CERES Cloud Properties: Update 2015

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CERES Science Team Mtg., ***Hampton, VA, 5-7 May 2015***

Topics

- Publications
- Calibrations

- Dependencies of cloud parameters
- Validation Comparisons
- GEO clouds

Update of CERES Cloud-related Papers since Oct 2014

Edition-2 related

Yan, H., J. Huang, P. Minnis, Y. Yi, S. Sun-Mack, T. Wang, and T. Nakajima, 2014: Comparison of CERES-MODIS cloud microphysical properties with surface observations over the Loess Plateau. *J. Quant. Spectros Rad. Trans.*, **153**, 65-76, doi:10.1016/j.jqsrt.2014.9.009.

Stanfield, R. E., X. Dong, B. Xi, A. D. Del Genio, P. Minnis, and J. Jiang, 2014: Assessment of NASA GISS CMIP5 and post-CMIP5 simulated clouds and TOA radiation budgets using satellite observations. Part II: TOA radiation budget and CREs. *J. Climate*, **28**, 1842-1864, doi:10.1175/JCLI-D-14-00249.1.

Wang, S., A. H. Sobel, A. Fridlind, Z. Feng, J. Comstock, P. Minnis, and M. L. Nordeen, 2015: Simulations of cloud-radiation interaction using large-scale forcing derived from the CINDY/DYNAMO northern sounding array. *J. Adv. Model. Earth Syst.*, submitted.

Edition-4+ related

Xi, B., X. Dong, P. Minnis, and S. Sun-Mack, 2014: Validation of CERES-MODIS Edition 4 marine boundary layer cloud properties using DOE ARM AMF measurements at the Azores. *J. Geophys. Res.*, **119**, doi: 10.1002/2014JD021813.

Painemal, D., S. Kato, and P. Minnis, 2014: Biomass burning and the dual microphysical behavior of boundary layer clouds in the southeast Atlantic. *J. Geophys. Res.*, **119**, 11288-11302, doi:10.1002/2014JD022182.

Liu, C., P. Yang, P. Minnis, N. Loeb, A. Heymsfield, C. Schmitt, 2014: A two-habit model for the microphysical and optical properties of ice clouds. *Atmos. Chem. Phys.*, **14**, 13719-13737, doi: 10.5194/acp-14-13719-2014.

Painemal, D., K.-M. Xu, A. Cheng, P. Minnis, and R. Palikonda, 2015: Mean structure and diurnal cycle of Southeast Atlantic boundary layer clouds: Insights from satellite observations and multi-scale modeling frameworks. *J. Climate*, **28**, 324-341, doi:10.1175/JCLI-D-14-00368.1.

Hong, G. and P. Minnis, 2015: Effects of inclusions on scattering properties of small ice cloud particles. *J. Geophys. Res.*, **120**, 2951-2969, doi:10.1002/2014JD022494.

Painemal, D., P. Minnis, and M. L. Nordeen, 2015: Aerosol variability, synoptic-scale processes and their link to the cloud microphysics over the northeast Pacific during MAGIC. *J. Geophys. Res.*, in press.

CERES Data Quality Summaries

- DQS for Ed4 nearly complete (34 pages so far)
- DQS for VIIRS Ed1 next
- DQS for GEOSat analyses?

MODIS Edition-4 beta 2 Cautions

- Error in model look-up tables discovered
  - *mismatch between 0.65 and 3.8-μm optical depths*
    - *affects particle size and phase selection primarily*
      - *impacts ADM selection => fluxes*
- Thick ice cloud-top height correction not applied
  - *affects cloud base and is inconsistent with VIIRS Ed1*
    - *can be applied externally post facto, simple equation*
- *CO2 thin ice cloud height correction to Zeff may OE radiative height*
  - *yields more accurate Ztop but underestimate OLR wrt CERES*
  - *Convinced SARB to use Zeff as before => better agreement w/ CERES*
  - *CO2 not used in GEOSat now, 2-channel SIST or VISST only used*
- Error in parameterization of 1.24 and 2.13 μm reflectances
  - *minor effect on Re retrievals and tau over ice/snow*
- *Errors in 1.24 and 2.13 μm reflectance models*
  - *significant effect on Re retrievals & tau over ice/snow*
  - *differences with VIIRS shown*
- *Bug in skin temp code, MODIS Ed4 & VIIRS Ed1*
  - *affects some desert temperatures, default to MOA*

CERES MODIS Status (Coll 5 Data)

- Ed2 processing
  - *Aqua: through December 2014, will continue until ED4 ADMs completed*
  - *Terra: through December 2014, will continue until Ed4 ADMs completed*

- Ed4 Beta-2 processing
  - *Aqua: through December 2010*
  - *Terra: through April 2011*

CERES VIIRS Status

- Ed1 delivered, processing begun
  - *Jan – July 2012; January, April, July 2013 run offline*

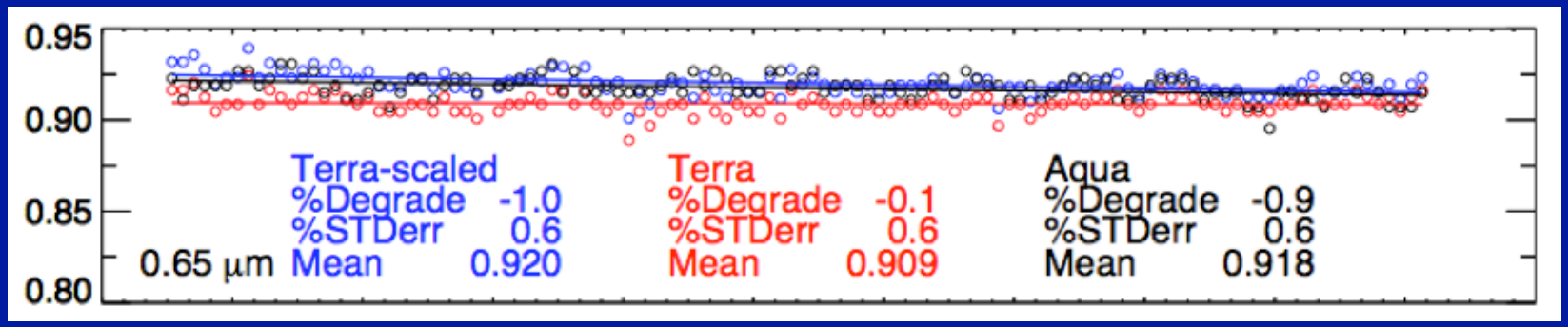
CERES GEOSat Status

- Ed4-beta: uses 3/4 channel cloud retrievals with appropriate satellites
  - *beta because cleaned data are not yet available*
  - *GOES: 68 months; MSG: 15 months; MTSAT: 22 months*

Calibrations

- C6 VIS channel on Terra steady after Xiong corrections

- C6 VIS channel on Aqua shows 1% degradation *(Doelling et al. TGRS, 2015)*
  - probably in C5, not corrected in Ed4

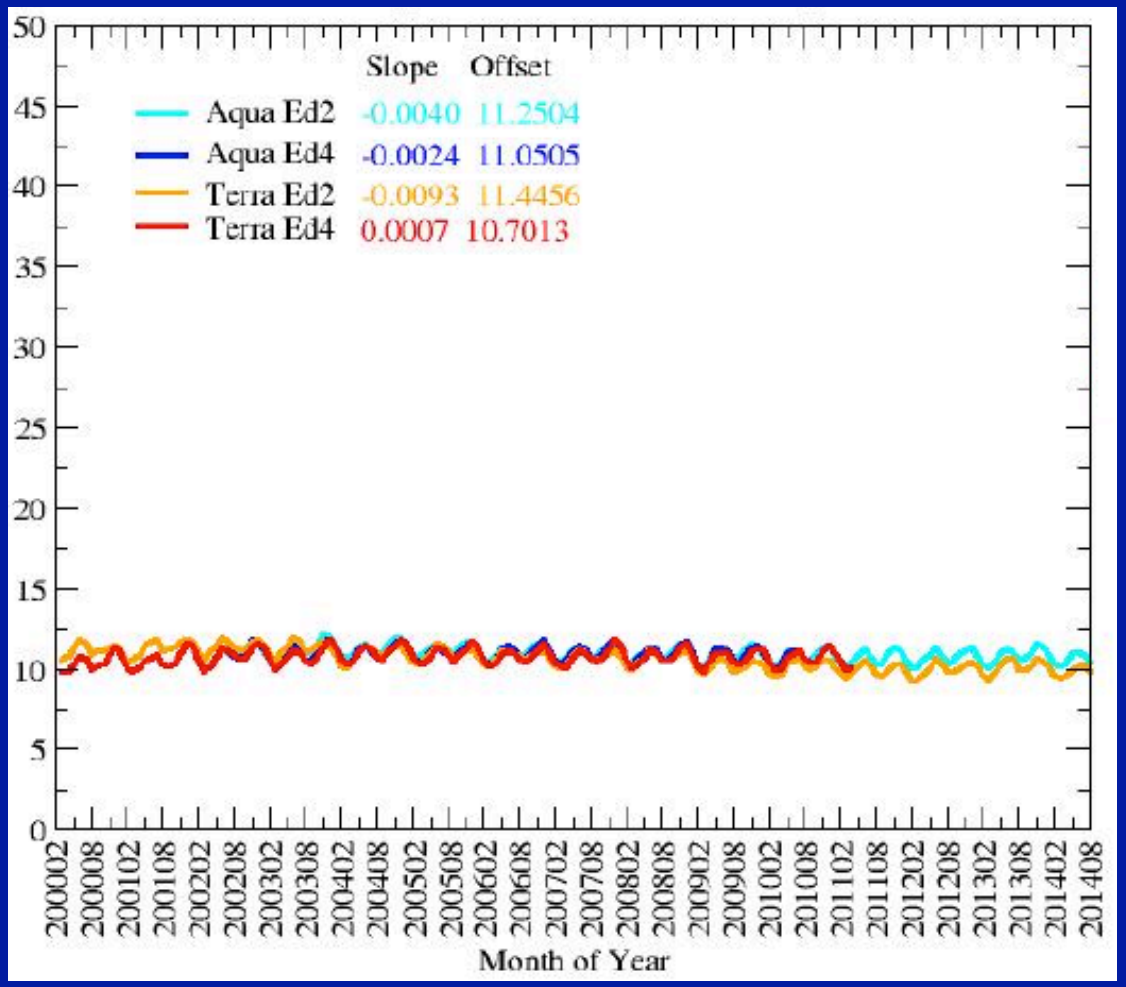


- This is likely to result in a trend for Aqua Ed4 clouds
  - next slide

- Collection-6 3.8-μm channel on Terra different from Collection-5
  - Ed4 uses homegrown normalization of Terra-to-Aqua C5

- Other C6 channels to be examined in detail

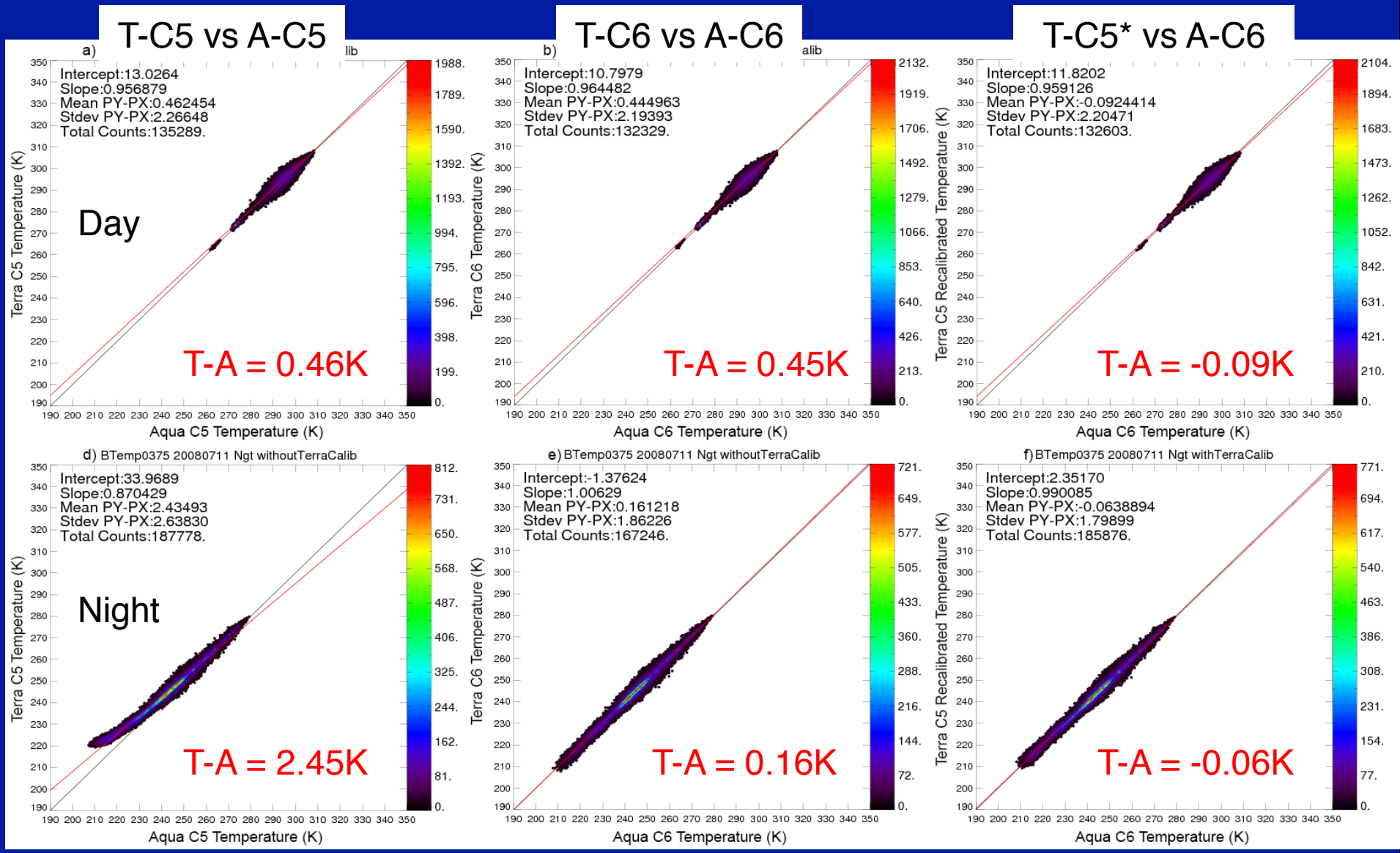
Trends in Cloud Optical Depth, Non-polar, Ed2 & Ed4



