RFI in passive remote sensing of Ocean Parameters

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GEOSS Workshop XXXVII – Data Quality and Radio Spectrum Allocation Impact on Earth Observations

Honolulu, Hawaii, USA
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Conclusion: Bandwidth Filter

- **AMSR-2 on GCOM-W1 (2011)**
  - Bandwidth Filter @ 10.65 GHz

- **AMSR-3 on GCOM-W2 (2015)**
  - May also Filter @ 18.7 GHz ???
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Protected Bands

- 7.9 GHz
  - None?

- 10.65 GHz
  - 10.68 – 10.70 global protection (for radio astronomy)
  - 10.60 – 10.68 local (threat of aeronautical mobile)

- 18.7 GHz
  - None?

PM EO requirements differ from Radio Astronomy
  - AMSR-E integration time = 2.5 milliseconds
  - Global Coverage
RFI

- **ground / ship based**
  - Ascension Island, Hawaii, Netherlands, etc.
- **GeoStationary Satellites**
  - Media Broadcasts (TV, Radio)
    - **Power**
    - **Direction**
    - **Frequency**
  - *Glint Angle*
    - A.K.A. “RFI Angle”
Geostationary RFI @ 10.65 GHz

Astra: 19.2° East Longitude

( RFID from 19° not obvious in eastern Mediterranean; highly consistent with power images shown here. )

Hotbird: 13.0° East Longitude

Astra: 19.2° E ▲

Hotbird: 13.0° E ▶
AMSR-E GeoStationary Glint Angles: 10°

10.65 GHz
SoM (2002-Jun)
AMSR-E GeoStationary Glint Angles: 15°

10.65 GHz SoM (2002-Jun)
AMSR-E GeoStationary Glint Angles: 20°

10.65 GHz SoM (2002-Jun)
Ascending passes

- Typical day of AMSR-E: 1:30 PM (daytime passes)
- RFI glint angles from: Hotbird, Astra and DirecTV
Satellite TV

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Longitude</th>
</tr>
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<tbody>
<tr>
<td>Astra (19.2° E)</td>
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<tr>
<td>Hotbird (13.0° E)</td>
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<tr>
<td>DirecTV-10 (102.8° W)</td>
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<tr>
<td>DirecTV-11 (99.2° W)</td>
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<td>Atlantic Bird 4A (7.2° W)</td>
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<tr>
<td>DirecTV-12 (102.8° W)</td>
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Year:
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
# Ocean Products

<table>
<thead>
<tr>
<th></th>
<th>6.9</th>
<th>10.65</th>
<th>18.7</th>
<th>23.8</th>
<th>36.5</th>
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<tbody>
<tr>
<td>SST Very Low</td>
<td>X</td>
<td>X</td>
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<tr>
<td>SST Low Res</td>
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<tr>
<td>Wind Low Res</td>
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<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Wind Med Res</td>
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<td>X</td>
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<td>X</td>
</tr>
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<td>x</td>
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<td>x</td>
</tr>
<tr>
<td>Wind Low Res</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Wind Med Res</td>
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<td>x</td>
<td>x</td>
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<tr>
<td>Water Vapor</td>
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<td>x</td>
<td>x</td>
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<tr>
<td>Cloud Liquid</td>
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<td>Rain Rate</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
AMSRE, 2008-Apr-10, Descending Passes
Surface Wind Speed, Zoom Factor = 2

Statistics:
- Min: 0.00
- Max: 15.80
- Mean: 6.58
- Rms: 2.57

Histogram:
- 0
- 1200
- 1860
- 620
- 0
- 5

18.7 GHz RFI

Map showing wind speed data with highlighted areas of RFI.
10.65 GHz RFI / AMSR-E / Europe

- SST low res (11 GHz +)
- Wind med res (18 GHz +)
- SST very low (7 GHz +)
- Wind low res (11 GHz +)
SST RFI Maps

• No RFI Filters Applied
• SST Low Res – SST Very Low Res
• Yearly Averages
• AMSR-E Mission Years 1 – 7
• Descending Passes
  – Geostationary -> Northern Hemisphere
SST RFI Maps

- No RFI Filters Applied
- SST Low Res – SST Very Low Res
- Yearly Averages
- AMSR-E Mission Years 1 – 7
- Ascending Passes
  - Geostationary -> Southern Hemisphere
ÅMSR-E Year 2

Δ SST (°C)
Old Version (~2005) Outdated
RFI Glint angle (17° in North Sea)
RFI increasing (power, freq, sources...?)
Filter All RFI angles < 25°
(heavy data loss)
Filter All RFI angles < 25°
(heavy data loss)

