Environmental Data Records from Special Sensor Microwave Imager and Sounder (SSMIS)

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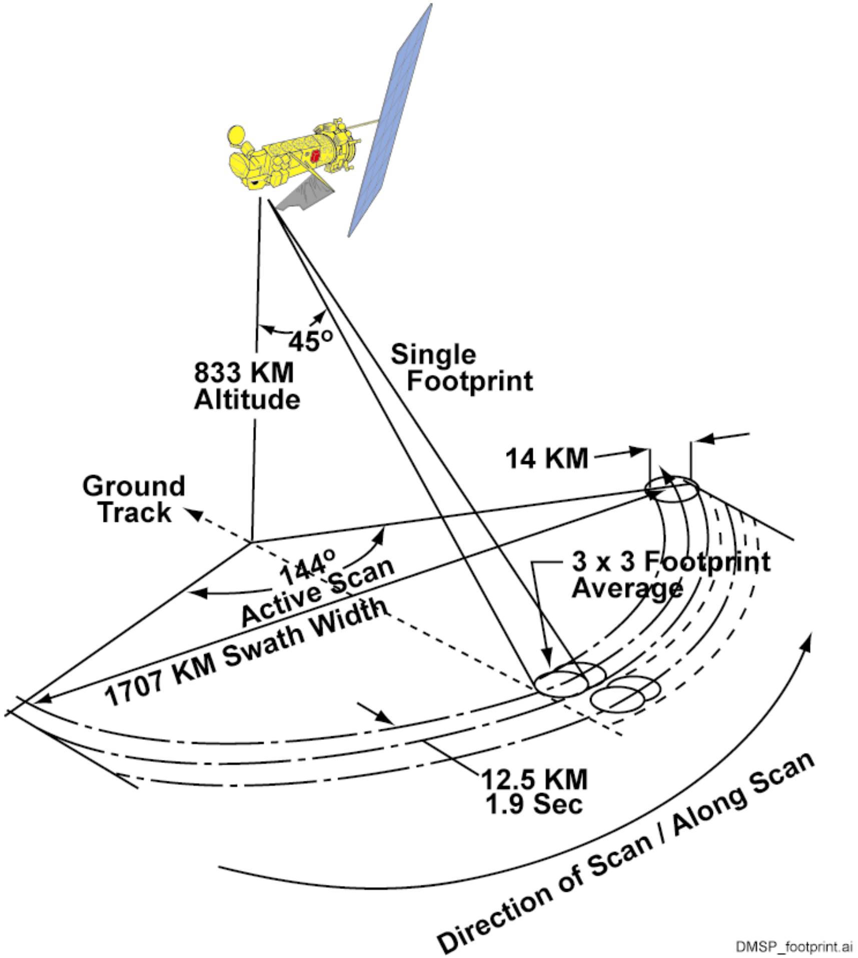
SSMIS Instrument Characteristics

- **The Defense Meteorological Satellite Program (DMSP) successfully launched the first of five Special Sensor Microwave Imager/Sounder (SSMIS) on 18 October 2003.**
- **SSMIS is a joint United States Air Force/Navy multi-channel passive microwave sensor**
- **Combines and extends the current imaging and sounding capabilities of three separate DMSP microwave sensors, SSM/T, SSM/T-2 and SSM/I, with surface imaging, temperature and humidity sounding channels combined.**
- **The SSMIS measures partially polarized radiances in 24 channels covering a wide range of frequencies (19 – 183 GHz)**
  - conical scan geometry at an earth incidence angle of 53 degrees
  - maintains uniform spatial resolution, polarization purity and common fields of view for all channels across the entire swath of 1700 km.



SSMIS Data Processing and Distribution at NESDIS

- NESDIS receives and distributes DMSP F-16/17 SSMIS Temperature Data Record (TDR) from FNMOC (original without anomaly correction)

- NESDIS also receives F16 SSMIS SDR data in BUFR format from FNMOC (with NRL/UK UPP-v2 anomaly correction)

- NESDIS/STAR developed its experimental anomaly correction scheme and applied to the original SSMIS TDR data

- All above mentioned data sets are available from NESDIS/OSDPD or NESDIS/STAR upon request

Thank Steve Swadley for providing F16 satellite antenna pattern correction coefficients at TDR level and linear-mapping coefficients for converting SSM/IS imaging channels to SSM/I-like channels at SDR level

SSMIS Heritage Products and *New Developments*

Heritage

- Total Precipitable Water
- Cloud Liquid Water
- Sea Surface Wind Speed
- Rain Rate
- Snow Cover
- Sea Ice Concentration

Experimental

- *Land Surface Temperature*
- *Land Surface Emissivity*
- *Cloud Ice Water Path*
- *Atmospheric Temperature*
- *Atmospheric Moisture*

Visit website for SSMIS Products Demonstration:
http://www.orbit.nesdis.noaa.gov/smcd/jcsda/SDS

Also see:

Sun, N., and F. Weng, 2008: Evaluation of Special Sensor Microwave Imager and Sounder (SSMIS) Environmental Data Record, IEEE Trans. Geosci. and Remote Sens., 46, 1006-1016

Yan, B., and F. Weng, 2008: Intercalibration between Special Sensor Microwave Imager and Sounder (SSMIS) and Special Sensor Microwave Imager (SSM/I), IEEE Trans. Geos. and Remote Sens., 46, 984-995

Total Precipitable Water (TPW)

Alishouse, J.C., S. A. Snyder, J. Vongsathorn, and R. R. Ferraro, "Determination of Oceanic Total Precipitable Water from the SSM/I," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 28, pp. 811-816, Sep 1990.

