Advances in AMSU Non-Sounding Products

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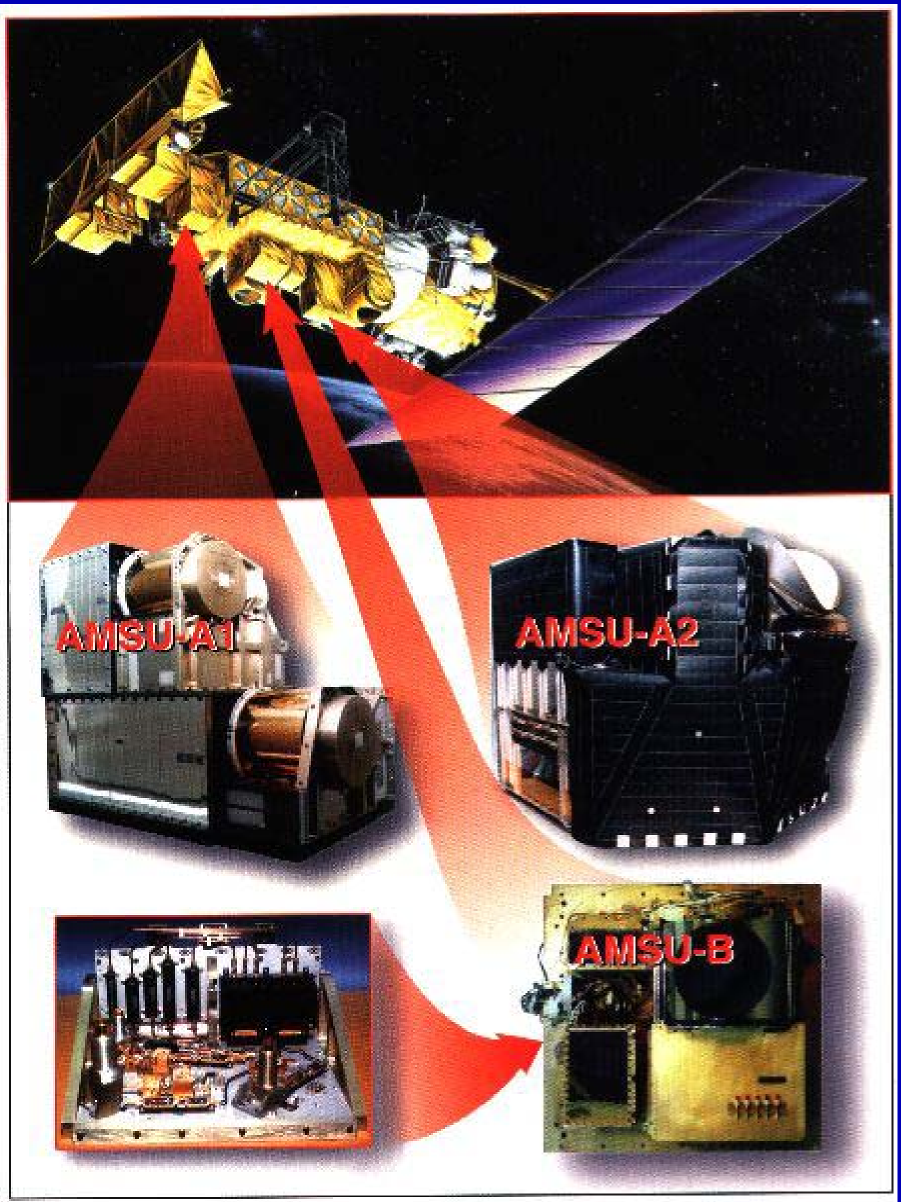
Outline

- Describe a new suite of operational non-sounding at NOAA/NESDIS

1. AMSU Sensor
2. Product Overview & Retrieval Algorithms
3. Examples
4. Future/Data Availability

NOAA AMSU Sensor

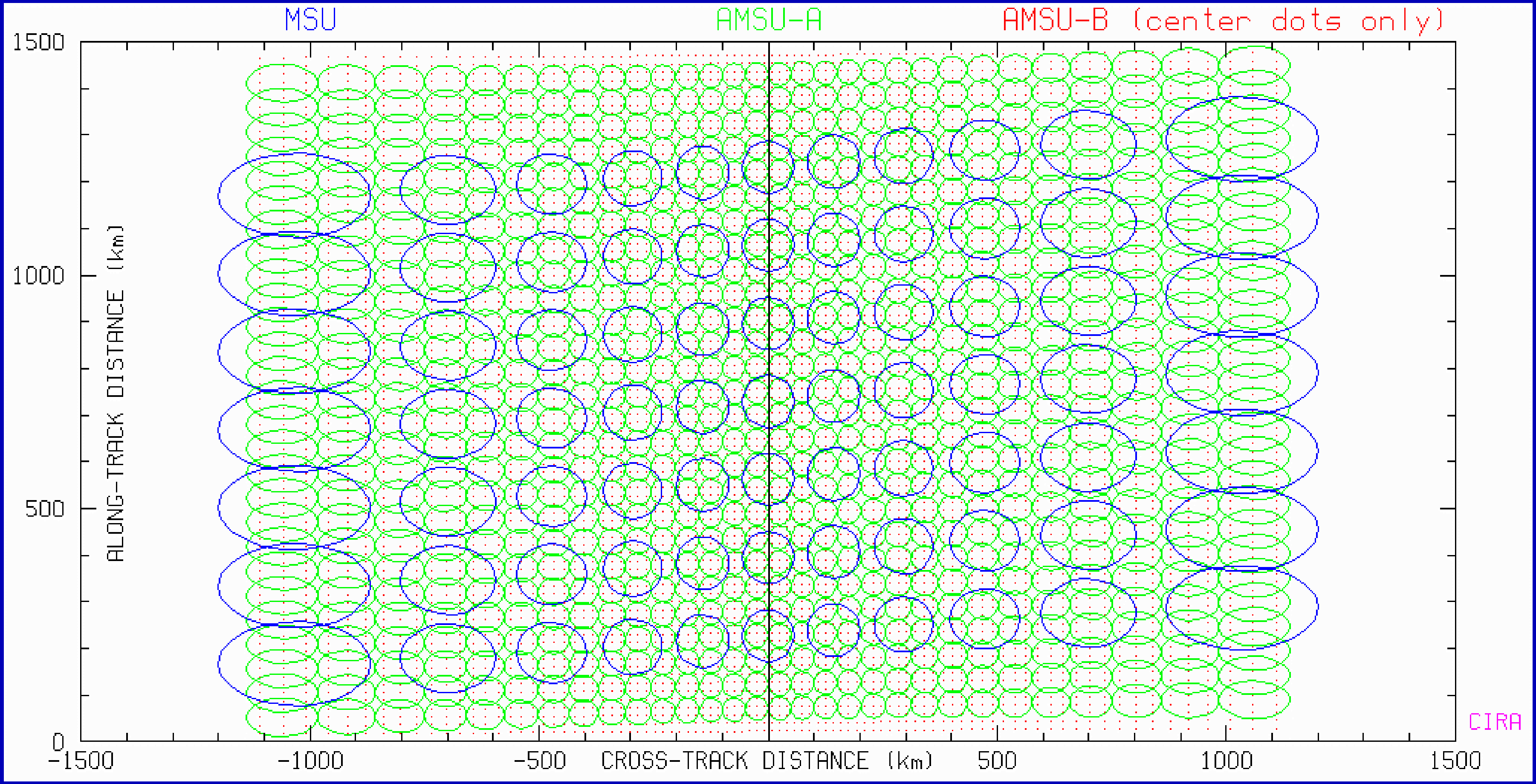


- Flown on NOAA-15 (May 1998) and NOAA-16 (Sept. 2000) satellites
- Contains 20 channels:
    - AMSU-A
        - 15 channels
        - 23 – 89 GHz
    - AMSU-B
        - 5 channels
        - 89 – 183 GHz
- 6-hour temporal sampling:
    - 130, 730, 1330, 1930 LST

AMSU Observation Frequencies

Channel	Frequency	Channel	Frequency
A1	23.8 GHz	A8	55.5 GHz
A2	31.4	A9-A14	57.290**
A3	50.3	A15	89.0
A4	52.8	B1	89.0
A5	53.6	B2	150.0
A6	54.4	B3-5	183.31**
A7	54.9		

AMSU-A and –B Scan Pattern



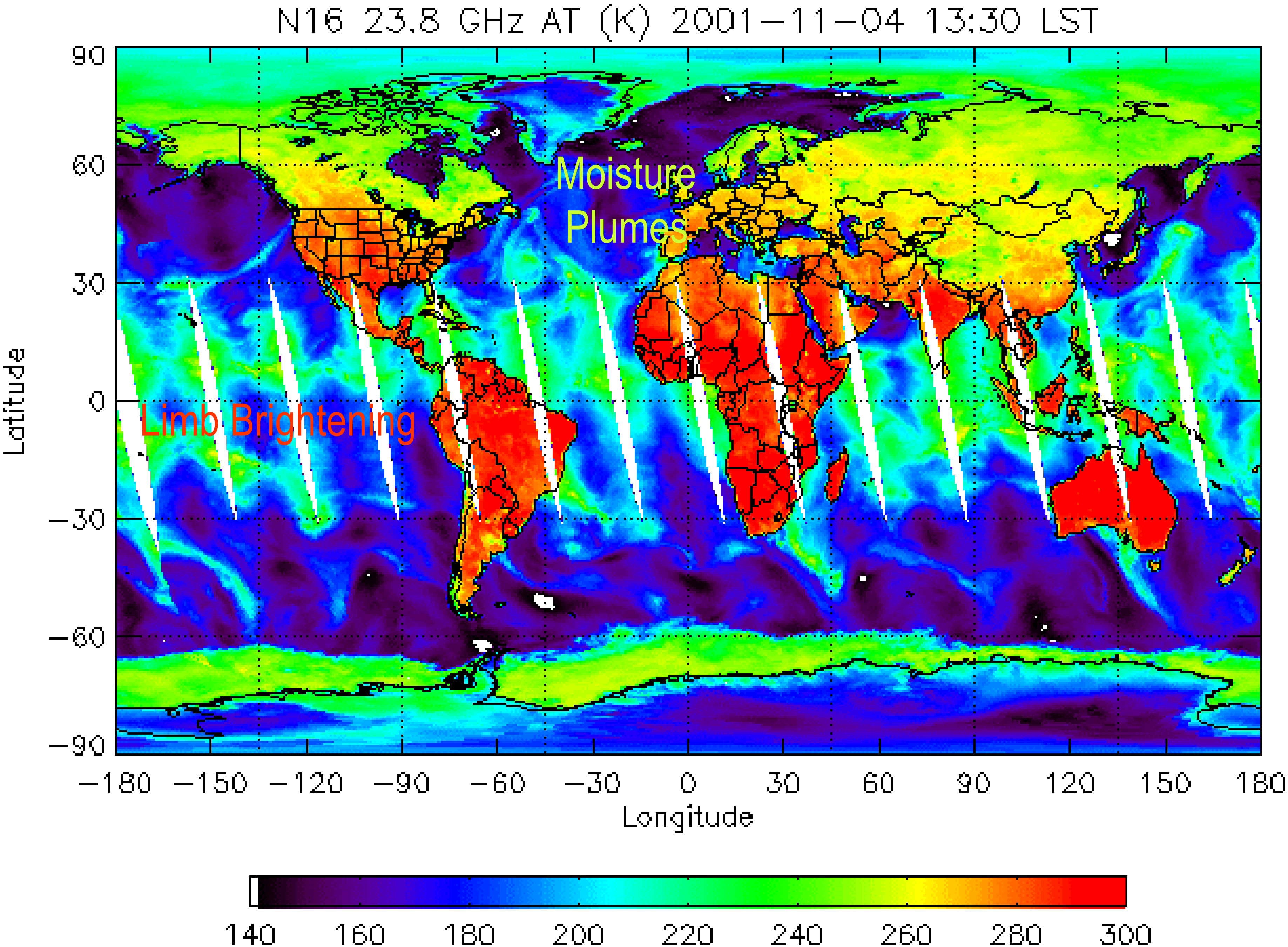
- Cross-track scan geometry
- 2200 km swath width
- AMSU-A (30 FOV/scan; 48 km @ nadir)
- AMSU-B (90 FOV/scan; 16 km @ nadir)

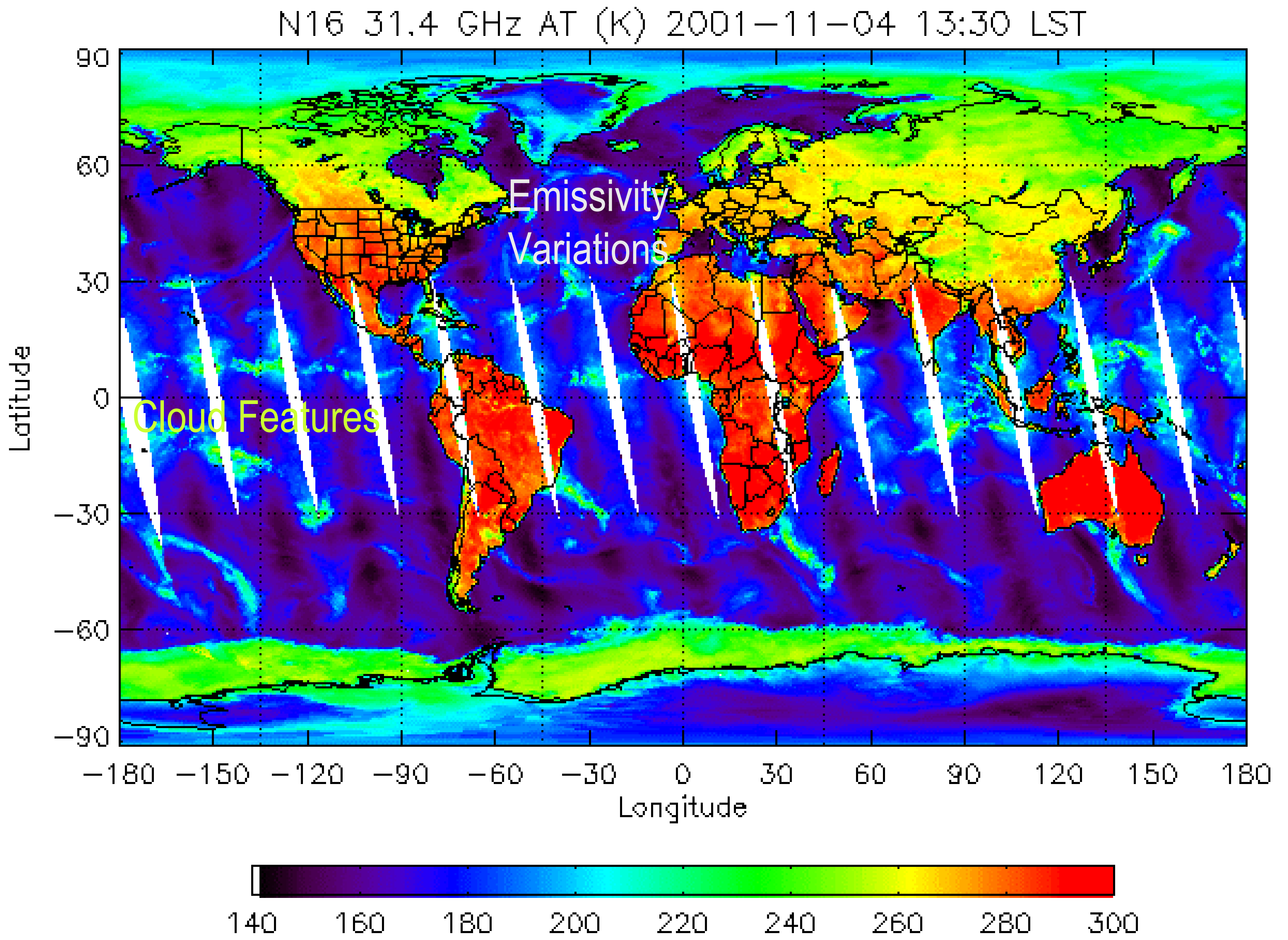
AMSU and SSM/I Comparison

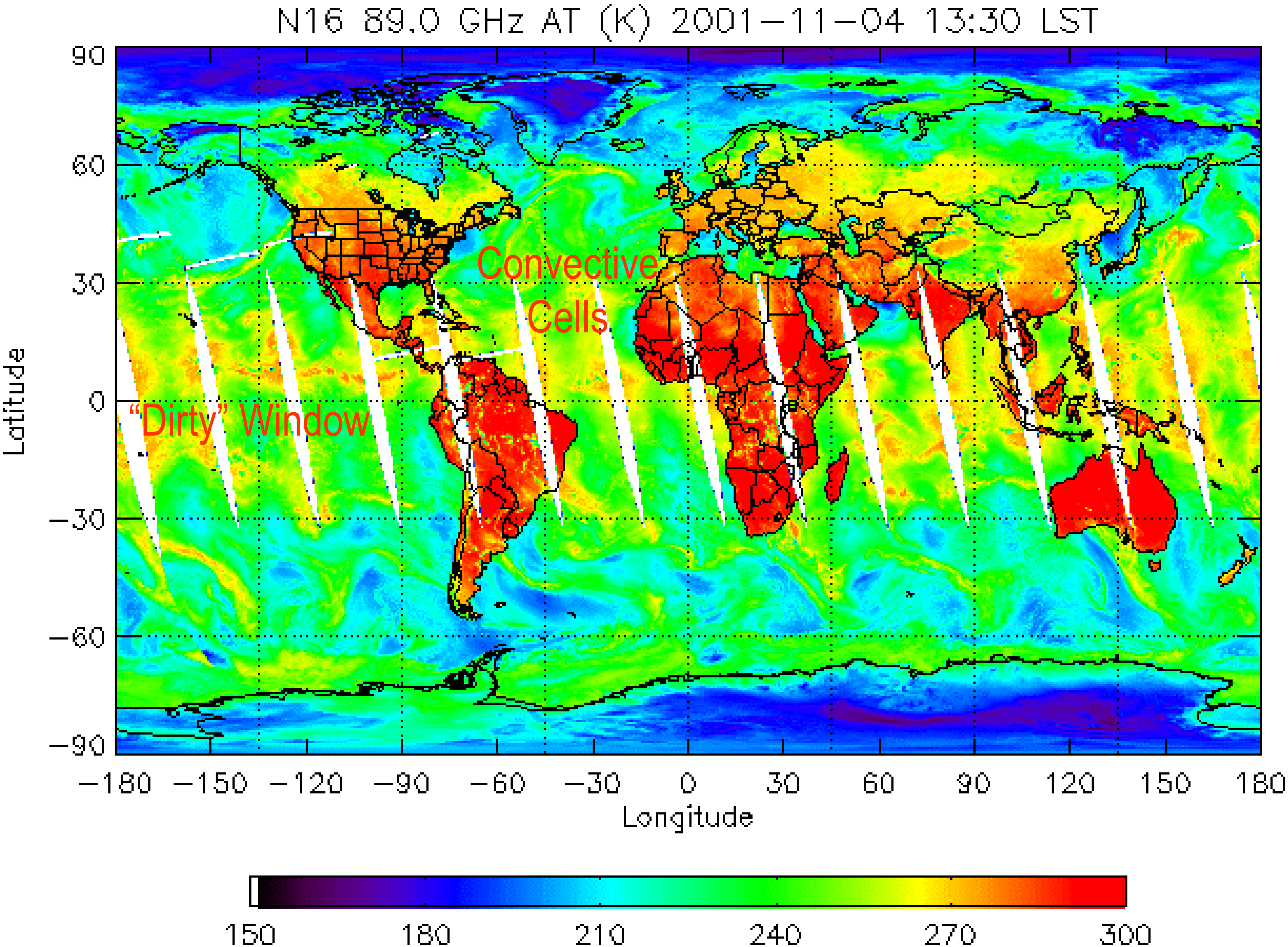
Parameter	AMSU	SSM/I
Window Channels	23.8,31.4,50.3,89.0 (A) *89.0, 150.0 (B)*	19.4,22.2,37.0,85.5
Polarization	Mixed	V & H
Scan Geometry	0 - 48 deg	Fixed 45 deg
FOV's	Vary with view angle: 45 (15) km/nadir 150 (50) km/limb	Vary with frequency: 15 km @ 85 GHz 60 km @ 19 GHz
Swath Width	~2200 km	~1400 km

