Two-Look Polarimetric (2LP) Microwave Radiometers for Ocean Vector Wind Retrieval

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Remote Sensing Systems

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Introduction

• US Department of Defense (DoD) recently funded a number of studies to defined future MW Weather Sensors (follow-on to SSM/I and SSM/IS programs)
• This time, priority was given to Ocean Vector Wind Retrievals
• Low-Cost was also a major requirement
• At least two of these studies recommended a two-look polarimetric (2LP) microwave radiometer: full 360° view, fully polarimetric.
• JPL’s 2LP radiometer, called the Compact Ocean Wind Vector Radiometer (COWVR) is currently selected for a space demonstration in the 2016 timeframe.
COWVR Instrument Overview

- Fully polarimetric microwave radiometer (18 channels):
  - 18.7, 23.8, 33.9 GHz
  - V,H,+45,-45,LCP,RCP
  - < 0.3 K TB uncertainty

- 360° conical imaging
  - Rotation rate: 30 RPM
  - Spatial resolution: < 35 km
    - 34x21 km@18.7 GHz; 18x11 km@33.9 GHz
  - Swath width: 1012 km
  - Earth Incidence Angle: 51.7°

- Internal Calibration
  - Correlated noise sources
  - PIN-diode Dicke switches

- Resources
  - Data rate: 77 kbps
  - Mass: 58.7 kg
  - Avg. Power: 41 W (inst. power)

- Heritage
  - Jason-2/3 Advanced Microwave Radiometer

- EDRs
  - Wind vector, precipitation, sea ice, precipitable water, cloud liquid water, snow depth, tropical cyclone intensity

For information on COWVR contact Shannon Brown (PI) shannon.t.brown@jpl.nasa.gov
Predicting 2LP Performance with WindSat

- Predict the performance of 2LP radiometers using actual WindSat fore and aft observations.
- First Time (to our knowledge) WindSat fore and aft data have been simultaneously used for retrievals
- Focus on performance before ambiguity removal algorithm to look at inherent skill of sensor
  - Skill Rate: Percentage of time first-ranked ambiguity is closest to true direction
  - Standard Deviation of First-Rank Ambiguity relative to buoys
2LP OVW Chi-Squared Algorithm

\[ \chi^2(\phi_{W,j}) = \sum_i \left[ \frac{T_{B,meas,i} - T_{B,rtm}(T_S, W, \phi_{W,j}, V, L, \theta_i, \varphi_i)}{\text{var}(T_{B,i})} \right]^2 \]

- RSS RTM: Meissner and Wentz [2006]; Meissner and Wentz [2012]
- 18 ‘Flavors’ of Observations provide a unique determination of wind direction.

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Channel Combination</th>
<th>Expected Error (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.7 GHz</td>
<td>V for-aft</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>H for-aft</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>T3 for</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>T3 aft</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>T4 for</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>T4 aft</td>
<td>0.2</td>
</tr>
<tr>
<td>18.7 GHz</td>
<td>V for-aft</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>H for-aft</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>T3 for</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>T3 aft</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>T4 for</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>T4 aft</td>
<td>0.1</td>
</tr>
<tr>
<td>37.0 GHz</td>
<td>V for-aft</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>H for-aft</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>T3 for</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>T3 aft</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>T4 for</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>T4 aft</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Satellite Datasets

- **WindSat 2LP**
  - Hilburn [2014]
  - Hilburn, Meissner, Wentz, and Brown [in preparation]
  - Time period: 2003-2014

- **QuikScat (V4)**
  - Ku-2011 GMF: Ricciardulli and Wentz [2011]
  - Time period: 1999-2009

- **ASCAT (V1)**
  - Consistent GMF for Ku- and C-bands: Ricciardulli and Wentz [2012]
  - Scatterometer Climate Data Records: Ricciardulli and Wentz [2014]
  - Time period of available data: 2007-2011

