Atmosphere Discipline's Efforts on MODIS/VIIRS Inter-Calibration

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MODIS/VIIRS Calibration Workshop, College Park, 1 May 2023

Agenda

- Brief refresher on Atmosphere Discipline approaches to MODIS/VIIRS inter-sensor relative radiometric evaluation and adjustments
  - Cloud Team (Meyer et al., 2020)
  - Deep Blue Aerosol Team (Sayer et al., 2016)
- Analysis tools developed in collaboration with the U. Wisconsin Atmosphere Science Investigator-led Processing System (A-SIPS)
  - VIIRS Atmosphere Discipline production center

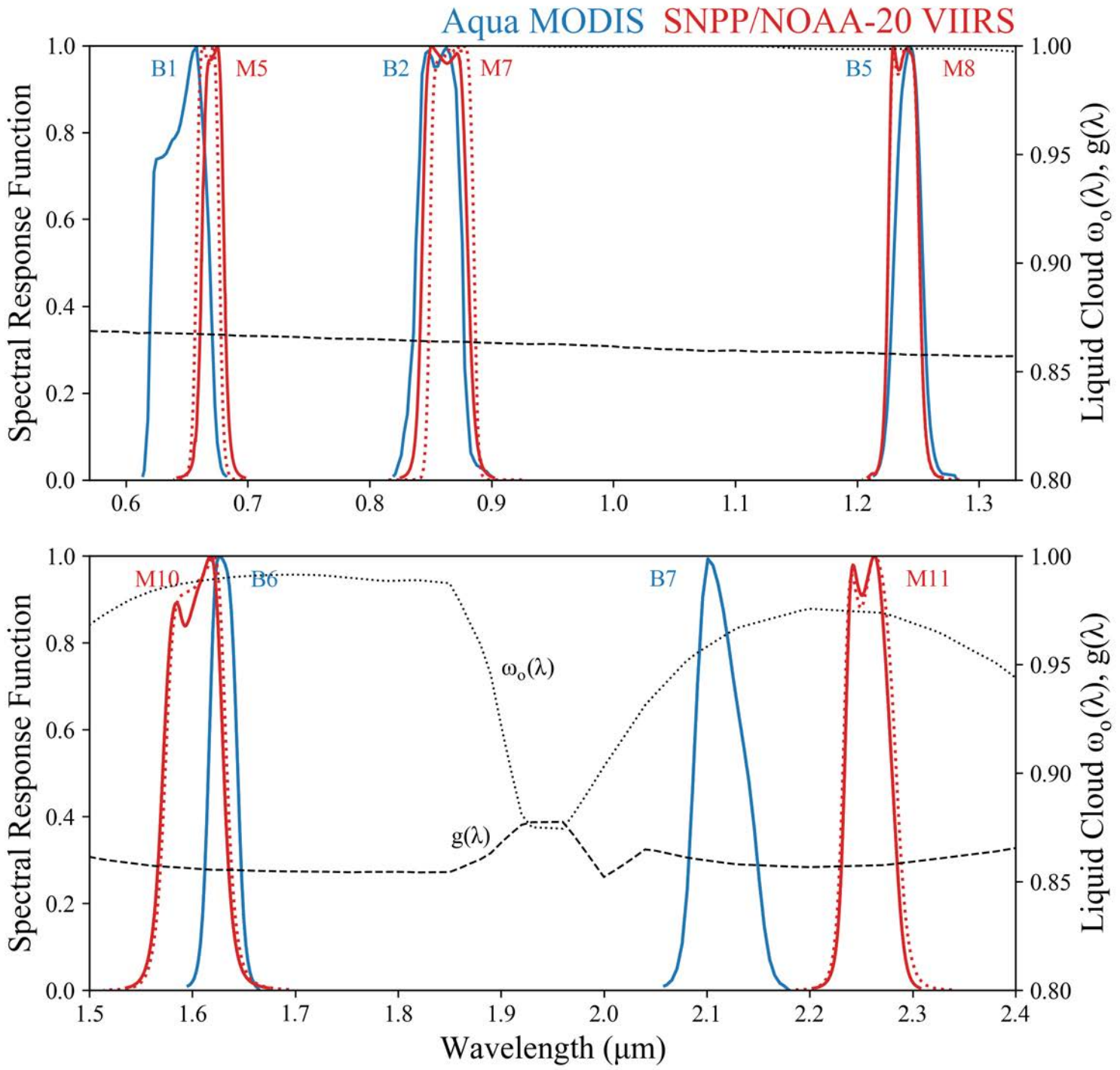
Goal

Use Aqua MODIS as a reference imager to derive spectral radiometric adjustments for SNPP and NOAA-20 VIIRS

