CERES Clouds Working Group Report

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AMA, Hampton, VA

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Thanks to Dave Doelling and the TISA/calibration teams!

Topics

- Satellite datasets and processing status
- Consistency of cloud properties across datasets
- Ed5 algorithm status and recent results

Clouds Processing Status (MODIS & VIIRS)

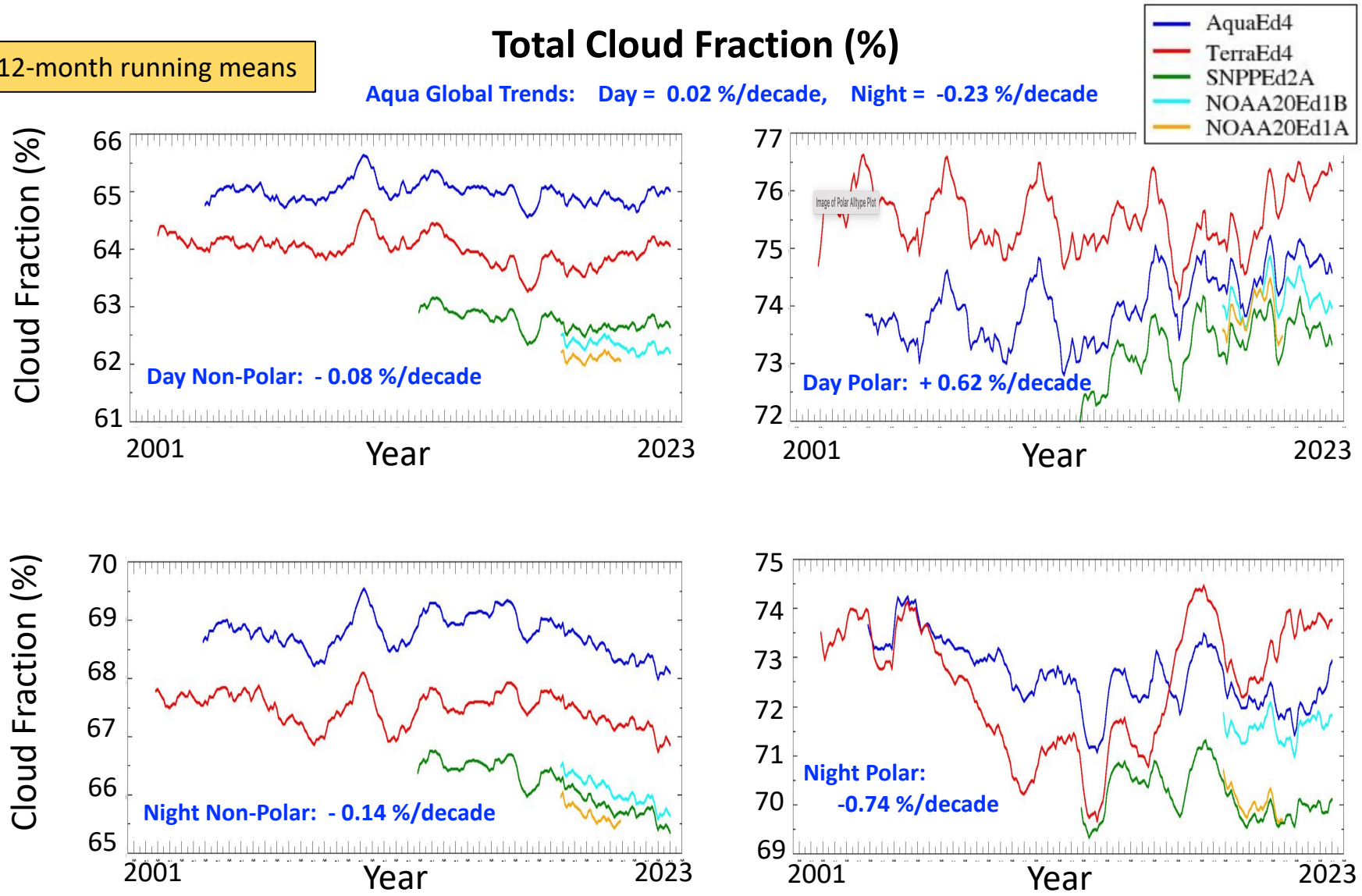
CERES-MODIS Edition 4 (*CDR)	*Aqua: Jul 2002 – Aug2023 (~ 21 y)* *Terra: Feb 2000 – Aug 2023 (~ 23.5 y)*	• *Uses frozen Ed4 cloud codes delivered in 2013* • *MODIS Collection 5 radiances thru Feb 2016,* • *MODIS Collection 6.1 March 2016 – present and scaled to C5 for consistency over entire record* • *Terra-MODIS normalized to Aqua-MODIS (Sun-Mack, et al. 2018)*
CERES-VIIRS Edition 1A	*SNPP: Jan 2012 – Jun 2021 (~ 9.5 y)* *NOAA-20: Jan 2018 – Jun 2021 (~ 3.5 y)*	• *Uses VIIRS Ed1A cloud code* • *SNPP uses forward processing calibrations (C1 radiances), not scaled to MODIS; has discontinuity ~2016 due to a calibration update by SIPS* • *N20 uses C2 radiances and scaled to MODIS C5*
CERES-VIIRS Edition 2A	*SNPP: Jan 2012 – Aug 2023 (~ 11.5 y)*	• *Uses VIIRS Ed1A cloud code* • *Uses C2 radiances and scaled to MODIS C5*
CERES-VIIRS Edition 1B (*CDR)	*NOAA-20: Jan 2018 – Aug 2023 (~ 5.5 y)*	• *Uses VIIRS Ed1b cloud code (temporary continuity version until Ed5 is released)* • *Fills Aqua-MODIS gap in Aug 2020*

Global Cloud Fraction Timeseries, 2000-2023
Consistency of Current Datasets

12-month running means

Total Cloud Fraction (%)

Aqua Global Trends: Day = 0.02 %/decade, Night = -0.23 %/decade



Aqua-MODIS is most stable long- term record. On average, no global trends in daytime cloud fraction since 2002. Slight decrease at night.

Terra-MODIS mostly consistent with Aqua but not as stable due to instrument/calibration changes leading to large artificial changes especially in polar regions at night.

VIIRS on NPP and NOAA-20 are tracking Aqua-MODIS well but algo's detect less clouds.

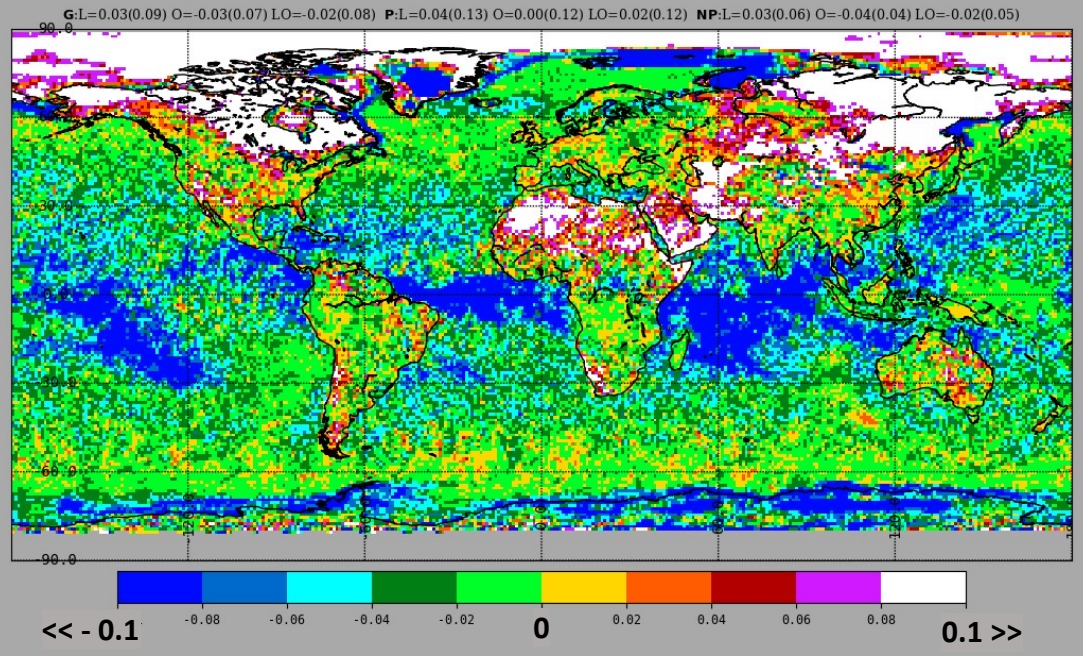
N20 Ed1B improved consistency with Ed4 in polar regions and non-polar ocean (not shown).

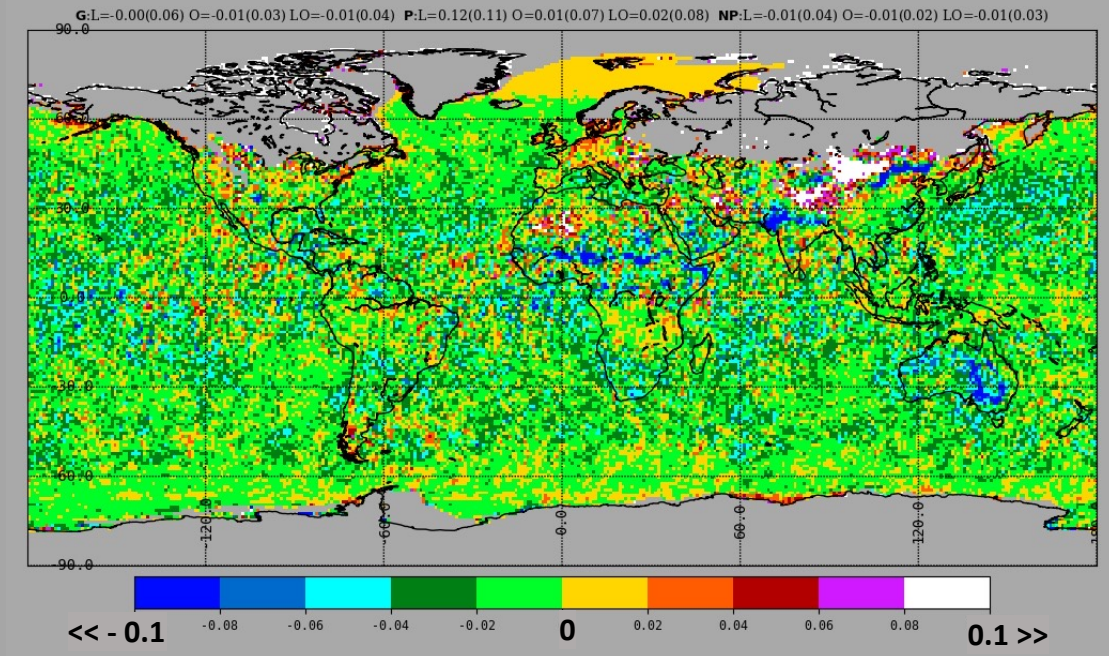
Non-polar (60N – 60S) trends show consistent decreases in last decade, especially at night.

NPP Ed2A – Ed4

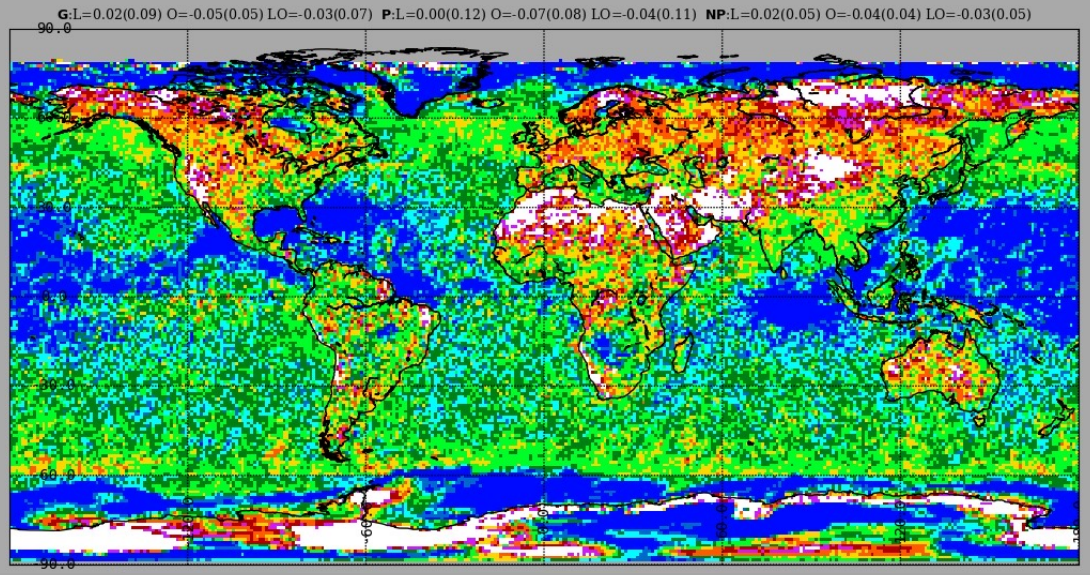
Nighttime Total Cloud Fraction Difference: VIIRS minus AQUA

Ed5 MV4

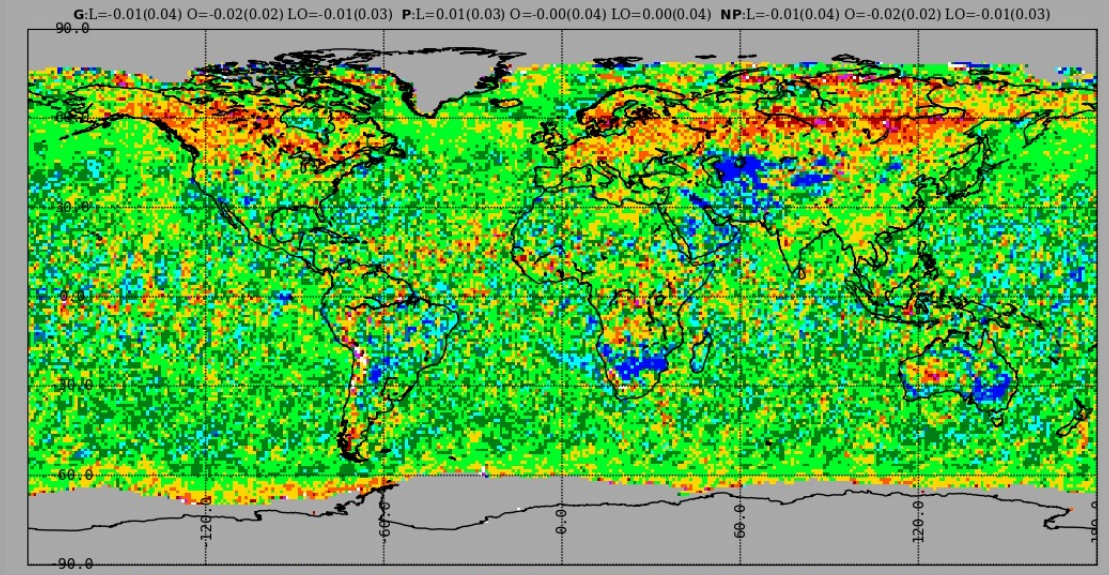




Jan 2019



July 2019



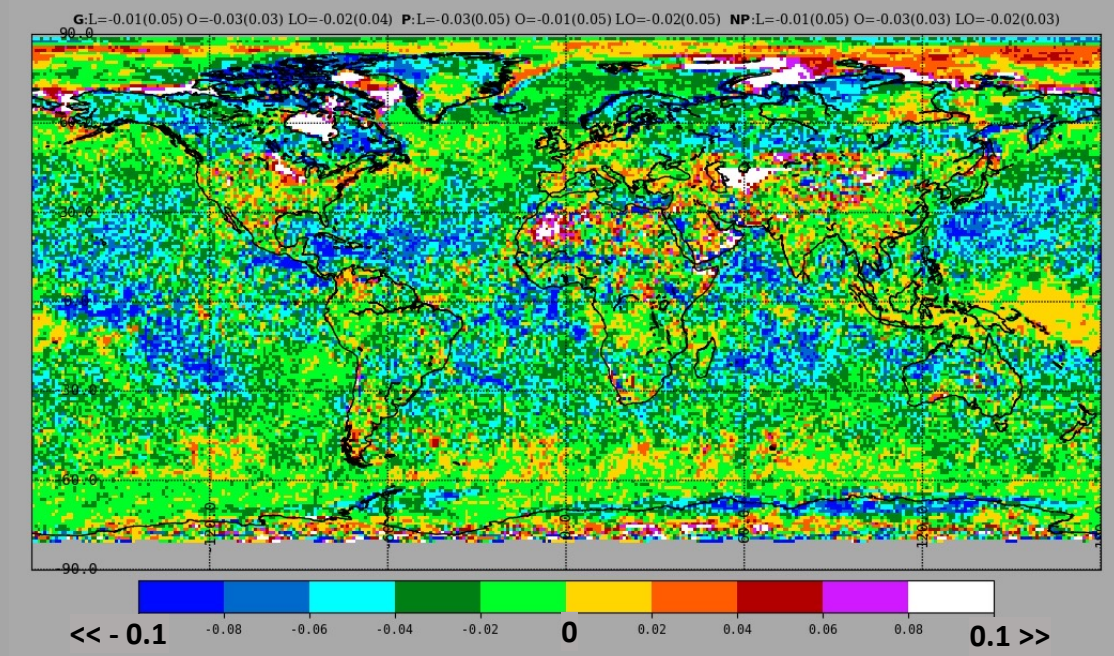
- VIIRS Ed1B tuning to MODIS Ed4 results mixed
- Fewer oceanic clouds detected from VIIRS

- Ed5 ocean consistency much better (VIIRS 2% lower)
- New land mask and Nnet for polar night coming soon

