CERES Cloud Working Group Report

CERES Science Team Mtg., Boulder, CO, 10-13 Sept 2018

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Thanks to Dave Doelling and his TISA/calibration teams!

Topics

- Publications update
- Processing status
- Cloud trends 2000-2018
- Cloud fraction: validation and comparisons
- VIIRS Ed2 plans
- Plans for MODIS Ed5 and continuity w/VIIRS
- GEO update (GOES-17)

Update of CERES Cloud-related Papers

Edition-4 related

McHardy, T. M., X. Dong, B. Xi, M. M. Thieman, P. Minnis, and R. Palikonda, 2018: Comparison of daytime low-level cloud properties derived from GOES and ARM SGP measurements. *J. Geophys. Res.,* 123, doi: 10.1002/2018JD0228911

Grosvenor, D. P., Sourdeval, O., Zuidema, P., Ackerman, A., Alexandrov, M. D., Bennartz, R.,…Painemal D…, et al. (2018). Remote sensing of droplet number concentration in warm clouds: A review of the current state of knowledge and perspectives. Reviews of Geophysics, 56, 409–453. https://doi.org/10.1029/2017RG000593

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. Geophys. Res Ltrs. Accepted.

Wall, C. J., D. L. Hartmann, M. M. Khaiyer, W. L. Smith, Jr., and P. Minnis, 2018: The lifecycle of convective clouds and the top-of-atmosphere radiation balance over the tropical west Pacific. *J. Climate*, in revision.

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, 2018: Global cloud detection for CERES Edition 4 using Terra and Aqua MODIS data. *IEEE Trans. Geosci. Remote Sens.*, **submitted**.

Minnis, P., S. Sun-Mack, C. R. Yost, Y. Chen, 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, 2018: Changes to CERES MODIS cloud product retrieval algorithms for Edition 4. *IEEE Trans. Geosci. Remote Sens.*, **in preparation**.

Su, W., L. Liang, D. R. Doelling, D. P. Duda, K. Khlopenkov, P. Minnis, M. M. Thiemann, N. G. Loeb, S. Kato, and F. G. Rose, 2018: Determining the shortwave radiative flux from the Earth Polychromatic Imaging Camera. J. Geophys. Res., submitted.

Duda, D. P., S. T. Bedka, D. Spangenberg, K. Khlopenkov, P. Minnis, and W. L. Smith, Jr., 2018: Comparison of 2006 and 2012 contrail analyses of northern hemispheric polar-orbiting satellite data. J. Climate, submitted.

Edition-5 related

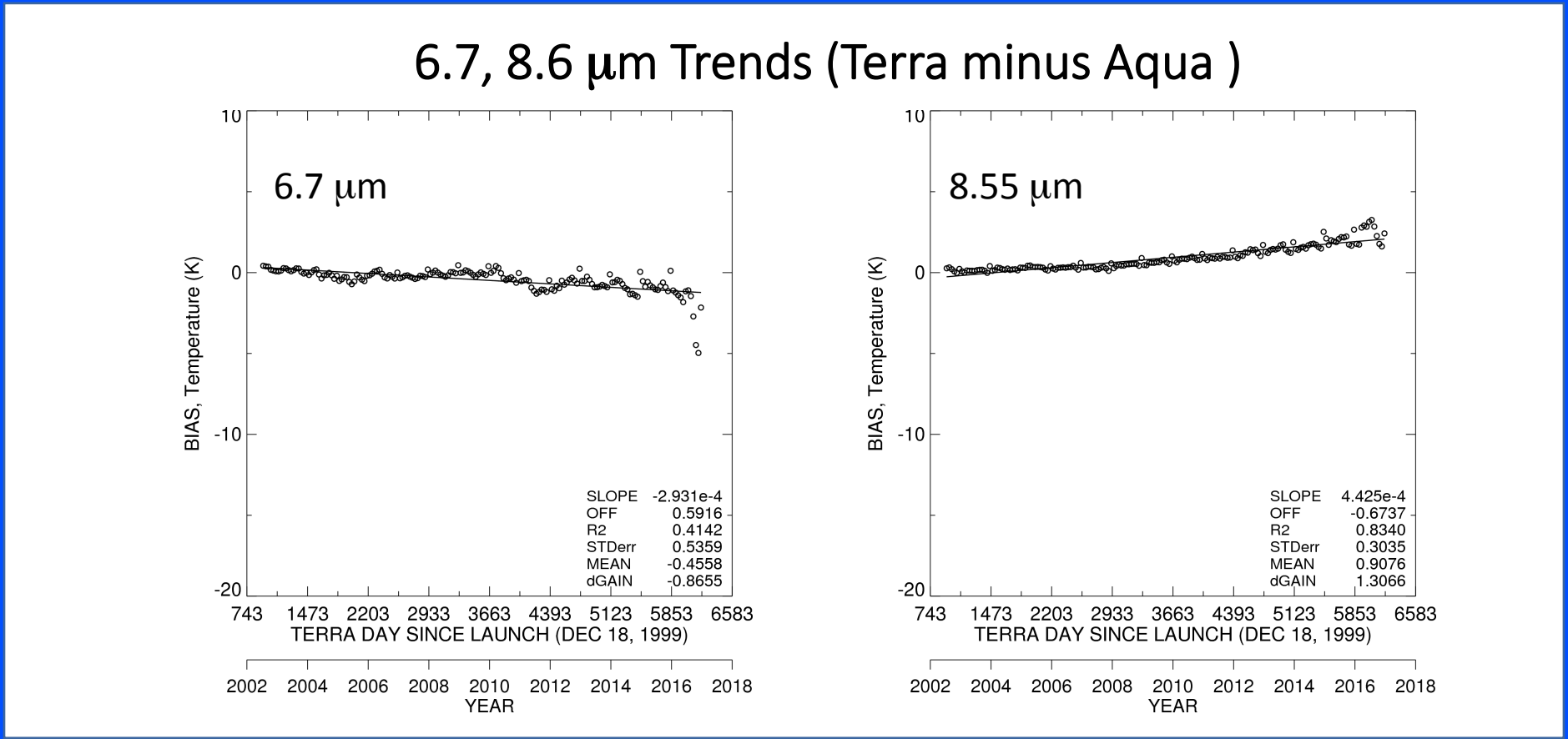
Saito, M., P. Yang, Y. Hu, X. Liu, N. Loeb, W. L. Smith, Jr., and P. Minnis, 2018: An efficient method for microphysical property retrievals in vertically inhomogeneous marine water clouds using MODIS-CloudSat measurements. *J. Appl. Meteor. Climatol.*, submitted

Clouds - Processing Status

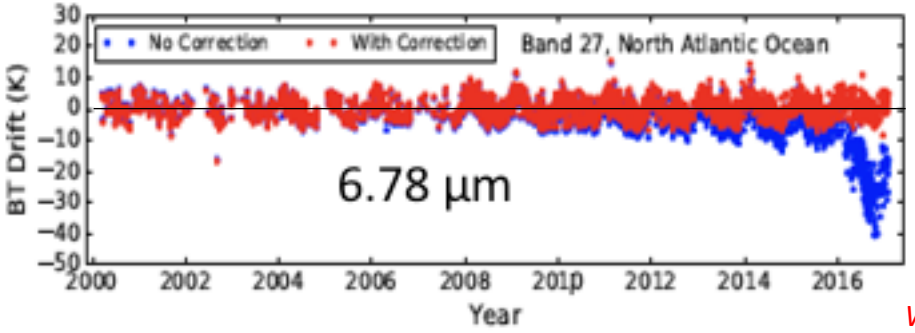
CERES-MODIS Edition 4 Status	*Aqua: Jul 2002 – Jul 2018 (~16 y)* *Terra: Feb 2000 – Jul 2018 (~18 y)* ***Imager Calibration Strategy:*** • ***MODIS Collection 5 thru Feb 2016,*** • ***MODIS Collection 6.1 March 2016 - present*** • ***C6.1 radiances are scaled to C5 for consistency over entire record*** • ***CWG developed and applied Terra/Aqua normalizations for C5 (Sun-Mack, et al. 2018)***
CERES-VIIRS Ed 1 Status	*SNPP: Jan 2012 – Apr 2018 (~6 y)* ***Imager Calibration Strategy:*** • ***Use forward processing calibrations*** • ***Inconsistencies possible in current record***

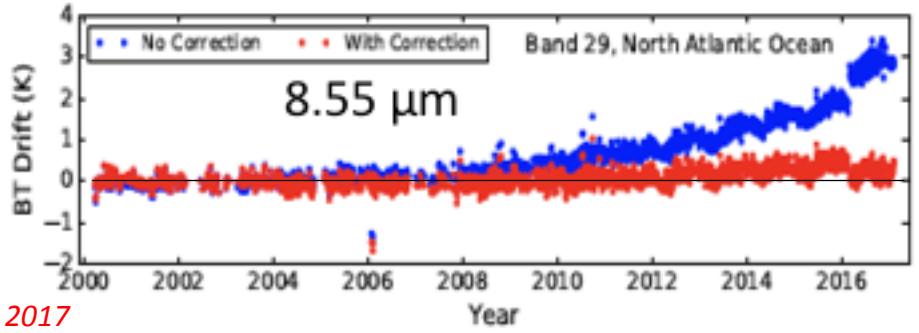
Unresolved Terra Calibration Issue (C5)

- 6.7 μm WV and 8.6 μm window channel began degrading on TERRA in 2008.
- Major anomaly in TERRA WV channel occurred in Feb 2016
- Used in cloud mask and for cloud phase selection
- Most significant impacts at night, polar regions; Some artificial trends evident after 2008.



Terra Calibration Issue Resolved in C6.1(?)

