CERES Cloud Properties: Ed4, SNPP & GEO Updates

P. Minnis, D. Doelling (calibration)

NASA Langley Research Center, Hampton, VA, USA

S. Sun-Mack (lead), Q. Trepte (mask), F-L. Chang (CO2, ML), T. Chee (web, DM), R. Arduini (RTM), K. Bedka (OT tops, AVHRR), S. Bedka (SIST), R. Brown (QC), Y. Chen (clr props, test runs), S. Gibson (graphics), E. Heckert (web, IG), G. Hong (models), M. Khaiyer (val), R. Palikonda (GEO), B. Scarino (cal), R. Smith (web, NPP), D. Spangenberg (polar), C. Yost (phase, validation)

SSAI, Hampton, VA, USA

P. W. Heck (retrieval algo)

CIMSS, U. Wisconsin, Madison, Wi, USA

P. Yang (ice model)

Texas A&M, College Station, TX, USA

CERES Science Team Meeting, LaJolla, CA, 29-31 October 2013

Topics

- **Publications**
- **Terra/Aqua** – Ed2, Ed4 in process
- **NPP** – Ed1, June 2013
- **GEOSat** – Ed 1, June 2013

Update of CERES Cloud-related Papers since Oct 2012

Edition-2 related

Stubenrauch, C., W. B. Rossow, S. Kinne, S. Ackerman, G. Cesana, H. Chepfer, B. Getzewich, L. DiGirolamo, A. Guignard, A. Heidinger, B. Maddux, P. Menzel, P. Minnis, C. Pearl, S. Platnick, C. Poulsen, J. Riedi, S. Sun-Mack, A. Walther, D. Winker, S. Zeng, and G. Zhao, 2013: Assessment of global cloud datasets from satellites: Project and database initiated by the GEWEX Radiation Panel. *Bull. Am. Meteorol. Soc.,* **94**, 1031-1049, doi: 10.1175/BAMS-D-12-00117.

Painemal, D., S. Kato, and P. Minnis, 2013: Biomass burning and the dual microphysical behavior of boundary layer clouds in the southeast Atlantic. Submitted, *Science*.

Stanfield, R. E., X. Dong, B. Xi, A. Kennedy, A. D. Del Genio, P. Minnis, and J. Jiang, 2013: Assessment of NASA GISS CMIP5 and post-CMIP5 simulated clouds and TOA radiation budgets using satellite observations. Part I: Cloud fraction and properties. *J. Climate*, submitted.

Edition-4/5 related

Painemal, D., P. Minnis, and L. O'Neill, 2013: The diurnal cycle of boundary layer height and cloud cover over the Southeast Pacific as observed by GOES-10. *J. Atmos. Sci.*, **70**, 2393-2408, doi:10.1175/JAS-D-12-0325.1.

Painemal, D., P. Minnis, and S. Sun-Mack, 2013: The impact of horizontal heterogeneities, cloud fraction, and cloud dynamcis on warm cloud effective radii and liquid water path from CERES-like Aqua MODIS retrievals. *Atmos. Chem. Phys.*, 13, 9997-10003, doi:10.5194/acp-13-9997-2013.

Sun-Mack, S., P. Minnis, Y. Chen, S. Kato, Y. Yi, S. Gibson, P. W. Heck, and D. Winker, 2013: Global cloudy boundary layer apparent lapse rates determined from CALIPSO and MODIS data. Submitted, *J. Appl. Meteorol. Climatol.*

Cloud Parameters in CERES Edition 2

Cloud Mask, Phase
Optical Depth, IR emissivity
Effective Radius/Diameter
Liquid/Ice Water Path
Cloud Effective Temperature
Cloud Top/ Bottom Pressure
Cloud Effective Pressure
Cloud Effective Height
Clear-sky Temperature

All data only available in SSF or 1° averages

New Cloud Parameters in CERES Edition 4

New Size Retrievals
Water droplet eff radius (1.24 μm)
Ice effective radius (1.24 μm)
Water droplet eff radius (2.1 μm)
Ice effective radius (2.1 μm)

CO2 Slicing
Cloud Top Pressure
Cloud Top Temperature
Cloud Top Height
IR Emissivity

Multilayer Cloud Retrieval (Ice Over Water)	
Multilayer Identification	
Upper Layer (Ice Clouds)	Lower Layer (Water Clouds)
Cloud Top Pressure	Cloud Top Pressure
Cloud Top Temperature	Cloud Top Temperature
Cloud Top Height	Cloud Top Height
Cloud Visible Optical Depth	Cloud Visible Optical Depth
Ice Effective Radius (3.7 μm)	Water Droplet Radius (3.7 μm)
Ice Effective Radius (2.1 μm)	Water Droplet Radius (2.1 μm)

All data available in SSF, 1° averages, & at pixel level

MODIS Processing Status

- Ed2 processing
  - *Aqua: through June 2013, will continue until ED4 ADMs completed*
  - *Terra: through June 2013, will continue until Ed4 ADMs completed*

- Ed4 re-delivered in February: known as Ed4 Beta-2, based on Coll. 5 data
  - *Revised boundary layer lapse rates*
  - *CO2-slicing bug fixed*
  - *Aqua: through February 2003*
  - *Terra: through September 2004*

MODIS Edition-4 beta 2 Caution

- Error in model look-up tables discovered

  - mismatch between 0.65 and 3.8-μm optical depths
  - affects particle size and phase selection primarily
  - secondarily affects optical depth & cloud fraction
  - impacts ADM selection => fluxes
  (See W. Su talk)

- New thick ice cloud top height correction overwritten in Ed4
  - effective height unchanged
  - Zt can be computed with a simple equation that will be provided in data summary

- No, you cannot not get healthcare at our website

Aqua FM3: 200801 daytime

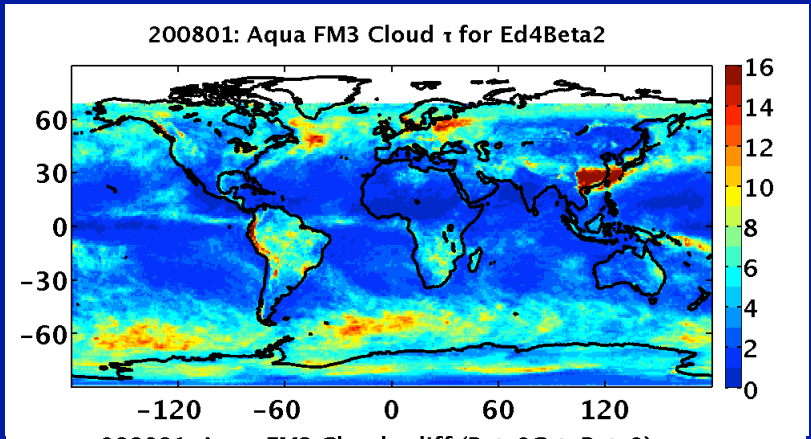
tau

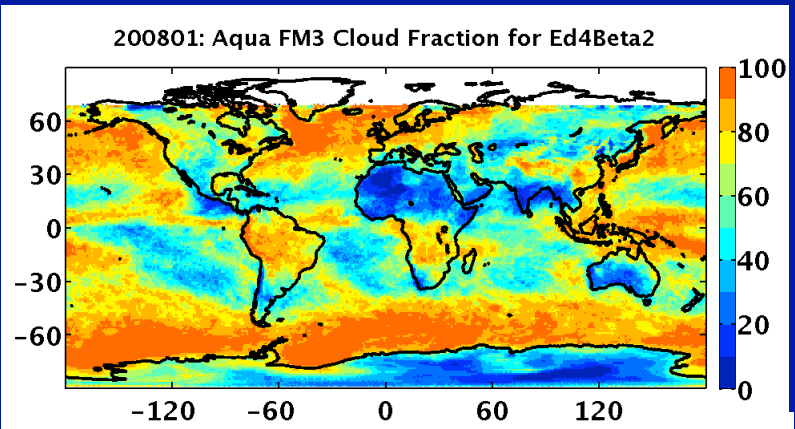
Cloud frac

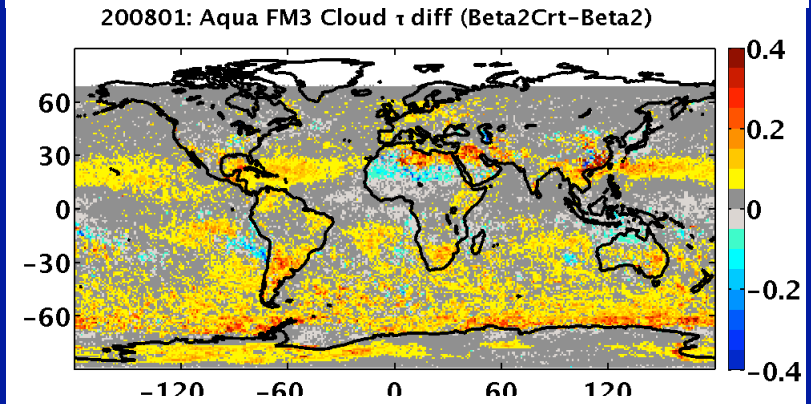
Mean

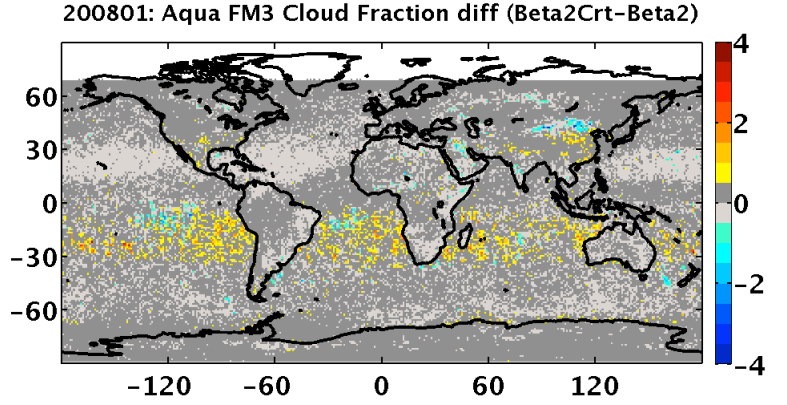
Diff.

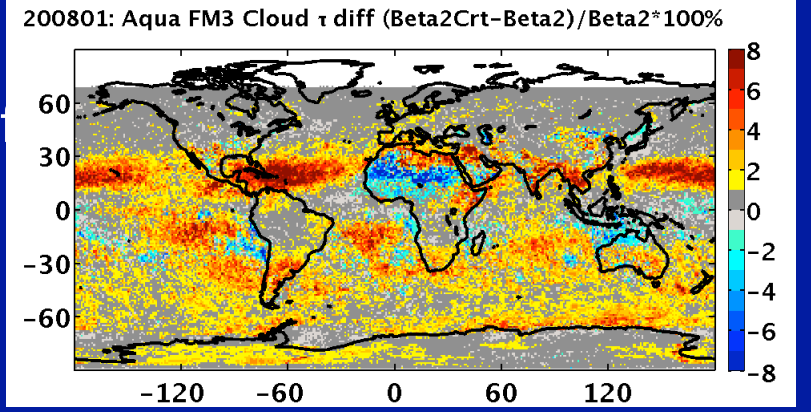
Rel. dif

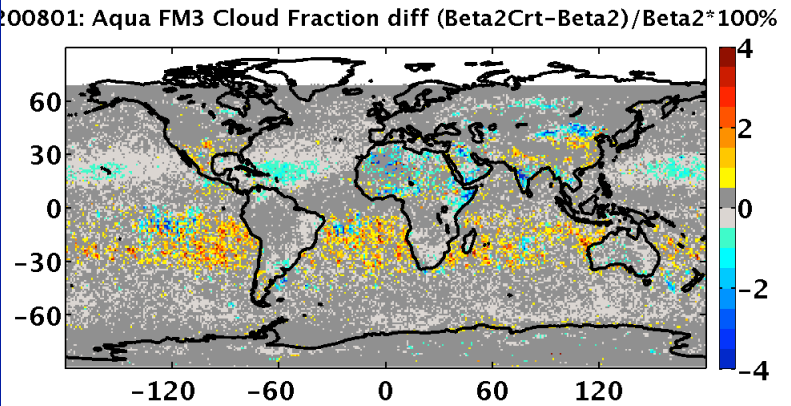












Aqua MODIS Ed-4 beta2 Validation

- Spatially/temporally matched cloud properties for 10 November 2012

- Selected MODIS cloud properties only – mask, cloud top height, optical depth
  - Limited memory & storage
  - No cloud base, WP
  - All matches near nadir

- CALIPSO data
  - 5-km cloud heights and optical depths, 80-km clouds excluded
  - 333-m cloud detections added for cloud mask comparison
  - Phase uses only pure phase cases from CALIPSO

H - Hit rate, fraction CALIPSO clouds detected

FC – fraction correct

FAR – false alarm rate

B – bias ratio

CSI – critical success index

HSS – Heidke skill score

Aqua cloud mask – global, 10 Nov 2012

ocean

SZA < 82.0 (day)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
MODIS	CLEAR	7430	(23.3%)	1430	(4.5%)	8860	(27.7%)
	CLOUD	1150	(3.6%)	21923	(68.7%)	23073	(72.3%)
	TOTALS	8580	(26.9%)	23353	(73.1%)	31933	(100.0%)

FC = 0.919 H = 0.939 FAR = 0.050
CSI = 0.895 B = 0.99 HSS = 0.80

SZA > 82.0 (night)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
MODIS	CLEAR	6732	(16.9%)	2813	(7.1%)	9545	(24.0%)
	CLOUD	1449	(3.6%)	28803	(72.4%)	30252	(76.0%)
	TOTALS	8181	(20.6%)	31616	(79.4%)	39797	(100.0%)

FC = 0.893 H = 0.911 FAR = 0.048
CSI = 0.871 B = 0.96 HSS = 0.69

82.0 < SZA < 88.5 (twilight)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
MODIS	CLEAR	184	(17.0%)	67	(6.2%)	251	(23.2%)
	CLOUD	34	(3.1%)	799	(73.7%)	833	(76.8%)
	TOTALS	218	(20.1%)	866	(79.9%)	1084	(100.0%)

FC = 0.907 H = 0.923 FAR = 0.041
CSI = 0.888 B = 0.96 HSS = 0.73

SZA > 88.5 (pitch black night)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
MODIS	CLEAR	6548	(16.9%)	2746	(7.1%)	9294	(24.0%)
	CLOUD	1415	(3.7%)	28004	(72.3%)	29419	(76.0%)
	TOTALS	7963	(20.6%)	30750	(79.4%)	38713	(100.0%)

FC = 0.893 H = 0.911 FAR = 0.048
CSI = 0.871 B = 0.96 HSS = 0.694

land

SZA < 82.0 (day)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
MODIS	CLEAR	6730	(35.5%)	2274	(12.0%)	9004	(47.5%)
	CLOUD	235	(1.2%)	9725	(51.3%)	9960	(52.5%)
	TOTALS	6965	(36.7%)	11999	(63.3%)	18964	(100.0%)

FC = 0.868 H = 0.810 FAR = 0.024
CSI = 0.795 B = 0.83 HSS = 0.73

SZA > 82.0 (night)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
MODIS	CLEAR	5831	(31.4%)	3374	(18.2%)	9205	(49.6%)
	CLOUD	760	(4.1%)	8611	(46.4%)	9371	(50.4%)
	TOTALS	6591	(35.5%)	11985	(64.5%)	18576	(100.0%)

FC = 0.777 H = 0.718 FAR = 0.081
CSI = 0.676 B = 0.78 HSS = 0.55

82.0 < SZA < 88.5 (twilight)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
MODIS	CLEAR	1108	(34.7%)	495	(15.5%)	1603	(50.2%)
	CLOUD	62	(1.9%)	1530	(47.9%)	1592	(49.8%)
	TOTALS	1170	(36.6%)	2025	(63.4%)	3195	(100.0%)

FC = 0.826 H = 0.756 FAR = 0.039
CSI = 0.733 B = 0.79 HSS = 0.65

SZA > 88.5 (pitch black night)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
MODIS	CLEAR	4723	(30.7%)	2879	(18.7%)	7602	(49.4%)
	CLOUD	698	(4.5%)	7081	(46.0%)	7779	(50.6%)
	TOTALS	5421	(35.2%)	9960	(64.8%)	15381	(100.0%)

FC = 0.767 H = 0.711 FAR = 0.090
CSI = 0.664 B = 0.78 HSS = 0.53

polar only

- 14% too clear over land at night

Aqua MODIS Cloud Mask Comparisons
Nov 10 2013

- Day: FC = 0.92 over ocean, 0.87 over land
- Night: FC = 0.89 over ocean, 0.77 over land
  - misses 14%
- Twilight: FC = 0.90 over ocean, 0.83 over land
- Tropics FC = 0.89 over ocean, 0.86 over land, day
  0.86 over ocean, 0.82 over land, night
- Midlat FC = 0.93 over ocean, 0.90over land, day
  0.93 over ocean, 0.77 over land, night
- Polar FC = 0.96 over ocean, 0.85 over land, day
  0.89 over ocean, 0.73 over land, night

Ed4 mask more accurate than Ed2 (see Sun-Mack talk)