N20 Ed1B – Ed4

Nighttime Total Cloud Fraction Difference: VIIRS minus AQUA

Ed5 MV4



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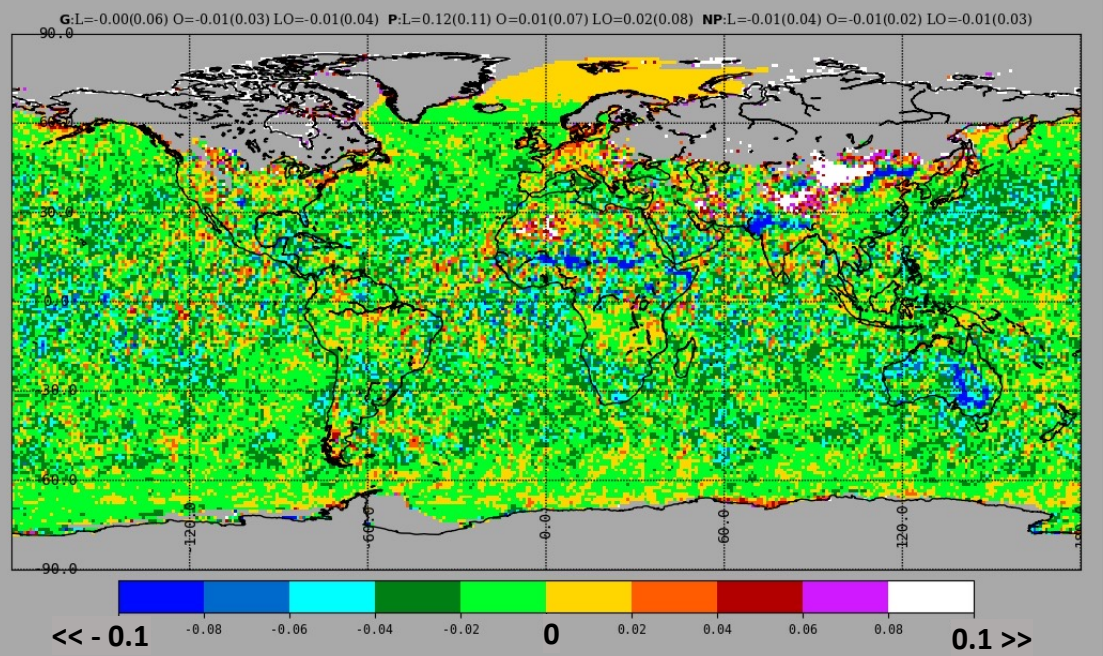
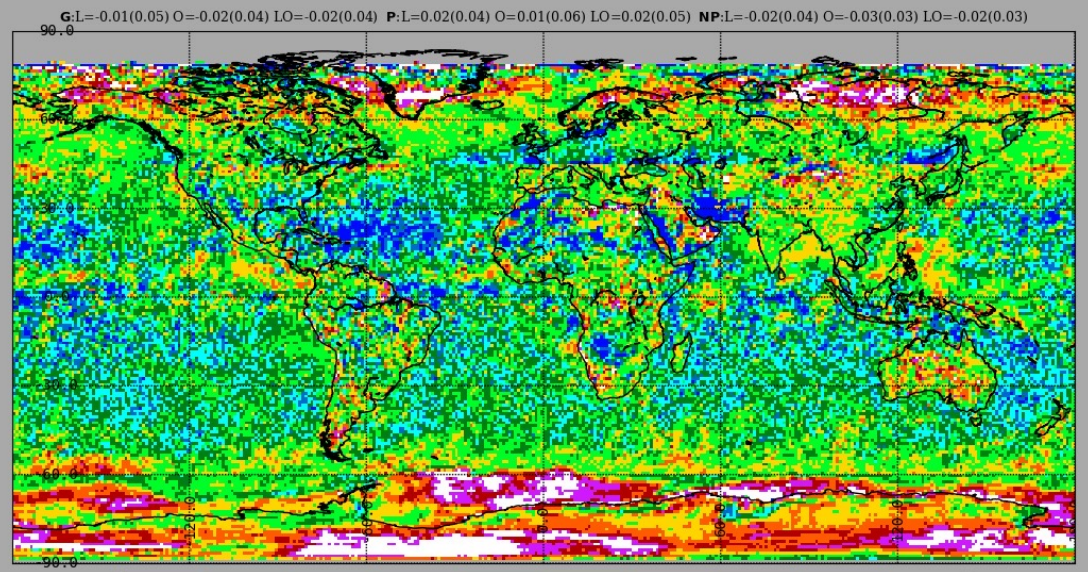
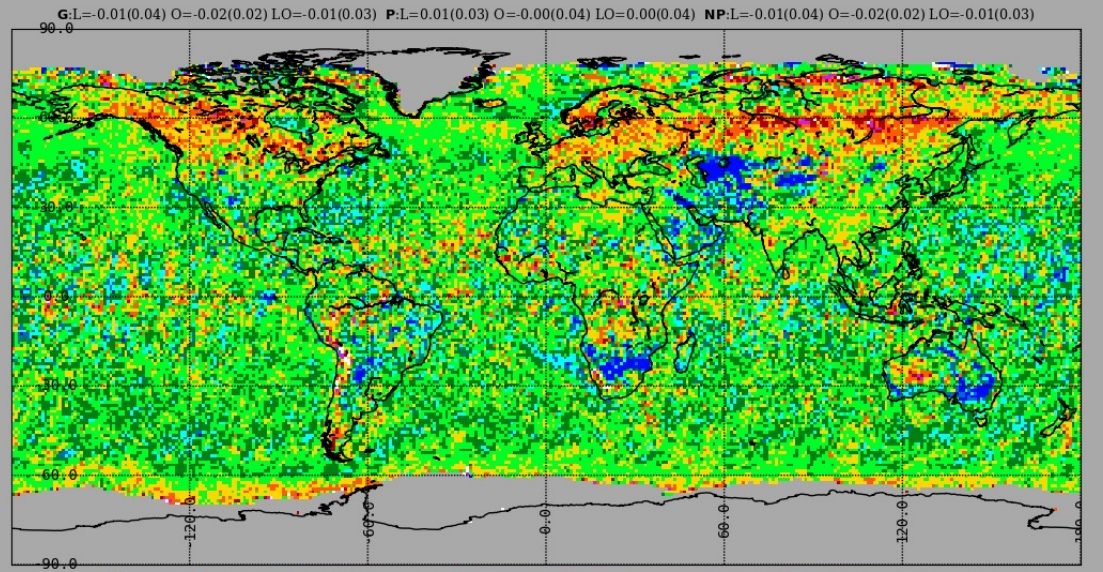




July 2019



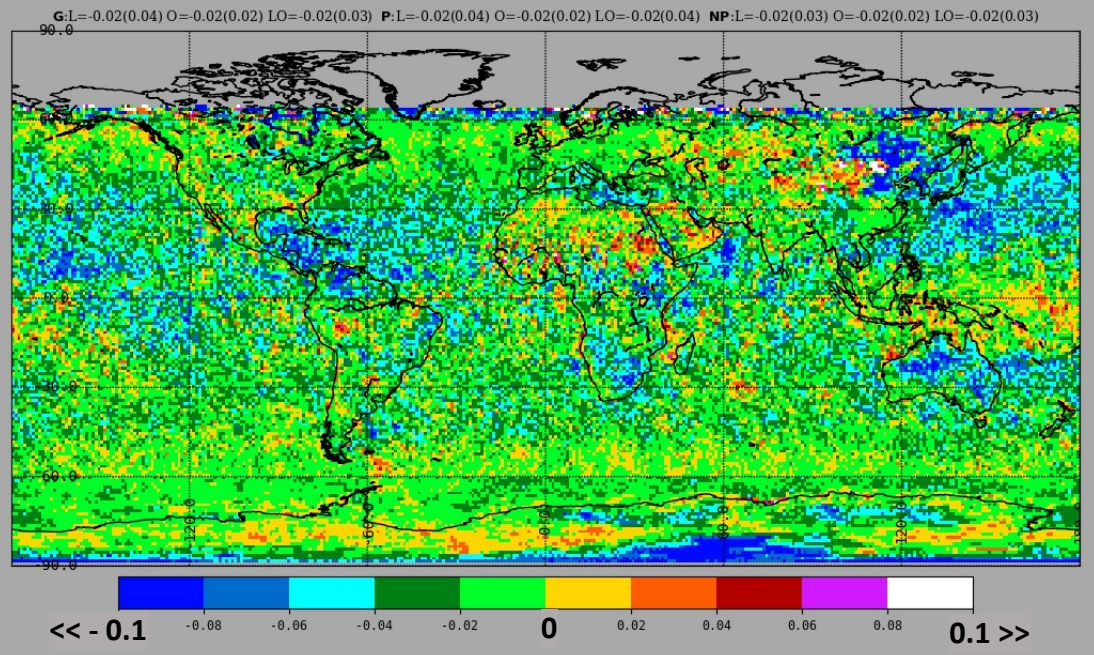
- VIIRS Ed1B tuning to MODIS Ed4 results mixed
- Fewer oceanic clouds detected from VIIRS

- Ed5 ocean consistency much better (VIIRS still a little low)
- New land mask and Nnet for polar night coming soon

NPP Ed2A – Ed4

Daytime Total Cloud Fraction Difference: VIIRS minus AQUA

Ed5 MV4



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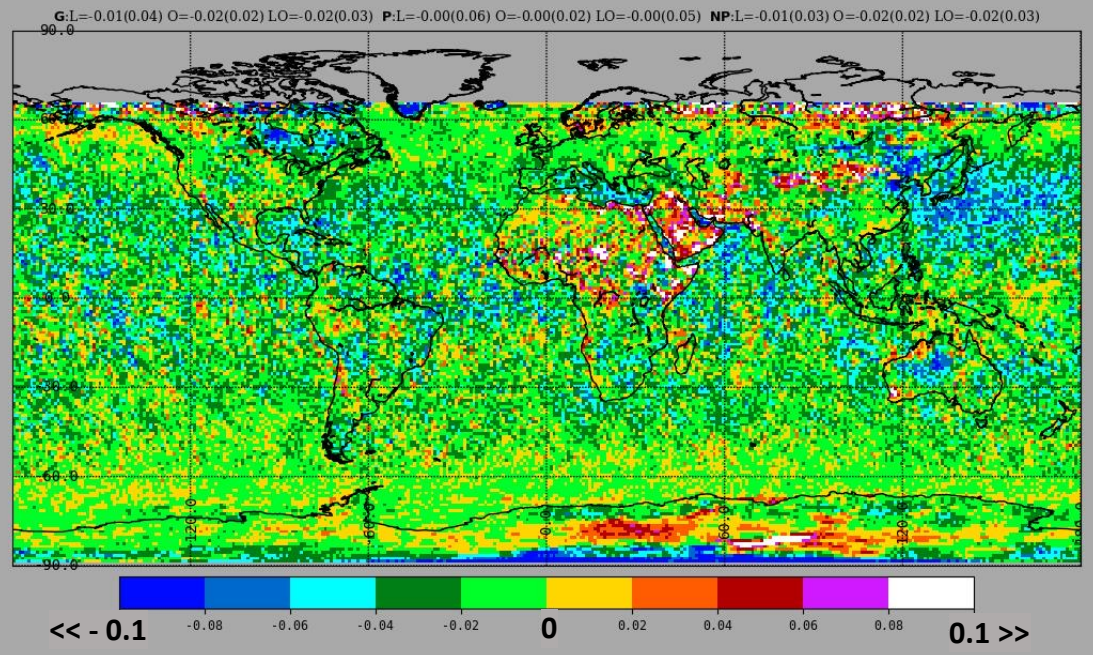
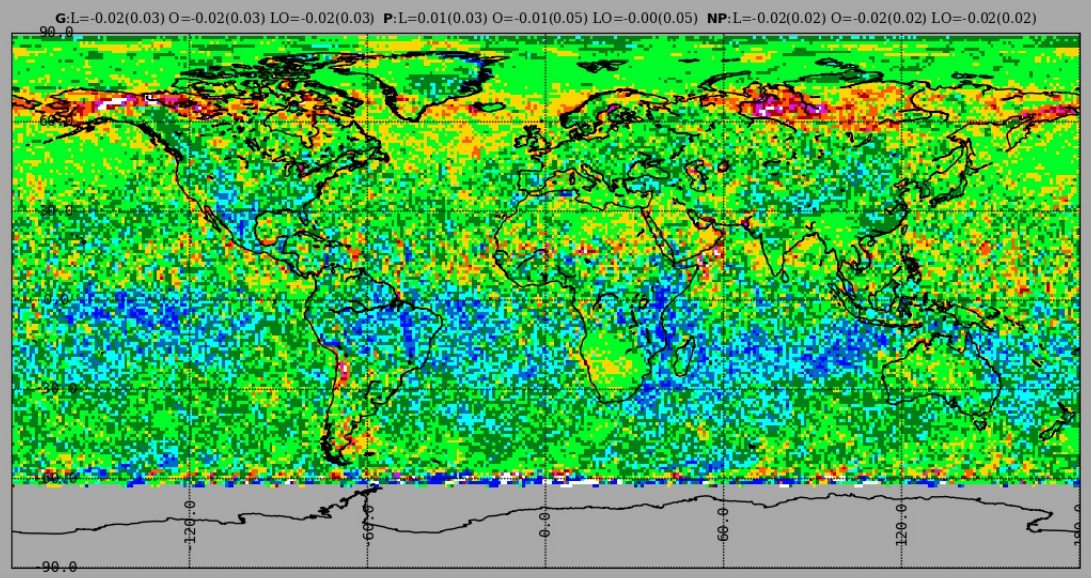
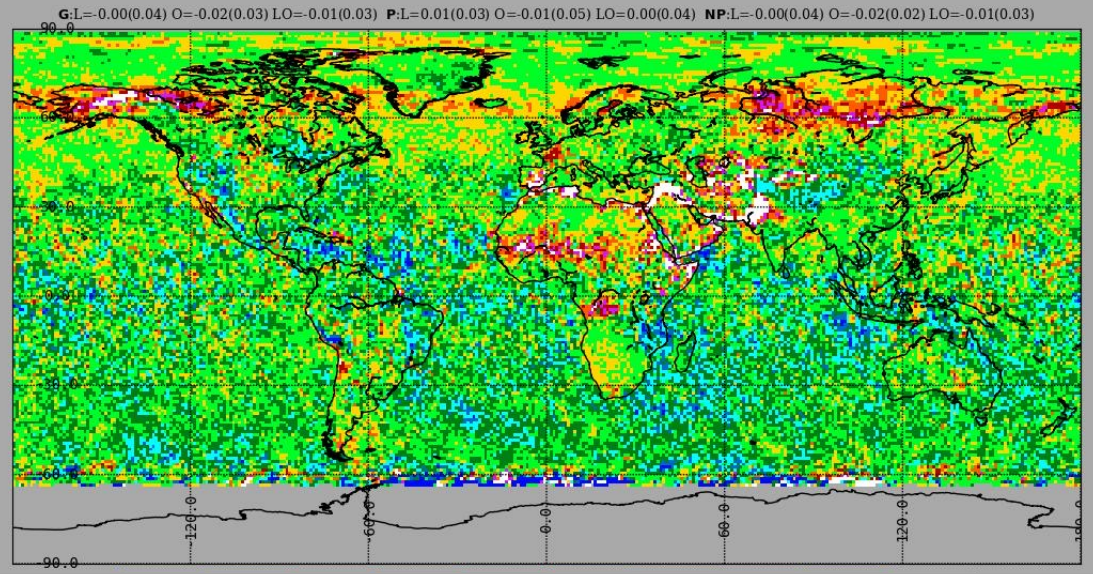




July 2019



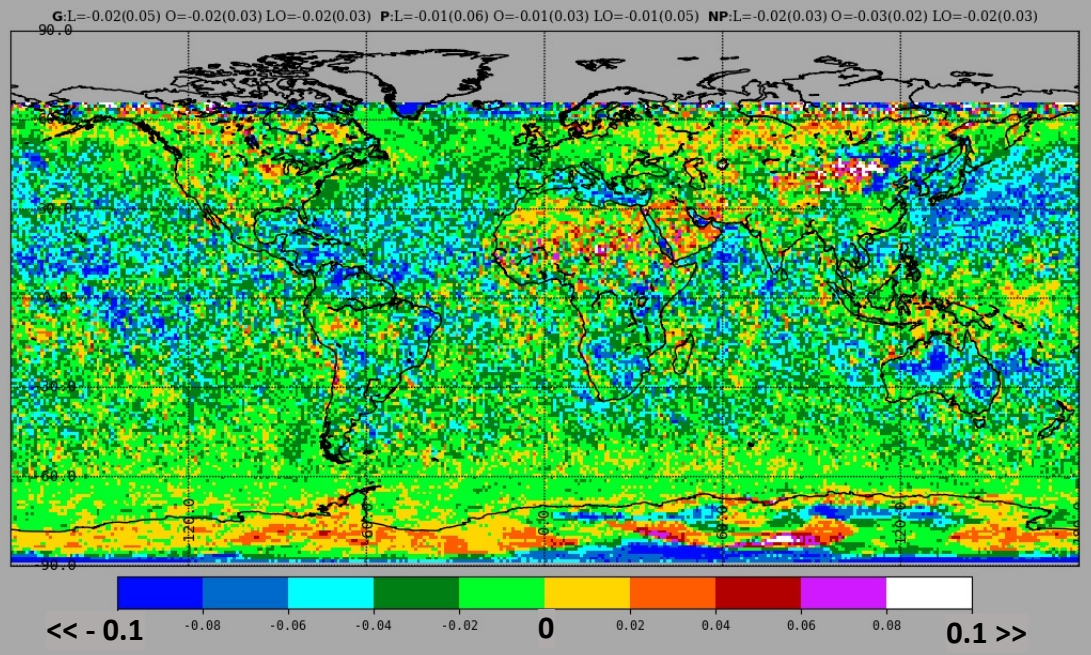
- Large regional diffs (3-8%) btwn VIIRS Ed2A and MODIS Ed4
- Fewer oceanic clouds detected from VIIRS

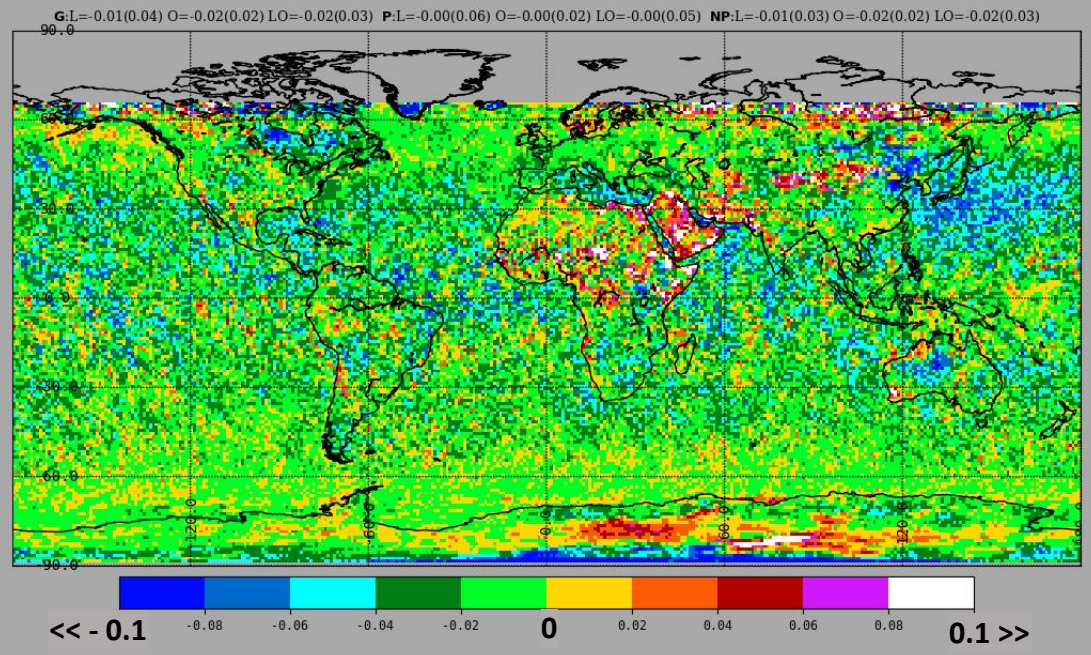
- Ocean and polar land consistency better with Ed5 approach
- Non-polar land mask tuning just started (GEOS-IT in place)

N20 Ed1B – Ed4

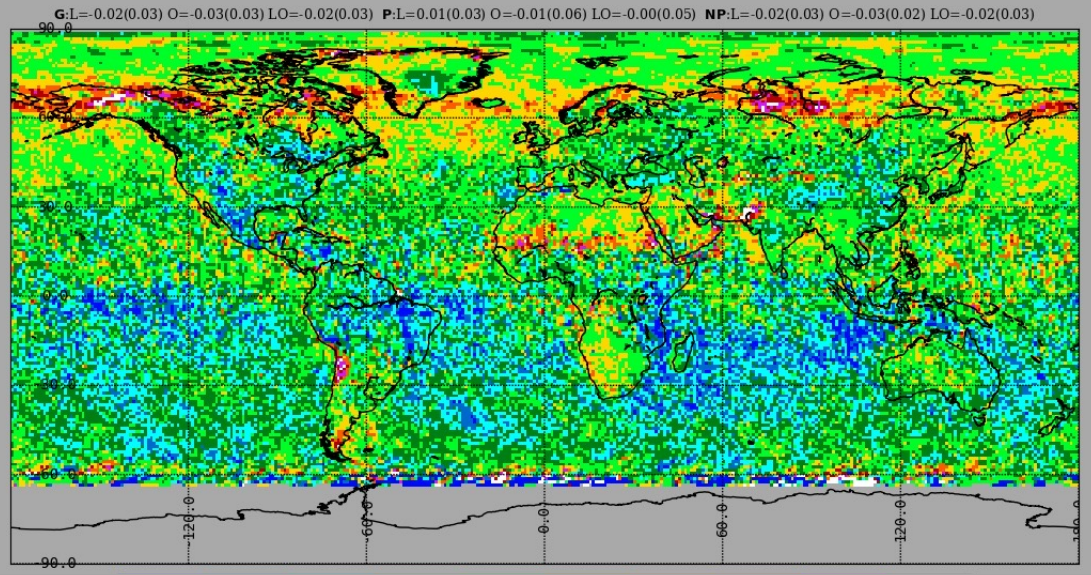
Daytime Total Cloud Fraction Difference: VIIRS minus AQUA

