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Uses of SSM/I/S and Future Microwave Imagers for Land & Terrestrial Science Studies

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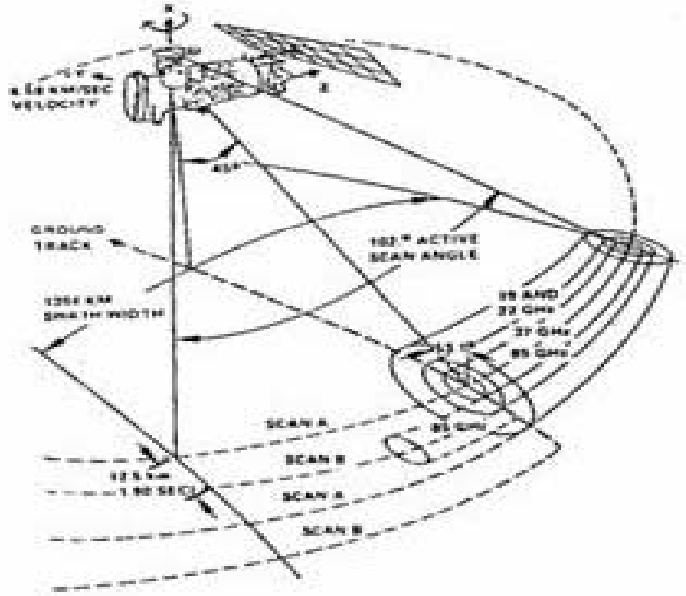
Special Sensor Microwave Imager (SSM/I/S)

- The most robust standing passive microwave time series
  - 20+ years and growing
  - 14+ years dual-satellite
  - 10+ years tri-satellite
  - Sensor stability
  - Full time duty cycle
  - 1400+ km swath width
- Seven channels
- 10+ derived products



Center Frequencies (GHz)	19.35	19.35	22.235	37.0	37.0	85.5	85.5
Polarization	V	H	V	V	H	V	H
Bandwidth (MHz)	250	250	250	1000	1000	1500	1500
Sensitivity (K)	0.6	0.6	0.6	0.6	0.6	1.1	1.1
IFOV (km x km)	69 x 43	69 x 43	60 x 40	37 x 28	37 x 29	15 x 13	15 x 13
Sampling Interval (km x km)	25 x 25	25 x 25	25 x 25	25 x 25	25 x 25	12.5 x 12.5	12.5 x 12.5
Integration Time (msec)	7.95	7.95	7.95	7.95	7.95	3.89	3.89
Main Beam Efficiency (%)	96.1	96.5	95.5	91.4	94.0	93.2	91.1
Beamwidth (half-power, degrees)	1.87	1.87	1.65	1.10	1.10	0.43	0.45

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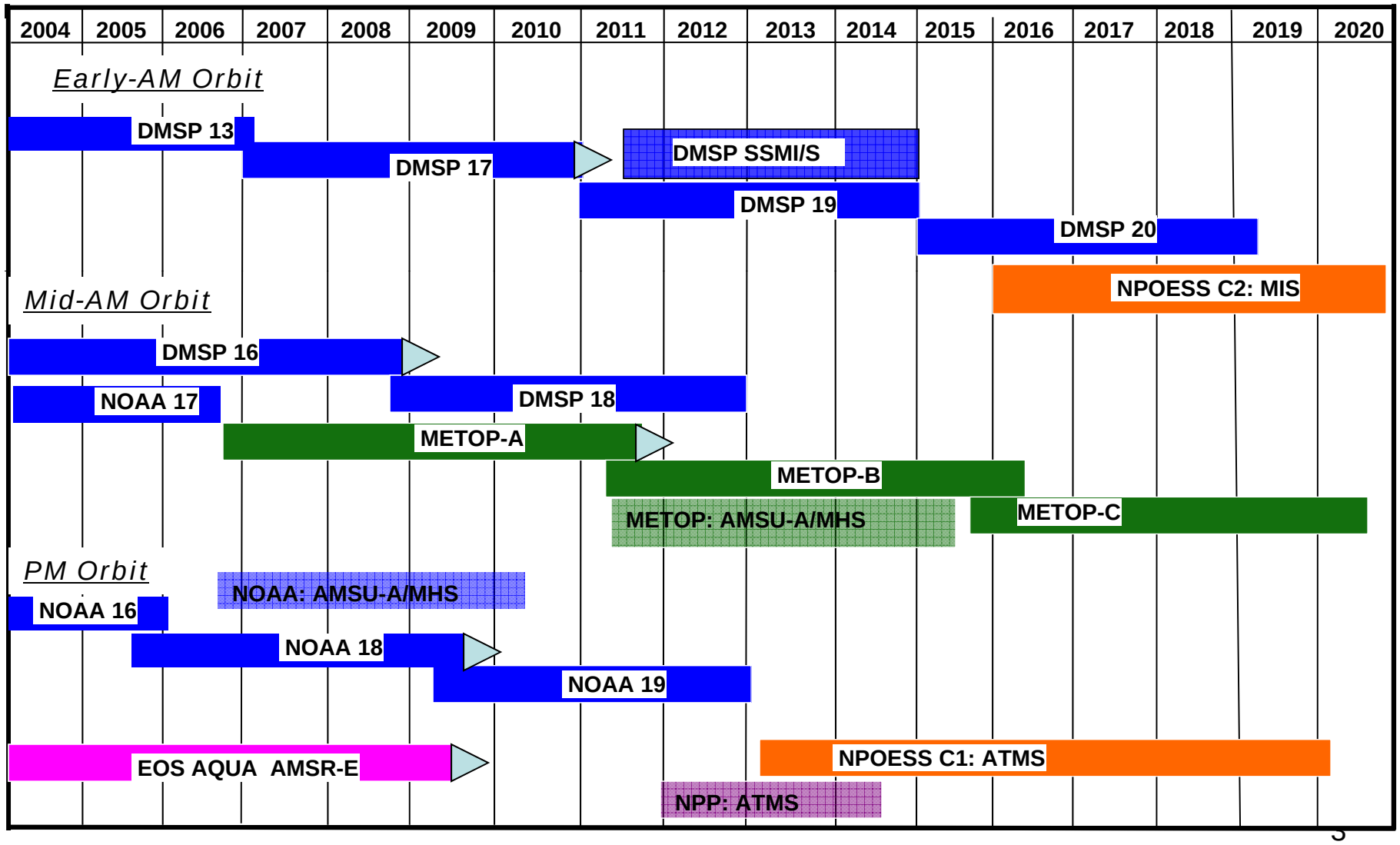
US Polar Missions with MW Sensors for Operational Uses



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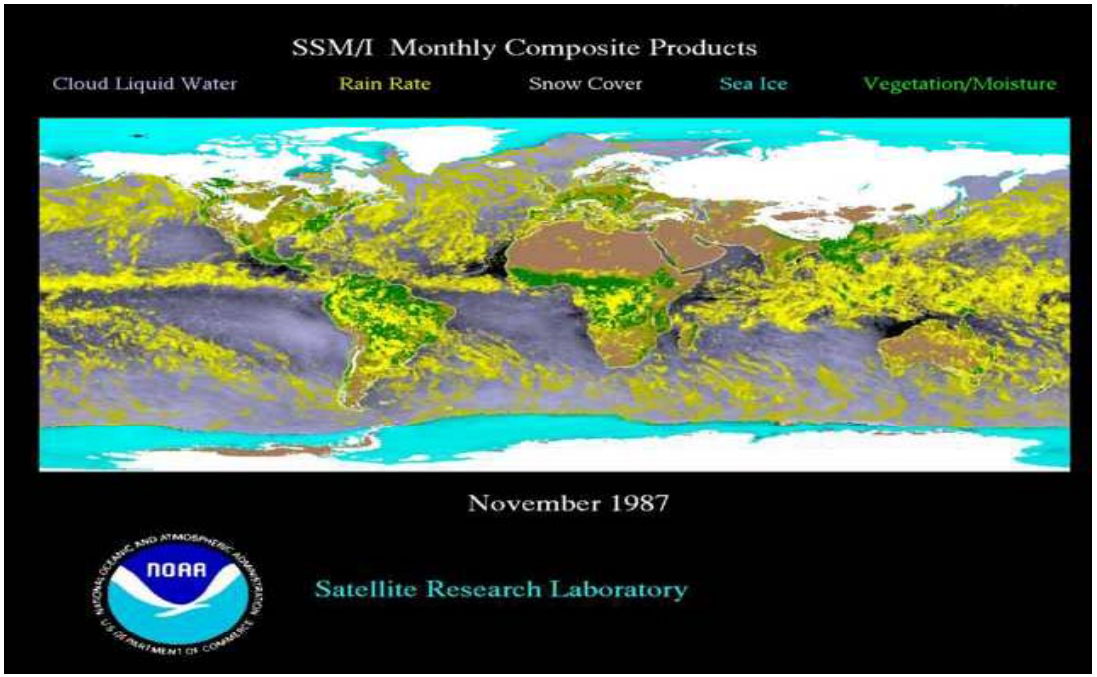
NESDIS SSM/I Environmental Data Records

- Precipitation rate
- Soil wetness
- Land surface emissivity
- Land surface temperature
- Snow cover
- Sea ice concentration
- Total precipitable water
- Cloud liquid water
- Ocean wind speed



A composite SSM/I EDR imager from SSM/ on board F8 satellite. This was a very first suite of operational SSM/I products distributed to the community

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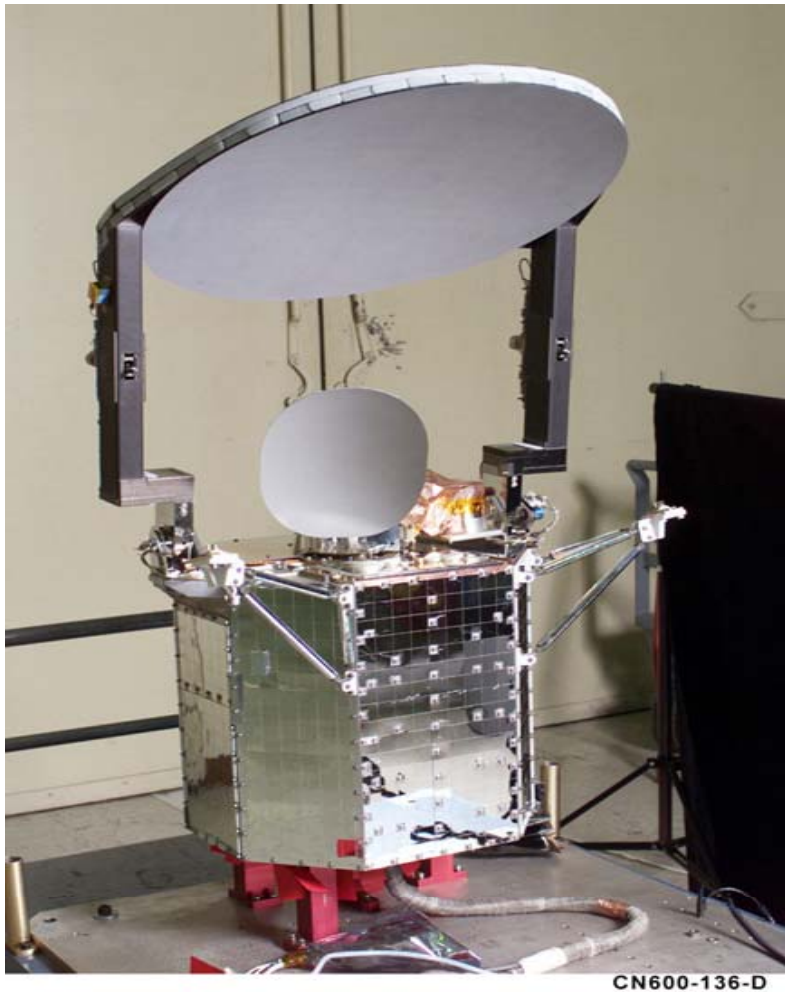
Microwave Antenna Subsystem and Calibration Subsystem

