Update on CERES Ed4 GEO Cloud Retrievals

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M. Nordeen (GEO), B. Scarino (cal, Tskin),
B. Shan (GEO avg), D. Spangenberg (everything), C. Yost (val)

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CERES Science Team Mtg., Reading, UK, 18-21 October 2016

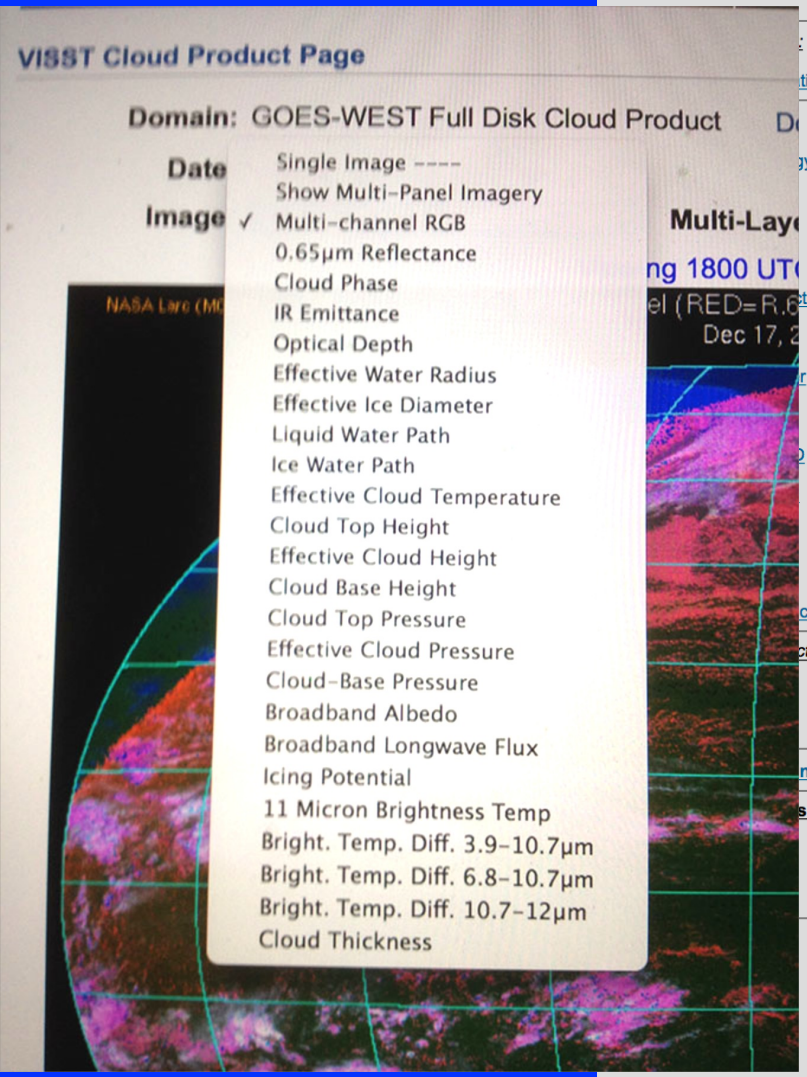
Objectives

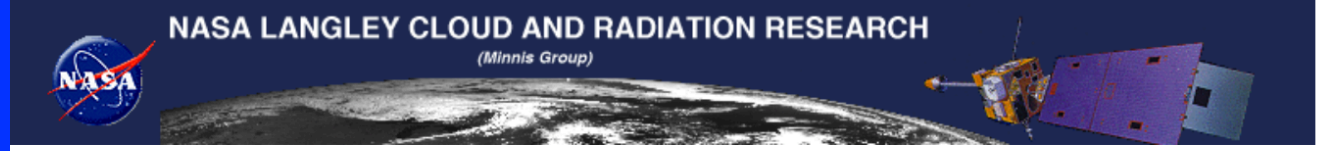
- Evaluate GEO cloud properties relative to Cloudsat/CALIPSO, relative to MODIS, and to check GEO to GEO consistency
- GEO cloud properties critical for time interpolating CERES measurements into Level-3 daily/monthly gridded products
- Emphasis on Himawari
  - Newest satellite (launched October 2014) replaced MTSAT ops July 2015 in CERES

NRT GEO Cloud Products

Data Can Be Accessed At

satcorps.larc.nasa.gov





User Warning, Please read !

Minnis Group Homepage

Real Time References

HIWC-2015 Cayenne

Satellite Imagery And Cloud Products Page

Real-time and Historical Cloud Product Loops: The cloud products are derived with VISST/SIST algorithm. Select a domain from the table below to access the real-time (blue cells) and archived products.

FULL-DISK CLOUD PRODUCTS (Real Time)					
GOES-WEST	GOES-EAST	METEOSAT	INSAT	HIMAWARI-8	MTSAT
New!! Merged Global Geostationary Gridded Cloud Products New!!					

CLOUD PRODUCTS				
GOES WEST	GOES EAST	METEOSAT	TWP DOMAIN	AVHRR/MODIS
North America (RR)		AMF-Azores	MTSAT	ARM-SGP
West CONUS	East CONUS	HIWC-Cayenne	MANUS	Alaska (Direct Broadcast)
MERGED CONUS		WEST EUROPE	AMIE (MTSAT and FENG-YUN)	Alaska (Relay)
ARM-SGP	ARM-SGP	EUROPE	HIWC	ARM-NSA
Alaska/NPacific	HIWC-2015-Puerto-Rico	ARM-NIAMEY	GOES-9	COVE
	HIWC-Cayenne		NAURU	
			DARWIN	

Real-time and Historical Satellite Imagery Loops: The links from the table below provide access to the real-time (blue cells) and historical image loops for various satellites.

SATELLITE IMAGERY				
N. America GOES-W	N. America GOES-E	Mid-Atlantic US	Southeast US	CONUS
E. Pacific GOES-E	SGP 1KM VIS GOES-E	TWP DARWIN MTSAT	TWP DARWIN FY2C	TWP DARWIN MTSAT & FY2C
CALWater-2/ACAPEX	Florida		GMS-5 TWP	PACS EPIC
Mid-West US (SGP)	Northeast US			
	Pacific/West			

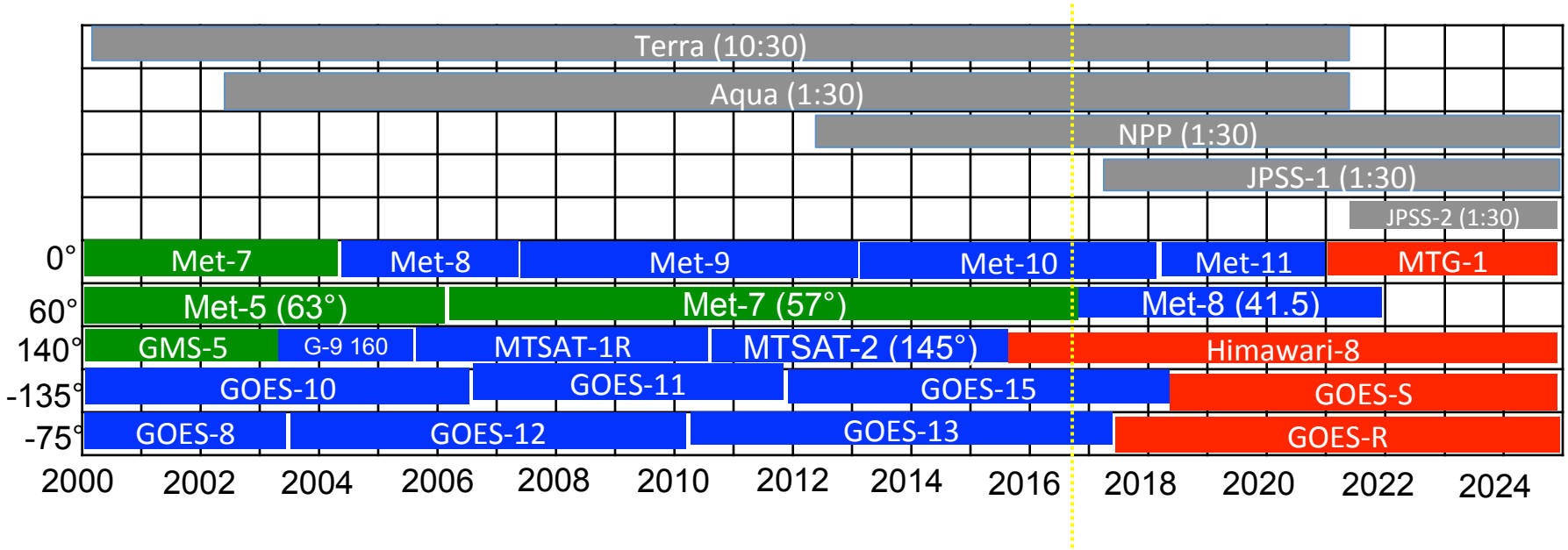
FULL-DISK SATELLITE IMAGERY				
GOES-W FD	GOES-E FD	MET/0E FD	MET-7/57E FD	HIMAWARI-8
		FY2D/86E FD	FY2C,E/105E FD	MTSAT FD

COMPOSITE SATELLITE IMAGERY	
A	ple MODIS

Data available digitally & graphically!

Java A viewing the

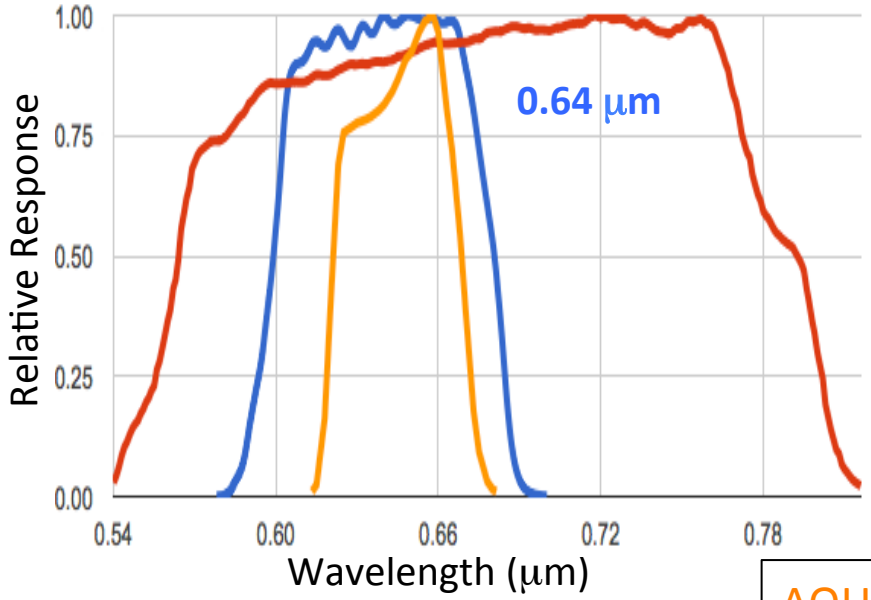
CERES record Geostationary Time Series

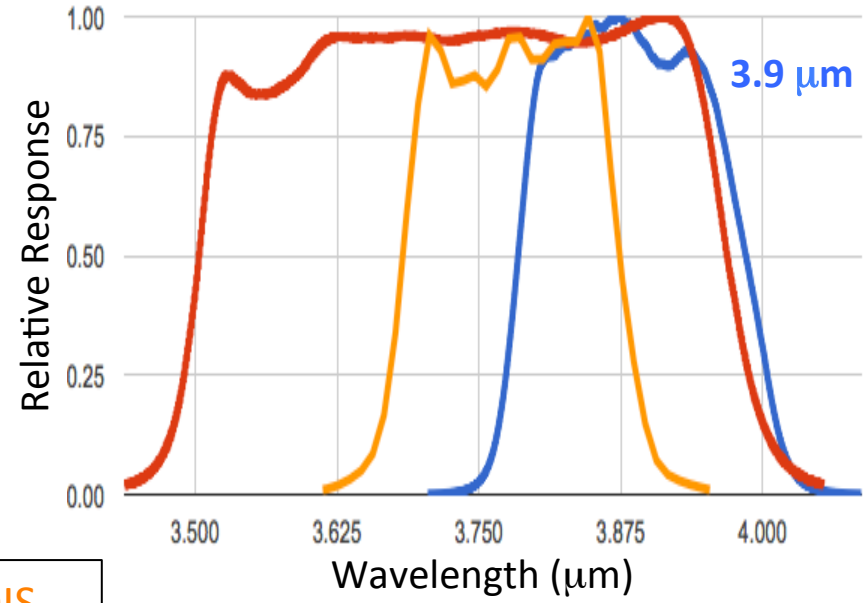


1st generation
2nd generation
3rd generation
MODIS/VIIRS

Various GEO's have different channels, resolutions

Himawari-8 first of 3rd generation satellites with advanced imager
- Improved spectral and spatial resolution, and precision

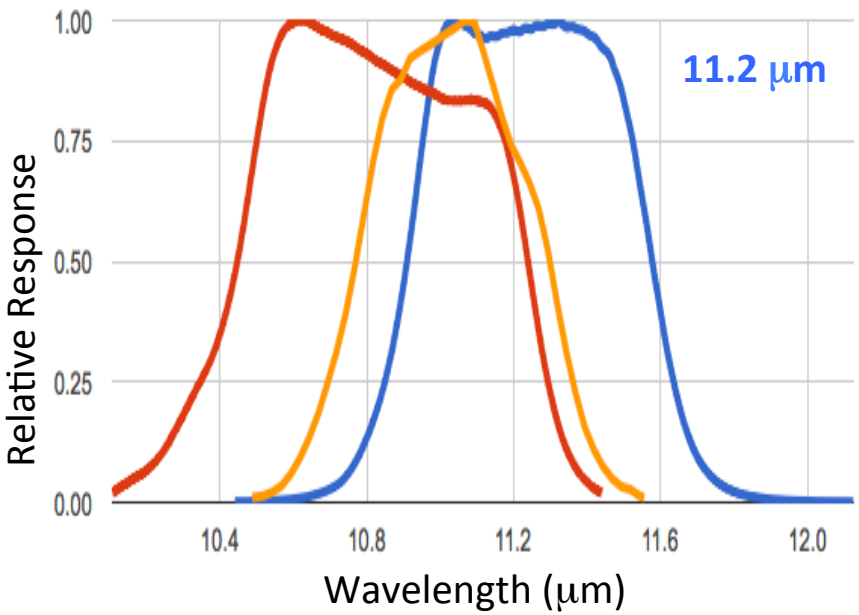


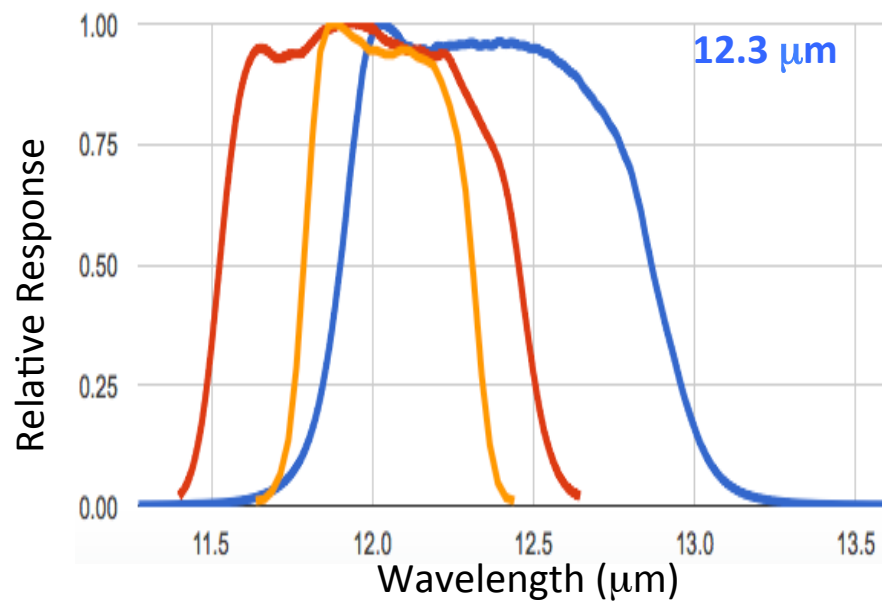


Original Himawari cloud analyses treated radiances like MTSAT

AQUA-MODIS
MTSAT
Himawari

New version incorporates Himawari specific SRF's in transmittance and emittance models





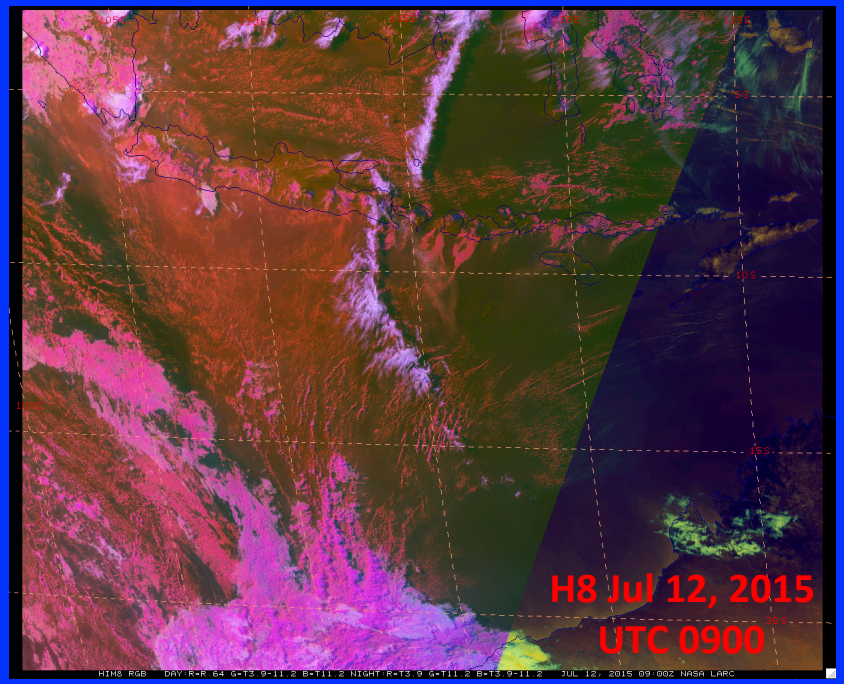
Initial Challenges with H8 Data

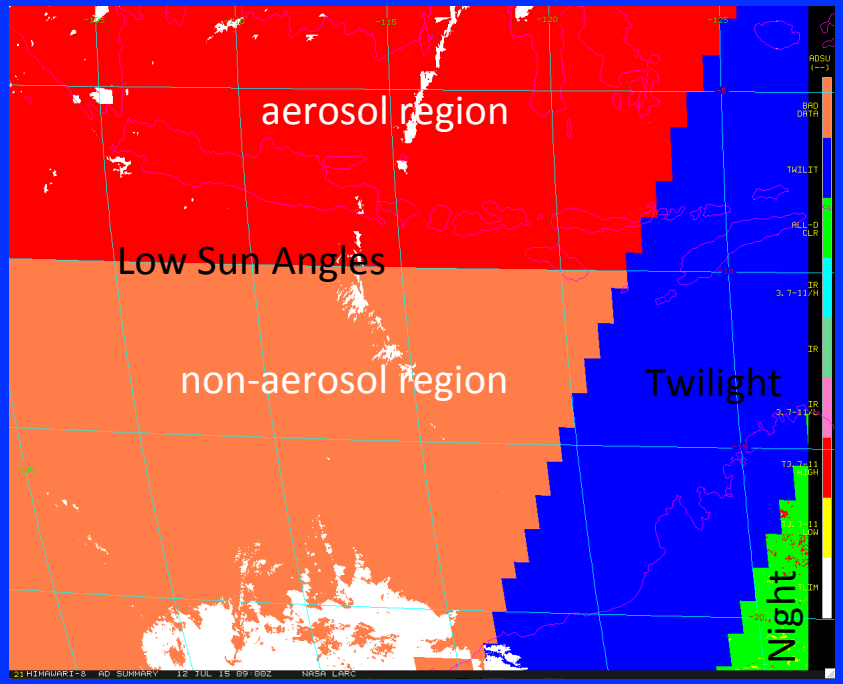
- Early analyses assumed MTSAT SRF's until the new emittance and transmittance models using H8 SRF's were developed
- More haze apparent at night (interpreted as thin cirrus, but not supported by CALIOP) – new emittance models helped
- Too much thin cirrus interpreted as low cloud (spectral response functions)
- Low cloud problems (discrimination from aerosols, pollution and biomass burning, issues with higher res)
- Aerosols of various types more apparent - need improved dust detection
- Problems along coast stand out more
  - Need improved clear sky maps; moving from single gridded mean vales to the use of dual land & ocean values in coastal regions (work in progress)
- Location, Tibetan plateau problems (high altitude, bright snow-free and snow surfaces, desert dust)
- High number of no retrievals (optical properties) for cloudy pixels (~ 10%) – resolution, cloud mask, emittance model problems

