Relative radiometric calibration – Addressing a key challenge for achieving continuity of NASA cloud climate data records from Aqua-MODIS to SNPP-VIIRS

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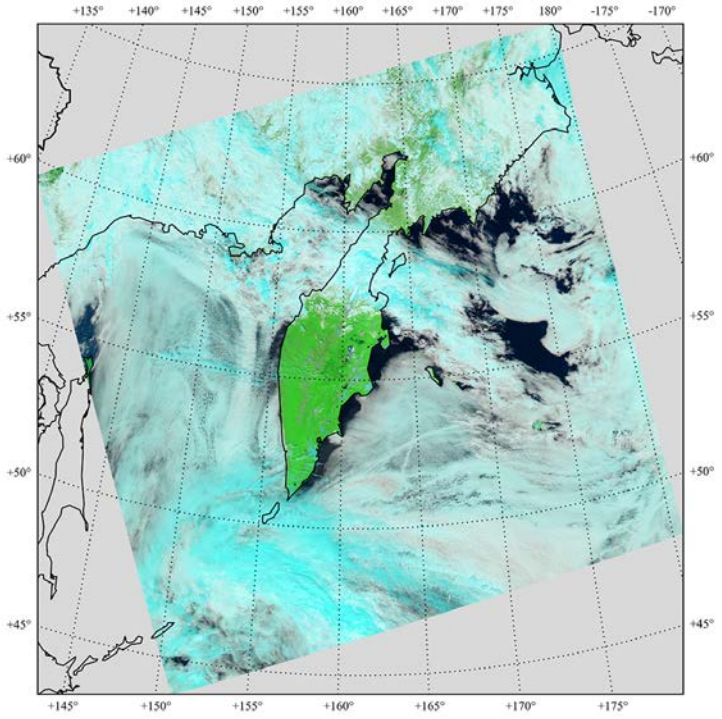
Statement of Need

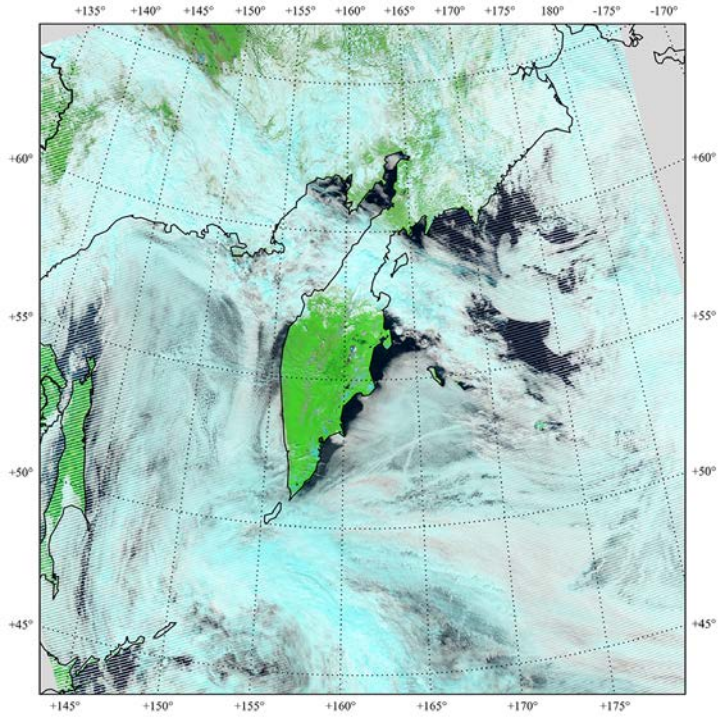
- Long-term cloud climate data records require merging the observational records of multiple instruments
- Because cloud retrievals are physically based and rely on absolute radiometry, inter-sensor relative radiometry (and radiometric stability) is fundamental to data record continuity
  - Much more challenging for solar channels where the absolute reflectance specifications can be greater than the expected climate change signals
- For the MODIS/VIIRS Science Team's continuity cloud optical properties product (CLDPROP), relative radiometric offsets (even those within specified instrument uncertainties) have induced large non-linear inter-sensor retrieval differences

