Progress/challenges in generating multi-instrument imager cloud data records: MODIS, VIIRS (and AHI)

Algorithm Development Team: S. Platnick[1], K. Meyer[1], G. Wind[1,2], N. Amarasinghe[1,2], C. Wang[1,3], B. Marchant[1,4], S. A. Ackerman[5], R. Holz[5], R. Frey[5], A. Heidinger[5,6], Y. Li[5]

MODAPS/LAADS (GSFC): B. Ridgway[1,2], S. Manoharan[1,2]

NASA Atmosphere SIPS (U. Wisconsin): S. Dutcher[5], P. Veglio[5], G. Quinn[5], L. Gumley[5]

[1]NASA GSFC, [2]SSAI, [3]U. MD/ESSIC, [4]USRA, [5]U. Wisc./CIMSS/SSEC, [6]STAR /NOAA

ICWG-2
Madison, WI
30 October 2018

Topics

- A MODIS Story
  - The struggle for radiometric stability & status of MODIS Terra & Aqua Collection 6.1 Cloud Property Products
- The MODIS/VIIRS Continuity Story
  - The NASA continuity product paradigm
  - Algorithm/production status and some initial results
- NASA AHI/ABI research algorithms

MODIS Atmosphere Team "Collection" History

Collection	Start of Reprocessing MODIS Terra	Start of Reprocessing MODIS Aqua
6.1	Sept. 2017 (completed Dec. 2017)	Dec. 2017 (completed March 2018)
6.0	2014	2013
5.1	2008	2008
5.0	2005	2005
4	2002	2002
3	2001	2002
1	2000	–

C6.0/C6.1 Cloud Product Highlights

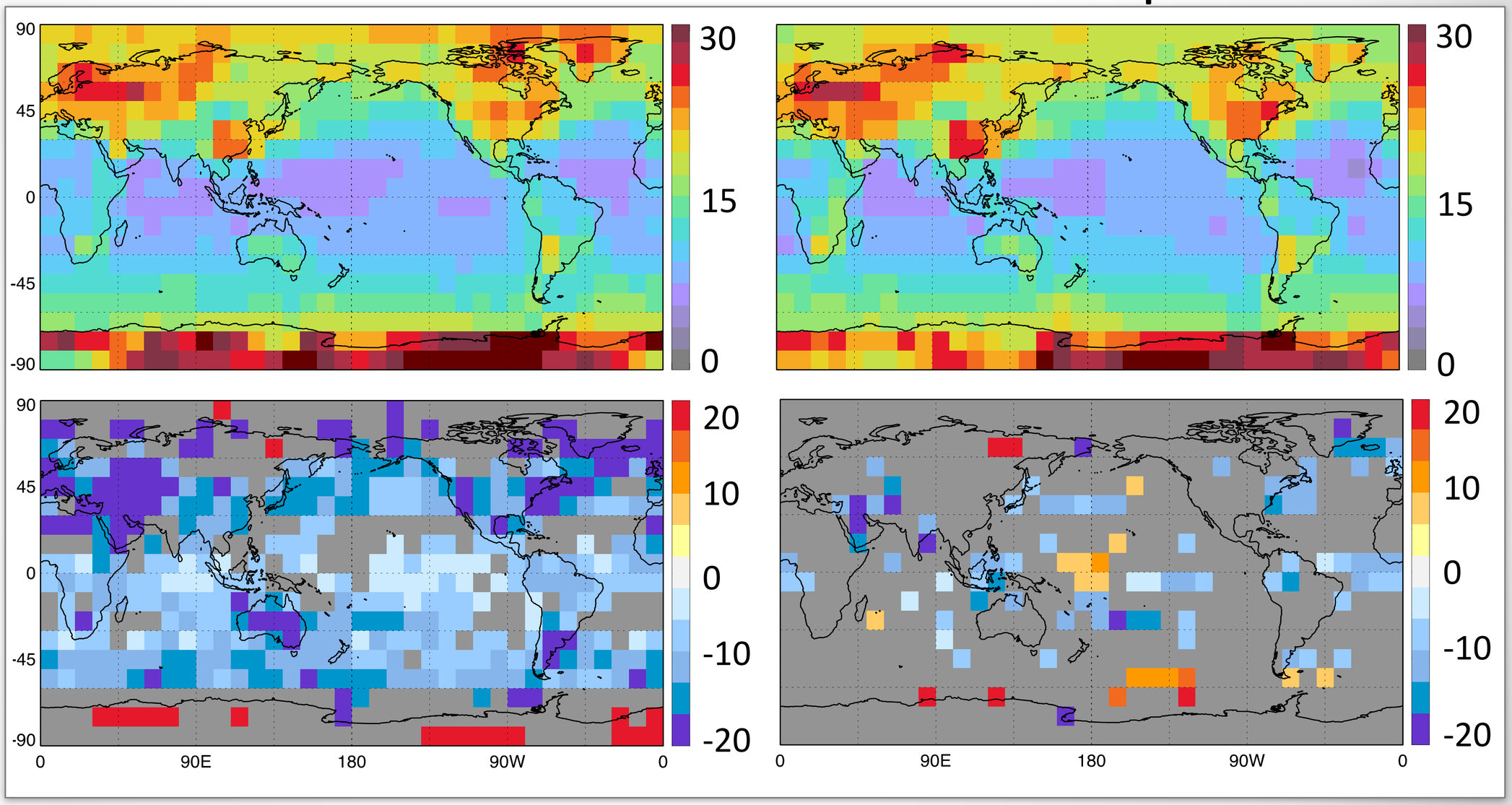
- L1B
  - C6.0: Aqua VNIR spatial “re-registration”, Terra VNIR/SWIR radiometric corrections (RVS)
  - C6.1: Terra IR cross-talk corrections, further Aqua/Terra RVS corrections
- C6 L2 cloud properties
  - Cloud mask threshold updates [MOD/MYD35]
  - New 1km cloud-top datasets: pressure, temp., height: [MOD/MYD06]
  - Optical/microphysical: phase, optical thickness, eff. radius: [MOD/MYD06]
    - New radiative transfer, ice particle models, phase algorithm, surface (C5 gap-filled land spectral albedo, variable wind speed ocean model). New error sources in pixel-level uncertainty calculations. Explicit spectral eff. radius retrievals. “Partly cloudy” pixel retrievals + failed retrieval info. [*Platnick et al.*, 2017, etc.]

Climate Record Challenges: Terra VNIR Calibration Story

Climate Record Challenges: Terra VNIR Calibration Story

C5.1 Cloud Optical Thickness (COT) annual mean, liq. water clouds

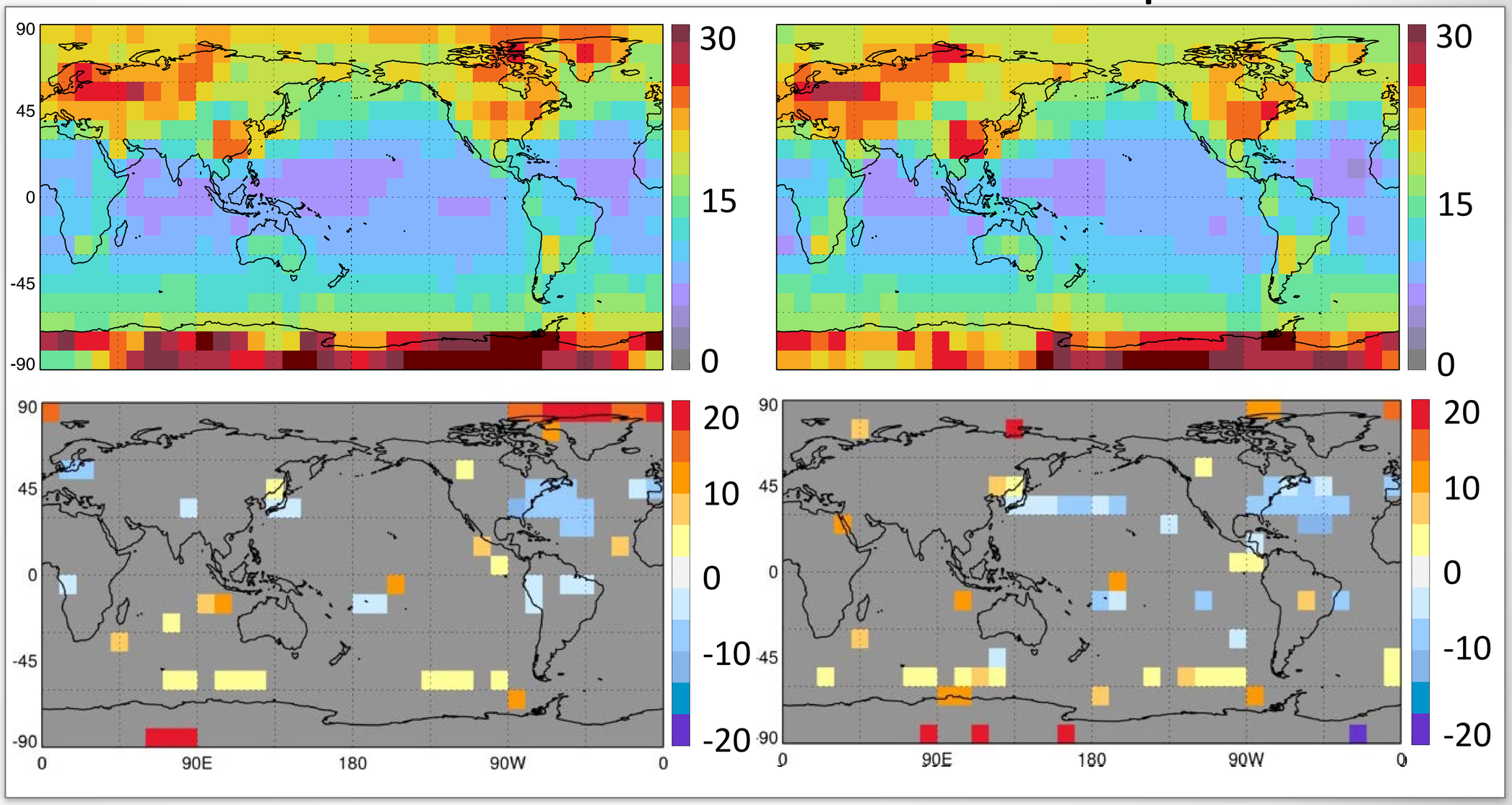
C5.1 COT trend (%/dec) July 2002-June 2010, 5% sig. level



