Mapping CrIS Spectral Radiances of CO2 and Water Vapor Bands to VIIRS

Sunny Sun-Mack¹, Yan Chen¹, William L. Smith, Jr.², Patrick Minnis¹, Fu-Lung Chang¹

(1) SSAI, Hampton, VA, USA
(2) NASA Langley Research Center, Hampton, VA

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Outline

• Why is this work needed?
  • the issue with SNPP-VIIRS
  • Possible solution

• Methodology

• Data involved in the mapping

• Results: pixel level images, global maps, scatterplots…

• Summary & Future Plans
The Issue with SNPP-VIIRS

• Terra & Aqua MODIS contain Water Vapor (WV) and CO2 bands:
  
  6.72 µm
  13.34 µm
  13.64 µm
  13.94 µm
  14.23 µm

• Unfortunately, SNPP-VIIRS lacks of WV and CO2 bands.

Inconsistency in CERES data between CERES-MODIS & CERES-VIIRS
Possible Solution

- Cross-track Infrared Sounder (CrIS):
  
  CrIS & VIIRS two independent instruments, but on the same S-NPP platform

- CrIS, hyperspectral instrument, contains 3 spectral band ranges covering:
  
  650 – 1096 cm\(^{-1}\) (713 channels, sampling 0.625 cm\(^{-1}\)) \(\Leftarrow\) CO2
  1210 – 1750 cm\(^{-1}\) (433 channels, sampling 1.25 cm\(^{-1}\)) \(\Leftarrow\) WV
  2155 – 2550 cm\(^{-1}\) (159 channels, sampling 2.5 cm\(^{-1}\))

- Use CrIS to produce MODIS-like WV & CO2 radiances
One CrIS Scan

Scan width ~ 2200 km (VIIRS ~ 3000 km)
Contains 30 Field of Regard (FOR)
Each FOR ~ 50 km, contains 3x3 footprints
Each footprint ~ 14 km

(from Han et al. [2013])
One CrIS Scan

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Contains 30 Field of Regard (FOR)
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Each footprint ~ 14 km

(from Han et al. [2013])

VIIRS Pixel

VIIRS at ASDC
2 x 2

CERES VIIRS Ed1 Processing
2 x 8
Methodology

• Mapping software (NWP-SAF AAPP)
  ATOVS and AVHRR Pre-processing (AAPP) package provided by Satellite Application Facilities for Numerical Weather Prediction (NWP SAF). Mapping VIIRS to CrIS.

• Modified AAPP package so that it would map CrIS to VIIRS, instead of VIIRS to CrIS.
Methodology - Conti

- MODIS-like WV and CO2 radiances can be calculated as:

\[ L_\lambda = \frac{\sum_i I_i R_i}{\sum_i R_i} \]

CrIS hyper-spectral radiance at the channel \( i \)

- Use trapezoidal approximation to optimize the accuracy of the radiance calculation
Methodology - Conti

• Due to the coarse CrIS spatial resolution, some VIIRS pixels do not have CrIS mapped values. Therefore a regional average filling method was applied to those VIIRS pixels.

• Append the 6 calculated MODIS-like radiances of CO2 and WV bands to the VIIRS Level 1B files.

  6.72 μm
  7.33 μm
  13.34 μm
  13.64 μm
  13.94 μm
  14.23 μm
Data

- Test Data: September 19, 2015

- S-NPP VIIRS NetCDF4 Product from NASA GSFC Land SIPS (with the subsetter provided by CERES):
  VNP0203IMD_SS

- CrIS SDR products from NOAA CLASS (~1.5 GB/month)
  GCRSO: Geolocation
  SCRIS: Radiances

- Relative Spectral Response (RSR) from MODIS Characterization Support Team:
  https://mcst.gsfc.nasa.gov/calibration/parameters
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Brightness Temperature (K)

BTemp (VIIRS with CrIS)

RGB

BTemp (Aqua-MODIS)

RGB

WV: 6.7 µm

Sept. 19, 2015 UTC 0230

200

212

224

236

248

260
CO2: 13.3 $\mu$m

Sept. 19, 2015 UTC 0230

Brightness Temperature (K)

BTemp (VIIRS with CrIS) RGB BTemp (MODIS) RGB
WV: 6.7 µm
Brightness Temperature, September 19, 2015, Night Time

Aqua-MODIS

VIIRS with CrIS
VIIRS with CrIS minus Aqua-MODIS

WV: 6.7 µm

BTemp Difference, September 19, 2015, Night Time
WV: 6.7 µm

BTemp Difference, September 19, 2015, Night Time

VIIRS with CrIS minus Aqua-MODIS

Frequency (number of counts) that VIIRS and Aqua-MODIS having the same colocated overpass
BTemp Difference, September 19, 2015, **Day Time**

WV: 6.7 µm

**VIIRS with CrIS minus Aqua-MODIS**

**Frequency (number of counts) that VIIRS and Aqua-MODIS having the same colocated overpass**
Comparison of Brightness Temperature at 6.7 µm between VIIRS with CrIS and Aqua-MODIS