Microwave Surface & Precipitation Products System (MSPPS) Product Suite

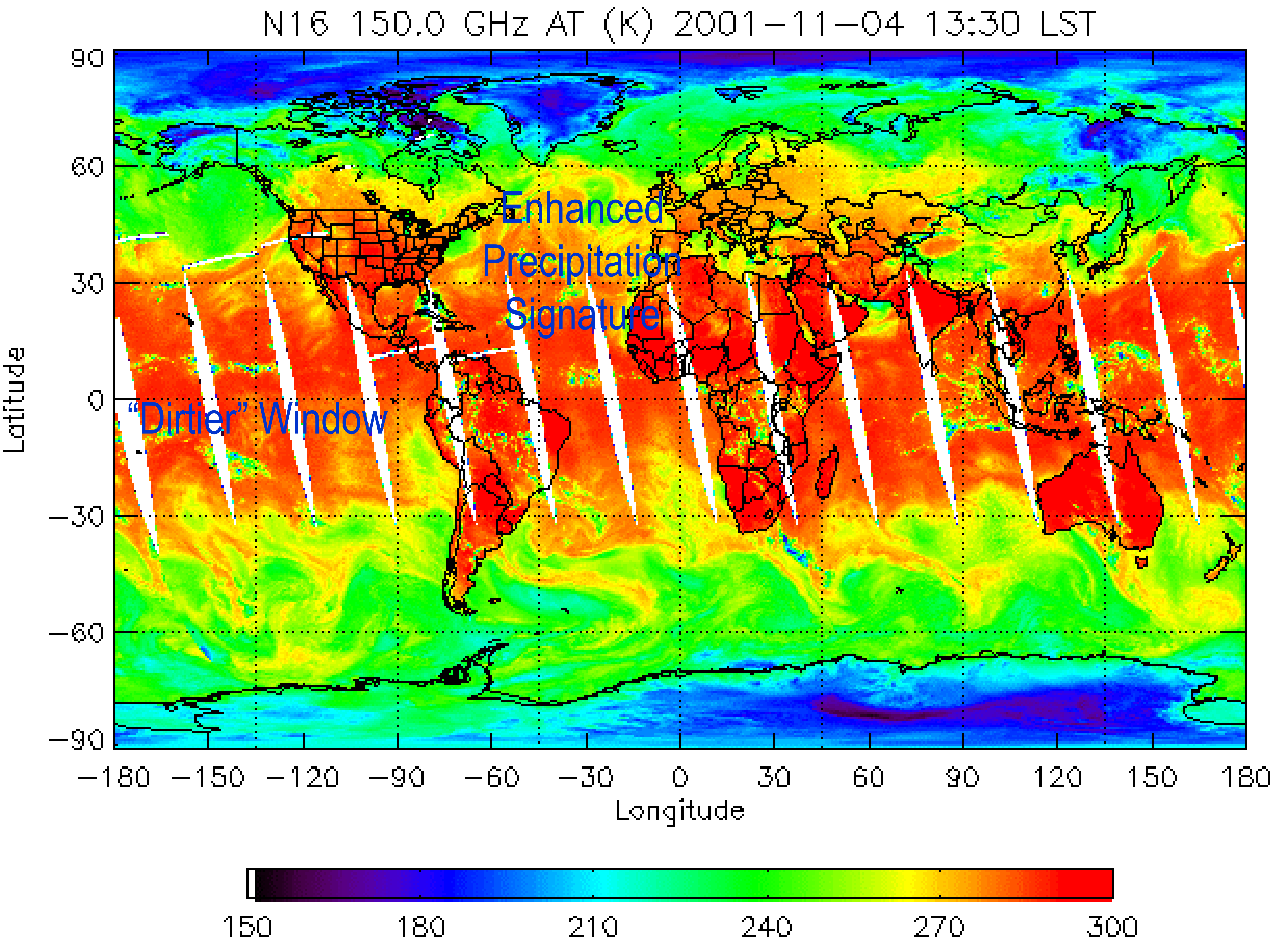
Product	Surface	AMSU-A	AMSU-B
Brightness Temperatures	Land/Ocean	●	●
Total Precipitable Water	Ocean	●	
Cloud Liquid Water	Ocean	●	
Rain Rate	Land/Ocean	●	●
Snow Cover	Land	●	●
Sea Ice Concentration	Ocean	●	
Ice Water Path	Land/Ocean		●
Land Surface Emissivity	Land	●	
Land Surface Temperature	Land	●	


N16 23.8 GHz AT (K) 2001-11-04 13:30 LST
Moisture
Plumes
Limb Brightening
Latitude
90
60
30
0
-30
-60
-90
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
Longitude
140
160
180
200
220
240
260
280
300


N16 31.4 GHz AT (K) 2001−11−04 13:30 LST
Emissivity Variations
Cloud Features
Latitude
90
60
30
0
−30
−60
−90
Longitude
−180 −150 −120 −90 −60 −30 0 30 60 90 120 150 180
140 160 180 200 220 240 260 280 300

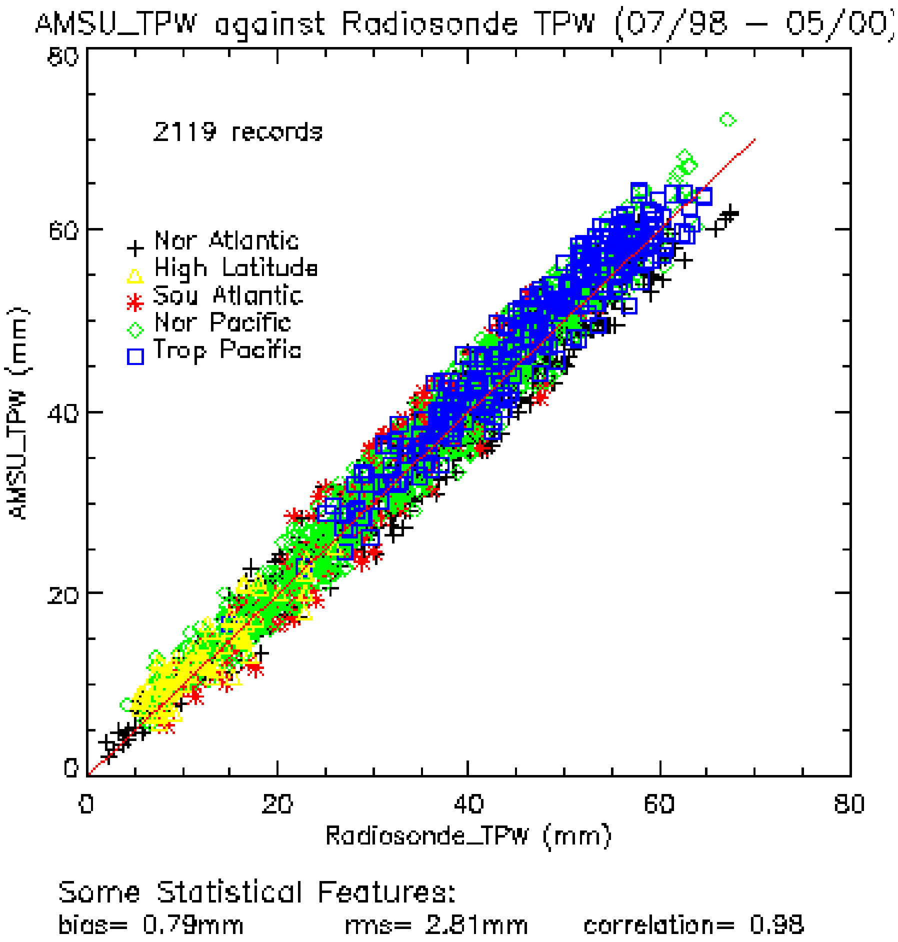


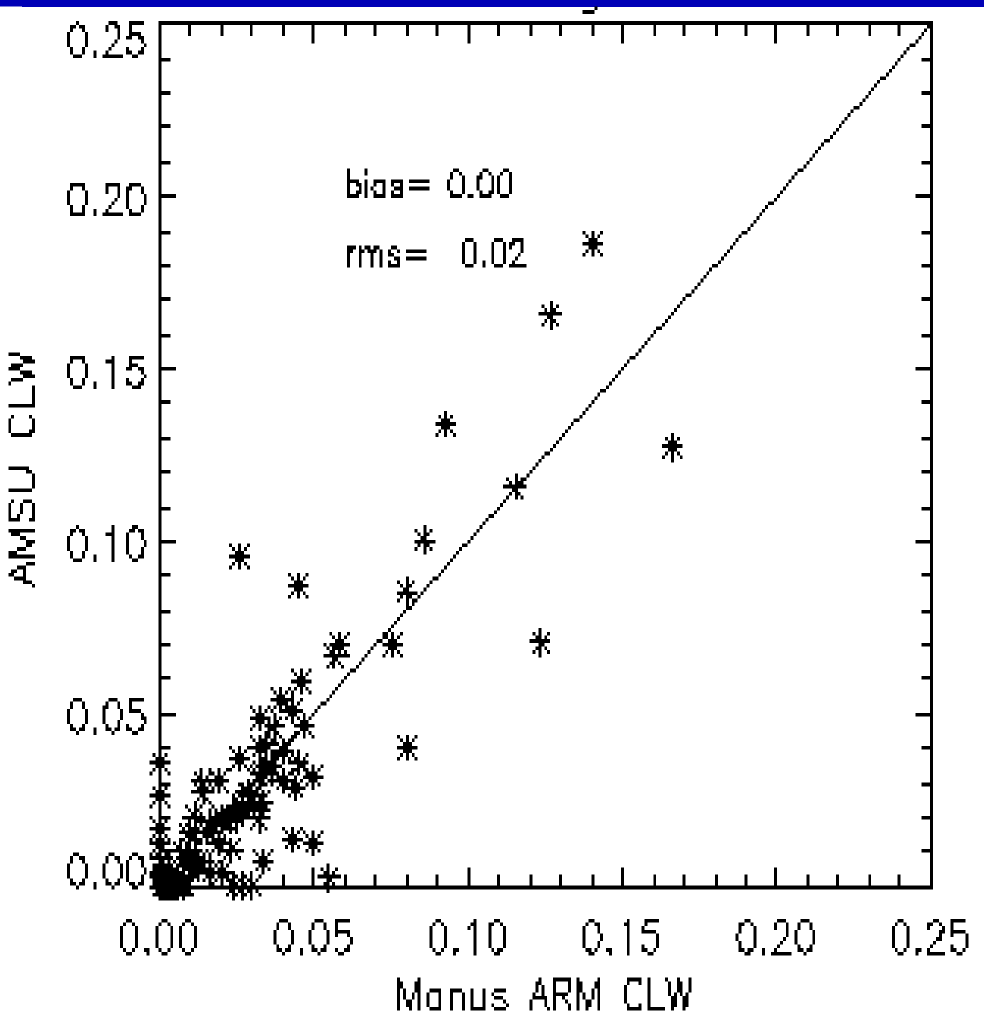
N16 89.0 GHz AT (K) 2001−11−04 13:30 LST
Convective Cells
"Dirty" Window
Latitude
90
60
30
0
−30
−60
−90
−180 −150 −120 −90 −60 −30 0 30 60 90 120 150 180
Longitude
150 180 210 240 270 300

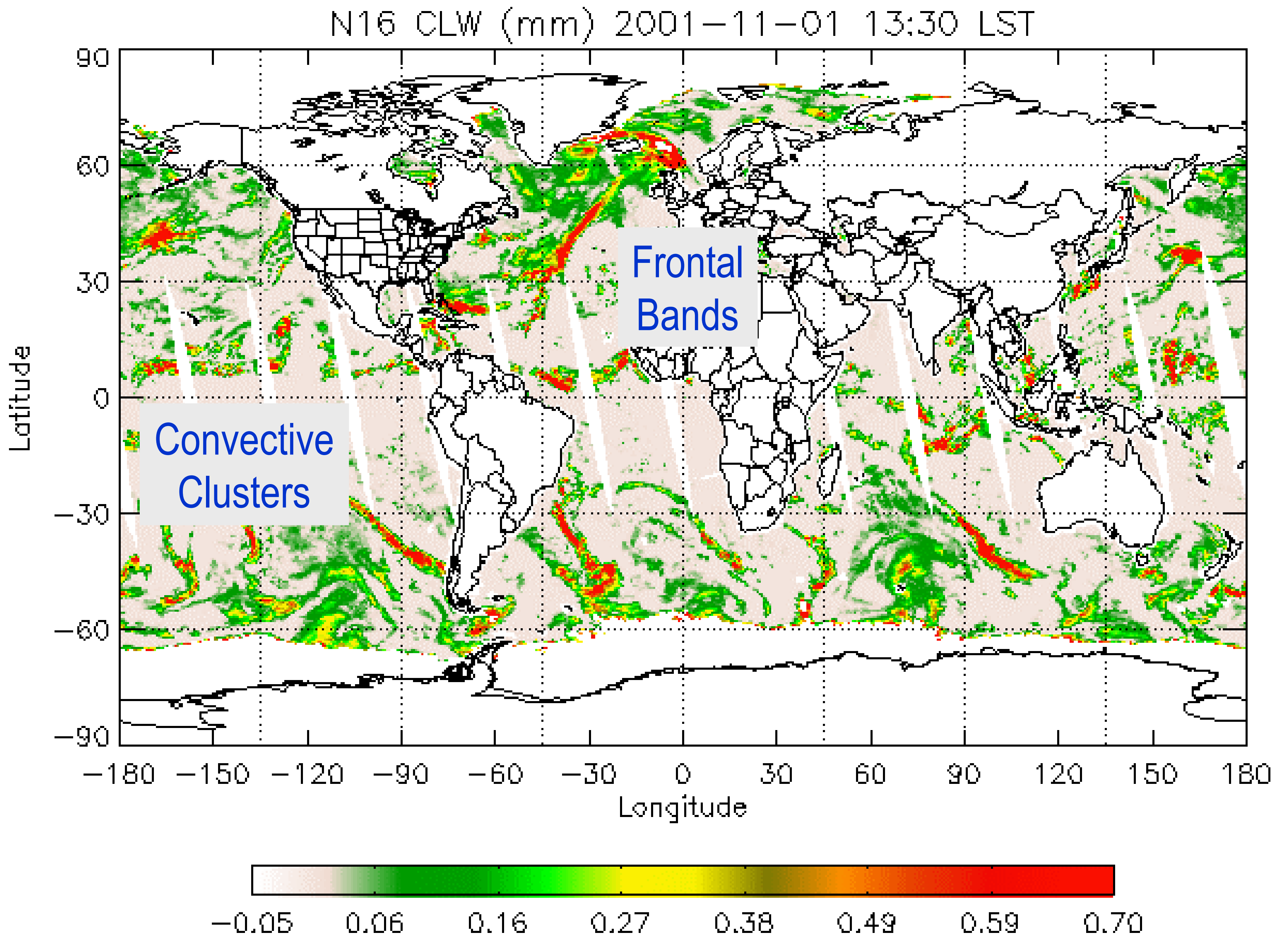

N16 150.0 GHz AT (K) 2001-11-04 13:30 LST
Enhanced
Precipitation
Signature
"Dirtier" Window
Latitude
90
60
30
0
−30
−60
−90
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
Longitude
150
180
210
240
270
300

Oceanic TPW and CLW

- $L = a_0[\ln(Ts - TB_{31}) - a_1\ln(Ts - TB_{23}) - a_2]$
- $V = b_0[\ln(Ts - TB_{31}) - b_1\ln(Ts - TB_{23}) - b_2]$

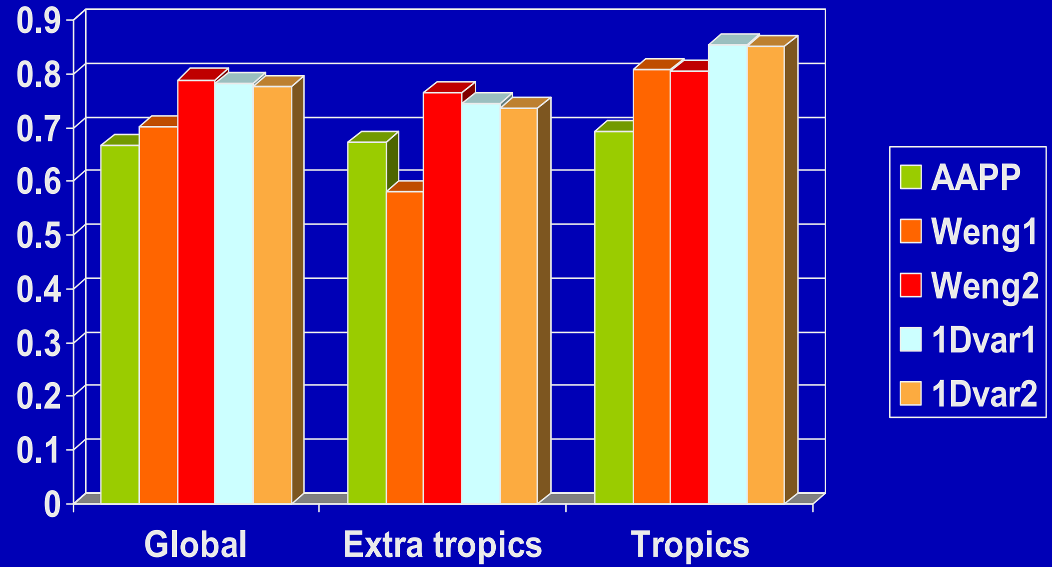





N16 CLW (mm) 2001−11−01 13:30 LST
Frontal Bands
Convective Clusters
90
60
30
0
−30
−60
−90
Latitude
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
Longitude
−0.05
0.06
0.16
0.27
0.38
0.49
0.59
0.70

