CERES Cloud Working Group Report

CERES Science Team Mtg., Hampton, VA, 7-9 May 2019

W. L. Smith, Jr.

NASA Langley Research Center, Hampton, VA

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S. Bedka (retrievals, val), C. Yost (val), G. Hong (models, night tau), Y. Chen (clr props, test runs),
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E. Heckert (web), B. Shan (GEO), R. Smith (web, NPP), D. Spangenberg (everything), Churngwei Chu (web)

SSAI, Hampton, VA

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P. Yang, S. Hioki (ice models), Texas A& M University

X. Dong, B. Xi, (validation), University of Arizona

Thanks to Dave Doelling and his TISA/calibration teams!

Topics

- Publications update
- Processing status
- C6.1 impacts on Terra Cloud Properties
- Progress for improved cloud properties over snow/ice
- GOES-17 update
- Recent validation results

Update of CERES Cloud-related Papers

Edition-4 related

Trepte, Q. Z., P. Minnis, S. Sun-Mack, C. R. Yost, Y. Chen, Z. Jin, G. Hong, F.-L. Chang, W.,L. Smith, Jr., K. Bedka, T.L. Chee, 2019: Global cloud detection for CERES Edition 4 using Terra and Aqua MODIS data. *IEEE Trans. Geosci. Remote Sens.*, **ED4 CLOUD MASK - accepted with minor revisions**.

Minnis, P., S. Sun-Mack, Y. Chen, C. R. Yost, W. L. Smith, Jr., F.-L. Chang, P. W. Heck, R. F. Arduini, Q. Z. Trepte, K. Ayers, K. Bedka, S. Bedka, R. R. Brown, D. R. Doelling, A. Gopalan, E. Heckert, G. Hong, Z. Jin, R. Palikonda, R. Smith, B. Scarino, D. A. Spangenberg, P. Yang, Y. Xie, and Y. Yi, 2019: CERES MODIS cloud product retrievals for Edition 4, Part I: Algorithm changes. IEEE Trans. Geosci. Remote Sens., **ED4 ALGORITHM - in preparation**.

Yost, C., P. Minnis, S. Sun-Mack, Y. Chen, and W. L. Smith, Jr., 2019: CERES MODIS cloud product retrievals for Edition 4, Part II: Comparisons to CloudSat and CALIPSO. IEEE Trans. Geosci. Remote Sens., **ED4 VALIDATION - - in preparation**.

Loeb, N. G., H. Wang, F. G. Rose, S. Kato, W. L. Smith, Jr., and S. Sun-Mack, 2019: Decomposing Shortwave Top-of-Atmosphere and Surface Radiative Flux Variations in Terms of Surface and Atmospheric Contributions, J. Climate, **accepted with minor revision.**

Kurzrock, F., Nguyen, H., Sauer, J., Chane Ming, F., Cros, S., Smith Jr., W. L., Minnis, P., Palikonda, R., Jones, T. A., Lallemand, C., Linguet, L., and Lajoie, G., 2019: Evaluation of WRF-DART (ARW v.3.9.1.1 and DART manhattan release) multi-phase cloud water path assimilation for short-term solar irradiance forecasting in a tropical environment, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2019-29, **in review.**

Sorooshian, A., and co-authors, 2019: Aerosol-Cloud-Meteorology Interaction Airborne Field Investigations: Using Lessons Learned from the US West Coast in the Design of ACTIVATE off the US East Coast. Bull. Amer. Meteor. Soc., 0, https://doi.org/10.1175/BAMS-D-18-0100.1

Ghate, V. P., Mechem, D. B., Cadeddu, M. P., Eloranta, E. W., Jensen, M. P., Nordeen, M. L. and Smith Jr, W. L. (2019), Estimates of Entrainment in Closed Cellular Marine Stratocumulus Clouds from the MAGIC Field Campaign. Q J R Meteorol Soc., 1– 14.https://doi.org/10.1002/qj.3514

Duda, D. P., S. T. Bedka, D. Spangenberg, K. Khlopenkov, P. Minnis, and W. L. Smith, Jr., 2019: Northern Hemisphere contrail properties derived from Terra and Aqua MODIS data for 2006 and 2012, Atmos. Chem. Phys., 19, 5313-5330, https://doi.org/10.5194/acp-19-5313-2019

Su, W., Liang, L., Doelling, D. R., Minnis, P., Duda, D. P., Khlopenkov, K. V., et al. (2018). Determining the shortwave radiative flux from Earth polychromatic imaging camera. Journal of Geophysical Research: Atmospheres, 123, 11,479– 11,491. https://doi.org/10.1029/2018JD029390

Painemal, D. (2018). Global estimates of changes in shortwave low-cloud albedo and fluxes due to variations in cloud droplet number concentration derived from CERES-MODIS satellite sensors. Geophysical Research Letters, 45, 9288– 9296. https://doi.org/10.1029/2018GL078880

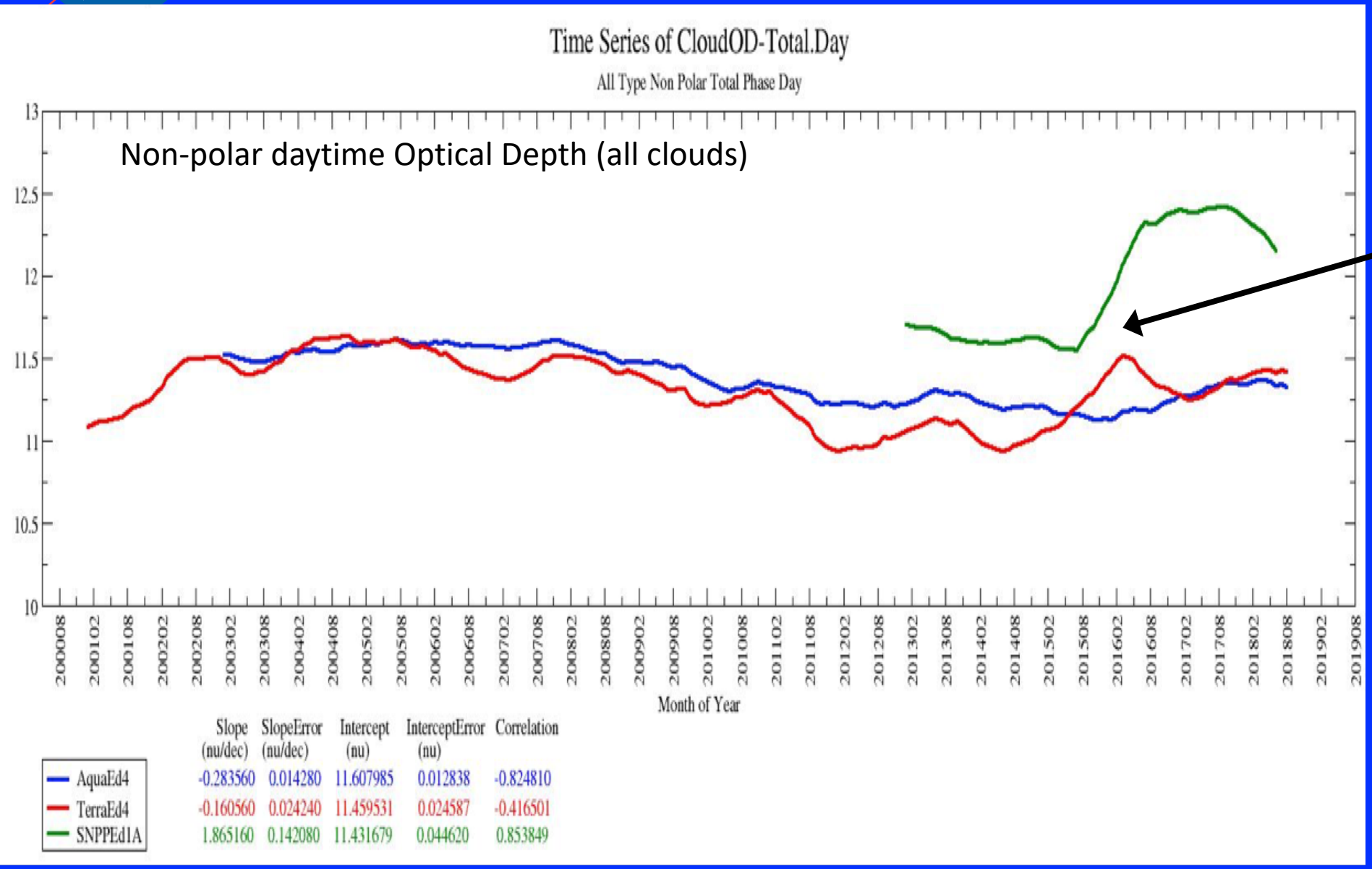
Wall, C.J., D.L. Hartmann, M.M. Thieman, W.L. Smith, and P. Minnis, 2018: The Life Cycle of Anvil Clouds and the Top-of-Atmosphere Radiation Balance over the Tropical West Pacific. J. Climate, 31, 10059–10080, https://doi.org/10.1175/JCLI-D-18-0154.1

Edition-5 related

Saito, M., Yang, P., Hu, Y., Liu, X., Loeb, N., Smith Jr, W. L., & Minnis, P. (2019). An efficient method for microphysical property retrievals in vertically inhomogeneous marine water clouds using MODIS-CloudSat measurements. *J. Geophys. Res.*, 124, 2174– 2193. https://doi.org/10.1029/2018JD029659

Clouds - Processing Status

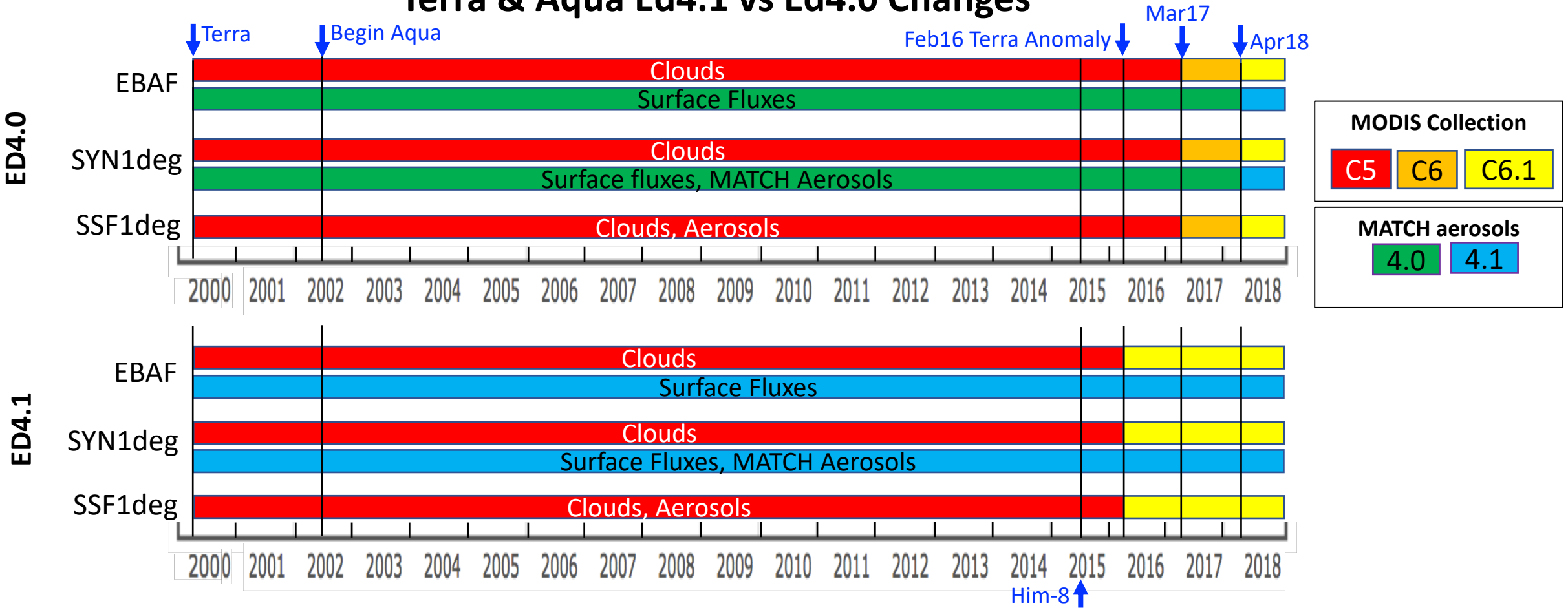
CERES-MODIS Edition 4 Status	*Aqua: Jul 2002 – Mar 2019 (~17 y)* *Terra: Feb 2000 – Mar 2019 (~18 y)* ***MODIS Calibration Strategy:*** • ***MODIS Collection 5 thru Feb 2016,*** • ***MODIS Collection 6.1 March 2016 - present*** • ***C6.1 radiances are scaled to C5 for consistency over entire record*** • ***CWG developed and applied Terra/Aqua normalizations for C5 (Sun-Mack, et al. 2018)***
CERES-VIIRS Ed 1 Status	*SNPP: Jan 2012 – Jan 2019 (~7 y)* ***Imager Calibration Strategy:*** • ***Use forward processing calibrations*** • ***Inconsistencies in current record*** ***Ed2 Changes:*** • ***Apply calibrations consistent w/MODIS*** • ***Re-evaluate for continuity w/ MODIS for Ed5***



Example of VIIRS calibration inconsistency appearing in 2016

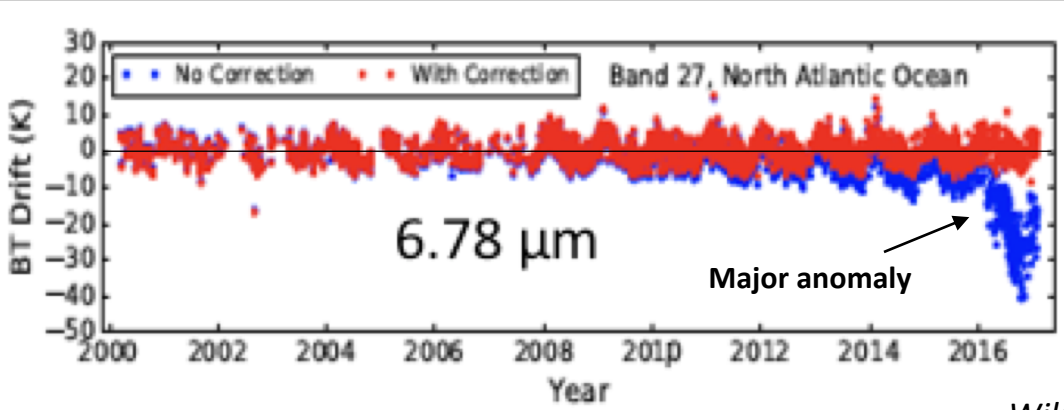
VIIRS Ed2 will have consistent calibration over the record and scaled to MODIS C6.1 (talk this afternoon, Doellling calibration team)

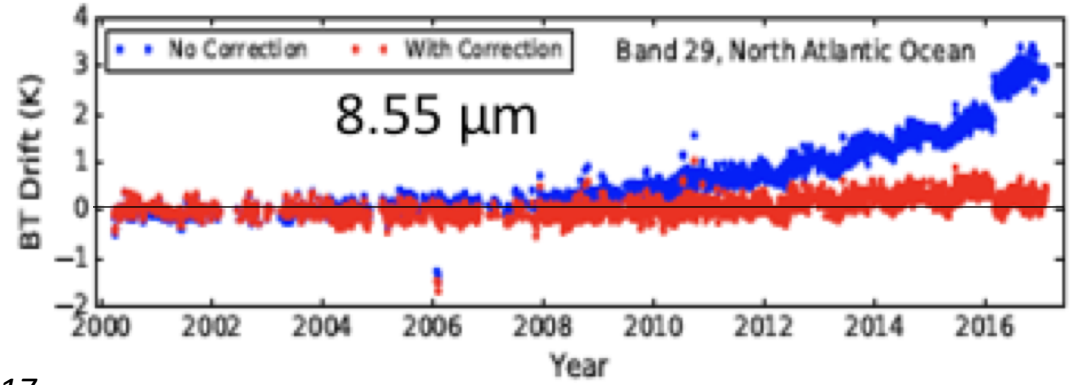
Terra & Aqua Ed4.1 vs Ed4.0 Changes



Parameter	ED4.0	ED4.1
MODIS-collection	Terra-MODIS 6.7, 8.6 µm striping, March 2016 to March 2018	MODIS C6.1 resolved the Terra-MODIS 6.7, 8.6 µm striping
MATCH-Edition	Large discontinuity between MODIS C5 & C6.1 AOD inputs	Uses MODIS C6.1 AODs as input for entire CERES record
MODIS Clouds	Impacted Terra cloud properties	Terra cloud properties corrected beginning in Feb 2016
GEO Clouds	Him-8, GOES-16,17, Met-8,11 cloud codes with bugs	Consistent cloud code using MATCH Ed4.1, begin July 2015
Surface fluxes	The clear-sky SW down surface flux was impacted by MODIS C5 & C6.1 AOD discontinuity	SYN surface fluxes, computed using consistent GEO cloud code with MATCH Ed4.1 and tuned fluxes to correct GEO TOA flux

Terra Calibration Issue - Corrected in C6.1



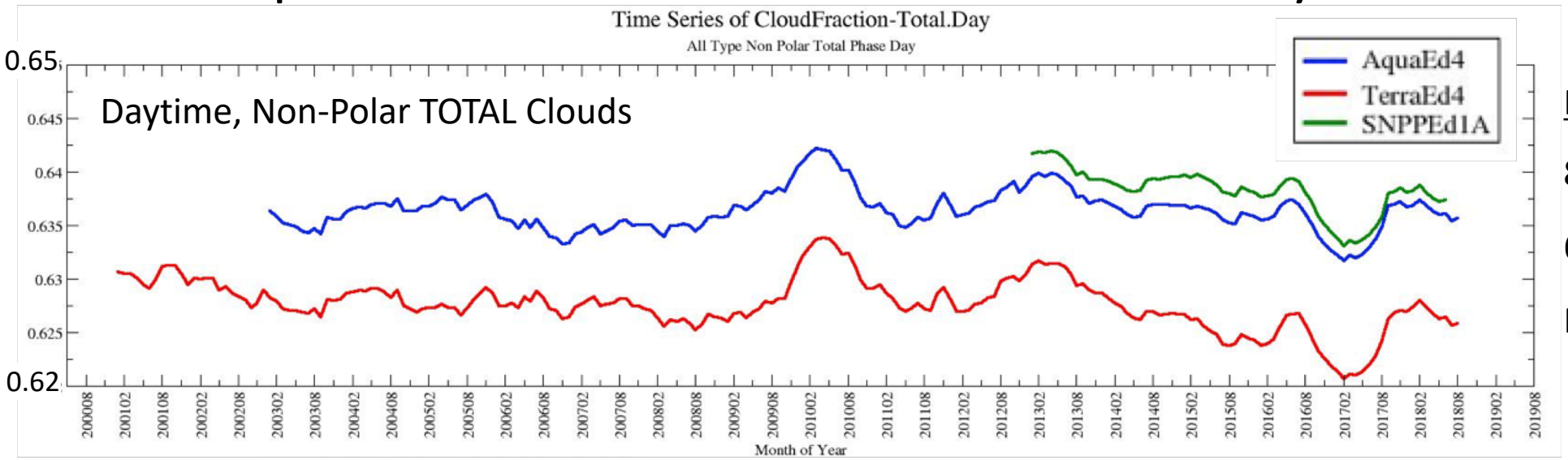


Wilson et al. RS, 2017

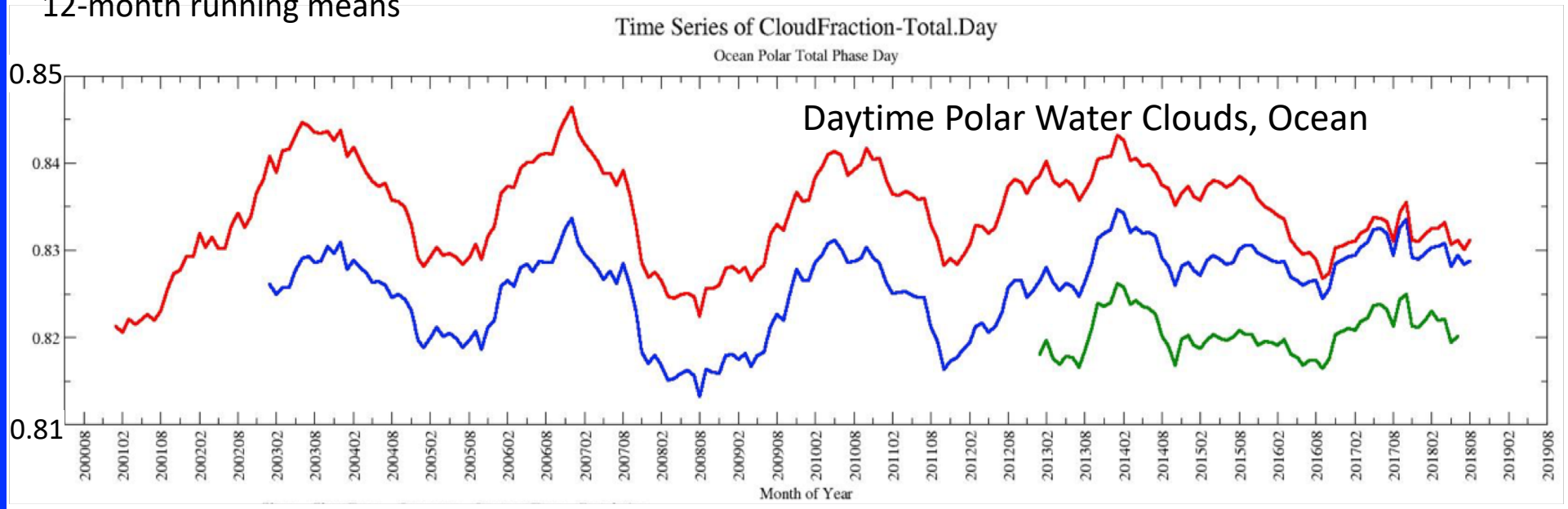
- 6.7 µm WV and 8.6 µm window channel began degrading on TERRA in mid 2000's.
- Major anomaly in TERRA WV channel occurred in Feb 2016
- These channels are used in cloud mask and for cloud phase selection
- Most significant impacts at night & polar regions; Some artificial cloud trends evident after 2008.
- MODIS C6.1 mostly corrected to achieve stable 6.7 and 8.6 µm radiances across the record
- Clouds reprocessed beginning in March 2016 with C6.1 corrections for 6.7 and 8.5 µm
  - creates discontinuity in some TERRA cloud properties

C6.1 Impact on Terra

Daytime Cloud Fraction



12-month running means



<u>Non-Polar Day</u>

8.6 µm used sparingly.

6.7 µm not used

Negligible impact

<u>Polar Day</u>

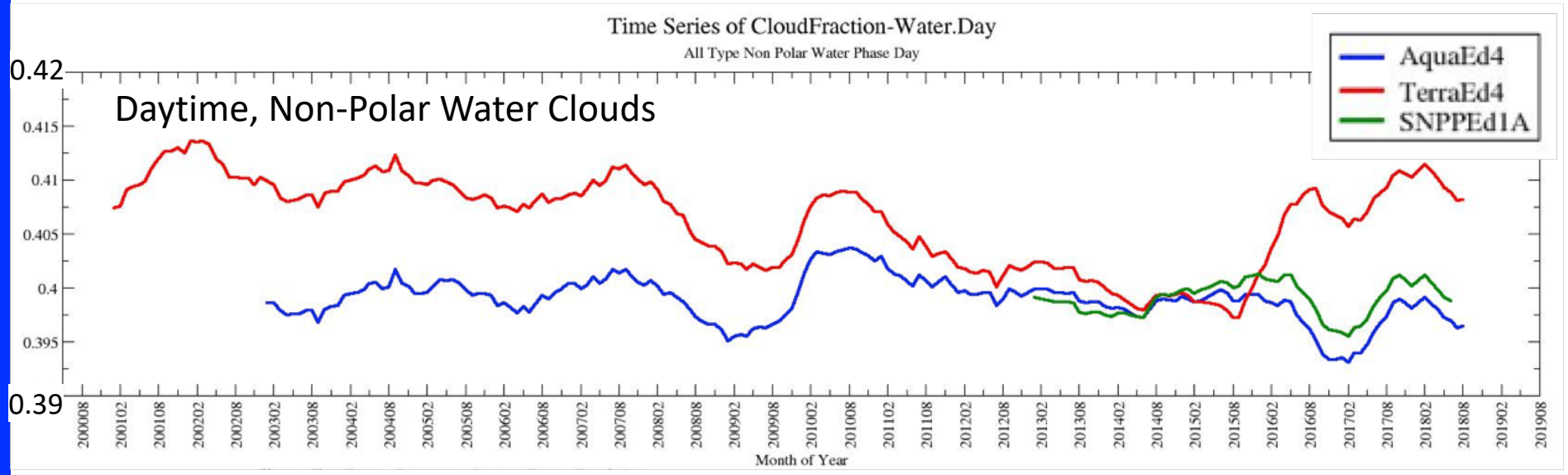
8.6 µm not used.

6.7 µm is used

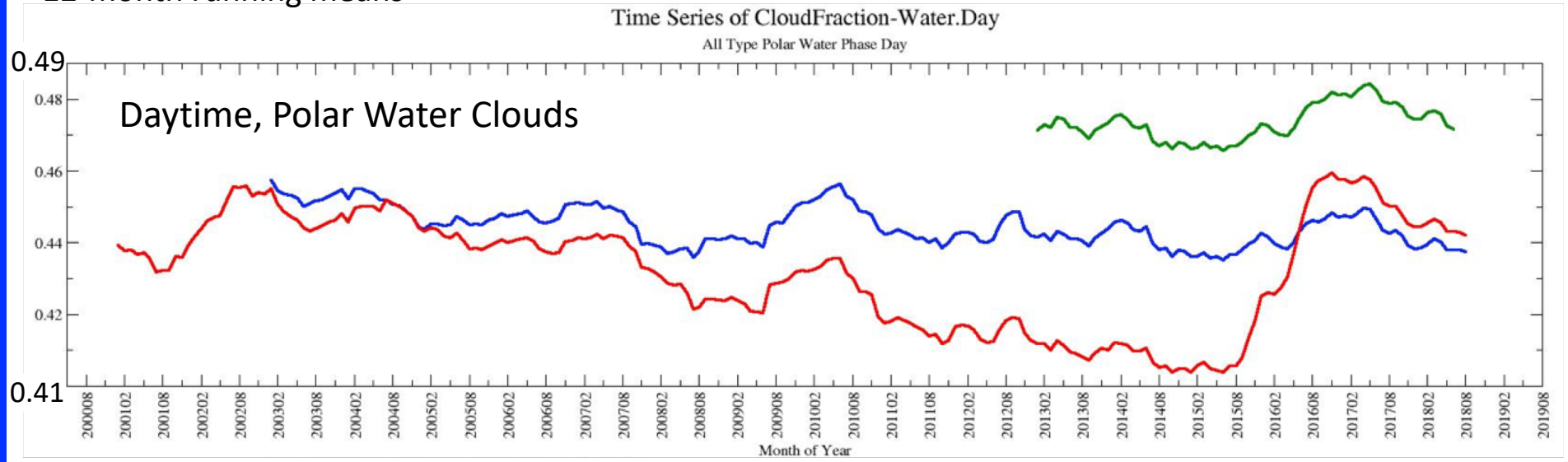
Low impact (0.5%)

C6.1 Impact on Terra

Daytime Cloud Phase



12-month running means



Non-Polar Day

8.6 µm used in phase logic.

1% increase in water clouds, decrease in ice clouds (not shown)

Terra water cloud fraction matches early part of record

Polar Day

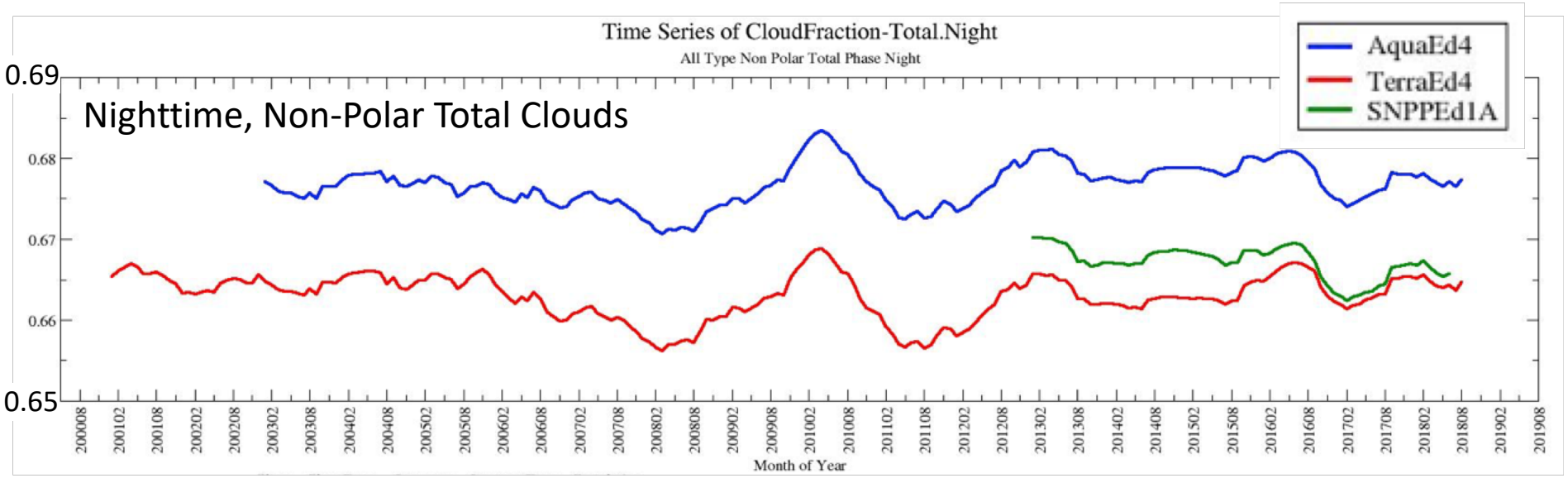
8.6 µm used in phase logic.