Algorithm Description:

$$TPW = 232.89 - 0.1486(TB_{19v}) - 0.3695(TB_{37v}) - [1.8291 - 0.006193(TB_{22v})]TB_{22v}$$

Calculate Scattering Index for rain areas

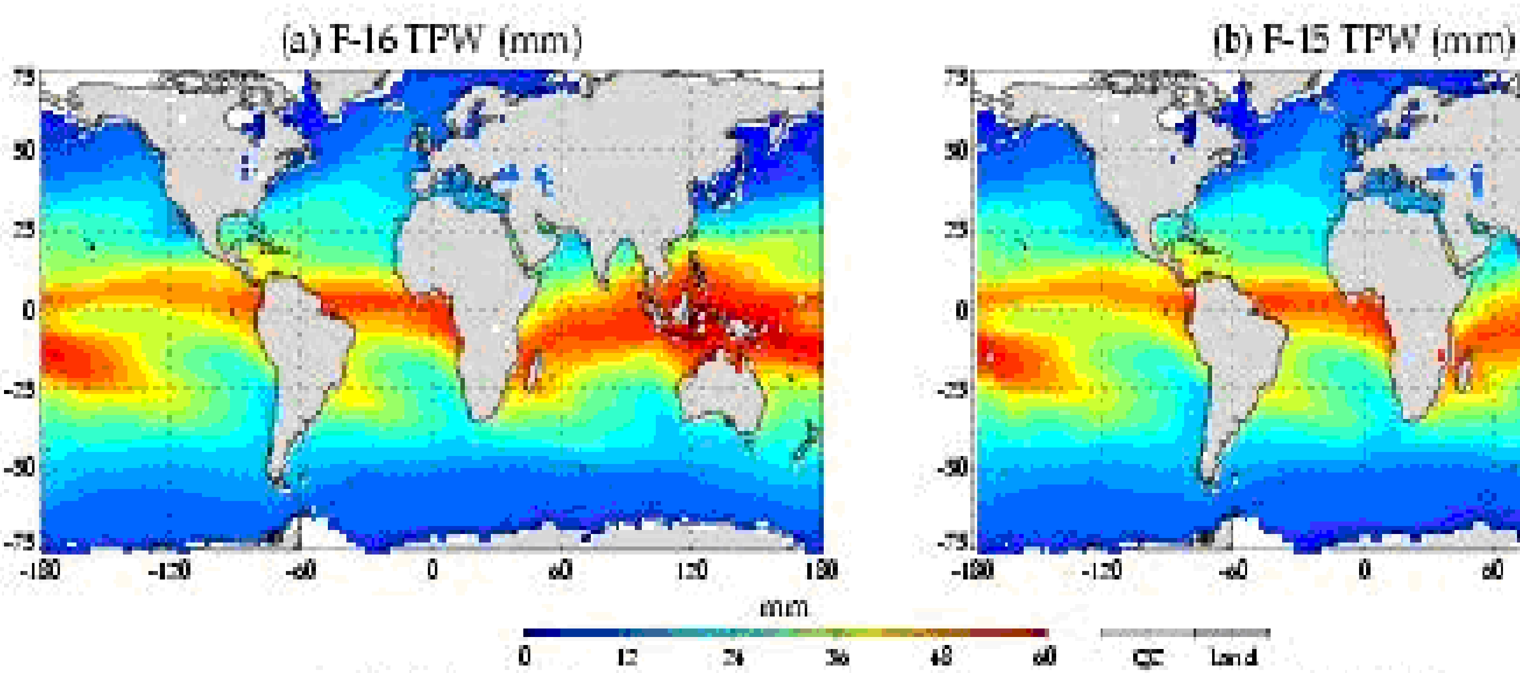
$$SI = EST_{TB_{85v}} - TB_{85v}$$

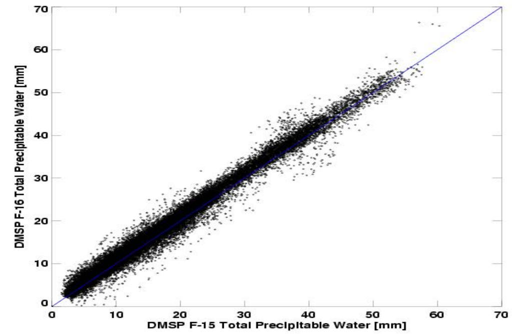
$$EST_{TB_{85v}} = \begin{cases} 438.5 - 0.46(TB_{19v}) - 1.735(TB_{22v}) + 0.00589(TB_{22v})^2, & land \\ -182.7 - 0.75(TB_{19v}) + 2.543(TB_{22v}) - 0.00543(TB_{22v})^2, & ocean \end{cases}$$

When Scattering Index is greater than 10K over ocean, which means rain is present, cubic correction is made to original TPW.

$$TPW_{corrected} = -3.753 + 1.507(TPW) - 0.1933(TPW)^2 + 0.00219(TPW)^3$$

Heritage Algorithm (TPW)





Cloud Liquid Water Path (LWP)