- **Quality-control**
  - “Rain free” requires radiometer rain = 0 mm/hour
  - Use sweet zone (3 or more flavors) for QuikScat, unless otherwise noted as full swath
  - Exclude retrievals with large sigma-0 residual (larger than 1.9)
In Situ Datasets

- Buoys: NDBC, MEDS, TAO, TRITON, PIRATA, RAMA
- Spatial radius: 25 km
- Temporal radius: 30 minutes
- WindSat had significant data outages in 2005
- From 2012 onward, buoy collocations decrease due to NOAA budget cuts for annual servicing
WindSat 2LP vs Chi-Square Residual

- The WindSat 2LP algorithm returns ambiguities ranked by sum of measured minus model TB difference squared, weighted by inverse of expected variance

- **TOP:**
  - The skill rate is better than 85% for residuals below 0.2 K, which is 90% of the vectors
  - The skill rate is better than 60% for residuals below 0.7 K, which is 99.6% of dataset

- **BOTTOM:**
  - Residuals above 0.7 K do not preferentially select either low or high winds
  - Thus, using 0.7 K as q/c threshold for rest of the statistics in this presentation; removes 0.4% of data
First Ranked Ambiguity vs Buoy Direction

- Shown: percentage of data in 3 deg by 3 deg bins of wind direction (meteorological)
- Rain free, buoy wind speeds > 3 m/s
- Dashed lines: +/- 20 deg

<table>
<thead>
<tr>
<th>Dataset</th>
<th>% within 20 deg of buoy</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCAT</td>
<td>54.45</td>
</tr>
<tr>
<td>QuikScat</td>
<td>82.18</td>
</tr>
<tr>
<td>QuikScat (full)</td>
<td>74.08</td>
</tr>
<tr>
<td>WindSat</td>
<td>72.90</td>
</tr>
</tbody>
</table>
Skill Rate vs Wind Speed

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Skill Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCAT</td>
<td>58.7</td>
</tr>
<tr>
<td>QuikScat (full)</td>
<td>79.6</td>
</tr>
<tr>
<td>WindSat</td>
<td>85.3</td>
</tr>
<tr>
<td>QuikScat</td>
<td>87.6</td>
</tr>
</tbody>
</table>
The only satellite to achieve better than 20 deg SD for FRA is WindSat, which does so for winds above 7 m/s.

WindSat achieves about 10 deg SD for winds above 10 m/s.

Understand that SDs > 50 deg (i.e. ASCAT) are due to relatively small number of very large differences (usually +/- 180 deg).

QuikScat SD are slightly better than WindSat for winds below 6 m/s.

QuikScat full swath is considerably worse than sweet zone for most winds.

QuikScat SD increases for winds above 9 m/s.

2LP radiometers do not require an ancillary wind field for ambiguity removal for winds above 6-7 m/s.
One-look has problems in:

- Low wind speeds (1, 3, 6)
- Near rain (2, 4)
- Moderate winds (5)
- Convergence zone (heavy black line) not clearly defined because of noisy vectors
Every vector is plotted

Date: 2008-01-01

Two-look is better in:

- Low wind speeds (1,3,6)
- Near rain (2,4)
- Moderate winds (5)
- Convergence zone (heavy black line) is clearly defined
Sea of Japan: Quik-Scat Example

- Different time of day
- Convergence zone... what convergence zone?
Conclusions

• 2LP radiometers provide ocean surface vector winds of comparable accuracy to scatterometers
• Vector wind retrievals from 2LP radiometers do not require an ancillary wind field for ambiguity removal for winds above 6-7 m/s.
• 2LP radiometers can also provide a full suite of climate variables:
  • Sea surface temperature through clouds (C-band required)
  • Total water vapor
  • Cloud liquid water path
  • Surface rain rate
  • Sea-Ice and snow
• Performance in rain need to be investigated

2LP Radiometers Appear to be a Cost-Effective Alternative for Sustainable OVW Climate Measurements

Take A Look For Yourself: 11 Years of Retrievals – REMSS.COM