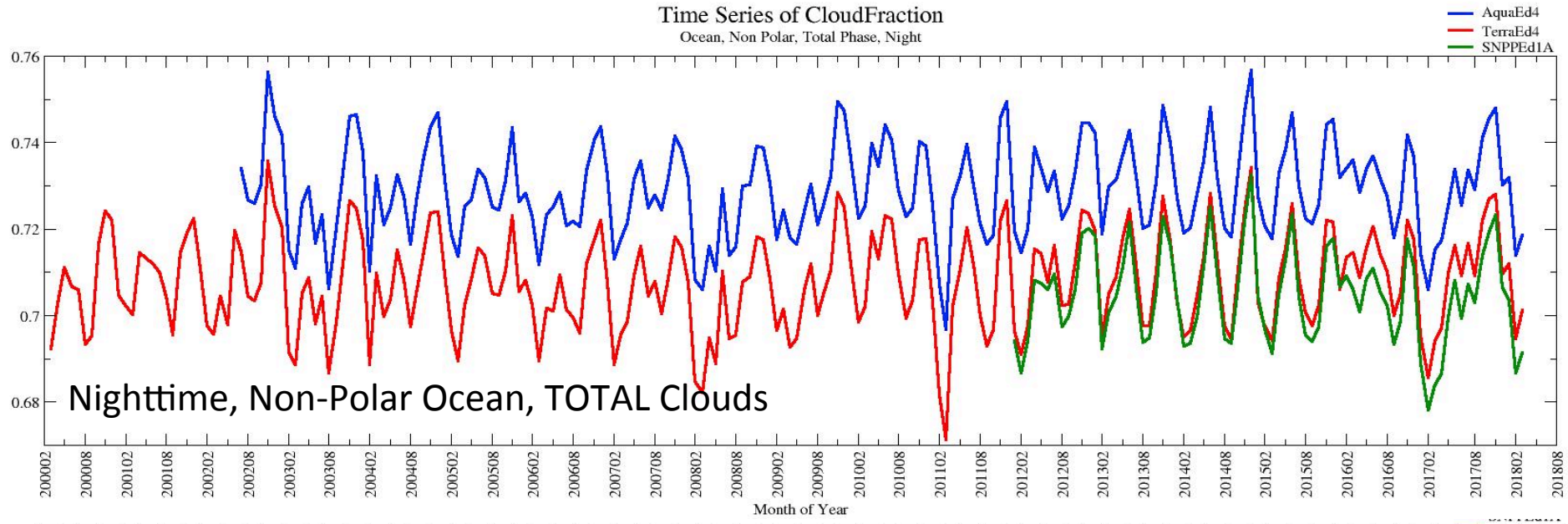




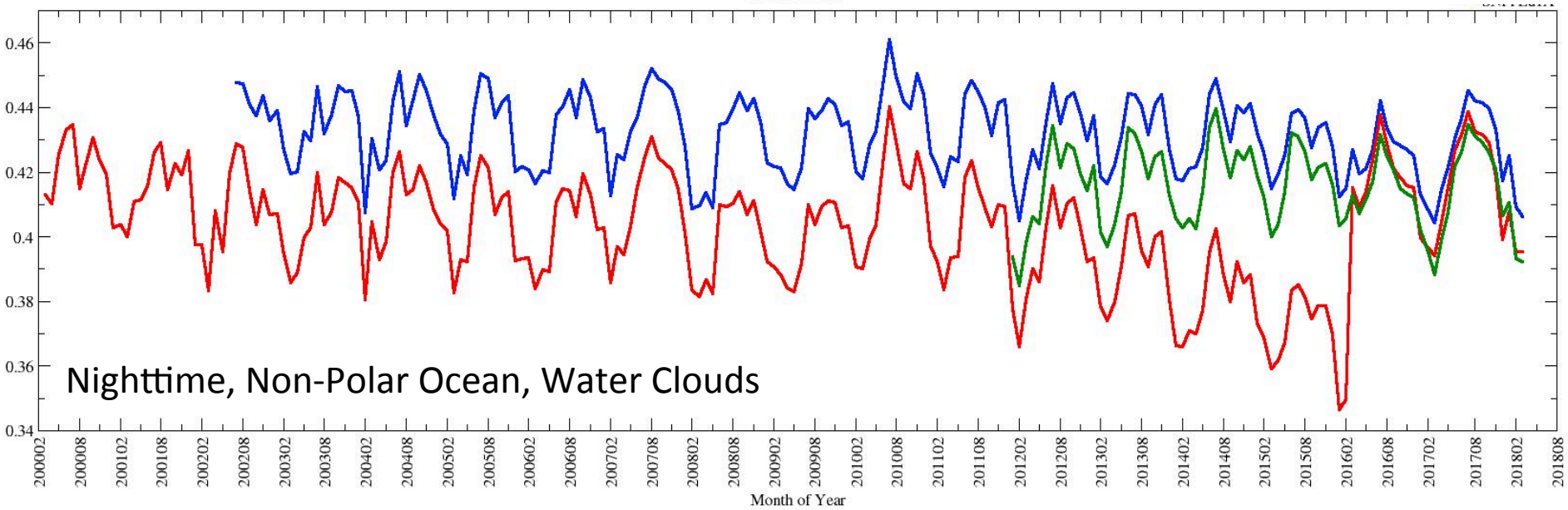
Wilson et al. RS, 2017

- MODIS C6.1 mostly corrected to achieve stable 6.7 and 8.6 µm radiances across the record
- Small bias (0.2 – 0.5 °K) still evident for 8.6 µm at end of record
- Decision made after last STM to scale C6.1 (March 2016) to C5 (2002) for processing after Feb 2016

Terra Calibration Issue Resolved in C6.1(?)



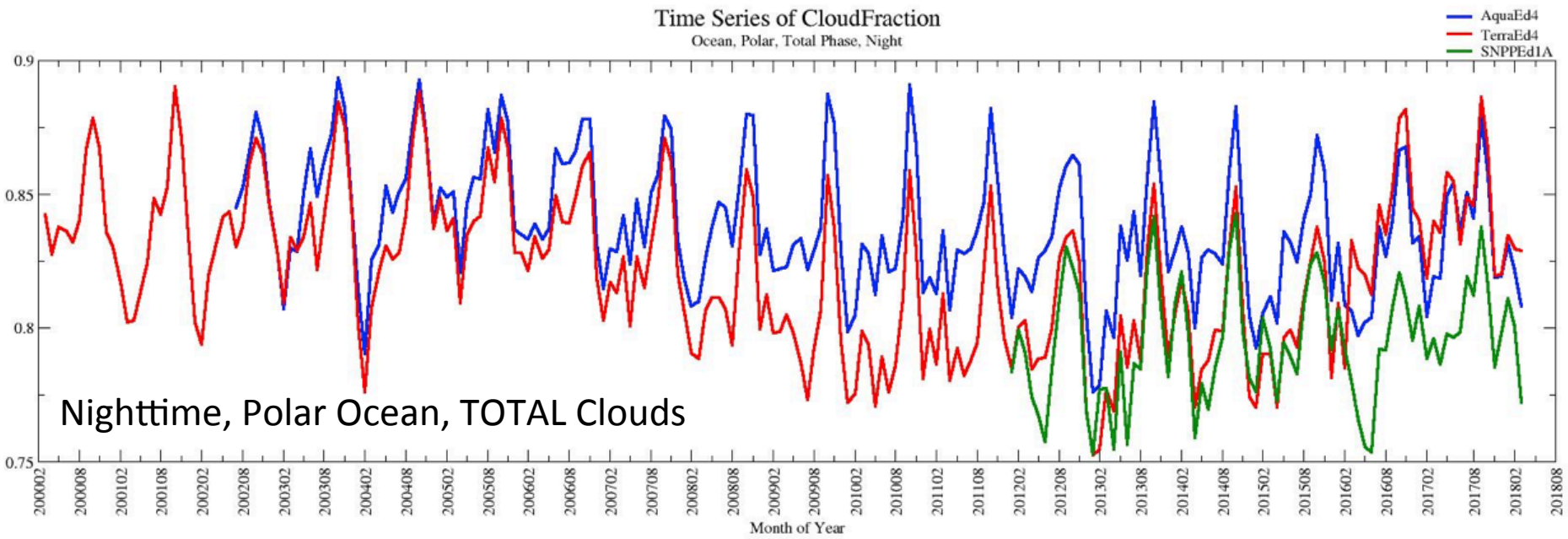
Total cloud fraction not impacted in non-polar regions

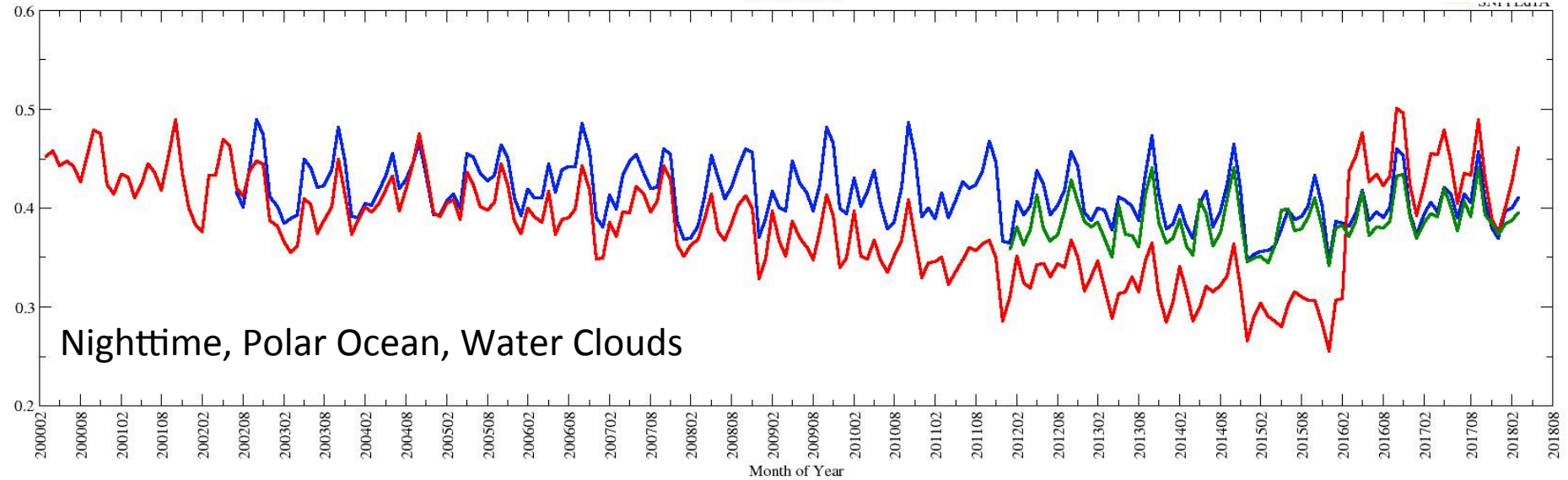


But, some impact to cloud phase and other cloud properties

Scaling procedure over-corrected slightly

Terra Calibration Issue Resolved in C6.1(?)





