Downscaling of AMSR-E Soil Moisture Using Thermal Sensors and a Physically-Based Model

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Introduction & Purpose

• Soil moisture is a critical variable for a wide variety of applications: hydrology, agriculture, climate change, and so on.
• The data is scarce; only in-situ point data can be found, and only in a small area.

AMSR-E Daily Soil Moisture Product

• Purpose:
  Examine utility of AMSR-E imagery for surface soil moisture mapping

The in-situ measurement at a NOAA soil moisture station
Availability of AMSR-E Soil Moisture Data & Its Limitations

- AMSR-E: Based on X-band (centered at 10.7 GHz). Wavelength not long enough to penetrate > 1 cm earth and vegetation canopy.
- AMSR-E: Coarse resolution (~25 km; 1-2 times per day)
Three Steps

1. Downscale SM from 25 km to 5 km using a thermal sensor & Von Karman wind turbulence model

2. Downscale SM from 5 km to 1 km based on the accumulated infiltrated rainfall for the previous consecutive four days till current day

3. Downscale SM from 1 km to 500m based on the quantity of flow accumulation.

Energy Balance

Precipitation Infiltration

Geomorphology (Flow Accumulation, & Saturated Hydraulic Conductivity)
Step 1 – Energy Balance

\[ SM_{MODIS, 5} = SM_{AMSR, 25} + \frac{\delta SM}{\delta SEE} \Delta SEE_{MODIS,5} \]

\[ SM_5 = SM_{AMSR, 25} + SM_c \cdot SMP_{MODIS,5} \]

\[ SMP_{MODIS, 5} = \frac{T_{MODIS, 25} - T_{MODIS, 5}}{T_{MODIS, 25} - T_{\min MODIS, 1}} \]

From Komatsu (2003):

\[ SM_c = SM_{co} \cdot (1 + \gamma/r_{ah}) \]

\[ SM_{co} \] is 0.01 for sand and 0.04 for clay.

Soil moisture model involves:
- Downscaling of AMSR-E imagery
- Adjustment based on:
  - MODIS imagery
  - von Karmann wind turbulence
  - soil properties (SSURGO).

\[ r_{ah} = \frac{1}{k^2 u} \left[ \ln \left( \frac{Z}{z_{om}} \right) \right]^2 \]
Step 1 – Energy Balance

- Deriving the soil temperature using MODIS surface temperature and a vegetation index.

\[ T_{\text{MODIS},n} = \left( T_{\text{surf, MODIS},n} - f_{v,\text{MODIS},n} \times T_{v,n} \right) / \left( 1 - f_{v,\text{MODIS},n} \right) \]

\[ f_{v,\text{MODIS},n} = \frac{\text{EVI}_{\text{MODIS},n} - \text{EVI}_{\text{min}}}{\text{EVI}_{\text{max}} - \text{EVI}_{\text{min}}} \]

- \text{EVI}_{\text{min}} \text{ & } \text{EVI}_{\text{max}} \text{ being the NDVI value corresponds to bare soil and fully vegetated pixels respectively}

- EVI was used instead of NDVI
STEP 2 – Precipitation & Infiltration

Daily Average of Soil Moisture at the Whetstone Station
July 1, 2008 to August 5, 2008

Daily Precipitation Accumulation at the Whetstone Station
July 1, 2008 to August 5, 2008
STEP 2 – Precipitation & Infiltration

- Spatial interpolation of gage data (IDW)
- Infiltration accounting using Horton’s equation
- Soil moisture contribution tabulated
Derived 1-km Soil Moisture

7/25/2008 1-km resolution soil moisture (blue = wet, red = dry)
Validation – Estimation vs. Observation

$R^2 = 0.628$
Conclusions

- Satellite soil moisture imagery (AMSR-E) has limited capacity to detect ground moisture conditions.
  - Dry surface conditions are detected better than wet conditions.
  - Surface depth of detection ~ 1 cm
- Downscaling of AMSR-E provides useful information when combined with:
  - MODIS Thermal IR
  - SSURGO soil properties
  - Antecedent precipitation
- Surface energy balance model provides means to estimate surface soil moisture and its spatial variability.
- Correlation to in-situ SM data is encouraging given data examined; more data set need to be studied.
- Automation of developed procedures is possible.
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Shei, Shei Discussion?
Used MODIS EVI Instead of NDVI Data

\[ EVI = 2.5 \times \frac{(NIR - RED)}{(NIR + C1 \times RED - C2 \times Blue + L)} \times 1 + L \]

- \( C1 = 6.0 \)
- \( C2 = 7.5 \)
- \( L = 1.0 \)

- Improve vegetation and background differentiation
- The use of blue band will correct the atmospheric aerosol scattering effect happening in red band.
- The fv is much improved.
**STEP 2**

- $\text{SM}_{1\text{km}} = \text{SM}_{5\text{km}} + \text{Adjusted SMc, }_{1\text{km}} * (\text{Infiltration} - \text{mean (Infiltration)})_{1\text{km}} / \text{SD (infiltration)}_{1\text{km}}$

- The stomatal resistance, $r_l$, of a single leaf has a value of about 100 s m$^{-1}$ under well-watered conditions. By assuming a vegetation height of 0.17 m, the surface resistance, $r_s$ [s m$^{-1}$], $\gamma$ becomes around 60 s/m.
## Validation

07/05/2008

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<th>RG3_WGEW</th>
<th>RG13_WGEW</th>
<th>RG14_WGEW</th>
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<th>RG20_WGEW</th>
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<th>Freeman Spring (%)</th>
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<th>Whetstone (%)</th>
<th>Kendall SoilHydrology &amp; RG82</th>
<th>LuckyHill Trench TDR</th>
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