CERES Cloud Working Group Report

CERES Science Team Mtg., Berkeley, CA, 29-31 May 2019

W. L. Smith, Jr.

NASA Langley Research Center, Hampton, VA

S. Sun-Mack (modis/viirs lead), P. Minnis (supreme advisor), Q. Trepte (mask), R. Palikonda (GEO), S. Bedka (retrievals, val), C. Yost (val), G. Hong (models, night tau), Y. Chen (clr props, test runs), M. Nordeen (GEO), D. Painemal (val) , B. Scarino (cal, Tskin), R. Brown (QC), F-L. Chang (CO2, ML), E. Heckert (web), B. Shan (GEO), R. Smith (web, NPP), D. Spangenberg (everything), Churngwei Chu (web), Zhujun Li (val)

SSAI, Hampton, VA

L. Nguyen (IT lead), *NASA Langley Research Center*

P. Heck (retrieval code), *CIMSS, UW-Madison*

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

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

Thanks to Dave Doelling and his TISA/calibration teams!

Topics

- VIIRS Ed2 Status
- Recent validation results
- Low-level cloud trends over the U.S.
- GOES-17 update

Update of CERES Cloud-related Papers (2019)

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., doi: 10.1109/TGRS.2019.2926620. **ED4 CLOUD MASK**

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 – First draft nearly complete**.

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 - - First draft completed**.

Loeb, N.G., H. Wang, F.G. Rose, S. Kato, W.L. Smith, and S. Sun-Mack, 2019: Decomposing Shortwave Top-of-Atmosphere and Surface Radiative Flux Variations in Terms of Surface and Atmospheric Contributions. J. Climate, 32, 5003–5019, https://doi.org/10.1175/JCLI-D-18-0826.1

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.: Evaluation of WRF-DART (ARW v3.9.1.1 and DART Manhattan release) multiphase cloud water path assimilation for short-term solar irradiance forecasting in a tropical environment, Geosci. Model Dev., 12, 3939–3954, https://doi.org/10.5194/gmd-12-3939-2019, 2019.

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

Albrecht, B., et al, 2019: Cloud System Evolution in the Trades – CSET, Following the evolution of boundary layer cloud systems with the NSF/NCAR GV. *Bull. Amer. Meteorol. Soc.*, **100**, 93-121, doi:10.1175/BAMS-D-17-0180.1.

Su, W., P. Minnis, L. Liang, D. P. Duda, K. Khlopenkov, M. M. Thiemann, Y. Yu, A. Smith, S. Lorentz, D. Feldman, and F. P. J. Valero, 2019: Determining the daytime Earth radiative flux from National Institute of Standards and Technology Advanced Radiometer (NISTAR) measurements. *Atmos. Meas. Tech.*, accepted.

Painemal, D., F.-L. Chang, R. Ferrare, S. Burton, Z. Li, W. L. Smith, Jr., P. Minnis, Y. Feng, and M. Clayton, 2019: Reducing uncertainties in satellite estimates of aerosol-cloud interactions over the subtropical ocean by integrating vertically resolved aerosol observations. *Atmos. Chem. Phys.*, submitted.

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

Minnis, P., S. Sun-Mack, W. L.Smith Jr., G. Hong, Y. Chen, "Advances in neural network detection and retrieval of multilayer clouds for CERES using multispectral satellite data," Proc. SPIE 11152, Remote Sensing of Clouds and the Atmosphere XXIV, 1115202 (9 October 2019), http://dx.doi.org/10.1117/12.2532931 **Improved ML clouds and ice cloud detection**

Clouds - Processing Status

CERES-MODIS Edition 4 Status	*Aqua: Jul 2002 – Aug 2019 (~17 y)* *Terra: Feb 2000 – Aug 2019 (~19 y)*
CERES-VIIRS Edition 1 Status	*SNPP: Jan 2012 – July 2019 (~7.5 y)*

MODIS/VIIRS Cloud Product Continuity

Terra and Aqua are near their end of lifetime; CERES continues on S-NPP and the JPSS series but will rely on cloud properties derived from the VIIRS imagers. Continuity between the MODIS and VIIRS cloud properties is essential.

Challenges for achieving continuity using different instruments:

(1) Spatial resolution and sampling

- VIIRS (375, 750 m) vs. MODIS (1000, 500, 250 m) at nadir
- VIIRS pixel size nearly constant with scan angle (unlike MODIS)

(2) Calibration

- Relative consistency between sensors is required including spectral band adjustments
- Solar reflectance channels most problematic (e.g. JPSS-1 is 2-4% higher than SNPP)

(3) Spectral coverage

- No CO_2 (13 μm) or Water Vapor (6.7 μm) channels on VIIRS
- 2.x μm window channels much different (MODIS 2.1 μm vs. VIIRS 2.2 μm)

CERES LEO Cloud Product Continuity

Ed4 MODIS designed to provide consistent cloud properties between Terra and Aqua and across their entire observational record

- Use same frozen retrieval algorithms
- Calibrations unified (all data scaled to Aqua MODIS Collection-5 radiances)
- Aqua-MODIS data provide the most consistent long-term cloud data record ever produced
- But, Ed4 Terra-MODIS not as consistent (degradation in several channels not addressed in Ed4)
  - primarily impacts polar cloud trends

MODIS Ed4 was not designed for continuity with VIIRS

- MODIS Ed4 delivered before VIIRS data became available (no experience with VIIRS)

Some continuity considerations were made during VIIRS Ed1 development

- Cloud mask tuning to help account for resolution and channel differences
- Split window method (11 and 12 µm) developed to aid in ice cloud height assignment and cloud phase determination to help achieve consistency with MODIS which relies heavily on the 13 µm channel

But, Ed1 uses forward processing calibrations (a significant update came in 2016)

- Inconsistencies in current record
- Not scaled to MODIS

VIIRS/MODIS Consistency Summary
(from previous meetings)

- VIIRS Ed1 and MODIS Ed4 cloud properties are tracking very well but are not consistent enough for continuity due to different channels being used in the algorithms, calibration inconsistencies, and resolution differences
- While there is excellent agreement in global mean cloud fractions for ice, liquid and total clouds, regional differences are large
- Largest differences are found for polar night cloud detection, cirrus detection everywhere, and cloud phase determination
- Inconsistent cloud phase determination leads to inconsistencies in other cloud properties (COD, Re, Z)
- Bug fixes and new models implemented in VIIRS Ed 1 also cause some differences

MODIS ED5 and VIIRS ED3 will have consistent calibrations, use a common set of spectral channels, employ forward models and algorithms that are as consistent as possible to achieve continuity

Status of VIIRS Edition-2 for S-NPP and JPSS-1

Primary objective is to normalize VIIRS calibrations to MODIS (use scaling factors)

- Evaluate consistency between Ed2 VIIRS and Ed4 MODIS cloud properties (different algos)
- Develop MODIS/VIIRS continuity algorithms for Ed5 (use common channels)

VIIRS Ed2 will use same cloud algorithms as in NPP VIIRS Ed1, but

- with L1 VIIRS Radiance Version 2 (in netCDF format)
- apply to both NPP and J1 **(the first delivery for J1)**
- L1 VIIRS Radiance Version 2 scaled to MODIS Collection 5

L1 NPP VIIRS Radiance V2 expected to be in production mid-November, 2019

L2 Aerosol Product

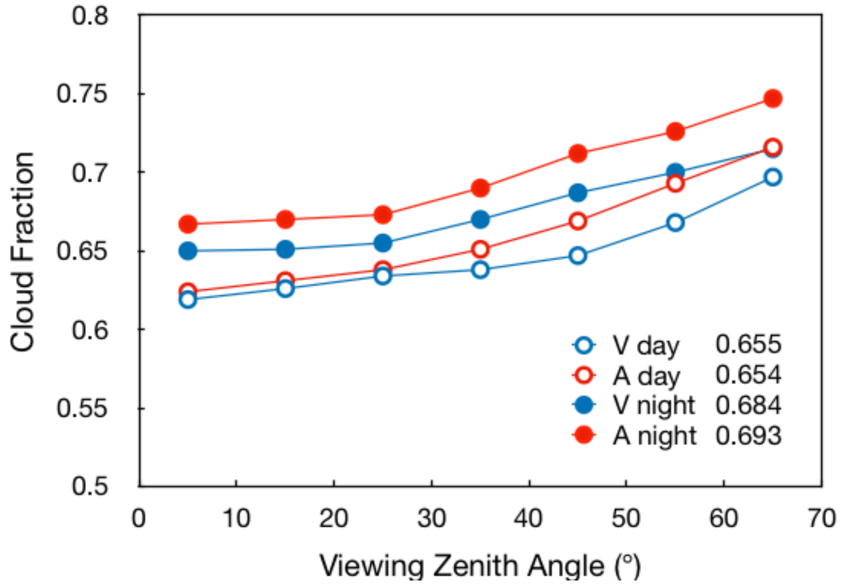
- Aerosol for CERES NPP-VIIRS Edition 2 (AERDB_L2_VIIRS_SNPP)
  - GSFC SNPP VIIRS Deep Blue (Deep Blue algo over land and SOAR for ocean)
- No Aerosol for CERES J1-VIIRS Edition 2

CERES Clouds Code is ready. Currently testing VIIRS -to- Aqua-MODIS scaling factors on NPP V1 and J1 V2.

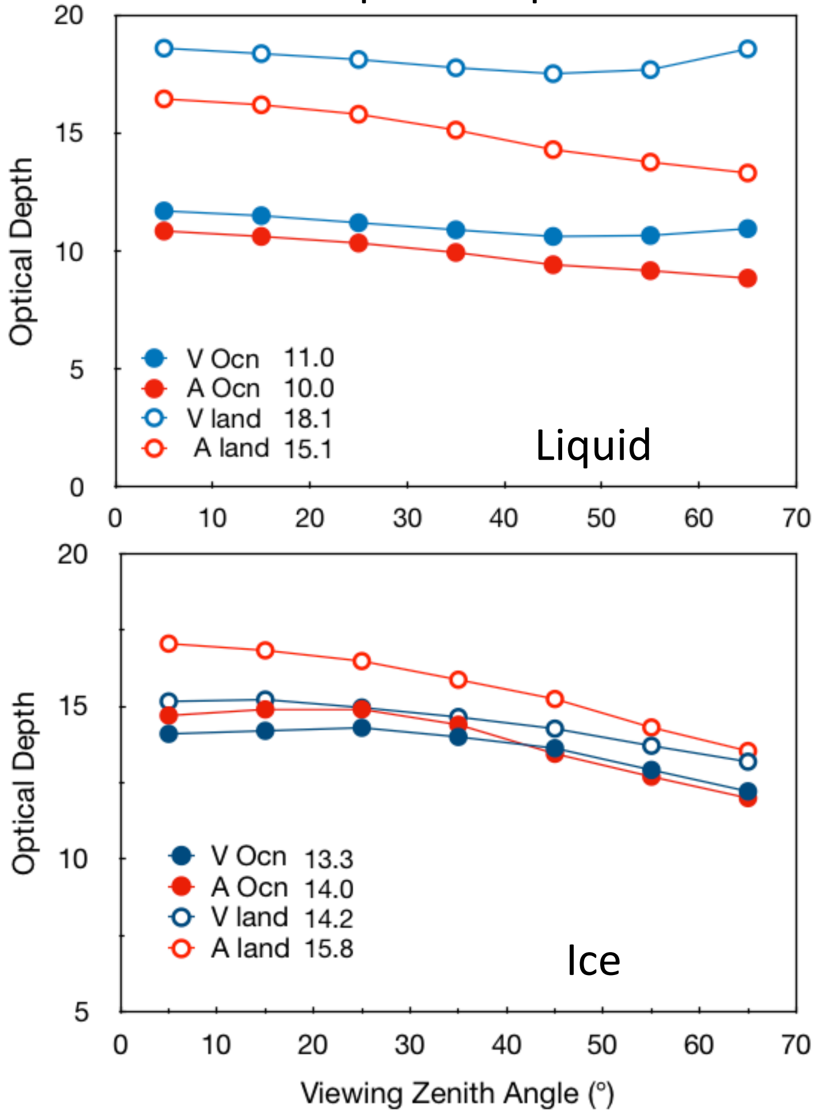
Viewing Angle Dependence, 2013 Nonpolar Averages

V – VIIRS, A- Aqua

Total Cloud Fraction



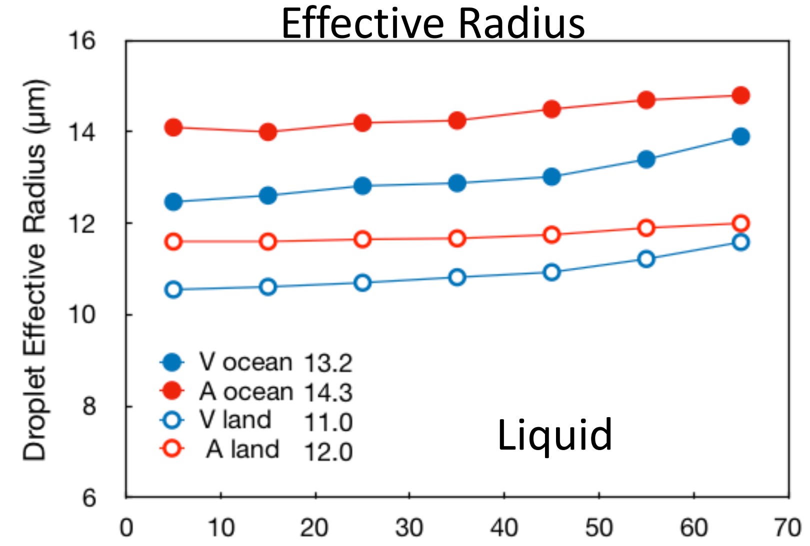
Optical Depth

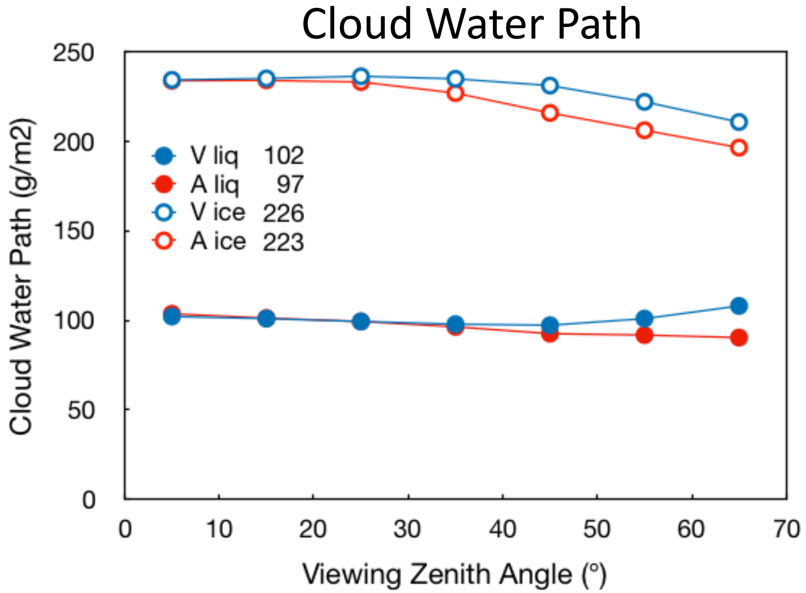


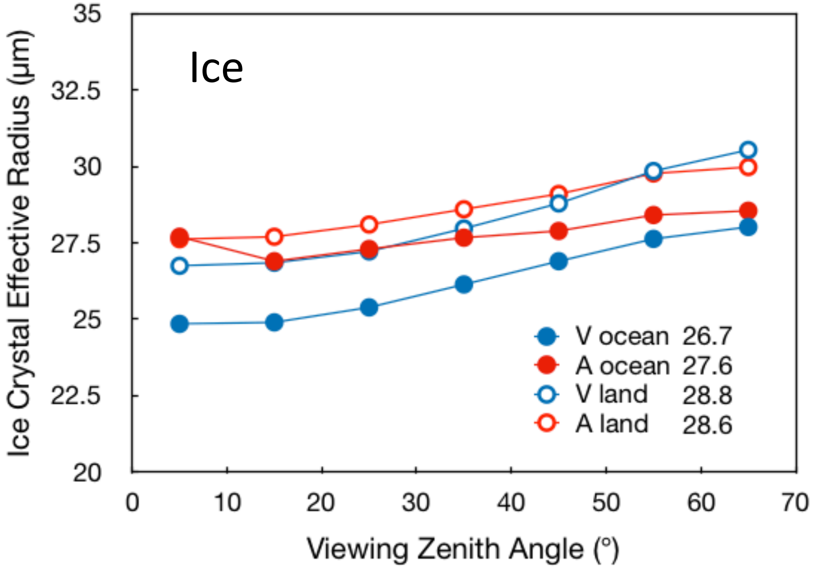
- VIIRS CF changes by ~11%, Aqua 14%
  - some impact of constant resolution w/VZA along scan path?
- MODIS COD drops more than VIIRS
  - 19% for ice, 18% for water
  - VIIRS only 4% for ice, 5% for water

Viewing Angle Dependence, 2013 Nonpolar Averages

V – VIIRS, A- Aqua







- VIIRS Re increases more than Aqua
  - 11% vs 4% for Aqua liquid
  - 13% vs 4% for Aqua ice
- VIIRS water path less dependent on VZA
  - Flat for water, -10% for ice
  - Aqua: -13%% for water, -16% for ice

- VIIRS constant resolution seems to diminish VZA dependence in most variables
- Broken clouds and 3-D effects still cause significant dependencies

Recent Validation & Comparisons with other Methods

Cloud Mask Paper

Qing Trepte et al., 2019: Global cloud detection for CERES Edition 4 using Terra and Aqua MODIS data. IEEE Trans. Geosci. Remote Sens., doi: 10.1109/TGRS.2019.2926620.

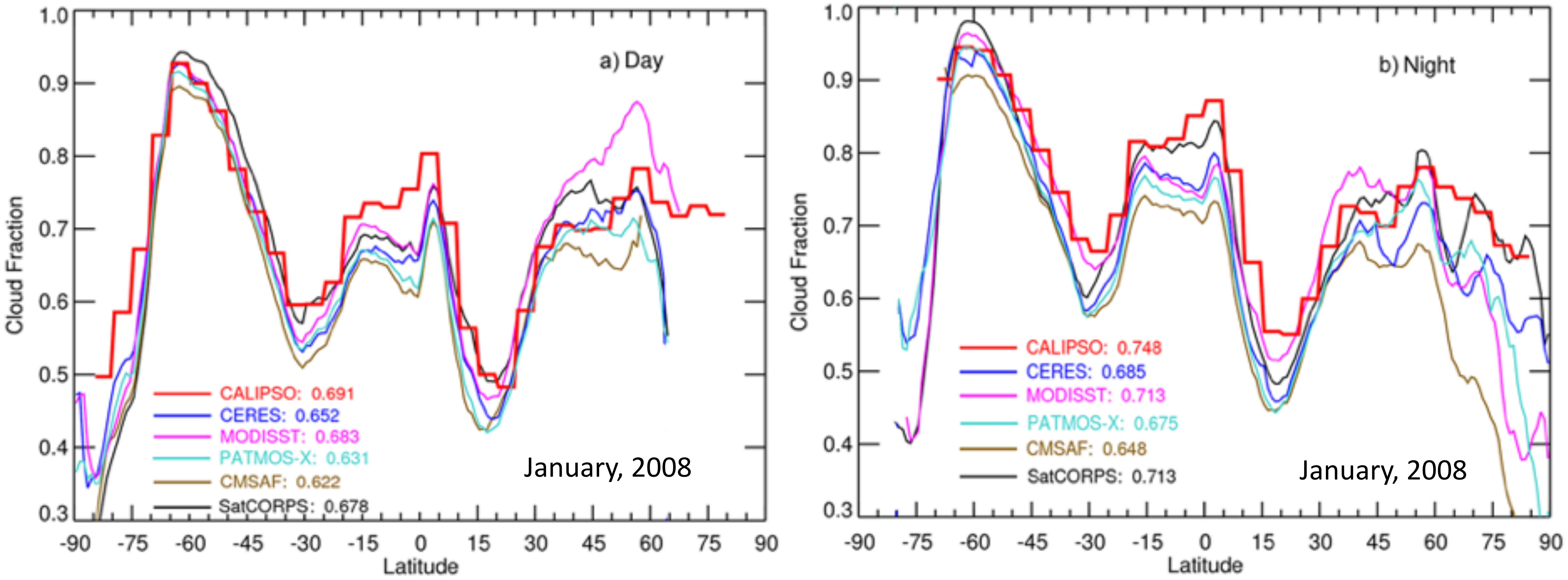
Cloud Algorithm Paper

Pat Minnis et al., 2019: CERES MODIS cloud product retrievals for Edition 4, Part I: Algorithm changes. IEEE Trans. Geosci. Remote Sens.

Validation Paper

Chris Yost et al.., 2019: CERES MODIS cloud product retrievals for Edition 4, Part II: Comparisons to CloudSat and CALIPSO. IEEE Trans. Geosci. Remote Sens.

CERES Ed4 Cloud Fraction vs other groups/satellites



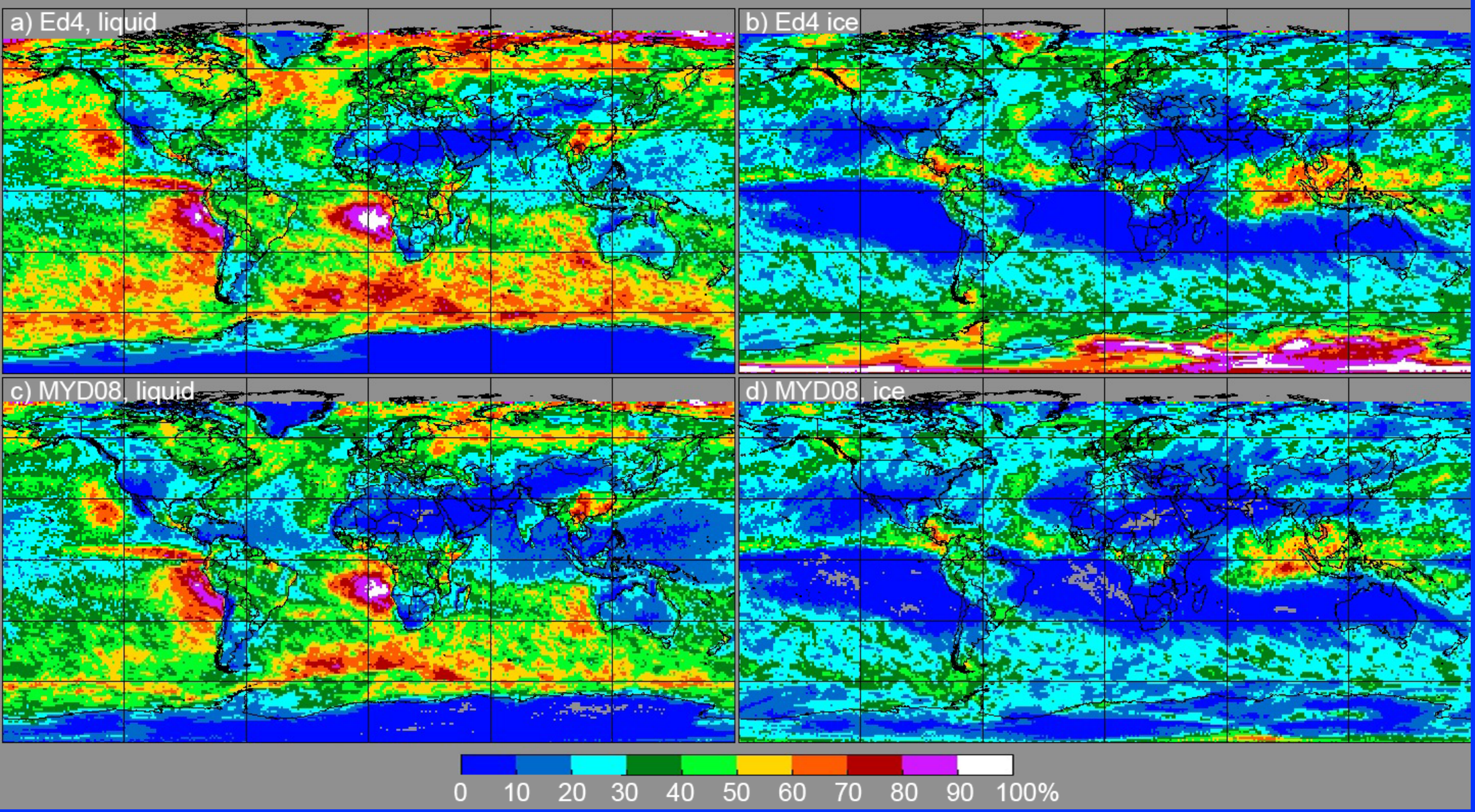
Monthly Mean Zonal Cloud Fraction Comparisons

Ed4 cloud mask paper
Trepte et al, 2019

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

Mean cloud fraction by phase from October 2008 Aqua MODIS data

Ed4 vs MYOD08



CERES Ed4 has fewer no retrievals and therefore larger ice and liquid cloud fractions than MYOD08

Ed4 phase validated extensively with CALIPSO (Yost et al. 2019, in prep)

Ed4 misses some thin Ci in overlapping conditions and has more water than CALIOP – new neural net method looks promising to address this in Ed5

	Liquid		Ice		Total	
Parameter	MYOD08	CM	MYOD08	CM	MYOD08	CM
NP Fraction retrieved	0.339 (0.367)	0.393	0.201 (0.197)	0.241	0.540 (0.564)	0.634
PO Fraction retrieved	0.358 (0.348)	0.391	0.226 (0.237)	0.353	0.584 (0.585)	0.743

Minnis et. al., 2019

CALIPSO and CERES Ed4 Aqua MODIS Cloud Phase Comparison Statistics

January, April, July, & October, 2015 & 2016.

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

CLASSIFICATION FOR SINGLE-PHASE 100% CLOUD-COVERED 5-KM FOOTPRINTS

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

- Daytime HR 92-97%
- Nighttime HR 80-90%
- Lowest skill scores over snow/ice
- Ice cloud false alarms pretty high at night

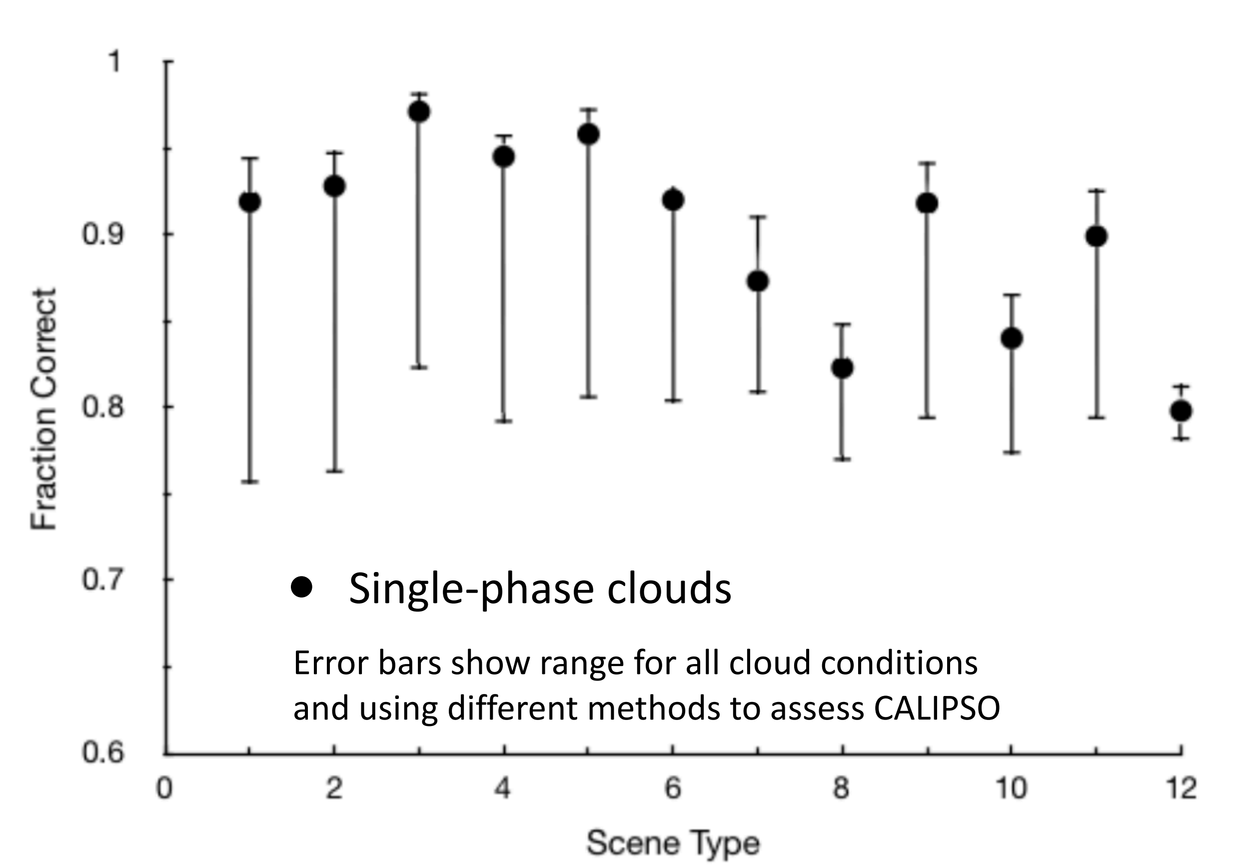
Yost et. al., 2019

Cloud Phase (Fraction Correct)

January, April, July, & October, 2015 & 2016.