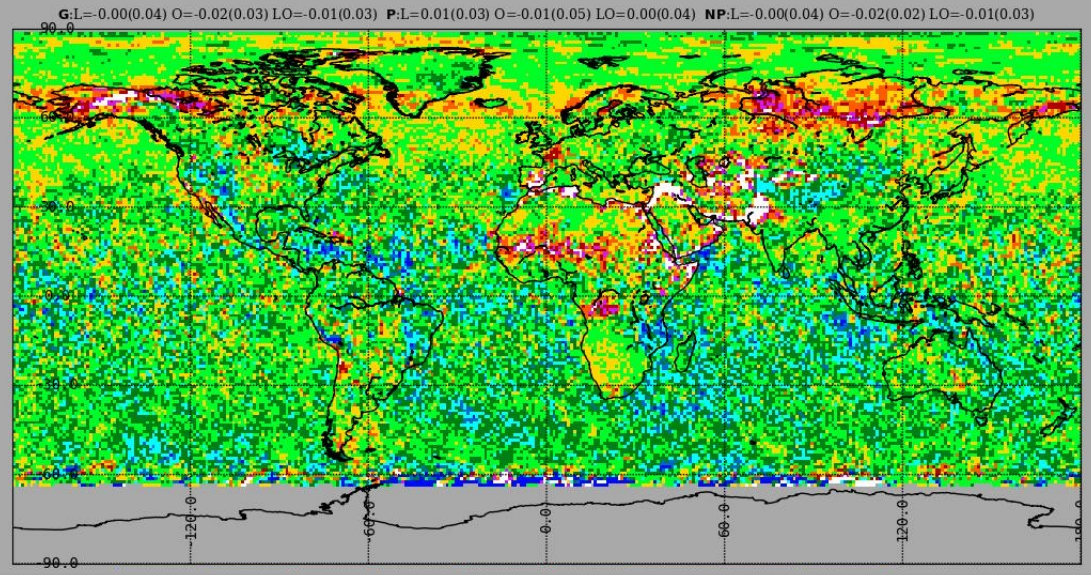
Ed5 MV4





Jan 2019





July 2019

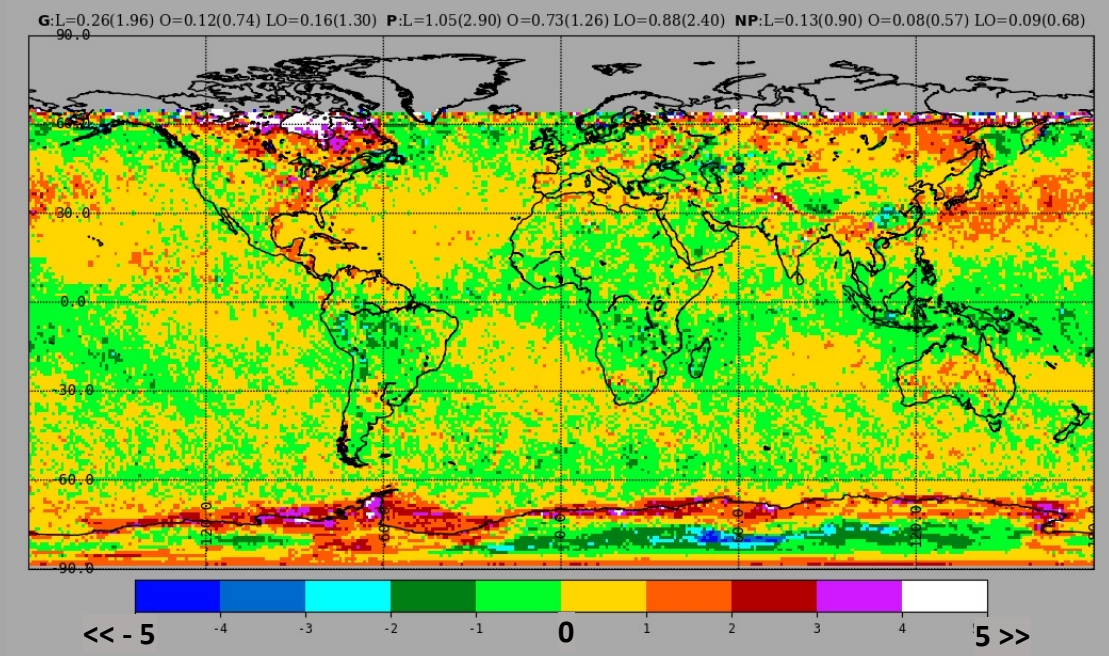
- Ed1B daytime cloud fraction similar to Ed1A
- Fewer oceanic clouds detected from VIIRS

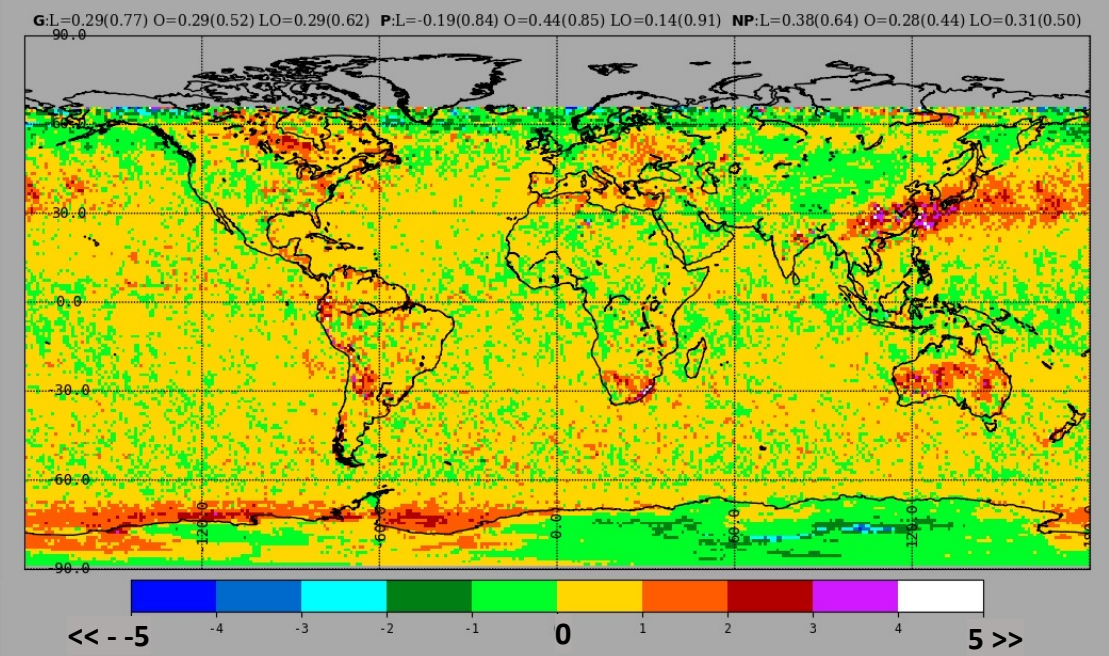
- Ocean and polar land consistency better with Ed5 approach
- Non-polar land mask tuning just started (GEOS-IT in place)

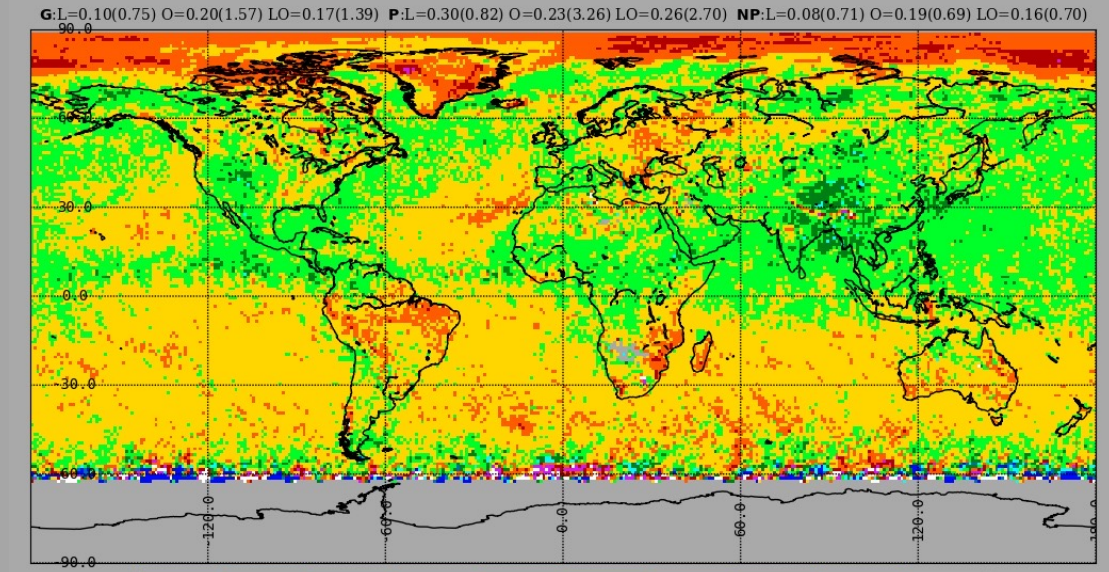
NPP Ed2A – Ed4

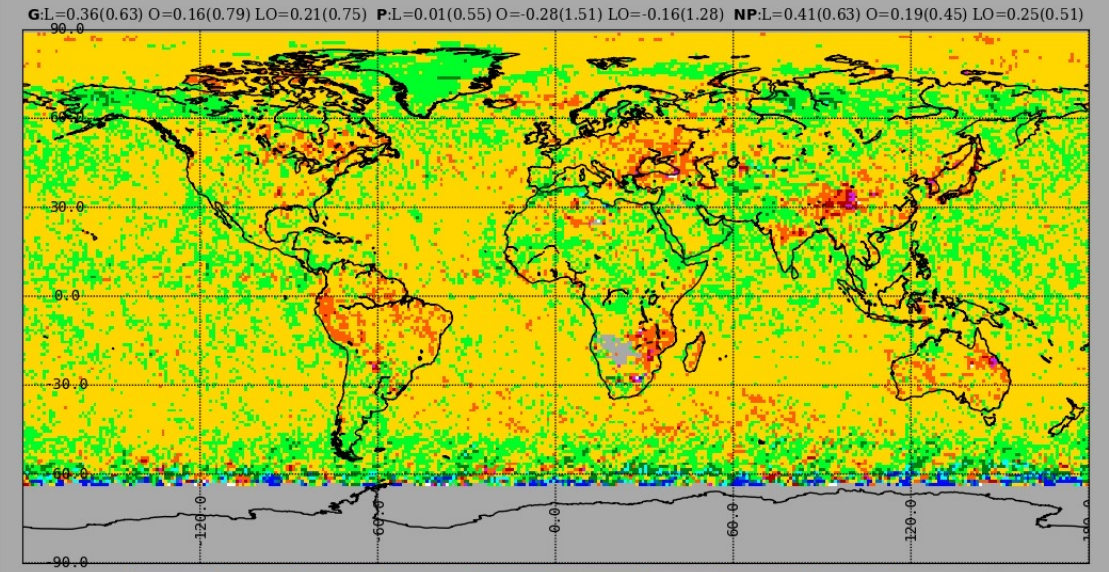
Daytime Cloud Optical Depth Differences: VIIRS minus AQUA

Ed5 MV4









- Larger differenes in areas with inconsistent cloud detection
- Poor consistency polar regions (Ed4 model interpolation bug)

- Ed5 COD consistency very good most ocean areas and over polar regions

Ed5 Cloud Algorithm Status

Ed5 LEO (MODIS and VIIRS)

- Ed5 processing framework for MODIS and VIIRS is completed.
- AQUA-MODIS radiance ingester modified to resurrect 1.6 um band (was not used in Ed4).
- Many bug fixes, algorithm and ancillary dataset improvements are already implemented including improved cloud masks, improved polar cloud properties utilizing the 1.6 µm band. Others in progress: skin temperature, polar night cloud detection, nighttime tau, cloud heights, phase and multi-layered clouds.
- Same algorithm being applied to both instruments using 11 common channels

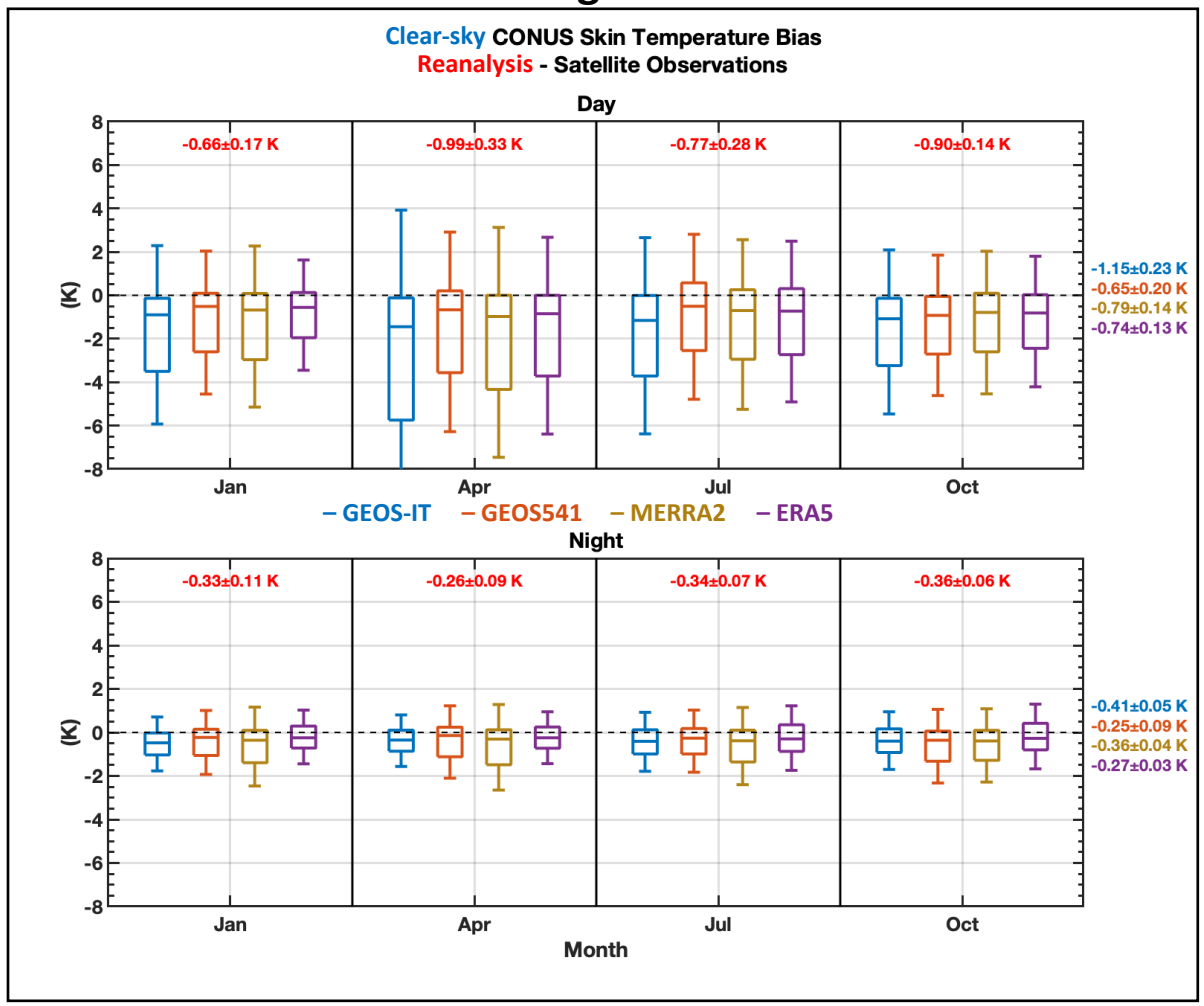
Ed5 GEO

- A common 3-channel algorithm is implemented in the CERES GEO processing framework for most satellites.
  - daytime: 0.63, 3.7, 11 µm (cloud mask, theoretical optical properties)
  - nighttime: 3.7, 6.7, 11 µm (cloud mask, theoretical optical properties for thin clouds, machine learning method for thick cloud optical properties also ready for implementation)
- A different algorithm is being developed for the 2-channel satellite (GMS-5, Met-5 and Met-7)
- Machine learning approaches to reduce artifacts in sunglint and solar terminator are ready for implementation.

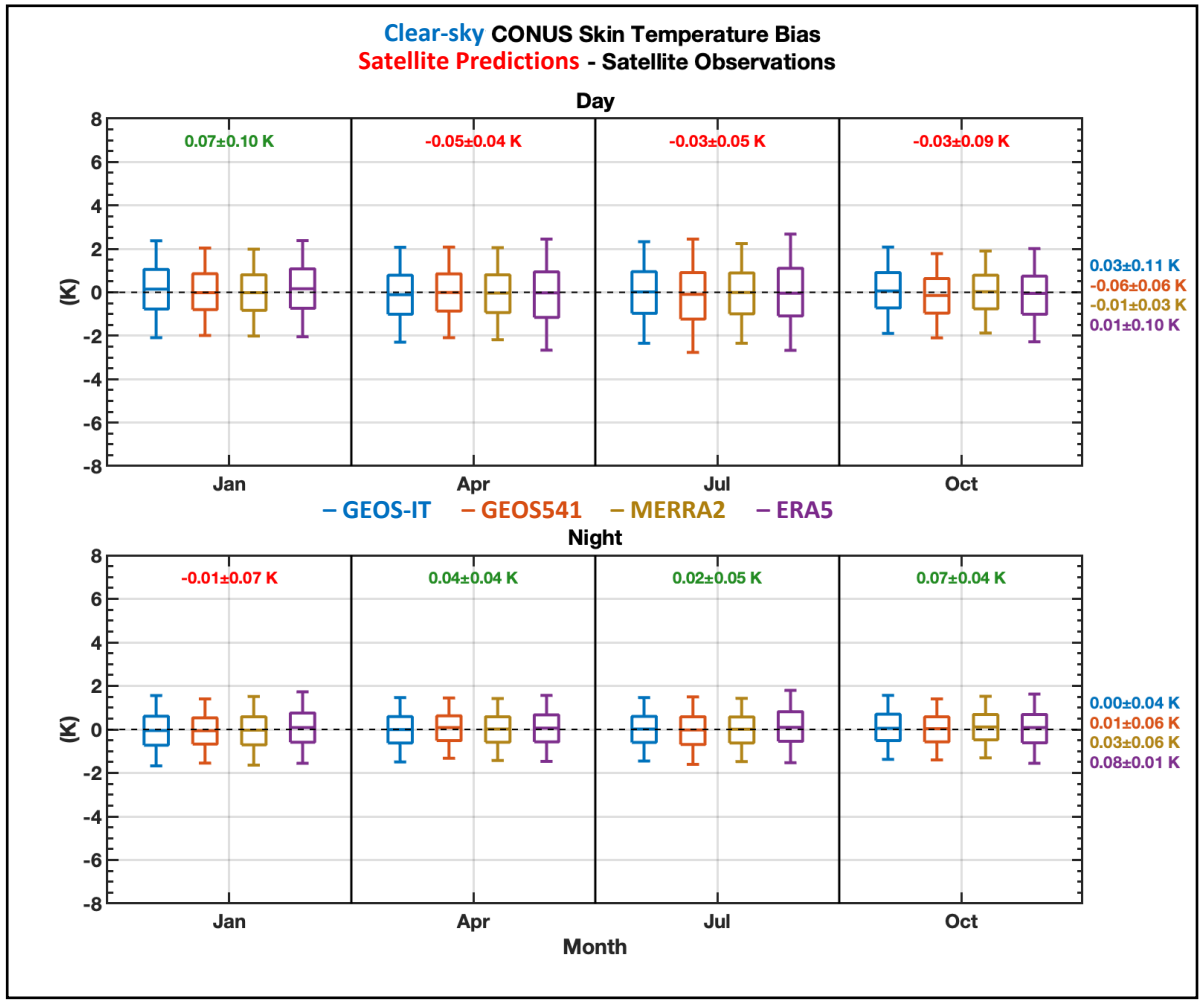
Critical ancillary datasets have recently become available (e.g. GOES-IT, MODIS C7), testing underway

