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

An Airborne Simulation of the SMAP Data Stream
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 x 6 patch array

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

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

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

**Aircraft simulator**

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

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

Azimuth:
- SMAP: rotating
- Aircraft simulator: left/right of track
Study site

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
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°
Normalization to 40° for PLIS

Original flight (HH-pol)  Normalized flight (HH-pol)  Reference (HH-pol)

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

<table>
<thead>
<tr>
<th>Incidence Angle (degree)</th>
<th>RMS Values (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>Original 7.5</td>
</tr>
<tr>
<td>40</td>
<td>Normalized 4.7</td>
</tr>
<tr>
<td>35</td>
<td>Normalized 2.9</td>
</tr>
<tr>
<td>30</td>
<td>Normalized 2.3</td>
</tr>
<tr>
<td>25</td>
<td>Normalized 1.8</td>
</tr>
</tbody>
</table>

(1° / ~90m)

An Airborne Simulation of the SMAP Data Stream
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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</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>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Normalized flight -- 22°</th>
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</thead>
<tbody>
<tr>
<td>RMSE (K)</td>
</tr>
<tr>
<td>Original</td>
</tr>
<tr>
<td>Normalized</td>
</tr>
</tbody>
</table>
Azimuth effect for PLIS

Reference

270°

240°

210°

150°

120°

90°

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

An Airborne Simulation of the SMAP Data Stream
Azimuth effect for PLMR

Reference (40°, H-pol)

RMSE vs Azimuth direction for PLMR
# Upscaling for PLIS

![Image of upscaling for PLIS](image)

<table>
<thead>
<tr>
<th>RMSE (dB) of upscaling</th>
<th>50m</th>
<th>150m</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>5.1</td>
<td>3.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RMSE (dB) of normalisation</th>
<th>10m</th>
<th>100m</th>
<th>500m</th>
</tr>
</thead>
<tbody>
<tr>
<td></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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