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

Scene #	Scene Type
	Day
1	Nonpolar, Land SIF
2	Polar Land SIF
3	Nonpolar Ocean, SIF
4	Polar Ocean, SIF
5	Global, SIF
6	Global, SIC
	Night
7	Nonpolar, Land SIF
8	Polar Land SIF
9	Nonpolar Ocean, SIF
10	Polar Ocean, SIF
11	Global, SIF
12	Global, SIC

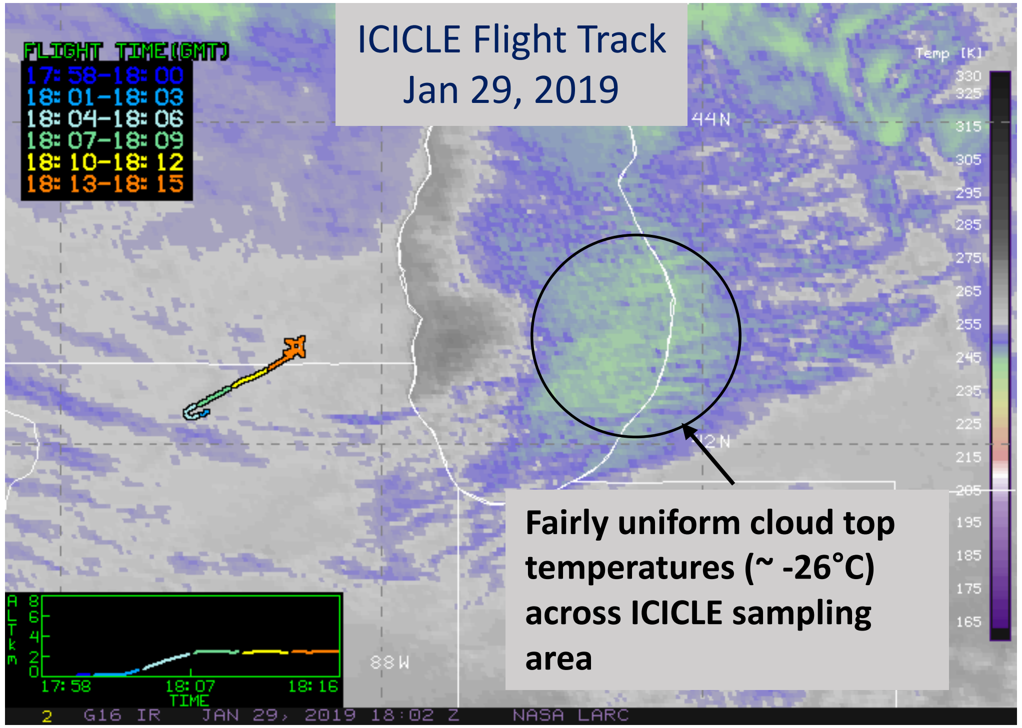


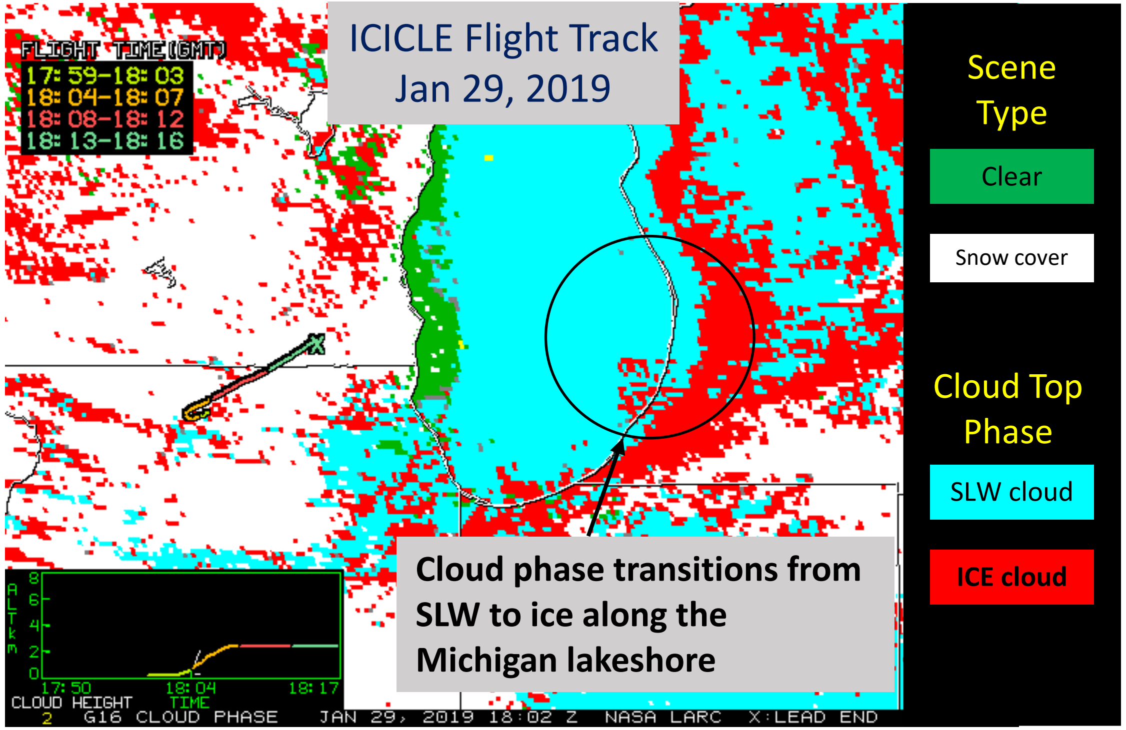
Accuracy depends on how you do the evaluation

Yost et. al., 2019

FAA In-Cloud ICing and Large drop Experiment (ICICLE)

- extensive, high quality, in-situ cloud microphysics dataset was collected



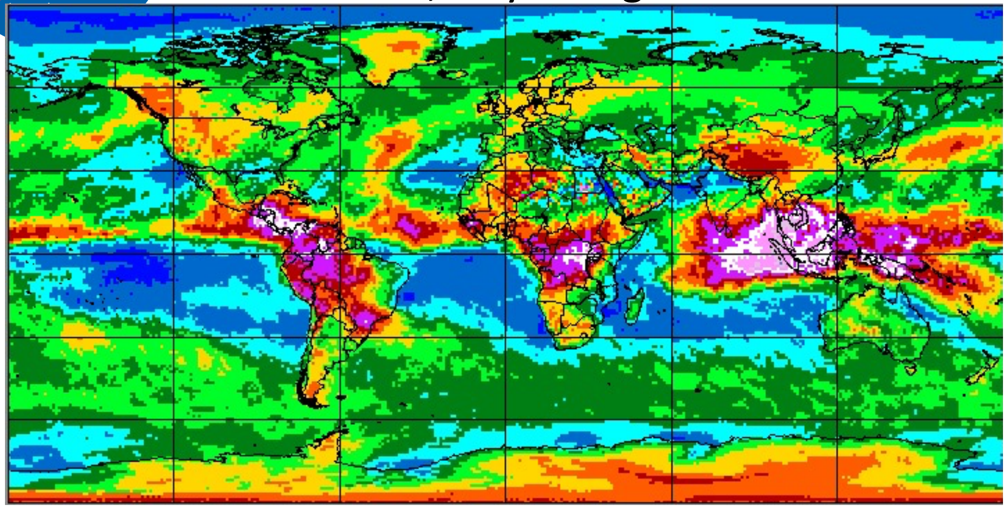


NASA LaRC SatCORPS

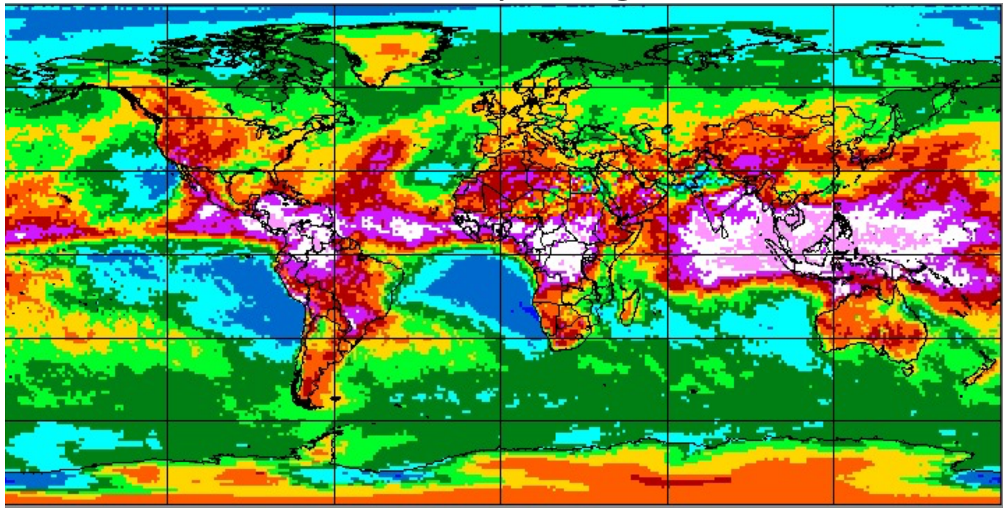
- ICICLE Convair-580 sampled super-cooled liquid clouds forming over Lake Michigan, and transition to glaciated, snow-producing clouds over western Michigan
- GOES-16 accurately captures phase transition across uniform cold cloud tops (~ -26°C)

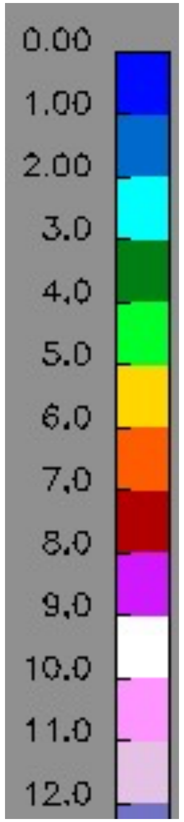
Mean Cloud Top Heights from Aqua MODIS, MODIS Science Team (MAST) & CERES Edition 4
October 2008

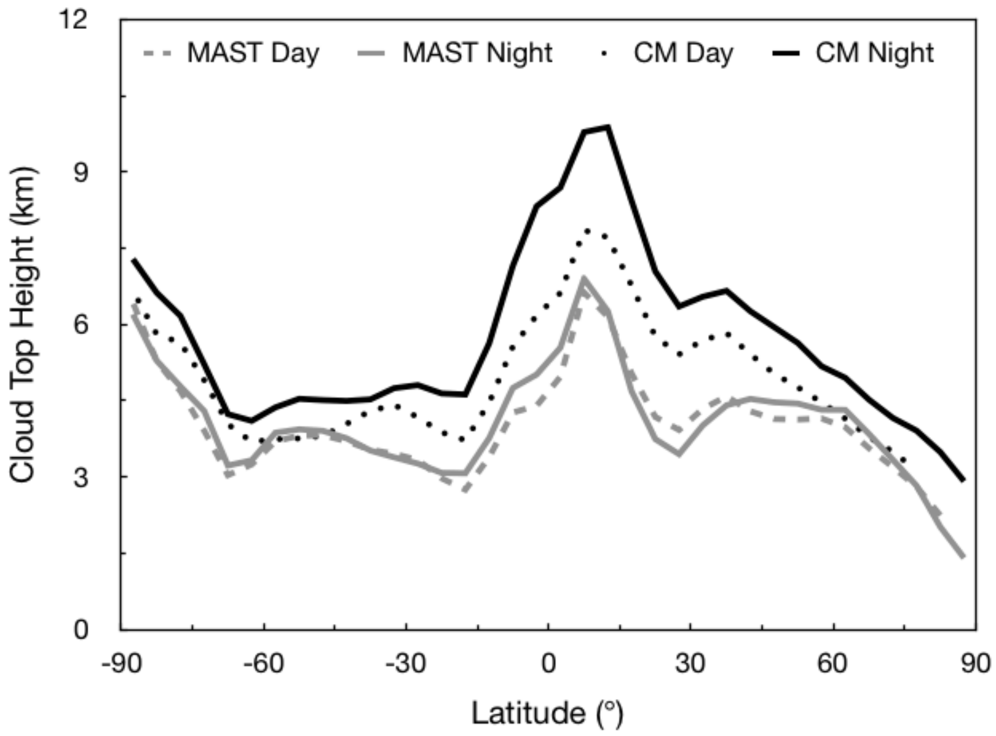
MAST, Day & Night



CERES, Day & Night





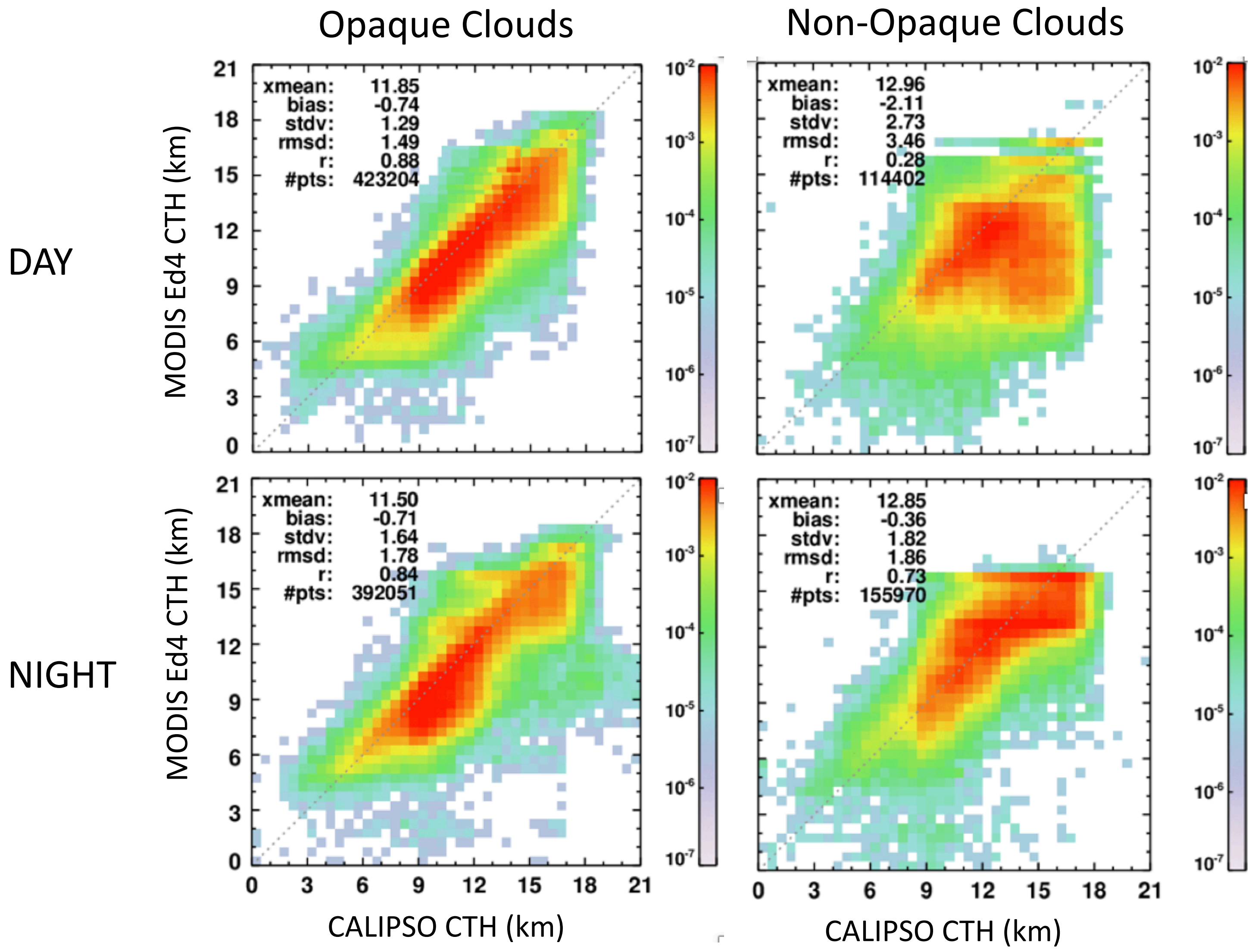


Global Mean Cloud Heights (km)

	MYD08	CERES Ed4
Day	4.12	5.03
Night	4.22	6.08

- On average, CERES clouds are ~1.4 km higher and in much better agreement with CALIPSO than MAST
- MAST has better day/night consistency (employs daytime IR method)

MODIS ED4 CLOUD HEIGHT COMPARISONS WITH CALIPSO
Single-layer Ice Clouds

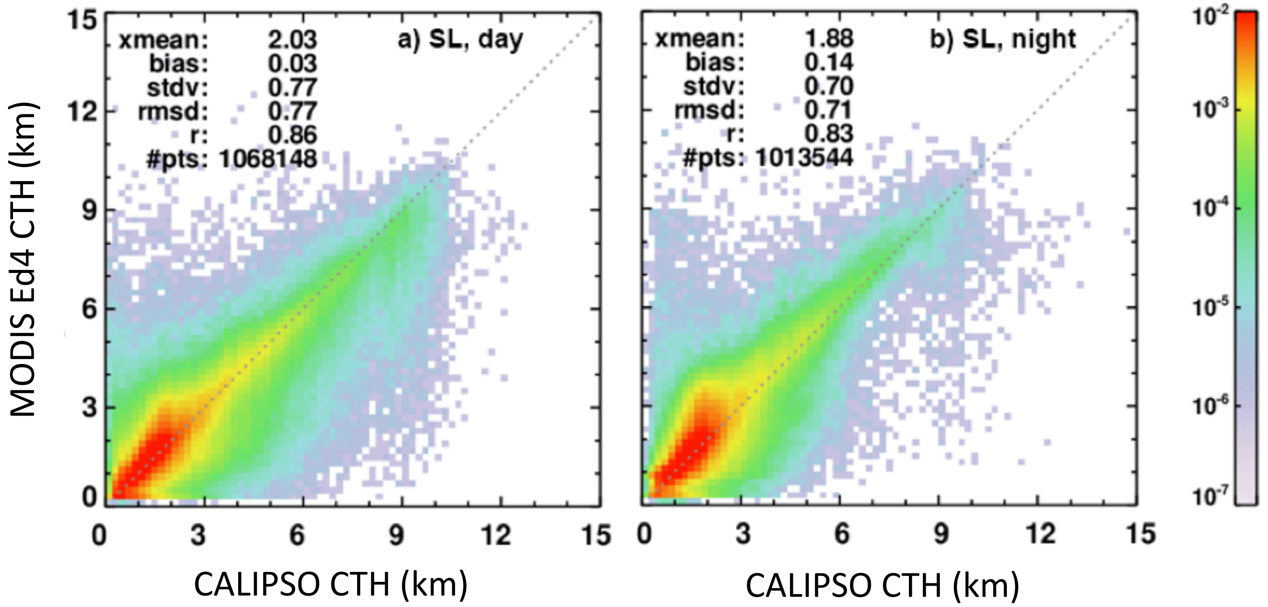


January, April, July, and October 2010

- Nighttime cirrus heights better than daytime
- New ice scattering model (THM) will improve agreement in Ed5
- Will still need more effective empirical adjustments than those applied in Ed4

MODIS ED4 CLOUD HEIGHT COMPARISONS WITH CALIPSO
Single-layer Water Clouds

January, April, July, and October 2010



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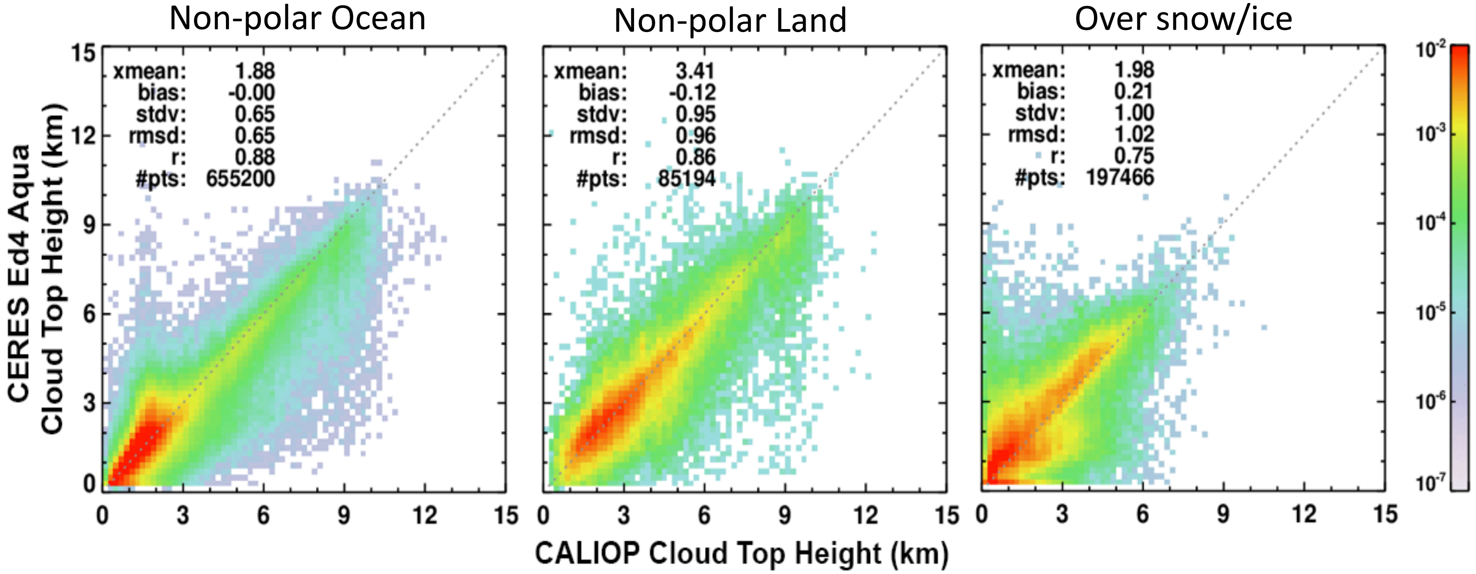
MODIS ED4 CLOUD HEIGHT COMPARISONS WITH CALIPSO
Single-layer Water Clouds

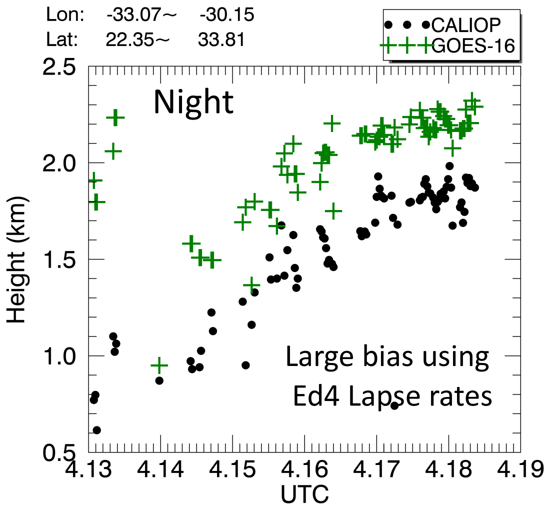


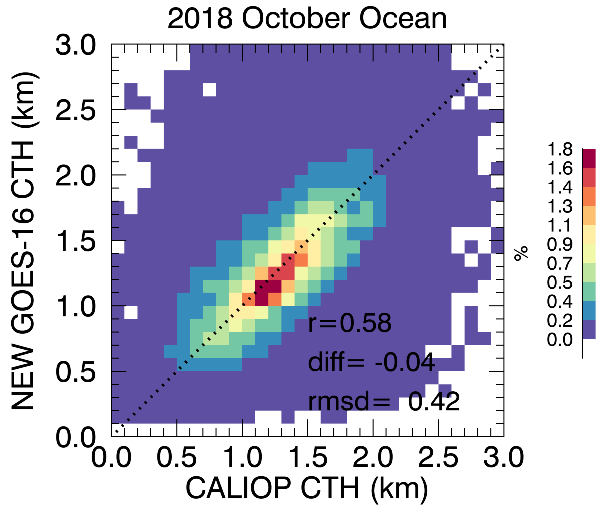
Current Lapse-rate method has pretty good skill overall but there are some problem areas for boundary layer clouds:

- Heights often too high over ocean
- Poor skill over land (too low during day; too high at night; poor correlation)

Zhujun Li testing new approaches:

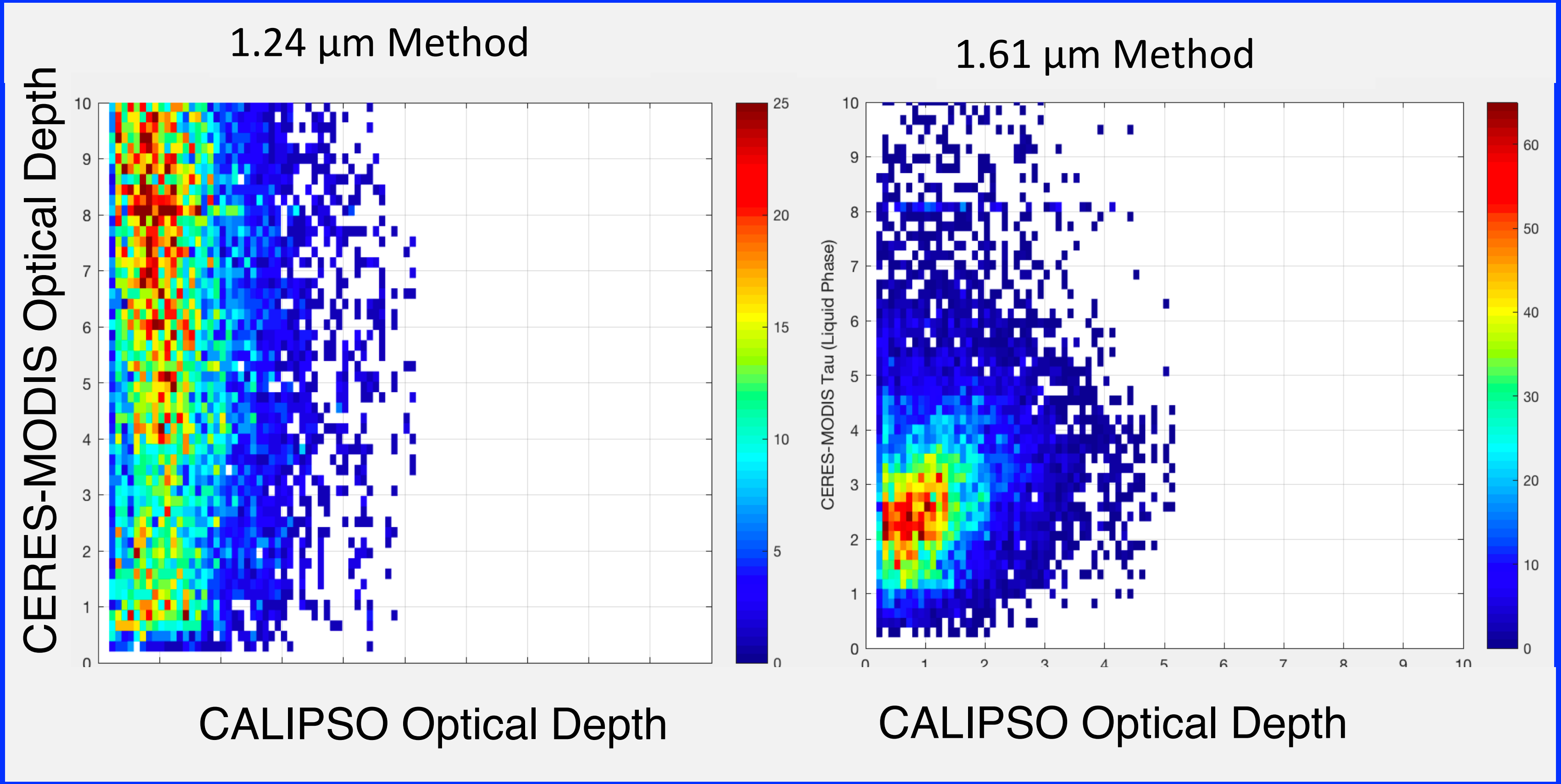
- Temperature dependent lapse rate method working much better over ocean
- Increased use of reanalysis data over land
  - PBL heights (RH profile)
  - Wet bulb temperature profiles





New lapse rate method reduces bias and rms over ocean

Cloud Optical Depths over Snow/Ice (Polar Regions)