Total cloud fraction is impacted in polar regions

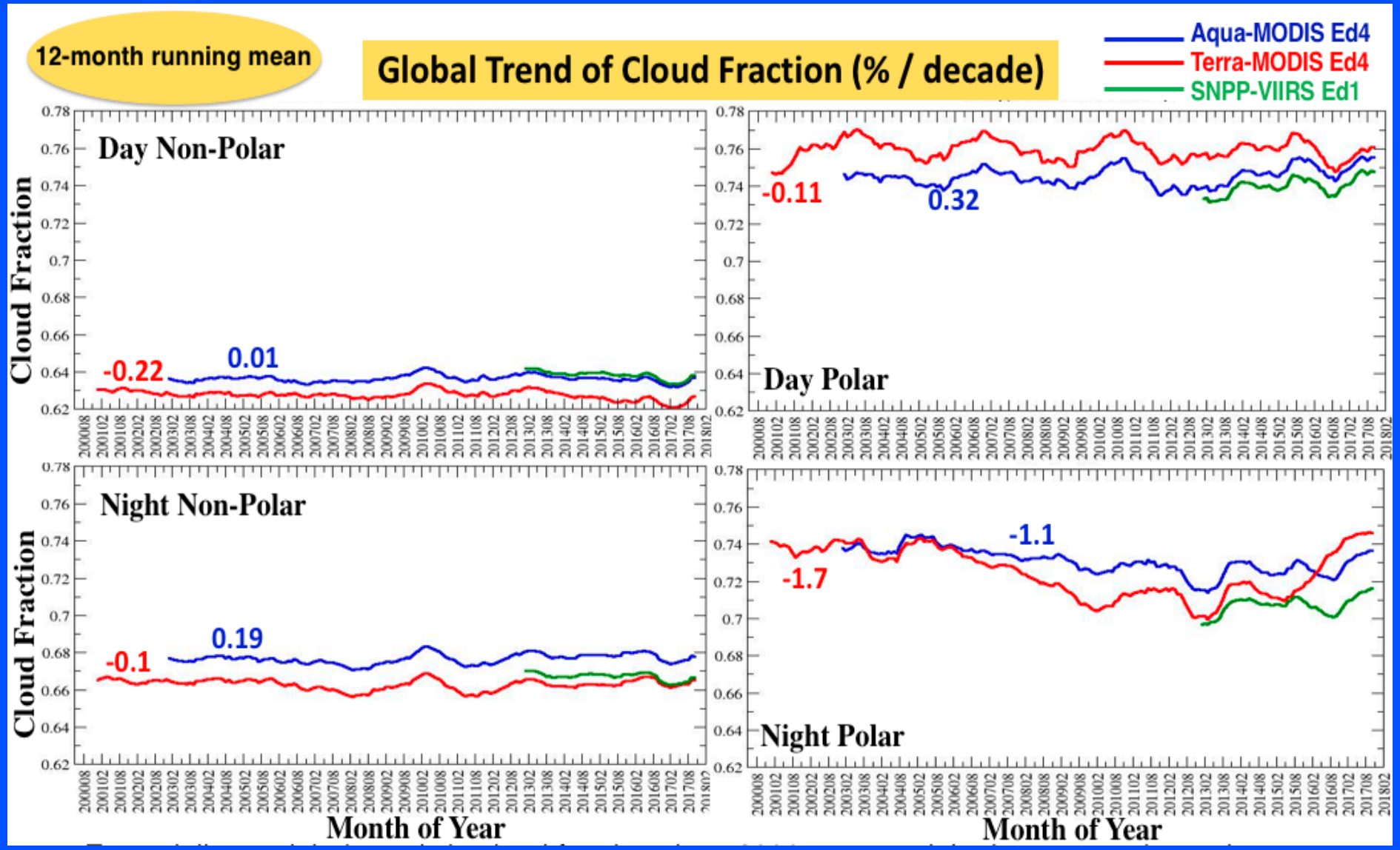
Cloud phase also impacted

Scaling procedure over-corrected slightly

Similar story over land

Still more work to do for Edition 5 Terra

Terra and Aqua Cloud Fractions, 2000-2018



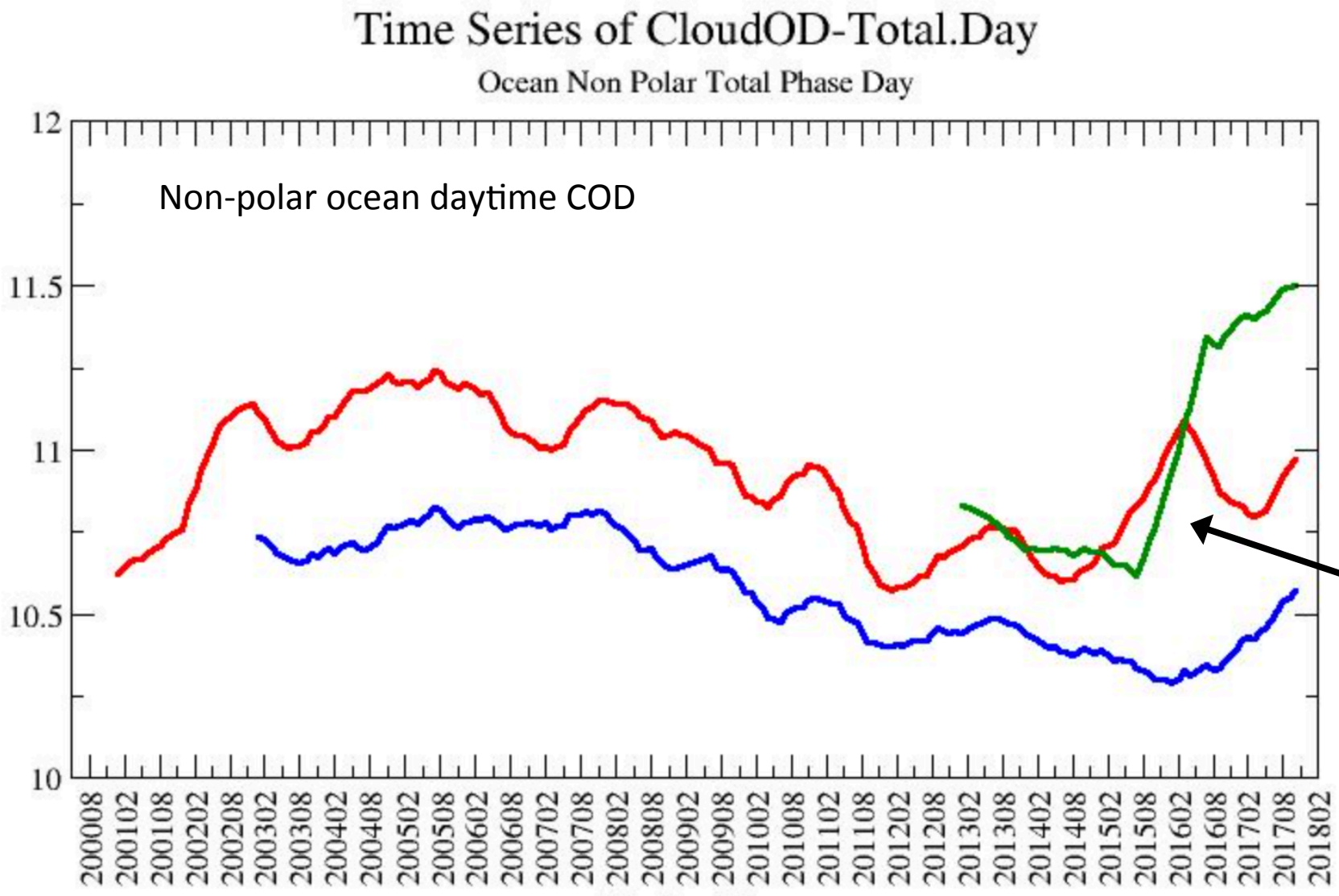
Essentially no global trends in cloud fraction since 2000, except for a decreasing trend at night over polar regions (~1% / decade).

4-y cycle in daytime polar (?)

Terra drop in polar night after 2008 caused by degrading water vapor channel

VIIRS tracks Aqua well but magnitudes differ

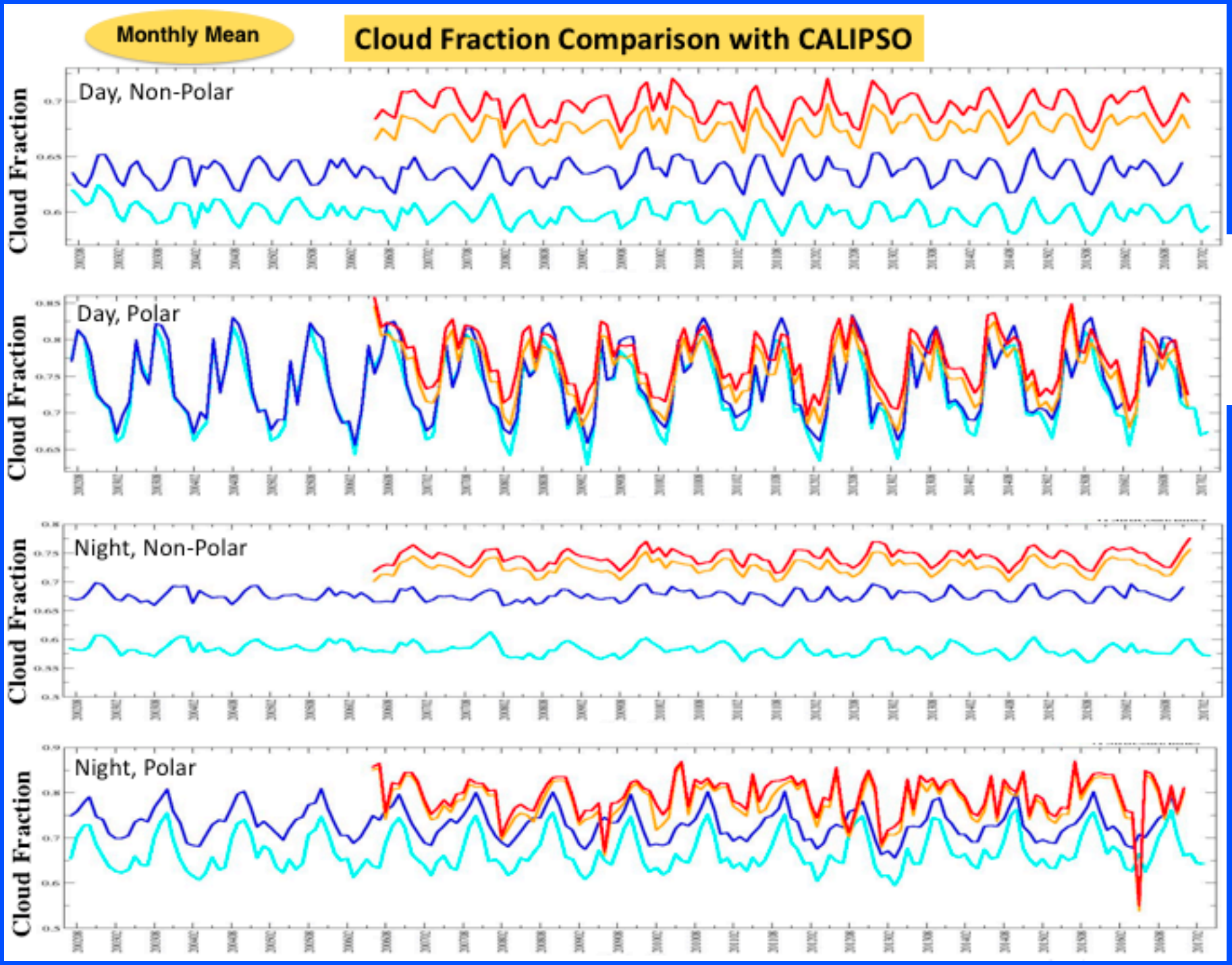
- Different resolutions
- Different channels/algos
- Bug fixes in VIIRS
- Calibration inconsistencies



	Slope (nu/mth)	SlopeError (nu/mth)	Intercept (nu)	InterceptError (nu)	Correlation
AquaEd4	-0.002789	0.000118	10.817362	0.012052	-0.872451
TerraEd4	-0.001506	0.000208	11.075826	0.024187	-0.455427
SNPPEd1A	0.015294	0.001419	10.515608	0.046897	0.821450