Deep Neural Network to Estimate Satellite Skin Temperature

Original



With DNN



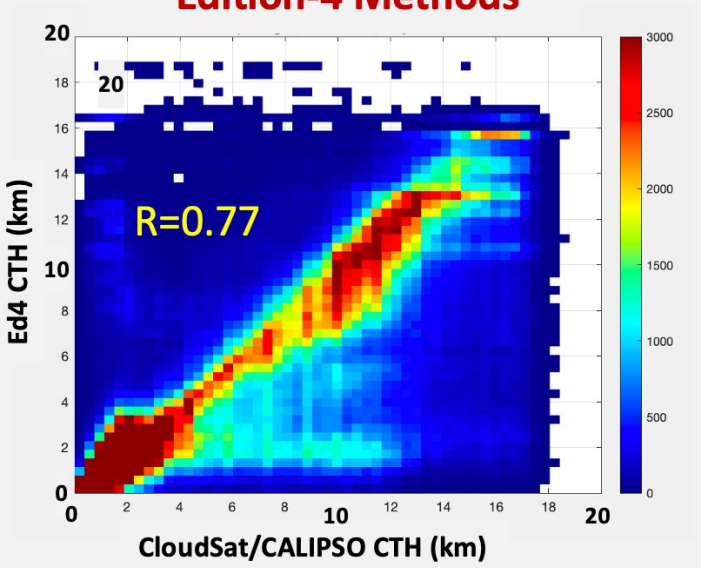
A DNN can consistently simulate satellite T_s from GMAO inputs

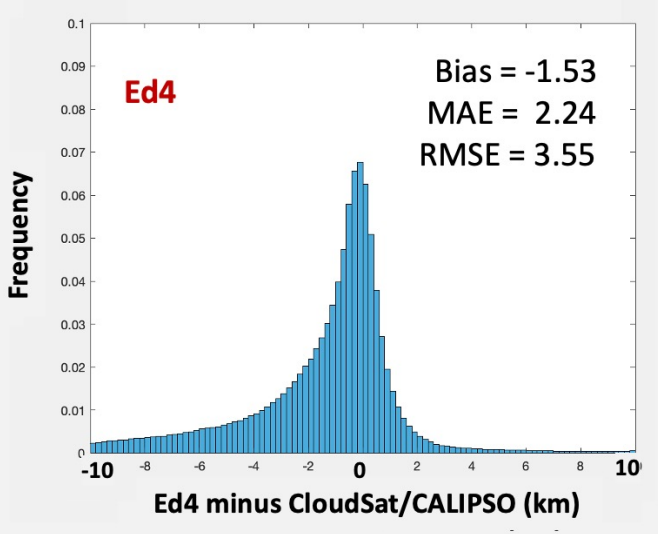
More on Thursday morning
By Ben Scarino

Higher Accuracy Cloud Top Heights using Neural Net

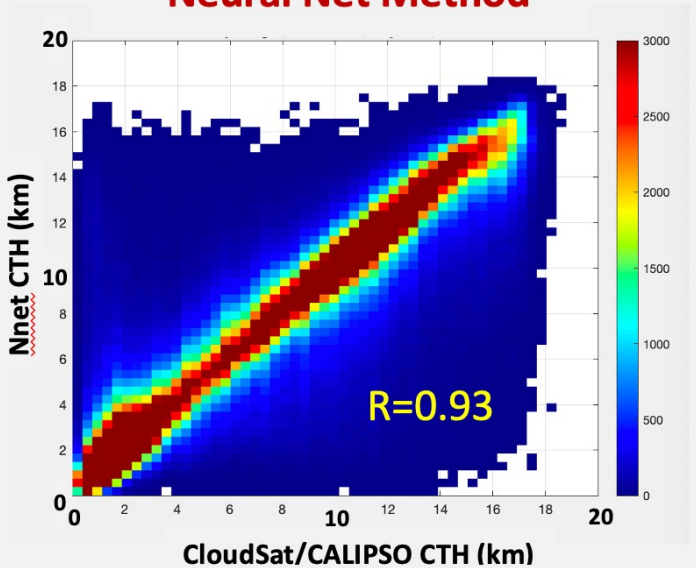
All clouds, daytime, snow/ice free

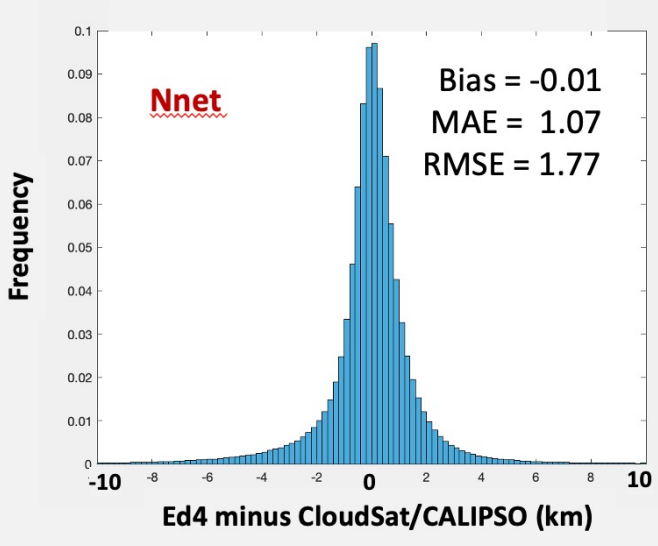
Edition-4 Methods





Neural Net Method





All Clouds

All	Nnet	Ed4
Bias	-0.01	-1.53
MAE	1.07	2.24
RMSE	1.77	3.55

High Clouds

High	Nnet	Ed4
Bias	-0.48	-2.75
MAE	1.18	3.14
RMSE	1.86	4.38

Mid Clouds

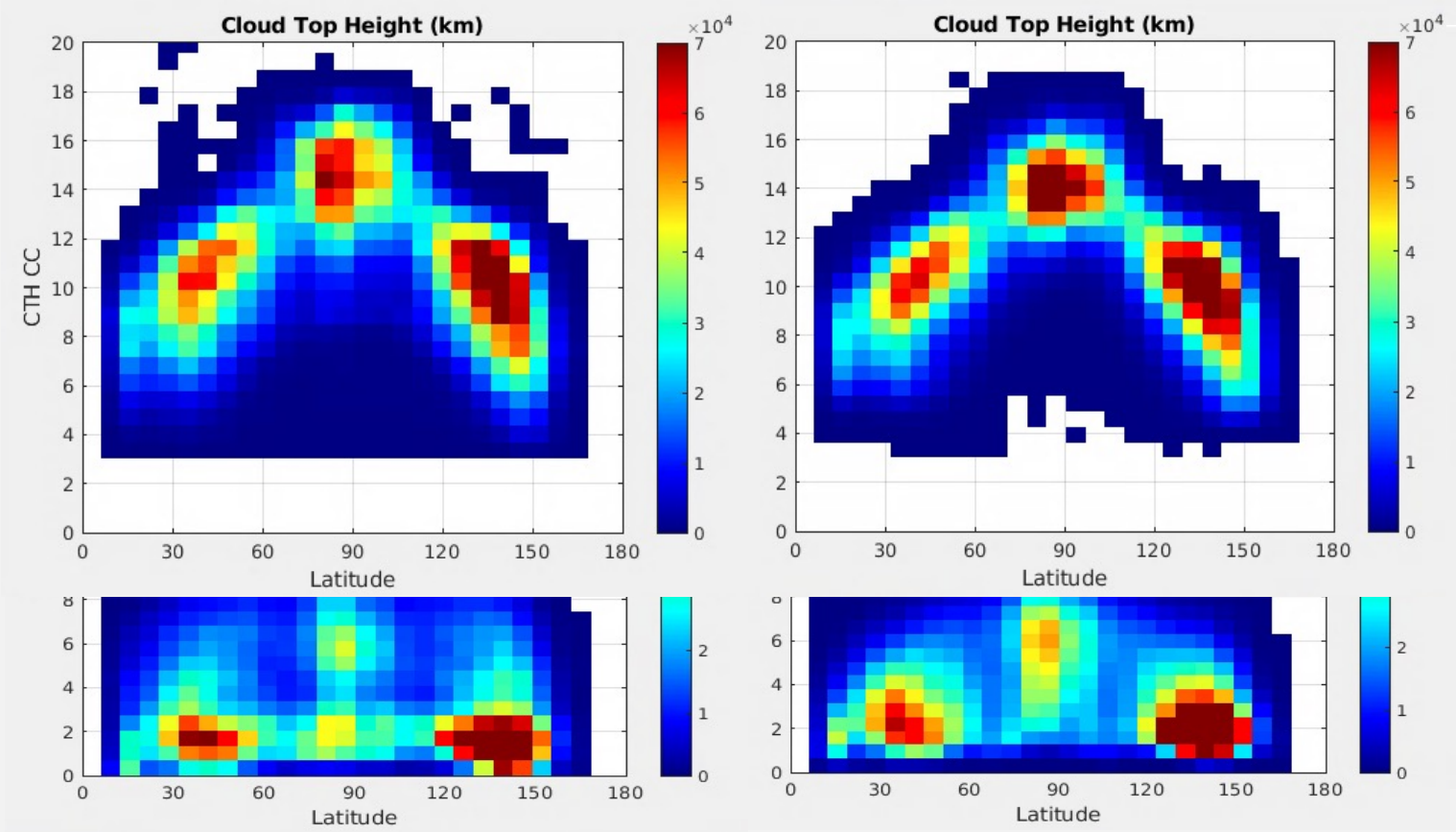
Mid	Nnet	Ed4
Bias	0.51	-0.80
MAE	1.14	1.63
RMSE	1.69	2.20

Low Clouds

Low	Nnet	Ed4
Bias	0.60	0.31
MAE	0.85	0.89
RMSE	1.64	2.01

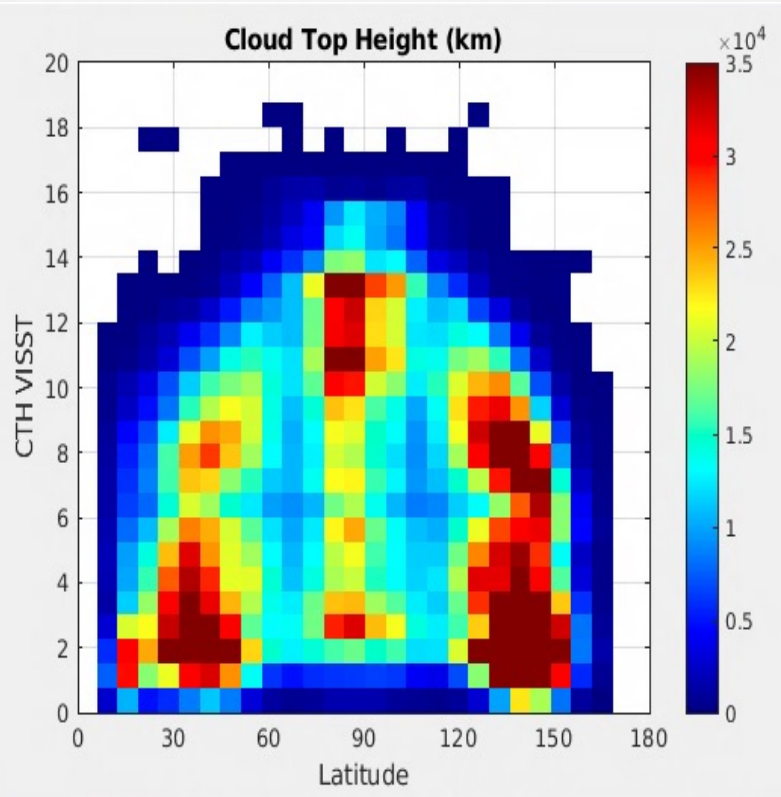
Zonal Distribution of both Upper & Lower Layer Cloud Top Heights
Snow Free Surfaces, Daytime, 2008

CTH, CC



CTH, NNet

CTH, Ed4



More on Thursday Morning
By Sunny Sun-Mack

CERES GEO CLOUDS UPDATE

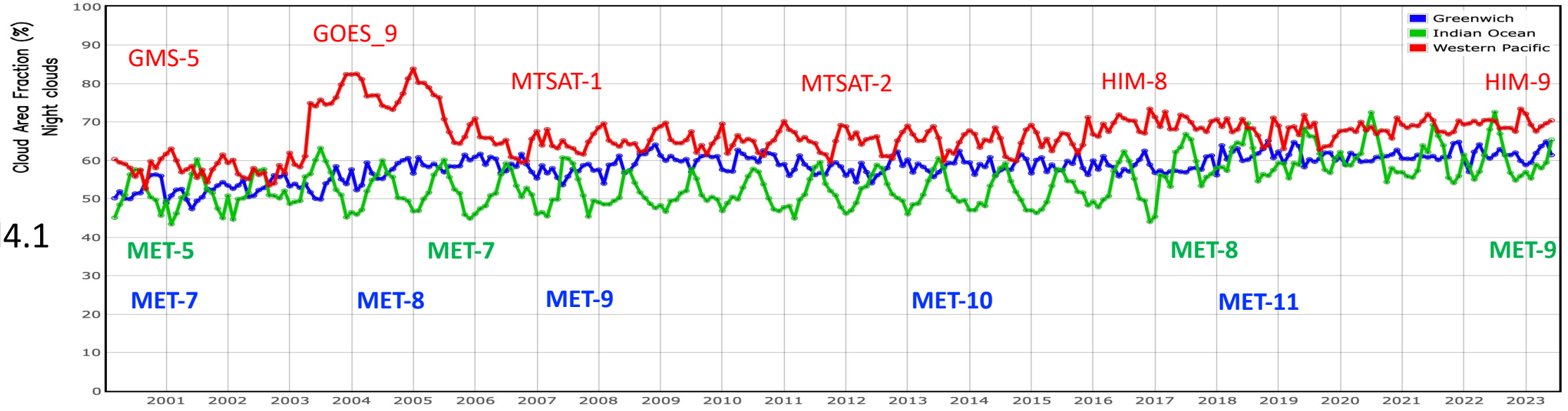
Updating Cloud Properties For GEOs With Two Channels

- Ed4 cloud properties derived from the 2-channel satellite (GMS-5, Met-5 & Met-7) are associated with the largest discontinuities in the GEO timeseries.
- The daytime (2-chan) and nighttime (11 µm only) algorithms were applied to modern satellites (Met-8 and Met-11 over Indian Ocean & W. Europe domains) so that they could be assessed against our 8-channel (multi-chan baseline) algorithm applied to the same SEVIRI imager data.
- Adjustments were made to the 2-chan algorithms to improve the consistency of the derived cloud properties with those from the multi-chan algorithm
- Entire record is currently being reprocessed for intermediate new version of SYN1deg, Ed4.2

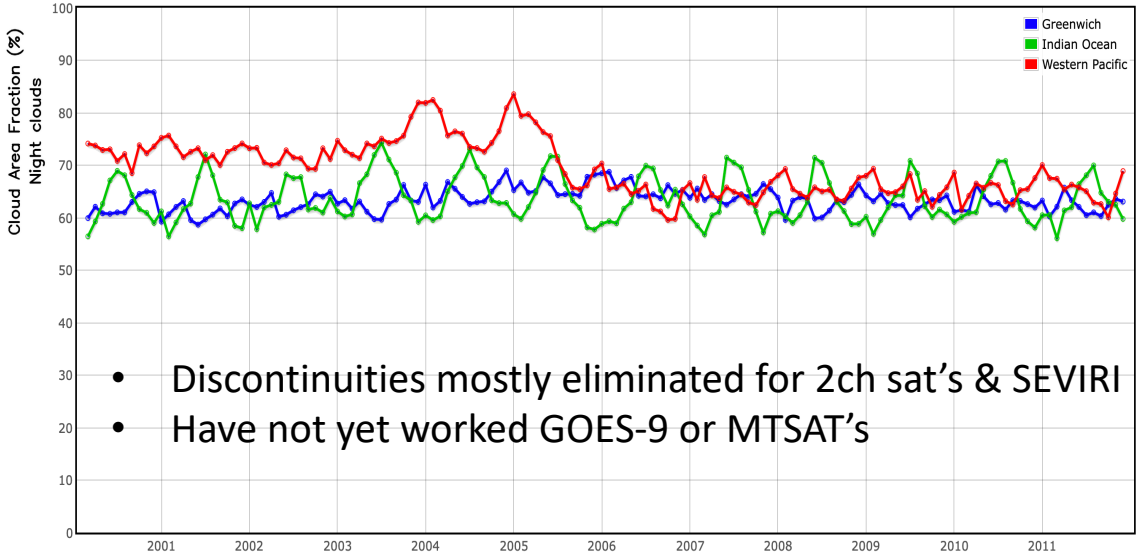
GEO Nighttime Cloud Fraction (60N – 60S)

Updated 2ch Satellites (MET-5, MET-7, GMS-5) & SEVIRI (Met-8 to MET-11)

Ed4.1

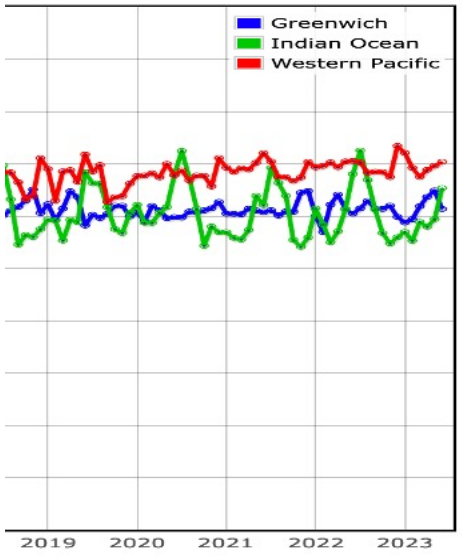


Ed4.2



- Discontinuities mostly eliminated for 2ch sat's & SEVIRI
- Have not yet worked GOES-9 or MTSAT's

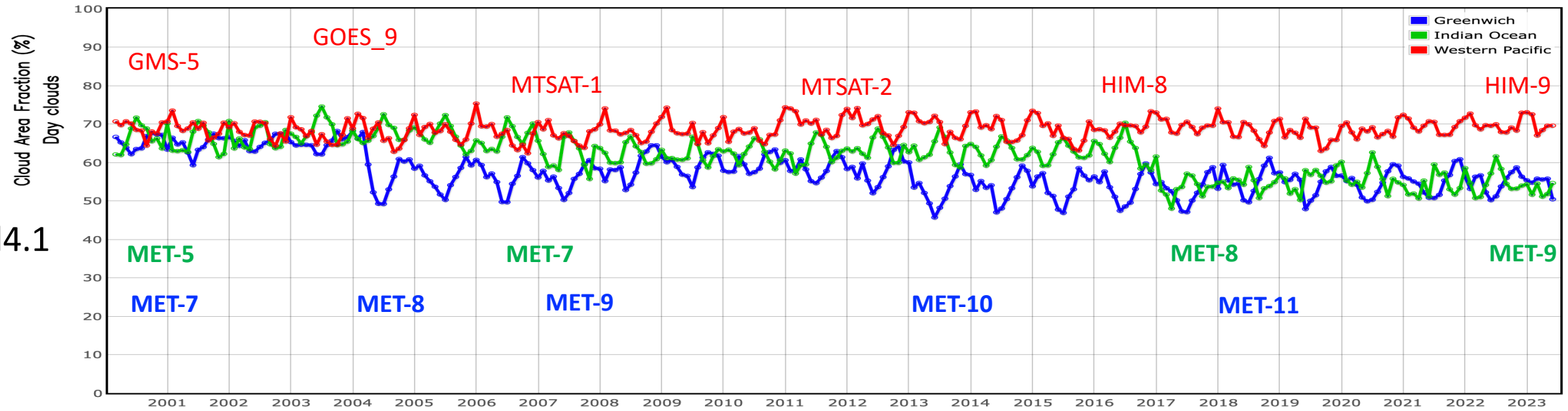
Not Re-processed Yet



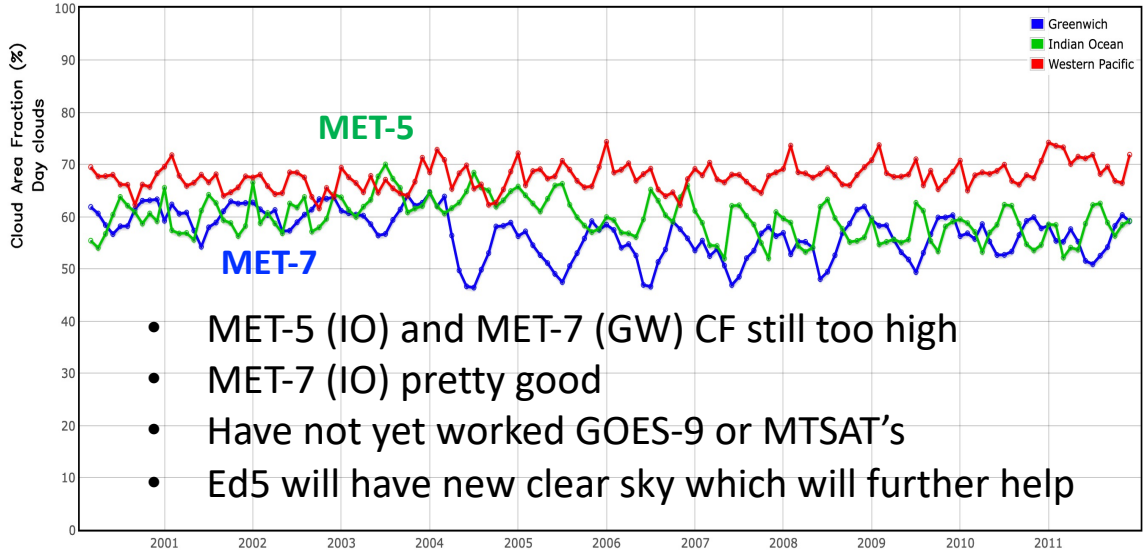
GEO Daytime Cloud Fraction (60N – 60S)