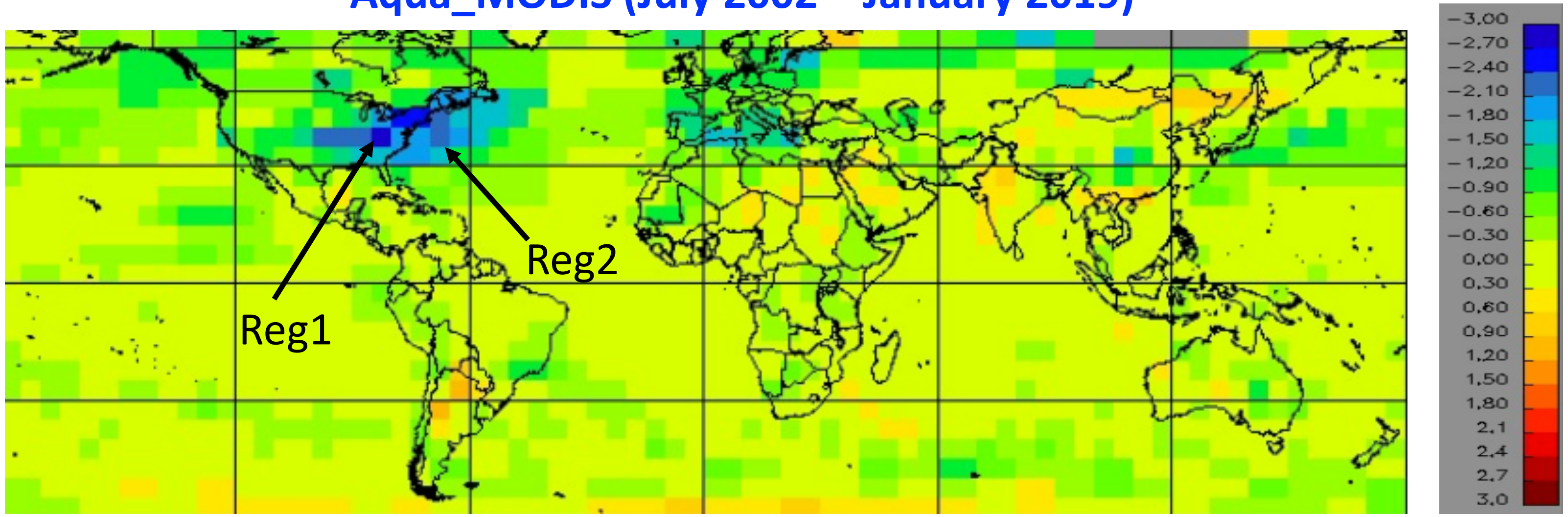
Ed4 1.24 µm optical depths retrieved over snow/ice seem to be too high for thinner clouds

A method using 1.61 µm has been implemented and compares better with CALIPSO

Sunny Sun-Mack will discuss this in detail on thursday

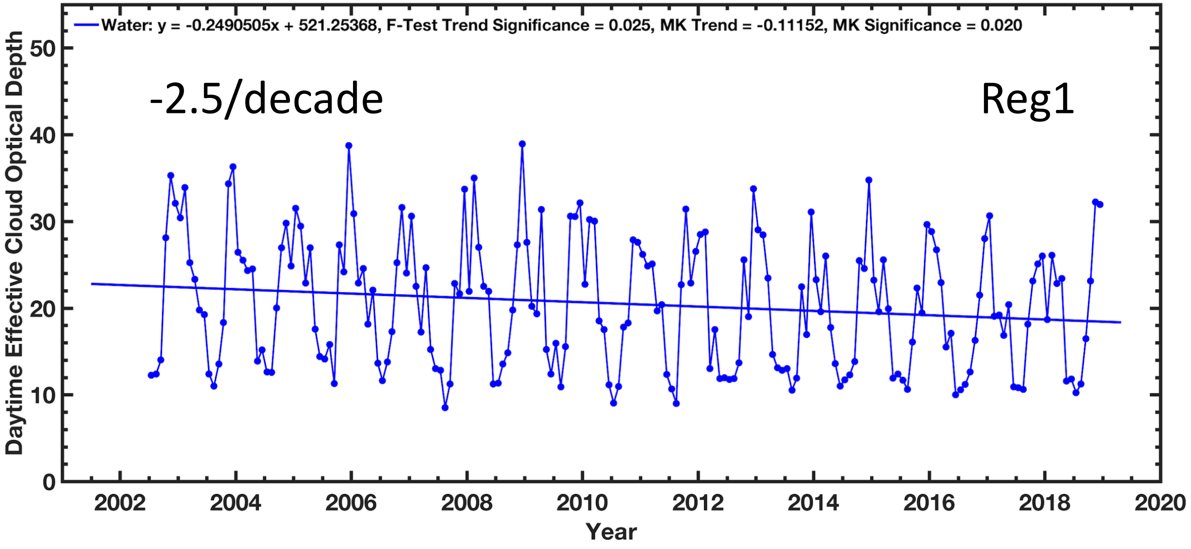
Regional trend of Liquid Cloud Optical Depth (per decade)

Aqua_MODIS (July 2002 – January 2019)

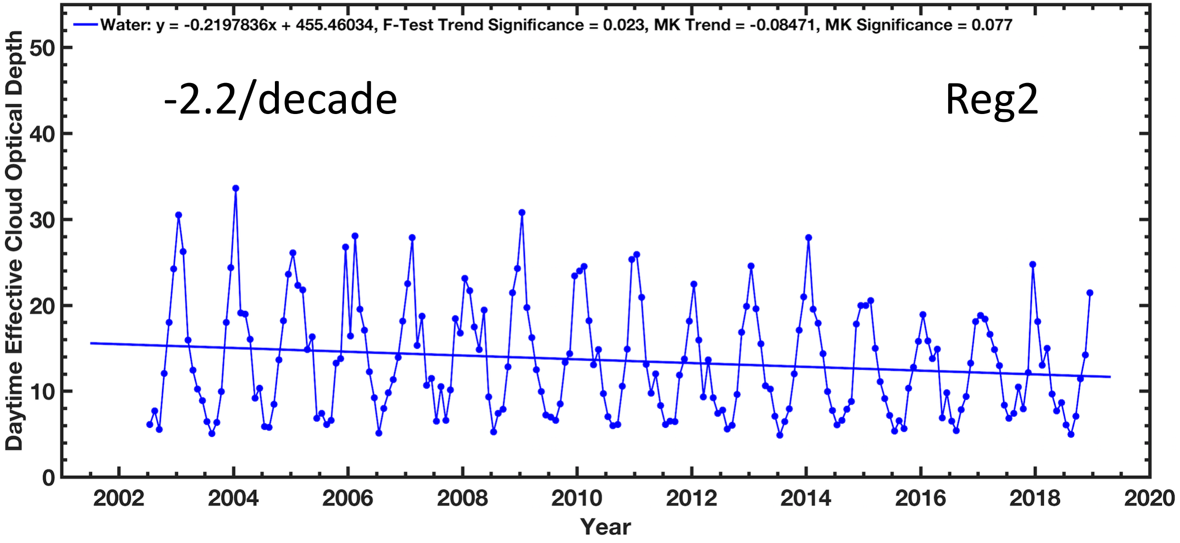


- Significant large negative trends in liquid COD over eastern U.S and adjacent Atlantic are found in 17 year CERES-MODIS record
- 10-15% COD reduction per decade dwarfs changes seen elsewhere

Liquid Cloud Optical Depth at 37.5N 82.5W (5 deg region)

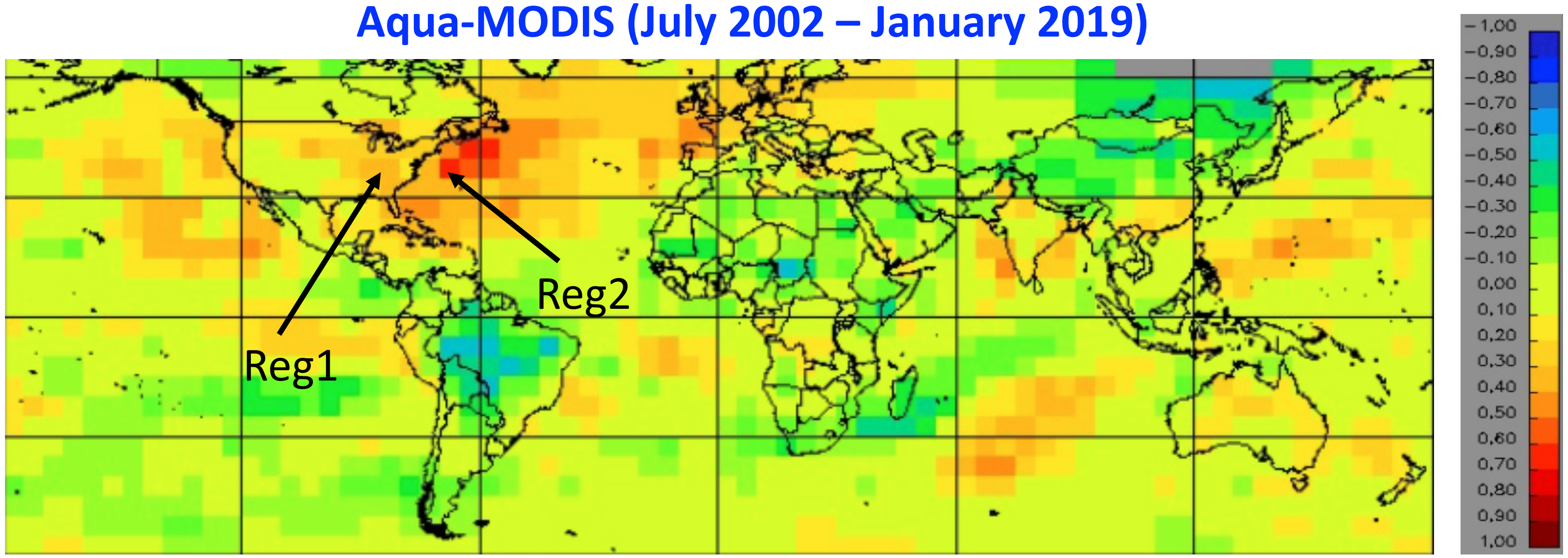


Liquid Cloud Optical Depth at 37.5N 67.5W



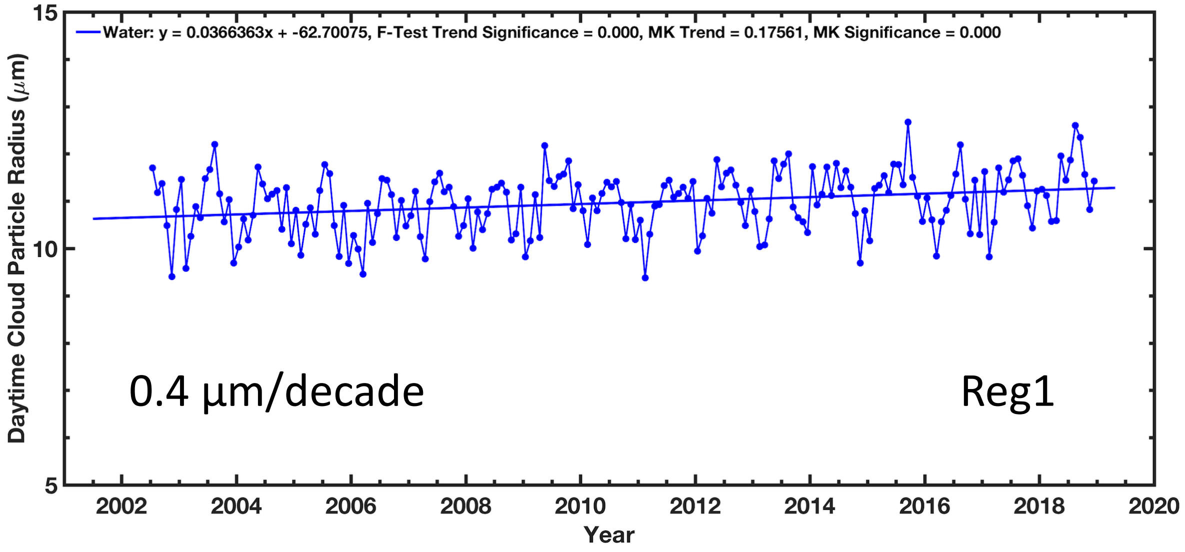
Regional trend of Liquid Cloud Effective Radius (R_e): µm / per decade

Aqua-MODIS (July 2002 – January 2019)



- A positive trend in liquid cloud R_e is also found, largest over the western Atlantic (~0.5 µm or 4% per decade)
- Increases most apparent after 2009

Liquid Cloud Effective Radius at 37.5N 82.5W (5 deg region)



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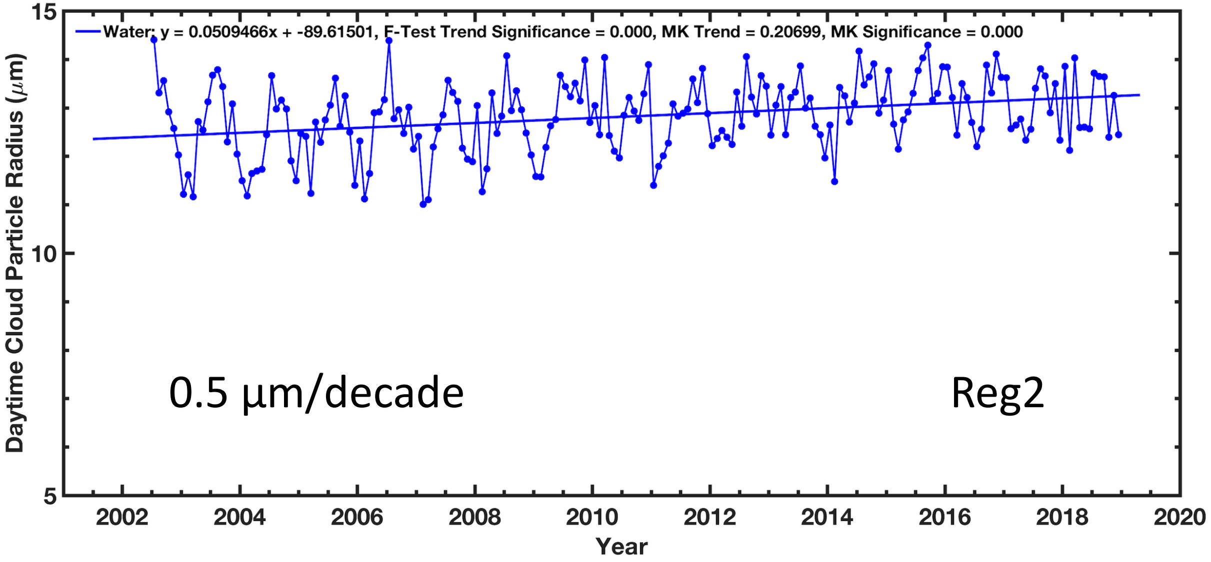
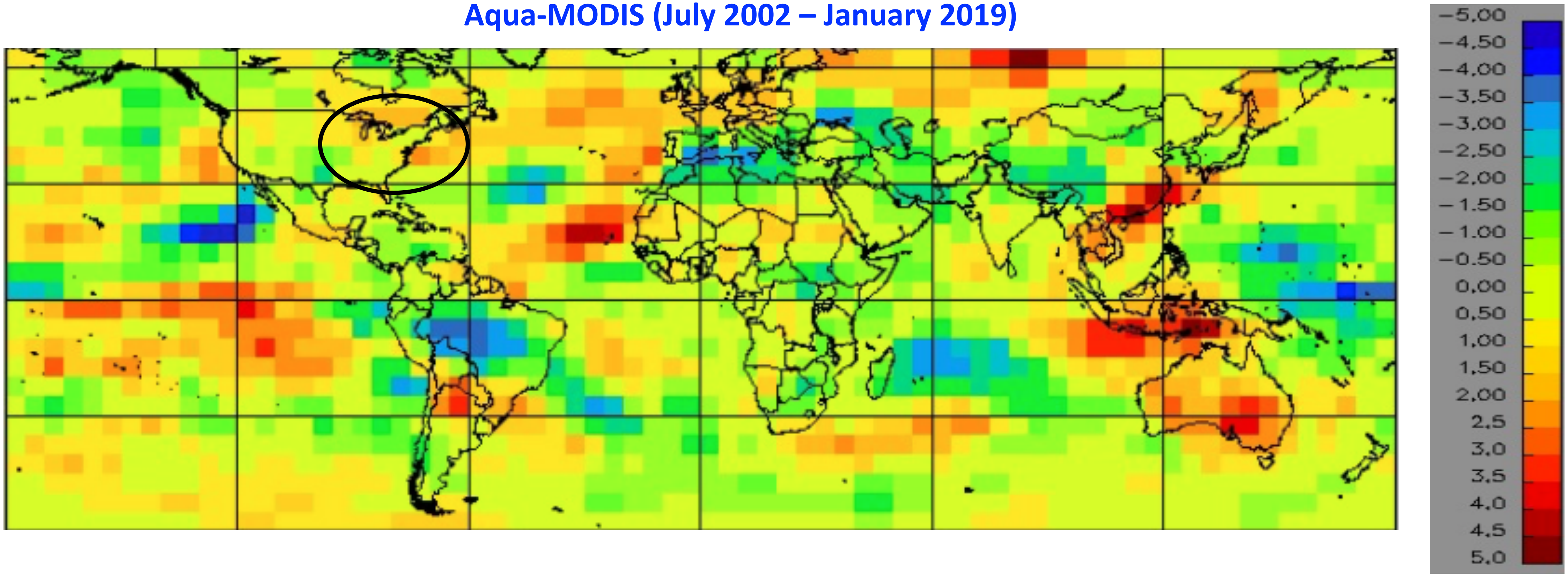


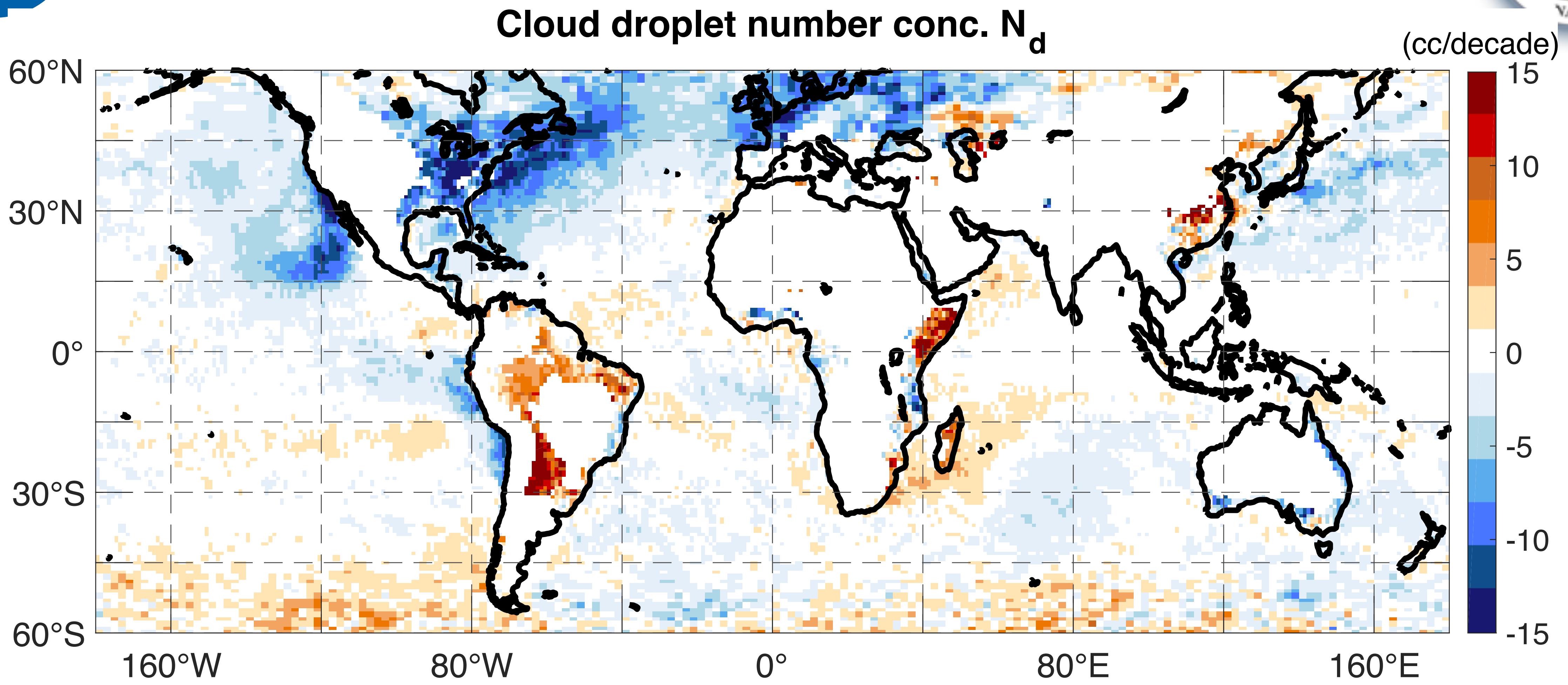
Regional Trend of Total Cloud Fraction: % / decade

Aqua-MODIS (July 2002 – January 2019)

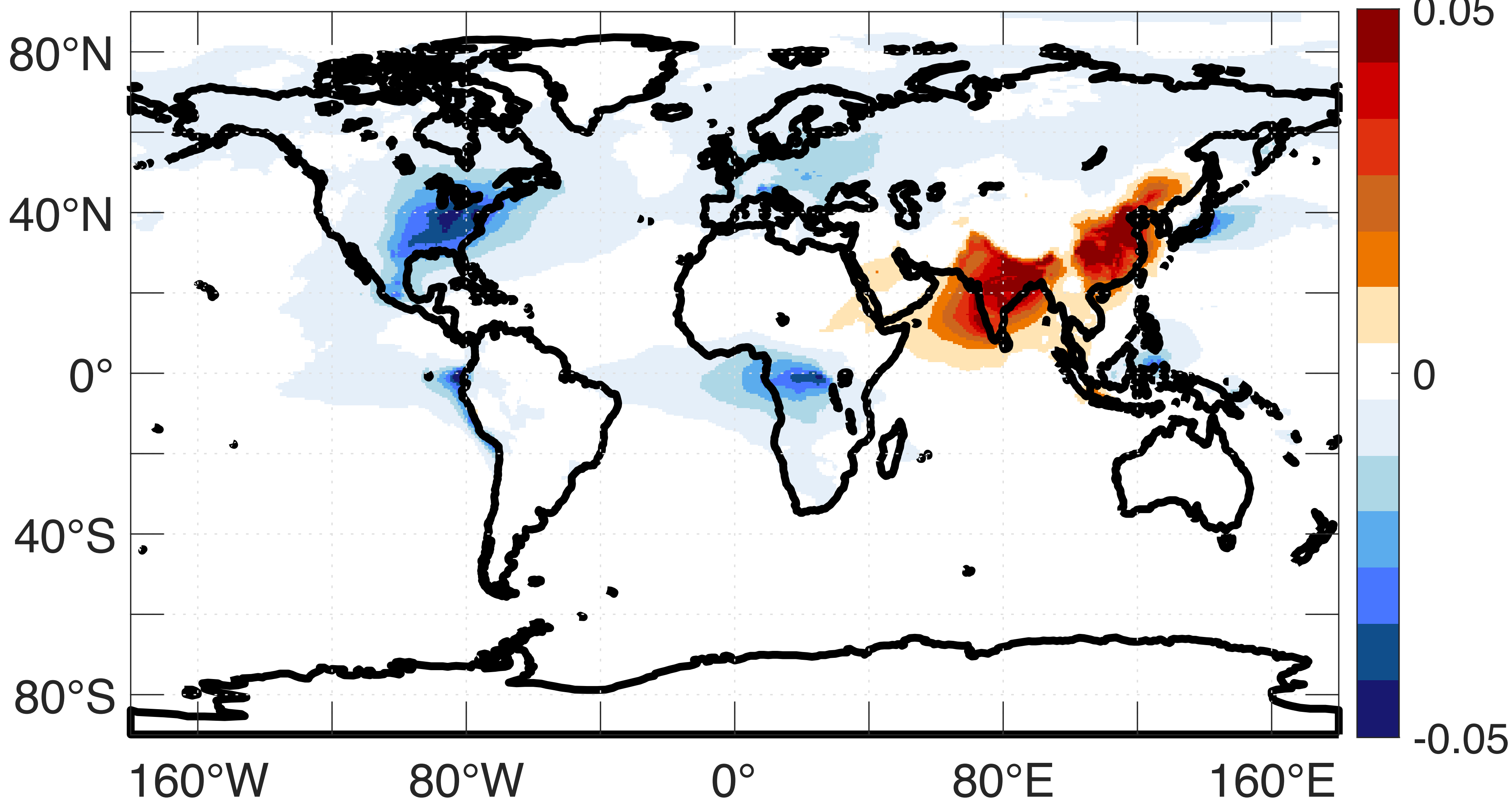


- Cloud fraction trends unremarkable compared to rest of world
- For Reg 1, no trend in total clouds (small increase in ice clouds, decrease in water clouds, 2.5%/decade)
- For Reg 2, total clouds increasing (2%), ice clouds increasing (3%), low clouds decreasing (1%)

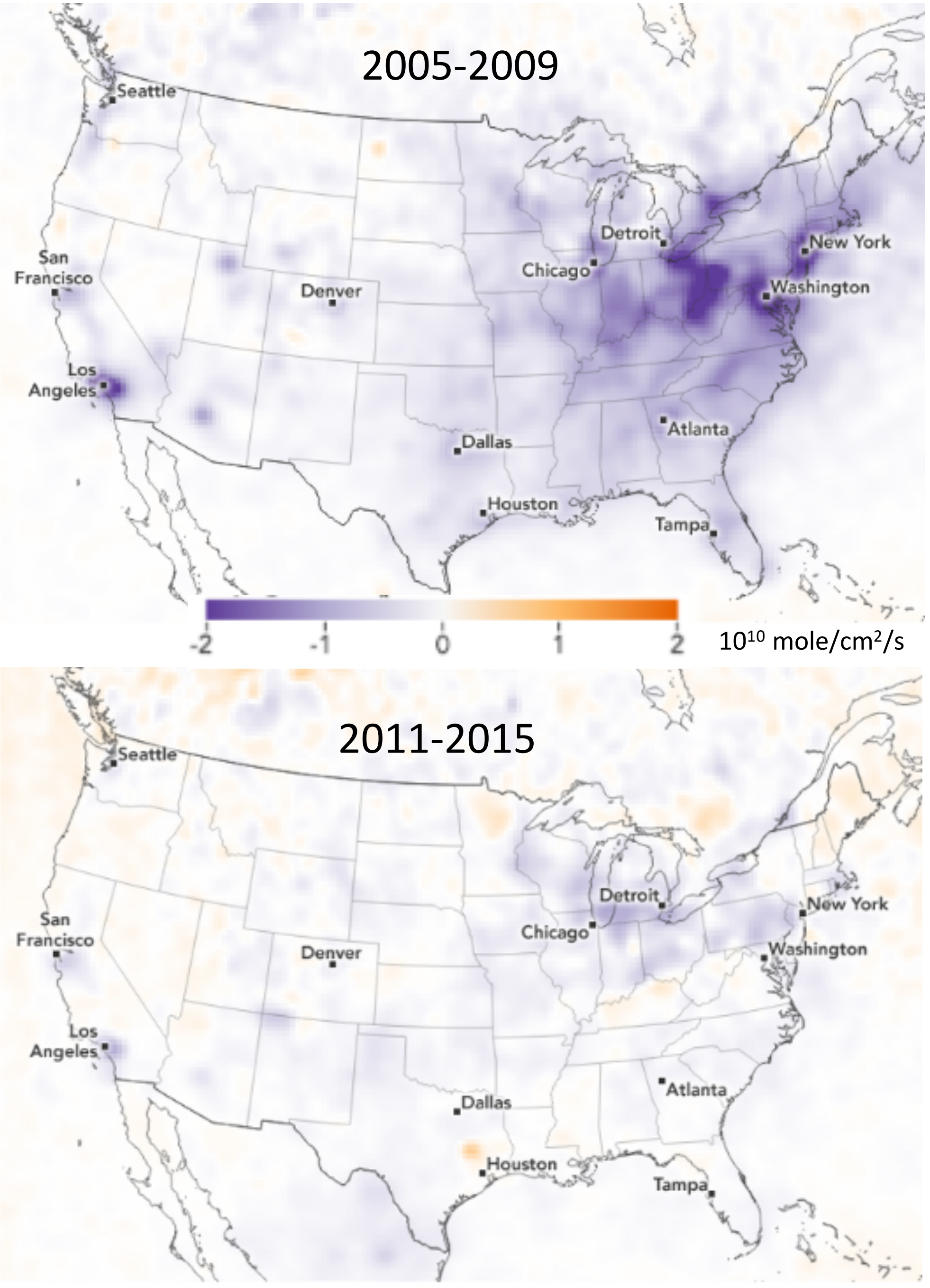
MODIS CDNC Trends per decade

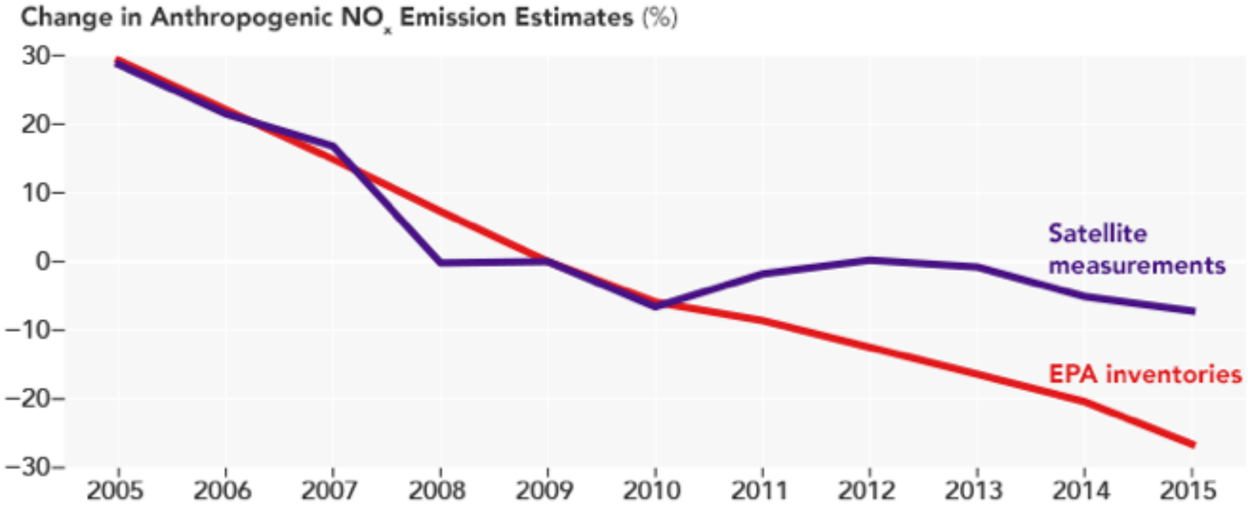


Sulfate AOD trend per decade



Change in anthropogenic NOx emissions





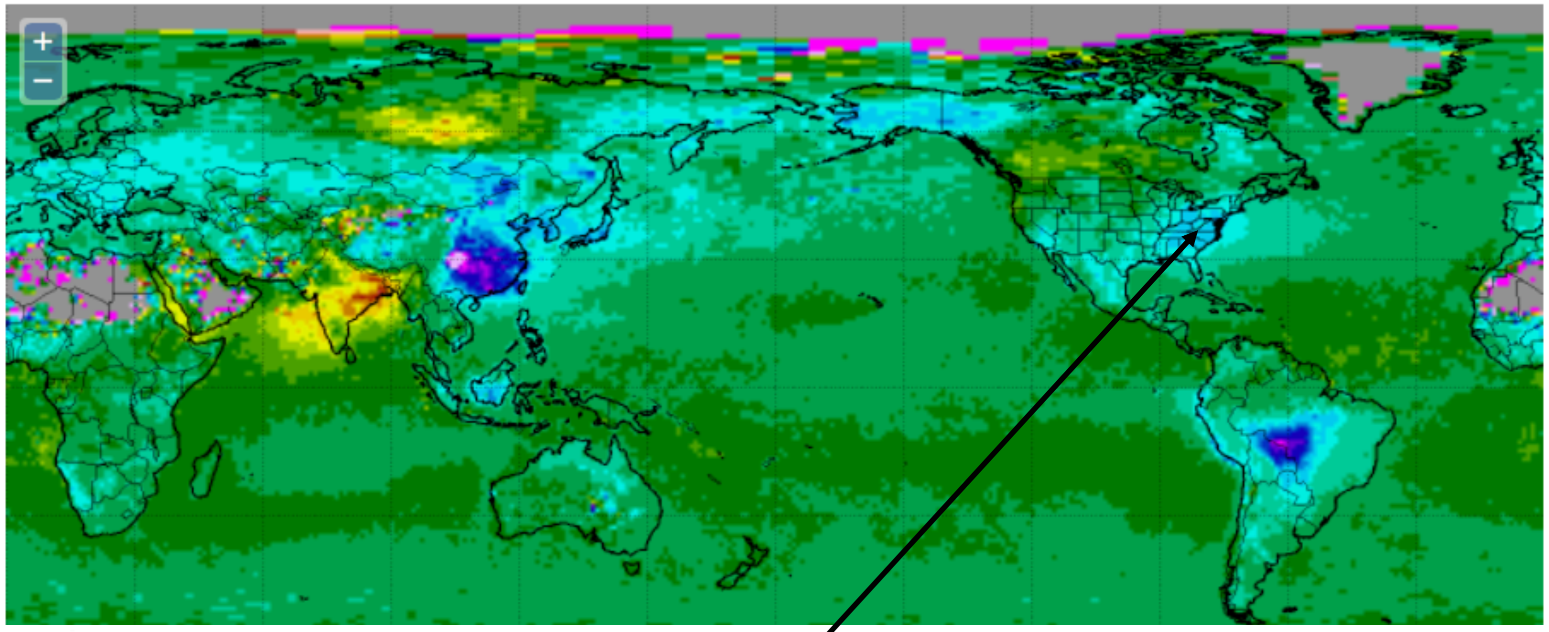
U.S. pollution emissions have been decreasing during the MODIS record