- Terra Ed2 trend due to calibration degradation quite evident over 15 years
  - 14.5% decrease
- Aqua Ed2 has 5% drop over 12 .5 years
- Terra Ed4 has ~1% increase in 11 years
- Aqua Ed4 has 2.6% drop over 8.5 years

- Correction to Terra C5 calibration good so far
- Drop in Aqua C5/C6 gains after 2007 manifest in both Ed2 & Ed4
  - will require recalibration for next version

Calibrations: 3.78 μm, 11 July 2008

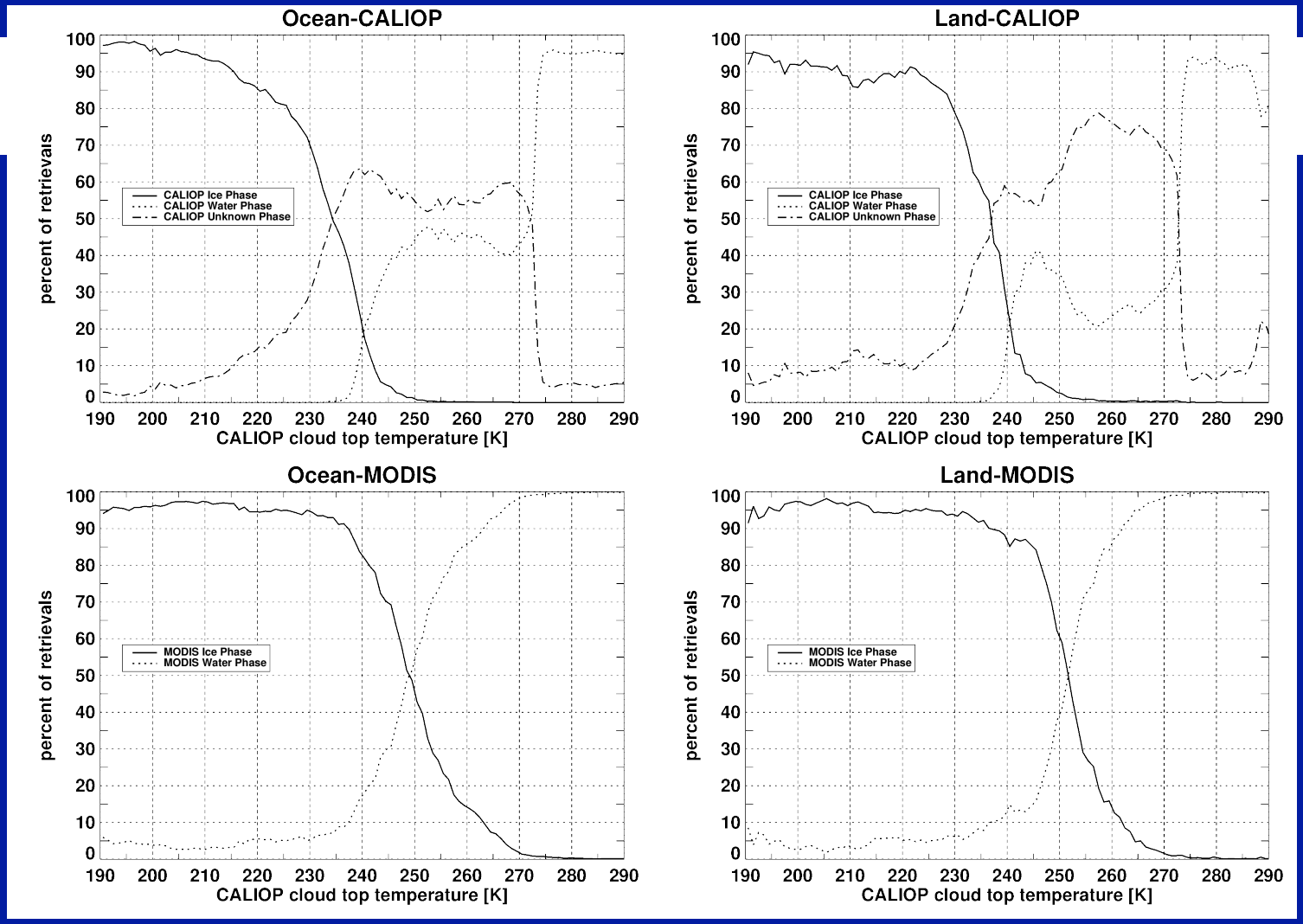


- C6 still has 0.2 – 0.5 K difference between Terra and Aqua
- C5* reduces Terra-Aqua difference to ~ -0.1 K

VALIDATION
&
VARIATIONS

SL Phase determination, CALIOP vs. Aqua, July 2013, All Times

Water: 49%
Ice: 28%
N/A: 23%

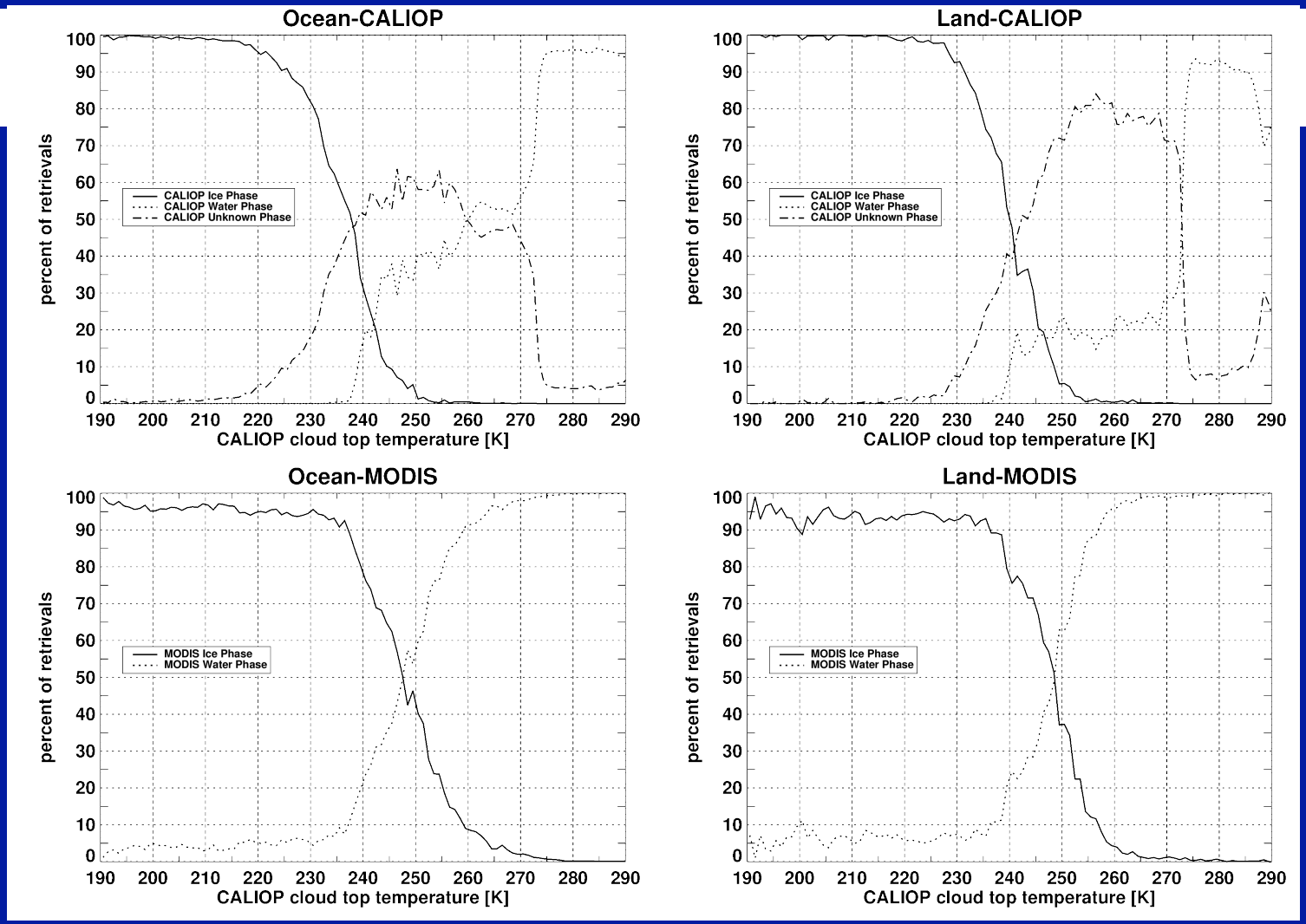


Water: 22%
Ice: 45%
N/A: 33%

- CAL ice > 50% at 233-237 K, but many unknown phase
- Aqua ice > 50% at 248-252K, no unknowns

SL Phase determination, CAL vs. Aqua, July 2013, Day, No Snow

Water: 54%
Ice: 28%
N/A: 18%

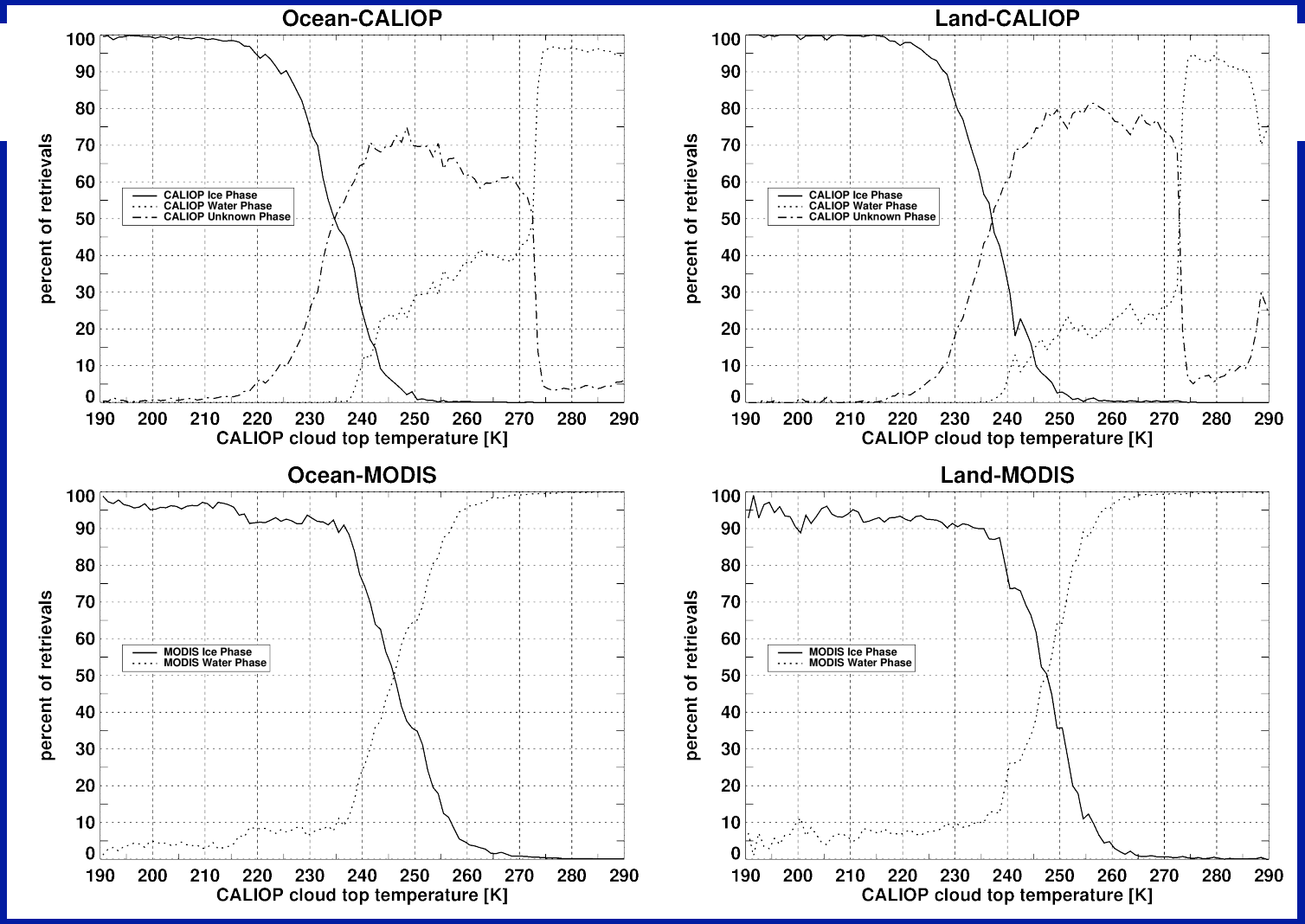


Water: 27%
Ice: 41%
N/A: 33%

- CAL ice > 50% at 238-240 K, but many unknown phases
- Aqua ice > 50% at 247-249 K, no unknowns