Example of VIIRS calibration inconsistency appearing in 2016

Time series comparison with CALIPSO



Aqua-MODIS Ed4
Aqua-MODIS Ed2
CALIPSO HiConf
CALIPSO HiConf. No80Res

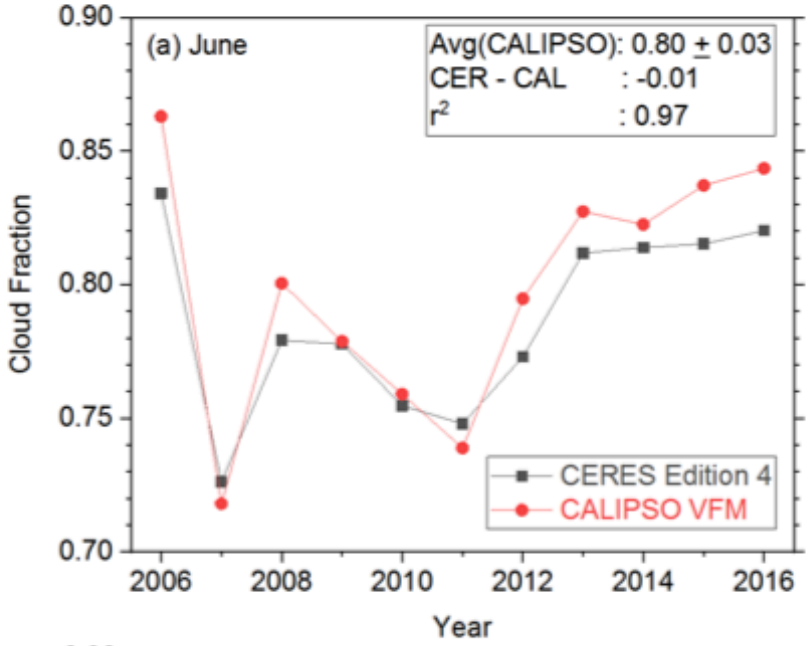
No global trends from CALIPSO either

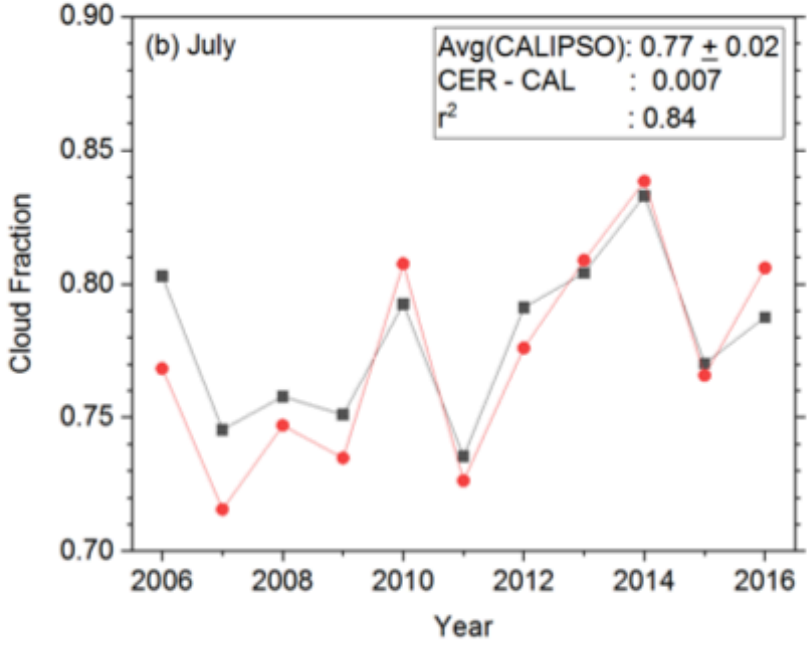
CERES cloud fractions (Aqua full swath) track CALIPSO well.

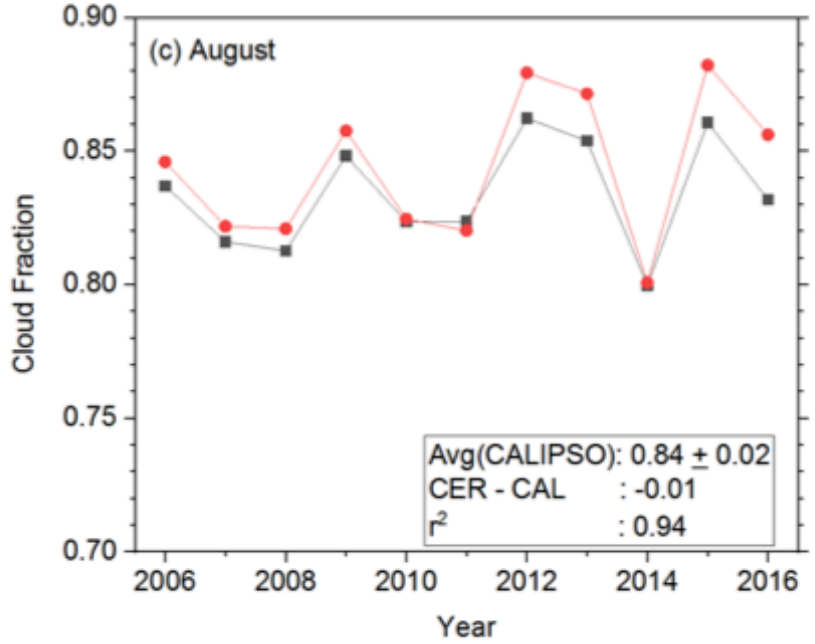
CERES cloud fraction is ~ 3% lower than CALIPSO, except day time polar.

CERES Ed4 picks up additional 4-5% of clouds compared with CERES Ed2, except day time polar (~1% larger)

Cloud Fraction Comparison (70°-90°N; Ocean Only; Daytime Only)







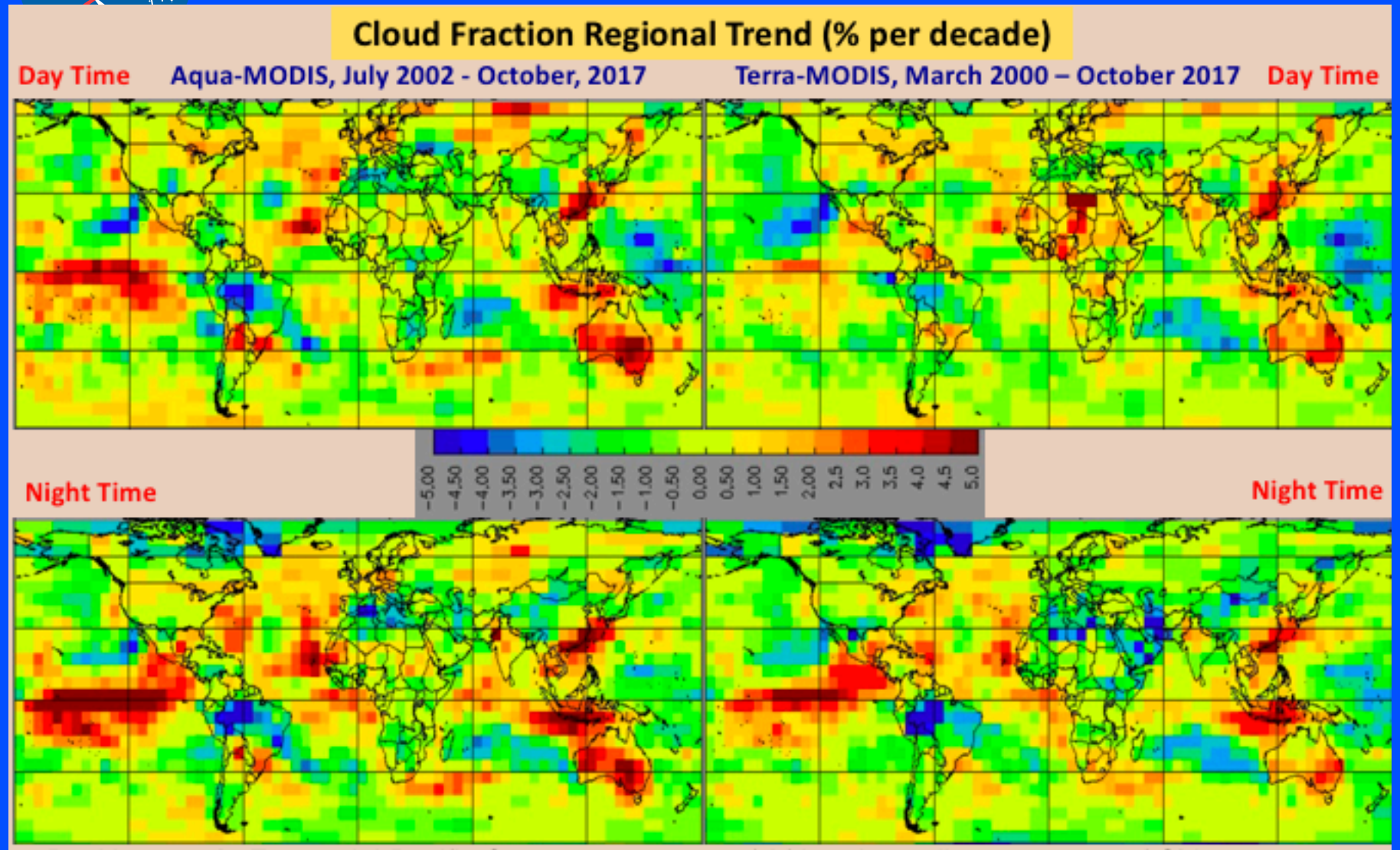
CERES Ed4 tracking arctic cloud changes well compared to CALIPSO

Details of Comparison:

- Ed4 MODIS Aqua from swath data, but restricted to VZA<5
- CALIPSO V3 VFM, selected only for high confidence clouds
- Remove CALIPSO clouds only detectable with 80 km resolution