Challenge

The analogous spectral channels on both imagers used for aerosol and cloud optical property retrievals in some cases still are quite different, particularly in spectral regions where single scattering properties vary strongly, e.g., for liquid clouds at right

ω_o: single-scattering albedo
g: asymmetry parameter



Starting Point: Radiometric Match Files

- Developed and processed by the A-SIPS
- Files include co-located Aqua MODIS and SNPP/NOAA-20 VIIRS L1B and L2 datasets
  - MYD02 L1B vs NASA VIIRS L1B (all M-band spectral channels)
    - **Aqua MODIS C6.1; SNPP VIIRS v2.0.2 (“C1”) and NOAA-20 VIIRS v3.0.0 (“C2”)**
  - Key MYD35 and MYD06 geophysical datasets (cloud mask, cloud-top/optical)
  - Includes only pixels meeting angle and temporal matching requirements
- The co-location and match software are designed to support future instruments including NOAA-21 and advanced GEO (AHI/ABI/AMI)
  - Note: The cloud and aerosol teams currently are funded to develop GEO products

Analysis Approach

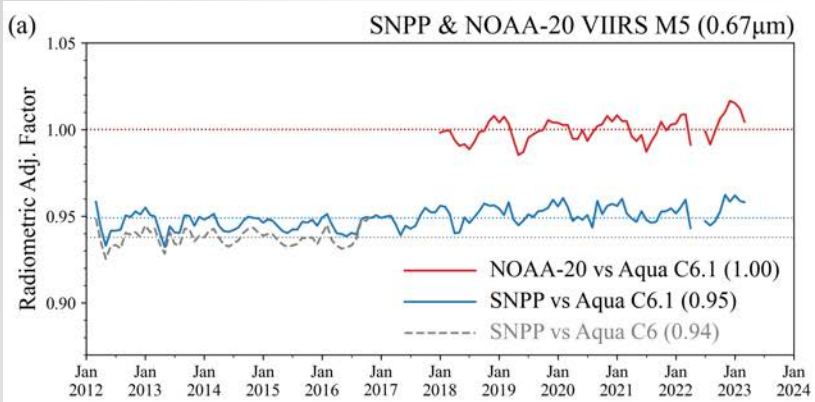
- Cloud Team (Meyer et al., 2020)
  - Homogeneous liquid phase clouds over oceans, ±60^{o} latitude
    - Bright scenes
    - Bore confidence in forward modeling liquid clouds (v. ice) to account for spectral mismatch
  - Temporal matching: $\Delta t < 10$min
  - Strict angle matching: view zenith and scattering angle differences < 1^{o}
- Deep Blue Aerosol Team (Sayer et al., 2017)
  - Clear sky scenes over oceans , ±60^{o} latitude
    - Total column H_2O < 3 cm
    - Computed sunglint contribution to reflectance < 0.01
  - Temporal matching: $\Delta t < 10$min
  - View zenith and scattering angle differences < 3^{o}
- **Both use Aqua MODIS as the reference, i.e., scale VIIRS to match MODIS**

