GCOM-W1/AMSR2
SOIL MOISTURE

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Outline

• AMSR2 Soil Moisture EDR Team Members
• Soil Moisture Sensor Overview
• AMSR2 Soil Moisture Algorithm
• AMSR2 Soil Moisture Data Product
• Summary and Path Forward
# AMSR2 Soil Moisture Team Members

<table>
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<tr>
<th>Team Member</th>
<th>Organization</th>
<th>Roles and Responsibilities</th>
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<tbody>
<tr>
<td>Xiwu Zhan</td>
<td>NESDIS-STAR</td>
<td>AMSR2 Soil Moisture Team Lead</td>
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<tr>
<td>Jicheng Liu</td>
<td>UMD-CICS/ NESDIS-STAR</td>
<td>SM Algorithm and Validation Lead</td>
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<tr>
<td>Tom King</td>
<td>IMSG/ NESDIS-STAR</td>
<td>GAASP Development Lead</td>
</tr>
<tr>
<td>Zorana Jelenak</td>
<td>UCAR/ NESDIS-STAR</td>
<td>JPSS GCOM-W1 EDR Lead</td>
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<tr>
<td>Ralph Ferraro</td>
<td>NESDIS-STAR</td>
<td>JPSS GCOM-W1 Project Deputy</td>
</tr>
<tr>
<td>Paul Chang</td>
<td>NESDIS-STAR</td>
<td>JPSS GCOM-W1 Project Lead</td>
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Soil Moisture Sensor Overview

- Soil Moisture remote sensing is based on the sensitivity of L/C/X band microwave emission to soil dielectric constant.
- Soil moisture capable passive microwave satellite sensors include: SMMR, SSM/I and SSMIS, AMSR/AMSR-E, WindSat, SMOS, AMSR2, GMI and SMAP.
- AMSR2 on board of JAXA’s GCOM-W1 satellite is currently the only operational passive microwave soil moisture sensor in NASA-NOAA JPSS program.
Table 6.1.10 - GCOM-W Soil Moisture

<table>
<thead>
<tr>
<th>EDR Attribute</th>
<th>Threshold</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable conditions</td>
<td>Delivered under “all weather” conditions</td>
<td>Delivered under “all weather” conditions</td>
</tr>
<tr>
<td>Sensing depth</td>
<td>Surface to -0.1 cm (skin layer)</td>
<td>Surface to -80 cm</td>
</tr>
<tr>
<td>Horizontal cell size</td>
<td>25 km (1)</td>
<td>3 km</td>
</tr>
<tr>
<td>Mapping uncertainty, 3 sigma</td>
<td>5 km</td>
<td>1 km</td>
</tr>
<tr>
<td>Measurement Uncertainty</td>
<td>6% volumetric RMSE (goal) with VWC &lt; 1.5 kg/m² or GVF &lt; 0.5 and &lt; 2 mm/hr precip rate</td>
<td>Surface: 5% 80 cm column: 5%</td>
</tr>
<tr>
<td>Measurement range</td>
<td>0 – 50% (2)</td>
<td>0 – 50%</td>
</tr>
<tr>
<td>Refresh</td>
<td>At least 90% coverage of the globe about every 20 hours (monthly average) (3)</td>
<td>n/s</td>
</tr>
</tbody>
</table>

Note:
(1) Per AMSR-E legacy and user convenience, 25km can be obtained with resampling AMSR-2 footprints to 25km. 3km could be obtained by interpolation with VIIRS optical observations.
(2) Absolute soil moisture unit (m³/m³ volume %) is preferred by most users of NWP community.
(3) This Refresh requirement is consistent with the AMSR-2 Cross-track Swath Width design of 1450 km for a single orbit plane.
**Table 6.1.11 - Surface Type (AMSR-2)**

