MiRS Algorithm for the SNPP/JPSS/GCOM-W
-Science and Products Overview-

Presented by

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- JPSS Program
- JCSDA

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- CIRA team
- OSPO team
- NPROVS team
- JPL team
- IPWG/UMD team
- CPTEC team/Brazil

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MiRS Concept

Conceptually, MiRS is the mirror image of CRTM

X: State vector of Geophysical Parameters (T, Q, Tskin, etc)

Y: State vector of Radiometric Measurements (MW, IR, etc)

K: Jacobians dY/dX

MiRS

X

Y + K
1D-Variational Retrieval/Assimilation

MiRS Algorithm

Measured Radiances

Simulated Radiances

Comparison: Fit Within Noise Level?

Yes

Solution Reached

No

Update State Vector

New State Vector

Update State Vector

Simulated Radiances

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MiRS General Overview

Vertical Integration and Post-Processing

Temp. Profile
Humidity Profile
Liq. Amount Prof
Ice. Amount Prof
Rain Amount Prof
Emissivity Spectrum

Core Products

TPW
RWP
IWP
CLW

1DVAR Outputs

-Sea Ice Concentration
-Snow Water Equivalent
-Ice Age
-Snow effective grain size
-Snow Pack Properties
-Land Moisture/Wetness
-Rain Rate
-Snow Fall Rate
-Wind Speed/Vector
-Cloud Top
-Cloud Thickness
-Cloud phase

May 2014
STAR JPSS Annual Science Meeting
Main Characteristics

- Significant leverage of RT science (and Jacobians) by using CRTM
- Resiliency to noise increases, channel failures.
- Valid for sensors for which CRTM is valid
- Trivial to extend to new sensors (main effort is validation)
- Valid in cloudy/precipitating conditions (as long as CRTM is valid)
- Valid over all surfaces (thanks to emissivity part of the state vector)

Most important:
- **Scientifically**: Consistent retrieval of parameters (atmos., cryosph., surface, hydrometeors) fitting channels simultaneously
- **Programmatically**: Cost effective approach (~ 7-13 products depending on sensor, ~10 sensors, sustained with a team of ~4-5)
## Applicability of MiRS –Products–

### Official Products

1. Temperature profile  
2. Moisture profile  
3. TPW (global coverage)  
4. Surface Temperature  
5. Emissivity Spectrum  
6. Surface Type  
7. Snow Water Equivalent (SWE)  
8. Snow Cover Extent (SCE)  
9. Sea Ice Concentration (SIC)  
10. Cloud Liquid Water (CLW)  
11. Ice Water Path (IWP)  
12. Rain Water Path (RWP)  
13. Rainfall rate

### Products being investigated

1. Cloud Profile  
2. Rain Profile  
3. Atmospheric Ice Profile  
4. Snow Temperature (skin)  
5. Sea Surface Temperature  
6. **Effective Snow grain size**  
7. **Multi-Year (MY) Type SIC**  
8. **First-Year (FY) Type SIC**  
9. Wind Speed  
10. Soil Wetness Index
MiRS is applied to a number of microwave sensors, each time gaining robustness and improving validation for Future New Sensors

- The same executable, forward operator, covariance matrix used for all sensors
- Modular design
- Cumulative validation and consolidation of MiRS

Applicability of MiRS – Sensors:

- DMSP SSMIS F16/17/F18
- Metop-A, B AMSU/MHS
- POES N18/N19
- AQUA GCOM-W AMSR-E, 2
- NPP/JPSS ATMS
- Megha-Tropiques SAPHIR/MADRAS
- TRMM/GPM TMI, GMI

✓: Applied Operationally (8)
✓: Research Mode or Routine processing (3)
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SNPP/ATMS
MiRS/ATMS Imagery & Sounding

MiRS/ATMS TPW

MiRS/ATMS T(p) -100mb-

MiRS/ATMS T(p) -200mb-

Presentation dedicated to MiRS-based Soundings will be given by C. Grassotti

TPW Diff. wrt ECMWF

100mb T(p) Diff. wrt ECMWF

200mb T(p) Diff. wrt ECMWF
Performances of MiRS TPW in exclusively rainy conditions over ocean surfaces present a good correlation, low bias and standard deviation.