Plot courtesy of N. Loeb

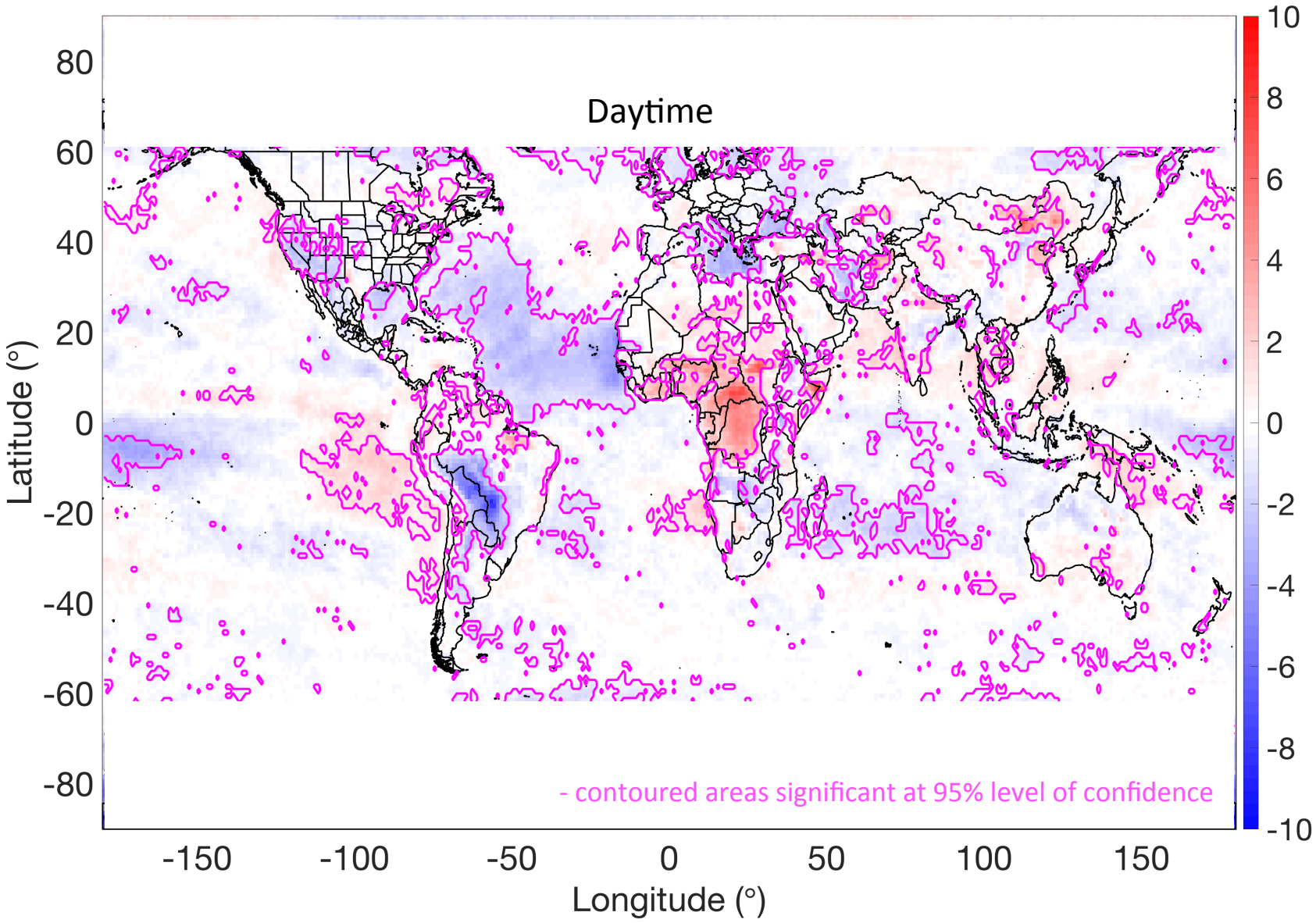
Terra and Aqua Cloud Fractions, 2000-2018



- Positive trend: Equatorial Pacific Ocean, west coast of Africa, Australia, east coast of China, India Ocean south of Indonesia
- Negative trend: Amazon (artifact by skin temp), Pacific Ocean north of Indonesia, southern India ocean

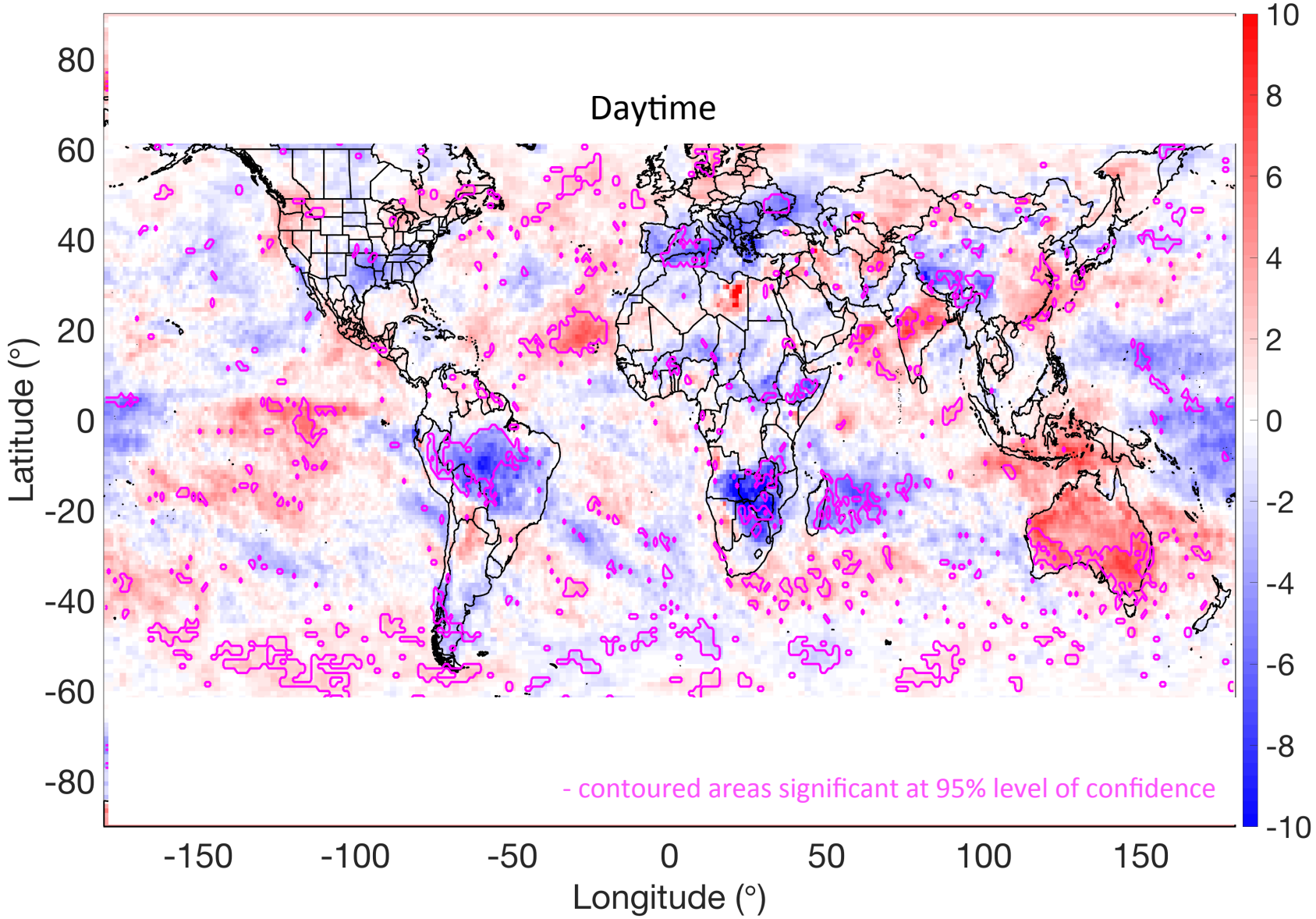
- No global trends but regional changes large in many areas - driven by natural variability, short record
- Patterns depend on when you start/stop time series (e.g. Australia)
- Good consistency between Aqua and Terra, day and night
- Potential for artifacts in some areas (Amazon basin?)

AVHRR 1981-2015: Total Cloud Percent Change/ Decade (Non-polar mean = -0.21)

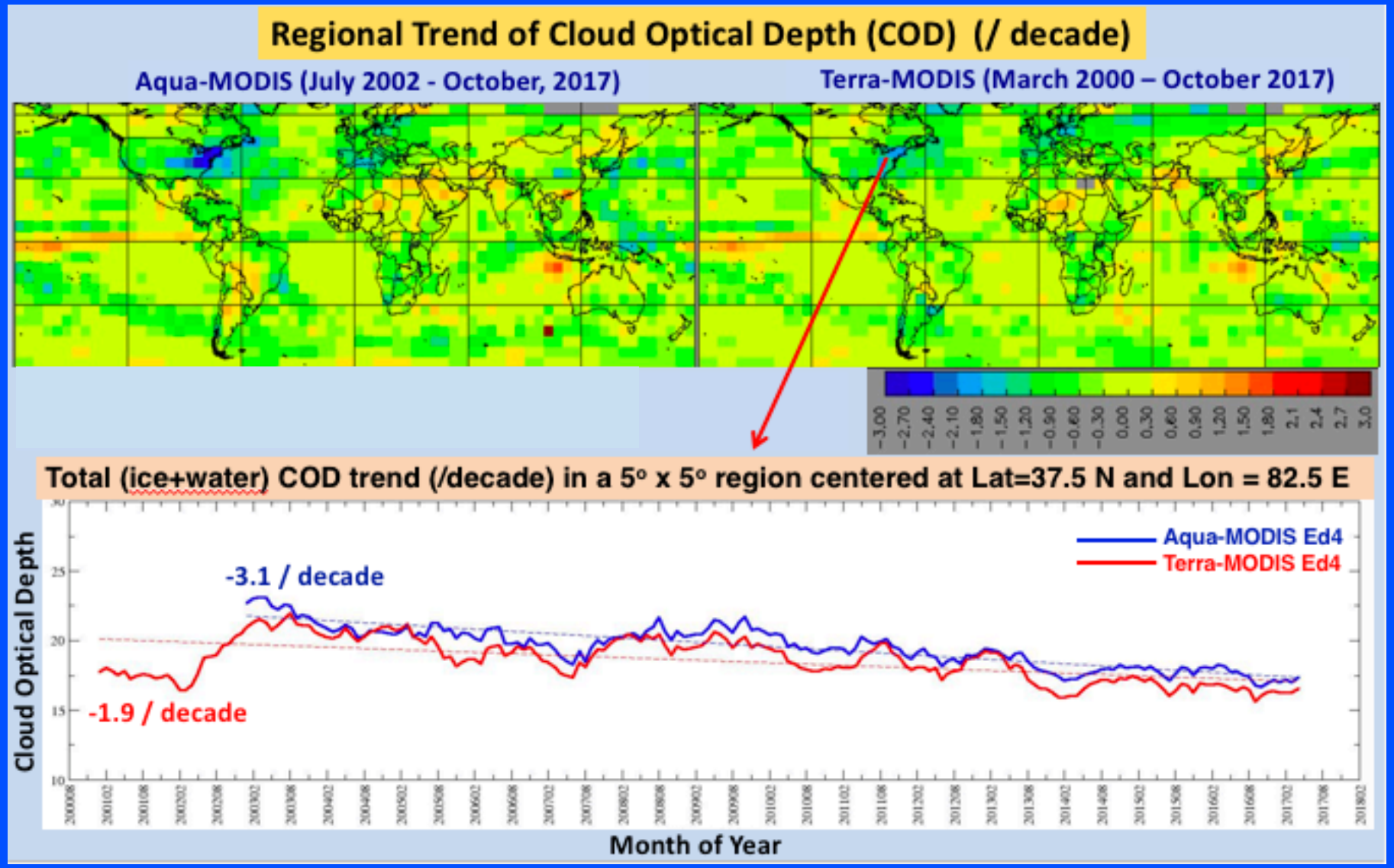


- Expect regional changes/ trends due to effects of natural variability to flatten over longer time records
- Version of CERES Ed4 adapted and applied to 35 year AVHRR record
- Still some ENSO signal over tropical Pacific?
- Interesting stratocu trends S. Hem
- Negative trend over Atlantic looks artificial (decreasing dust?)