- Including 80-km clouds reduces these numbers by ~0.02 to 0.03

80-km clouds excluded

========== SZA < 82.0 (day) ==========

		CALIPSO CLEAR		CALIPSO CLOUD		CALIPSO TOTALS	
MODIS	CLEAR	14160	(27.8%)	3704	(7.3%)	17864	(35.1%)
	CLOUD	1385	(2.7%)	31648	(62.2%)	33033	(64.9%)
	TOTALS	15545	(30.5%)	35352	(69.5%)	50897	(100.0%)

FC = 0.900 H = 0.895 FAR = 0.042
CSI = 0.861 B = 0.93 HSS = 0.77

========== SZA > 82.0 (night) ==========

		CALIPSO CLEAR		CALIPSO CLOUD		CALIPSO TOTALS	
MODIS	CLEAR	12563	(21.5%)	6187	(10.6%)	18750	(32.1%)
	CLOUD	2209	(3.8%)	37414	(64.1%)	39623	(67.9%)
	TOTALS	14772	(25.3%)	43601	(74.7%)	58373	(100.0%)

FC = 0.856 H = 0.858 FAR = 0.056
CSI = 0.817 B = 0.91 HSS = 0.65

========== 82.0 < SZA < 88.5 (twilight) ==========

		CALIPSO CLEAR		CALIPSO CLOUD		CALIPSO TOTALS	
MODIS	CLEAR	1292	(30.2%)	562	(13.1%)	1854	(43.3%)
	CLOUD	96	(2.2%)	2329	(54.4%)	2425	(56.7%)
	TOTALS	1388	(32.4%)	2891	(67.6%)	4279	(100.0%)

FC = 0.846 H = 0.806 FAR = 0.040
CSI = 0.780 B = 0.84 HSS = 0.68

========== SZA > 88.5 (pitch black night) ==========

		CALIPSO CLEAR		CALIPSO CLOUD		CALIPSO TOTALS	
MODIS	CLEAR	11271	(20.8%)	5625	(10.4%)	16896	(31.2%)
	CLOUD	2113	(3.9%)	35085	(64.9%)	37198	(68.8%)
	TOTALS	13384	(24.7%)	40710	(75.3%)	54094	(100.0%)

FC = 0.857 H = 0.862 FAR = 0.057
CSI = 0.819 B = 0.91 HSS = 0.65

80-km clouds included in analysis

========== SZA < 82.0 (day) ==========

		CALIPSO CLEAR		CALIPSO CLOUD		CALIPSO TOTALS	
MODIS	CLEAR	14160	(26.4%)	5215	(9.7%)	19375	(36.1%)
	CLOUD	1385	(2.6%)	32857	(61.3%)	34242	(63.9%)
	TOTALS	15545	(29.0%)	38072	(71.0%)	53617	(100.0%)

FC = 0.877 H = 0.863 FAR = 0.040
CSI = 0.833 B = 0.90 HSS = 0.72

========== SZA > 82.0 (night) ==========

		CALIPSO CLEAR		CALIPSO CLOUD		CALIPSO TOTALS	
MODIS	CLEAR	12563	(20.7%)	7675	(12.6%)	20238	(33.3%)
	CLOUD	2209	(3.6%)	38323	(63.1%)	40532	(66.7%)
	TOTALS	14772	(24.3%)	45998	(75.7%)	60770	(100.0%)

FC = 0.837 H = 0.833 FAR = 0.055
CSI = 0.795 B = 0.88 HSS = 0.61

========== 82.0 < SZA < 88.5 (twilight) ==========

		CALIPSO CLEAR		CALIPSO CLOUD		CALIPSO TOTALS	
MODIS	CLEAR	1292	(28.7%)	717	(15.9%)	2009	(44.6%)
	CLOUD	96	(2.1%)	2398	(53.3%)	2494	(55.4%)
	TOTALS	1388	(30.8%)	3115	(69.2%)	4503	(100.0%)

FC = 0.819 H = 0.770 FAR = 0.038
CSI = 0.747 B = 0.80 HSS = 0.62

========== SZA > 88.5 (pitch black night) ==========

		CALIPSO CLEAR		CALIPSO CLOUD		CALIPSO TOTALS	
MODIS	CLEAR	11271	(20.0%)	6958	(12.4%)	18229	(32.4%)
	CLOUD	2113	(3.8%)	35925	(63.8%)	38038	(67.6%)
	TOTALS	13384	(23.8%)	42883	(76.2%)	56267	(100.0%)

FC = 0.839 H = 0.838 FAR = 0.056
CSI = 0.798 B = 0.89 HSS = 0.60

Aqua Cloud Phase – global

ocean

SZA < 82.0 (day)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
MODIS	WATER	6357 (67.3%)	64 (0.7%)	6421 (68.0%)
	ICE	141 (1.5%)	2884 (30.5%)	3025 (32.0%)
	TOTALS	6498 (68.8%)	2948 (31.2%)	9446 (100.0%)

FC = 0.978 B = 1.026 HSS = 0.950
Hw = 0.978 FARw = 0.010 Hi = 0.978 FARi = 0.047

SZA > 82.0 (night)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
MODIS	WATER	6503 (65.7%)	223 (2.3%)	6726 (67.9%)
	ICE	370 (3.7%)	2806 (28.3%)	3176 (32.1%)
	TOTALS	6873 (69.4%)	3029 (30.6%)	9902 (100.0%)

FC = 0.940 B = 1.049 HSS = 0.861
Hw = 0.946 FARw = 0.033 Hi = 0.926 FARi = 0.116

82.0 < SZA < 88.5 (twilight)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
MODIS	WATER	43 (35.8%)	0 (0.0%)	43 (35.8%)
	ICE	48 (40.0%)	29 (24.2%)	77 (64.2%)
	TOTALS	91 (75.8%)	29 (24.2%)	120 (100.0%)

FC = 0.600 B = 2.655 HSS = 0.302
Hw = 0.473 FARw = 0.000 Hi = 1.000 FARi = 0.623

SZA > 88.5 (pitch black night)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
MODIS	WATER	6460 (66.0%)	223 (2.3%)	6683 (68.3%)
	ICE	322 (3.3%)	2777 (28.4%)	3099 (31.7%)
	TOTALS	6782 (69.3%)	3000 (30.7%)	9782 (100.0%)

FC = 0.944 B = 1.033 HSS = 0.870
Hw = 0.953 FARw = 0.033 Hi = 0.926 FARi = 0.104

land

SZA < 82.0 (day)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
MODIS	WATER	1093 (38.7%)	93 (3.3%)	1186 (42.0%)
	ICE	66 (2.3%)	1575 (55.7%)	1641 (58.0%)
	TOTALS	1159 (41.0%)	1668 (59.0%)	2827 (100.0%)

FC = 0.944 B = 0.984 HSS = 0.884
Hw = 0.943 FARw = 0.078 Hi = 0.944 FARi = 0.040

SZA > 82.0 (night)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
MODIS	WATER	295 (12.3%)	84 (3.5%)	379 (15.8%)
	ICE	183 (7.7%)	1830 (76.5%)	2013 (84.2%)
	TOTALS	478 (20.0%)	1914 (80.0%)	2392 (100.0%)

FC = 0.888 B = 1.052 HSS = 0.622
Hw = 0.617 FARw = 0.222 Hi = 0.956 FARi = 0.091

82.0 < SZA < 88.5 (twilight)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
MODIS	WATER	40 (8.2%)	5 (1.0%)	45 (9.2%)
	ICE	120 (24.6%)	323 (66.2%)	443 (90.8%)
	TOTALS	160 (32.8%)	328 (67.2%)	488 (100.0%)

FC = 0.744 B = 1.351 HSS = 0.288
Hw = 0.250 FARw = 0.111 Hi = 0.985 FARi = 0.271

SZA > 88.5 (pitch black night)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
MODIS	WATER	255 (13.4%)	79 (4.1%)	334 (17.5%)
	ICE	63 (3.3%)	1507 (79.1%)	1570 (82.5%)
	TOTALS	318 (16.7%)	1586 (83.3%)	1904 (100.0%)

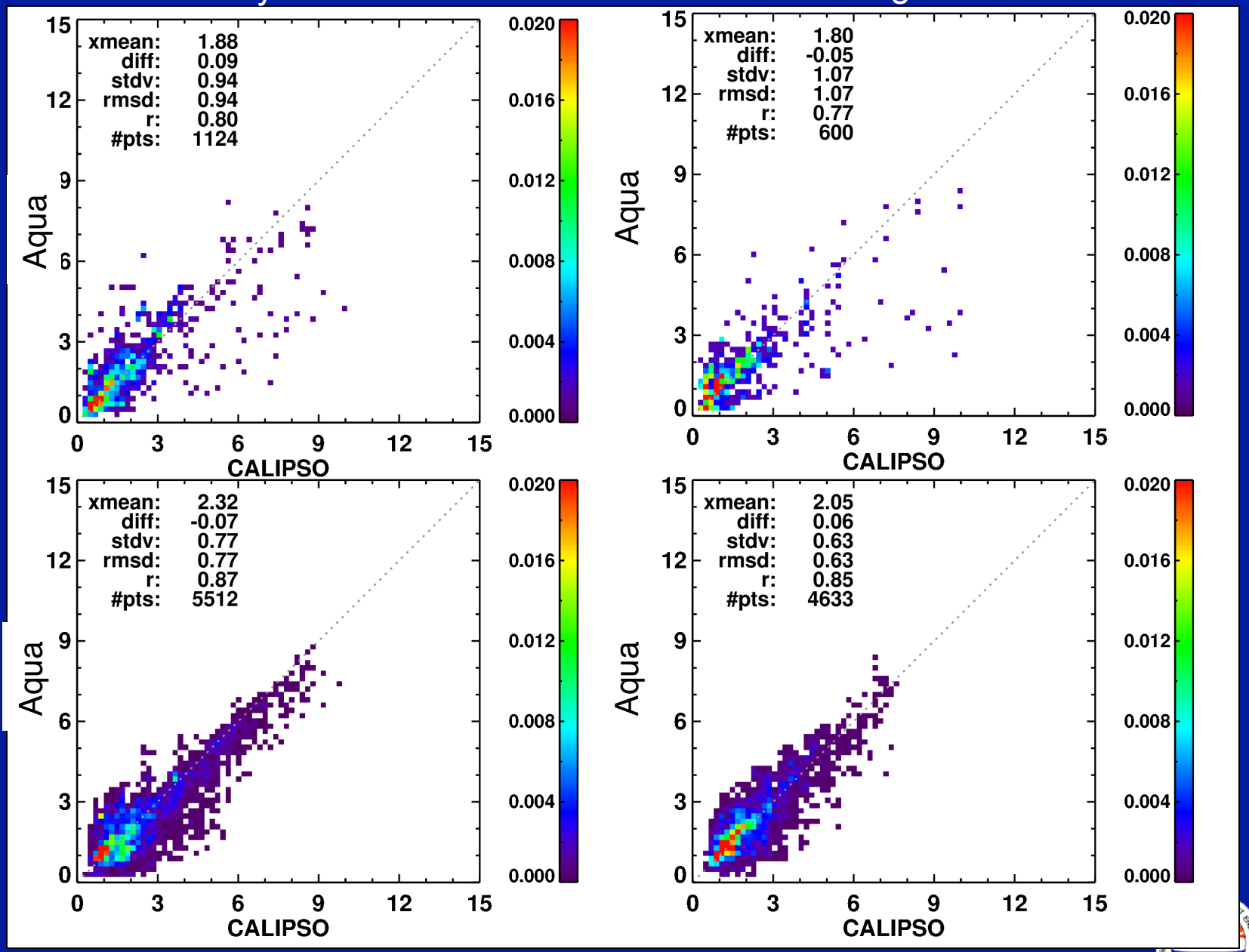
FC = 0.925 B = 0.990 HSS = 0.737
Hw = 0.802 FARw = 0.237 Hi = 0.950 FARi = 0.[illegible]

Aqua Ed-4 Single-layer Cloud Phase Comparisons

- Compares CALIPSO's highest cloud phase with Aqua phase
  - *Multilayer clouds will be hardest to classify*

- Day: FC = 0.98 over ocean, 0.94 over land
- Night: FC = 0.94 over ocean, 0.89 over land
  - *tends to OE ice*
- Twilight: FC = 0.60 over ocean, 0.74 over land
  - all polar
- Tropics FC = 0.98 over ocean, 0.92 over land, day
  0.95 over ocean, 0.90 over land, night
- Midlat FC = 0.99 over ocean, 0.95 over land, day
  0.95 over ocean, 0.95 over land, night
- Polar FC = 0.94 over ocean, 0.95 over land, day
  0.89 over ocean, 0.83 over land, night

cloud top height – liquid



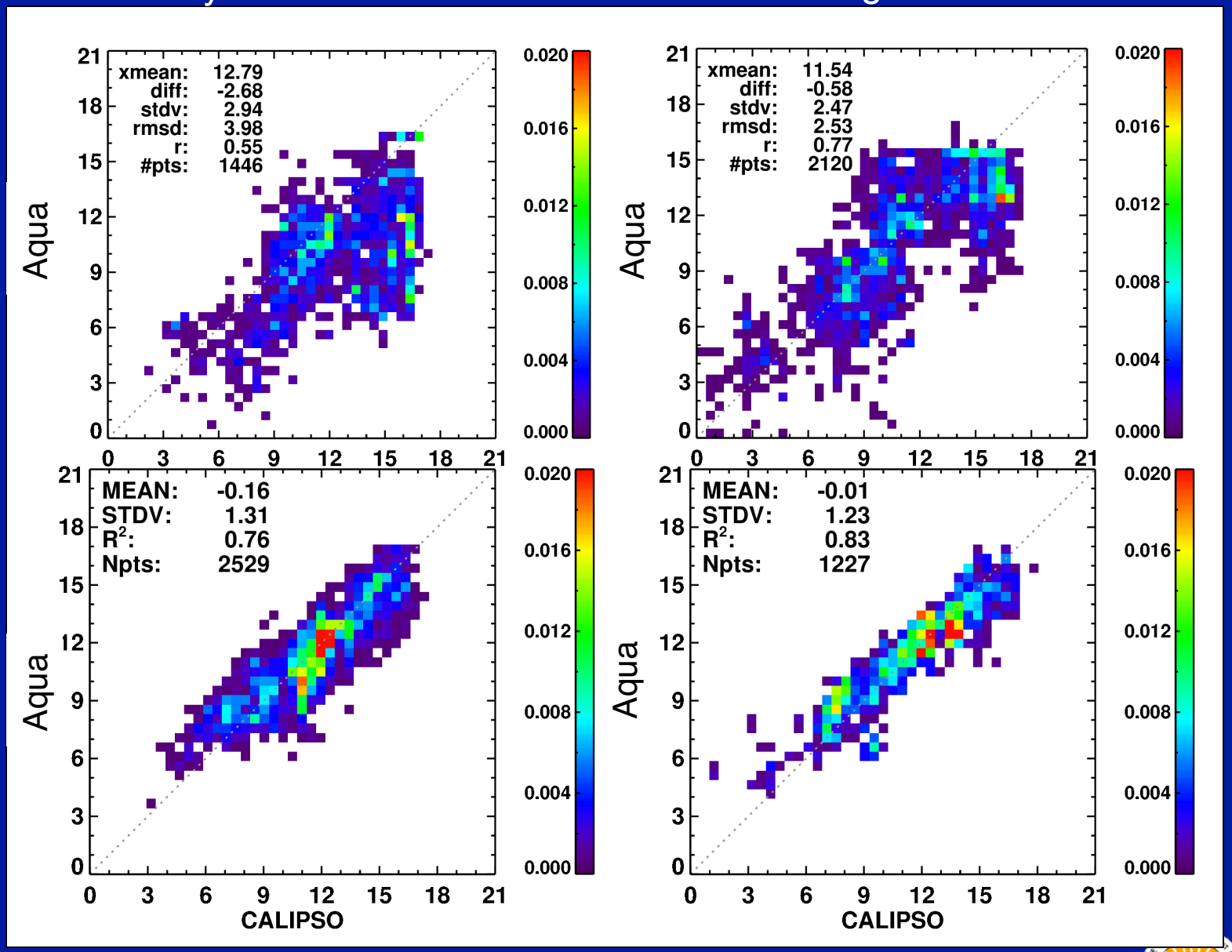
cloud top height – ice, Zt correction applied

