CRTM and Data Assimilation activities at STAR supporting JPSS

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Outline

- CRTM
  - Status
  - Cal/Val and algorithm support
  - Current and future development

- Data Assimilation
  - Current activities
  - STAR plans/priorities
CRTM activities
## CRTM Development History

**CRTM Version** | **Date** | **Enhancements** |
--- | --- | ---|
2.0/2.0.5 | 12/2011 | • New user interface |
2.1/2.1.1 | 3/2012 | • SOI solver  
• Fastem5  
• MW Land Surface Emissivity Model  
• NLTE Correction |
2.1.3 | 6/2013 | • Implement reflection correction in Fastem (use clear-sky trx)  
• Enhanced absorption coefficients (6 absorbers)  
• Solar irradiance in spectral coefficient files (CrIS)  
• IRSSEM improvements |
2.2.1 | 4/2015 | • Enable reflection correction for non-scattering clouds  
• Fastem6  
• Revert to box car SRF for SNPP ATMS |
2.2.3 | 8/2015 | • IRRSEM improvements |
2.3 (current) | 11/2017 | • NOAA-20 coefficients  
• ATMS snow and sea-ice emissivity models  
• Cloud fraction capability  
• Reflection correction (use cloudy trx)
## CRTM Cal/Val and algorithm support

### Applications applied to JPSS data

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>CRTM v.</th>
<th>Current use</th>
<th>Some desired enhancements?</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICVS</td>
<td>2.0.5-2.3</td>
<td>Forward operator, clear-sky, ocean</td>
<td>Ocean emissivity/reflectance modeling</td>
</tr>
<tr>
<td>MiRS</td>
<td>2.1.1</td>
<td>Forward operator, K-matrix, all-sky variational retrieval</td>
<td>Hydrometeor handling (scattering properties)</td>
</tr>
<tr>
<td>ACSPO</td>
<td>2.1.3</td>
<td>Forward operator, clear-sky, ocean</td>
<td>IRSSEM, reflectance enhancements, aerosol handling (species, scattering)</td>
</tr>
<tr>
<td>Enterprise Cloud Products</td>
<td>2.1.3</td>
<td>Long-wave IR clear-sky transmittance profiles</td>
<td>Shortwave IR transmittance, cloudy transmittances</td>
</tr>
<tr>
<td>Enterprise Volcanic Ash</td>
<td>2.1.3</td>
<td>Long-wave IR clear-sky transmittance profiles</td>
<td>Shortwave IR transmittance, cloudy transmittances</td>
</tr>
</tbody>
</table>

*All applications could benefit from improved efficiency*
CRTM current development

Expected to have impacts on JPSS sensors

• JCSDA partners collectively manage CRTM development (B. Johnson lead)
• STAR-led contributions to JCSDA CRTM project
  • Code management, new sensors, testing & maintenance, package/delivery of software
  • Surface emissivity modeling, BRDF improvements (CSEM)
  • Modernization of LBLRTM with through the Community Line-By-Line Model (CLBLM)
  • Extension to UV sensors
• Summary of other JCSDA projects
  • Fast solvers for scattering
  • Full Stokes polarization
  • Improvements to aerosol/hyrometeor scattering properties/LUTs
  • Improved code efficiency (vectorization/OpenMP)
• Next release is v3.0 ~Jan/Feb 2019
Objective: Release of the CSEM package and integration into CRTM

- CSEM is OOP-based system to compute emissivity and BRDF over all surfaces, in the MW, IR and Vis
  - Easy to integrate and test new emissivity models
  - Easy to interface with other tools (e.g. CRTM)
  - Includes tangent-linear and adjoint

Enhancements over existing CRTM surface emissivity models

<table>
<thead>
<tr>
<th>Microwave</th>
<th>Vis/IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved NESDIS Land Phys. Model</td>
<td>UW IR Emissivity Atlas (SEEBOR)</td>
</tr>
<tr>
<td>Semi-physical ATMS Snow Model</td>
<td>UW Vis/NIR BRDF Atlas (Vidot &amp; Borbas)</td>
</tr>
<tr>
<td>Semi-Physical ATMS Sea-ice Model</td>
<td></td>
</tr>
<tr>
<td>TELSEM 1, 2 (climatology)</td>
<td></td>
</tr>
</tbody>
</table>

CSEM can be used as a stand-alone package or interface with other tools
CRTM current developments (CSEM)
The Community Surface Emissivity Model (CSEM)