Initial MODIS/VIIRS Cloud Optical Property Comparisons

6 July 2014



Aqua MODIS (B7-B2-B1)
0200 UTC



SNPP VIIRS (M11-M7-M5)
0154, 0200 UTC

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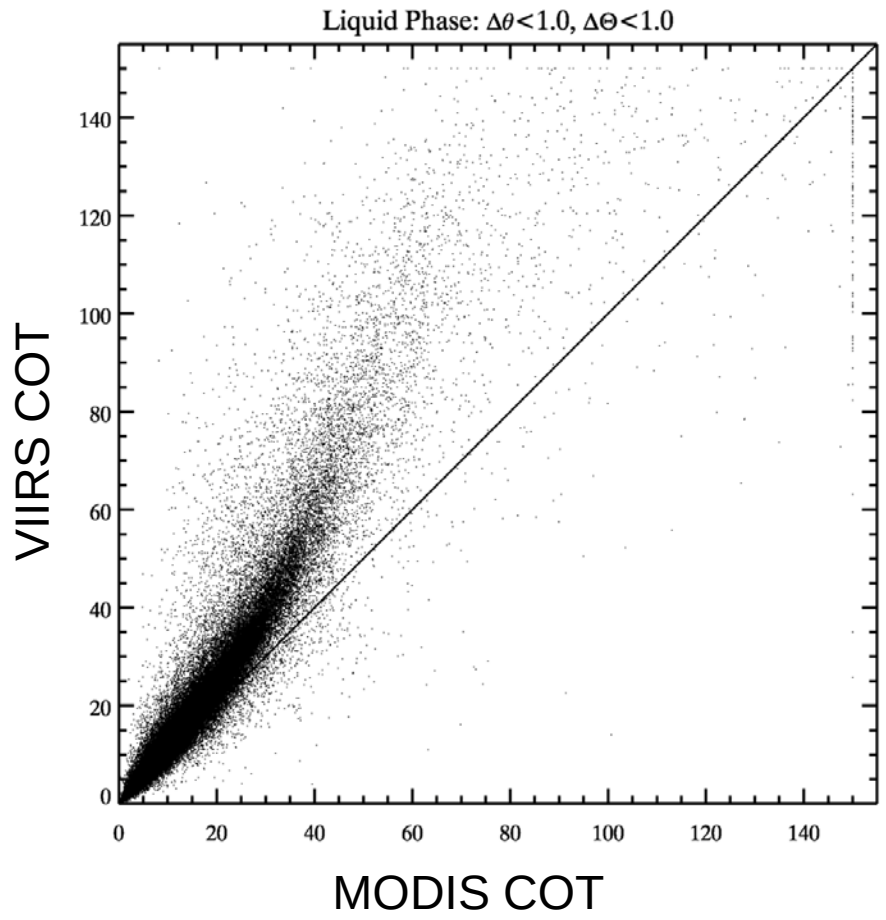


COT = Cloud Optical Thickness

Statement of Problem

- COT retrieval differences strongly imply radiometric offsets between Aqua MODIS and SNPP VIIRS solar reflectance channels
  - Relative radiometric differences can also impact cloud particle size retrievals (CER) and thermodynamic phase determination as well as certain cloud mask tests
- Offsets also found by other Atmosphere algorithm teams (e.g., Aerosol Deep Blue [*Sayer et al.*, 2017])

CLDPROP Cloud Optical Property Solar Spectral Channels

MODIS	VIIRS	Primary Retrieval Parameter
0.66µm (B1)	0.67µm (M5)	COT over land
0.86µm (B2)	0.87µm (M7)	COT over water
1.24µm (B5)	1.24µm (M8)	COT over snow/ice
1.64µm (B6)	1.61µm (M10)	CER; supplemental COT over snow/ice coupled with 2.13/2.25µm
2.13µm (B7)	2.25µm (M11)	CER

Radiometric adjustment factors to either MODIS or VIIRS are necessary in order to reconcile observed retrieval differences.