Climate Record Challenges: Terra VNIR Calibration Story

C5.1 Cloud Optical Thickness (COT) annual mean, liq. water clouds

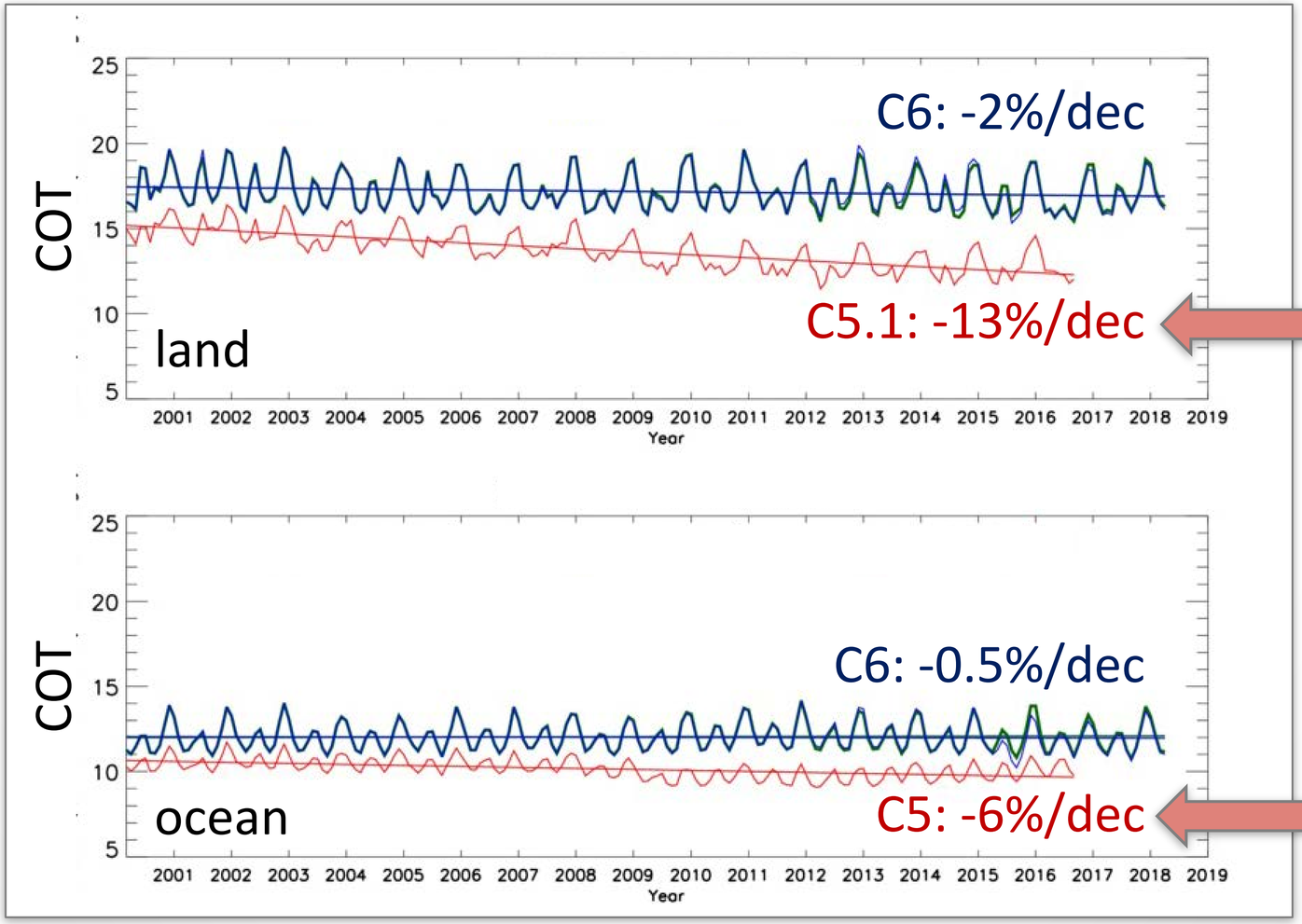
C6.1 COT trend (%/dec) July 2002-June 2017, 5% sig. level



Climate Record Challenges: Terra VNIR Calibration Story

Terra MODIS Liquid water Cloud Optical Thickness (COT) Trends

18-yr time series, ±60° zonal mean

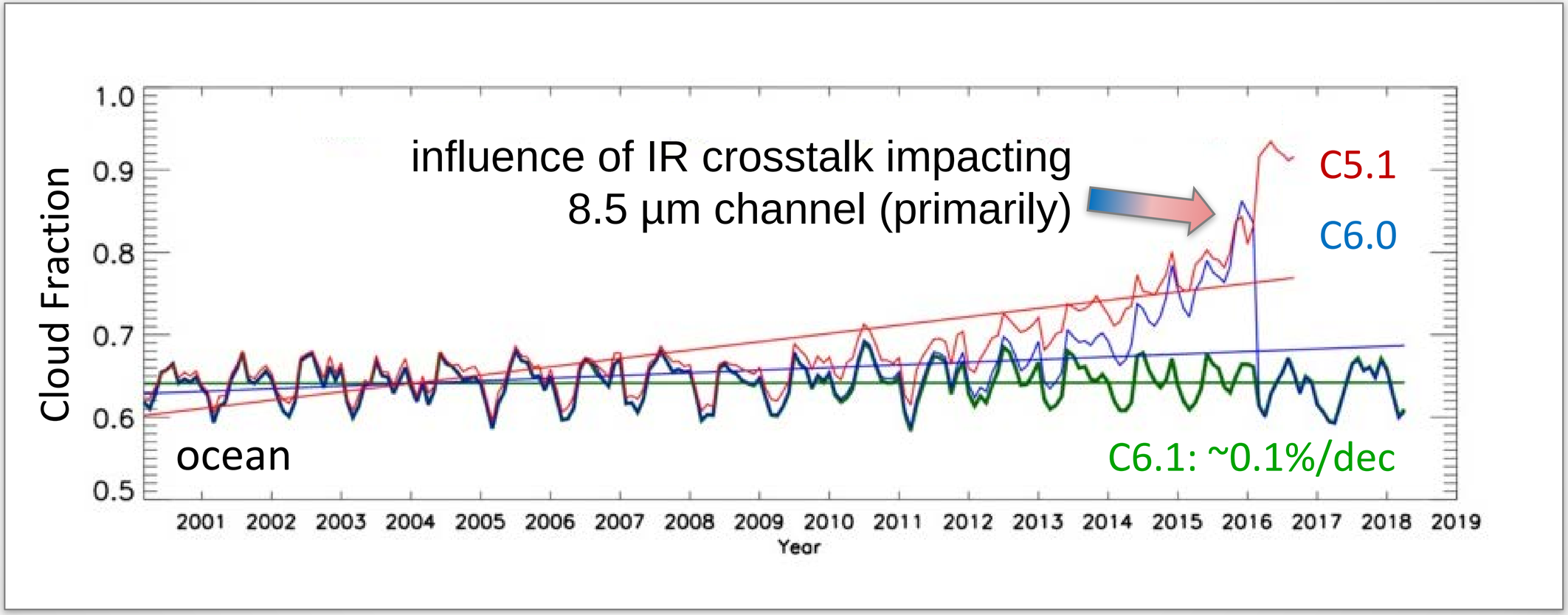


influence of 0.67 µm channel calibration drift (RVS)

0.86 µm drift

Climate Record Challenges: Terra IR Calibration Story

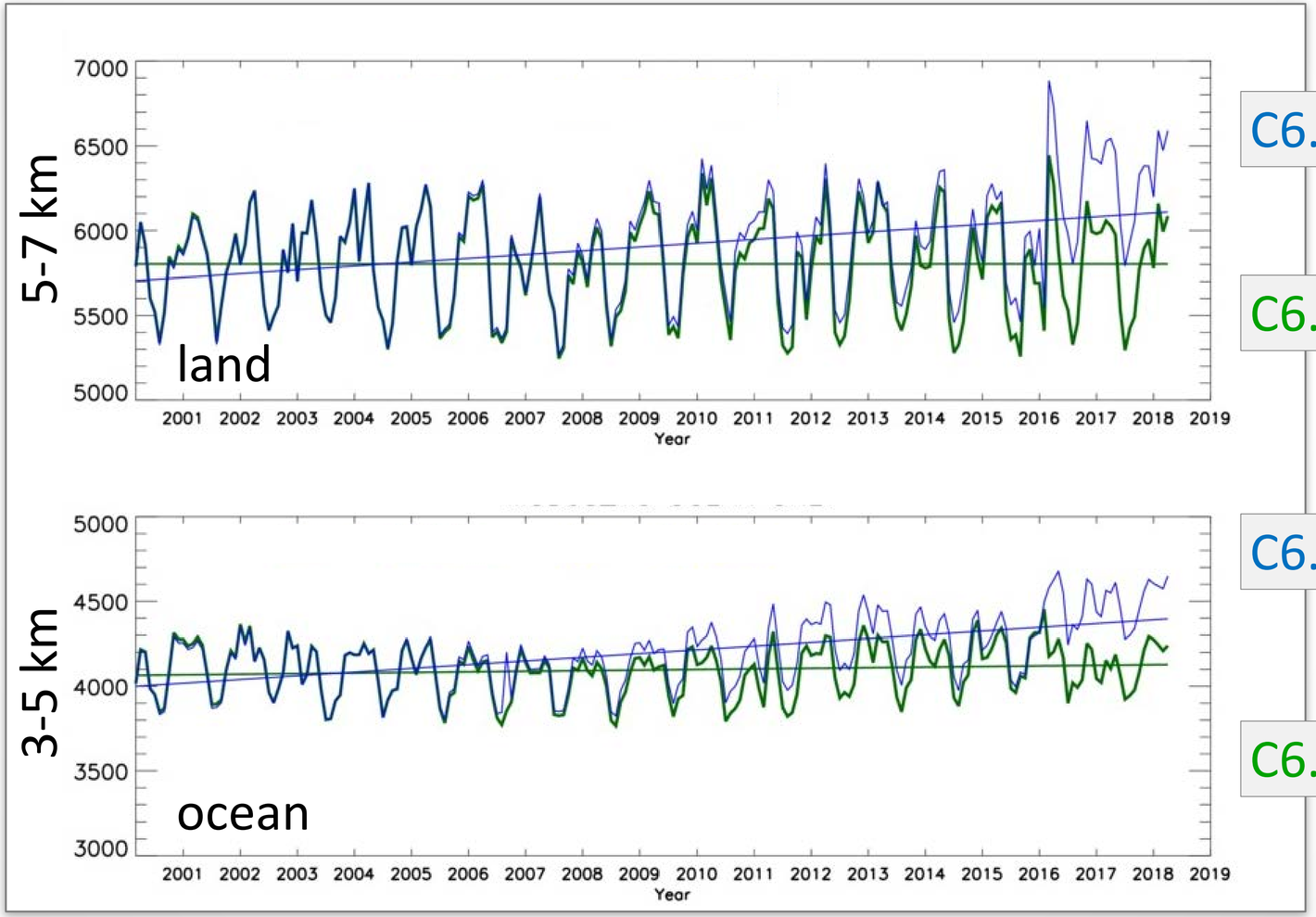
Cloud Fraction, Terra 18-yr time series, ±25° zonal mean over ocean