day

night

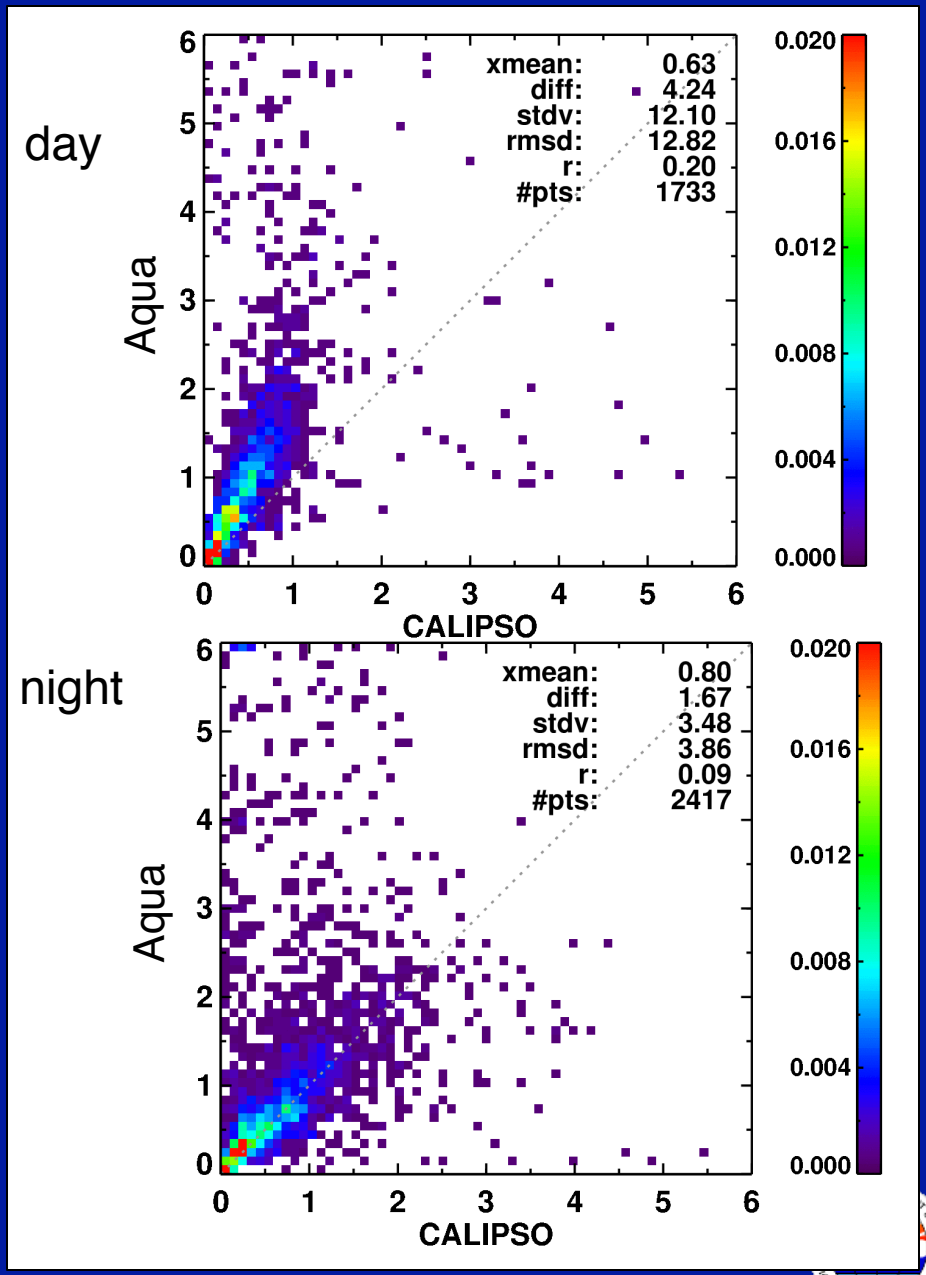
thin

thick



cloud optical depth – ice, thin clouds only

- Daytime cirrus tau ~ 75% > CALIPSO
  - Need scattering phase function for ice with $g \sim 0.75$
    - *next gen from P Yang*
- Nighttime cirrus tau very close to CALIPSO for most points
  - multilayer clouds in this set



Aqua Cloud Height Validation

Type	mean dif	RMSd	Zt correction mean dif	Zt correction RMSd
Ice				
Thin, day	-2.68	3.98		
Thin, night	-0.58	2.53		
Thick, day	-1.73	2.20	-0.16	1.23
Thick, night	-1.33	-1.9	0.01	1.78
Water				
Thin, day	0.09	0.94		
Thin, night	-0.05	1.07		
Thick, day	-0.07	0.77		
Thick, night	0.06	0.63		

VIIRS Cloud Retrievals

- VIIRS data run well all the way thru the system

- corr-k changes & VIIRS solar constants implemented

- cloud reflectance models have been revised several times
  - had some difficulties & changes at both ends
  - "final"models being tested this week

- background maps and snow models updated

- Mask has been tuned, validation results presented below

- Multilayer algorithm delivered by FL Chang
  - uses 8.5, 11, and 12 μm instead of 11 and 13.4 μm

- Deliver Ed1, End of November 2013

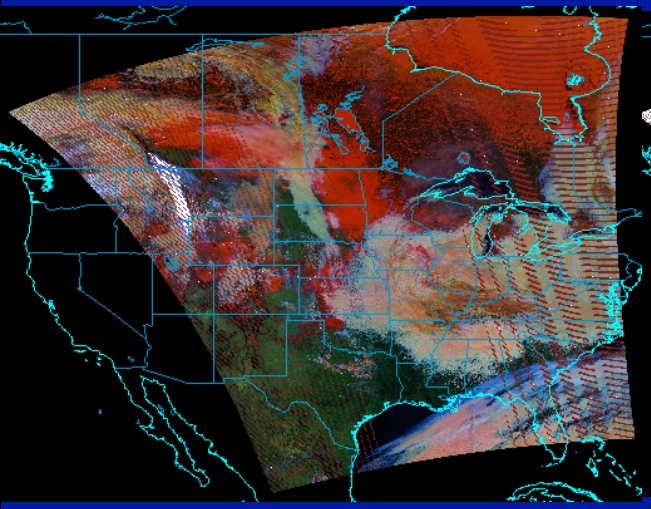
VIIRS Cloud Mask Changes

- Reduced striping in observations (in framework)
- Switched from 2.25 to 1.6 μm
- Converted VIIRS mask output to netCDF and display in McIDAS-V (VIIRS binary output size too big to be displayed in original IBMdx)
- Use VIIRS Corr K and 1.6-μm snow model
- Improved twilight and Nighttime polar cloud detection

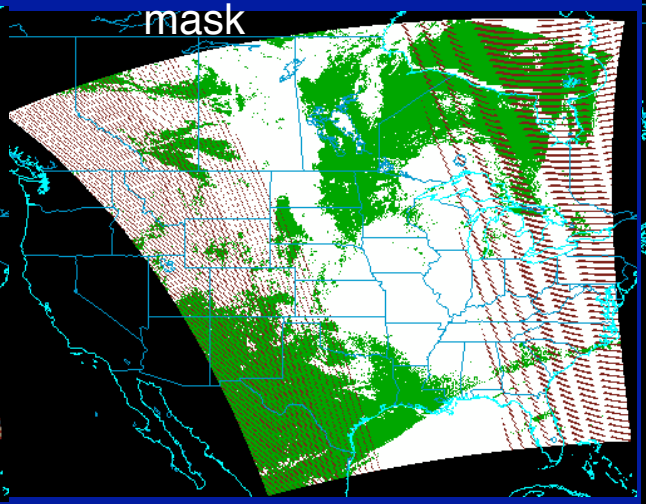
VIIRS Daytime Cloud Mask

Daytime U.S. March 1, 2013, UTC 1905-1910

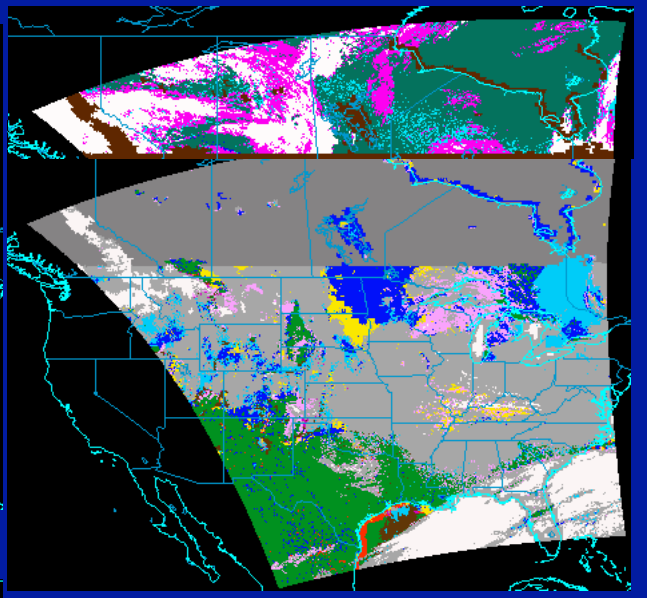
RGB



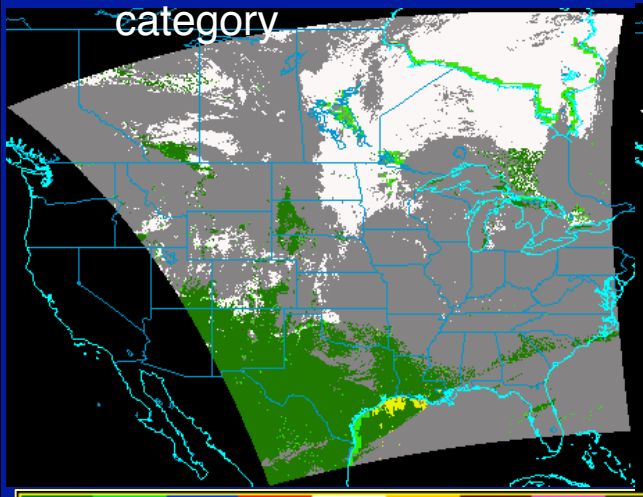
VIIRS 2.25 mask



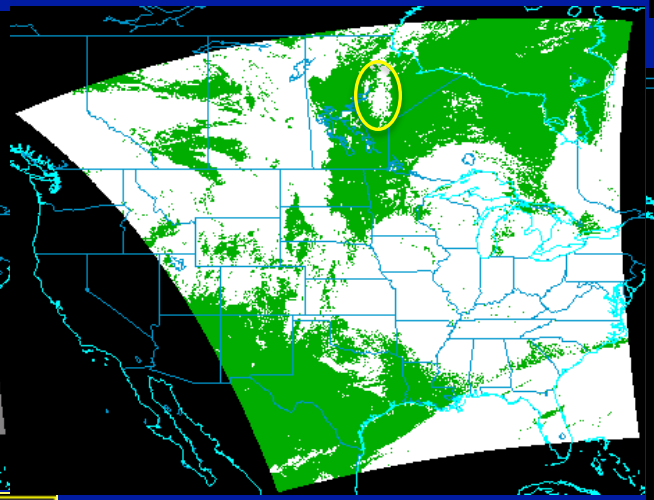
Polar Smy / AB Smy



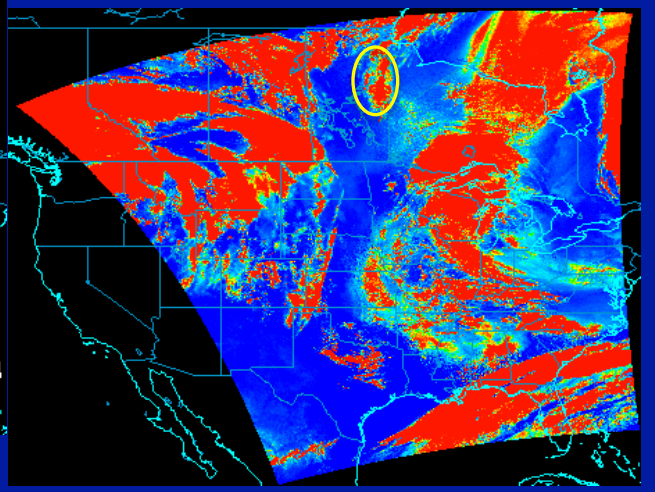
VIIRS clear category



VIIRS 1.6



VIIRS Ref 1.38

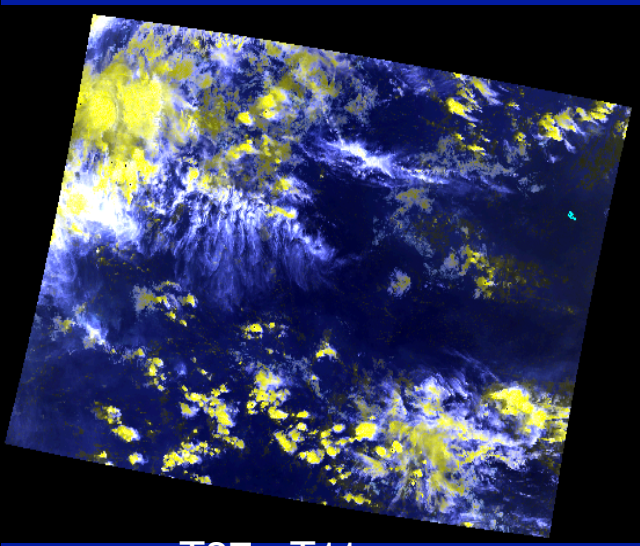


- Smooth transition from non-polar to polar, no line
- Picked up thin Ci over snow