Atlantic Bird 4A @ 7.2 ° W

AMSRE 2009-April
Filter All RFI angles < 25°
(heavy data loss)
RFI angles vary regionally
Atlantic Bird 4A filtered
Ground sources filtered
Chi-square probability, October 1, 2009 – December 31, 2009

WindSat-NRL Ascending view of Sky Brazil and EutelSat W2A

Data image courtesy of:
Ian Stuart Adams / Michael H. Bettenhausen / Li Li / Peter W. Gaiser
Remote Sensing Division / Naval Research Laboratory / Washington, DC
Eutelsat W2A at 10.0°E

Latest additions: Atlantic Bird 4A and Eutelsat W2A

Global

Europe

Africa
WindSat-NRL / Decending / 2003

Data image courtsey of:
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Ocean-Reflected Radio-Frequency Interference

Overview

Ocean-Reflected RFI (a.k.a. Geostationary Glint)
The proliferation of fixed-satellite service (FSS) systems has led to unprecedented global access to telecommunications. Such systems rely on geostationary satellites to broadcast signals to a predetermined region where receivers are configured to intercept these signals, which are broadcast within controlled radio-frequency bands. Some of these allocated bands are shared with or are adjacent to bands that have been allocated for passive Earth exploration-satellite service (EESS), i.e., passive satellite remote sensing. While FSS systems focus downlinks towards terrestrial users, the finite properties of antenna patterns combined with the concentration of populations in coastal regions result in considerable levels of radiation targeting coastal oceans. It is this radiation that reflects off the ocean surface and into the field-of-view of space-borne microwave radiometers. The sensitivity of radiometers, particularly those with polarimetric capabilities, means even small levels of radio-frequency interference (RFI) can corrupt geophysical retrievals.

Frequency Information

<table>
<thead>
<tr>
<th>WindSat Description</th>
<th>AMSR-E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freq. (GHz)</td>
<td>Channels</td>
</tr>
<tr>
<td>6.8</td>
<td>v/h</td>
</tr>
<tr>
<td>10.7</td>
<td>v/h, +/-45, lhc/rhc</td>
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“fully stabilized marine satellite TV systems, brings you digital satellite TV entertainment, including HDTV, whether you’re at anchor or offshore”

(NOT Seen in AMSR-E)
Challenges

- RFI can be strong compared to Earth’s passive emissions
  - 10° K common
  - Correction very difficult compared to, for example:
    - 2° K lunar contamination in cold mirror
    - 5° K swath edge contamination
  - RFI contaminated data flagged and removed
    - So far no corrections attempted
  - Fairly easy to identify and flag strong RFI
    - Even easier to overflag and lose good data

- Weak RFI difficult to detect
  - Not bad for some applications (NRT, weather, …)
  - Not good for climate data records
Moving Target

- RFI is changing constantly
  - Ground sources often sporadic / intermittent
  - Geostationary glint angles are easy, but:
    - New satellites are launched
    - Satellites are launched with reserve capacity
      » New transponder beams serving new markets
      » New frequency channels come online anytime

- Should RFI be filtered:
  - Consistently across time span of dataset?
  - As needed to remove growing RFI?
Negative Impacts on Data

- **7.9 GHz**
  - SST (very low res)

- **10.65 GHz**
  - SST
  - Wind (low res)

- **18.7 GHz**
  - SST (mostly in cold waters)
  - Wind
  - Vapor, cloud, rain:
    - Effect is more subtle, but causing much data loss
    - Throwing out much good data with filter
Negative Impacts on Data

- SSTs, especially in Mediterranean and North Sea
  - AMSR-E nighttime (1:30 AM) passes heavily impacted
  - Diurnal Warming Studies impacted
  - Foundation SSTs impacted

- Trend Studies
  - RFI may cause spurious trends
    - Trends should be examined regionally
Temperature Trends

- Oxygen channels (MSU 50.3 - 57.95 GHz) safe from RFI???
- Collision avoidance systems in development?
- Take / Buy back frequencies near protected bandwidth
  - Broadcast compression can do more with less
- Cluster geostationary satellites to minimize impact
  - Many spaced evenly over globe, some clustered (DirecTV)
- Yaw to face poles (4x/day; 160 times more often than TRMM)
- Forward and rear look (like WindSat)
- Keep observation bandwidth narrow
  - example: WindSat wider than AMSR-E @ 18.7 GHz
  - Avoid trending wider; evaluate making narrower
  - Bandwidth Filters: keep the edge out
- Work with it: Adaptive Algorithms
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Sub Bands?
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Mahalo