SL Phase determination, CAL vs. Aqua, July 2013, Day, Global

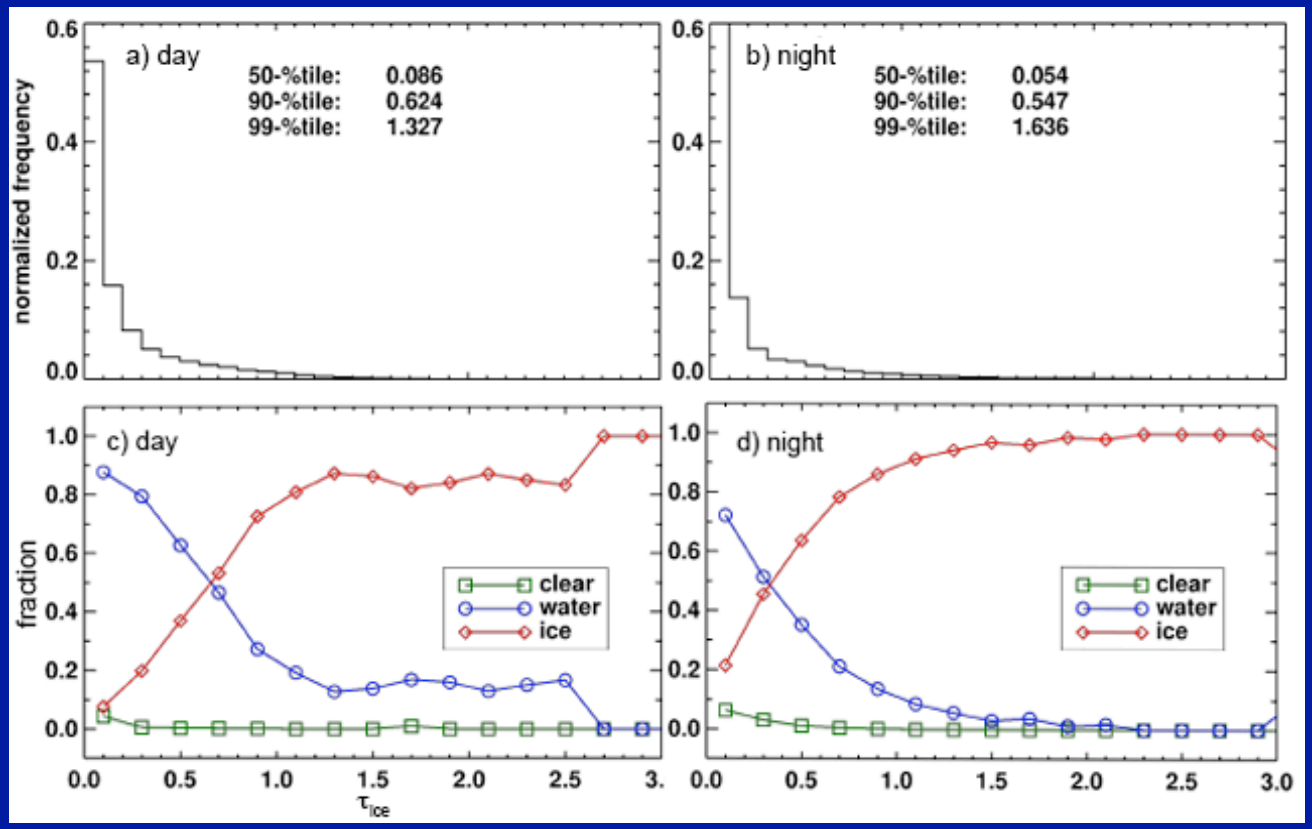
Water: 52%
Ice: 24%
N/A: 24%



Water: 28%
Ice: 32%
N/A: 40%

- CAL ice > 50% at 235-237 K, but many unknown phases
- Aqua ice > 50% at 245-248 K, no unknowns
- Distributions different? Need to eliminate unknown cases

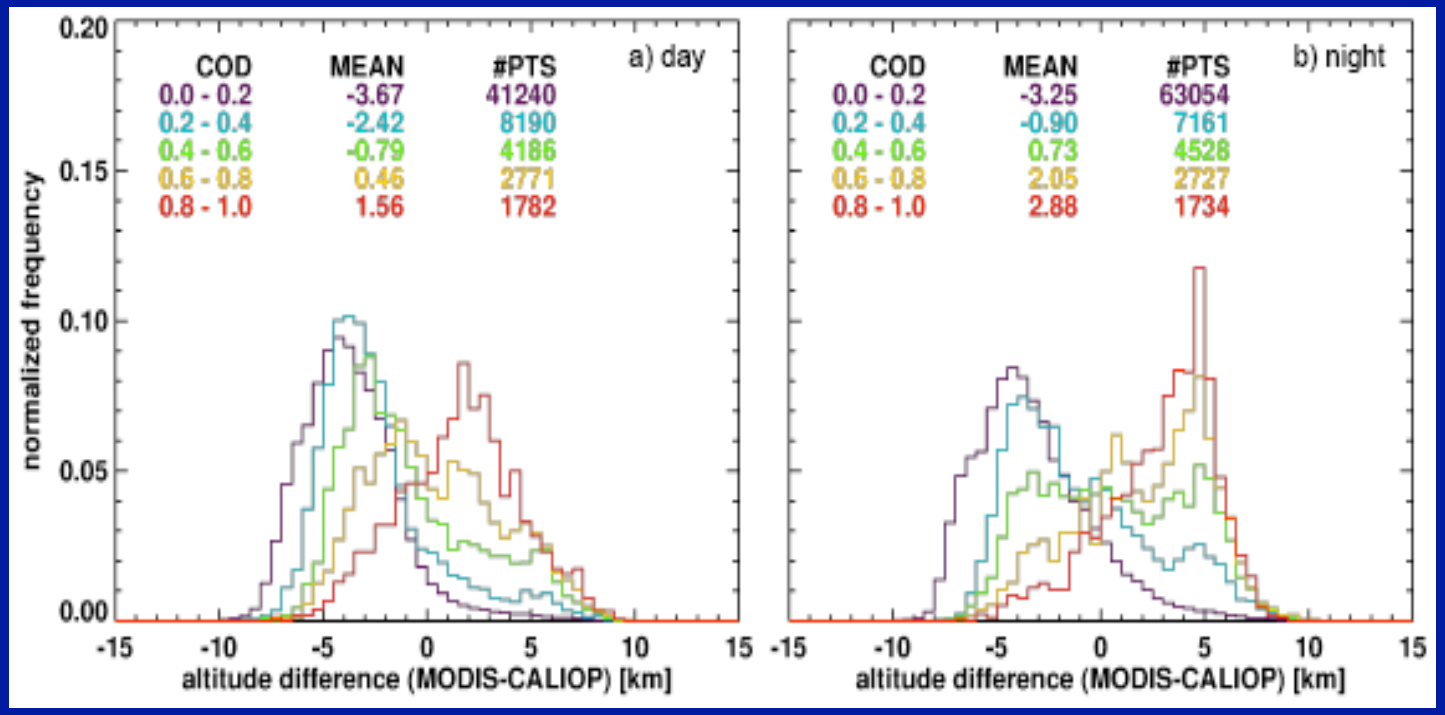
Variation of VISST Phase Determination for Multilayered Clouds as Function of Upper Layer CALIPSO Optical Depth



- Day, $\tau_{UL} < 0.62$ for 90% of thin cirrus over low water clouds
  - *phase more likely to water than ice when $\tau_{UL} < 0.62$*
- Night, $\tau_{UL} < 0.55$ for 90% of thin cirrus over low water clouds
  - *phase more likely to water than ice when $\tau_{UL} < 0.36$*

=> one reason for more ice clouds at night

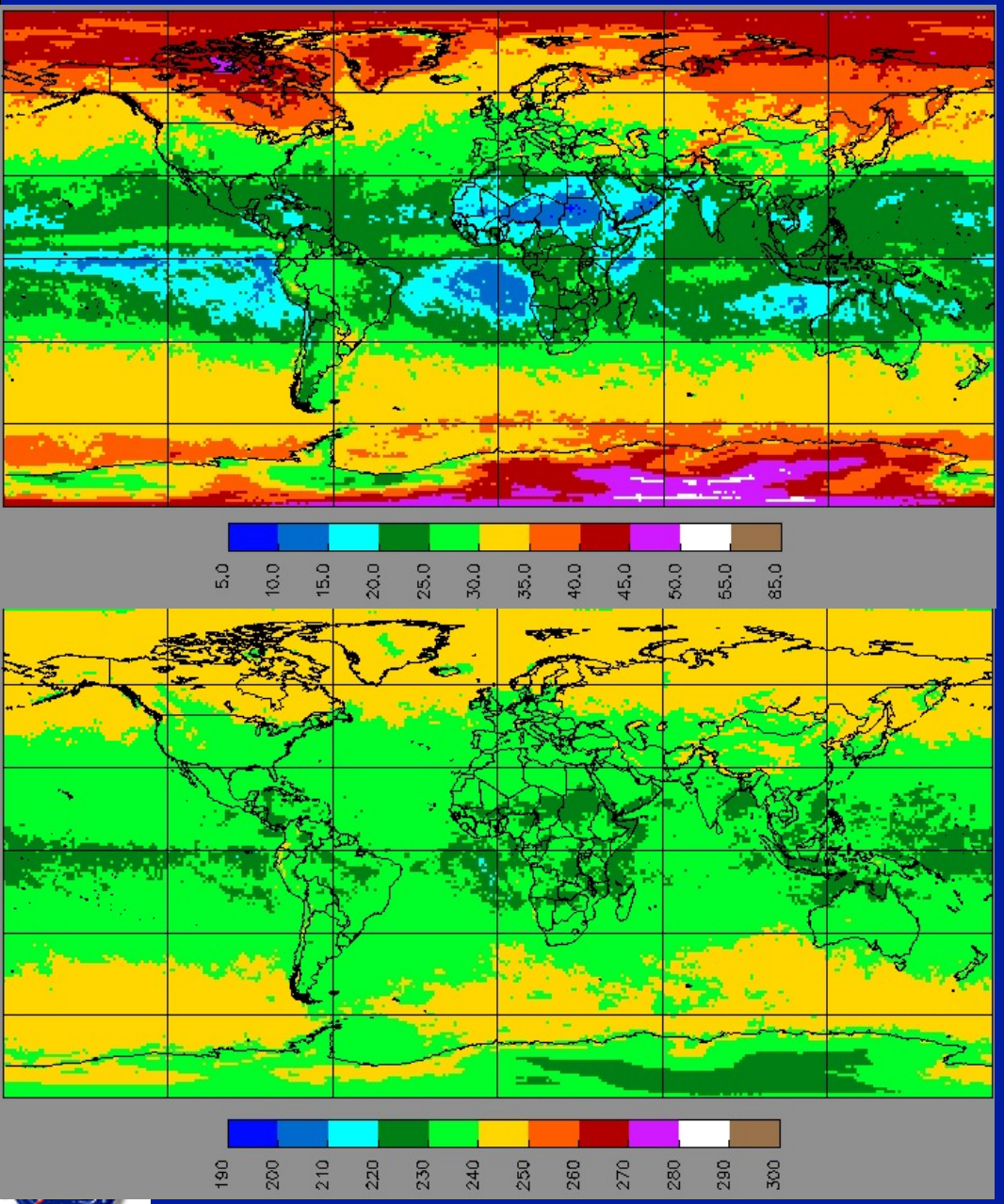
Difference of VISST Effective Height and CALIPSO Mean Height Z_{CML} for Multilayer Clouds as Function of τ_{UL}



$$DZ = Z_{cld} - Z_{CML}$$

- Day, $\tau_{UL} \sim 0.53$ for $Z_{cld} = Z_{CML}$ for thin cirrus over low water clouds
  - *most values of Zcld will be close to Z_{LL}*
- Night, $\tau_{UL} \sim 0.42$ for $Z_{cld} = Z_{CML}$ for thin cirrus over low water clouds
  - *most values of Zcld will be close to Z_{LL}, but fewer than for day*

Temperature Dependence of Re(ice)