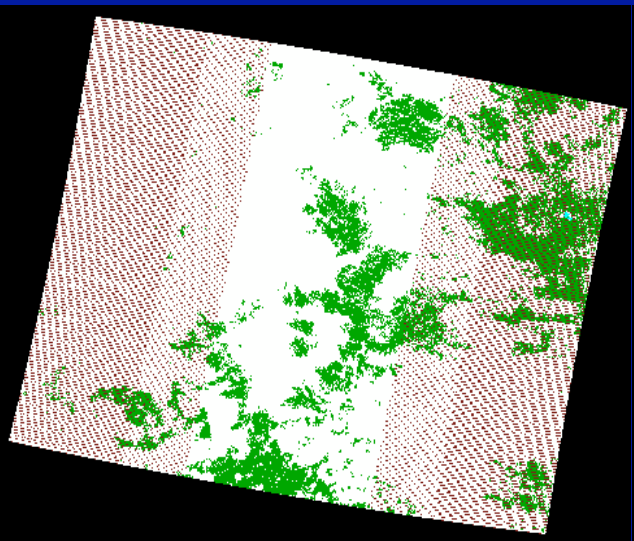
VIIRS Nighttime Cloud Mask

Night time Pacific Ocean October 9, 2012, UTC 1240

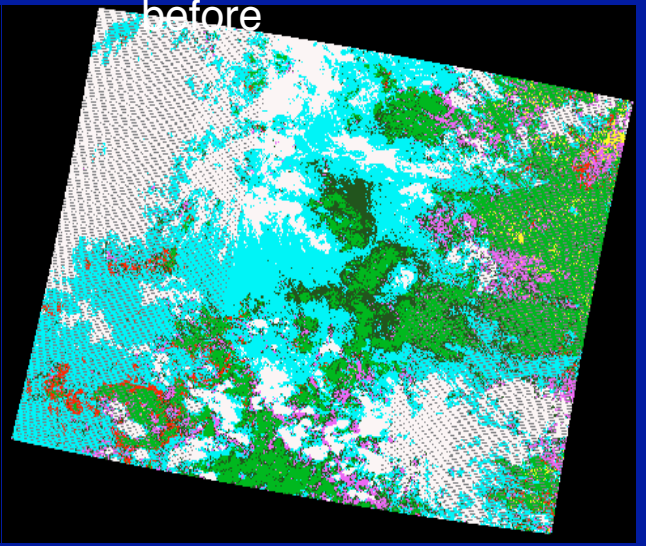
RGB



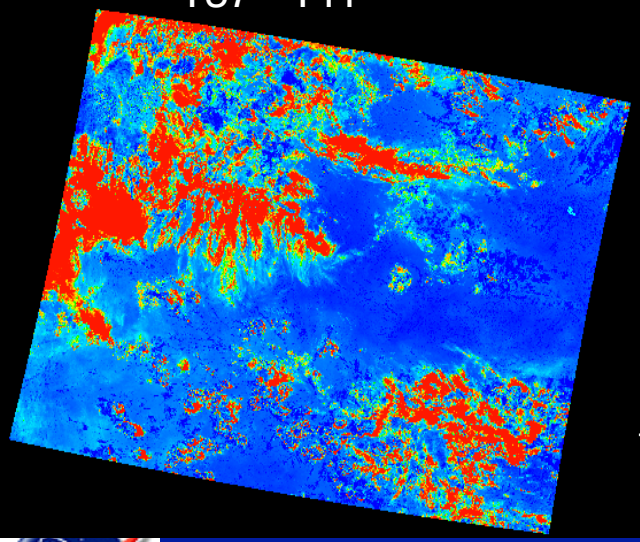
VIIRS mask before



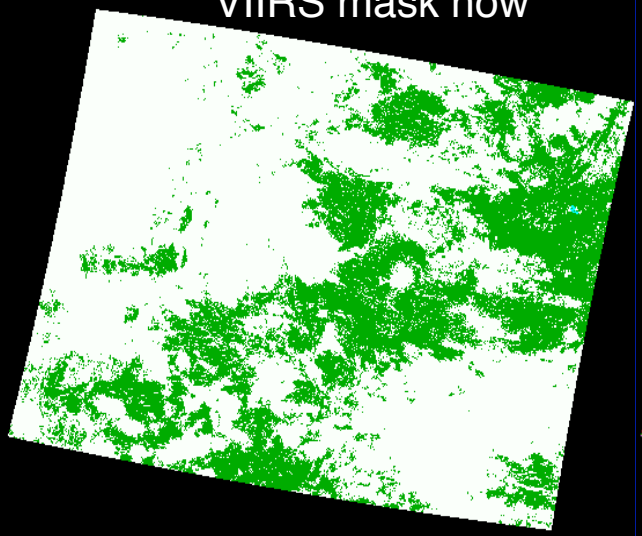
AD Summary before



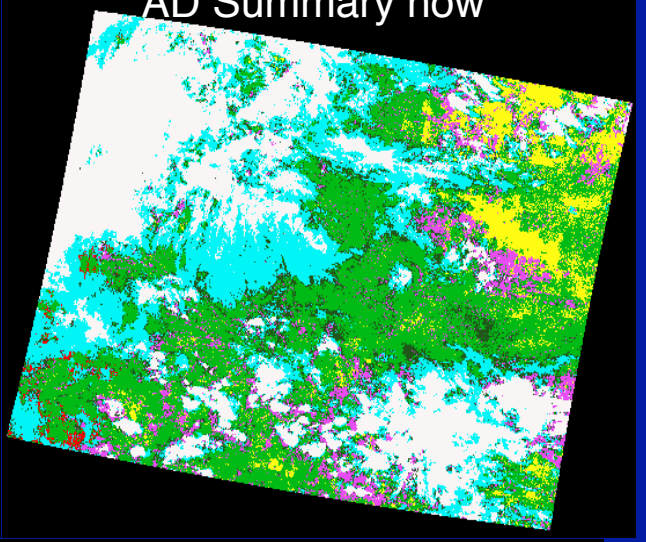
T37 - T11

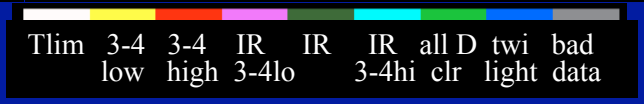


VIIRS mask now



AD Summary now

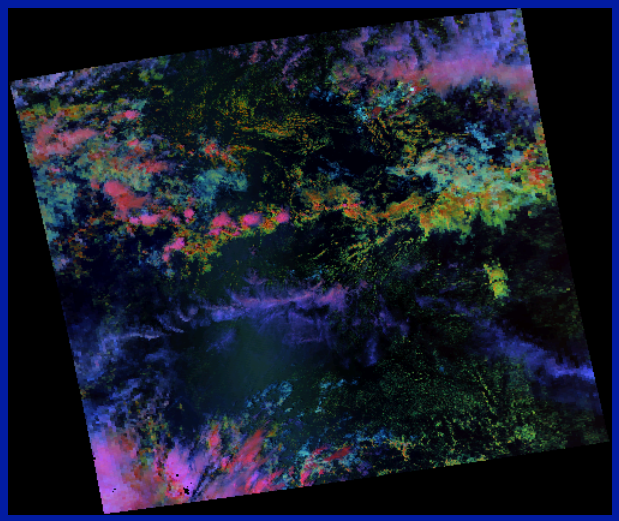


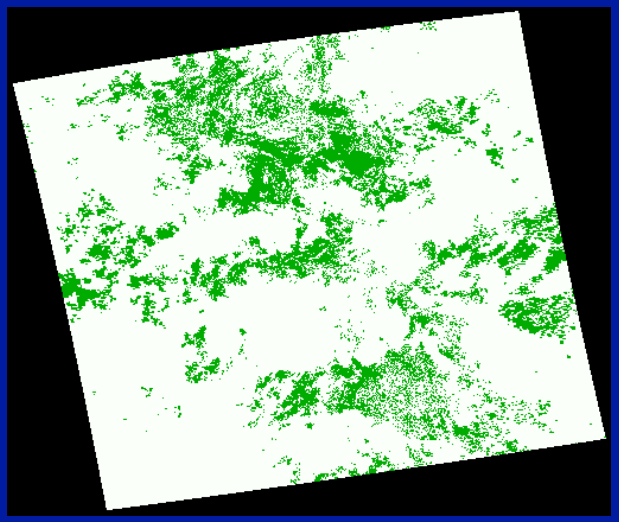


Matched MODIS and VIIRS Cloud Mask

Daytime, Pacific Ocean, Nov 13, 2012, UTC 0055

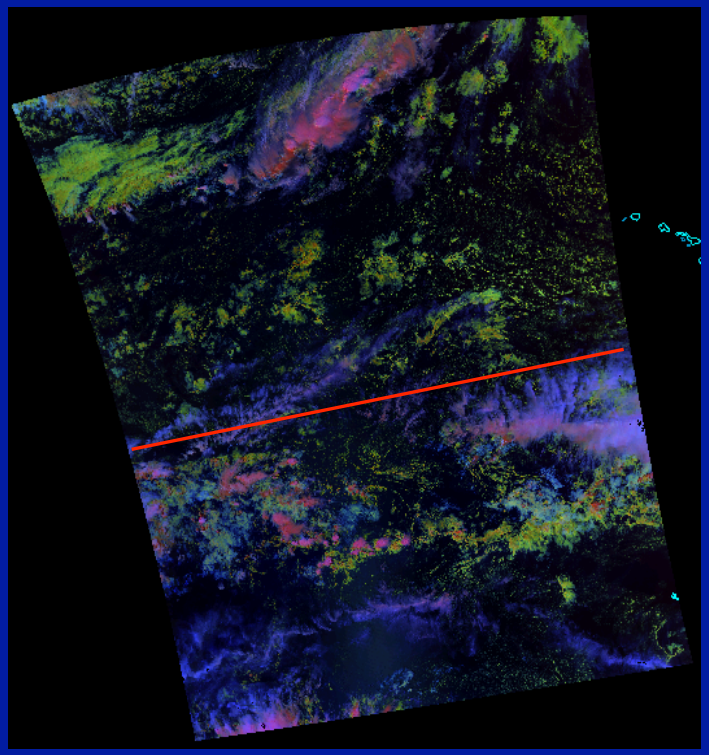
Aqua

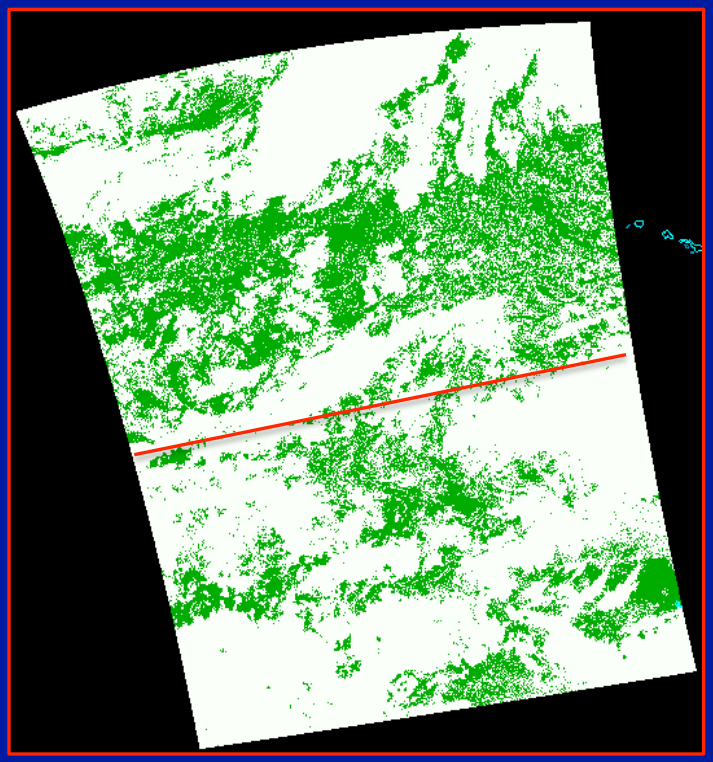




CM Ed4
Aqua 2.1 mask

VIIR
S



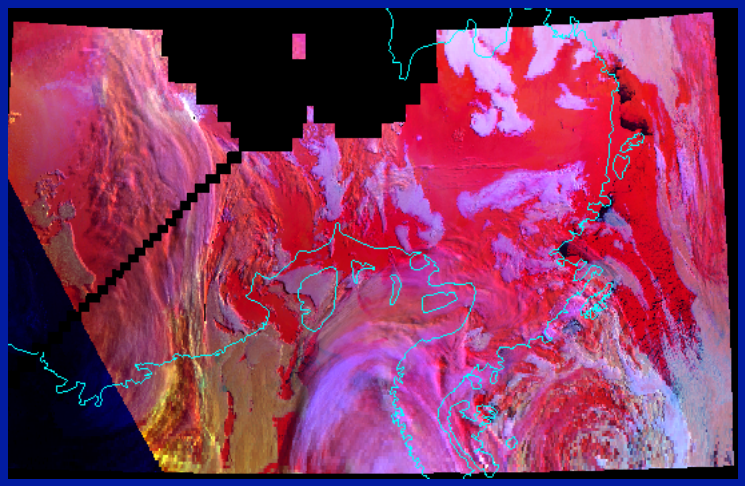


VIIRS 1.6
mask

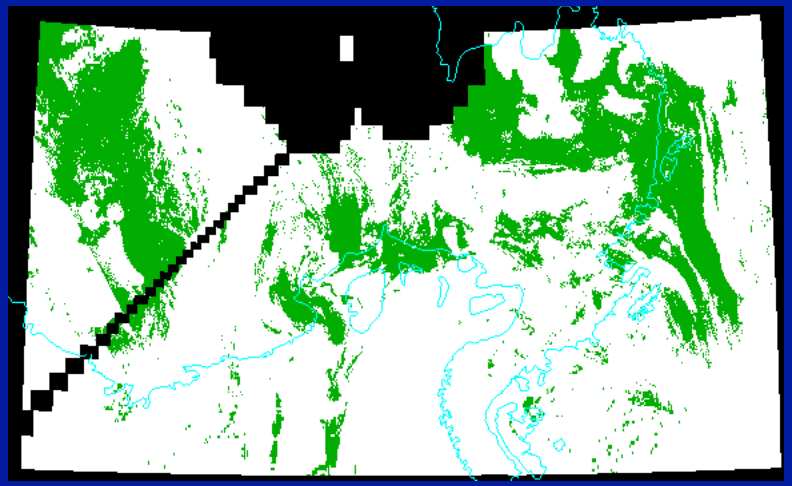
Matched MODIS and VIIRS Cloud Mask

Daytime, Antarctica, Nov 07, 2012, UTC 2230 - 2235

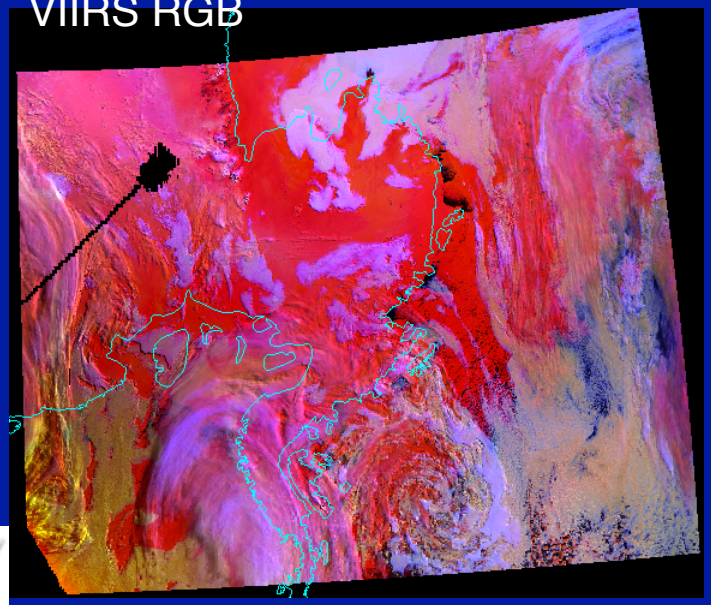
Aqua RGB



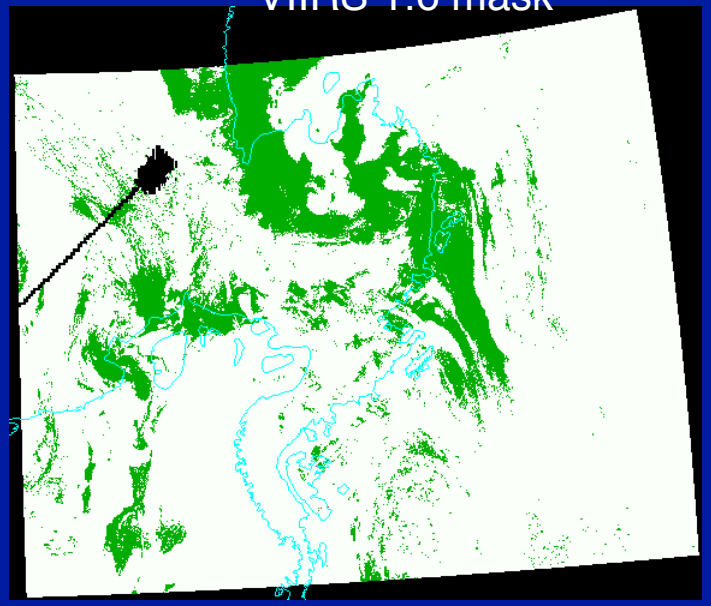
CM Ed4 Aqua 2.1 mask



VIIRS RGB

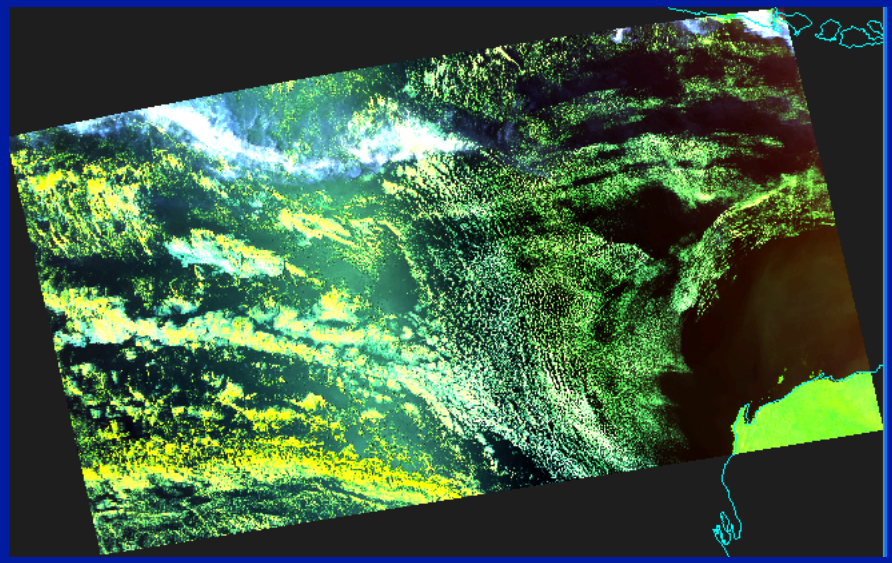


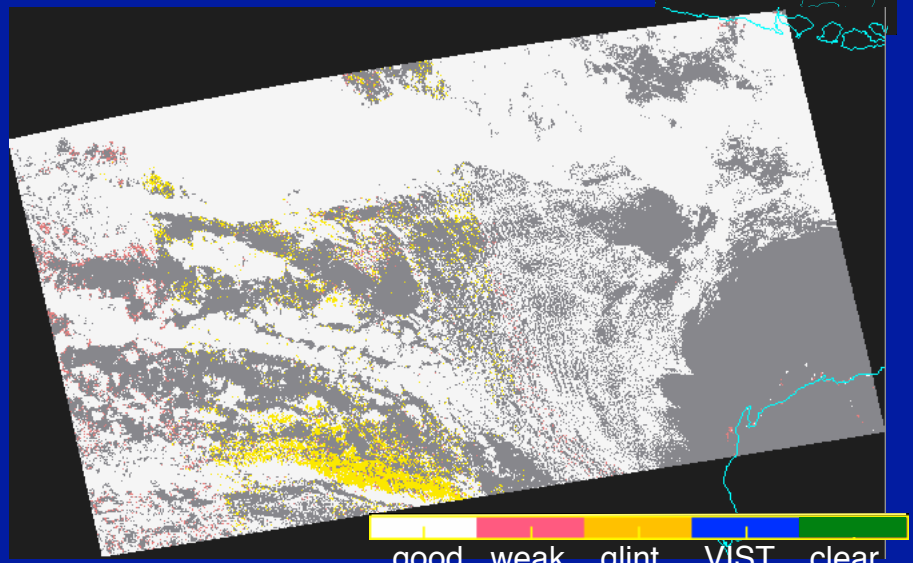