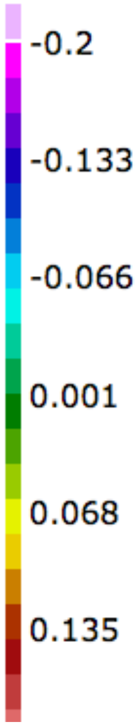
Largest decreases over eastern U.S. and major cities from 2005-2008, then unexpectedly levels off – implications for air quality management

Relative contribution of different sources of emission changing

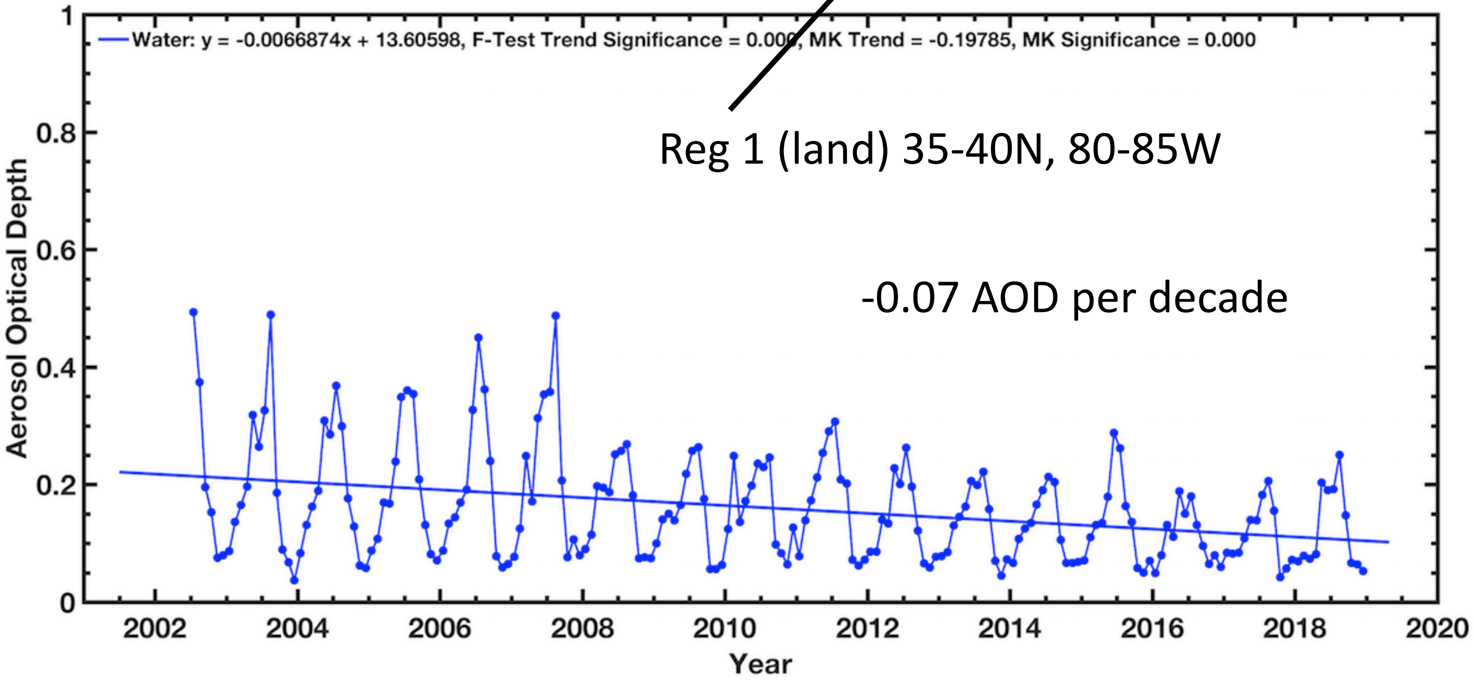
Jiang et al., PNAS, 2018

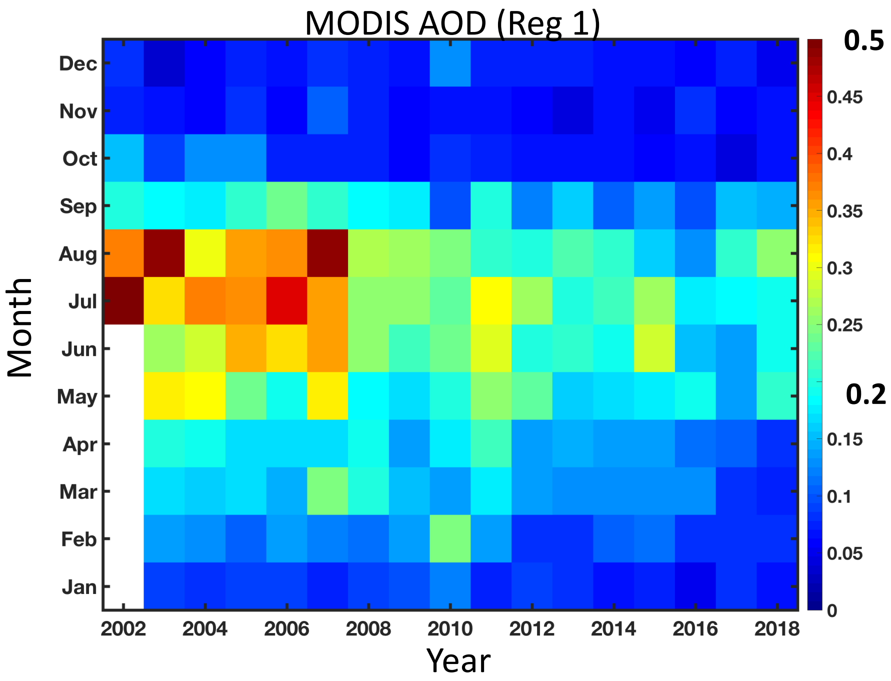
MODIS 0.55 µm Aerosol Optical Depth Trends (per decade)



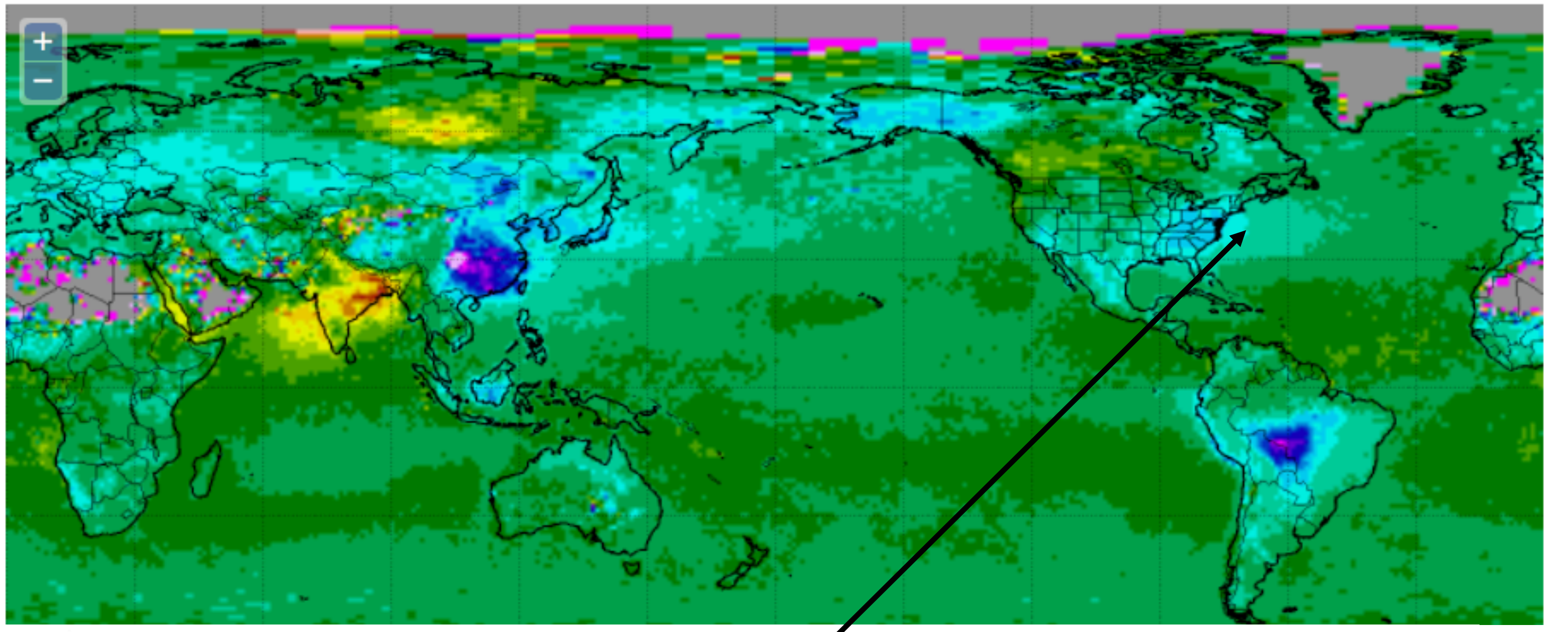


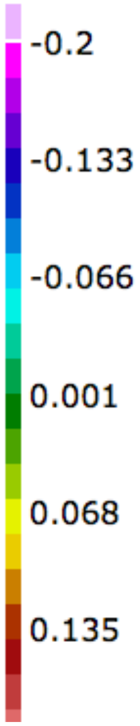
- AOD is also decreasing over eastern U.S
- Largest decreases early in record from Feb-Oct



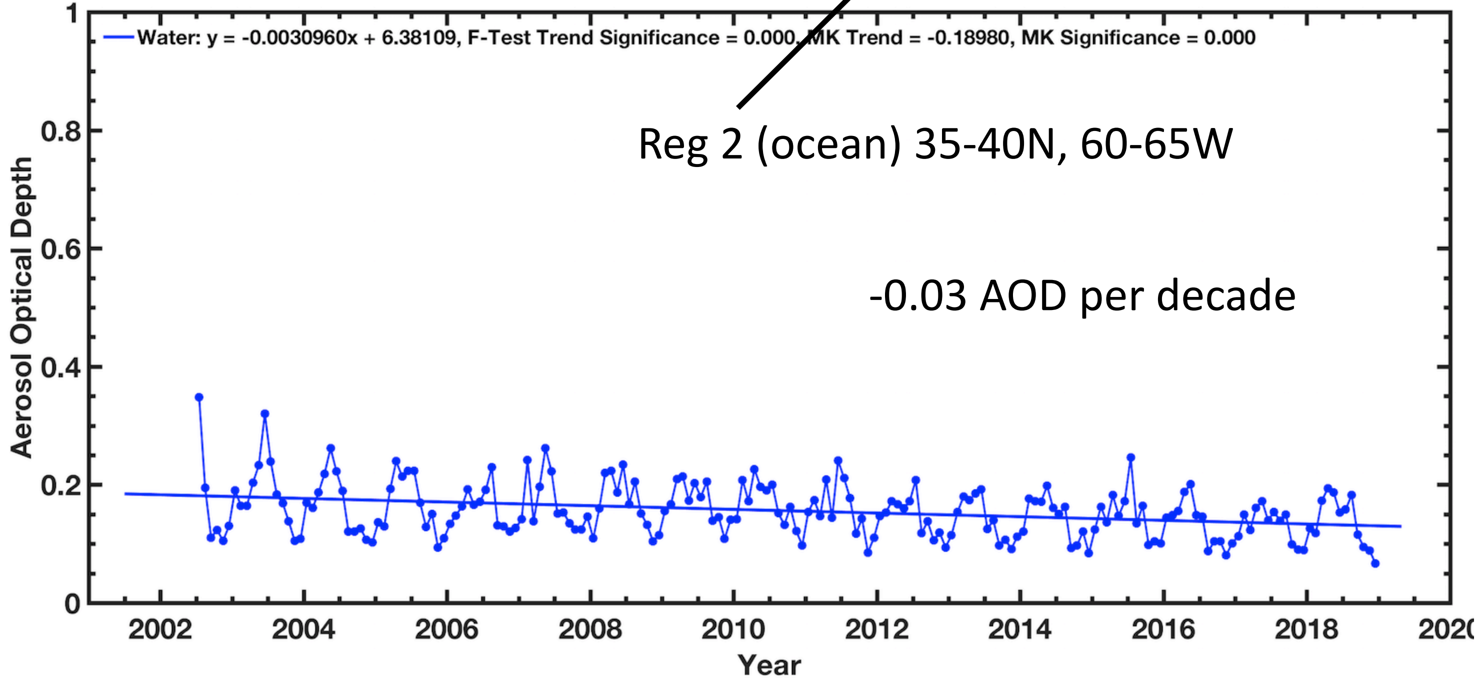


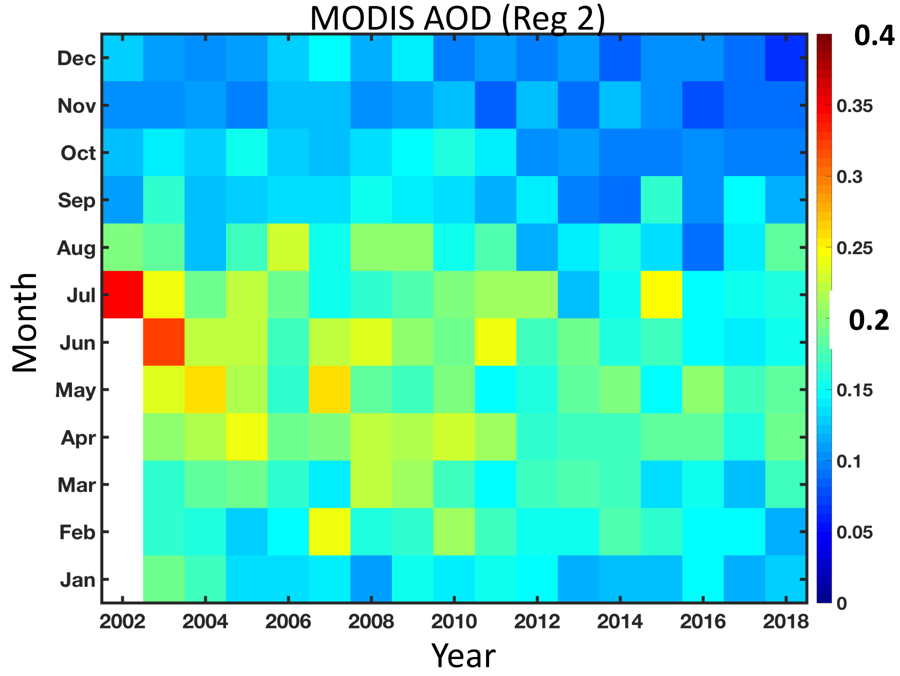
MODIS 0.55 µm Aerosol Optical Depth Trends (per decade)





- Similar story downwind over the ocean but changes not as large
- Aerosol and cloud property relationships over the eastern U.S. appear to be well correlated
- Still need to look for possible meteorological changes
- Plan to look at new FBCT product (radiative trends)





GEO UPDATE (GOES-17)

ABI cooling system not operating at capacity on the new GOES-17 satelllite

- 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

- 3.9, 10.35 µm channels ok
- 8.5 11.2, 12.3, 13.3 µm NOT ok

Will impact ability to derive accurate and consistent cloud properties at bad image times

Fake News!! →

ESTIMATED CHANNEL AVAILABILITY

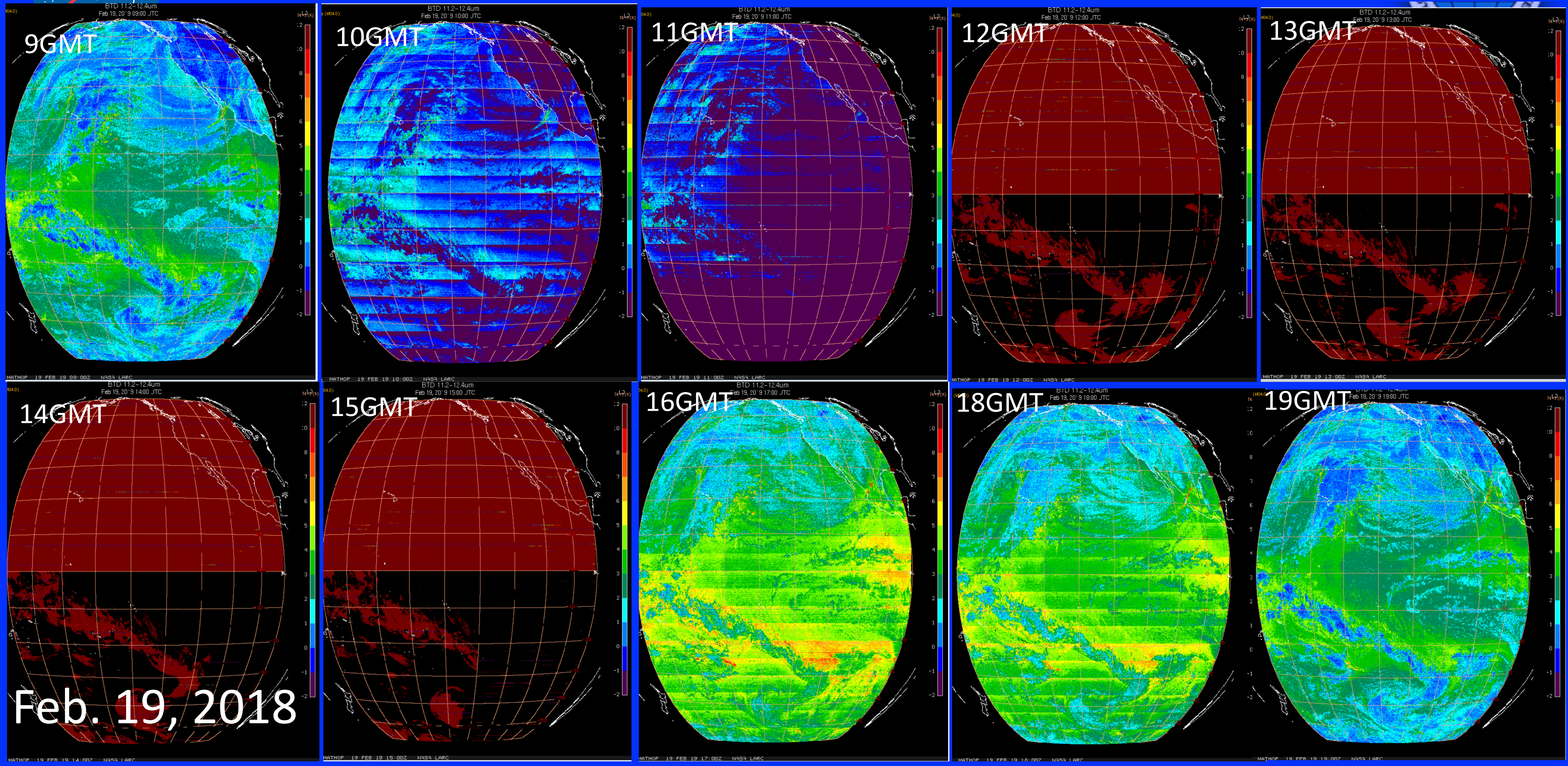
Below is the current assessment of channel availability, **as of September 13, 2018.**
Note: This is a preliminary estimate that is subject to change as experts refine channel availability.

COLOR KEY:	Available 24hrs/day	Availability Exceptions

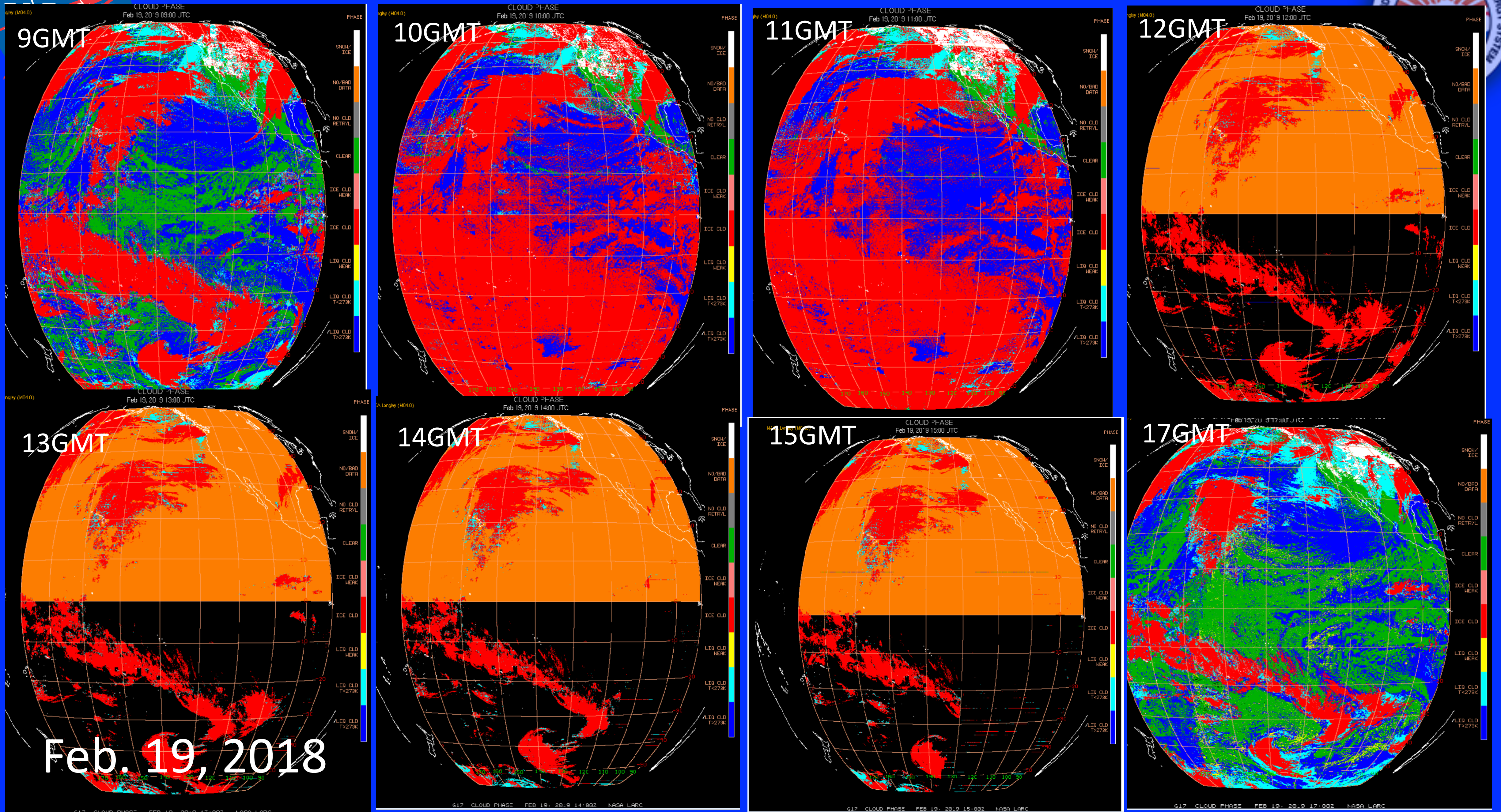
Tables scroll horizontally on smaller windows and devices.

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

Example showing 11-12µm Brightness Temperature Differences



CERES-GEO DERIVED CLOUD TOP PHASE



What to do?

- Need an objective way to flag bad images
- Could fill gaps with linear interpolation (TISA group)
- Or, somehow use the good channels to extract more information…

What to do?

