NPOESS Interests and Data Support

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Soil Moisture Active-Passive (SMAP) Mission
Arlington, VA
July 9, 2007
Mission

Provide a national, operational, polar-orbiting environmental capability

Achieve National Performance Review savings by converging DoD and NOAA polar satellite programs

Incorporate new technologies from NASA and others

International Cooperation (EUMETSAT)
NPOESS Certified Program - 38 IORD EDRs

**MISSION AREAS**
- Atmosphere
- Climate
- Land
- Ocean
- Space Environment

**MI S**
(TBD)
- Cloud Liquid Water
- Precipitation Type/Rate
- Precipitable Water
- Sea Surface Winds
- Cloud Ice Water Path
- Surface Wind Stress
- Total Water Content

**SEM**
(5)
- Auroral Boundary
- Auroral Energy Deposition (Deg)
- Energetic Ions (Deg)
- Med Energy Chgd Parts (Deg)
- Supra-Therm-Aurora Prop (Deg)

**VIIRS**
(22)
- Albedo (Surface)
- Cloud Base Height
- Cloud Cover/Layers
- Cloud Effective Part Size
- Cloud Optical Thickness
- Cloud Top Height
- Cloud Top Pressure
- Cloud Top Temperature
- Land Surface Temp
- Surface Type
- Net Heat Flux
- Ocean Color/Chlorophyll
- Suspended Matter
- Vegetation Index
- Aerosol Optical Thickness
- Aerosol Particle Size
- Ice Surface Temperature
- Imagery
- Sea Ice Characterization
- Snow Cover/Depth
- Sea Surface Temperature
- Soil Moisture (Deg)

**CrIS/ATMS**
(3)
- ATM Vert Moist Profile
- ATM Vert Temp Profile
- Pressure (Surface/Profile)

**OMPS-N**
(1)
- O3 Total Column (also CrIS)
- O3 Profile (OMPS, Nadir Only, Deg)

* Final MIS EDRs will be determined after MIS selection

**KEY**
- Underlined = NPP EDRs (24)
- = NPOESS Key Performance Parameters
- BOLD CAPS = LRD Environmental Data Records

05 October 2006
DOC, NOAA, NESDIS, Integrated Program Office
M. Bonadonna, M. Haas, D. Stockton, J. Whitcomb
Soil moisture is Category 1-A Key Performance Parameter (KPP) Requirement

JROC-Approved NPOESS IORD-II EDR:
“Key Performance Parameter (KPP) 4.1.6.1.6 …Soil moisture measurements are needed to derive trafficability information useful for support of the deployment of amphibious and ground forces.”

Definitions:
“KPPs are those parameters so significant that failure to meet the threshold is cause for the system to be reevaluated or the program to be reassessed or terminated.”

Category “A”: “There is a value to the Government if thresholds are exceeded and/or objectives are approached.”

Notes:
NPOESS has 55 EDR Requirements (38 addressed by current NPOESS configuration); 6 Are (EDR) KPPs
VIIRS at a Glance

- VIIRS: Visible Infrared Imaging Radiometer Suite
- VIIRS will continue the observational program of:
  - OLS: Optical Line Scanner
  - AVHRR: Advanced Very High Resolution Radiometer
  - SeaWiFS: Sea Wide-Field Sensor
  - MODIS: Moderate Resolution Imaging Spectroradiometer
- VIIRS will provide operational and research users with:
  - Spectral coverage from 412 nm to 12 microns
    - Moderate resolution (~742 m at nadir) radiometric quality data
    - Imagery at 371 m nadir resolution in 5 bands
  - Complete global daily coverage with a single sensor
- Routine data products of:
  - Cloud cover, cloud layers
  - Cloud and aerosol physical properties
  - Land & ocean biosphere properties, snow & ice
  - Sea Surface Temperature, Land & Ice Temperatures
Soil Moisture Key Performance Parameter (KPP)
  – Evaluation of Soil Moisture utility based on availability of 6-GHz, 10-GHz and 19/18-GHz measurements

Considerations for microwave sounding
  – Utility for Numerical Weather Prediction (NWP)
  – System reliability for delivering temperature and moisture profile KPPs

Cost relationships of channel selection and reflector size
  – 6-GHz / larger reflector: Soil Moisture, Sea Surface Temperature
  – Polarimetric channels: Sea Surface Wind Direction
  – 50 to 60-GHz channel suite with 166/183-GHz channels: Atmospheric Temperature and Moisture Profiles
  – Sensor and Reflector Size relationship to cost

Acquisition strategy
  – Use models of similar successful sensor developments
Soil Moisture IORD Specification and NPOESS Approach

• Requirements

<table>
<thead>
<tr>
<th>Systems Capabilities</th>
<th>IORD-II Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Threshold</strong></td>
<td><strong>Objective</strong></td>
</tr>
<tr>
<td>Sensing Depth</td>
<td>0.1 cm</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>1-4 km Clear</td>
</tr>
<tr>
<td></td>
<td>40-50 km Cloudy</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>10% (40-50 km Cloudy)</td>
</tr>
<tr>
<td></td>
<td>20% (1-4 km, clear)</td>
</tr>
<tr>
<td>Latency</td>
<td>90 minutes</td>
</tr>
<tr>
<td>Refresh</td>
<td>8 hours</td>
</tr>
</tbody>
</table>