Global Performance of Cloud Retrievals (HKS Score)

The Weng2 method is clearly more skillful than Weng1 or AAPP. The Weng2 method does, however, show no advantage over Weng1 in the tropics. The two 1D-vars show a similar level of skill to the Weng2 method. The Weng2 method also shows less month-to-month variation in skill, especially in the northern hemisphere (note each month is represented by data from the 15th day of each month)

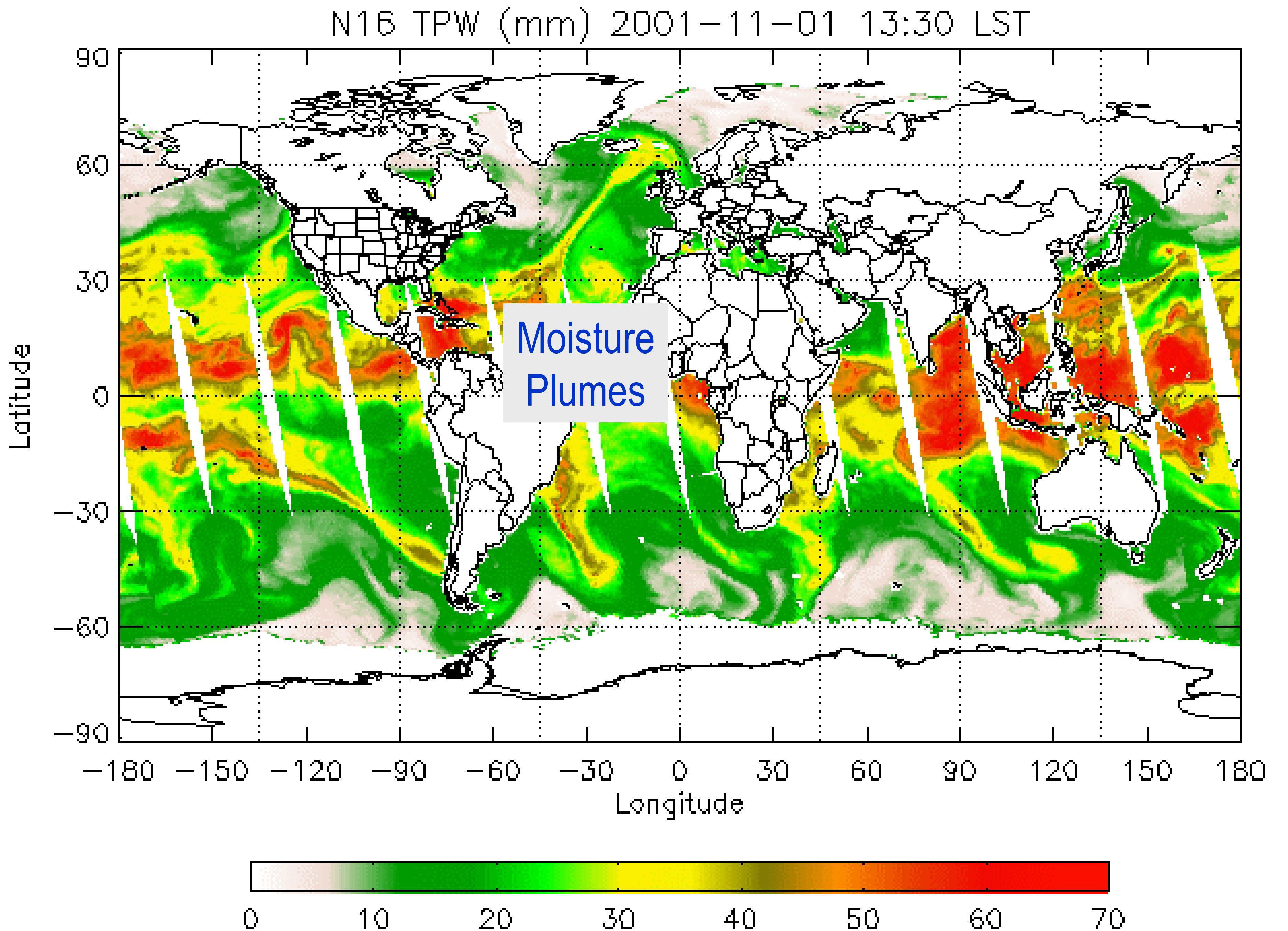


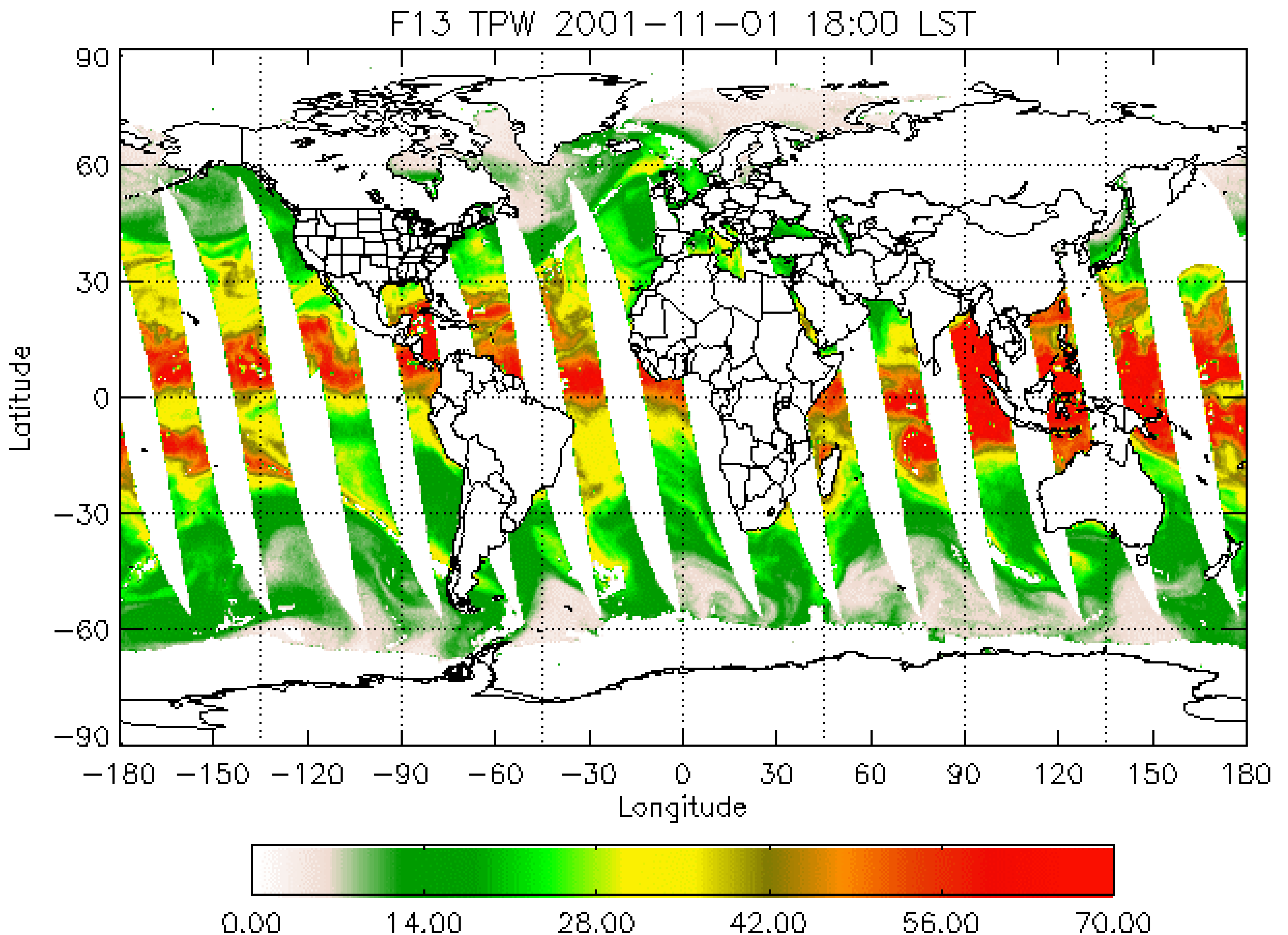
Hansen-Kuiper score = H-F

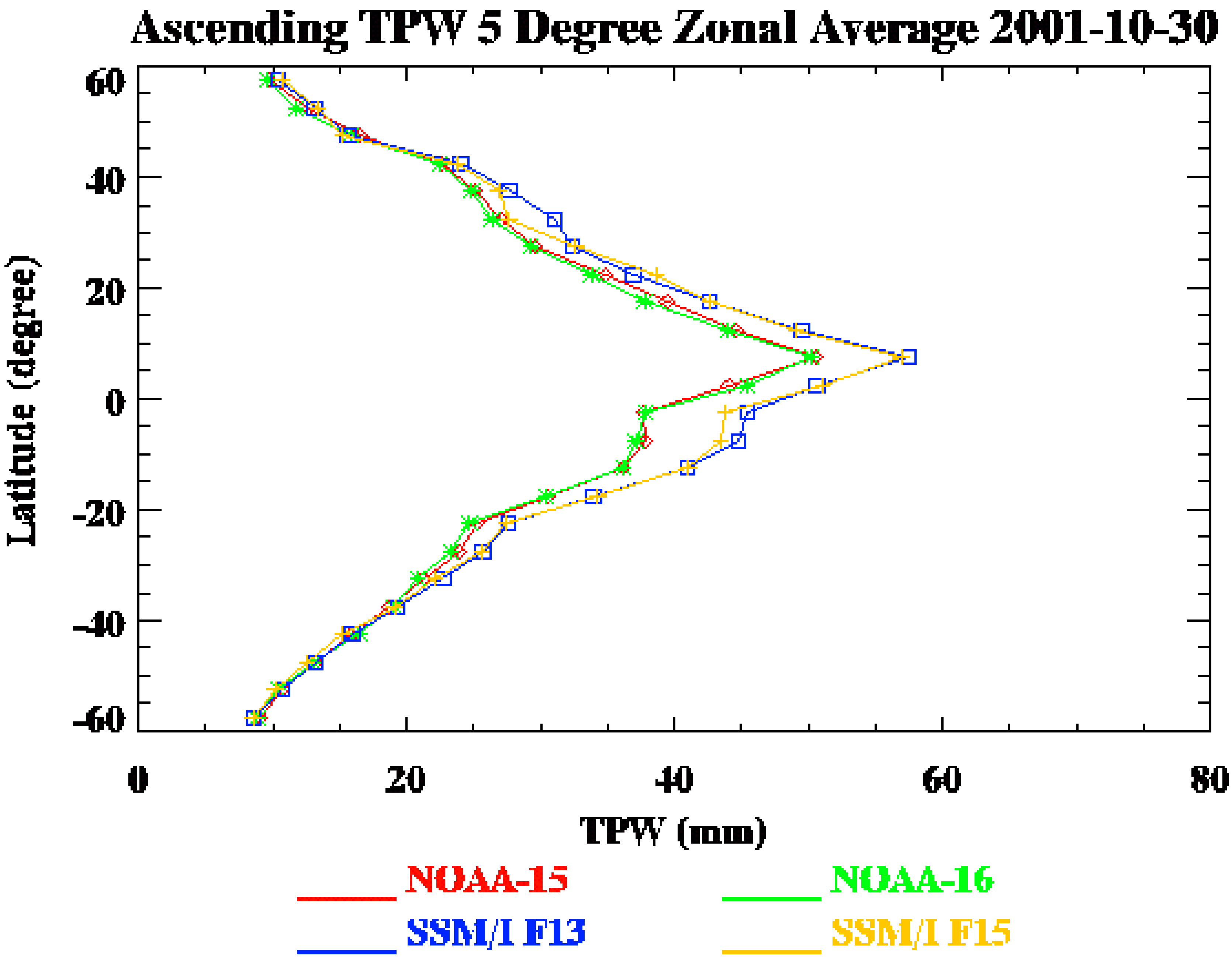
where H=Hit rate and F=false alarm rate.

H = Number where LWP > 70 gm^{-2} and validation dataset = cloudy divided by total number where validation dataset=cloudy

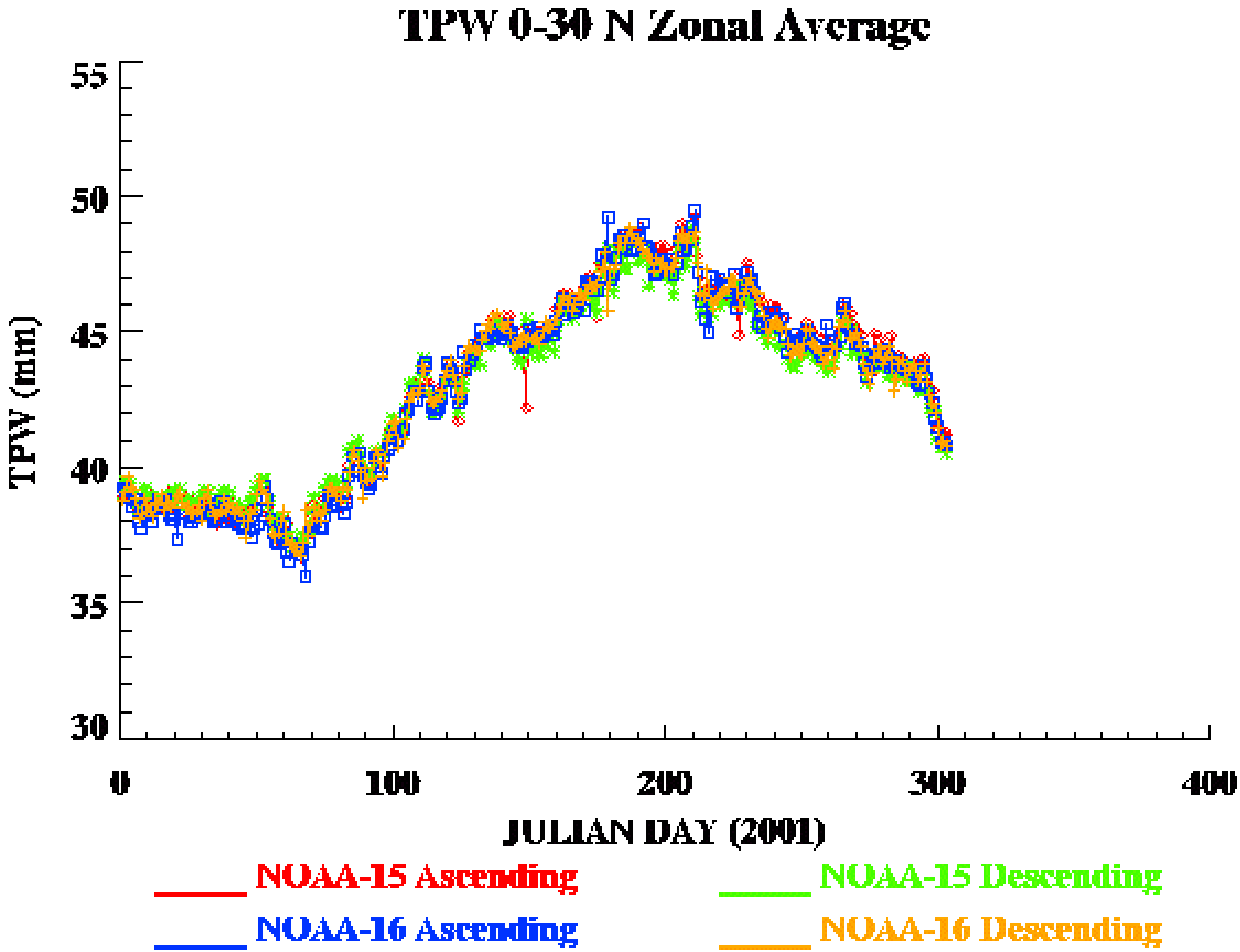
F = Number where LWP > 70 gm^{-2} and validation dataset = clear divided by total number where validation dataset=clear


N16 TPW (mm) 2001-11-01 13:30 LST
Moisture Plumes
Latitude
90
60
30
0
−30
−60
−90
−180 −150 −120 −90 −60 −30 0 30 60 90 120 150 180
Longitude
0 10 20 30 40 50 60 70


F13 TPW 2001-11-01 18:00 LST
90
60
30
0
−30
−60
−90
Latitude
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
Longitude
0.00
14.00
28.00
42.00
56.00
70.00



Ascending TPW 5 Degree Zonal Average 2001-10-30
60
40
20
0
-20
-40
-60
Latitude (degree)
0
20
40
60
80
TPW (mm)
NOAA-15
NOAA-16
SSM/I F13
SSM/I F15



TPW 0-30 N Zonal Average
TPW (mm)
55
50
45
40
35
30
0
100
200
300
400
JULIAN DAY (2001)
NOAA-15 Ascending
NOAA-15 Descending
NOAA-16 Ascending
NOAA-16 Descending