VIIRS 1.6 mask

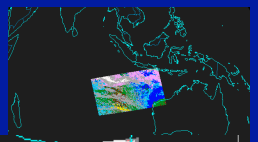


VIIRS Cloud mask

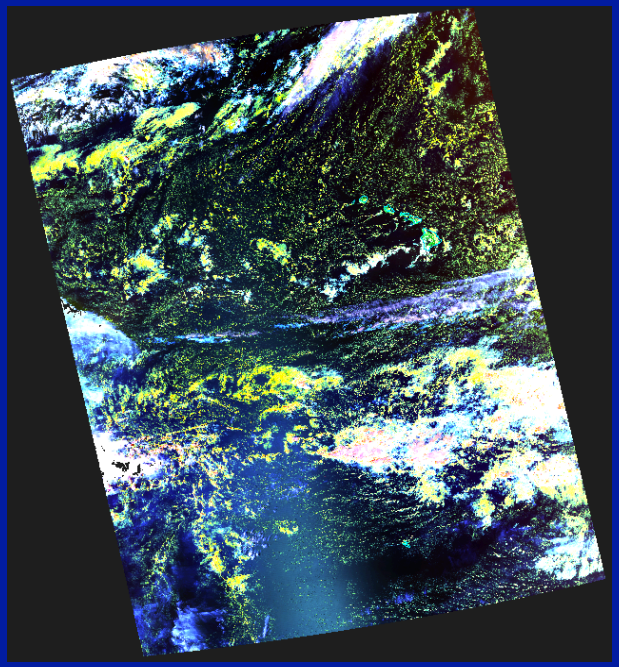
Indian Ocean Nov 10, UTC 0640, 2012

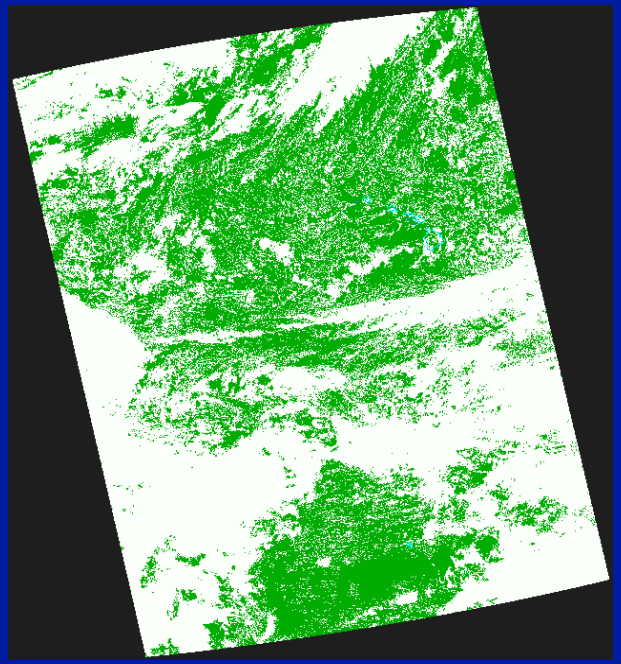


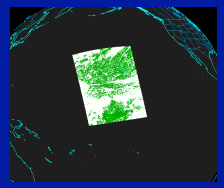




Pacific Ocean Nov 10, UTC 0000 - 0010, 2012







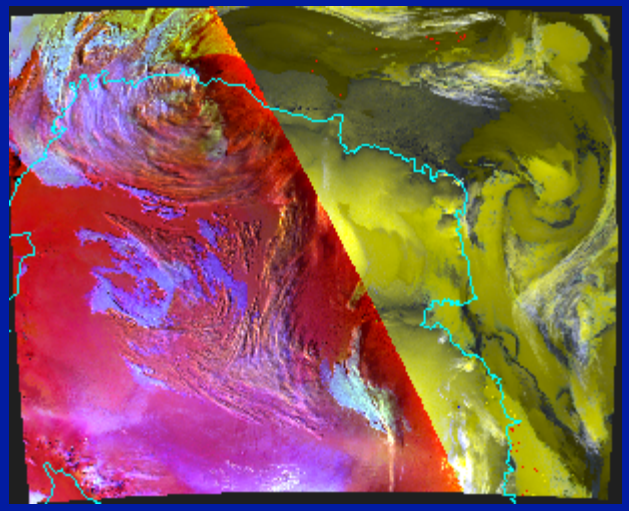
Improving VIIRS Twilight and nighttime Polar Cloud Mask

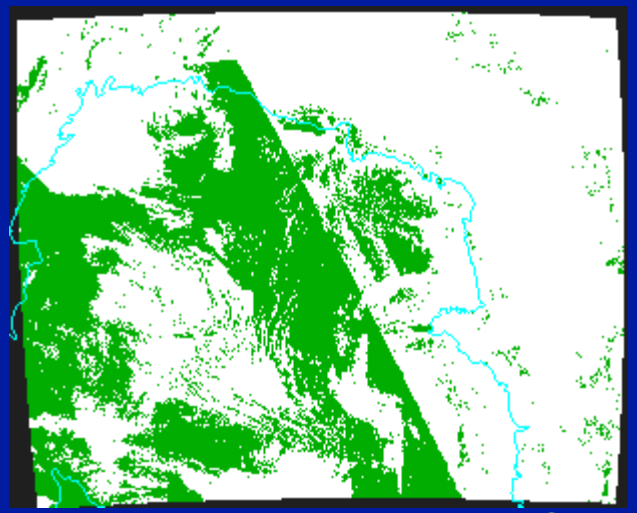
VIIRS RGB

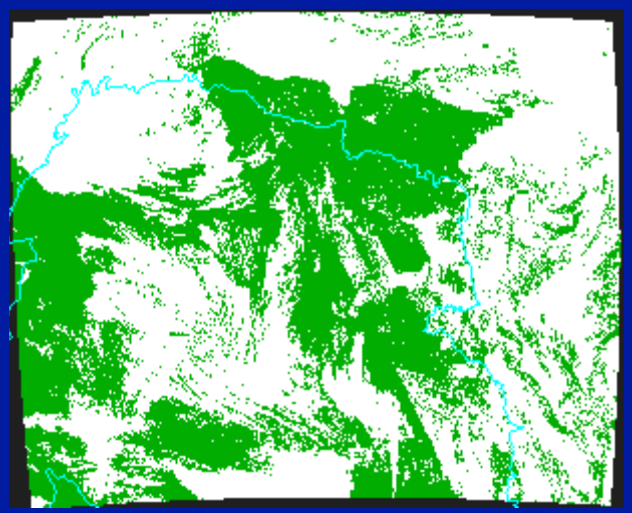
Antarctica November 10, 2012, UTC 1945-1950

Mask before

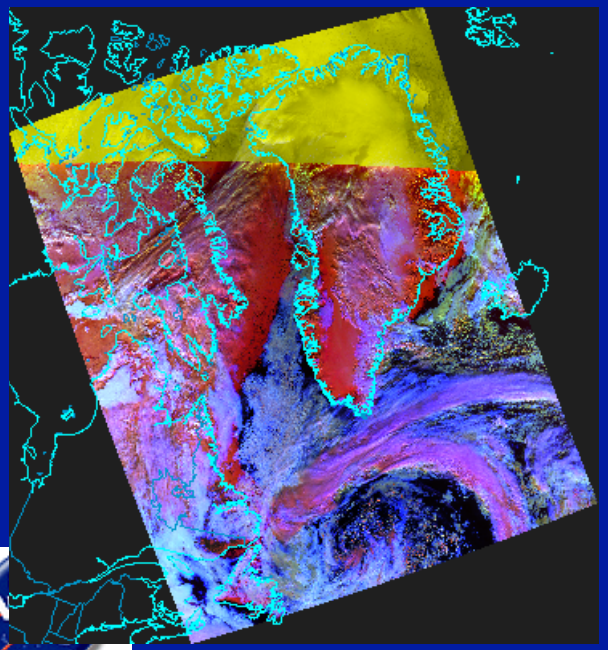
Mask after

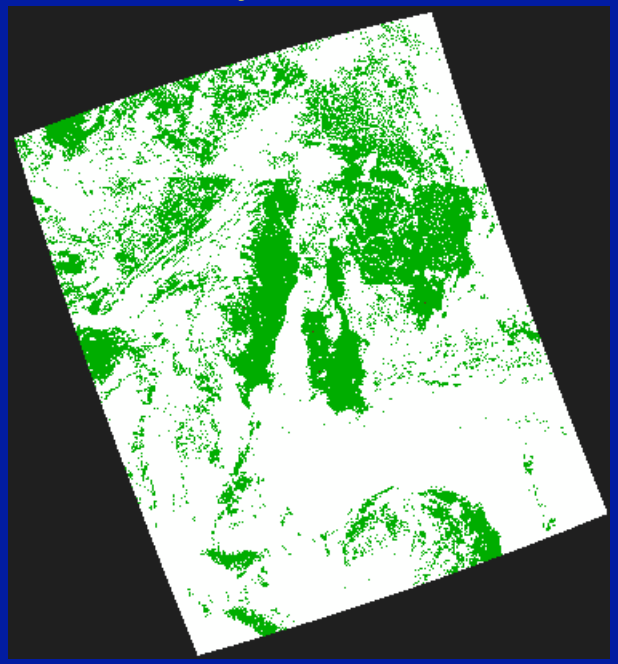


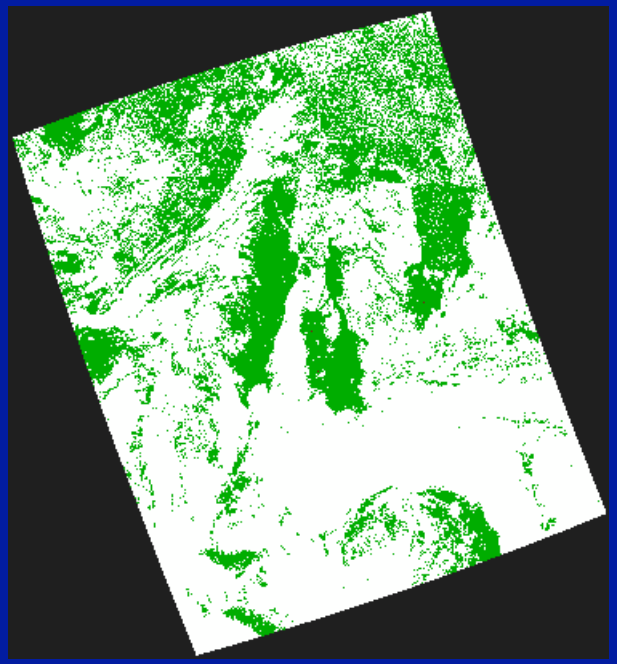




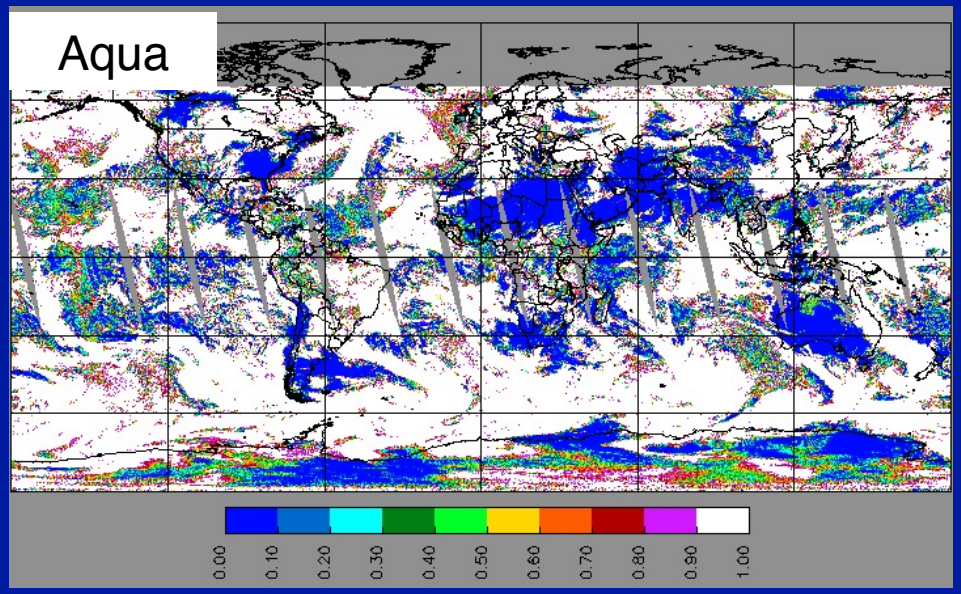
Greenland February 14, 2013, UTC 1530-1535

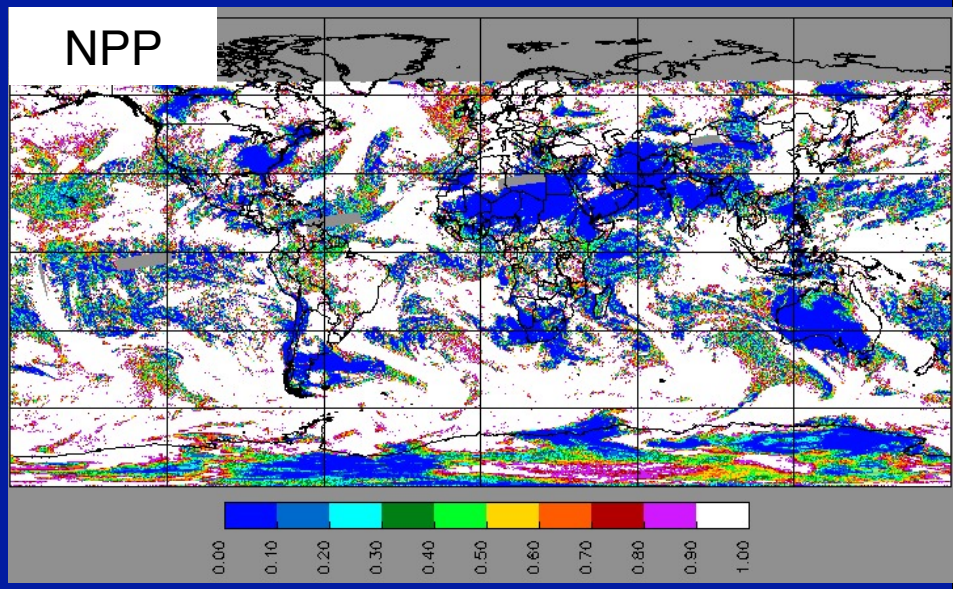


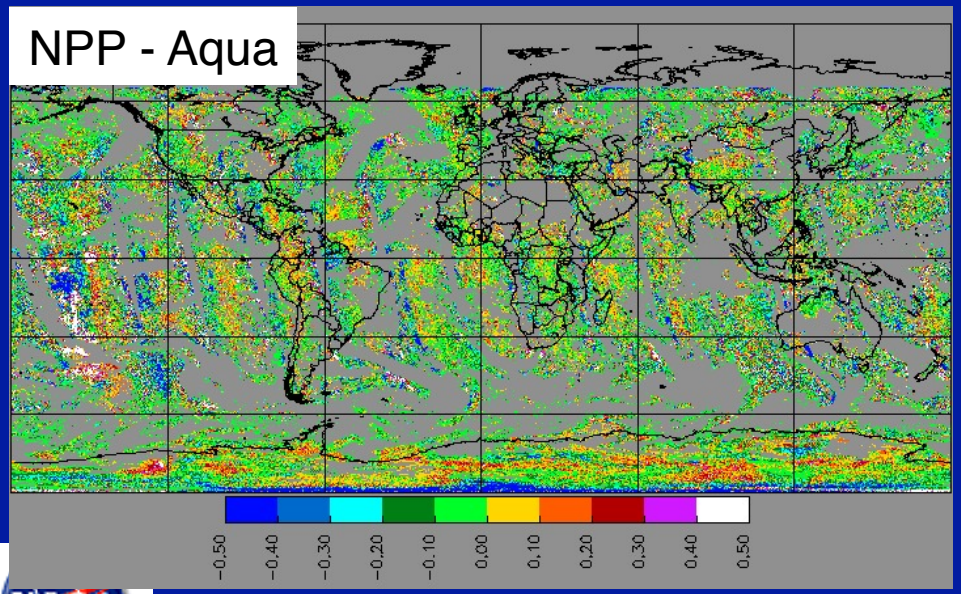




Total Daytime Cloud Fraction, November 10, 2012



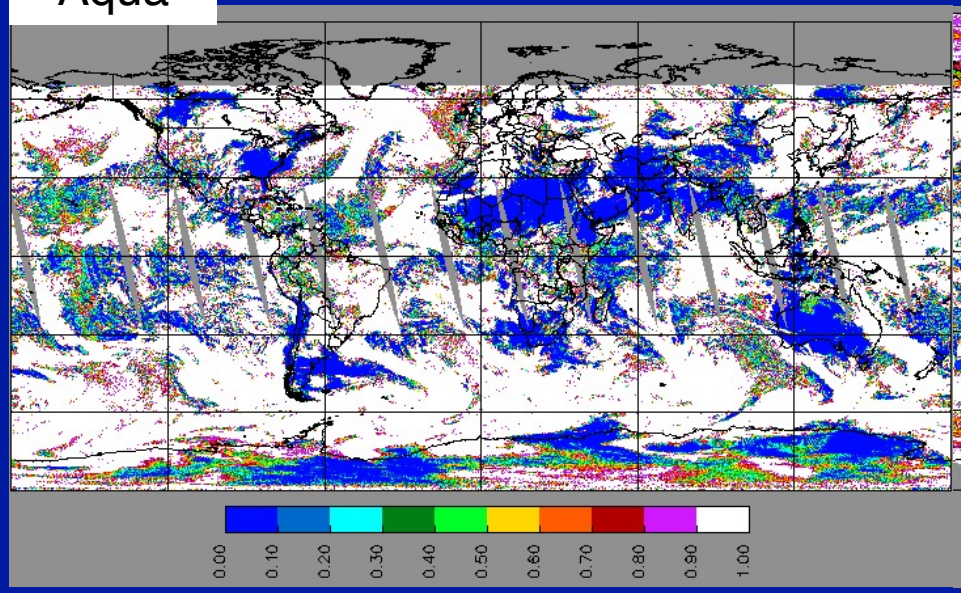




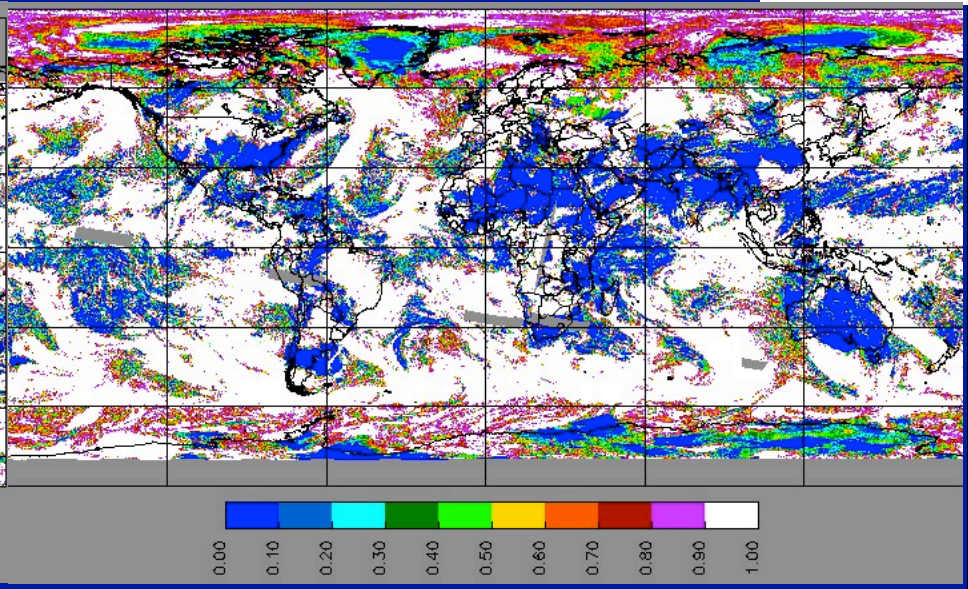
- Cloud amounts much closer than previous mask, especially in Ant.
  - V-A = -0.016
- Larger differences mostly due to movement of storms

