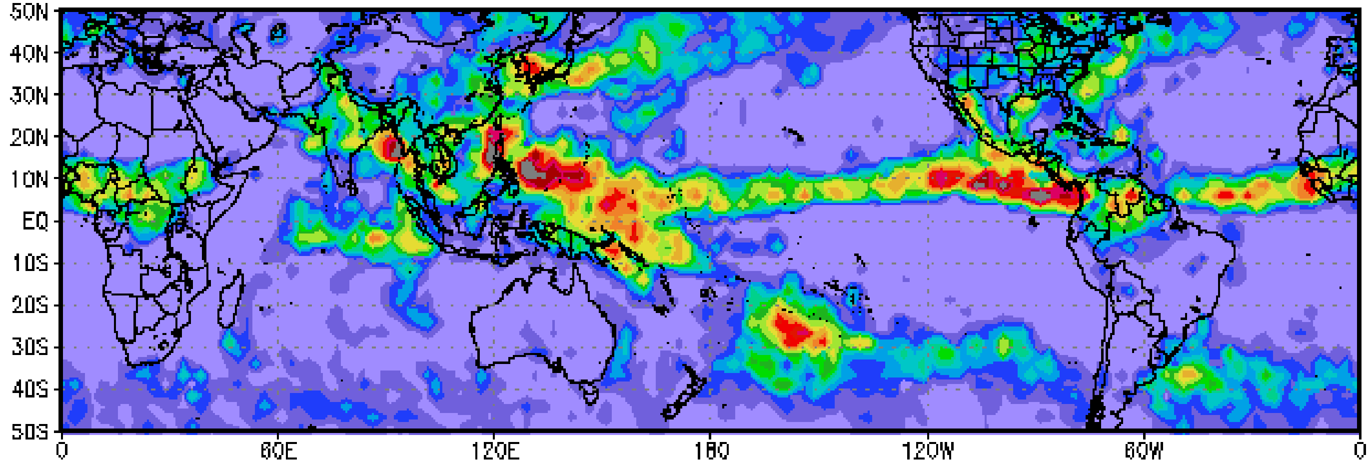
UNCORRECTED	CORRECTED	
		**OCEAN**
		**LAND**



