Development of the NPOESS Microwave Imager/Sounder (MIS) Instrument Concept

Introduction

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) is developing a replacement for the Conical-scanning Microwave Imager/Sounder (CMIS), the Microwave Imager/Sounder (MIS). The MIS will perform key measurements for the NPOESS system including Soil Moisture and Sea Surface Winds. Other environmental parameters related to conical-scanning microwave radiometers and MIS include Atmospheric Temperature and Moisture Profiles, Sea Surface Temperature, integrated atmospheric moisture and precipitation measurements. The importance of MIS-related measurements to meteorology, weather forecasting and climatology is demonstrated by the role of measurements from several MIS-legacy sensors including the DMSP Special Sensor Microwave Imager (SSM/I) and Imager/Sounder (SSMIS), as well as the TRMM Microwave Imager (TMI), the EOS Advanced Microwave Scanning Radiometer (AMSR-E), and the Satellite-based Vector Winds Measuring System (WindSat).

MIS Design Priorities

The June 5, 2006 Acquisition Decision Memorandum (ADM) directs NPOESS not to fall below heritage on its Key Performance Parameters (KPP) and emphasized the importance of continuity in data measurements. However, in order to better prioritize the range of capabilities represented by the CMIS requirements as derived from the NPOESS IORD II and the current DMSP capabilities represented by SSMIS, prioritization of EDR capabilities of MIS was requested from the NPOESS Senior User Advisory Group (SUAG). For this prioritization the capabilities of MIS were split into five (5) categories: the first category represents the current imaging capabilities of the SSMIS; the second represents the sounding capability of the SSMIS; the third represents performance from the 6-GHz channels; the fourth represents sea surface wind direction performance (at WindSat levels) and the fifth represents the SSMIS upper atmospheric temperature sounding of SSMIS, a capability currently unique to SSMIS. These priorities for MIS were set by the SUAG in the order presented:

1) Core Imaging capabilities
2) Atmospheric Temperature and Moisture Sounding
3) Sea Surface Temperature – Low Frequency
4) Sea Surface Wind Direction
5) Upper Atmospheric Temperature Sounding

Of note, the MIS requirements provide NPOESS' Soil Moisture and Wind Speed Key parameters. The NPOESS Advanced Technology Microwave Sounder (ATMS) and Cross-track Infrared Sounder (CrIS) provide AVMP and AVTP and the Visible Infrared Imaging Radiometer Suite (VIIRS) provides SST and Imagery. Upper Atmospheric Sounding (UAS) is not included on the NPOESS C2 MIS (FM1) but will be included on FM2 for NPOESS C3. The reason for excluding UAS on FM1 is due to its low operational readiness state. The next DMSP launch (F18) should address sensor data shortfalls for SSMIS sounding including UAS. UAS is considered to be a straightforward incremental capability to add for FM2 and NPOESS is currently defining requirements for UAS on MIS FM2.

MIS Sensor definition (Flight Model 1)

The trade space associated with the MIS design requirements is bounded by the heritage SSM/I and SSMIS sensors (0.6m main reflector; channel frequencies > 18 GHz) and the CMIS design (2.2m main reflector; channel frequencies from 6.2 – 183 GHz). This is a wide range of sensor capability, cost, and associated mass and power requirements for accommodation on the NPOESS spacecraft. Figure 1 summarize the relative performance that could be obtained from sensor configurations that spanned the wide range of the trade study. The approach was to define two increments in the size of the main reflector: A=1.2m and B=1.8m and three general channel sets: the basic capability includes core imaging (10 – 89 GHz), Type 1 includes core imaging with polarimetric capability (10 P/M; 18 P/M and 18 L/R; and 37 PM) and finally Type 2 adds sounding (+50 and 183 GHz channel suites).

MIS Performance compared to IORD II requirements

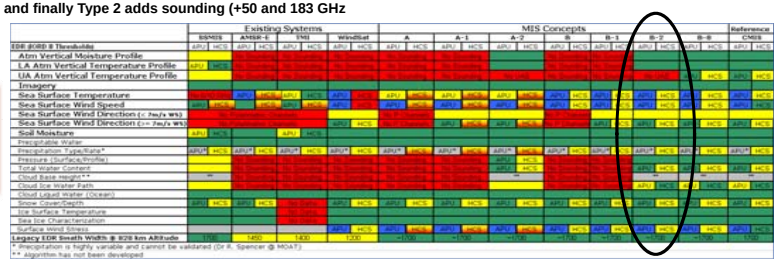

Figure 1. The Special Sensor Microwave Imager/Sounder (SSMIS) on the Defense Meteorological Satellite Program (DMSP) F16 spacecraft.