4% increase in water clouds, decrease in ice clouds (not shown)

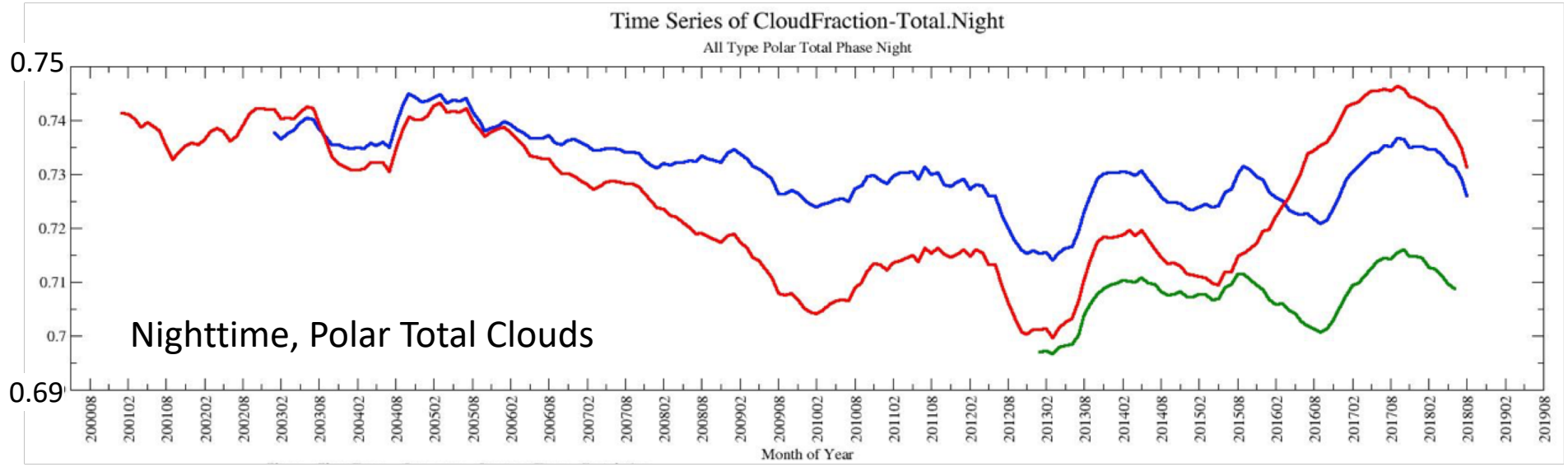
Terra water cloud fraction overshoots early part of record

C6.1 Impact on Terra

Nighttime Cloud Fraction



12-month running means



Non-Polar Night

6.7, 8.6 µm used sparingly.

Low impact (0.5%)

Polar Night

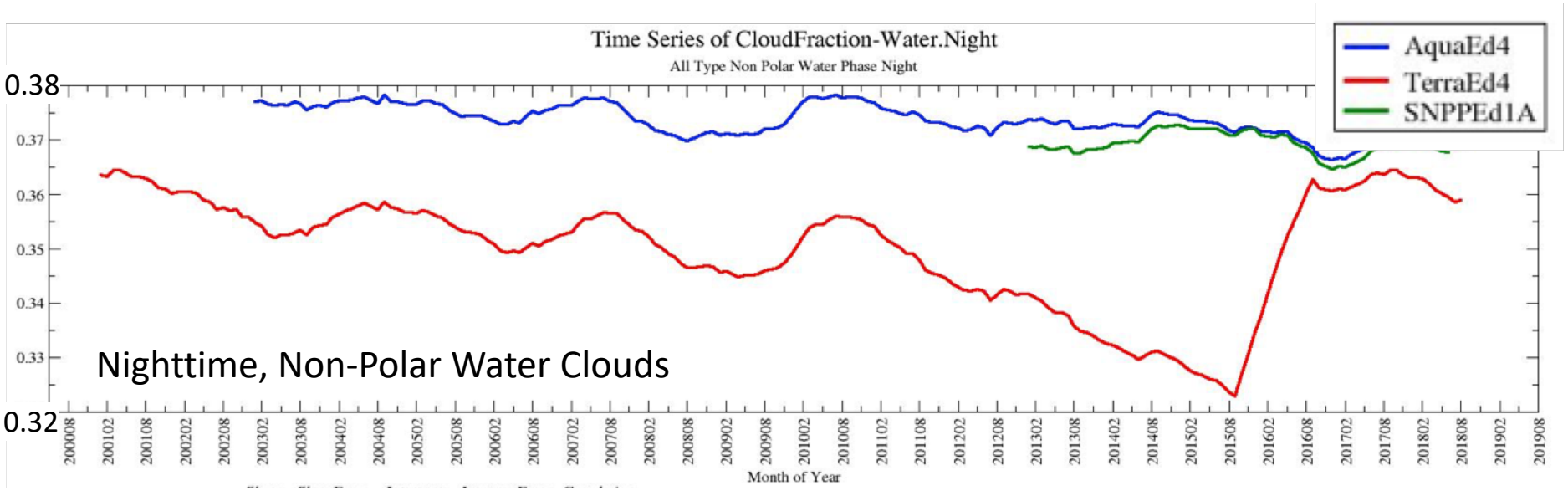
6.7 and 8.6 µm are used.

3% increase in clouds

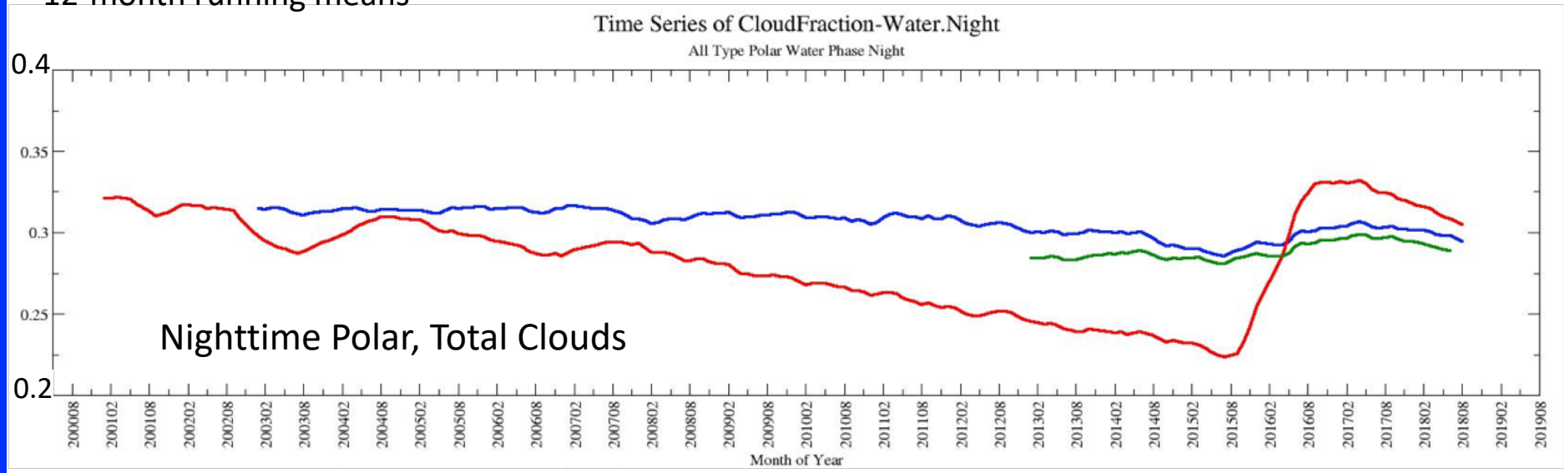
Scaling procedure overcorrected slightly

C6.1 Impact on Terra

Nighttime Cloud Phase



12-month running means



Non-Polar Night

8.6 µm used in phase logic.

4-5% increase in water clouds, decrease in ice clouds (not shown)

Terra water cloud fraction a little high

Polar Night

8% increase in water clouds

Scaling procedure overcorrected slightly

6.7 or 8.5 µm degrading again? Doelling group is checking it out

Summary of switch to C6.1 (Terra impacts)

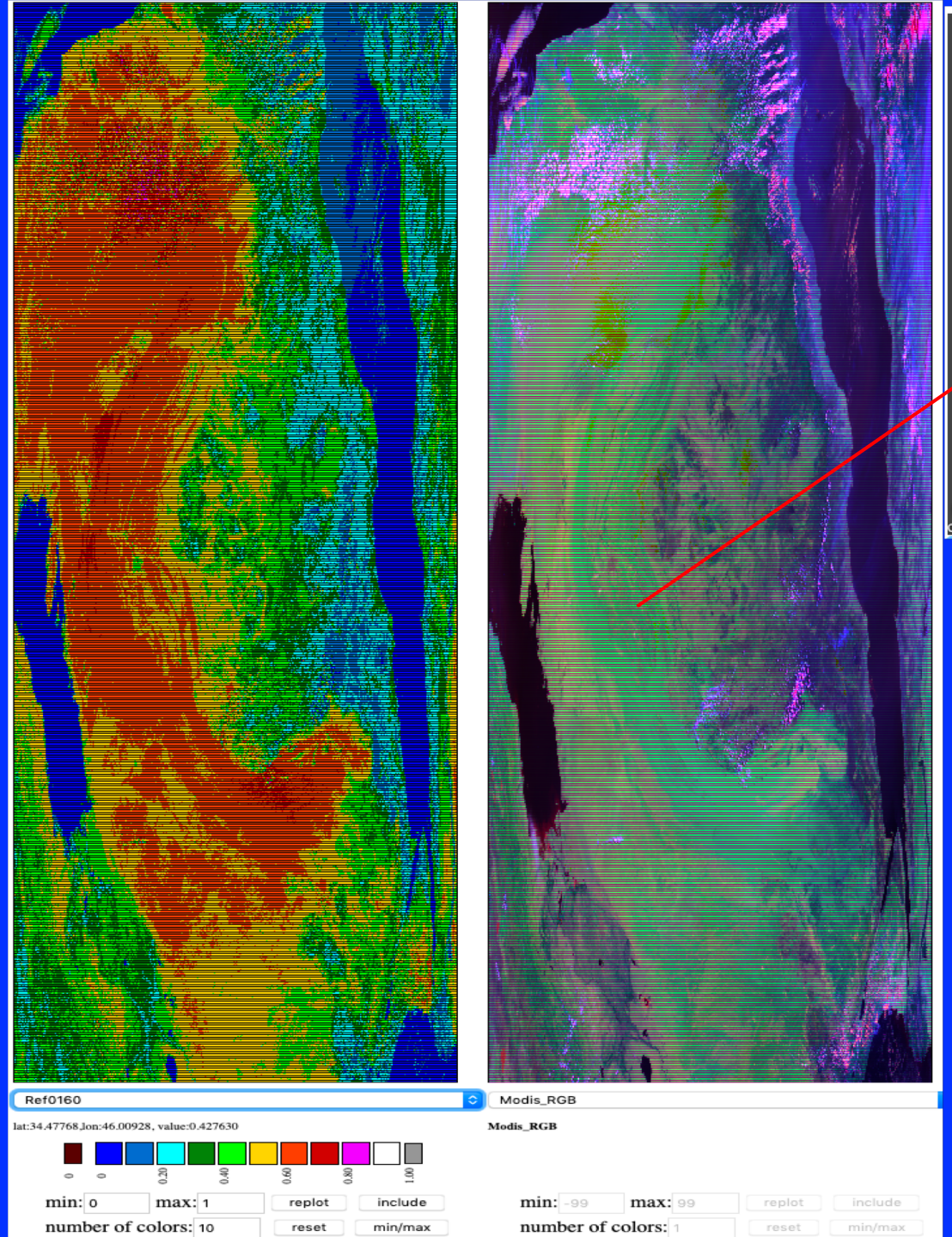
- Artificial trends in Terra cloud properties are evident due to the degradation of 6.7 and 8.6 µm channels in C5 from ~2008 until Feb 2016 when a major anomaly in the 6.7 µm band occurred. These trends can not be addressed until a full reprocessing for Ed5
- C6.1 significantly improves these channels.
- Using the C6.1 corrections, the Terra-Modis clouds were reprocessed beginning in March 2016 with the objective to return to pre-degradation levels.
- Thus discontinuities exist in some Terra cloud properties beginning in March 2016.
- Nighttime and polar regions are affected the most (cloud fraction and phase were shown)
- The cloud phase discontinuities leads to discontinuities in other cloud properties (e.g. R_e and CTH)

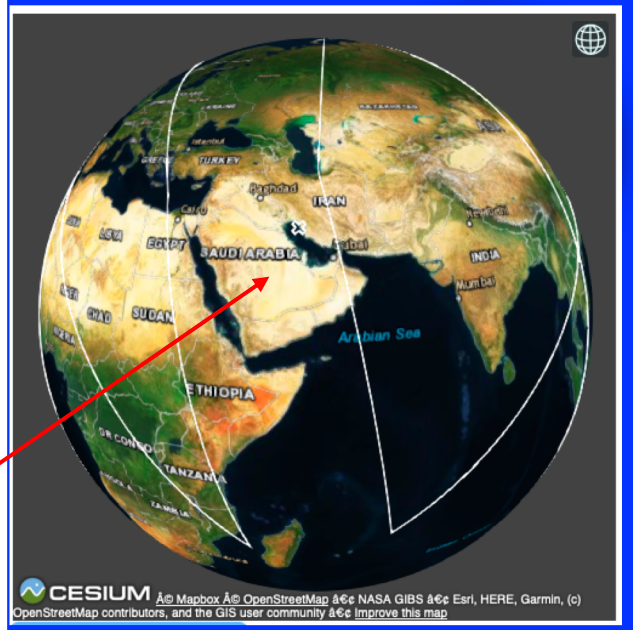
Toward more accurate and consistent cloud properties over snow (daytime)

Issues over Snow	Different channels used in **cloud mask** • 2.1 µm for Aqua & Terra since Aqua 1.6 µm has problems (1.6 um preferred though) • Only 5 of 20 1.6 um detectors on AQUA are fully functional – not used in CERES Ed4 • 2.25 µm on VIIRS much different that MODIS 2.1 µm (thus VIIRS uses 1.6 µm) **Cloud Retrievals**: • Vis channel not useful for thin clouds over snow • Current approach uses 1.2 µm for MODIS and VIIRS • 0.64, 1.2, 1.6, 2.1 µm channels sensitive to different ranges of Tau - Hybrid approach may be best but would need to use common channels
Possible Solutions	• Restore 1.6 µm channel on AQUA (utilize good detectors in subsetting) • Continue with 1.2 um for Tau, switch to 1.6 µm, or develop hybrid approach • 1.6 µm or a 0.64/1.6 µm hybrid could be applied to newer GEO's (1.2 µm not on GEO) • Cloud properties and clear sky reflectances from the various channels over snow/ice need further evaluation to help solve this (new study underway for the ARISE period)

MODIS 1.6 μm reflectance from Aqua delivered to LaRC, **subsetted at every other scanline and every other pixel, no regard for bad detectors**

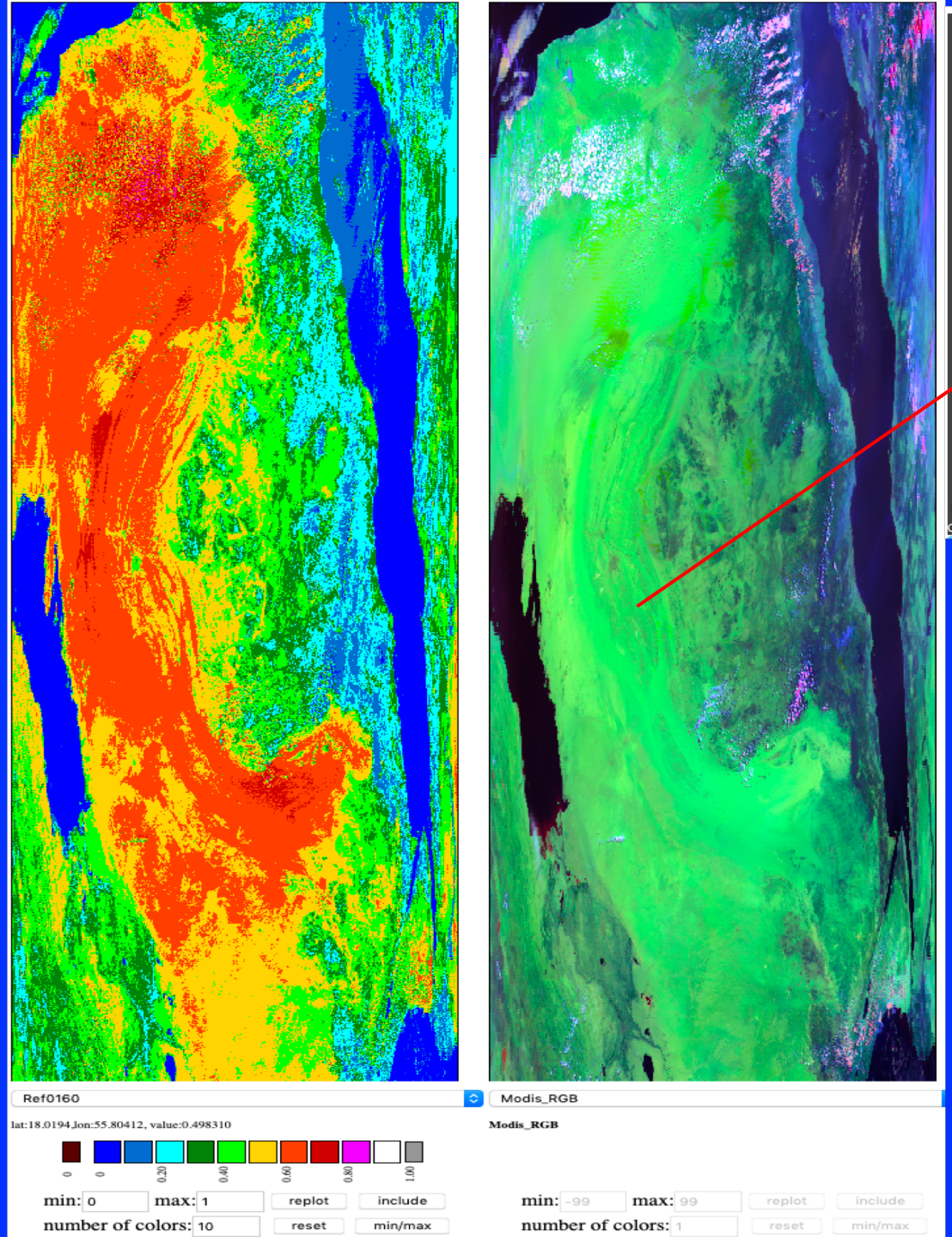
Stripping: Bad detectors: 3 & 7

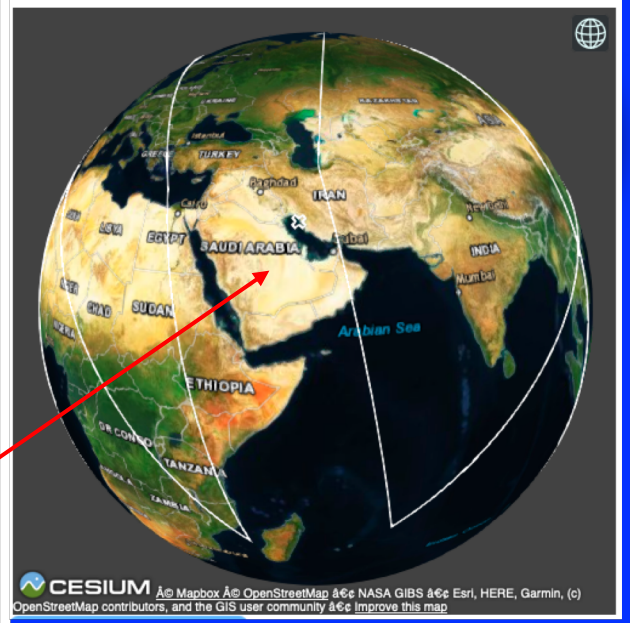




Aqua 2018 09

Aqua 1.6 μm reflectance from MODIS, **replacing bad detectors 3 & 7 with the nearest good detectors 2 & 6 respectively.**

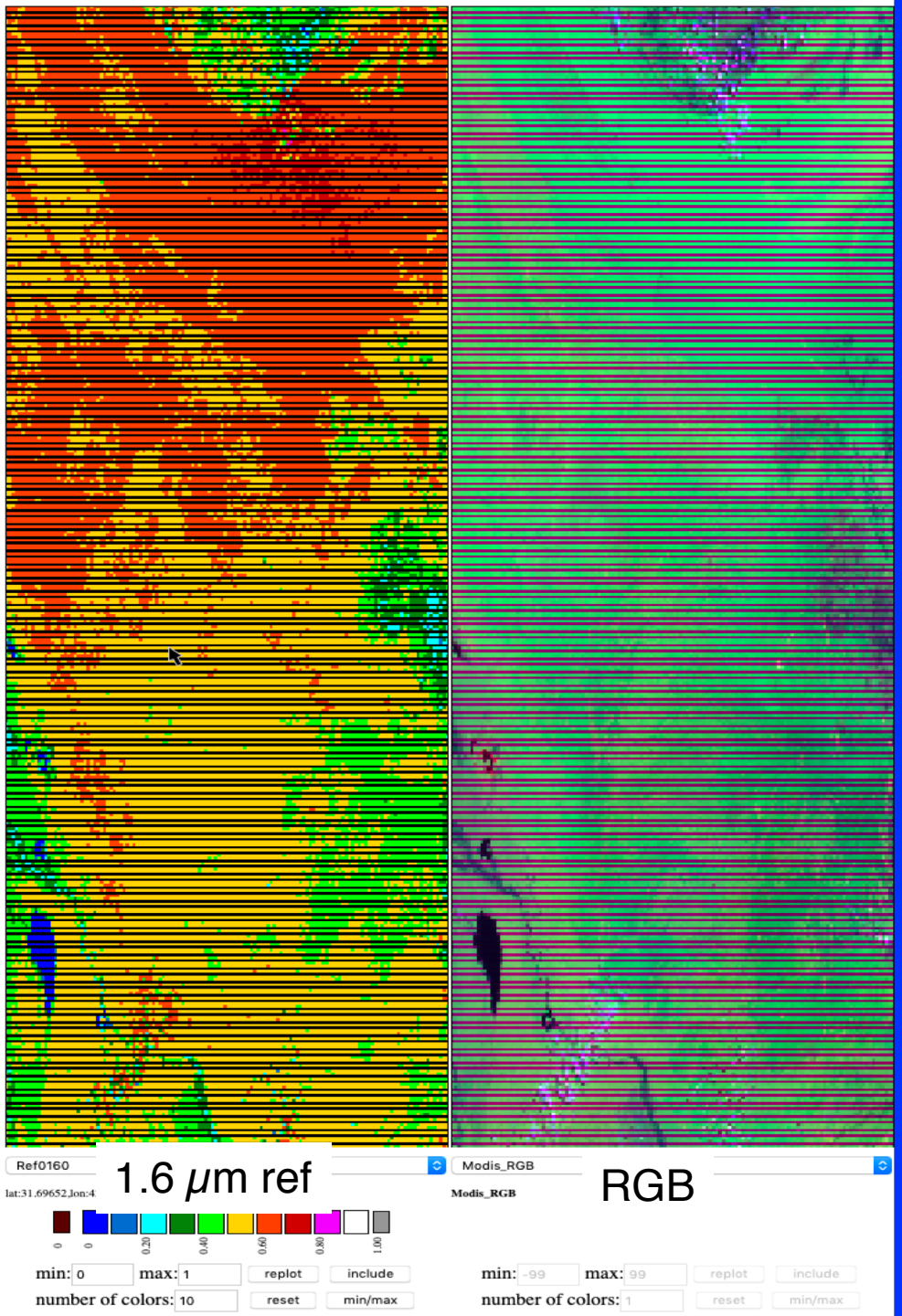


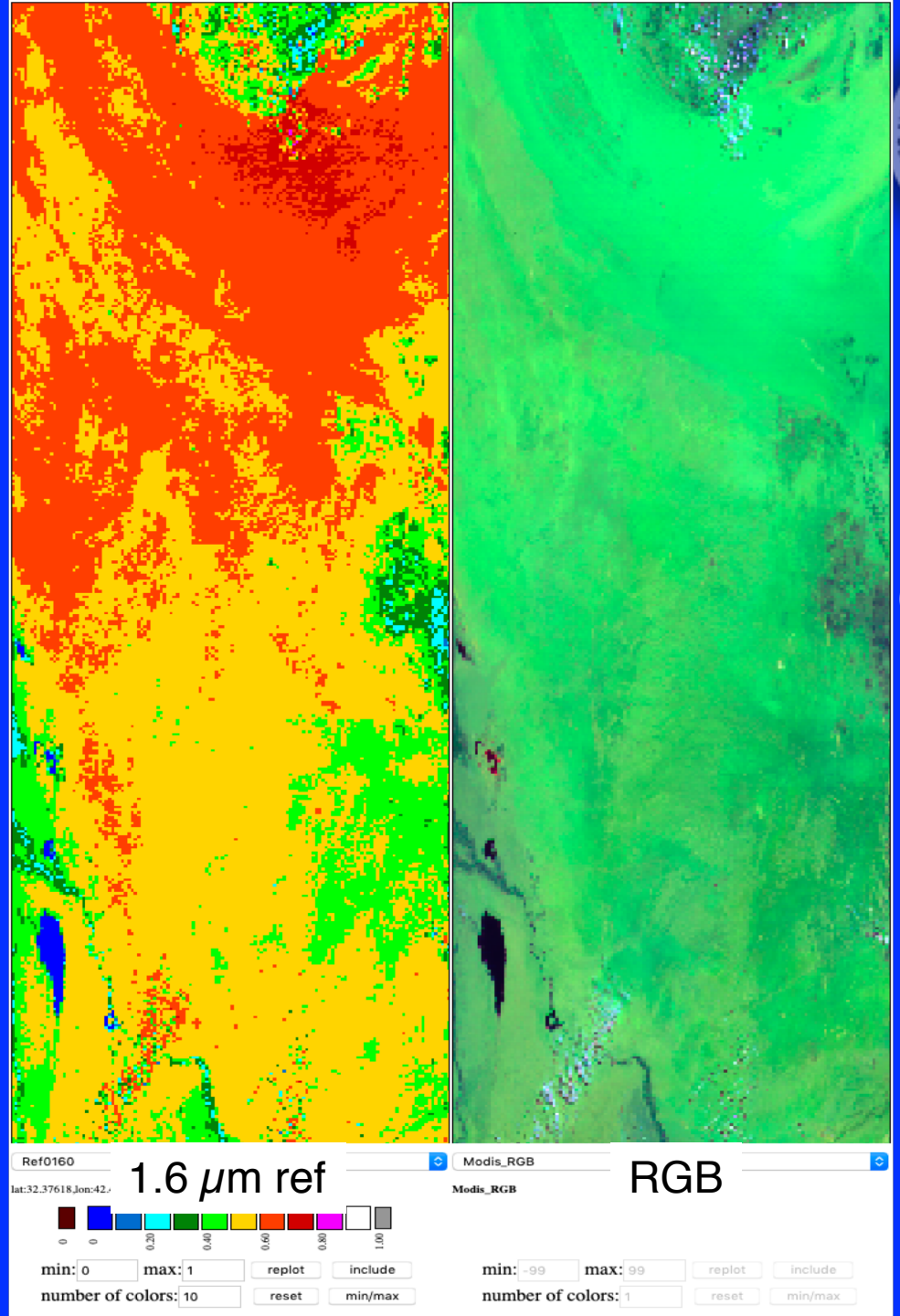


Aqua 2018 09

Zoomed in

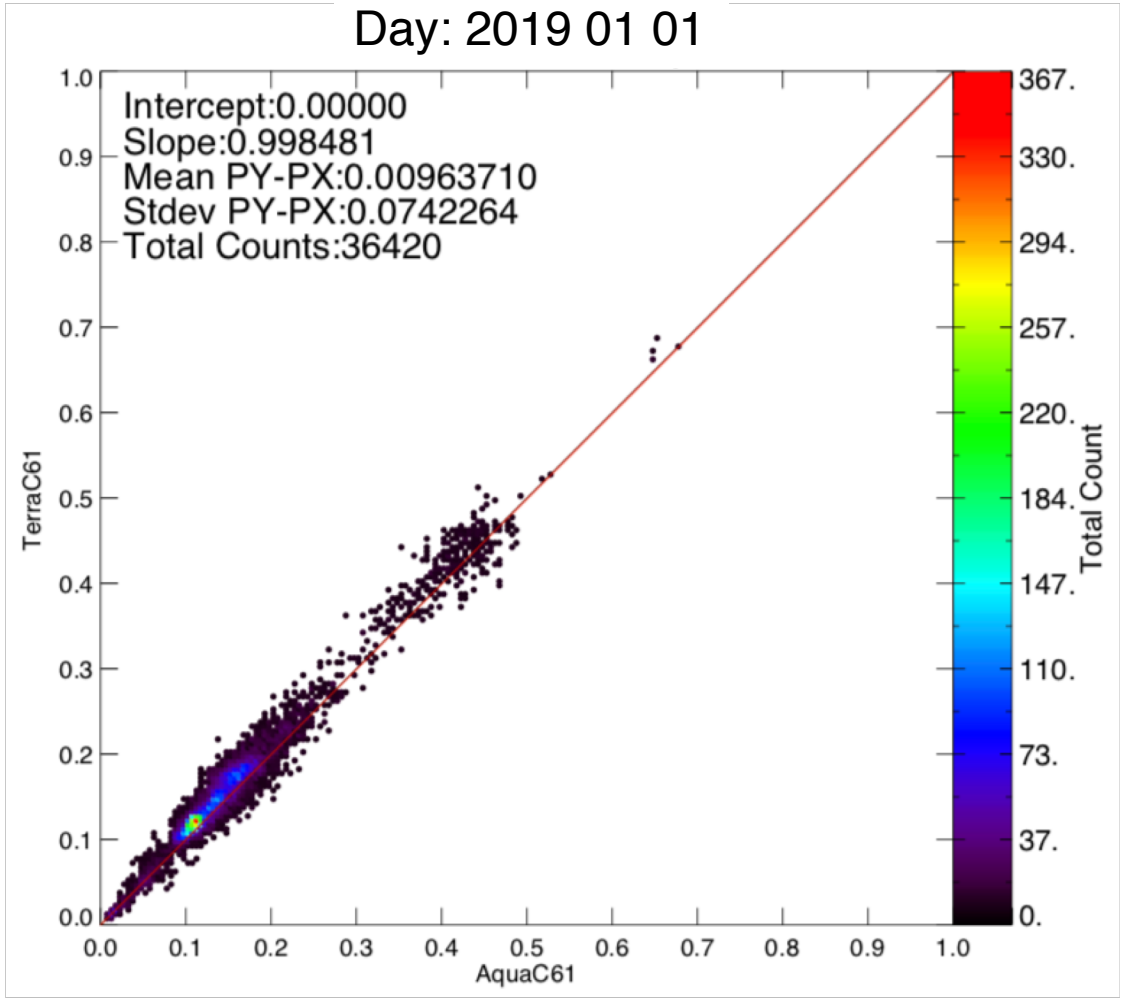
Before
(1.6 μm ref)