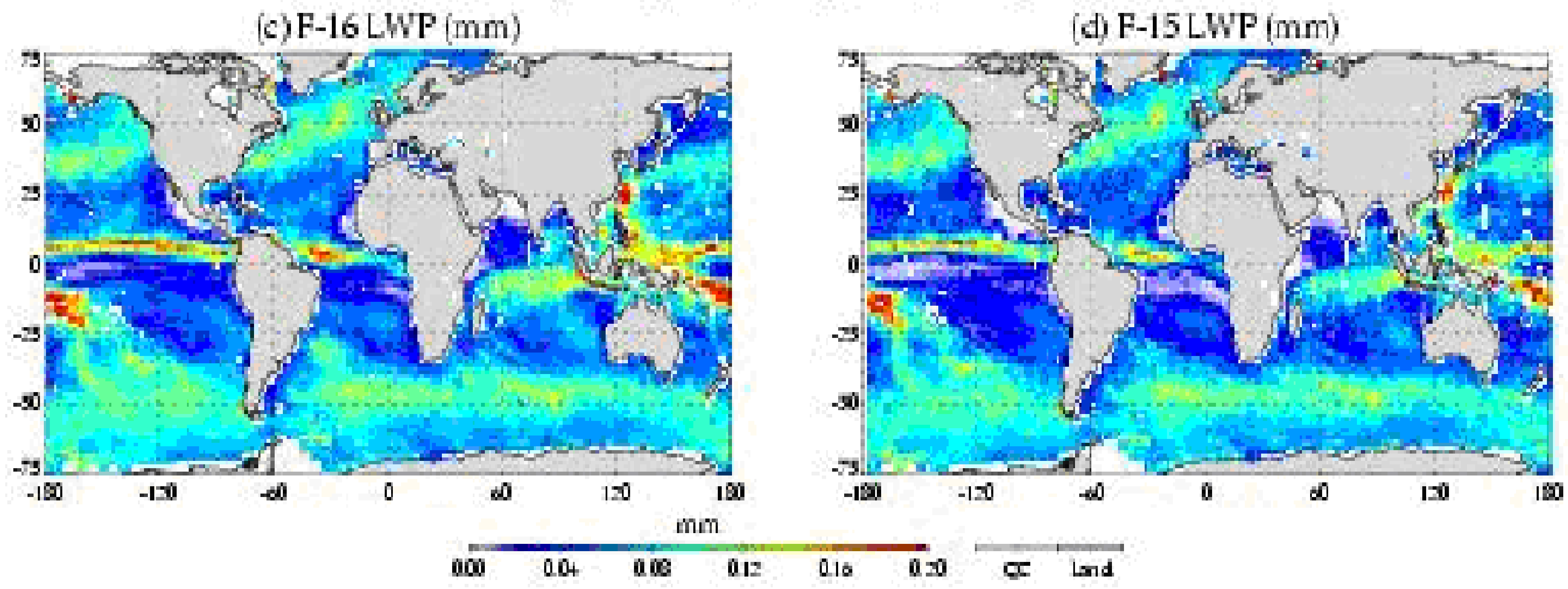
Weng, F. and N. C. Grody, "Retrieval of Cloud Liquid Water Using the Special Sensor Microwave Imager (SSM/I)," *Journal of Geophysical Research-Atmospheres*, vol. 99, pp. 25535-25551, Dec 20 1994

Weng, F., N. C. Grody and R. R. Ferraro and A. Basist and D. Forsyth, 1997: Cloud liquid water climatology derived from the Special Sensor Microwave Imager. *J. Climate*, 10, 1086-1098.

Algorithm Description:

$$LWP = \begin{cases} -3.20[\ln(290 - TB_{19v}) - 2.8 - 0.42\ln(290 - TB_{22v})], & LWP > 0.7 \\ -0.44[\ln(290 - TB_{85h}) - 1.6 + 1.35\ln(290 - TB_{22v})], & LWP > 0.28 \; and \; TPW < 30 \\ -1.66[\ln(290 - TB_{37v}) + 2.9 + 0.35\ln(290 - TB_{22v})], & else \end{cases}$$

Heritage Algorithm (LWP)



Surface Precipitation (Rain Rate)

Ferraro, R.R. and G. F. Marks, "The Development of SSM/I Rain-Rate Retrieval Algorithms Using Ground-Based Radar Measurements," *Journal of Atmospheric and Oceanic Technology*, vol. 12, pp. 755-770, Aug 1995.

Algorithm Description:

Over Land

$$SI = EST_{TB_{85v}} - TB_{85v}$$

$$EST_{TB_{85v}} = \begin{cases} 438.5 - 0.46(TB_{19v}) - 1.735(TB_{22v}) + 0.00589(TB_{22v})^2, & land \\ -182.7 - 0.75(TB_{19v}) + 2.543(TB_{22v}) - 0.00543(TB_{22v})^2, & ocean \end{cases}$$

When Scattering Index is greater than 10K

$$RR = 0.00188 * SI^{2.03434}$$

Heritage Algorithm (RR)

Over oceans

$$Q_{19} = -2.70*[Ln(290 - TB_{19v}) - 2.8 - 0.42*Ln(290 - TB_{22v})], \quad TB_{19v} < 285, TB_{22v} < 285$$

$$Q_{37} = -1.15*[Ln(290 - TB_{37v}) - 2.9 - 0.349*Ln(290 - TB_{22v})], \quad TB_{37v} < 285, TB_{22v} < 285$$

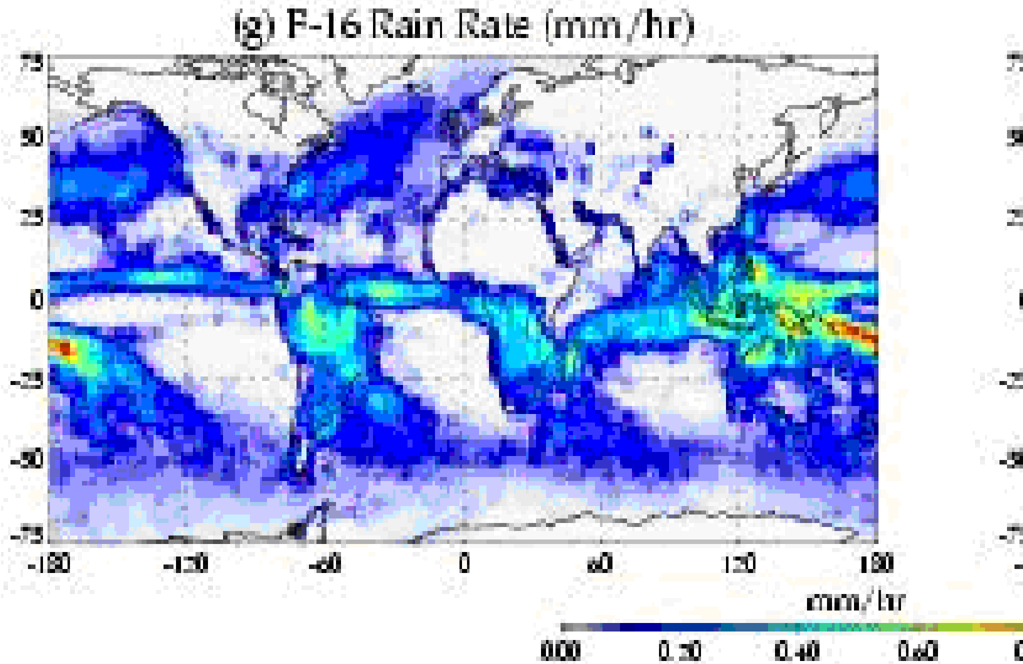
If Q_{19} is greater than 0.6,

$$RR = 0.001707*(Q_{19}*100)^{1.7359}$$

If Q_{37} is greater than 0.2,

$$RR = 0.001707*(Q_{37}*100)^{1.7359}$$

Heritage Algorithm (RR)