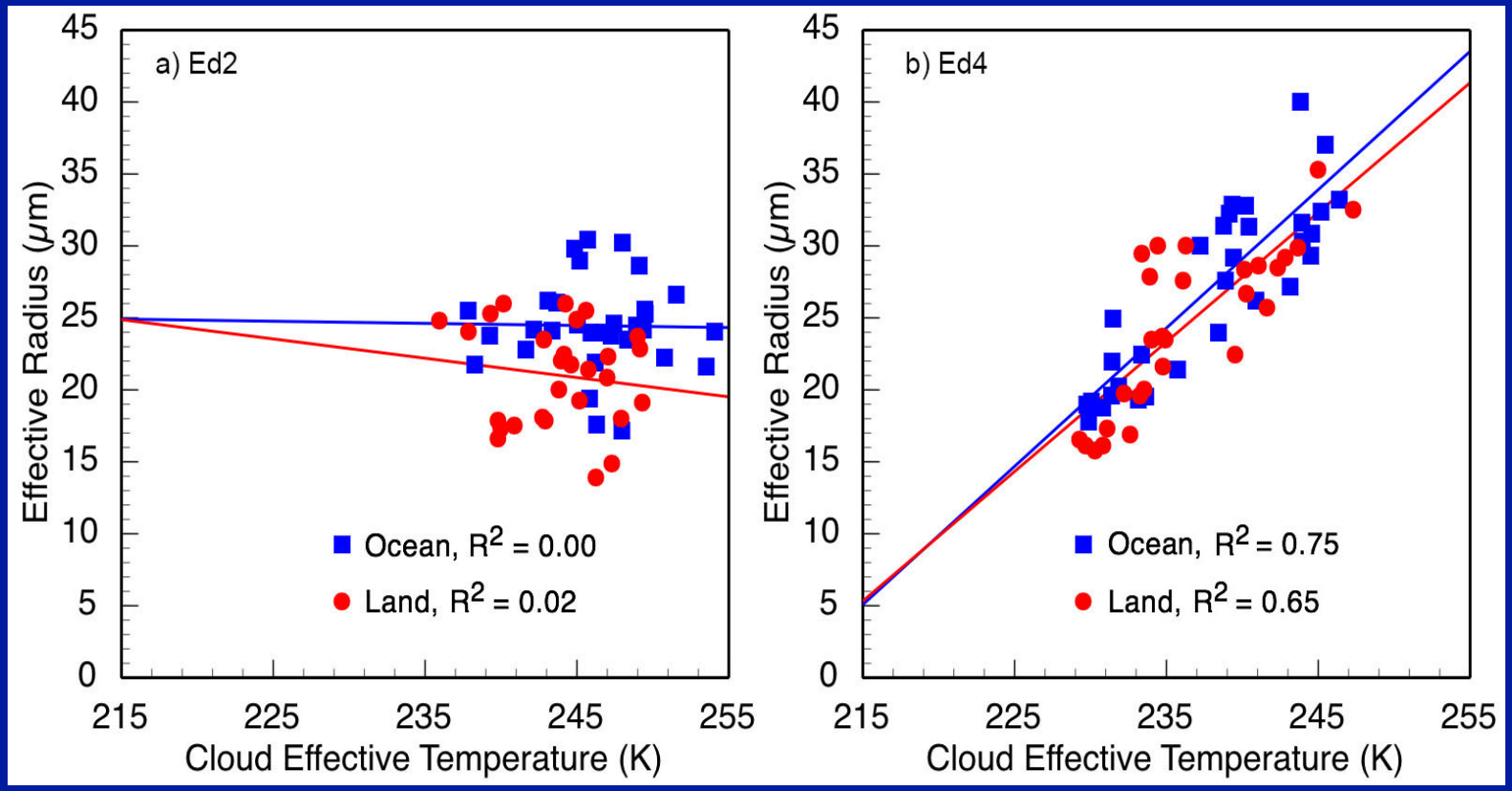


In situ data have long shown that ice particle size increases with temperature.

- We should expect the same from remotely sensed cloud tops

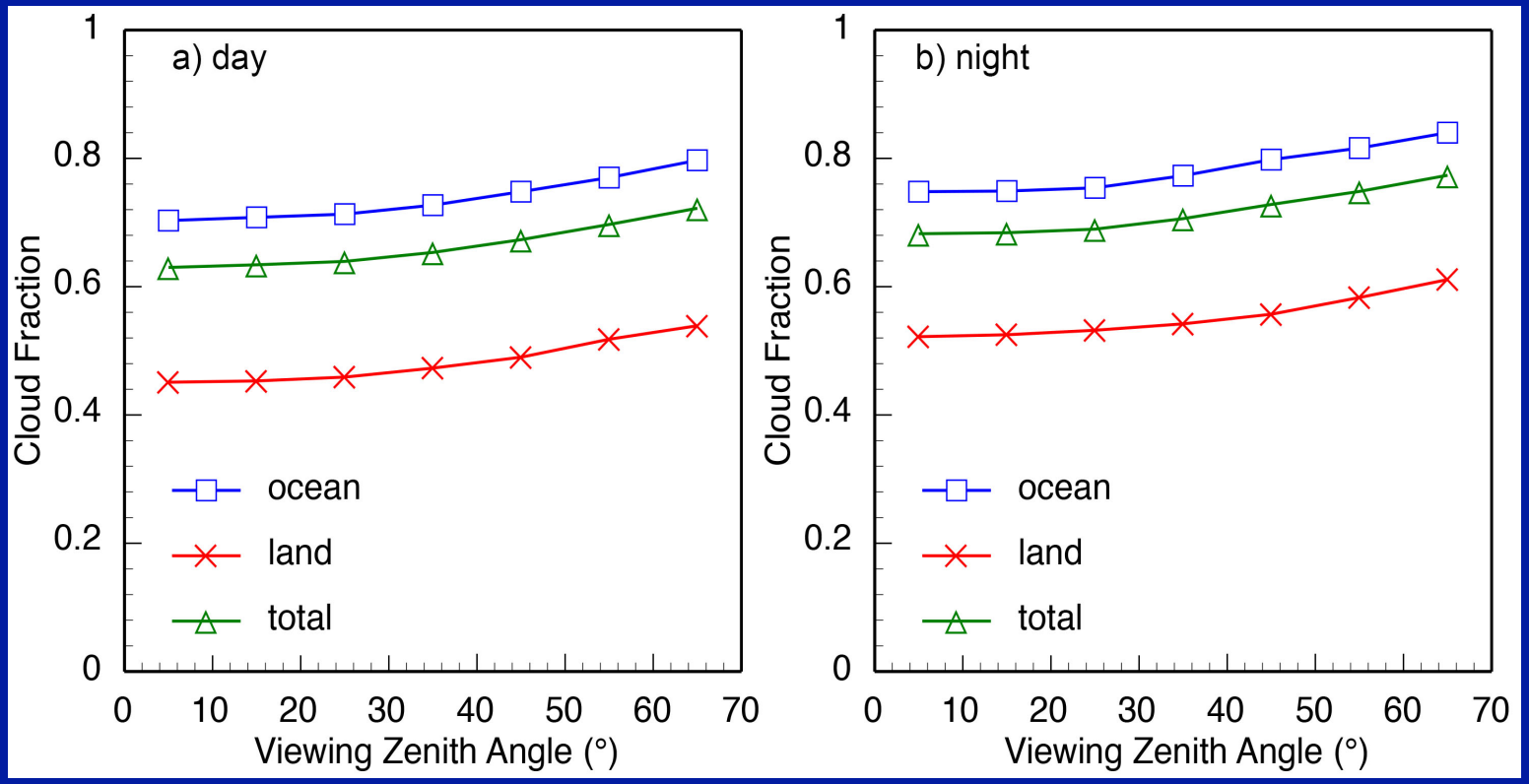
Temperature Dependence of Re(ice): Correlation

2004 Nonpolar Aqua MODIS Zonal Mean Ice Re vs Tcld



- Edition 2: no correlation between Re and Tcld
- Edition 4: strong correlation found
  - *Ed4 results consistent with expected variations*
  - *indicates significant improvement in retrievals*

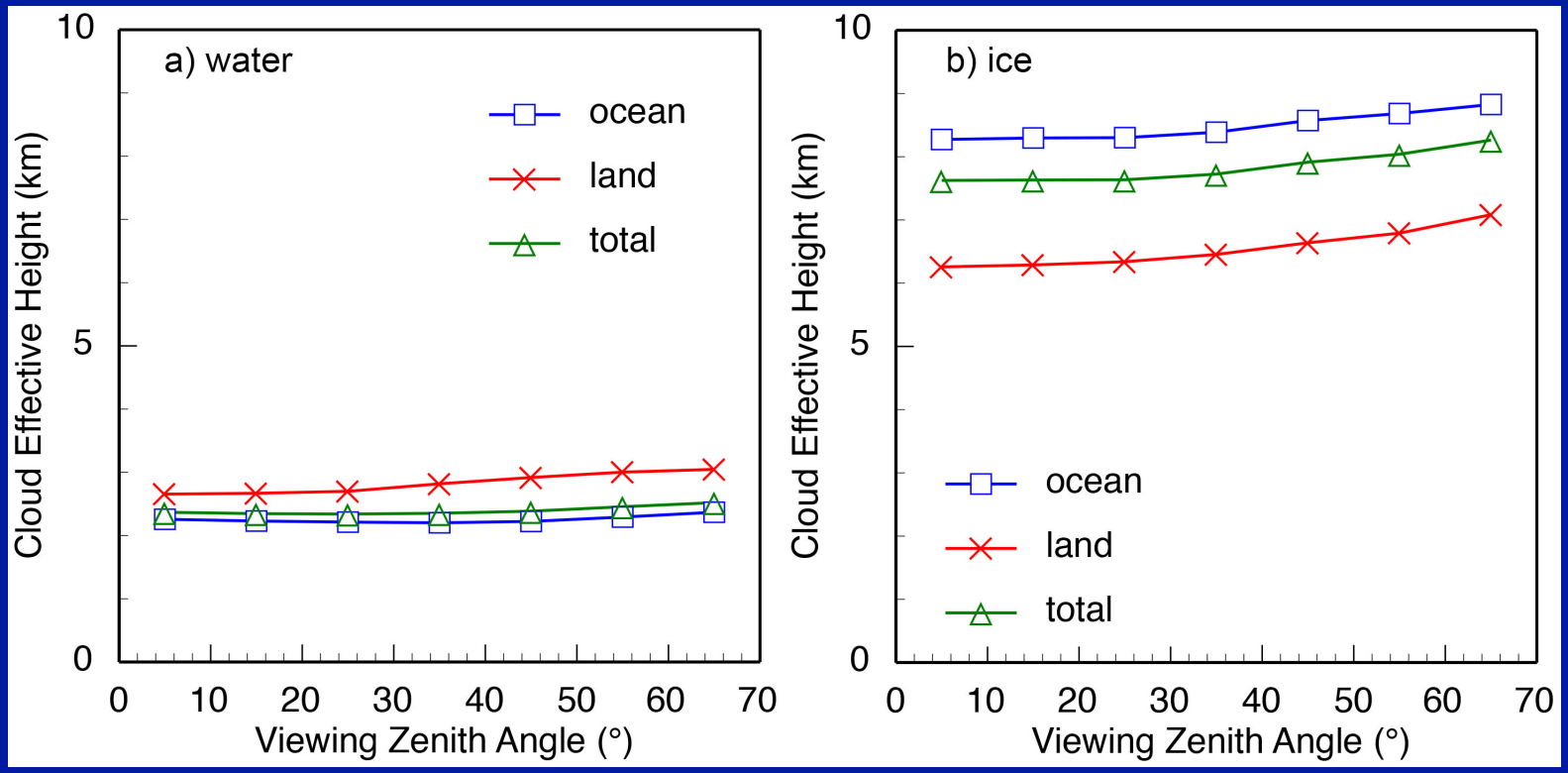
Viewing Zenith Angle Dependence of Cloud Fraction Aqua 2004



Ocean:	day, 13% increase to 65°;	12% rise at night
Land:	day, 19% increase;	17% rise at night
Total:	day, 15% increase;	13% rise at night

- CERES fraction VZA variation < that of MODIS Collection 6

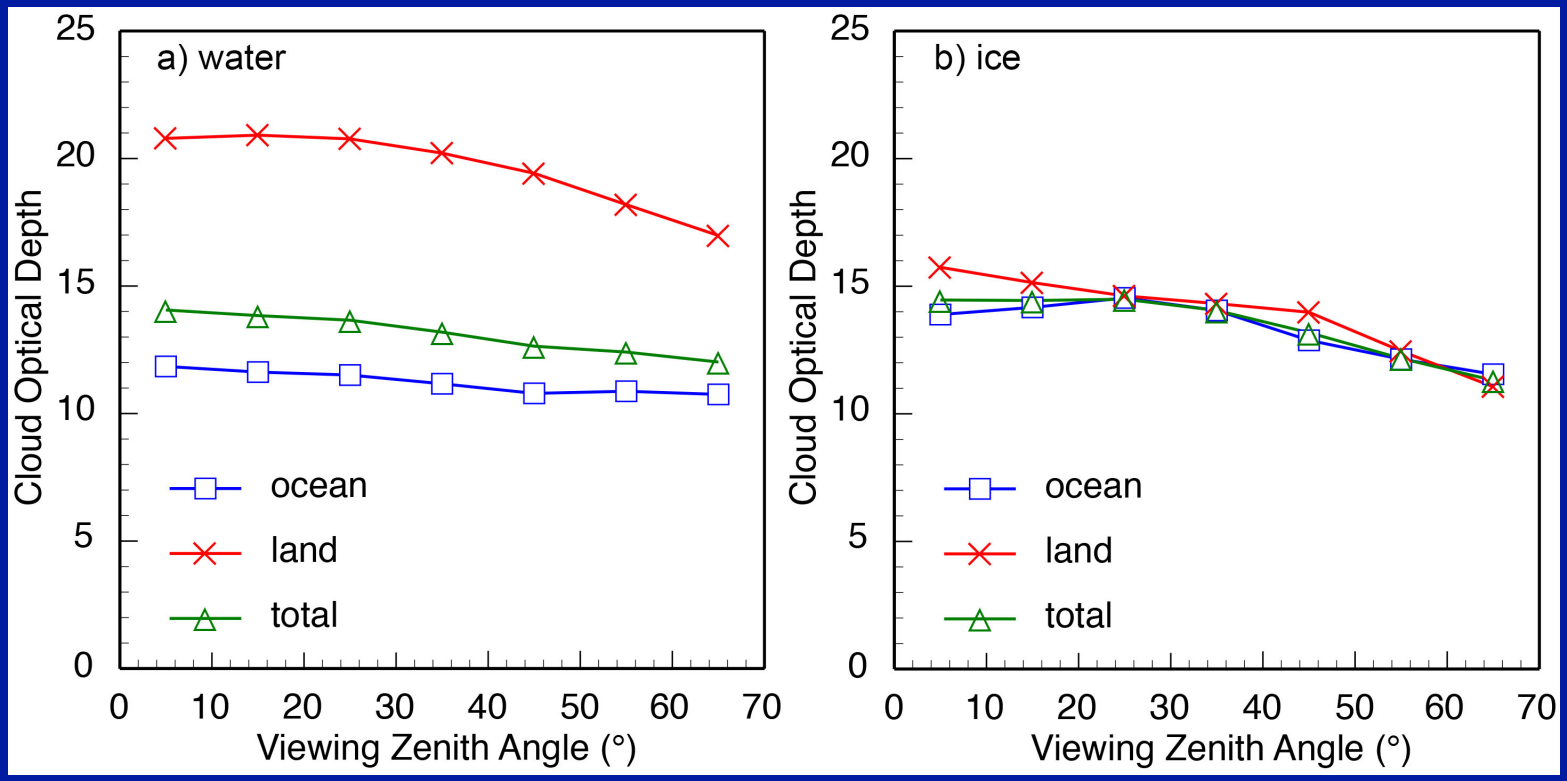
Viewing Zenith Angle Dependence of Cloud Height Day, Aqua 2004