Starting Point: Radiometric Match Files

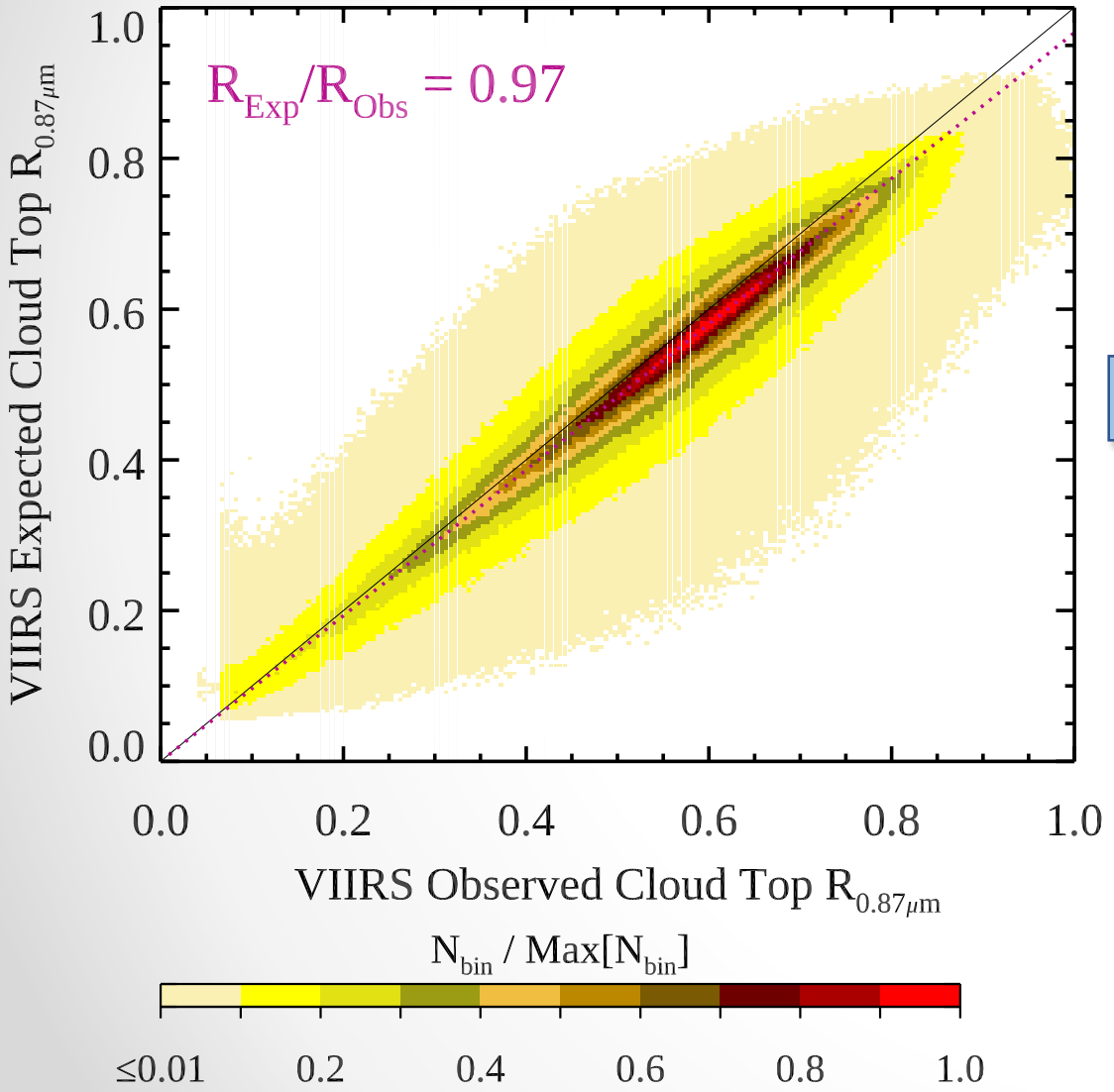
- Files contain co-located MODIS and VIIRS data
  - March 2012 – April 2018
  - MYD02 L1B vs NASA VIIRS L1B v2
    - All spectral channels included (solar + IR)
  - Key MYD35 and MYD06 geophysical parameters (cloud mask, cloud top and optical properties)
  - Includes only those co-located pixels having similar observation times and sun-satellite view geometries
    - MODIS and VIIRS view zenith and scattering angles match to within ±1^{o}
    - *Liquid phase clouds* over oceans, ±60^{o} latitude, low heterogeneity scenes
- Capability developed and implemented by the Atmosphere SIPS (production center) at U. Wisc.