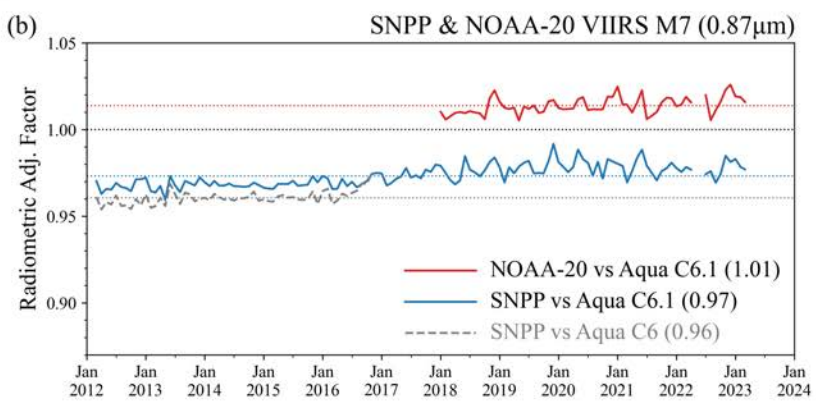
Cloud Team Methodology

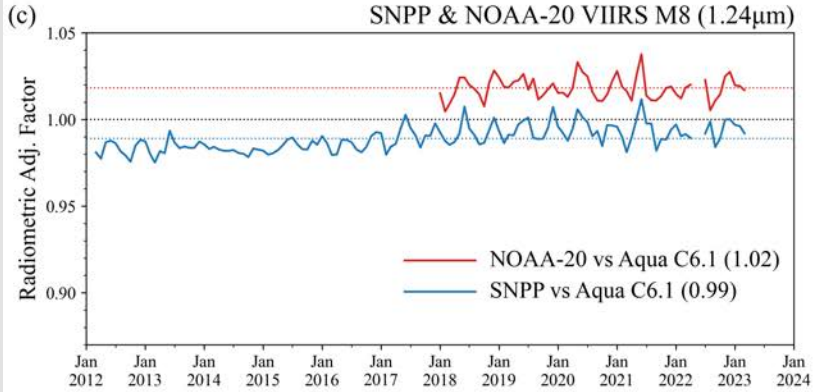
- MODIS cloud optical/microphysical retrievals + VIIRS reflectance LUT => **VIIRS expected top-of-cloud reflectance at pixel level**
- MODIS (MYD06) cloud-top pressure + VIIRS L1B + atmospheric correction => **VIIRS observed top-of-cloud reflectance at pixel level**
- Aggregate pixel-level expected/observed reflectance into monthly joint histograms => monthly VIIRS radiometric adjustment factors
- Final VIIRS (SNPP or NOAA-20) radiometric adjustment factors derived from time series of monthly values

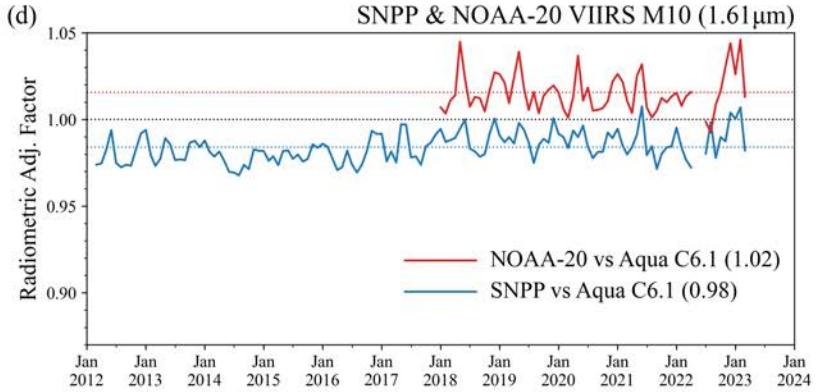
$$\boldsymbol{VIIRS\ Radiometric\ Adjustment}(\lambda) = \frac{\boldsymbol{VIIRS\ Expected\ TOC\ Refl.}(\lambda)}{\boldsymbol{VIIRS\ Observed\ TOC\ Refl.}(\lambda)}$$

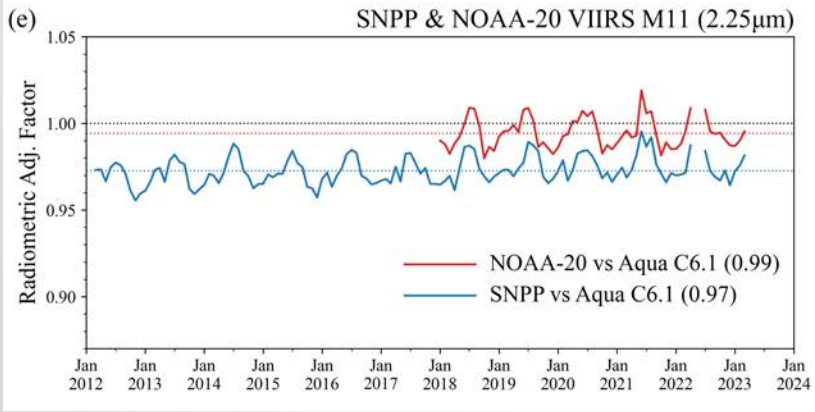
$$\lambda = [\mathbf{0.67}\mu m\ (M5), \mathbf{0.87}\mu m\ (M7), \mathbf{1.24}\mu m\ (M8), \mathbf{1.61}\mu m\ (M10), \mathbf{2.25}\mu m\ (M11)]$$











- Radiometric adjustments applied to VIIRS L1B prior to ingestion into CLDMSK and CLDPROP algorithms.
  - Both SNPP and NOAA-20
  - Defined as time series (left) means
- Values are reported in CLDPROP L2 global metadata

Open Access Article

Derivation of Shortwave Radiometric Adjustments for SNPP and NOAA-20 VIIRS for the NASA MODIS-VIIRS Continuity Cloud Products