Snow Cover

Grody, N,C. and A. N. Basist, "Global identification of snowcover using SSM/I measurements," *Ieee Transactions on Geoscience and Remote Sensing*, vol. 34, pp. 237-249, Jan 1996

Algorithm Description:

Calculate index:

$$Index\ 1 = TB_{22v} - TB_{85v}$$

$$Index\ 2 = TB_{19v} - TB_{37v}$$

$$Index\ 3 = TB_{19v} - TB_{19h}$$

$$Index\ 4 = TB_{37v} - TB_{85v}$$

If Index 2 is greater than Index1, Index1 is set to Index2.
If Index 1 is greater than 0, snow is present.
However, error is corrected under following four conditions,

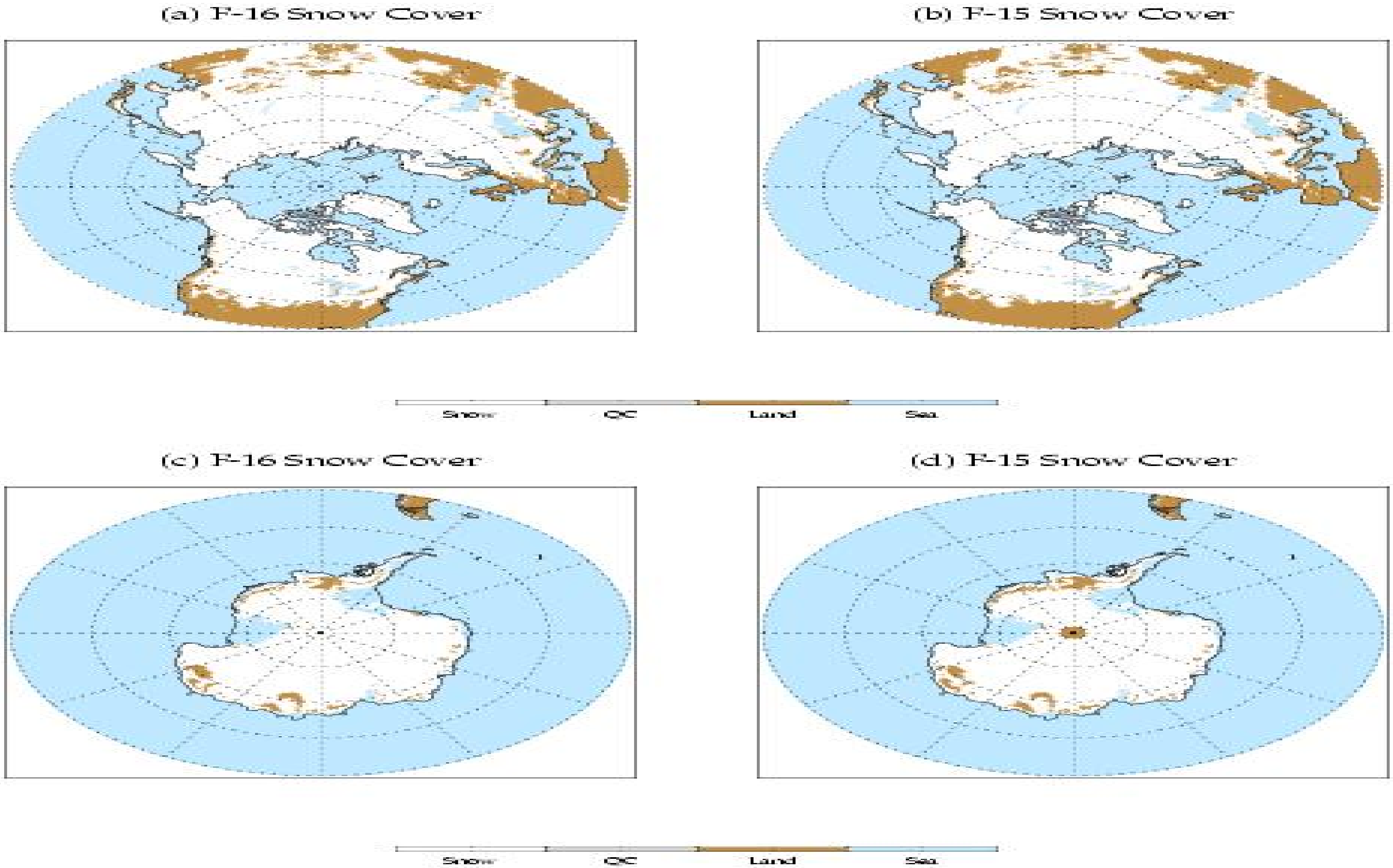
$$TB_{22v} >= 254\ \&\ Index1 < 2$$

$$TB_{22v} >= 258\ ||\ TB_{22v} >= (165 + 0.49 * TB_{85v})$$

$$Index1 <= 6\ \&\ Index3 >= 8$$

$$Index3 >= 18\ \&\ Index2 <= 10\ \&\ Index4 <= 10$$

Heritage Algorithm (Snow Cover)



Sea Ice Concentration

Ferraro, R. R., F. Weng, N. Grody, and A. Basist, 1996: An eight year (1987-1994) time series of rainfall, clouds, water vapor, snow and sea ice derived from SSM/I measurements, *Bull. Amer. Meteor. Soc.*, 77, *891-905.*