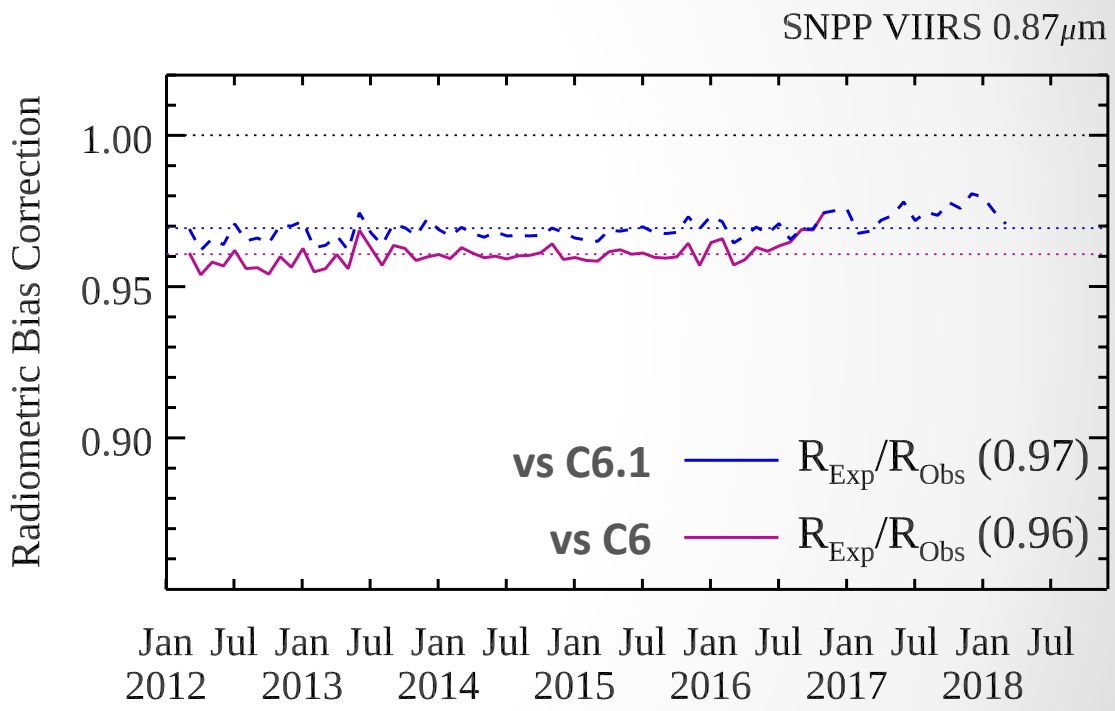
Cloud Algorithm Team Analysis

- Methodology:
  - MODIS COT,CER + VIIRS reflectance LUT => **VIIRS expected top-of-cloud reflectance at pixel-level**
  - MODIS (MYD06) CTP + VIIRS L1B + atmospheric correction => **VIIRS observed top-of-cloud reflectance at pixel-level**
  - Monthly VIIRS expected vs VIIRS observed spectral top-of-cloud reflectance joint histograms => Monthly VIIRS radiometric adjustment factors
  - Final VIIRS radiometric adjustment factors derived from time series of monthly values

$$\textbf{\textit{Radiometric Adjustment}} = \frac{\textbf{\textit{VIIRS Expected TOC Refl.}}}{\textbf{\textit{VIIRS Observed TOC Refl.}}}$$

Example: VIIRS M7 (0.87μm)





Final Radiometric Adjustments

Adjustments for CLDMSK/CLDPROP Products

VIIRS Channel		M5 (0.67μm)	M7 (0.87μm)	M8 (1.24μm)	M10 (1.61μm)	M11 (2.25μm)
Radiometric Adjustment (Expected VIIRS TOC/Observed)	vs C6	0.94	0.96	0.98	0.98	0.97
	vs C6.1	0.95	0.97	0.99	0.98	0.97

Aerosol DB Team Adjustments
(vs C6, including trends)

