Data Inter-comparisons of the CrIS Interferometers on Suomi-NPP and NOAA-20

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Outline

• Goals
• Approach
• Comparison Data Selection
• Radiative Transfer Code Inputs
• Initial Results
• Next Steps
Goal of this Effort

- Monitor CrIS interferometers by direct data comparison
  - Both sensor datasets must be consistent for maximum value
  - Continuous monitoring supports early problem detection
- SNPP and N-20 are in same orbit, 50 minutes apart
  - Simultaneous Nadir Overpasses (SNOs) never occur
  - Views overlap, but with geometry and time difference
- Current comparisons use SNO with intermediate reference
  \[(N20 - \text{ref}) - (SNPP - \text{ref}) = N20 - SNPP\]
  - Spectral reference data sources are:
    - AIRS spectrometer (on Aqua satellite)
    - IASI interferometers A and B (on Metop satellites)
- This study investigates use of a radiative transfer code to create another reference for continuous comparisons
CrIS Interferometer on NOAA-20/SNPP

SNPP and NOAA-20 in Polar Orbit

±50° Cross Track Scans

CrIS Swath 2200 km

ATMS Swath 2500 km

3x3 array of CrIS FOVs (each at 14-km diameter)

Cross-track Infrared Spectrometer 2x Global Coverage Twice Daily
Temporal and Spatial Separation

- **View geometry:** zenith (nadir) angles 10° to 60°
  - Azimuth angles: ~ 180° different
- **Time separation:** 50 minutes
  - Changing weather conditions
  - Solar effects (heating/cooling)
- **Spatial resolution:** Comparable to CrIS footprint (14 km nadir)
Clear Conditions Comparison Example

**Spectral Radiance**

- **LWIR**
- **MWIR**
- **SWIR**

**Brightness Temperature Difference**
Approach

\[ N20(\nu) - SNPP(\nu) = \Delta L_{atm}(\nu) + L_{error}(\nu) \]

\[ \Delta L_{atm}(\nu) = \text{radiance difference due to } \Delta WX (\text{atm, surface } T) \]
\[ L_{error}(\nu) = \text{error discrepancy of interest} \]

• Use atmospheric radiative transfer code to calculate \( \Delta L_{atm}(\nu) \)

\[ \Delta L_{atm}(\nu) = RT_{calc}(\nu)_{N20} - RT_{calc}(\nu)_{SNPP} \]

Then \( N20(\nu) - SNPP(\nu) - \Delta L_{atm}(\nu) = L_{error}(\nu) \)

• This study uses MODTRAN 6 as the radiative transfer code (RTcalc)
  – 0.1 cm\(^{-1}\) band models, CorK, and line-by-line option
  – Convolved with sinc function to match CrIS resolution

• The real challenge lies in determining model inputs
  – Require atmospheric profiles that match each CrIS measurement to compensate for weather condition differences
Comparison Selection Criteria

- Clear sky conditions
  - Clouds are too variable over 50-minute time scale
- For initial testing: clear sky ocean conditions
- Forecast models include cloud cover outputs that support automatic detection of clear areas
  - Combine results from all models for a robust result
  - Effective initial filter of CrIS data
- Currently use GIS software to create clear sky mask from weather model cloud cover, then extract CrIS view intersections within this clear area
- Plan to extend this to include clear sky land conditions
  - Eventual goal of automated selection for hands-off operation
Radiative Transfer Model Inputs

- Difficult part is not the model, but rather the inputs to the model
- Atmospheric inputs with sufficient fidelity to distinguish differences on scales that matter to a CrIS comparison
  - Temporal: 50 minutes
  - Spatial: 20 km or less
- Regional models have needed temporal and spatial resolution
  - Global models are developing in same direction
- Primary data needed for CrIS bands
  - Altitude profiles of T, H$_2$O, O$_3$, CO$_2$, CO, CH$_4$, N$_2$O
  - Surface temperature + emissivity
Molecular Contributions to Spectrum

![Spectrum Diagram]

- LWIR
- MWIR
- SWIR

CrIS Bands
Sources of Atmospheric Profile Data

- Global and regional numerical weather models used in this study
  
<table>
<thead>
<tr>
<th>Model</th>
<th>Temporal</th>
<th>Spatial</th>
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<tbody>
<tr>
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<tr>
<td>NAM</td>
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<td>0.05, 3 km</td>
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</table>

- Regional models meet resolution requirements but are incomplete
  - Daily forecast products (not archives) must be used
  - Missing ozone, end above the troposphere
  - Hybrid profiles necessary to fill in missing pieces

- The forecast models are steadily advancing in coverage/resolution
- Anticipate global coverage with this resolution within a year or two
Coverage of Regional Models Used

Rapid Refresh (RAP)
~11 km resolution

GFS and GEOS-FP have global coverage ~0.25°

NAM and HRRR CONUS
~3 km resolution

NAM and HRRRv3 Alaska
~3 km resolution
Additional Profile Data (not yet used)

- Trace gas vertical profiles
  - ECMWF – CAMS Near-Real-Time
    - O$_3$, CH$_4$, some NOx (but not N$_2$O)
  - NASA GEOS-FP
    - CO$_2$ and CO
- Ocean surface temperatures
- GFS high-resolution global skin temperature
  - Hourly, ~11 km resolution
- ECMWF 3 hr weather forecasts
- ECMWF Hires
- Re-analysis datasets (ERA-5)
Creating MODTRAN Inputs

- Profile data obtained through database queries of weather data near spatial location of ground footprint and time.
- User-defined atmosphere profile inputs generated from this data:
  - Pressure, temperature, altitude, water, and ozone.
- When profiles are incomplete, the global models are searched and provide data used to fill gaps and upper atmosphere.
- Surface temperature obtained from weather model.
- Additional inputs obtained from some models:
  - Visibility
  - Aerosol inputs
- Geometry created from satellite location and view angle.
Sample Atmospheric Profiles

• Composite profiles
  – Global models fill gaps and upper atmosphere
Examples of Correction Improvement LWIR

- Green: Residual from N20 – SNPP
- Black: MODTRAN correction ($M_{SNPP} - M_{N20}$)

- Green: Same residual N20 – SNPP
- Red: Residual after SDL’s correction
Green: Residual from N20 – SNPP
Black: MODTRAN correction (M_{SNPP} – M_{N20})

Green: Same residual N20 – SNPP
Red: Residual after SDL’s correction
SWIR Full-resolution Band

- Green: Residual from N20 – SNPP
- Black: MODTRAN correction ($M_{SNPP} - M_{N20}$)

- Green: Same residual N20 – SNPP
- Red: Residual after SDL’s correction
Comparisons in Progress

- **Initial Results**
  - Reduce discrepancy from ~1 K down to the 0.1 K range
  - Compensates for nadir angle differences well
  - RAP and NAM model results performing better than HRRR

- **Small sample size**

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1.141 0.180 0.197 0.201
Next Steps

• Initial results show encouraging trends
  – WX model data appears to have adequate temporal and spatial resolution to capture changes over the 50-minute interval between CrIS spectra
  – Current sample too small for any statistical conclusions yet

• MODTRAN 0.1 cm\(^{-1}\) band model option provides rapid answers at required fidelity

• SDL will work to refine these results and improve the profile selection
  – Additional profile and surface data sources will be added
  – Additional test cases to be added for comparisons over more of the sensor background signal range (near equator to poles)