• Approach: *move toward IORD requirements for depth, uncertainty and resolution*
  – Build on heritage technology and risk reduction
  – Improve model physics and retrieval algorithm
  – Study synergism of microwave and Vis/IR data
  – Address depth requirement through data assimilation
## SMAP Exceeds IORD Threshold and Approaches Objective Requirement

<table>
<thead>
<tr>
<th>Systems Capabilities</th>
<th>IORD-II Requirements</th>
<th>SMAP</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Threshold</td>
<td>Objective</td>
</tr>
<tr>
<td>Sensing Depth</td>
<td>0.1 cm</td>
<td>80 cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Most Vegetation)</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>1-4 km Clear</td>
<td>2 km All Weather</td>
</tr>
<tr>
<td></td>
<td>40-50 km Cloudy</td>
<td>Clear and Cloudy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 km Radar 1.2 GHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40 km Radiom. 1.4 GHz</td>
</tr>
</tbody>
</table>

### Comparison to Alternatives and Capability:

**Higher Frequency Microwave Radiometers:** Limited to Sensing the Surface Moisture at Coarse Resolution and Across Low to Moderate Vegetation Cover Regions

**SMAP Low Frequency Microwave Measurements:** Capable of Sensing Through Most Vegetation Cover and Soil Moisture to Greater Depth

**SMAP Added Active Radar Measurements:** Achieve Higher Resolution Mapping for Key DoD Applications
NPOESS will benefit from SMAP mission:
• Better accuracy and higher resolution
• Wider range of validity
• Improved MIS algorithm performance
  – Better estimation of vegetation effects
• Cal/Val
  – Data/resource sharing, planning and coordination
• Potential synergy of L- to X-band data
  – Significant sensitivities to both soil moisture and vegetation
Potential NPOESS Support to SMAP

• **NPOESS bus support through P3I program**
  – Pre-Planned Program Improvements (P3I) process.
  – The P3I program allows for continued examination of possible solutions to NPOESS mission needs, including new or modified instrumentation in future space segments beyond NPOESS Initial Operational Capability (IOC).

• **NPOESS Ground System support**
• **NPOESS Cal/Val system and procedures**
T430 structure has ample growth margin for sensor growth

<table>
<thead>
<tr>
<th>Satellite</th>
<th>NPP</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
</tr>
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<tbody>
<tr>
<td>Launch</td>
<td>Sep 2009</td>
<td>2013</td>
<td>2016</td>
<td>2020</td>
<td>2022</td>
</tr>
<tr>
<td>Nodal Time</td>
<td>1330</td>
<td>1330</td>
<td>0530</td>
<td>1330</td>
<td>0530</td>
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<tr>
<td>VIIRS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Microwave Imager/Sounder</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

NPOESS BUS:

Unused Real Estate: 10-17 ft²

NO P3I on NPOESS C1

From Stan Schneider/IPO
Current NPOESS Research Activities

- **Gravite Lab**
  - Government Resource for Algorithm Verification & Independent Test & Evaluation
  - Build end-to-end simulator, infrastructure and tools
  - Integrate all elements of Cal/Val
- **EDR algorithm (uncertainty and resolution)**
  - Microwave & Vis/IR
- **Data Assimilation (Depth)**
- **RFI mitigation**
  - hardware and software
- **Field experiments**
  - Soil moisture and snow
Algorithm Study Priorities

- Algorithm performance error model
  - Surface state, heterogeneity
- The effects of:
  - Water body fraction, vegetation, surface roughness
- RFI mitigation requirements
- In-situ data requirements
  - Coverage, vegetation regime, standardization, stability
- Synergy of MW and Vis/IR
Baseline WindSat land algorithms have been developed.

- **Soil Moisture Retrieval**
  - WindSat Global Soil Moisture (Fraction), 1-12 September 2003

- **Vegetation Water Content Retrieval**
  - WindSat Global Vegetation (kg/m²), 1-12 September 2003

- **Snow Water Equivalent Retrieval**
  - WindSat Snow Water Equivalent Retrieval, 24 Hour Averaged Composite Ice Conc. From 00Z 1/4/2002 to 00Z 5/2002

- **Sea Ice Concentration Retrieval**
  - NH WindSat Modified MSG Image 24 Hour Averaged Composite Ice Conc. From 00Z 1/4/2002 to 00Z 5/2002
A four-dimensional data assimilation (4DDA) methodology to retrieve deep soil moisture profiles using the WindSat data.
RFI Mitigation

• 6 GHz Measurements over land will require effective RFI mitigation
  – CMIS planned 4x190 MHz sub-bands covering from 6.2 – 7.3 GHz

• Alternatives for MIS include
  – Alternate center frequencies near 5.75 GHz with time domain mitigation
  – 6.8 GHz center frequency with frequency domain mitigation (FFT)
  – Sub-banding similar to CMIS
When: Ames, Iowa.
Objective: Polarimetric signature, Satellite Ca/Val.
Measurements: APMIR, WindSat, AMSR-E, In-Situ Soil Moisture, Vegetation, Dew, CO2 flux
Sponsors: NRL/ONR, NPOESS IPO, THP/NASA.

APMIR Data Capturing Soil Moisture Variations

Very Dry

Very Wet

Drying

APMIR on NRL P-3
Summary

• The SMAP mission will provide an important risk reduction for NPOESS MIS to move toward IORD specifications in terms of measurement uncertainty and resolution.

• NPOESS can potentially accommodate SMAP instrument through its P3I program

• NPOESS can potentially provide Ground System support

• Leveraging NPOESS and SMAP Cal/Val system and procedures will result in better efficiency and lower cost