Climate Record Challenges: Terra IR Calibration Story

Cloud Top Height, Terra 18-yr time series, ±60° zonal mean

influence of IR crosstalk



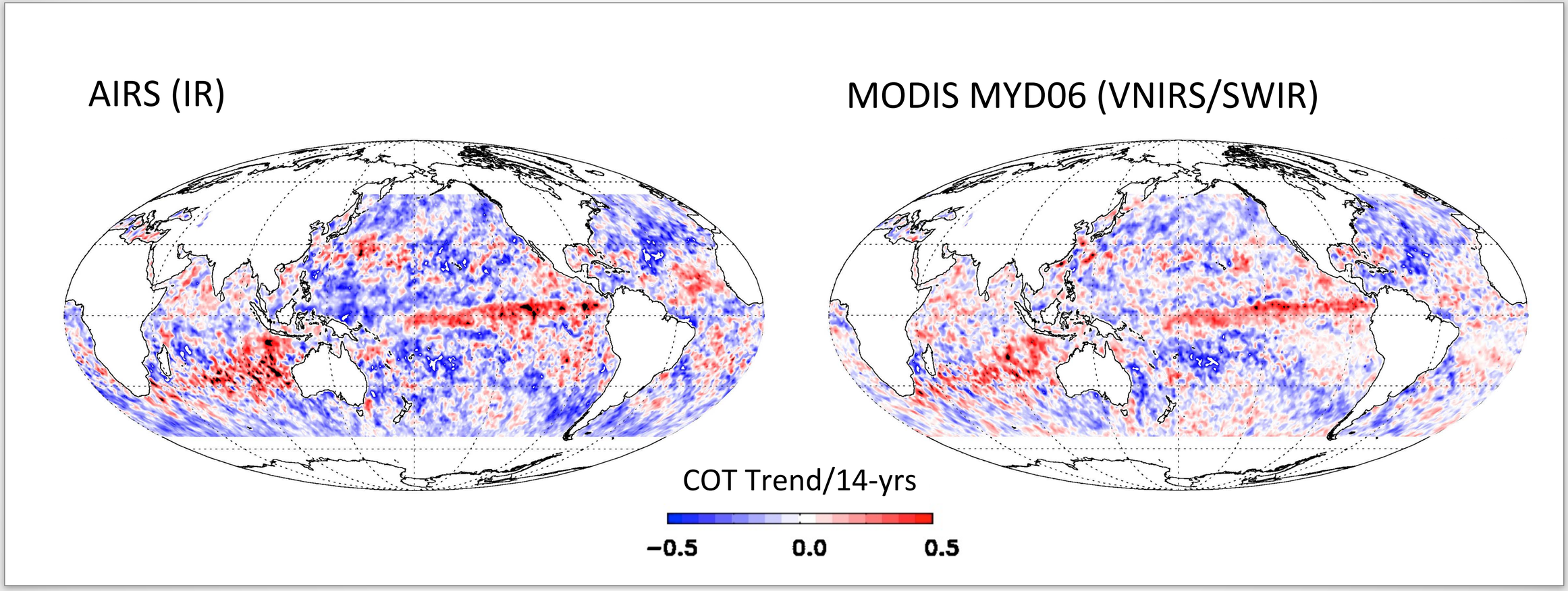
C6.0: 4%/dec

C6.1: ~0%/dec

C6.0: 5%/dec

C6.1: ~1%/dec

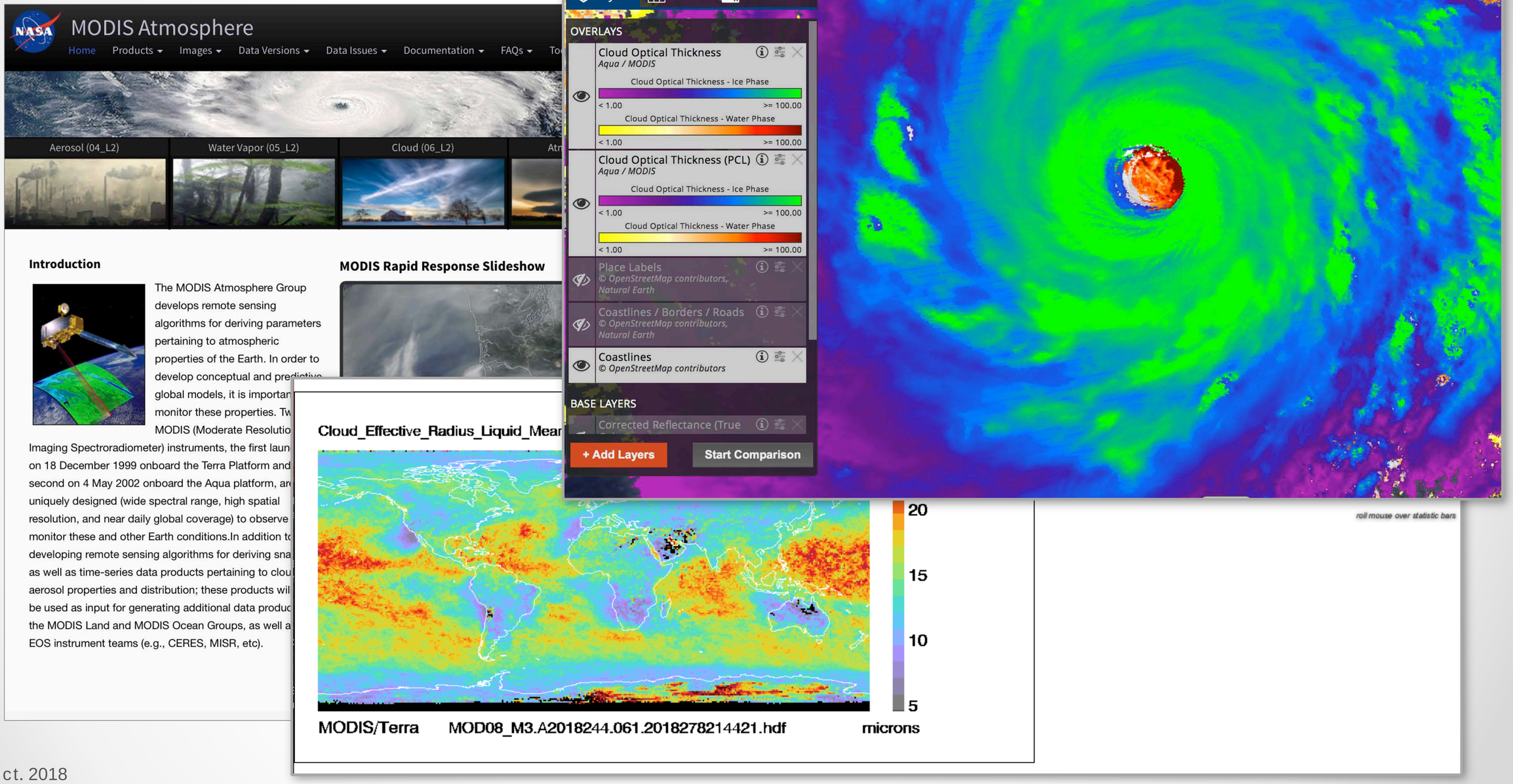
AIRS & MODIS Ice COT Trends (2002-2016)



Courtesy of Brian Kahn

(*AIRS trend presentation Thursday morning!*)

Web Presence



Topics

- A MODIS Story
  - The struggle for radiometric stability & status of MODIS Terra & Aqua Collection 6.1 Cloud Property Products
- The MODIS/VIIRS Continuity Story
  - The NASA continuity product paradigm
  - Algorithm/production status and some initial results
- NASA AHI/ABI research algorithms

Background

- History: direct continuity between MYD35/MYD06 not feasible

  NASA VIIRS Cloud EDR Assessment Report (2013), EOS-SNPP Continuity White Paper (2011/12), NASA Science Teams (2013, 2017)

- Paradigm: product continuity requires continuity of algorithms in addition to instruments, infrastructure support, etc.

- MODIS/VIIRS approach: develop a common algorithm for both VIIRS and MODIS using common/near-common spectral bands.
  - cloud mask and optical properties (MOD06/MOD35 Collection 6 heritage: *Ackerman, Platnick, et al.*)
  - cloud-top properties (GOES-R AWG heritage: *Heidinger et al.*)
  - MOD08-consistent L3 via SIPS code/infrastructure + algorithm team supplied config. file

Major Challenges for MODIS/VIIRS Cloud Product Continuity

- Spectral coverage (most direct challenge)
  - "**2.x μm**" window band: **VIIRS 2.25 μm vs. MODIS 2.13 μm** channel
  - VIIRS missing MODIS CO_2 and H_2O absorption channels
- Spatial resolution and spatial/temporal sampling
  - VIIRS (750, 375 m) vs. MODIS (1000 , 500 , 250 m) at nadir
  - VIIRS pixel size DOES NOT increase as substantially with scan as MODIS
  - Missing M-band bow-tie pixels are "added" by Atmosphere SIPS for all results that follow
- Relative radiometric calibration in solar reflectance channels
  - Requires spectral bias corrections (*Meyer et al.* Th presentation)