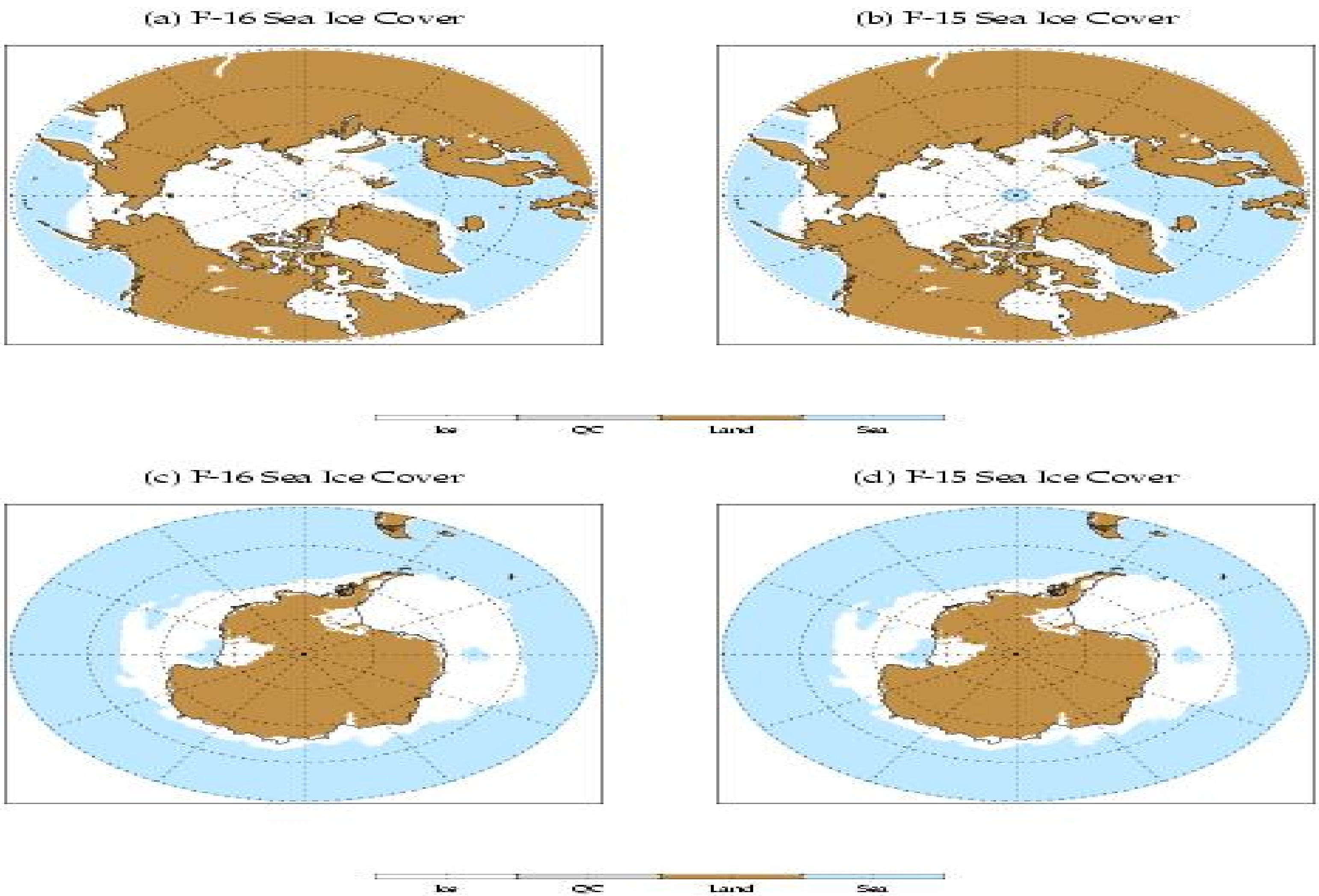
Algorithm Description:

For area north of 44.4^{0}N and south of 52.0^{0}S

$$\begin{aligned} ICE = \; & 91.9 - 2.99(TB_{22v}) + 2.85(TB_{19v}) \\ & - 0.39(TB_{37v}) + 0.50(TB_{85v}) \\ & + 1.01(TB_{19h}) - 0.90(TB_{37h}) \end{aligned}$$

When ICE is greater than 70%, Sea Ice is assumed present.