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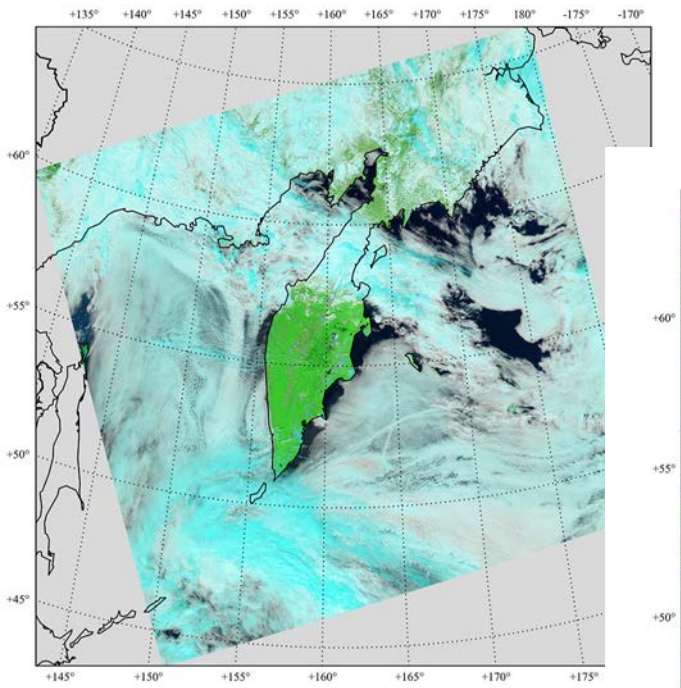
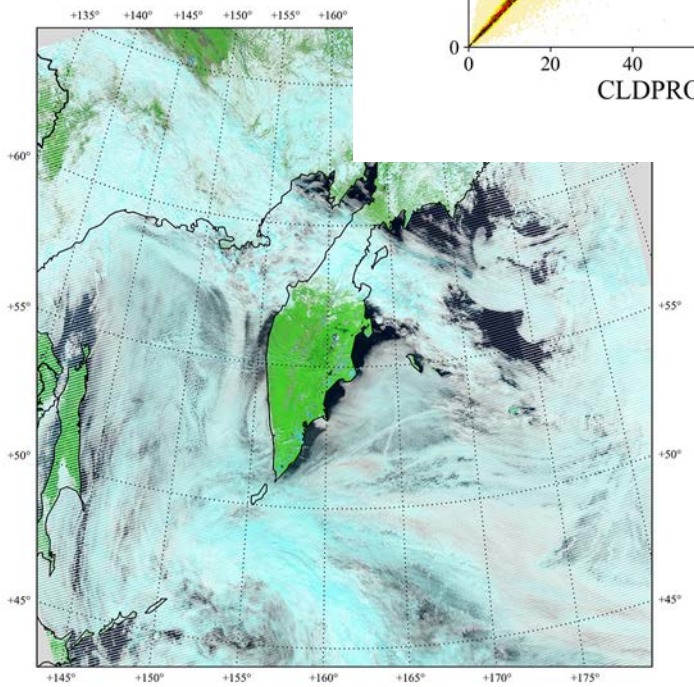
VIIRS Wavelength (Band Designation)			0.67 µm (M5)	0.87 µm (M7)	1.24 µm (M8)	1.61 µm (M10)	2.25 µm (M11)
Radiometric Adjustment Factor	NOAA-20	vs MODIS C6.1	1.0	1.01	1.02	1.02	0.99
	SNPP	vs MODIS C6.1	0.95	0.97	0.99	0.98	0.97
		vs MODIS C6	0.94	0.96	0.98	0.98	0.97
		Deep Blue Gain Factors	*0.941*	*0.963*	*1.011*	*0.981*	*0.931*

End Results

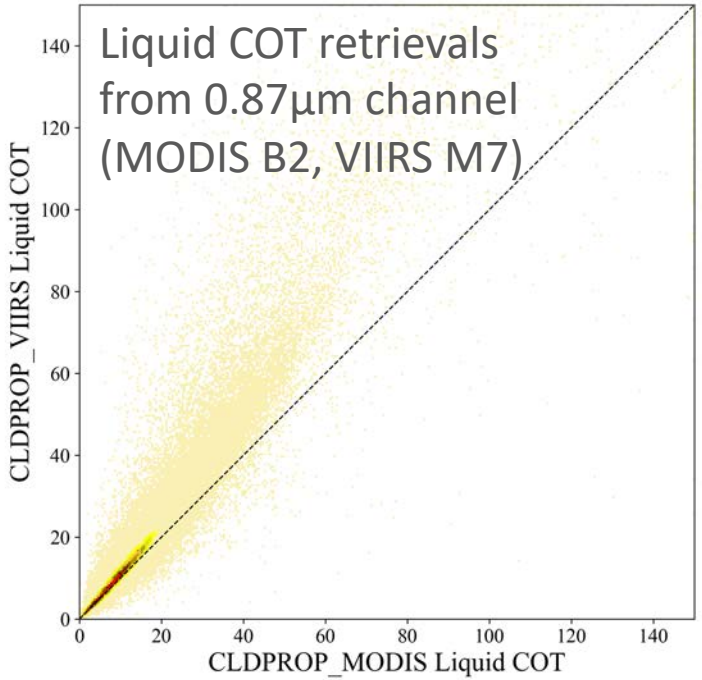
- Applying derived radiometric adjustments to VIIRS yields improved retrieval agreement with MODIS, here for liquid cloud optical thickness