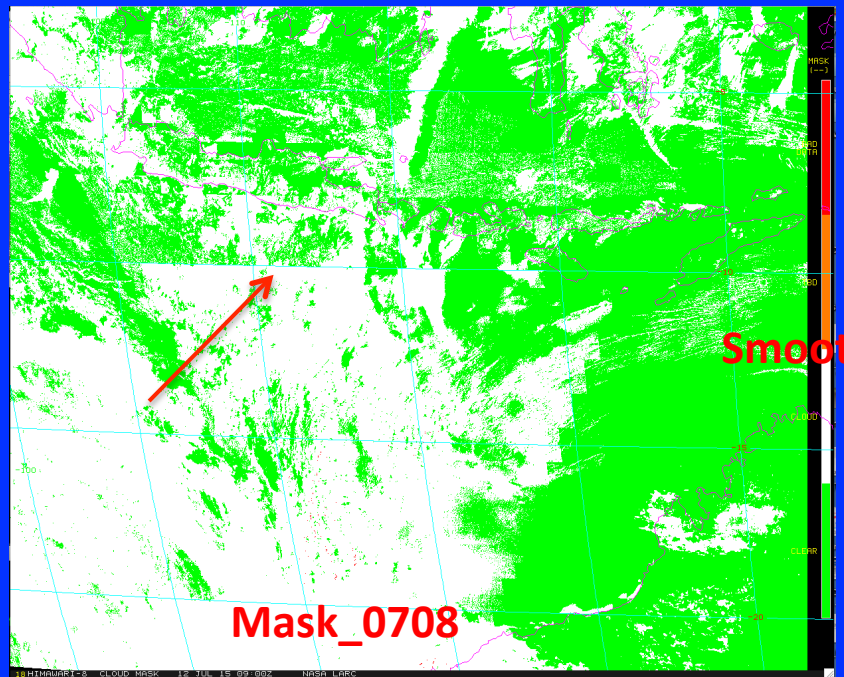
GEO Cloud Mask Update

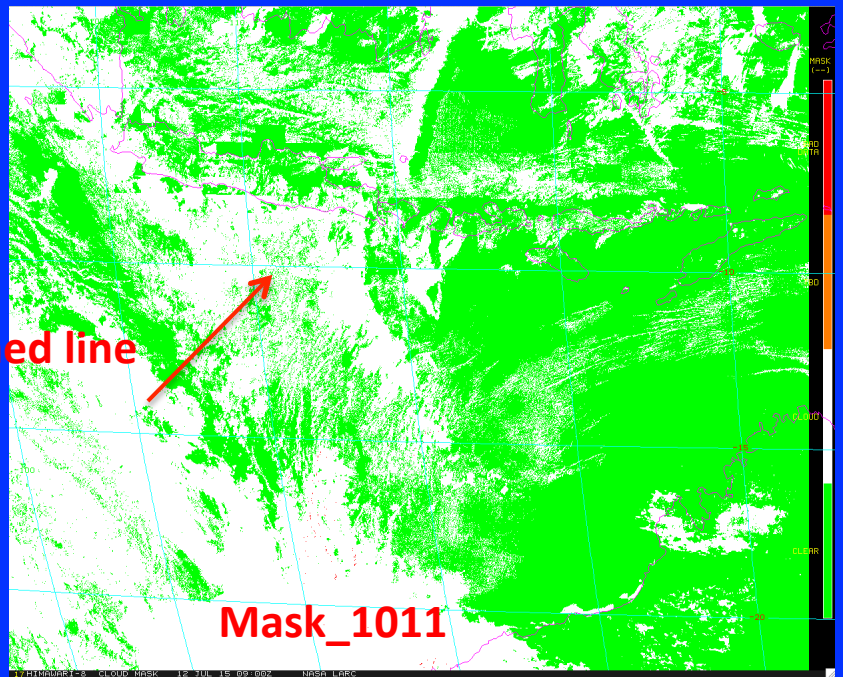
- **Improved Himawari daytime ocean low clouds and aerosol detection**
  - Reduced the discontinuity line across the aerosol region at low Sun angles
  - Developed and improved heavy dust and aerosol test
- **Improved MSG missing low clouds off African Coast**
- **Improved GOES-15 cloud detection at low Sun angles seen in MAGIC Field Experiments.**

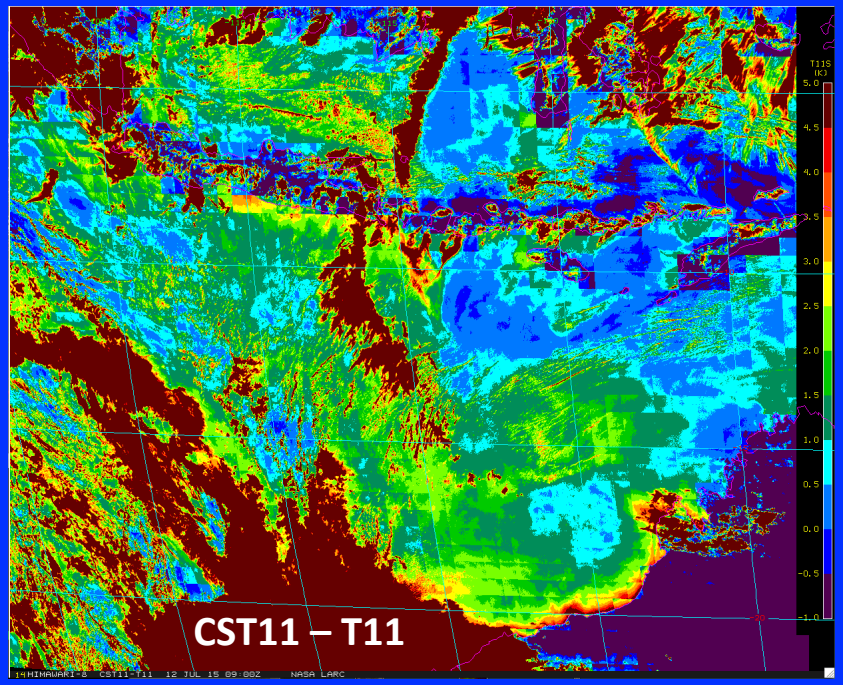
Problems with finite boundaries for various cloud mask tests

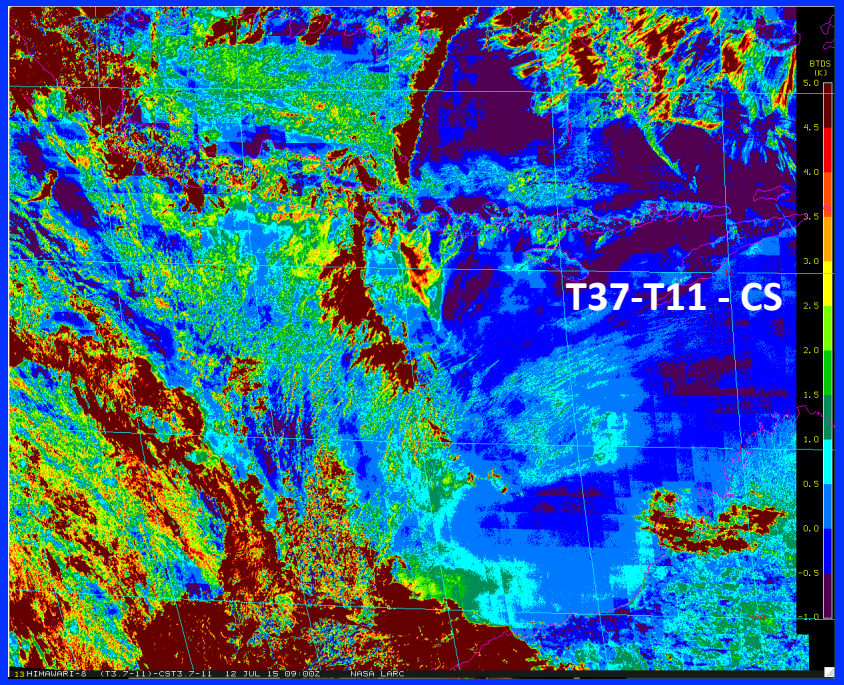


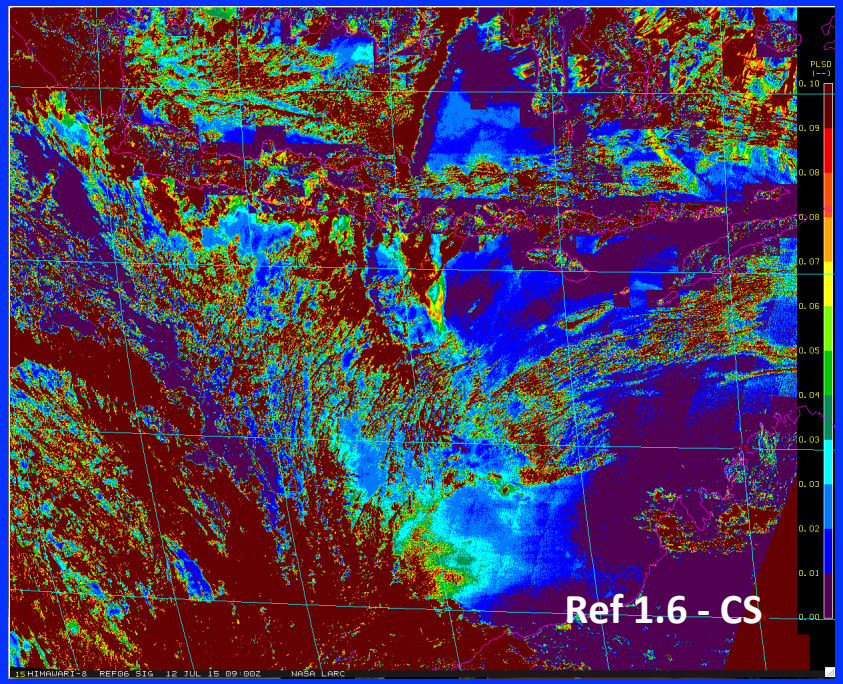







CST11 – T11


T37-T11 - CS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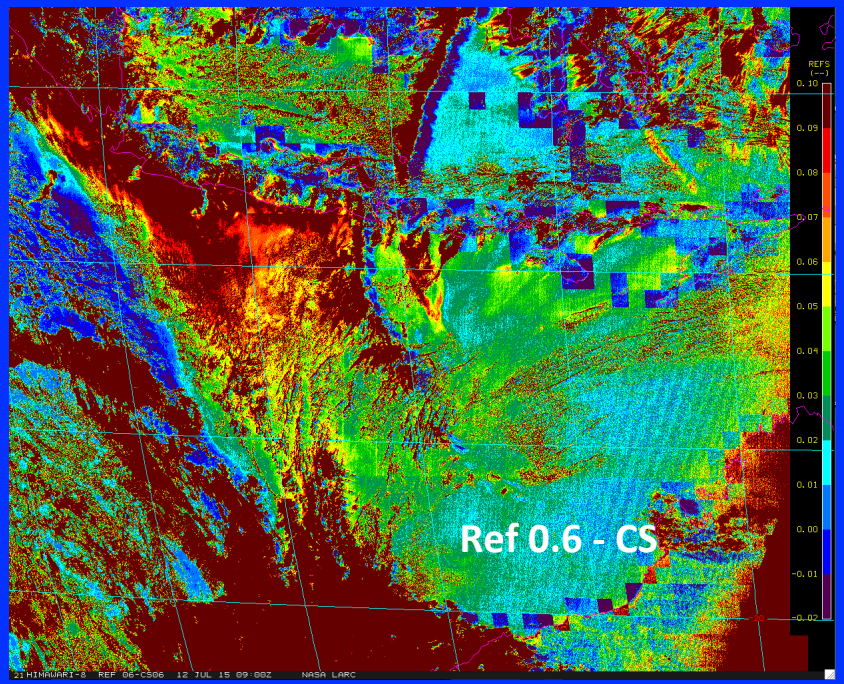
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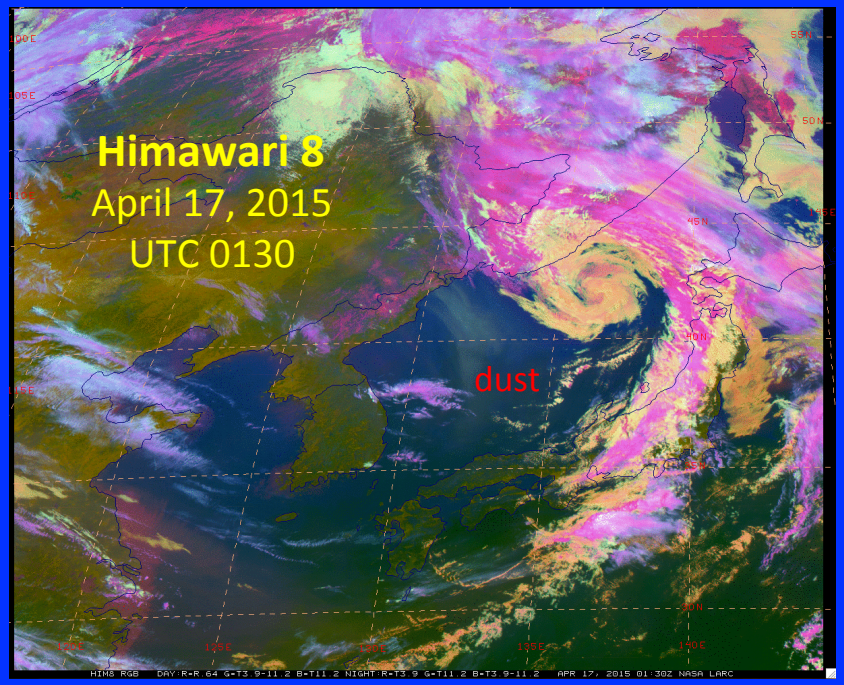
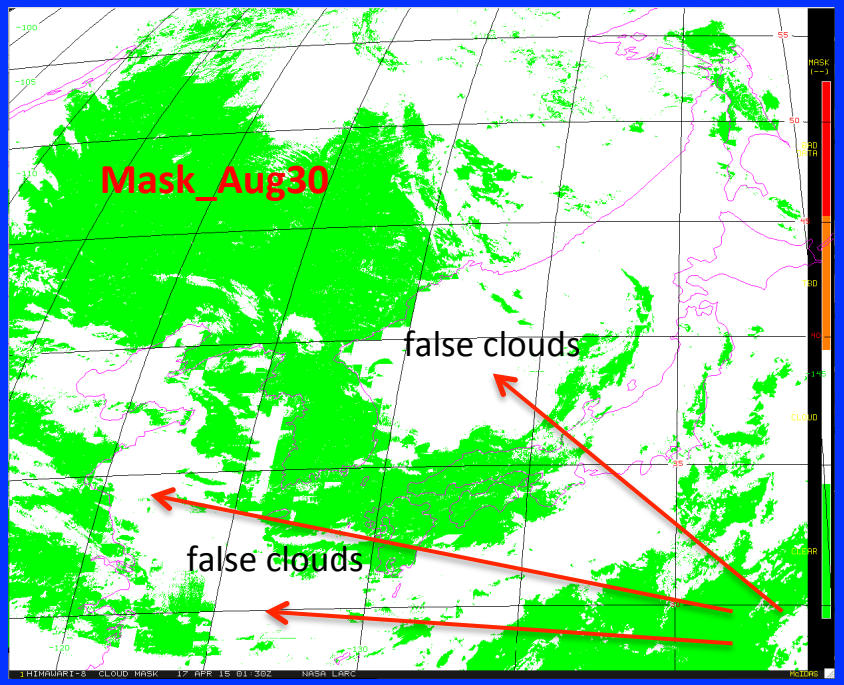
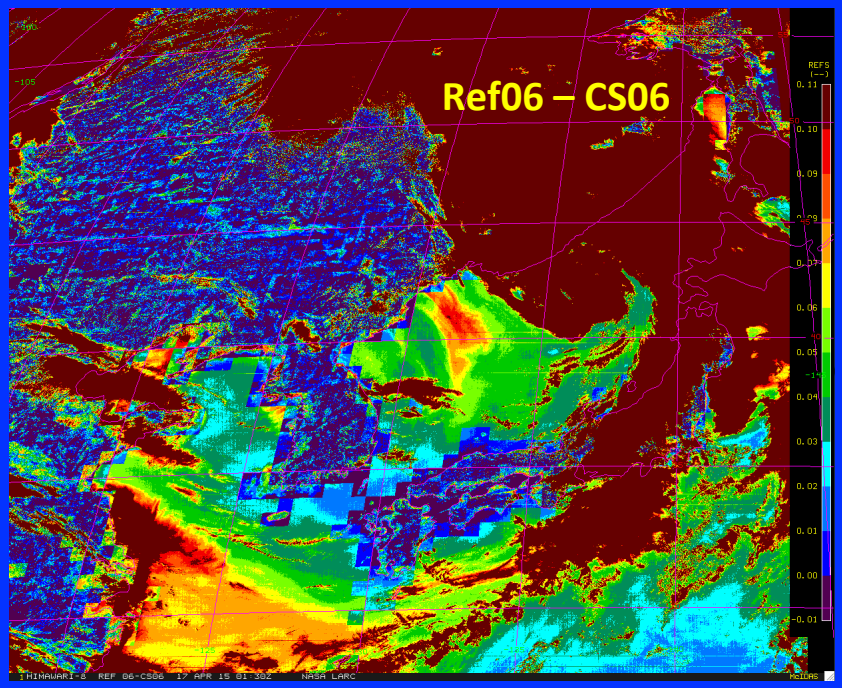
Heavy Dust and Aerosol Improvements