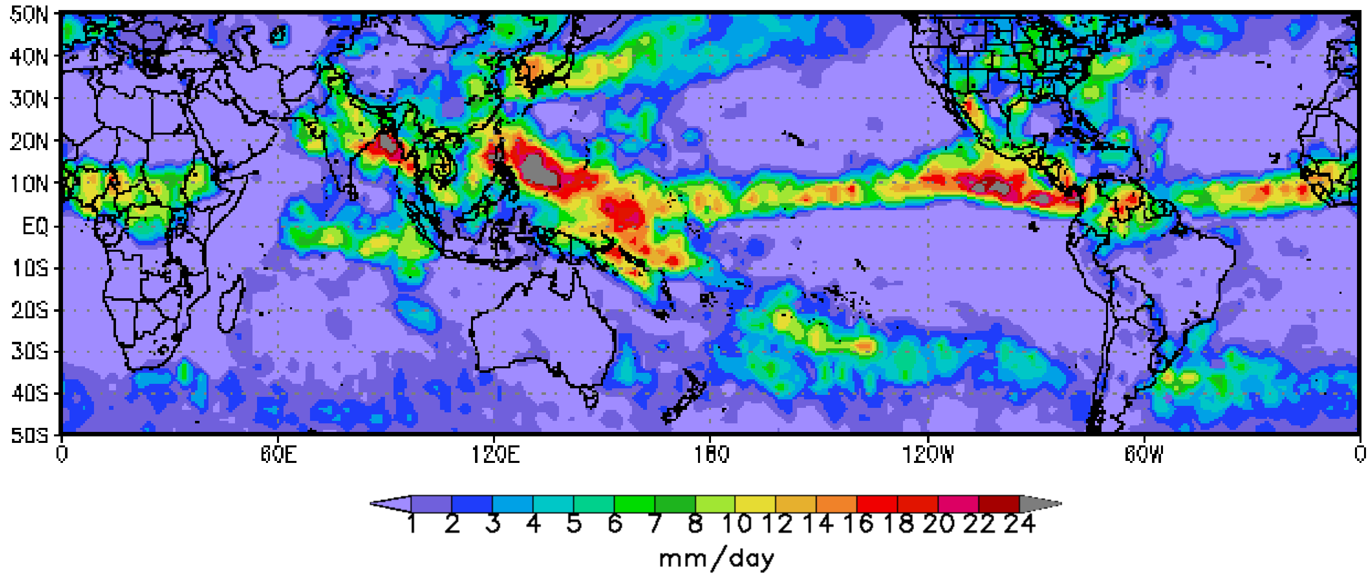
SSMI/S F16 - Uncorrected



SSMI/S F16 - Corrected

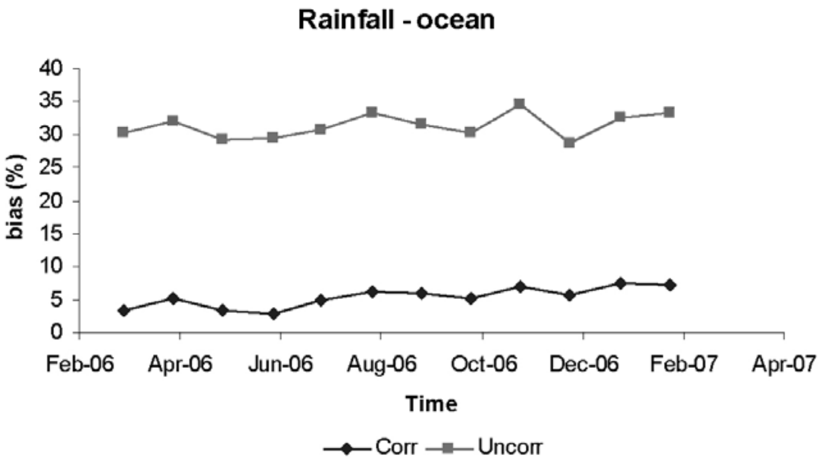


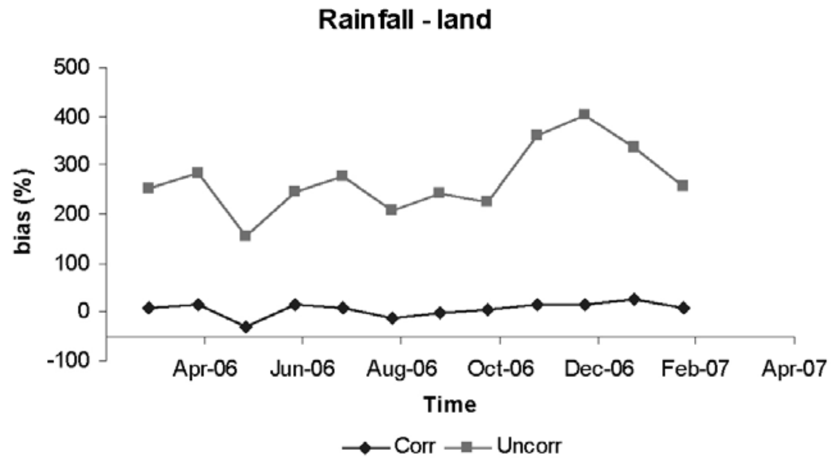
SSMI F15

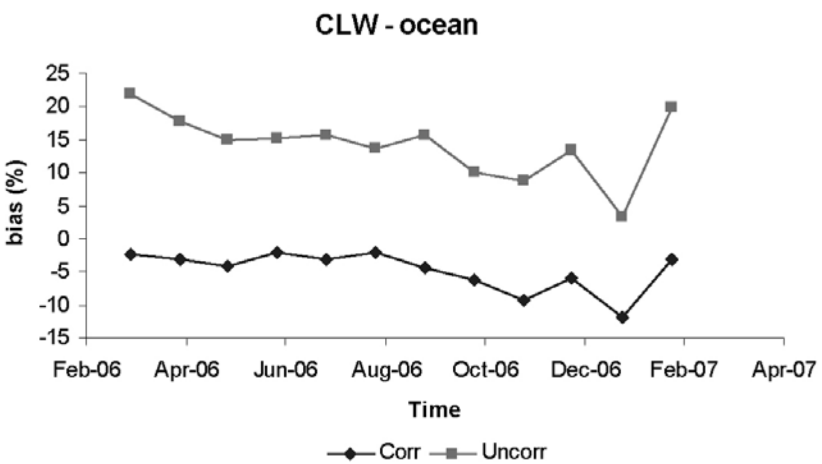


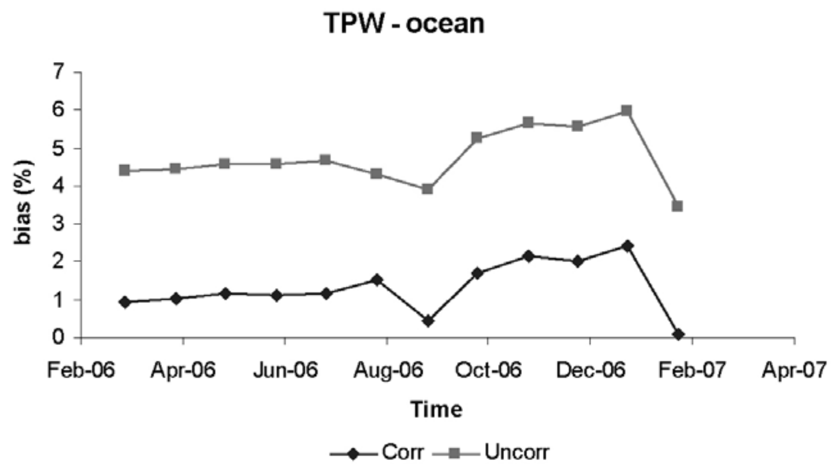
SSMI/S F16 - Corrected

Validation results