Aqua-MODIS 2003-2017: Total Cloud Percent Change/Decade (Non-polar avg = 0.11%)



MODIS Ed4 Cloud Trends



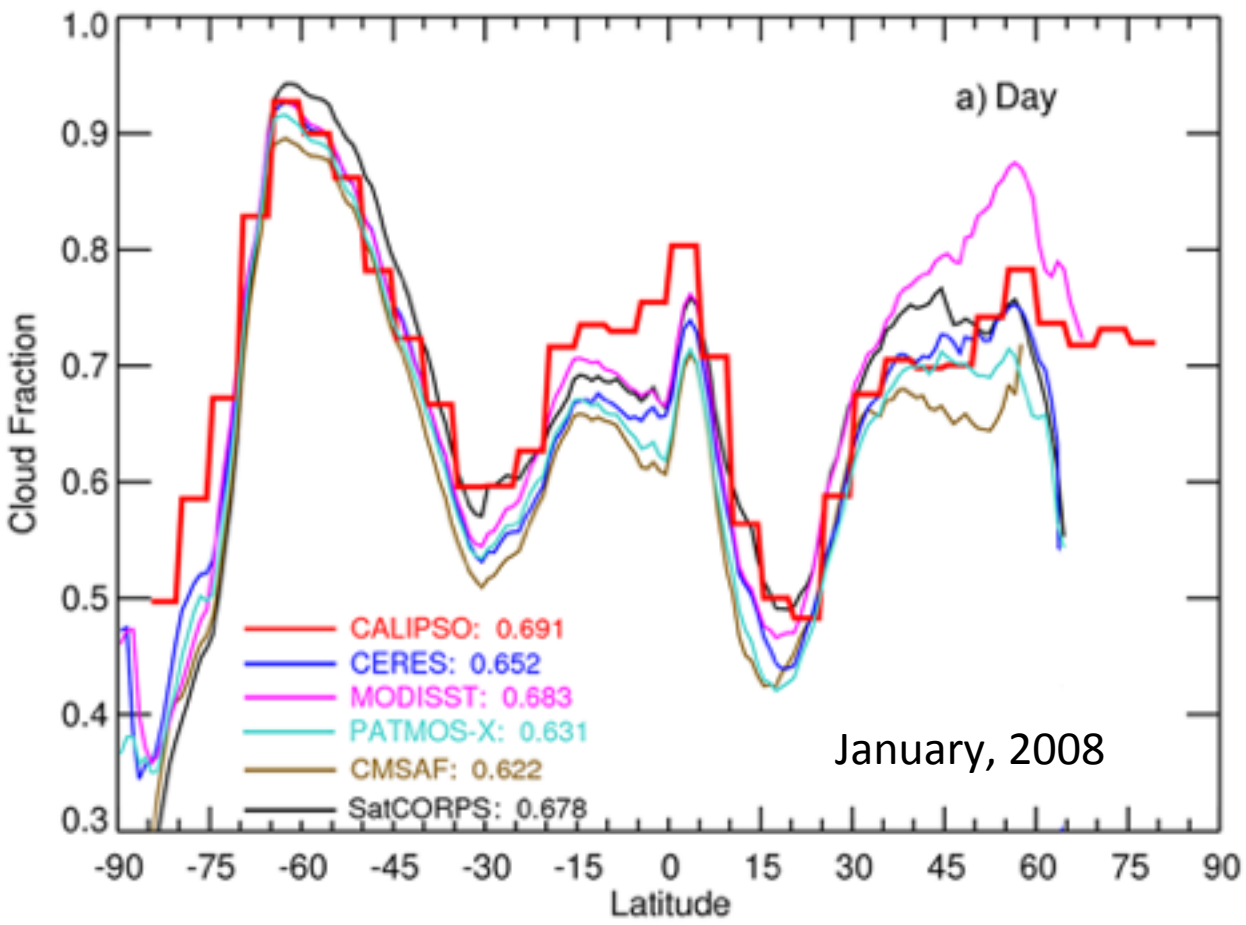
Interesting regional trend over NE U.S and adjacent Atlantic

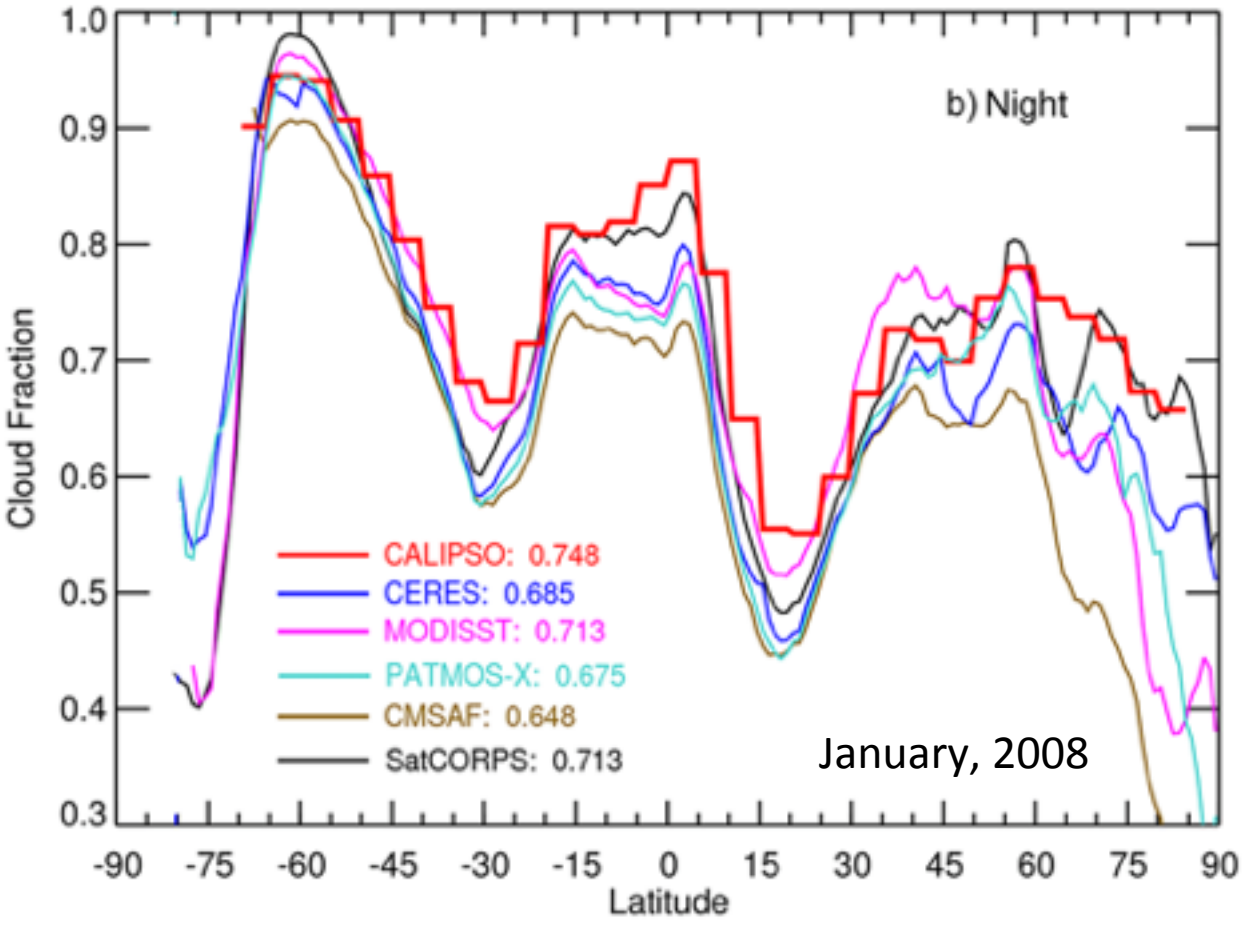
High cloud fraction increasing (not shown)

Strong negative trend in COD from Aqua and Terra MODIS

Note Calibration problem in beginning of Terra record

CERES Ed4 Cloud Fraction vs other groups/satellites



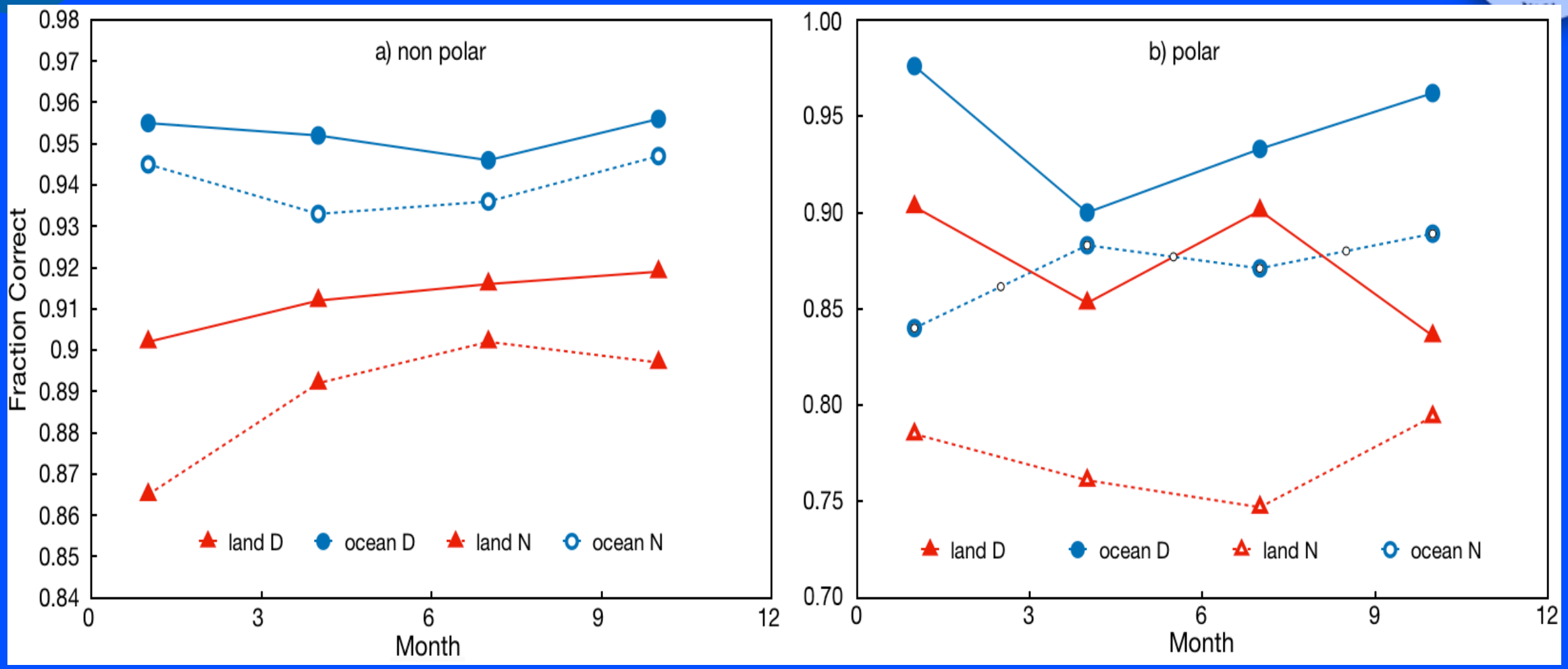


Highlights from Ed4 cloud mask paper
Trepte et al, 2018, submitted

Monthly Mean Zonal Cloud Fraction Comparisons

- CALIPSO highest, CMSAF lowest (mean values in legend)
- SatCORPS, PATMOS-X from AVHRR
- CERES MODIS Ed4 generally in the middle

MODIS Ed4 Cloud Fraction Accuracy
(compared to CALIPSO VFM)



Highlights from Ed4 cloud mask paper
- Trepte et al, 2018, submitted

Cloud detection over dark, uniform surfaces easier (open ocean highest accuracy)
Good day/night consistency exc. Polar land (nighttime just a few percent lower)
Polar night over land has lowest accuracies (< 80%)

MODIS Ed4 Cloud Fraction
Comparisons with CALIPSO

Table V. Performance metrics of CERES Ed4 cloud mask using matched CALIPSO and Aqua MODIS data for January, April, July, and October 2007. CALIPSO 1-km layer product used as in [33].