Spectral Challenges

Red: principal bands used in cloud phase/optical algorithms

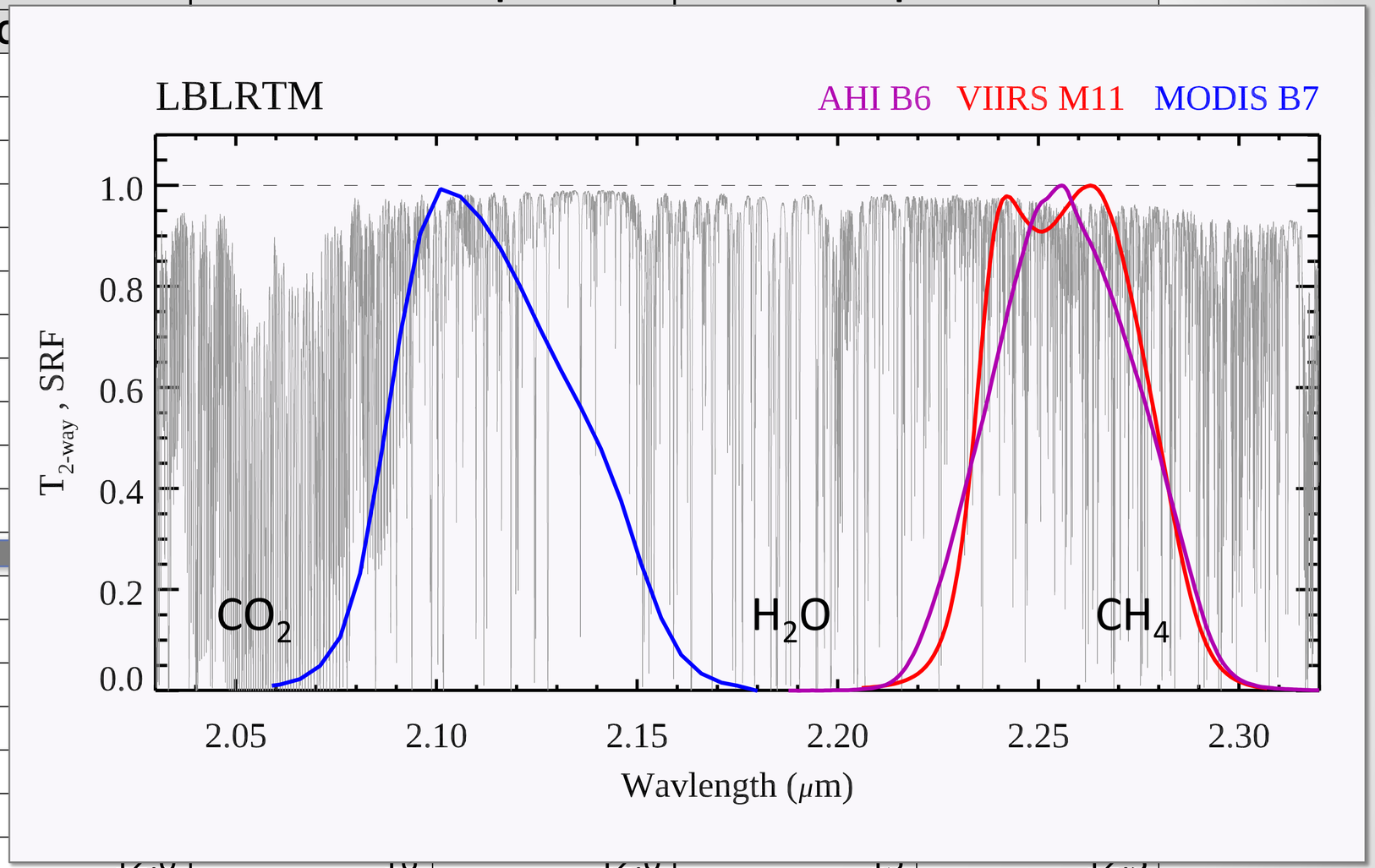
Blue: used in cloud mask

Orange: used for cloud top properties

MODIS cloud bands		VIIRS M-band equivalent		AHI equivalent		
Band No.	CWL (μm)	Band No.	CWL (μm)	Band No.	CWL (μm)	
8	0.42	1	0.42			
9	0.44	2	0.45			
3	0.47	3	0.49	1	0.47	
4	0.56	4	0.56	2	0.51	AHI-only
1	0.65	5	0.67	3	0.64	
2	0.86	7	0.87	4	0.86	
18	0.905					
19	0.940					
5	1.24	8	1.24			
26	1.38	9	1.38		1.37	ABI-only
6	1.64	10	1.61	5	1.61	
7	2.13	11	2.25	6	2.24	
20	3.75	12	3.74	7	3.90	
21/22	3.96	13	4.05			
27	6.75			8, 9	6.19, 6.93	
28	7.33			10	7.34	
29	8.55	14	8.55	11	8.44	
31	11.0	15	10.8	14	11.2	
32	12.0	16	12.0	15	12.3	
33	13.3			16	13.3	
34	13.6					
35	13.9					
36	14.2					

Spectral Challenges

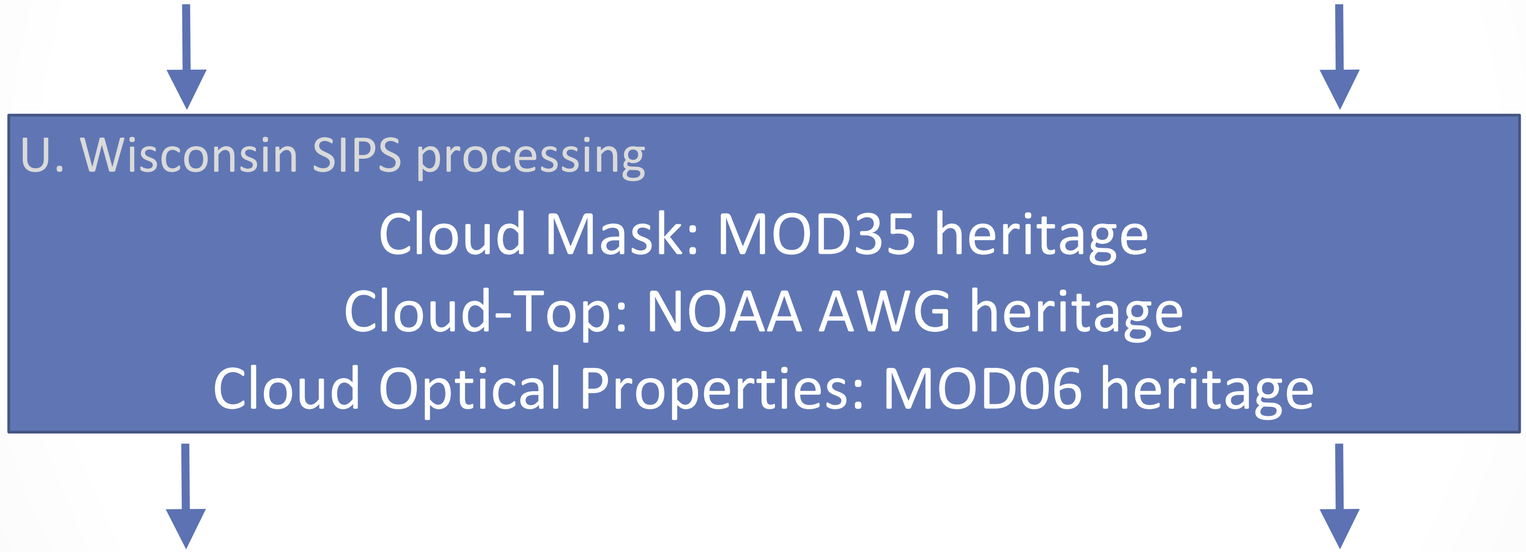
MODIS cloud bands		VIIRS M-band equivalent		AHI equivalent	
Band No.	C				
8					
9					
3					
4					
1					
2					
18					
19					
5					
26					
6					
7					
20					
21/22					
27					
28					
29					
31					
32					
33	13.3			16	13.3
34	13.6				
35	13.9				
36	14.2				



Chapter 1: Strategy – Common MODIS & VIIRS Algorithms

MODIS L1B + Geolocation
MOD02, **MOD03**
(channel subset common w/VIIRS)

NASA VIIRS L1B (with restored bow-tie pixel deletions* + VNIR/SWIR radiometric adjustments*) + Geolocation
VNP02MOD, **VGEOM**



MODIS Continuity Products
CLDMSK_L2_MODIS_Aqua
CLDPROP_L2_MODIS_Aqua

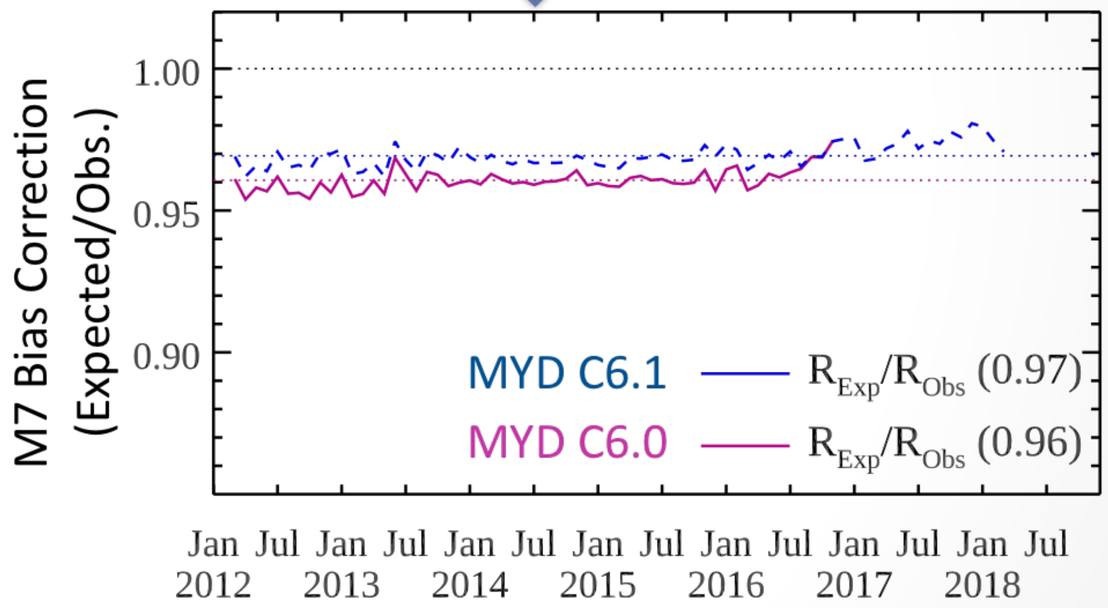
VIIRS Continuity Products
CLDMSK_L2_VIIRS_SNPP
CLDPROP_L2_VIIRS_SNPP

* Atmosphere SIPS intermediate L1B product

Chapter 2: Calibration (of course) - Relative Radiometry

Methodology: low, homogeneous marine liquid water cloud reflectance targets, MODIS & VIIRS solar/view angle match to better than 1°

VIIRS Channel	M5 (0.67µm)	M7 (0.87µm)	M8 (1.24µm)	M10 (1.61µm)	M11 (2.25µm)
Radiometric Bias Correction (Expected VIIRS TOA/Observed)	*0.95*	**0.97**	**0.99**	**0.98**	**0.97**



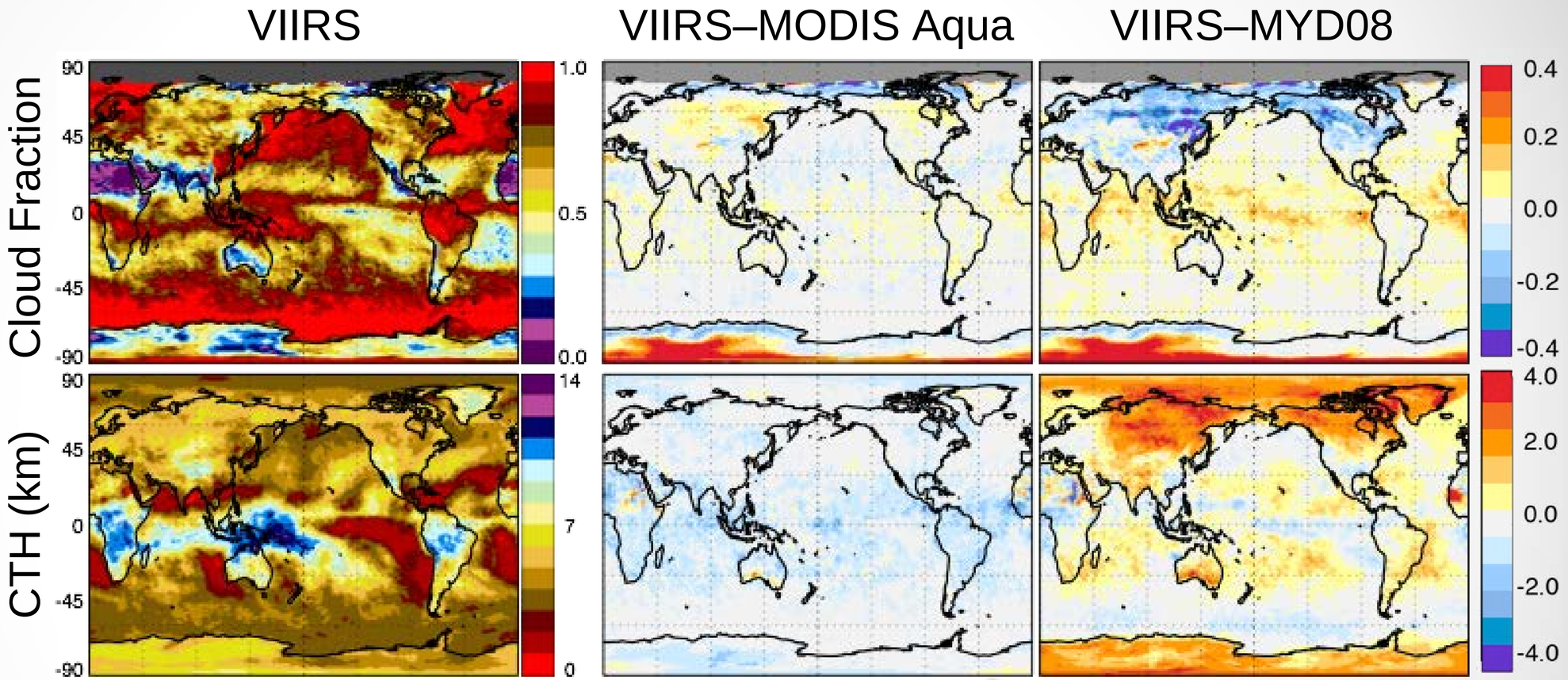
See Kerry Meyer presentation Thursday morning!