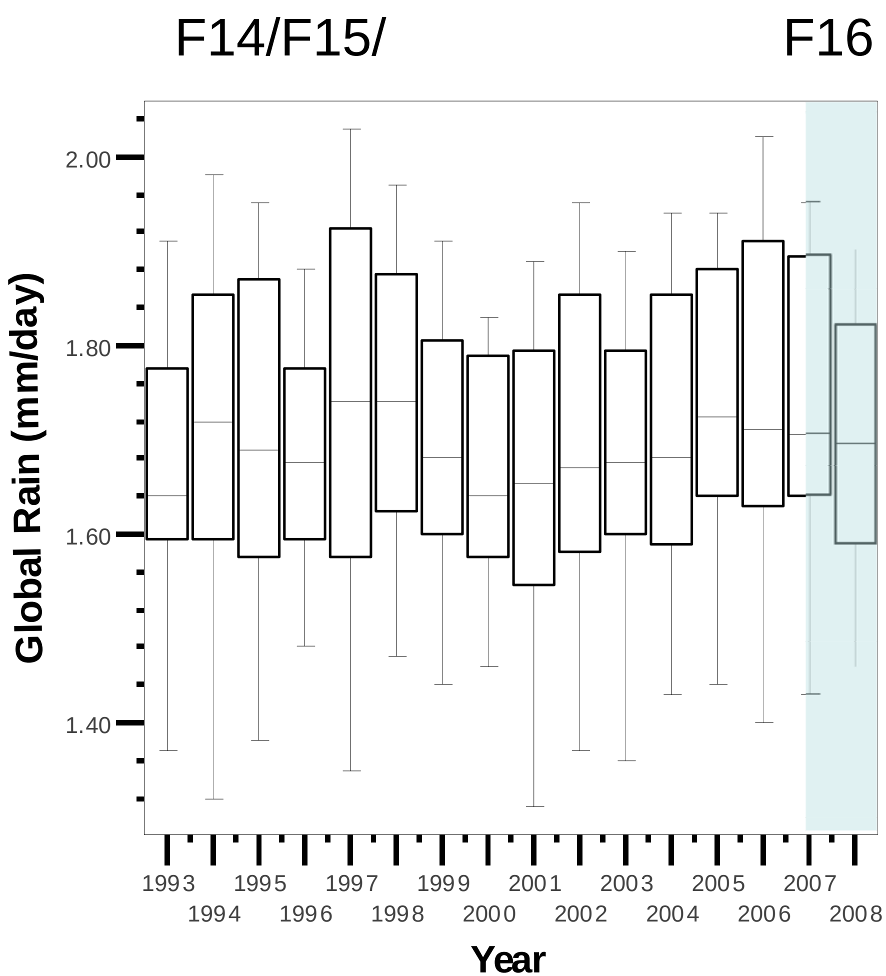


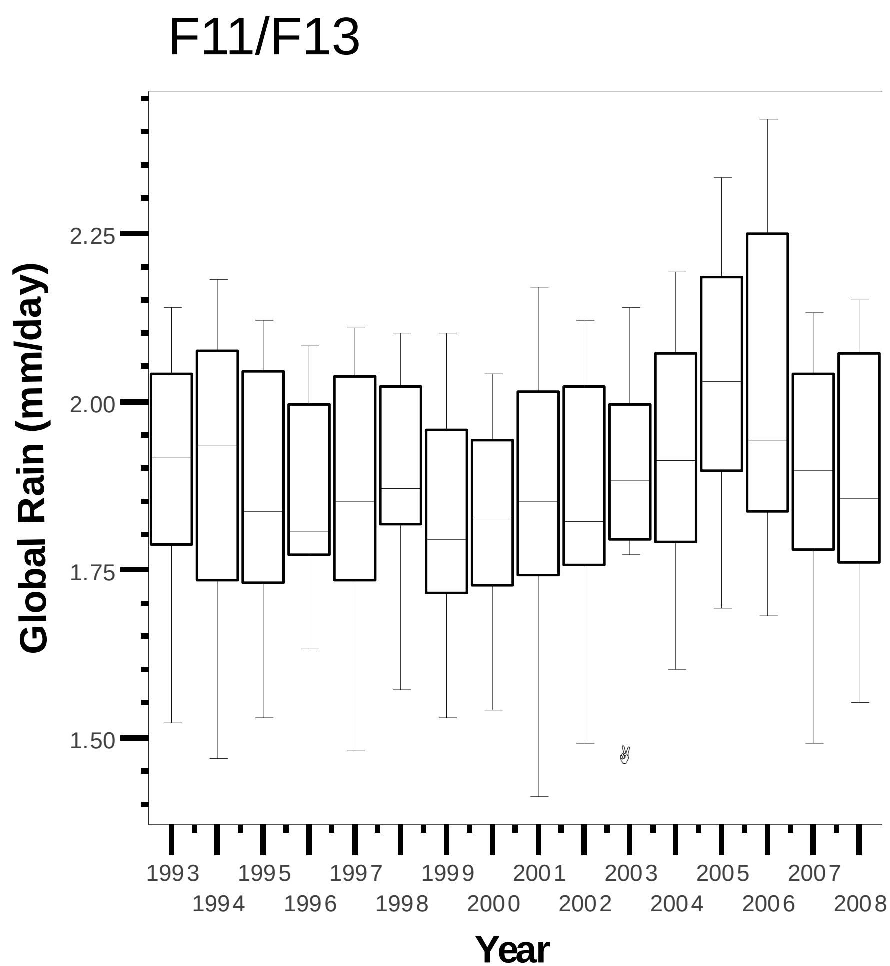


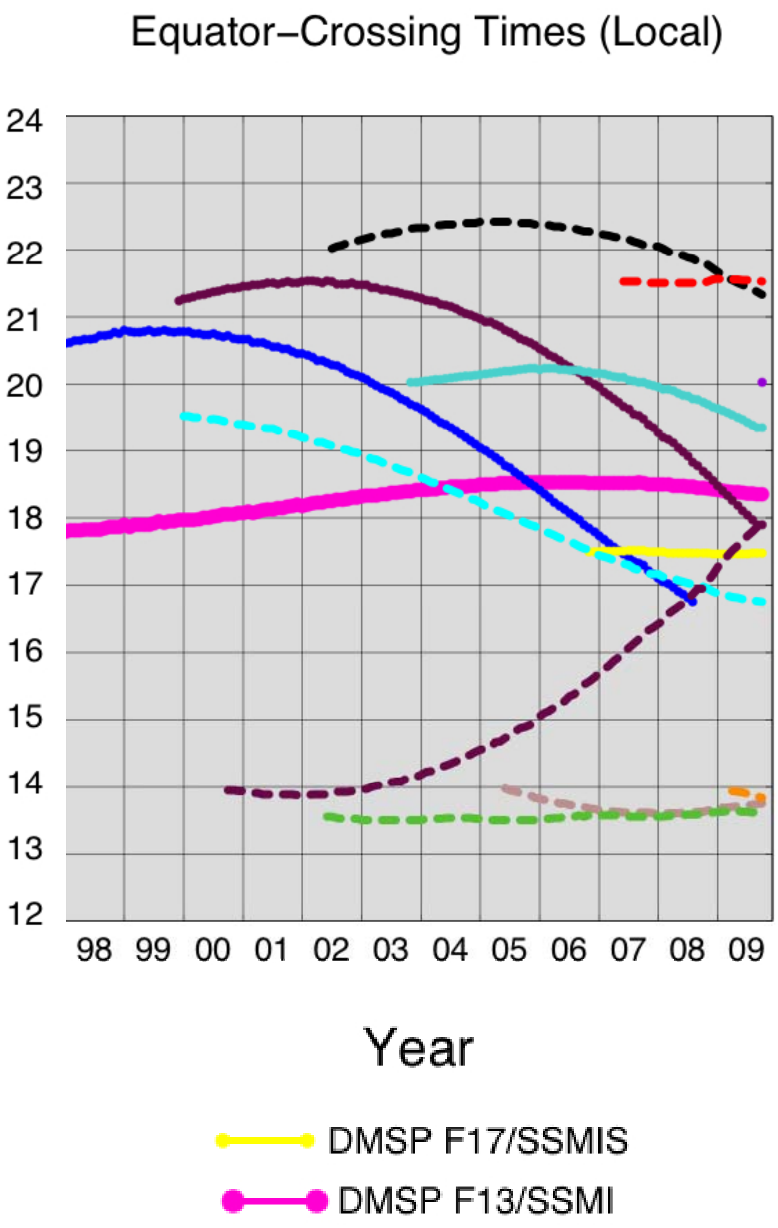




Rainfall rates – Annual Distribution

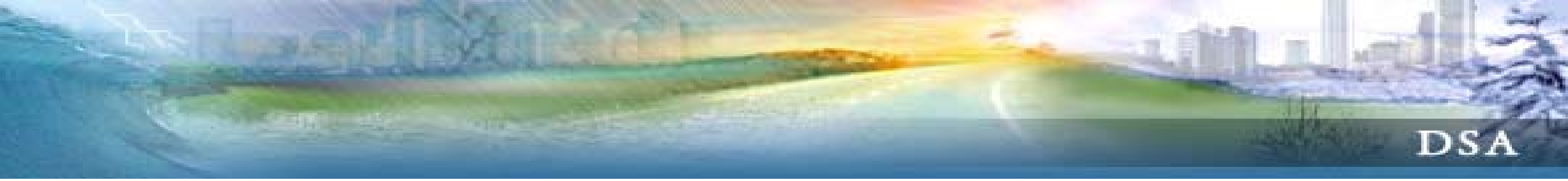


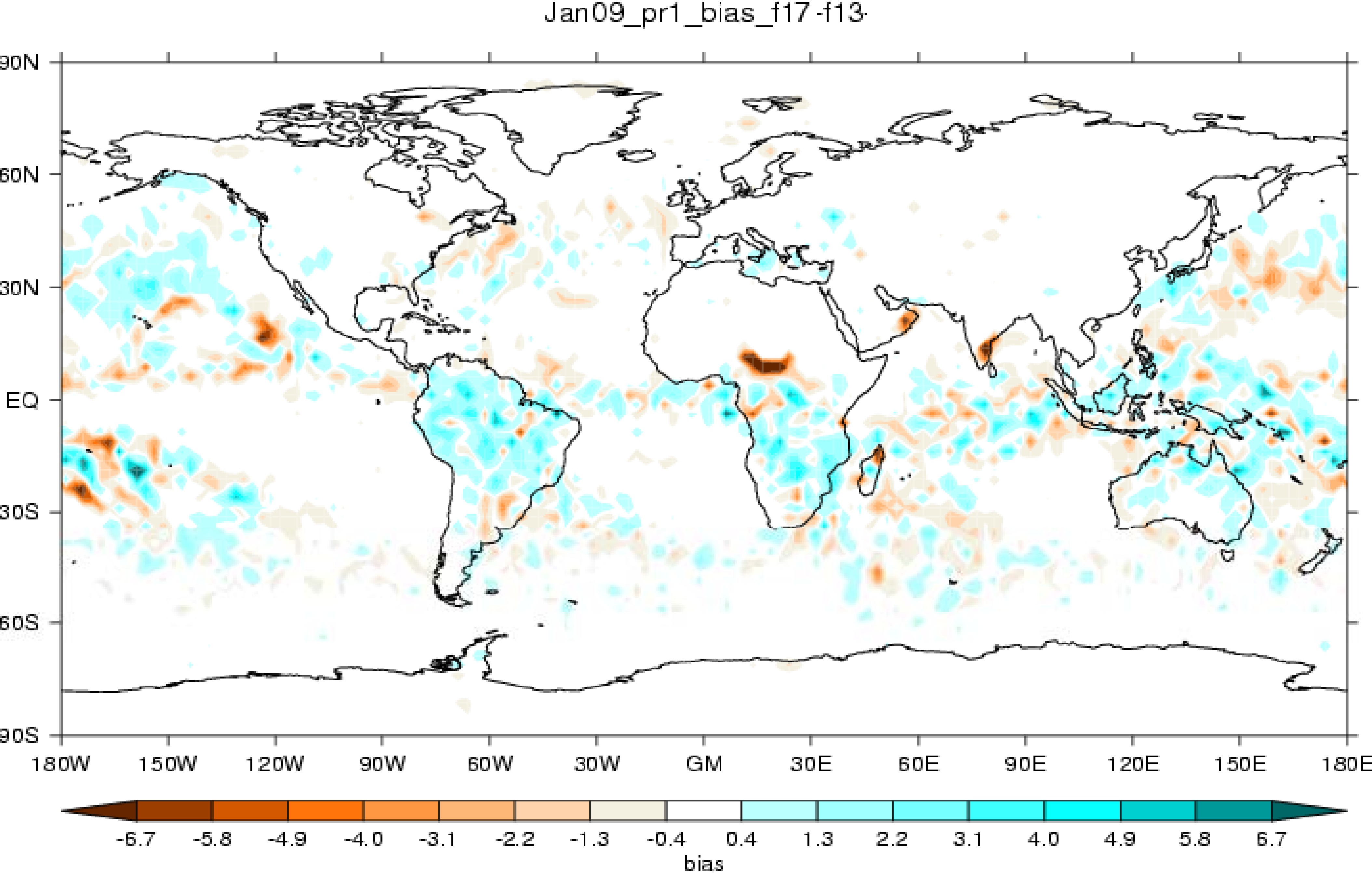


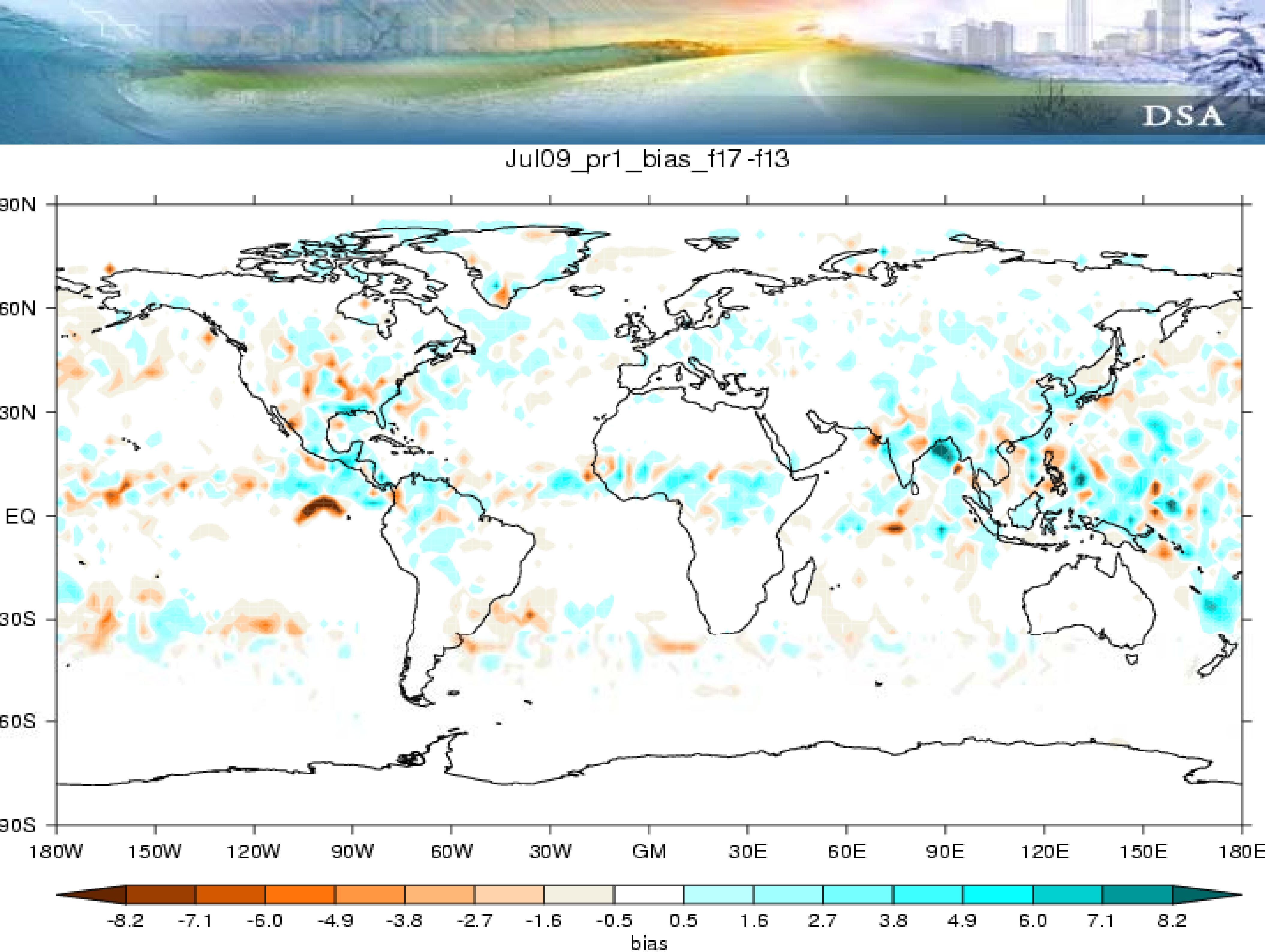


F17-F13 Comparisons