Ocean:	water, 0.11 km increase to 65°;	ice, 0.61 km rise
Land:	water, 0.39 km increase;	ice, 0.83 km rise
Total:	water, 0.19 km increase;	ice, 0.64 km rise

- T11 colder with VZA
  - *fewer holes between clouds*
  - *radiating temperature higher in cloud*

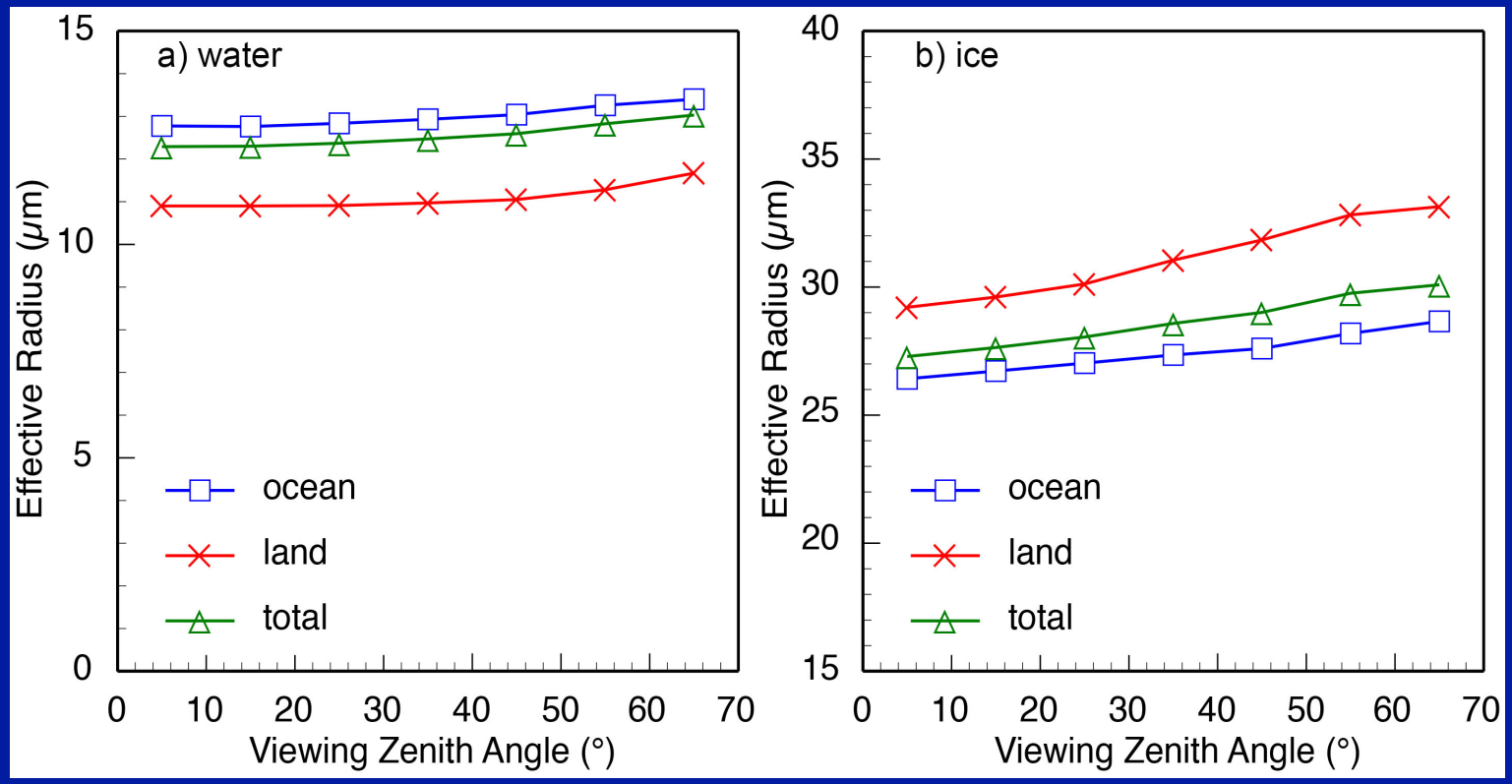
Viewing Zenith Angle Dependence of Cloud Optical Depth Day, Aqua 2004



Ocean:	water, 10% decrease to 65°;	ice, 20% drop
Land:	water, 23% decrease;	ice, 42% drop
Total:	water, 15% decrease;	ice, 26% drop

- more, thinner clouds seen at high VZA
- *broken clouds become overcast with lower reflectance than OC*

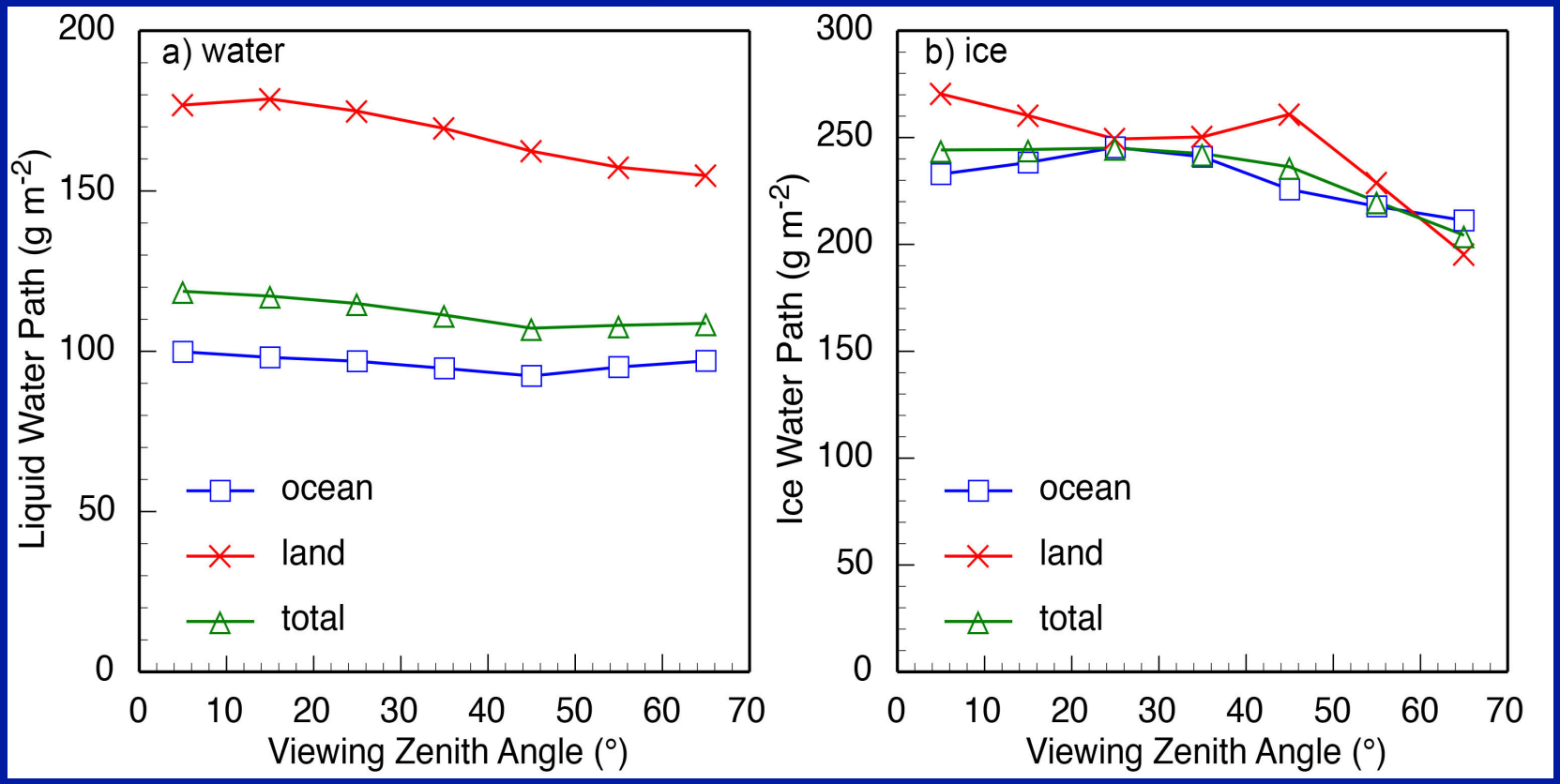
Viewing Zenith Angle Dependence of Cloud Particle Radius Day, Aqua 2004



Ocean:	water, 5% increase to 65°;	ice, 8% rise
Land:	water, 7% increase;	ice, 13% rise
Total:	water,5% increase;	ice, 10% rise

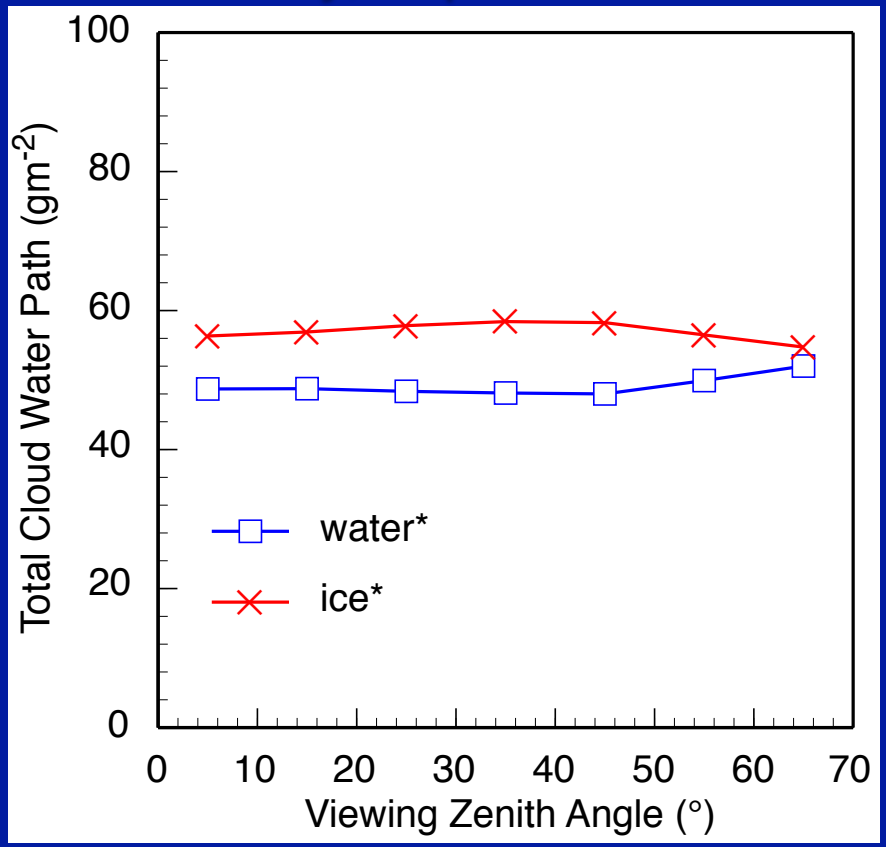
- Partially compensates optical depth decrease with VZA

Viewing Zenith Angle Dependence of Cloud Water Path Day, Aqua 2004



Ocean:	water, 3% decrease to 65°;	ice, 10% drop
Land:	water, 14% decrease;	ice, 38% drop
Total:	water, 7% decrease;	ice, 18% drop

Viewing Zenith Angle Dependence of Total Cloud Water Path Day, Aqua 2004



LWP* = LWP(VZA)*CFL(VZA); IWP* = IWP(VZA)*CFI(VZA)