Separated dust with other types of aerosols


Himawari 8
April 17, 2015
UTC 0130
dust


Mask_Aug30
false clouds
false clouds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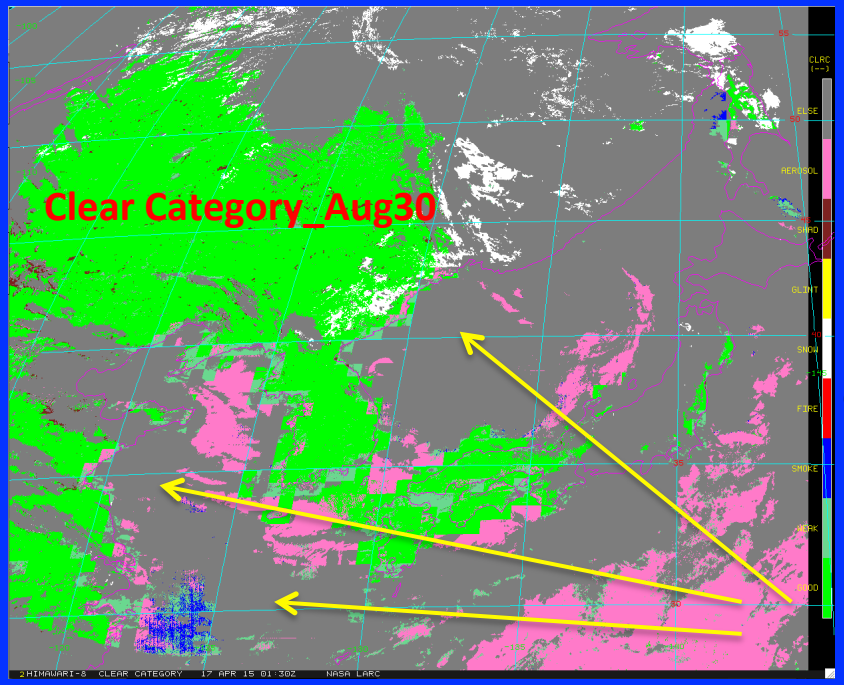
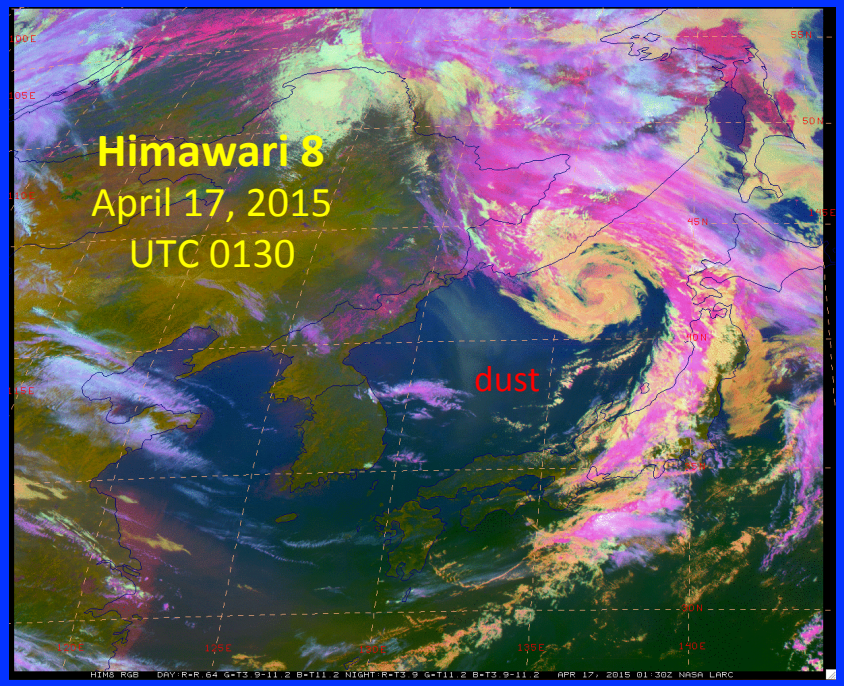
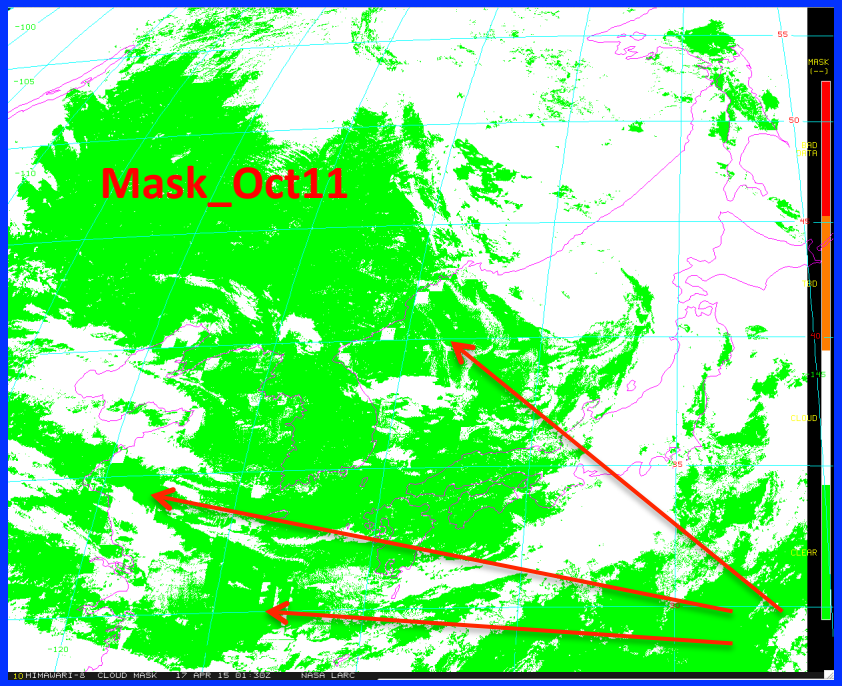
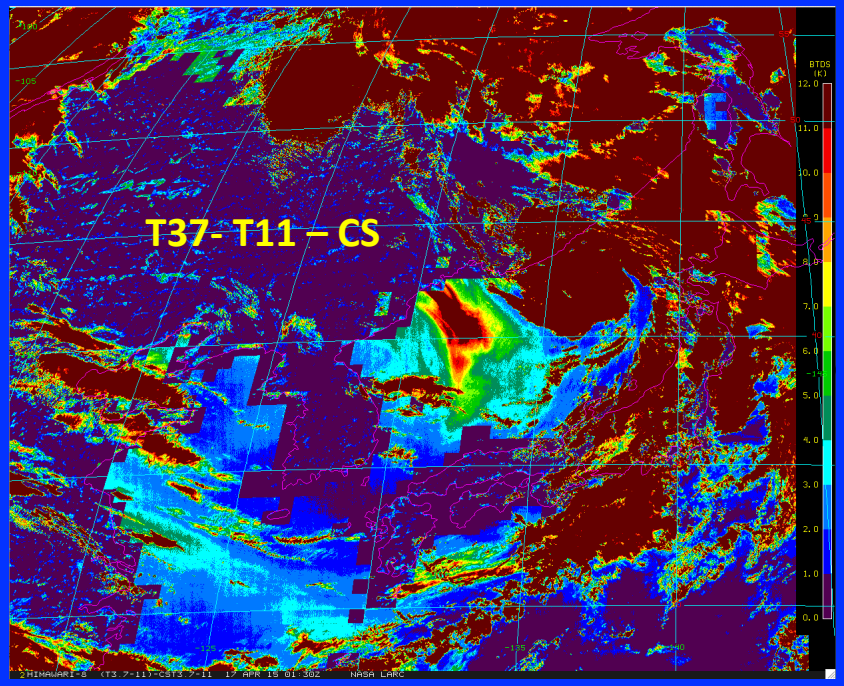
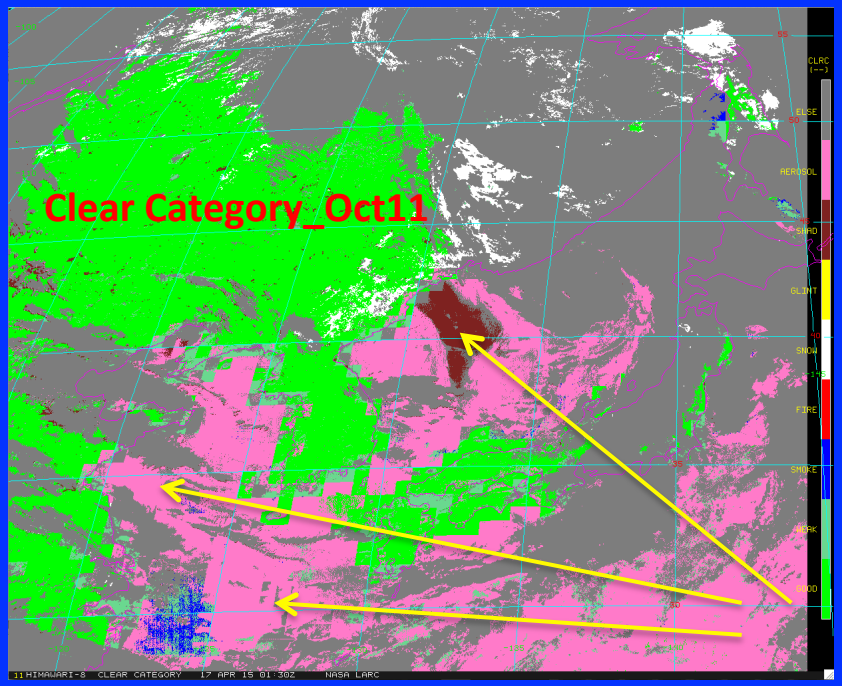

Clear Category_Aug30

good
weak smk
fire
snow
glint
dust
arsl
else

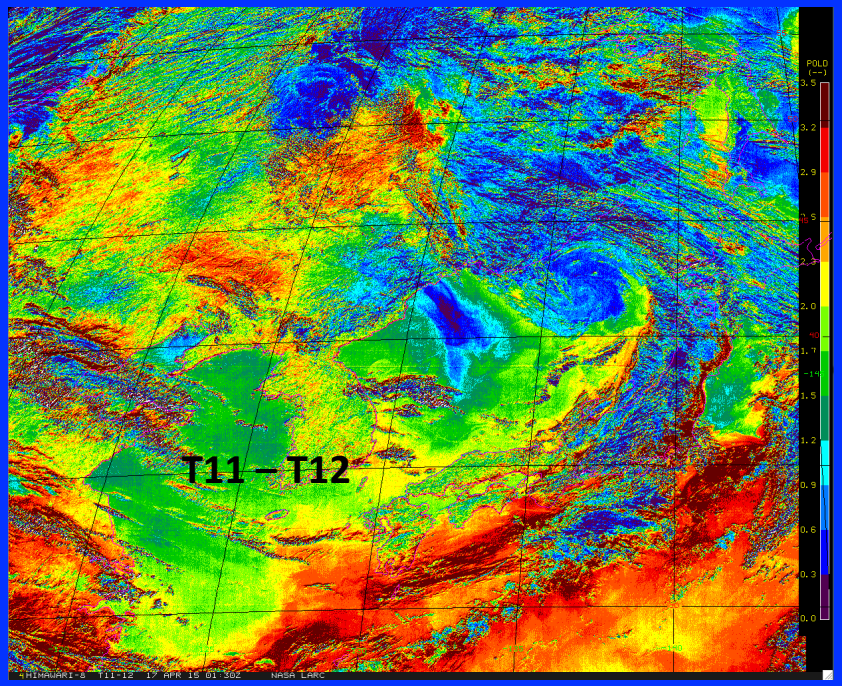

Himawari 8
April 17, 2015
UTC 0130
dust

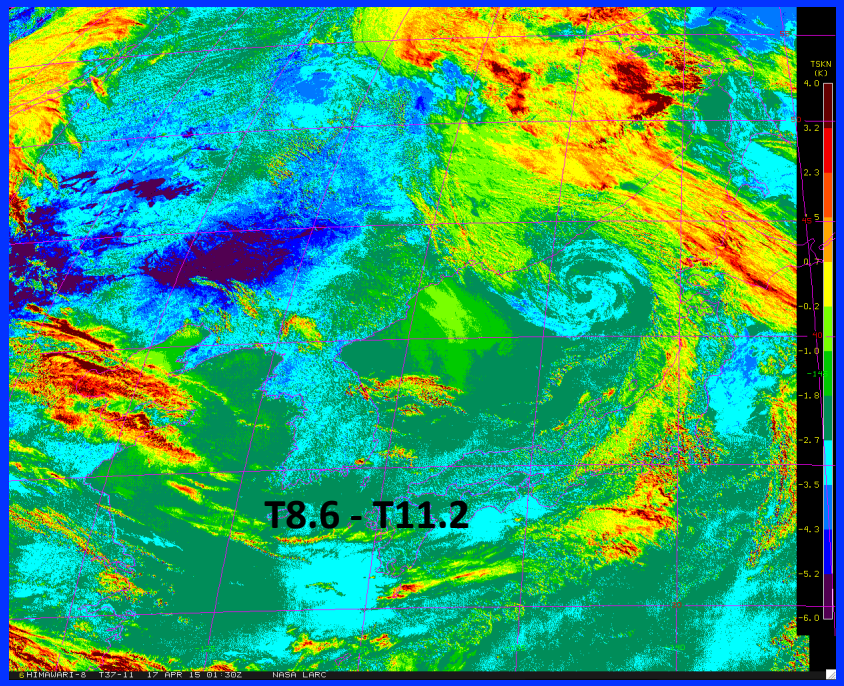

Mask_Oct11

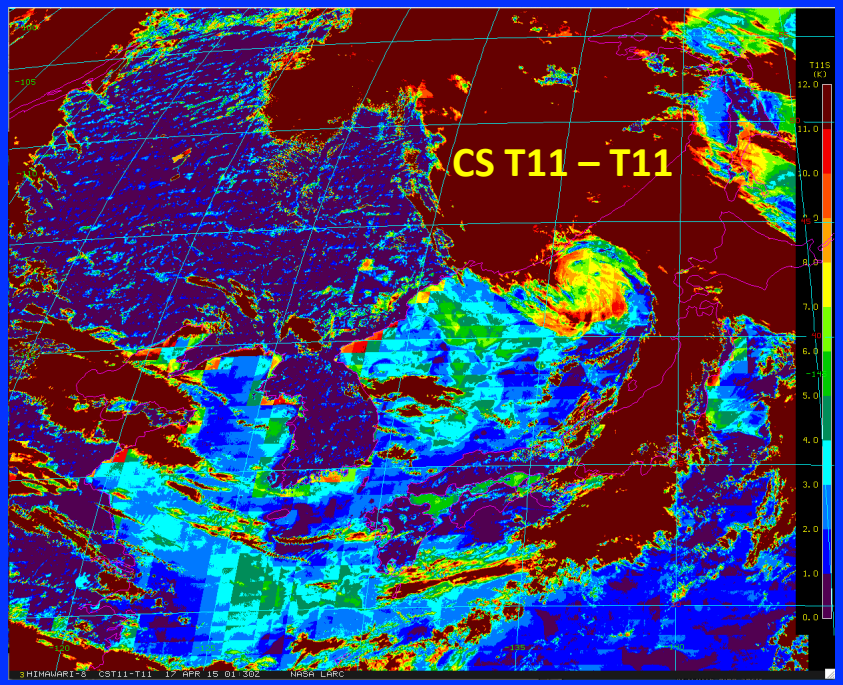

T37- T11 – CS

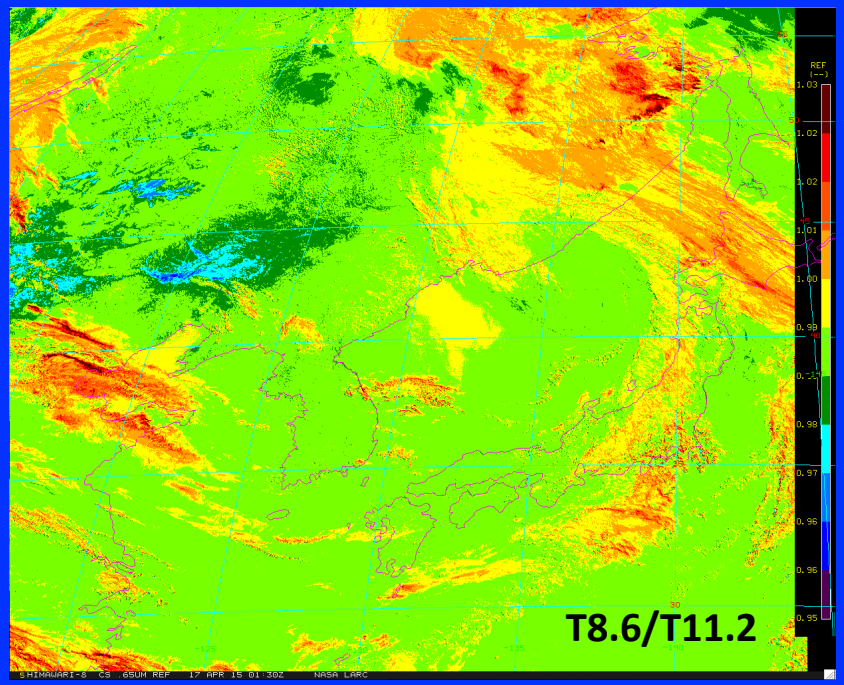

Clear Category_Oct11

good
weak smk
fire
snow
glint
dust
arsl
else

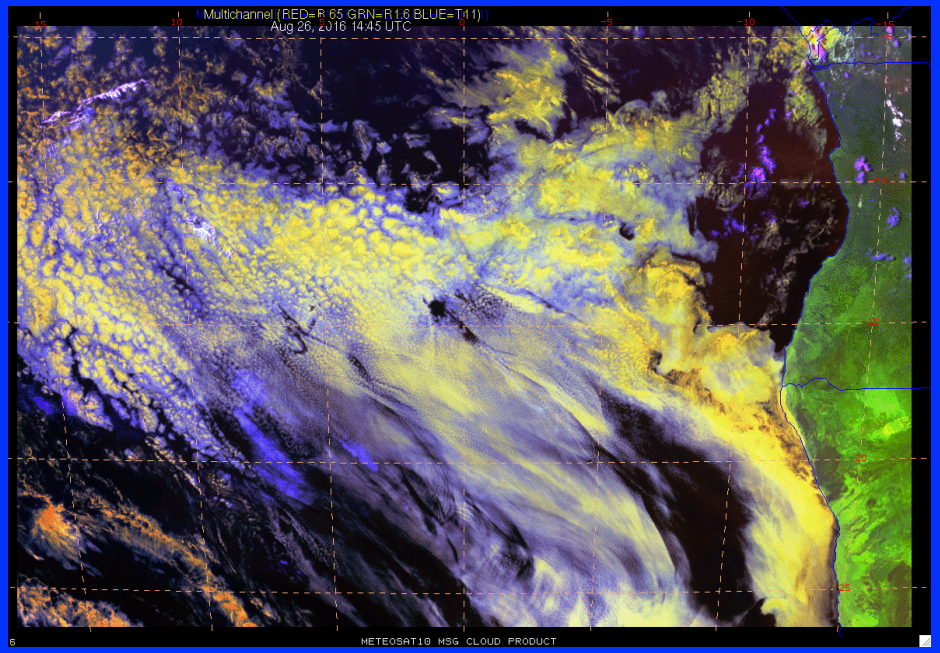

T11 – T12

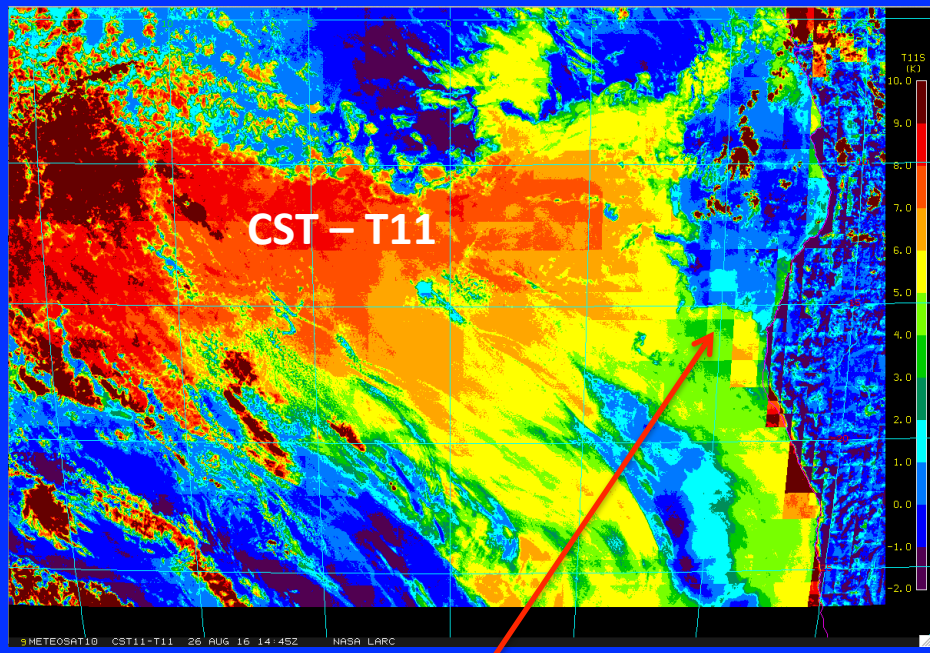

T8.6 - T11.2


CS T11 – T11


T8.6/T11.2

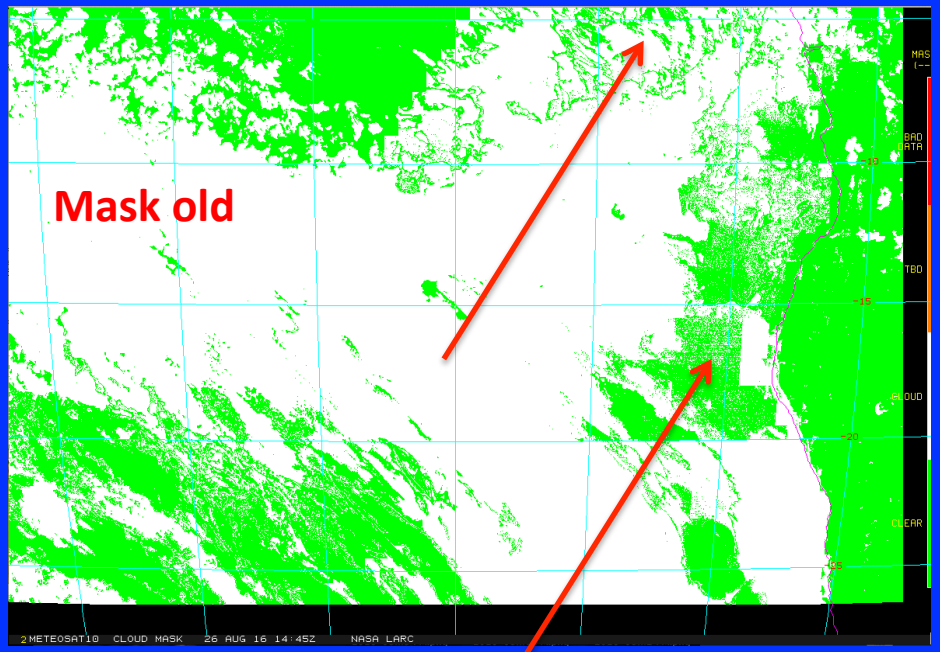
MeteoSat 10 Cloud Mask Improvement along West Africa Coast