Updated 2ch Satellites (MET-5, MET-7, GMS-5)

Ed4.1

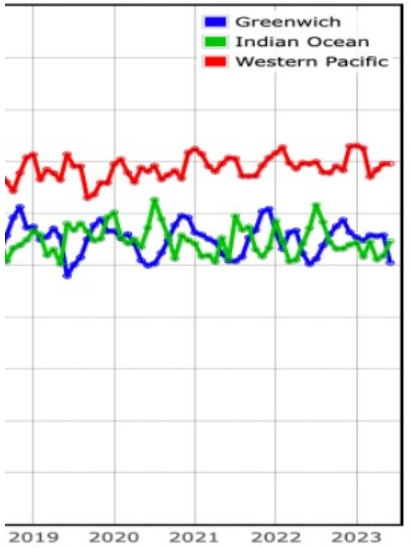


Ed4.2



- MET-5 (IO) and MET-7 (GW) CF still too high
- MET-7 (IO) pretty good
- Have not yet worked GOES-9 or MTSAT's
- Ed5 will have new clear sky which will further help

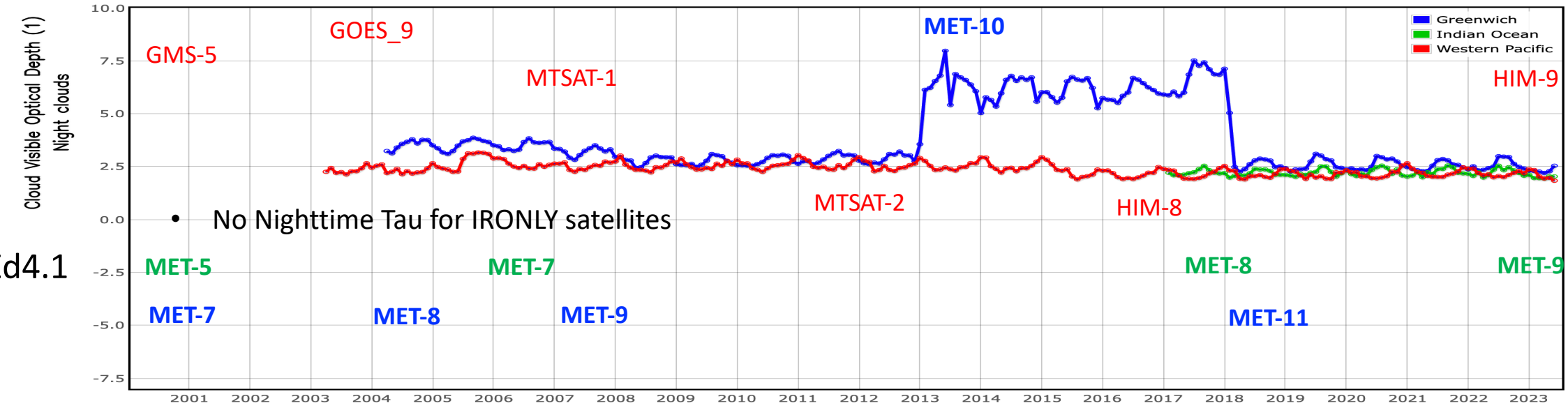
Not Re-processed Yet



GEO Nighttime Cloud Optical Depth (60N – 60S)

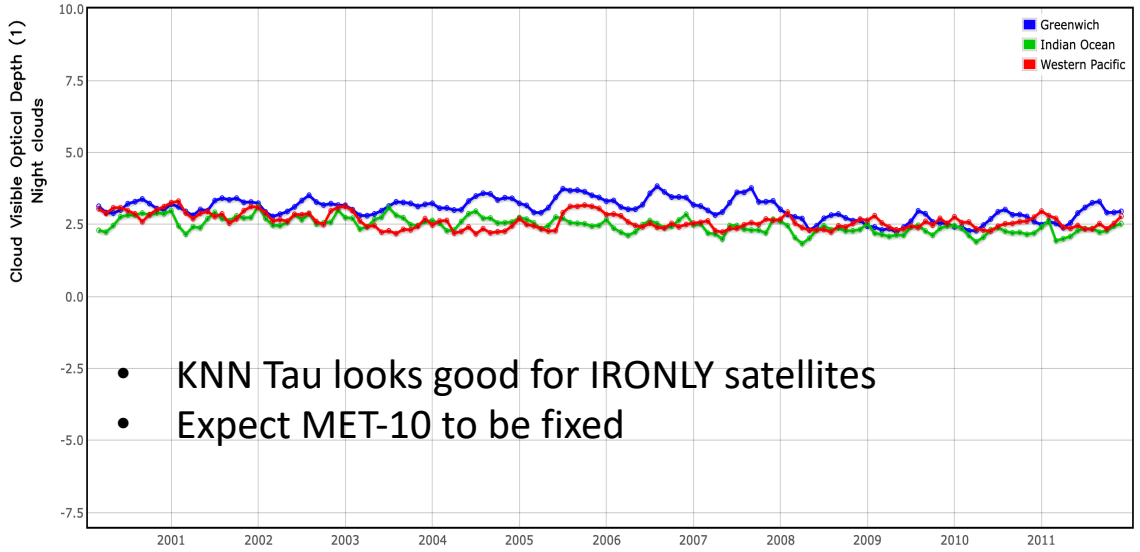
Updated 2ch Satellites (MET-5, MET-7, GMS-5) & SEVIRI (Met-8 to MET-11)

Ed4.1



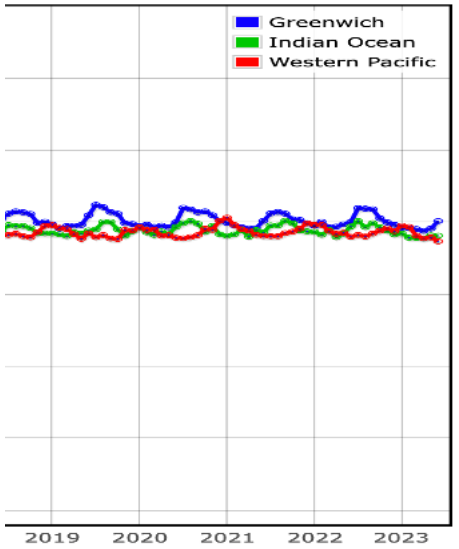
- No Nighttime Tau for IRONLY satellites

Ed4.2



- KNN Tau looks good for IRONLY satellites
- Expect MET-10 to be fixed

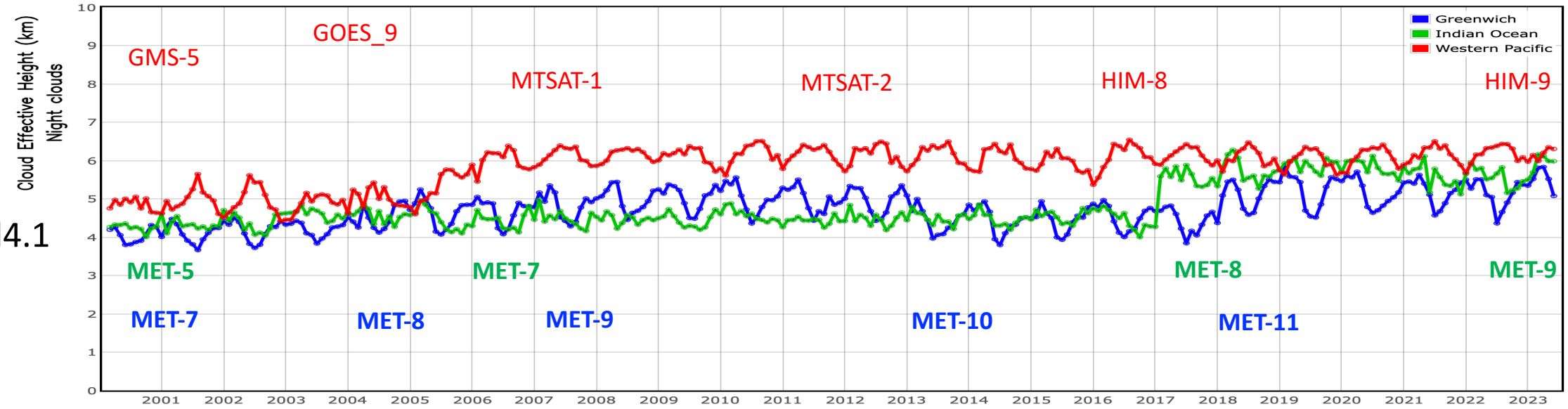
Not Re-processed Yet



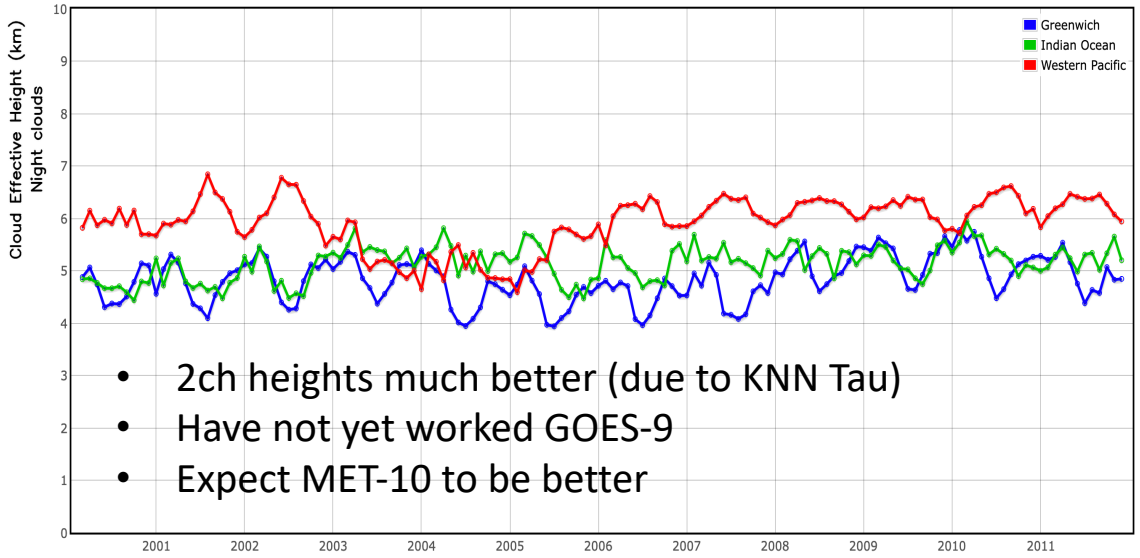
GEO Nighttime Cloud Height (60N – 60S)

Updated 2ch Satellites (MET-5, MET-7, GMS-5) & SEVIRI (Met-8 to MET-11)

Ed4.1

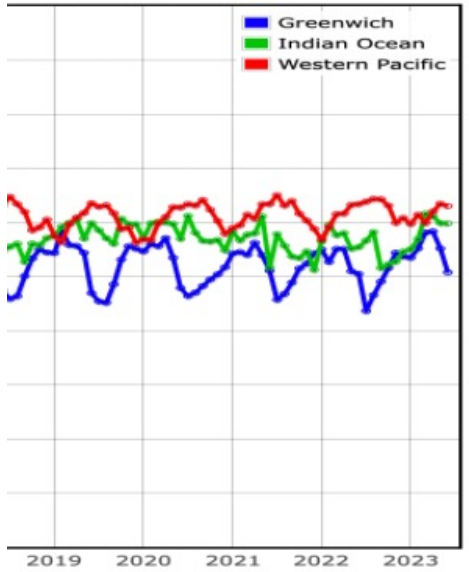


Ed4.2



- 2ch heights much better (due to KNN Tau)
- Have not yet worked GOES-9
- Expect MET-10 to be better

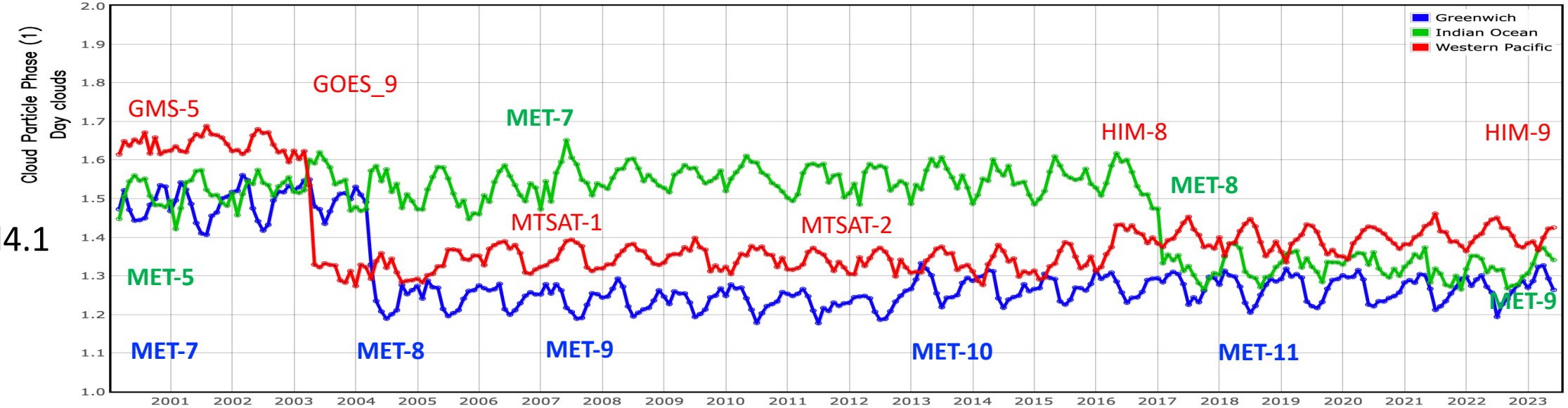
Not Re-processed Yet



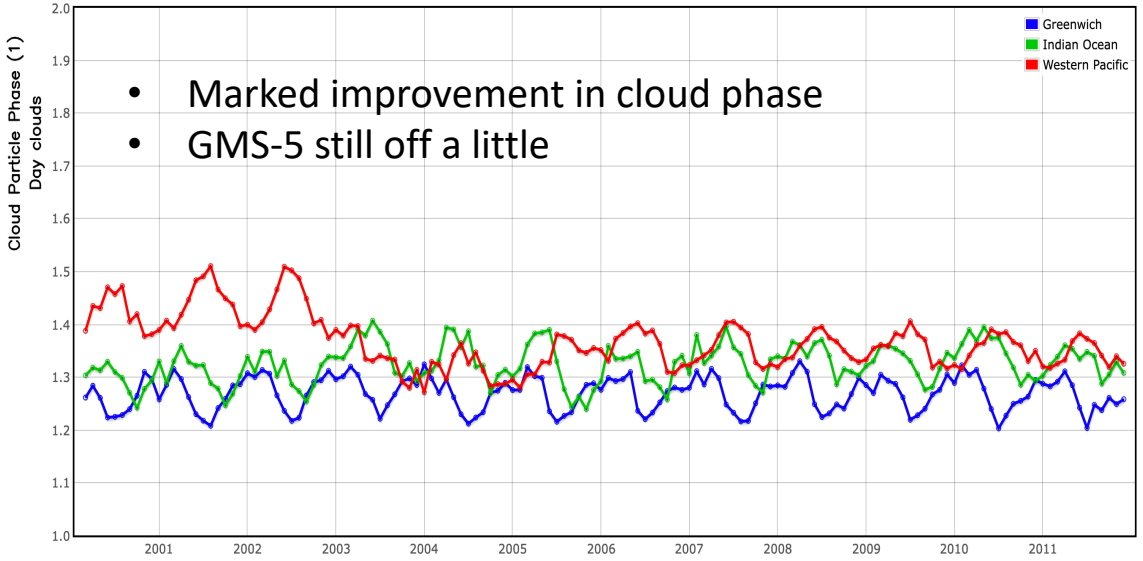
GEO Daytime Cloud Phase Fraction (60N – 60S)

Updated 2ch Satellites (MET-5, MET-7, GMS-5)

Ed4.1

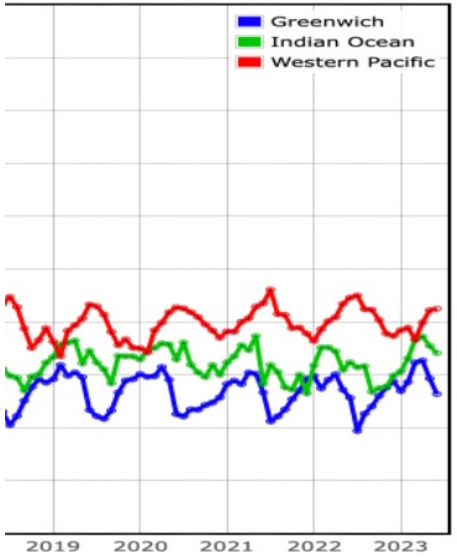


Ed4.2



- Marked improvement in cloud phase
- GMS-5 still off a little

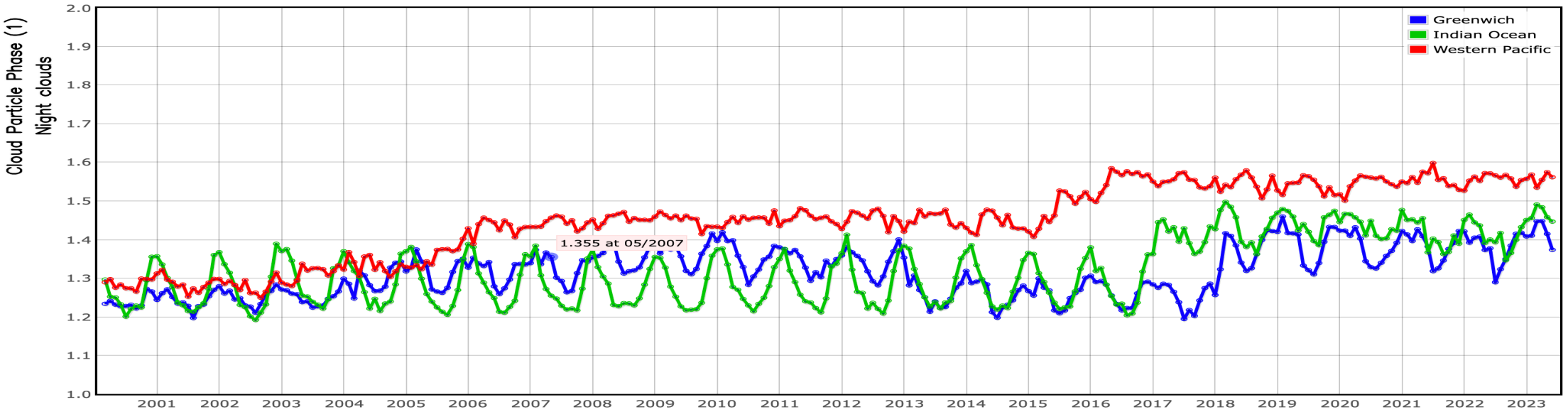
Not Re-processed Yet



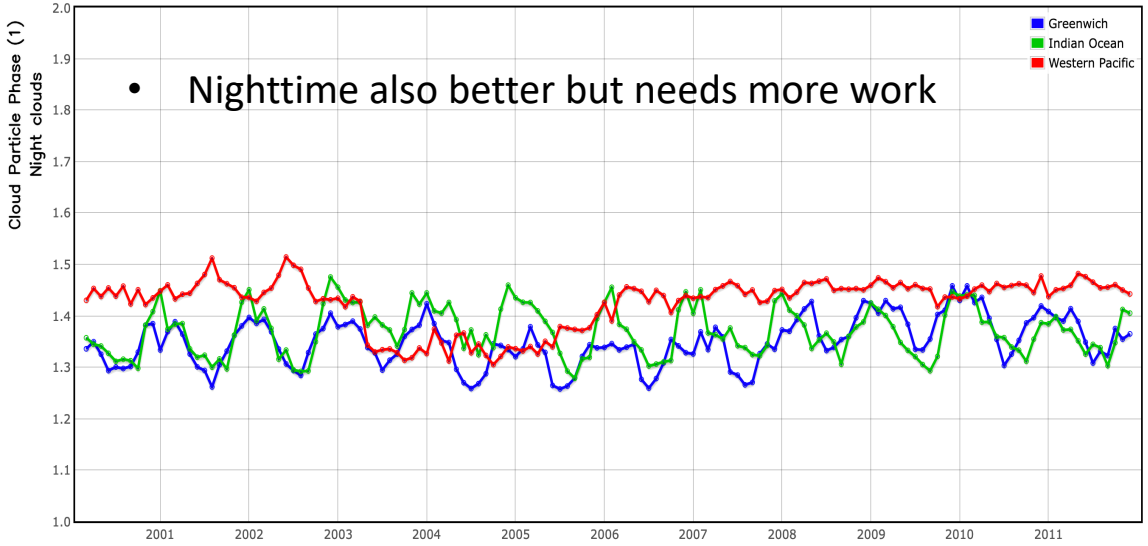
GEO Nighttime Cloud Phase Fraction (60N – 60S)