September 19, 2015, Co-located overpasses between Aqua-MODIS & VIIRS

Day Time

Night Time

<table>
<thead>
<tr>
<th></th>
<th>Mean (StdDev)</th>
<th></th>
<th>Mean (StdDev)</th>
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<tbody>
<tr>
<td>Aqua</td>
<td>236.4( 7.68)</td>
<td>VIIRS with CrIS</td>
<td>235.8( 7.51)</td>
</tr>
<tr>
<td>Y-X</td>
<td>-0.631( 0.993)</td>
<td>RMS</td>
<td>1.18</td>
</tr>
<tr>
<td>N</td>
<td>628219</td>
<td></td>
<td>1837247</td>
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</tbody>
</table>

R = 0.992
Y = 7.33309 + 0.966313*X

R = 0.996
Y = 7.57899 + 0.965531*X

WV: 6.7 µm
CO2: 13.3 µm
Comparison of Brightness Temperature at 13.3 µm between VIIRS with CrIS and Aqua-MODIS

September 19, 2015, Co-located overpasses between Aqua-MODIS & VIIRS

Day Time

Night Time

<table>
<thead>
<tr>
<th>Method</th>
<th>Mean (StdDev)</th>
<th>N</th>
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<tbody>
<tr>
<td>Aqua</td>
<td>247.5 (12.92)</td>
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<tr>
<td>VIIRS</td>
<td>248.2 (13.03)</td>
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<td>Y-X</td>
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<td>RMS</td>
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<tr>
<th>Method</th>
<th>Mean (StdDev)</th>
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<tbody>
<tr>
<td>Aqua</td>
<td>235.4 (17.53)</td>
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<td>VIIRS</td>
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<td>Y-X</td>
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<td>RMS</td>
<td>1.74</td>
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Sept. 19, 2015 UTC 0230

VIIRS CO2 Height (with CrIS)

VIIRS Height (without CrIS)

Aqua CO2 Height

CO2 Cloud Top Height (km)

0.0

3.2

6.4

9.6

12.8

16.0
Sept. 19, 2015
UTC 0140

VIIRS CO2 Height (with CrIS)
VIIRS Height (without CrIS)
Aqua CO2 Height
CO2 Cloud Top Height, 20150919, day + night, co-located overpasses

Aqua-MODIS

VIIRS without CrIS (using 11/12 um)

VIIRS with CrIS
VIIRS without CrIS (11/12 µm) minus Aqua-MODIS

CO2 Cloud Top Height Difference 20150919 day + night

VIIRS with CrIS minus Aqua-MODIS
Day Time

Comparison of CO2 Cloud Top Height

September 19, 2015, co-located overpasses

VIIRS without CrIS (11 & 12 μm)

VIIRS with CrIS (11 & 13.3 μm)

N = 254845.

Mean ( StdDev)

Aqua 7.01( 2.88)
VIIRSEd1A 8.27( 2.84)
Y-X 1.26( 1.78)
RMS( 2.18)............

N = 207246.

Mean ( StdDev)

Aqua 6.75( 2.78)
VIIRS 6.87( 2.77)
Y-X 0.125( 1.20)
RMS( 1.21).............
Comparison of CO2 Cloud Top Height
September 19, 2015, co-located overpasses

**Night Time**

VIIRS without CrIS (11 & 12 µm)

VIIRS with CrIS (11 & 13.3 µm)

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<td>N= 453835.</td>
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<tr>
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<tr>
<td>Aqua</td>
<td>6.84(2.28)</td>
<td>VIIRS</td>
<td>6.92(2.24)</td>
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<td>VIIRSed1A</td>
<td>8.16(2.42)</td>
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<tr>
<td>Y-X</td>
<td>1.33(1.76)</td>
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<td>0.087(1.08)</td>
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<tr>
<td>RMS</td>
<td>2.20</td>
<td></td>
<td>1.08</td>
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Summary

• Initial mapping of CrIS to VIIRS for MODIS-like CO2 and WV bands looks promising

• Brightness temperatures:
  VIIRS mapped from CrIS agree with Aqua-MODIS within ~ 0.5 K for both CO2 and WV bands.

• CO2 slicing cloud top height:
  VIIRS with CrIS agrees with Aqua-MODIS within ~0.1 km
  VIIRS without CrIS (VIIRS-Ed1) ~ 1.3 km higher than Aqua-MODIS

• By mapping CrIS to VIIRS, CERES-VIIRS is much more consistent with CERES-MODIS
Future Plan

• If we decide to bring CrIS to VIIRS,

  - Will map CrIS to VIIRS edges (~300 km on each side of VIIRS swath), probably at the reduced accuracy

  - Either, subscribe 2 CrIS data to Langley ASDC:
    GCRSO (Geolocation) and SCRIS (Radiances)

  - Or, if Land SIPS has access to CrIS data, CERES could deliver mapping software to LSIPS to be part of CERES subsetter