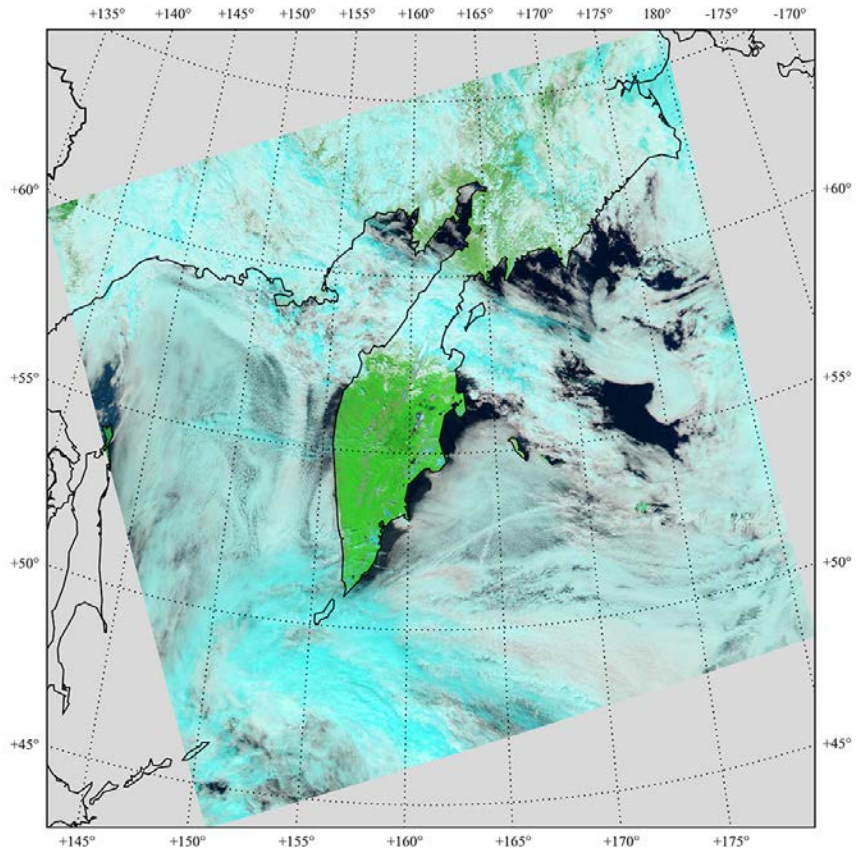
VIIRS band	Gain correction	Linear trend parameters, $a + b\,t$	
		a	b
412 nm (M01)	0.995 (±0.006)	–	–
440 nm (M02)	1.000 (±0.004)	–	–
490 nm (M03)	0.992 (±0.004)	–	–
550 nm (M04)	0.956 (±0.009)	–	–
670 nm (M05)	0.941 (±0.008)	–	–
745 nm (M06)	0.966 (±0.005)	–	–
865 nm (M07)	0.963 (±0.004)	0.9544 (±0.0016)	0.0018 (±0.0003)
1240 nm (M08)	1.011 (±0.009)	1.003 (±0.0029)	0.0019 (±0.0006)
1610 nm (M10)	0.981 (±0.011)	0.9646 (±0.0033)	0.0035 (±0.0007)
2250 nm (M11)	0.931 (±0.018)	–	–

Sayer et al. [2017]

Radiometric adjustments are applied to VIIRS L1B internally by each algorithm.

For CLDMSK/CLDPROP products, this occurs prior to cloud mask → cloud top → cloud optical property algorithm chain.

Impacts of Adjustments



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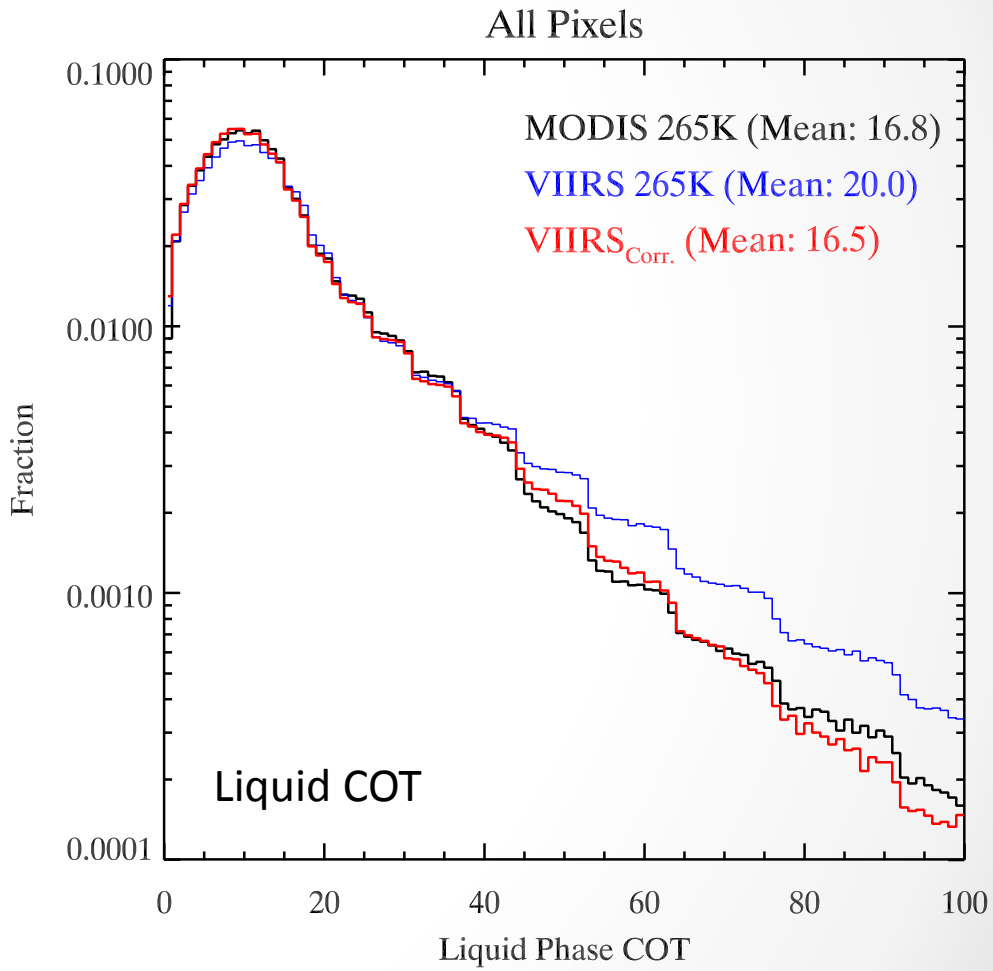