Updated 2ch Satellites (MET-5, MET-7, GMS-5)

Ed4

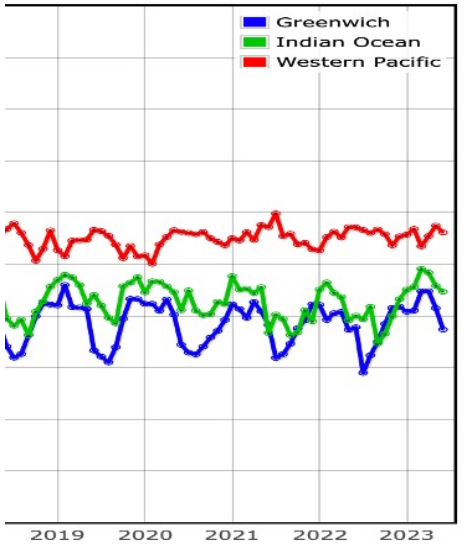


Ed4.2



- Nighttime also better but needs more work

Not Re-processed Yet

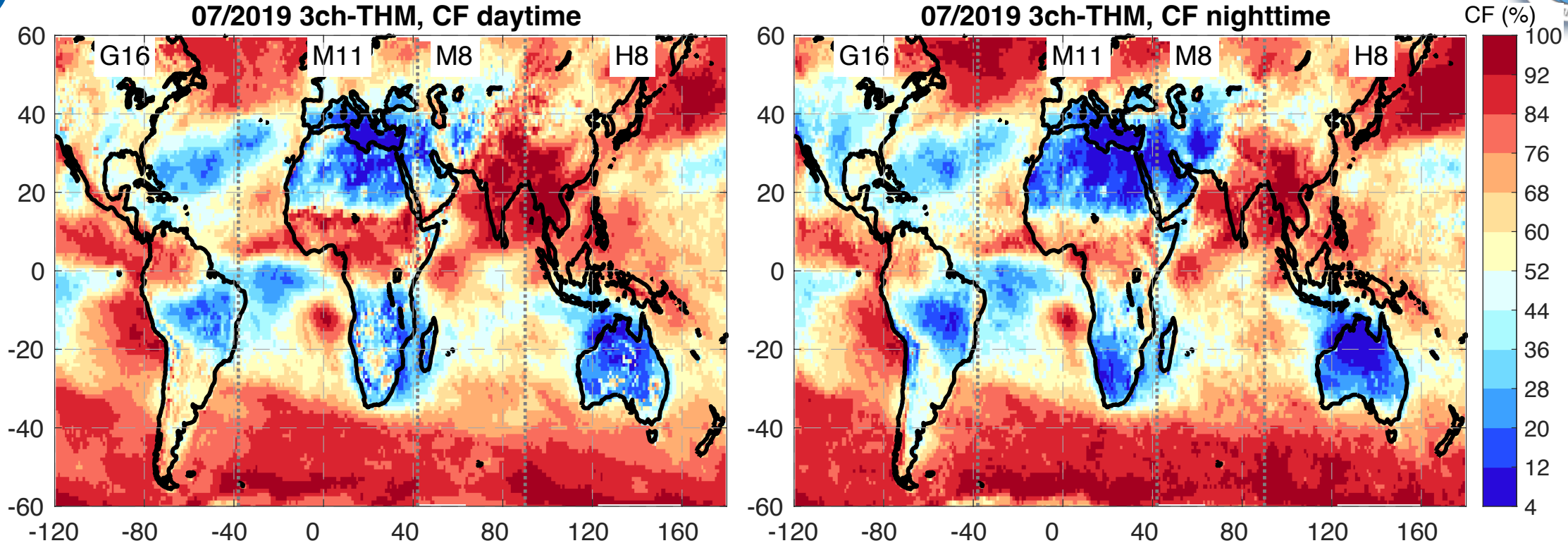


CERES GEO CLOUDS UPDATE

Initial evaluation of 3-ch algorithm

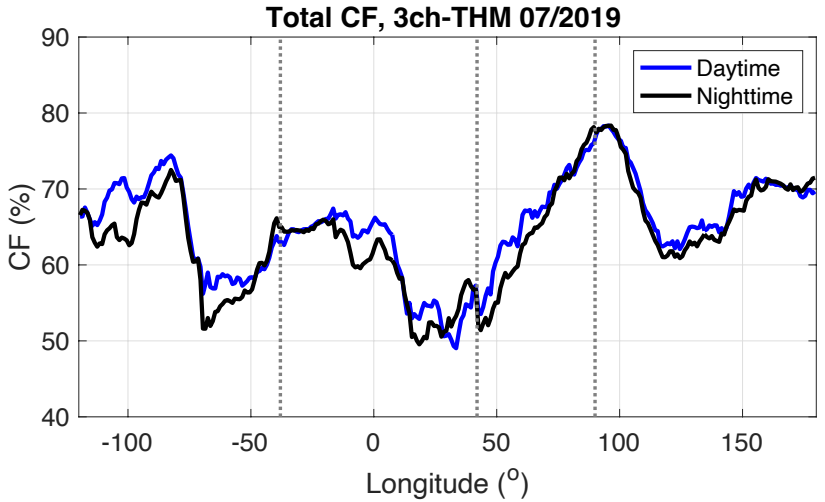
- Monthly cloud properties from G16, M11, M8, and H8 for July 2019
- New nighttime algo (KNN) not yet implemented but ready

Total Cloud Fraction

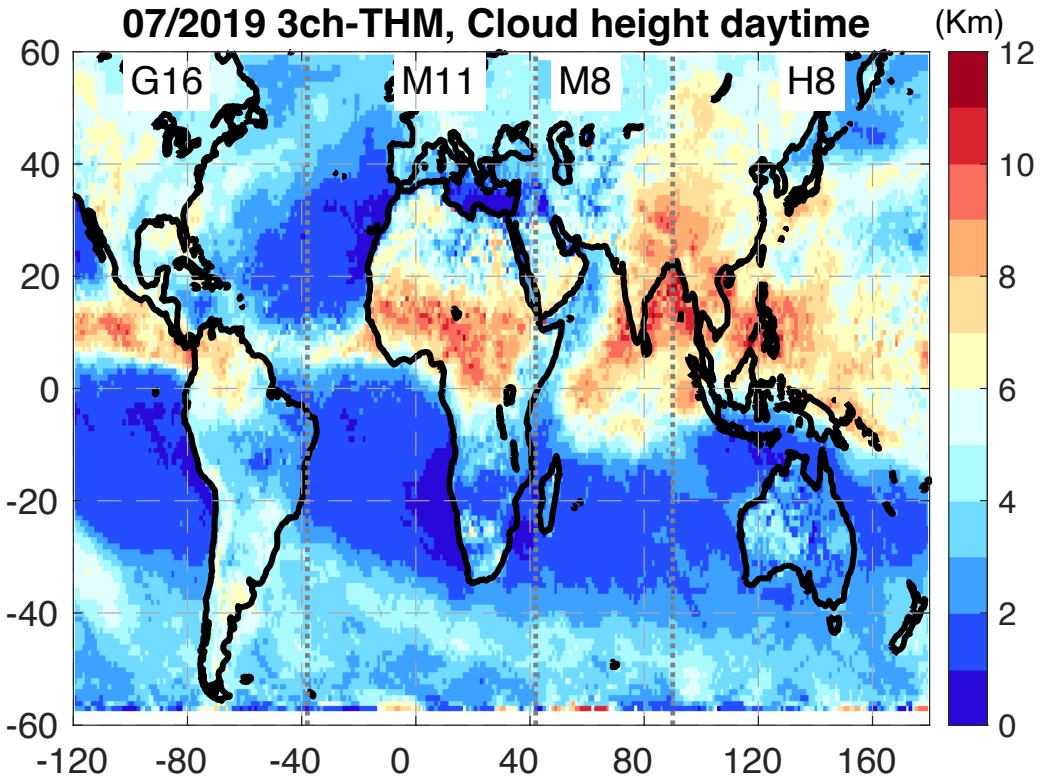


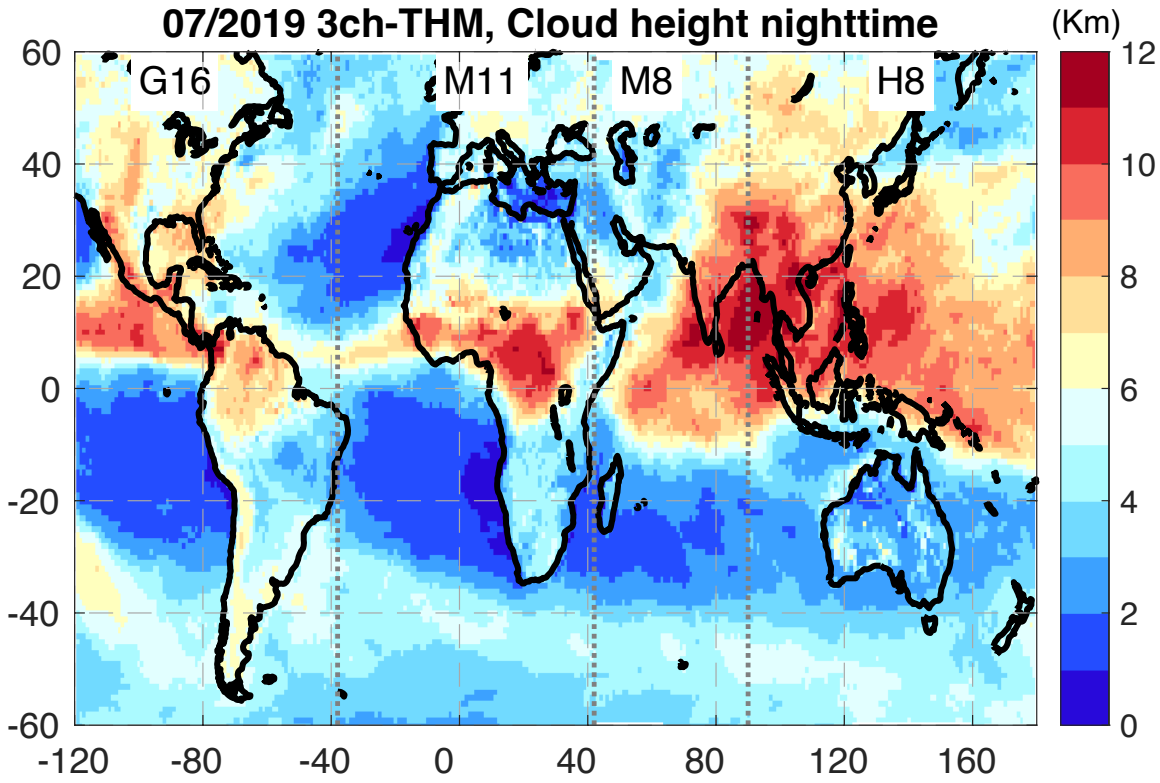
Daytime, SZA<75˚
Nighttime, SZA>90˚

Zonal view:

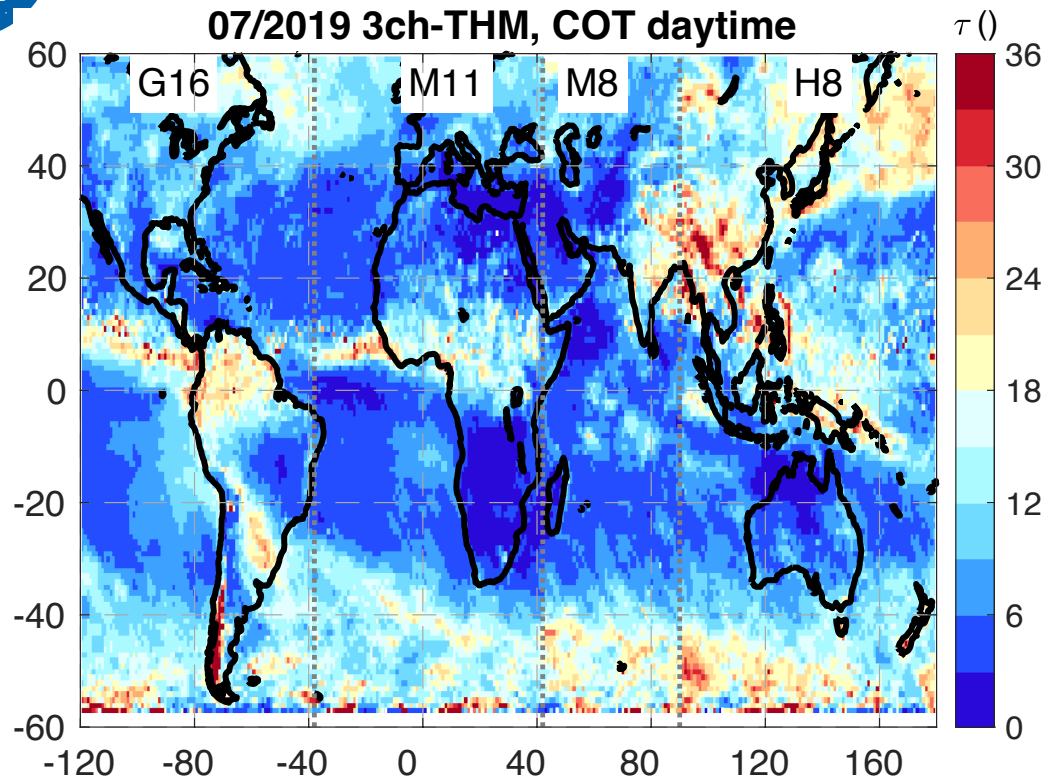


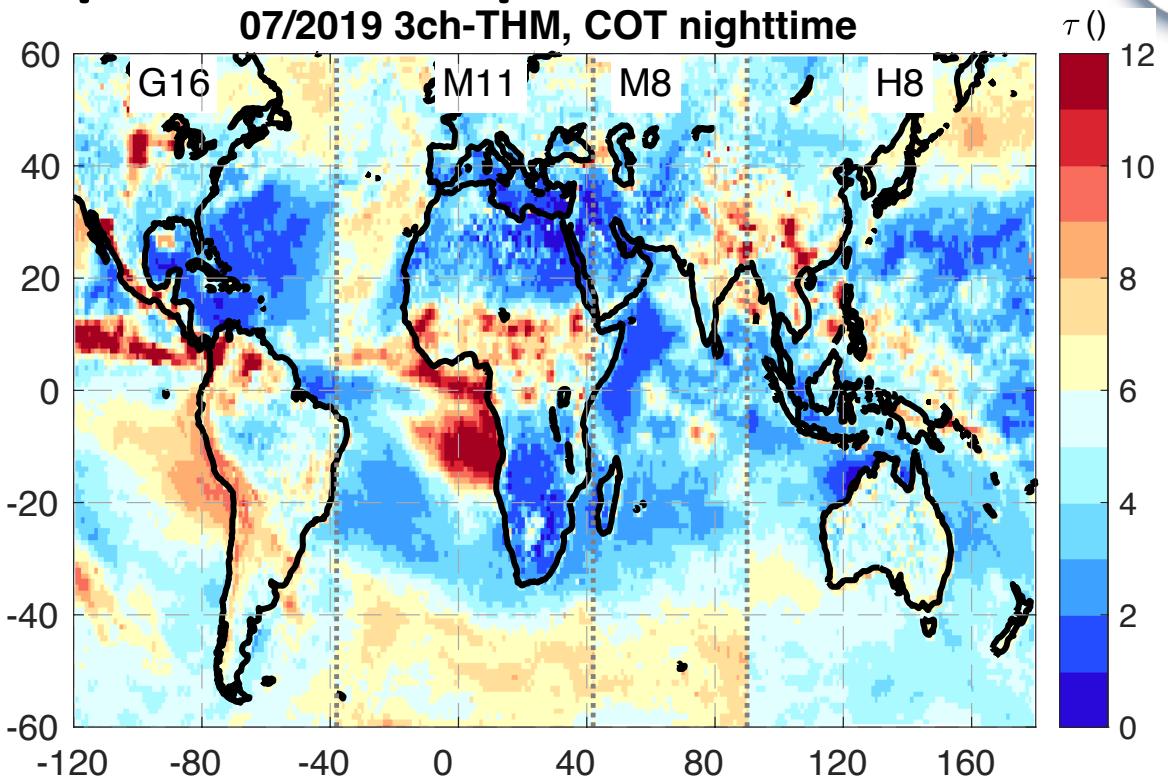
Cloud height



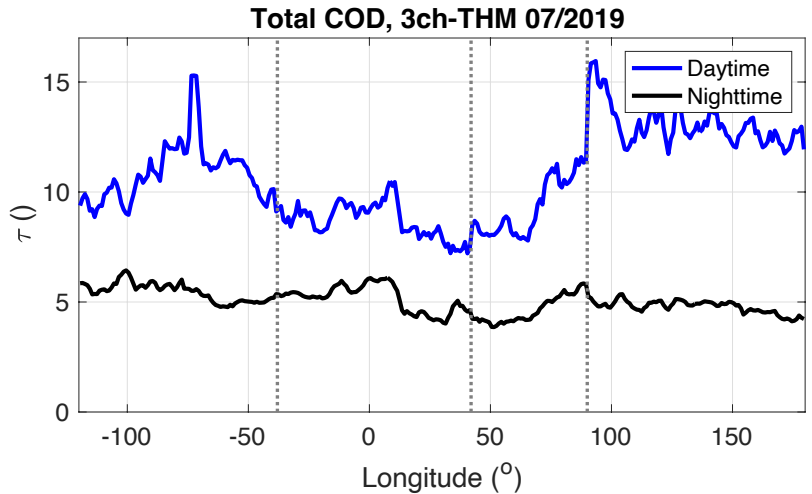


Total cloud optical depth



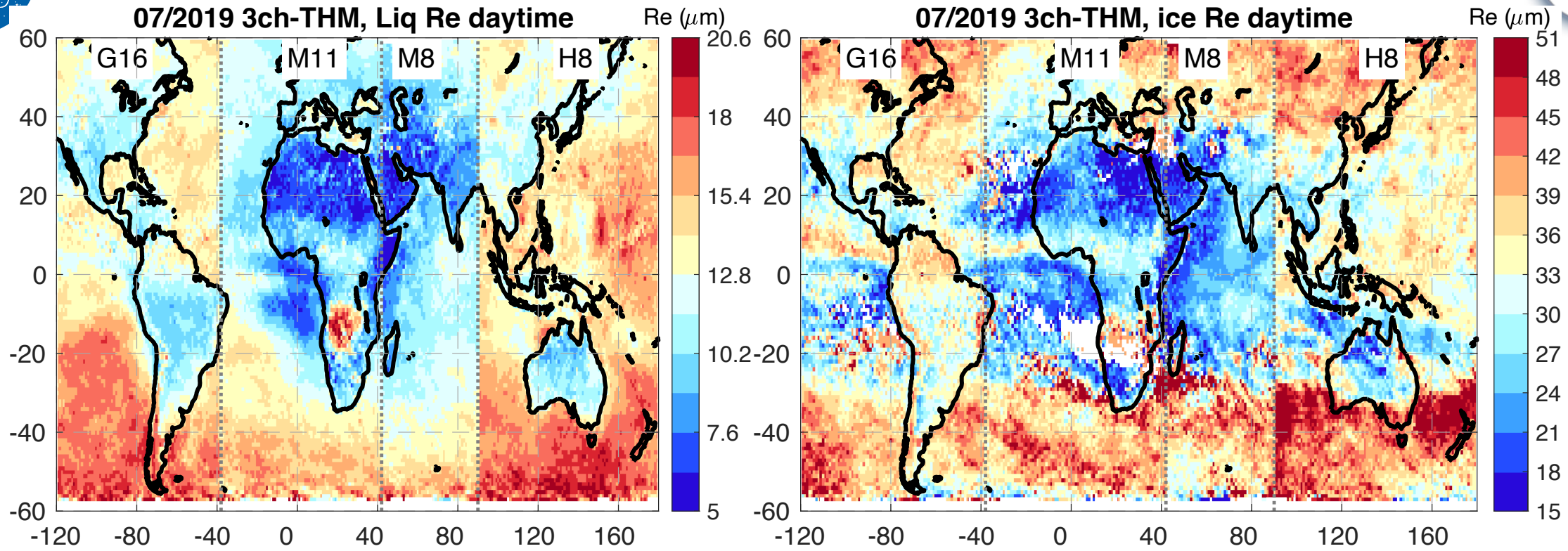


Zonal view:

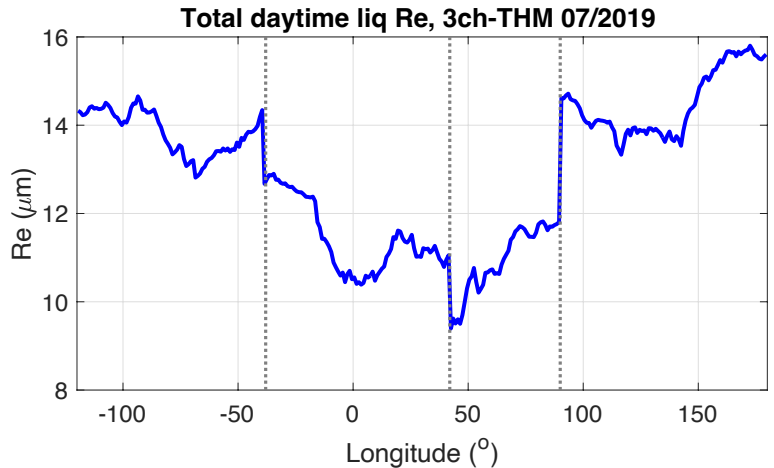


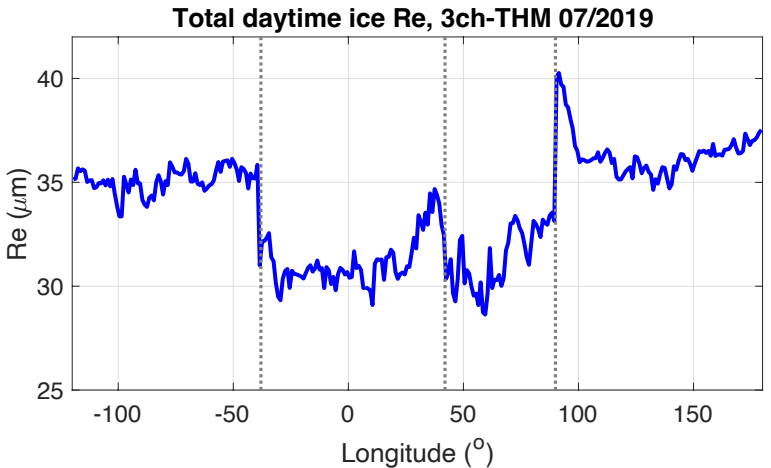
Nighttime algorithm updates not yet implemented in 3ch code

Daytime particle size (Liquid and ice)

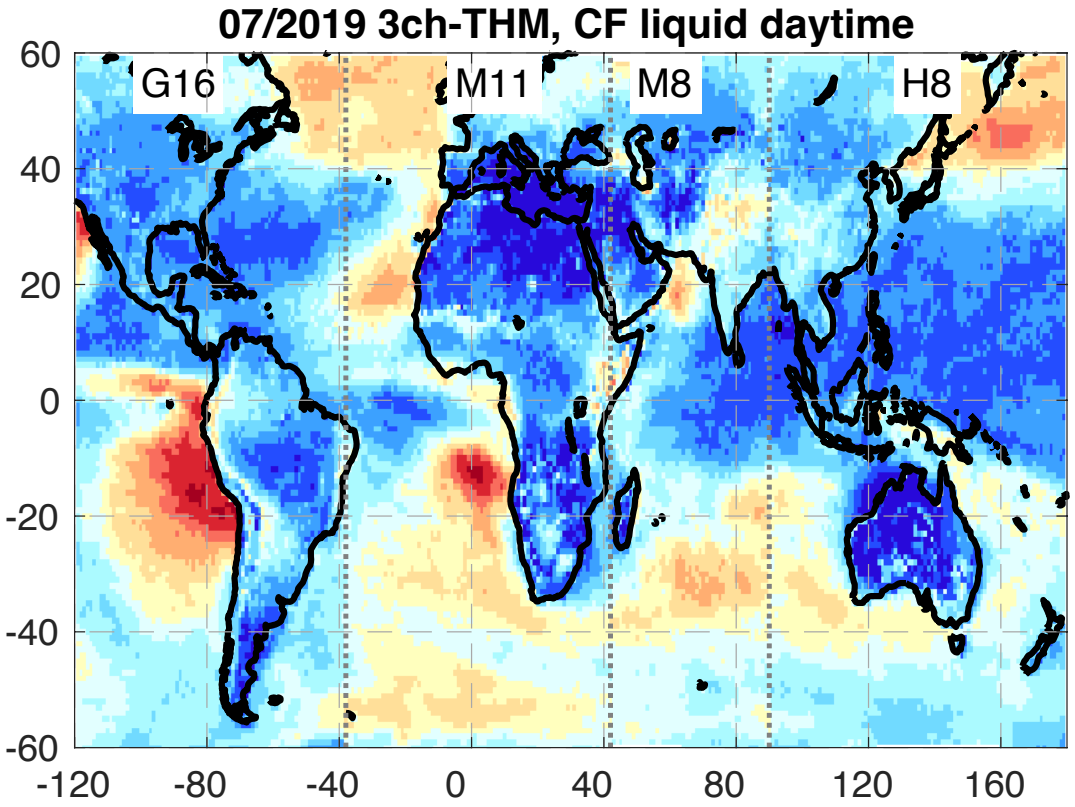


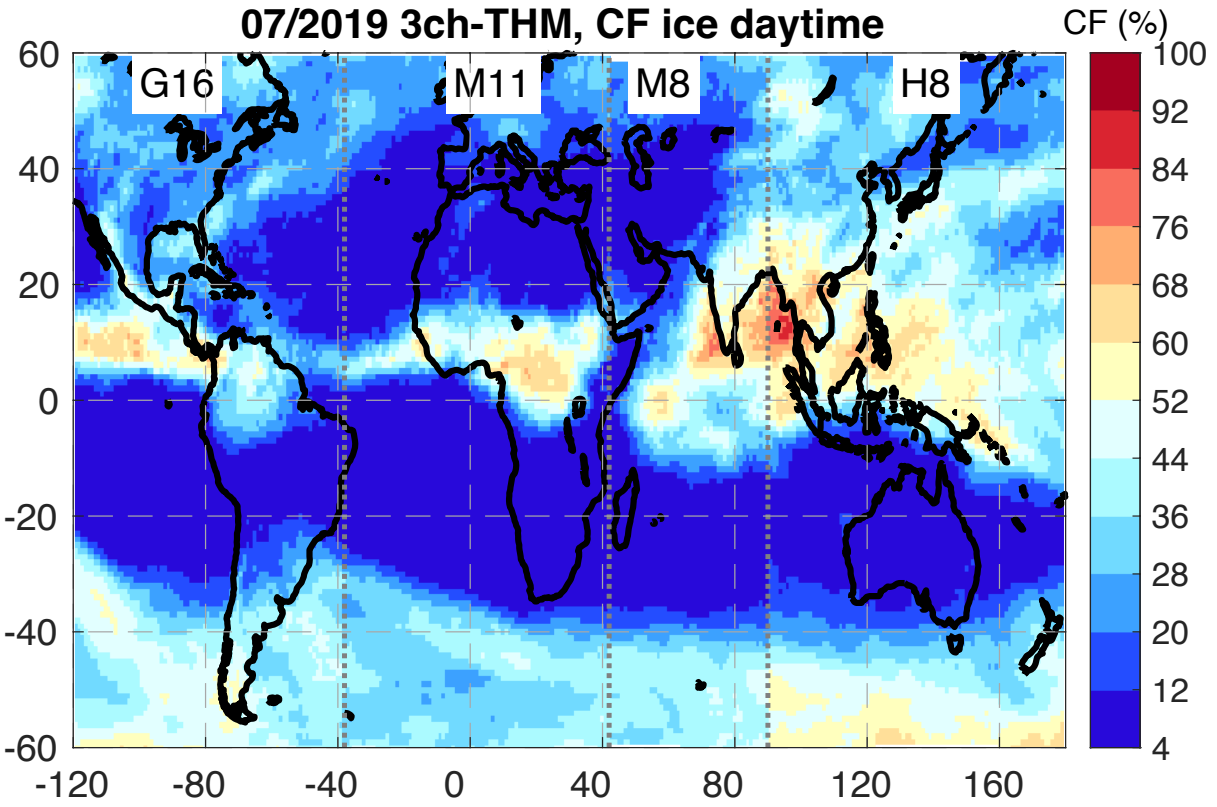
Zonal view:





Liquid and ice CF





Summary mean values Ed4 and 3ch (Ed5)

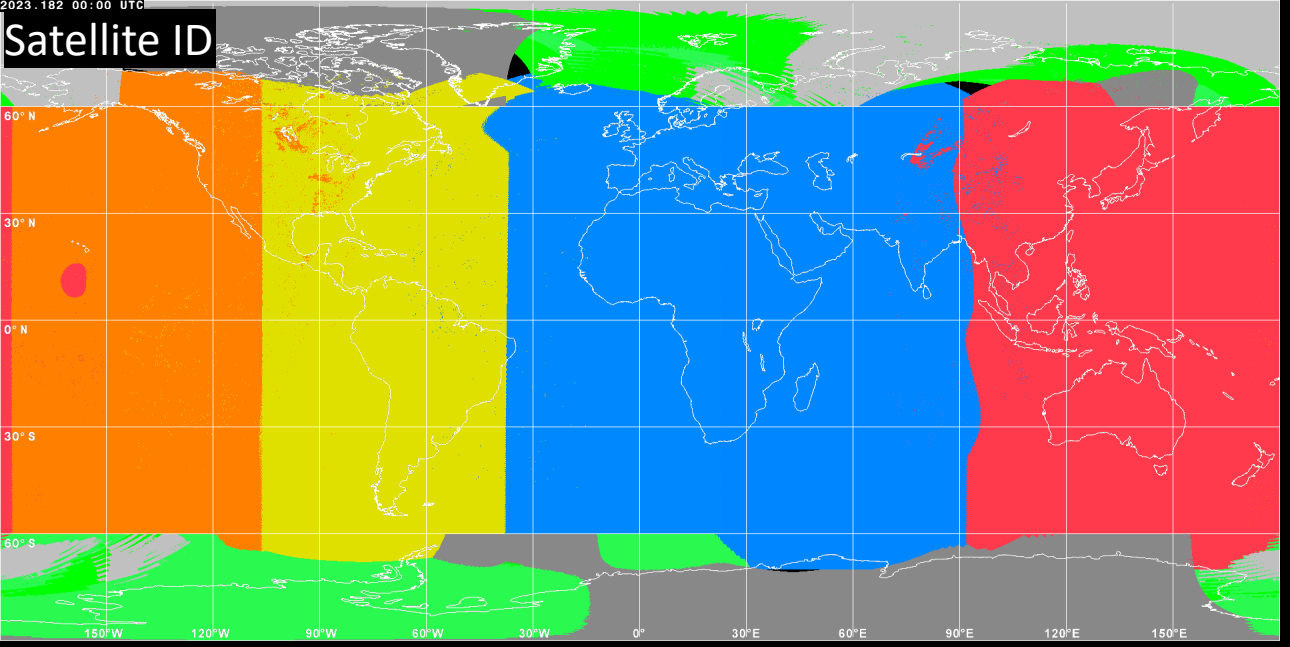
Variable	Ed4 (8ch)	Ed5 (3ch)
Total CF (day)	67.4 %	65.3%
Total CF (night)	65.3%	63.8%
Total cloud temp (day)	271 K	271.3 K
Total Cloud temp (night)	263.2 K	265.1 K
Total Cloud height (day)	4.2 km	4.0 km
Total Cloud height (night)	5.4 km	4.9 km
Total tau (day)	10.9	10.7
total tau (night)	5.1	5.0
Liquid Re (day)	15.1 μm	12.9 μm
Ice Re (day)	45 μm	33.8 μm

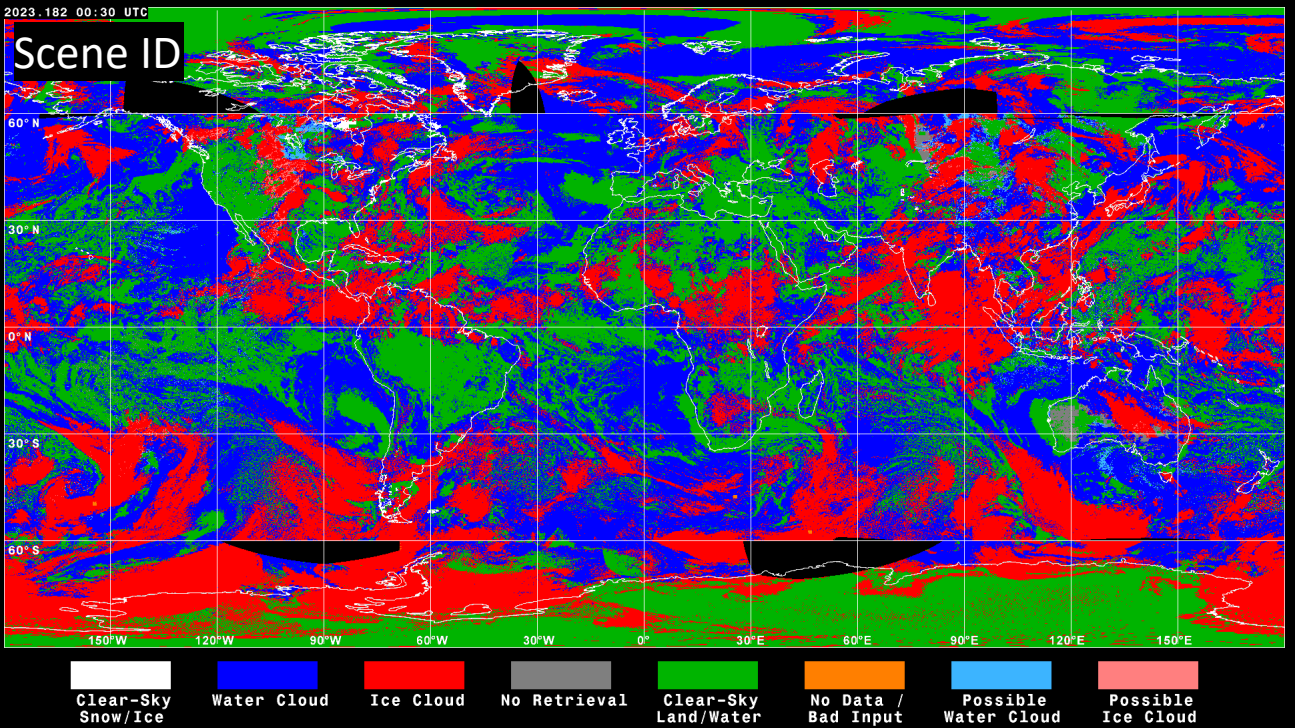
CERES GEO CLOUDS UPDATE

Next steps for 3-ch algorithm

- Revise Meteosat 3.9 µm solar constants
- Implement new nighttime algorithm
- Revise cloud mask over land
- Expand testing to other satellites
- Optimize 2ch algorithm for consistency