Total: LWP*, 8% increase to 65°; IWP*, 3% drop

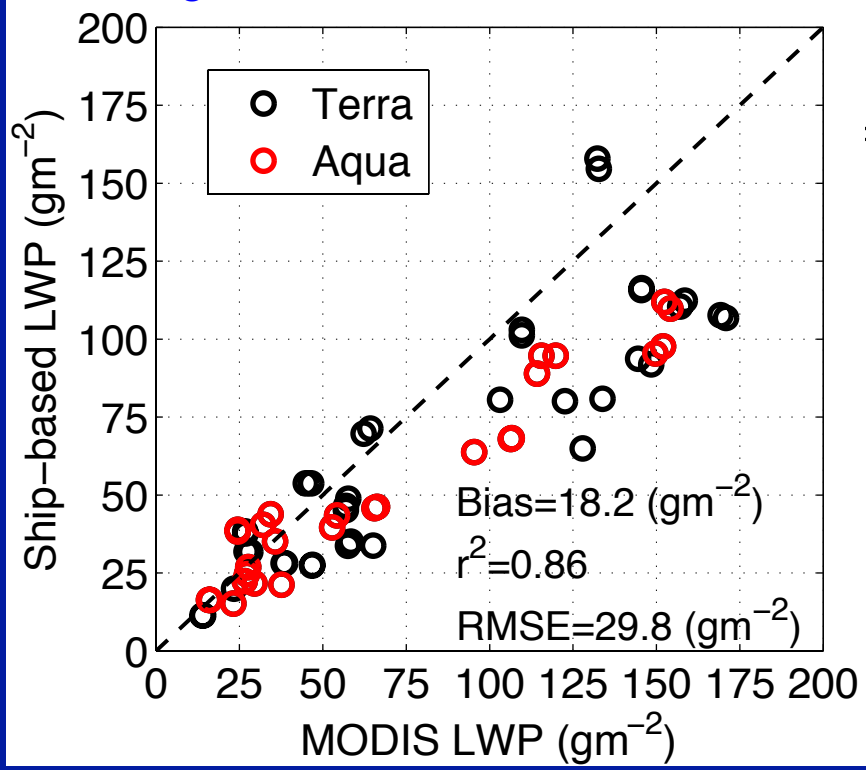
VZA dependencies are mostly canceled out for cloud water path
Essentially no VZA dependence for normalized CWP

Do you believe in magic?

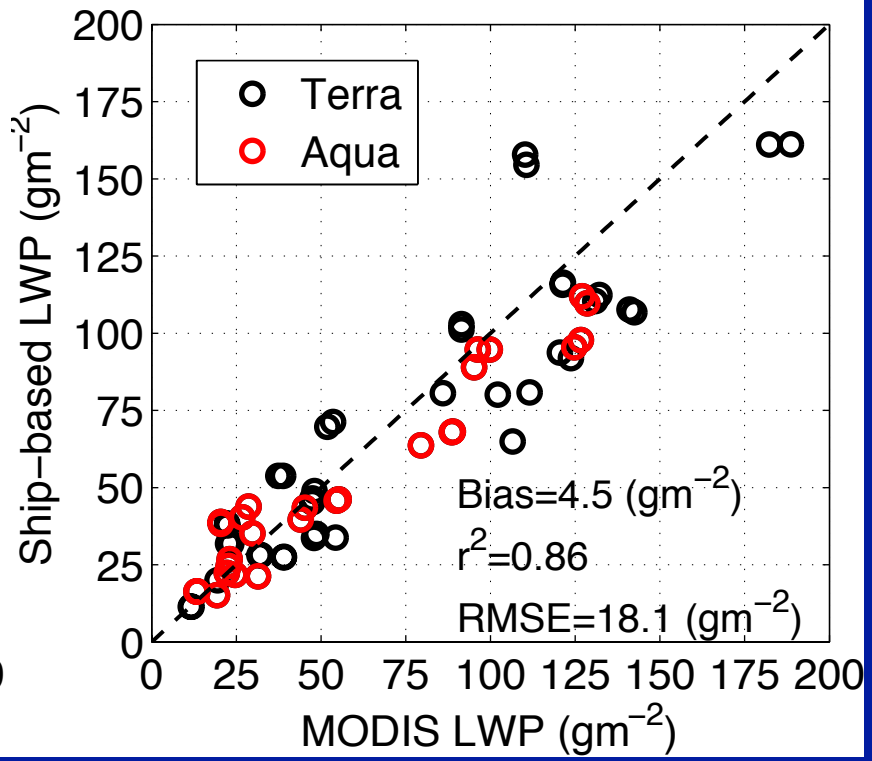
Marine Stratus LWP Comparison, **MAGIC** vs **CERES** MODIS

ASR MAGIC deployment instrumented a Hawaii-LA freighter with ARM instruments for 1 year. MWR was included. June-July 2013 MODIS data matched with ship. LWP computed from COD & Re two ways.

Homogeneous: LWP = 0.667 τ * Re



Adiabatic: LWP = 0.555 τ * Re



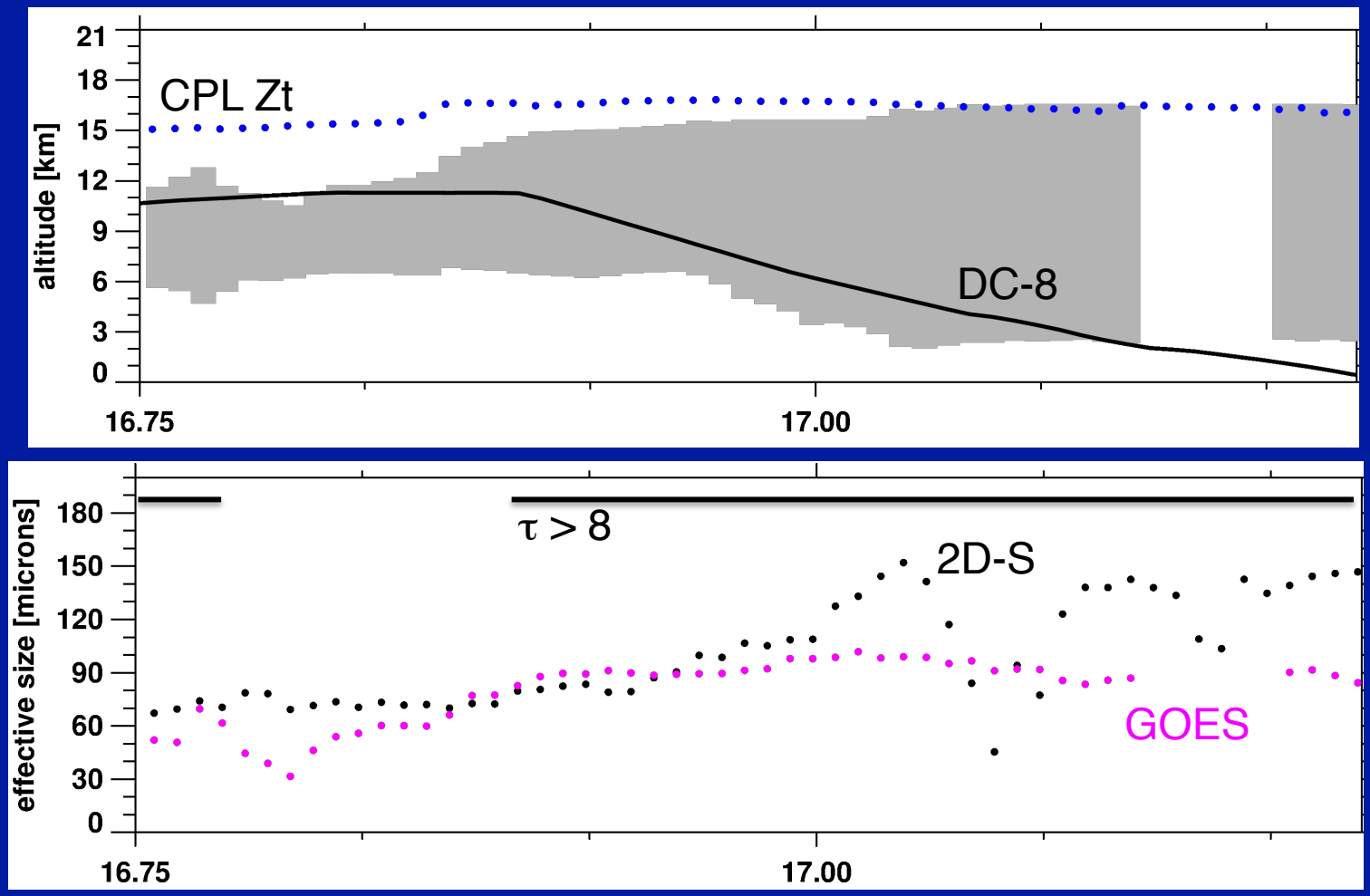
- Adiabatic bias only 1/4th that of homogeneous assumption
  - recommend use adiabatic approach for LWP computations
  - *at least, for stratus*

SEAC^{4}RS

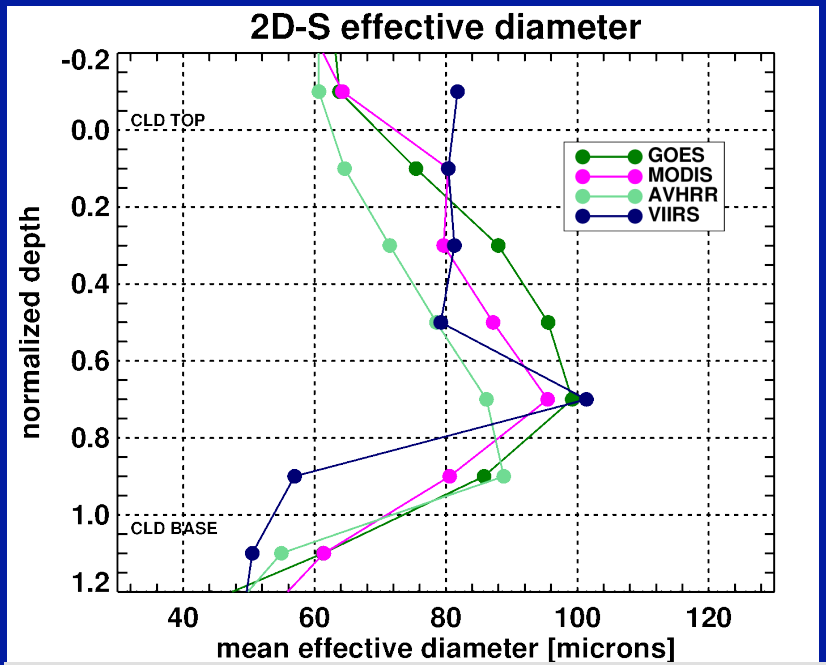
DC-8, Lear Jet, and ER-2 flights in aerosols, convective clouds, and cirrus mostly over SE US, 2013