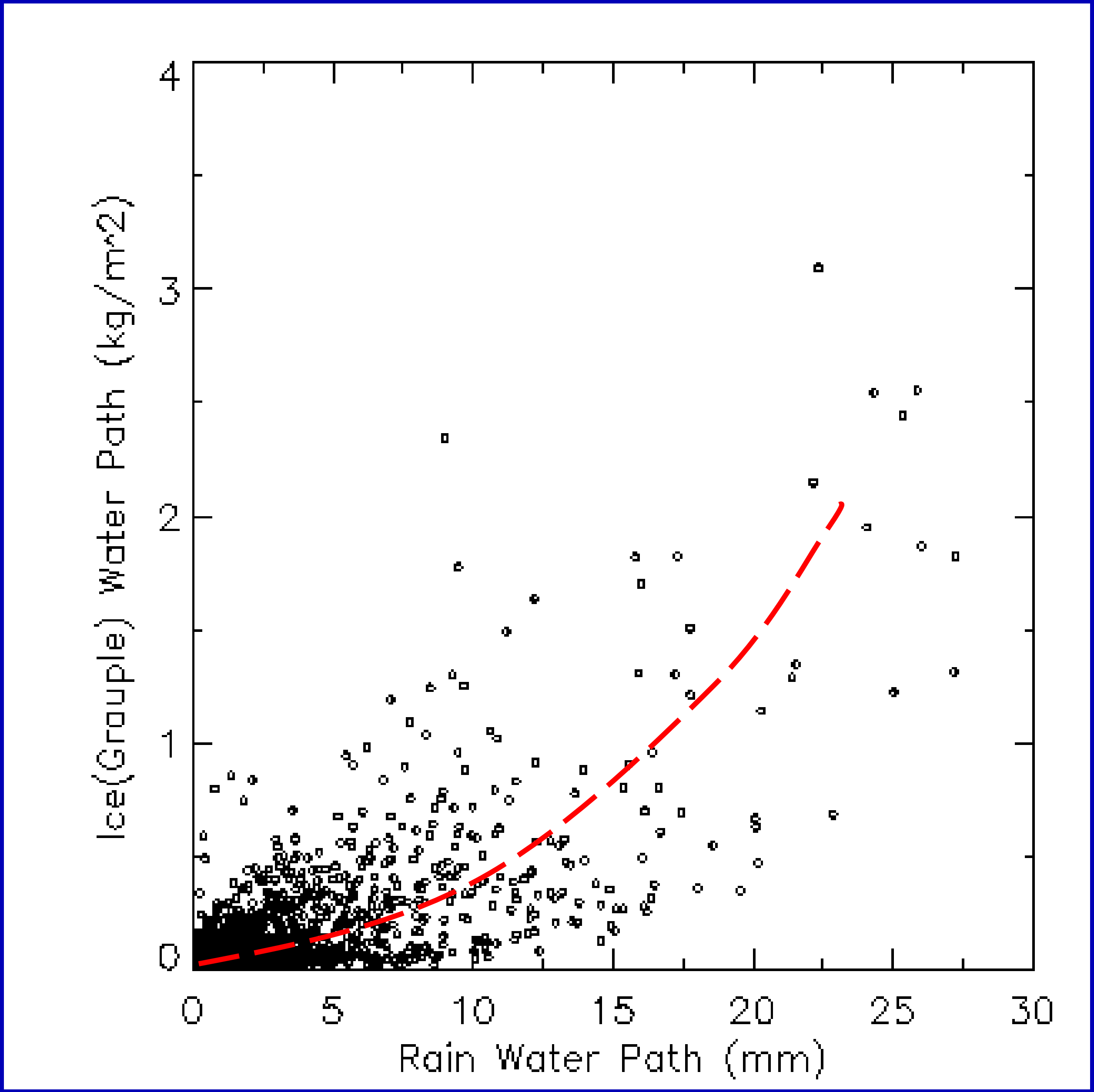
Ice Water Path & Rain Rate

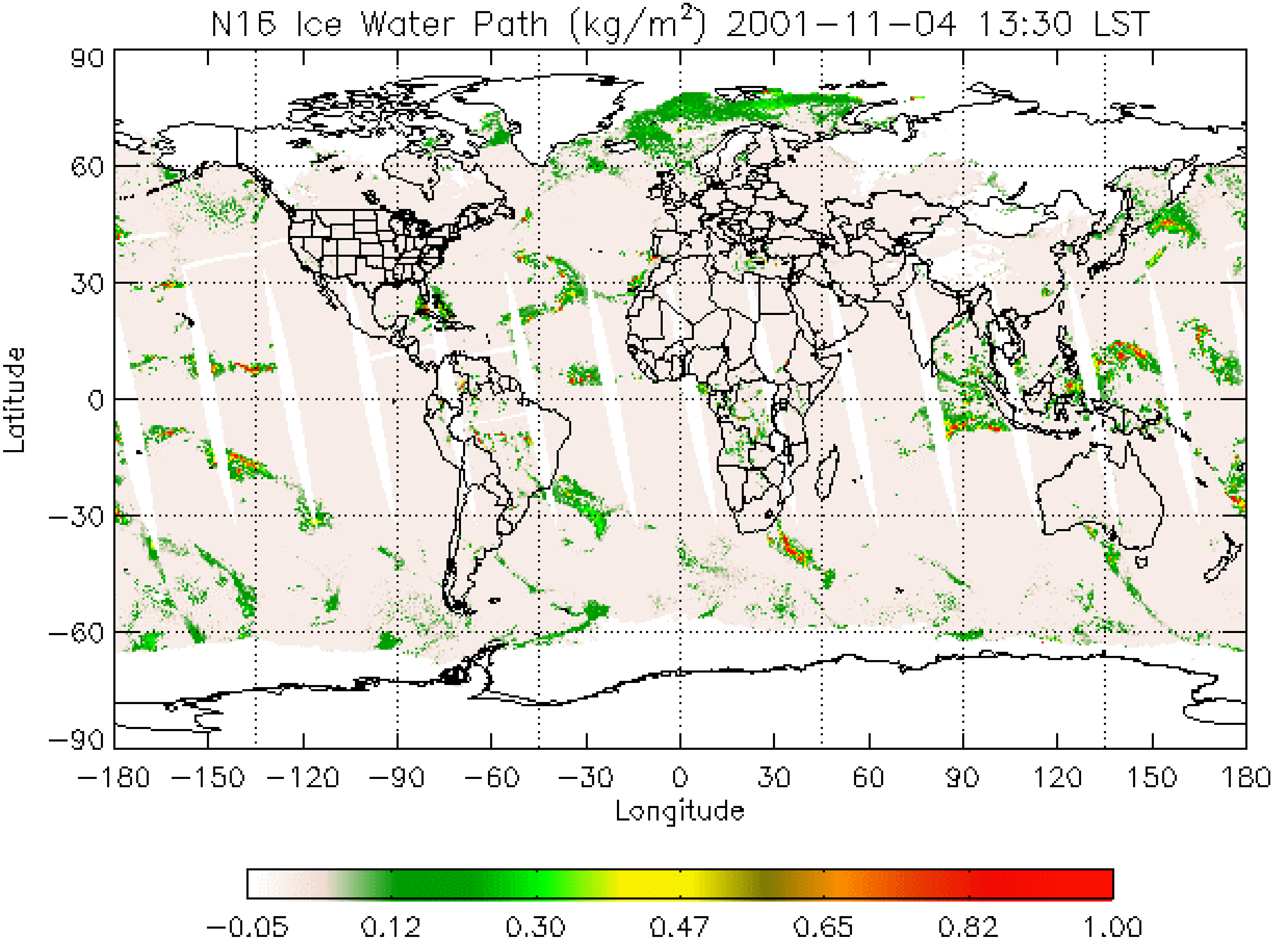
- Physical retrieval of ice water path (IWP) and particle size (De) using AMSU-B 89 and 150 GHz:
  - De ~ $\Omega(89)/\Omega(150)$
  - IWP ~ De*$(\Omega/\Omega(89,150))$

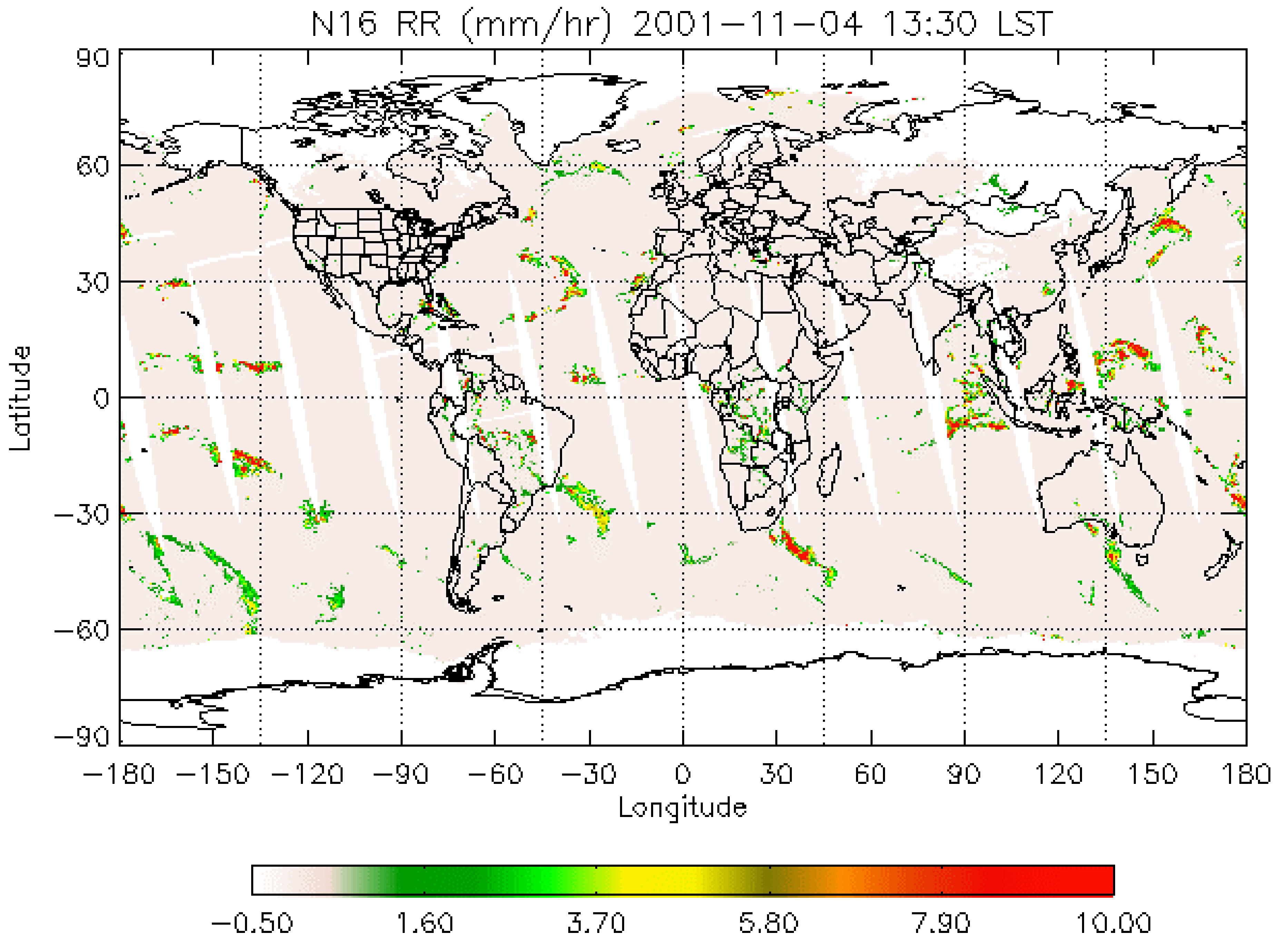
Zhao and Weng (2002, JAM)

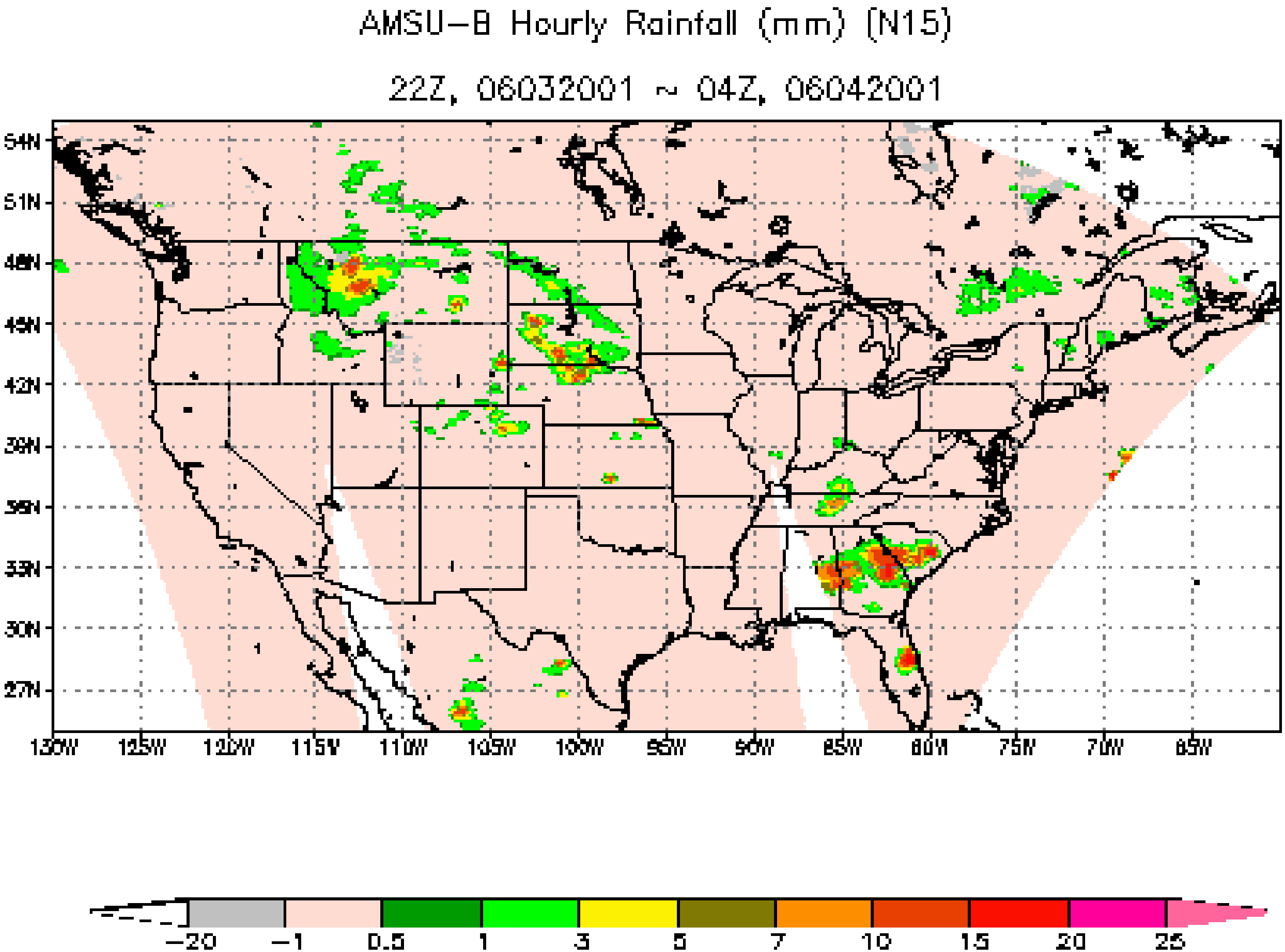
- Assumptions made on size-distribution & density
- IWP to rain rate based on limited cloud model data and comparisons with in situ data: $RR = A_0 + A_1 * IWP + A_2 * IWP^2$
- Effects of surface misidentification (desert & snow) reduced using 89 and 150 GHz