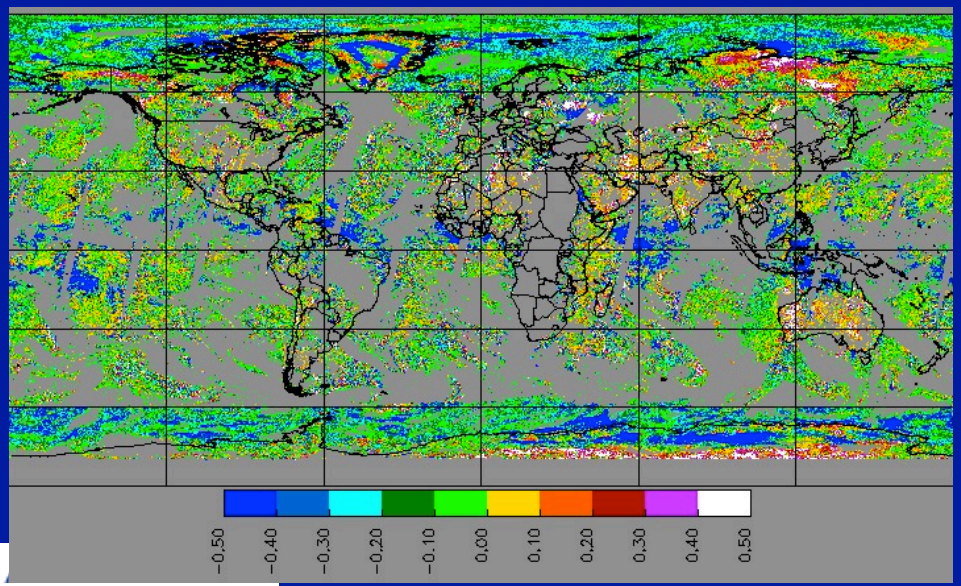
Total Night Cloud Fraction, November 10, 2012

Aqua



NPP



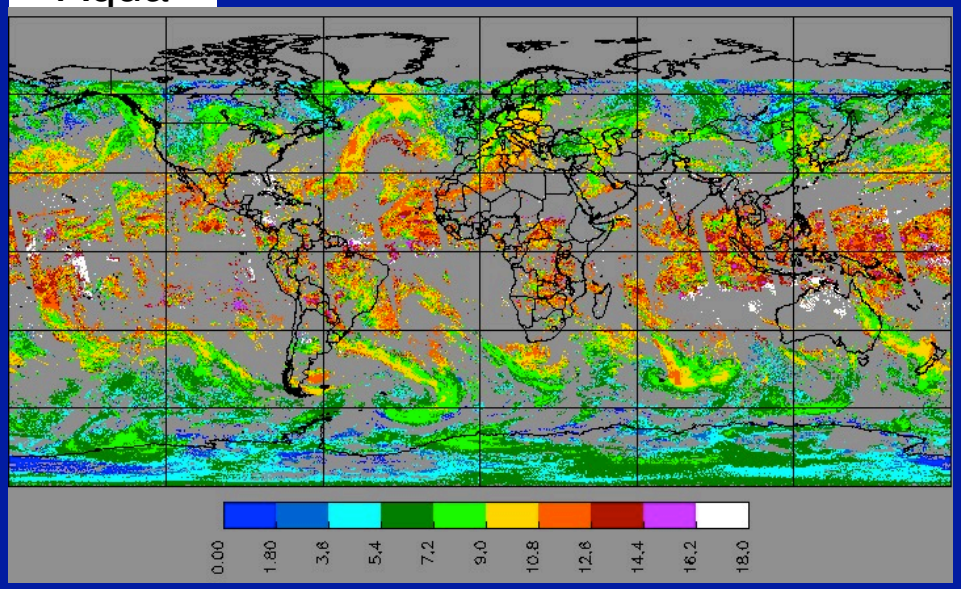


NPP - Aqua

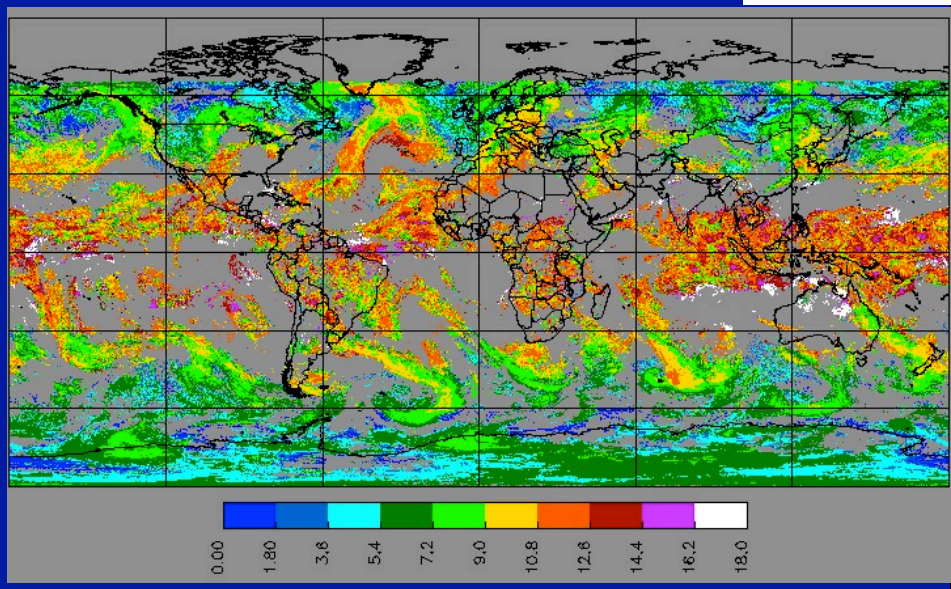
- Cloud amounts much closer than previous mask, except over polar areas
  - V – A = -0.050
- Some thin cirrus or small Cu missed by VIIRS in tropics

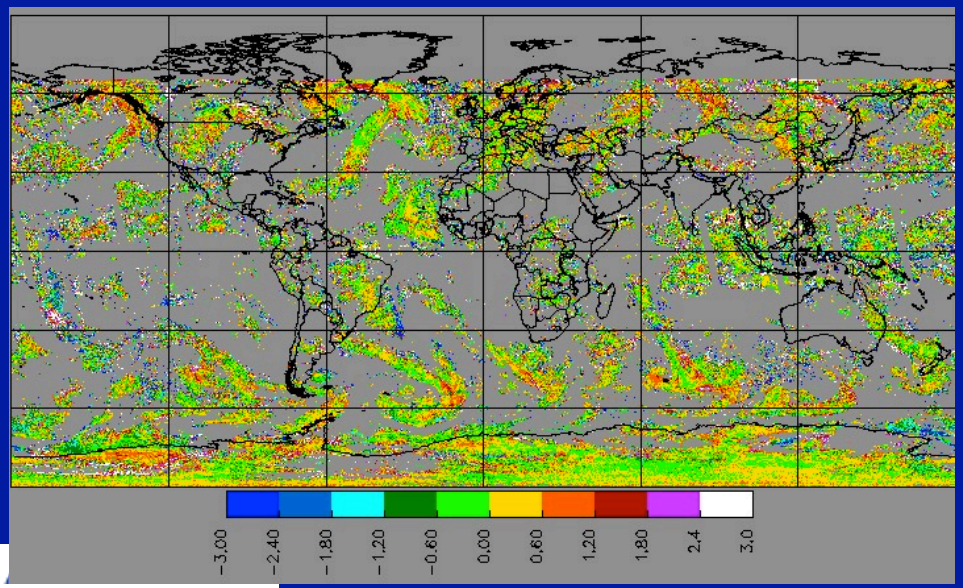
Total Day Water VISST Cloud Top Height, November 10, 2012

Aqua



NPP





NPP - Aqua

- Most ice heights within 0.5 km for nonpolar:
  - VIIRS Water Zt 0.4 km < Aqua
  - VIIRS Ice Zt 0.1 km >

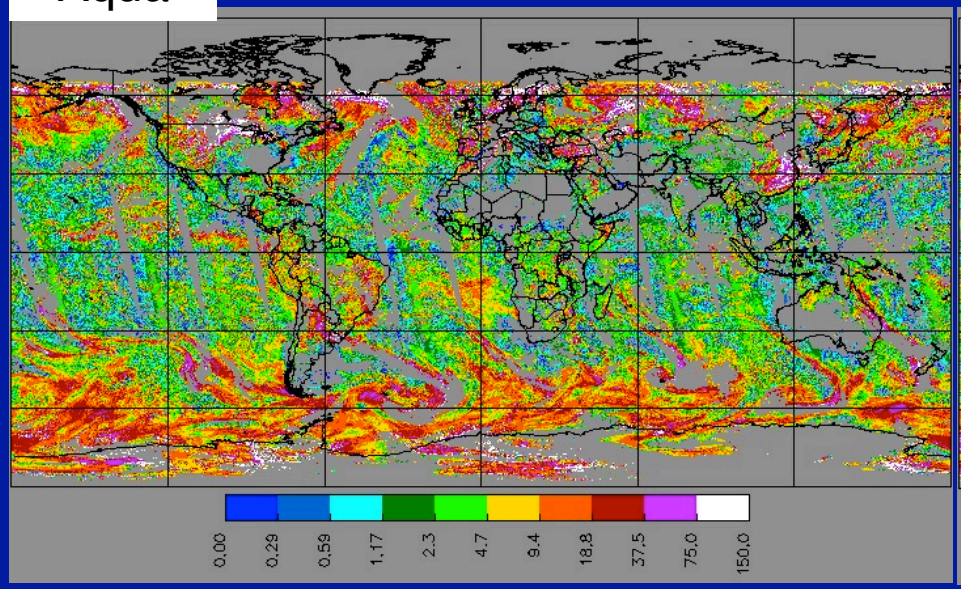
Aqua Night

  - VIIRS Water Zt 0.1 km < Aqua
  - VIIRS Ice Zt =

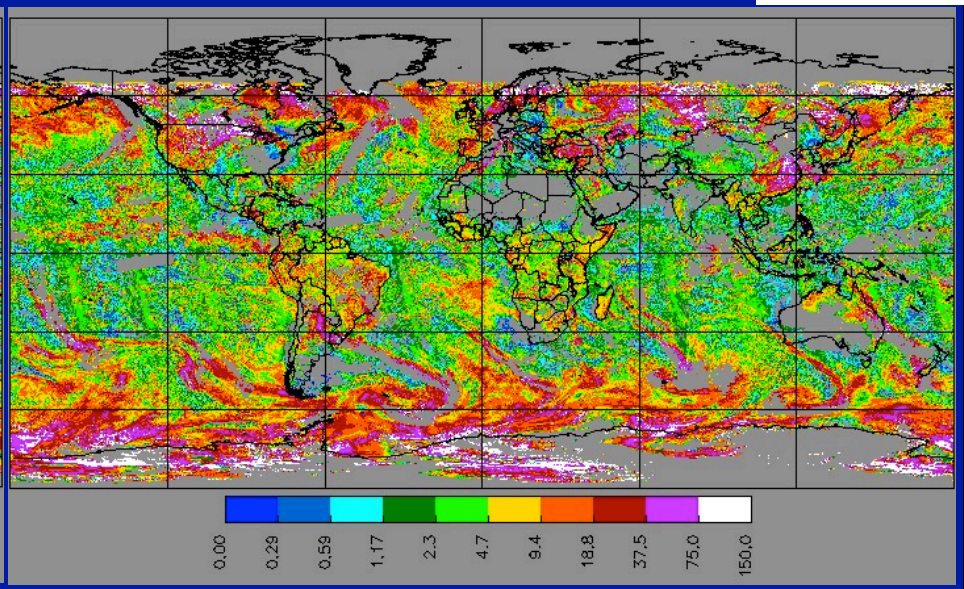
Aqua

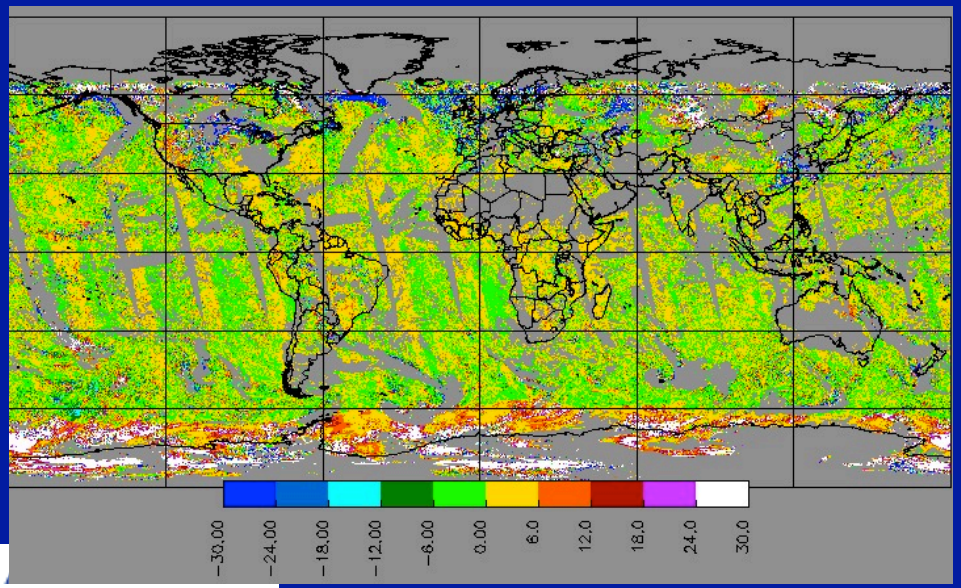
Total Day Optical Depth, November 10, 2012

Aqua



NPP



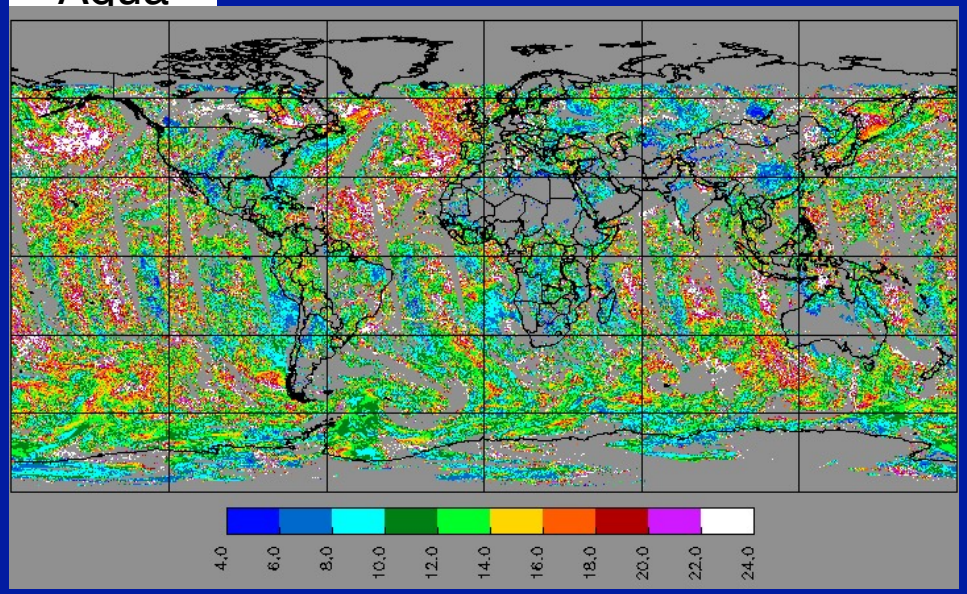


NPP - Aqua

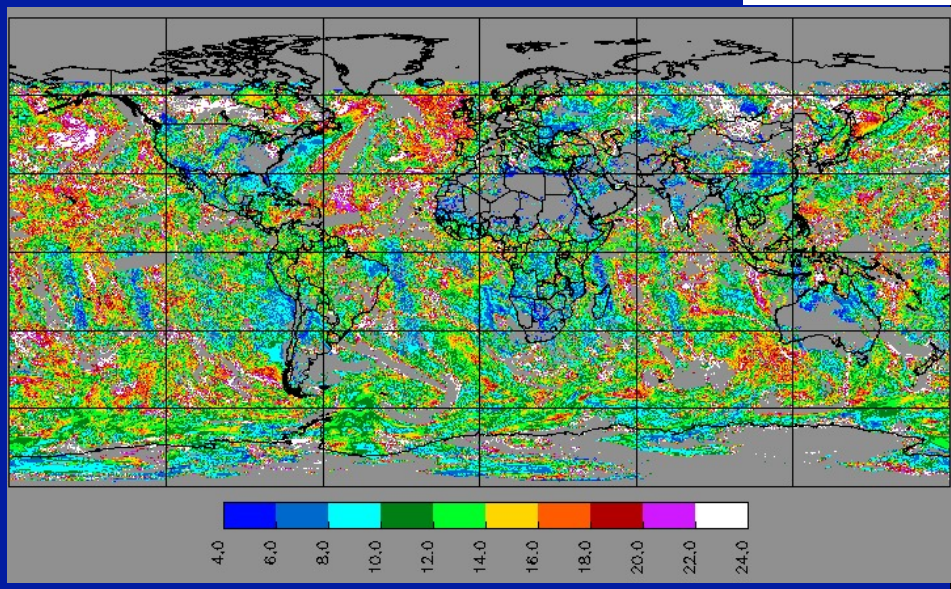
- Systematic differences in back & forward directions, for nonpolar:
  - VIIRS Water COD 0.2 < Aqua
  - VIIRS Ice COD 0.5 < Aqua
- Some differences due to phase differences
- Large biases over snow
  - 1.24 μm model questions