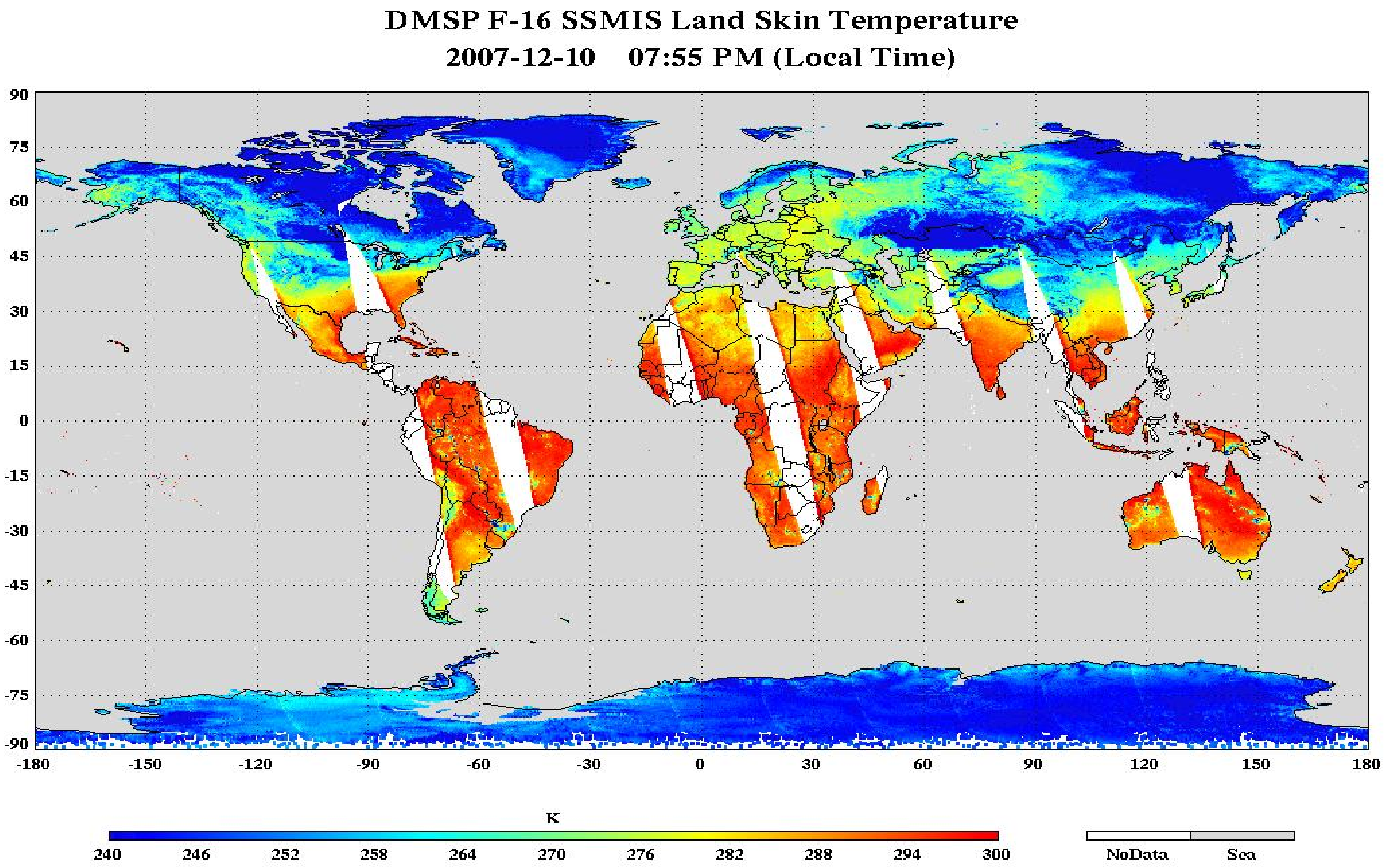
Heritage Algorithm (Sea Ice)



Land Surface Temperature (LST)

$$
\begin{aligned}
LST = & \; 0.02509 \, [1.7167 - 0.005514 \, (TB_{22v})] TB_{22v} \\
& - [0.1083 + 0.001976 \, (TB_{37v})] TB_{37v} \\
& + [1.1763 - 0.000636 \, (TB_{85v})] TB_{85v}
\end{aligned}
$$

Land Surface Temperature (Experimental)



Land Surface Emissivity (LSE)

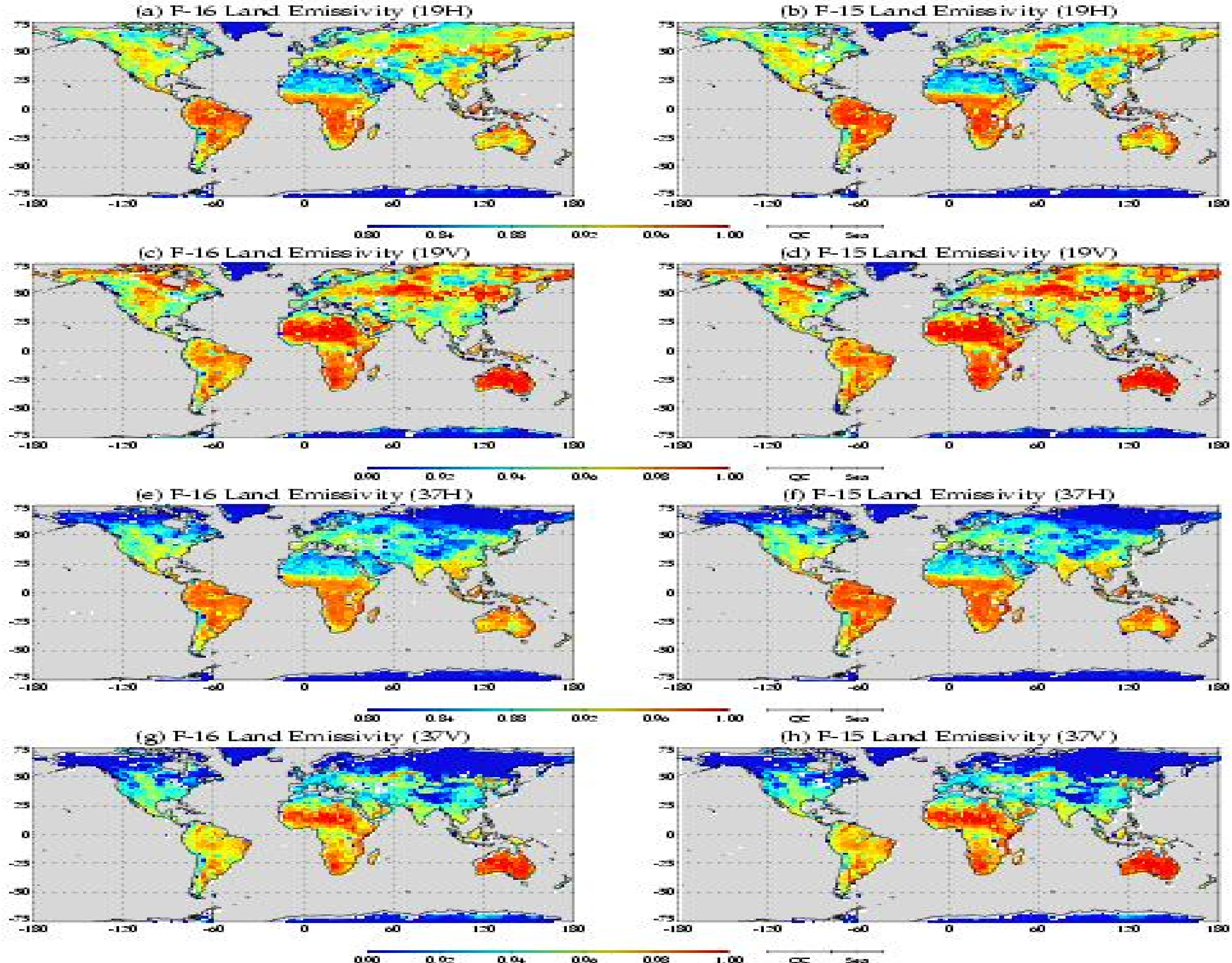
Algorithm Description:

For channels at 19V/H, 22V, 37V/H. emissivity is derived as

$$\varepsilon = a_0 + a_1(TB_{19v}) + a_2(TB_{19h}) + a_3(TB_{22v})$$
$$a_4(TB_{37v}) + a_5(TB_{37h}) + a_6(TB_{85v}) + a_7(TB_{85h})$$

For channels at 85V/H

$$\varepsilon = b_0 + [b_1 + b_2(TB_{37v})](TB_{37v})$$
$$[b_3 + b_4(TB_{85v})](TB_{85v}) + [b_5 + b_6(TB_{85h})](TB_{85h})$$



(a) F-16 Land Emissivity (19H)
(b) F-15 Land Emissivity (19H)
0.80 0.84 0.88 0.92 0.96 1.00
QC Sea
(c) F-16 Land Emissivity (19V)
(d) F-15 Land Emissivity (19V)
0.90 0.92 0.94 0.96 0.98 1.00
QC Sea
(e) F-16 Land Emissivity (37H)
(f) F-15 Land Emissivity (37H)
0.80 0.84 0.88 0.92 0.96 1.00
QC Sea
(g) F-16 Land Emissivity (37V)
(h) F-15 Land Emissivity (37V)
0.90 0.92 0.94 0.96 0.98 1.00
QC Sea

Cloud Ice Water Path (IWP)

Weng, F. and N. C. Grody, 2000: Retrieval of ice cloud parameters using a microwave imaging radiometer, *J. Atmos. Sci.*, 57, 1069-1081.

Zhao, L. and F. Weng, 2002: Retrieval of ice cloud parameters using the Advanced Microwave Sounding Unit (AMSU). *J. Appl. Meteorol.* , 41, 384-395.

IWP is derived from SSMIS using two primary SSMIS channels at 91.655 GHz and 150 GHz

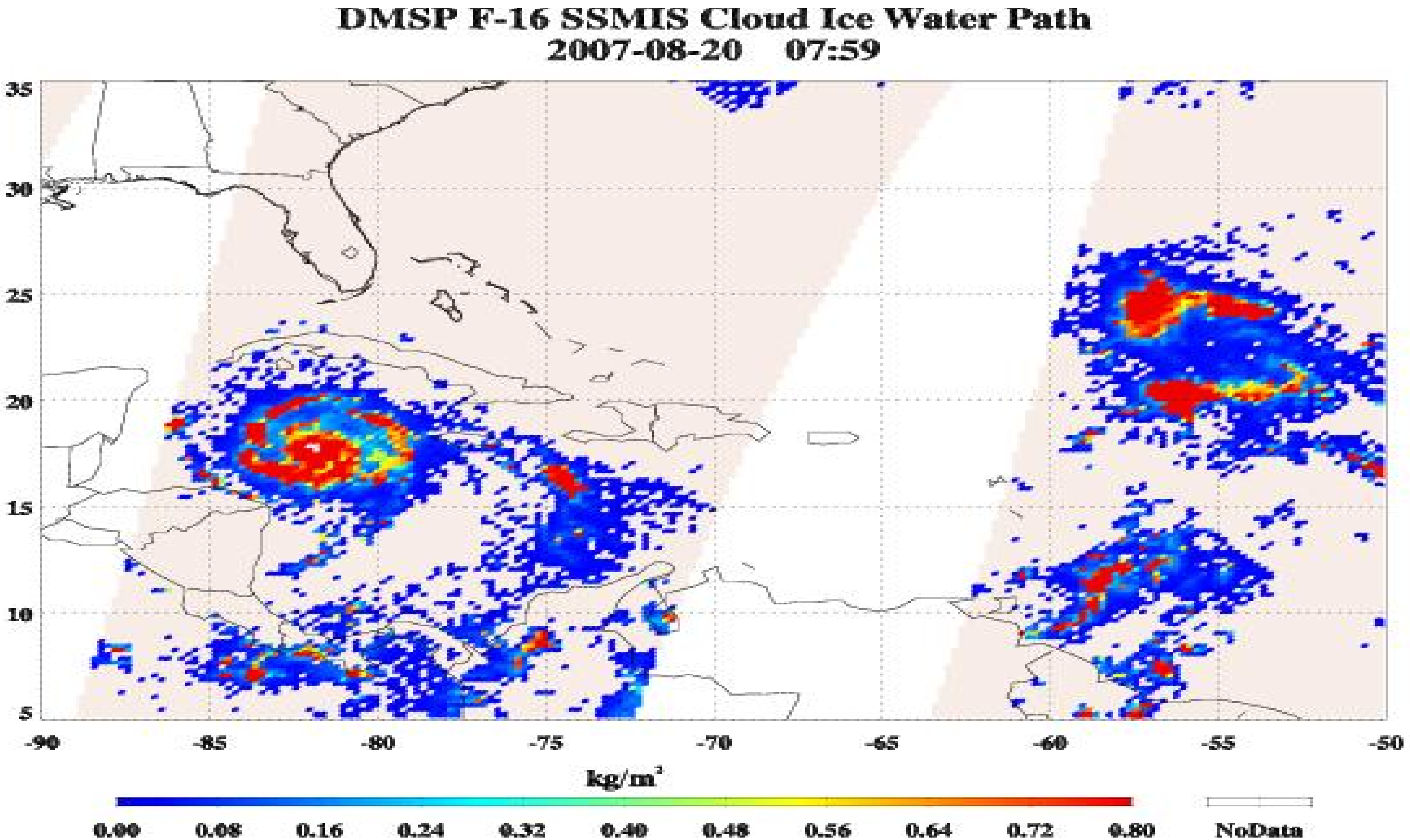
$$IWP = \frac{\Omega_{91v} * De * COS\vartheta * \rho_{ice}}{\Omega_N} \qquad D_e = \exp[a_0 + a_1 \ln(r) + a_2 \ln^2(r)]$$