Particle Size & Height Comparisons

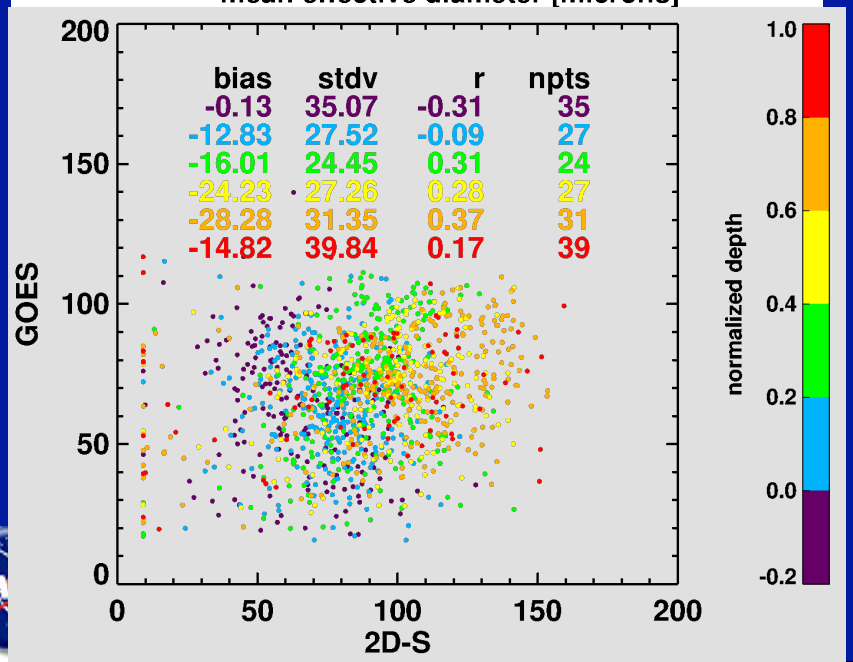
13 September, Coordinated DC-8 & ER-2

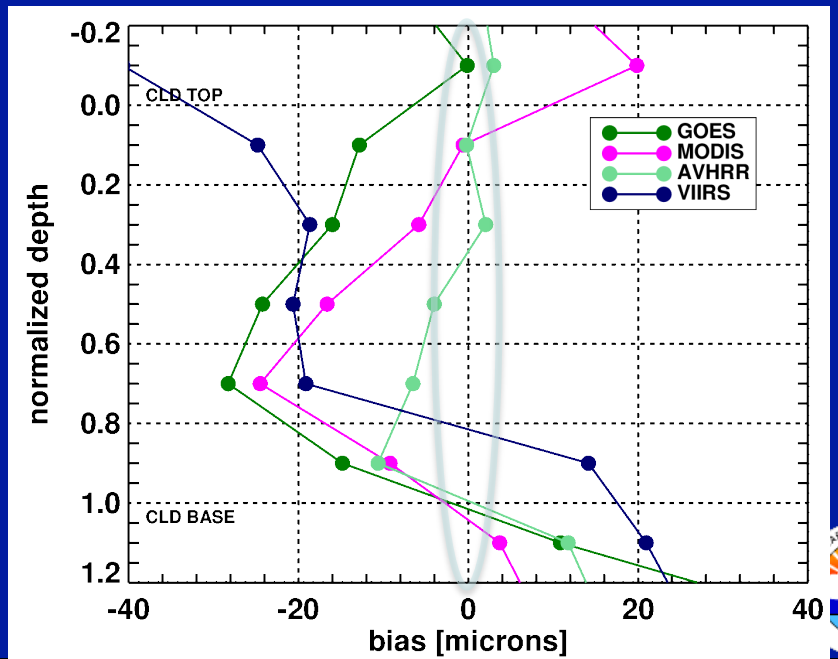


Ice Particle Size Comparisons: All SEAC^{4}RS Days



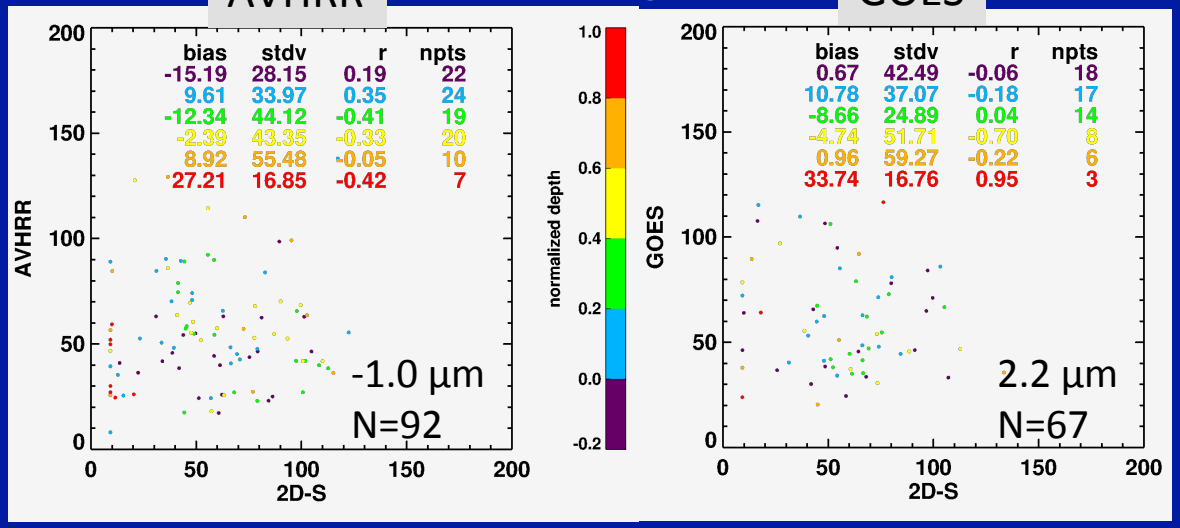
- De(DC8) increases with depth from cloud top
  - decreases to bottom from 0.7 level
- De(sat) smallest bias in top layer of cloud
  - VIIRS difference: sampling?
  - all other imagers have similar bias structure
- De(sat) greatest bias at 0.7 level
- De(sat) based on 3.7 µm, bias expected



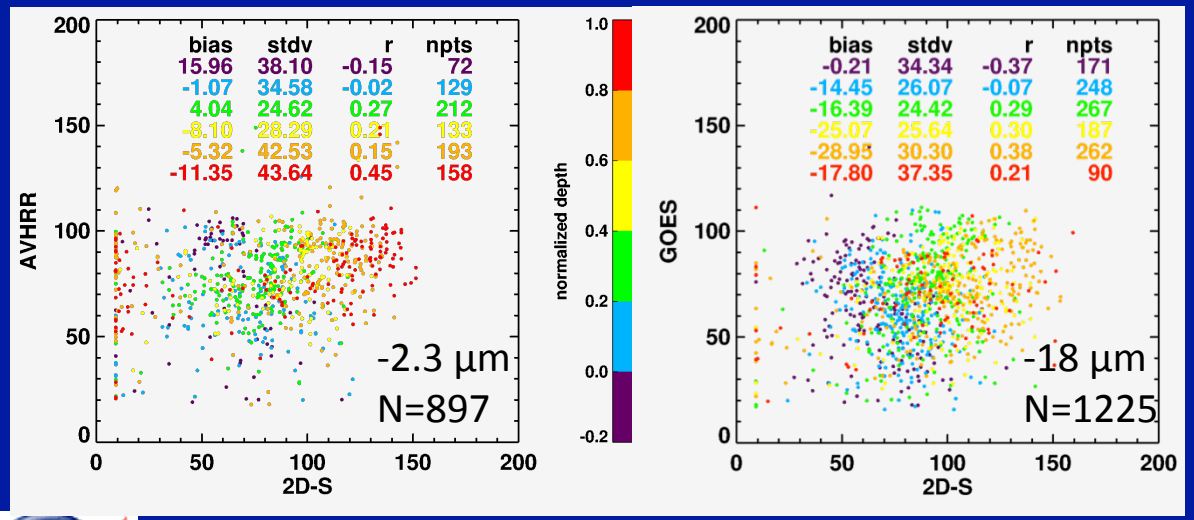


Ice Particle Size Comparisons: τ dependence

AVHRR — $\tau < 3$ — GOES



$\tau > 3$



$\tau < 3$

- agreement in the mean
  - crossover near 0.3 level
- scatter quite high, expected
- 3.75 µm should be good for determining thin cirrus De
  - seen in previous studies

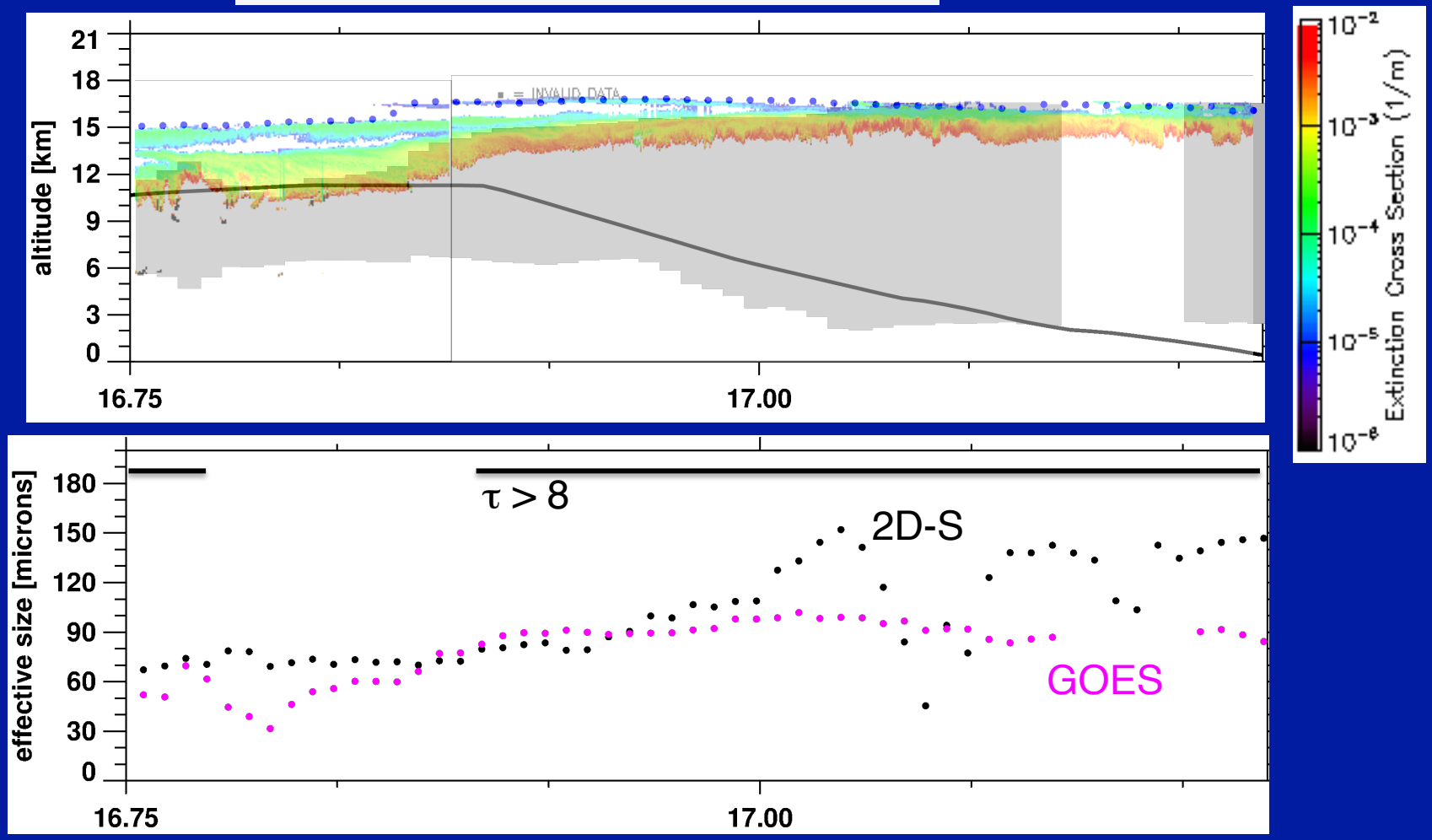
$\tau > 3$

- negative biases
  - VIIRS & MODIS = -10.4 µm
- crossover near 0 level
- expect better agreement with longer wavelength retrievals

- When quantified for more τ intervals, possible to infer integrated De for all τ?