### Summary of TPW Performance

<table>
<thead>
<tr>
<th></th>
<th>Bias (mm)</th>
<th>Stdv (mm)</th>
<th>Corr.</th>
<th>RMSE (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean</td>
<td>0.46</td>
<td>2.55</td>
<td>0.98</td>
<td>2.59</td>
</tr>
<tr>
<td>Land</td>
<td>0.48</td>
<td>4.47</td>
<td>0.95</td>
<td>4.50</td>
</tr>
<tr>
<td>Sea-Ice</td>
<td>0.42</td>
<td>1.28</td>
<td>0.82</td>
<td>1.35</td>
</tr>
<tr>
<td>Snow</td>
<td>0.25</td>
<td>0.89</td>
<td>0.93</td>
<td>0.92</td>
</tr>
</tbody>
</table>

### Comparison vs. ECMWF

<table>
<thead>
<tr>
<th></th>
<th>SNPP bias/stdv (mm)</th>
<th>NOAA-19 bias/stdv (mm)</th>
<th>Metop-A bias/stdv (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean</td>
<td>7.25/15.40 (%)</td>
<td>8.26/15.69 (%)</td>
<td>8.89/13.7 (%)</td>
</tr>
<tr>
<td>Land</td>
<td>2.39/23.65 (%)</td>
<td>5.68/23.76 (%)</td>
<td>2.57/22.11 (%)</td>
</tr>
</tbody>
</table>

### Comparison vs. Radiosonde

- **SNPP**: 7.25/15.40 (%), 8.26/15.69 (%), 8.89/13.7 (%)
- **NOAA-19**: 2.39/23.65 (%), 5.68/23.76 (%), 2.57/22.11 (%)

### Angle dependence of MiRS TPW Perfs in Rainy Sky - Ocean Surfaces

No significant scan dependence in the TPW differences with NWP analyses.
- Good performances of MiRS/ATMS wrt SURFARD ground measurements (correlation of 0.79)

- Performances are also consistent when snow is detected over the surface (green dots)
Right – Time series of MiRS SIC performance (NH) for various sensors (ATMS in Orange)

Bottom – Monthly SIC from MiRS ATMS for 2013
Independent RR Validation (IPWG)

- Monitor a running time series of statistics relative to rain gauges
- Intercomparison with other PE algorithms and radar
- MiRS composite uses all microwave sensors
- Tightening of RTM uncertainty in June 2011 improves POD & Heidke

**HEIDKE SCORE**

**RMSE**

**POD**
GCOM-W AMSR-2
Products from MiRS/AMSR2 include TPW, Cloud, SST, Emissivity, SIC, Age, Snow, LST, RR, and lower tropospheric sounding.

- Good agreement with ECMWF.
- Performances (2.35 mm std deviation) are similar to AMSU/MHS & SSMI/S instruments (global coverage).
Sea Ice Type (MY & FY): MiRS / OSI SAF

Qualitative assessment of the sea-ice type from MiRS (based on AMSR2 and POES data) by comparing it to EUMETSAT OSI SAF.

The OSI SAF algorithm uses a Bayesian method, SSMIS + ASCAT. It also uses estimates of uncertainty to weight the observations.
GCOM-W AMSR-2 has a number of window channels that are sensitive to different atmospheric column depths, presenting a potential for lower tropospheric moisture profiling.
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MiRS from microwave sensors are included in the blended TPW. Extension in progress (for more sensors, over sea-ice, snow, etc)

Slide courtesy of the OSPO website: Effort led by CIRA: S. Kidder, J. Forsyth, L. Zhao and R. Ferraro
The bias of RI index (between obs. and RII algorithm output) is 1.67 when MiRS/ATMS data is used as inputs and 1.87 when GFS is used.