We are exploring a 'Data Fusion' approach to extrapolate information from a previous good image time to a bad image time

- Uses unaffected bands to transfer information from a previously unaffected hour
- Employs KDTREE - multivariate nearest neighbor search algorithm
  - developed by industry, highly efficient
  - available in MatLab and other programming languages
  - Method has been demonstrated to create the missing 6.7 µm and 13 µm channels for VIIRS using CrIS data – i.e. make VIIRS more like MODIS (Weisz et al 2017)
  - UW-Madison/NOAA testing the creation of synthetic GOES-17 radiances to replace bad images affected by the cooling issue
- Two approaches being tested by CERES CWG
  1. Create the missing radiance fields synthetically and apply cloud retrieval algorithm to derive cloud properties
  2. Create synthetic cloud properties (translate cloud properties from good hour to a bad hour)

Both approaches are based on use of two unaffected bands; 7 (3.9 µm) and 13 (10.3 µm)

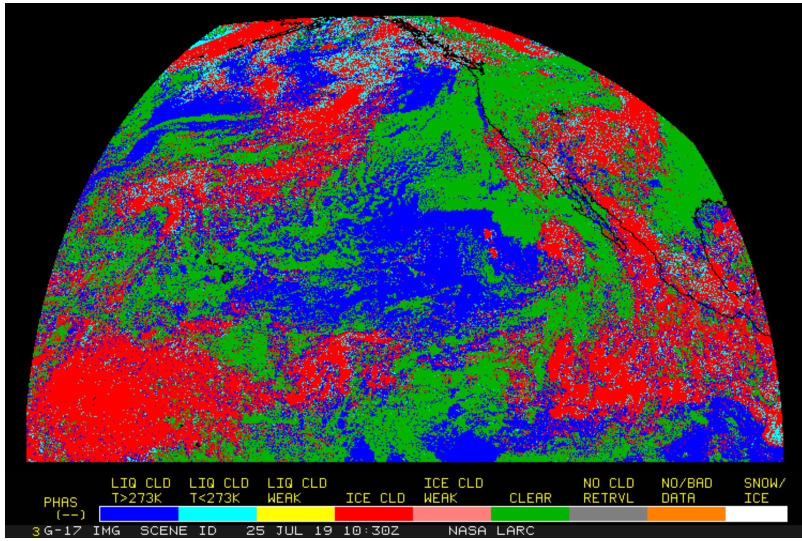
GOES-17 NIGHT-TIME IR-SENSOR COOLING PROBLEM MITIGATION using KD-TREE approach

Initial Test Case

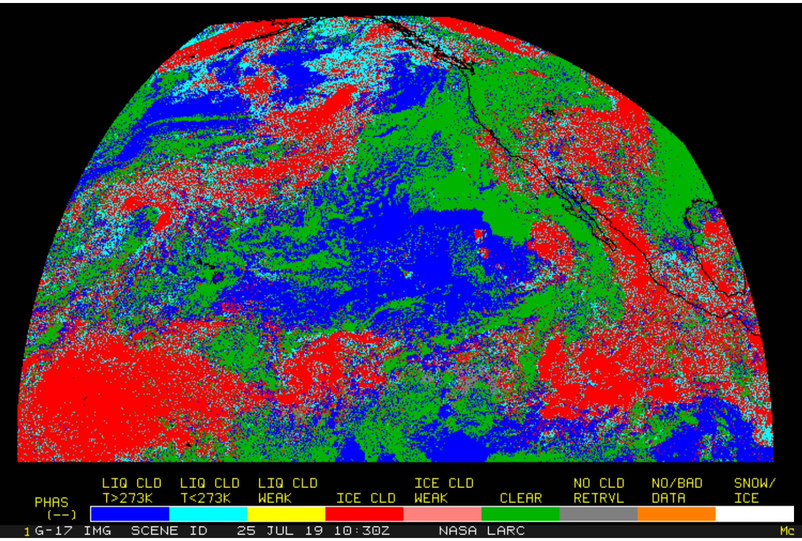
- GOES-17 nighttime data from 25th July, 2019
- The 0930 UTC image is used as the reference (unaffected by Eclipse)
- Synthetic BTs created at 1030, 1130 and 1230 UTC for Bands 11(8.4mm), 14(11.2mm), 15(12.3mm), and 16(13.3mm)
- CERES GEO cloud retrieval algorithm run using the synthetic BTs for these bands.
- synthetic cloud properties for the 3 hours based also created based on those retrieved at 0930 UTC (cloud_phase, cloud_visible_optical_depth, and cloud_top_height)

GOES-17 , 10:30 UTC, 25th July, 2019

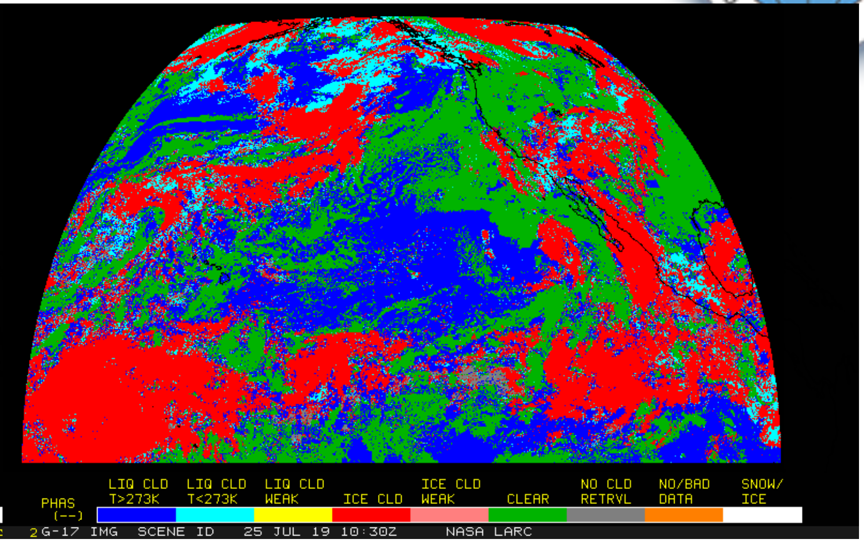
PHASE FROM SYNTHETIC RAD



SYNTHETIC PHASE



REGULAR PHASE



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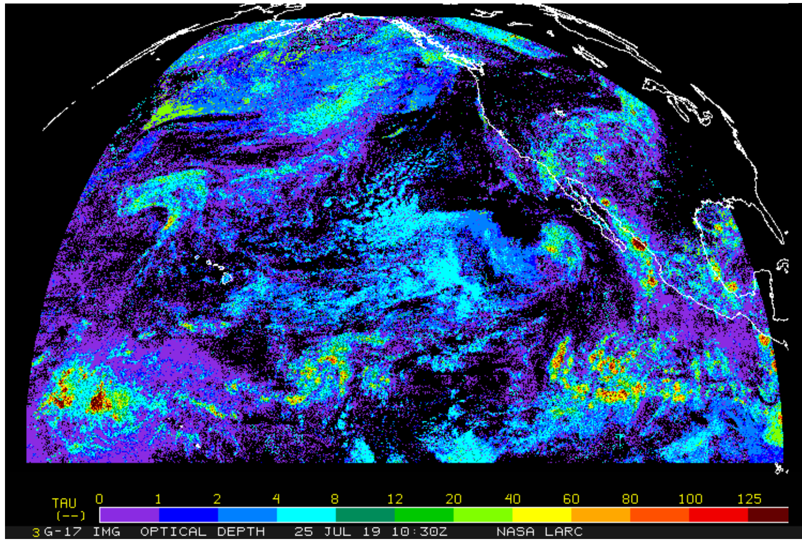

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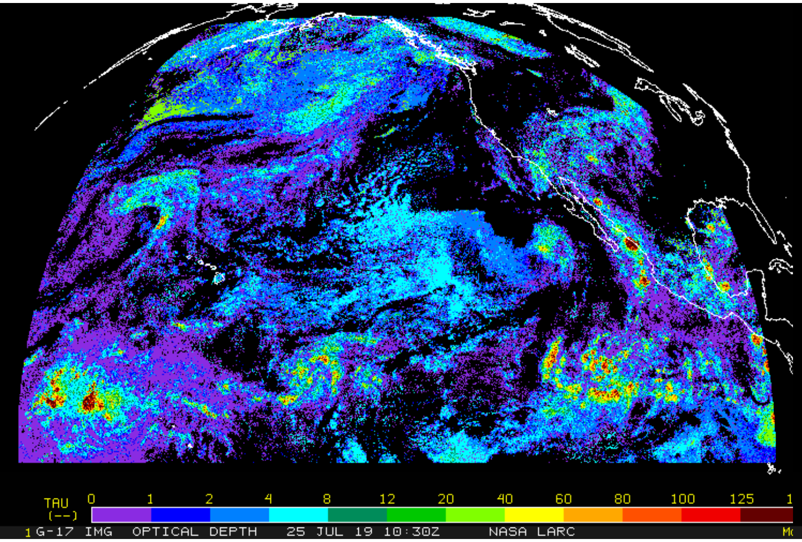

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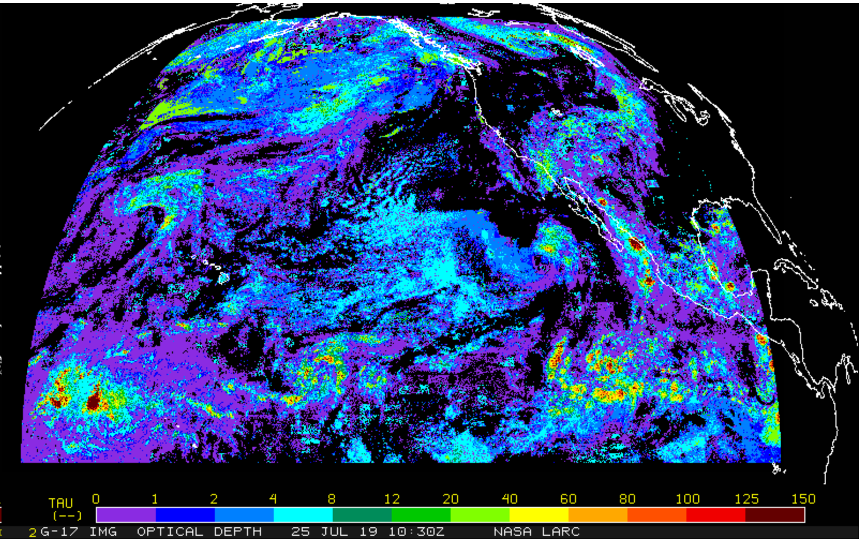

GOES-17 , 10:30 UTC, 25th July, 2019

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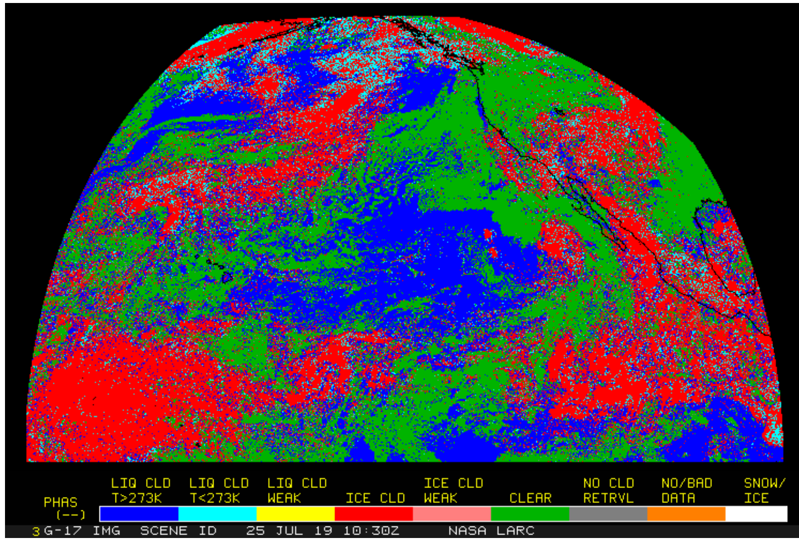

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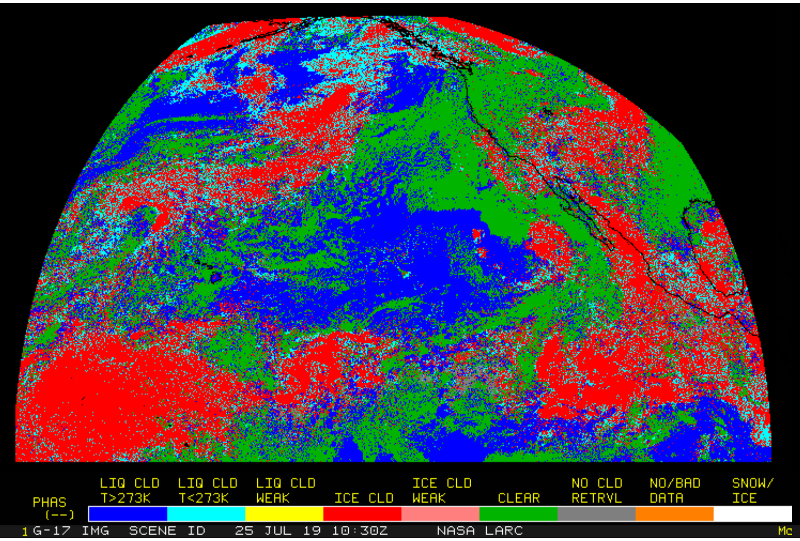

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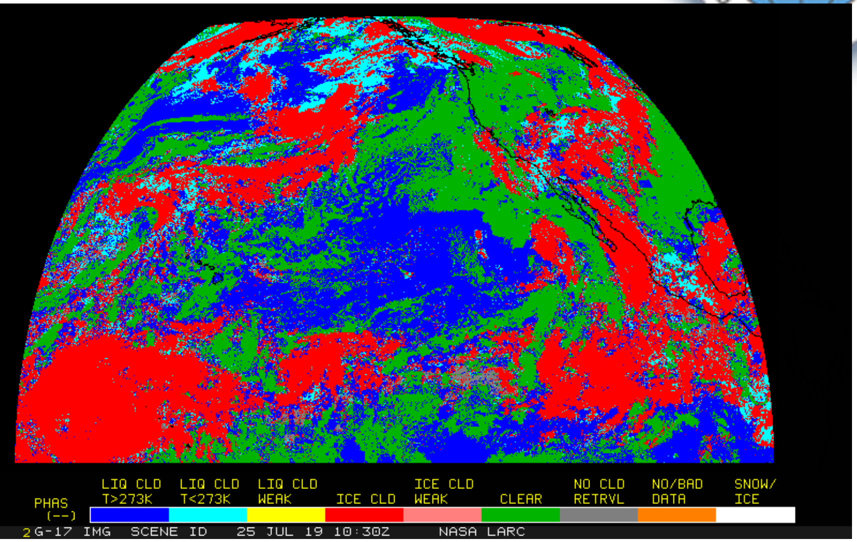

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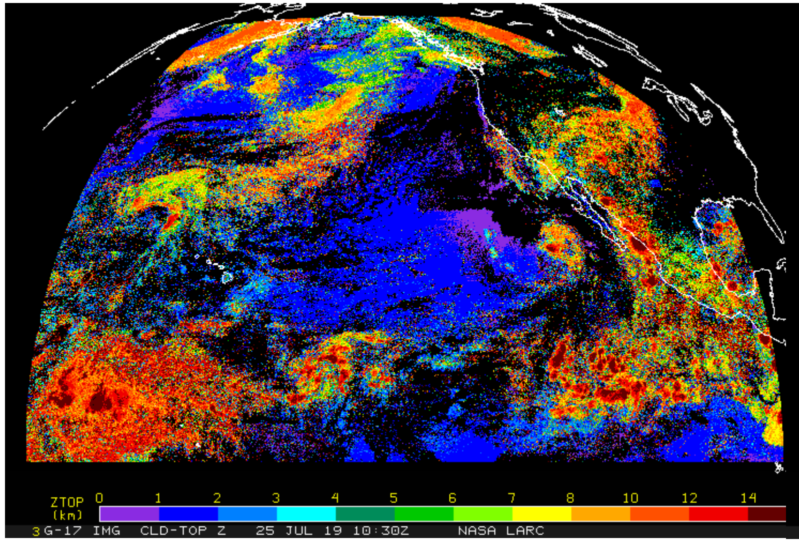

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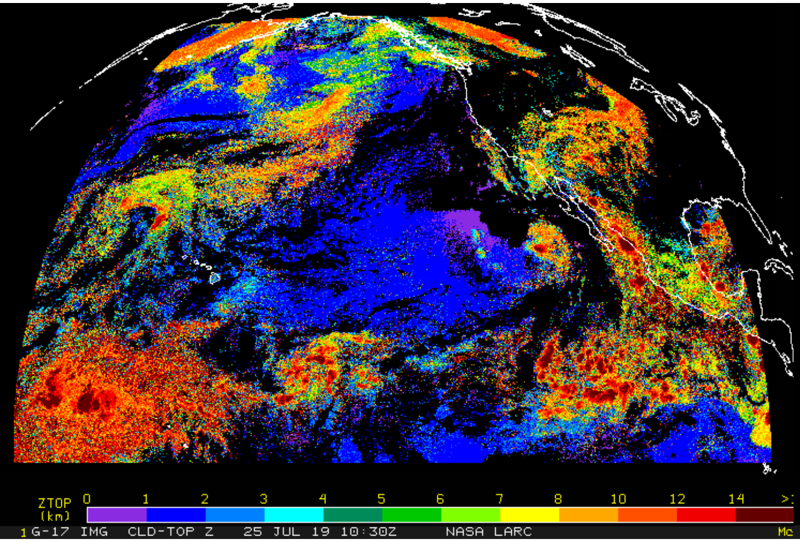

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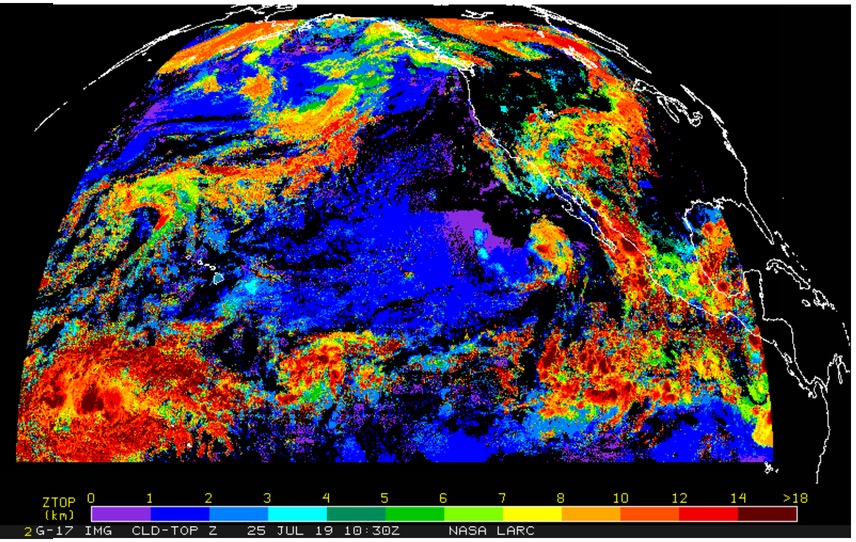

GOES-17 , 10:30 UTC, 25th July, 2019

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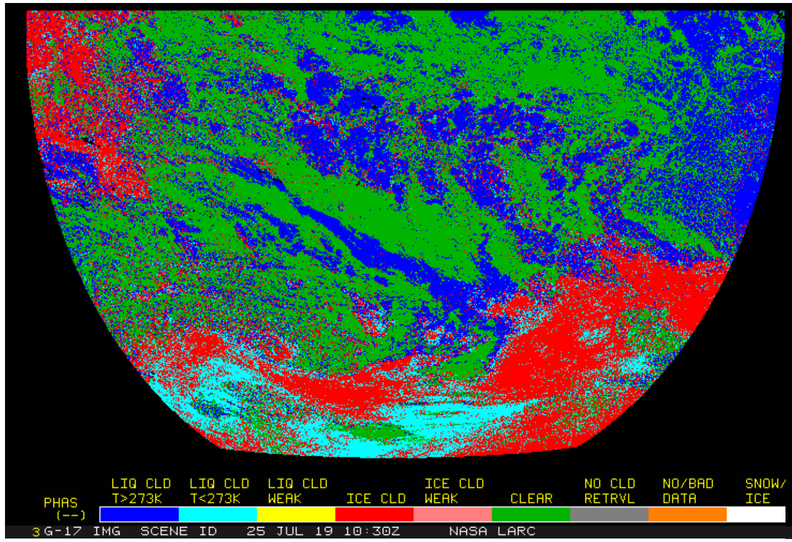

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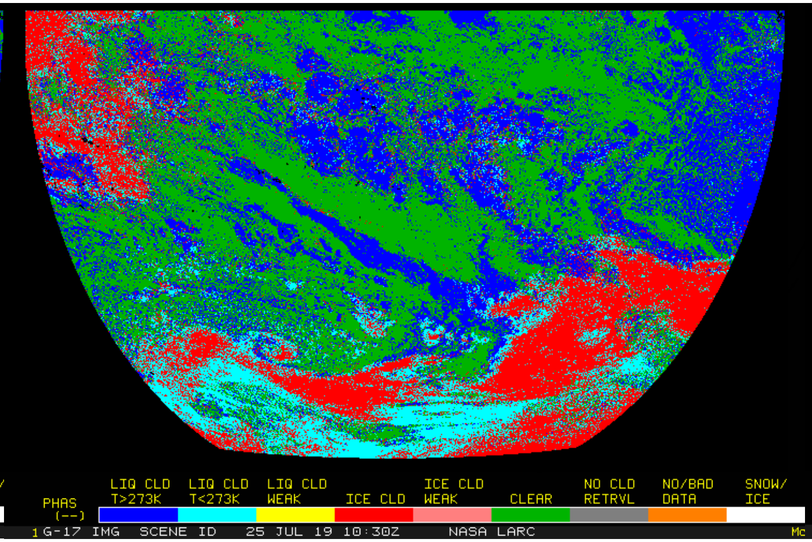

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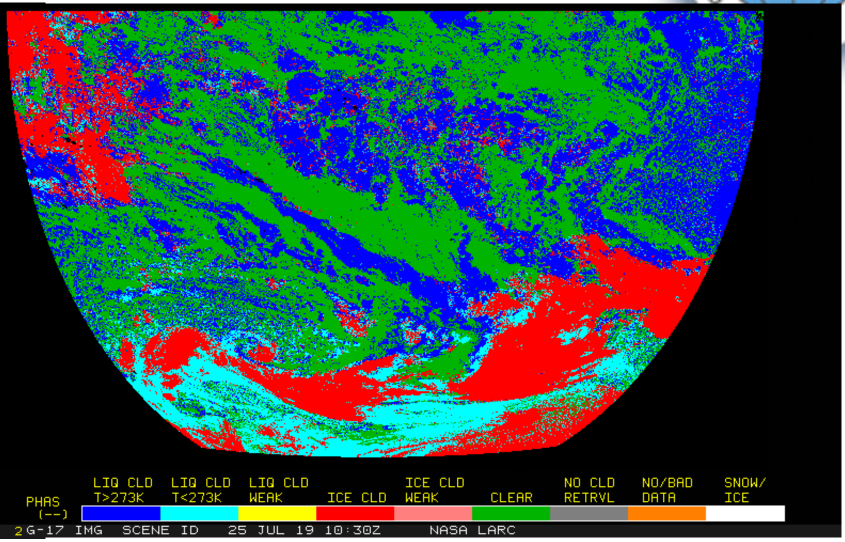

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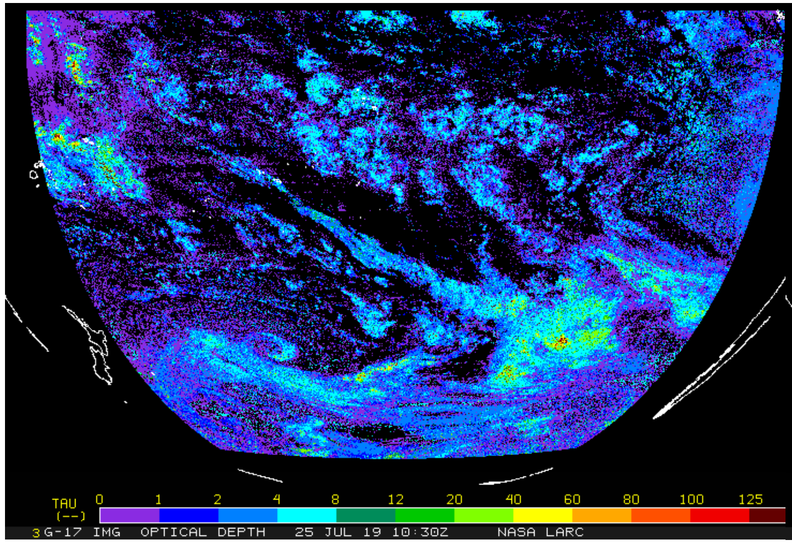

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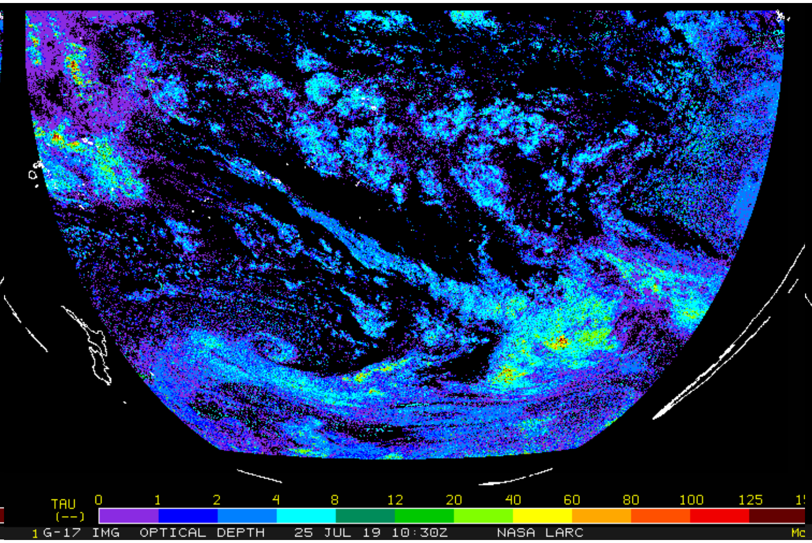

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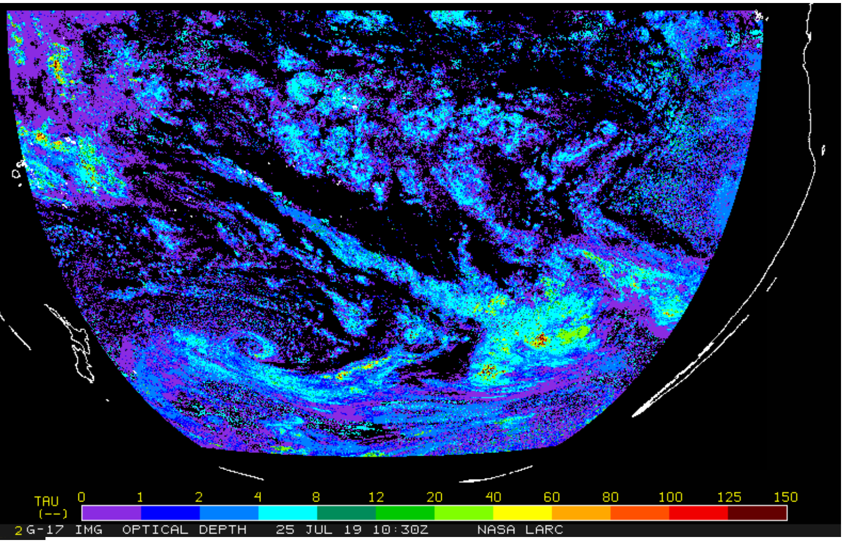

GOES-17 , 10:30 UTC, 25th July, 2019

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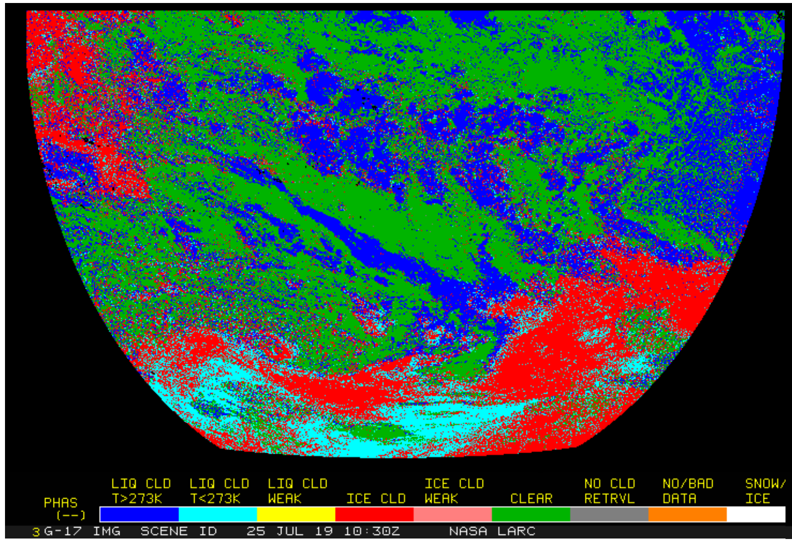

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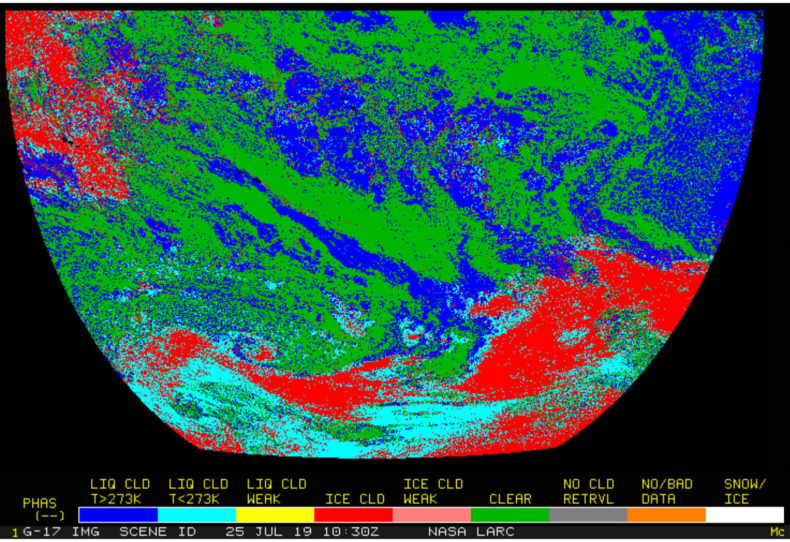

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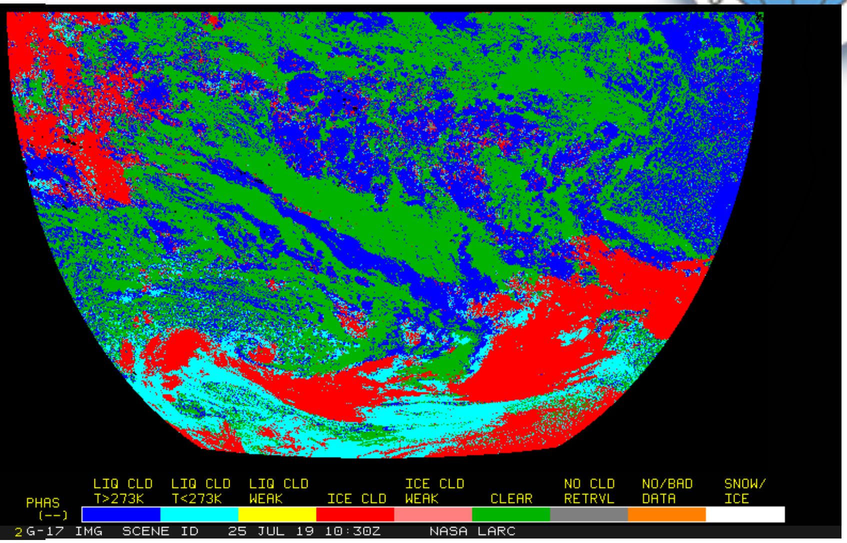