- Main-reflector conically scans the earth scene
- Sub-reflector views cold space to provide one of two-point calibration measurements
- Warm loads are directly viewed by feedhorn to provide other measurements in two-point calibration system
- It is not an end to end calibration system



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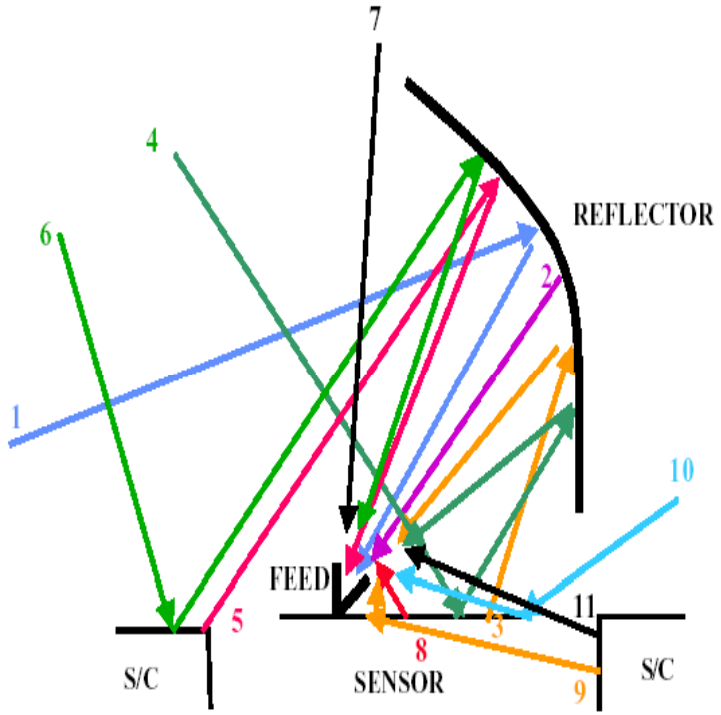
Microwave Instrument Calibration Components

1. Earth scene Component
2. Reflector emission
3. Sensor emission viewed through reflector,
4. Sensor reflection viewed through reflector,
5. Spacecraft emission viewed through reflector,
6. Spacecraft reflection viewed through reflector,
7. Spillover directly from space,
8. Spillover emission from sensor,
9. Spillover reflected off sensor from spacecraft,
10. Spillover reflected off sensor from space,
11. Spillover emission from spacecraft



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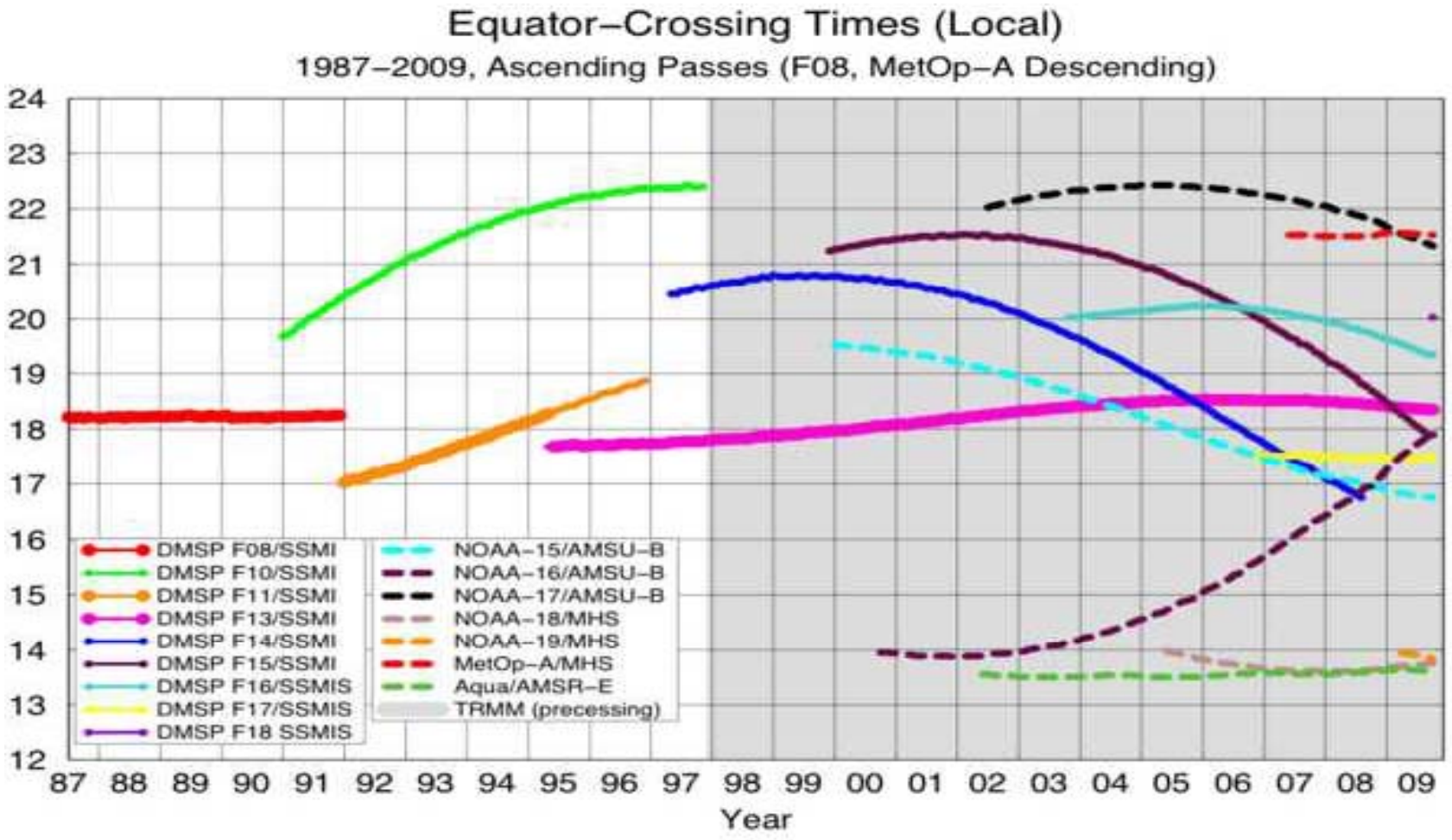
DMSP Radiometer Record (SSM/I and SSMIS)



Thickest lines denote GPCP calibrator.

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

A Fundamental Climate Data Record of SSM/I/S and Future Microwave Imagers
SDS Project funded by NCDC

Christian Kummerow and Wesley Berg, CSU
Fuzhong Weng and Song Yang, NOAA/NESDIS

Proposed Tasks:

- Develop and produce a Level 1A dataset in NetCDF (i.e. L1BASE).
- Reconstruct the most complete possible time series of SSM/I TDR data.
- Revisit quality control procedures.
- Characterize anomalous emission/reflection.
- Characterize RFI and develop correction algorithms (e.g. RADCAL)
- Characterize warm load instability, solar/stray light contamination, and compute solar angles for analysis of spacecraft heating on calibration.
- Characterize sensor specific antenna pattern function for TA to TB conversion.
- Characterize errors in pixel geolocation, and thus Earth incidence angle.
- Characterize and correct for intersensor biases using multiple approaches.
- Produce an FCDR of Tbs from SSM/I and SSMIS along with processing code.
- Full documentation of the procedures for going from Level 1A to the FCDR dataset.

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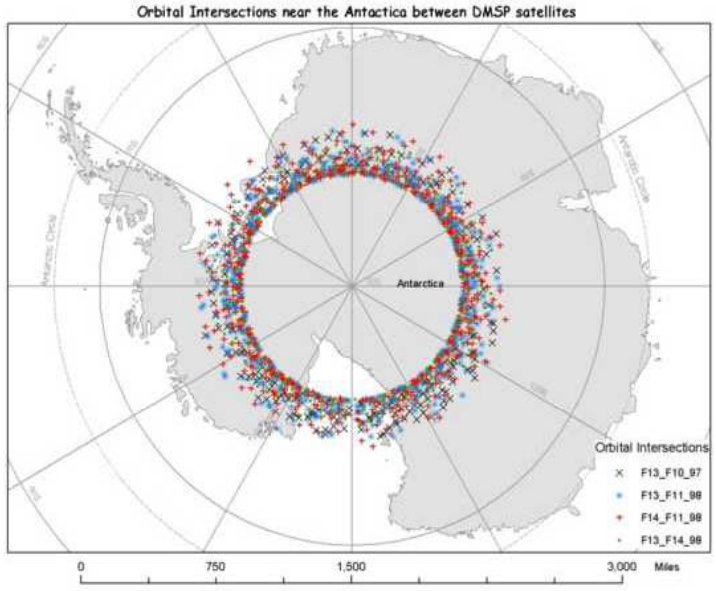
GSICS Microwave Imager Baseline Calibration

- NOAA: Developed unique technique for matching SSM/I obs from two DMSP satellites
  - Simultaneous conical over-passing
  - Characterize biases according to surface type
- CM-SAF
  - Statistical intercalibration (histogram equalisation)
  - Intercomparison
- Work with CSU (Kummerow) and RSS (Wentz)
  - Independent calibration approach
  - Intercomparison
- Work with NASA GPM Cross-Calibration team
  - TMI and SSM/I
  - Windsat and SSM/I



Simultaneous observations from DMSP F10 and F11 satellites over Antarctic continent

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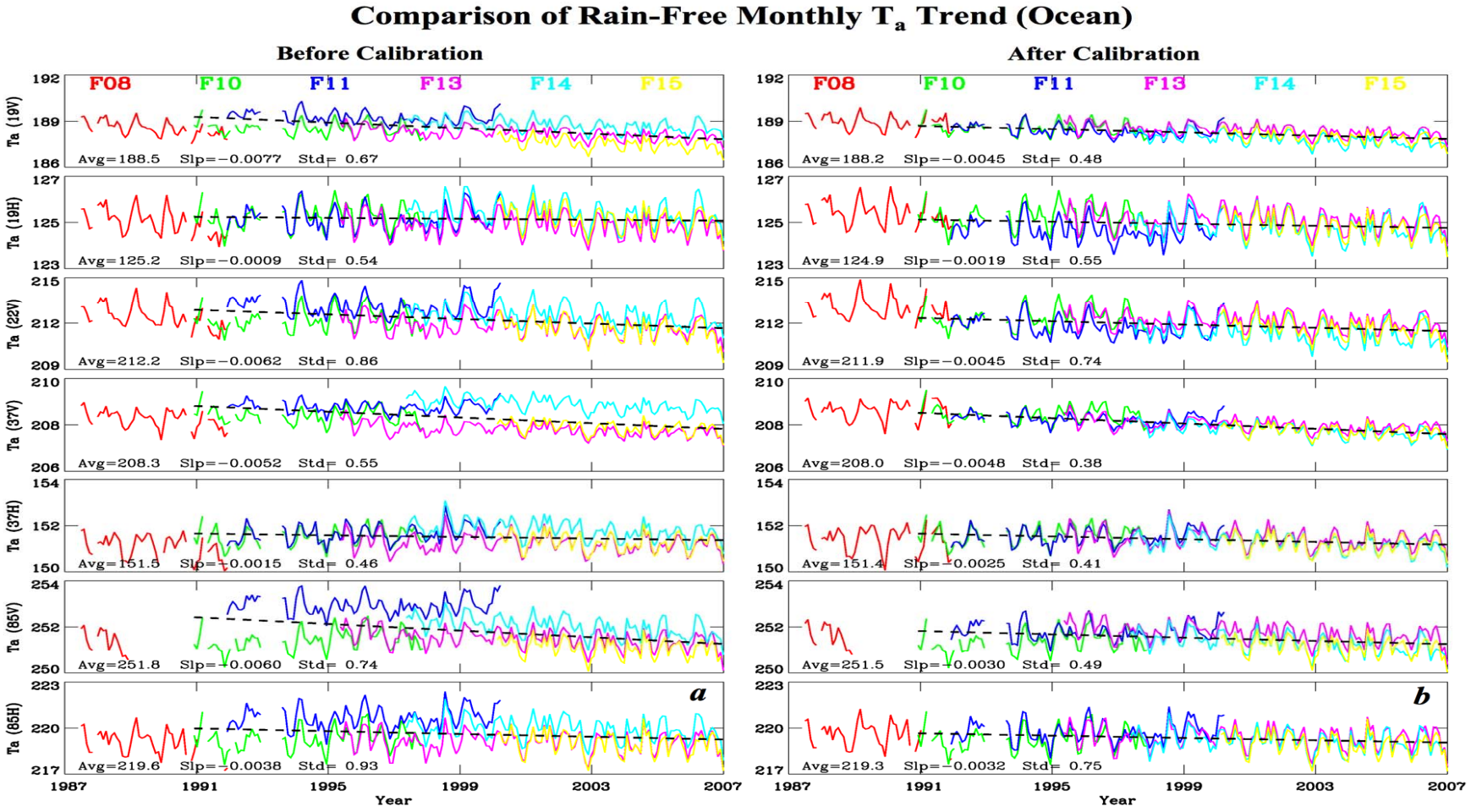
NOAA preliminary Results: SSM/I TDR Trends