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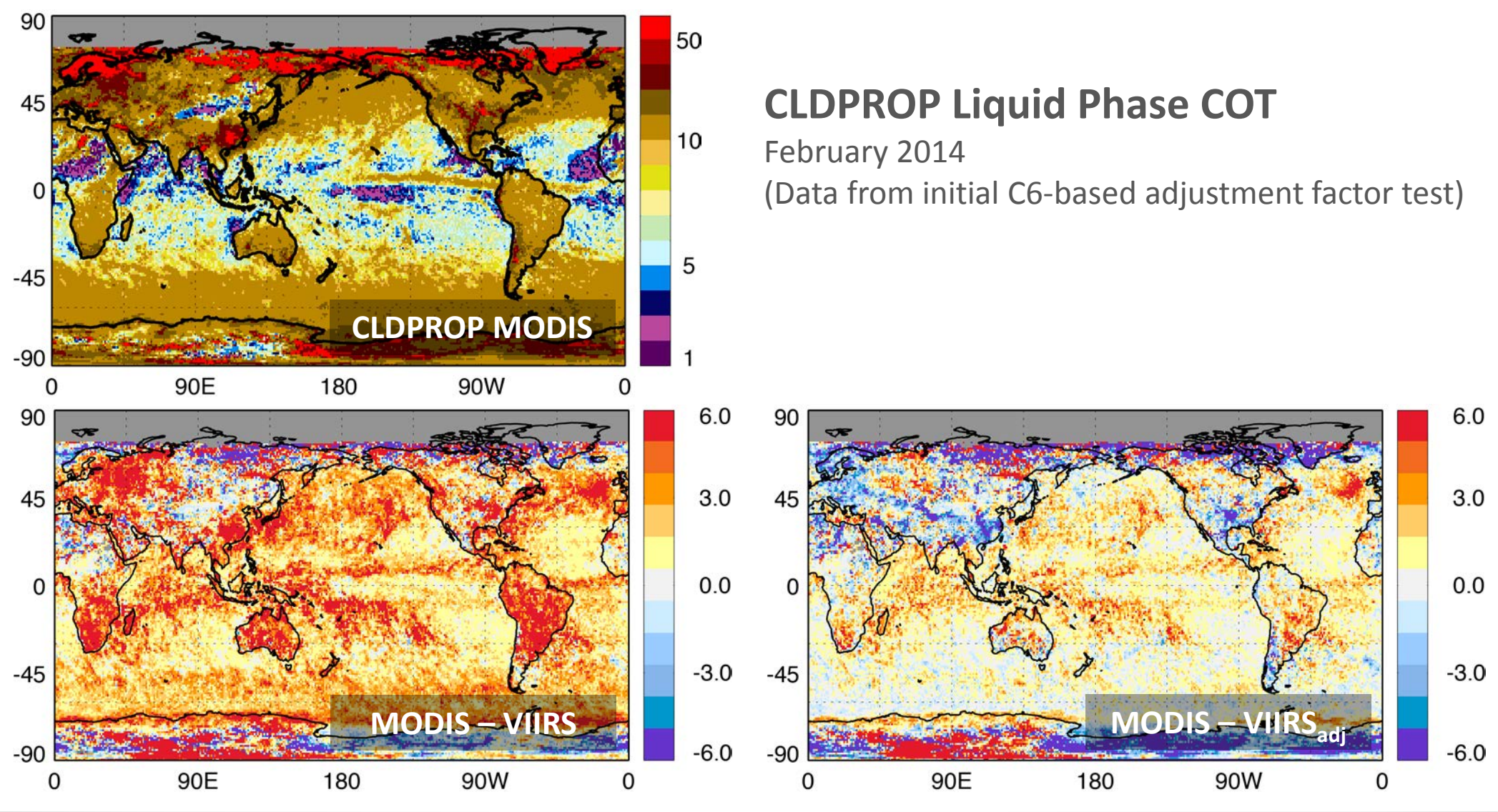