Ice Water Path & Rain Rate

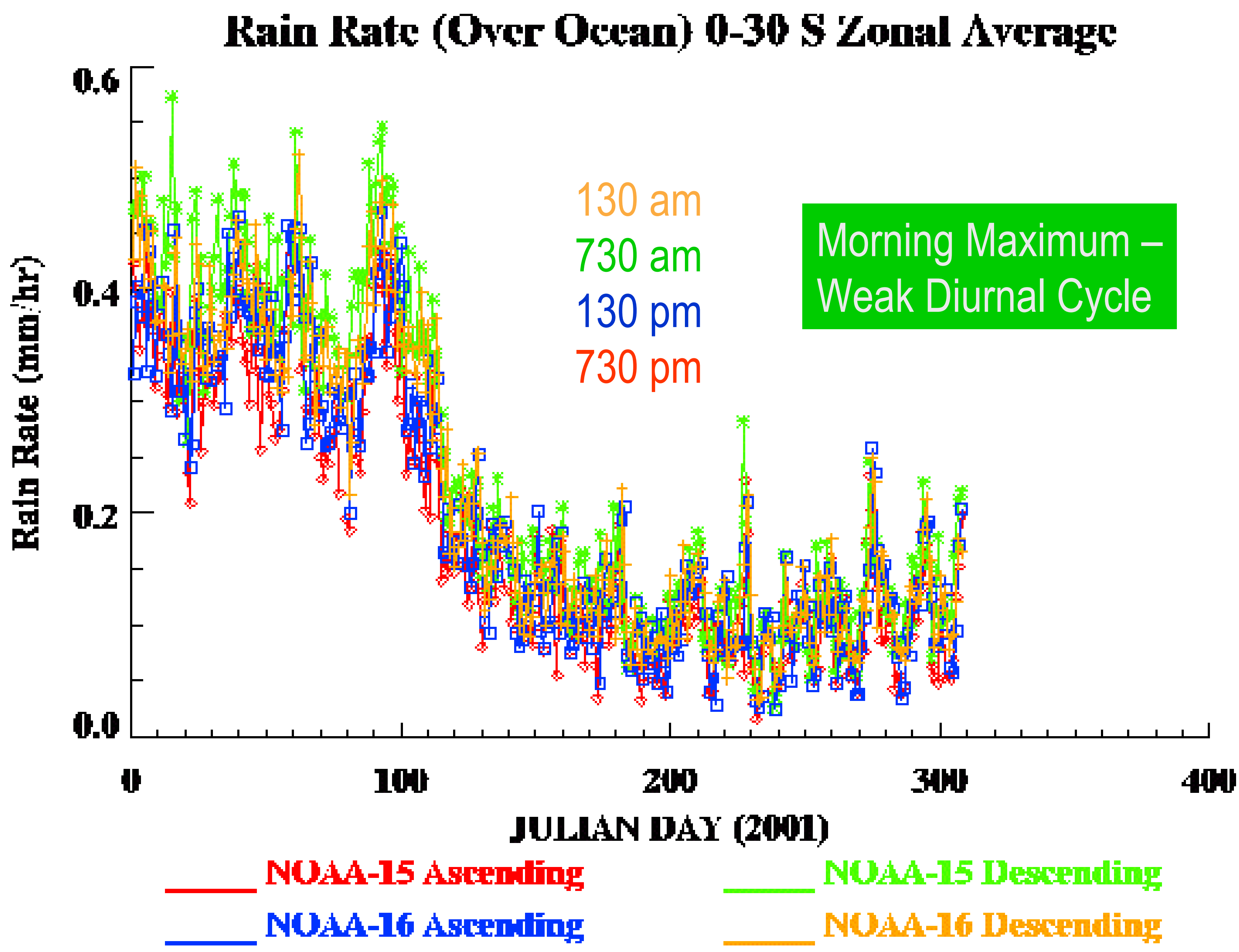


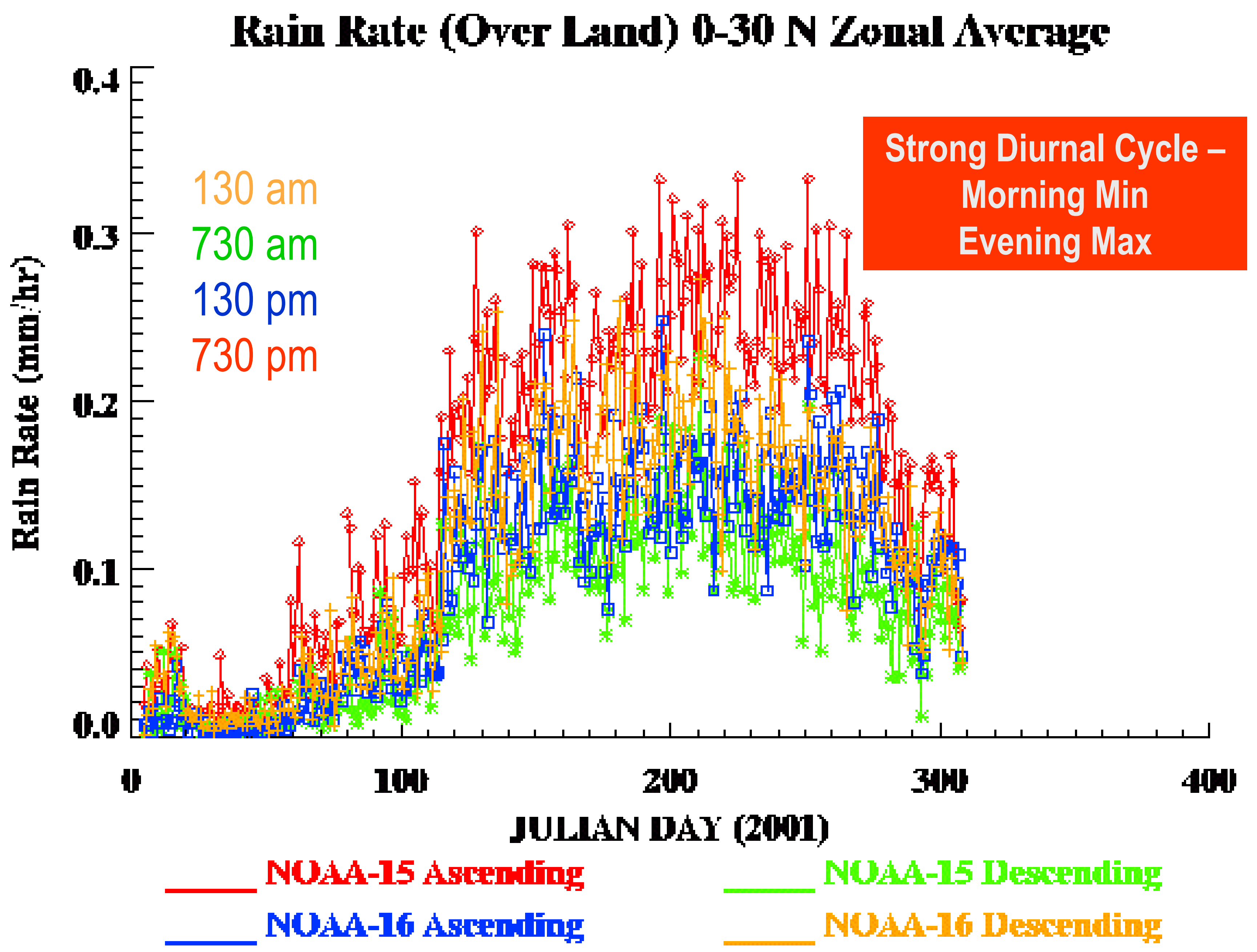

N16 Ice Water Path (kg/m²) 2001-11-04 13:30 LST
90
60
30
0
−30
−60
−90
Latitude
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
Longitude
−0.05
0.12
0.30
0.47
0.65
0.82
1.00


N16 RR (mm/hr) 2001-11-04 13:30 LST
90
60
30
0
−30
−60
−90
Latitude
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
Longitude
−0.50
1.60
3.70
5.80
7.90
10.00



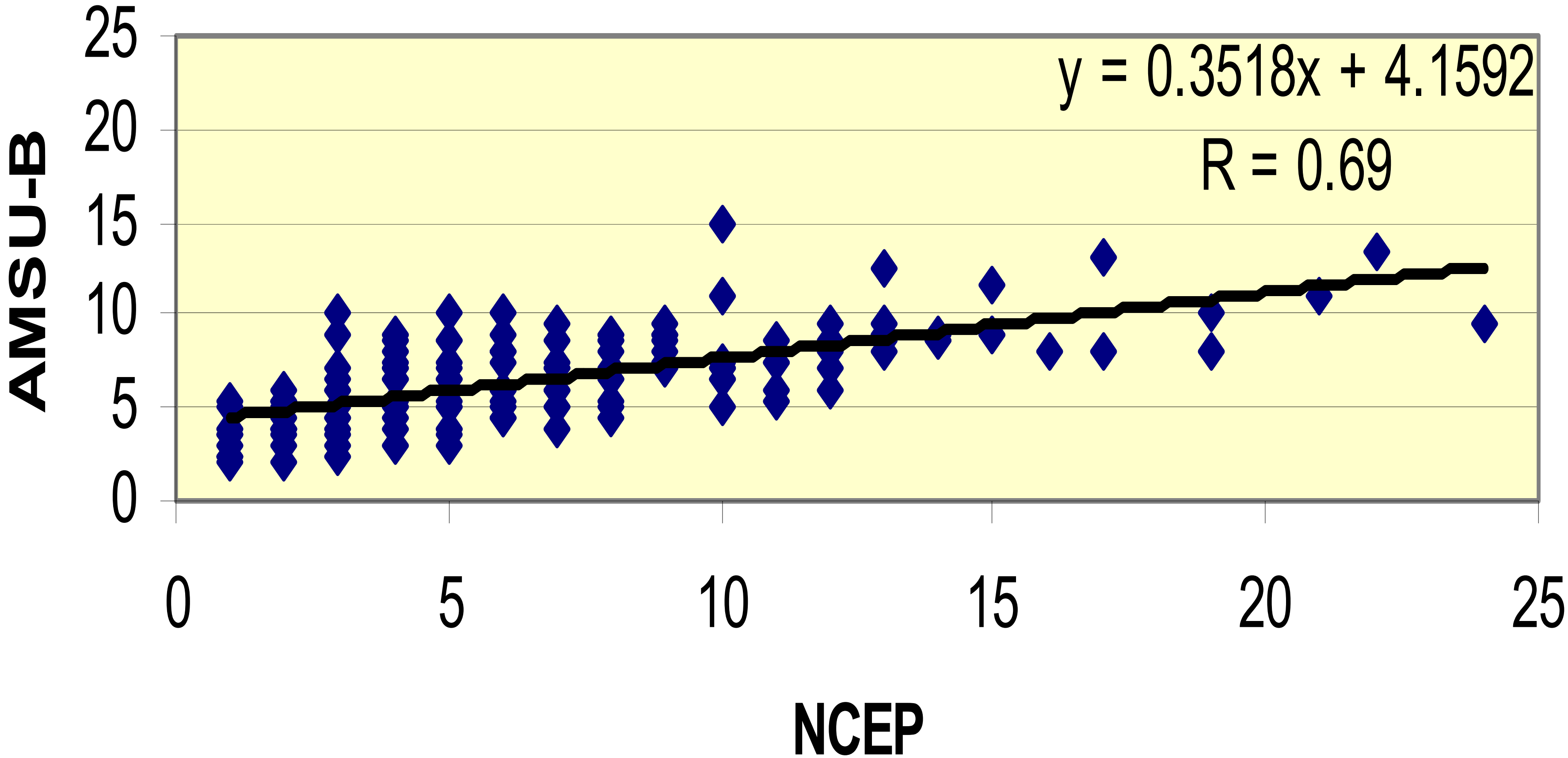
AMSU-B Hourly Rainfall (mm) (N15)
22Z, 06032001 ~ 04Z, 06042001
54N
51N
48N
45N
42N
39N
36N
33N
30N
27N
130W
125W
120W
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
65W
-20
-1
0.5
1
3
5
7
10
15
20
25


Rain Rate (Over Ocean) 0-30 S Zonal Average
Rain Rate (mm/hr)
0.6
0.4
0.2
0.0
0
100
200
300
400
JULIAN DAY (2001)
130 am
730 am
130 pm
730 pm
Morning Maximum –
Weak Diurnal Cycle
NOAA-15 Ascending
NOAA-15 Descending
NOAA-16 Ascending
NOAA-16 Descending


Rain Rate (Over Land) 0-30 N Zonal Average
Strong Diurnal Cycle –
Morning Min
Evening Max
130 am
730 am
130 pm
730 pm
Rain Rate (mm/hr)
0.4
0.3
0.2
0.1
0.0
0
100
200
300
400
JULIAN DAY (2001)
NOAA-15 Ascending
NOAA-15 Descending
NOAA-16 Ascending
NOAA-16 Descending

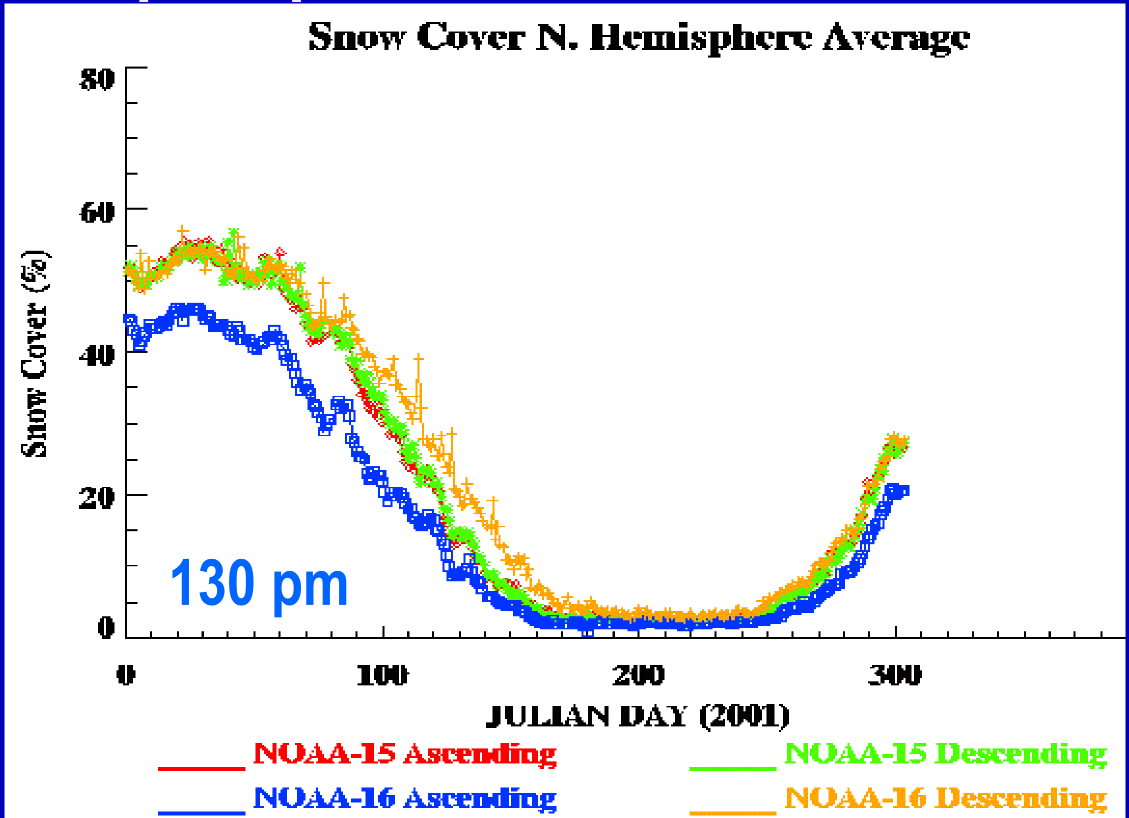
AMSU-B vs NCEP (BINNED DATA)

JUNE5-8-01 T. S. ALLISON



Snow Cover

- ω_{31} = TB $_{23}$ - TB $_{31}$ - 2.0 *(best for refrozen snow)*
- ω_{89}= TB $_{23}$ - TB $_{89}$ - 3.0 *(best for new/shallow snow)*
- If ω_{31} < 3 and TB $_{23}$ < 215 K *(glacial snow)*
- There are also checks to eliminate false signatures of snow due to precipitation and cold deserts.

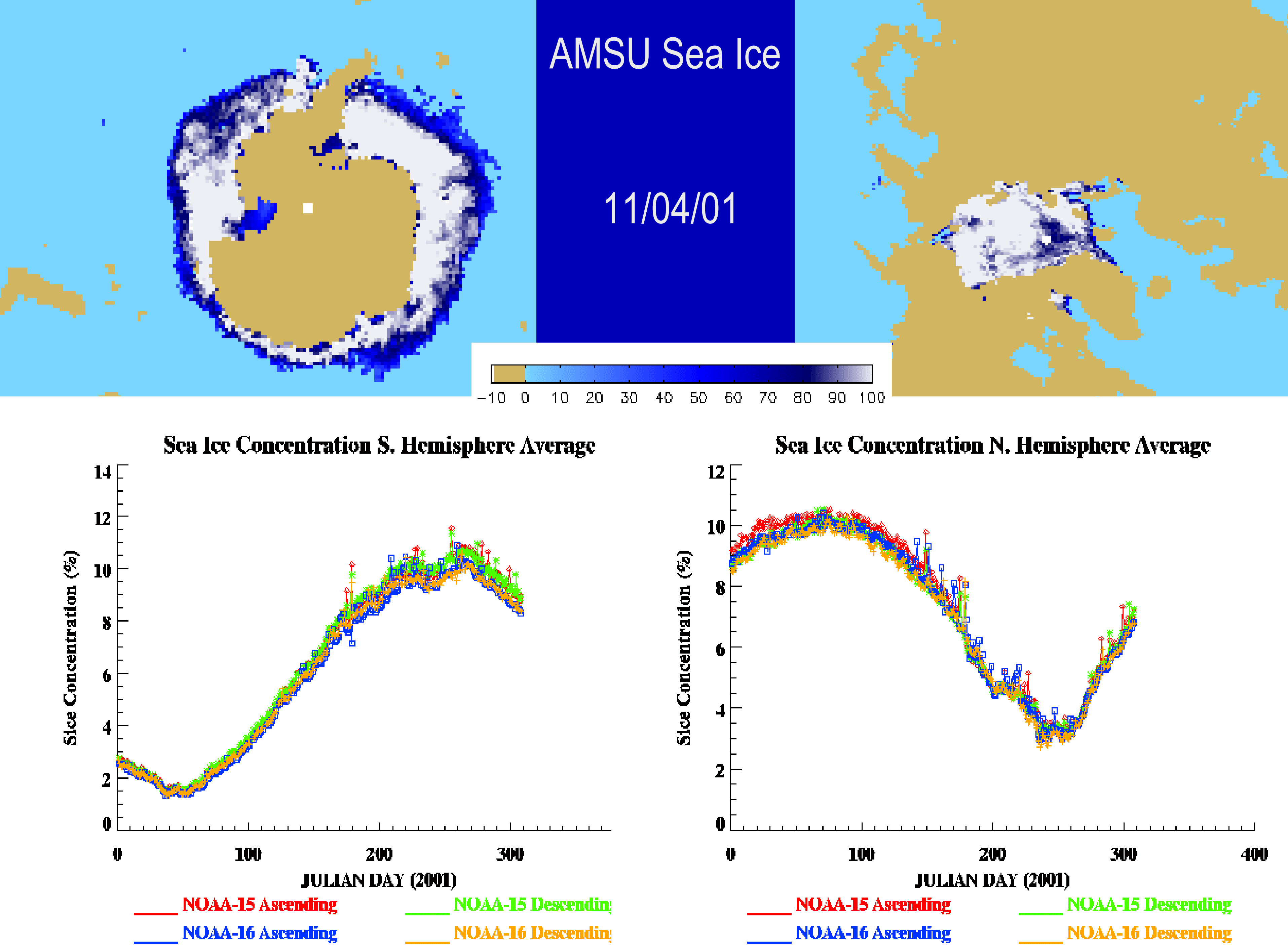


SSM/I F13 Snow Cover (NH) 11-04-2001

AMSU N15 Snow Cover (NH) 11-04-2001

Sea Ice Concentration

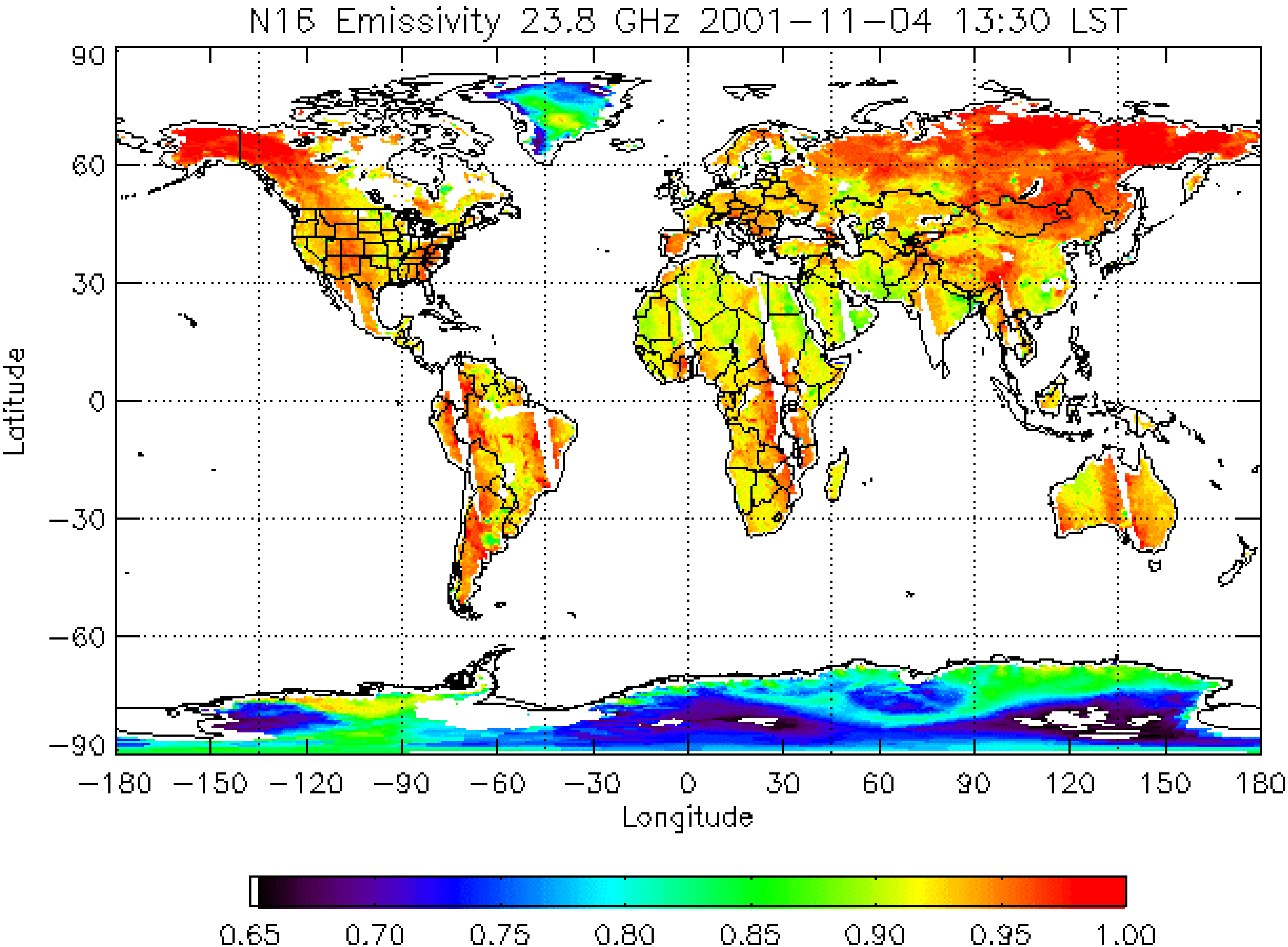
- ϵ_{23} = a + b TB_{23} + c TB_{31} + d TB_{50}, where coefficients are function of $\mu = \cos(\theta)$
- $\epsilon_{water} = 0.1824 + 0.9048\,\mu - 0.6221\,\mu^2$
- $$\epsilon_{ice} = \begin{cases} 0.93 & \text{if } (TB_{23} - TB_{31}) < 5\text{ K} \quad \textit{first-year} \\ 0.87 & \text{if } 5 \leq (TB_{23} - TB_{31}) \leq 10\text{ K} \\ 0.83 & \text{if } 10 < (TB_{23} - TB_{31}) \quad \textit{multi-year} \end{cases}$$
- Sea Ice (%) =100 (e - ewater) / (eice - ewater)