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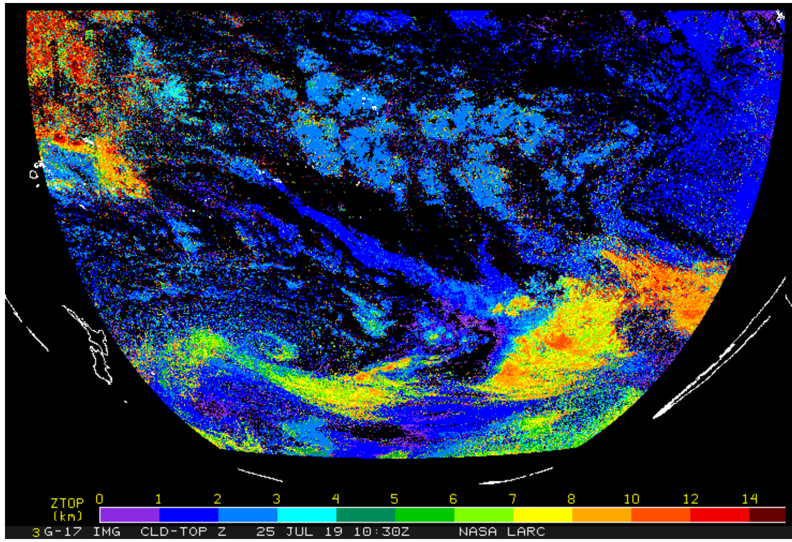

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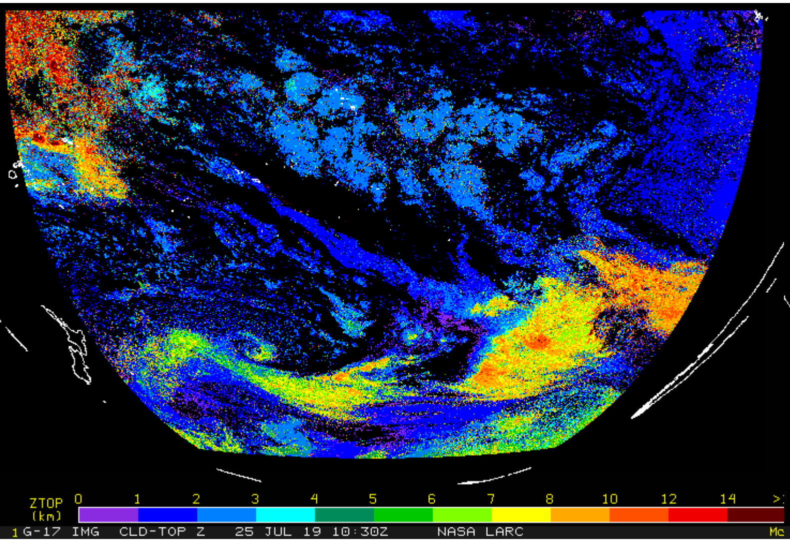

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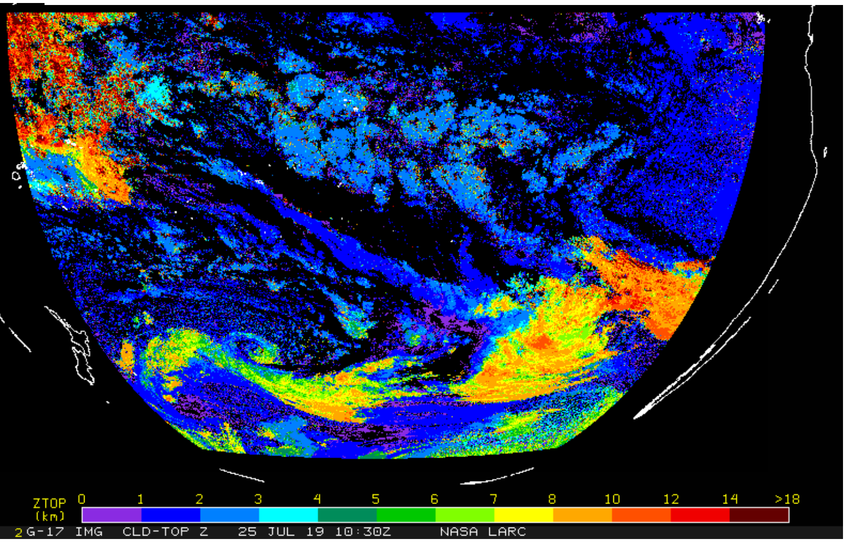

GOES-17 , 11:30 UTC, 25th July, 2019

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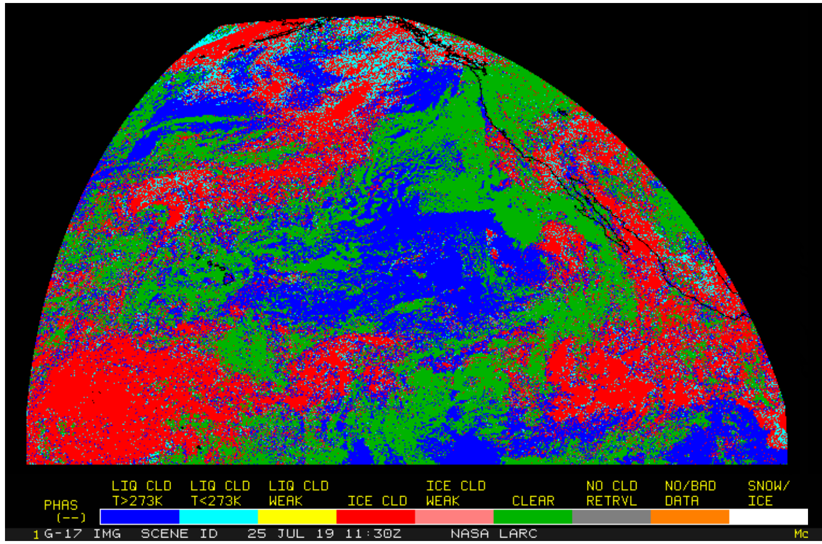

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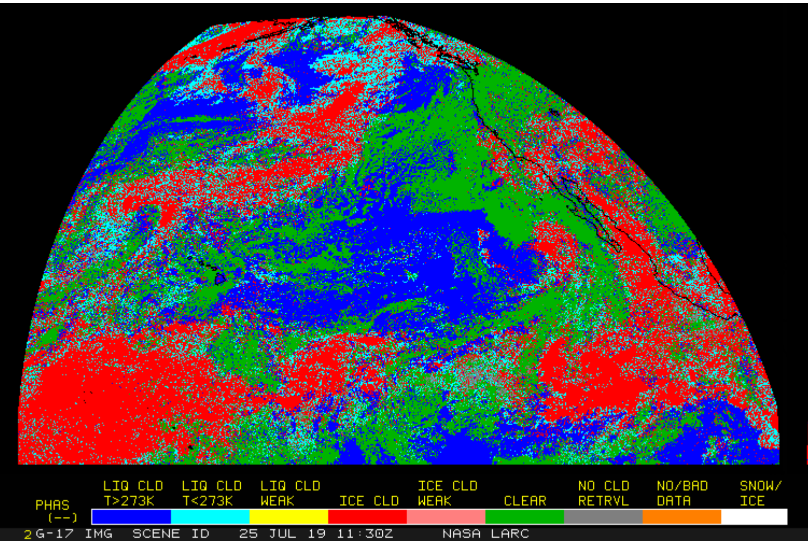

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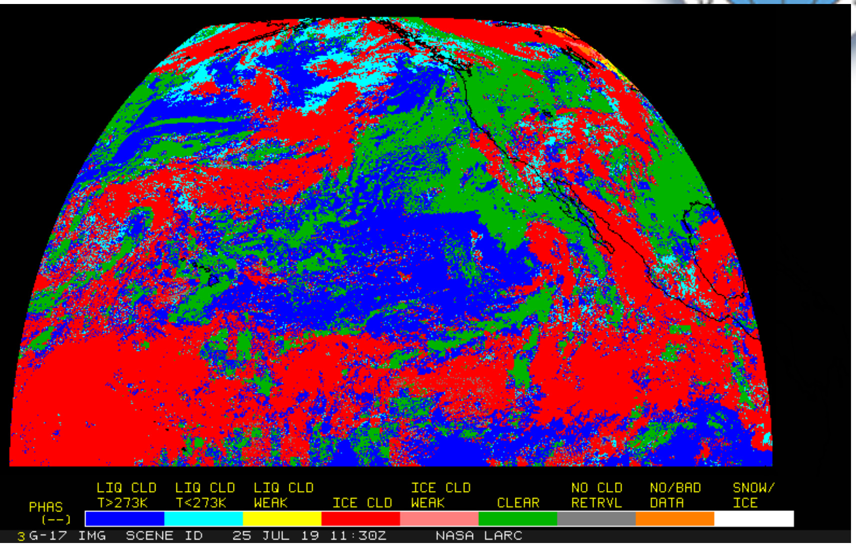

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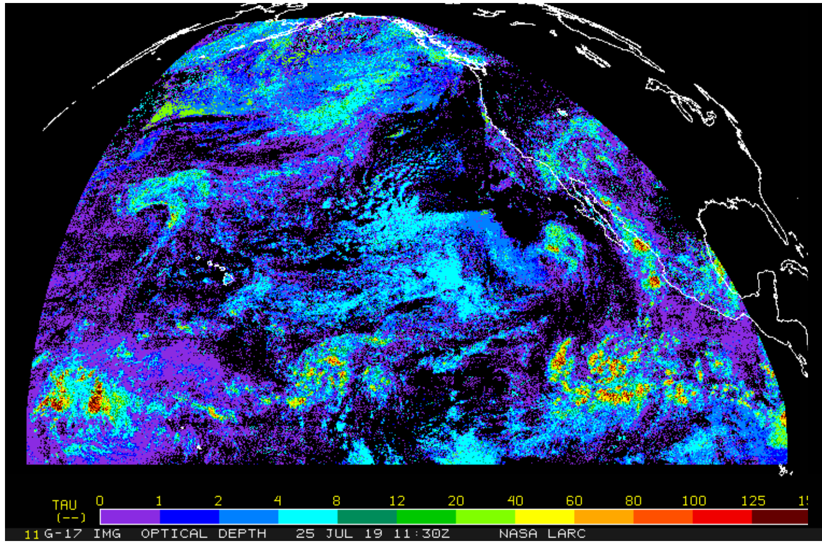

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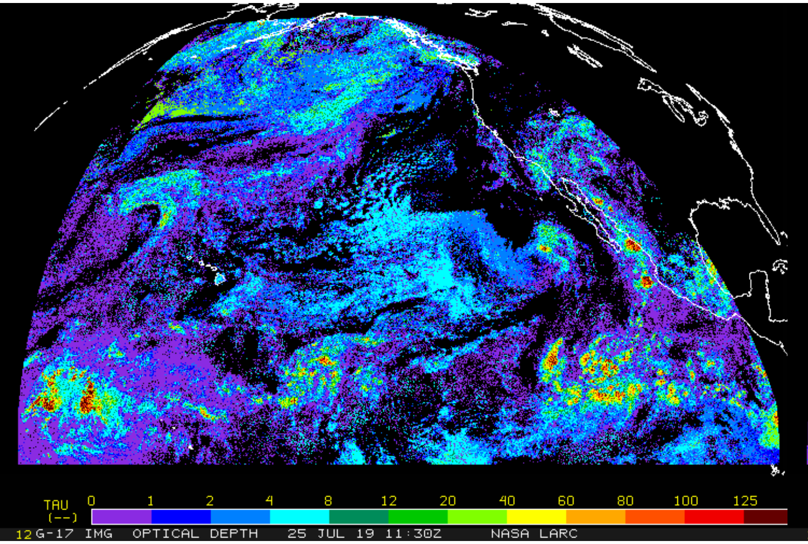

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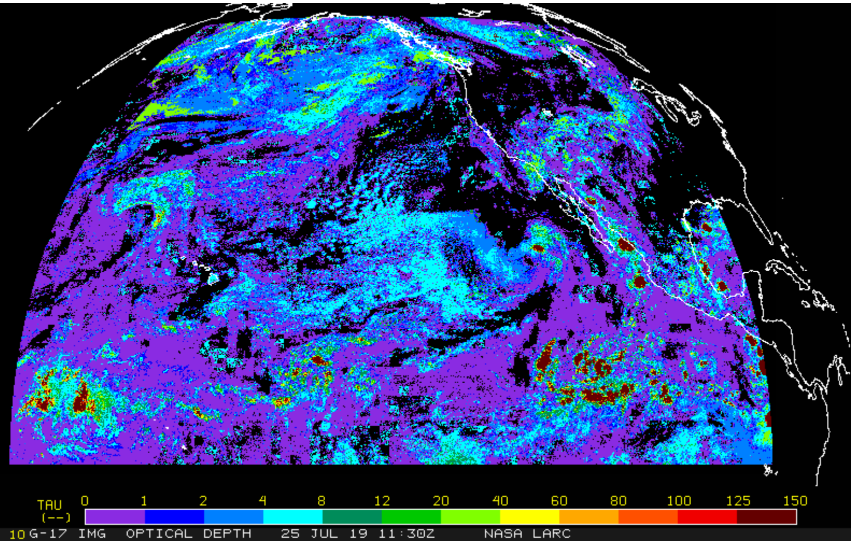

GOES-17 , 11:30 UTC, 25th July, 2019

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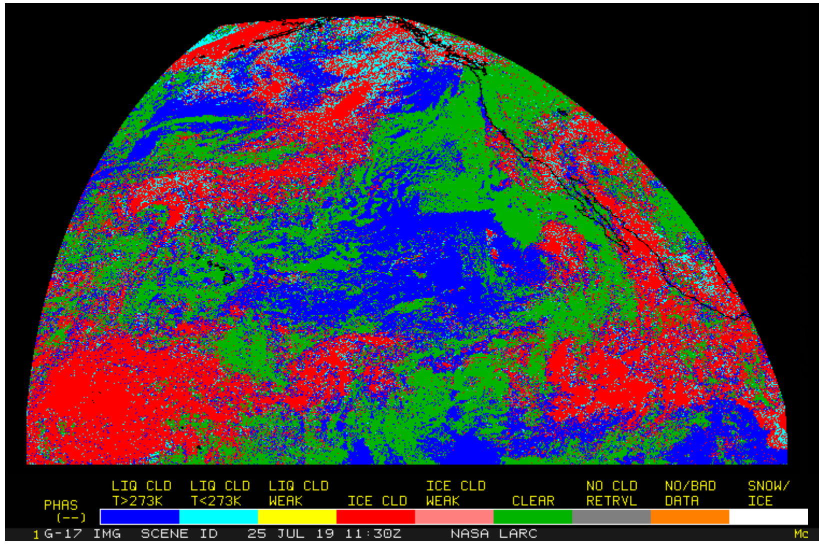

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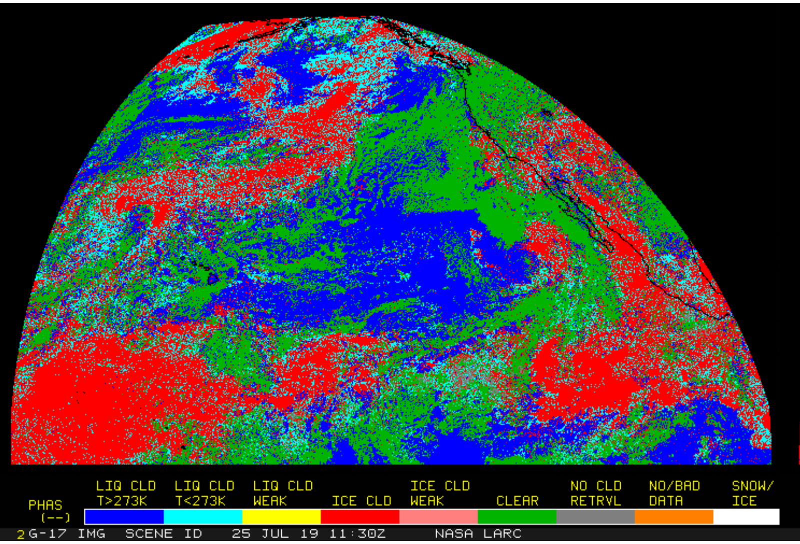

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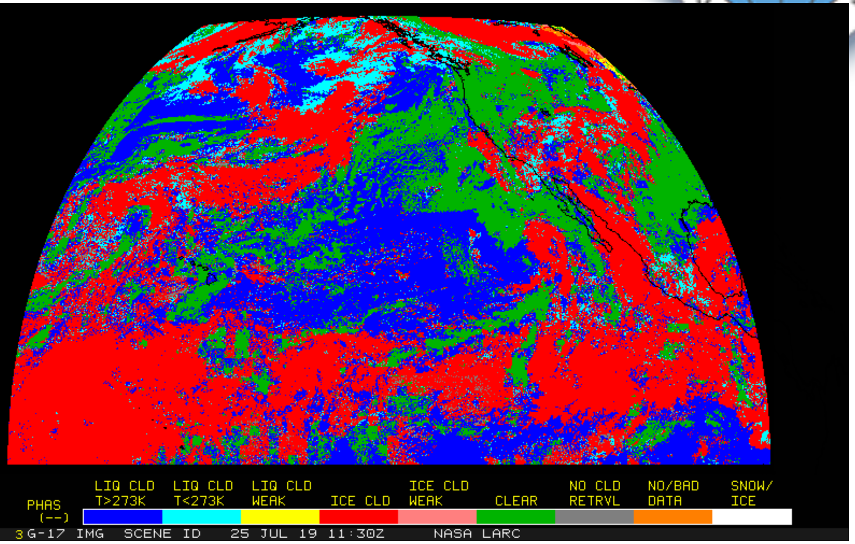

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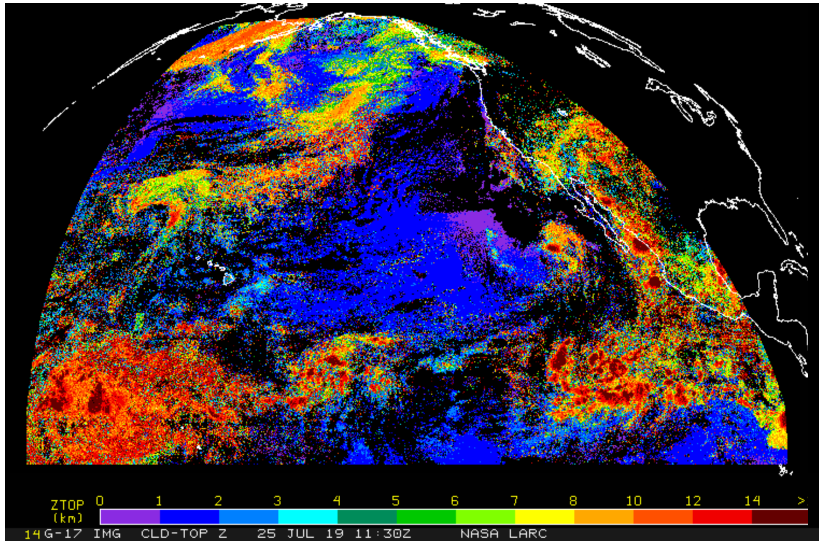

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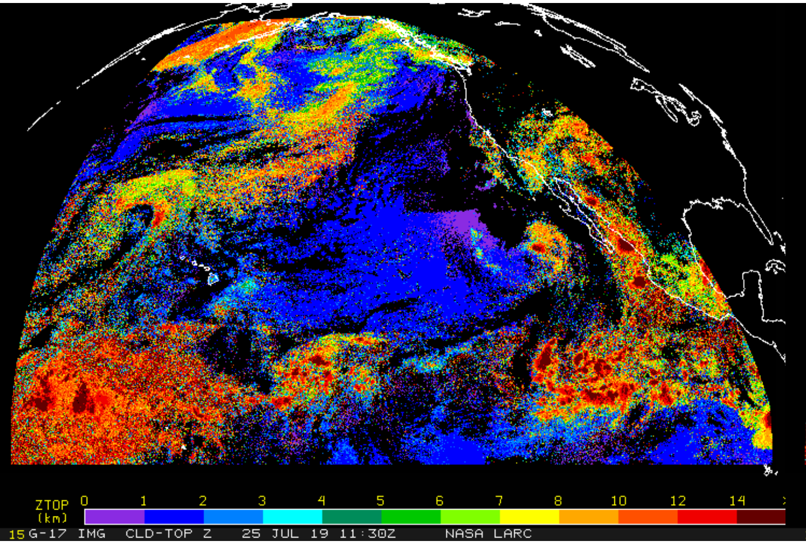

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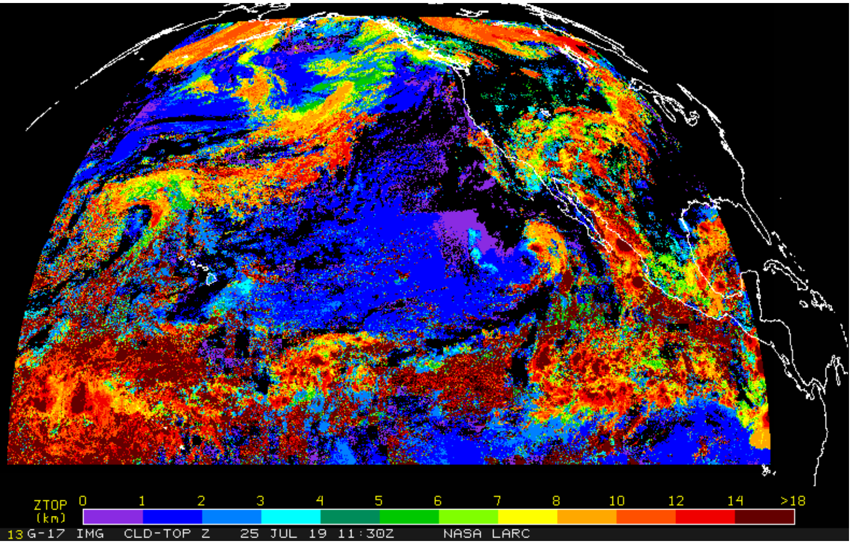

GOES-17 , 11:30 UTC, 25th July, 2019

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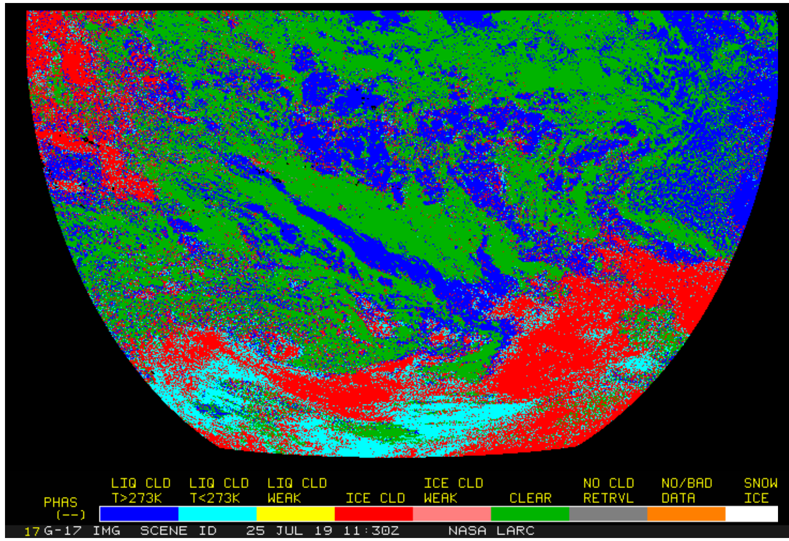

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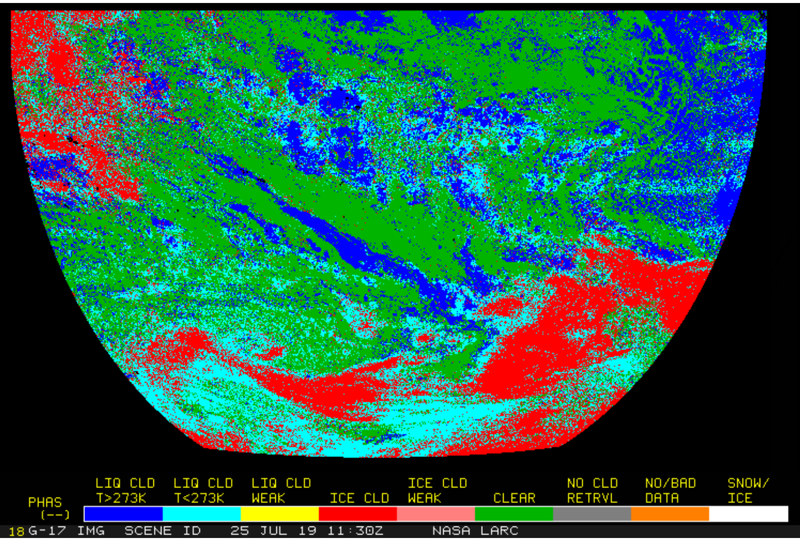

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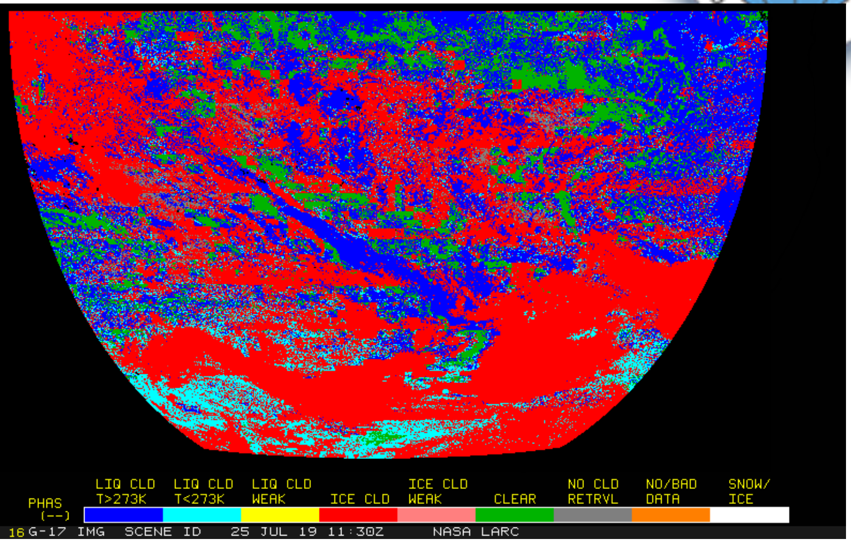
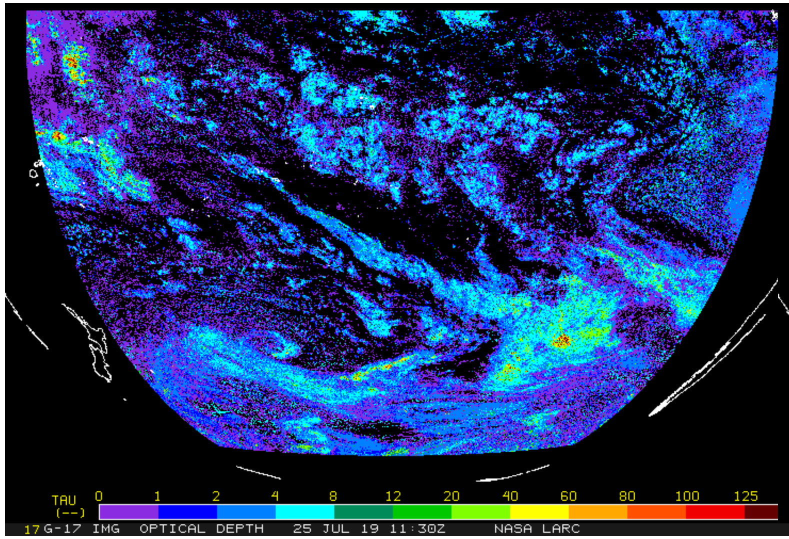


TAU FROM SYNTHETIC RAD



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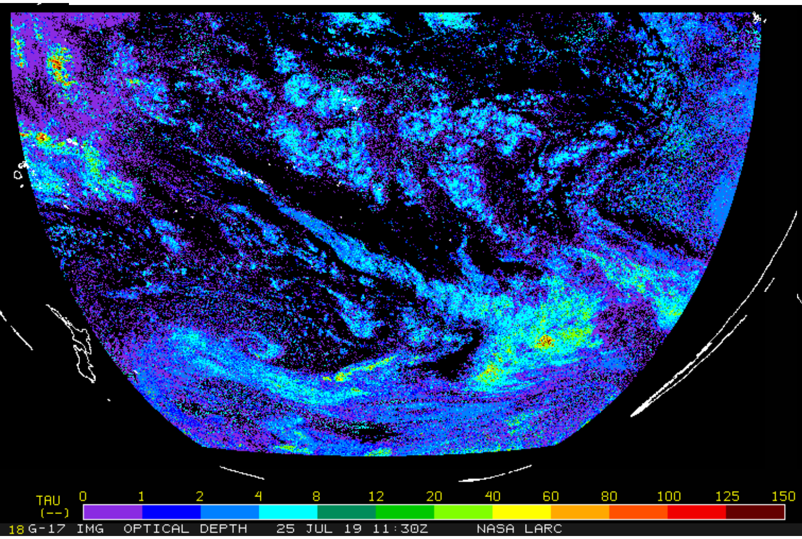