Chapter 3: Status and Some Lessons Learned (thus far)

Monthly Means
Feb 2014

- Most recent version of common algorithm, includes SW Radiometric Bias Correction
- Pixel-weighted multi-day aggregation over common MODIS swath
- Day + Night

common algorithm

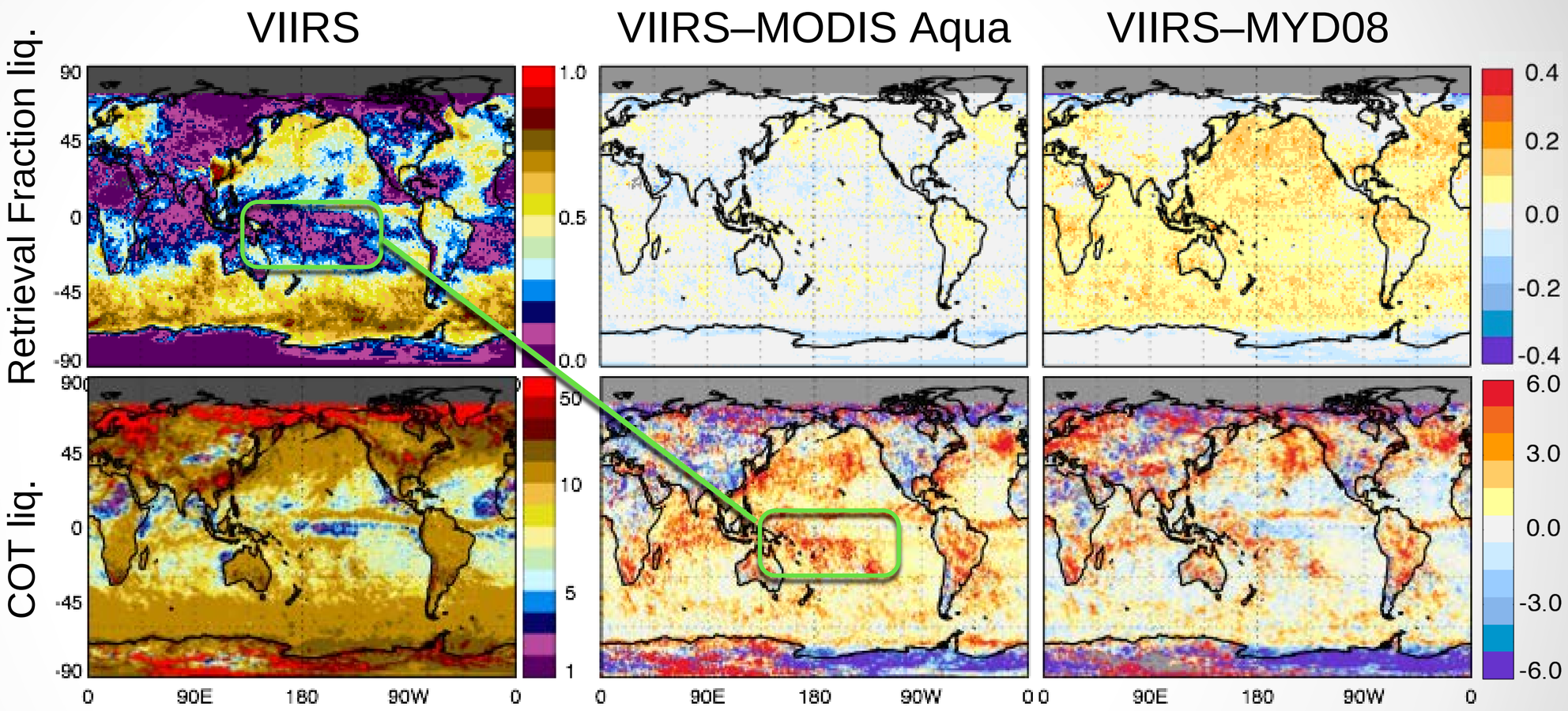


=> a separate MODIS product run with the common algorithm is required for continuity

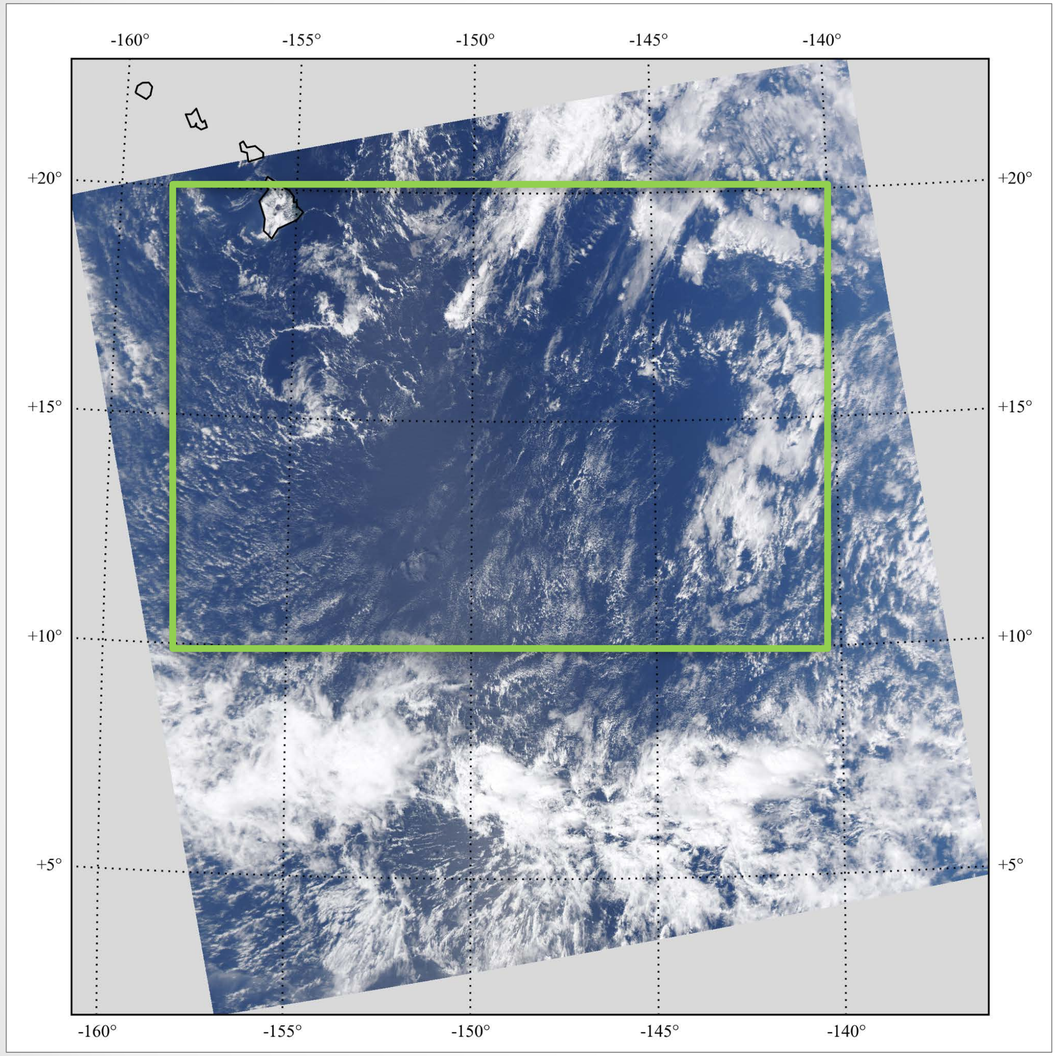
Monthly Means
Feb 2014

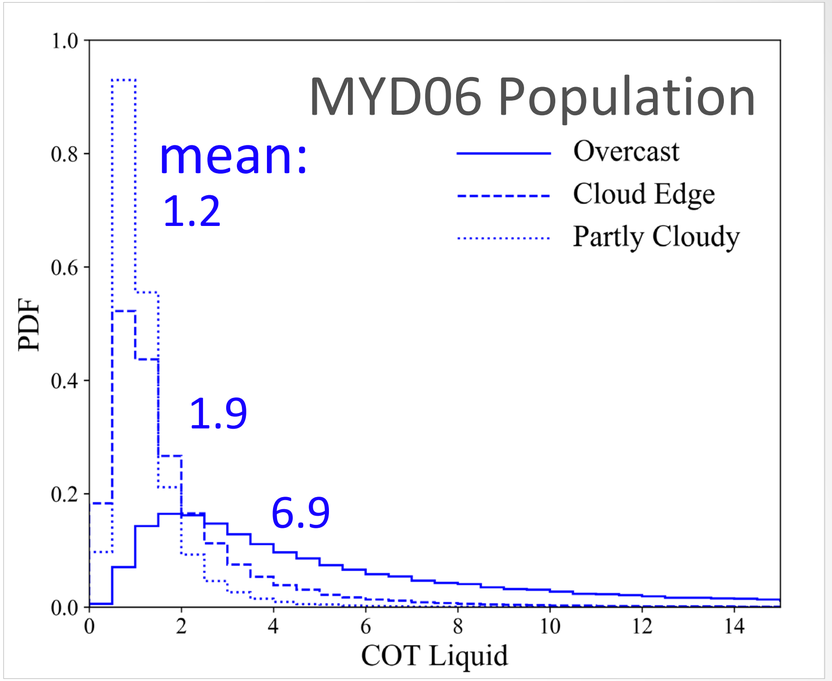
- Most recent version of common algorithm, includes SW Radiometric Bias Correction
- Pixel-weighted multi-day aggregation over common MODIS swath
- Daytime only
- Highest Quality (non-“Partly Cloudy” pixels)

