The Soil Moisture Active Passive Experiments: SMAPEx

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SMAP Specifications
Launch: NASA, 2014
Frequency band: L-band
Incidence angle: 40°
Azimuth direction: conically-scanning antenna
Resolution: Soil Moisture ~9km -- 36km radiometer + 3km radar
Repeat: 2-3 days

The Soil Moisture Active Passive mission

Radiometer observation ~36km + Radar observation ~3km = Downscaled product ~9km

Algorithms
Active Passive Retrieval and Downscaling
Objectives

1. Radar-only soil moisture retrieval (3km)
   Verify baseline algorithms proposed for SMAP

2. Radiometer-only soil moisture retrieval (36km)
   Use the SMAP radar information on surface roughness and vegetation structure (3km) to aid the soil moisture retrieval from the SMAP radiometer (40km)

3. Active-Passive soil moisture product (9km)
   Use the high resolution (3km) but noisy SMAP radar observations to downscale the accurate but low resolution (36km) radiometer footprint

Simulated fields of a) 3km truth soil moisture and retrieved soil moisture for b) 40km passive microwave observations, c) 3km radar observations and d) 3km merged passive microwave and radar observations (Zhan et al., 2006).
Airborne simulator

**L-band radiometer (PLMR)**
- **6 x Vis/NIR/SWIR/TIR**
- **PLMR**: Polarimetric L-band Multibeam Radiometer
  - Frequency/bandwidth: 1.413GHz/24MHz
  - Polarisations: V and H
  - Resolution: ~1km at 10,000ft flying height
  - Incidence angles: ±7, ±21.5, ±38.5° across track
  - Antenna type: 8 x 8 patch array

**L-band radar (PLIS)**
- **PLIS**: Polarimetric L-band Imaging SAR
  - Frequency/bandwidth: 1.26GHz/30MHz
  - Polarisations: VV, VH, HV and HH
  - Resolution: ~10m
  - Inc. angles 15°-45° on both sides of aircraft
  - Antenna type: 2x2 patch array

LE0453434 LE0882509
Motivation

Pre-launch active-passive algorithm validation largely based on synthetic studies & few airborne data sets

TEST DATA
- Datasets:
  - $T_B$ at 36km
  - $\sigma^\circ$ at 3km

EVALUATION DATA
- Reference dataset:
  - $T_B$/SM at 1km
- Downscaled product:
  - $T_B$/SM at 9km

SMAP Data Simulation
Simulation of SMAP data

**SMAP**
- Radiometer $T_B$
  - 36 km
  - H&V pol
  - L-band
  - Incidence angle: 40°

- Radar $\sigma$
  - 3 km
  - HH, VV & HV pol
  - L-band
  - Incidence angle: 40°

  Azimuth: rotating

**Aircraft simulator**
- PLMR $T_B$
  - 1 km
  - H&V pol
  - L-band
  - Incidence angle: ±7°, ± 21.5° and ± 38.5°

- PLIS $\sigma$
  - 10-30 m
  - HH, VV & HV pol
  - L-band
  - Incidence angle: 15°- 45°

  Azimuth: left/right of track

**Upscaling**

**Incidence angle normalization**

**Azimuth effect**
Soil Moisture Active Passive Experiments (SMAPEx)
Location: Yanco, Murrumbidgee Catchment, NSW;
Field campaigns:  SMAPEx-1 (5th-10th July 2010)
   SMAPEx-2 (4th-8th Dec 2010)
   SMAPEx-3 (5th-23rd Sept 2011)

Flights
Regional flight, Target flights, Transect flight;
Multi-angle flights and multi-azimuth flights

Ground sampling
Soil moisture; and vegetation
Target flights

**Multi-angle flights**
- at 3,000m altitude

**Multi-azimuth and multi-resolution flights**
- both at 1,500m altitude

<table>
<thead>
<tr>
<th>Area</th>
<th>Center Latitude</th>
<th>Center Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34°42.63'S</td>
<td>146°6.27'E</td>
</tr>
<tr>
<td>2</td>
<td>34°51.11'S</td>
<td>146°6.61'E</td>
</tr>
</tbody>
</table>
Calibration

- A single set of calibration solutions for PLIS have been derived for each campaign based on daily calibration flights.
- Absolute calibration accuracy for PLIS based on the PRCs from SMAPEX-3 is $\sim0.93\,\text{dB}$.
- Relative calibration (start and end of the flight) accuracy for PLIS is $\sim0.8\,\text{dB}$.
- The calibration procedure for PLMR is mature and is accurate to $\sim2\,\text{K}$.

Flight line
Swath
Ground soil moisture
Project Overview

Real time information on soil moisture variability at high resolution is vital for sustainable land and water management. NASA’s next generation soil moisture dedicated mission, Soil Moisture Active Passive (SMAP), will provide this information through the synergy of L-band (1.4GHz) active (radar) land passive (radiometer) microwave observations. The Soil Moisture Active Passive Experiments (SMAPEX) consist a series of three field experiments specifically designed to contribute to the development of soil moisture retrieval algorithms from radar and radiometer for the SMAPEX mission. The SMAPEX experiments are currently the only pre-launch SMAP validation campaigns planned for Australia.