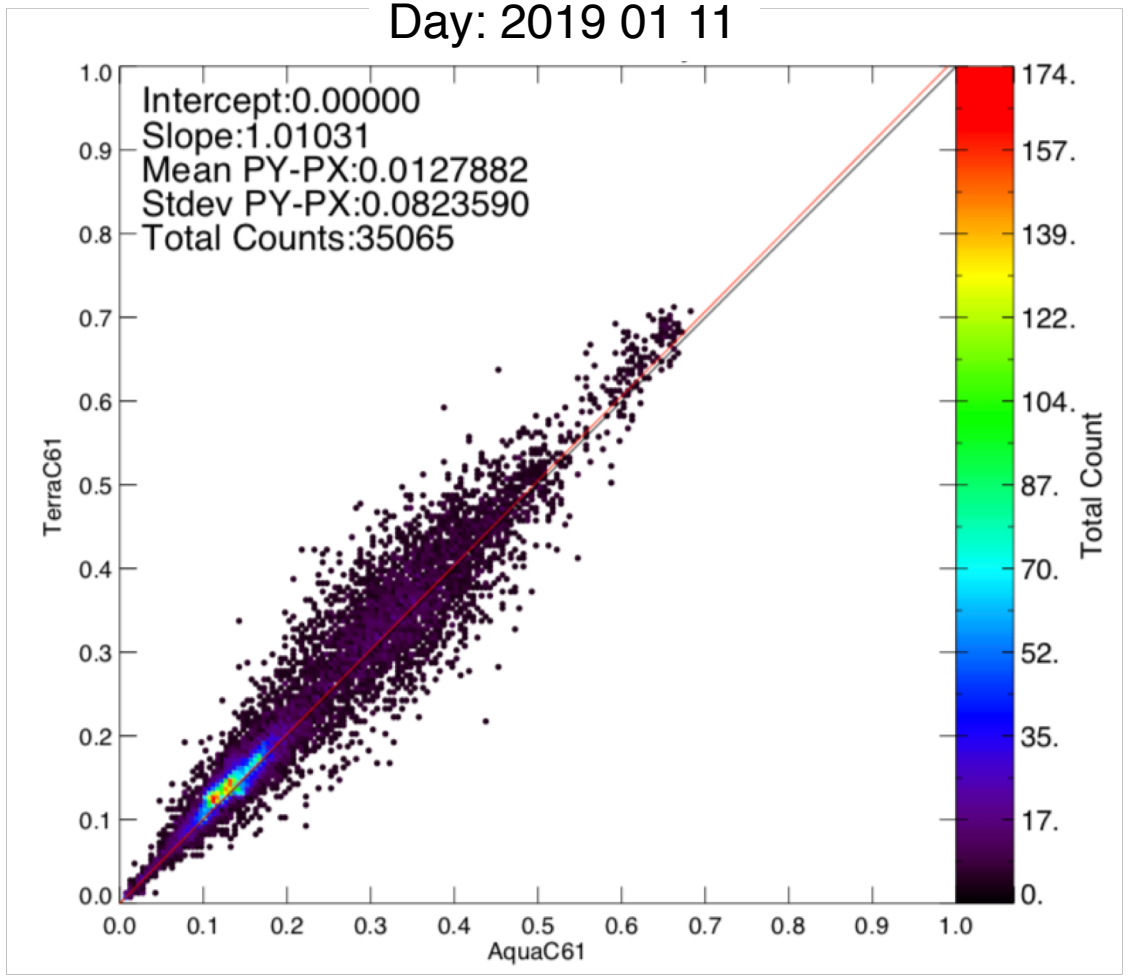




After
(1.6 μm ref)

Comparison of 1.6 μm reflectance between Aqua-MODIS and Terra-MODIS (matched time / angles / geolocation)





Summary of AQUA MODIS 1.6 μm subsetter work

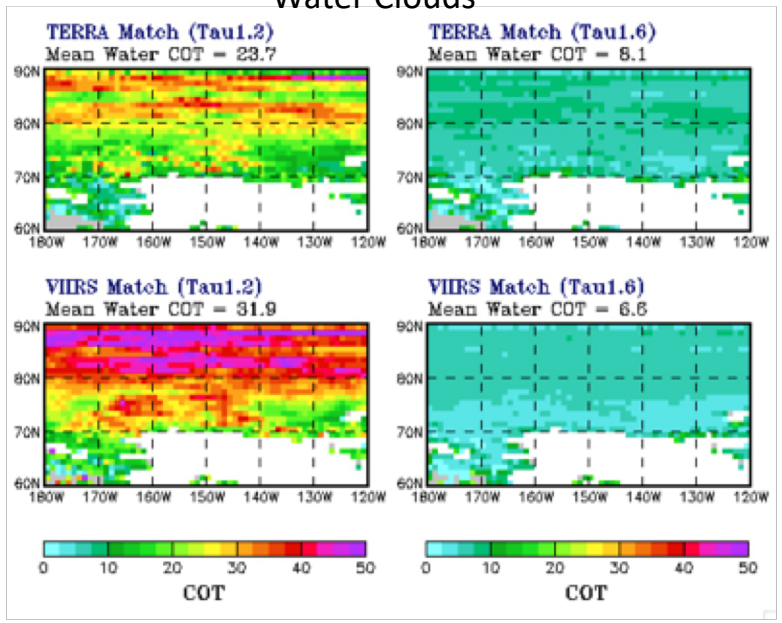
- The MODIS subsetter, replacing “bad” detectors with the nearest “good” detectors for 1.6 μm, was coded and delivered to Goddard LSIPS in late 2018.
- LSIPS tested and CERES Clouds validated the outputs.
- **LSIPS implemented the new MODIS subsetter to Goddard PGE92 6.1.1.**
- **Starting January 1st, 2019, subsetted Aqua MODIS C6.1 at ASDC Langley should contain good 1.6 μm radiances.**
- **Since 1.6 um exists in all 4 instruments (Terra-MODIS, Aqua-MODIS, NPP-VIIRS, and NOAA20-VIIRS), 1.6 um could be used in both cloud mask and cloud optical depth retrieval over snow/ice surfaces in Edition5. This will require using MODIS Collection 7 or Aqua-MODIS C6.1 re-subset and re-delivery from launch to December 31, 2018.**

New testbed developed for polar cloud retrieval evaluation and to guide Ed5 ARISE Period (Sept 2014) over Arctic Ocean

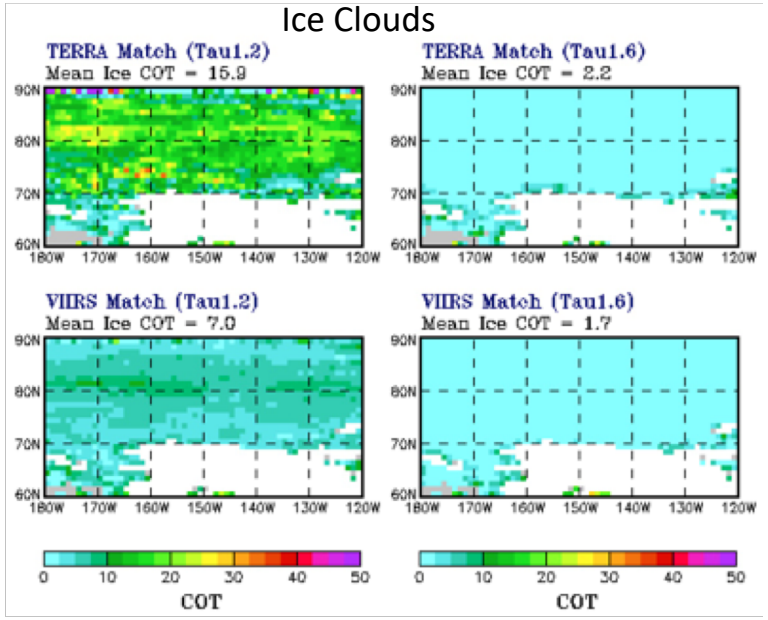
Standard datasets (1.24 µm for Tau): Aqua and Terra MODIS Ed4, SNPP Ed1
Test datasets (1.64 µm Tau) : Terra-MODIS, SNPP-VIIRS (1.64 µm Tau)
Test datasets (THM for ice clouds): Terra and Aqua MODIS

ARISE aircraft data and CALIPSO/CloudSat will provide groundtruth

Water Clouds



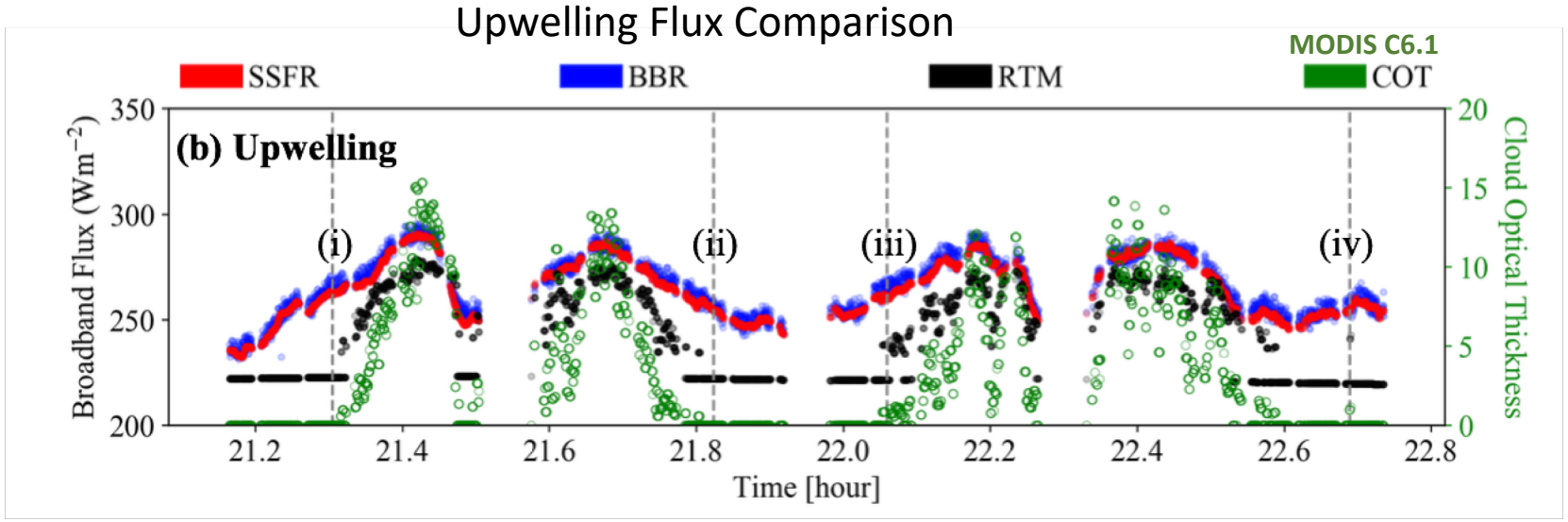
Ice Clouds

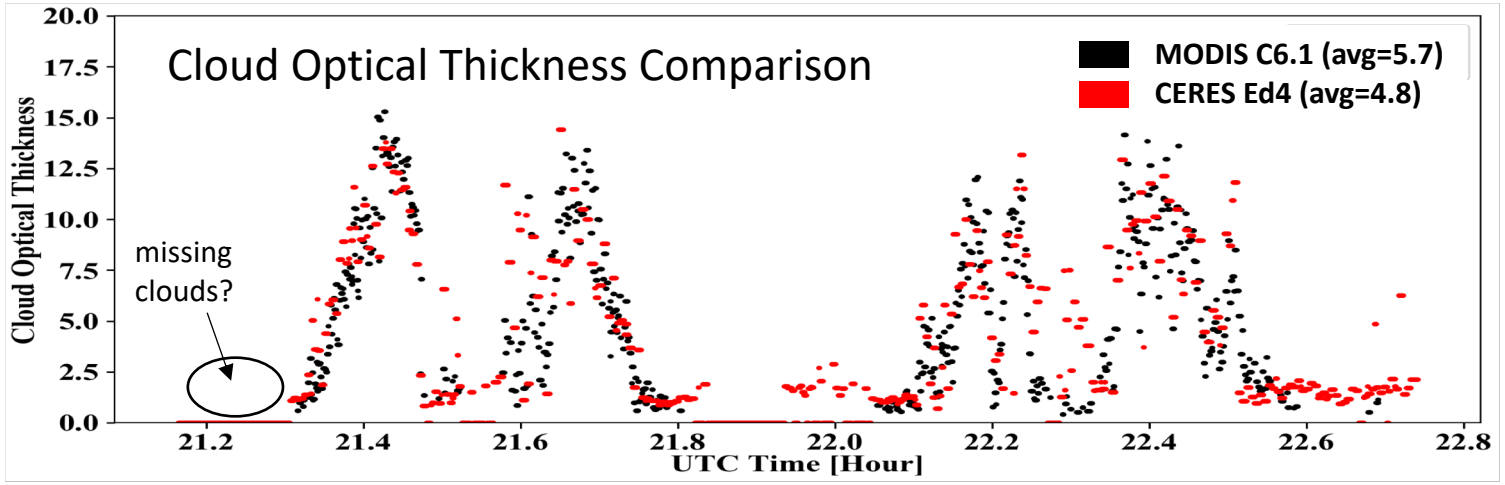


- Optical thickness a critical parameter being evaluated
- VIIRS 1.2 Tau for water clouds much higher than MODIS
- Terra 1.2 Tau for ice much higher than VIIRS (bug in Ed4 1.2 µm ice models)
- Terra and VIIRS 1.6 match pretty well for ice and water clouds

ARISE Radiative Closure Tests

Sept 11, 2014 (7km, above low level cloud)





H. Chen and S. Schmidt, U. of Colorado

Excellent agreement between spectral (SSFR) & broadband (BBR) radiometers

Upwelling flux calculations (RTM) incorporate MODIS COT

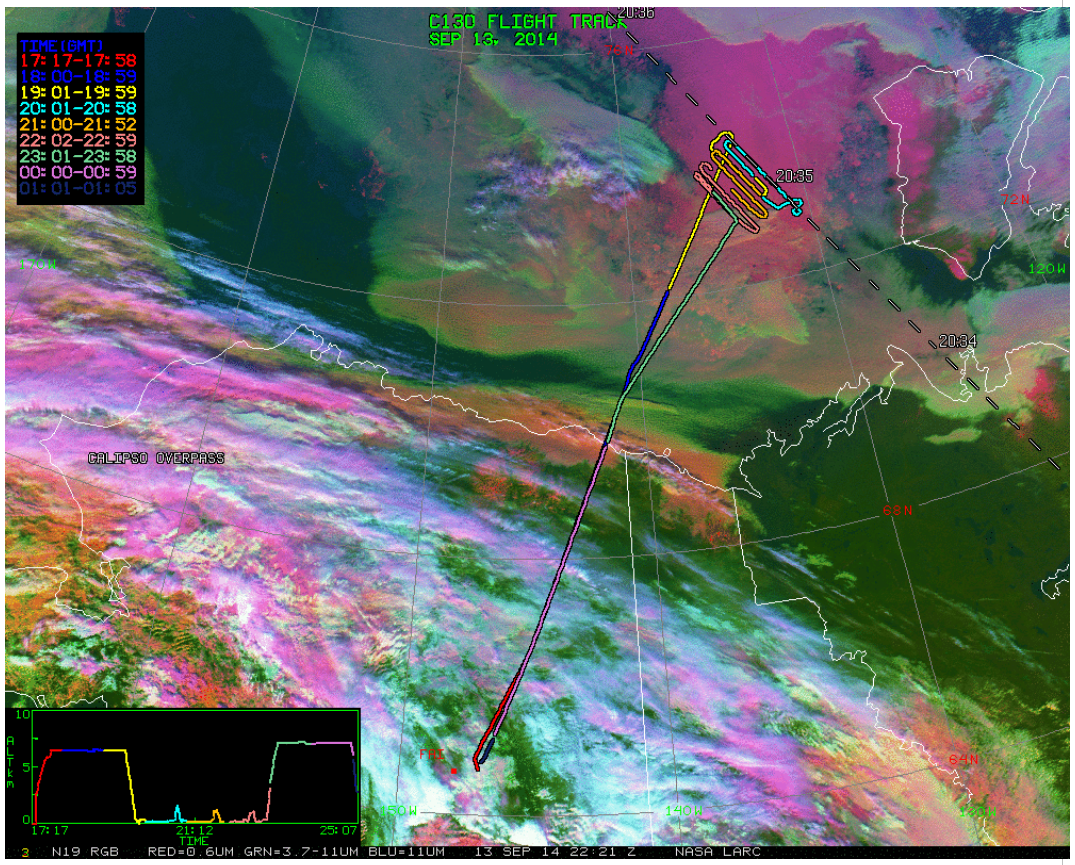
- ~10 Wm^{-2} (4%) darker than observations
- measurement uncertainty ~3%
- MODIS COT too low? Sfc albedo?
- Some cirrus contamination overhead

CERES Ed4 and C6.1 COT agree well where they overlap

CERES Ed4 retrieving many more thin clouds than C6.1

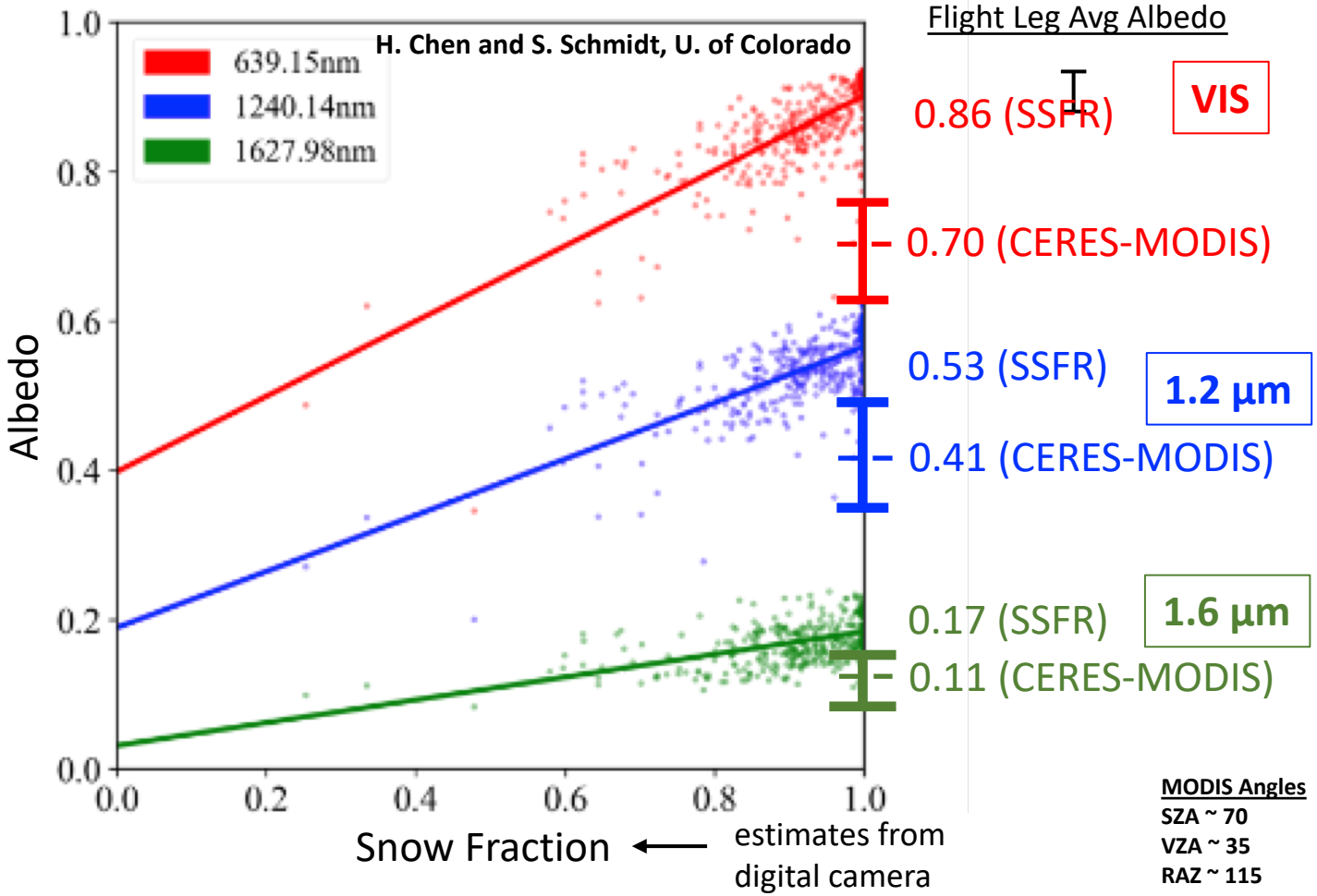
ARISE Sea-ice Spectral Albedo Comparison

Sept 13, 2014 (20 UTC)



Clear sky albedo's computed for 10 minute Flight leg

C-130 Spectral Solar Flux Radiometer (SSFR)



- Accurate BRDF's (anisotropic factors) needed to estimate clear sky reflectances for imager cloud mask & retrievals
- MODIS albedo's are 23% (vis), 29% (1.2µm), 54% (1.6µm) lower then SSFR BRDF errors??

1.24 µm clear sky reflectance evaluation

CERES Ed4 Observed minus Predicted 1.24 µm Reflectance differences (AQUA-MODIS)

Snow covered surfaces

For January, April, July, and October 2015, tiles having ≥ 20% clear pixels

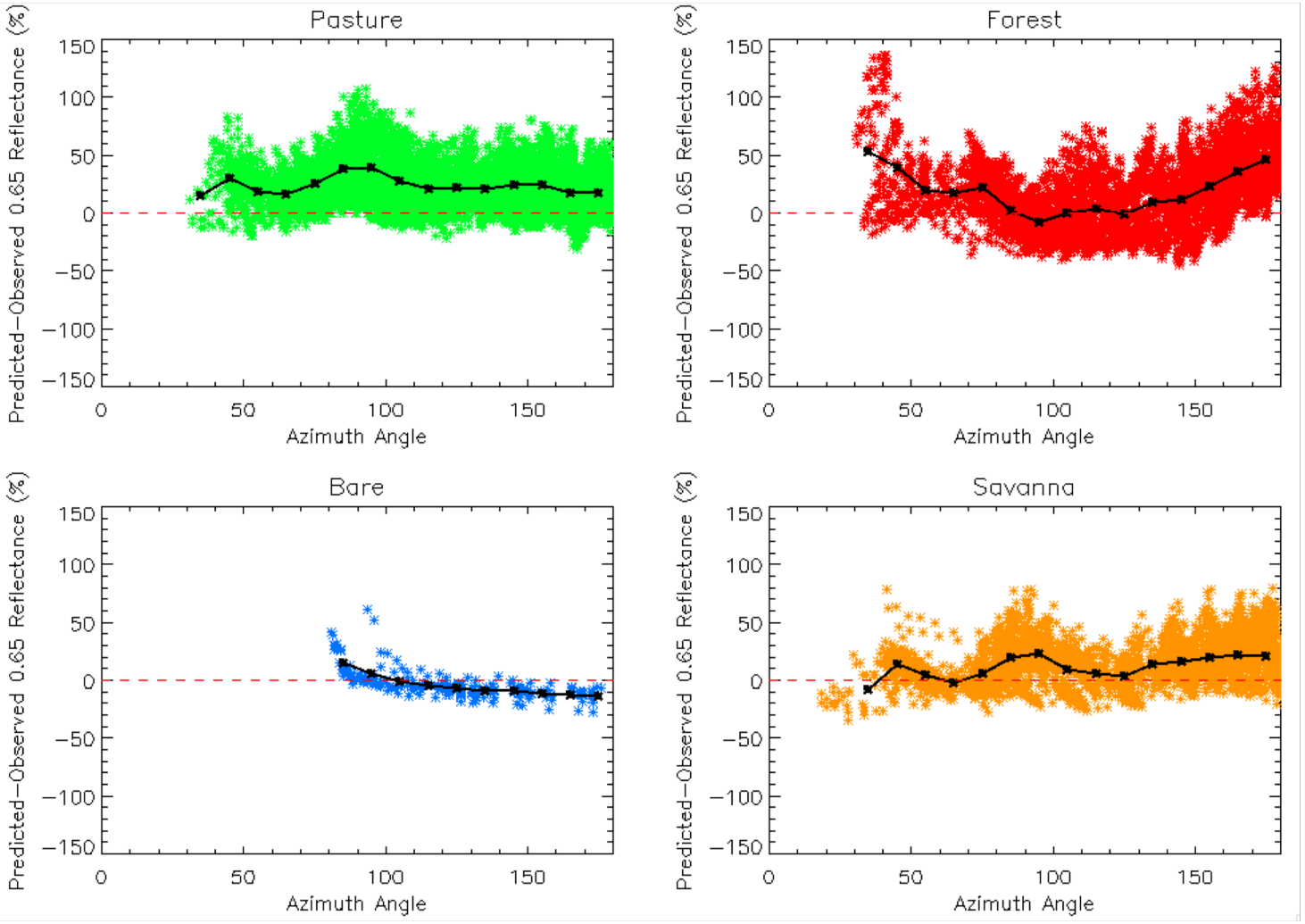
Surface Family	All clear types			Strong clear only			N_s/N_a
	Mean	Std Dev	N_a (x10^6)	Mean	Std Dev	N_s (x10^6)	(%)
Ocean	-0.024	0.050	1.35	-0.020	0.048	1.31	97
Bog	-0.021	0.083	0.34	-0.026	0.069	0.31	92
Forest	-0.027	0.063	0.23	-0.027	0.061	0.22	96
Pasture	-0.030	0.066	0.16	-0.028	0.061	0.13	81
Savannah	-0.025	0.076	0.30	-0.025	0.073	0.28	93
Desert	-0.023	0.090	0.03	-0.019	0.082	0.02	67
Perm Snow	-0.030	0.046	1.94	-0.030	0.045	1.94	100

Clear sky updating procedures in CERES reduces uncertainties in clear sky models (BDRF's and DRM's)

Clear Sky Radiance Assessments and Refinements for Ed5

Critical for GEO's where we've found large uncertainties – employs static maps, no clear sky updating

Assessment of GOES-16 Predicted Clear Sky Reflectance (0.64 µm)



Evaluations are underway for all surfaces (land, ocean, snow) to refine methods for Ed5 (GEO and LEO)

Current TISA GEO methodology employs surface BRDF's from Kriebel (1978) aircraft measurements

Predicted clear sky values generally higher than GOES-16 observations over vegetated surfaces by 10-50%

Errors a function of solar and view angles

Can affect cloud mask and other cloud properties

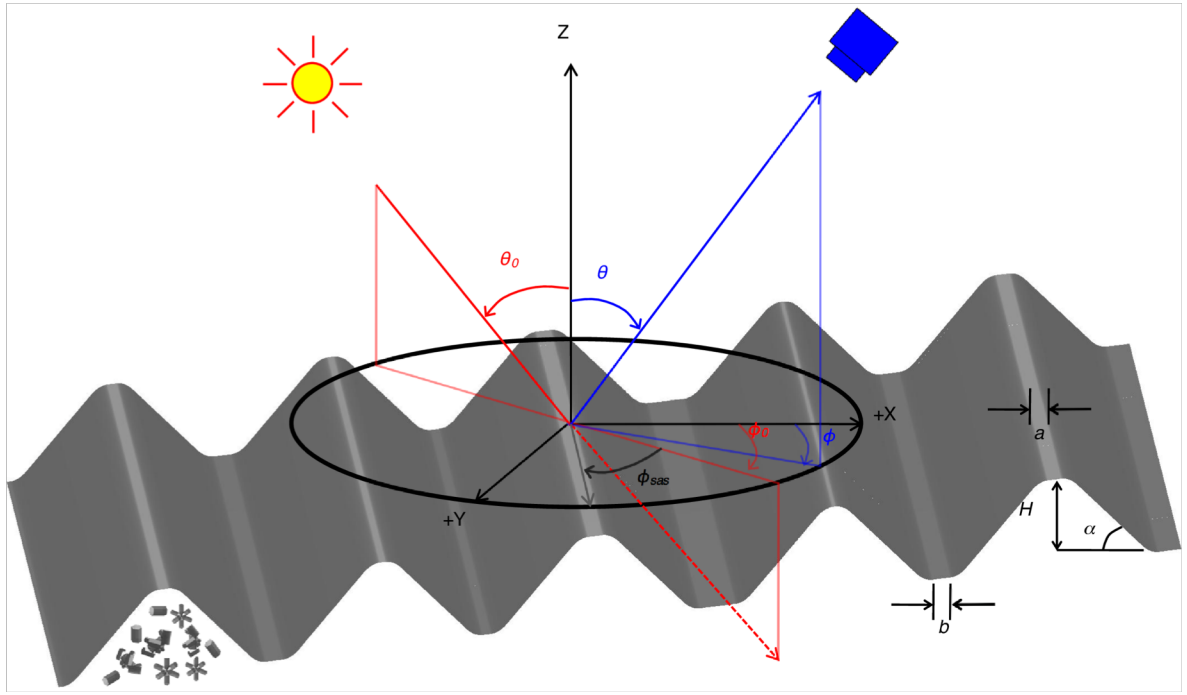
New or Revised Models for Predicting Clear-Sky Reflectance over Snow/Ice surfaces (various channels; 0.64, 1.24, 1.6, 2.1 μm°

G. Hong

1. Pure snow - 3D surface model.

   Ridge Height=20 cm, Mean Width of Ridge=10 cm
   Mean Width of Groove = 20 cm, Slope=25°

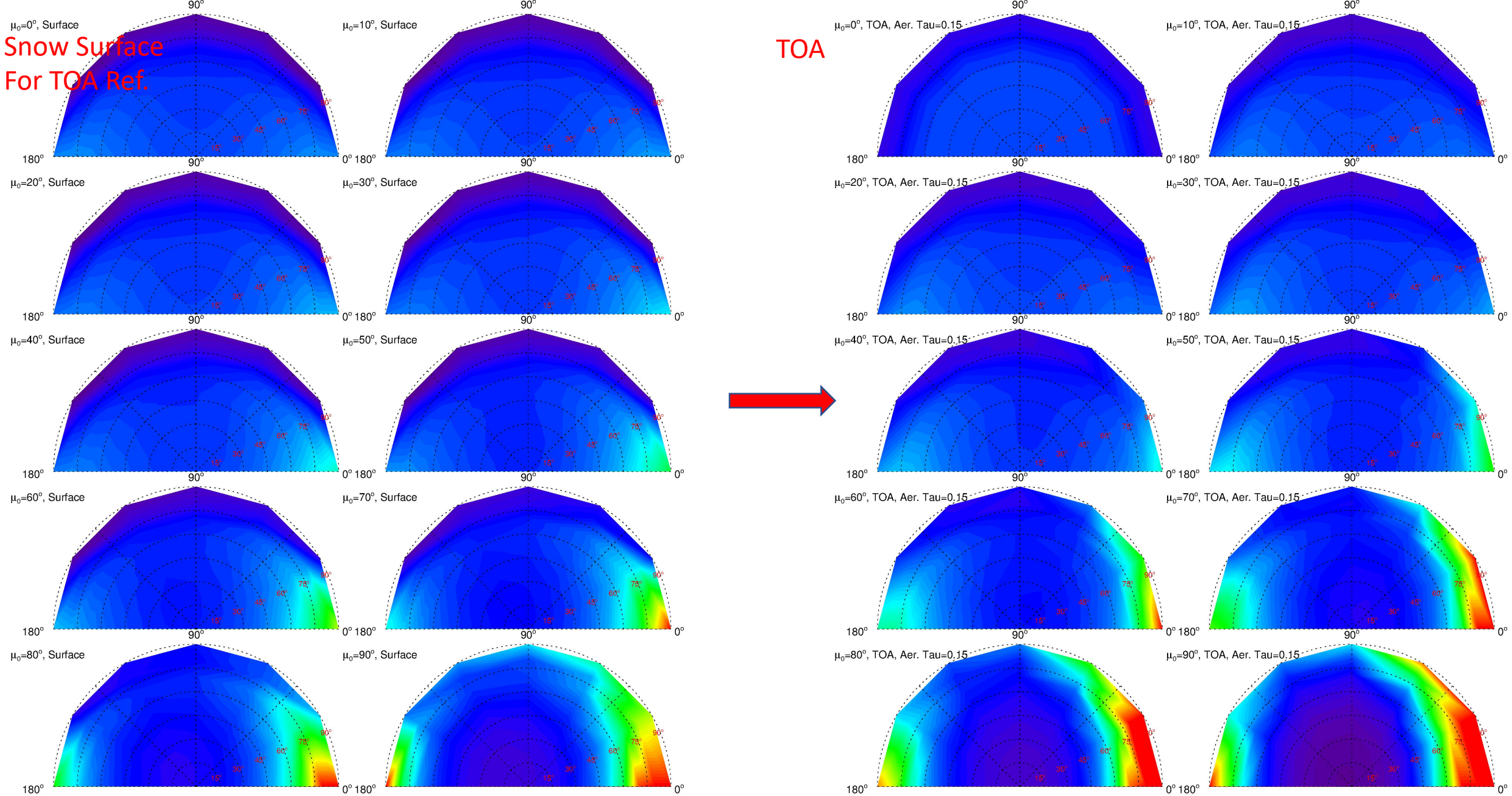
Sastrugi are essentially snow dunes caused by wind, piling snow up along the direction of the wind. Dimensions vary with wind speed and variability. 3D surface snow model simulates different macrophysical properties of sastrugi, including groove and ridge widths(random values with a mean), ridge heights, and slopes.