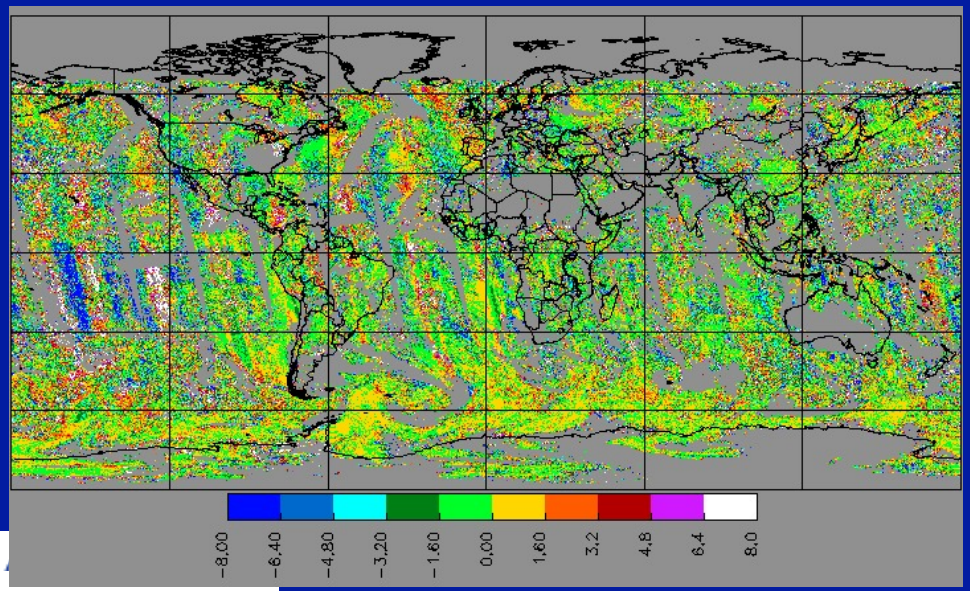
Total Day Water Re, November 10, 2012

Aqua



NPP





NPP - Aqua

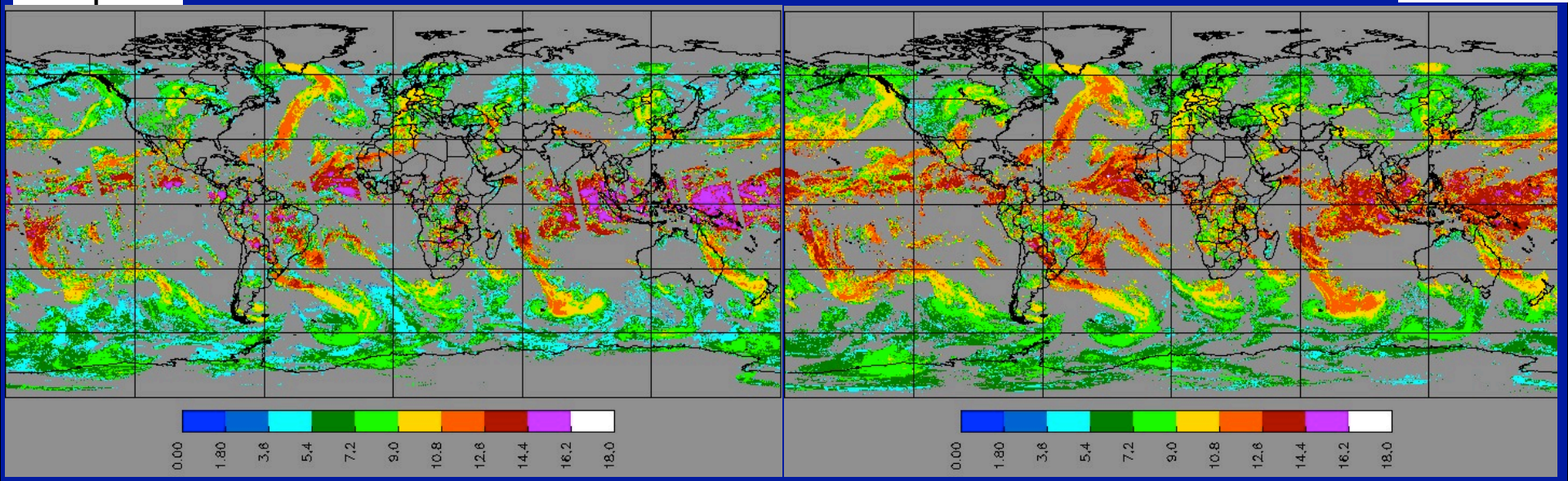
- Systematic differences in back & forward directions, for nonpolar:
  - VIIRS Water Re 0.4 μm < Aqua
  - VIIRS Ice Re 1.9 μm > Aqua

- 1.2 μm bias over snow

CO2 vs IR BTD Cloud Height, November 10, 2012

Aqua

NPP



- VIIRS heights lower in thin tropical areas
- VIIRS heights greater in midlatitudes
- VIIRS, on average, 0.9 km higher than CO2
- Results appear suitable for multilayer analysis
  - see Chang presentation

NPP VIIRS Ed-1 Validation

- Spatially/temporally matched cloud properties for 10 November 2012

- Selected VIIRS cloud properties only – mask, cloud top height, optical depth
  - Limited memory & storage
  - No cloud base, WP
  - All VZAs included, matched to within 15 minutes to CALIPSO

- CALIPSO data
  - 5-km cloud heights and optical depths
  - 333-m cloud detections added for cloud mask comparison

H - Hit rate, fraction CALIPSO clouds detected

FC – fraction correct

FAR – false alarm rate

B – bias ratio

CSI – critical success index

HSS – Heidke skill score

VIIRS cloud mask - global

ocean

SZA < 82.0 (day)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
VIIRS	CLEAR	10075	(22.8%)	1895	(4.3%)	11970	(27.0%)
	CLOUD	2053	(4.6%)	30245	(68.3%)	32298	(73.0%)
	TOTALS	12128	(27.4%)	32140	(72.6%)	44268	(100.0%)

FC = 0.911 H = 0.941 FAR = 0.064
CSI = 0.885 B = 1.00 HSS = 0.77

SZA > 82.0 (night)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
VIIRS	CLEAR	10720	(18.3%)	7587	(12.9%)	18307	(31.2%)
	CLOUD	1286	(2.2%)	39050	(66.6%)	40336	(68.8%)
	TOTALS	12006	(20.5%)	46637	(79.5%)	58643	(100.0%)

FC = 0.849 H = 0.837 FAR = 0.032
CSI = 0.815 B = 0.86 HSS = 0.61

82.0 < SZA < 88.5 (twilight)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
VIIRS	CLEAR	250	(17.4%)	264	(18.4%)	514	(35.9%)
	CLOUD	10	(0.7%)	909	(63.4%)	919	(64.1%)
	TOTALS	260	(18.1%)	1173	(81.9%)	1433	(100.0%)

FC = 0.809 H = 0.775 FAR = 0.011
CSI = 0.768 B = 0.78 HSS = 0.53

SZA > 88.5 (pitch black night)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
VIIRS	CLEAR	10470	(18.3%)	7323	(12.8%)	17793	(31.1%)
	CLOUD	1276	(2.2%)	38141	(66.7%)	39417	(68.9%)
	TOTALS	11746	(20.5%)	45464	(79.5%)	57210	(100.0%)

FC = 0.850 H = 0.839 FAR = 0.032
CSI = 0.816 B = 0.87 HSS = 0.61

land

SZA < 82.0 (day)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
VIIRS	CLEAR	10464	(37.5%)	3065	(11.0%)	13529	(48.5%)
	CLOUD	750	(2.7%)	13610	(48.8%)	14360	(51.5%)
	TOTALS	11214	(40.2%)	16675	(59.8%)	27889	(100.0%)

FC = 0.863 H = 0.816 FAR = 0.052
CSI = 0.781 B = 0.86 HSS = 0.72

SZA > 82.0 (night)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
VIIRS	CLEAR	8348	(29.1%)	5550	(19.4%)	13898	(48.5%)
	CLOUD	1122	(3.9%)	13660	(47.6%)	14782	(51.5%)
	TOTALS	9470	(33.0%)	19210	(67.0%)	28680	(100.0%)

FC = 0.767 H = 0.711 FAR = 0.076
CSI = 0.672 B = 0.77 HSS = 0.53

polar

82.0 < SZA < 88.5 (twilight)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
VIIRS	CLEAR	1470	(31.2%)	820	(17.4%)	2290	(48.6%)
	CLOUD	215	(4.6%)	2210	(46.9%)	2425	(51.4%)
	TOTALS	1685	(35.7%)	3030	(64.3%)	4715	(100.0%)

FC = 0.780 H = 0.729 FAR = 0.089
CSI = 0.681 B = 0.80 HSS = 0.56

SZA > 88.5 (pitch black night)

		CALIPSO CLEAR		CALIPSO CLOUD		TOTALS	
VIIRS	CLEAR	6878	(28.7%)	4730	(19.7%)	11608	(48.4%)
	CLOUD	907	(3.8%)	11450	(47.8%)	12357	(51.6%)
	TOTALS	7785	(32.5%)	16180	(67.5%)	23965	(100.0%)

FC = 0.765 H = 0.708 FAR = 0.073
CSI = 0.670 B = 0.76 HSS = 0.52

VIIRS Cloud Mask Comparisons
72K pixels, 3 day, Nov 2013

- Day: FC = 0.91 over ocean, 0.86 over land
- Night: FC = 0.85 over ocean, 0.77 over land
  - misses a few
- Twilight: FC = 0.81 over ocean, 0.78 over land
- Tropics FC = 0.88 over ocean, 0.86 over land, day
  0.87 over ocean, 0.80 over land, night
- Midlat FC = 0.92 over ocean, 0.89 over land, day
  0.91 over ocean, 0.82 over land, night
- Polar FC = 0.96 over ocean, 0.85 over land, day
  0.75 over ocean, 0.78 over land, night

VIIRS mask nearly as accurate as MODIS

VIIRS Cloud Phase – global

ocean

SZA < 82.0 (day)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
VIIRS	WATER	7344 (64.0%)	89 (0.8%)	7433 (64.8%)
	ICE	70 (0.6%)	3975 (34.6%)	4045 (35.2%)
	TOTALS	7414 (64.6%)	4064 (35.4%)	11478 (100.0%)

FC = 0.986 B = 0.995 HSS = 0.970
Hw = 0.991 FARw = 0.012 Hi = 0.978 FARi = 0.017

SZA > 82.0 (night)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
VIIRS	WATER	7802 (63.8%)	218 (1.8%)	8020 (65.6%)
	ICE	259 (2.1%)	3954 (32.3%)	4213 (34.4%)
	TOTALS	8061 (65.9%)	4172 (34.1%)	12233 (100.0%)

FC = 0.961 B = 1.010 HSS = 0.913
Hw = 0.968 FARw = 0.027 Hi = 0.948 FARi = 0.061

82.0 < SZA < 88.5 (twilight)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
VIIRS	WATER	12 (13.0%)	1 (1.1%)	13 (14.1%)
	ICE	11 (12.0%)	68 (73.9%)	79 (85.9%)
	TOTALS	23 (25.0%)	69 (75.0%)	92 (100.0%)

FC = 0.870 B = 1.145 HSS = 0.593
Hw = 0.522 FARw = 0.077 Hi = 0.986 FARi = 0.139

SZA > 88.5 (pitch black night)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
VIIRS	WATER	7790 (64.2%)	217 (1.8%)	8007 (66.0%)
	ICE	248 (2.0%)	3886 (32.0%)	4134 (34.0%)
	TOTALS	8038 (66.2%)	4103 (33.8%)	12141 (100.0%)

FC = 0.962 B = 1.008 HSS = 0.915
Hw = 0.969 FARw = 0.027 Hi = 0.947 FARi = 0.060

land

SZA < 82.0 (day)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
VIIRS	WATER	1239 (39.3%)	95 (3.0%)	1334 (42.3%)
	ICE	58 (1.8%)	1763 (55.9%)	1821 (57.7%)
	TOTALS	1297 (41.1%)	1858 (58.9%)	3155 (100.0%)

FC = 0.952 B = 0.980 HSS = 0.900
Hw = 0.955 FARw = 0.071 Hi = 0.949 FARi = 0.032

SZA > 82.0 (night)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
VIIRS	WATER	525 (18.6%)	63 (2.2%)	588 (20.8%)
	ICE	122 (4.3%)	2115 (74.9%)	2237 (79.2%)
	TOTALS	647 (22.9%)	2178 (77.1%)	2825 (100.0%)

FC = 0.935 B = 1.027 HSS = 0.808
Hw = 0.811 FARw = 0.107 Hi = 0.971 FARi = 0.055

82.0 < SZA < 88.5 (twilight)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
VIIRS	WATER	37 (8.3%)	1 (0.2%)	38 (8.5%)
	ICE	71 (15.9%)	337 (75.6%)	408 (91.5%)
	TOTALS	108 (24.2%)	338 (75.8%)	446 (100.0%)

FC = 0.839 B = 1.207 HSS = 0.436
Hw = 0.343 FARw = 0.026 Hi = 0.997 FARi = 0.174

SZA > 88.5 (pitch black night)

		CALIPSO WATER	CALIPSO ICE	CALIPSO TOTALS
VIIRS	WATER	488 (20.5%)	62 (2.6%)	550 (23.1%)
	ICE	51 (2.1%)	1778 (74.7%)	1829 (76.9%)
	TOTALS	539 (22.7%)	1840 (77.3%)	2379 (100.0%)

FC = 0.953 B = 0.994 HSS = 0.865
Hw = 0.905 FARw = 0.113 Hi = 0.966 FARi = 0.022

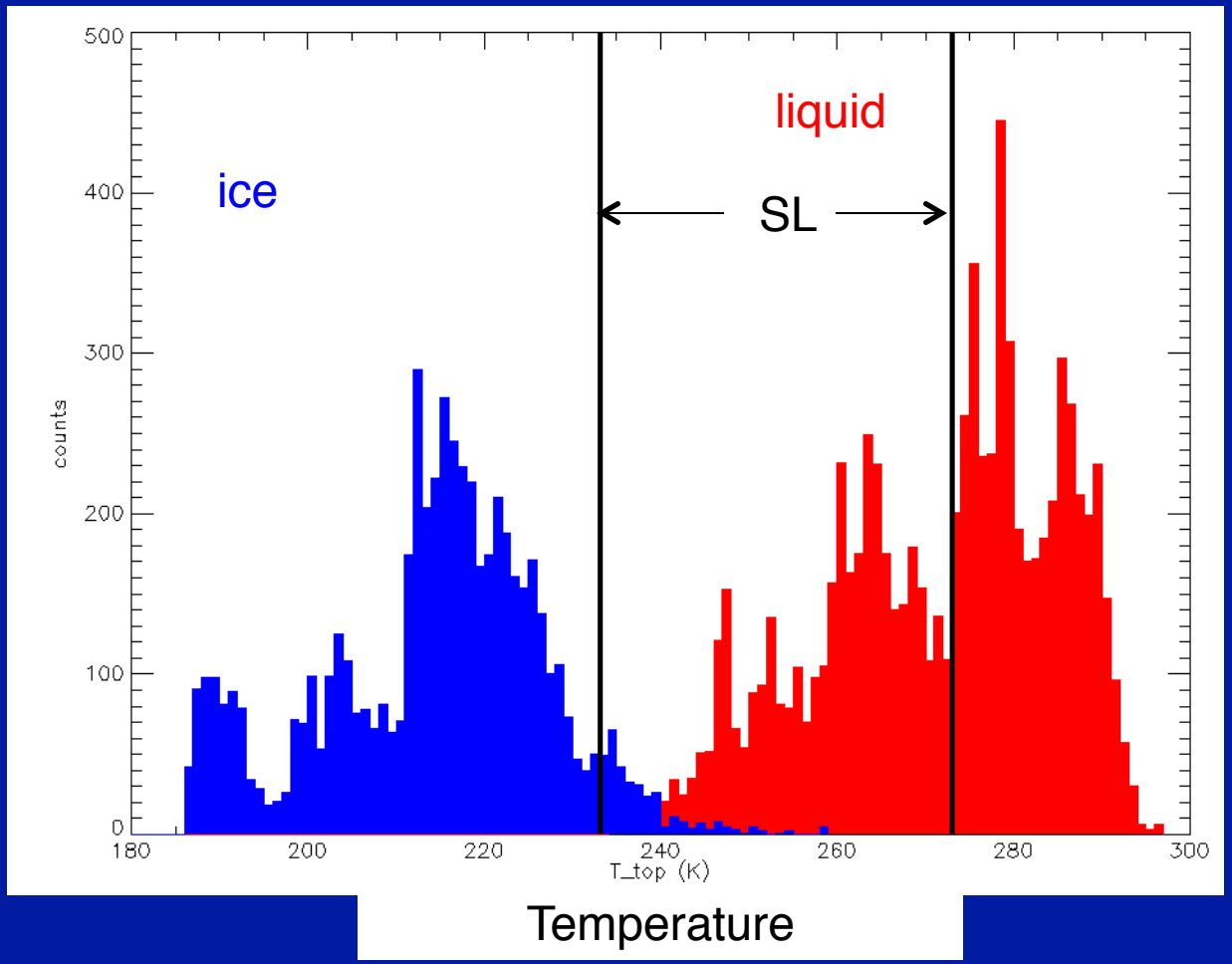
VIIRS Cloud Phase Comparisons

- Compares VIIRS phase with CALIPSO 100% ice or water
  - *Only 30% of cloudy pixels*