Comparison of SSM/I Monthly Oceanic Rain-free TDR Trend using F13 satellite as a reference. The trend at TDR level from all satellites are more consistent after calibration

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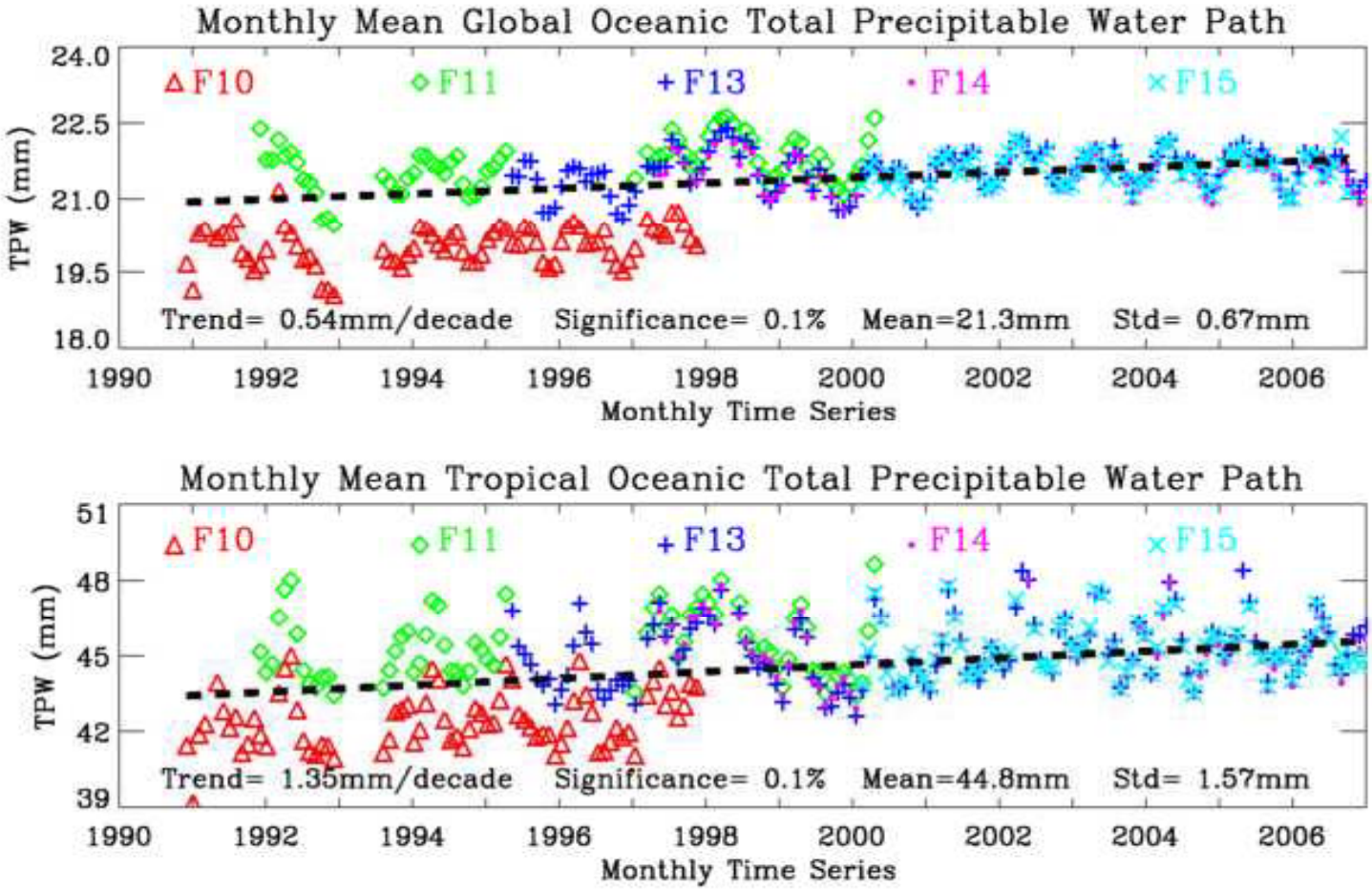
SSM/I Total Precipitable Water Trend Before Cross-Calibration



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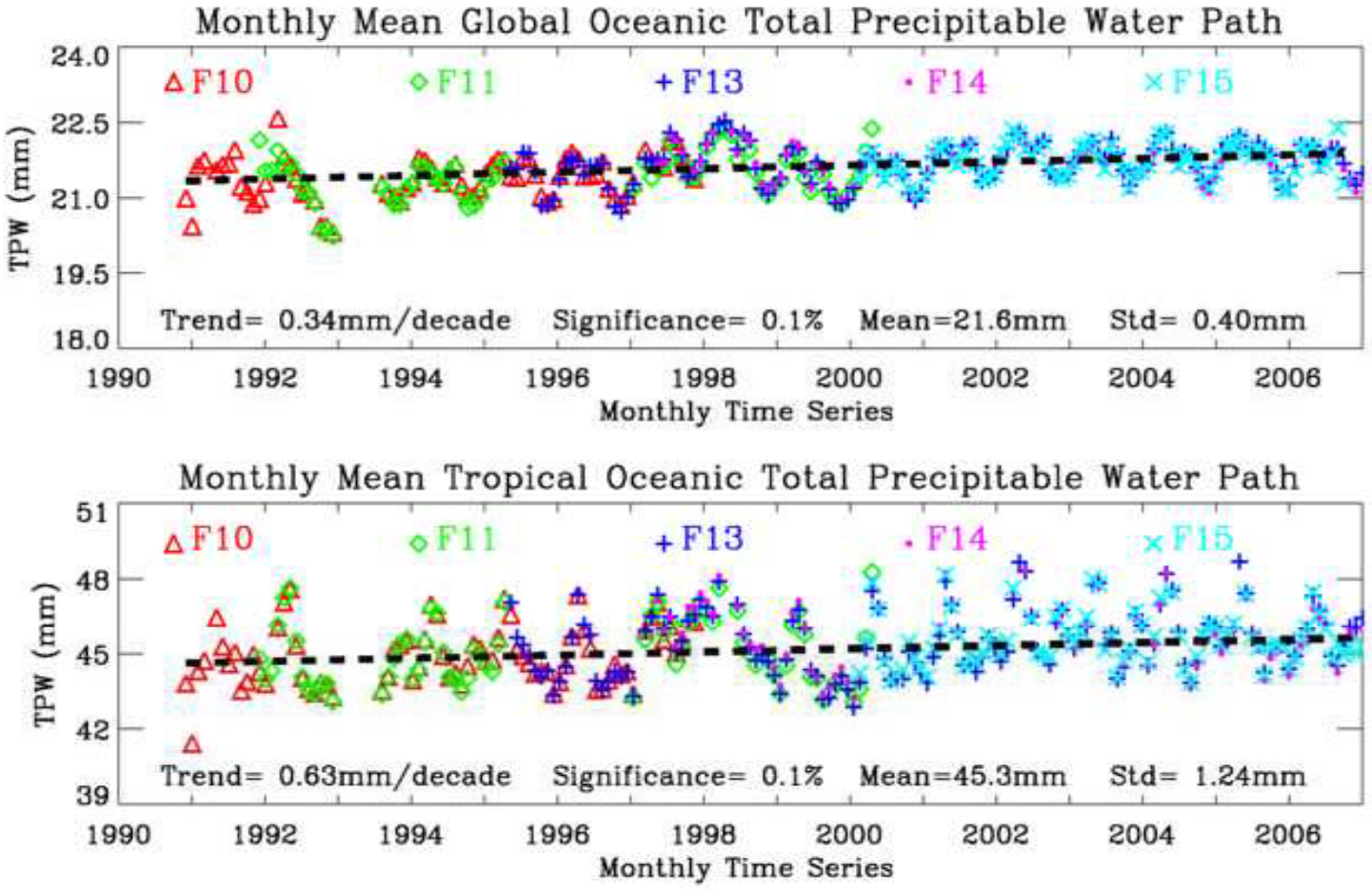
SSM/I Total Precipitable Water Trend After Cross-Calibration



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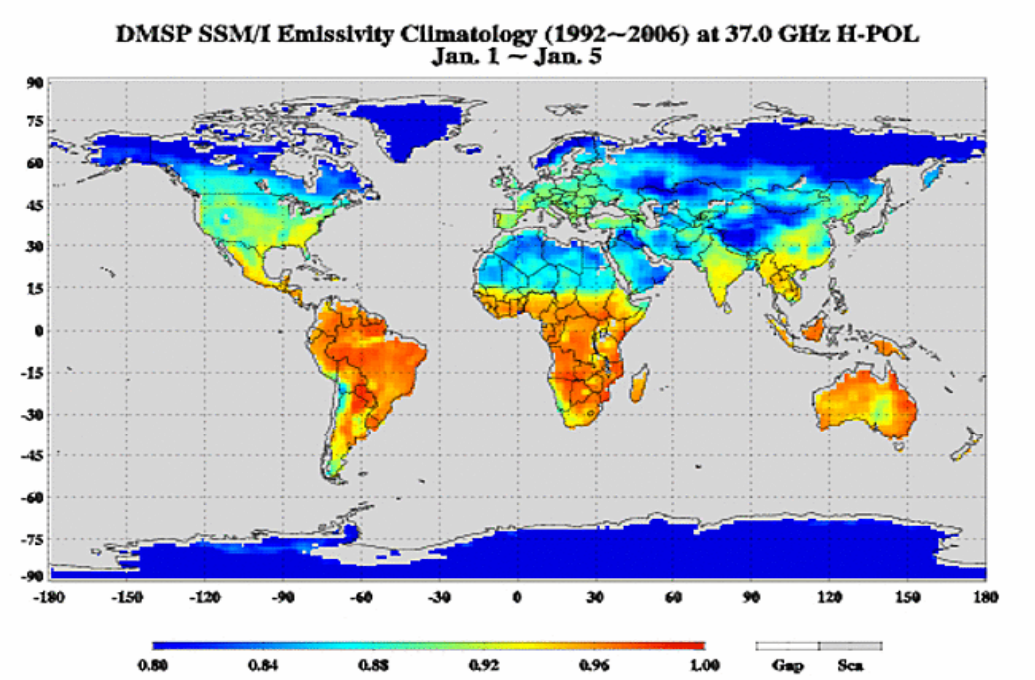
SSM/I Data Set: Global Land Emissivity Fifteen Year Pentad Time Series