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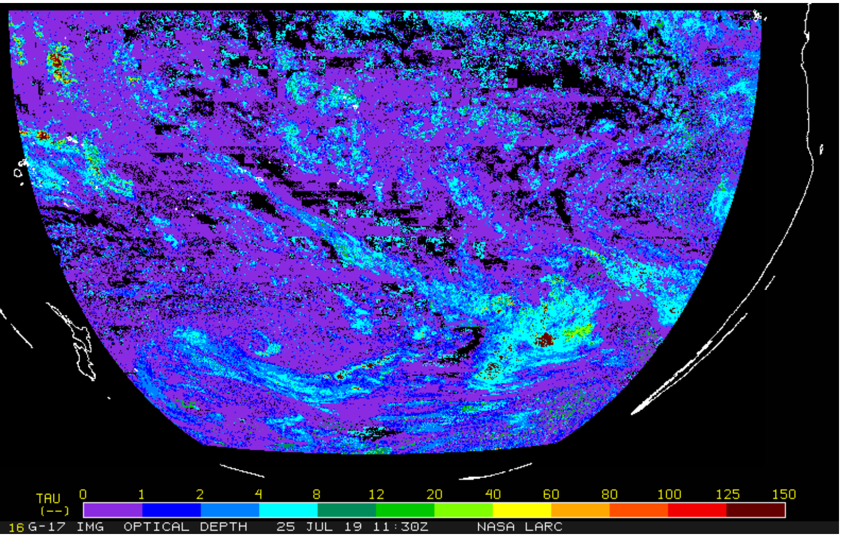
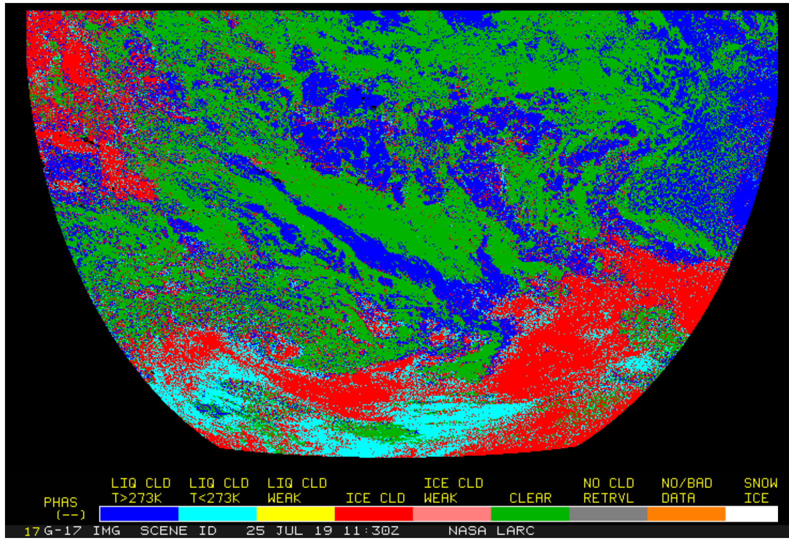


GOES-17 , 11:30 UTC, 25th July, 2019

PHASE FROM SYNTHETIC RAD



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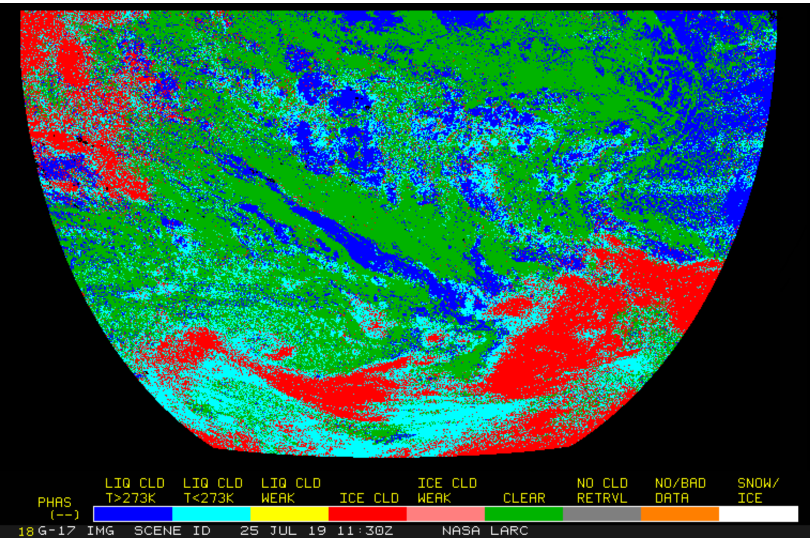

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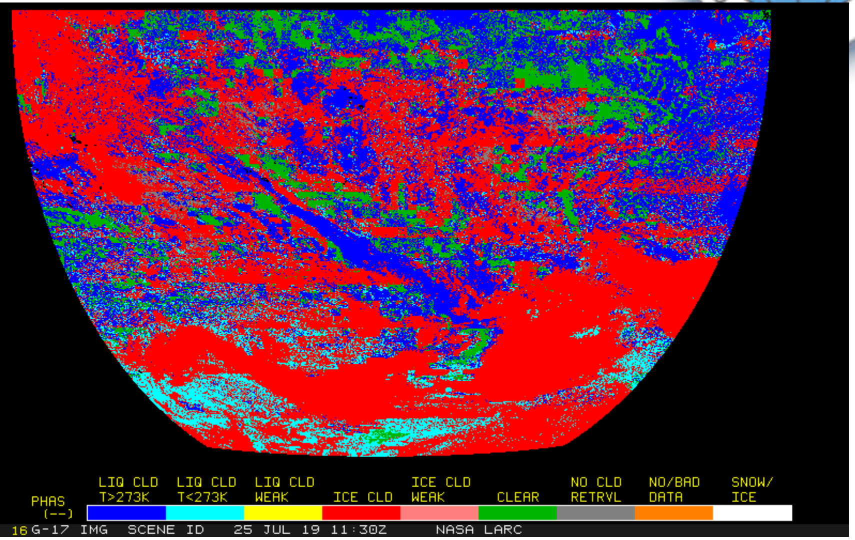
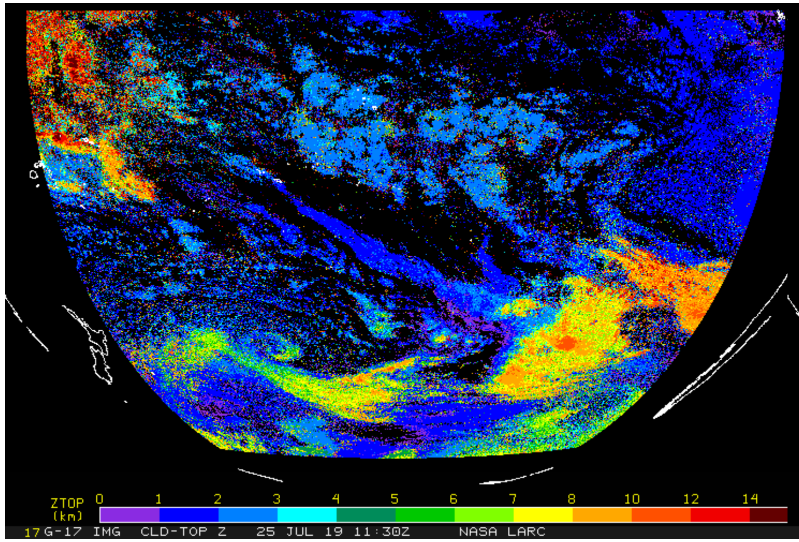
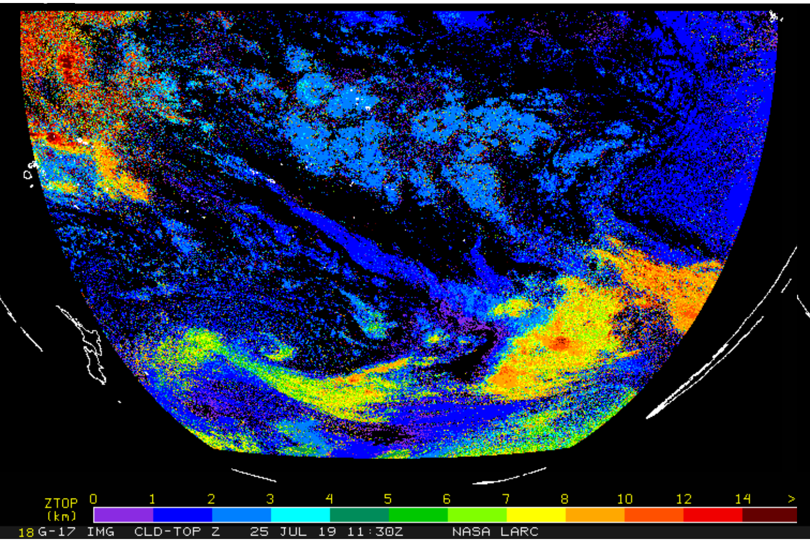


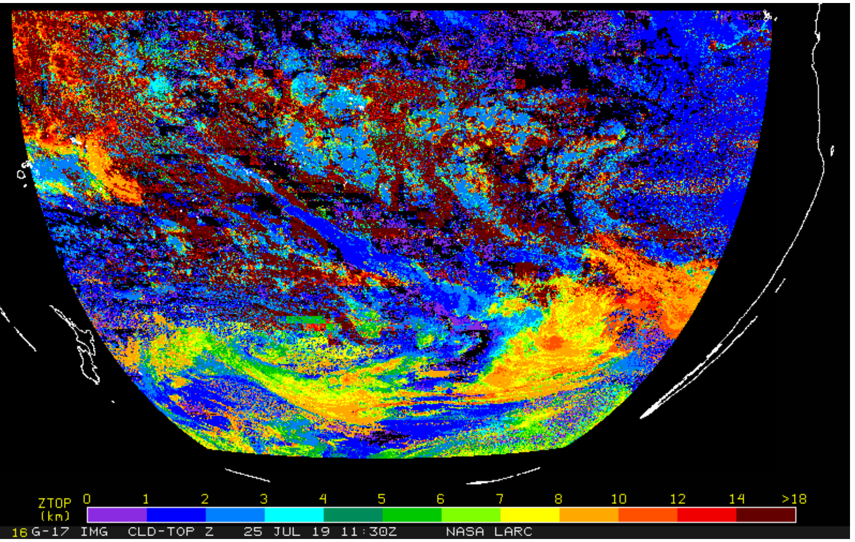
ZTOP FROM SYNTHETIC RAD



SYNTHETIC ZTOP

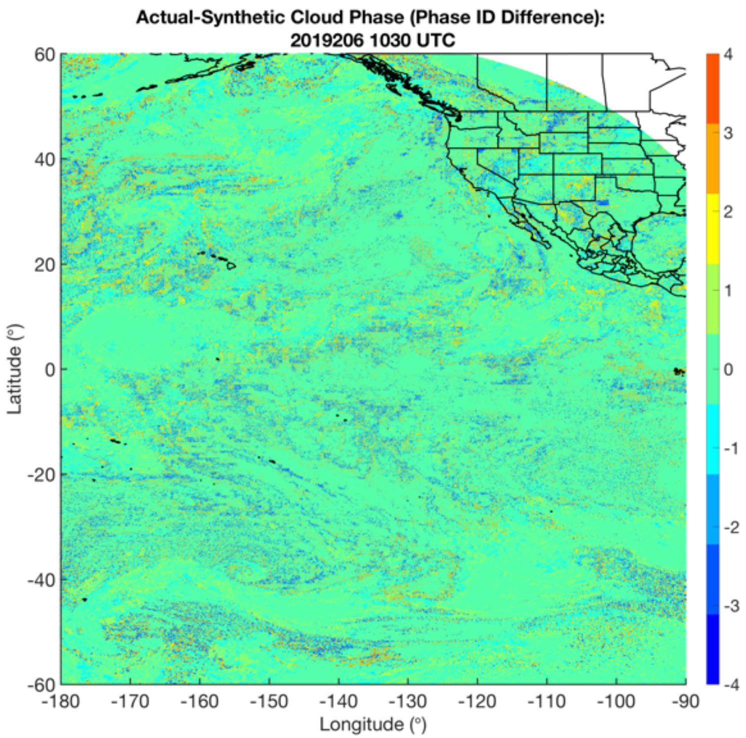


REGULAR ZTOP

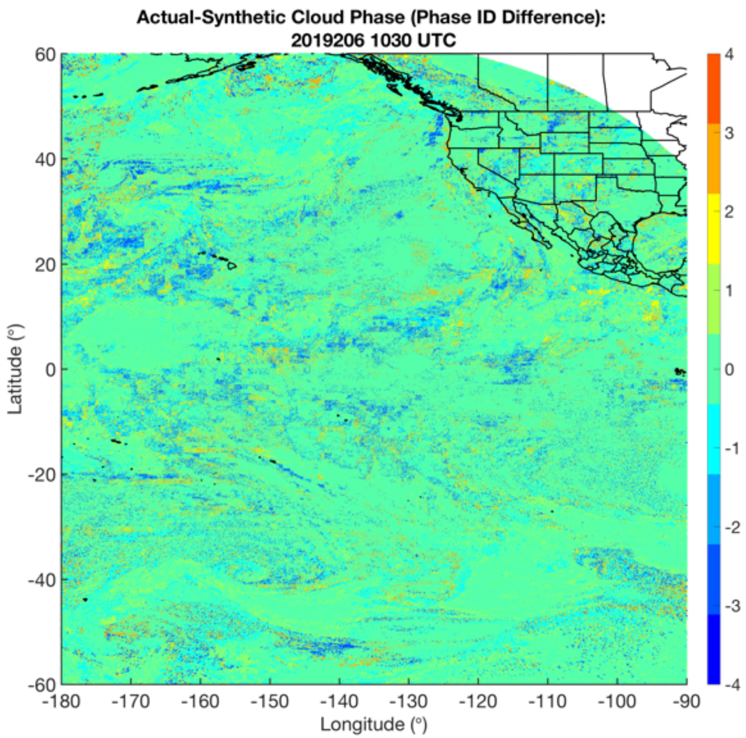


10: 30 UTC

Synthetic Phase vs. Regular Phase



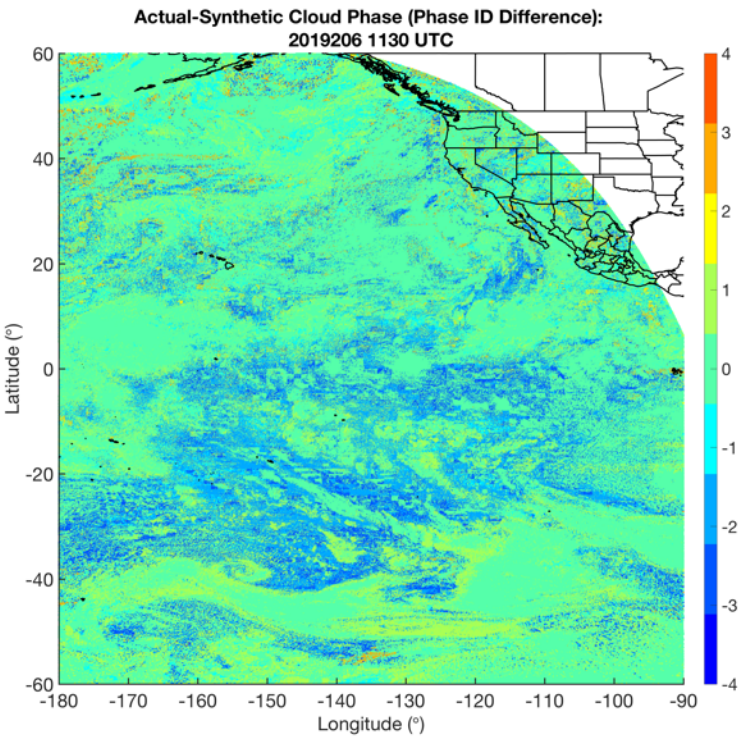
Phase From Synthetic Rad vs. Regular Phase



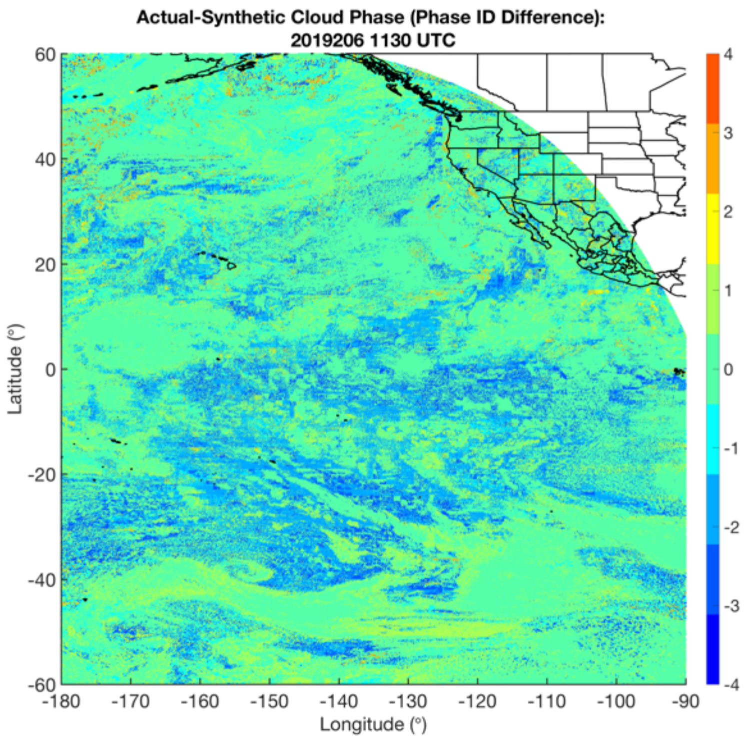
Decent agreement overall but somewhat noisy
Synthetic phase looks a little better than that retrieved from synthetic radiances

11: 30 UTC

Synthetic Phase vs. Regular Phase

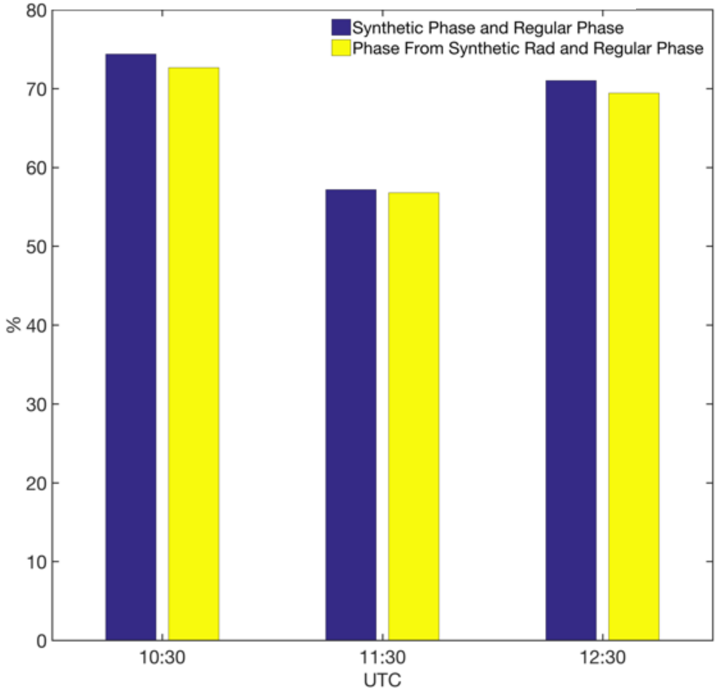


Phase From Synthetic Rad vs. Regular Phase



CLOUD PHASE AGREEMENT

SYNTHETIC VS RETRIEVED



Agreement much worse at 1130 UTC
- Standard retrieval affected by Eclipse problem

Blue: Synthetic Phase

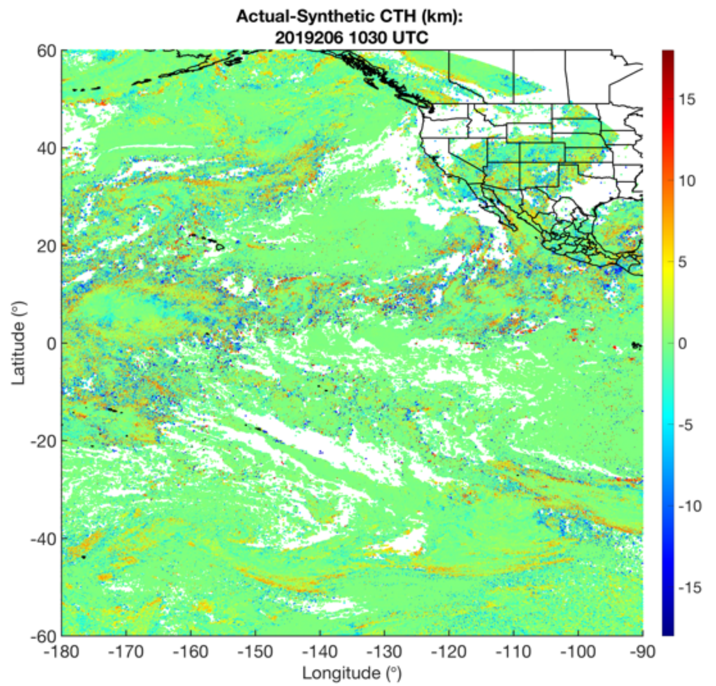
Yellow: Phase from synthetic radiances

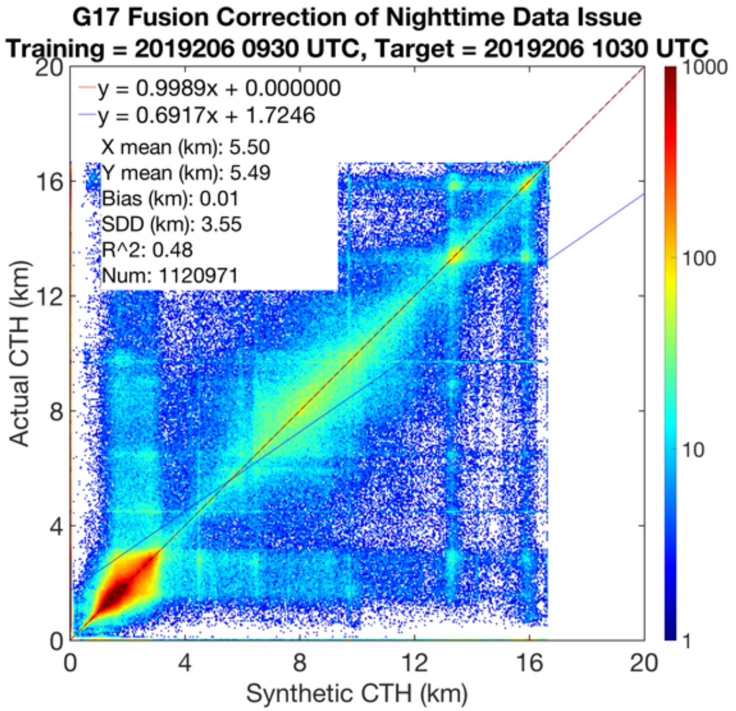
Both compared to retrieved phase from observed radiances

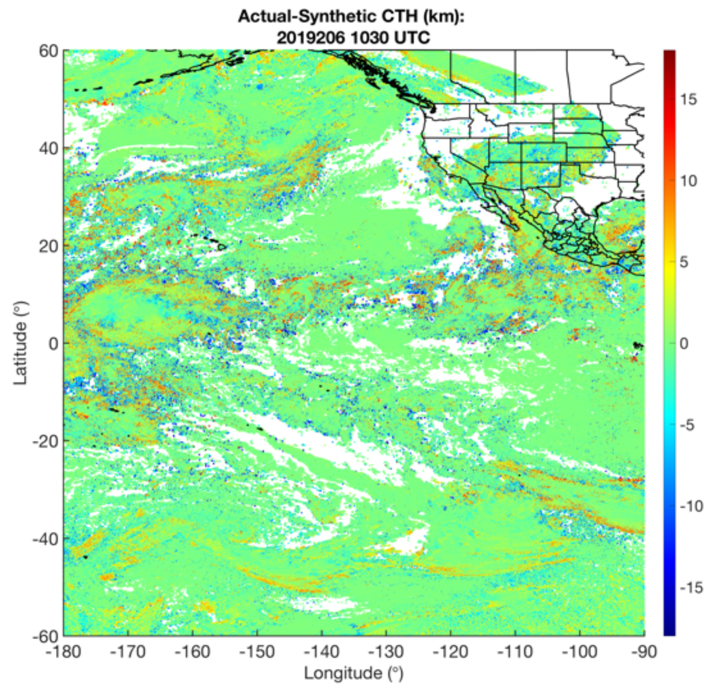
Note: 1130 utc has bad obs (Eclipse)