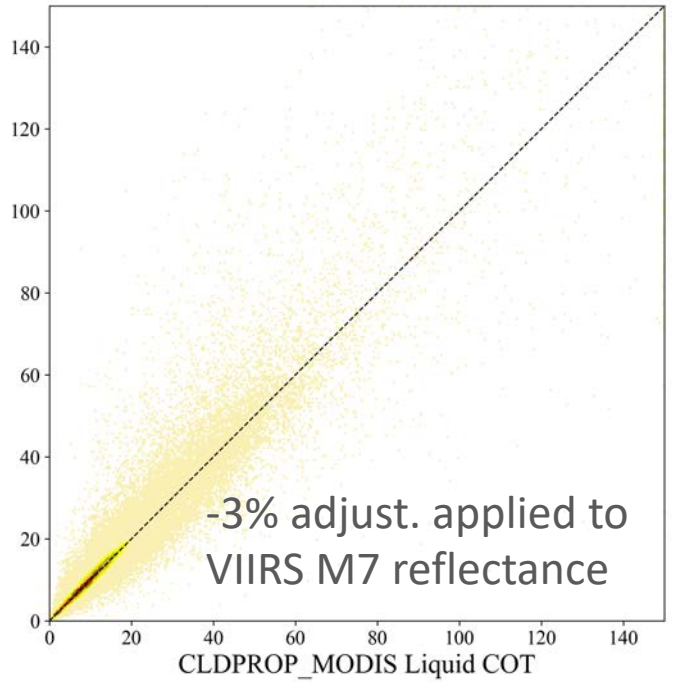


Aqua MODIS
6 July 2014 (0200 UTC)



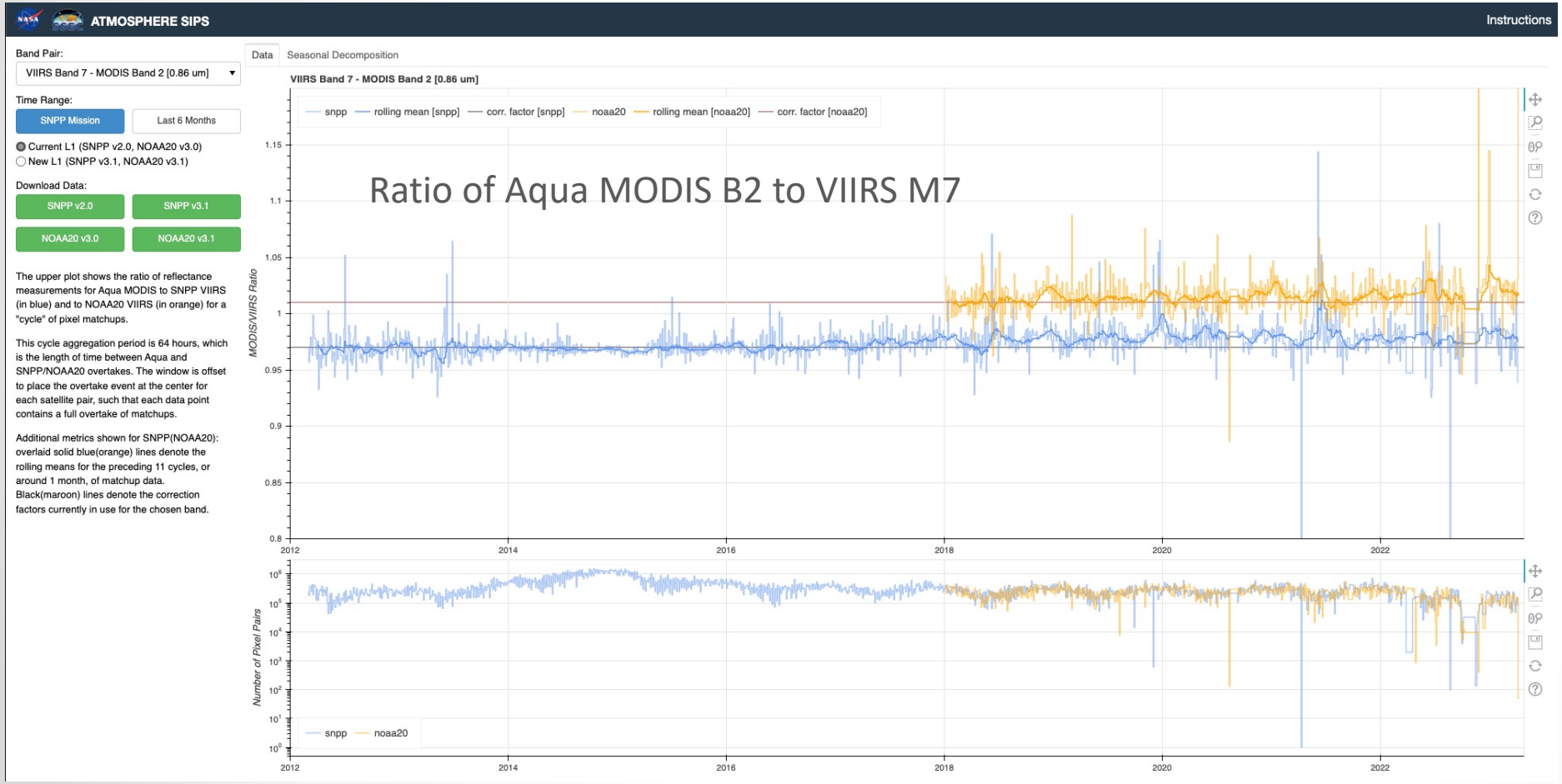
SNPP VIIRS
6 July 2014 (0154, 0200 UTC)