2. Four Kriebel vegetated surfaces, Bog, Savannah, Pasture, forest.

3. Snow covered land – 'Hybrid' models based on combining 3D pure snow with Kriebel surfaces.

4. Anisotropic factors at the TOA using standard atmospheres, continental AOT 0.15.



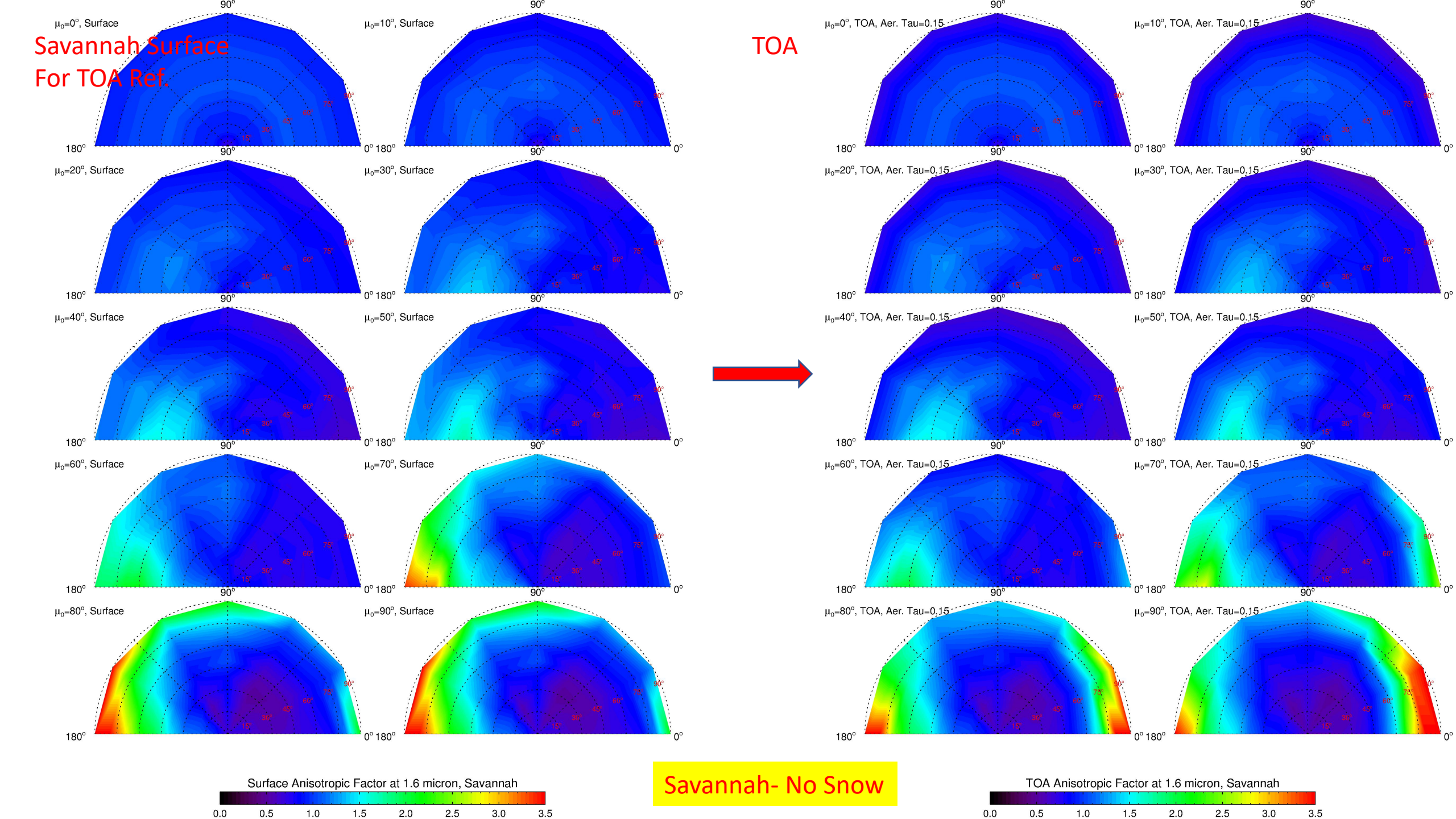
Pure Snow

Surface Anisotropic Factor at 1.6 micron, Snow Surface

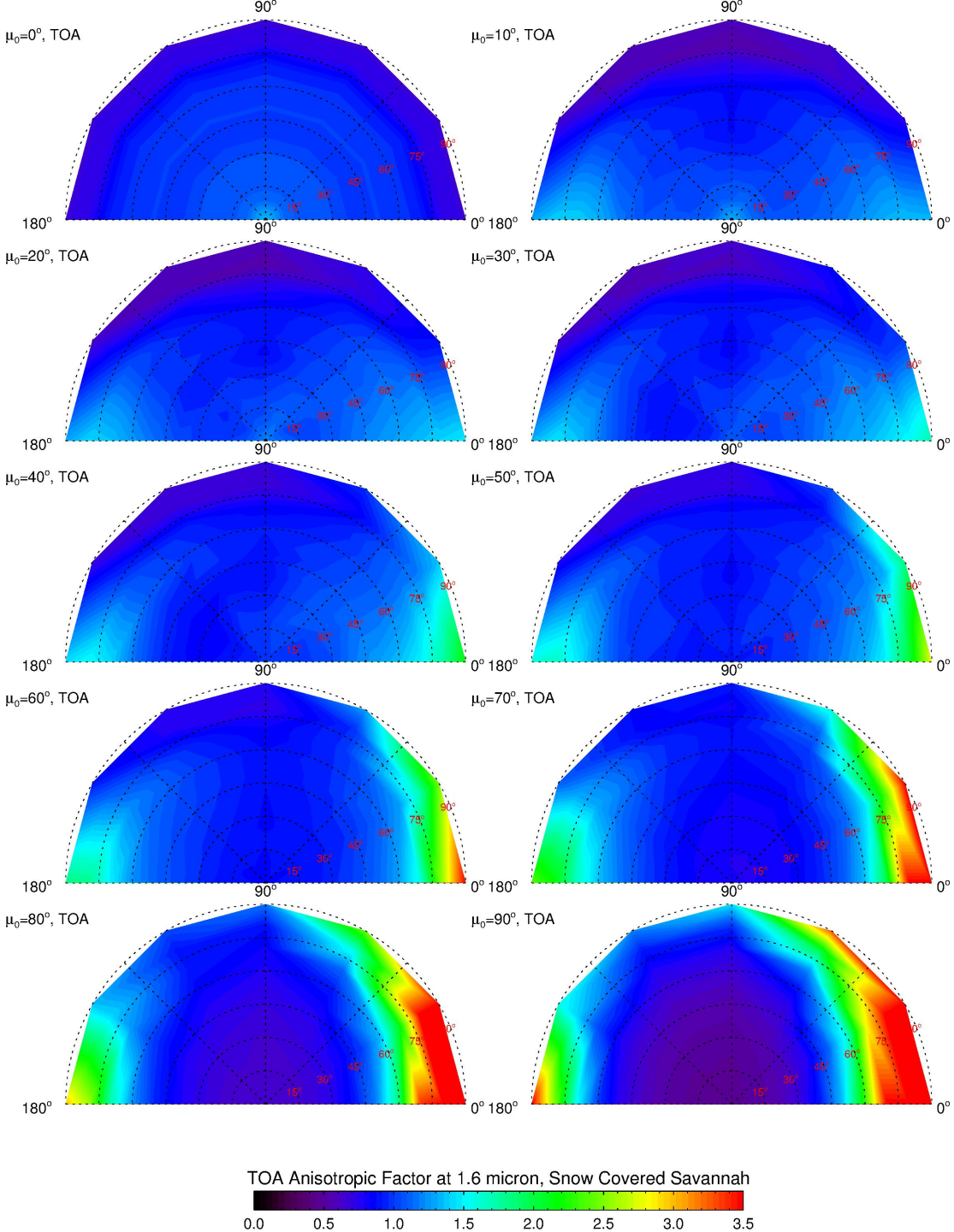
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5

TOA Anisotropic Factor at 1.6 micron, Snow Surface

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5


Savannah Surface
For TOA Ref.
TOA
μ0=0°, Surface
μ0=10°, Surface
μ0=20°, Surface
μ0=30°, Surface
μ0=40°, Surface
μ0=50°, Surface
μ0=60°, Surface
μ0=70°, Surface
μ0=80°, Surface
μ0=90°, Surface
μ0=0°, TOA, Aer. Tau=0.15
μ0=10°, TOA, Aer. Tau=0.15
μ0=20°, TOA, Aer. Tau=0.15
μ0=30°, TOA, Aer. Tau=0.15
μ0=40°, TOA, Aer. Tau=0.15
μ0=50°, TOA, Aer. Tau=0.15
μ0=60°, TOA, Aer. Tau=0.15
μ0=70°, TOA, Aer. Tau=0.15
μ0=80°, TOA, Aer. Tau=0.15
μ0=90°, TOA, Aer. Tau=0.15
90°
180°
0°
Surface Anisotropic Factor at 1.6 micron, Savannah
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
Savannah- No Snow
TOA Anisotropic Factor at 1.6 micron, Savannah
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5

Hybrid Results
Anisotropic Factors at the TOA
(1.6-micron)
Snow Covered Savannah



Evaluations with satellite clear sky reflectances are underway

GEO UPDATE (GOES-17)

The Good News

GOES-17 with 16-band ABI launched March 2018 and became operational Feb 18, 2019

GOES-17 is replacing GOES-15 as GOES-West (180°W to 95°W domain).

GOES-15 scheduled to be decommissioned in early July

Since GOES-16 and -17 have identical imagers, we can apply the GOES-16 cloud algorithm to GOES-17.

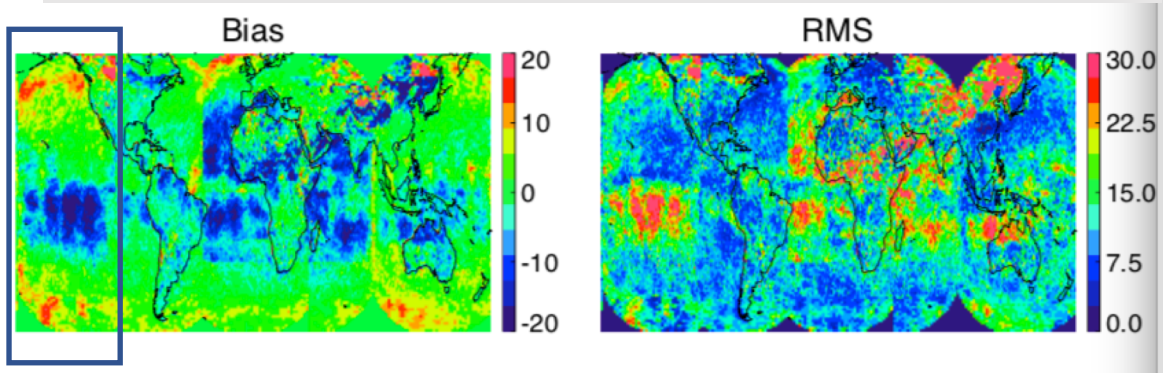
Initial Evaluation of GOES-17 cloud properties

- GOES-17 and GOES-15 regional cloud properties compared to coincident Terra and Aqua-MODIS (within +- 15 minutes) for Dec 18
- Want to see that GOES-17 is more consistent with MODIS than GOES-15

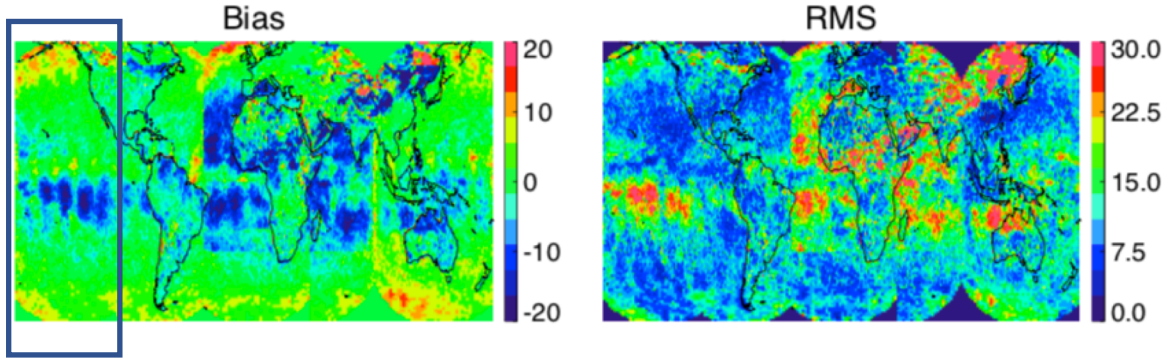
Launch of GOES-17 aboard an Atlas V

GOES-17 Cloud Fraction is more consistent with MODIS (daytime)

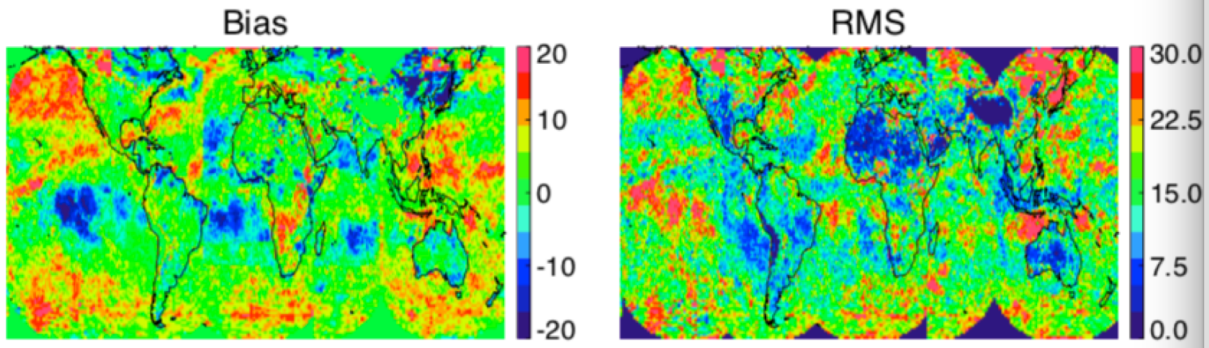
GOES-15 minus MODIS Total Cloud Amount (Daytime)



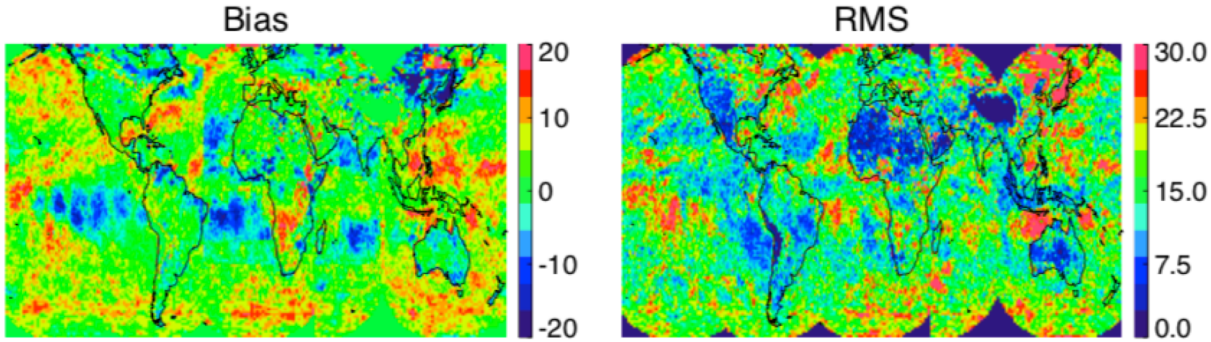
GOES-17 minus MODIS Total Cloud Amount (Daytime)



GOES-15 minus MODIS Low Cloud Amount (Daytime)

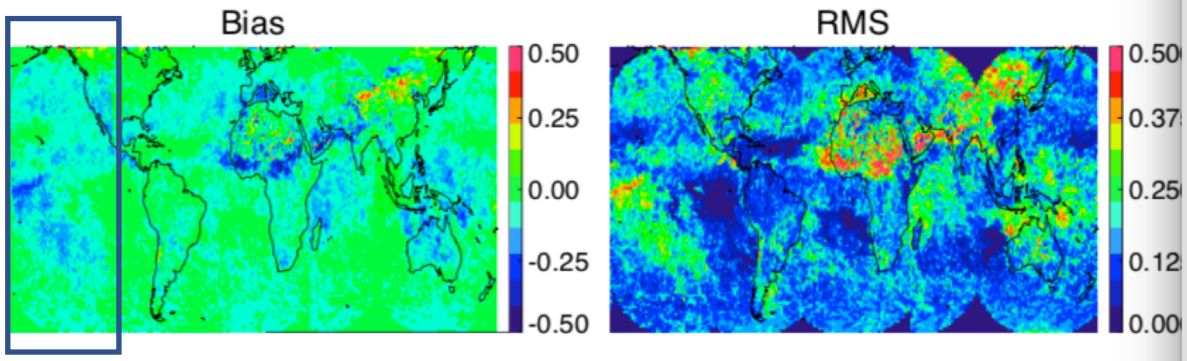


GOES-17 minus MODIS Low Cloud Amount (Daytime)

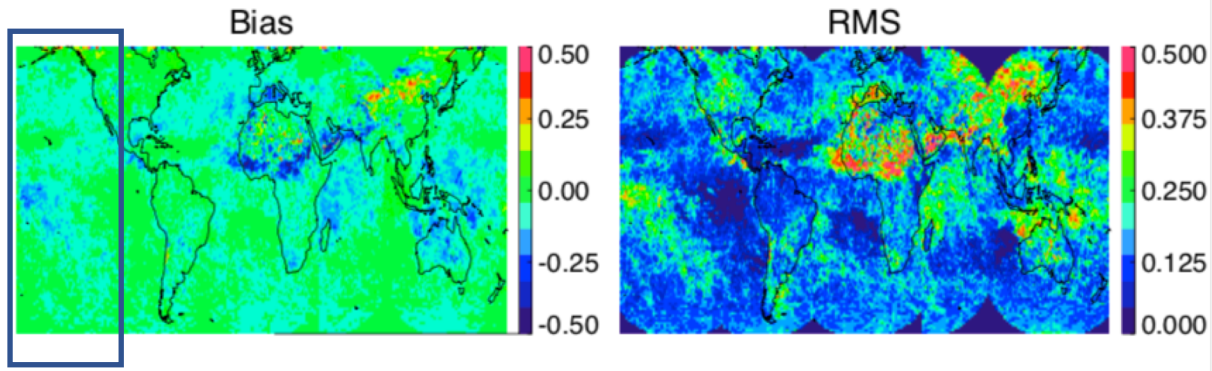


GOES-17 cloud phase and optical depth more consistent with MODIS (daytime)

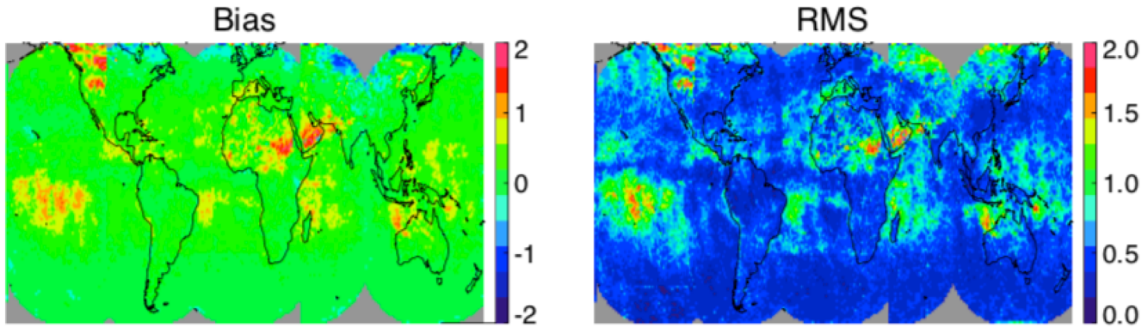
GOES-15 minus Cloud Phase (Daytime)



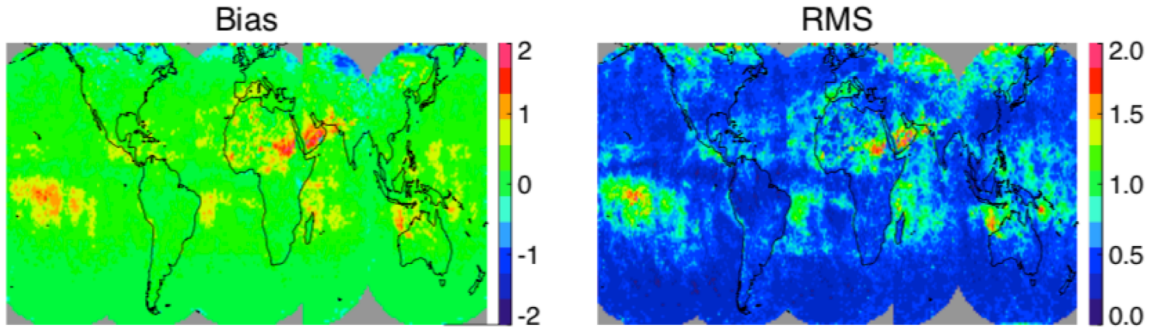
GOES-17 minus MODIS Cloud Phase (Daytime)



GOES-15 minus MODIS Optical Depth (Daytime)

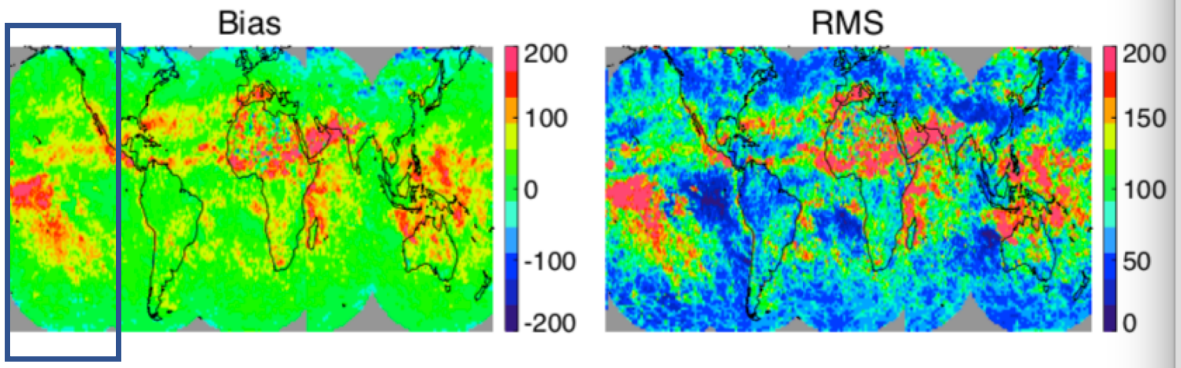


GOES-17 minus MODIS Optical Depth (Daytime)

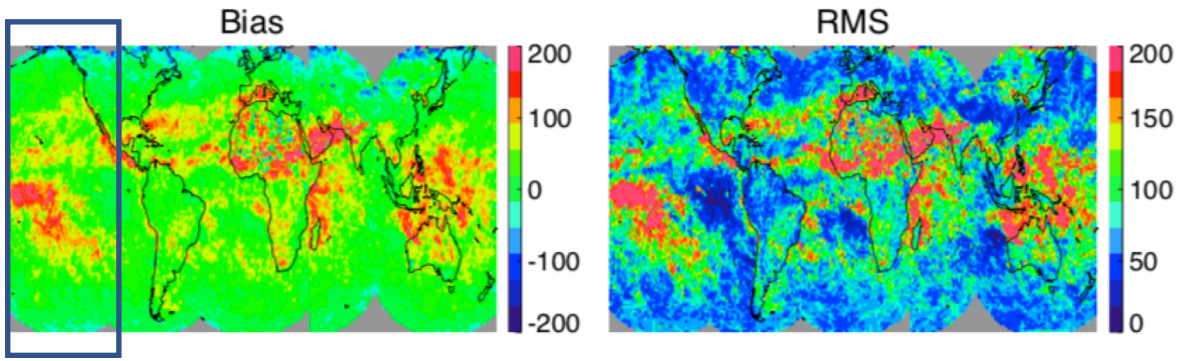


Cloud Effective Pressure found to be very similar for GOES-15 & -17 (daytime)

GOES-15 minus Cloud Pressure (Daytime)



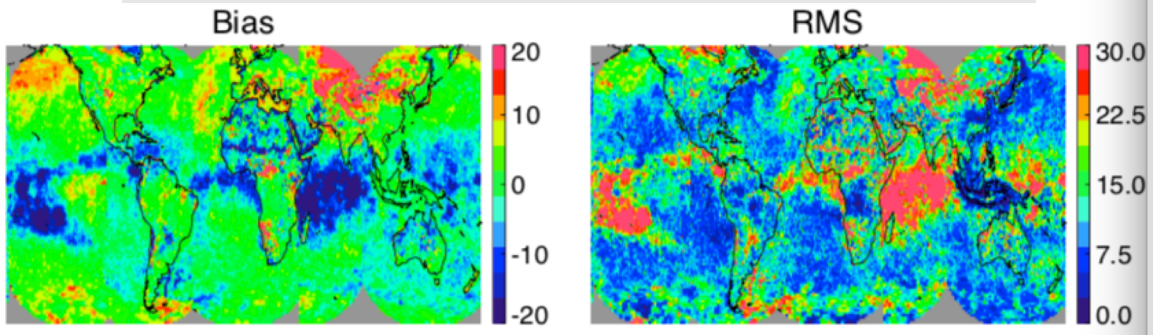
GOES-17 minus MODIS Cloud Pressure (Daytime)



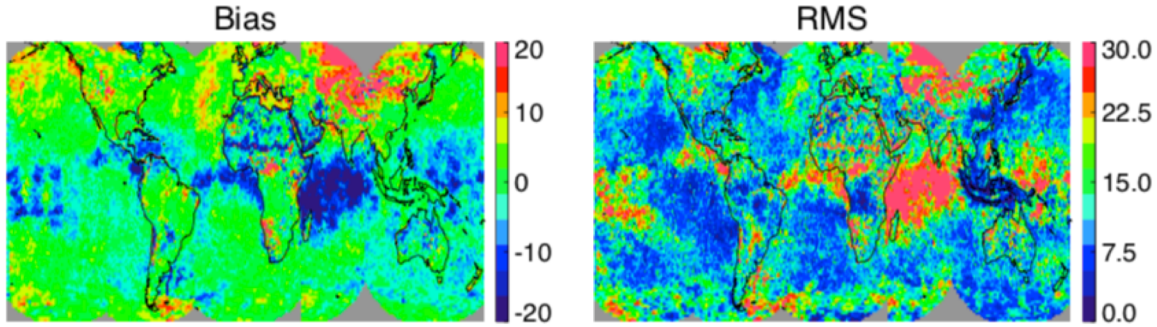
Similar bias, lower RMS fo G17 when compared with MODIS