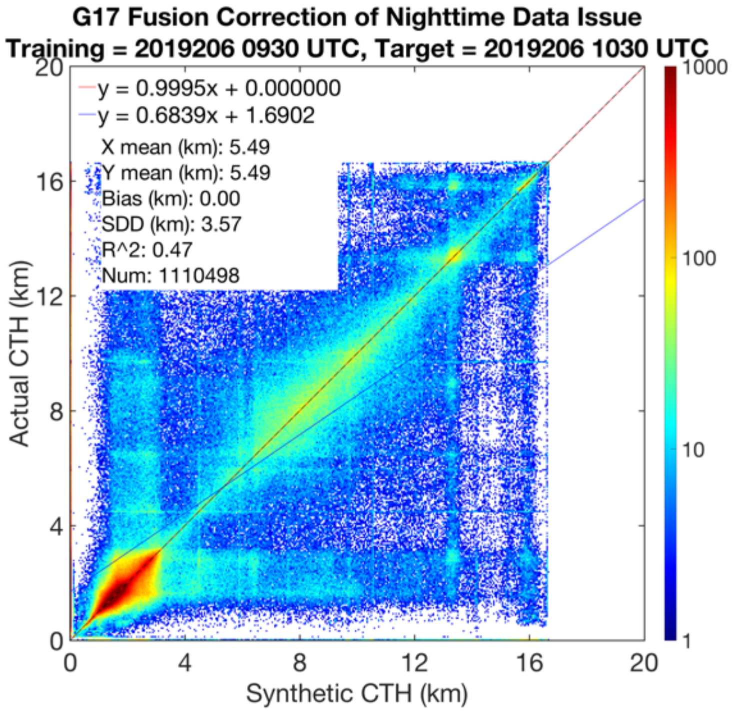
10: 30 UTC

Synthetic CTH vs. Regular CTH





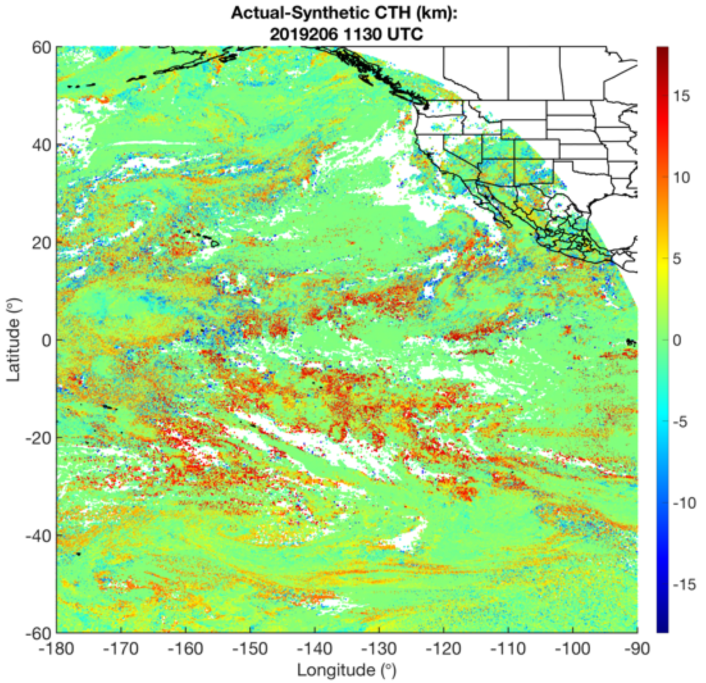


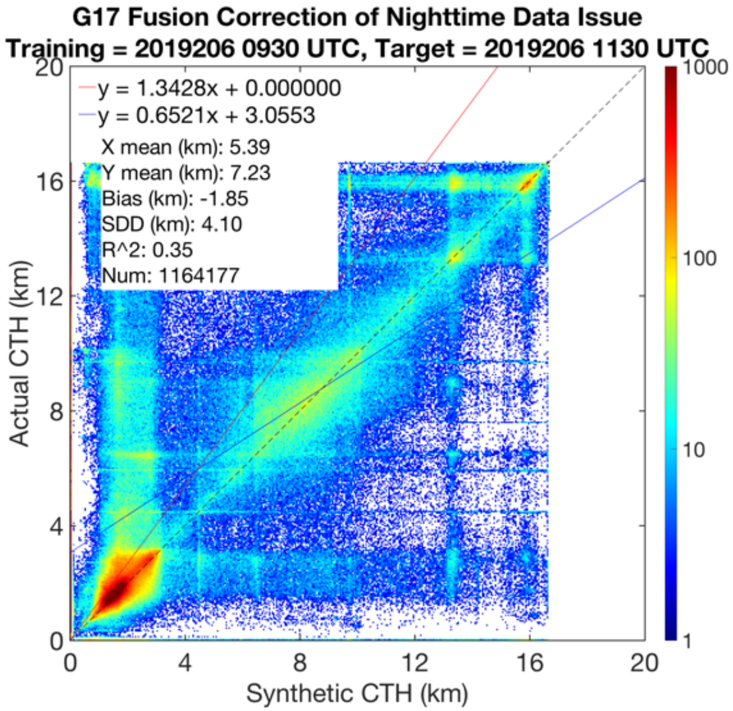


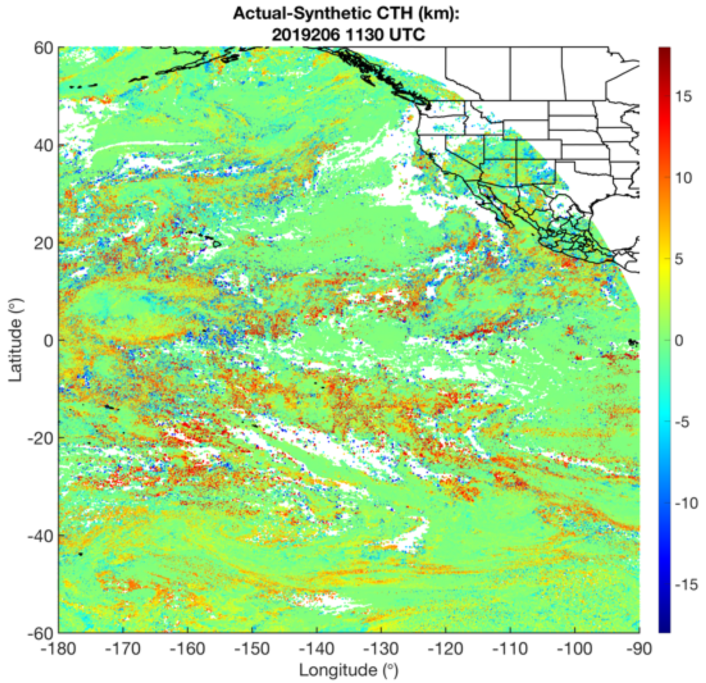
CTH From Synthetic Rad vs. Regular CTH

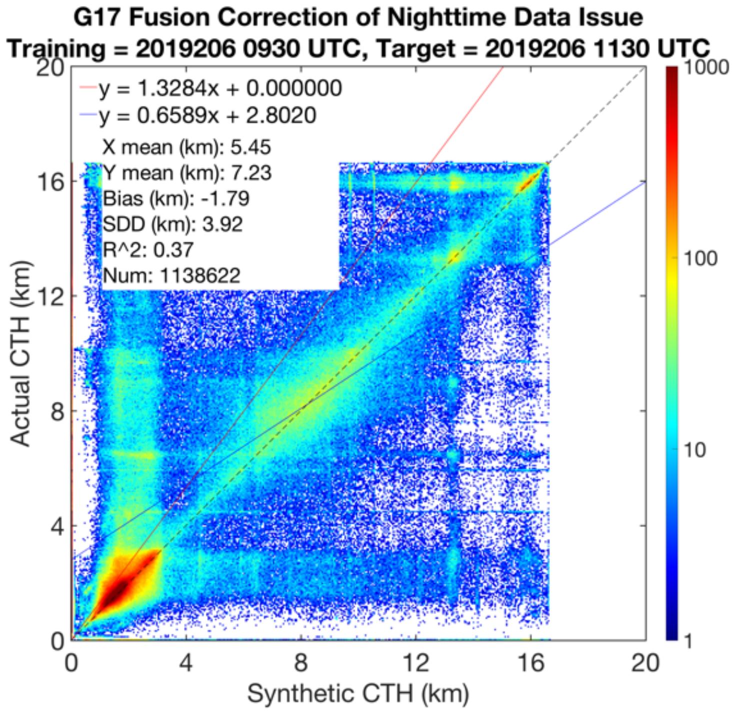
11: 30 UTC

Synthetic CTH vs. Regular CTH





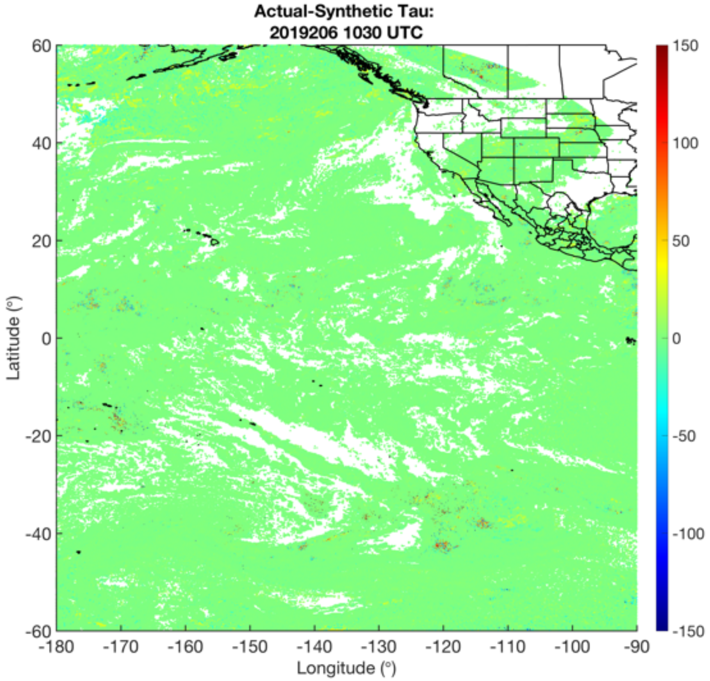


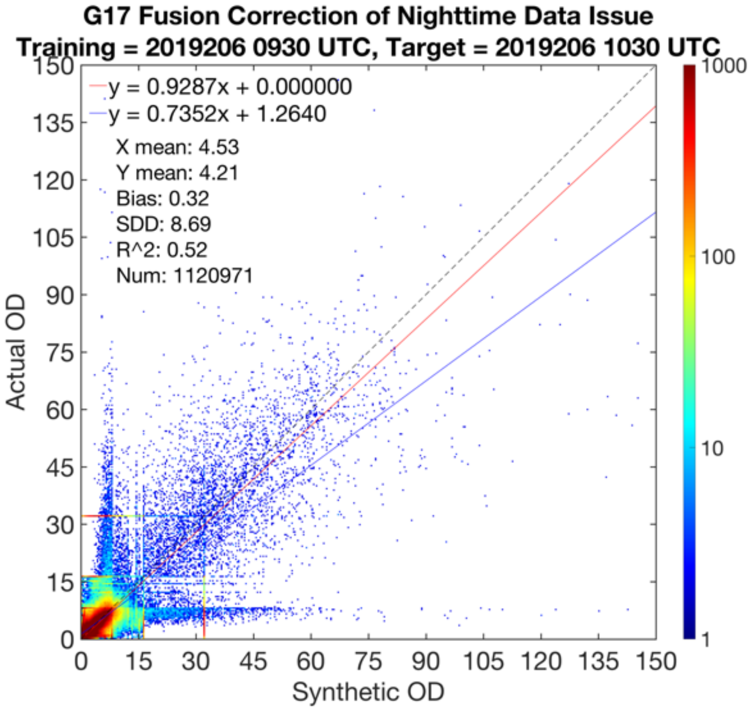


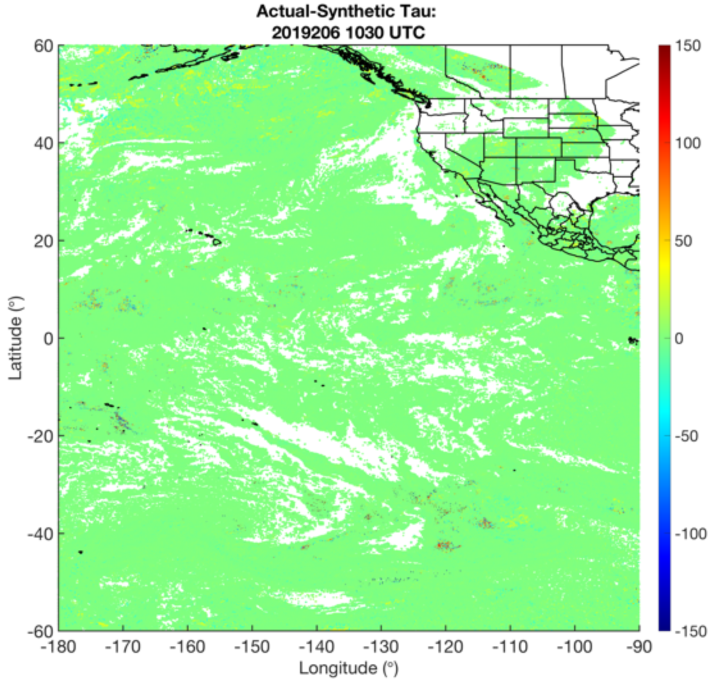
CTH From Synthetic Rad vs. Regular CTH

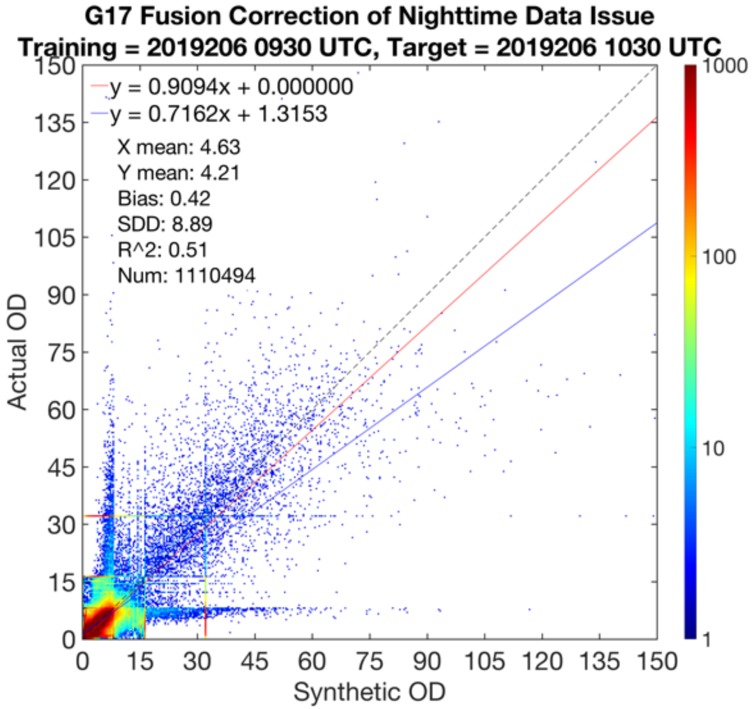
10: 30 UTC

Synthetic Tau
vs.
Regular Tau





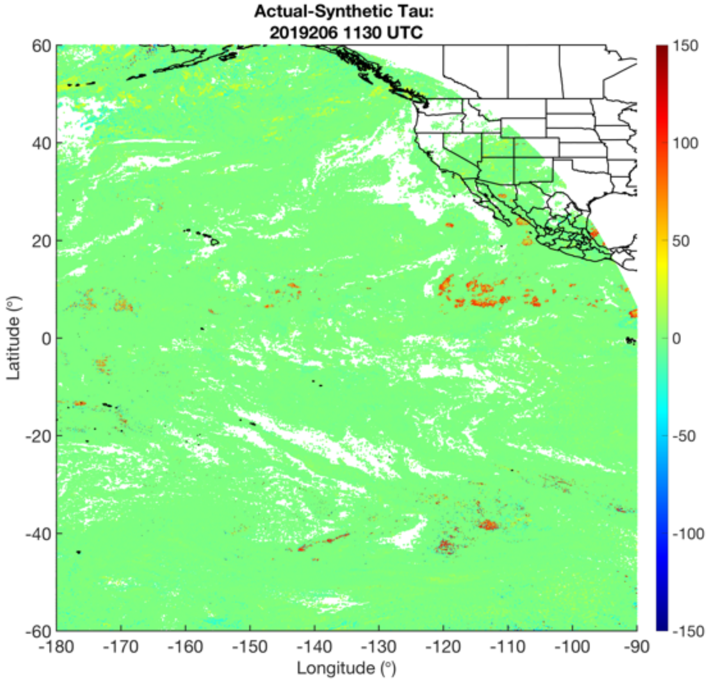


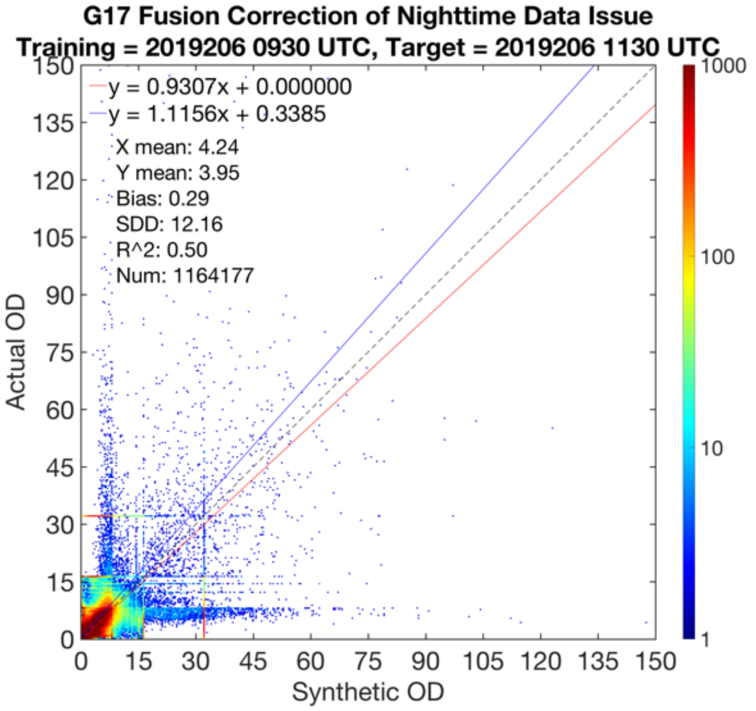


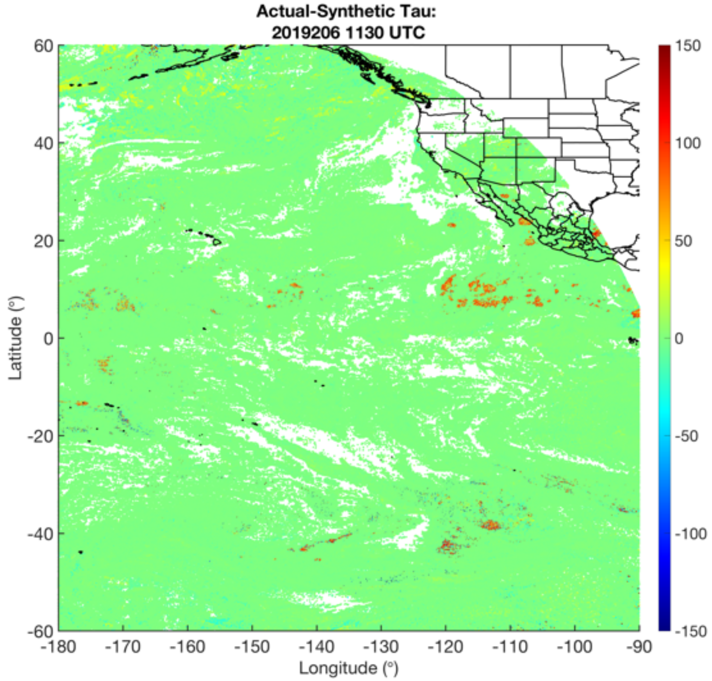
Tau From
Synthetic Rad
vs.
Regular Tau

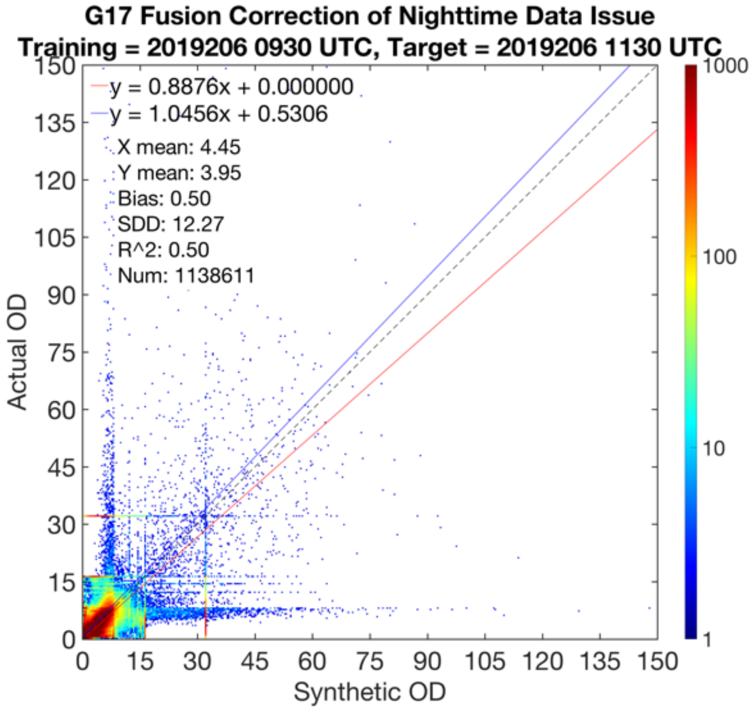
11: 30 UTC

Synthetic Tau
vs.
Regular Tau









Tau From
Synthetic Rad
vs.
Regular Tau

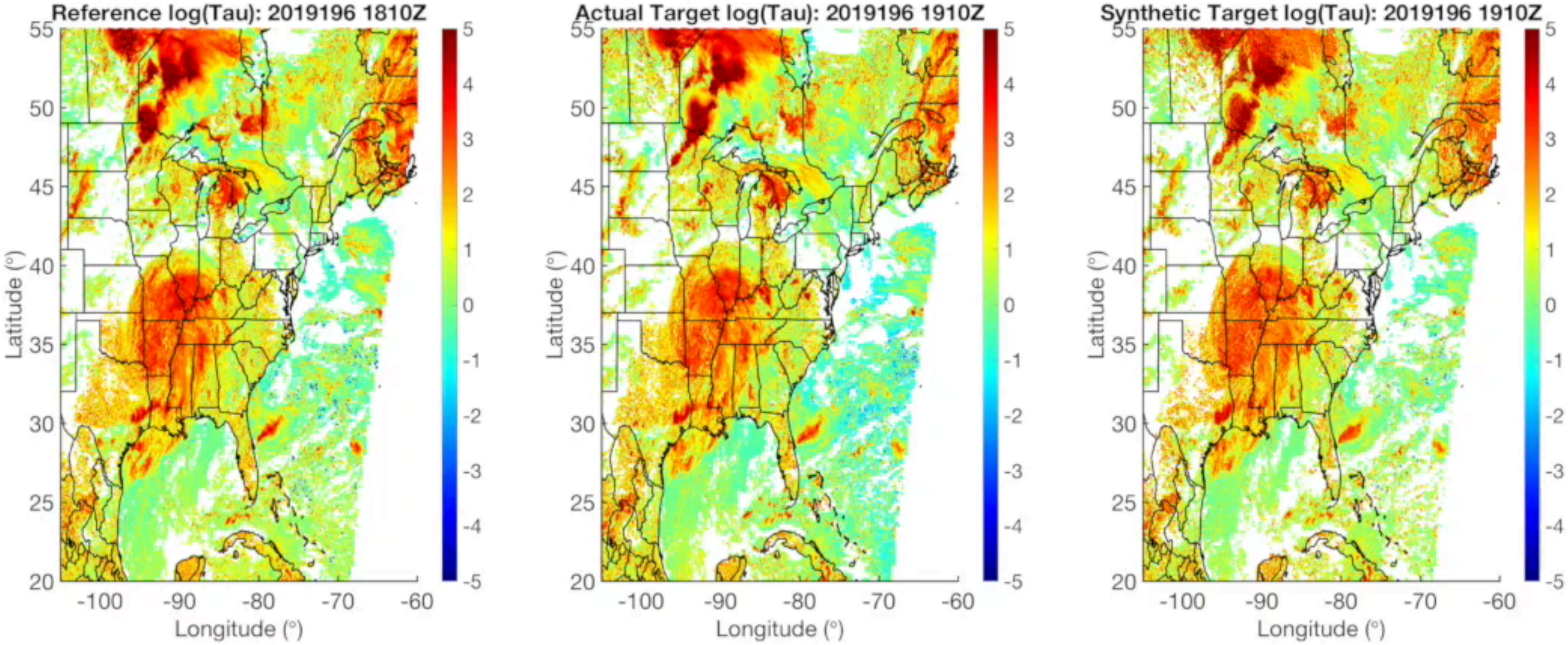
STATISTICAL COMPARISON OF SYNTHETIC CLOUDS VS RETRIEVED VALUES

NOTE: 1130 UTC IS A BAD HOUR AFFECTED BY ECLIPSE

CTH	Bias (km)	SDD (km)	R^2
10:30/Synthetic	0.01	3.55	0.48
10:30/From Syn Rad	0.00	3.57	0.47
11:30/Synthetic	-1.85	4.10	0.35
11:30/From Syn Rad	-1.79	3.92	0.37
12:30/Synthetic	-0.23	3.74	0.44
12:30/From Syn Rad	-0.22	3.72	0.43
Tau	**Bias**	**SDD**	**R^2**
10:30/Synthetic	0.32	8.69	0.52
10:30/From Syn Rad	0.42	8.89	0.51
11:30/Synthetic	0.29	12.16	0.50
11:30/From Syn Rad	0.50	12.27	0.50
12:30/Synthetic	0.16	9.99	0.49
12:30/From Syn Rad	0.32	10.21	0.48

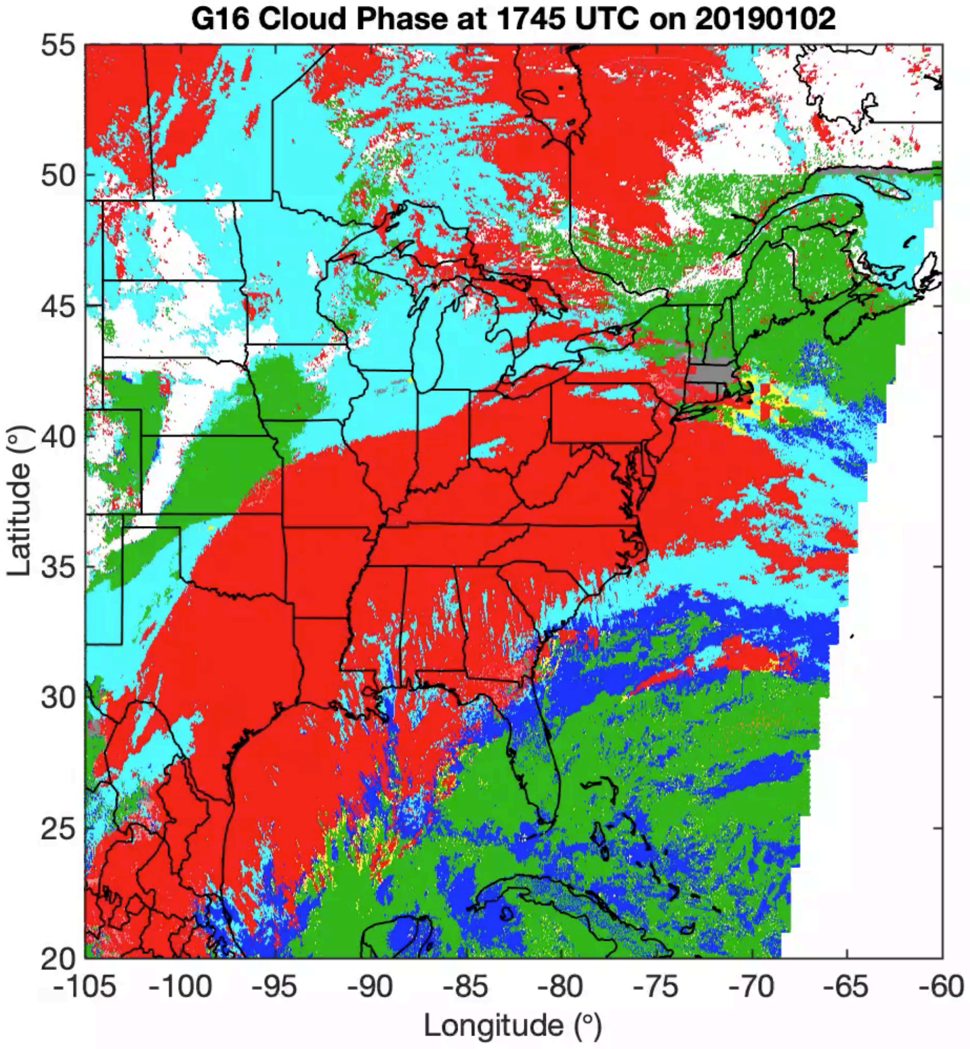
Example for Cloud Optical Thickness (COT)

- Reference image (or training) is JD 196 at 18 UTC (left image)
- COT retrievals from standard cloud product shown in middle (note terminator effects, default values)
- Synthetic COT (right) generated using 3 IR channels, lat/lon in nearest neighbor search minimization

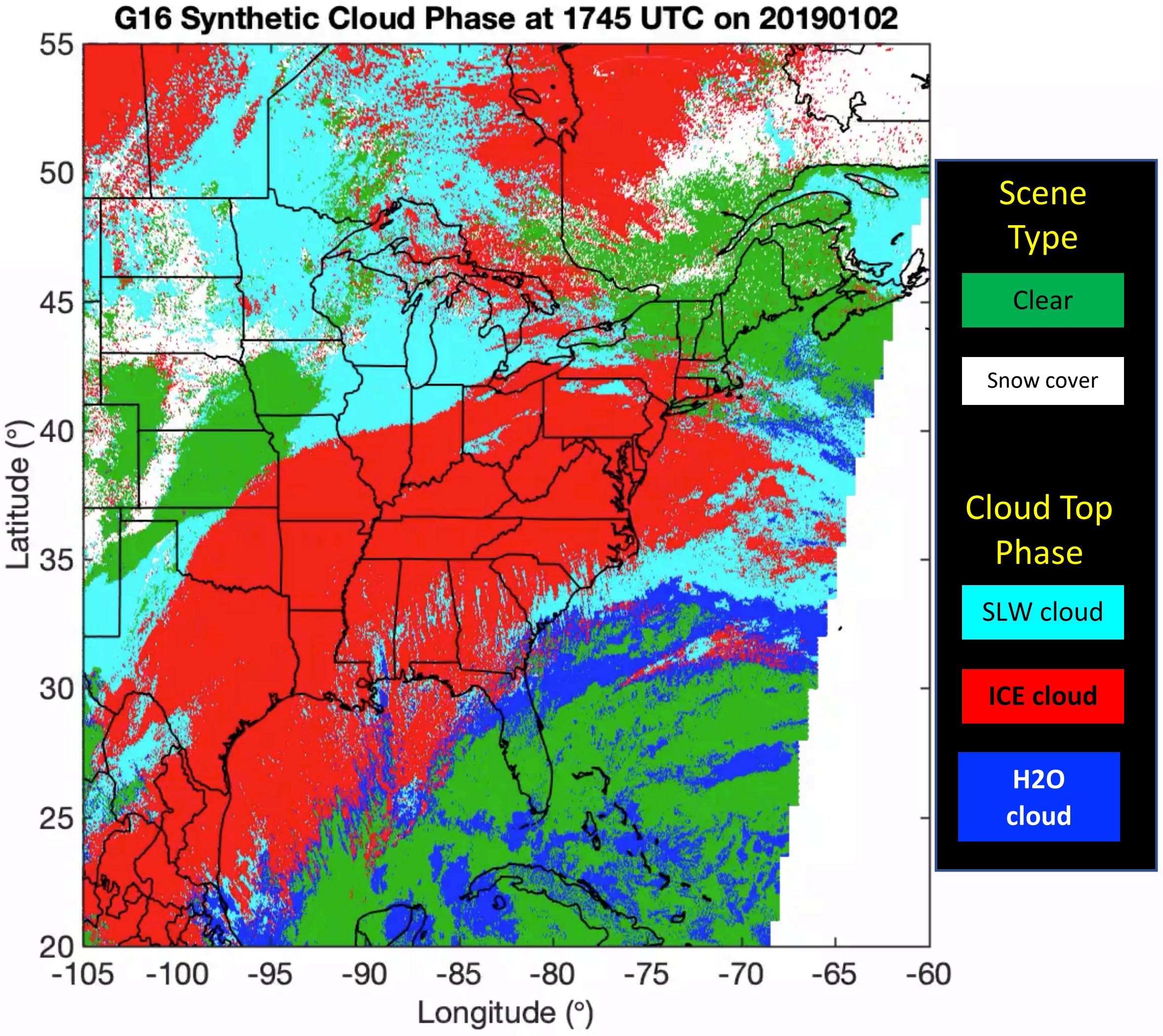


Upshot: Method produces more realistic nighttime COT (albeit synthetic), eliminates terminator issues, and matches the COT observations the next day quite well

Standard Cloud Top Phase Product



Synthetic Cloud Top Phase Product



QUESTIONS ?