VIIRS SNPP/NOAA 20 UW A-SIPS Monitoring Tool

- The cloud team's Aqua MODIS – VIIRS (SNPP and NOAA-20) radiometric analysis code is implemented at A-SIPS and running in NRT
- Public web "dashboard" developed by A-SIPS (Z. Griffith) to facilitate monitoring by team
  - "Per cycle" (64 hrs) and rolling (~monthly) means, seasonal decomposition for trends
  - Automated alert system to identify drifts/outliers



SNPP (Blue)
NOAA-20 (Orange)

https://sips.ssec.wisc.edu/intercalibration/intercalibration

VIIRS SNPP/NOAA 20 UW A-SIPS Monitoring Tool

Example: SNPP VIIRS M7 vs Aqua MODIS B2 Drift

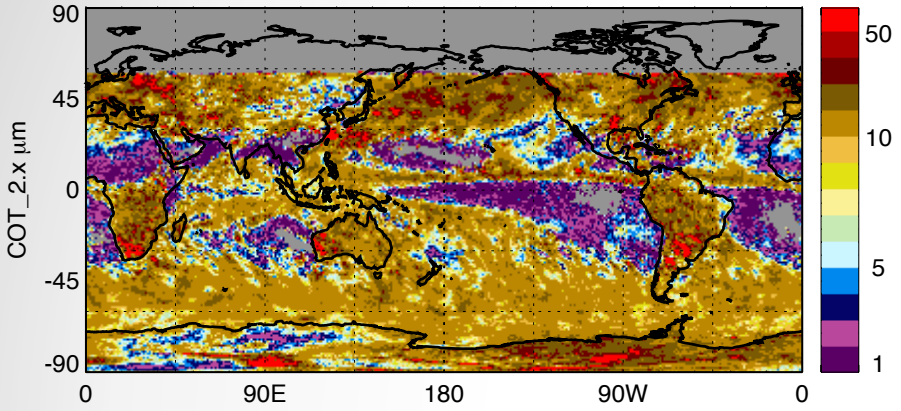
SNPP (Blue)

NOAA-20 (Orange)

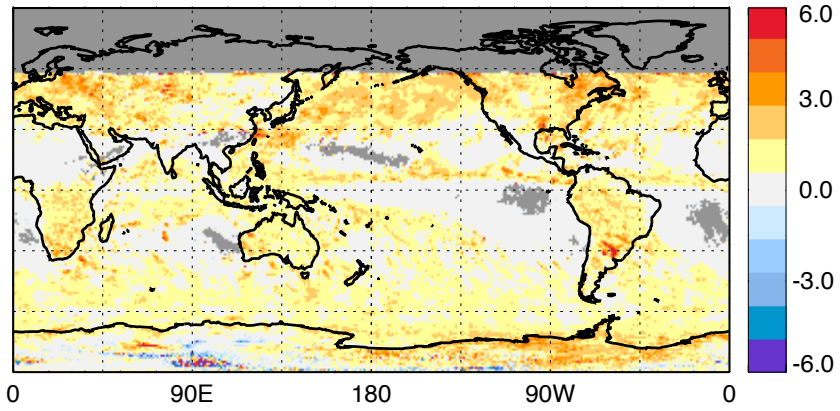
MODIS/SNPP VIIRS calibration ratio for the 0.87µm channel begins to increase starting in 2016, from 0.97 to ~0.98 by Dec 2020