Nighttime Improvements with GOES-17

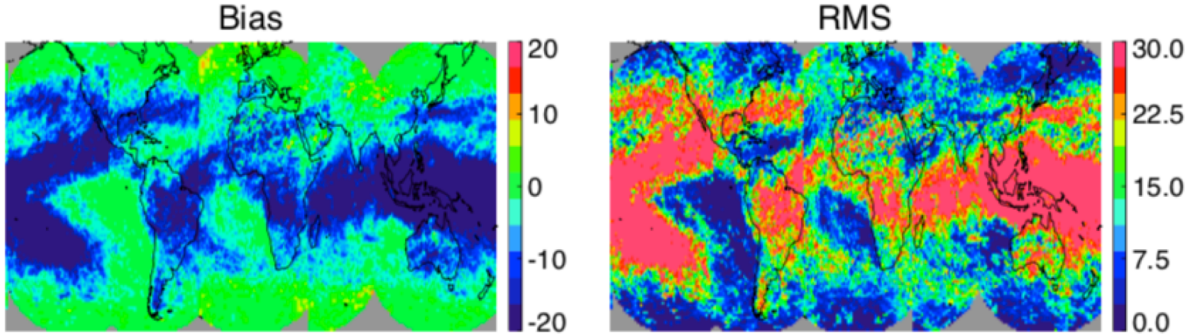
GOES-15 minus MODIS Total Cloud Amount



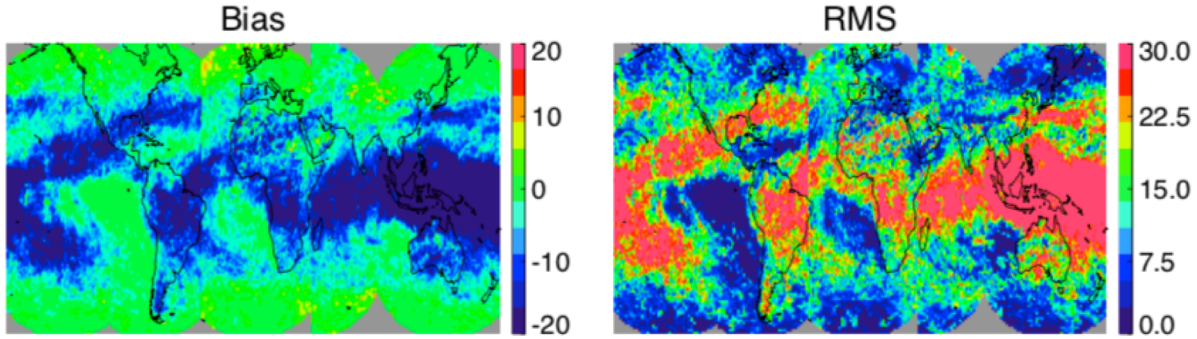
GOES-17 minus MODIS Total Cloud Amount



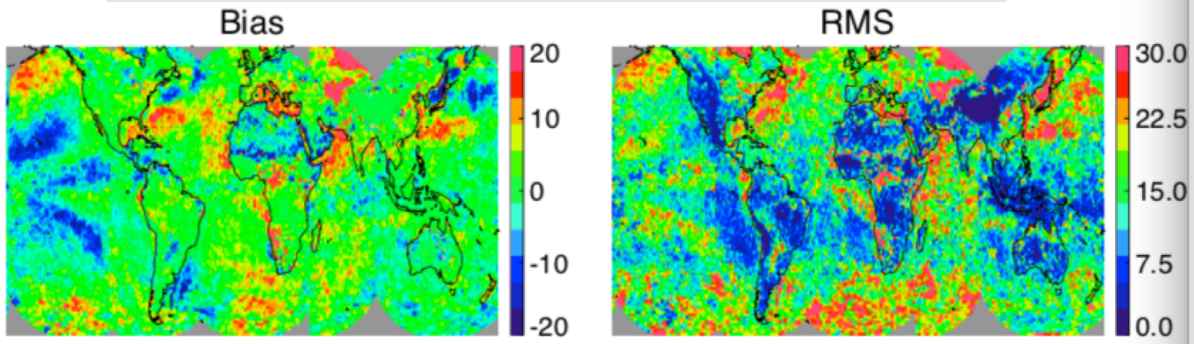
GOES-15 minus MODIS High Cloud Amount



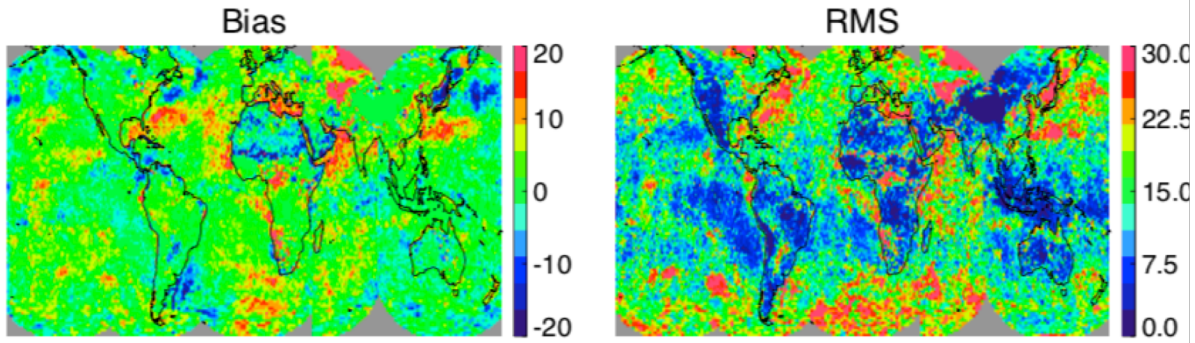
GOES-17 minus MODIS High Cloud Amount



GOES-15 minus MODIS Low Cloud Amount

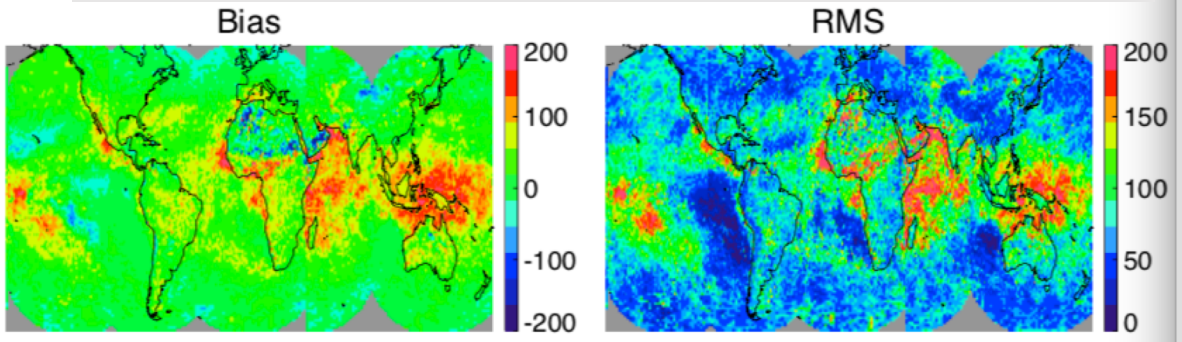


GOES-17 minus MODIS Low Cloud Amount

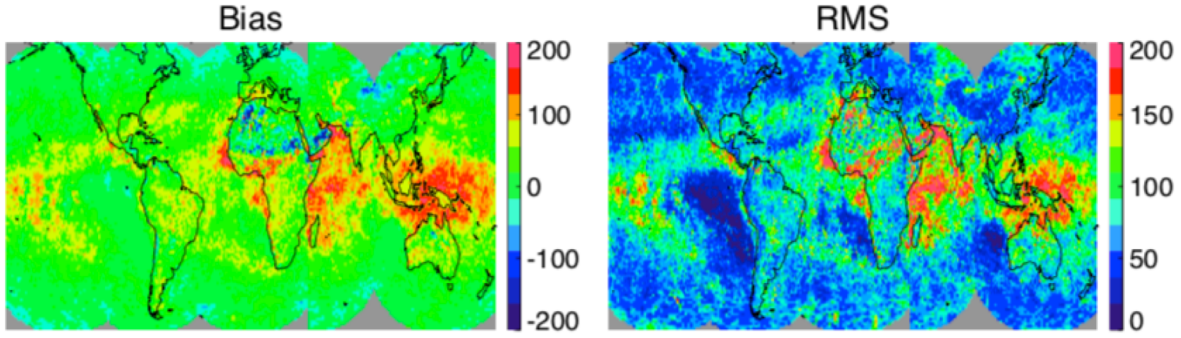


Nighttime Improvements with GOES-17 Effective Pressure

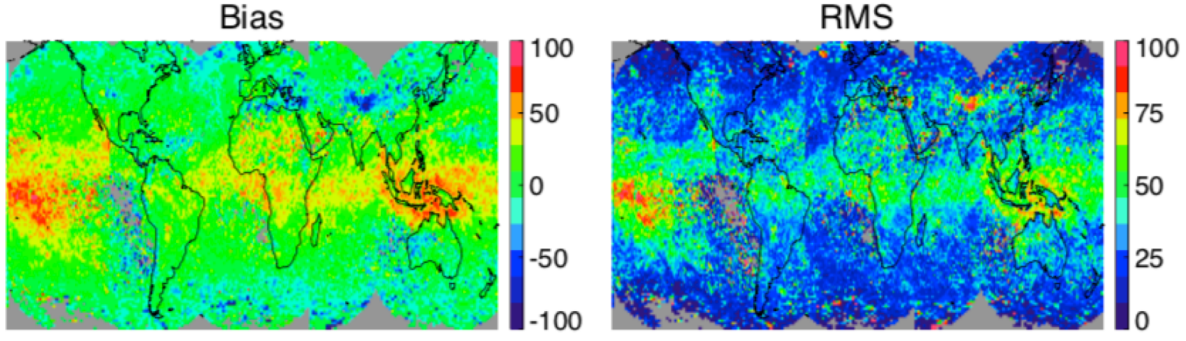
GOES-15 minus MODIS Total Effective Pressure (mb)



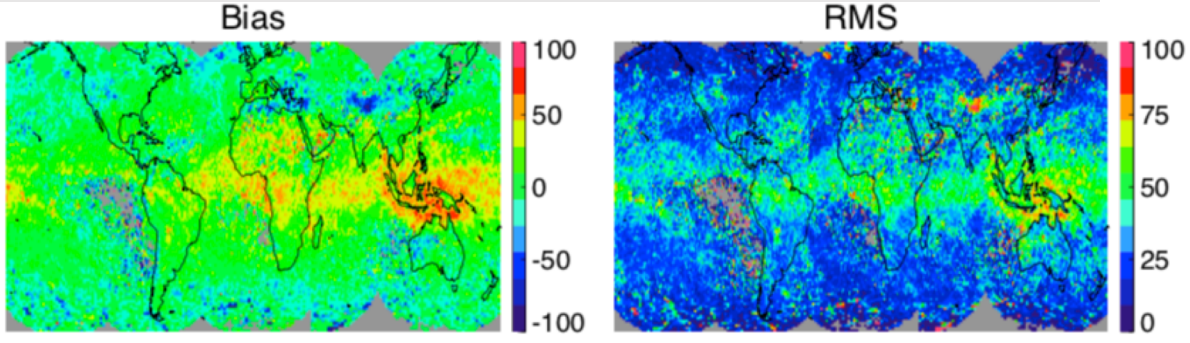
GOES-17 minus MODIS Total Effective Pressure (mb)



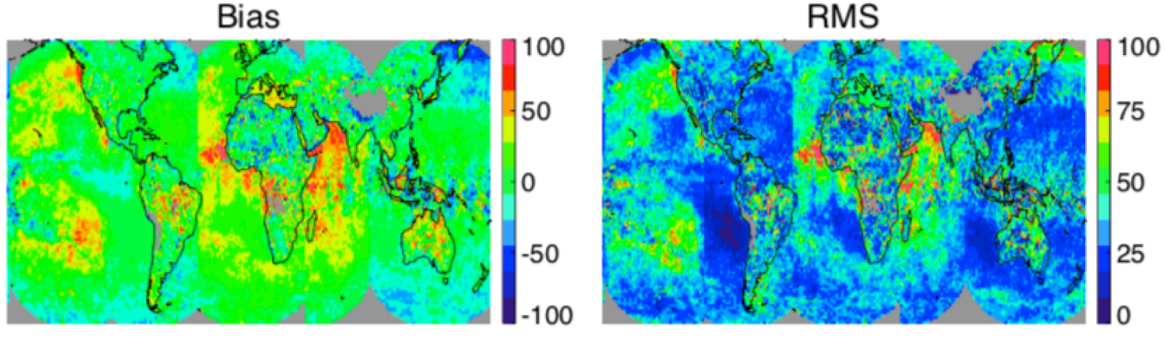
GOES-15 minus MODIS High Cld Effective Pressure (mb)



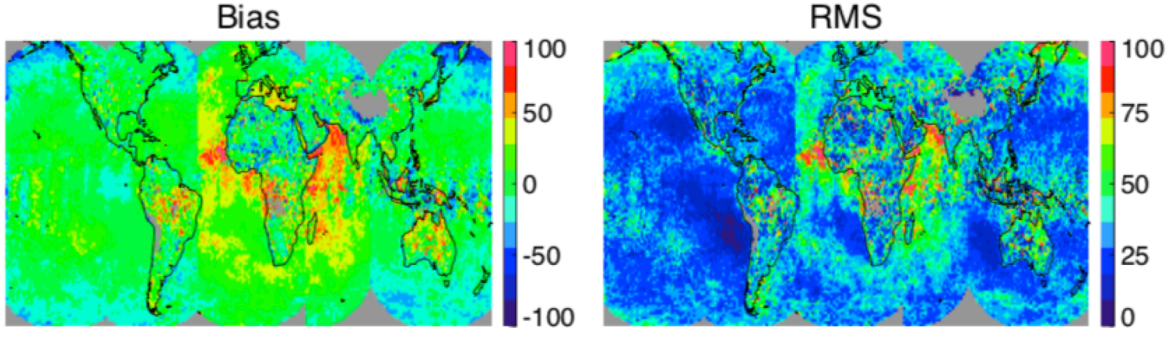
GOES-17 minus MODIS High Cld Effective Pressure (mb)



GOES-15 minus MODIS Low Cld Effective Pressure (mb)

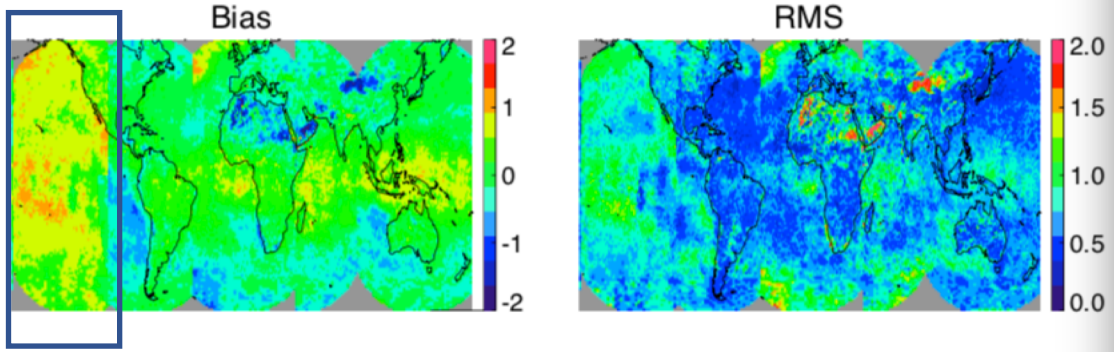


GOES-17 minus MODIS Low Cld Effective Pressure (mb)

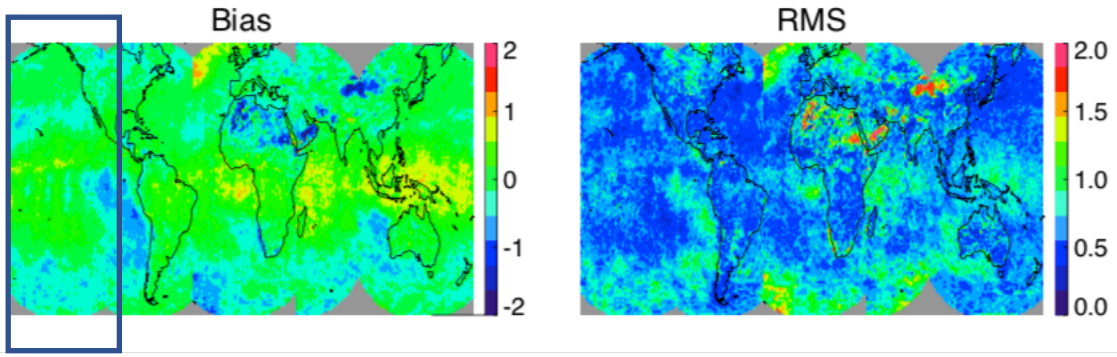


Nighttime Improvements with GOES-17 Optical Depth

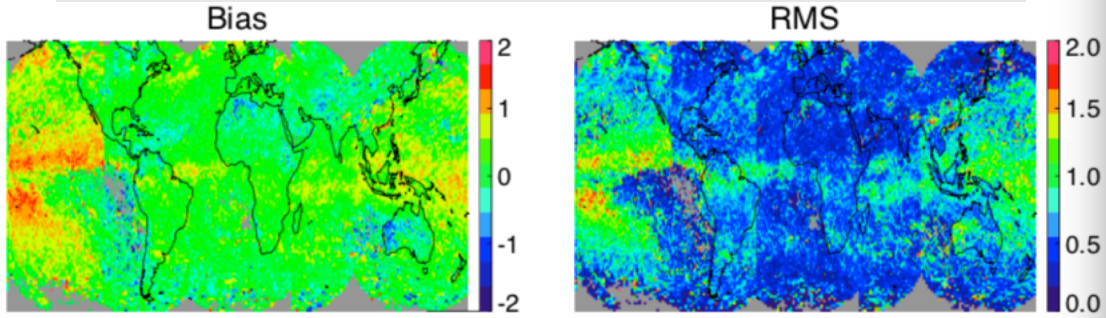
GOES-15 minus MODIS Total Cld Optical Depth



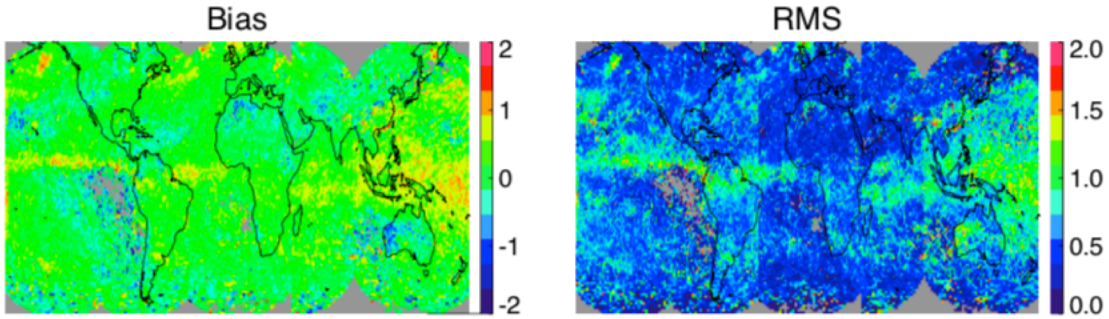
GOES-17 minus MODIS Total Cld Optical Depth



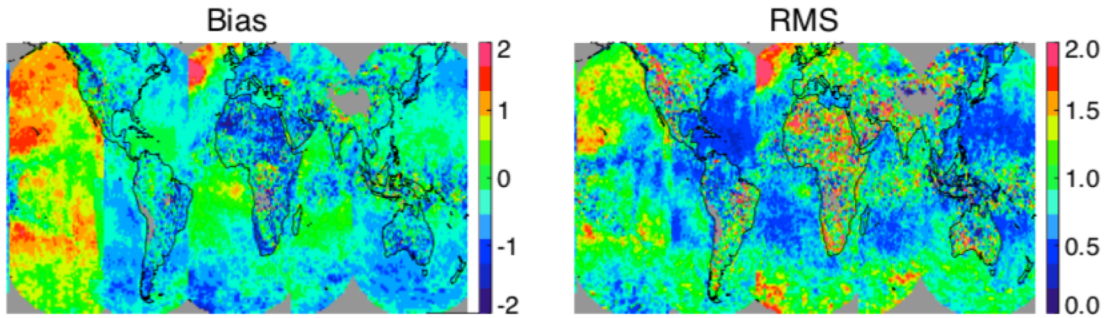
GOES-15 minus MODIS High Cld Optical Depth



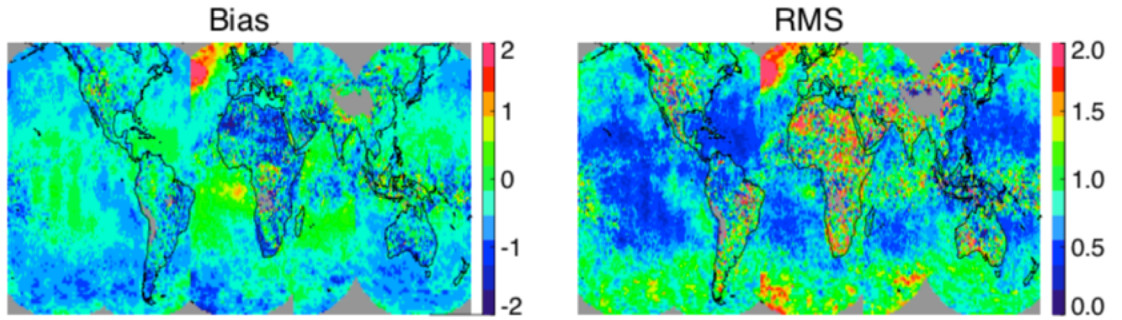
GOES-17 minus MODIS High Cld Optical Depth

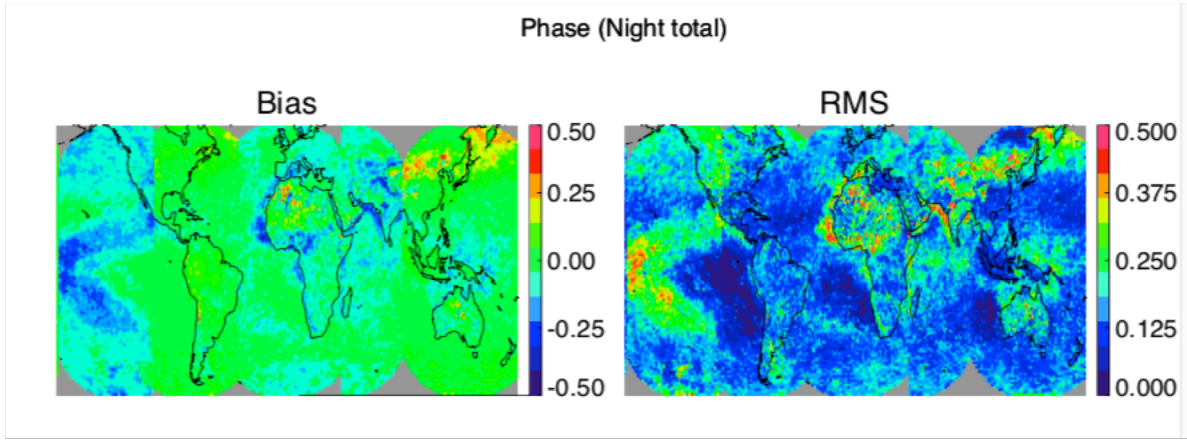


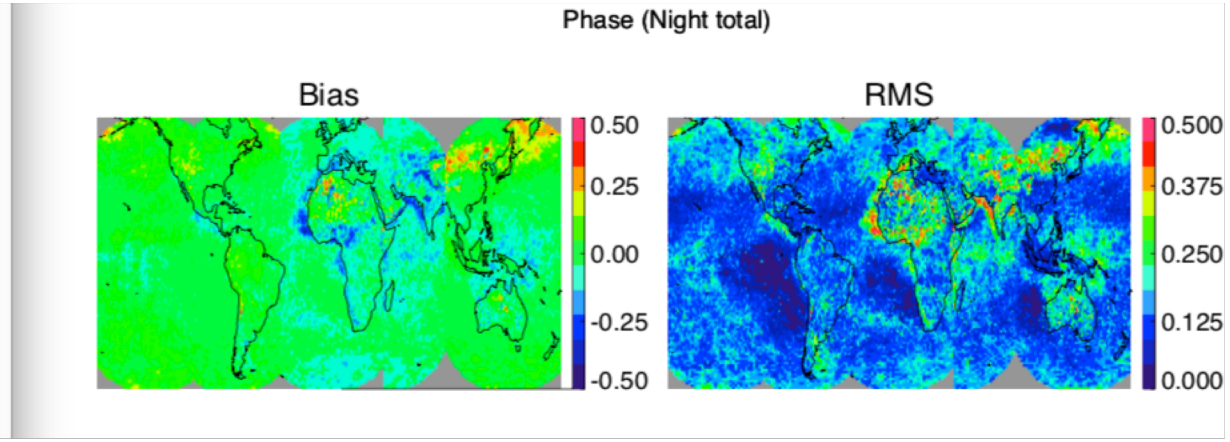
GOES-15 minus MODIS Low Cld Optical Depth



GOES-17 minus MODIS Low Optical Depth







GOES-17 cloud products are much iproved over GOES-15, more consistent with MODIS, and very consistent with GOES-16

GOES-17 code is essentially ready to go but….

GEO UPDATE (GOES-17)

Now the Bad News

ABI cooling system not operating at capacity on GOES-17

- Can degrade IR data or render it unusable for 2-6 hours at night
- Greatest impact during eclipse season near equinox's (~40 days?) when detectors are heated by direct sunlight
- No impact near solstices but not yet clear how long this lasts.
- Impact on derived products worse than imagery for qualitative use in NWS

Impact to CERES: Some IR data unusable for variable lengths of time across midnight depending on the time of year

Launch of GOES-17 aboard an Atlas V

ESTIMATED CHANNEL AVAILABILITY

Below is the current assessment of channel availability, **as of September 13, 2018**.
Note: This is a preliminary estimate that is subject to change as experts refine channel availability.

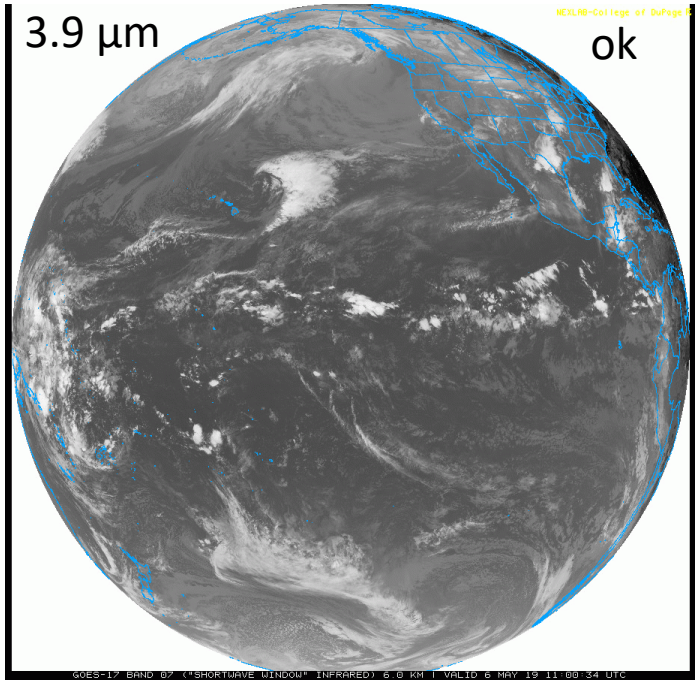
COLOR KEY:	Available 24hrs/day	Availability Exceptions

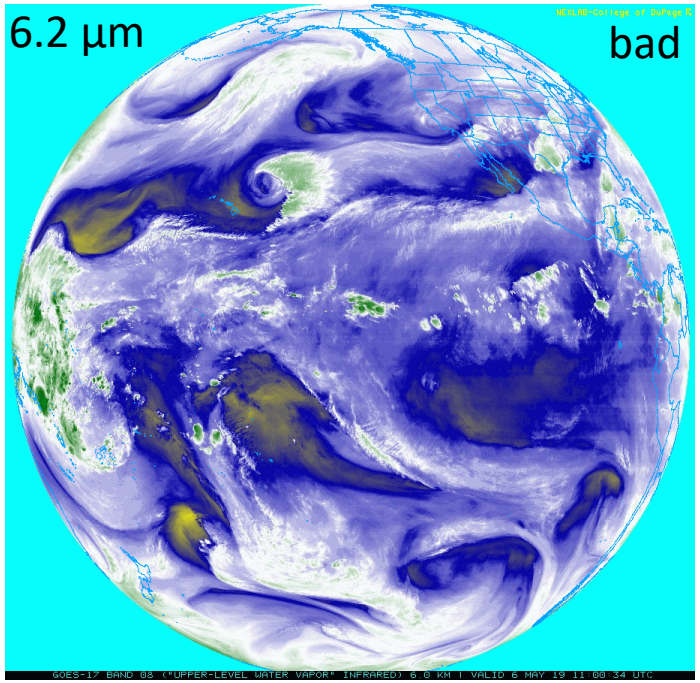
Tables scroll horizontally on smaller windows and devices.

