Downscaling radiometer derived soil moisture using Radar and Visible/Near Infrared data

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Literature


Radar
July 10 - 13

- PALS passive: 1K (bias); 0.2K (stability)
- PALS active: 2dB (bias); 0.2dB (stability)
- UAVSAR residual error by instrument: 3 dB for agricultural areas; 2.6 dB for forests
• Approximately linear dependence of radar backscatter change on soil moisture change\(^2\)

\[
\sigma_{pp}^0 = C + Dm_v
\]  
(1)

• Assume \(C\) does not change at the scale of few days, \(D\) depends on vegetation attenuation

\[
\Delta\sigma_{pp}^0 = D\Delta m_v
\]  
(2)

• Relative sensitivity is a function of vegetation opacity only\(^1\)

\[
\frac{D}{D_0} = f(\tau)
\]  
(3)

• Combining (2) and (3)

\[
\Delta\sigma_{pp}^0 = f(\tau)D_0\Delta m_v
\]  
(4)

• Substituting and writing for \(m_v\)

\[
\Delta m_v = \frac{\Delta\sigma^0}{S_0}
\]  
(5)

• Expressing \(m_v\) change at a lower resolution (radiometer \(X\)),

\[
S_0 = f(\tau)D_0
\]

\[
\Delta m_{v,X} = \frac{1}{N} \sum m_{v,x}
\]  
(6)

• Evaluation of \(S\) at lower resolution

\[
S_0 = \frac{1}{N} \sum \Delta\sigma^0_x
\]  
(7)

• For SMPVEX12, \(\tau\) was unchanged within footprint, soil moisture change at the higher spatial resolution (radar \(x\))

\[
\Delta m_{v,x} = \frac{\Delta\sigma^0_x}{S_0}
\]  
(8)

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Disaggregated Soil Moisture

PALS (1500 m)

UAVSAR (800 m)

Box shows covered time period
Overall Estimated Δ vs. In Situ Δ

### PALS

<table>
<thead>
<tr>
<th>Number of Points</th>
<th>R²</th>
<th>Slope</th>
<th>RMSE (m³/m³)</th>
<th>Bias (m³/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0&lt;VWC&lt;1.5</td>
<td>64</td>
<td>0.79</td>
<td>1.939</td>
<td>0.0101</td>
</tr>
<tr>
<td>1.5&lt;VWC&lt;2</td>
<td>68</td>
<td>0.703</td>
<td>1.458</td>
<td>0.087</td>
</tr>
<tr>
<td>2&lt;VWC&lt;2.5</td>
<td>23</td>
<td>0.87</td>
<td>1.607</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>VWC&gt;2.5</td>
<td>48</td>
<td>0.666</td>
<td>1.432</td>
<td>-0.019</td>
</tr>
</tbody>
</table>

### UAVSAR

<table>
<thead>
<tr>
<th>Number of Points</th>
<th>R²</th>
<th>Slope</th>
<th>RMSE (m³/m³)</th>
<th>Bias (m³/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0&lt;VWC&lt;1.3</td>
<td>60</td>
<td>0.667</td>
<td>1.542</td>
<td>0.079</td>
</tr>
<tr>
<td>1.3&lt;VWC&lt;1.8</td>
<td>22</td>
<td>0.628</td>
<td>1.257</td>
<td>0.096</td>
</tr>
<tr>
<td>1.8&lt;VWC&lt;2.2</td>
<td>27</td>
<td>0.641</td>
<td>2.257</td>
<td>0.141</td>
</tr>
<tr>
<td>VWC&gt;2.2</td>
<td>40</td>
<td>0.794</td>
<td>1.89</td>
<td>0.072</td>
</tr>
</tbody>
</table>
Disaggregated UAVSAR $\Delta \Theta$ At 5M Resolution ($m^3/m^3$)

**Canola**

**Soybeans**

**Corn**

The 5m UAVSAR displays the crop features such as rows and smaller features of wetting and drying.
Validation of Disaggregated UAVSAR $\Delta \theta$ (5m)

From the days of July 5-July 3, July 8-July 5, July 10-July 8, Jul 13-July 10

<table>
<thead>
<tr>
<th>Site</th>
<th>Type</th>
<th>Number</th>
<th>$R^2$</th>
<th>Slope</th>
<th>RMSE ($m^3/m^3$)</th>
<th>Bias ($m^3/m^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site-14</td>
<td>Soybeans</td>
<td>22</td>
<td>0.514</td>
<td>1.171</td>
<td>0.186</td>
<td>-0.168</td>
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<tr>
<td>Site-62</td>
<td>Canola</td>
<td>31</td>
<td>0.767</td>
<td>1.471</td>
<td>0.058</td>
<td>-0.038</td>
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<tr>
<td>Site-63</td>
<td>Soybeans</td>
<td>32</td>
<td>0.79</td>
<td>1.24</td>
<td>0.044</td>
<td>-0.032</td>
</tr>
<tr>
<td>Site-71</td>
<td>Corn</td>
<td>51</td>
<td>0.46</td>
<td>2.82</td>
<td>0.145</td>
<td>0.008</td>
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<tr>
<td>Site-111</td>
<td>Soybeans</td>
<td>64</td>
<td>0.676</td>
<td>0.998</td>
<td>0.077</td>
<td>-0.027</td>
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<tr>
<td>Site-112</td>
<td>Soybeans</td>
<td>32</td>
<td>0.739</td>
<td>0.802</td>
<td>0.04</td>
<td>-0.02</td>
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</table>