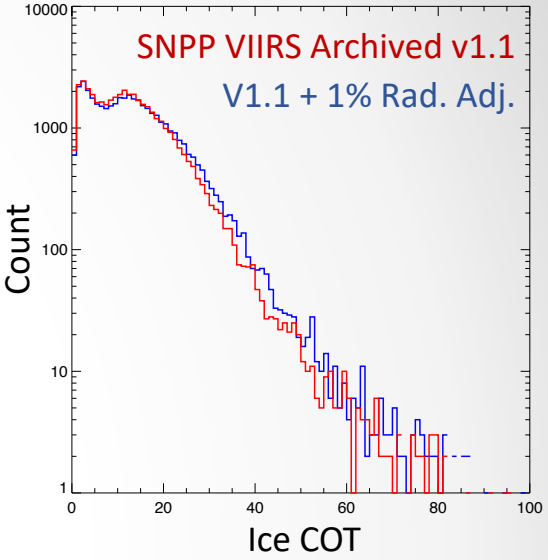
Is this ~1% drift in 0.87µm relative radiometry important?

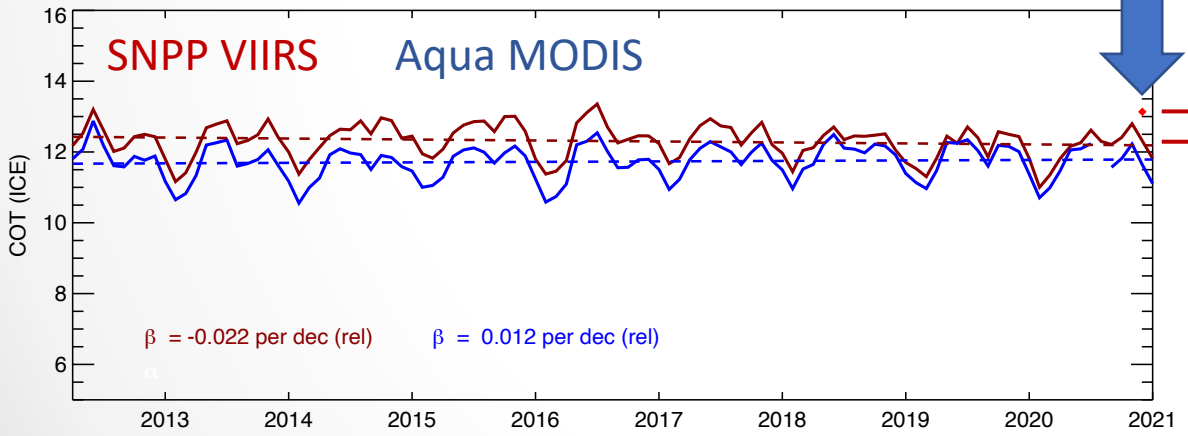
SNPP VIIRS Ice COT, Dec 2020



ΔCOT_{VIIRS} after 1% adjustment to 0.87µm (M7)





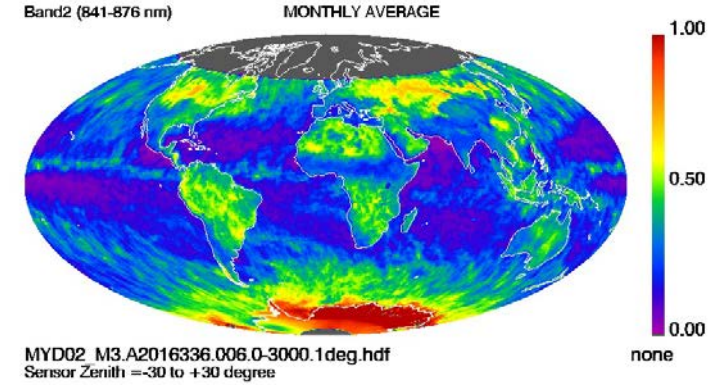


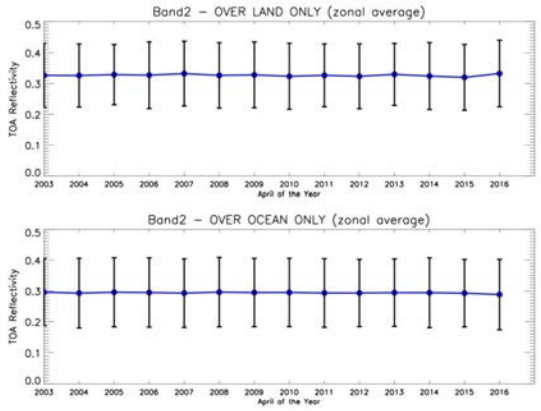
ΔCOT_{VIIRS} (Dec 2020)
~8% increase

Additional Tools: L1B Aggregations

Current Atmosphere Discipline Team Website:

- Daily/monthly gridded aggregation imagery
- Yearly time series imagery (through 2016)



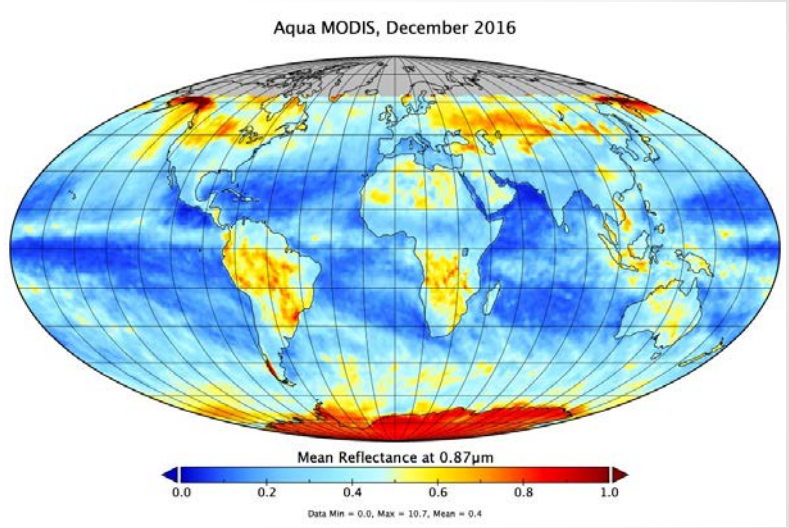


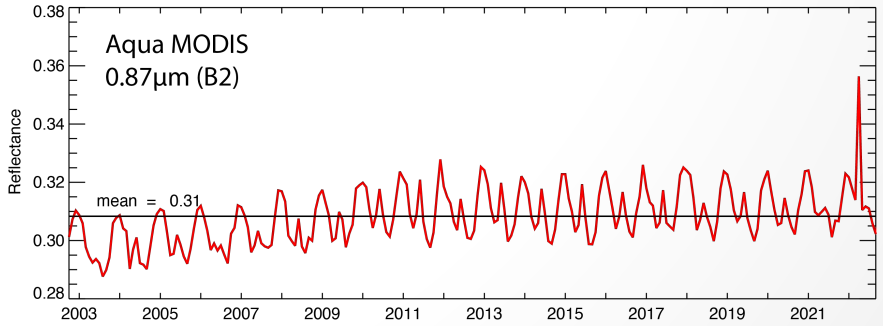
https://atmosphere-imager.gsfc.nasa.gov/images/l1b-aggregation

Updated L1B aggregation capabilities in development:

- Leverages A-SIPS Yori L3 code
- Daily/monthly gridded aggregations over entire Terra/Aqua MODIS and SNPP/NOAA-20+ VIIRS data records

Examples from science test runs.
New imagery capabilities under development, will replace existing website browse.





Summary

- Radiometric adjustment factors to key solar reflectance channels are necessary to reconcile observed MODIS/VIIRS retrieval differences
  - Important to note that both instruments can be within their absolute calibration specifications yet still exhibit a radiometric offset that can impact inter-sensor geophysical product continuity
- The Atmosphere Discipline teams have derived SNPP and NOAA-20 VIIRS adjustment factors using Atmosphere SIPS-produced match files
  - Adjustments generally consistent between the Cloud and Deep Blue Aerosol teams for overlapping channels
  - Applied to SNPP/NOAA-20 VIIRS since Aqua MODIS is the reference record
- The Atmosphere Discipline and the A-SIPS have leveraged these efforts to develop tools to monitor relative radiometry in near real-time
  - Web-based interface displaying Cloud team's intercalibration
  - L1B aggregation tools.

Challenges Moving Forward

- Considering multi-imager climate data records, calibration stability cannot be assessed for each imager independently, as changes to one or both instruments can adversely affect product continuity
  - Updates to relative radiometric adjustments should be derived and applied as necessary.
- Potential disconnects between different L2 algorithm teams who are applying independent radiometric adjustments
- For the Atmosphere products, processing paradigm may need rethinking
  - Forward processing near real-time (NRT) only, climate archive processing replacing NRT following periodic radiometric assessments?
- How do we continue these efforts after the loss of our Aqua MODIS reference imager?