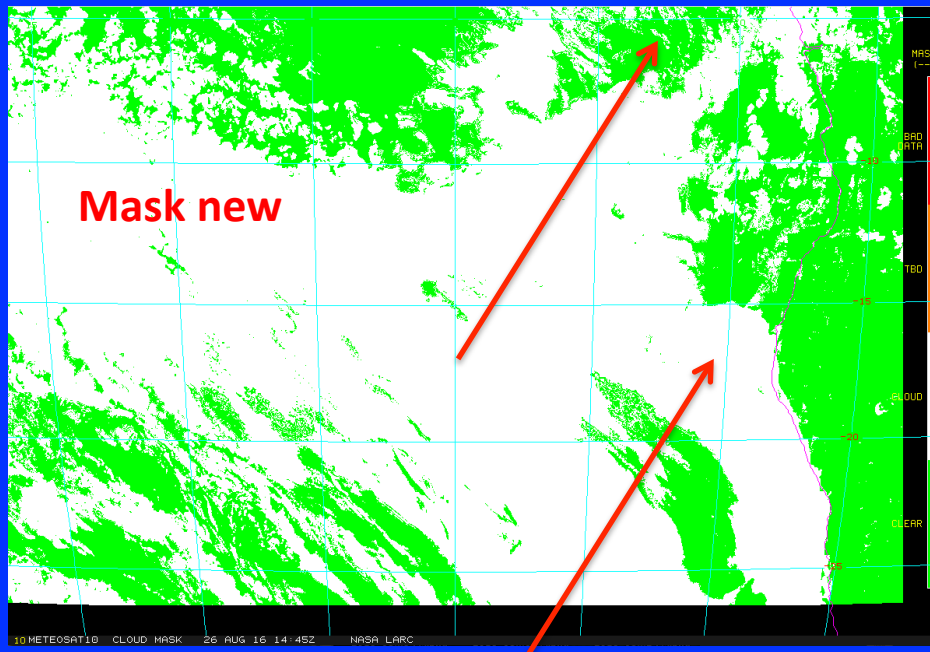


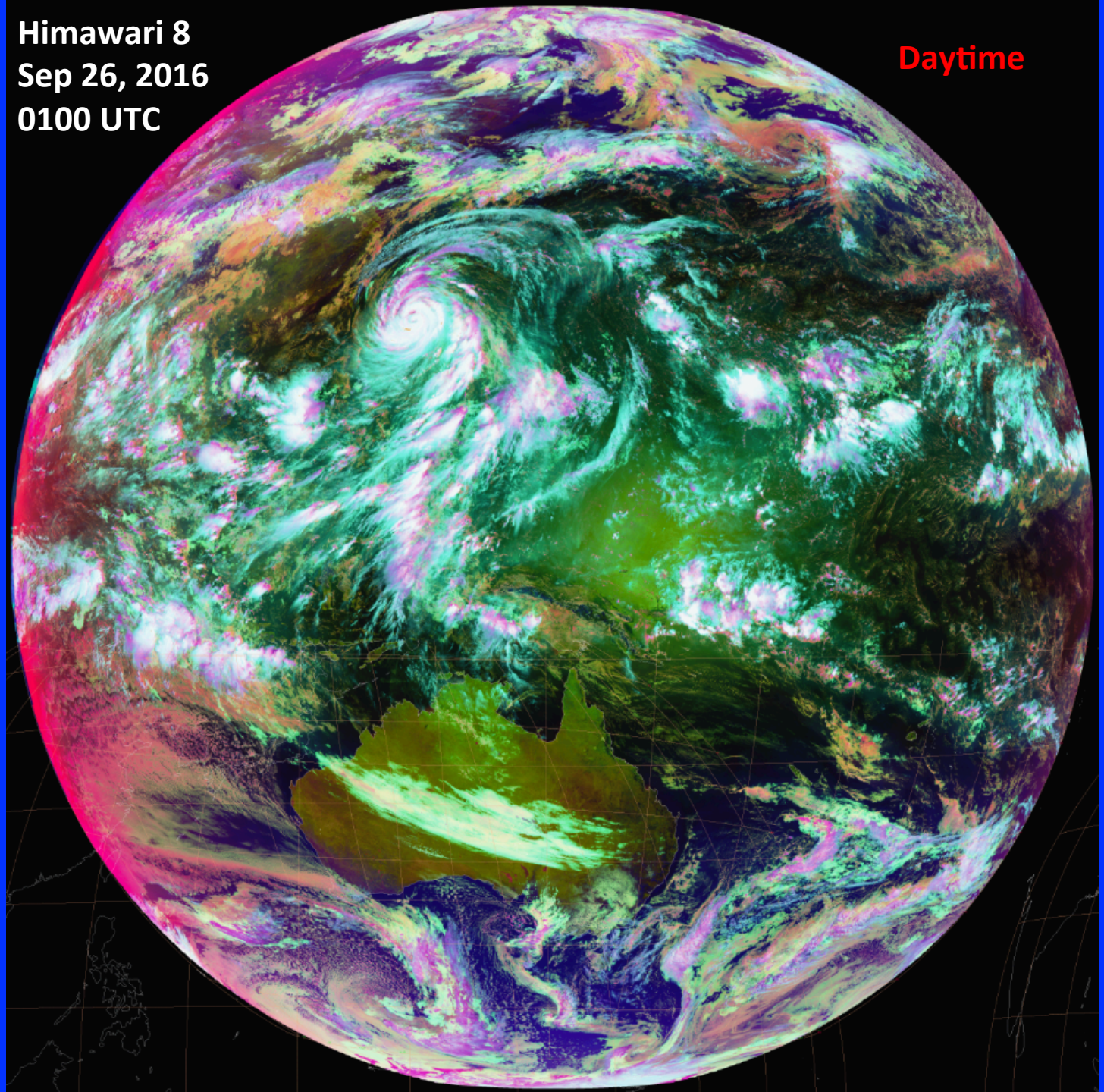


Aug 26, 2016, MeteoSat 10, UTC 14:45

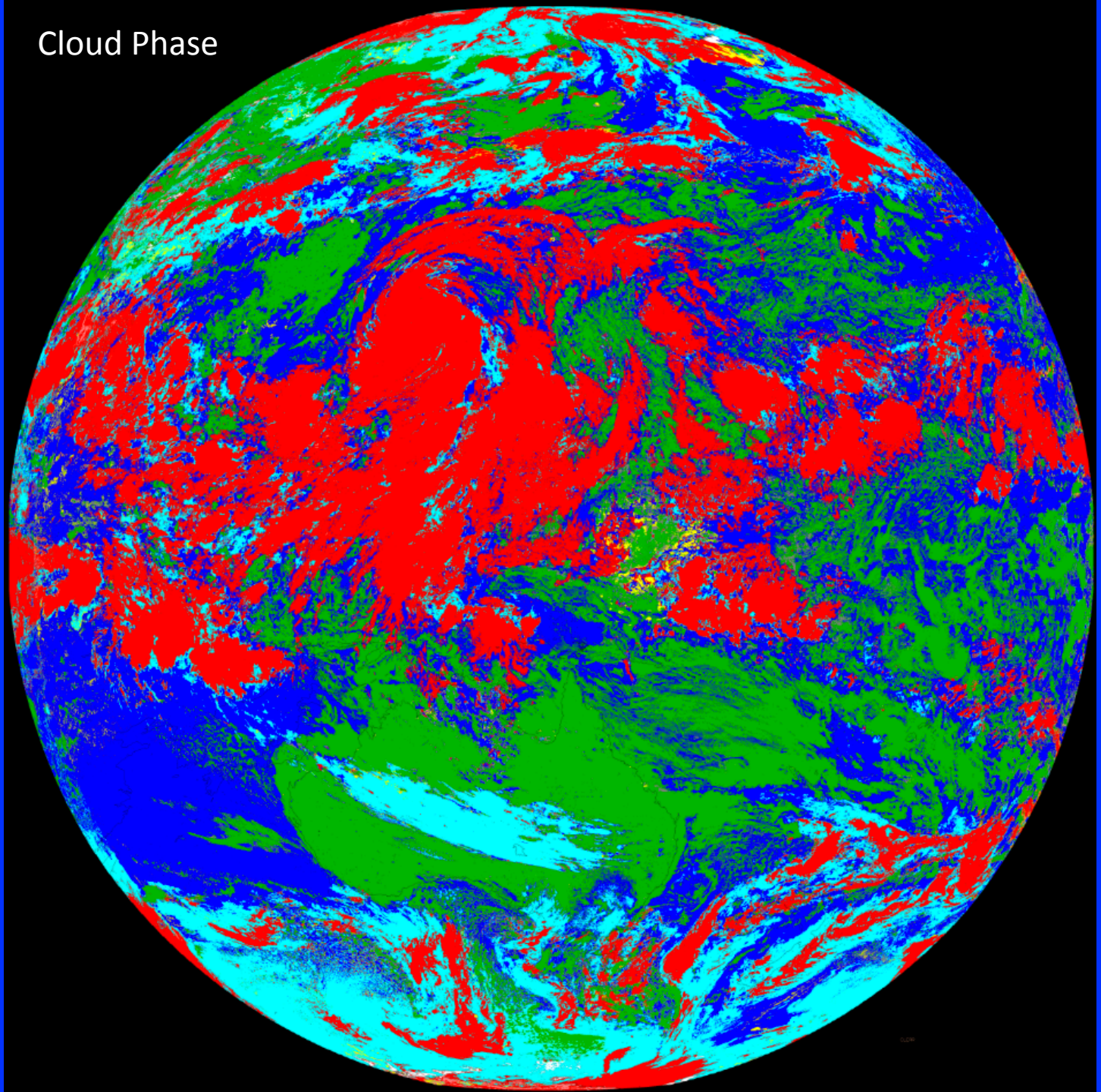
< 5K

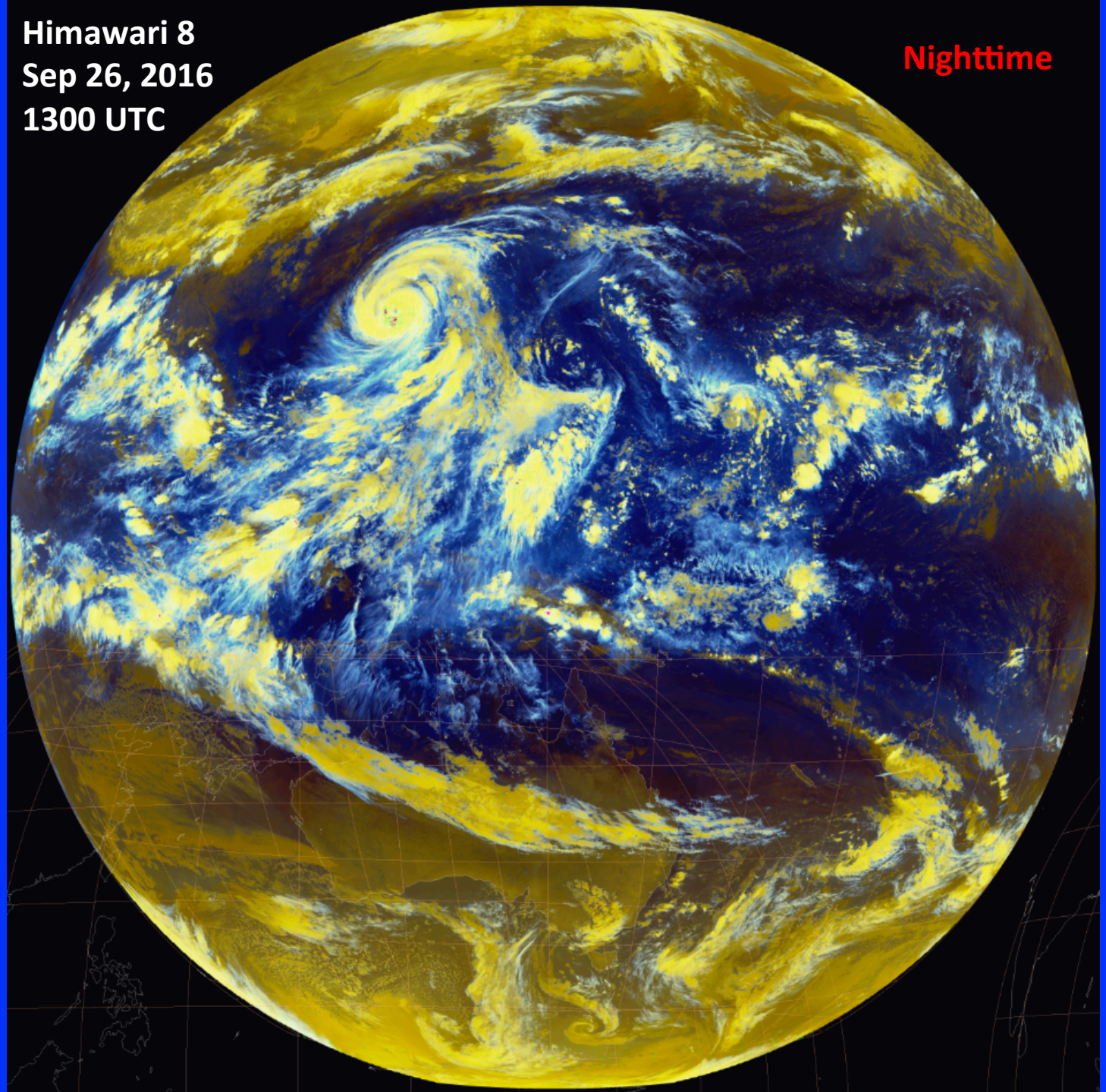




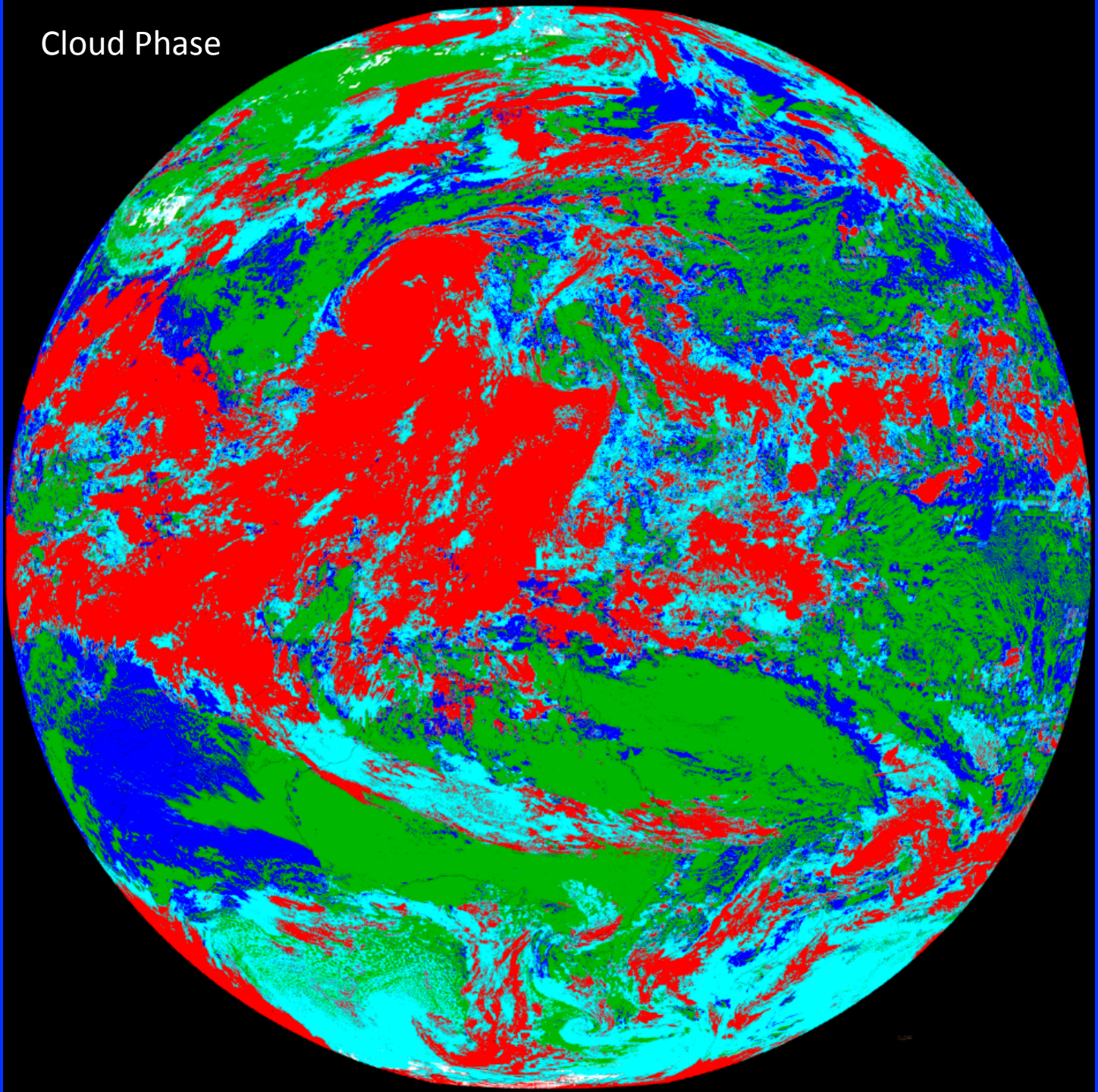

Himawari 8
Sep 26, 2016
0100 UTC
Daytime

Cloud Phase


Liq cld T>273
Liq cld T<273
Liq cld weak
Ice cld
Ice cld weak
clear
no retrvl
bad data
snow ice


Himawari 8
Sep 26, 2016
1300 UTC
Nighttime

Cloud Phase

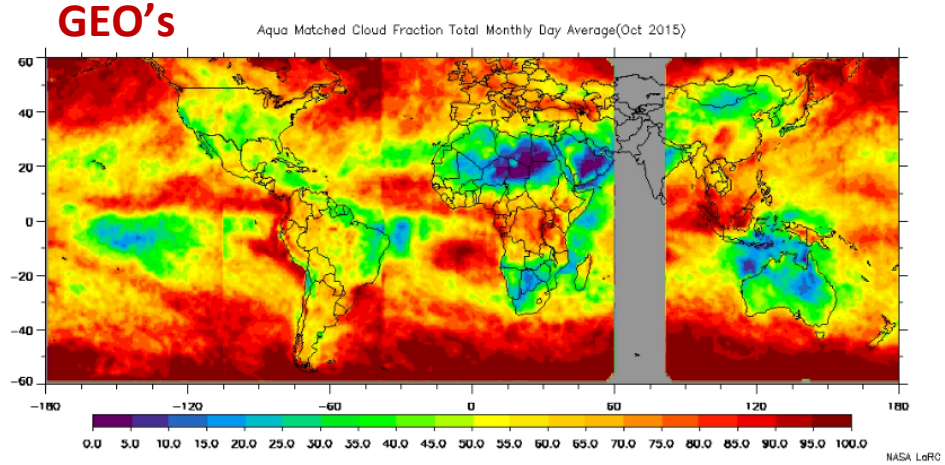

Liq cld T>273
Liq cld T<273
Liq cld weak
Ice cld
Ice cld weak
clear
no retrvl
bad data
snow ice

GEO Comparisons with AQUA-MODIS

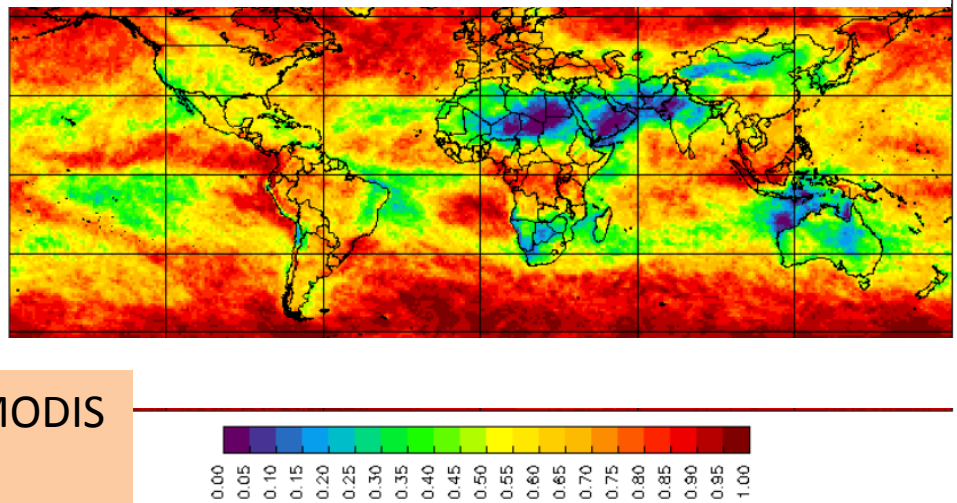
How consistent are the various GEO cloud properties with MODIS?