O-B over land using NESDIS Land Physical Model
(TOP: CRTM 2.3) (Bottom: CSEM)

REL 2.3
23.8GHz

REL 2.3
50.3GHz

TELSEM

CSEM

Demonstration of CSEM improvements

O-B over sea-ice for 50.3 GHz
(TOP: TELSEM) (Bottom: CSEM)

CSEM

REL 2.3

CSEM

CSEM

The Community Surface Emissivity Model (CSEM)
Objective: Development/release of the Community Line-By-Line Model (CLBLM)

- Monochromatic RTM to train CRTM fast model
- Modernization of heritage LBLRTM
  - Refactored/modular code
  - Improved I/O
  - Redesigned RT/Jacobian routines
  - Double line-shape convolution scheme for improved narrow-lines
- CLBLM Alpha released 1/2018
- CLBLM v1.0 released 8/2018
Data assimilation activities
Objective: Increase the number and quality of ATMS surface-sensitive (non-ocean) observations assimilated (NOAA GDAS/GFS)

• Requires accurate forward operator
• ...which requires accurate surface characterization (e.g. emissivity)

Implement in 2 phases

• Improve the background surface emissivity
• Implement surface emissivity as a control variable in the GSI

Compare Current Land Model in CRTM and TELSEM2 for background

<table>
<thead>
<tr>
<th></th>
<th>CRTM</th>
<th>TELSEM 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface type</td>
<td>All</td>
<td>Land &amp; sea-ice only</td>
</tr>
<tr>
<td>Frequency</td>
<td>3 – 190 GHz</td>
<td>10 – 700 GHz</td>
</tr>
<tr>
<td>Polarization</td>
<td>H + V</td>
<td>H + V</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>0.25°</td>
<td>0.25°</td>
</tr>
<tr>
<td>Temporal Resolution</td>
<td>Instantaneous</td>
<td>Monthly</td>
</tr>
<tr>
<td>Base</td>
<td>“Physical”</td>
<td>Empirical</td>
</tr>
</tbody>
</table>

CSEM improved Land Emissivity physical model will also be tested
Data assimilation activities

ATMS surface-sensitive radiance assimilation

### Improving the background: 31 GHz Emissivity from 2 GDAS Cycles

<table>
<thead>
<tr>
<th>O-B Stats</th>
<th>CRTM</th>
<th>TELSEM 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number count</td>
<td>4104</td>
<td>8050</td>
</tr>
<tr>
<td>Bias</td>
<td>-0.4</td>
<td>0.05</td>
</tr>
<tr>
<td>Std. dev.</td>
<td>2.0</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Replacing the background to use TELSEM2 increases x2 the number of observations assimilated (from 2 GDAS cycles)
Data assimilation activities
ATMS surface-sensitive radiance assimilation

Improving the analysis: O-B, O-A, and Obs Count from 9 GDAS Cycles

While replacing the background (orange) improves the observation count, implementing emissivity as control variable improves the analysis.

Further improvement can be realized:
• Use off-diagonal elements of emissivity covariance matrix
• Improve bias correction over land
CrIS and IASI shortwave IR 4 µm band assimilation
(Boukabara, Ide, Garrett, Barnet)
• Assess CRTM capability
  • NLTE, shortwave reflectance
• Extend global DA
  • Dynamic CO2/N2O, obs errors, etc.
• Assess analysis and forecast impact vs longwave IR

Improve PMW all-sky radiance retrieval/assimilation
• Utilize datasets like GPM 2BCSATGPM
  • Quantify accuracy of CRTM in precip for ATMS
• ... or GPROF
  • Training set to improve a-priori of hydrometeor microphysical properties

Chen et al. 2013

Data assimilation/CRTM activities
Other efforts at STAR
Summary
Focus on Future Efforts

Cal/Val Systems and Science Support from CRTM
• Address priorities and needs of STAR EDR, Cal/Val teams
  • Science needs, e.g. improvements to quality of output
  • Technical needs, e.g. supporting transitions to new versions

Science/Coordination Support for Data Assimilation
• Address priorities across STAR, NESDIS (program offices)
  • Assimilation of land EDRs (LST, GVF, soil moisture)
  • Assimilation of ocean EDRs (SST, color)
  • Assimilation of cryospheric products (IST, SIC, Snow Cover/SWE)
  • Assimilation of trace gases, aerosol (V8Tot/Pro, AOD)