- Equator-Crossing Times ~1.5 hours apart.
- Ascending node close to the convection peak.
- No direct match-up between both satellites.
- It's known that F17 still have some solar intrusion problems…
- .. but F17 is closest satellite to the early morning constellation (see figure), so it's our best option for climate products generation (SSMI, GPCP)


DSA


Jan09_pr1_bias_f17-f13
90N
60N
30N
EQ
30S
60S
90S
180W
150W
120W
90W
60W
30W
GM
30E
60E
90E
120E
150E
180E
-6.7
-5.8
-4.9
-4.0
-3.1
-2.2
-1.3
-0.4
0.4
1.3
2.2
3.1
4.0
4.9
5.8
6.7
bias



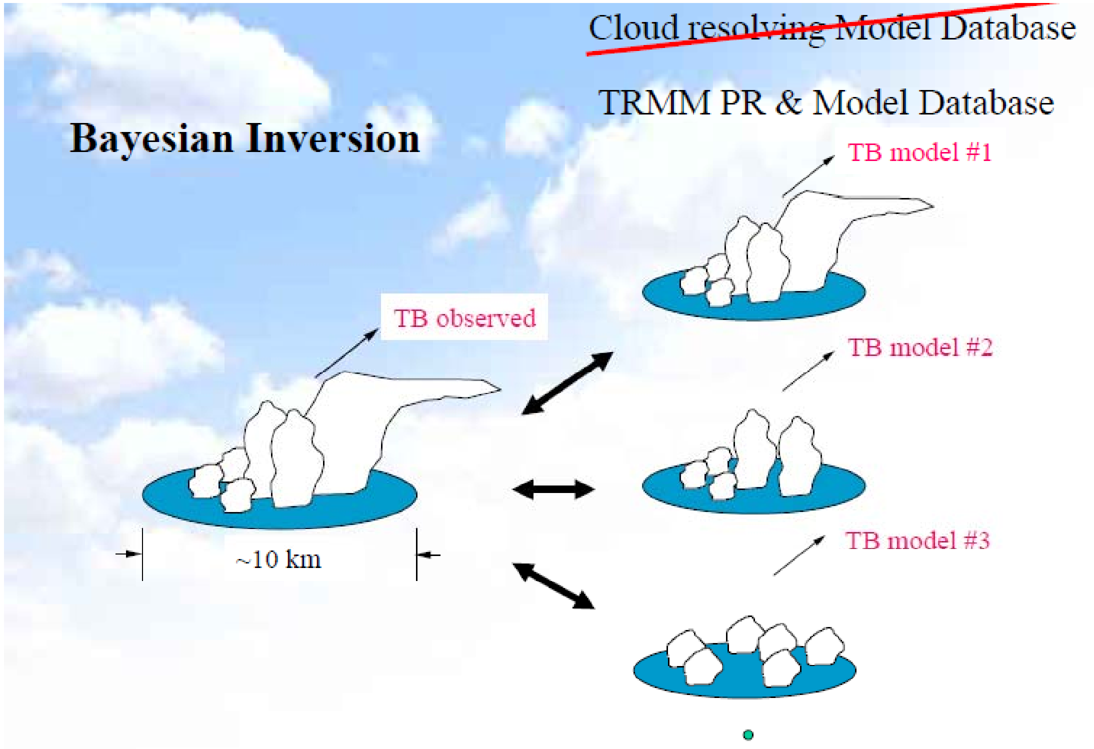
DSA
Jul09_pr1_bias_f17-f13
90N
60N
30N
EQ
30S
60S
90S
180W
150W
120W
90W
60W
30W
GM
30E
60E
90E
120E
150E
180E
-8.2
-7.1
-6.0
-4.9
-3.8
-2.7
-1.6
-0.5
0.5
1.6
2.7
3.8
4.9
6.0
7.1
8.2
bias

INSTANTANEOUS RETRIEVALS: GPROF ALGORITHM

- Simulated radiometer footprints and calculated radiance indices of the algorithm's database are shown at right, while the observed footprint and radiance indices are at left.