Oct 2015 Cloud Fraction - DAYTIME

GEO's



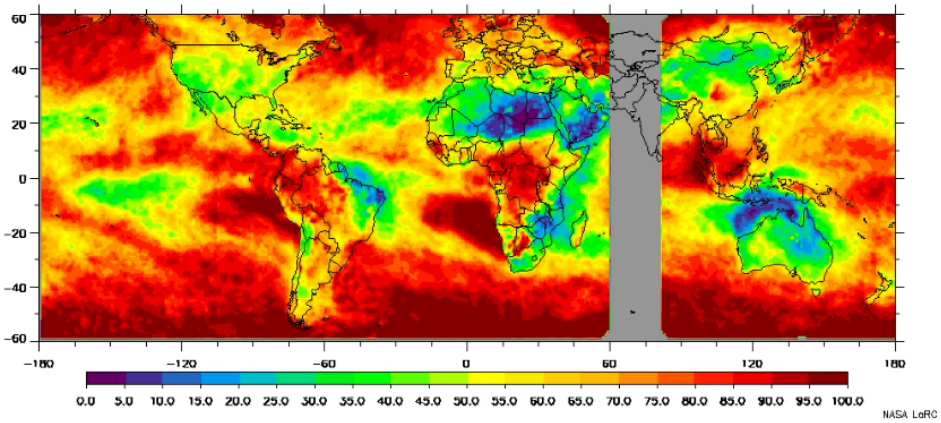
AQUA-MODIS



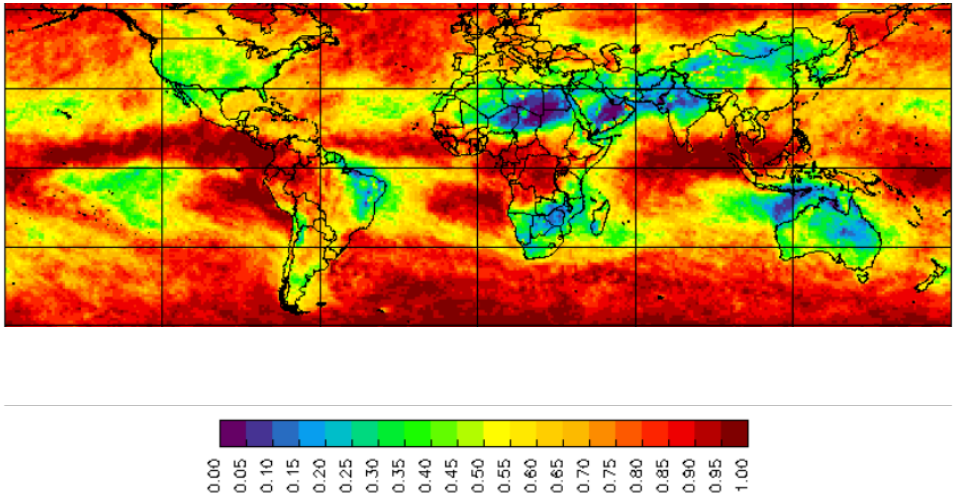
- Similar patterns, generally consistent with MODIS
- More GEO clouds at higher latitudes
- GEO to GEO consistency looks good

Oct 2015 Cloud Fraction - NIGHTTIME

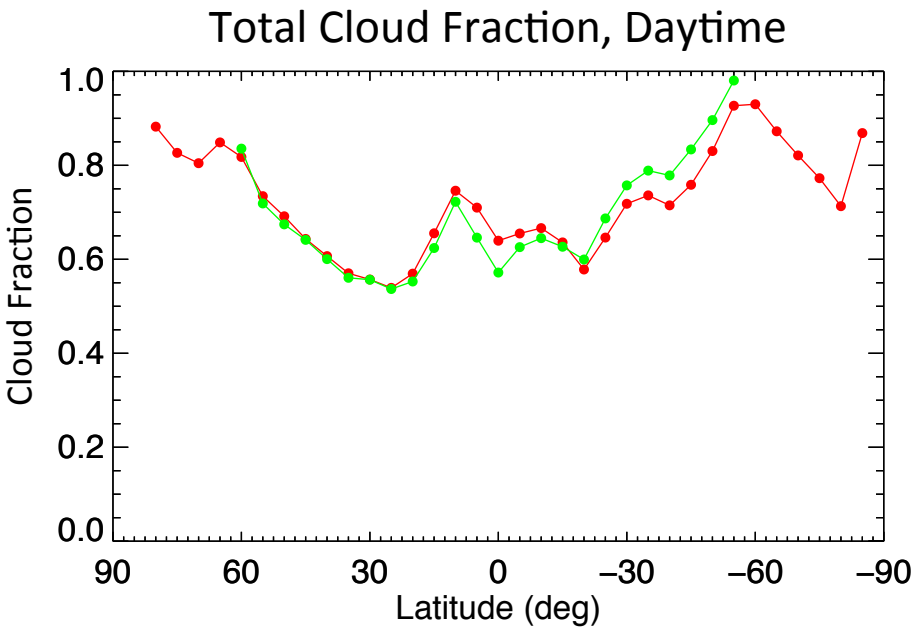
GEO's



AQUA-MODIS



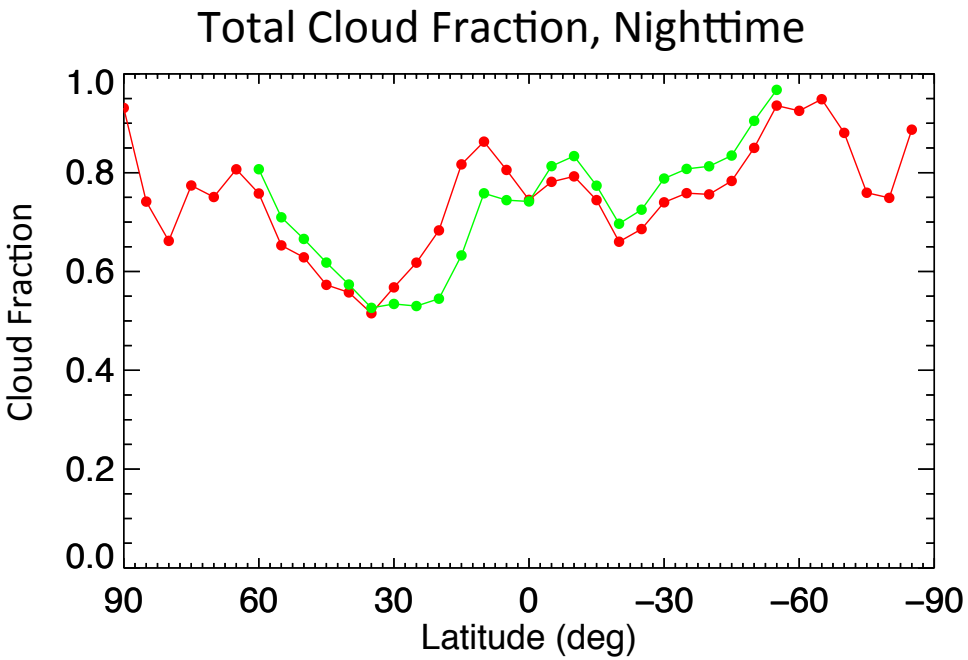
GEO vs MODIS Cloud Fraction October, 2015



GLOBAL MEANS

CERES MODIS = 0.68

CERES-GEO = 0.66



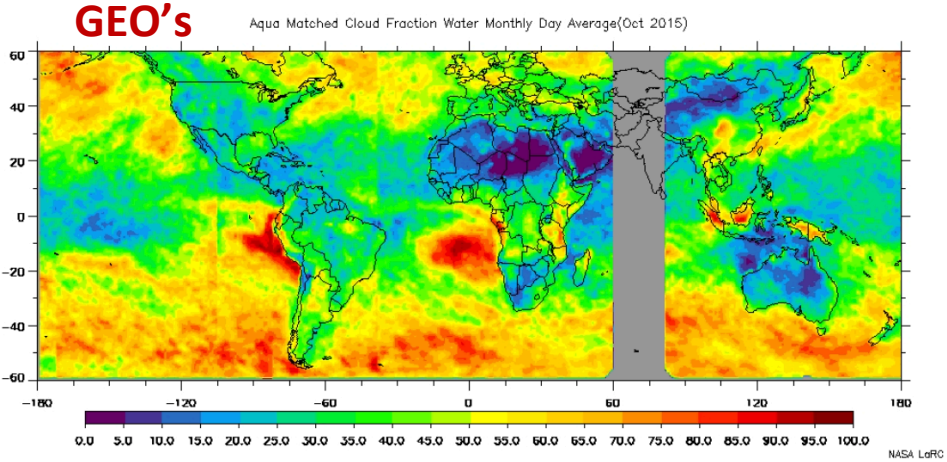
GLOBAL MEANS

CERES MODIS = 0.73

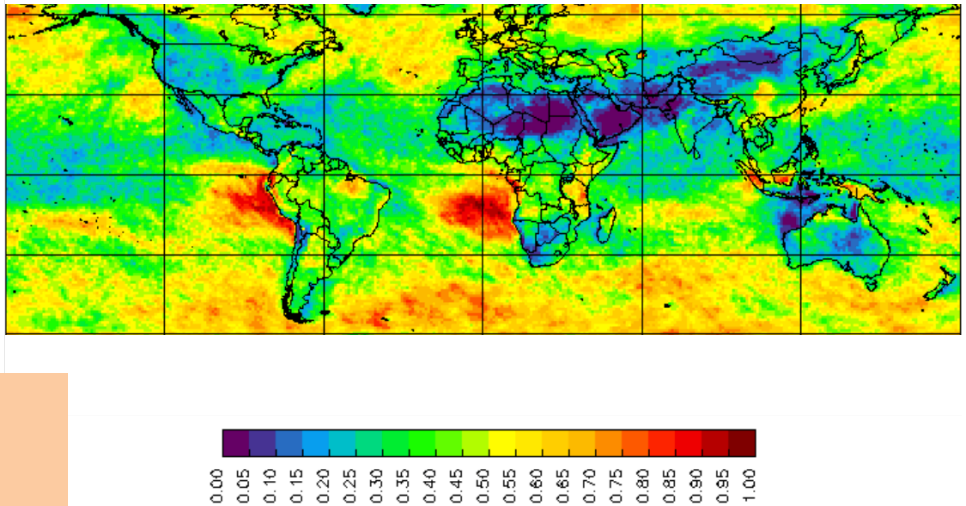
CERES-GEO = 0.70

Oct 2015 Liquid Cloud Fraction - DAYTIME

GEO's



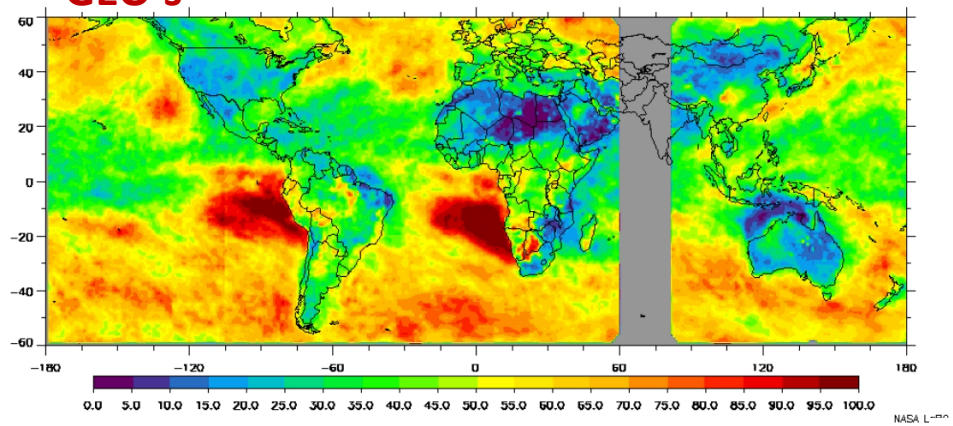
AQUA-MODIS



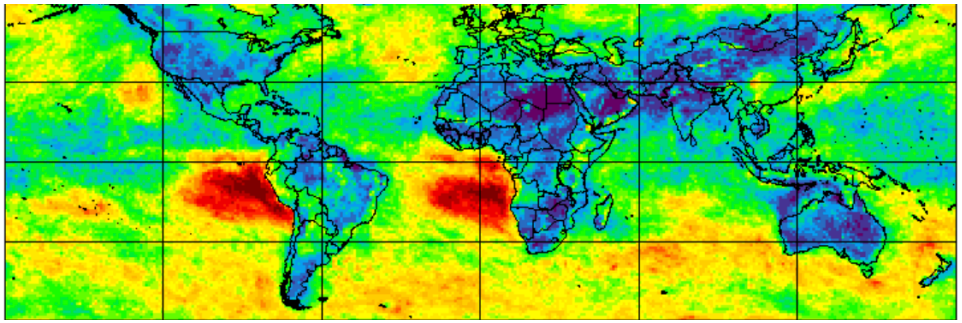
- More GEO liquid clouds at higher lats (day)
- More GEO water clouds at night everywhere

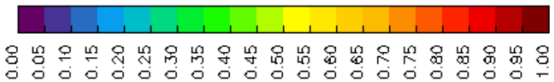
Oct 2015 Liquid Cloud Fraction - NIGHTTIME

GEO's



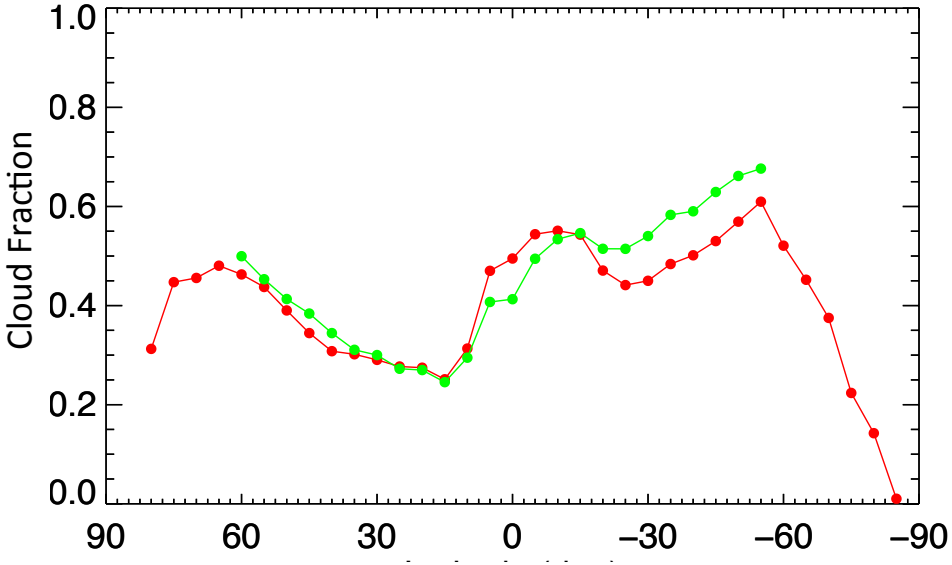
AQUA-MODIS





GEO vs MODIS Liquid Cloud Fraction October, 2015

Liquid Cloud Fraction, Daytime

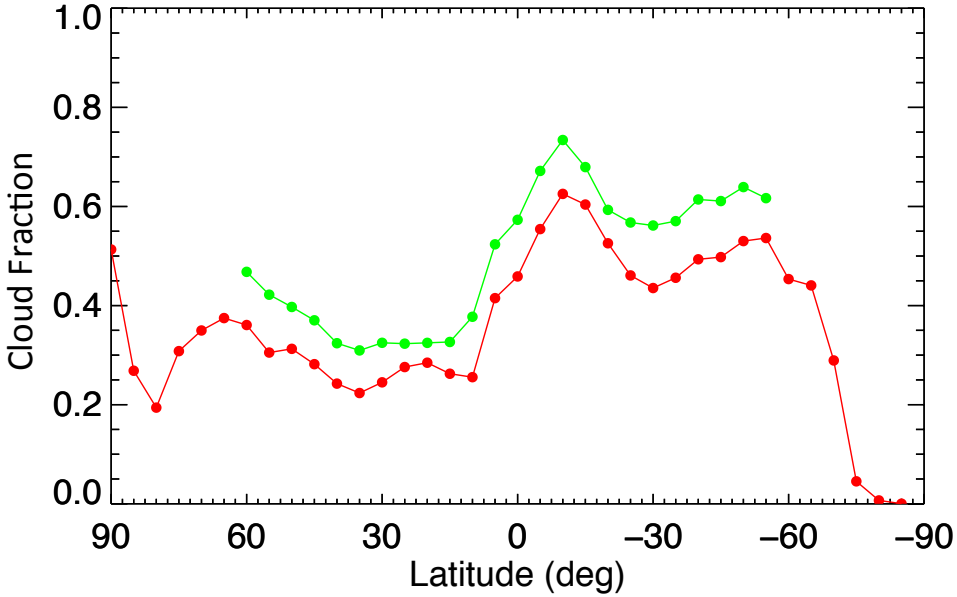


GLOBAL MEANS

CERES MODIS = 0.43

CERES-GEO = 0.43

Liquid Cloud Fraction, Nighttime



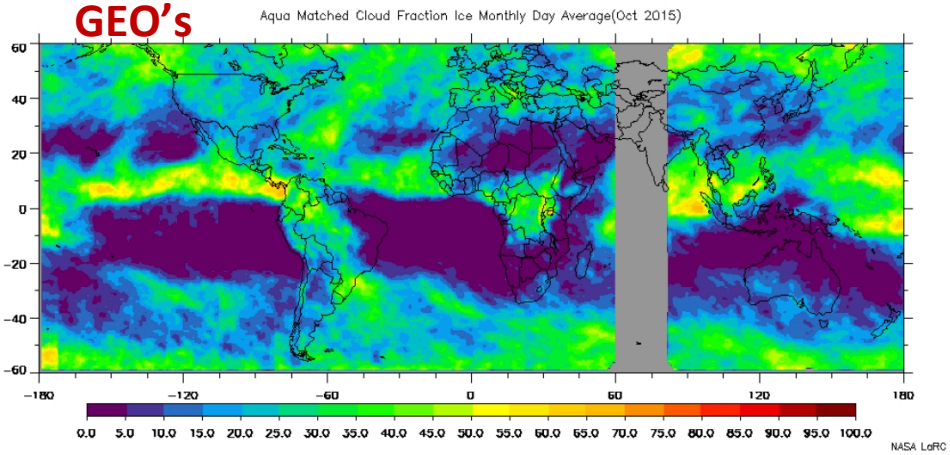
GLOBAL MEANS

CERES MODIS = 0.41

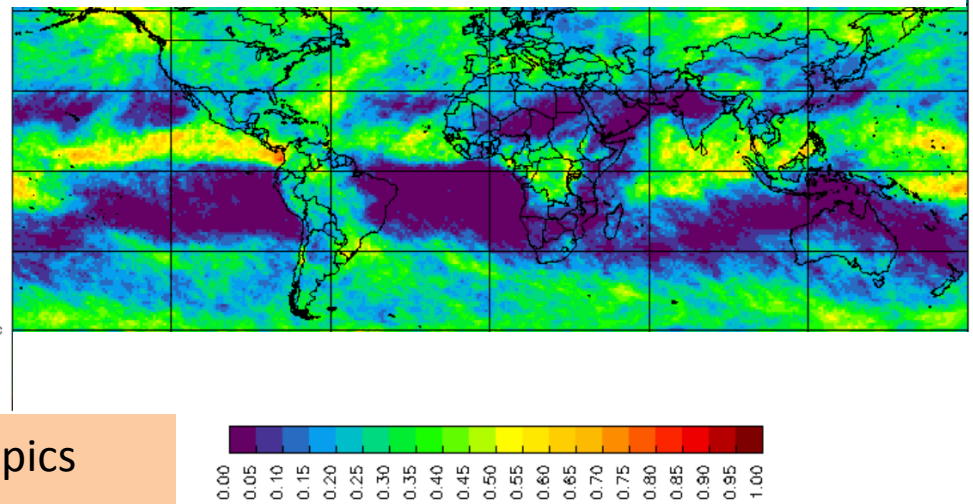
CERES-GEO = 0.49

Oct 2015 Ice Cloud Fraction - DAYTIME

GEO's



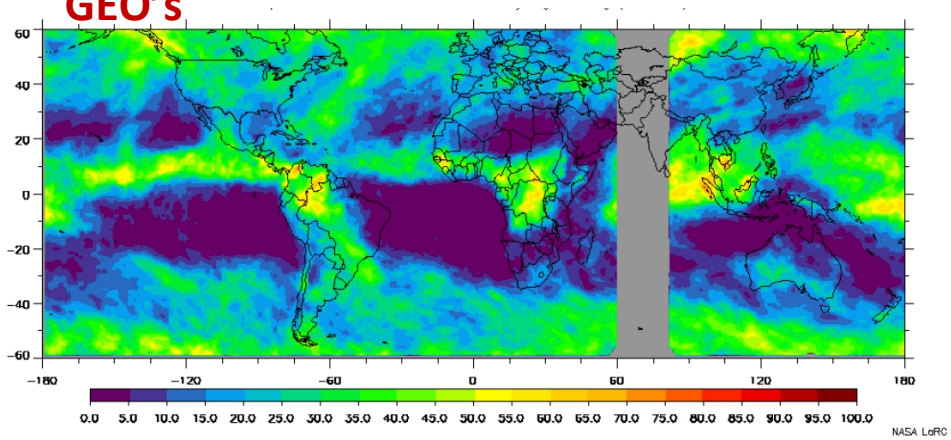
AQUA-MODIS



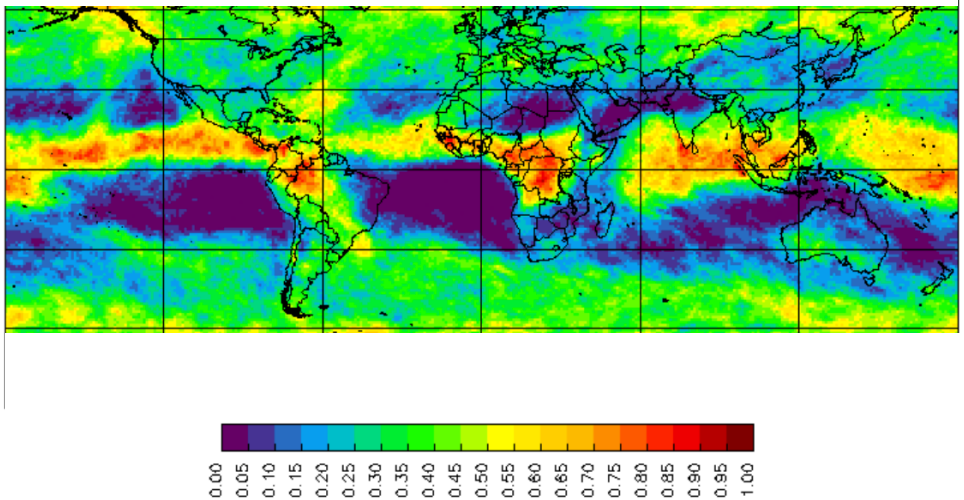
- Less GEO Ice clouds (day & night) except tropics during daytime which agrees well

