An Airborne Simulation of the SMAP Data Stream

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The Soil Moisture Active Passive mission

**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

**Algorithms**
Active Passive Retrieval and Downscaling
Airborne simulator

**L-band radiometer (PLMR)**
- Frequency/bandwidth: 1.413GHz/24MHz
- Polarisations: V and H
- Resolution: ~1km at 10,000ft flying height
- Incidence angles: $\pm 7^\circ$, $\pm 21.5^\circ$, $\pm 38.5^\circ$ across track
- Antenna type: 8 x6 patch array

**L-band radar (PLIS)**
- 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

**PLMR: Polarimetric L-band Multibeam Radiometer**

**PLIS: Polarimetric L-band Imaging SAR**
Motivation

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

TEST DATA

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

Downscaled product:
- $T_B$/SM at 9km

EVALUATION DATA

Reference dataset:
- $T_B$/SM at 1km

SMAP Data Simulation
Simulation of SMAP data

SMAP

<table>
<thead>
<tr>
<th>Radiometer $T_B$</th>
<th>36km</th>
<th>H&amp;V pol</th>
<th>L-band</th>
<th>Incidence angle: 40°</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radar $\sigma$</strong></td>
<td>3km</td>
<td>HH, VV &amp; HV pol</td>
<td>L-band</td>
<td>Incidence angle: 40°</td>
</tr>
<tr>
<td>Azimuth: rotating</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Incidence angle normalization**

**Aircraft simulator**

<table>
<thead>
<tr>
<th>PLMR $T_B$</th>
<th>1km</th>
<th>H&amp;V pol</th>
<th>L-band</th>
<th>Incidence angle: $\pm 7°$, $\pm 21.5°$ and $\pm 38.5°$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PLIS $\sigma$</strong></td>
<td>10-30m</td>
<td>HH, VV &amp; HV pol</td>
<td>L-band</td>
<td>Incidence angle: 15° - 45°</td>
</tr>
<tr>
<td>Azimuth: left/right of track</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An Airborne Simulation of the SMAP Data Stream
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°42.83'S</td>
<td>146°6.27' E</td>
</tr>
<tr>
<td>2</td>
<td>34°51.11'S</td>
<td>146°6.91' E</td>
</tr>
</tbody>
</table>
Caveat

- Calibration solutions used here for PLIS are still preliminary
- Absolute calibration accuracy for PLIS based on SMAPEx-3 is ~0.8dB
- Application of a specific SMAPEx-3 calibration to other dates results in ~1.5dB error

- The calibration procedure for PLMR is mature and is accurate to ~2K
Normalization to 40° for PLIS

8 strips from 8 flights (HH-polarization)
Incidence angle: 42.5°~37.5°

Reference 40° map
Normalization to 40° for PLIS

See poster: WEP. P. 5, Wednesday 25th July 17:20-19:00

“A cumulative distribution function based method for normalising …”
Normalization to 40° for PLIS

(1° / ~90m)
Normalization to 40° for PLMR
Normalization to 40° for PLMR

normalized flight (7°, H-pol)

<table>
<thead>
<tr>
<th>RMSE(K)</th>
<th>1km</th>
<th>3km</th>
<th>6km</th>
</tr>
</thead>
<tbody>
<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>
</tr>
</tbody>
</table>

Normalized flight -- 22°

<table>
<thead>
<tr>
<th>RMSE (K)</th>
<th>1km</th>
<th>3km</th>
<th>6km</th>
</tr>
</thead>
<tbody>
<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>
</tbody>
</table>
Azimuth effect for PLIS

Reference
270°

240°

210°

150°

120°

90°

Normalized to 40° at HH-pol

MONASH University

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Azimuth effect for PLIS

RMSE vs Azimuth direction for PLIS

Reference

Azimuth=240

at 10m

at 100m

at 500m

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Azimuth effect for PLMR

Reference (40°, H-pol)

RMSE vs Azimuth direction for PLMR
## Upscaling for PLIS

### RMSE (dB) of upscaling

<table>
<thead>
<tr>
<th></th>
<th>50m</th>
<th>150m</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE</td>
<td>5.1</td>
<td>3.3</td>
</tr>
</tbody>
</table>

### RMSE (dB) of normalisation

<table>
<thead>
<tr>
<th></th>
<th>10m</th>
<th>100m</th>
<th>500m</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE</td>
<td>4.7</td>
<td>2.3</td>
<td>2.9</td>
</tr>
</tbody>
</table>
Upscaling for PLMR

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

(Data collected on 23rd Sept. 2011)
Future work

• Refine the PLIS calibration and repeat the analysis

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

• Produce a time sequence of simulated SMAP data

• Undertake soil moisture retrievals from 1km PLMR (passive only), validated with higher resolution PLMR data and ground observations, for:
  • Evaluation of SMAP downscaling algorithms based on simulated SMAP data from airborne simulator, and
  • Evaluation of proposed active-passive retrieval algorithms using 1km and 36km radar/radiometer data
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