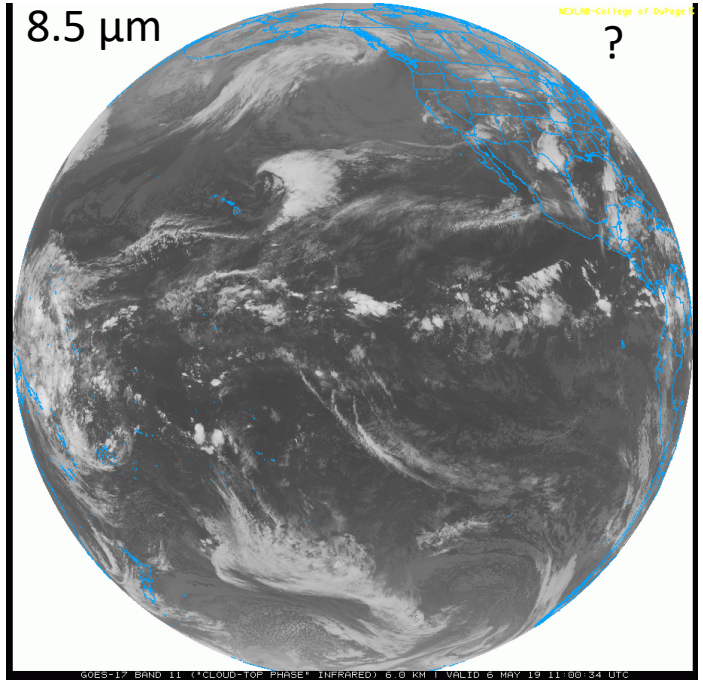
Band	Channel	Function	Estimated Unsaturated Signal Cold Season (Solstice)	Estimated Unsaturated Signal Warm Season (Pre-Eclipse)
1	0.47 µm	Blue	24 hr	24 hr
2	0.64 µm	Red	24 hr	24 hr
3	0.86 µm	Veggie	24 hr	24 hr
4	1.38 µm	Cirrus	24 hr	24 hr
5	1.61 µm	Snow/Ice	24 hr	24 hr
6	2.25 µm	Cloud Particle Size	24 hr	24 hr
7	3.90 µm	Shortwave Window	24 hr	24 hr
8	6.18 µm	Upper-Level Water Vapor	24 hr	18 - 20 hr
9	6.95 µm	Mid-Level Water Vapor	24 hr	18 - 20 hr
10	7.34 µm	Lower-Level Water Vapor	24 hr	18 - 20 hr
11	8.50 µm	Cloud-Top Phase	24 hr	21 hr
12	9.61 µm	Ozone	24 hr	18 - 20 hr
13	10.35 µm	Clean IR Longwave Window	24 hr	24 hr
14	11.20 µm	IR Longwave Window	24 hr	24 hr
15	12.30 µm	Dirty Longwave Window	24 hr	21 hr
16	13.30 µm	CO2 Longwave Infrared	24 hr	18 - 20 hr

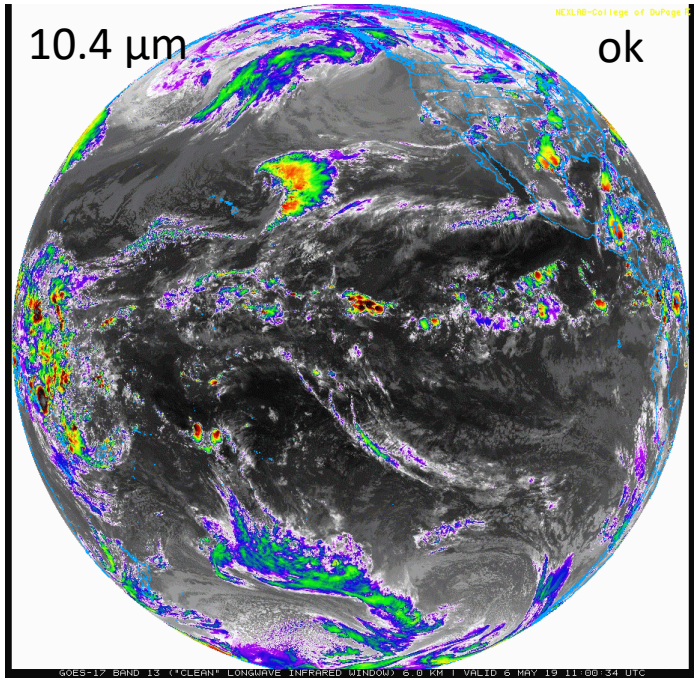
Fake News!! →

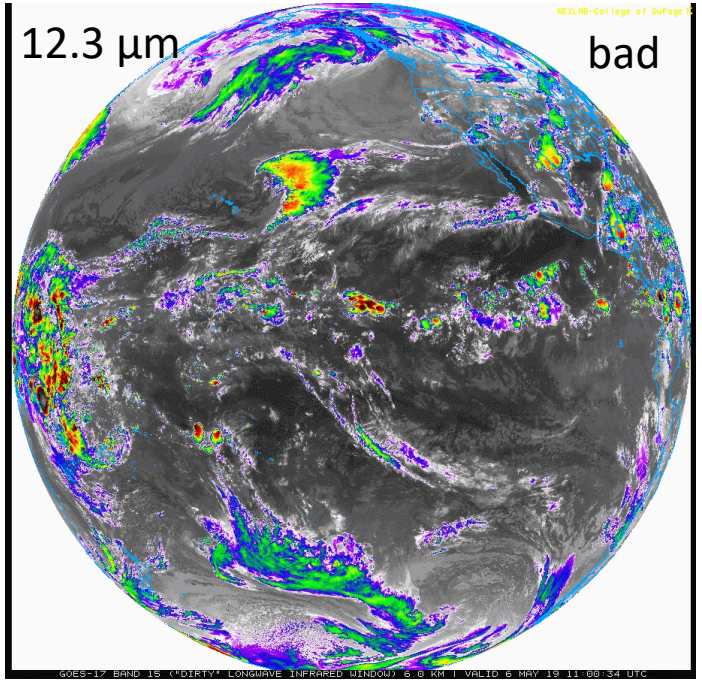
May 6
2019

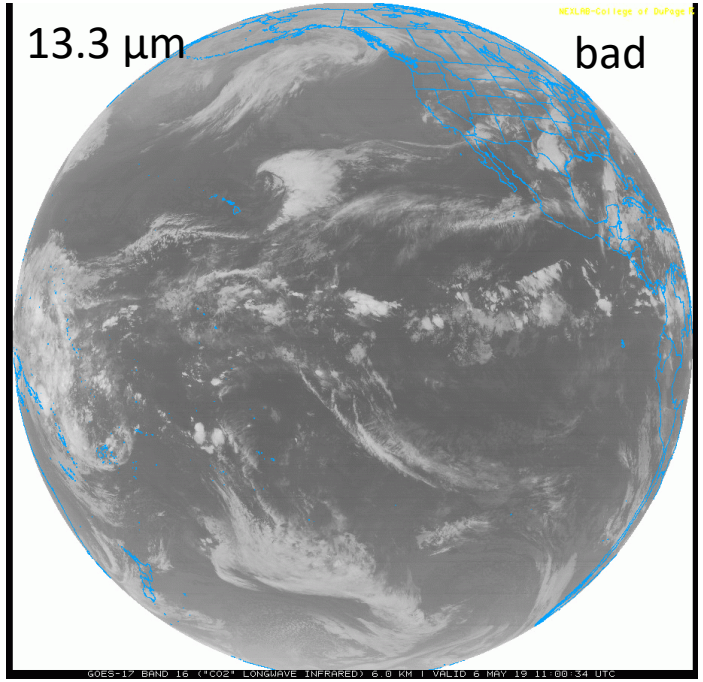




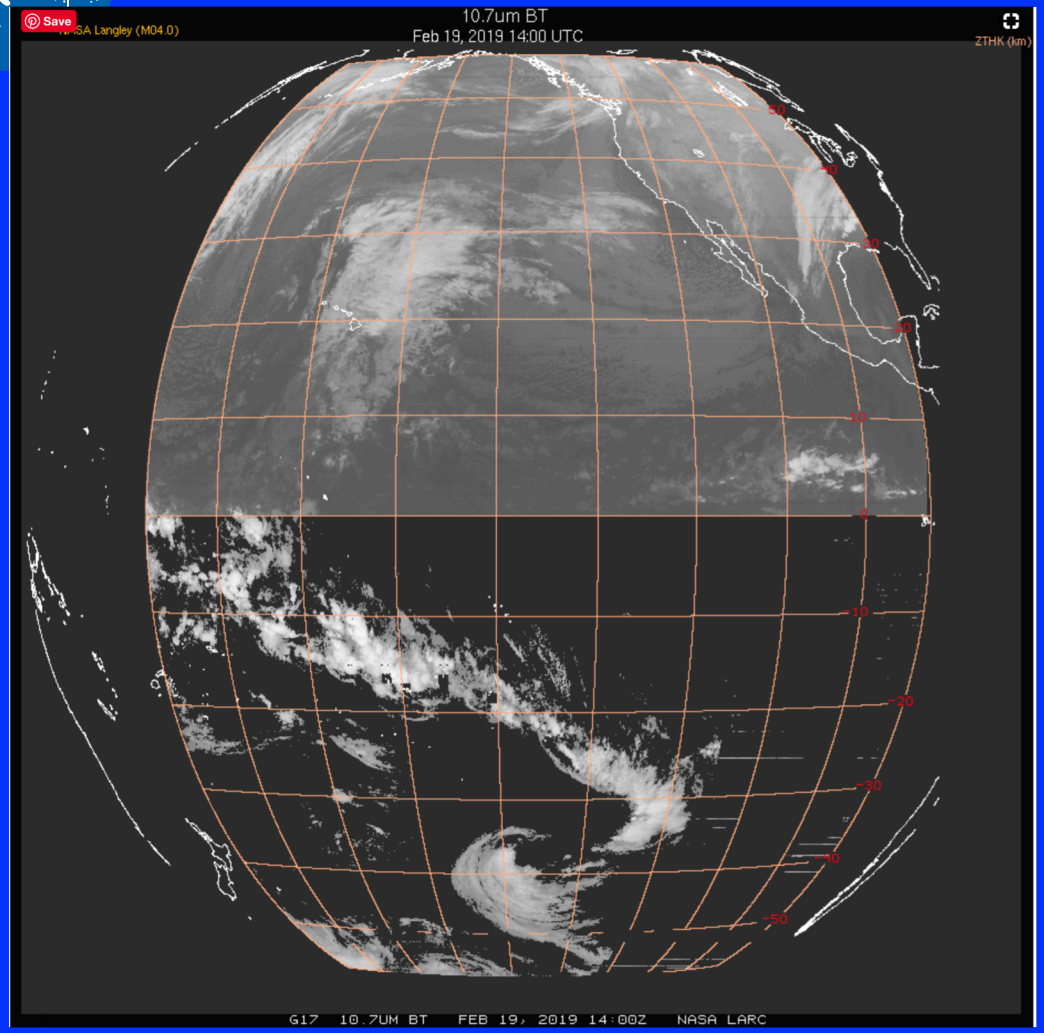




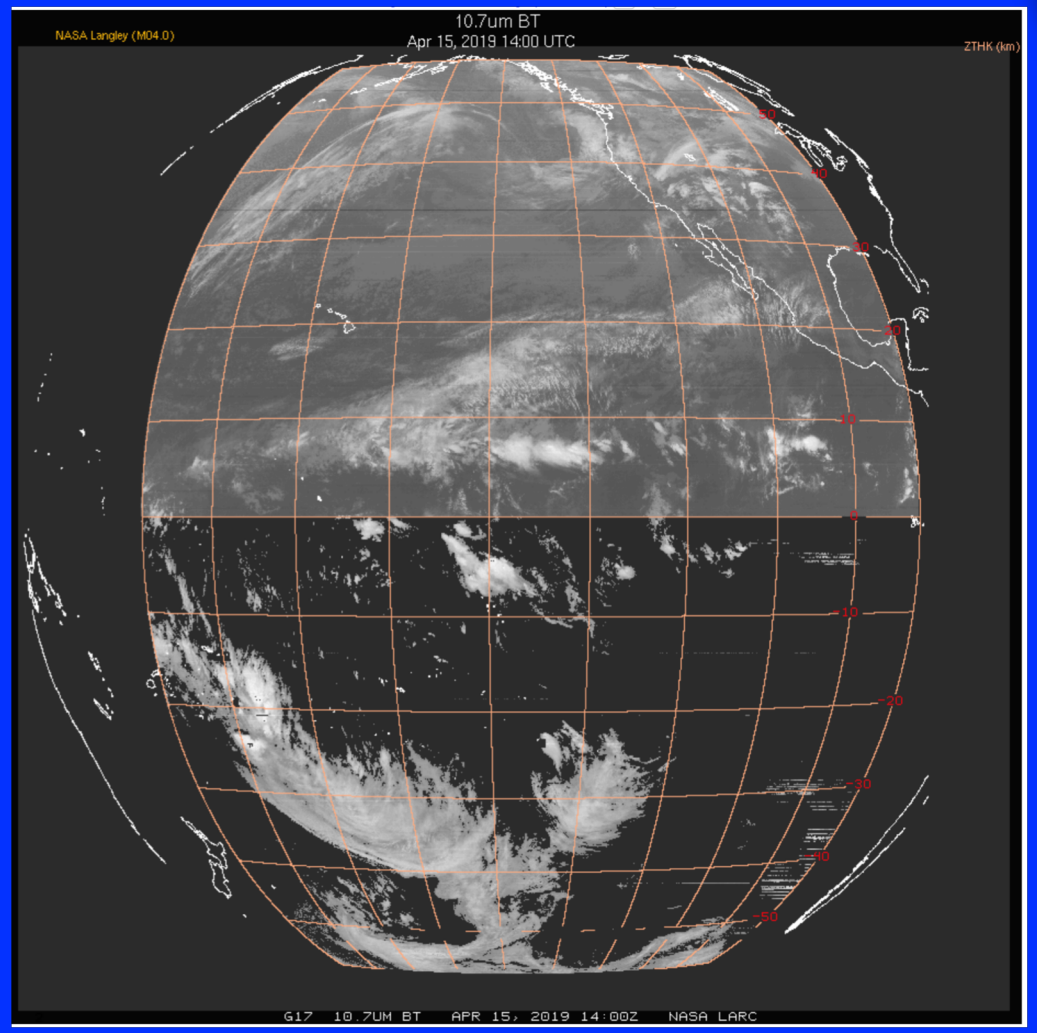


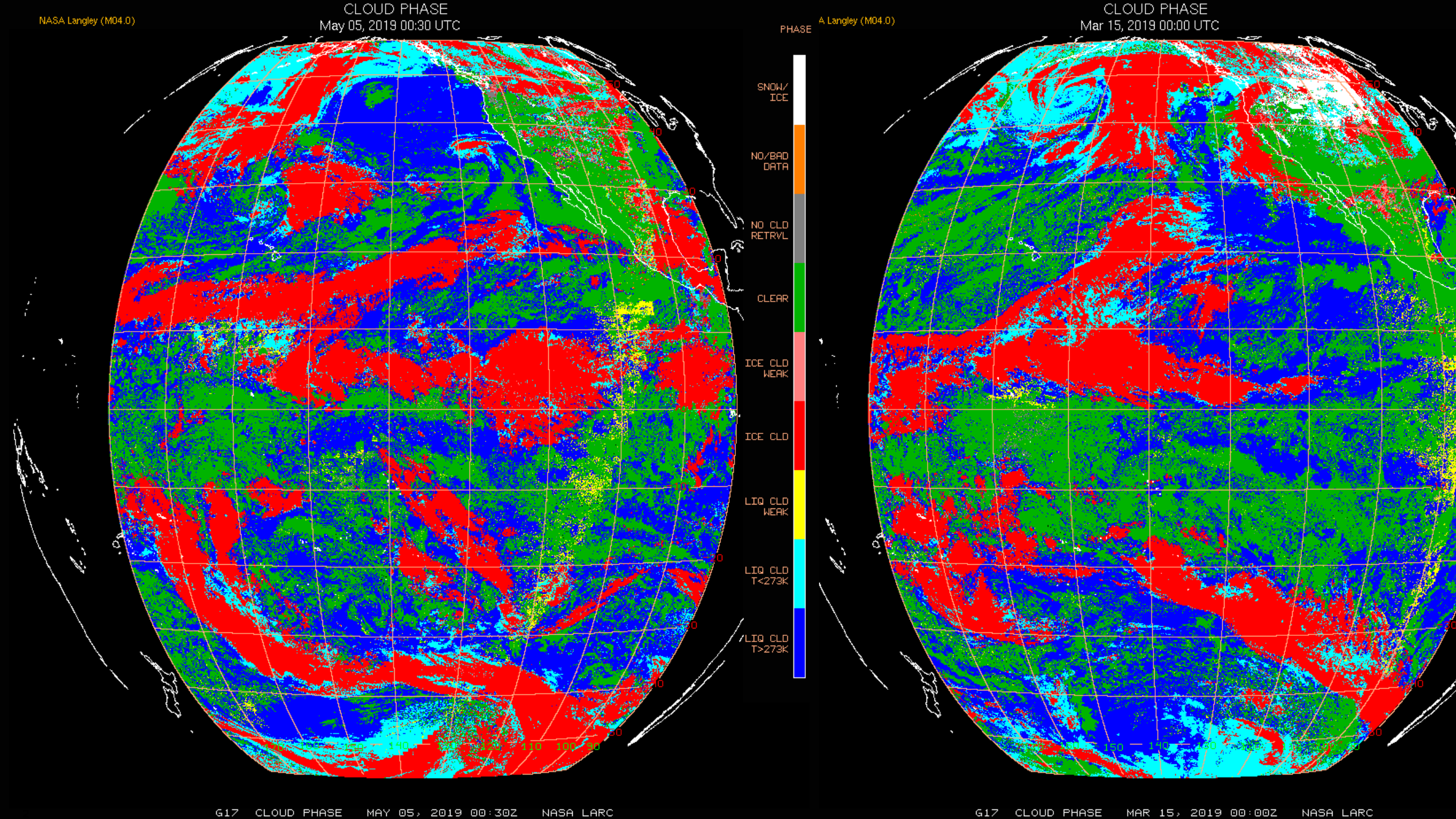


11µm BT, Feb 19, 2019, 14GMT

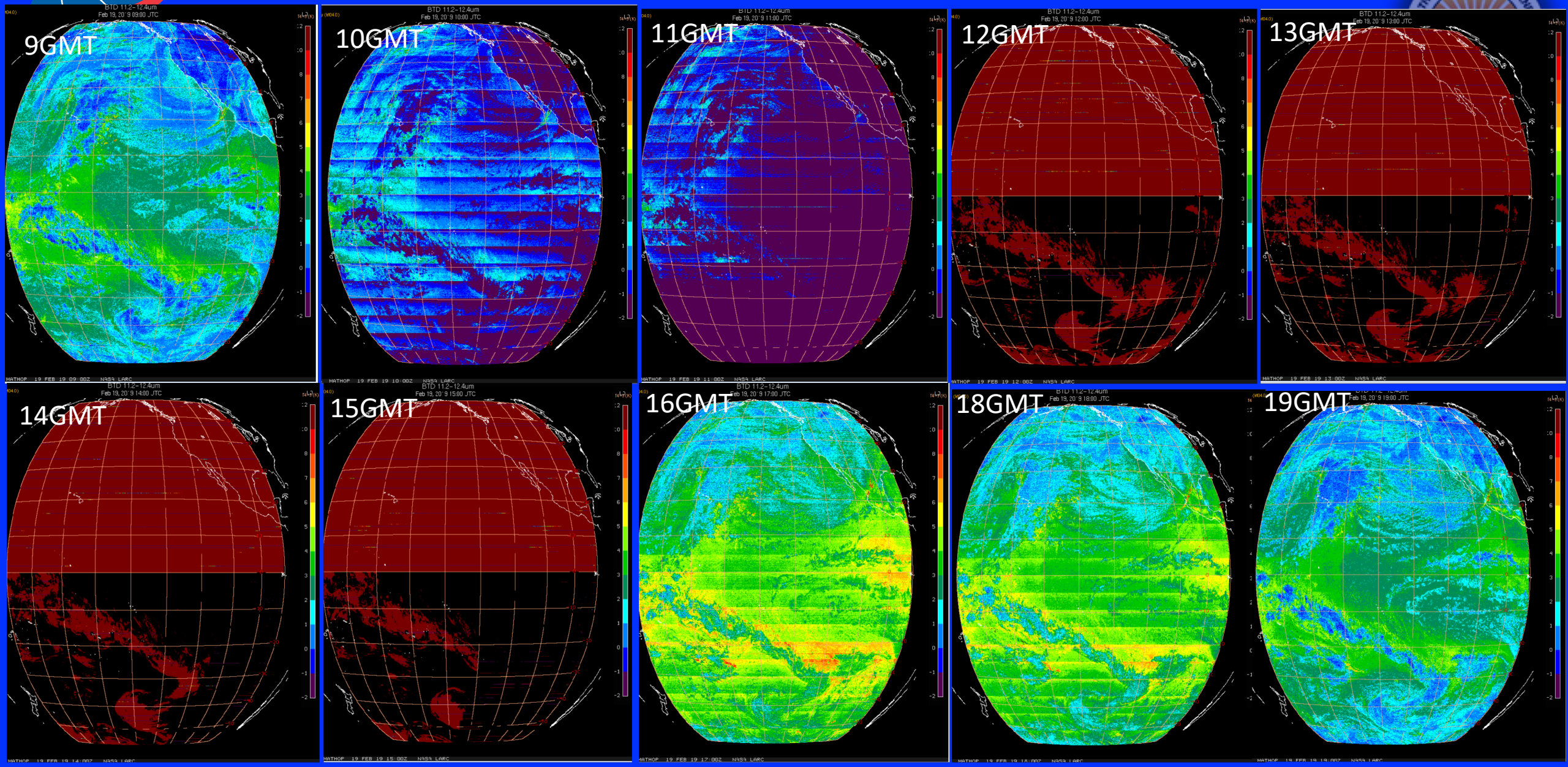


11µm BT, April 15, 2019, 14GMT

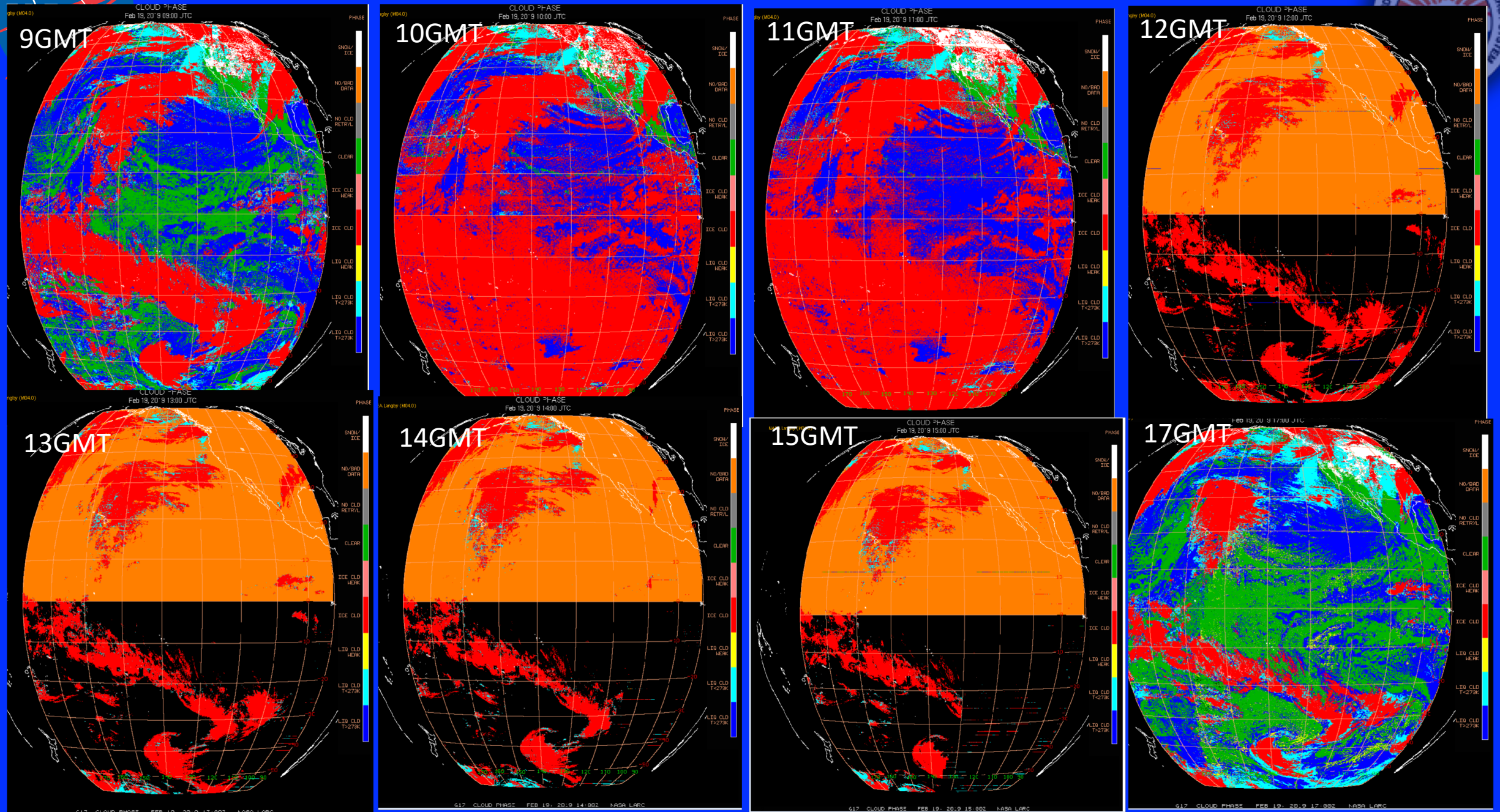



NASA Langley (M04.0)
CLOUD PHASE
May 05, 2019 00:30 UTC
PHASE
SNOW/ ICE
NO/BAD DATA
NO CLD RETRVL
CLEAR
ICE CLD WEAK
ICE CLD
LIQ CLD WEAK
LIQ CLD T<273K
LIQ CLD T>273K
A Langley (M04.0)
CLOUD PHASE
Mar 15, 2019 00:00 UTC
G17 CLOUD PHASE MAY 05, 2019 00:30Z NASA LARC
G17 CLOUD PHASE MAR 15, 2019 00:00Z NASA LARC

11-12µm BTD, Feb. 19, 2018



Cloud phase, Feb. 19, 2018



What to do?

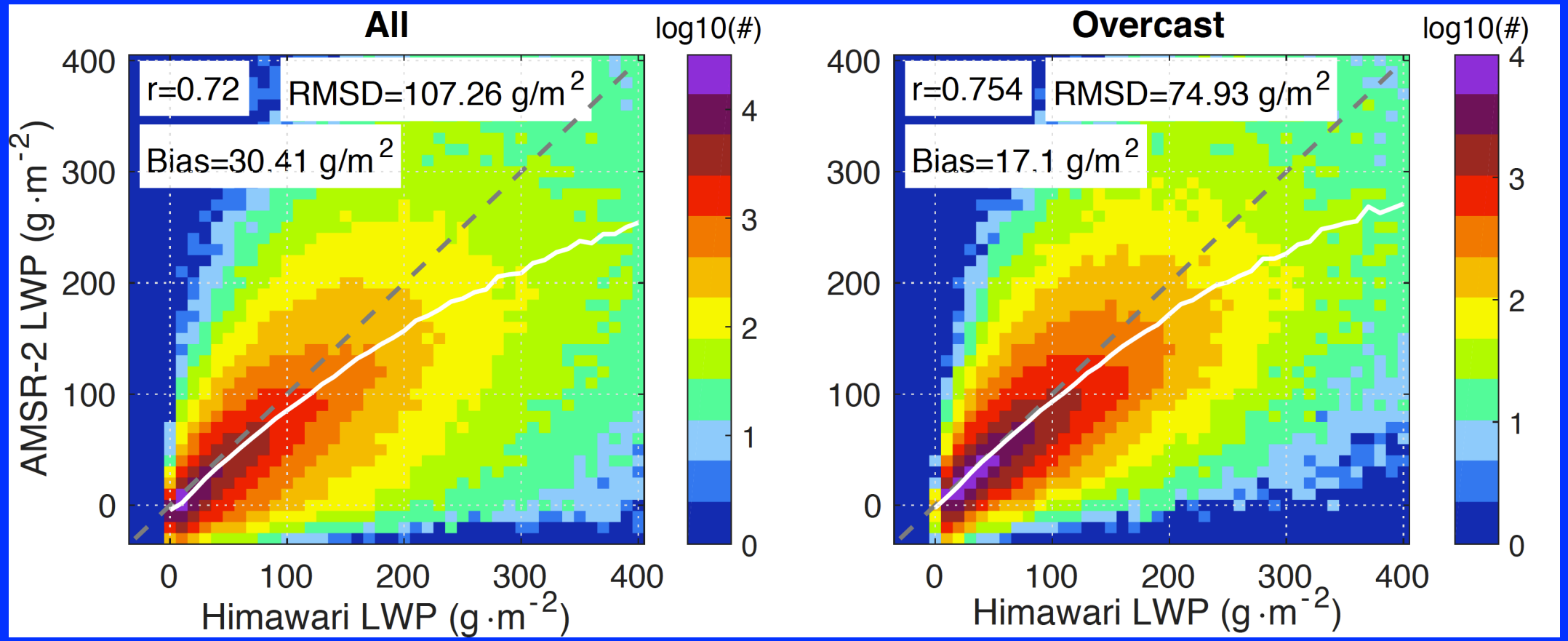
- Need an objective way to flag bad images to determine when not to process
- Will have to fill gaps with linear interpolation (TISA group)
- Was hopeful we might be able to fill gaps with an objective method using the good radiances but there may not be enough information. Might be worth trying but a more thorough assessment of impacts to the radiances is needed.
- Information from NOAA not particularly useful

Recent Validation

Himawari LWP comparison with AMSR-2

SOCRATES Field Campaign Period (Jan-Feb, 2018)

Southern ocean low level clouds

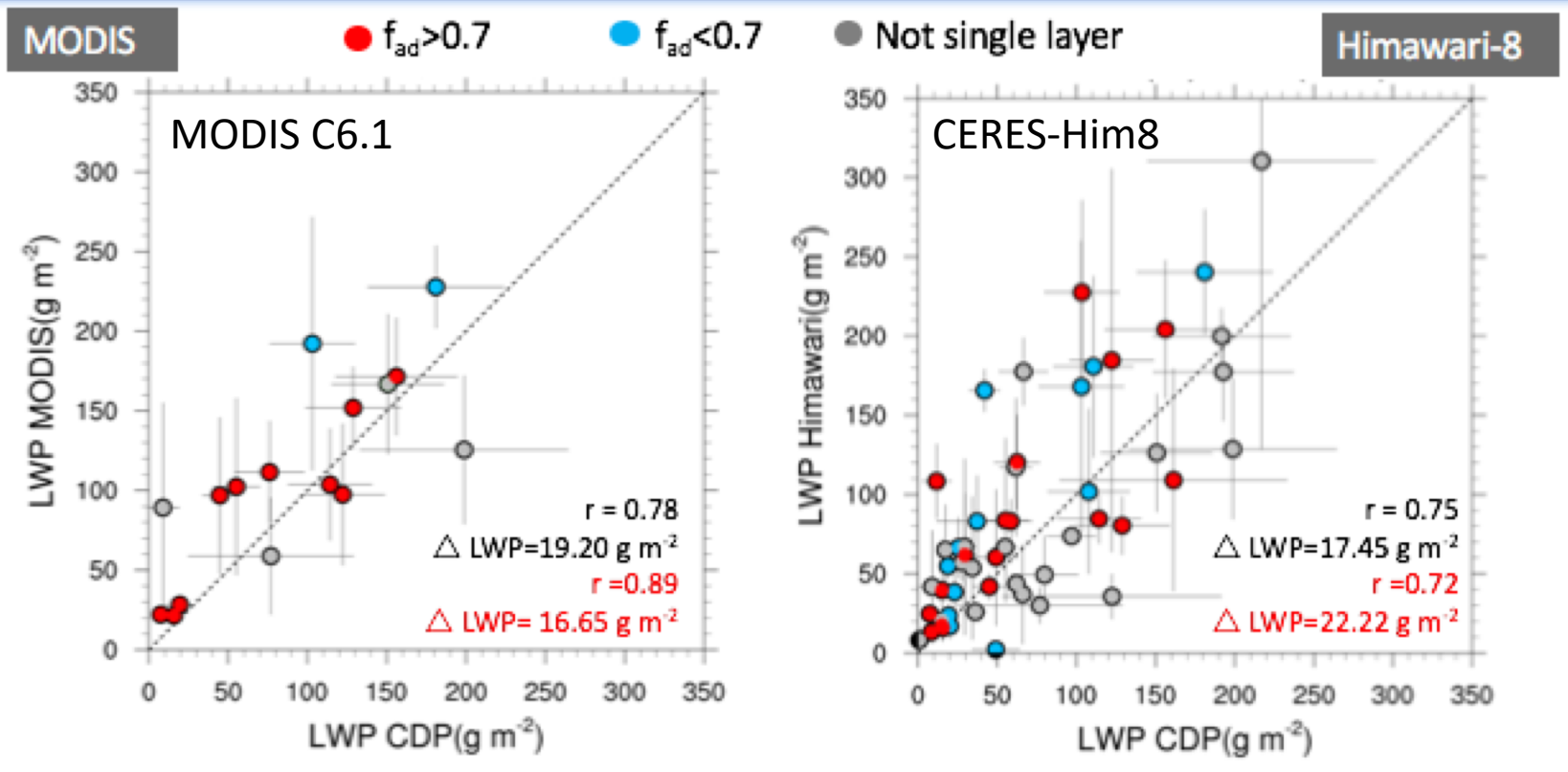


- White lines are binned averages
- Good correlation and excellent agreement for LWP < 100 gm-2
- Known AMSR-2 retrieval problems at larger LWP's (underestimates)