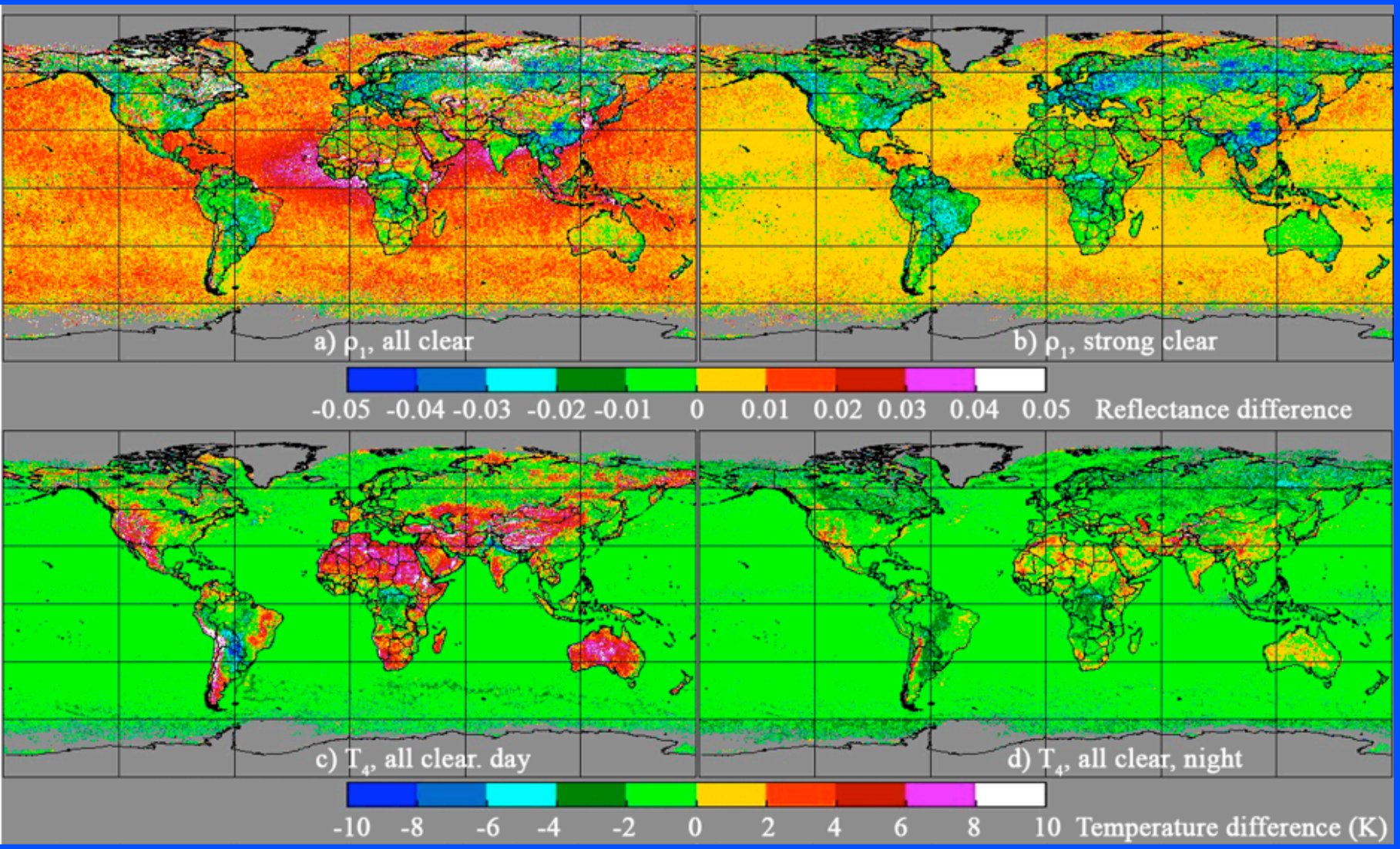
	Ocean	Land	Snow	Arctic	Antarctic	Desert
Day						
POD	0.963	0.941	0.880	0.912	0.899	0.940
HKSS	0.895	0.878	0.749	0.808	0.794	0.850
FAR	0.020	0.025	0.065	0.034	0.057	0.030
Bias	0.008	-0.009	0.010	-0.021	0.014	0.000
N (x 10^3)	2699	658	217	297	596	260
Night						
POD	0.953	0.911	0.810	0.808	0.816	0.899
HKSS	0.848	0.824	0.629	0.524	0.633	0.774
FAR	0.020	0.032	0.059	0.104	0.068	0.054
Bias	-0.007	-0.025	-0.072	0.016	-0.047	0.007
N (x 10^3)	2869	749	344	365	1277	276
Day & Night						
POD	0.958	0.925	0.837	0.855	0.843	0.919
HKSS	0.874	0.849	0.673	0.651	0.684	0.810
FAR	0.021	0.029	0.061	0.072	0.065	0.042
Bias	0.000	-0.017	-0.041	-0.001	-0.028	0.003
N (x 10^3)	5568	1408	561	662	1873	536

Lots of other comparisons, statistics, stratifications in cloud mask paper

See Trepte et al, 2018 for details

Clear Sky Radiance Evaluation

Observed – Predicted, for January, April, July, and October 2015



- Reasonably accurate predictions of clear sky radiances needed for cloud mask and cloud properties
- Tend to underestimate ocean reflectance: should use aerosol dependent model. Current model has fixed aerosol and wind speed
- Overestimate reflectance over forest/mixed areas when green: BRDF?

- Clear sky temperature differences large over deserts and high altitude land regions (mostly attributed to model Tskin problems)

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?*

Toward MODIS Ed5 and Continuity with VIIRS (Ed3)

MODIS Ed5	***Expected changes/updates from Ed4:*** • *Drop 6.7 μm and 13 μm channels (not available on VIIRS)* • *New calibrations: Fix early Terra record, use latest MODIS Collection, other adjustments as needed (e.g. scalings for satellite-satellite consistency)* • *Implement new ice scattering models from P. Yang group (Two-habit model)* • *Ensure that consistent approaches/models for clear sky radiance estimates and atmospheric corrections are applied to MODIS and VIIRS* • *Numerous bug fixes (many already implemented in VIIRS Ed1)* • *New retrieval methods TBD (new nighttime tau algo, new multilayer approach, new CWP and thickness parameterizations)* • *Other?*
VIIRS Ed3	***For continuity, goal is to develop MODIS Ed5 first, then apply directly to VIIRS (Ed3):*** • *Some tuning may still be needed (imager resolutions different)* • *Consistent daytime methods over snow is an outstanding issue*

How to Achieve MODIS/VIIRS consistency for clouds 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 tho) • 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 not useful for thin clouds over snow • Current approach uses 1.2 um for all satellites • NIR (1.2, 1.6, 2.1 mm) channels sensitive to different ranges of tau - Hybrid approach may be best

Possible Solutions	• Restore 1.6 μm channel on AQUA - some success already demonstrated - would require new delivery of entire AQUA MODIS radiance record (for that channel) - Other wise do the best we can for the mask with what's available • Continue with 1.2 um for Tau or develop hybrid approach (multiple channels to extend range)

GEO UPDATE (GOES-17)

GOES-17 launched March 2018

ABI cooling system not operating at capacity

- Can render IR data unusable for 2-6 hours at night
- Only occurs during eclipse season near equinox's (~40 days?) when detectors are heated by direct sunlight

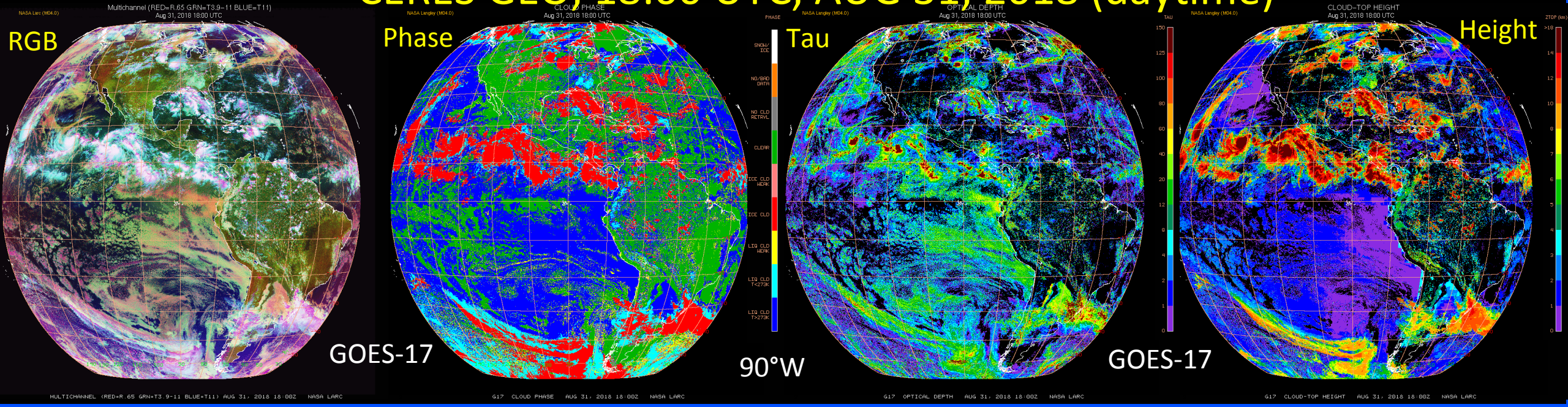
Impact to CERES: IR data unusable for ~3 hours near midnight, late N.hem winter/early fall