SMAPEX has utilized airborne radar and radiometer data to replicate the SMAP configuration in terms of frequency, viewing angle and resolution ratio. The main instruments flown are the Polarimetric L-band Multibeam Radiometer (PLMR) and the Polarimetric L-band Imaging Scatterometer (PLIS), with additional thermal infrared radiometer and multispectral sensors for monitoring of vegetation properties and surface temperature. SMAPEX has been undertaken in the “Yanco” study area, a semi-arid agricultural area in the Murrumbidgee catchment, south-eastern Australia. The main flights include coverage of a 36km x 38km area, equivalent to a SMAP radiometer pixel, with a 2-3 days "revisit" time to simulate SMAP observations both in spatial and temporal resolution. These airborne observations were undertaken at approximately 3000m (AGL) altitude to provide radiometer and radar data and derived soil moisture content at respectively 1km and 10-30m. Auxiliary flights...
Normalization to 40° for PLIS

8 strips from 8 flights (HH-polarization)
Incidence angle: 42.5°~37.5°
Normalization to 40° for PLIS

Note: The CDFs used in this study are from small sample sizes. Results may be improved by using a larger sample of data.
Normalization to 40° for PLIS

Normalized flight (HH-pol)

<table>
<thead>
<tr>
<th>RMSE (dB)</th>
<th>10m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>5.7</td>
</tr>
<tr>
<td>Normalized</td>
<td>3.7</td>
</tr>
</tbody>
</table>

RMSE vs Angle (1° /
Normalization to 40° for PLMR
Normalization to 40° for PLMR

<table>
<thead>
<tr>
<th>Normalized flight (7°, H-pol)</th>
<th>1km</th>
<th>3km</th>
<th>6km</th>
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<tbody>
<tr>
<td>RMSE (K)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Original</td>
<td>13.7</td>
<td>12.6</td>
<td>11.2</td>
</tr>
<tr>
<td>Normalized</td>
<td>7.4</td>
<td>5.7</td>
<td>3.0</td>
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<table>
<thead>
<tr>
<th>Normalized flight -- 22°</th>
<th>1km</th>
<th>3km</th>
<th>6km</th>
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<tbody>
<tr>
<td>RMSE (K)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Original</td>
<td>11.6</td>
<td>7.2</td>
<td>6.6</td>
</tr>
<tr>
<td>Normalized</td>
<td>6.7</td>
<td>4.0</td>
<td>2.9</td>
</tr>
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</table>
Azimuth effect for PLIS

Reference

Normalized to 40° at HH-pol
Azimuth effect for PLIS

RMSE vs Azimuth direction for PLIS

Reference
Azimuth=240

at 10m

at 100m

at 500m

MONASH University
Azimuth effect for PLMR

Reference (40°, H-pol)

RMSE vs Azimuth direction for PLMR
UpScaling for PLIS

<table>
<thead>
<tr>
<th></th>
<th>50m</th>
<th>150m</th>
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<tbody>
<tr>
<td>RMSE (dB) of upscaling</td>
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<td>2.1</td>
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<table>
<thead>
<tr>
<th></th>
<th>10m</th>
<th>100m</th>
<th>500m</th>
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</thead>
<tbody>
<tr>
<td>RMSE (dB) of normalisation</td>
<td>3.7</td>
<td>2.0</td>
<td>1.8</td>
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Upscaling for PLMR

Panciera, Walker et al. (2009), RSE
Example of simulated data

(Data collected on 7th Sept. 2011)
Baseline downscaling algorithm for SMAP

- Near-linear relationship between Radar backscatter and Brightness Temperature (ATBD, algorithm for SMAP mission)

\[ \beta \text{ estimation} \]

\[ \gamma \text{ estimation} \]

\[ T_B(C) + \beta \times (\sigma_{vv}(M) - \sigma_{vv}(C)) + \gamma \times (\sigma_{hv}(C) - \sigma_{hv}(M)) = T_B(M) \]

See Poster by Wu et al. tomorrow
### Active-passive downscaling results

<table>
<thead>
<tr>
<th></th>
<th>D2</th>
<th>D5</th>
<th>D9</th>
<th>Average</th>
</tr>
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<tbody>
<tr>
<td>Pol.</td>
<td>H</td>
<td>V</td>
<td>H</td>
<td>V</td>
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<tr>
<td>1km</td>
<td>12.2</td>
<td>9.6</td>
<td>10.8</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td>11.4</td>
<td>9.4</td>
<td>9.6</td>
<td>8.0</td>
</tr>
<tr>
<td>3km</td>
<td>9.4</td>
<td>7.4</td>
<td>7.1</td>
<td>5.3</td>
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<tr>
<td></td>
<td>9.0</td>
<td>7.3</td>
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<td></td>
<td>7.1</td>
<td>6.3</td>
<td>4.0</td>
<td>3.3</td>
</tr>
</tbody>
</table>

- Results on V-pol are better than H-pol
- Improvement by including vegetation conditions
Passive microwave soil moisture retrieval

- SMAPEX-1 and SMAPEX-2 target pixels (100m)
- Retrieval using default model parameters
- Pixels with VWC sampled at exactly the same location

RMSE = 0.05
Bias = -0.004
Passive microwave soil moisture retrieval

All pixels, with averaged VWC for each type of land cover
Active microwave VWC retrieval

Vegetation Water Content and Depolarization - SMAPEX-3

All channels

de-polarization ratio HV-VV [dB]
Active microwave soil moisture retrieval

Alfa approximation change detection testing - SMAPEx3

Dielectric constant [\%]

Day
Future work

• Try and eliminate any angle normalisation contributions to the azimuth and scaling results and assess georegistration contributions

• Undertake soil moisture retrievals from 1km PLMR (passive only), validated with higher resolution PLMR data and ground observations, for evaluation of SMAP soil moisture retrieval algorithms based on simulated SMAP data

• Testing of SMAP default radiometer parameters

• Testing of SMAP radar baseline algorithms

• Testing of alternate active-passive downscaling algorithms; there is about 4K downscaling error in the current baseline algorithm
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