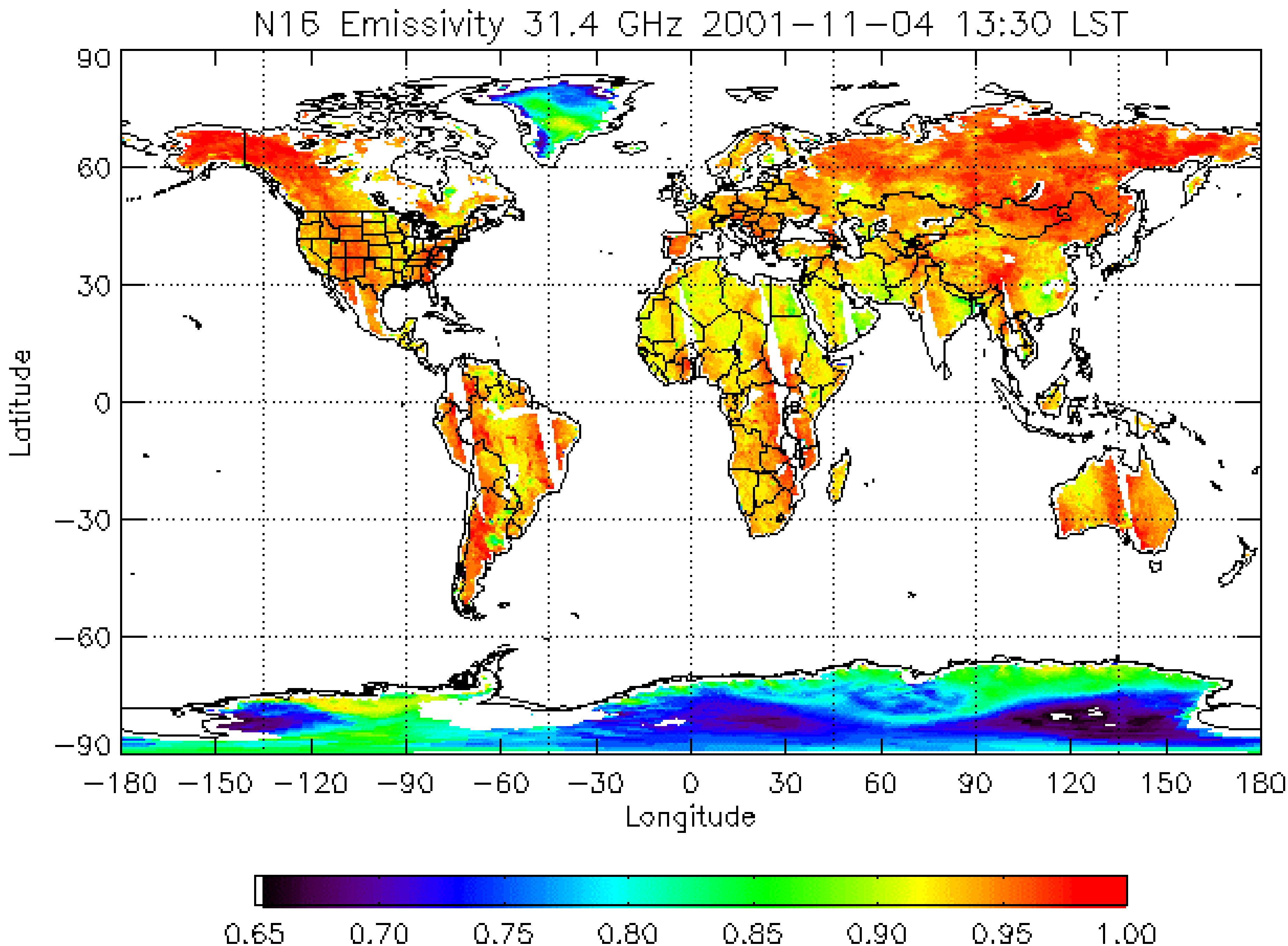


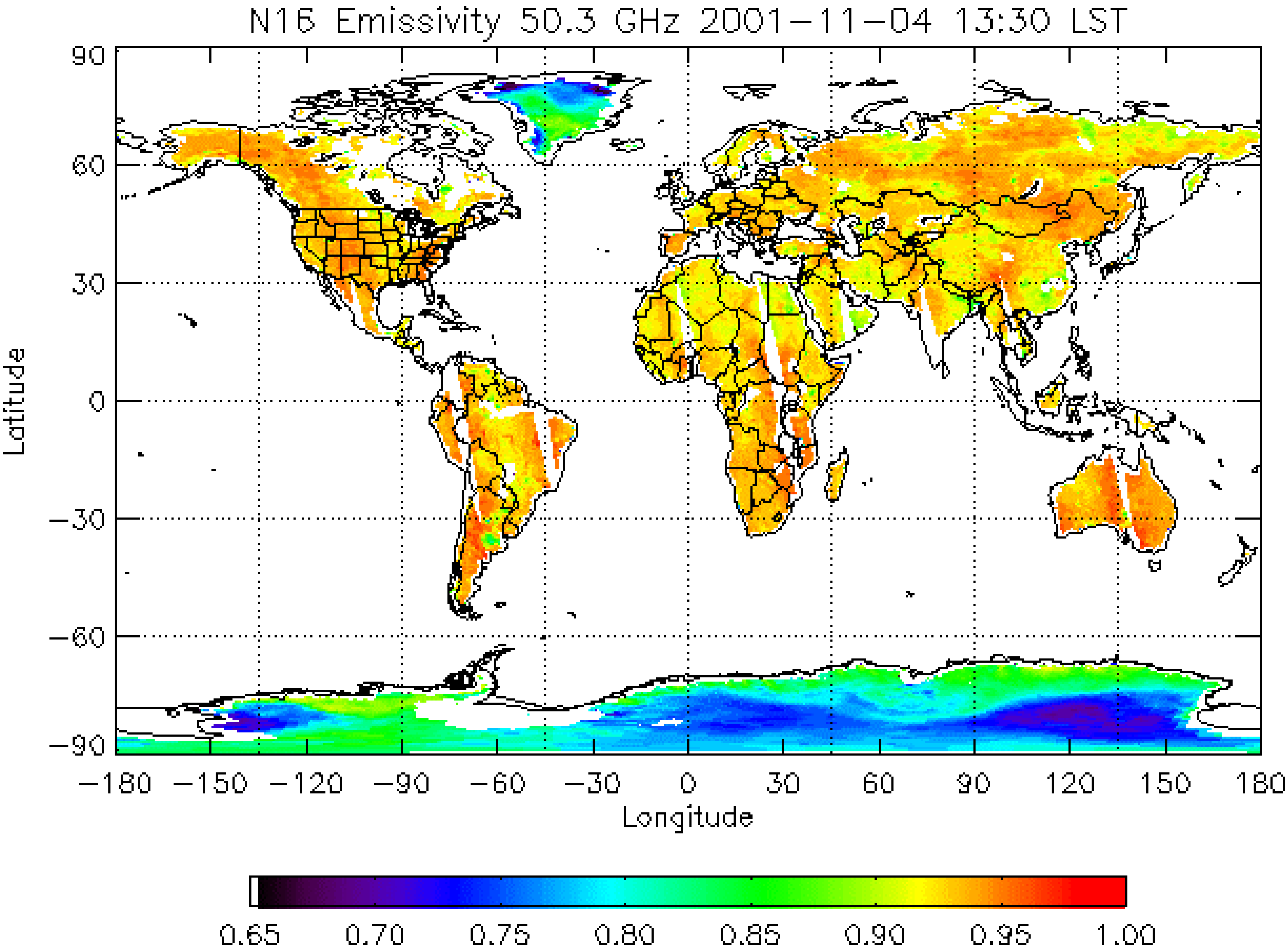
AMSU Sea Ice
11/04/01
−10 0 10 20 30 40 50 60 70 80 90 100
Sea Ice Concentration S. Hemisphere Average
SIce Concentration (%)
JULIAN DAY (2001)
Sea Ice Concentration N. Hemisphere Average
SIce Concentration (%)
JULIAN DAY (2001)
NOAA-15 Ascending
NOAA-15 Descending
NOAA-16 Ascending
NOAA-16 Descending

Land Surface Emissivity

- ε derived for 23, 31 and 50 GHz
- $\varepsilon_i = b_{0,i} + b_{1,i}\,TB_{23} + b_{2,i}\,TB^2_{23}$
  $+ b_{3,i}\,TB_{31} + b_{4,i}\,TB^2_{31}$ where i=1,2,3
  $+ b_{5,i}\,TB_{50} + b_{6,i}\,TB^2_{50}$
- Coefficients derived through regression relationships between “truth” emissivity and brightness temperatures
- The truth is defined by removing the atmospheric effects.


N16 Emissivity 23.8 GHz 2001-11-04 13:30 LST
90
60
30
0
−30
−60
−90
Latitude
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
Longitude
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00

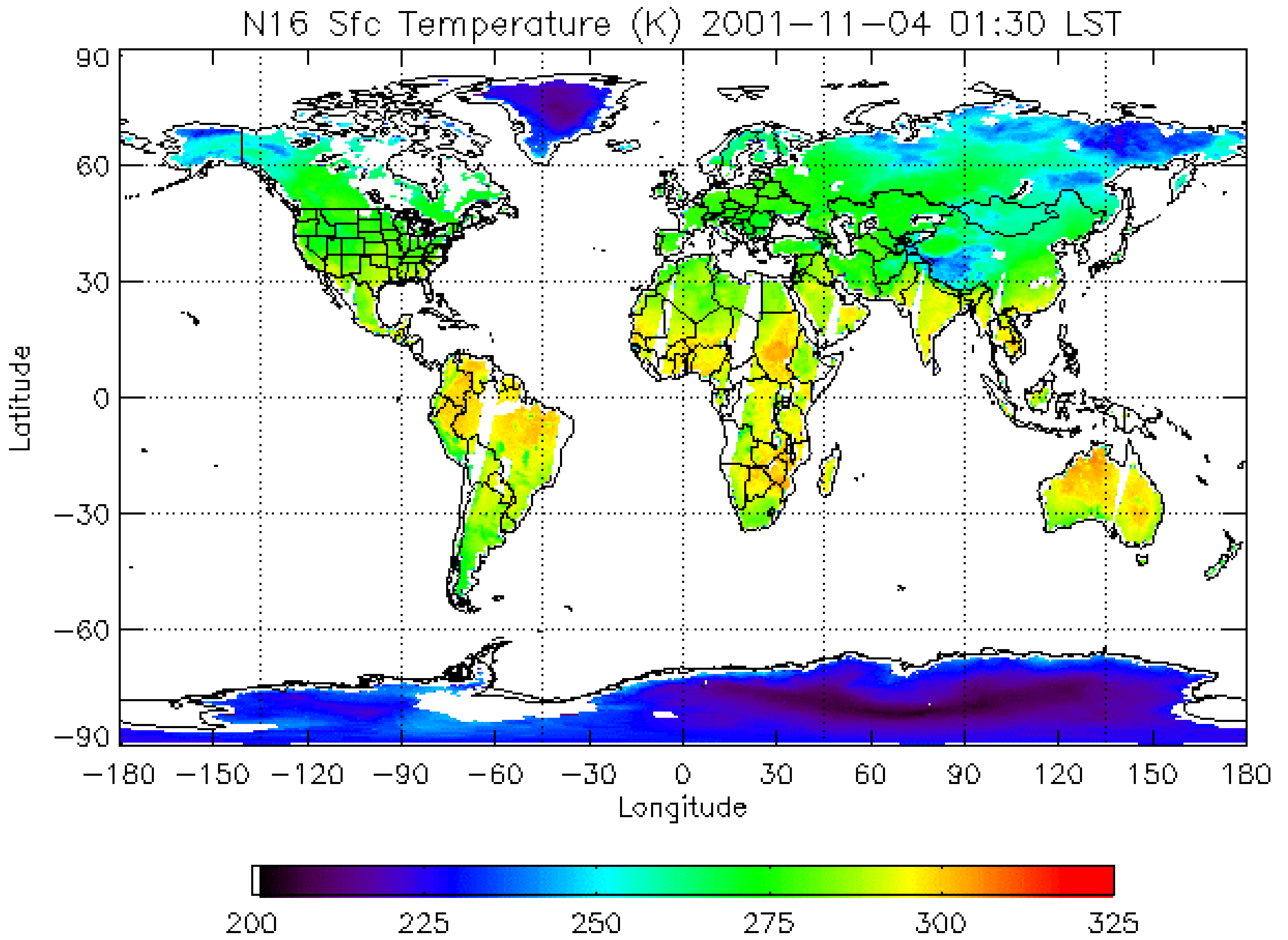

N16 Emissivity 31.4 GHz 2001-11-04 13:30 LST
90
60
30
0
−30
−60
−90
Latitude
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
Longitude
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00



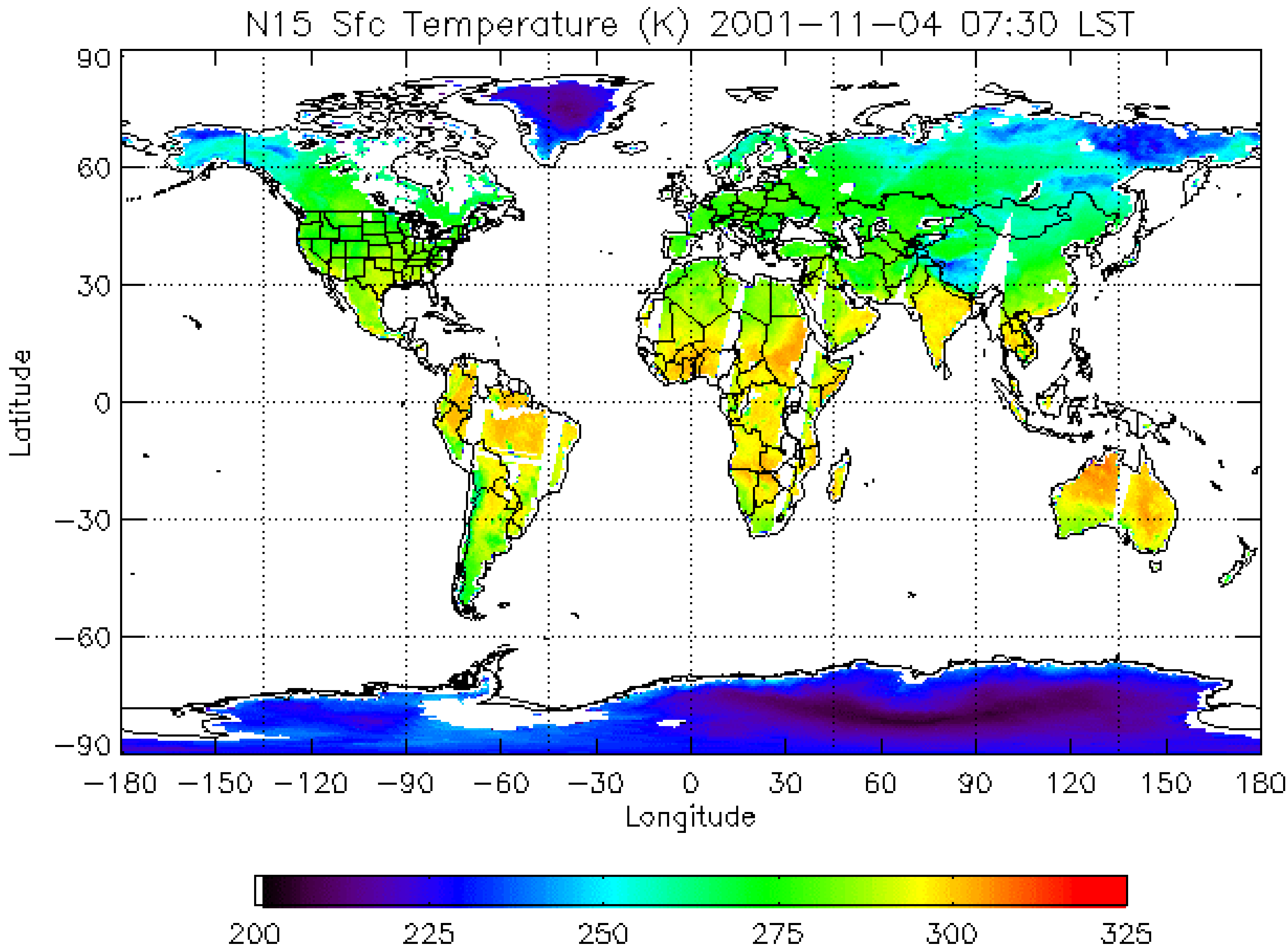
N16 Emissivity 50.3 GHz 2001-11-04 13:30 LST
Latitude
90
60
30
0
−30
−60
−90
−180 −150 −120 −90 −60 −30 0 30 60 90 120 150 180
Longitude
0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00