CLDPROP Liquid Phase COT

February 2014

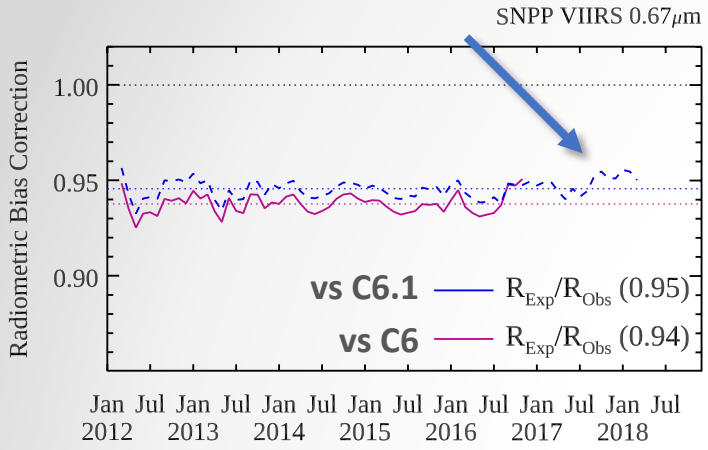
(Data from initial C6-based adjustment factor test)

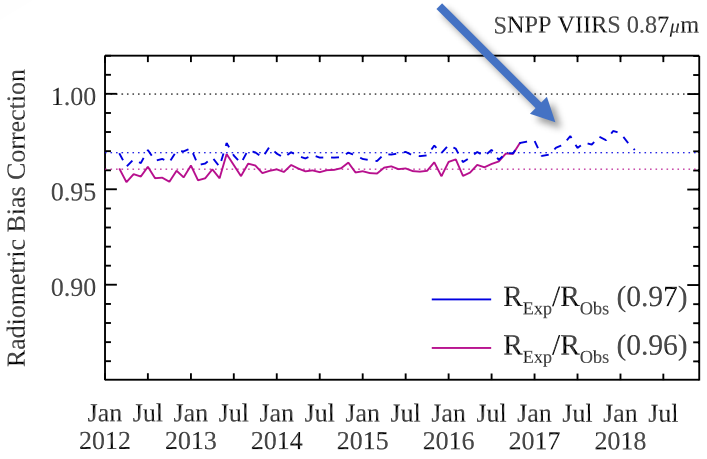
Summary

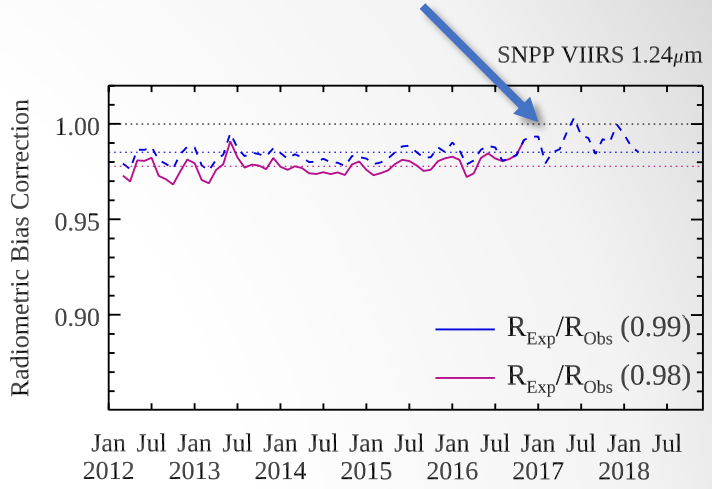
- Radiometric adjustment factors to key solar reflectance channels necessary to reconcile observed retrieval differences
  - Important to note that both instruments can be within their absolute calibration specifications yet still exhibit a radiometric offset that can impact inter-sensor geophysical product continuity
- Cloud Team derived VIIRS adjustment factors using Atmosphere SIPS-produced match files
  - Adjustments generally consistent with Aerosol DB team for overlapping channels
  - Applied to VIIRS since MODIS is the reference record
- Improvement seen in COT retrieval continuity, though other factors continue to confound