<table>
<thead>
<tr>
<th>EDR Attribute</th>
<th>Threshold (1)</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable conditions</td>
<td>Delivered under “all weather” conditions</td>
<td>Delivered under “all weather” conditions</td>
</tr>
<tr>
<td>a. Horizontal cell size</td>
<td>25 km</td>
<td>1 km</td>
</tr>
<tr>
<td>b. Mapping uncertainty, 3σ</td>
<td>5 km</td>
<td>1 km</td>
</tr>
<tr>
<td>c. Measurement Range</td>
<td>8 hydrological classes (2)</td>
<td>13 classes of land types listed in Note (3)</td>
</tr>
<tr>
<td>d. Measurement Precision</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>e. Measurement Accuracy</td>
<td>70% for 17 types</td>
<td>80%</td>
</tr>
<tr>
<td>f. Refresh</td>
<td>&gt;90% coverage of globe every 20 hrs (4)</td>
<td>n/s</td>
</tr>
</tbody>
</table>

Note:
(1) Satisfied by VIIRS under “probably clear” and “probably cloudy” conditions.
(2) 1) Standing water, 2) Dense veg (jungle), 3) Herb veg, 4) Desert, 5) Snow, 6) Urban, 7) Wetland, 8) Raining area
(4) Consistent with AMSR2 cross-track swath width of 1450km.
Soil Moisture Algorithm Overview

Multi-channel Inversion (MCI) Algorithm

(Njoku & Li, 1999)

\[
\min \{ \chi^2 \} = \sum_{i=1}^{6} \left( \frac{T_{B,i}^{obs} - T_{B,i}^{cmp}}{\sigma_i} \right)^2
\]

\[
T_{B,i}^{cmp} = T_s \{ e_{r,i} \exp (-\tau_i/\cos \theta) + (1 - \omega) [1 - \exp (-\tau_i/\cos \theta)] [1 + (1-e_{r,i})\exp (-\tau_i/\cos \theta)] \}
\]

\[
\tau_i = b \times VWC
\]

\[
e_{r,i} = f(e_s, h)
\]

\[
e_s = f(\varepsilon) \quad -- \text{Fresnel Equation}
\]

\[
\varepsilon = f(SM) \quad -- \text{Mixing model (Dobson et al)}
\]

\[
T_{B,i}^{obs} = T_{B06h}, T_{B06v}, T_{B10h}, T_{B10v}, T_{B18h}, T_{B18v}
\]
Land Parameter Retrieval Model (LPRM) :

\[ \text{min} \{ \delta = T_{Bh}^{obs} - T_{Bh}^{cmp} \} \]

\[ T_{Bh}^{cmp} = T_{s} \left\{ e_{h,r} \exp \left( -\tau / \cos \theta \right) + (1 - \omega) \left[ 1 - \exp \left( -\tau / \cos \theta \right) \right] \left[ 1 + (1 - e_{h,r}) \exp \left( -\tau / \cos \theta \right) \right] \} \]

\[ \tau = f(\text{MPDI}) \]

\[ \text{MPDI} = \frac{T_{Bv} - T_{Bh}}{T_{Bv} + T_{Bh}} \]

\[ e_{h} = f(e_{s}, h, Q) \]

\[ e_{s} = f(\varepsilon) \quad \text{-- Fresnel Equation} \]

\[ \varepsilon = f(\text{SM}) \quad \text{-- Mixing model (Wang & Schmugge)} \]

\[ T_{s} = f(T_{B37v}) \text{ or } T_{s}^{LSM} \]

\[ T_{Bh}^{obs} = T_{B06h}, T_{B10h} \text{ or } T_{B18h} \]
Single Channel Algorithm (SCA) :

\[ T_{B10h} = T_s \left[ 1 - (1-e_r) \exp \left(-\frac{2\tau}{\cos \theta}\right) \right] \]

\[ \tau = b \times VWC, \quad VWC = f(\text{NDVI}) \]

\[ e_h = f(e_v, h, Q) \]

\[ e_s = f(\varepsilon) \quad \text{-- Fresnel Equation} \]

\[ \varepsilon = f(\text{SM}) \quad \text{-- Mixing model} \]

\[ T_s = f(T_{B37v}) \text{ or } T_s^{LSM} \]
AMSRT2 Soil Moisture Algorithm

**SCA:** Inverse tau-omega equation of a $TB_h$ (C/X-band) for $SM$ with $tau$ from $NDVI$ and $T_s$ from $TB_{36v}$. Used in SMOPS