common algorithm

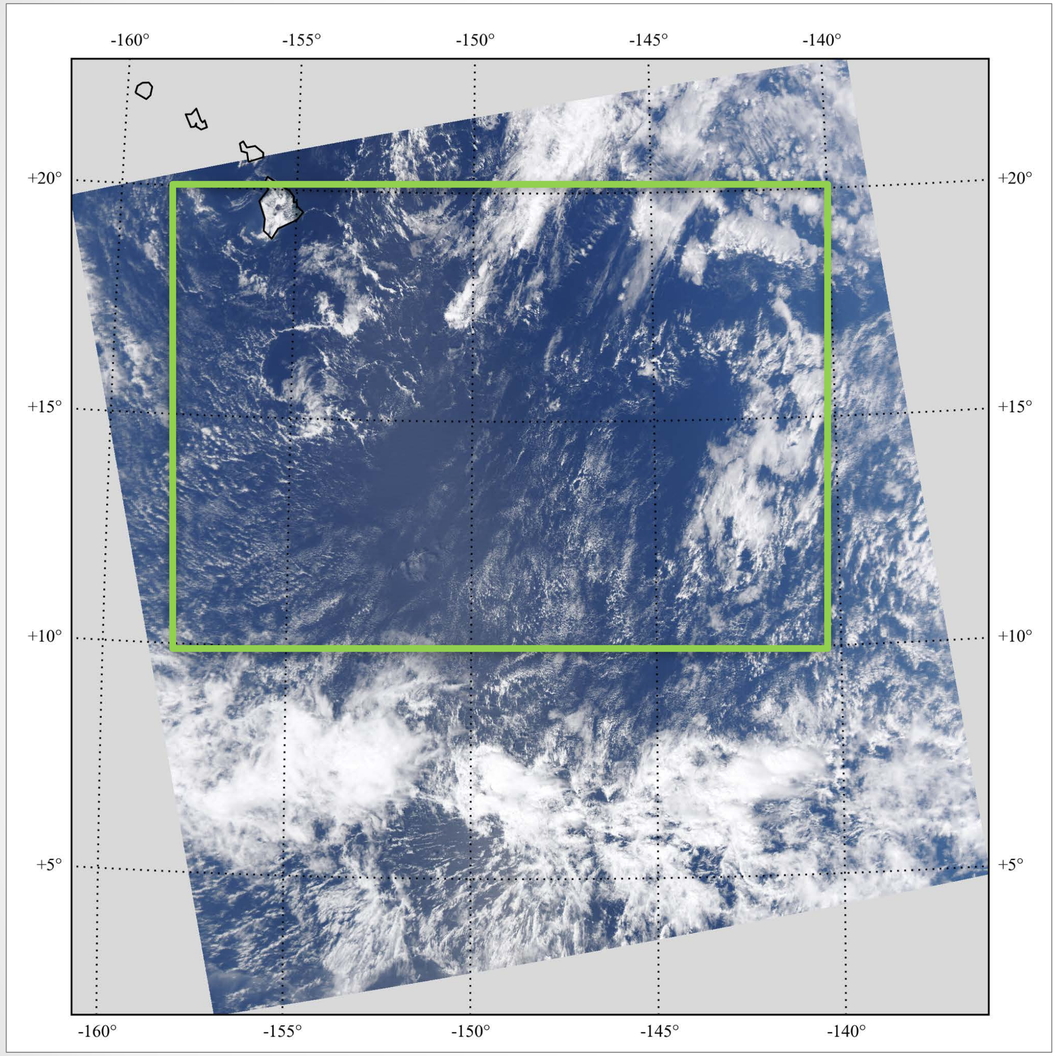


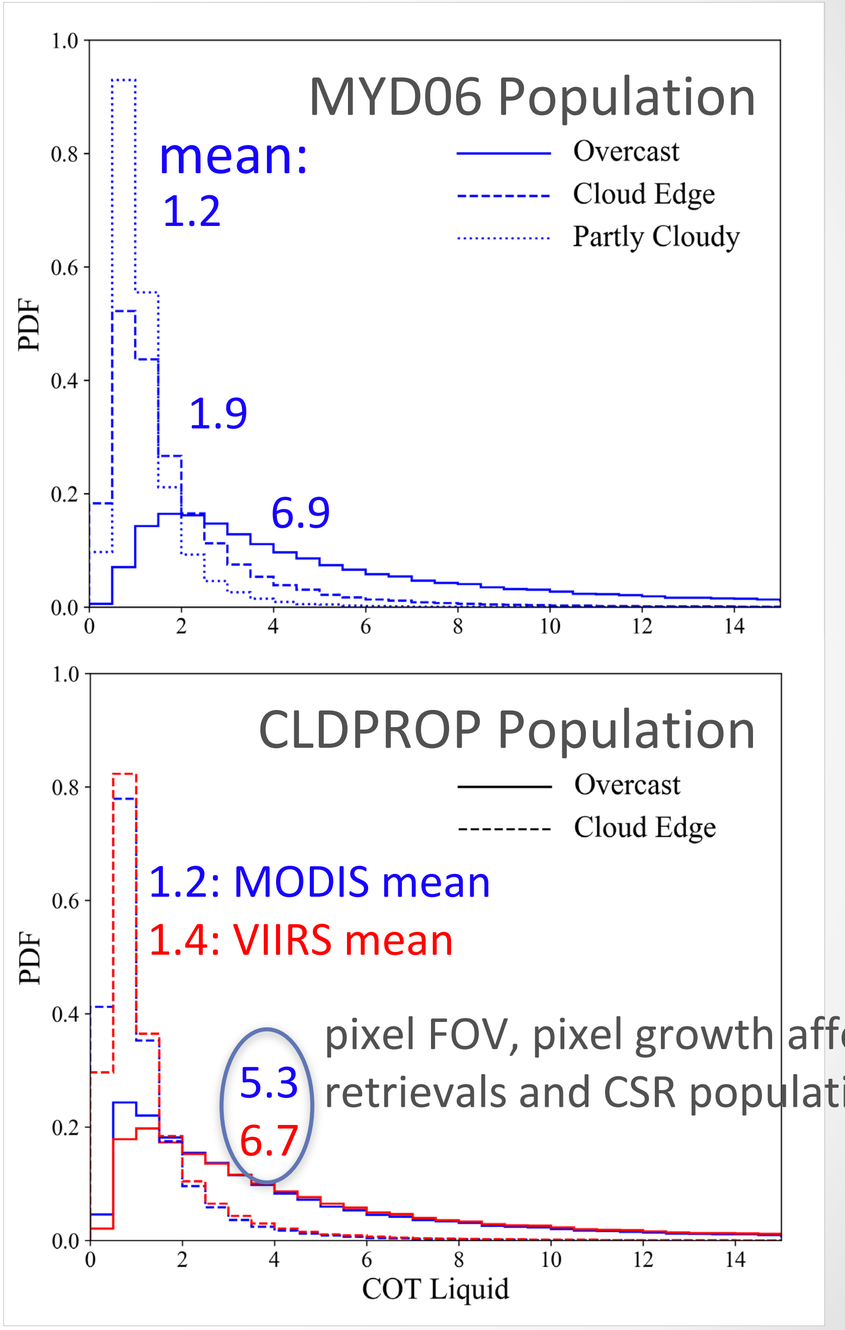
19 Feb. 2014 (N. Pacific)





19 Feb. 2014 (N. Pacific)





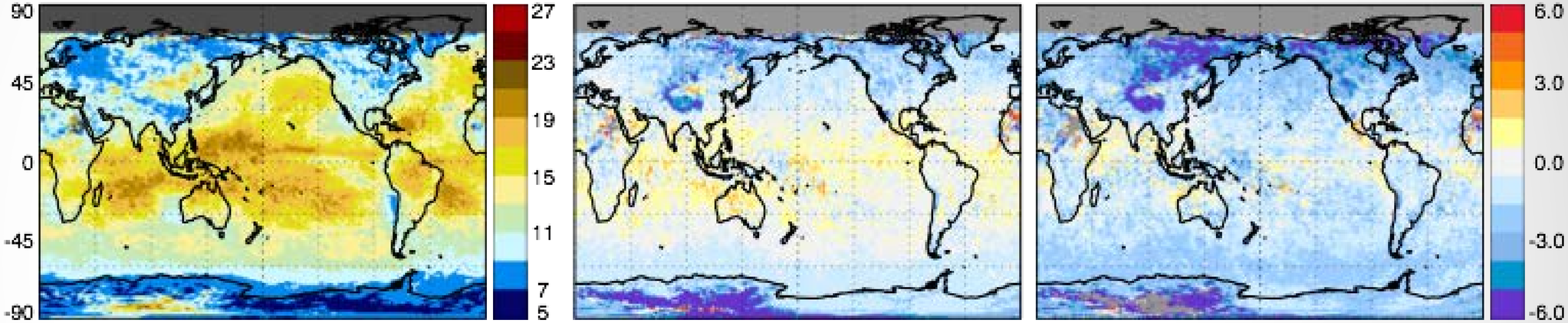
Liquid Water CER_2.x (μm) Comparisons

Monthly Means
Feb 2014

- Most recent version of common algorithm, includes SW Radiometric Bias Correction
- Pixel-weighted multi-day aggregation over common MODIS swath
- Daytime only
- Highest Quality (non-“Partly Cloudy” pixels)