Global Cloud Composites (GCC) from Satellites

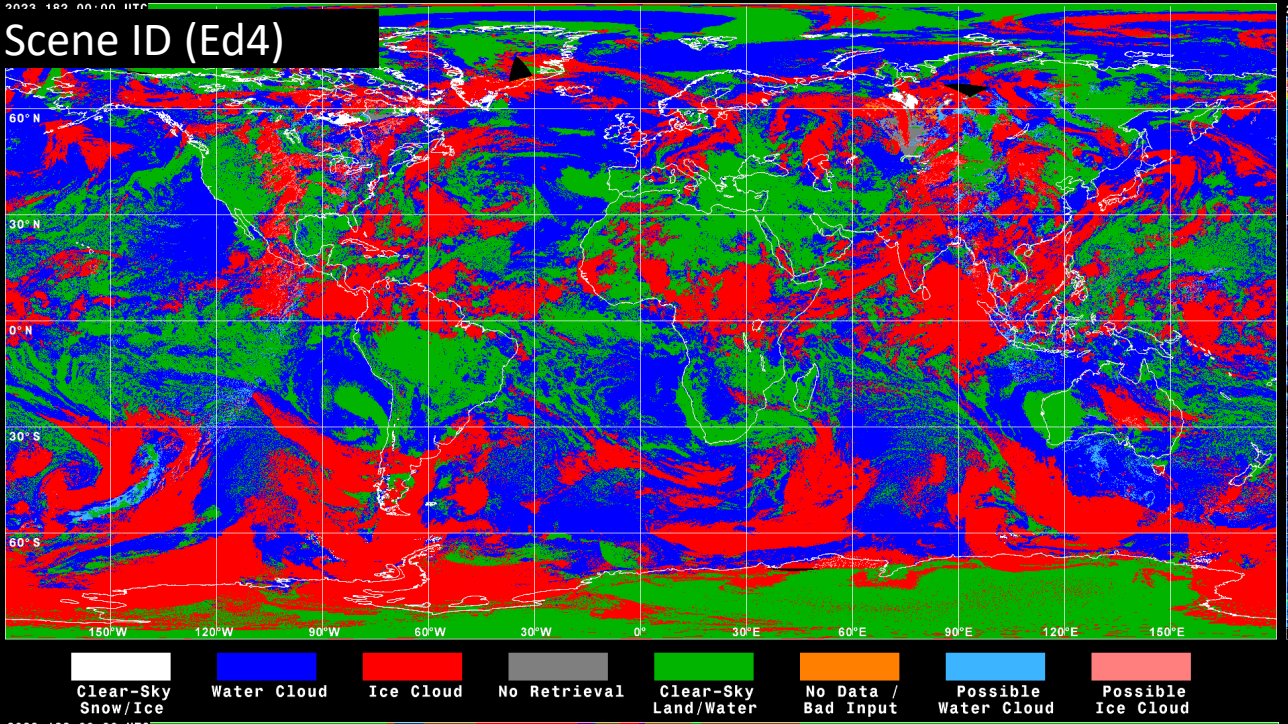


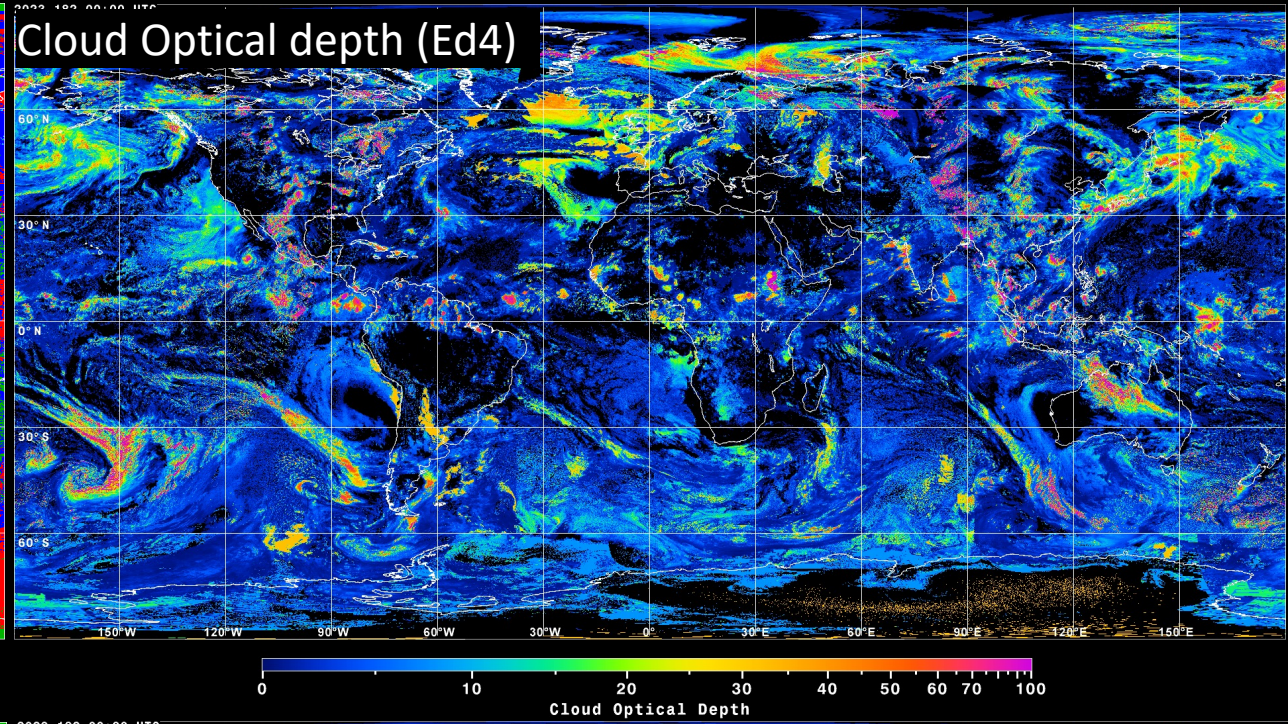


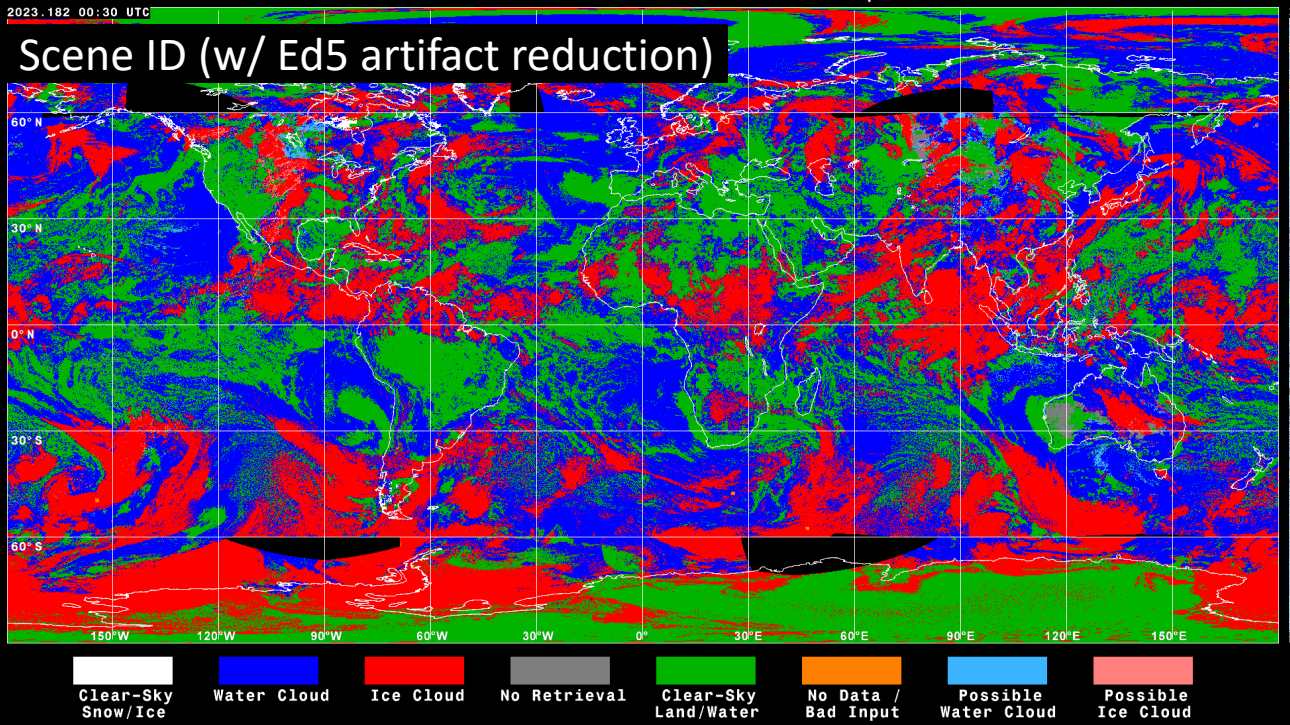
Objectives: Optimally combine radiances and derived products (cloud properties and radiative fluxes) from multiple GEO and LEO satellite imagers as seamlessly as possible and at high resolutions

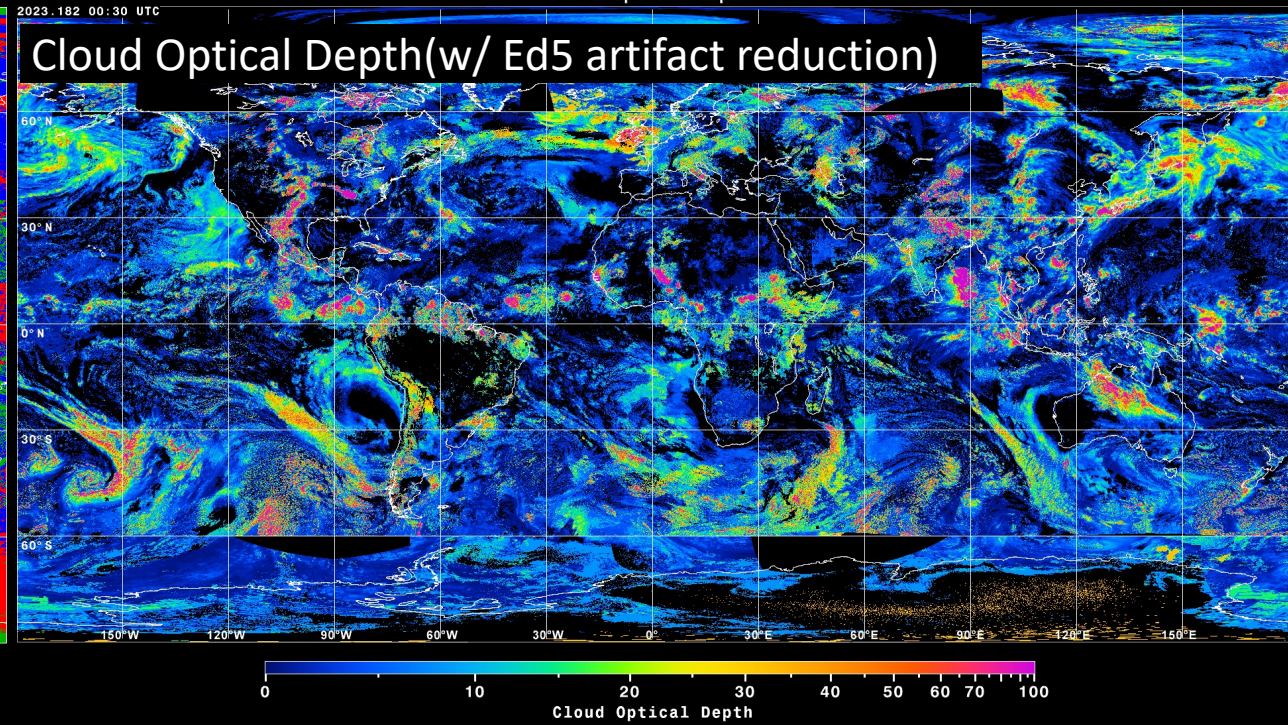
- Partially funded by NASA SNWG to produce a multi-year, hourly dataset to serve modeling needs related to cloud parameterizations
- Day & Night, 3-km grid, 30-60 minutes
- Incorporates many CERES Ed5 cloud algorithm enhancements to improve accuracies, cross-platform consistency, and reduce artifacts (e.g sunglint, terminator)

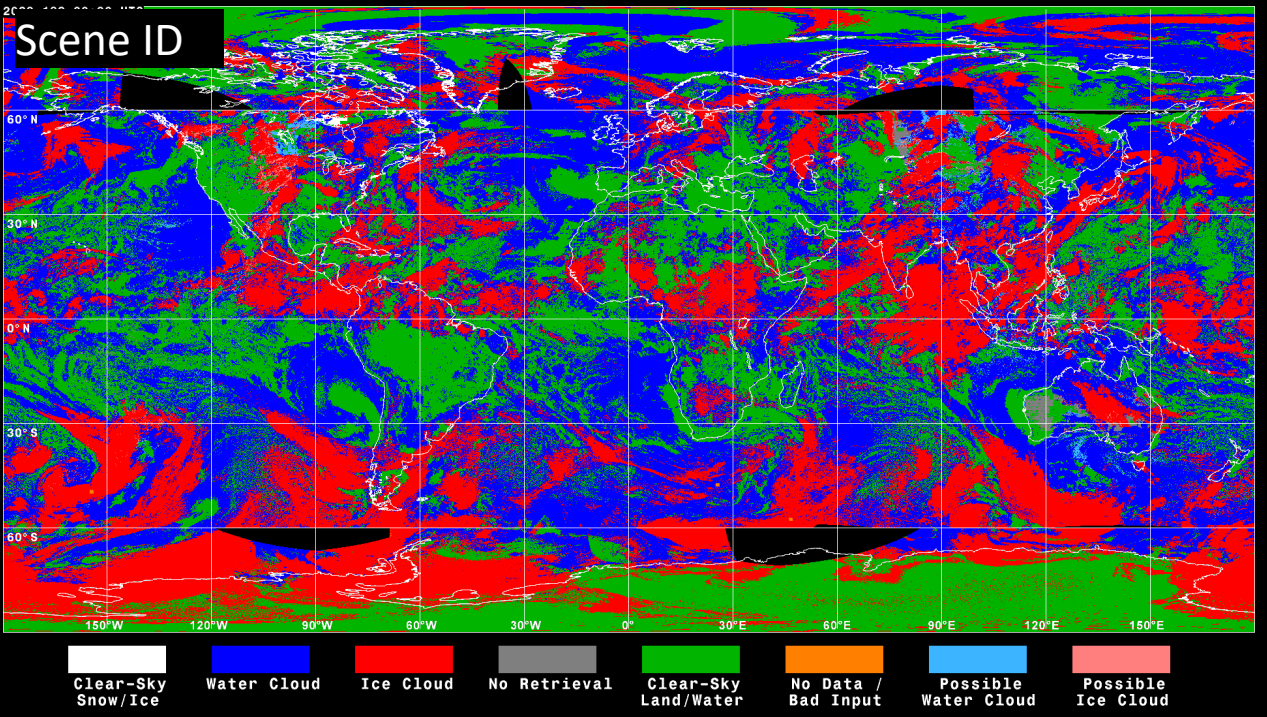
System is expected to be new backbone to support SatCORPS stakeholders with low latency data needs e.g. NCEP, CERES FLASHFlux, NASA POWER, DOE ARM, field campaigns, etc.

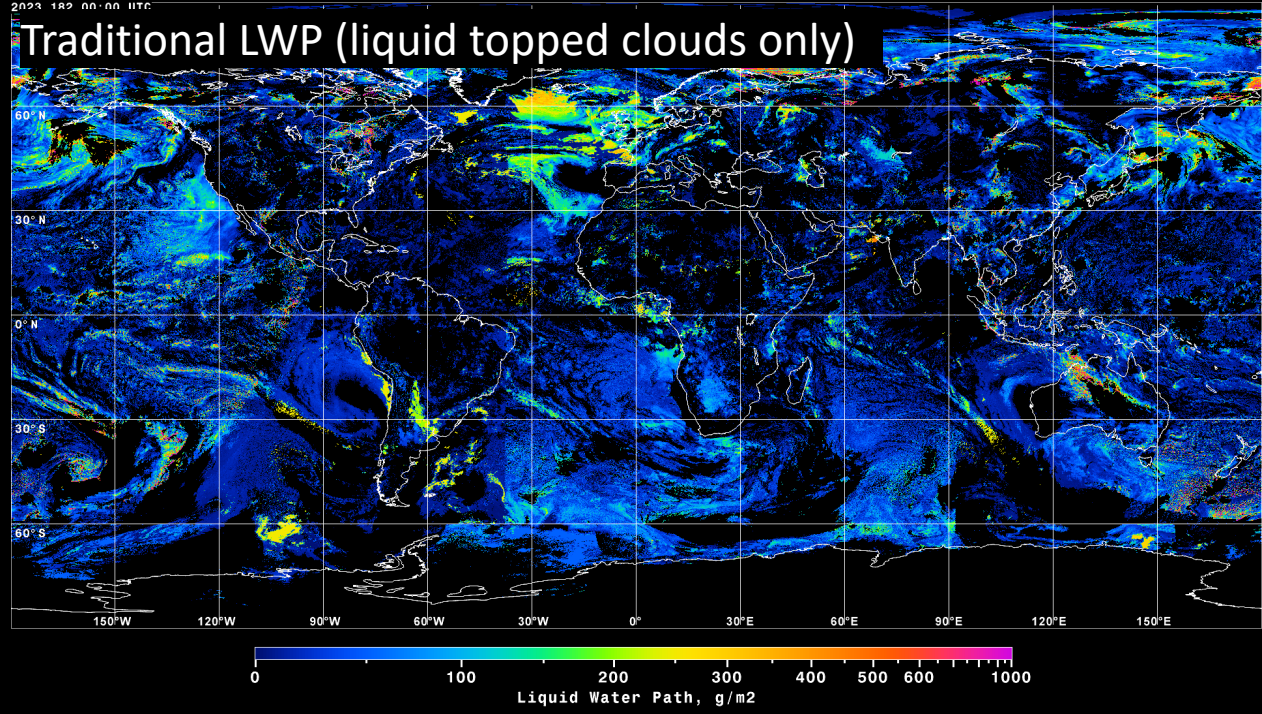

Scene ID (Ed4)
60°N
30°N
0°N
30°S
60°S
150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E
Clear-Sky Snow/Ice
Water Cloud
Ice Cloud
No Retrieval
Clear-Sky Land/Water
No Data / Bad Input
Possible Water Cloud
Possible Ice Cloud

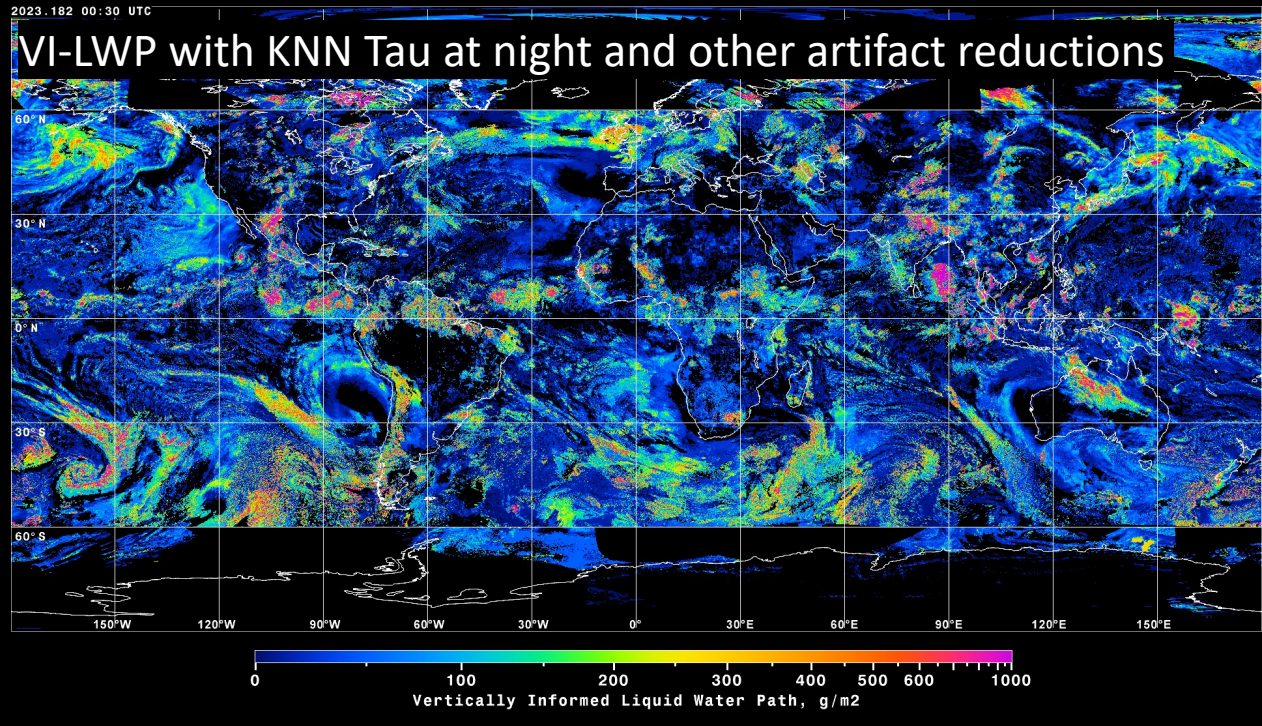

Cloud Optical depth (Ed4)
60°N
30°N
0°N
30°S
60°S
150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E
0 10 20 30 40 50 60 70 100
Cloud Optical Depth


2023.182 00:30 UTC
Scene ID (w/ Ed5 artifact reduction)
60°N
30°N
0°N
30°S
60°S
150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E
Clear-Sky Snow/Ice
Water Cloud
Ice Cloud
No Retrieval
Clear-Sky Land/Water
No Data / Bad Input
Possible Water Cloud
Possible Ice Cloud


2023.182 00:30 UTC
Cloud Optical Depth(w/ Ed5 artifact reduction)
60°N
30°N
0°N
30°S
60°S
150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E
0 10 20 30 40 50 60 70 100
Cloud Optical Depth

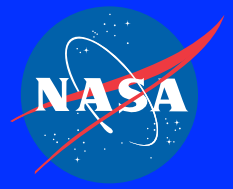






New parameterizations for ice and liquid water path

- Incorporates cloud vertical structure information from CloudSat/CALIPSO
- Incorporates thermodynamic phase partitioning from cloud models and aircraft observations
- Enables simultaneous estimates of IWP and LWP in ice overlapping liquid cloud conditions
  - more analogous to what models produce



QUESTIONS ?