- Large season change at higher frequencies
- Large polarization difference for several surfaces (e.g. desert, snow, flooding)
- Emissivity of desert decreases with frequency



SSM/I surface emissivity climatological data set is developed at various time scales (e.g. pentad, weekly and monthly, anomaly). SSM/I sensors from F10 to 15 satellites are intercalibrated to a reference satellite (F13)

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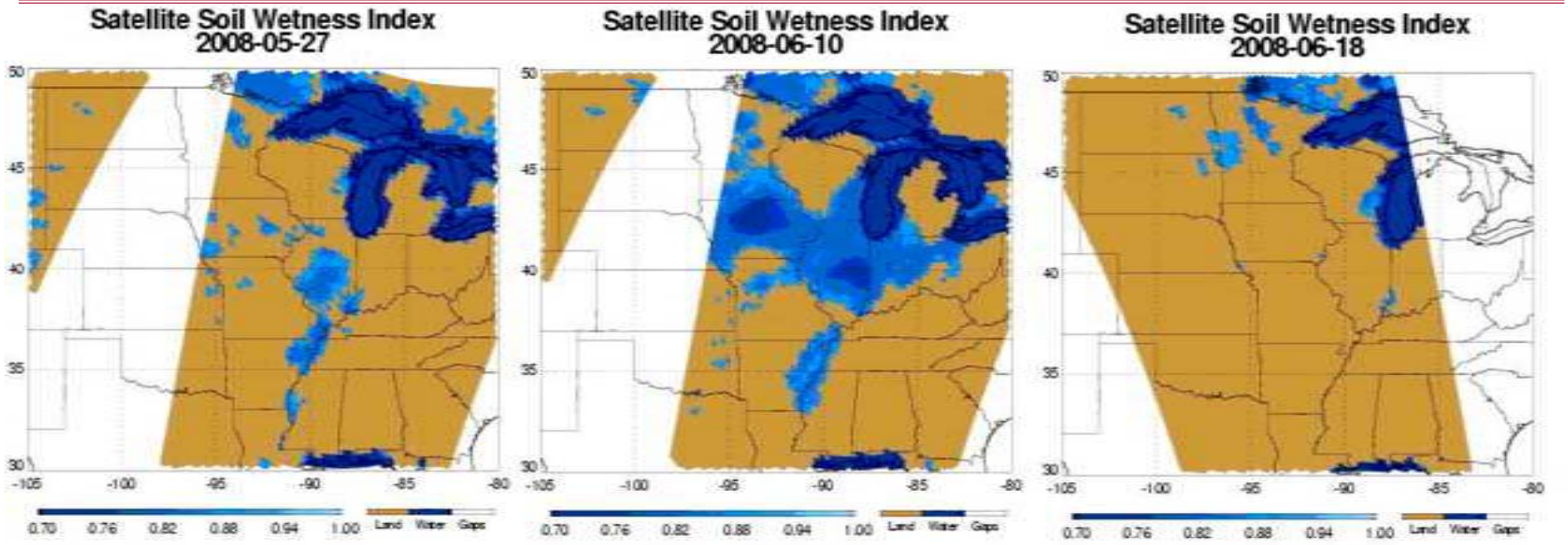
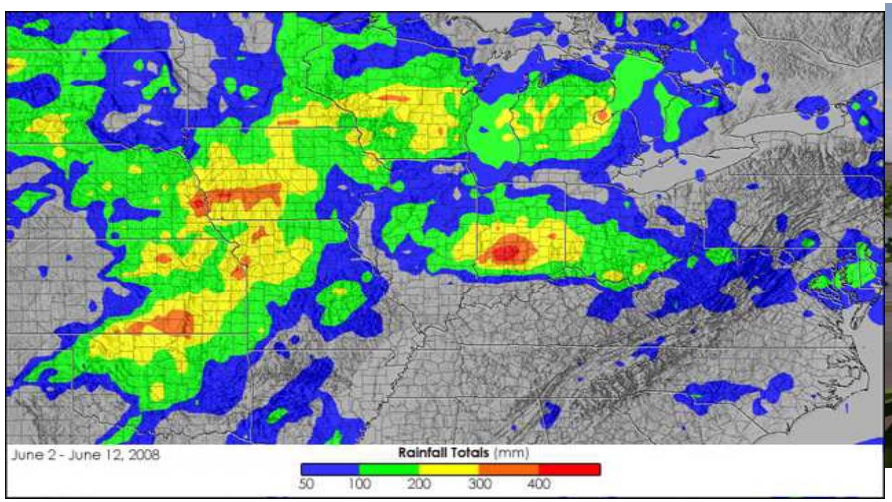
Direct Applications of SSM/I Emissivity Data Base for Monitoring the 2008 IOWA Flood





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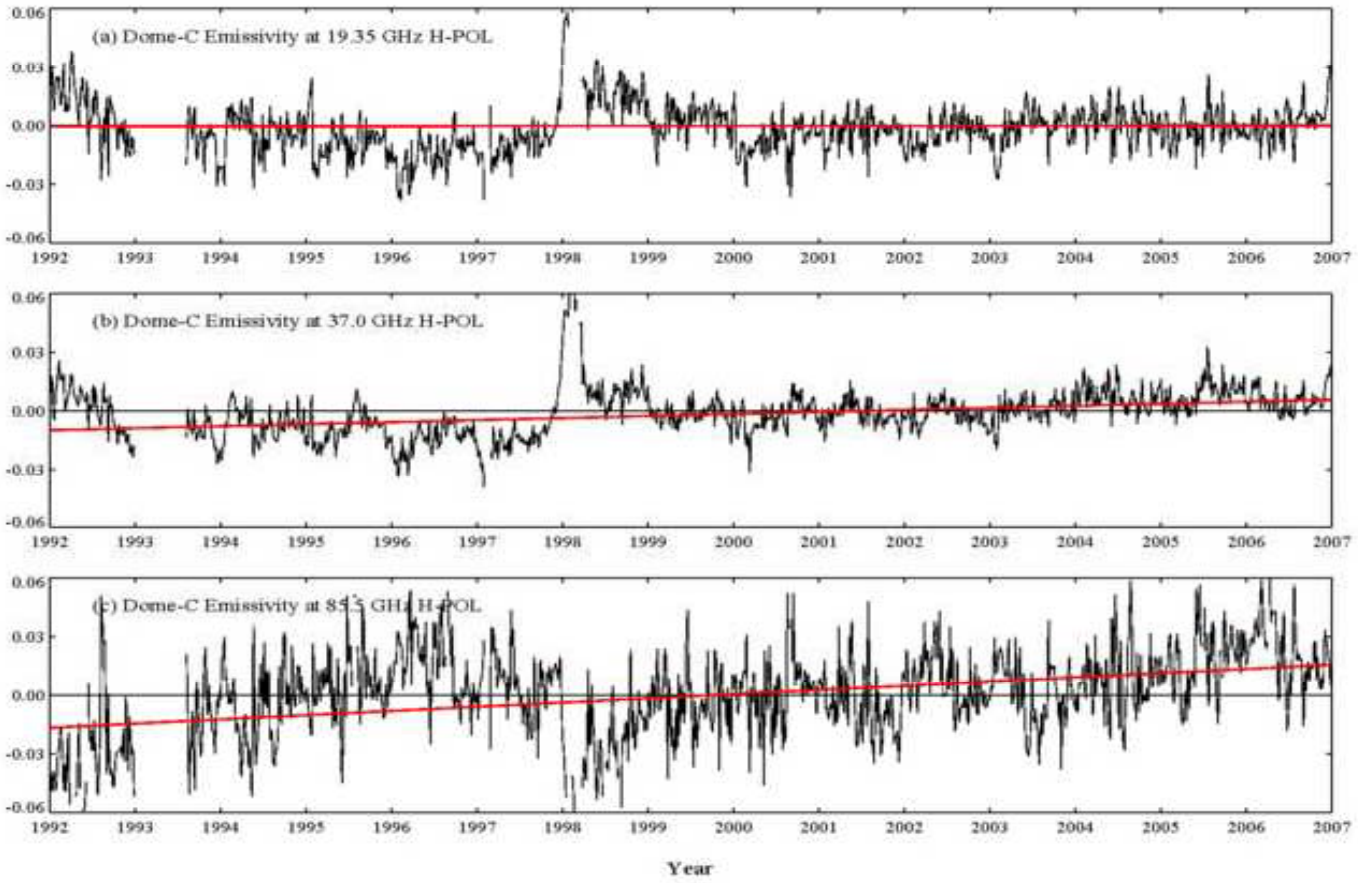
Monitoring the Calibration Site Stability from SSM/I Emissivity Trend (DOME-C, Antarctic)



DOME-C (75° 06‘ S 123° 23‘ E) emissivity (19.35H/37.0H/85.5H) presents increasing trends during the processing period of time (1992-2006).

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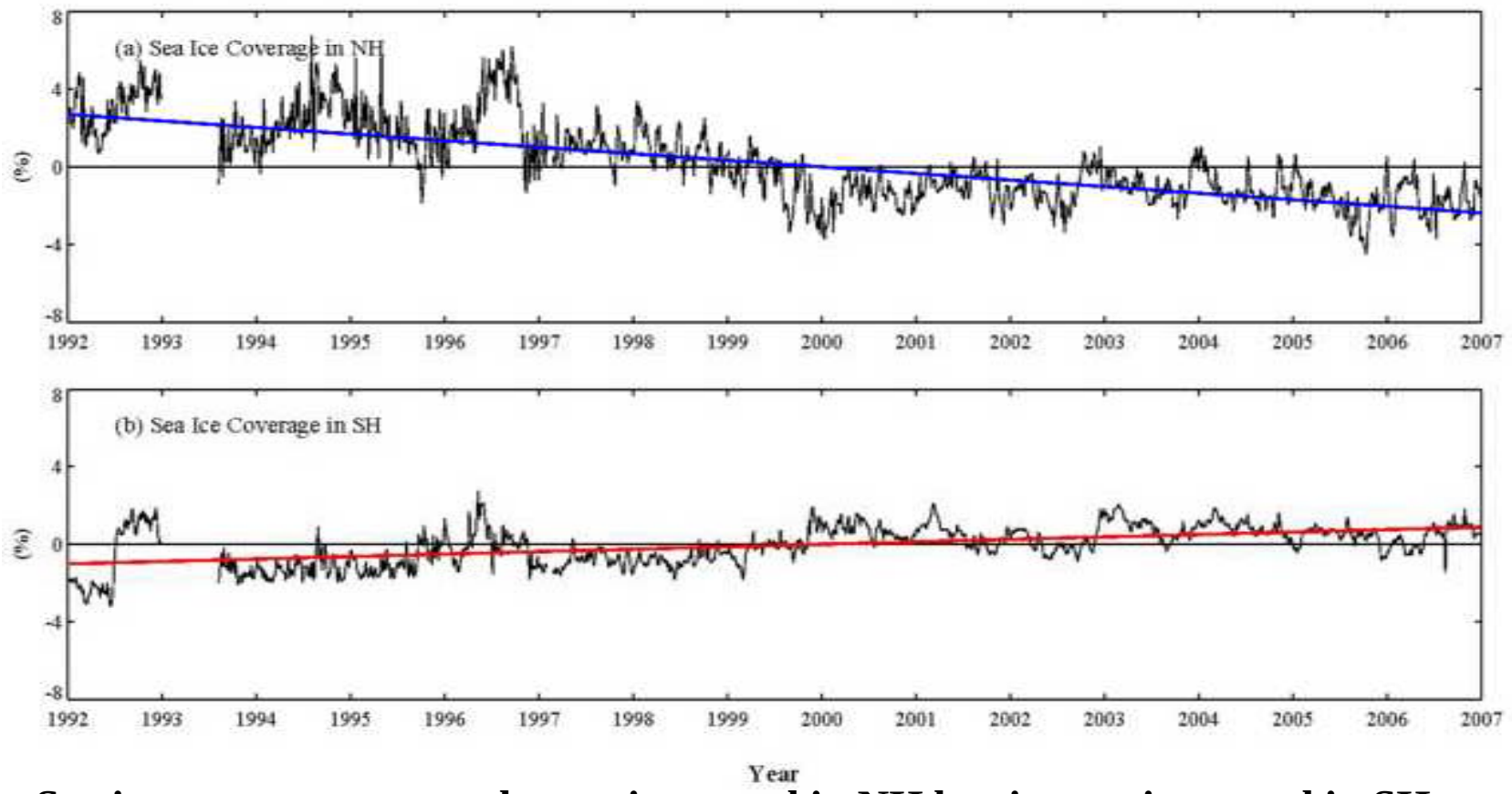
SSM/I Derived Sea Ice Concentration Trend



Sea ice cover presents a decreasing trend in NH but increasing trend in SH during the processing period of time (1992-2006).