MIS Sensor Concept

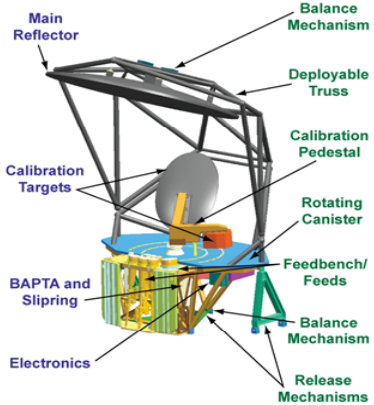

Figure 2. The MIS sensor concept showing key aspects of the electrical and mechanical sensor subsystems

The MIS FM1 conceptual design is shown above in Figure 2. Of note is the 1.8 meter aperture, 41 channels including 6-, 10-, 18-, 37-, and 89-GHz imaging channels, and atmospheric vertical moisture and temperature profiling channels (50- and 183-GHz, respectively).

NPOESS C2 Sensor (2016)

- 1.8m main reflector
  - Core Imaging Channels: 10 VH; 23 VH, 18 VH, 37 VH, 89 VH
  - Atmospheric Sounding: 50.3 – 57 GHz; 166 & 183.31 GHz
  - Low Frequency: 6.8 VH (with RFI mitigation)
  - Polarimetric Channels: 10 PM; 19 PMLR; 37 PM
  - Upper Air sounding: 60 – 63 GHz (C3 Increment)
- Key EDRs: Soil Moisture, Sea Surface Winds, Sea Surface Wind Direction, Sea Surface Temperature
  - Swath Width: ~1,700 km
  - Calibration: 2-point calibration
  - Deployable structure

Conclusion

This poster summarizes two (2) important aspects of the NPOESS MIS development: 1) evaluation of the available trade space defined by existing DMSP heritage and the NPOESS CMIS and 2) key performance aspects of the sensor configuration for NPOESS C2.

MIS EDR Capabilities

The MIS sensor offers improvements over several of its heritage operational sensors as well as other legacy missions:

Figure 3a shows global regions defined by 'bare soil' (areas in green). In contrast, Figure 3b shows the regions where Soil Moisture retrieval can be performed with the addition of a 6-GHz measurement capability (areas in green) defined by regions of vegetation cover < ~1.5 kg/m^2 (in general, excluding only dense vegetation and forested regions). The advantage of 6-GHz measurement capability is clearly justified (Images are provided by the U.S. Army)

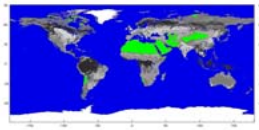

Figure 3a. Bare Soil Regions Soil Moisture Capability

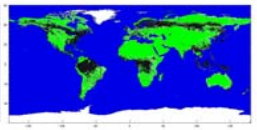

Figure 3b. CMIS Soil Moisture Capability

The MIS sensor is expected to produce sea surface wind vectors of similar quality as the on-orbit performance demonstrated by WindSat. Figure 4 shows a sample of Sea Surface Wind Direction (SSWD) data from WindSat.

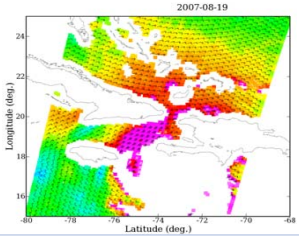

Figure 4. Wind direction retrievals using WindSat data in the Caribbean 19-Aug-2007.

Although SSWD is not an NPOESS KPP, wind direction retrievals support improvements to the SSWS KPP and Sea Surface Temperature (SST), Figure 5. SSWD capability provided by WindSat has shown significant utility for improving forecasts and represents an important capability that can be provided by an operational MIS sensor on NPOESS.

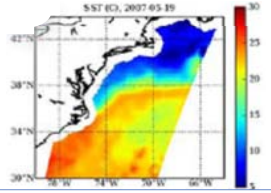

Figure 5. Sea Surface Temperature retrievals using WindSat data from May 19, 2007.

The MIS sounding design draws heavily from the DMSP SSMIS conical sounding configuration. Several improvements are being applied to the conical sounding design on MIS to address calibration shortfalls experienced with the SSMIS sensor that currently limit the amount of data available for assimilation.

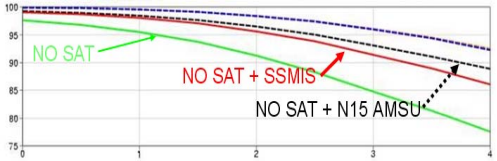

Figure 6. SSMIS F16 500 mb anomaly correlation in the Southern Hemisphere using European Centre for Medium Range Weather Forecasts (ECMWF) model. Courtesy Graeme Kelly (ECMWF).

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