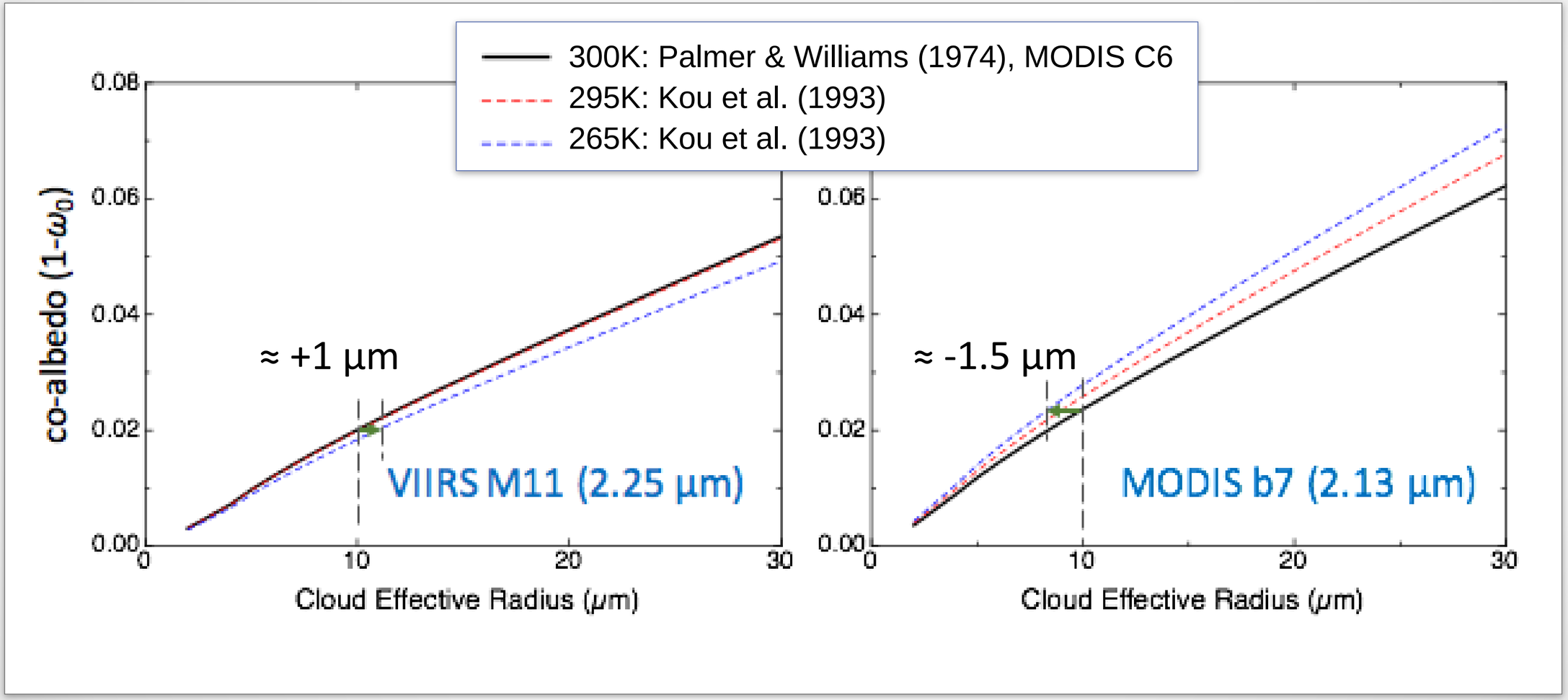
common algorithm

VIIRS | VIIRS–MODIS Aqua | VIIRS–MYD08



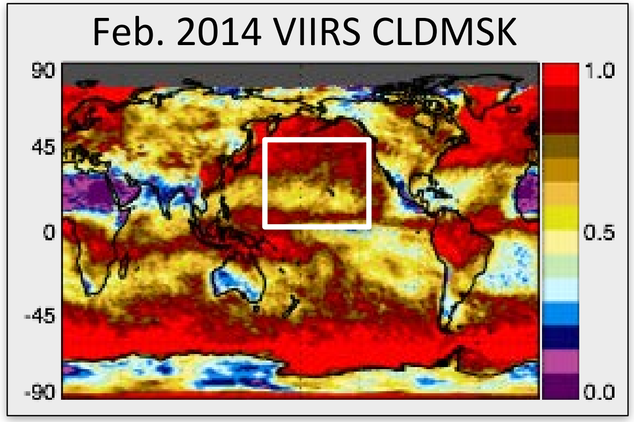
Pixel-level analysis of bias between CER_2.25 μm (VIIRS) and CER_2.13 μm (MODIS) suggested a fundamental inconsistency in the RT fwd model. ???

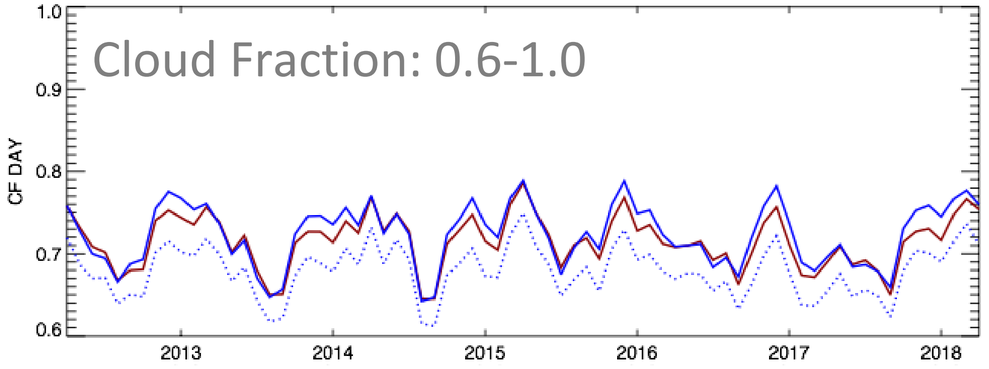
Sensitivity of 2.x μm co-albedo to complex index of refraction

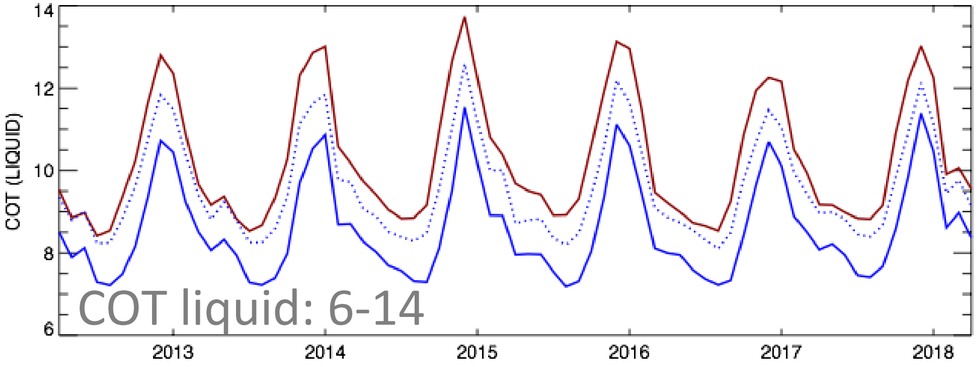


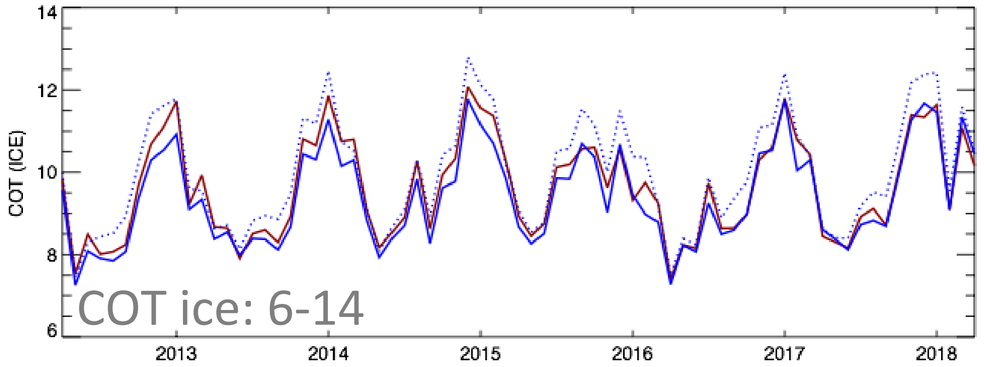
6-yr Time Series, N. Pacific

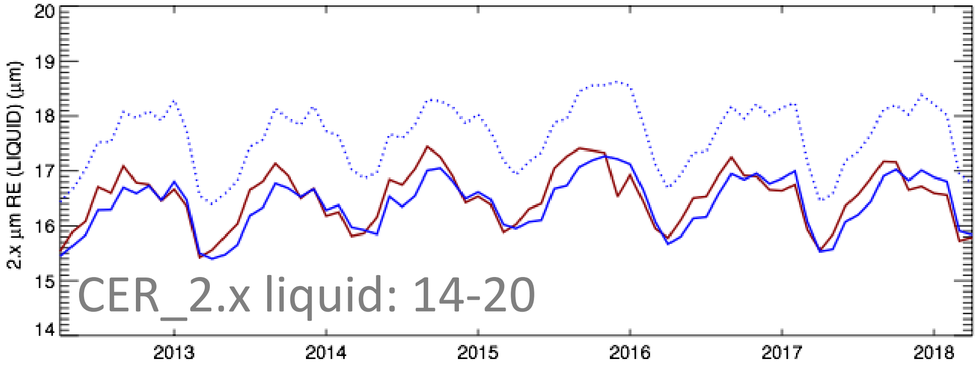
— VIIRS continuity — MODIS continuity ····· MYD08

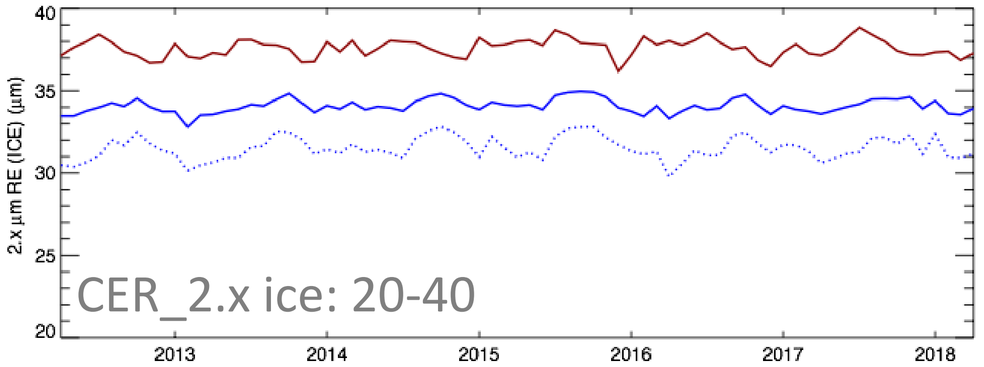










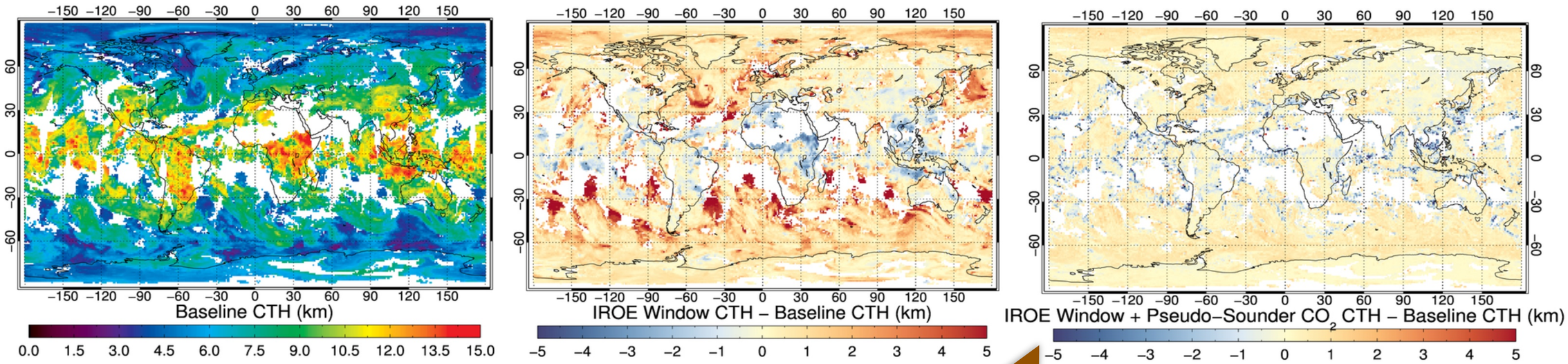


Ice Cloud Height: Sounder-like Spatial Study with Aqua MODIS

IR Optimal Estimation Algorithm, *Chenxi Wang et al.*

Daily Cloud-top Height Comparisons (April, 17, 2015)

Day + Night



Baseline Algorithm:
Window (8.5, 11, 12) +
CO_2 (13.3, 13.6, 13.9 µm) bands

Window – Baseline

[Window + CO_2 avg'd over sounder FOV] – Baseline

pseudo-sounder CO_2 channel spatial resolution biases relatively small except near cloud edges