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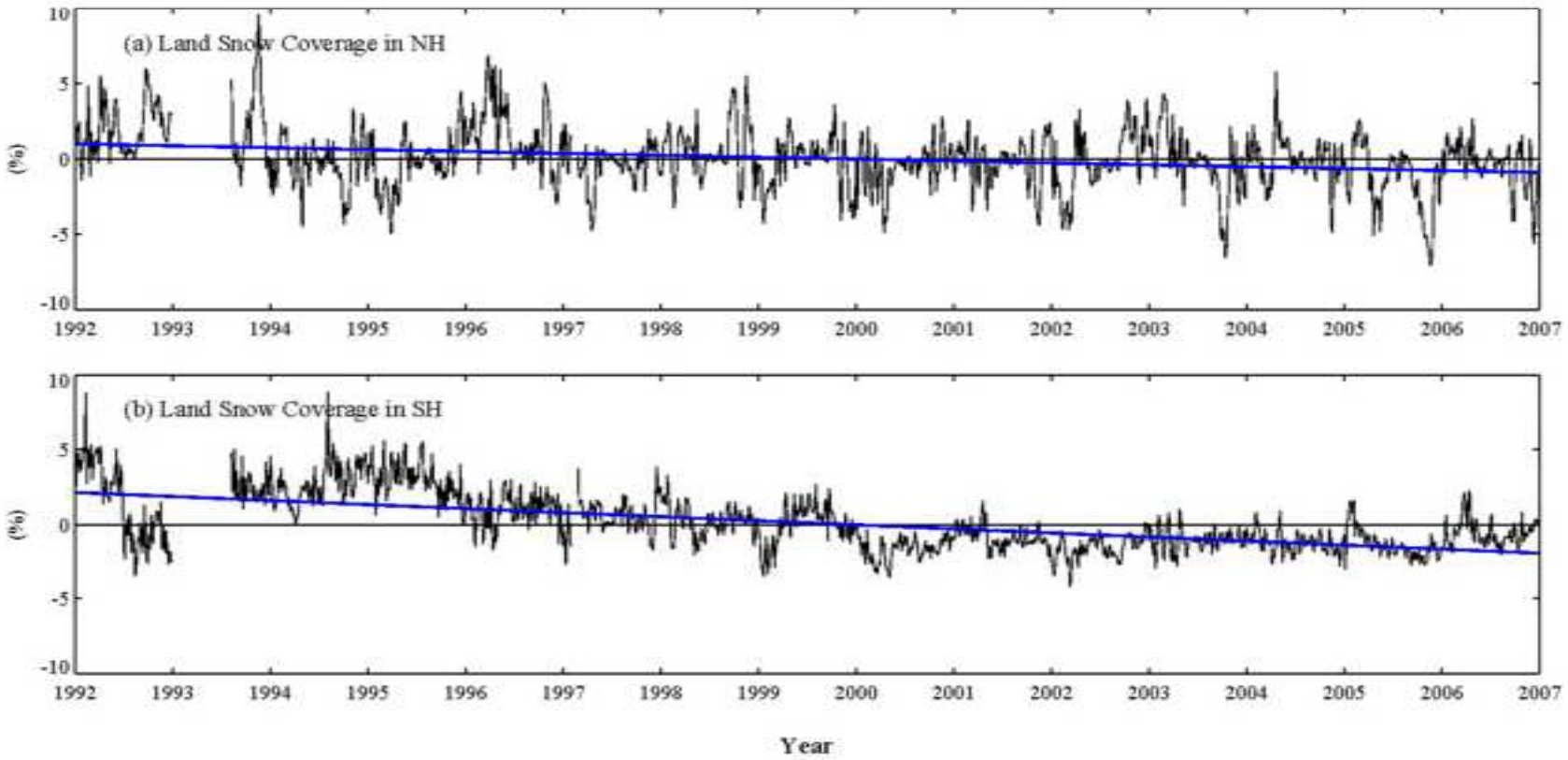
SSM/I Derived Snow Cover Trend



Snow cover presents decreasing trends in both NH and SH during the processing period of time (1992-2006)

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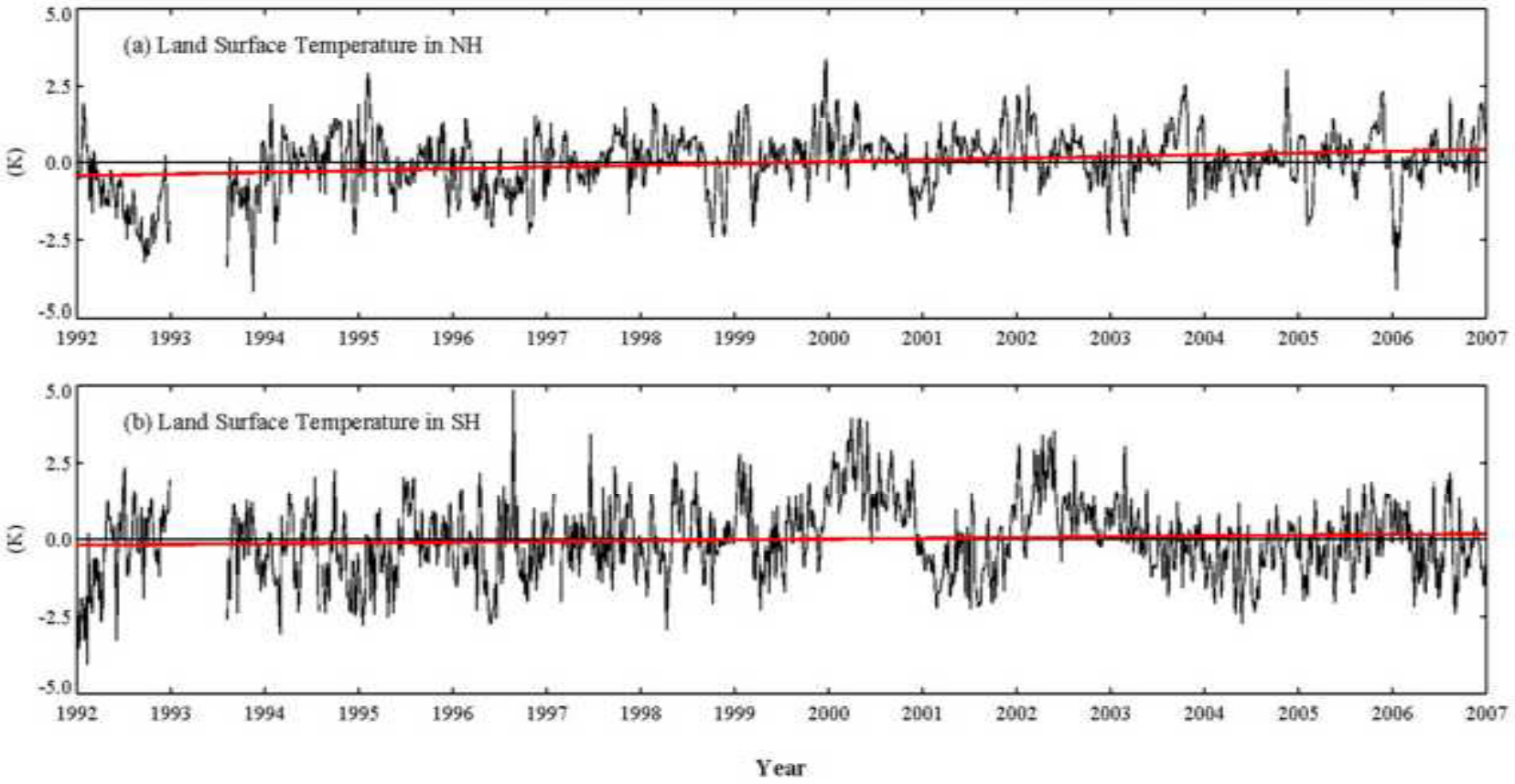
SSM/I Derived Land Surface Temperature



Land surface temperature presents increasing trends in both NH and SH during the processing period of time (1992-2006).

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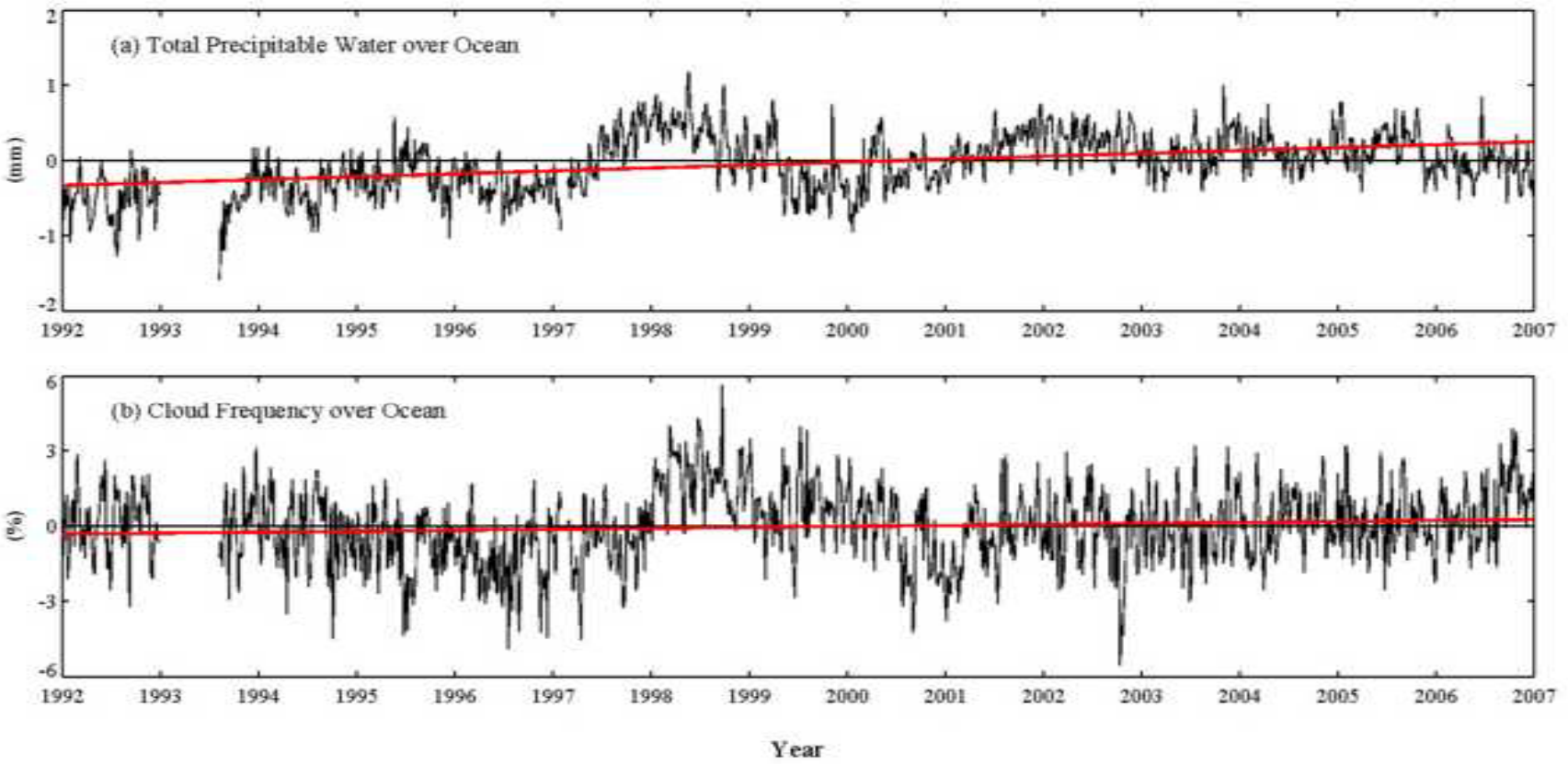
SSM/I Derived Total Precipitable Water Trend



Oceanic integrated water vapor content (TPW) and cloud coverage (between 60N and 50S) presents increasing trends in both NH and SH during the processing period of time (1992-2006). The 97/98 strong El Nino event is clearly shown in the time series.