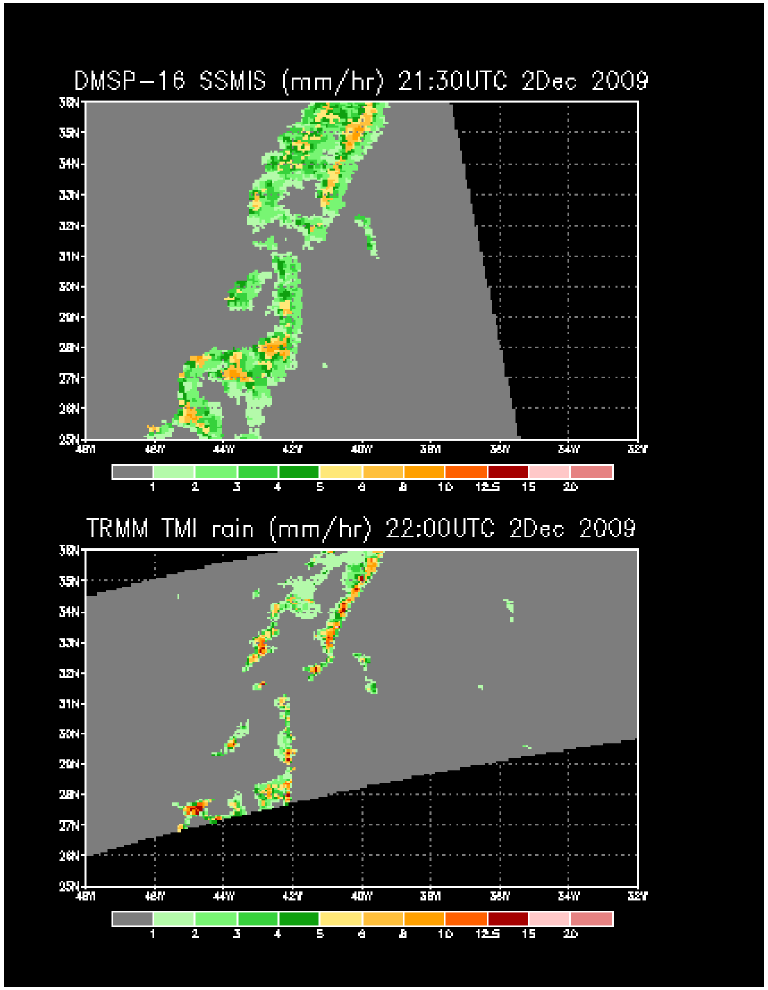
- Observed radiance indices are compared to each set of simulated radiance indices in the database.

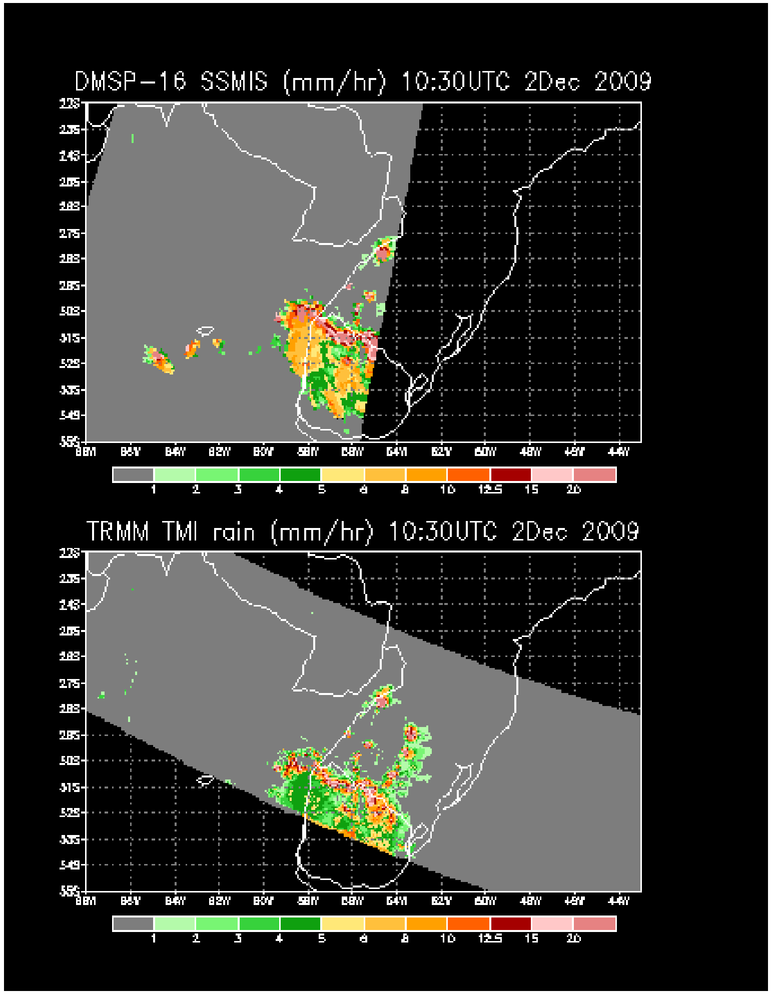
- Those simulations that are more radiatively consistent with the observations contribute strongly to the GPROF estimate of the parameters, while those simulations that are less consistent radiatively contribute much less.