<table>
<thead>
<tr>
<th>Site</th>
<th>UAVSAR $\theta$ ($m^3/m^3$)</th>
<th>In Situ $\theta$ ($m^3/m^3$)</th>
<th>Difference $\theta$ ($m^3/m^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site-14</td>
<td>0.113</td>
<td>0.049</td>
<td>0.064</td>
</tr>
<tr>
<td>Site-62</td>
<td>0.081</td>
<td>0.052</td>
<td>0.029</td>
</tr>
<tr>
<td>Site-63</td>
<td>0.061</td>
<td>0.049</td>
<td>0.012</td>
</tr>
<tr>
<td>Site-71</td>
<td>0.169</td>
<td>0.038</td>
<td>0.131</td>
</tr>
<tr>
<td>Site-111</td>
<td>0.128</td>
<td>0.106</td>
<td>0.022</td>
</tr>
<tr>
<td>Site-112</td>
<td>0.062</td>
<td>0.062</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Summary - Radar

- Downscaling using PALS radar and UAVSAR both result in good results. The exception is the method – as PALS radiometer and radar have same spatial resolution (1500m), there was an up-scaling of the radiometer (to 4500m) followed by downscaling (to 1500m). In the case of UAVSAR (field scale 800m) no such exercise was conducted.
- The 5m UAVSAR was used to downscale to specific points in each field and this illustrates the higher spatial resolution: UAVSAR can pick out crop rows.
- Crop type does not influence the downscaling results.
Visible/Near Infrared

There also exists a simple method based on thermal inertia using vegetation surface temperature from MODIS to downscale AMSR-E derived soil moisture from 0.25° to 1km
Average soil moisture versus day-night temperature difference

Look-up tables are created using MODIS Ts, NDVI and N/GLDAS soil moisture making this method computationally efficient.
1 KM, AMSR-E AND NLDAS SOIL MOISTURE FOR OKLAHOMA

1 km $\theta_{av}$ from May 22, 2004

AMSR-E $\theta_{av}$ from May 22, 2004

NLDAS $\theta_{av}$ from May 22, 2004

1 km $\theta_{av}$ from July 17, 2005

AMSR-E $\theta_{av}$ from July 17, 2005

NLDAS $\theta_{av}$ from July 17, 2005

1 km $\theta_{av}$ from August 9, 2005

AMSR-E $\theta_{av}$ from August 9, 2005

NLDAS $\theta_{av}$ from August 9, 2005

SMAP Calibration Validation Meeting September 1-3 2015
1KM, AMSR-E AND NLDAS SOIL MOISTURE FOR LITTLE WASHITA

SMAP Calibration Validation Meeting September 1-3 2015
Dry down at catchment scale

Maps are produced using 0.25° satellite soil moisture that is downscaled to 1km spatial resolution using the physical relationship between vegetation and surface temperature over a 20 year period.

This method is validated using an in-situ observational network

## VALIDATION WITH LITTLE WASHITA MICRONET OBSERVATIONS

<table>
<thead>
<tr>
<th></th>
<th>Day</th>
<th>Dataset</th>
<th>Slope</th>
<th>RMSE ($m^3/m^3$)</th>
<th>Unbiased RMSE ($m^3/m^3$)</th>
<th>Spatial Standard Deviation ($m^3/m^3$)</th>
<th>Number of Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2004</td>
<td>1km Downscaled</td>
<td>0.316</td>
<td>0.06</td>
<td>0.024</td>
<td>0.017</td>
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<td></td>
<td>AMSR-E</td>
<td>0.057</td>
<td>0.053</td>
<td>0.021</td>
<td>0.001</td>
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<tr>
<td></td>
<td>NLDAS</td>
<td>0.138</td>
<td>0.049</td>
<td>0.026</td>
<td>0.01</td>
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<tr>
<td></td>
<td>Micronet</td>
<td></td>
<td></td>
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<td>0.027</td>
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<tr>
<td>July 2005</td>
<td>1km Downscaled</td>
<td>0.1</td>
<td>0.058</td>
<td>0.03</td>
<td>0.029</td>
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<td>68</td>
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<tr>
<td></td>
<td>AMSR-E</td>
<td>0.062</td>
<td>0.038</td>
<td>0.03</td>
<td>0.004</td>
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<tr>
<td></td>
<td>NLDAS</td>
<td>0.068</td>
<td>0.051</td>
<td>0.032</td>
<td>0.002</td>
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<tr>
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<td>Micronet</td>
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<td>0.028</td>
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<tr>
<td>Total</td>
<td>1km Downscaled</td>
<td>0.208</td>
<td>0.059</td>
<td>0.027</td>
<td>0.023</td>
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<tr>
<td></td>
<td>AMSR-E</td>
<td>0.06</td>
<td>0.046</td>
<td>0.026</td>
<td>0.003</td>
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<td>NLDAS</td>
<td>0.103</td>
<td>0.05</td>
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<td>Micronet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.028</td>
<td></td>
</tr>
</tbody>
</table>
If needed...

• We can harness the power of MODIS [Surface Temperature and NDVI] to downscale the SMAP Radiometer derived soil moisture
• This will be limited by cloud cover and very high vegetation regions
• Look up tables can be refined using a suite of models. Regional models with higher spatial resolution can help to improve downscaled resolution/accuracy
Thank you