Oct 2015 Ice Cloud Fraction - NIGHTTIME

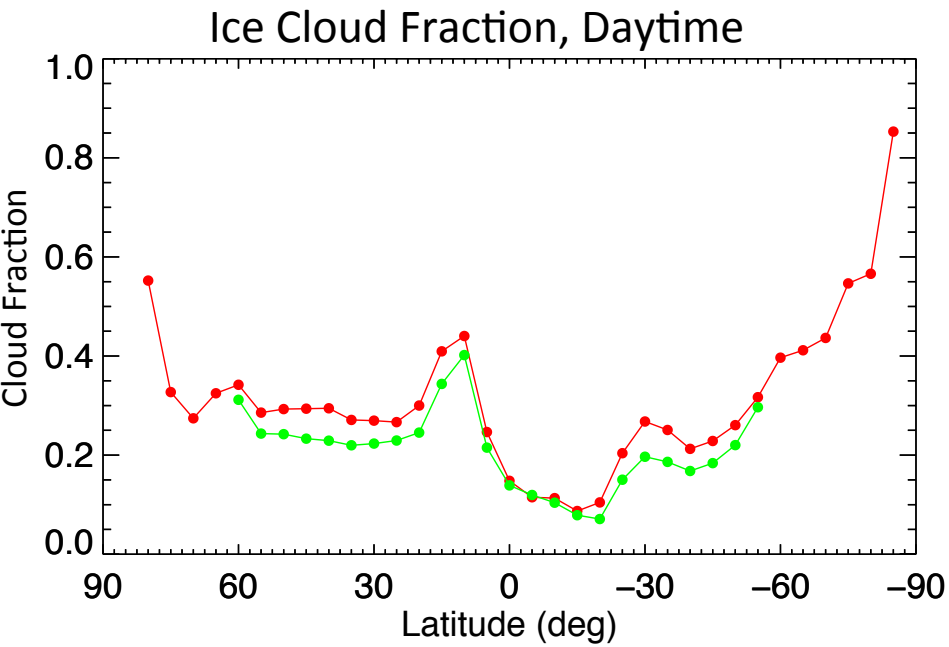
GEO's

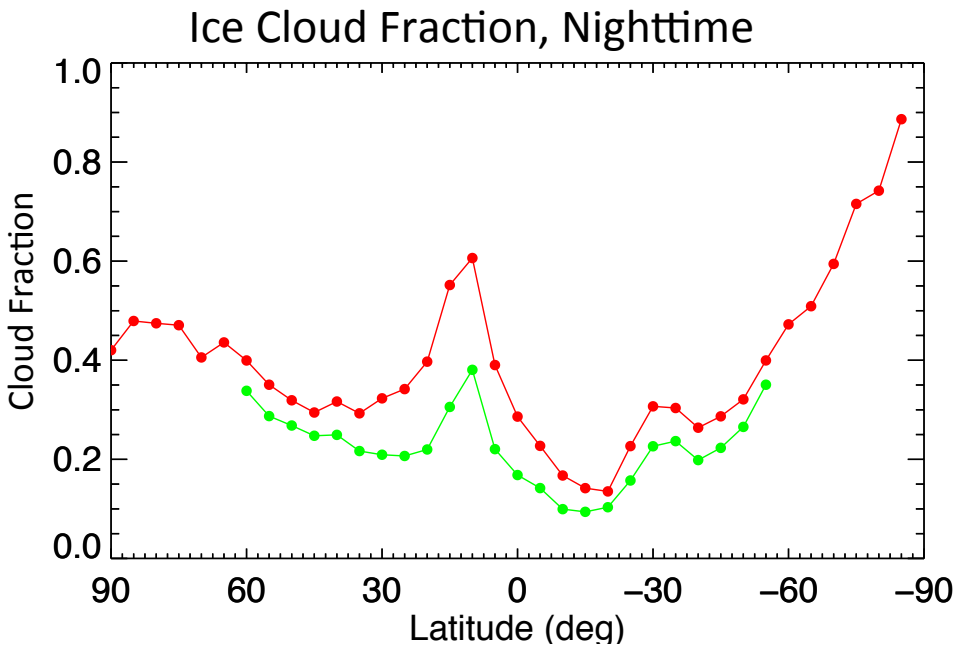


AQUA-MODIS



GEO vs MODIS Ice Cloud Fraction October, 2015





GLOBAL MEANS

CERES MODIS = 0.25

CERES-GEO = 0.20

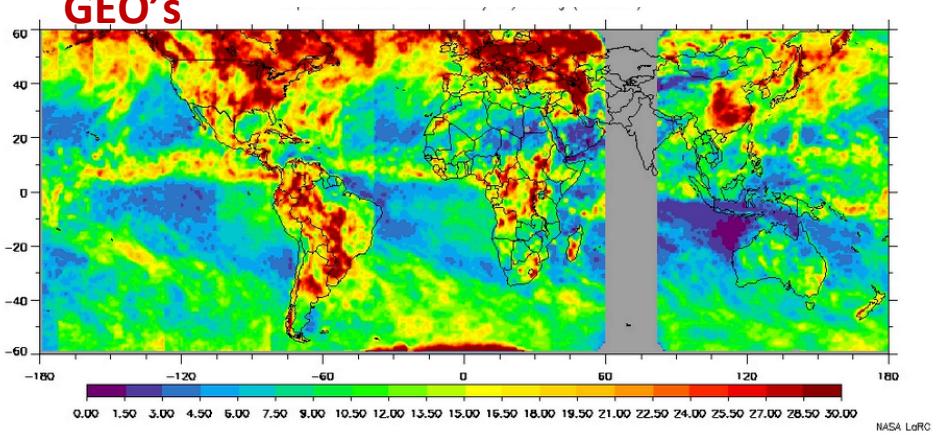
GLOBAL MEANS

CERES MODIS = 0.32

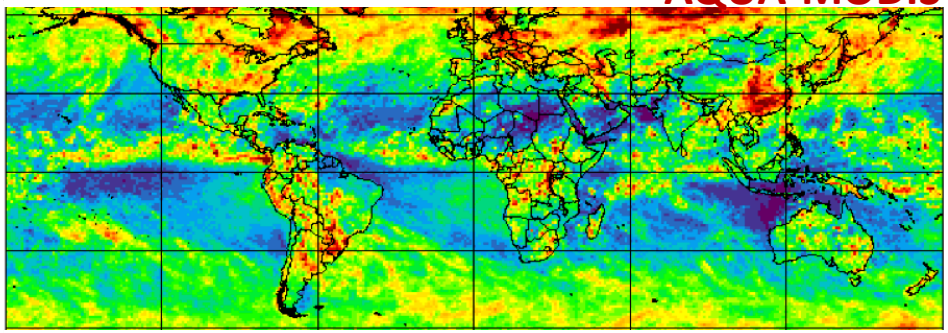
CERES-GEO = 0.21

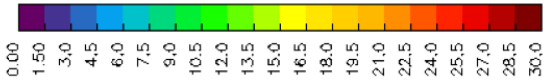
Oct 2015 Cloud Optical Depth - DAYTIME

GEO's



AQUA-MODIS

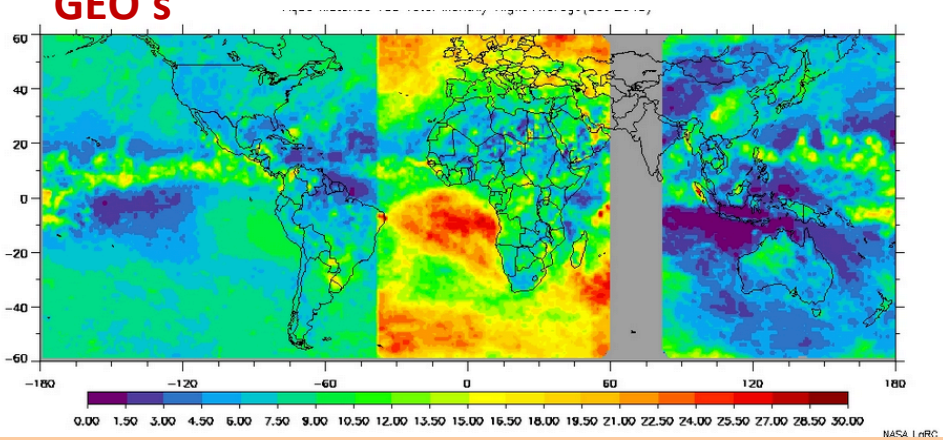




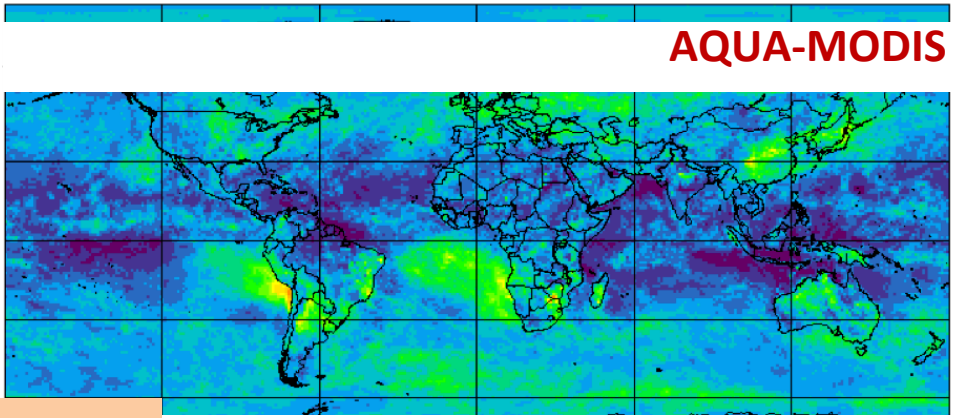
- GEO Daytime Optical depths a little higher (less ice clouds?)

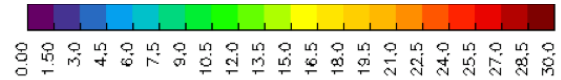
Oct 2015 Cloud Optical Depth - NIGHTTIME

GEO's



AQUA-MODIS

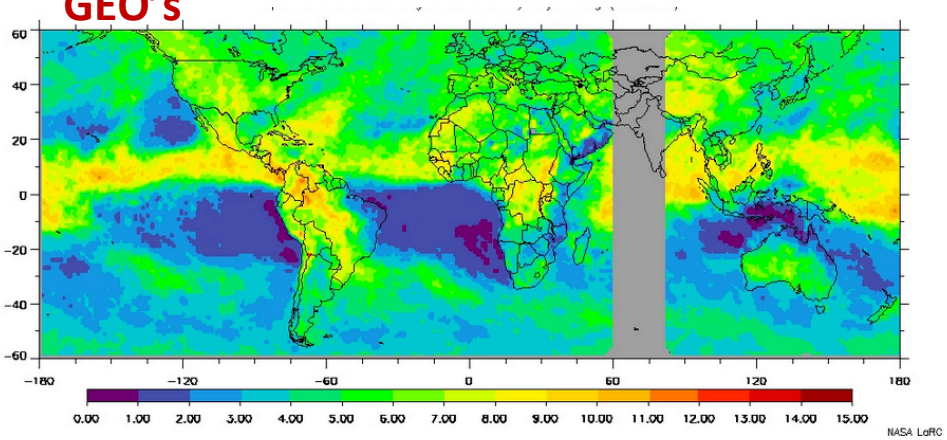




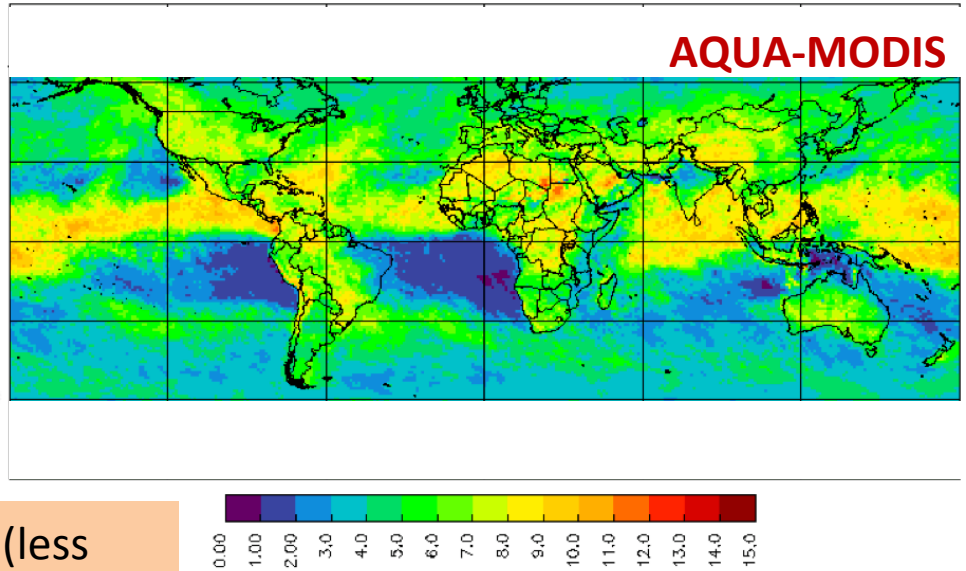
- Ignore Meteosat result (plotting error)
- GEO nighttime COD designed to retrieve higher
- Next edition will be more consistent

Oct 2015 Cloud Top Height - DAYTIME

GEO's



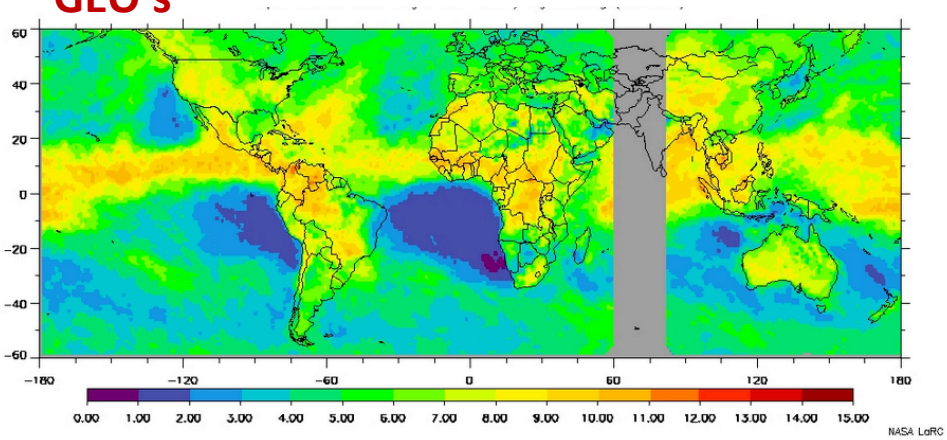
AQUA-MODIS



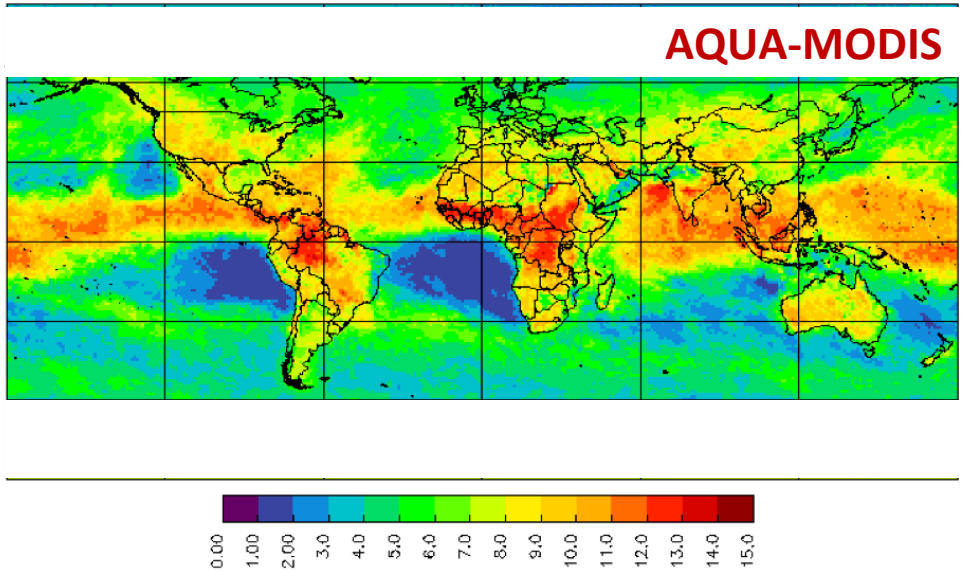
- GEO higher CTH's a little lower than MODIS (less high clouds and more liquid clouds in GEO)

Oct 2015 Cloud Top Height - NIGHTTIME

GEO's

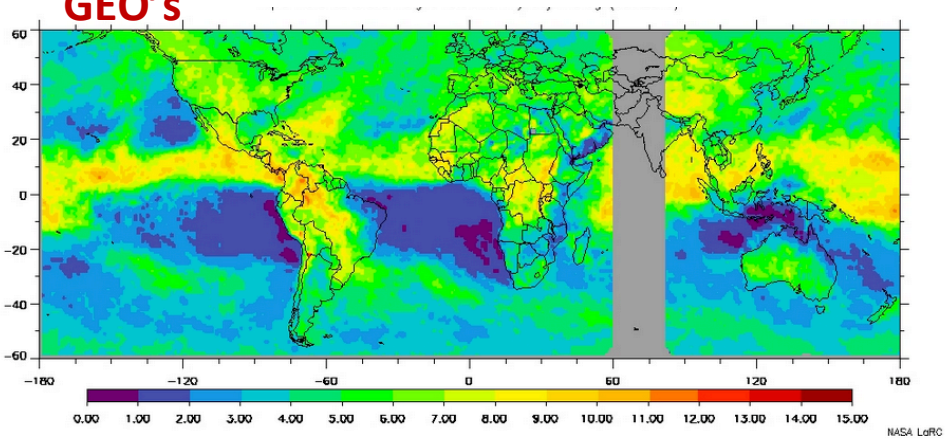


AQUA-MODIS

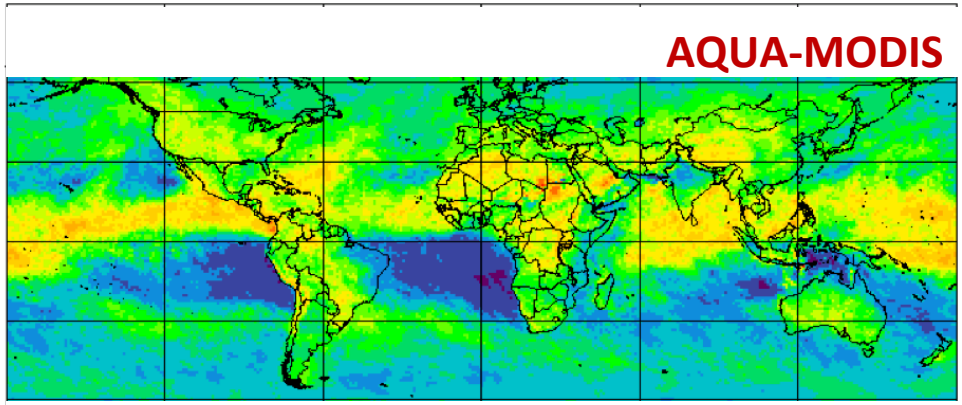


Oct 2015 Cloud Top Height - DAYTIME

GEO's

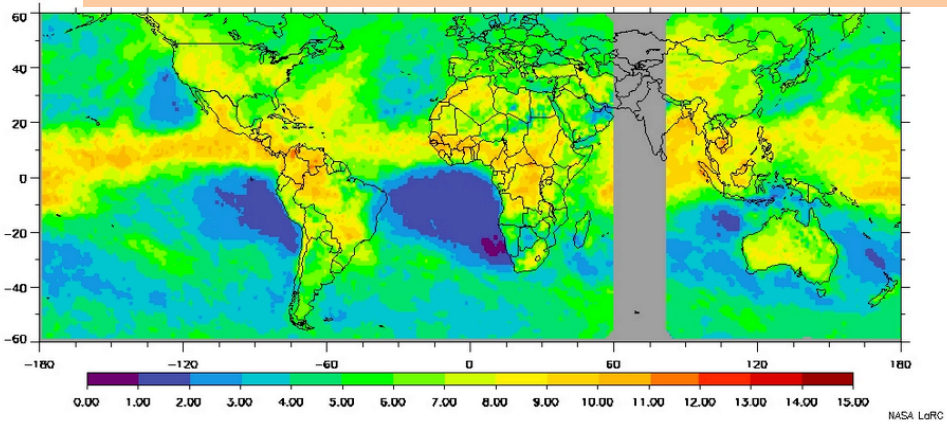


AQUA-MODIS

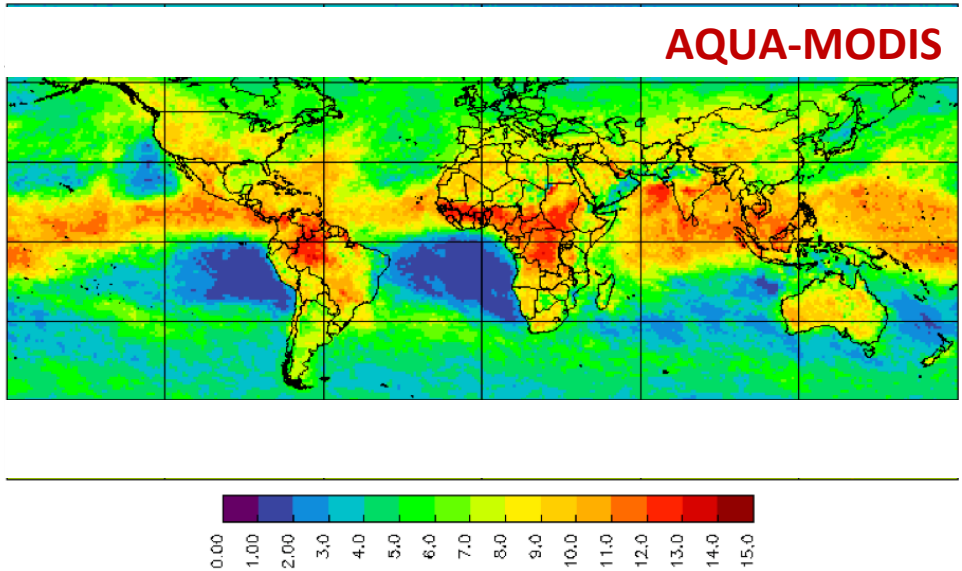


- OVERALL, GEO to GEO consistency when compared to MODIS for the cloud properties shown here appears to be pretty good