Preliminary results for the RII forecast show up to 3.1% increase in Brier Skill Score with the use of MiRS/ATMS data, and for the center-fix algorithm up to 10% better center location as compared to the first guess position from the NHC real-time forecast positions.

Slide courtesy of Galina Chirokova and Mark DeMaria
### Data Assimilation Applications (MIIDAPS)

- **Efforts are on going to:**
  - Use MiRS technology (1DVAR) as a pre-processor to NWP
  - Allows uniform quality control of satellite data, rain and ice detection, coast contamination, RFI for imagers, etc
  - Implement dynamically-retrieved emissivity in the NWP
  - Assess assimilating sounding products in cloudy/rainy conditions

Goal is to have a community QC tool for satellite data assimilation pre-processing: extend the MIIDAPS to all Sensors (IR & MW, geo/Pol)
Time series of MiRS-derived Products

One algorithm approach
One radiative transfer
One set of assumptions,
Applied to all sensors, in all areas
In theory should make interpretation easier
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Recommendation & Future Plans

- **On-Going & Planned:**
  - Megha-Tropiques SAPHIR
  - GCOM-W AMSR-2
  - High spatial Resolution for existing sensors
  - To new Products: Sea Ice Age, Snow grain size
  - New Science: Dynamic Background (emissivity, sounding etc)
  - Extended validation using independent evaluations (RR, Soundings, SIC, IWP, Emiss, etc)

- **Leveraging NOAA Activities in Support of JCSDA:**
  - Strong coordination with JCSDA activities (MIIDAPS)
  - CRTM constant improvements
  - Cloudy& rainy radiance assimilation
  - Extension of MIIDAPS to IR sensors could benefit MiRS
  - Access to S4 supercomputer

- **Conclusions & Recommendations:**
  - MiRS is the consolidated algorithm at NOAA, for processing microwave sensors
  - It is applicable to ~10 sensors, to produce ~7-13 products for each sensor
  - It is expected it will be applied to JPSS ATMS sensors and GCOM-W AMSR2
  - Extension to IR, done in the context of MIIDAPS, could extend applicability
Hurricane Rapid Intensification

MiRS/ATMS T,RH profiles used to compute (case of Hurricane Leslie, 2012):
- Radial-height cross section
- Temperature Anomaly
- 500-800 mb averaged values

These are fed to:
- Maximum Potential Intensity (MPI) algor.

MPI is then fed to:
- Rapid Intensification Index (RII) algor.

Slide courtesy of Galina Chirokova and Mark DeMaria
NPROVS performs assessment and intercomparisons by comparing several algorithms/several sensors to common reference of radiosondes.
AMSR-2 Cryospheric Products

OSI-SAF Total SIC

OSI-SAF Total Ice Type

MiRS FY Ice Conc.

MiRS Total Ice Conc.

MiRS MY Ice Conc.
Inter Consistency in MiRS Retrievals for Climate Applications

Example of Tskin

Importance of the diurnal cycle and sensor measurement sampling in time and space
Advantages & Disadvantages of MiRS

- **Pros:**
  - Flexible and physical approach
  - Highly cost-effective: Cost to extend to new sensors greatly reduced (avoids stove-piping on both the sensors side and the products side).
  - MiRS can be consistently applied to sounders, imagers and combinations
  - MiRS uses the CRTM as forward operator (leverage of resources and science)
  - Applicable consistently on all surfaces and runs in all-weather conditions
  - Dual application for inversion and satellite data assimilation

- **Cons:**
  - Computationally expensive, although highly parallelizable (1D processing)
  - Cost effective approach, but need to sustain expertise in sounding, cryosphere, hydrometeors, surface emission, radiative transfer, calibration, etc in a single team (requires an efficient and strongly multi-disciplinary team)
  - Heavy constraints on the science approach: MiRS expected performances are the same as the single-product, single-sensor type algorithms, but with the significant added constraint that all parameters should fit all measurements simultaneously (keeps all results in check)