- Day: FC = 0.99 over ocean, 0.95 over land
- Night: FC = 0.96 over ocean, 0.95 over land
- Twilight: FC = 0.87 over ocean, 0.84 over land

- Tropics FC = 0.98 over ocean, 0.92 over land, day
  0.95 over ocean, 0.93 over land, night
- Midlat FC = 0.99 over ocean, 0.95 over land, day
  0.97 over ocean, 0.97 over land, night
- Polar FC = 0.99 over ocean, 0.97 over land, day
  0.97 over ocean, 0.84 over land, night

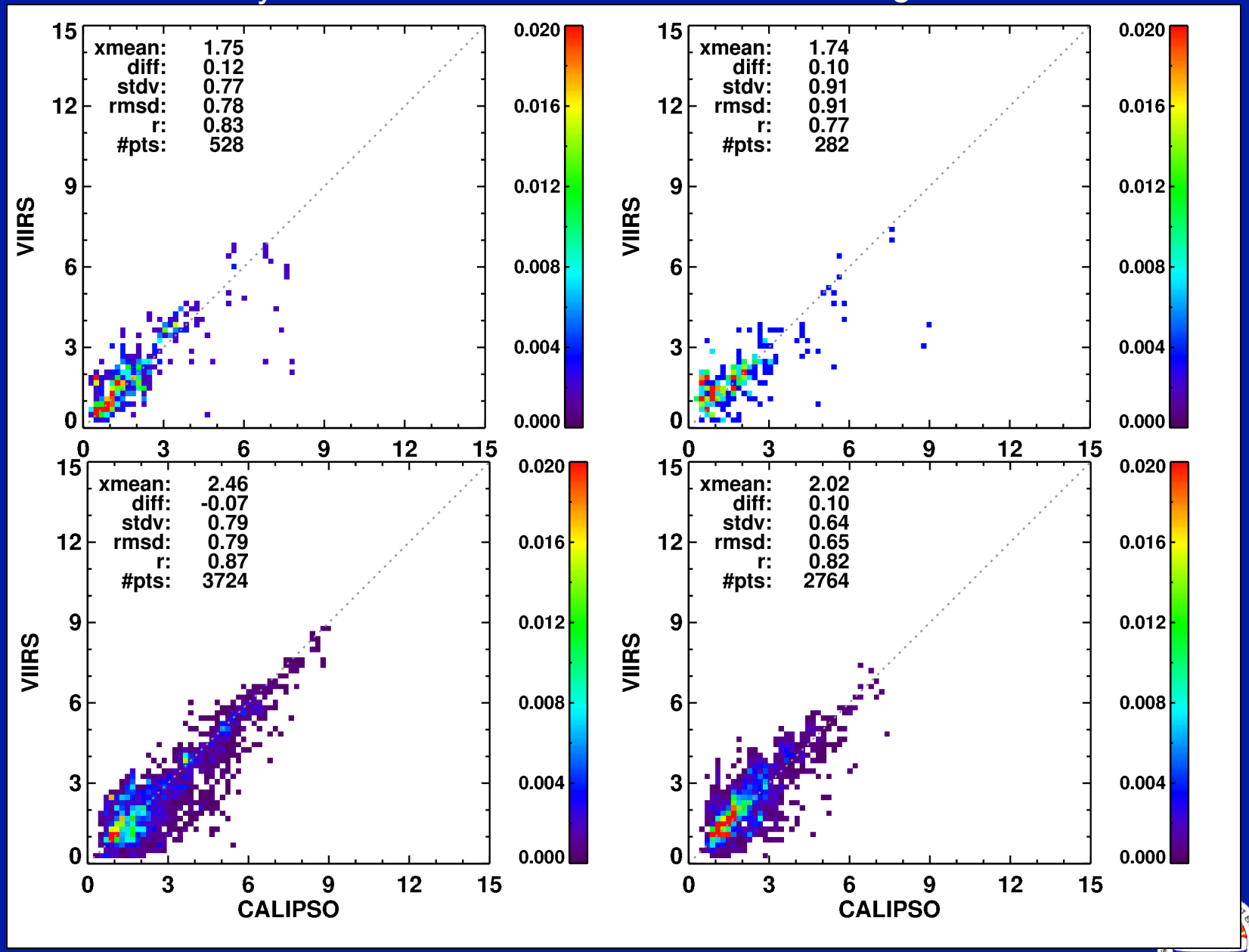
Temperature Distribution of Phase from CALIPSO
November 10, 2012



Temperature

- For pure phase clouds, SL range dominated by liquid tops
- Results can be used to improve nighttime phase

cloud top height – liquid



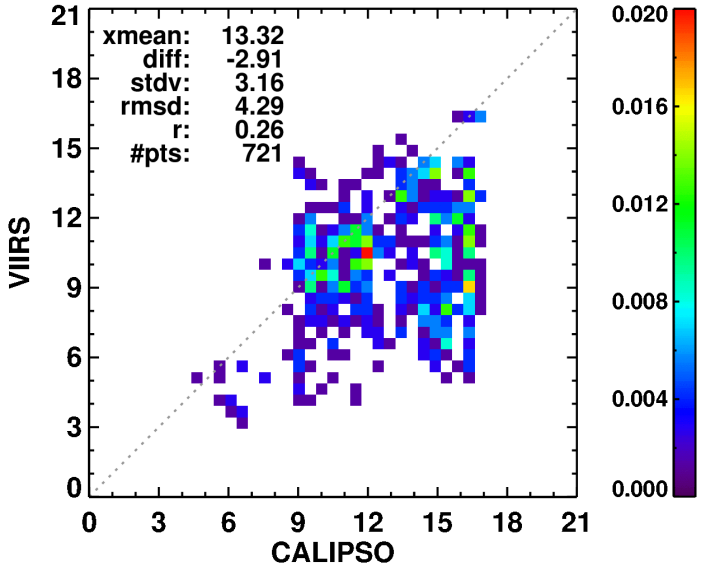
cloud top height – ice, Zt correction applied

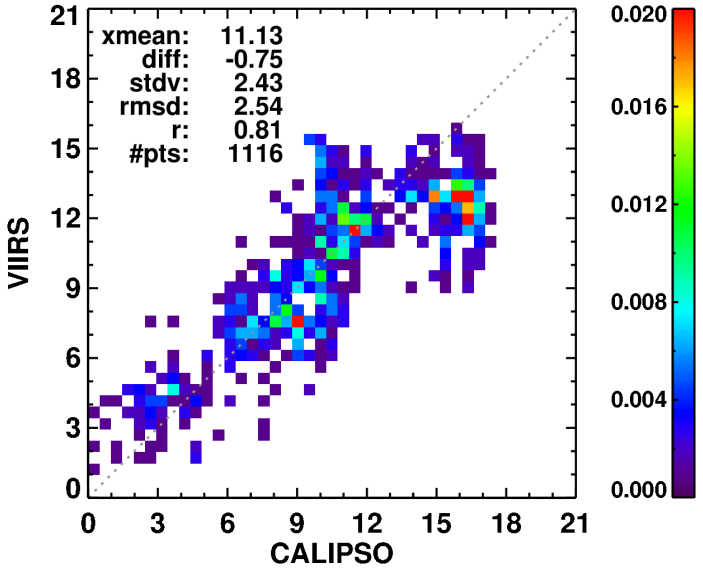
day

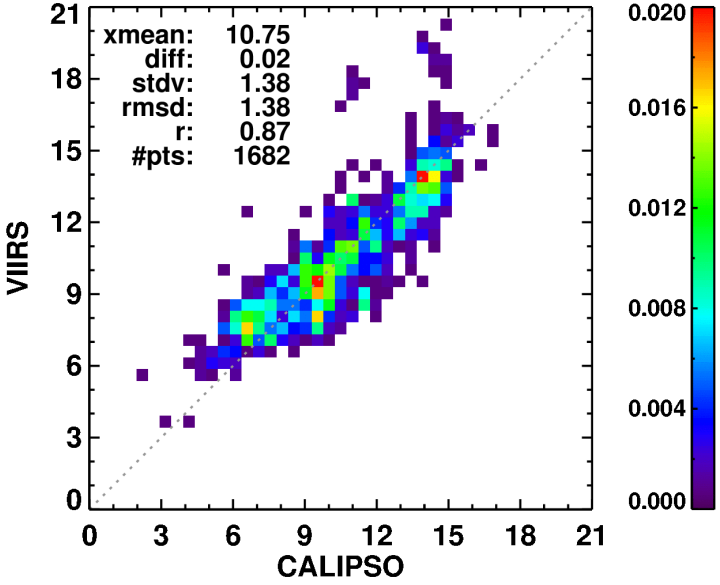
night

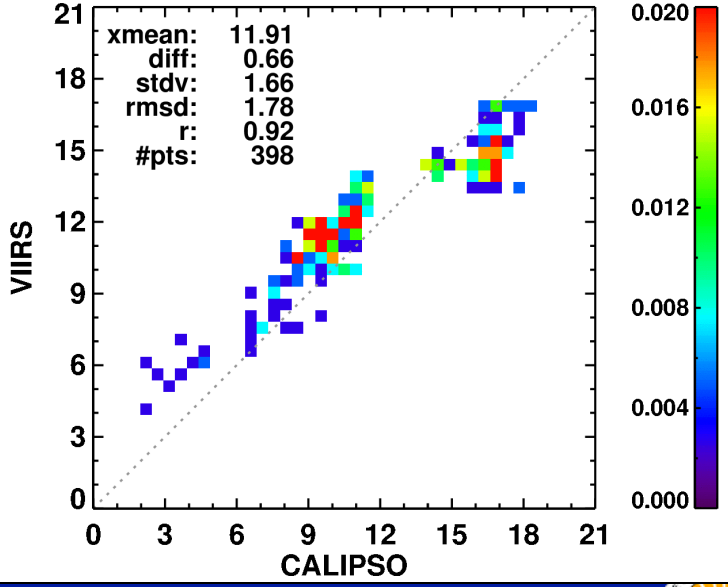
thin

thick



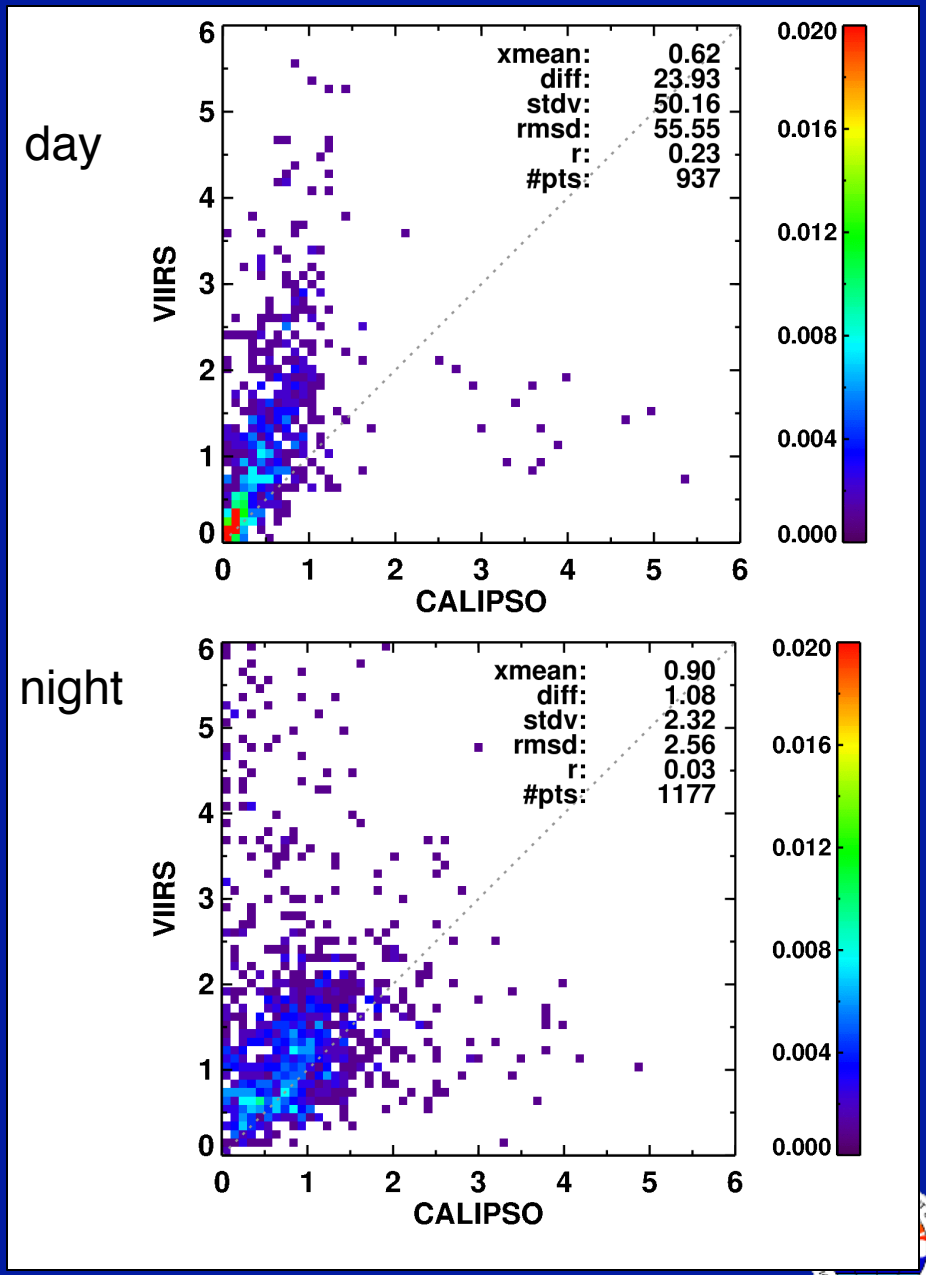






cloud optical depth – ice, thin clouds only

- Daytime cirrus tau ~ 75% > CALIPSO
  - Need scattering phase function for ice with $g \sim 0.75$
    - *next gen from P Yang*
- Nighttime cirrus tau not as close to CALIPSO as Aqua
  - Need revised 11 & 12 μm infrared emittance models?



Cloud Height Validation, Pure vs Total

Type	mean dif	RMSd
Ice		
Thin, day	-2.91	4.29
Thin, night	-0.75	2.54
Thick, day	-0.02	1.38
Thick, night	0.66	1.78
Water		
Thin, day	0.12	0.78
Thin, night	0.10	0.91
Thick, day	-0.07	0.79
Thick, night	0.10	0.65

VIIRS vs Aqua Ed-4 via CALIPSO

Initial results show

- Aqua cloud fraction > VIIRS by 2% from monthly averages
  - 3-day CALIPSO comparisons show VIIRS cloud fraction nealry as good as Aqua in all categories
  - *need days for other months for firm conclusions*

- Aqua and VIIRS cloud phase very similar

- Aqua and VIIRS cloud height comparisons with CALIPSO very similar, except VIIRS a little worse at night for thin ice clouds

- Aqua and VIIRS thin ice cloud optical depths similar, except VIIRS a little worse at night (emittance models?)

Need additional data!

Remaining Tasks for VIIRS Ed2 Delivery

- Last polar night mask tweaks
  - Qing on it this week

- Test final models: this week
  - will not worry about accuracy of 1.24 and 1.6 μm Re
    consider for NPP Ed2

- Run 4 test months

- Deliver by Thanksgiving