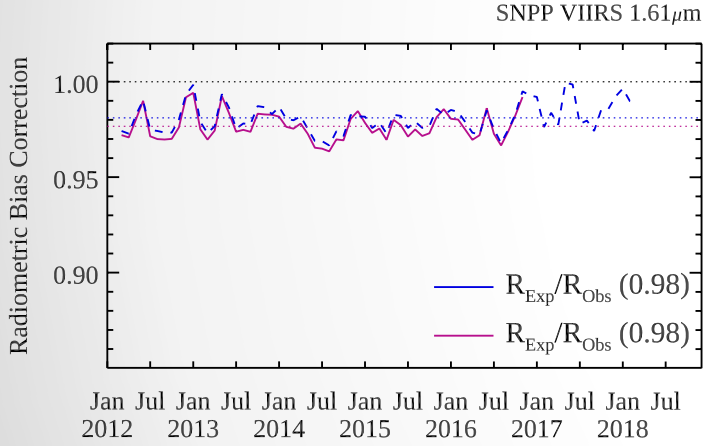
Challenges Moving Forward

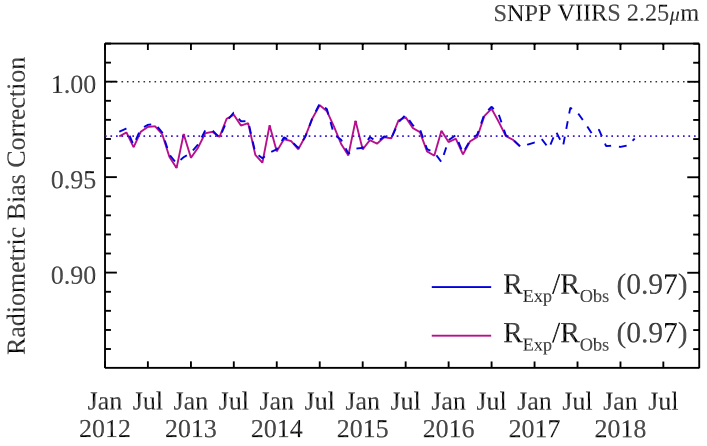
- Potential disconnects between different L2 algorithm teams who are applying independent radiometric adjustments
- MODIS and VIIRS stability cannot be assessed independently, as changes to one or both instruments can adversely affect product continuity
  - Updates to relative radiometric adjustments should be derived and applied as necessary.
  - Note: We're also tracking absolute sensor stability via independent L1B aggregations.
- For the cloud products, processing paradigm may need rethinking
  - Forward processing near real-time (NRT) only, climate archive processing replacing NRT following periodic radiometric assessments?

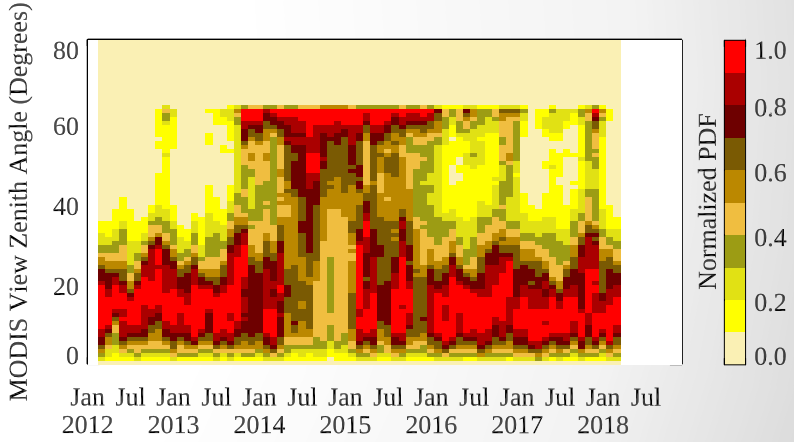












Ongoing Challenge: Accounting for temporal radiometric drifts in one or both instruments.

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