**LPRM:** Inverse tau-omega equations of $TB_h$ and $TB_v$ (C/X-band) for $tau$ and $SM$ with $T_s$ from $TB_{36v}$

**Hybrid:** Use LPRM inversed $tau$ in SCR for AMSR2 soil moisture EDR
AMSR2 Soil Moisture Products

• AMSR2 soil moisture EDR is generated with the hybrid algorithm implemented in NESDIS GCOM-W1 AMSR2 Algorithm Software Processor (GAASP) using AMSR2 6.9/7.3GHz H-pol TB data, available as Level 2 swath product
• Global 0.25 degree (Level 3) gridded AMSR2 soil moisture data product are made available through NESDIS Global Soil Moisture Operational Product System (SMOPS) in 6 hour or daily NetCDF and GRIB2 files
• Algorithm Readiness Review for the Day 2 EDR of GCOM-W1 products was held in May 2016
• SMOPS update for AMSR2 to provide Level 3 global soil moisture product for users was delivered to OSPO in July and Operation Readiness Review (ORR) of the SMOPS update is arranged later this month
AMSR2 Soil Moisture Performance

Comparison with in situ Measurements of SCAN Sites

- Number of Stations: 150
- Mean correlation coefficient: 0.545
- Mean Bias: 0.021
- Mean RMSE: 0.038
AMSR2 Soil Moisture Performance

Phillipsburg, KS

- Number of days: 268
- Mean correlation coefficient: 0.840
- Mean Bias: -0.042
AMSR2 Soil Moisture Performance

- Number of days: 257
- Mean correlation coefficient: 0.354
- Mean Bias: -0.131

Milford, UT
AMSР2 SM vs Other SM Products: Phillipsburg, KS
(γ: correlation coefficient; RMSE: Root Mean Square Error)

AMSР2: γ=0.84; RMSE=0.023

ASCAT: γ=0.51; RMSE=0.090

SMAP: γ=0.84; RMSE=0.050

SMOS: γ=0.63; RMSE=0.065
AMSR2 SM vs Other SM Products: Milford, UT
(γ: correlation coefficient; RMSE: Root Mean Square Error)
AMSR2 Soil Moisture EDR Overview

- Performance generally meets requirements
- Reprocessing Plan/Status: in development
- Long Term Monitoring/Website Links:
  - SMOPS website at STAR is in development
  - SMOPS update for AMSR2 at OSPO is ready for review later this month
- Enterprise Algorithm Status: SMOPS?
- Users Feedback:
  - NCEP use of SMOPS data are in research mode
  - SMOPS products are used in DoD AFWA and USDA FAS operationally
  - SMOPS products are used for Blended Drought Index
Readiness for Follow-on Satellites

• Significant Algorithm changes is planned for GCOM-W2 if any
  – SCA will be calibrated with VIIRS EVI or LAI for better counting of
    vegetation water content impact

• Pre-launch Characterization
  – N/A

• Post-Launch Cal/Val Plans
  – Data Sets/Planned Field Campaigns : N/A
  – Schedules and Milestones: N/A

• Accomplishments and Highlights Moving forward
  – A NASA funded project may leverage an effort of downscaling
    AMSR2/3 soil moisture data product for high resolution data need

• Major Risks/Issues/Challenges/ and Mitigation
  – No GCOM-W1 follow-on satellite is approved yet

• Collaboration with Stake Holders/User Agencies
  – Interaction with user community has been frequent
Summary

• GCOM-W1/AMSR2 soil moisture EDR has been generated by NESDIS GAASP as Day 2 product
• AMSR2 soil moisture EDR quality is compatible with other available satellite products and meets JPSS accuracy requirements generally
• NESDIS SMOPS is going to ingest AMSR2 soil moisture EDR and merge it with other global soil moisture data products to provide NCEP and other operational users with 6 hour and daily gridded products from next month
Path Forward

• FY17 Milestones:
  – AMSR2 soil moisture EDR comprehensive validation with global in situ measurement networks and other soil moisture data products
  – Improve user applications by providing more quality control information of products

• Alternate Algorithms and Future Improvements
  – Algorithm refinement and validation with VIIRS EVI replacing NDVI as input
  – Downscaling algorithm development and validation for high resolution data needs

• Preparation for future satellites: n/a
Thanks!