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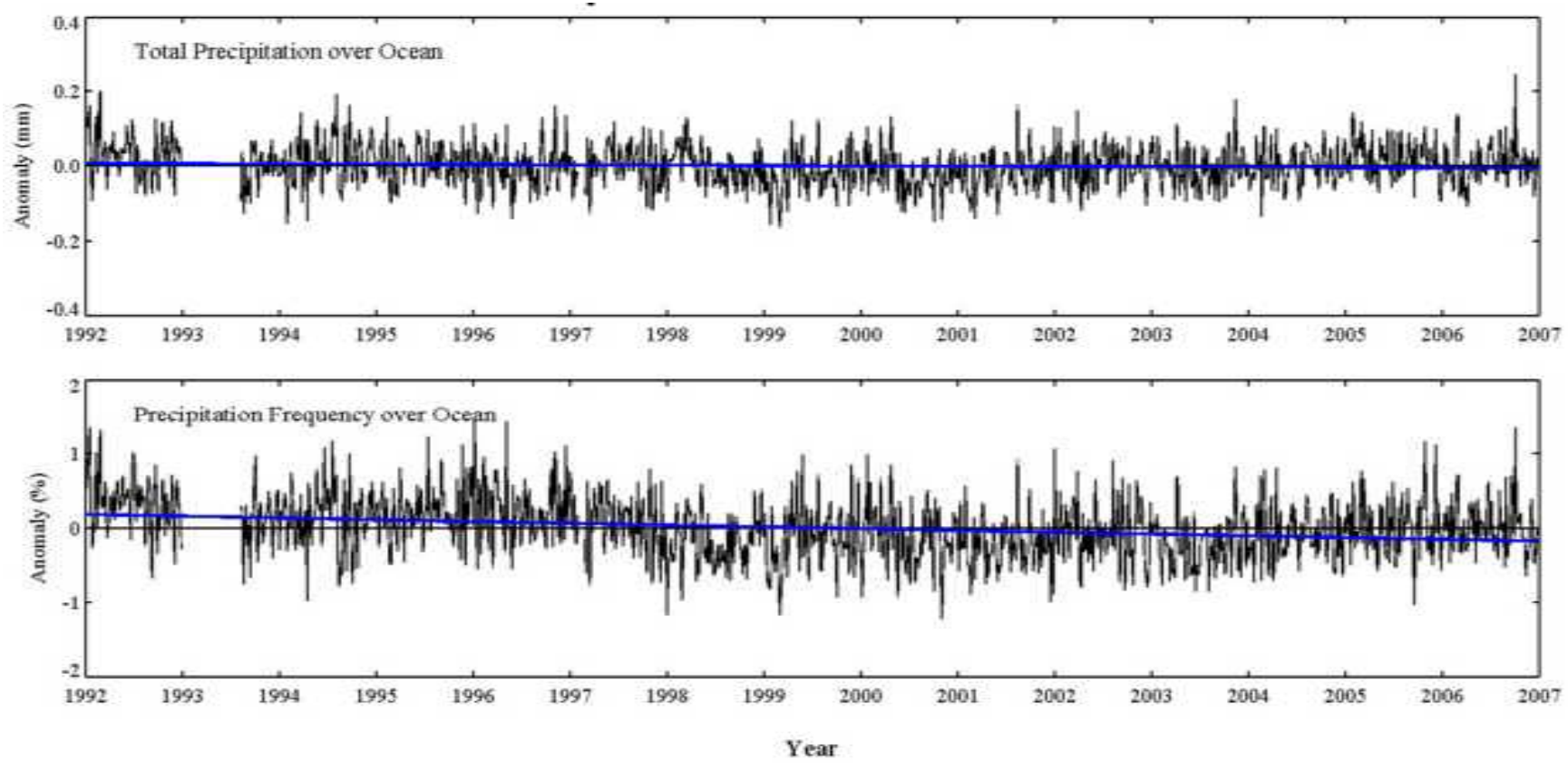
SSM/I Derived Precipitation Trend



Oceanic total precipitation and rainfall percentage (between 60N and 50S) presents decreasing trends during the processing period of time (1992-2006).

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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.

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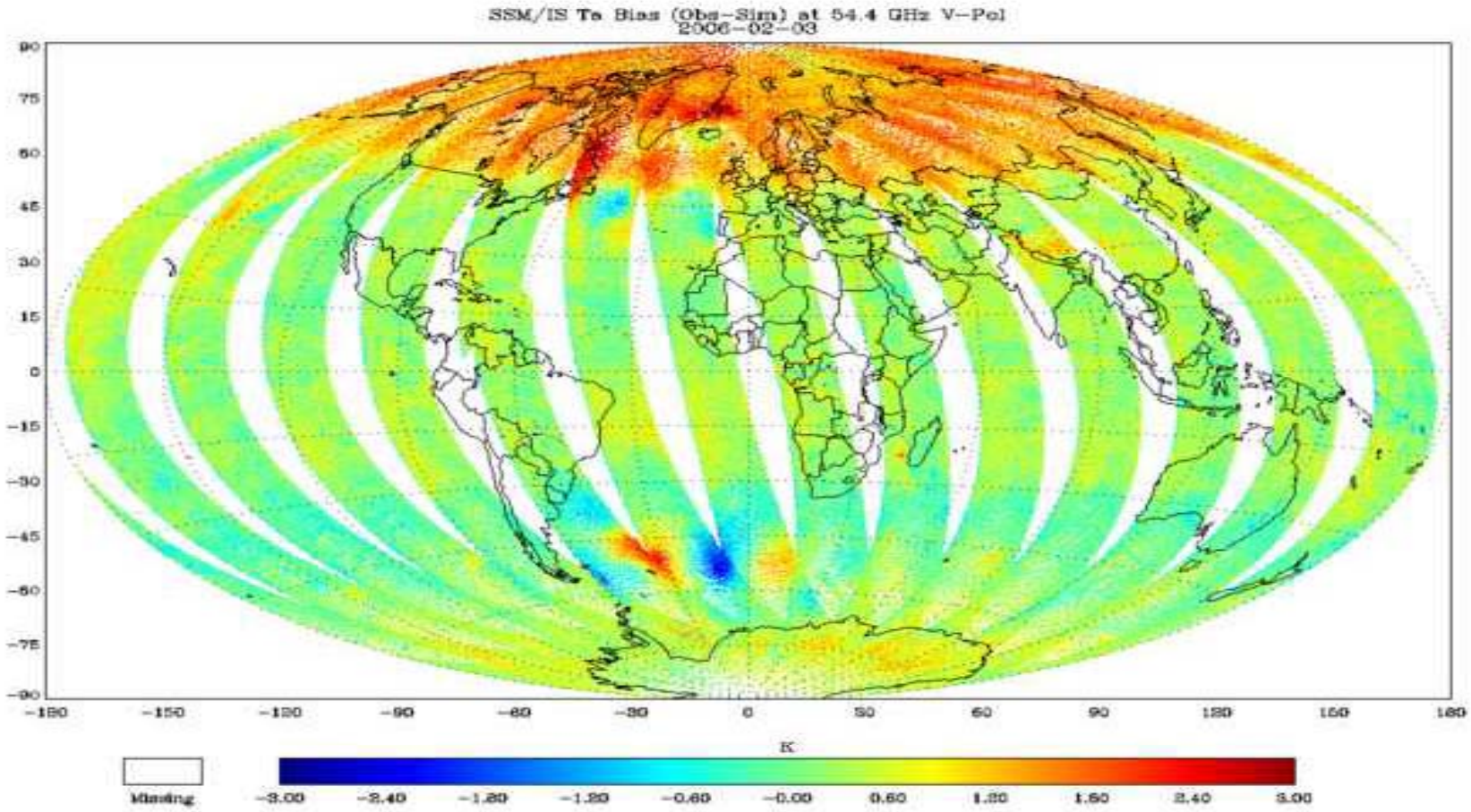
SSMIS Anomaly Distribution



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SSMIS Calibration – Community Efforts

- NRL/UK MetOffice SSMIS Unified Pre-processor (3 versions released)
  - Correct antenna emission for LAS
  - Removal of warm load anomaly
  - Linear mapping of SSMIS imager to its predecessor (SSM/I)
  - Doppler shift correction for UAS
  - Spatial averaging to reduce to the sub-Kelvin levels
- NOAA/NESDIS SSMIS Calibration Algorithm
  - Correct antenna emission for LAS
  - Removal of warm load anomaly
  - UAS bias removal using SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) measurements simulated as truth
  - Spatial filter for noise reduction
  - Linear mapping of SSMIS imager to its predecessor (SSM/I)
  - Inter-sensor calibration for SSMIS imager non-linearity (for climate reprocessing)

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SSMIS Precipitation Products from MIRS (Principal Investigator: Sid Boukabara)