Himawari LWP comparison with In-situ

SOCRATES Field Campaign Period (Jan-Feb, 2018)

Southern ocean low level clouds



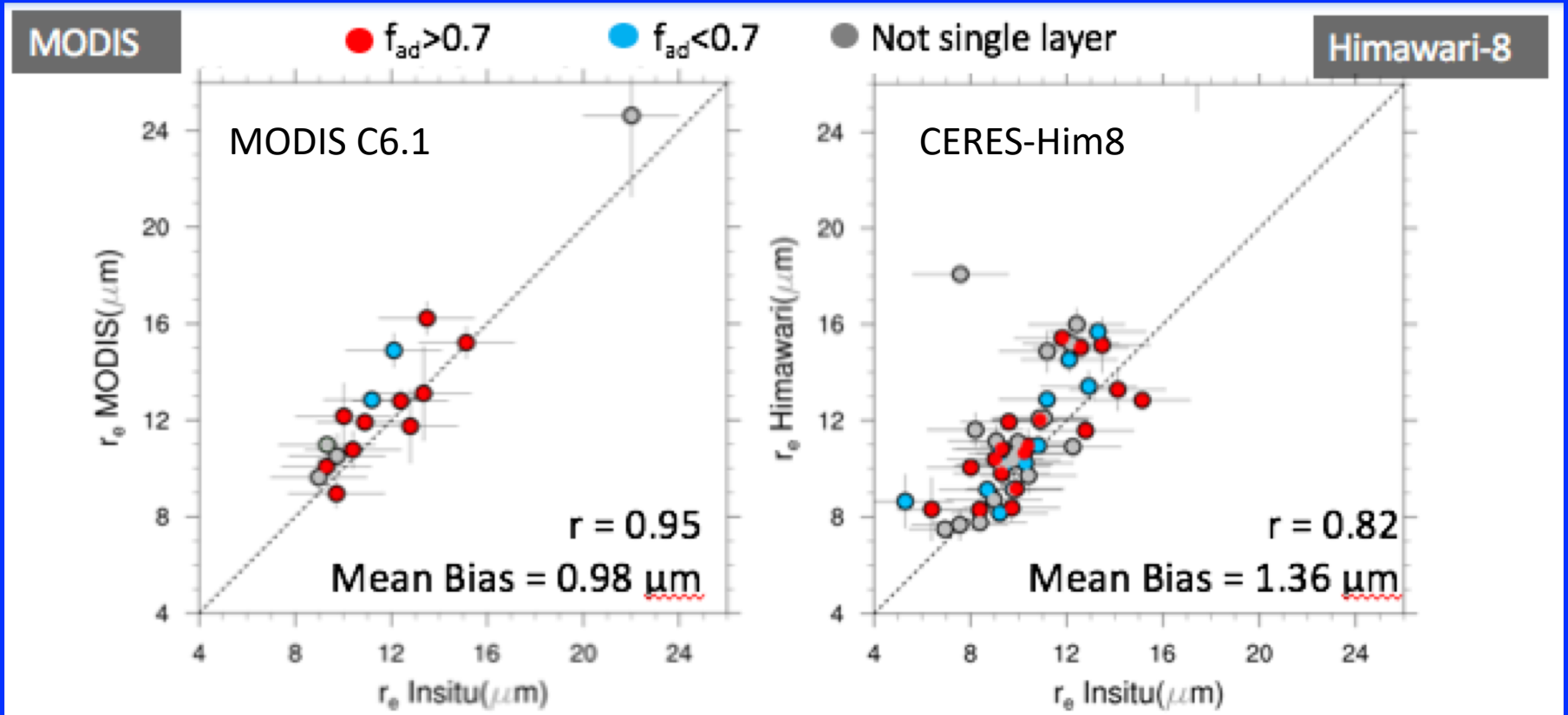
Good correlation and overall agreement with in-situ data. Satellite about 10% higher

Courtesy of L. Kang, U. of Washington

Himawari R_e comparison with In-situ data

SOCRATES Field Campaign Period (Jan-Feb, 2018)

Southern ocean low level clouds



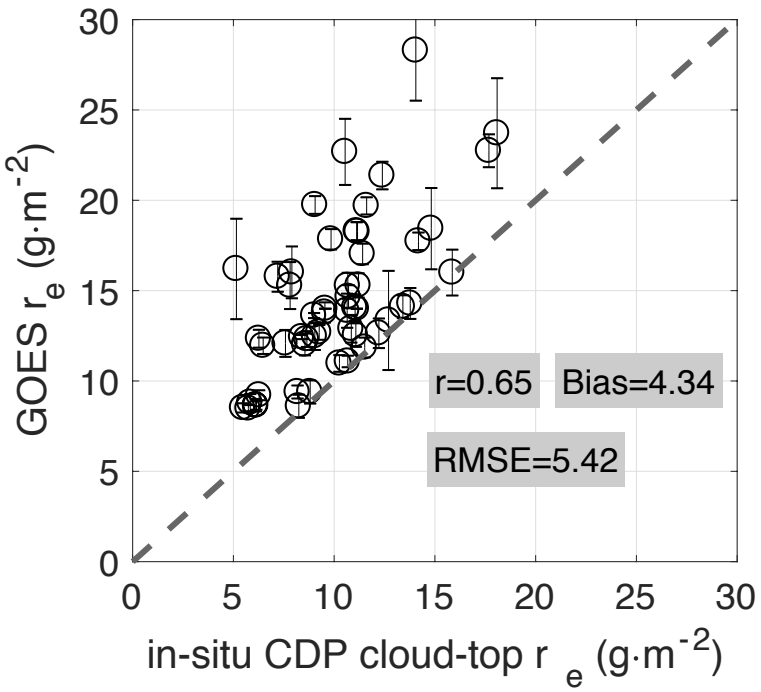
MODIS C6.1 and CERES Him-8 Re bias about 1 µm, well correlated with in-situ data

Courtesy of L. Kang, U. of Washington

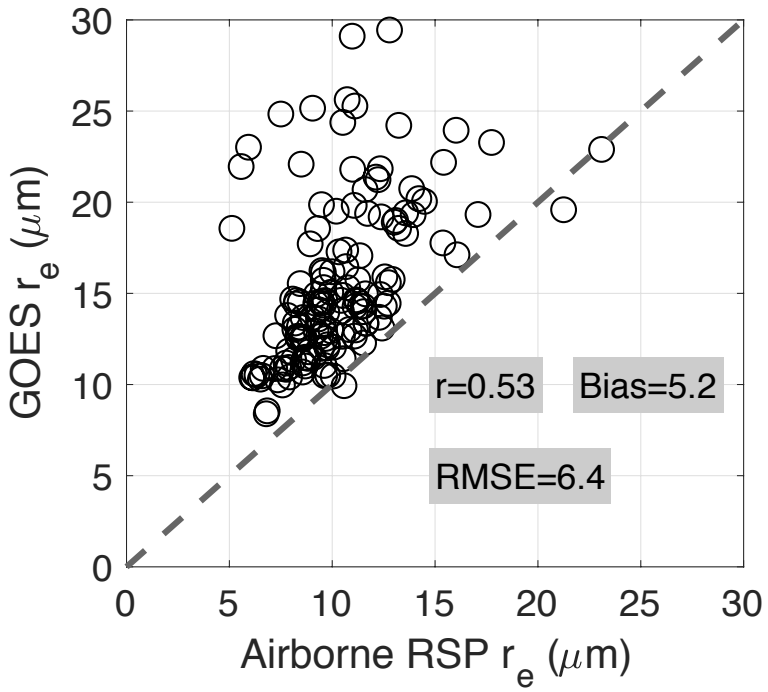
Effective Radius Comparisons with NAAMES Field Campaign Data

North Atlantic low level cloud

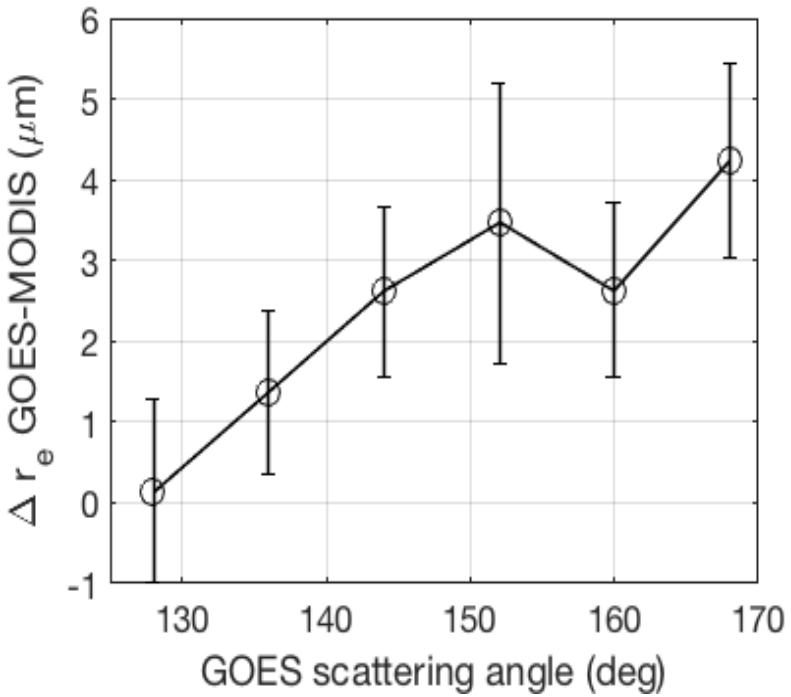
GOES vs In-situ CDP



GOES vs Airborne Polarimeter



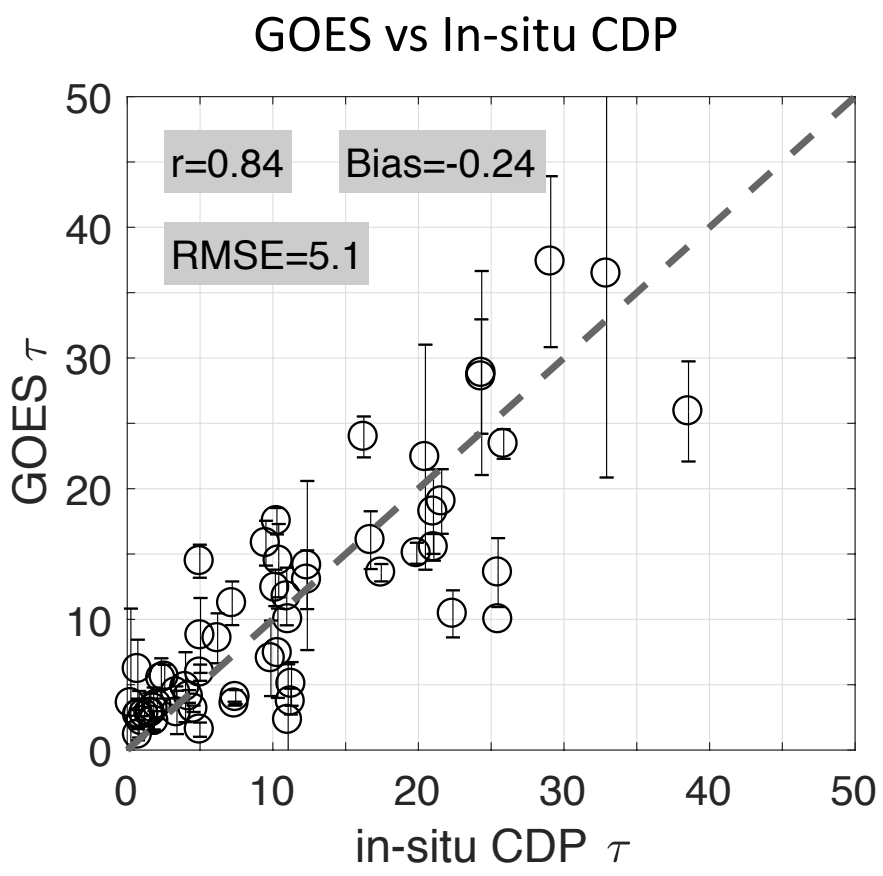
GOES vs CERES-MODIS

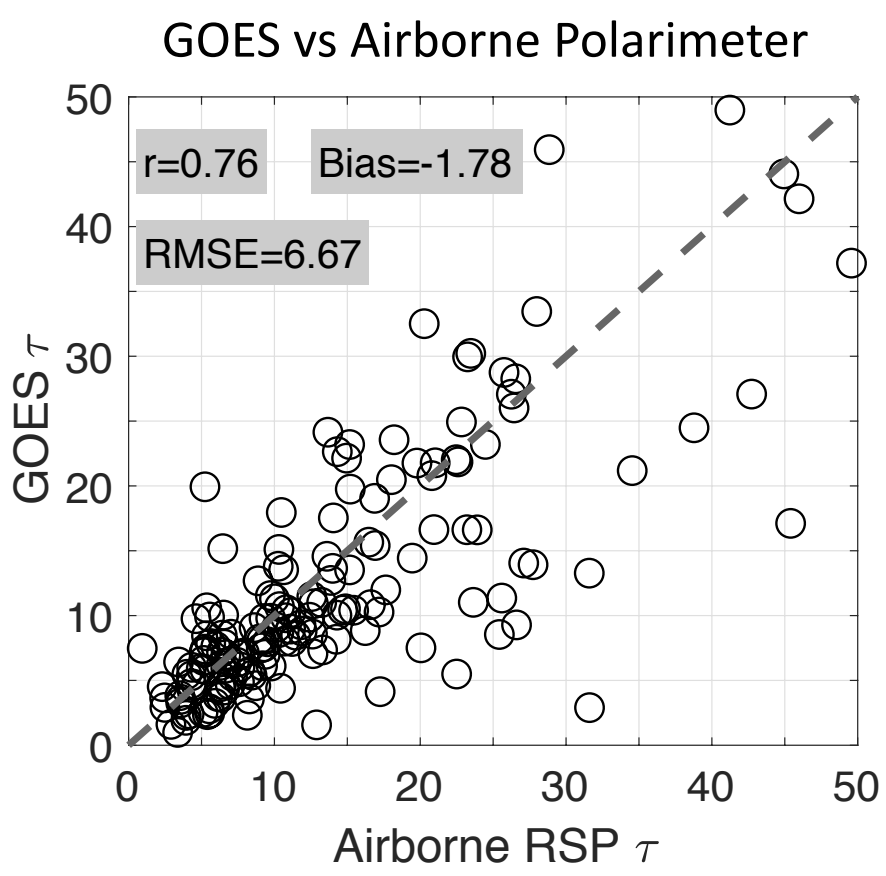


Significant bias of retrieved R_e at large backscatter angles (i.e.. from GOES over NAAMES sampling area & period)
We have plans to further evaluate this and develop corrections

Optical Depth Comparisons with NAAMES Field Campaign Data

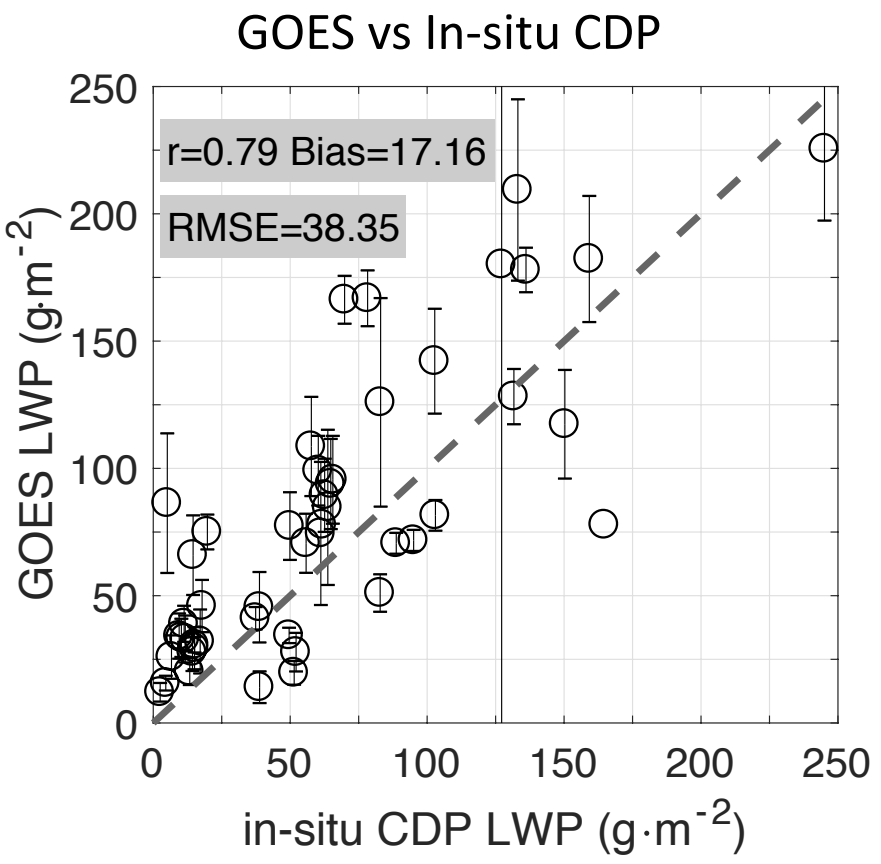
North Atlantic low level cloud





LWP Comparisons with NAAMES Field Campaign Data

North Atlantic low level clouds



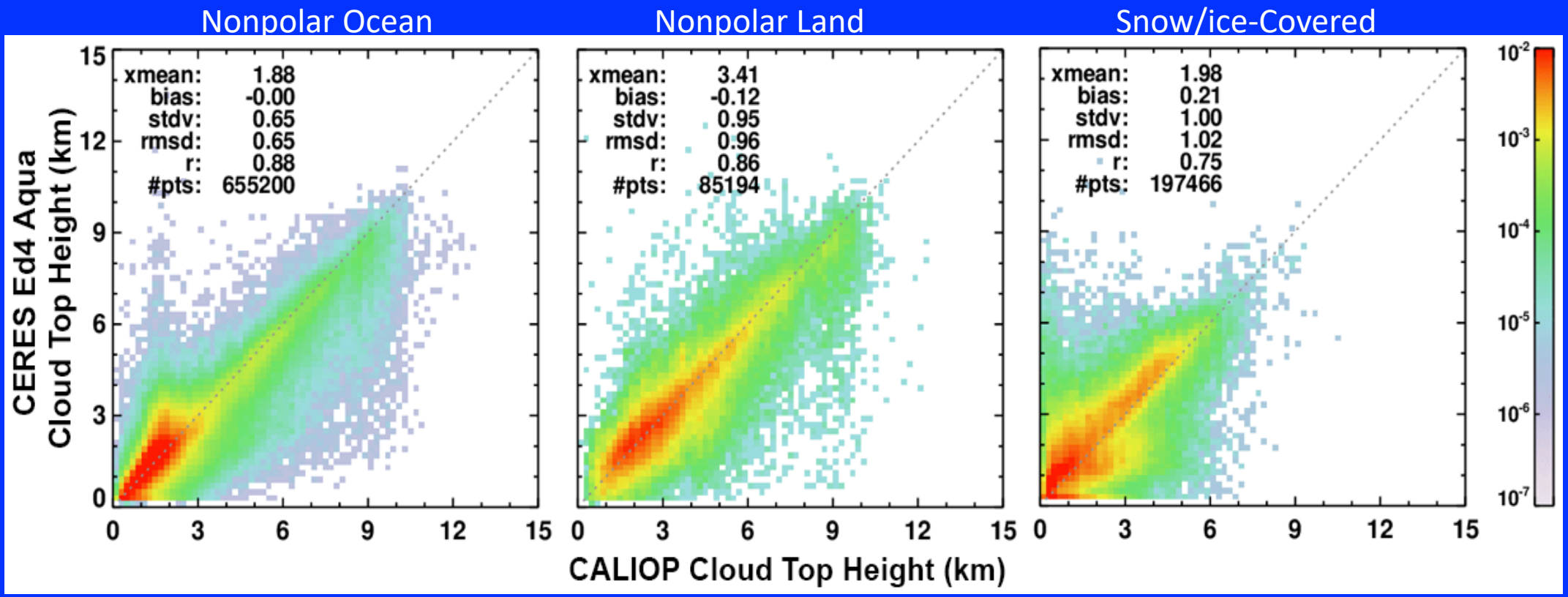
CALIPSO and CERES Ed4 Aqua MODIS Cloud Phase Comparison Statistics

100% cloud-covered 5-km footprints. January, April, July, & October, 2015 & 2016.

SIF: snow/ice-free, SIC: snow/ice-covered

Scene #	Scene Type	Fraction Correct (HR)	Bias	Ice FAR	Water FAR	Hanssen-Kuiper	# x 10^3	% all matches
	Day							
1	Nonpolar, Land SIF	0.919	-0.049	0.034	0.098	0.874	555	64.7
2	Polar Land SIF	0.928	-0.011	0.096	0.051	0.849	123	61.5
3	Nonpolar Ocean, SIF	0.971	0.006	0.048	0.014	0.947	2,371	71.2
4	Polar Ocean, SIF	0.945	0.023	0.173	0.018	0.880	308	65.0
5	Global, SIF	0.958	-0.003	0.053	0.027	0.923	3,358	69.1
6	Global, SIC	0.920	0.036	0.157	0.032	0.851	719	64.3
	Night							
7	Nonpolar, Land SIF	0.873	0.051	0.137	0.109	0.715	598	68.5
8	Polar Land SIF	0.823	0.132	0.280	0.050	0.679	124	69.3
9	Nonpolar Ocean, SIF	0.918	0.048	0.174	0.027	0.851	2,500	69.5
10	Polar Ocean, SIF	0.840	0.135	0.336	0.023	0.746	384	67.5
11	Global, SIF	0.899	0.061	0.187	0.036	0.817	3,606	69.1
12	Global, SIC	0.798	0.186	0.252	0.034	0.520	1,381	74.0

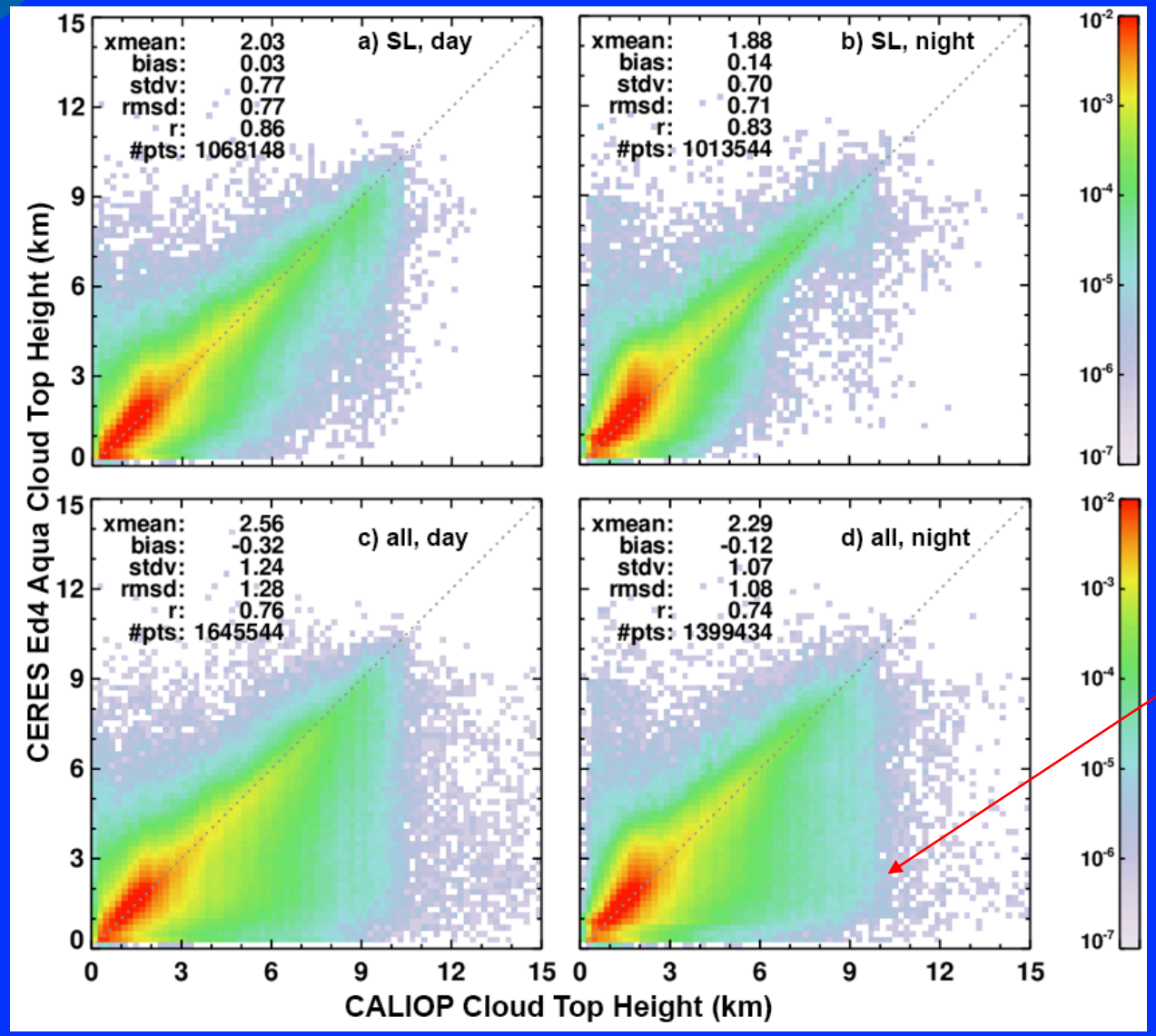
Cloud top height comparison - overcast 100% liquid cloud tops
Ed4 vs CALIOP



CALIOP single layer only
Daytime, January, April, July, and October 2010

Cloud top height comparison - overcast 100% liquid cloud tops

Ed4 vs CALIOP



- Single-layer bias increases at night to 0.14 km
  - Lapse rate? Emissivity estimate?
- Mean bias
  - single layer water: 0.08 ± 0.75 km
  - all overcast water: -0.24 ± 1.17 km
- Upper water layers are optically thin
  - Affects optical depth interpretation
    - greater impact during day

CALIOP single layer and all layer combinations. January, April, July, and October 2010

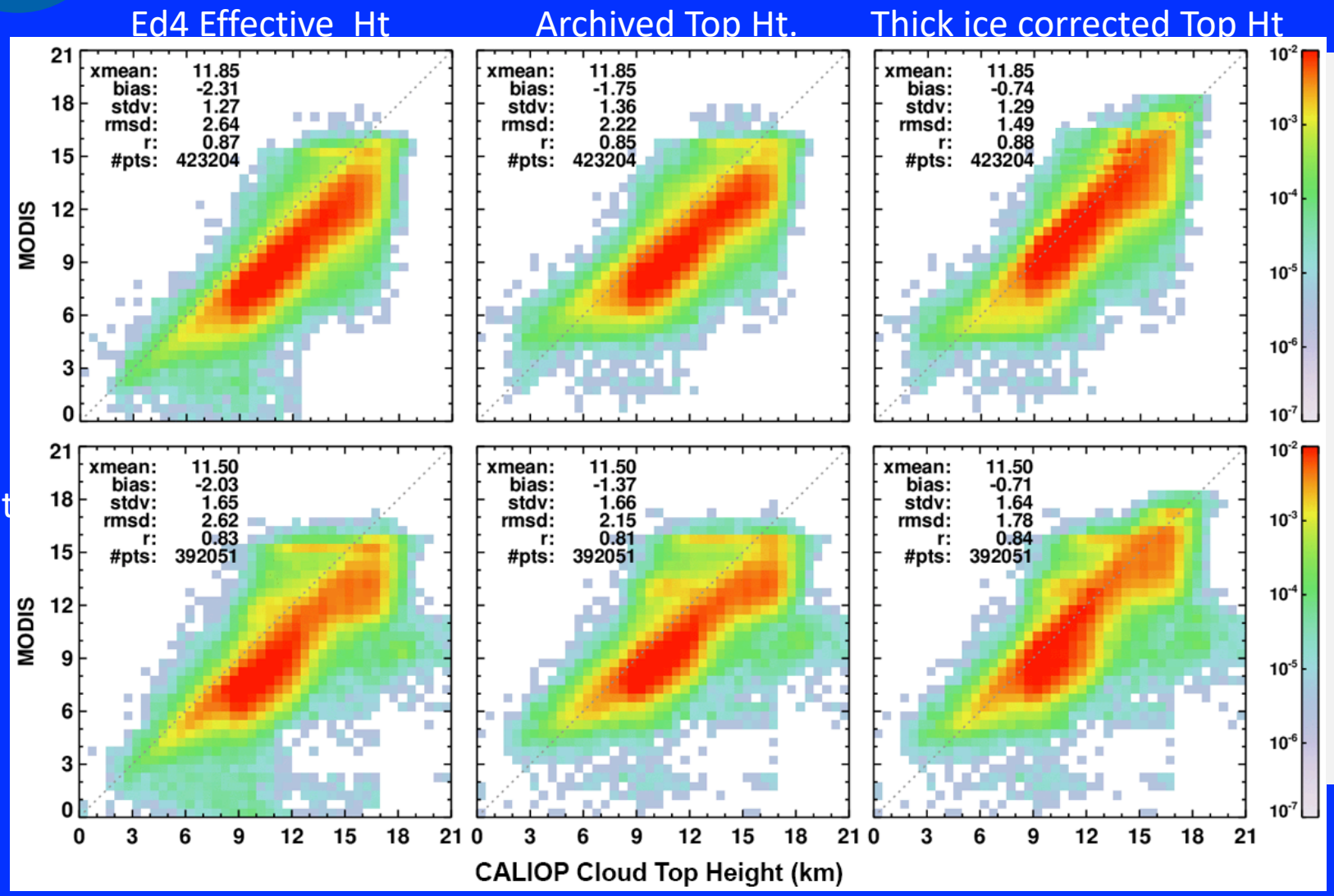
CERES Ed4 Aqua MODIS liquid water cloud-top height differences (Ed4 – CALIOP)

Single-phase top100% cloud-covered footprints. January, April, July, & October, 2010.