Land Surface Temperature

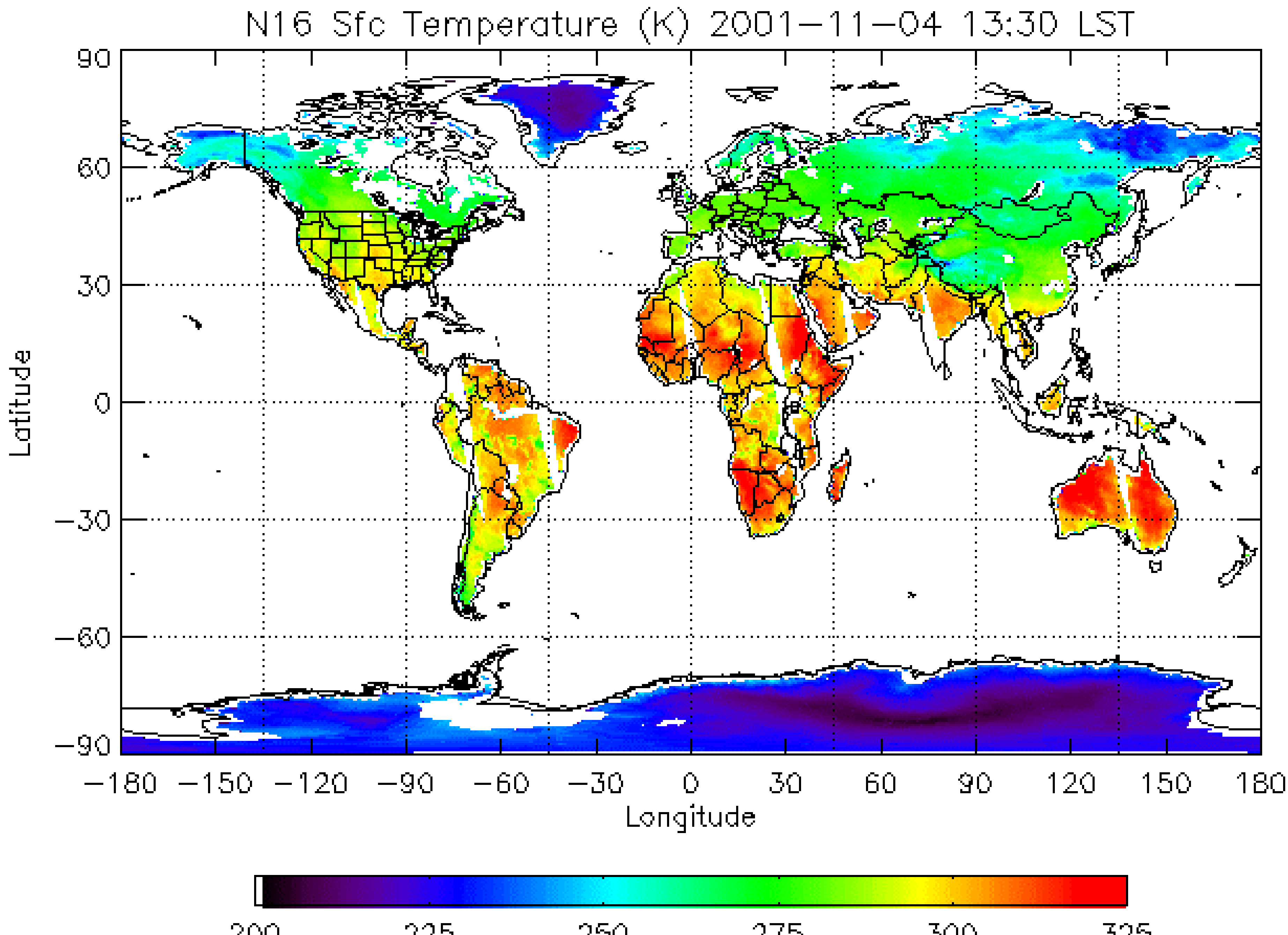
- Regression relationship between TB’s and NWP global model fields
- $T_{sfc} = f(TB_{23}, TB_{31}, TB_{50}, \mu)$
  - Includes linear and non-linear terms



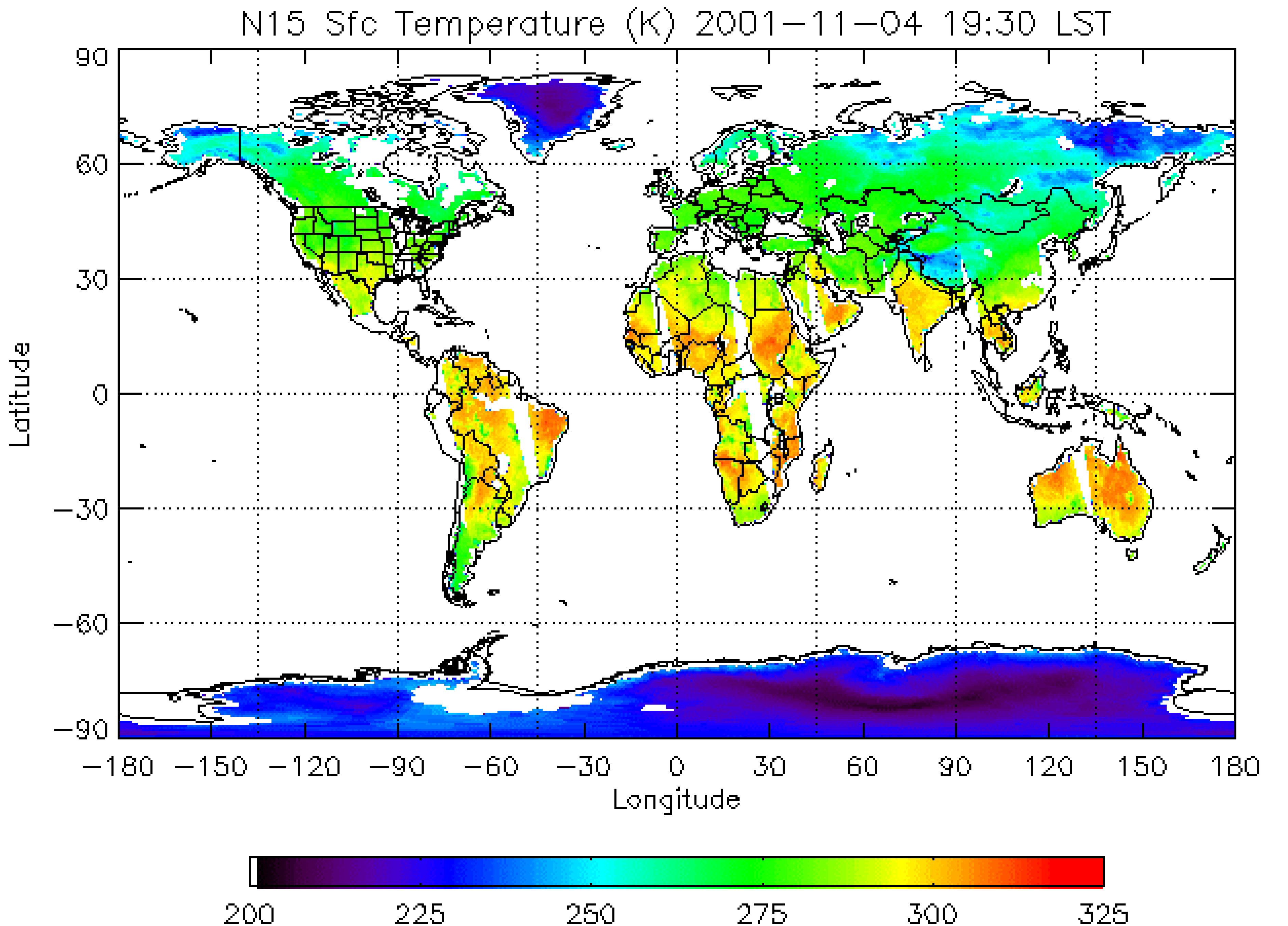
N16 Sfc Temperature (K) 2001-11-04 01:30 LST
90
60
30
0
-30
-60
-90
Latitude
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
Longitude
200
225
250
275
300
325



N15 Sfc Temperature (K) 2001-11-04 07:30 LST
90
60
30
0
−30
−60
−90
Latitude
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
Longitude
200
225
250
275
300
325

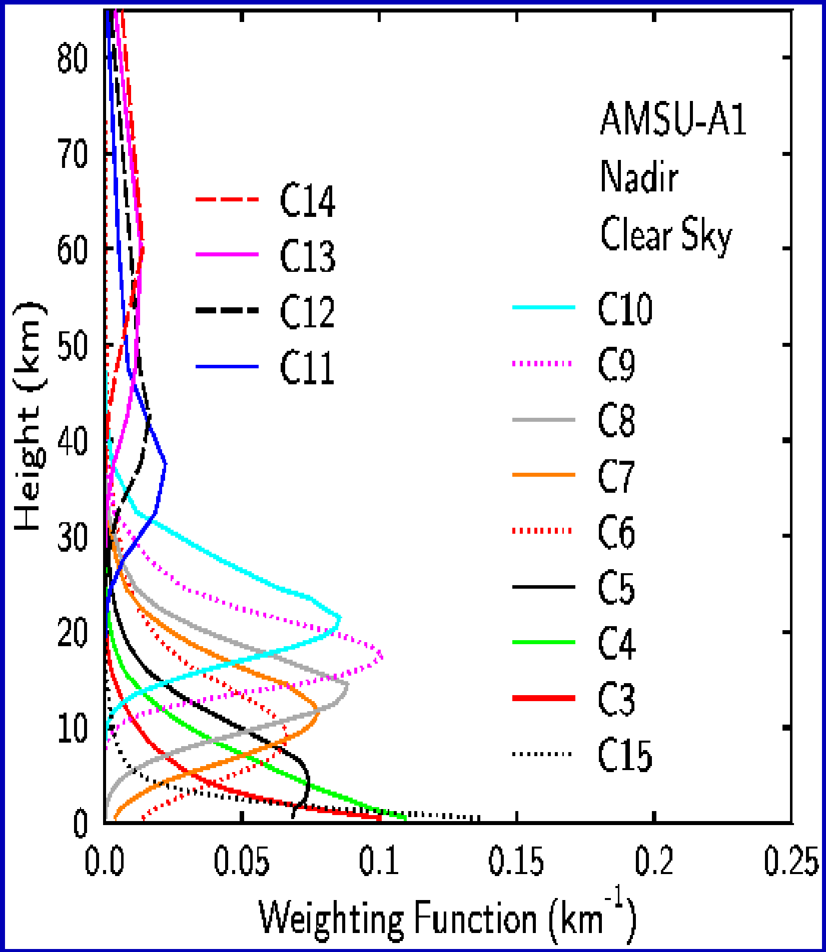


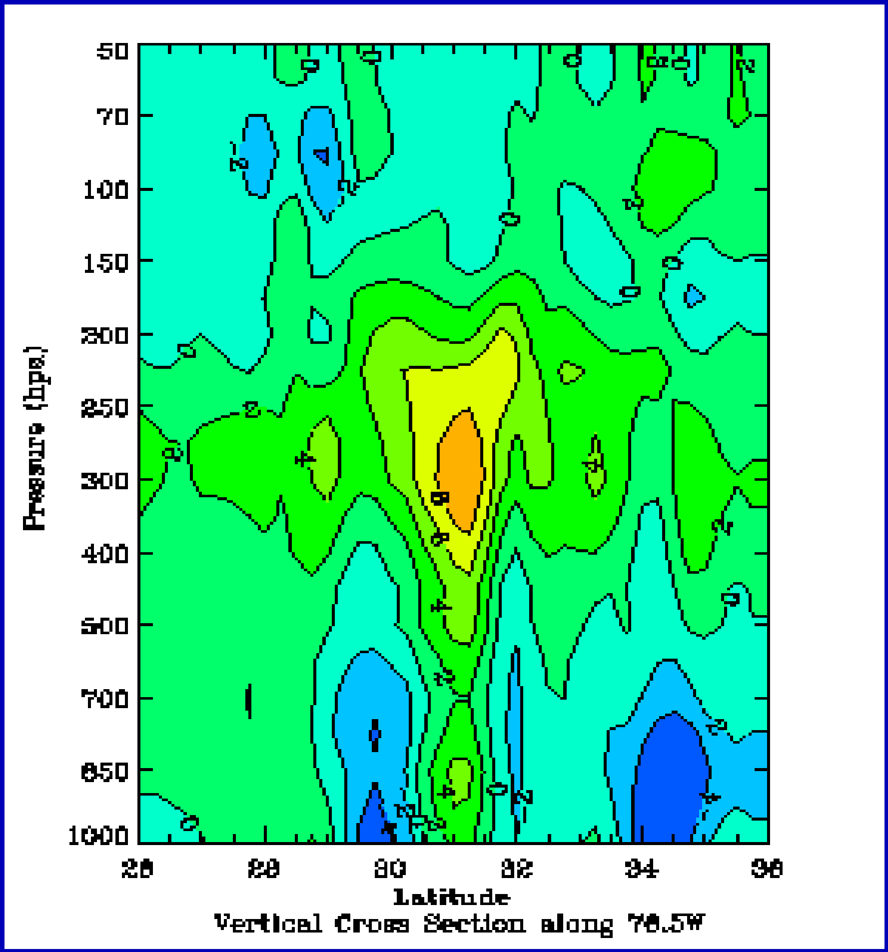
N16 Sfc Temperature (K) 2001-11-04 13:30 LST
90
60
30
0
−30
−60
−90
Latitude
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
Longitude
200
225
250
275
300
325



N15 Sfc Temperature (K) 2001−11−04 19:30 LST
90
60
30
0
−30
−60
−90
Latitude
−180 −150 −120 −90 −60 −30 0 30 60 90 120 150 180
Longitude
200 225 250 275 300 325