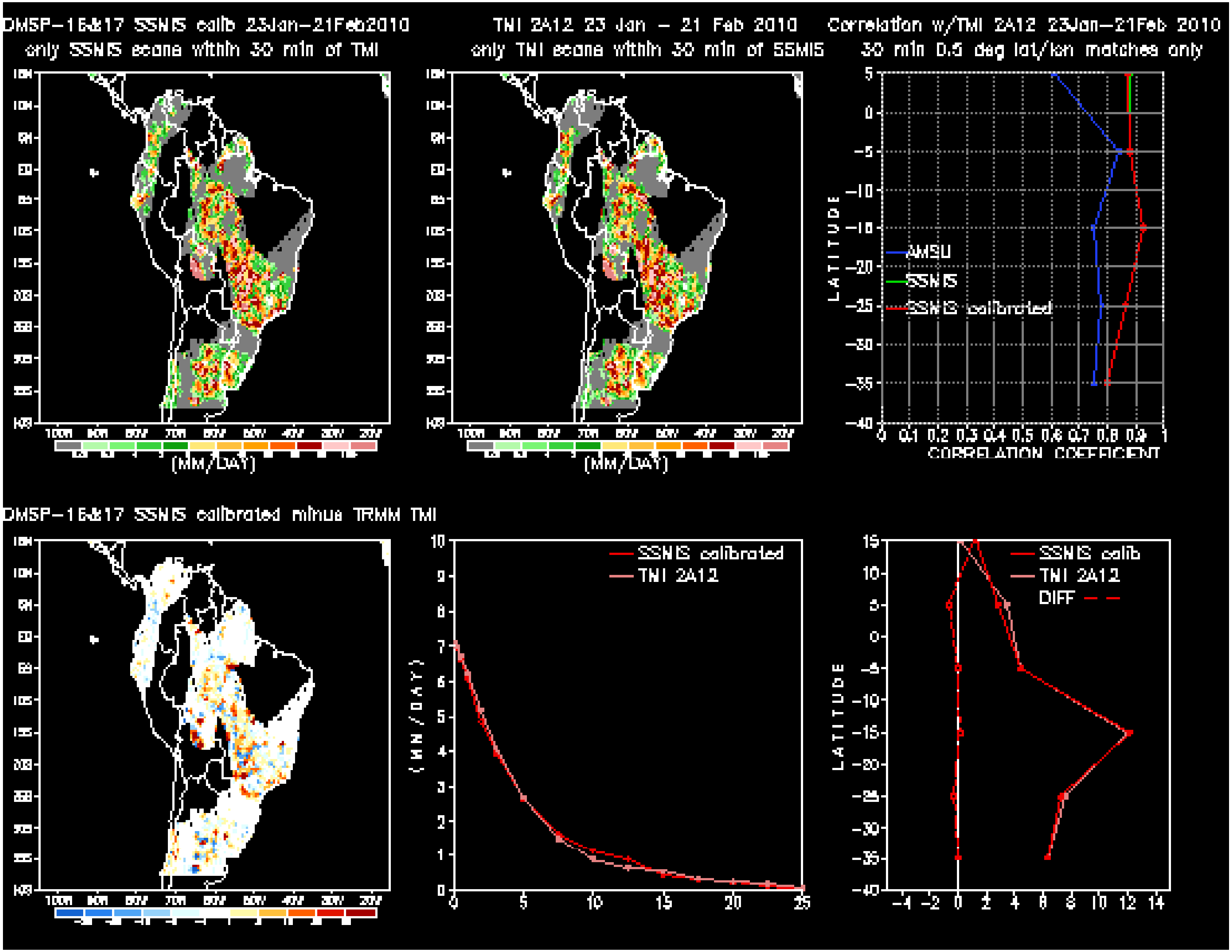
$$P(\mathbf{R}\,|\,\mathbf{T}_b) \propto P(\mathbf{R}) \times P(\mathbf{T}_b\,|\,\mathbf{R})$$

INSTANTANEOUS RETRIEVALS: GPROF/TMI – GPROF/SSMIS





DSA



DMSP-16&17 SSMIS calib 23Jan-21Feb2010
only SSMIS scans within 30 min of TMI
(MM/DAY)
TMI 2A12 23 Jan - 21 Feb 2010
only TMI scans within 30 min of SSMIS
(MM/DAY)
Correlation w/TMI 2A12 23Jan-21Feb 2010
30 min 0.5 deg lat/lon matches only
AMSU
SSMIS
SSMIS calibrated
LATITUDE
CORRELATION COEFFICIENT
DMSP-16&17 SSMIS calibrated minus TRMM TMI
SSMIS calibrated
TMI 2A12
(MM/DAY)
SSMIS calib
TMI 2A12
DIFF
LATITUDE

Summary and Conclusions

- The statistical analysis performed with this SCO dataset after applying the proposed scheme, shows a lower bias and high correlation between SSM/I and SSMI/S retrievals when compared with raw SSMI/S retrievals for all variables.

- The proposed correction scheme is not time dependent, as it is shown in the time series analysis. This fact is a key issue for using SSMI/S retrievals for continuing the 21-years SSM/I-based data set.

- Future research should be conducted in order to compare statistical properties of monthly retrievals among different satellites using a longer dataset and different retrieval algorithms.