SIF: snow/ice-free, SIC: snow/ice-covered

	Single Layer, CALIOP 100% Liquid			SL & ML, CALIOP 100% liquid			SL & ML, CALIOP, 100% liquid tops		
Scene Type	CALIOP Mean Height (km)	Mean Difference (Std Dev) (km)	% of all	CALIOP Mean Height (km)	Mean Difference (Std Dev) (km)	Percent of all matches	CALIOP Mean Height (km)	Mean Difference (Std Dev) (km)	# Samples x 10^3
Day									
Nonpolar Land SIF	3.41	-0.12 (0.95)	51	3.48	-0.24 (1.05)	57	4.11	-0.56 (1.35)	169
Polar Land SIF	2.33	-0.02 (0.81)	55	2.35	-0.05 (0.84)	56	2.91	-0.43 (1.16)	55
Nonpolar Ocean SIF	1.88	0.00 (0.65)	71	1.95	-0.07 (0.76)	75	2.42	-0.34 (1.19)	929
Polar Ocean, SIF	1.79	0.01 (0.76)	62	1.81	-0.02 (0.80)	63	2.20	-0.36 (1.19)	163
Global, SIC	1.98	0.21 (1.00)	60	1.98	0.19 (1.01)	60	2.27	-0.10 (1.31)	330
Global	2.03	0.03 (0.77)	65	2.08	-0.03 (0.85)	68	2.56	-0.32 (1.24)	1,646
Night									
Nonpolar Land SIF	3.43	0.10 (0.87)	60	3.45	0.04 (0.91)	65	3.98	-0.25 (1.19)	108
Polar Land SIF	2.26	0.09 (0.87)	64	2.27	0.07 (0.88)	66	2.68	-0.20 (1.14)	32
Nonpolar Ocean SIF	1.80	0.11 (0.61)	76	1.87	0.06 (0.67)	83	1.87	-0.13 (1.02)	921
Polar Ocean, SIF	1.73	0.39 (0.74)	67	1.74	0.37 (0.75)	68	2.07	0.09 (1.12)	136
Global SIC	1.61	0.11 (0.90)	68	1.61	0.10 (0.90)	69	1.87	-0.14 (1.14)	202
Global	1.88	0.14 (0.70)	72	1.94	0.09 (0.74)	78	2.29	-0.12 (1.07)	1,399

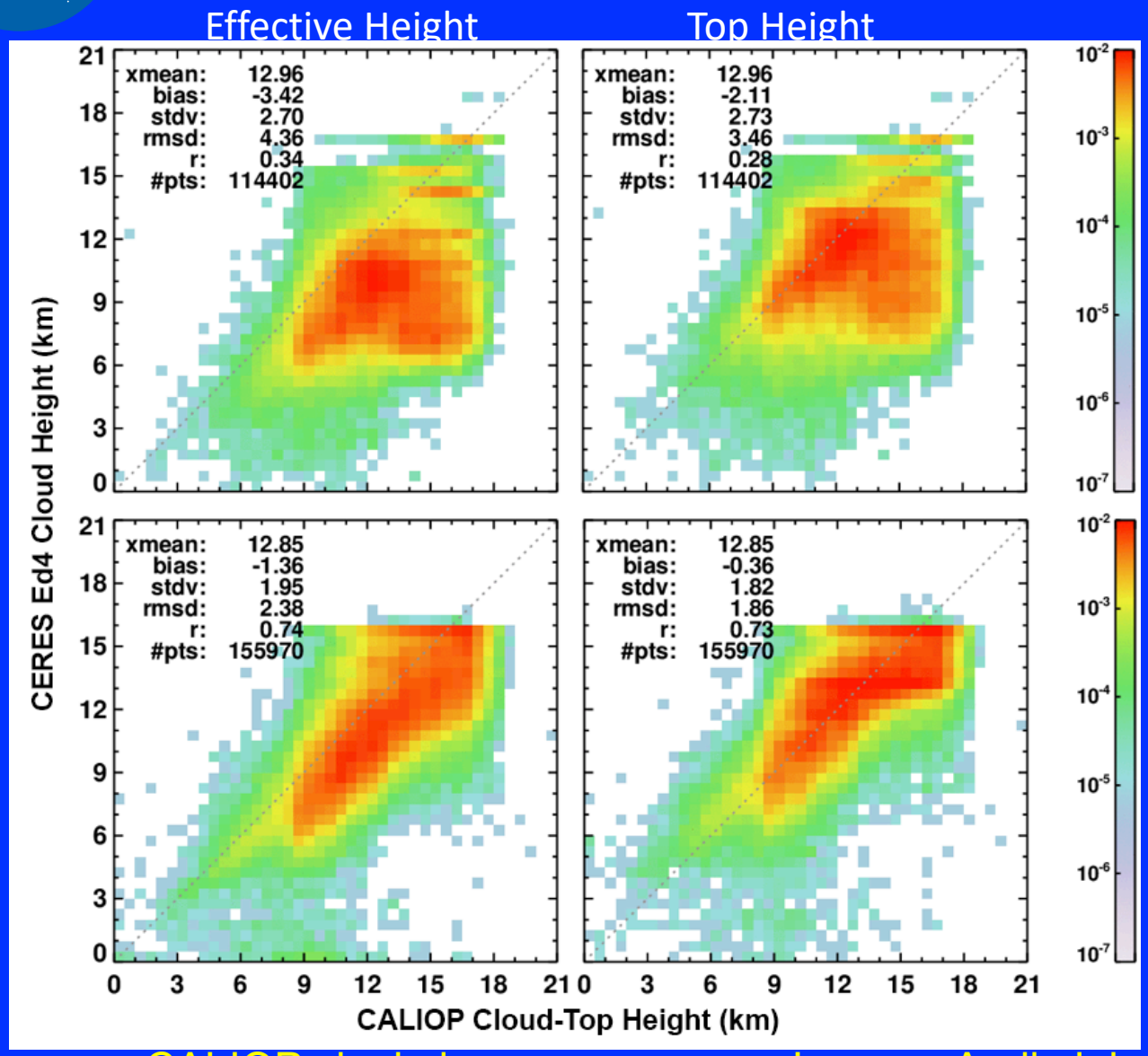
Cloud top height comparison - opaque overcast 100% ice cloud tops
Ed4 vs CALIOP



- Effective radiative height for opaque ice clouds is 2.0 - 2.3 km below the physical top
- Ed2 correction mistakenly applied, overwriting Ed4 thick-ice correction accounts for only ~0.50 km, so mean underestimate of ~1.5 km realized
- Ed4 correction applied by user will only halve the bias.
- Need new correction for Ed5:
  - temperature dependent?
  - NN?

CALIOP single layer opaque. January, April, July, and October 2010

Cloud top height comparison – non-opaque overcast 100% ice cloud tops
Ed4 vs CALIOP



- Effective radiative height for non-opaque ice clouds averages ~1.4 km below the physical top (based on night IR methotd)

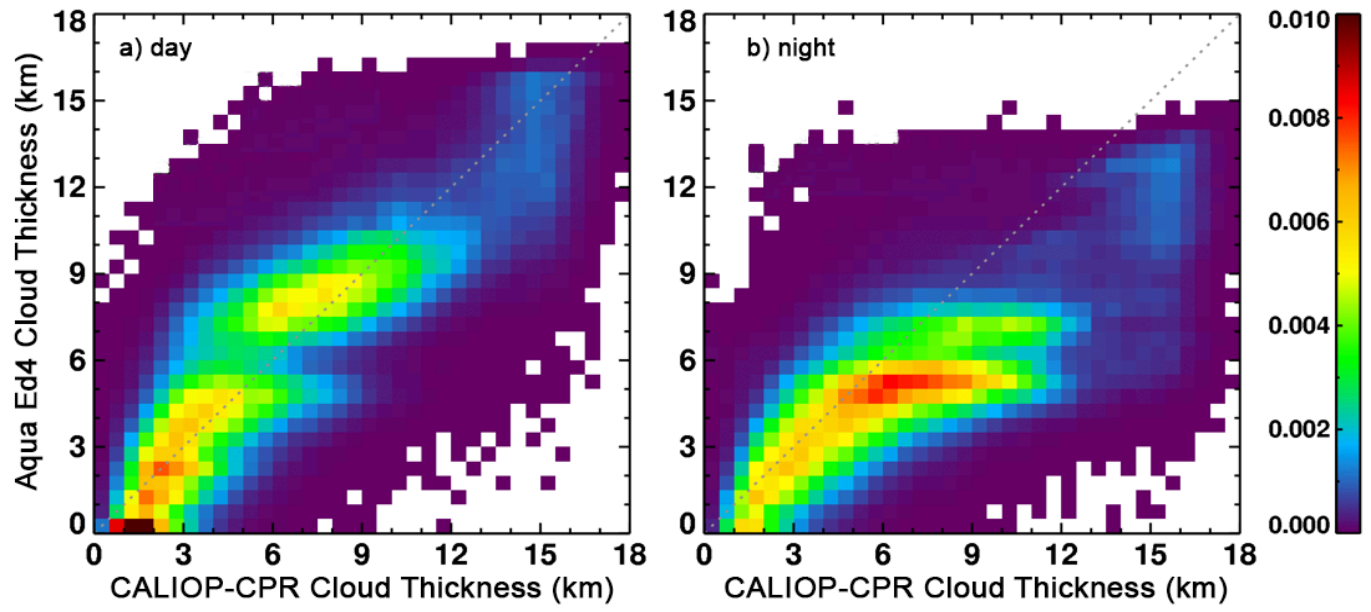
- Ed4 thin-ice correction accounts for only ~1.0 km, so mean underestimate of ~0.4 km realized

- Much greater bias for daytime heights, due to
  - *single-habit ice model*
  - *clear reflectance biases?*
  - *use default heights for some options in Ed4 logic for no retrievals (Note striping)*

- Need revised approach for Ed5:
  - *temperature dependent height correction*
  - *opt for IR approach for defaults*
  - *improve clear reflectance*
  - *two-habit model*

Non-opaque CALIOP single layer over ocean. January, April, July, and October 2010

Ice Cloud Thickness Comparisons: Ed4 vs CloudSat-CALIPSO, JAJO 2010

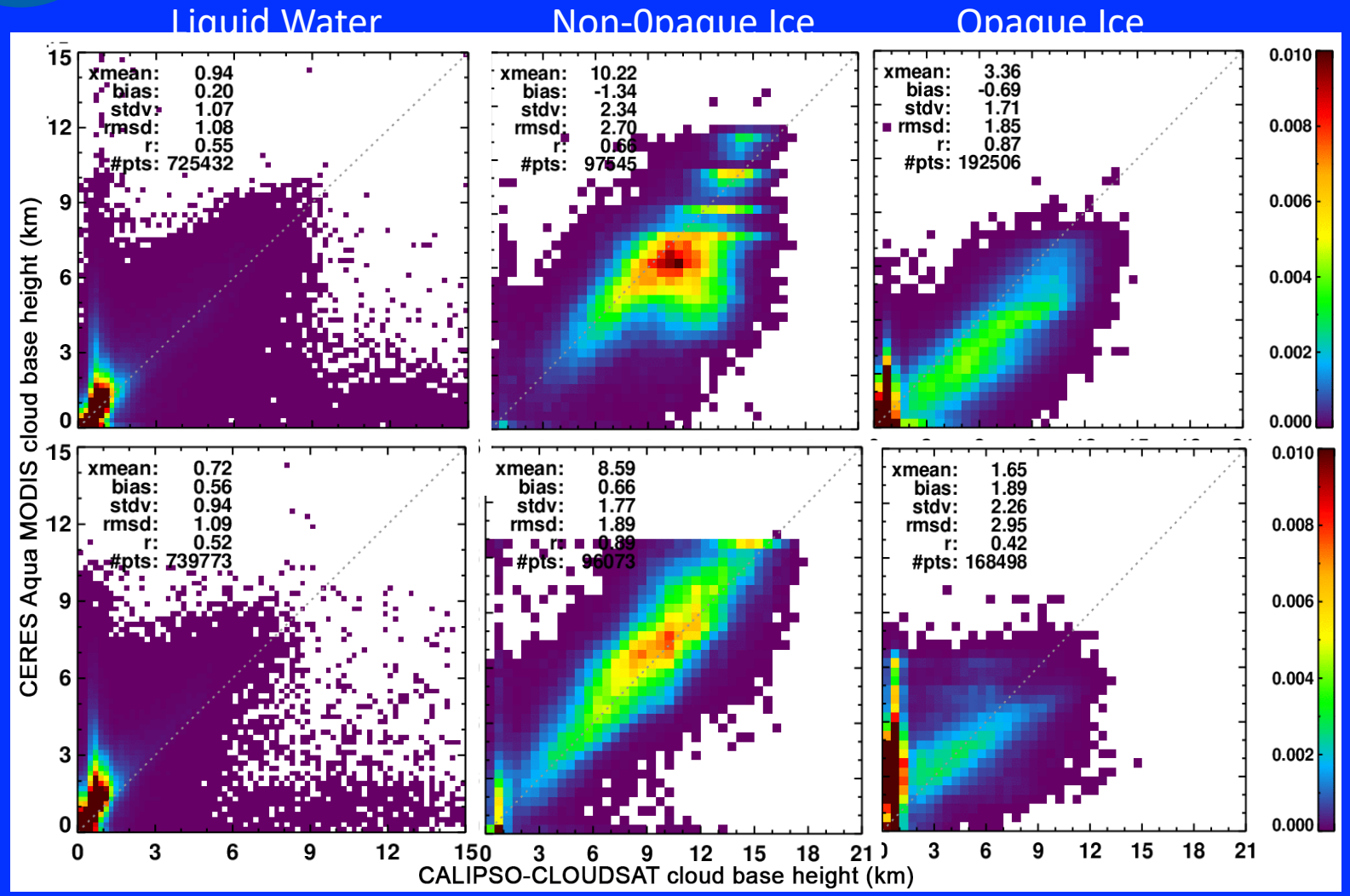


- Thick ice cloud depth captured during day
  - some improvements possible
    - *more temperature dependence?*
- Nocturnal depth somewhat capped
  => biases
  - NN IR approach at night may help

Single-Layer Cloud Thickness (H) and Base Height (Z_b)Differences, CC- Ed4, JAJO 2010, Ice/Snow-free surfaces, Standard Deviations of Differences in Parentheses

Category	Day			Night		
	H(CC), km	H(Ed4)-H(CC), km	N x 10^3	H(CC), km	H(Ed4)-H(CC), km	N x 10^3
All	6.19	-0.07 (2.05)	435	6.85	-1.74 (2.42)	455
Non-opaque, t_{cc} < 3	2.54	-0.71 (1.57)	122	3.39	-1.02 (1.57)	136
t_{cc} < 10	3.91	-0.23 (1.92)	257	6.06	-1.69 (2.36)	383

Single-layer base height comparison over snow-/ice free surfaces: CALIPSO/CloudSat vs. CERES Aqua MODIS Ed4, JAJO 2010.



- Bias for water positive:
  - indicates thickness is too small
- Bias for non-opaque ice
  - **day:** -1.3 km, not thick enough
    - *evident in thickness plot*
  - **night:** 0.7 km, not thick enough
- Opaque ice bias
  - **day:** nearly same as top
    - *thickness is good*
  - **night:** too high,
    - *thickness improvements will help*

QUESTIONS ?

Toward VIIRS Ed2

VIIRS Edition 2

Delivery target : early-mid 2019

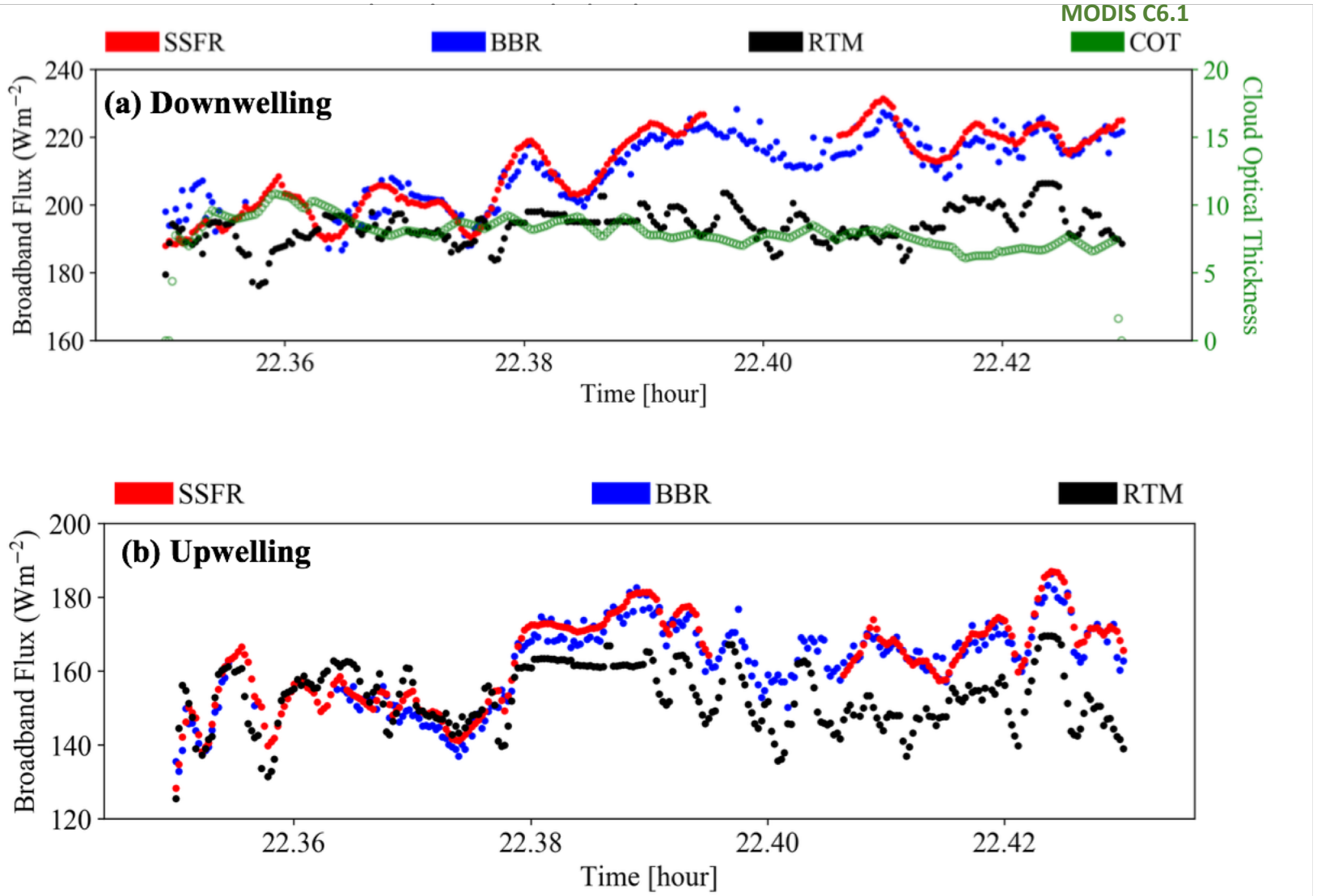
Deliver same code for SNPP and JPSS-1

Expected changes/updates from Ed1:

- *VIIRS data format: Need to start acquiring netcdf format from Land SIPS*
  - Already doing this for J1 but SNPP is temporary hdf format
- *New calibrations: SNPP/JPSS-1 consistency, scale to MODIS C5 (?)*
- *Bug Fixes (TBD): Many MODIS Ed4 bugs already fixed in VIIRS Ed1*
- *Bring in GSFC aerosol product (used to reduce false clouds)*
- *Other?*

ARISE Radiative Closure Tests

Sept 13, 2014 (7km, below low level cloud)



Excellent agreement between spectral (SSFR) & broadband (BBR) radiometers

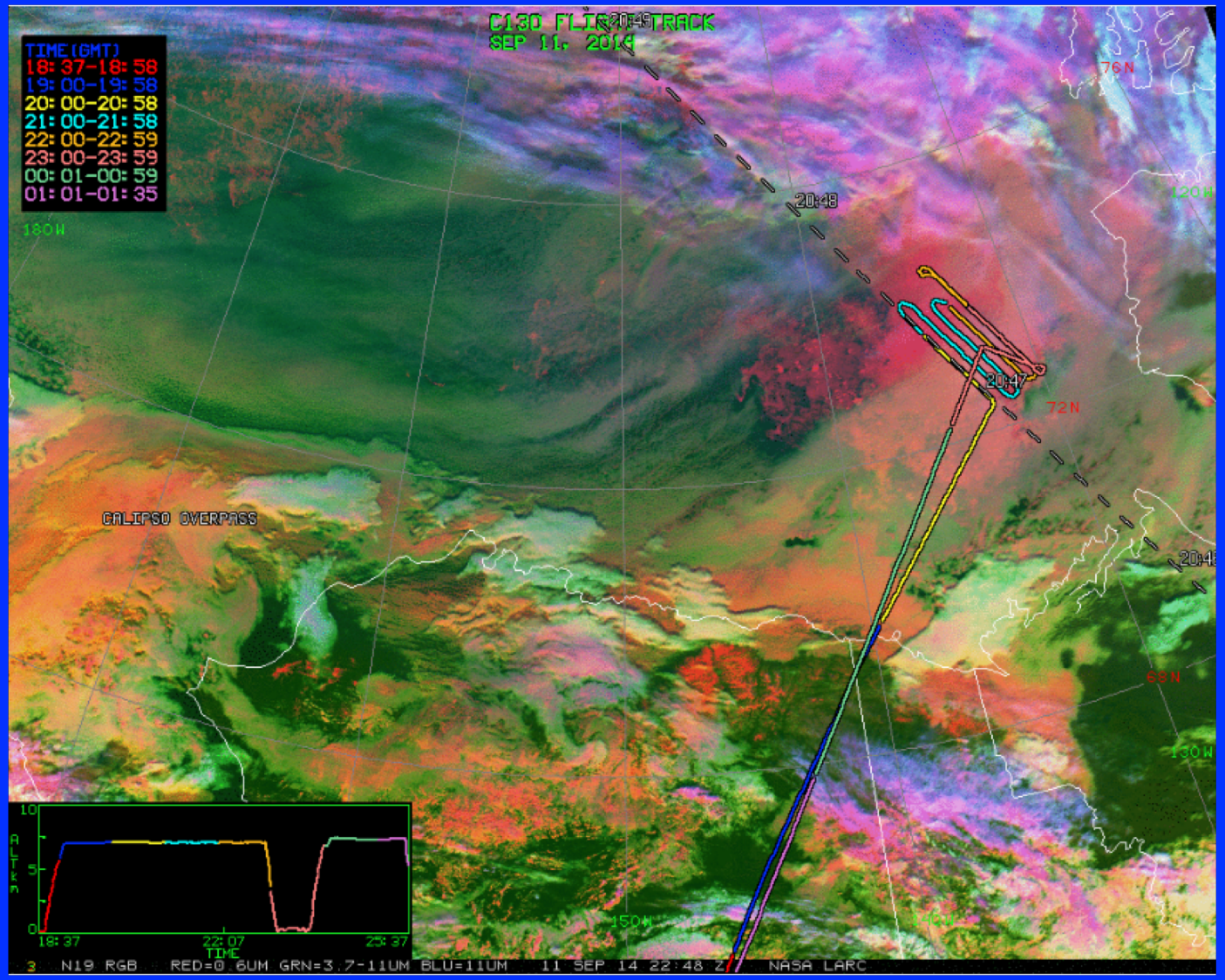
Upwelling flux calculations (RTM) incorporate MODIS COT

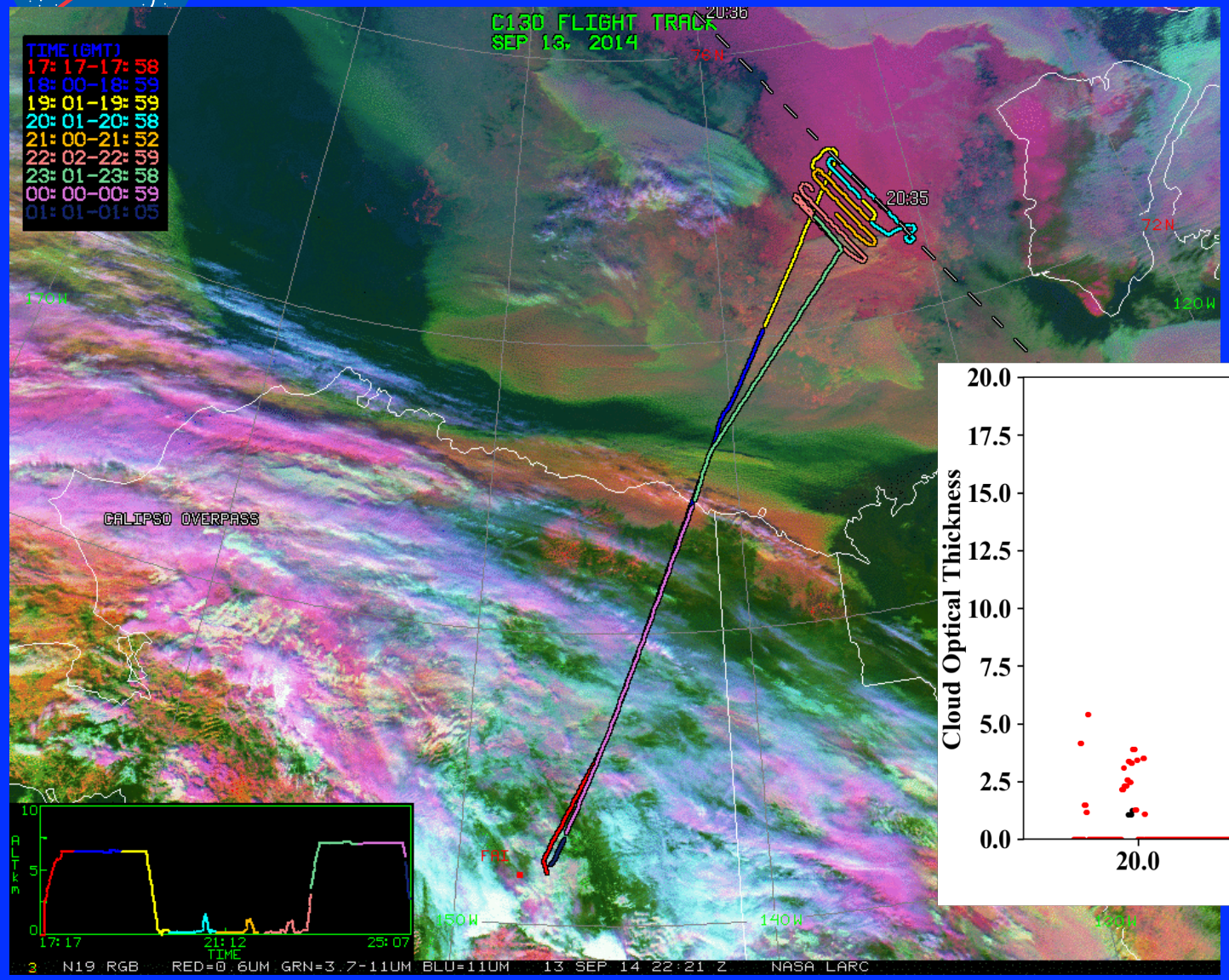
RTM and upwelling observations agree to within ~8 W/m^2 on average

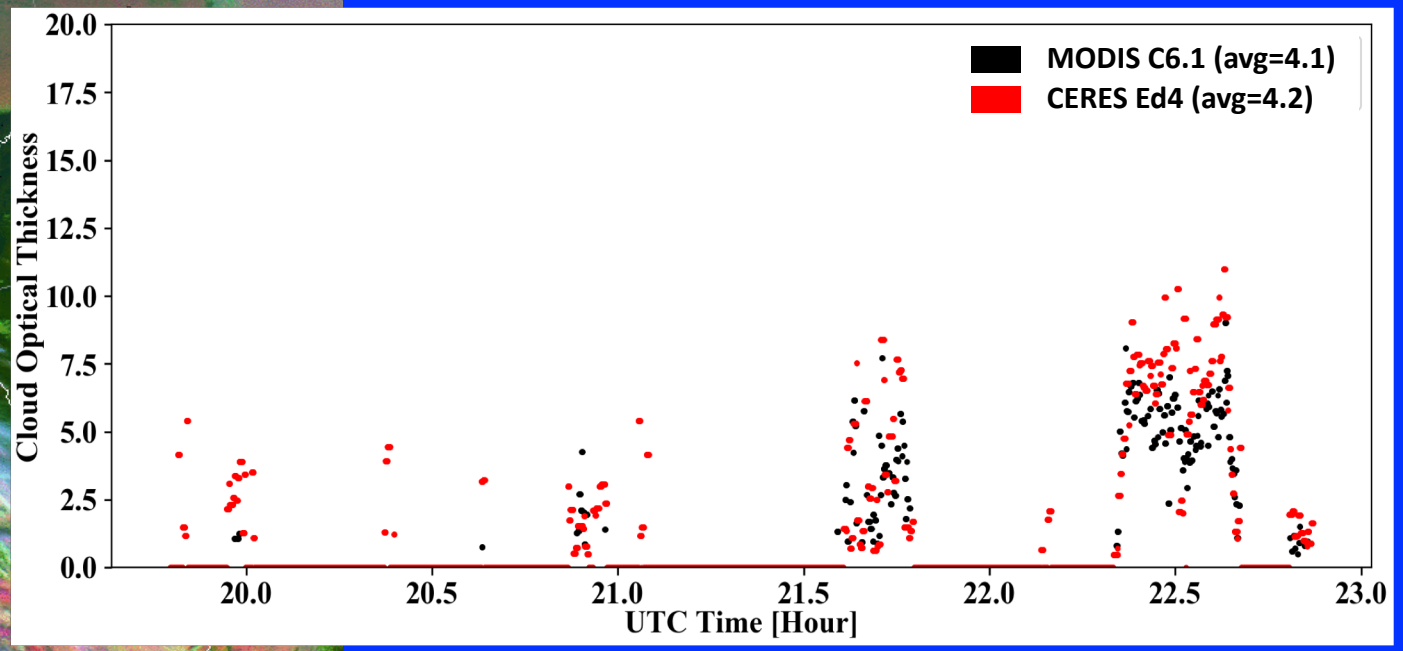
Calculations employ surface albedo parameterization from data shown earlier – otherwise the differences are much larger

ARISE Radiative Closure Tests

Sept 11, 2014 (7km, above low level cloud)




C130 FLIGHT TRACK
SEP 13, 2014
TIME(GMT)
17: 17-17: 58
18: 00-18: 59
19: 01-19: 59
20: 01-20: 58
21: 00-21: 52
22: 02-22: 59
23: 01-23: 58
00: 00-00: 59
01: 01-01: 05
20:35
20:36
74N
72N
170W
120W
150W
140W
CALIPSO OVERPASS
FIRE
ALTK
TIME
17:17
21:12
25:07
N19 RGB RED=0.6UM GRN=3.7-11UM BLU=11UM 13 SEP 14 22:21 Z NASA LARC


MODIS C6.1 (avg=4.1)
CERES Ed4 (avg=4.2)
Cloud Optical Thickness
UTC Time [Hour]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
20.0
20.5
21.0
21.5
22.0
22.5
23.0