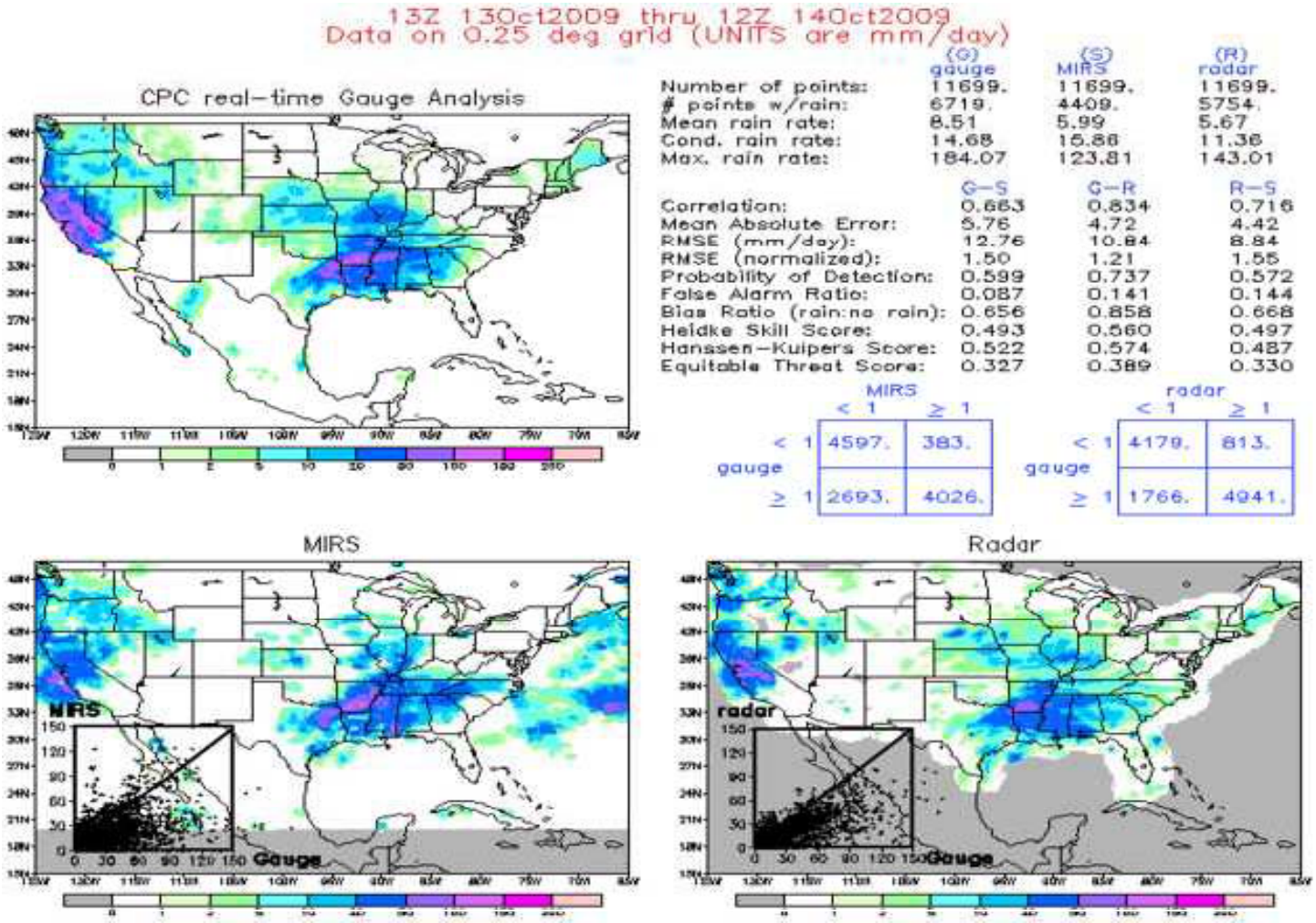

Image taken from IPWG web site: credit to John Janowiak

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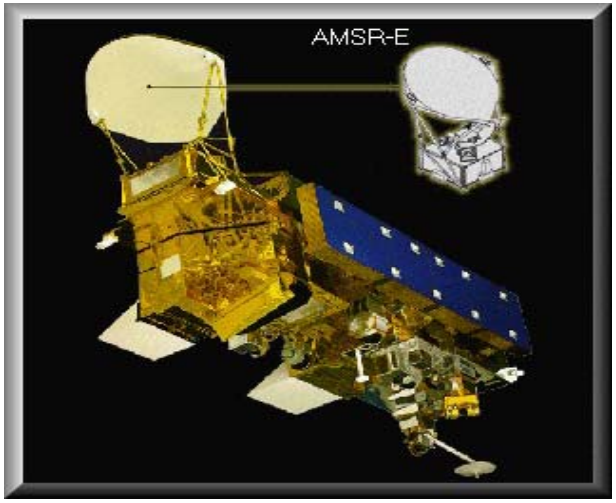
Aqua AMSR-E Land Products

- Ocean products: RWP, LWP, SST,SSW,CIWP,TPW, Rain rate, Sea ice concentration
- Land products: LST, Soil moisture,Rain rate,Snow cover, Snow/Ice Types, Snow equivalent water



Parameters	SMMR (Nimbus-7)	SSM/I (DMSP-F08,F10,F11,F13,F15)	AMSR (Aqua, ADEOS-II)
Time Period	1978 to 1987	1987 to Present	Beginning 2001
Frequency (GHz)	6.6, 10.7, 18, 21, 37	19.3, 22.3, 36.5, 85.5	6.9, 10.7, 18.7, 23.8, 36.5, 89.0
Sample Footprint Sizes (km)	148 x 95 (6.6 GHz) 27 x 18 (37 GHz)	37 x 28 (37 GHz) 15 x 13 (85.5 GHz)	74 x 43 (6.9 GHz) 14 x 8 (36.5 GHz) 6 x 4 (89.0 GHz)

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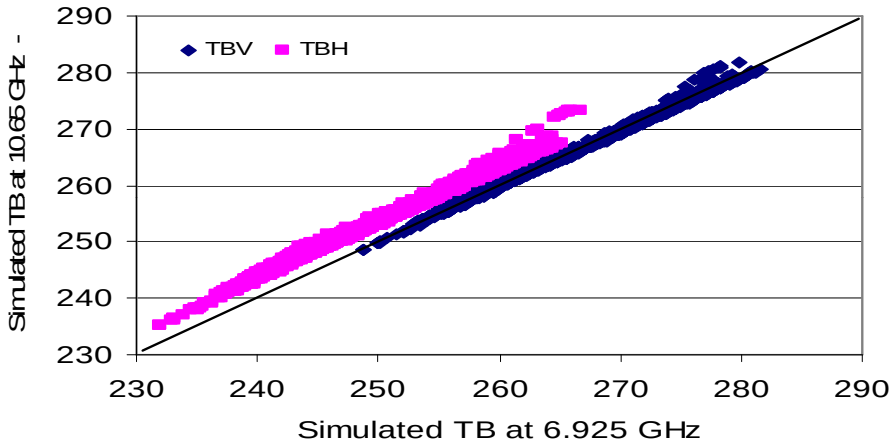
AMSR-E Radio Frequency Interference

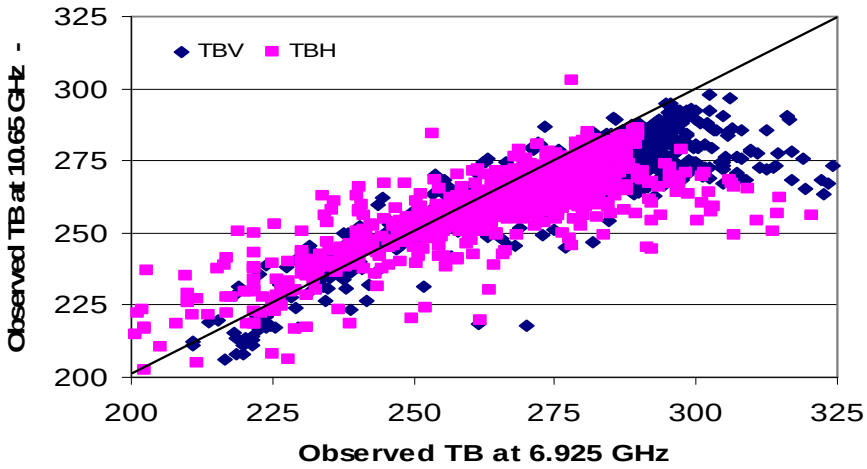
Issues:

- AMSR-E 6 GHz was contaminated by the ground-based transmitters
- Soil moisture products are also noisy and unusable for land and terrestrial research



Solutions

- Uses of forward models with land emissivity model to simulate TB at 6 GHz
- Differences between simulated and measured Tb can indicate the RFI intensity



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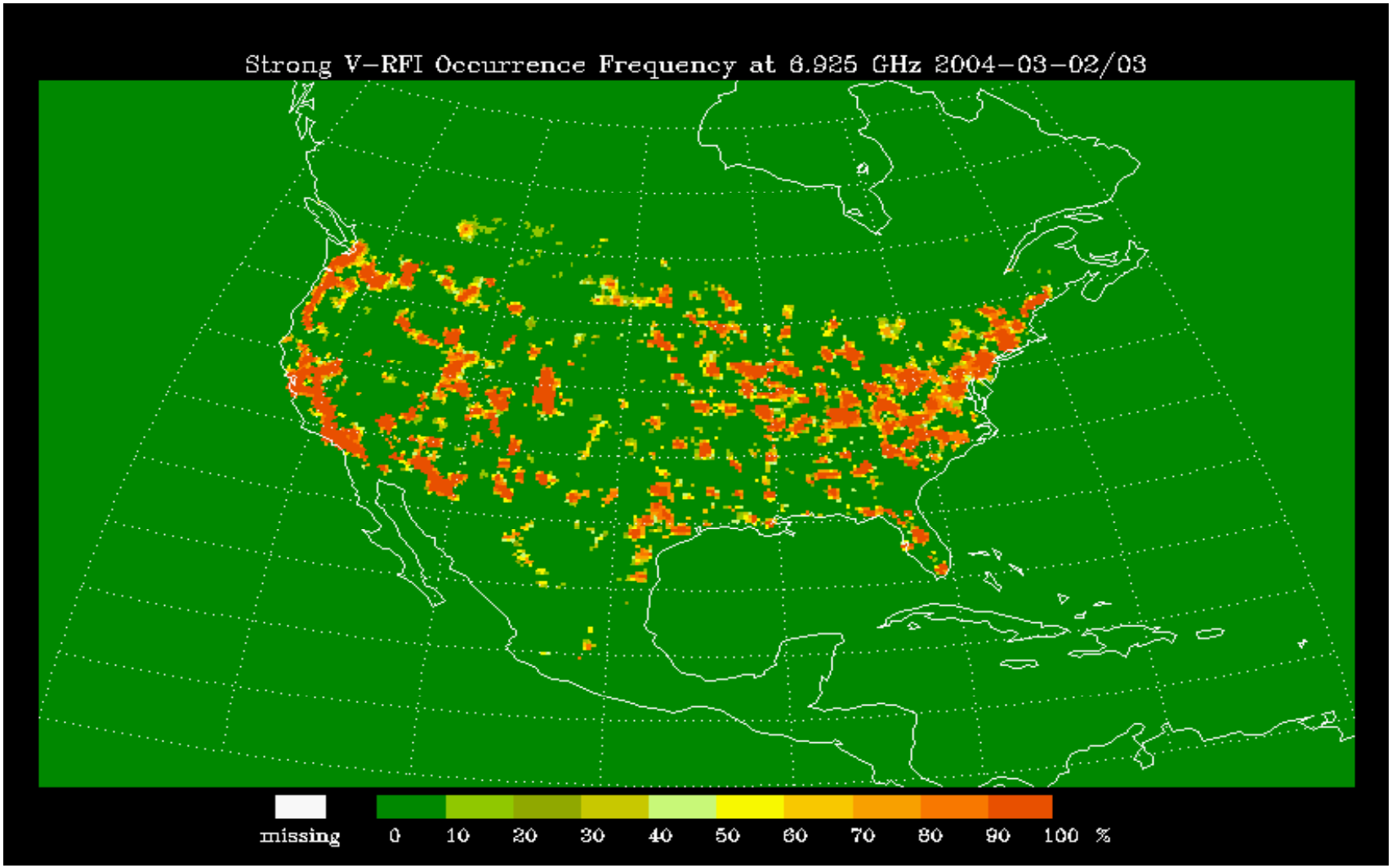
AMSR-E 6.9 GHz RFI Detection