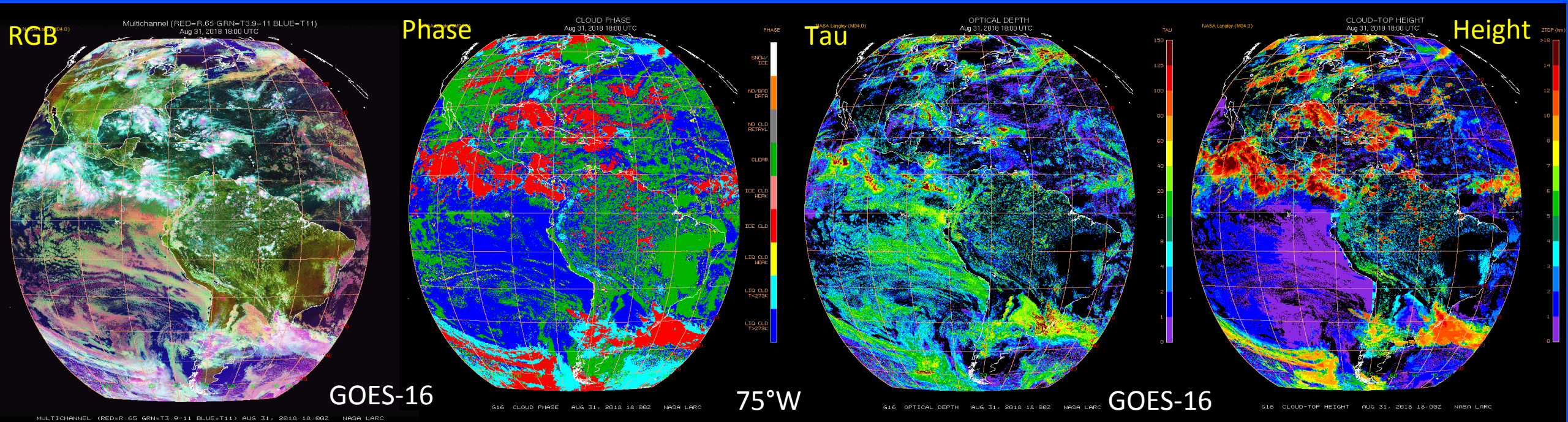
Still scheduled to become operational Western CONUS satellite (135°W) in late fall 2018

GOES-17 expected to operate in tandem with GOES-15 for an extended period of time

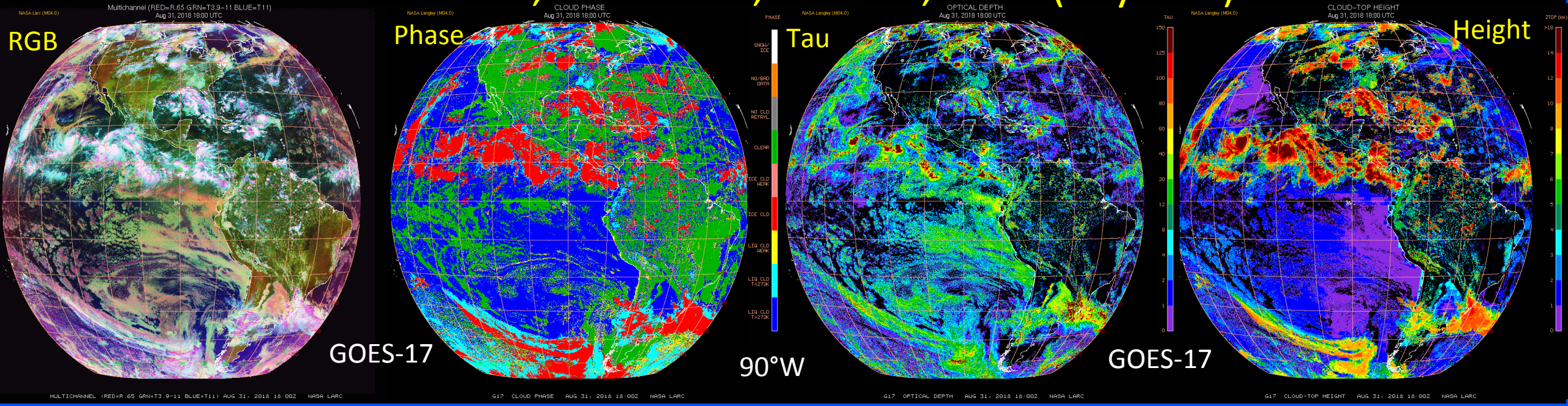
Launch of GOES-17 aboard an Atlas V

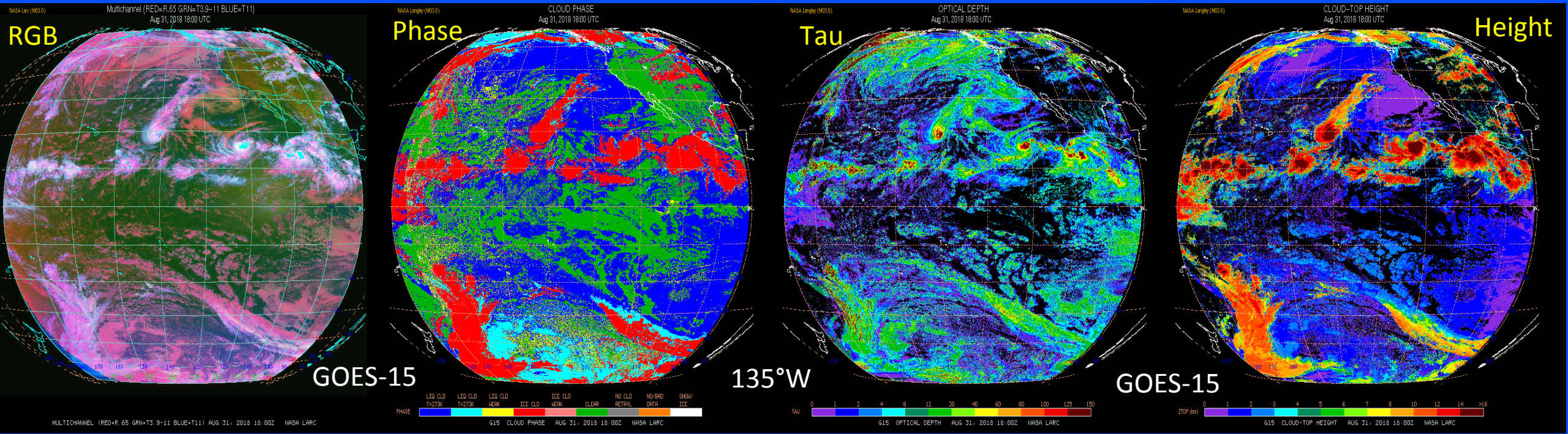
CERES GEO, 18:00 UTC, AUG 31, 2018 (daytime)



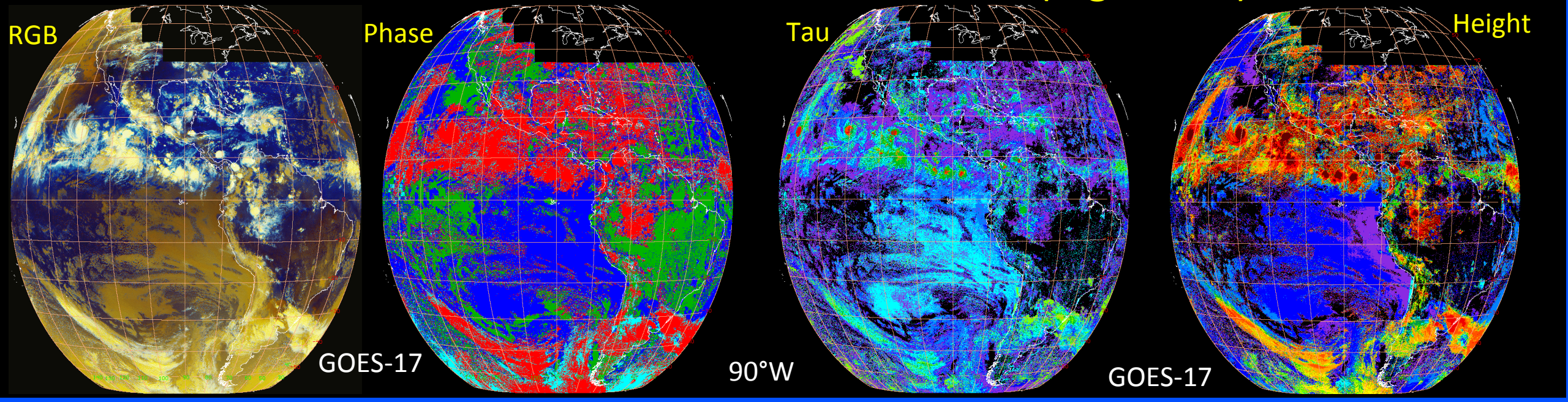


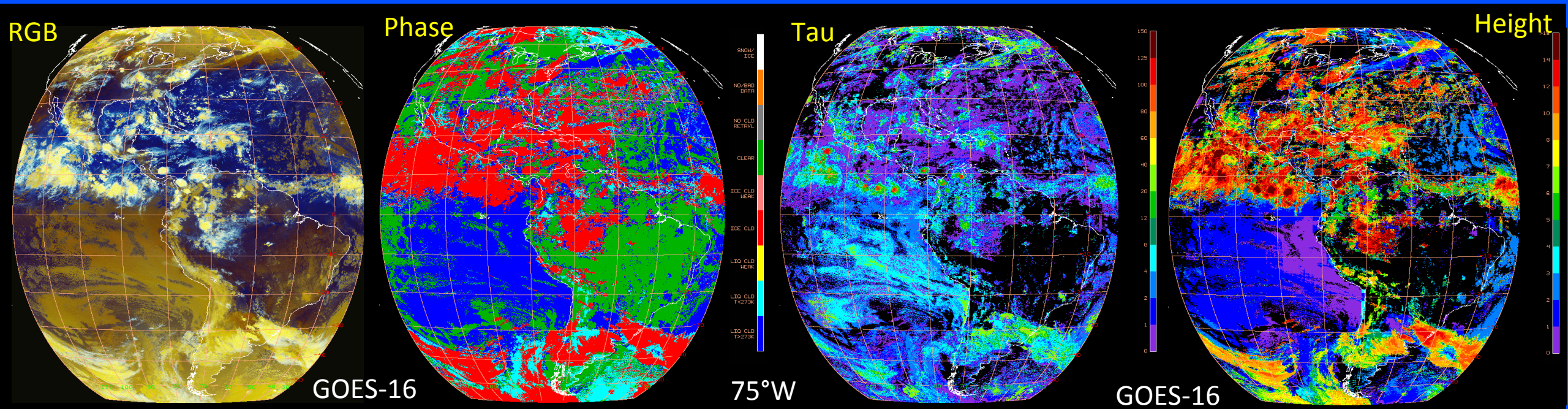
CERES GEO, 18:00 UTC, AUG 31, 2018 (daytime)





CERES GEO, 18:00 UTC, AUG 31, 2018 (nighttime)





QUESTIONS ?