Surface Soil Drying Observed by AMSR-E in the Mongolian Plateau

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1. Background and purposes
2. Research method
3. AMSR-E soil moisture estimation
4. Ground-based soil moisture analysis
5. Conclusions

Firenze
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Background

◊ Important role of soil moisture behaviors of the Mongolian plateau in water cycle and vegetation change in East Asia.

◊ Long term monitoring of soil moisture by satellites (AQUA, ALOS · · ·) and ground-based stations for CEOP and GEOSS.
Purposes

○ Grasping the real condition of soil moisture behaviors in the Mongolian plateau

○ Long-term monitoring of soil moisture in the Mongolian plateau by AMSR-E and ground-based stations
Mongolian plateau

Vegetation conditions in Mongolia
Soil moisture monitoring by AMSR-E (AQUA)

AMSР-E (Advanced Microwave Scanning Radiometer-EOS) of AQUA (EOS Aqua Launch: May 4, 2002): AMSR-E in PM Orbit

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>6.9</th>
<th>10.6</th>
<th>18.7</th>
<th>23.8</th>
<th>36.5</th>
<th>89.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground solution (km)</td>
<td>43</td>
<td>29</td>
<td>16</td>
<td>18</td>
<td>8.2</td>
<td>3.5</td>
</tr>
<tr>
<td>Bandwidth (MHz)</td>
<td>350</td>
<td>100</td>
<td>200</td>
<td>400</td>
<td>1000</td>
<td>3000</td>
</tr>
<tr>
<td>Polarization</td>
<td>Horizontal and vertical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observation swath</td>
<td>1,450 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute accuracy</td>
<td>1K(1σ) target</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Radiative Transfer Equation for Vegetated Area

\[ T_b = e_{soil} \cdot T_s \cdot e^{-\tau_c} + \left( 1 - \omega_c \right) T_c \cdot \left( 1 - e^{-\tau_c} \right) \]

- \( T_b \): brightness temp.
- \( T_c \): canopy physical temp.
- \( \omega_c \): single scatt. albedo
- \( \tau_c \): optical depth
- \( T_s \): soil physical temp.
- \( e_{soil} \): soil emissivity

Radiation from land surface attenuated in vegetation layer
Upward radiation emission from vegetation layer
**ISW - PI algorithm (by Prof. Koike)**

\[
ISW = \frac{T_{b\_high} - T_{b\_low}}{\frac{1}{2}(T_{b\_high} + T_{b\_low})}
\]

**Index of Soil Wetness**

:High soil moisture → High ISW

*low*: 6GHz H p.
*high*: 37GHz H p.

\[
PI = \frac{T_{b\_v} - T_{b\_h}}{\frac{1}{2}(T_{b\_v} + T_{b\_h})}
\]

**Polarization Index**

:Vegetation → Low PI

*low*: 6GHz H p.
*high*: 37GHz H p.
18GHz h: H p.
v: V p.

**Forward Model**

\[
\begin{align*}
&M_v \\
\rightarrow & e_{\text{soil}} \\
\rightarrow & \Gamma \\
\rightarrow & e_{\text{soil}} \\
\rightarrow & \text{emissivity} \\
\rightarrow & \text{calculated brightness temp.} \\
\rightarrow & T_b
\end{align*}
\]

\[
\begin{align*}
&\lambda, W_c \\
\rightarrow & \tau_c \\
\rightarrow & T
\end{align*}
\]

**Reverse Convert**

(make Lookup Table)

\[
\begin{align*}
&M_v \\
\rightarrow & ISW, PI
\end{align*}
\]

**Reversion Analysis**

\[
\begin{align*}
&T_b_{\text{obs}} \\
\rightarrow & PI_{\text{obs}}, ISW_{\text{obs}} \\
\rightarrow & M_v, W_c
\end{align*}
\]

**Forward Model**

- **Volumetric Soil Moisture**
- **Dielectric Constant**
- **Fresnel Power Reflectivity**
- **Physical Temperature**
- **Optical Depth**
- **Emissivity**
- **Calculated Brightness Temperature**

**Index of Soil Wetness**

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**Polarization Index**

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*low*: 6GHz H p.
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Validation results in 2003 (All: Ground-based area soil moisture at the 3cm depth, Descending: AMSR-E soil moisture < Average absolute error: AVE = 2.1377 > SM: soil moisture)
Ten day change of the AMSR-E soil moisture estimation from June to Sep. in 2006 in the Mongolian plateau

Applicable conditions: 60% ≥ soil moisture, 2Kg/m² ≥ plant water
Ten day change of the AMSR area-averaged soil moisture estimation (SMarea) in the main part of the Mongolian plateau in each year.
Yearly change of the AMSR-E area-averaged soil moisture estimation (SMarea) in the main and eastern parts of the Mongolian plateau.
Working stations in the MAVEX (Mongol AMSR/AMSR-E/ALOS Validation Experiment) study area as of Dec., 2007:

- AWS (Automatic Weather Station),
- ASSH (Automatic Station for Soil Hydrology),
- SA: Study area of AMPEX/MAVEX, UB: Ulaanbaatar
A time series of the daily area-averaged soil moisture \( VWC_{\text{area}} \) at the 3 and 10 cm depths in the study area from 2001 to 2006.

\[
VWC_{\text{area}} = \frac{\sum (SM_{\text{ASH}} - n + \cdots + SM_{\text{AWS}} - m)}{N}
\]

\( VWC_{\text{area}} \): daily mean areal soil moisture, \( SM \): soil moisture, 
\( n \): ASSH number, \( m \): AWS site, \( N \): number of stations

3 cm depth

10 cm depth

Slightly decreasing

A time series of the daily area-averaged soil moisture \( VWC_{\text{area}} \) at the 3 and 10 cm depths in the study area from 2001 to 2006.
A time series of daily mean temperatures of soil surface: $T_s$ and air: $T_a$, daily mean net radiation: $R_n$ and precipitation: $P$ at MGS and DRS from Sep. 2000 to June 2006.
Yearly change of the area-averaged soil moisture (SMarea) at the 0-10 cm depth of NAMHEM in the main and eastern parts of the Mongolian plateau.
Conclusions

∅ Slight decline of the AMSR-E soil moisture estimation for the last five years in the Mongolian plateau

∅ Overestimation of the ASMR-E soil moisture observation

∅ Continuing a long term monitoring of soil moisture by AMSR-E and ground-based stations

∅ Challenging to make a synergy observation of soil moisture by AMSR-E, ALOS and SMOS