where

$$r = \frac{\Omega_{91}}{\Omega_{150}} = \frac{\Omega_{N_{91}}}{\Omega_{N_{150}}} \qquad \Omega = \frac{TB(Estimated) - TB(Observed)}{TB(Observed)}$$

$$\Omega_N = \exp[b_0 + b_1 \ln(D_e) + b_2 \ln^2(D_e)]$$

Ice Water Path (Experimental)



IWP-based Rain Rate Algorithm

Rain rate can also be retrieved from IWP using the following equations, (Zhao and Weng, 2001)

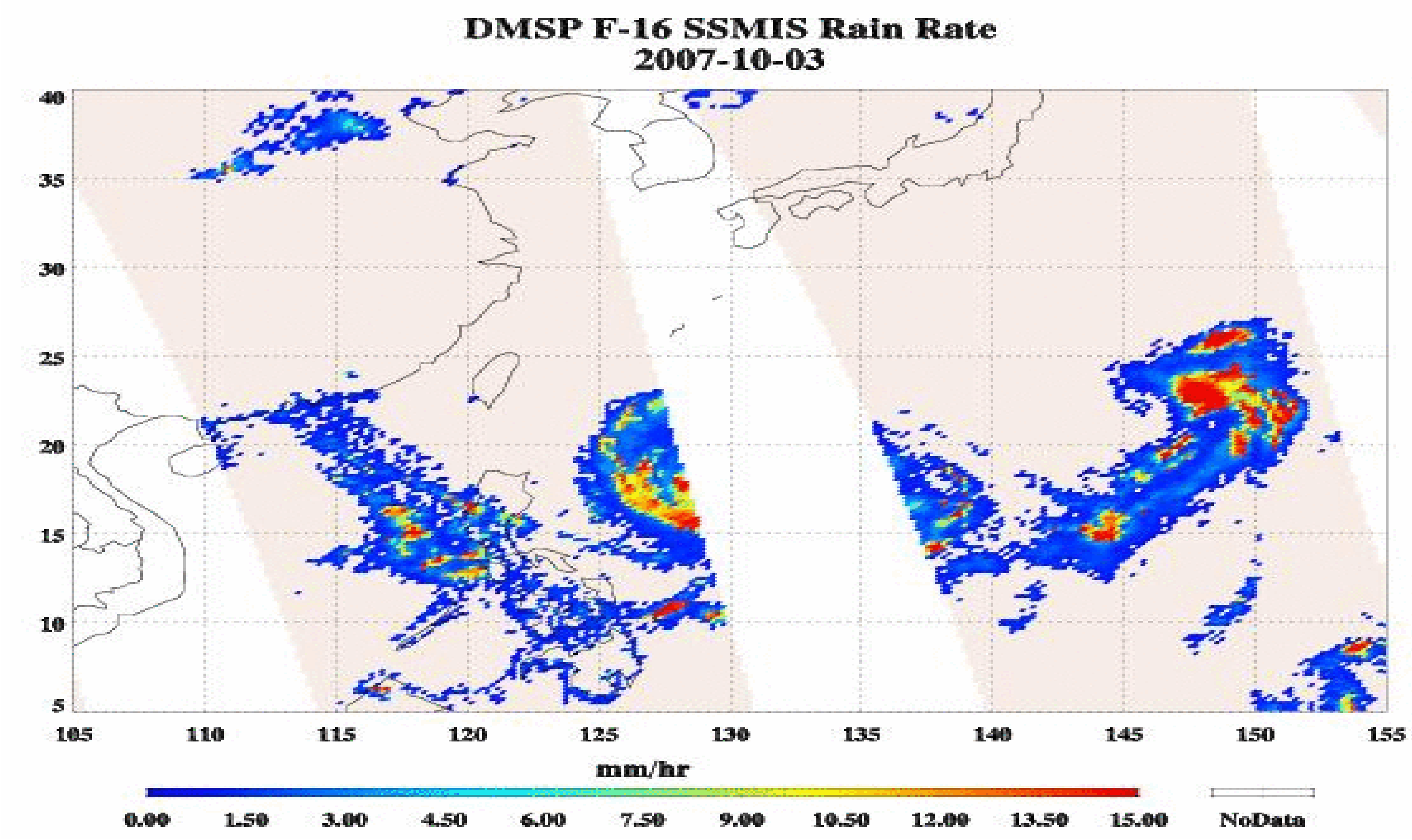
$$RR = 0.321717 + 16.5043 * IWP - 3.3419 * IWP^2$$

Over ocean, Rain Rate is only retrieved when CLW > 0.2 mm and IWP > 0.05 kg/m^2 and De > 0.4 mm.

Over land, rain rate is retrieved when IWP > 0.05 kg/m^2 and De > 0.4 mm and Tb(91.655) – Tb(150) > 3 K

Surface Precipitation (Experimental)

Typhoon Luosha



Summary

- F16 SSMIS calibration algorithms work well for eliminating the radiance anomalies associated with antenna emission and contamination of calibration targets.

- All SSM/I heritage products are generated and appear reasonable.

- SSMIS precipitation algorithm can be significantly improved through uses of high frequency channel at 91 and 150 Ghz which are more sensitive to light rain and falling snow events.

- Several experimental environmental products are being developed at NESDIS through Microwave Integrated Retrieval System (e.g. T, Q, Hydrometeor profiles, etc.)