Hurricane Temperature & Wind

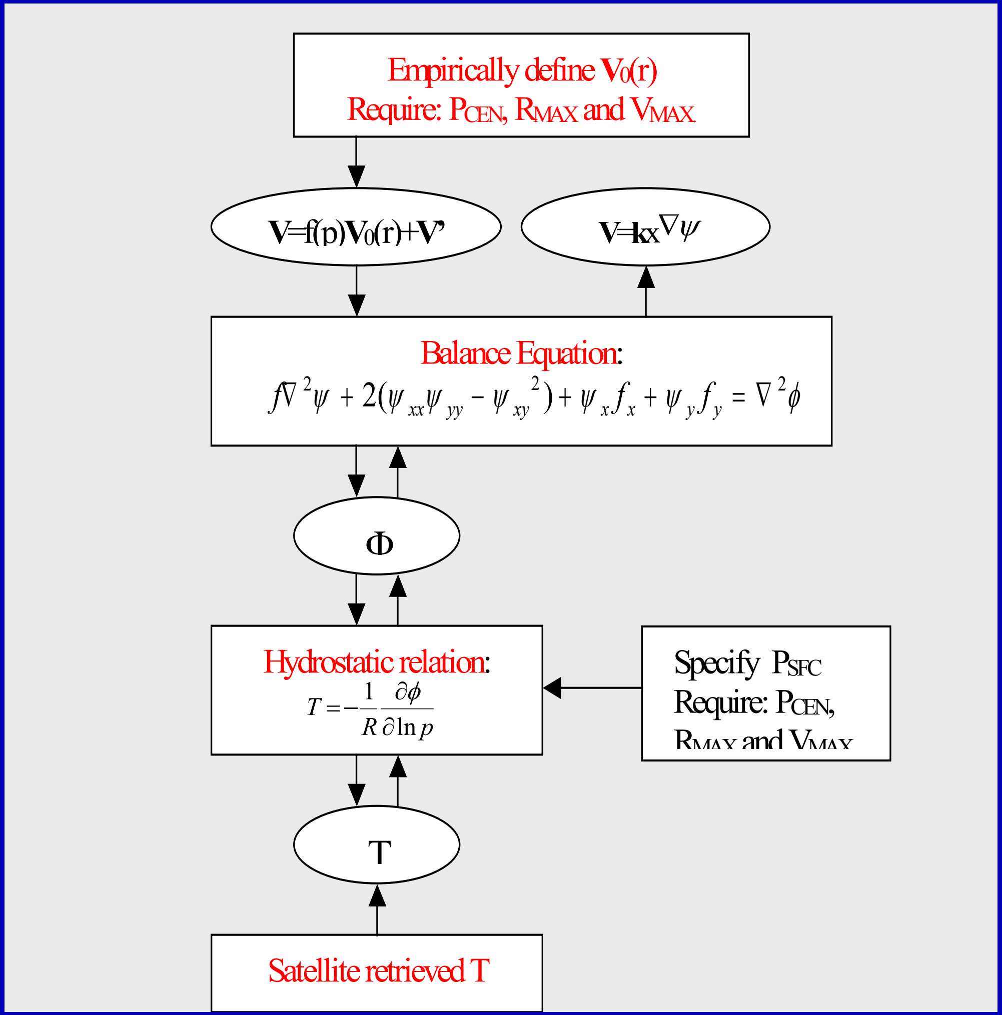




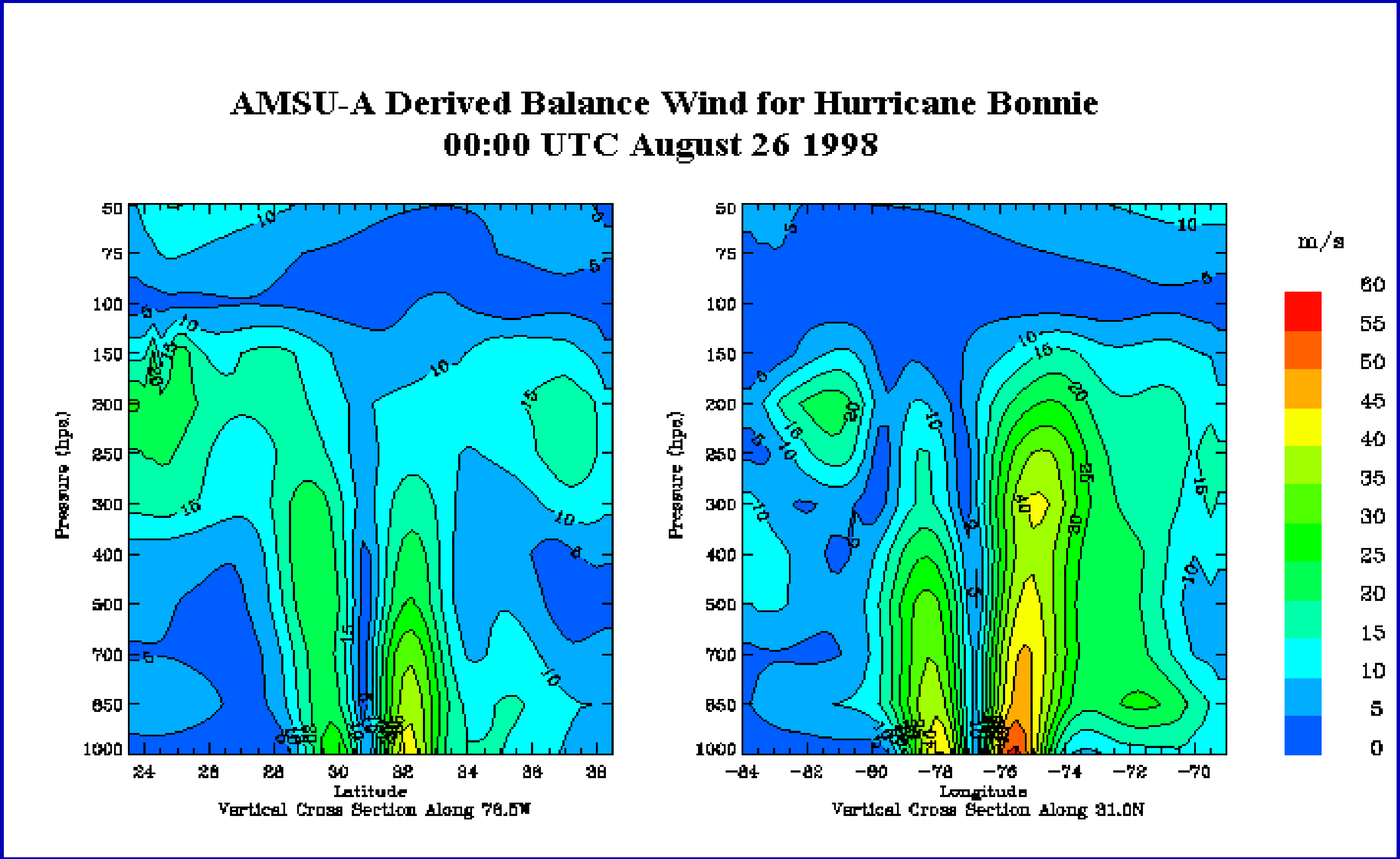
Hurricane Bonnie

Balanced Wind Retrieval

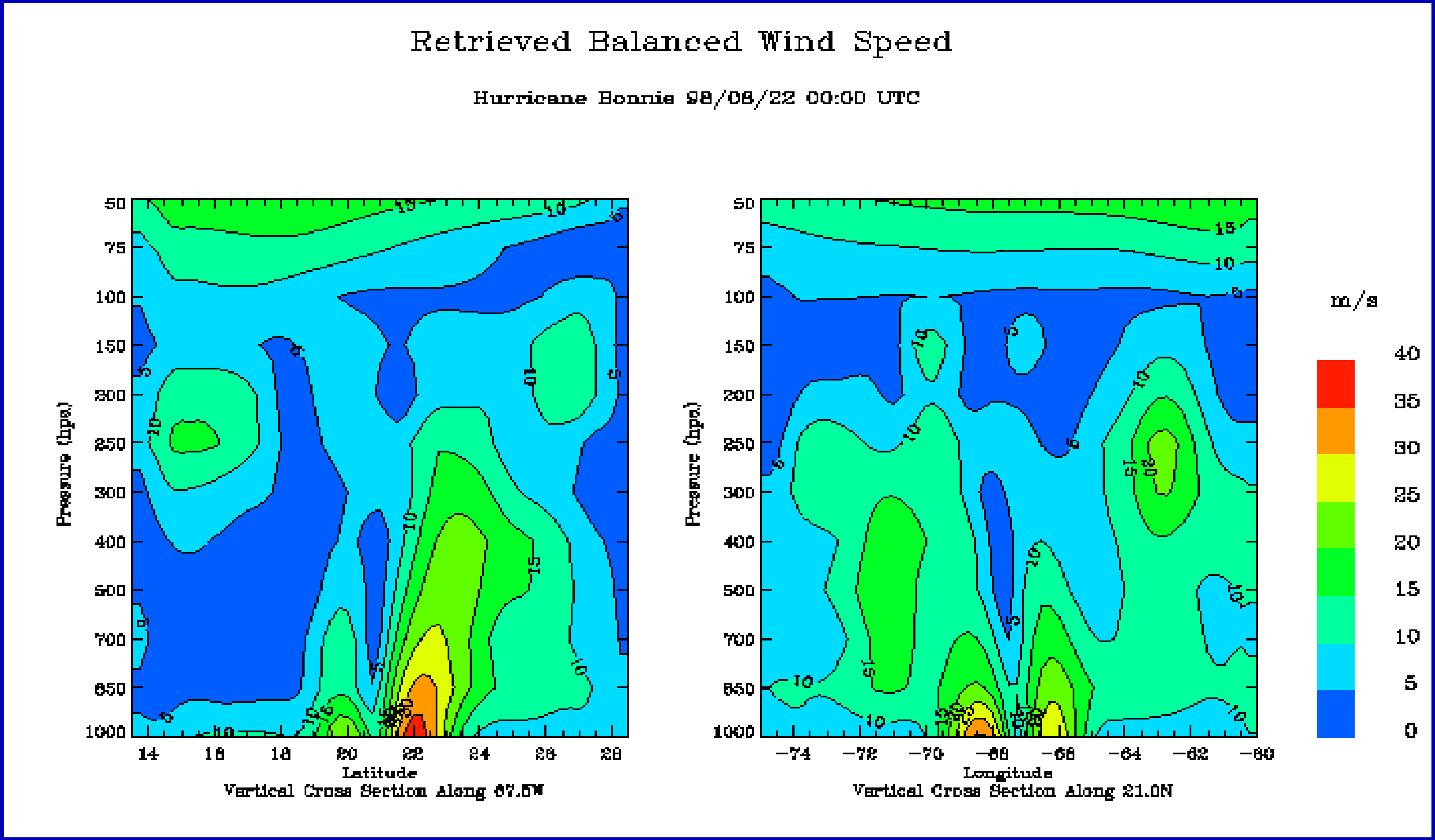
- Retrieve temperatures from AMSU
- Derive geopotential using hydrostatic equation
- Solve the balance equation for streamfunction
- Calculate wind vectors from streamfunction



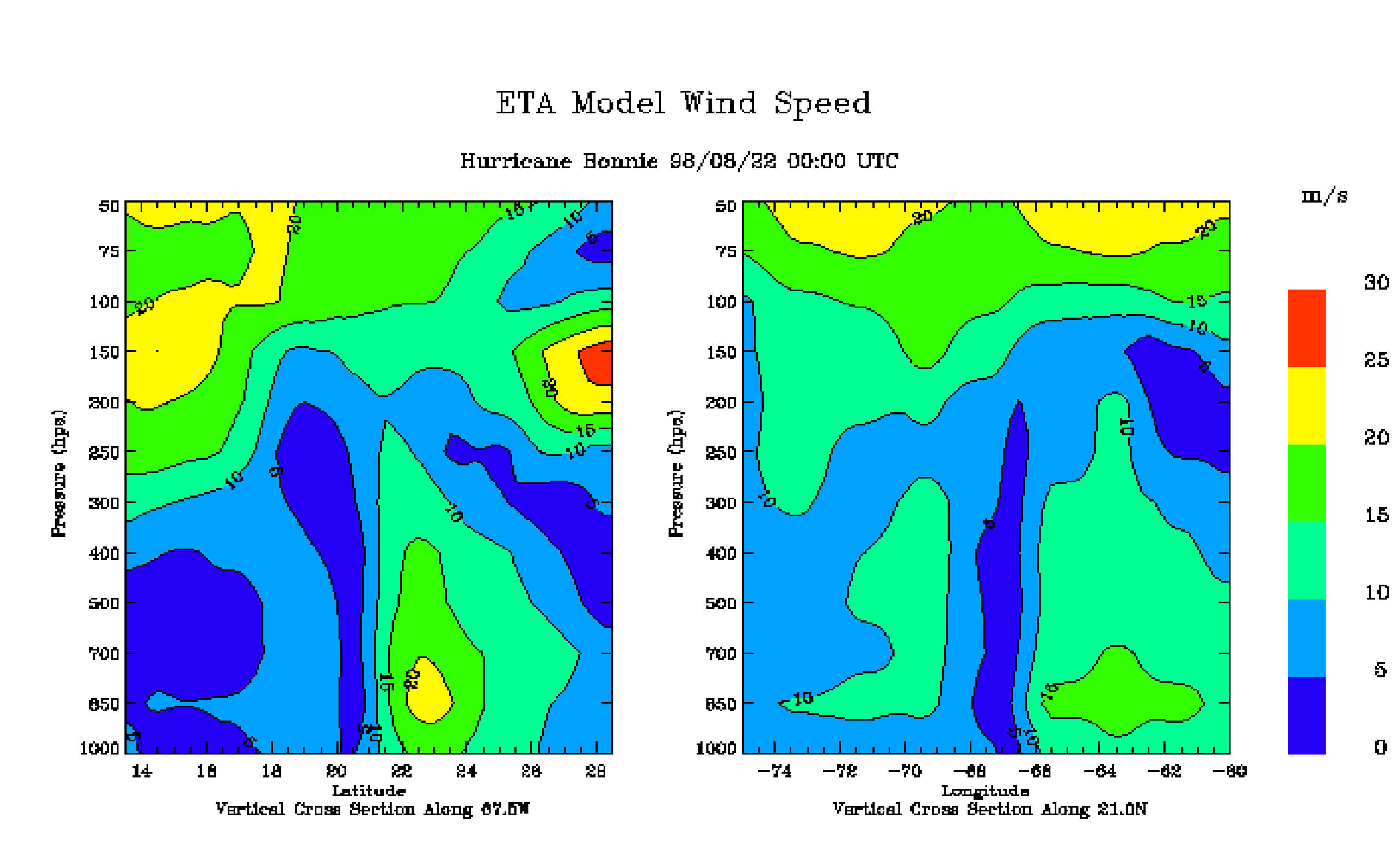
AMSU Derived Balanced Winds During the Mature Stage



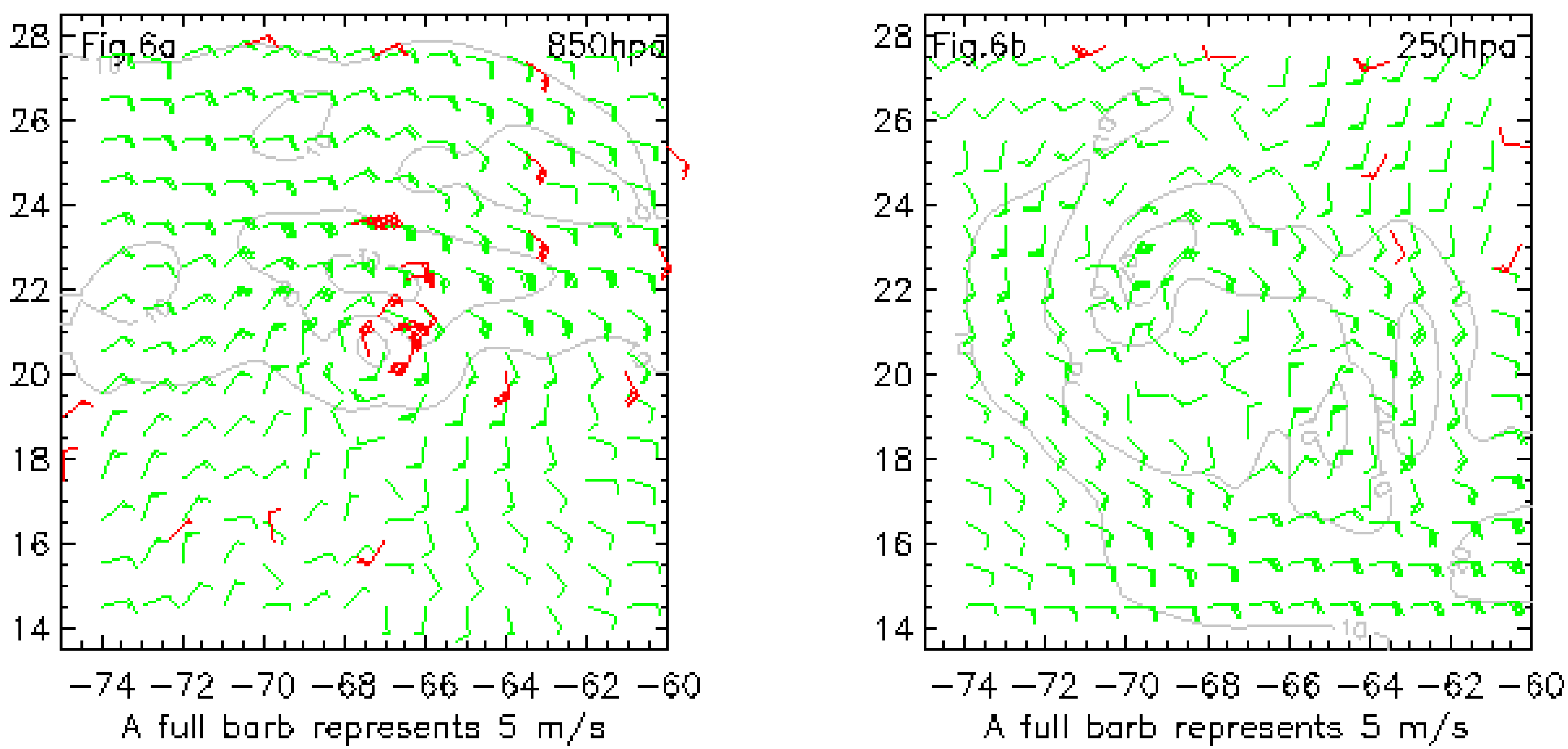
AMSU Derived Balanced Winds During the Incipient Stage



NCEP Eta Model Winds During the Incipient Stage

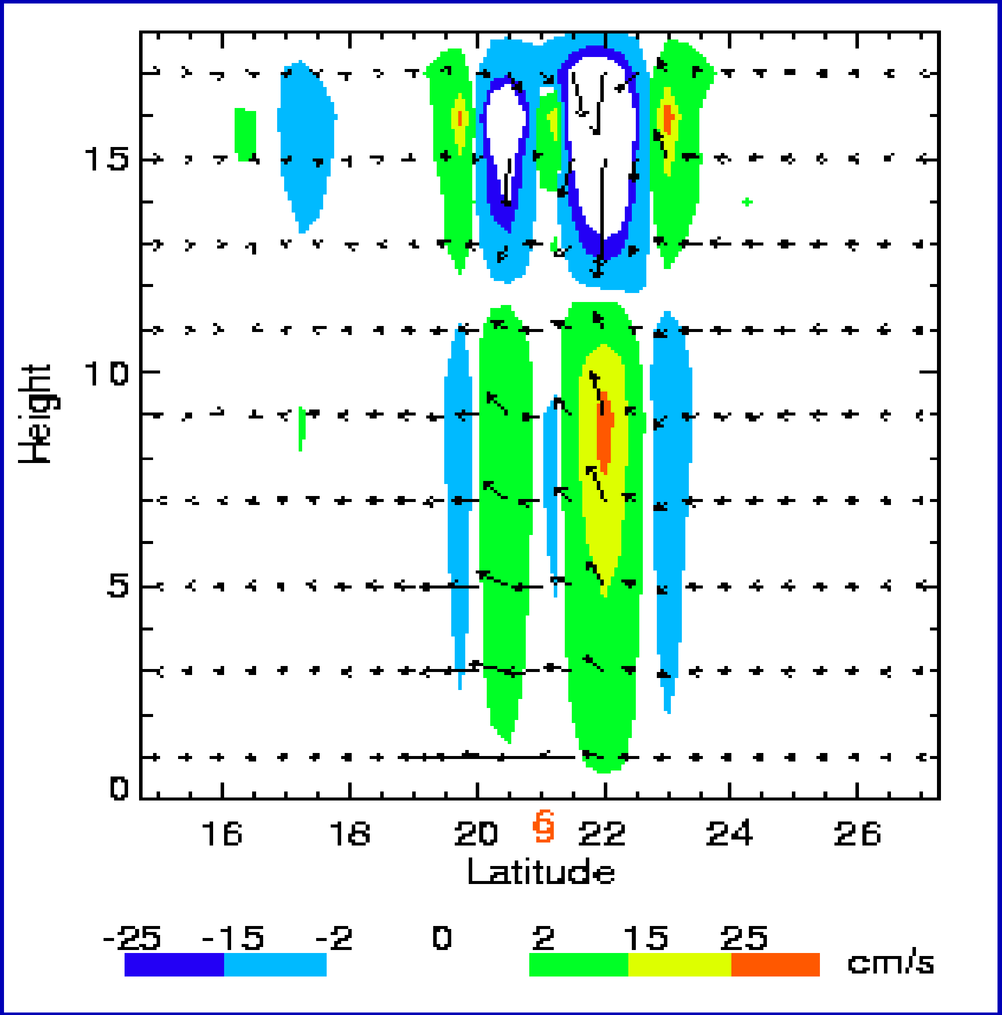


AMSU Derived Balanced Wind vs. GPS Dropsonde Measurements



Vertical Motion Derived from AMSU Rain Rate

- AMSU rain rate is used to derive the latent heat profile
- Latent heat is used to solve vertical velocity by solving the omega equation
- Continuity equation is used to derive the divergent wind.
- Shown are composite balanced and divergence and vertical motion of hurricane Bonnie



Future Plans

- Continue operational generation of AMSU nonsounding products through NOAA-M,N,N’
- Algorithm improvements
  - Improved physical models
  - Better sensor characterization
- New algorithms being considered
  - Snow depth
  - Soil wetness (temporal information)
- Synergy with NWP assimilation

References

- Ferraro, R.R, F. Weng, N.C. Grody and L. Zhao, 2000: Precipitation characteristics over land from the NOAA-15 AMSU Sensor. *Geophy. Res. Let.*, **27**, 2669-2672.
- Weng, F., B. Yan and N. Grody, 2001: A microwave land emissivity model. *J. Geophys. Res.,* **106**, 20,115-20,123.
- Zhao, L. and F. Weng, 2002: Retrieval of ice cloud properties using the Advanced Microwave Sounding Unit (AMSU). *J. Appl. Meteor.,* **41***, 384-395.*
- Zhu, T., D. Zhang, and F. Weng, 2002: A hurricane model initialization scheme using AMSU*, MWR (accepted).*
- Weng, F. et al, 2002: AMSU cloud and precipitation algorithms. *Radio Science (submitted).*

Data Availability & Information

- Our web site:

http://orbit-net.nesdis.noaa.gov/arad2/microwave.html

- Data formats:
  - HDF-EOS
  - BUFR (~2002)
  - McIDAS (AWIPS ~2002)
- NESDIS/OSDPD:
  - Operational Request
  - SAA (~2002)
- NESDIS/ORA:
  - Weng/Ferraro/Grody