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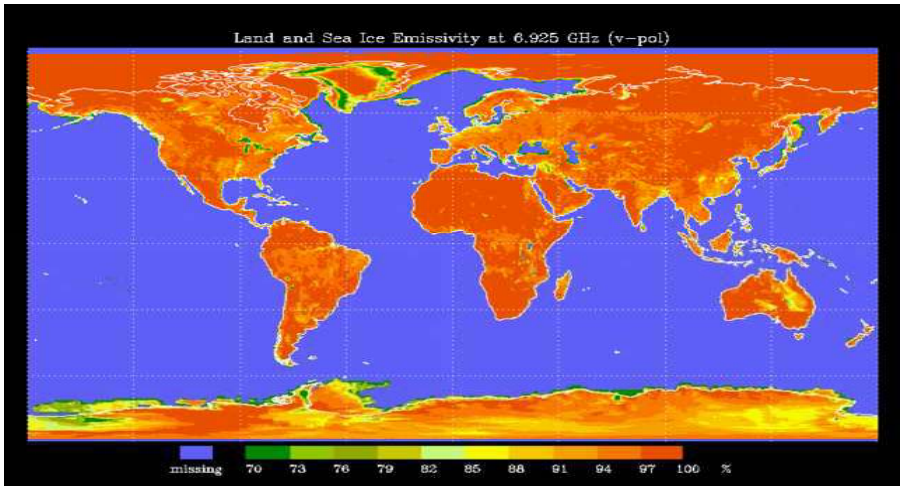
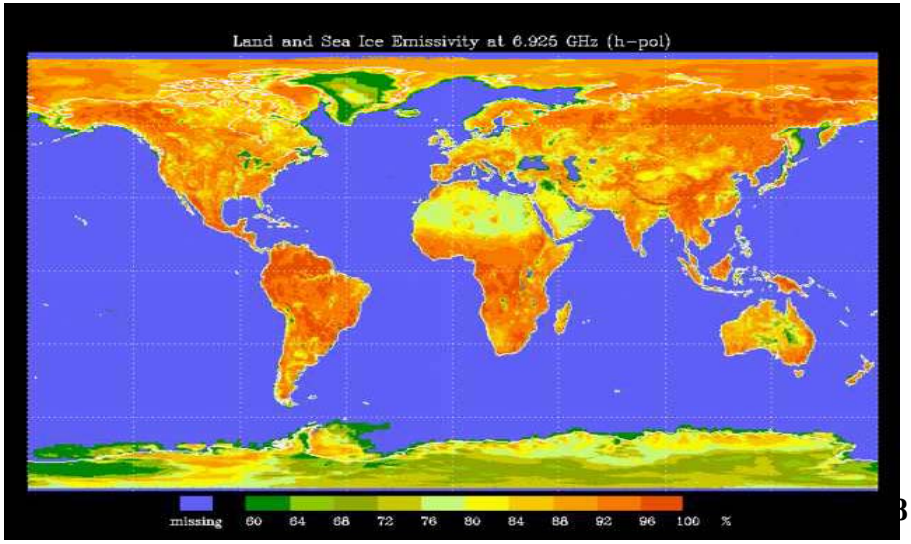
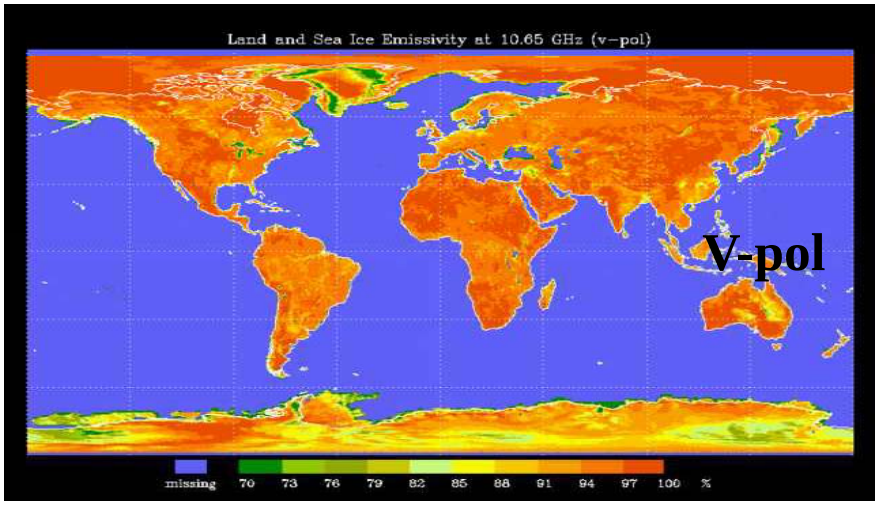
AMSR-E Surface Emissivity

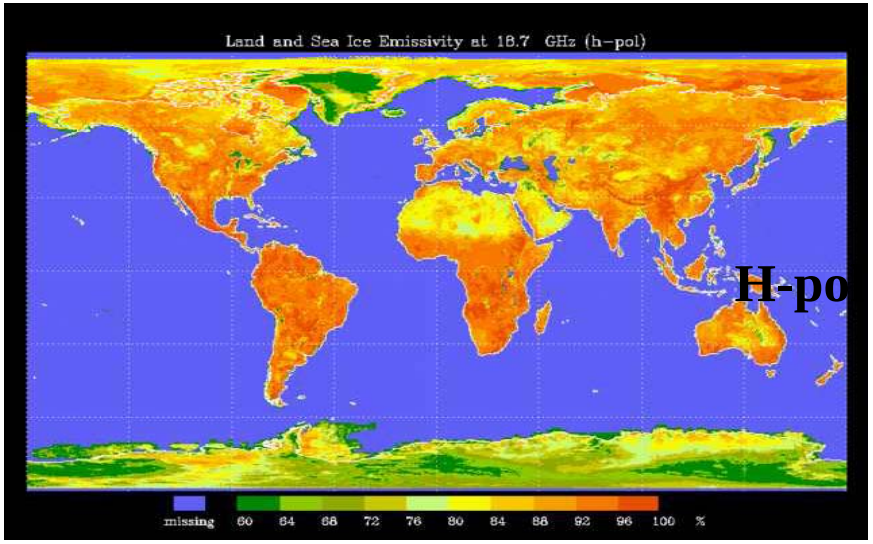
6.9 GHz





10.7 GHz





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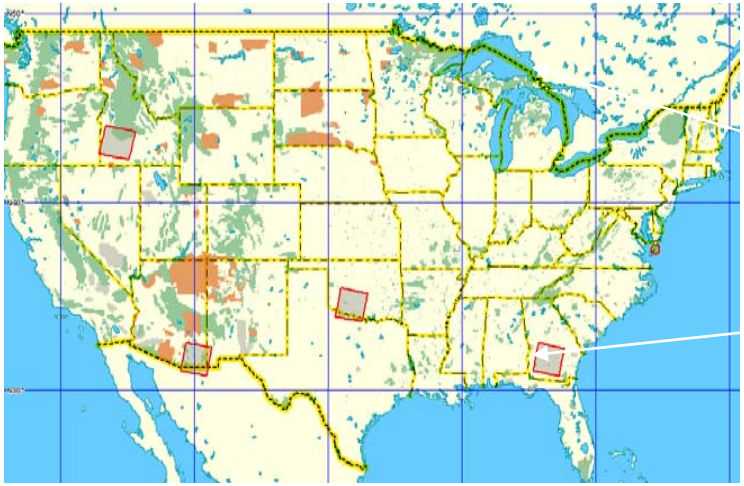
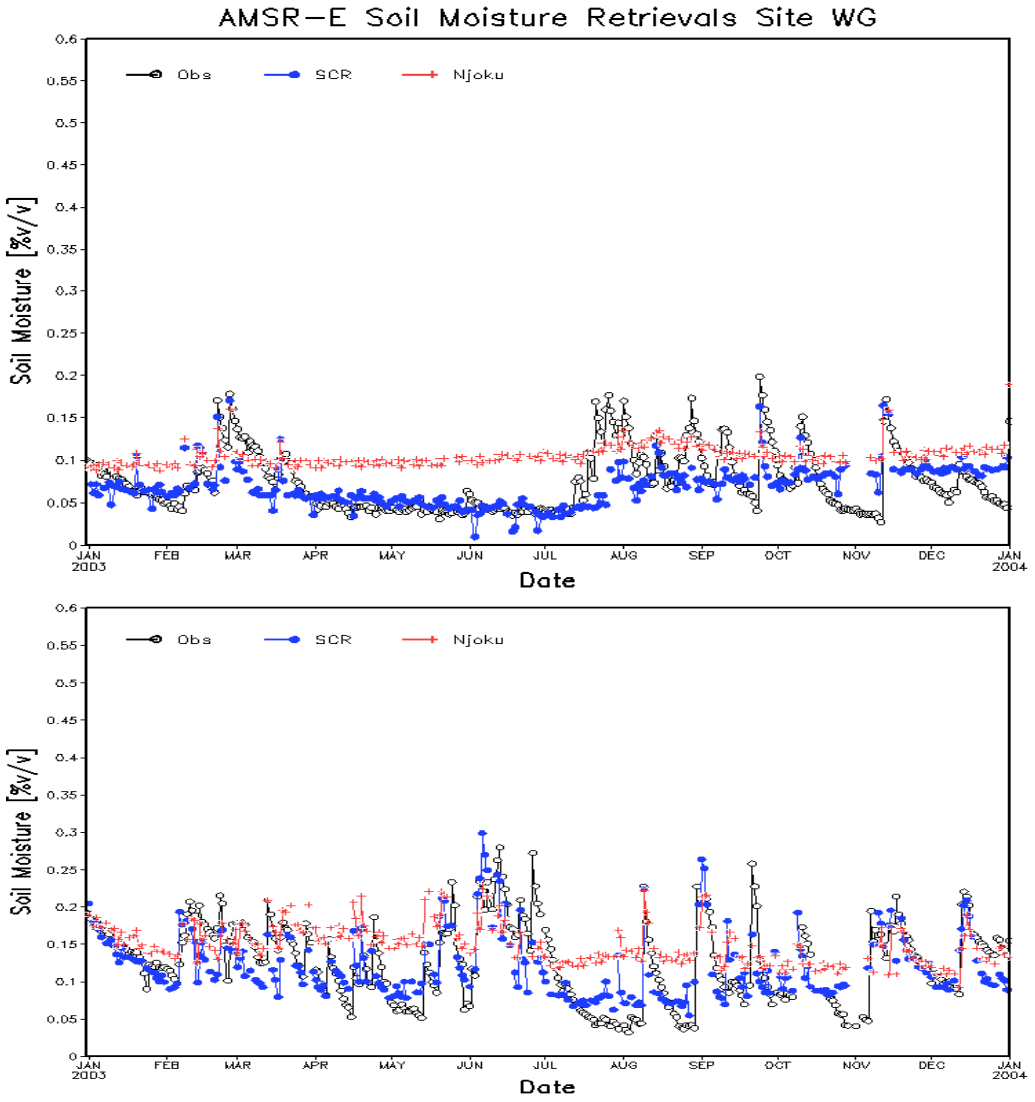
AMSR-E Soil Moisture Products (Principal Investigator: Jerry Zhan)

USDA Ground Network: USDA-ARS has set up a ground soil moisture observation network (two sites are used here):

- ✓ ***Stevens Water Hydra Probes are used***
- ✓ ***21 sites in Walnut Gulch, AZ (31.7N, -110.0W) - WG***
- ✓ ***20 sites in Little Washita, OK (34.9N, -98.1W) - LW***
- ✓ ***Sensor depth is 5cm for most sites***
- ✓ ***Data are continuously recorded at 20-60min intervals***





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Summary and Conclusions

- SSM/I/S has provided a longest microwave imager data record in history since 1987 for land/terrestrial science studies. The instrument is very stable and unique for climate studies.

- STAR microwave imager cross-calibration procedure has improved the quality of SSM/I products and resulted in consistent trends (TPW, snow/sea ice cover, etc.). The SSM/I data from 1992 and 2007 has been reprocessed and made available for community assessments.

- The Radio Frequency Interference (RFI) from the ground-based transmitters with microwave thermal emission is getting more severe at L, C, and X-bands. If RFI signal is not detected and eliminated, the quality of microwave products is seriously downgraded