G



AQUA-MODIS



Himawari Validation with CALIOP and Consistency check with MODIS and other GEO's

A-Train/GEOsat Cloud Properties

- Spatially/temporally matched cloud properties for October 2015
  - Version 6.0 of A-Train matching code
  - Matched nearest 1 pixel to CALIPSO track
  - MODIS Edition 4 Beta 2 retrievals
  - GEO Edition 4 Himawari-8 retrievals
- CALIPSO data
  - Vertical Feature Mask (VFM): number of cloud layers, SL/ML identification, cloud phase, and layer opacity
  - 5-km Cloud Layers product: cloud altitudes, optical depths, and IWP
  - 333-m Cloud Layers product: low-cloud altitudes
- Parallax correction implemented on GEO retrievals
- CALIPSO VFM to determine cloud opacity
- Additional changes

Cloud Mask Validation

Snow and ice free regions only

Himawari-8 (AQUA-MODIS) vs CALIOP

	FRACTION CORRECT	FALSE-ALARM RATE	HEIDKE SKILL SCORE	NUMBER OF MATCHES
DAYTIME				
Land & Ocean	0.83 (0.89)	0.16 (0.06)	0.63 (0.75)	117579 (401420)
Ocean	0.83 (0.89)	0.17 (0.07)	0.60 (0.75)	90635 (304031)
Land	0.84 (0.88)	0.13 (0.04)	0.69 (0.75)	26944 (97389)
NIGHTTIME				
Land & Ocean	0.85 (0.87)	0.10 (0.06)	0.67 (0.69)	119496 (407161)
Ocean	0.85 (0.88)	0.11 (0.06)	0.64 (0.69)	91562 (310111)
Land	0.85 (0.84)	0.09 (0.05)	0.71 (0.68)	27934 (97050)

Overall skill with H8 not quite as good as MODIS (but, much improved over earlier results)

Cloud Mask Validation

Snow and ice free regions only

GOES-E (AQUA-MODIS) vs CALIOP

	FRACTION CORRECT	FALSE-ALARM RATE	HEIDKE SKILL SCORE	NUMBER OF MATCHES
DAYTIME				
Land & Ocean	0.85 (0.89)	0.08 (0.05)	0.66 (0.74)	101543 (265758)
Ocean	0.86 (0.90)	0.09 (0.05)	0.68 (0.77)	70588 (184441)
Land	0.81 (0.86)	0.06 (0.04)	0.62 (0.70)	30955 (81317)
NIGHTTIME				
Land & Ocean	0.86 (0.88)	0.07 (0.04)	0.65 (0.71)	101392 (263288)
Ocean	0.88 (0.90)	0.06 (0.04)	0.67 (0.71)	67896 (182652)
Land	0.81 (0.85)	0.10 (0.03)	0.60 (0.70)	33496 (80636)

GOES-E also not quite as good as MODIS but fairly consistent with H8
MSG (not shown) most consistent with H8

Cloud Phase Validation

Snow and ice free regions only

Himawari-8 (AQUA-MODIS) vs CALIOP

	FRACTION CORRECT	Ice FAR	Liquid FAR	HEIDKE SKILL SCORE	NUMBER OF MATCHES
DAY					
Land & Ocean	0.88 (0.92)	0.07 (0.07)	0.16 (0.09)	0.75 (0.84)	39372 (149155)
Ocean	0.90 (0.94)	0.06 (0.07)	0.14 (0.06)	0.78 (0.88)	31701 (115974)
Land	0.81 (0.86)	0.11 (0.06)	0.25 (0.20)	0.61 (0.72)	7671 (33181)
NIGHT					
Land & Ocean	0.84 (0.87)	0.09 (0.19)	0.20 (0.09)	0.67 (0.73)	40439 (152883)
Ocean	0.86 (0.87)	0.10 (0.20)	0.17 (0.07)	0.69 (0.74)	32428 (121517)
Land	0.78 (0.84)	0.08 (0.16)	0.33 (0.20)	0.56 (0.67)	8011 (31366)

MODIS has better skill

GEO Liquid cloud FAR pretty high but ICE FAR lower than MODIS (too few GEO ice clouds)

Cloud Phase Validation

Snow and ice free regions only

GOES-E (AQUA-MODIS) vs CALIOP

	FRACTION CORRECT	Ice FAR	Liquid FAR	HEIDKE SKILL SCORE	NUMBER OF MATCHES
DAY					
Land & Ocean	0.90 (0.94)	0.03 (0.06)	0.15 (0.06)	0.79 (0.88)	36884 (106194)
Ocean	0.91 (0.96)	0.02 (0.06)	0.13 (0.03)	0.81 (0.91)	27990 (78967)
Land	0.86 (0.89)	0.03 (0.06)	0.23 (0.16)	0.72 (0.78)	8894 (27227)
NIGHT					
Land & Ocean	0.85 (0.89)	0.08 (0.16)	0.19 (0.07)	0.68 (0.78)	39024 (106552)
Ocean	0.86 (0.91)	0.08 (0.17)	0.16 (0.05)	0.71 (0.80)	27677 (80162)
Land	0.80 (0.83)	0.08 (0.15)	0.28 (0.20)	0.61 (0.65)	11347 (26390)

GOES-E cloud phase accuracy relative to MODIS accuracy is very similar to H8

Summary

- CERES GEOsat cloud processing completed through July 2015
- HIMIWARI-8 cloud algorithm nearing finalization
  - Surprising number of challenges for legacy cloud algorithms
  - Highest GEO priority for CERES CWG over the past 6 months
  - Cloud mask has undergone rigorous evaluation and significant improvements have been made
  - Cloud phase adjustments needed based on comparisons with MODIS and CALIOP
- CALIOP version 4 will give us a better handle on aerosol vs cloud problems
- Vailidation is also being done using CATS on ISS but has been less useful than CALIOP due to more obvious problems with cloud aerosol discrimination
- Now retrieving marine aerosol OD in our real time GEO proocessing and will add this to CERES GEO in the next edition.

SPARES

GEO-LEO CORRESPONDING VIS-IR IMAGERY BANDS (μm)

future

#	Himawari -8/ AHI	MTSAT-2/ IMAGER	MSG/ SEVIRI	MTG/ FCI	KOMPSAT -2A/AMI	FY-4/ AGRI	GOES-R/ABI	GOES -15	GOES -11	SNPP,JPSS/ VIIRS	Terra, Aqua/ MODIS	GCOM-C/SGLI	NOAA/ AVHRR
1	0.47			0.444	0.455	0.47	0.47			0.488 (M03)	0.488	0.490 (VN4)	
2	0.51			0.510	0.511					0.555 (M04)	0.531	0.530 (VN5)	
3	0.64	0.68	0.635	0.640	0.642	0.65	0.64	0.65	0.65	0.672 (M05) 0.64 (I01)	0.667	0.6735 (VN7,VN8,P1)	0.630
4	0.86		0.81	0.865	0.860	0.825	0.86			0.865 (M07) 0.865 (I02)	0.870	0.8685 (VN10, VN11, P2)	0.862
				0.914							0.905		
				1.380	1.38	1.375	1.38			1.378 (M09)	1.375	1.380 (SW2)	
5	1.6		1.64	1.610	1.61	1.61	1.61			1.610 (M10) 1.61 (I03)	1.640	1.630 (SW3)	1.61
6	2.3			2.250		2.25	2.26			2.250 (M11)	2.130	2.210 (SW4)	
7	3.9	3.7	3.92	3.80	3.85	3.75	3.90	3.90	3.90	3.70 (M12) 3.74 (I04)	3.750		3.74
8	6.2	6.8	6.25	6.30	6.24	6.25	6.15	6.55	6.75		6.715		
9	6.9				6.95	7.1	7.00						
10	7.3		7.35	7.35	7.34		7.40				7.325		
11	8.6		8.70	8.70	8.60	8.5	8.50			8.55 (M14)	8.550		
12	9.6		9.66	9.66	9.63		9.70				9.730		
13	10.4	10.8	10.8	10.50	10.43	10.7	10.3	10.70	10.70	10.763 (M15)		10.8 (T1)	10.80
14	11.2				11.20	11.0	11.2			11.45 (I05)	11.030		
15	12.4	12.0	12.0	12.30	12.30		12.3		11.95	12.013 (M16)	12.020	12.0 (T2)	12.00
16	13.3		13.4	13.30	13.30	13.5	13.3	13.35			13.335		

A-Train/GEOsat Cloud Properties

- Spatially/temporally matched cloud properties for ICWG golden day August 19, 2015 (Himawari-8)
  - Version 6.1 of A-Train matching code
  - Matched nearest 1 pixel to CALIPSO track
  - "06Oct2016" version of Himawari retrievals
- CALIPSO data
  - Vertical Feature Mask (VFM): number of cloud layers, SL/ML identification, cloud phase, and layer opacity
  - 5-km Cloud Layers product: cloud altitudes, optical depths, and IWP
  - 333-m Cloud Layers product: low-cloud altitudes
- Parallax correction implemented
- CALIPSO VFM to determine cloud opacity
- Additional changes

Cloud Mask Validation

HIMIWARI August 19, 2015

	FRACTION CORRECT	FALSE-ALARM RATE	HEIDKE SKILL SCORE	NUMBER OF MATCHES
DAYTIME				
Full Disk, Land & Ocean, Snow/Ice-free	0.869	0.097	0.65	10345
Full Disk, Ocean, Snow/Ice-free	0.868	0.102	0.63	8506
Full Disk, Land, Snow/Ice-free	0.874	0.071	0.72	1839
NIGHTTIME				
Full Disk, Land & Ocean, Snow/Ice-free	0.882	0.069	0.68	14028
Full Disk, Ocean, Snow/Ice-free	0.891	0.067	0.67	10646
Full Disk, Land, Snow/Ice-free	0.854	0.077	0.68	3382

GEO & CALIPSO Cloud Detection Comparison (±15 min)

January 2010 (red numbers); April 2013 (blue numbers)

		Daytime (SZA<82)		Nighttime (SZA>=82)	
		CALIPSO		CALIPSO	
GOES-W		clear	cloud	clear	cloud
GOES-11 GOES-15	clear	22.4% 21.6%	6.4% 8.8%	15.5% 17.0%	7.9% 8.5%
	cloud	6.9% 5.1%	64.2% 64.5%	5.6% 4.7%	70.9% 69.8%
	Fraction Correct	FC = 0.866 FC = 0.861		FC = 0.865 FC = 0.868	

		Daytime (SZA<82)		Nighttime (SZA>=82)	
		CALIPSO		CALIPSO	
GOES-E		clear	cloud	clear	cloud
GOES-13 GOES-13	clear	23.7% 27.1%	8.5% 11.1%	19.7% 22.4%	9.1% 10.1%
	cloud	6.3% 4.7%	61.5% 57.2%	4.9% 4.7%	66.3% 62.8%
	Fraction Correct	FC = 0.851 FC = 0.843		FC = 0.860 FC = 0.853	

		Daytime (SZA<82)		Nighttime (SZA>=82)	
		CALIPSO		CALIPSO	
		clear	cloud	clear	cloud
MeteoSat-9 MeteoSat-10	clear	32.0% 28.9%	9.9% 12.2%	27.5% 25%	12.0% 13.1%
	cloud	4.7% 4.2%	53.4% 54.7%	3.1% 4.0%	57.4% 57.8%
	Fraction Correct	FC = 0.854 FC = 0.836		FC = 0.848 FC = 0.829	

		Daytime (SZA<82)		Nighttime (SZA>=82)	
		CALIPSO		CALIPSO	
		clear	cloud	clear	cloud
MTSAT-1R MTSAT-2R	clear	18.0% 18.1%	6.8% 6.7%	16.5% 19.5%	10.8% 14.1%
	cloud	7.6% 8.0%	67.6% 67.2%	4.7% 3.0%	68.0% 63.4%
	Fraction Correct	FC = 0.856 FC = 0.853		FC = 0.845 FC = 0.829	

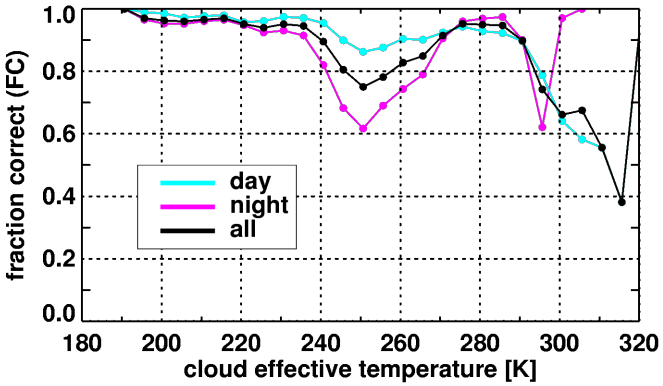
- Day, FC < than FC for Aqua (0.896); Night, FC < FC for Aqua (0.90)
  - expect smaller FC, off-nadir and lo-res data
- GOES-W best (most ocean?) Meteosat worst(desert coastline?)