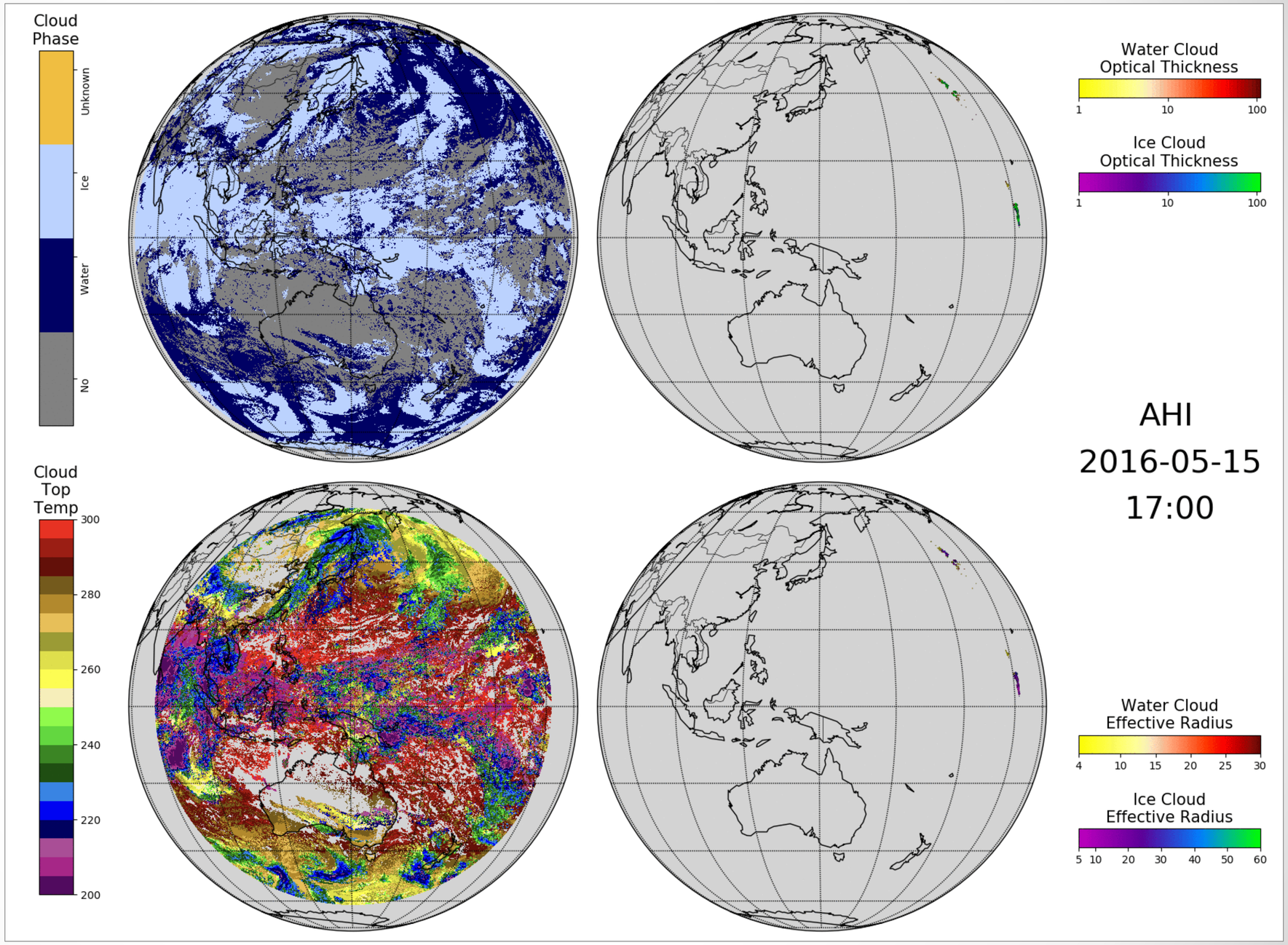
Topics

- A MODIS Story
  - The struggle for radiometric stability & status of MODIS Terra & Aqua Collection 6.1 Cloud Property Products
- The MODIS/VIIRS Continuity Story
  - The NASA continuity product paradigm
  - Algorithm/production status and some initial results
- NASA AHI/ABI research algorithms

GSFC GEO Cloud Continuity Research Efforts

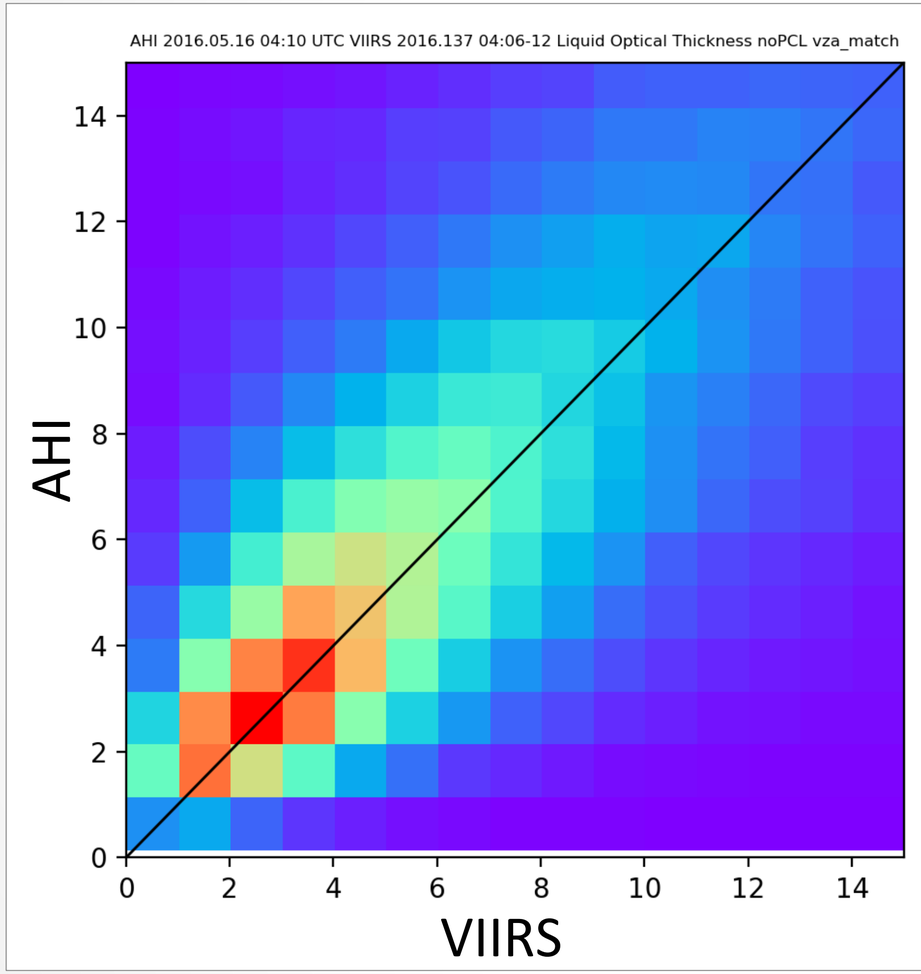
- Since VIIRS and ABI/AHI have similar spectral bands, a ‘seed’ effort was initiated by NASA to demonstrate porting VIIRS atmosphere algorithms to ABI/AHI.
  - Leverages U. Wisconsin SIPS capabilities for a limited research study for both cloud and aerosol algorithm teams; cloud team also leveraging SEVIRI effort (SEV06)
  - Initial cloud effort: 2km retrievals, cloud optical retrievals (AWG cloud mask & cloud-top), focused on AHI
  - Includes discussions with NOAA STAR and how to work collaboratively on tasks that best leverage agency activities

AHI preliminary NASA cloud research products 15-16 May 2016

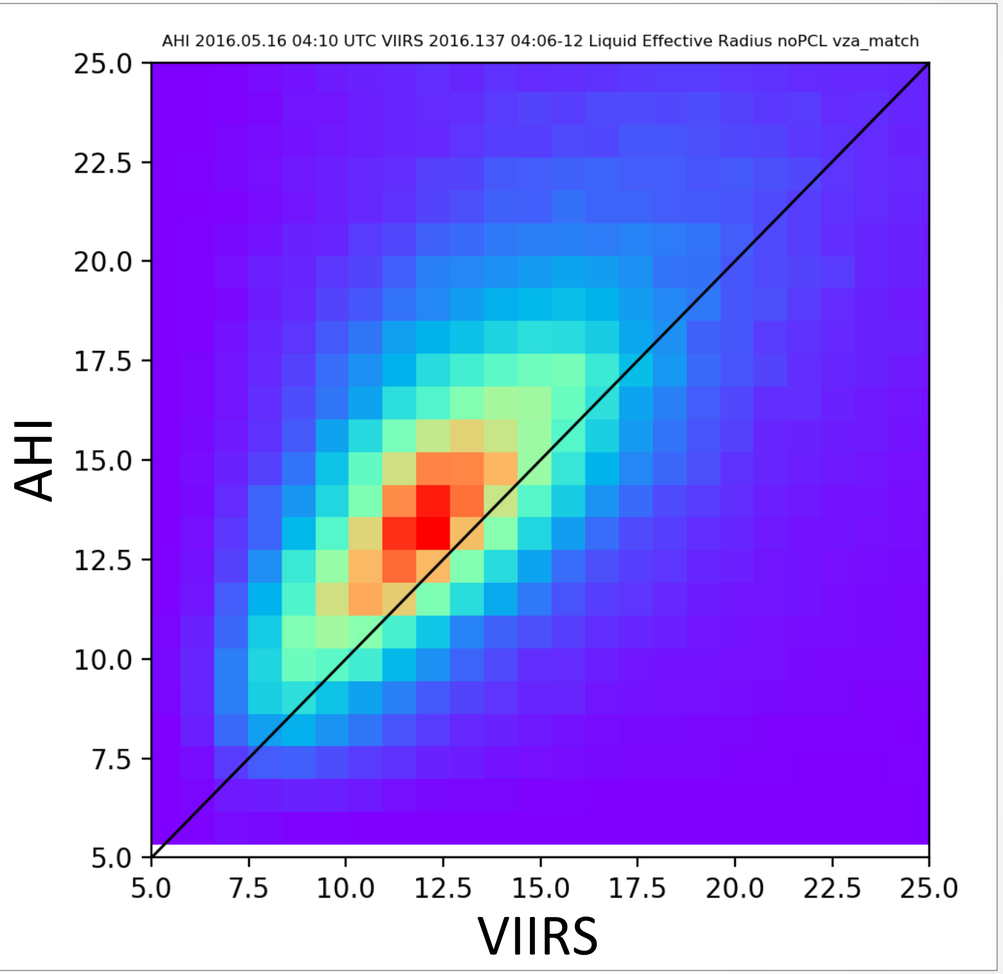


AHI vs VIIRS Retrievals: contiguous cloudy pixels only

COT-liquid



CER-liquid 2.24 µm



For overlap region defined by VZA ≤15°, ≤ 5 min (16 May 2016)

MODIS/VIIRS Cloud Continuity (CLDMSK/CLDPROP) Summary

- Shortwave radiometric data record continuity is challenging, even with the same instrument (MODIS Aqua/Terra). More so for different instruments.
- Impact of 2.x μm window channel placement on optical properties (ice as well as liquid) requires understanding spectral imaginary index of refraction.
- Next Steps:
  - Public release: Imminent
  - Algorithm: Further investigation of index of refraction sensitivity (ice as well as liquid), FOV/sampling aggregation sensitivities, and use of CrIS to compensate missing VIIRS IR absorption channels (longer term).
  - Science assessment: time series analysis, include “cloud radiative effect” datasets and assess radiative continuity, user community feedback, …
  - GEO algorithms: continue efforts as feasible, assess ability to tie in with LEO products