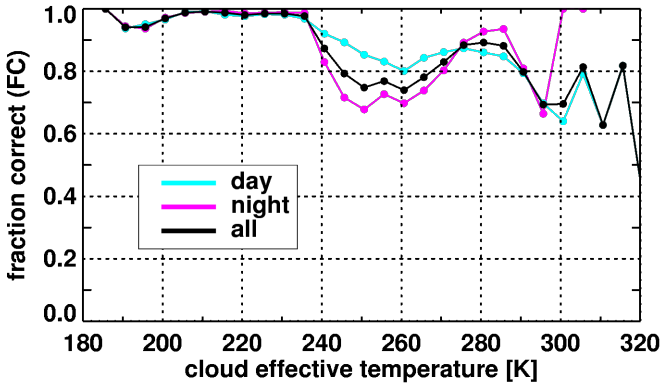
cloud phase

fraction correct as function of cloud effective temperature

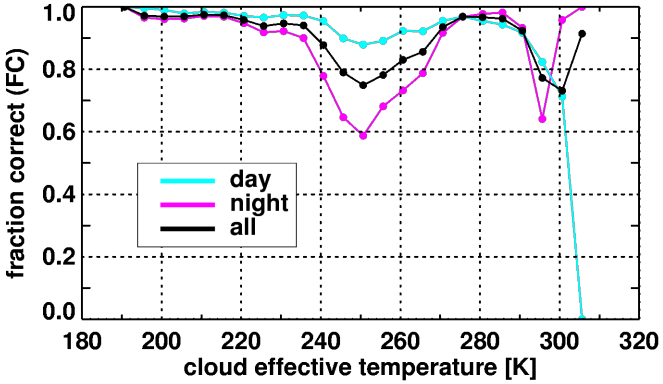
MODIS | **Him-8**

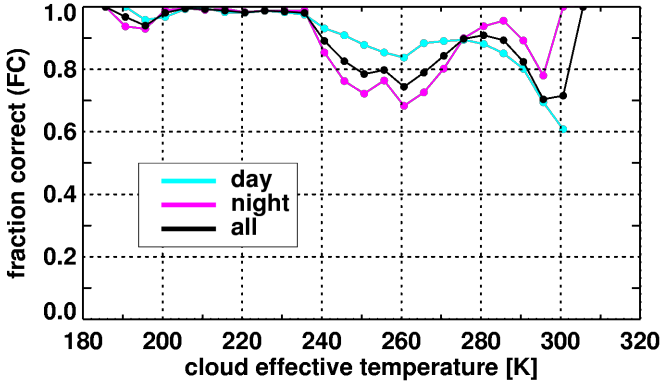
Full-disk, snow/ice free



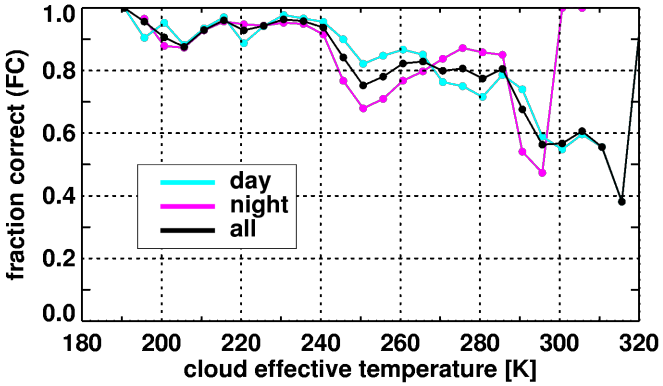


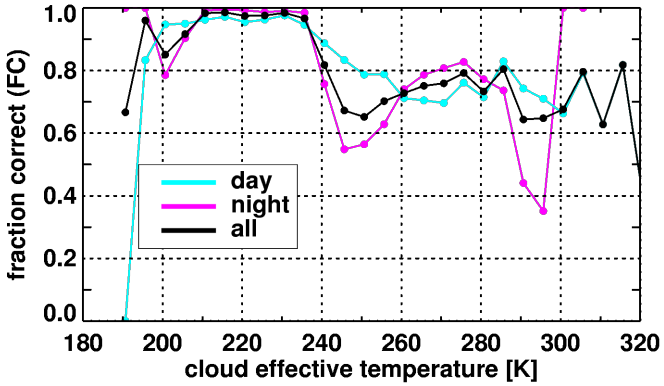
Full-disk, snow/ice free, ocean





Full-disk, snow/ice free, land



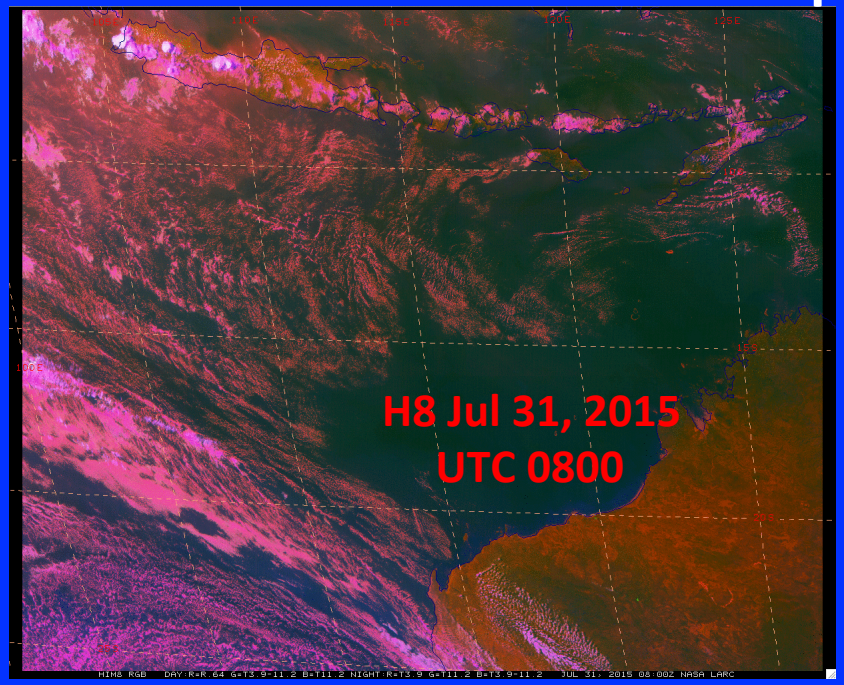


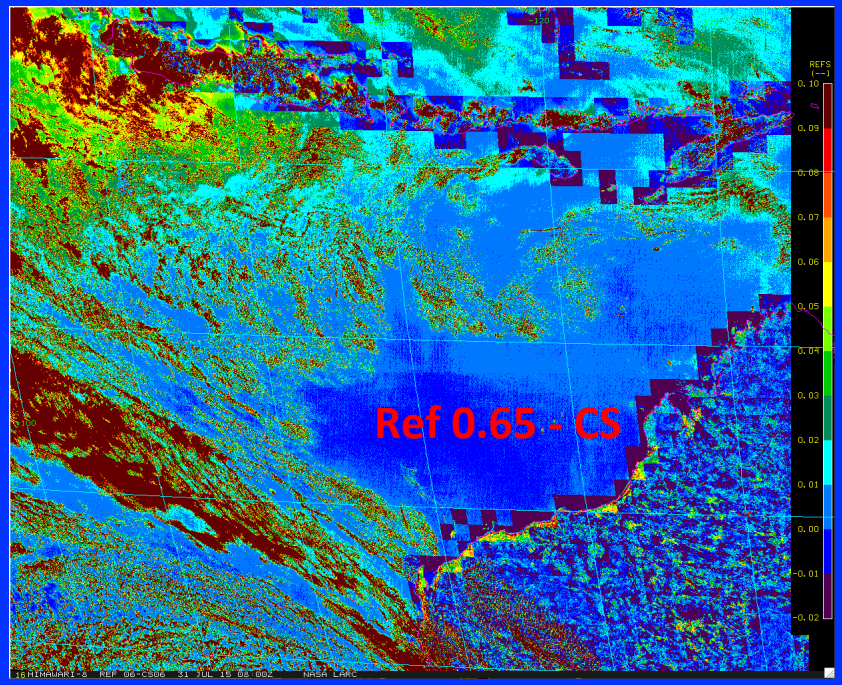
CERES GEO Satellites

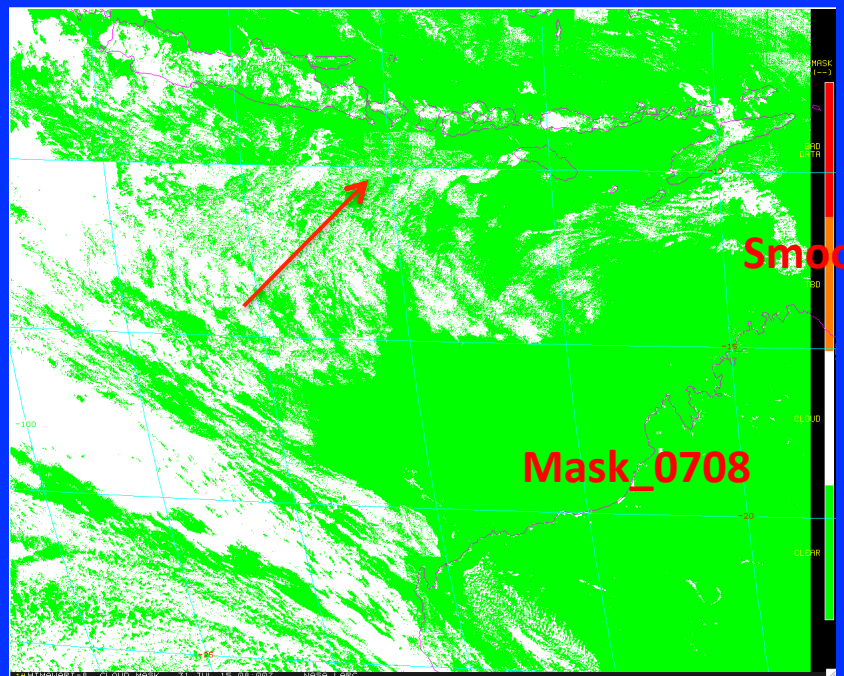
Various satellites have different channel combinations, number of channels

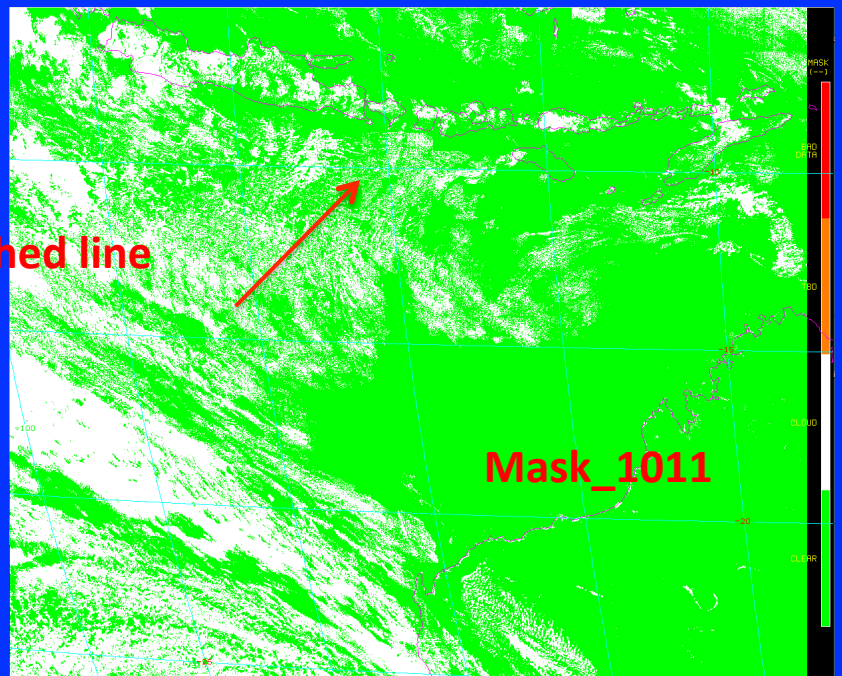
- Himawari data use same flow as Terra, VIIRS, and MSG, using 1.6, not 2.3 μm
- MSG and Himawari use Terra MODIS Polar Daytime/Twilight Masks
- Applied MSG snow detection to Himawari, differs from MODIS & VIIRS

Coastline problems

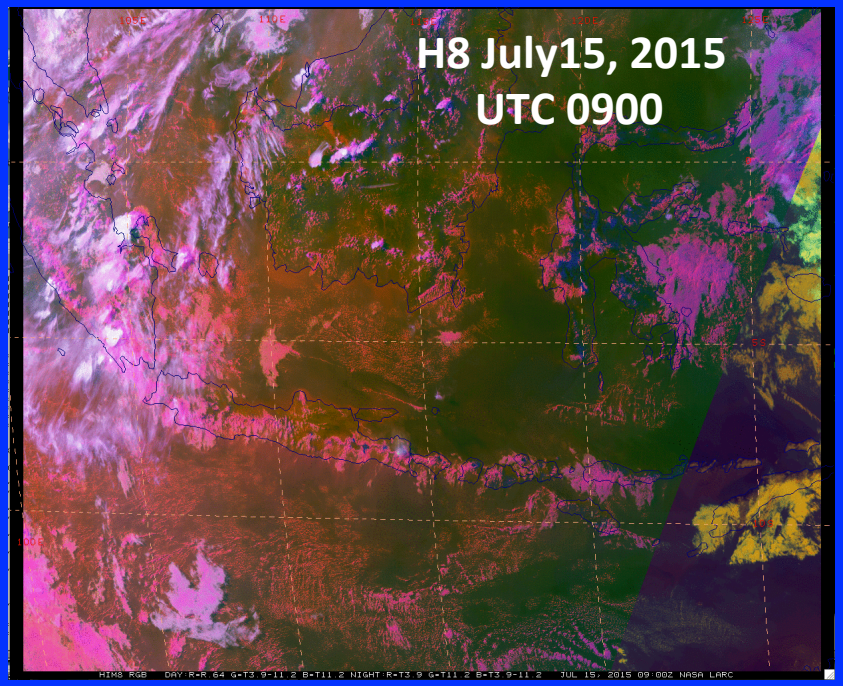


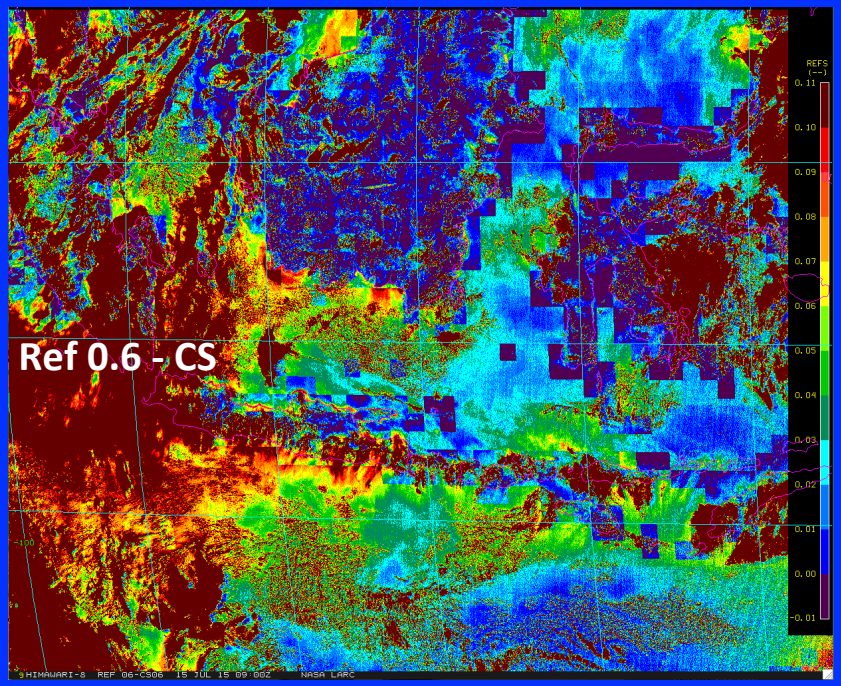


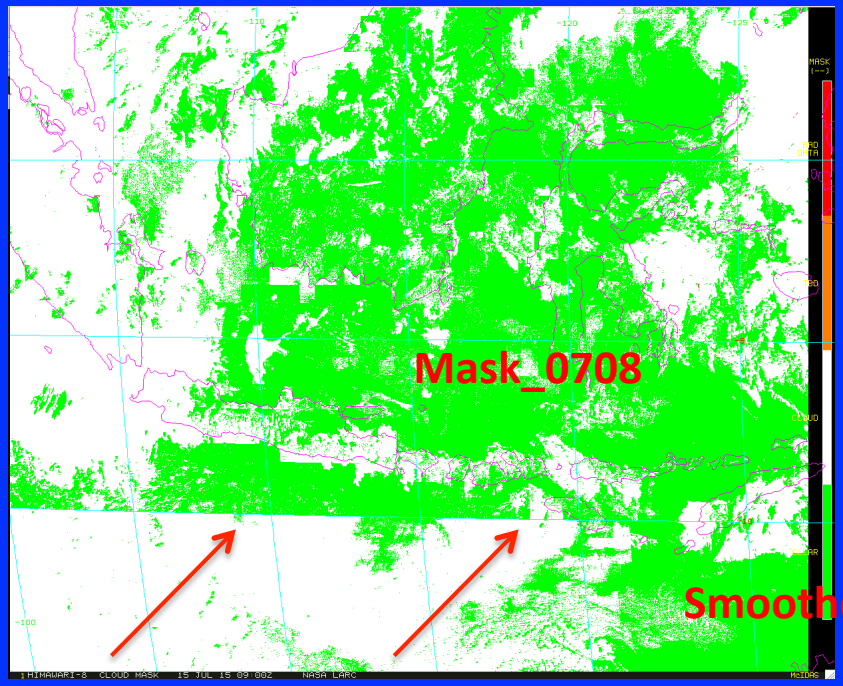


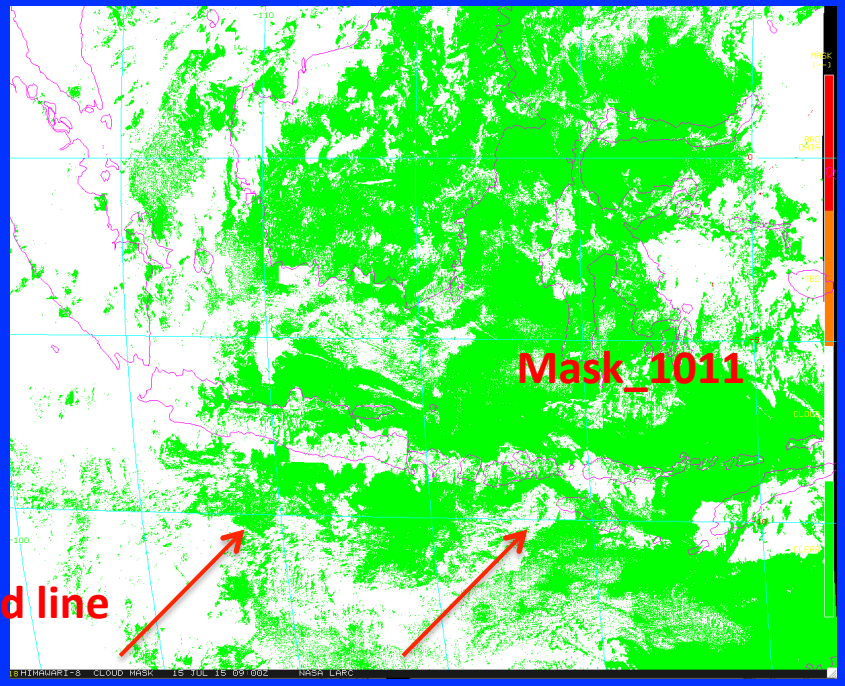


Smoothed line







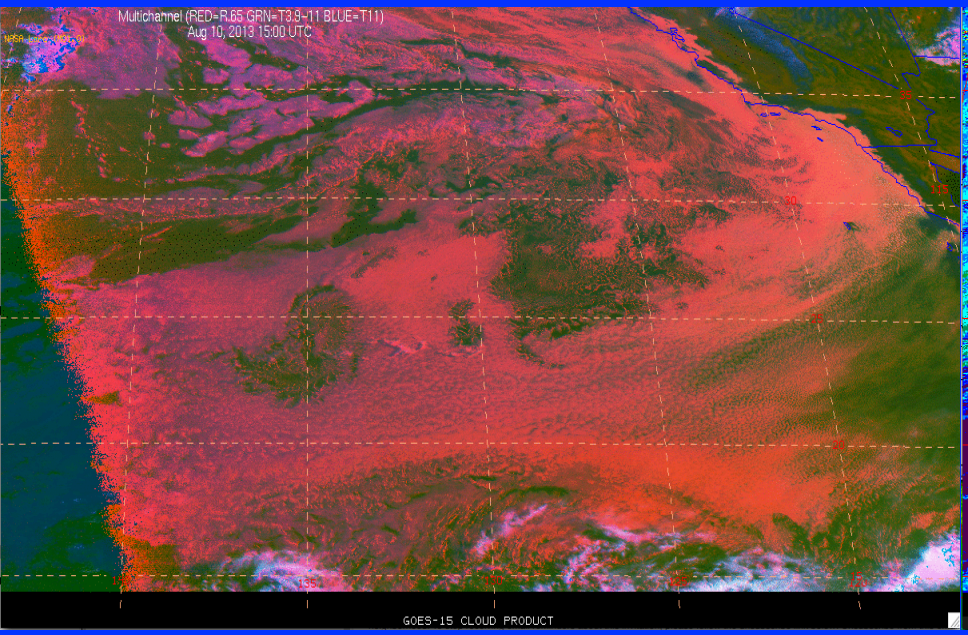


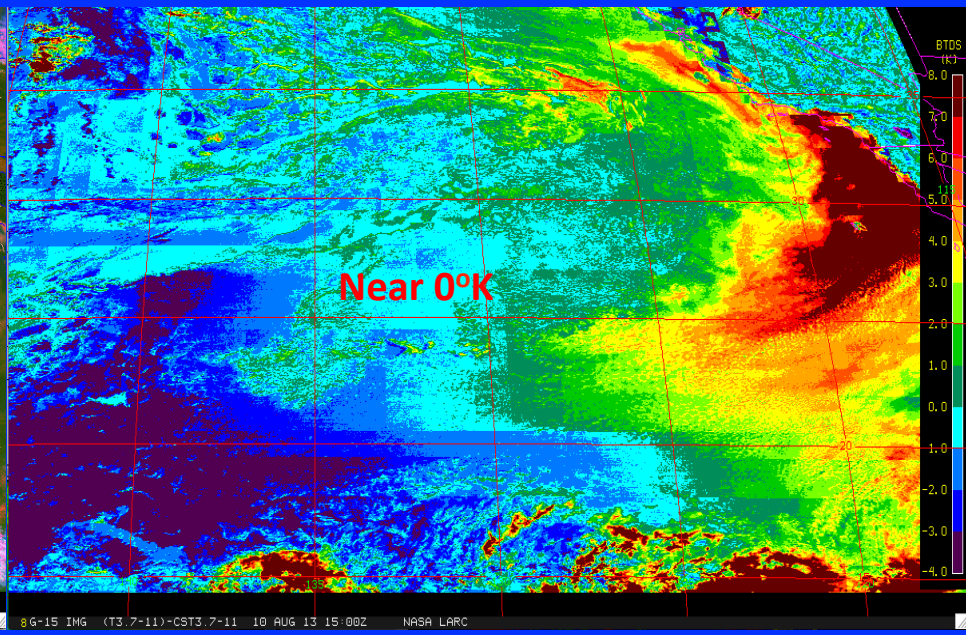
Smoothed line

Picked up GOES-15 missing low clouds at low Sun angles

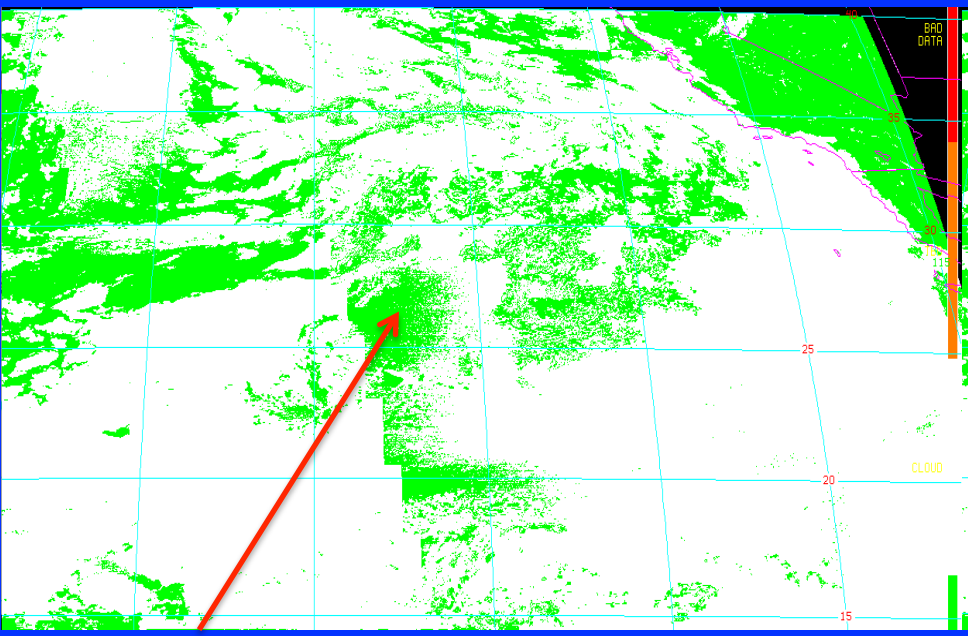
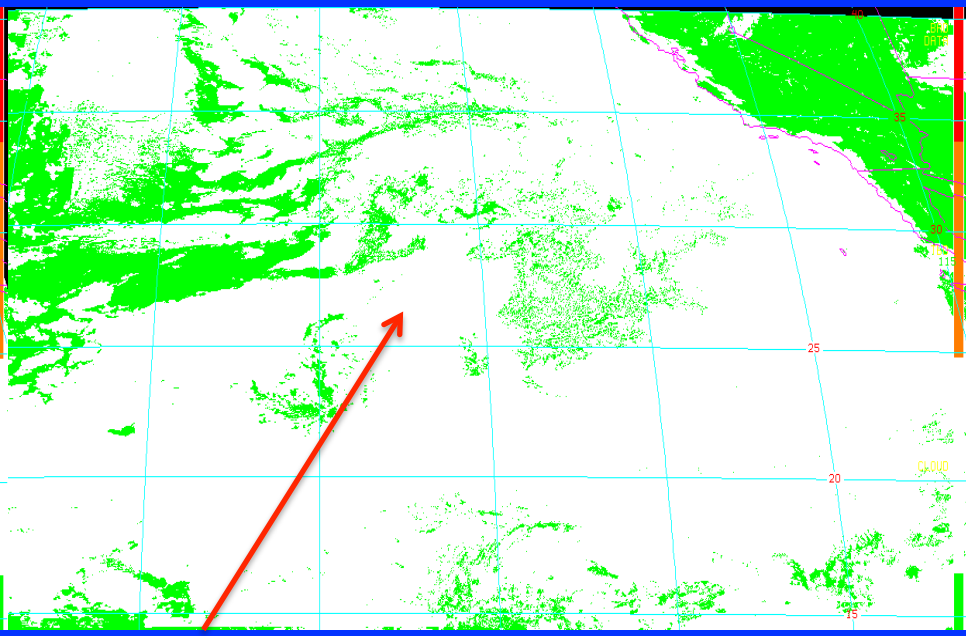
GOES-15, August 10, 2013, 1500 Z

T39 – T11 - CS





Old Mask



New Mask