Particle Size & Height Comparisons

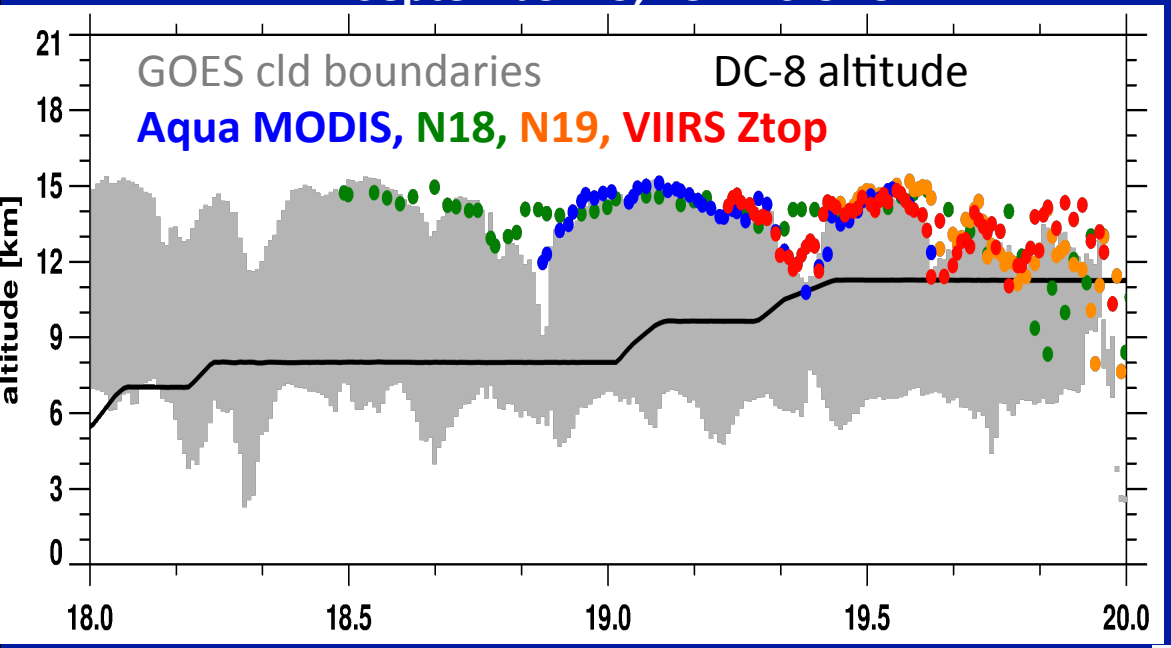
13 September, Coordinated DC-8 & ER-2

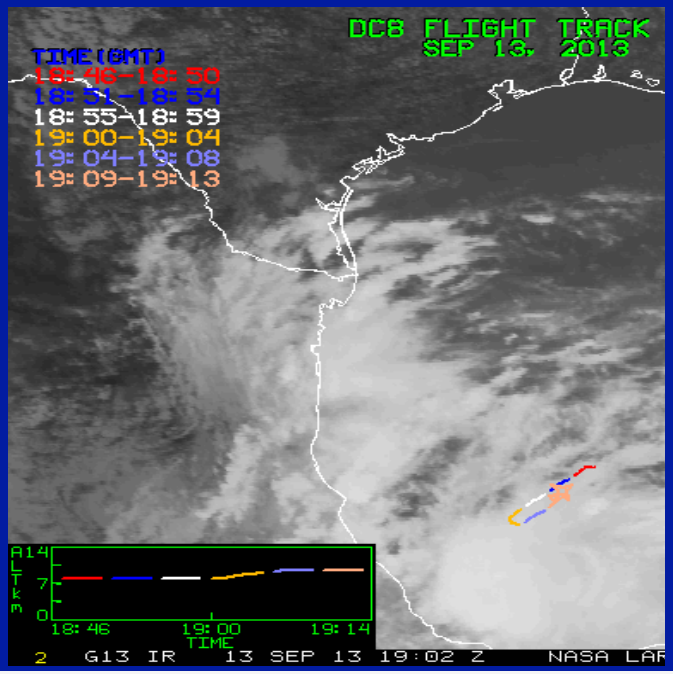


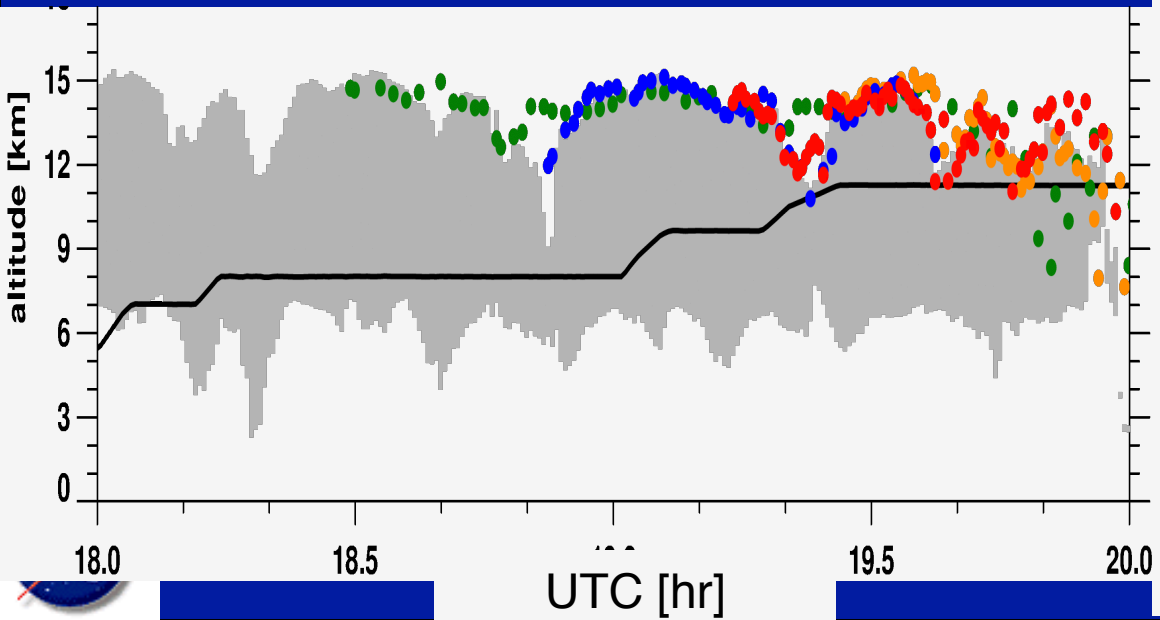
- GOES misses diffuse cloud section, underestimates physical height,
- more $\tau < 8$ corresponds to $\tau < 3$ for CPL, so t is likely underestimated for ice clouds
- De crossover point varies as scatter indicates, here De matches 5-7 km below cloud top

Cloud Heights Along DC-8 & ER-2 Flight Tracks

September 13, 18 – 20 UTC

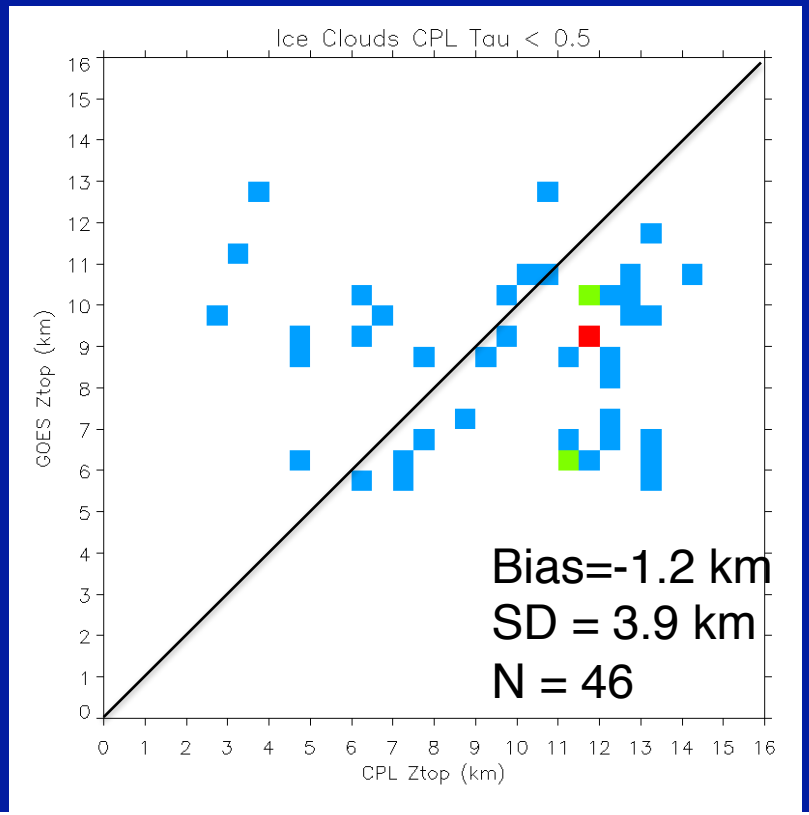


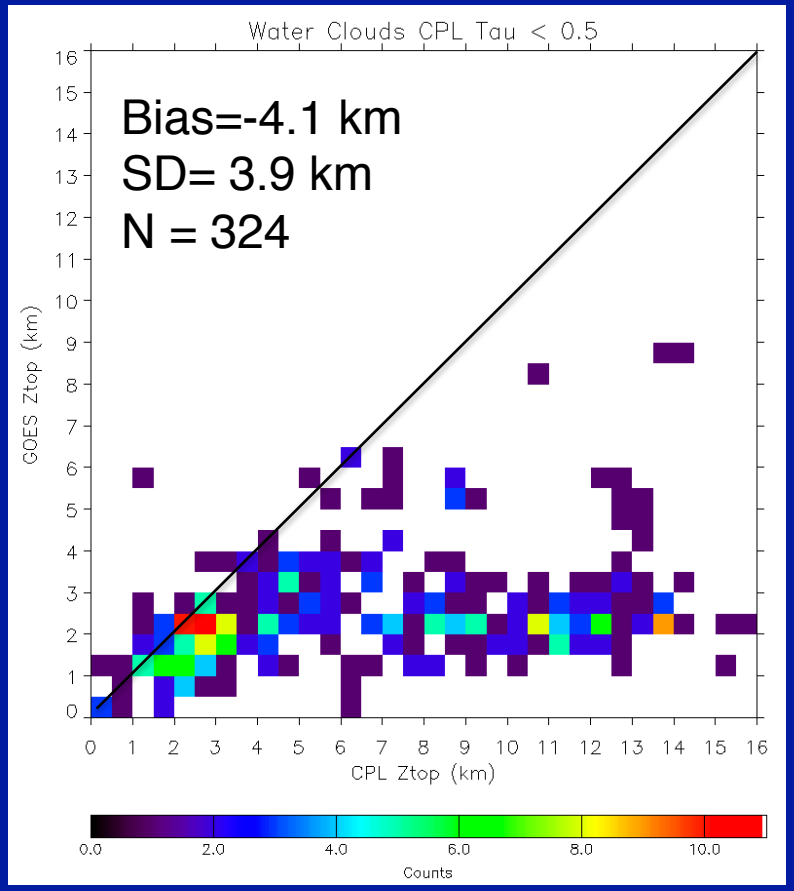


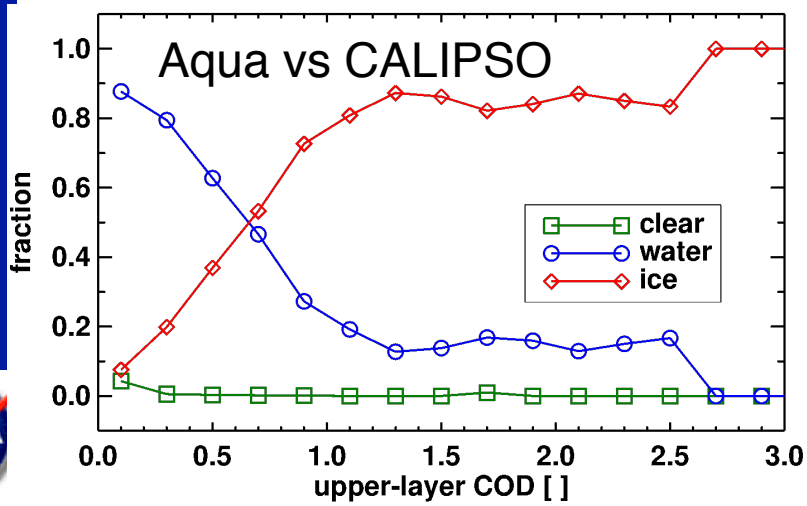


- All 5 satellites produce nearly identical heights
  - N18 less consistent because of VZA & resolution effects
- Thick cloud correction accounts for much of diffuse cloud top (CPL at bottom) but pileus and some very low extinction cirrus still apparent above corrected cloud heights

Cloud Heights: GOES vs CPL, τ(CPL) < 0.5

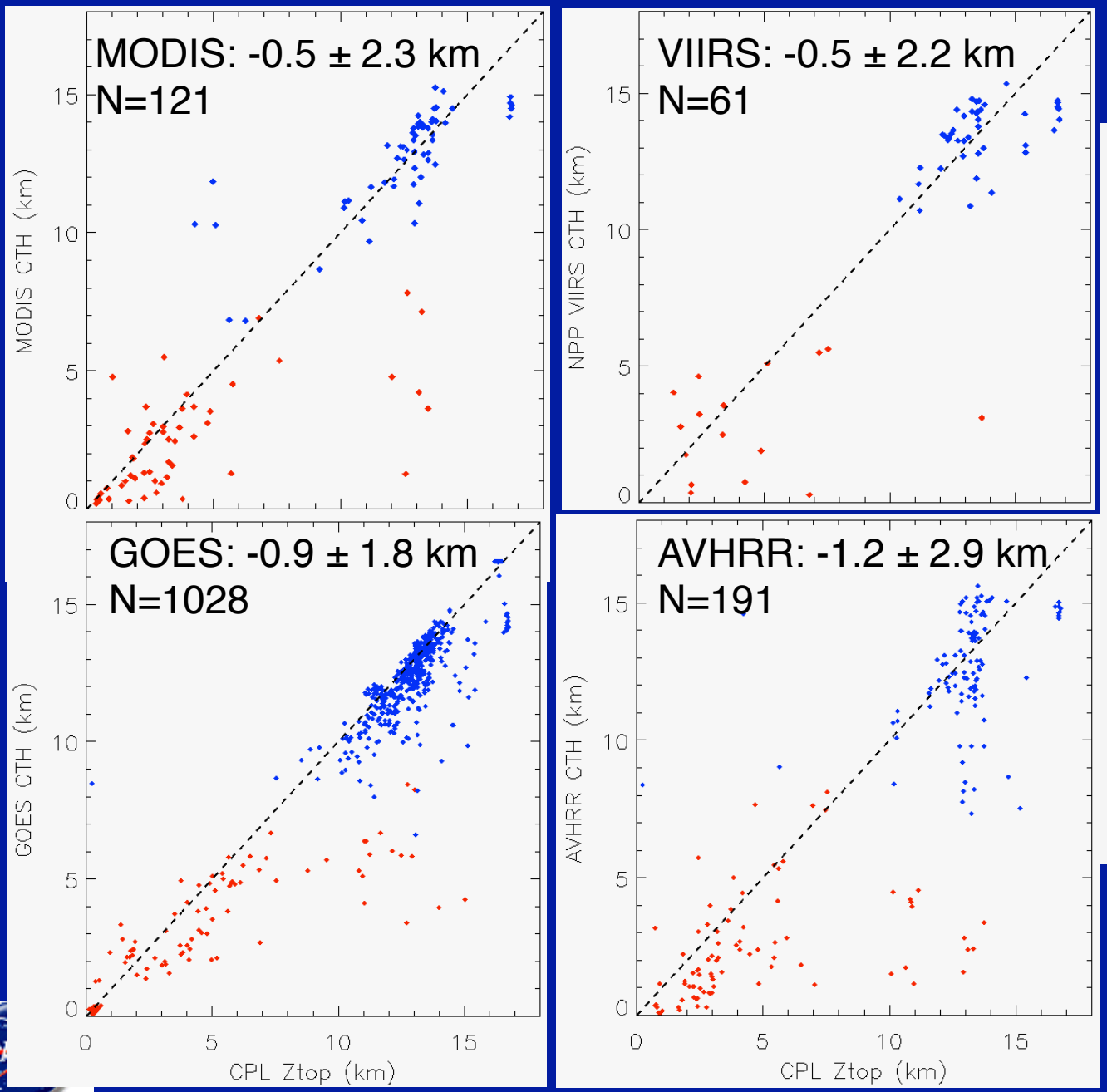






- Most $\tau < 0.5$ cases are likely multilayered, misclassified phase
- Typically, algorithm selects water phase when upper layer $\tau < 0.5$

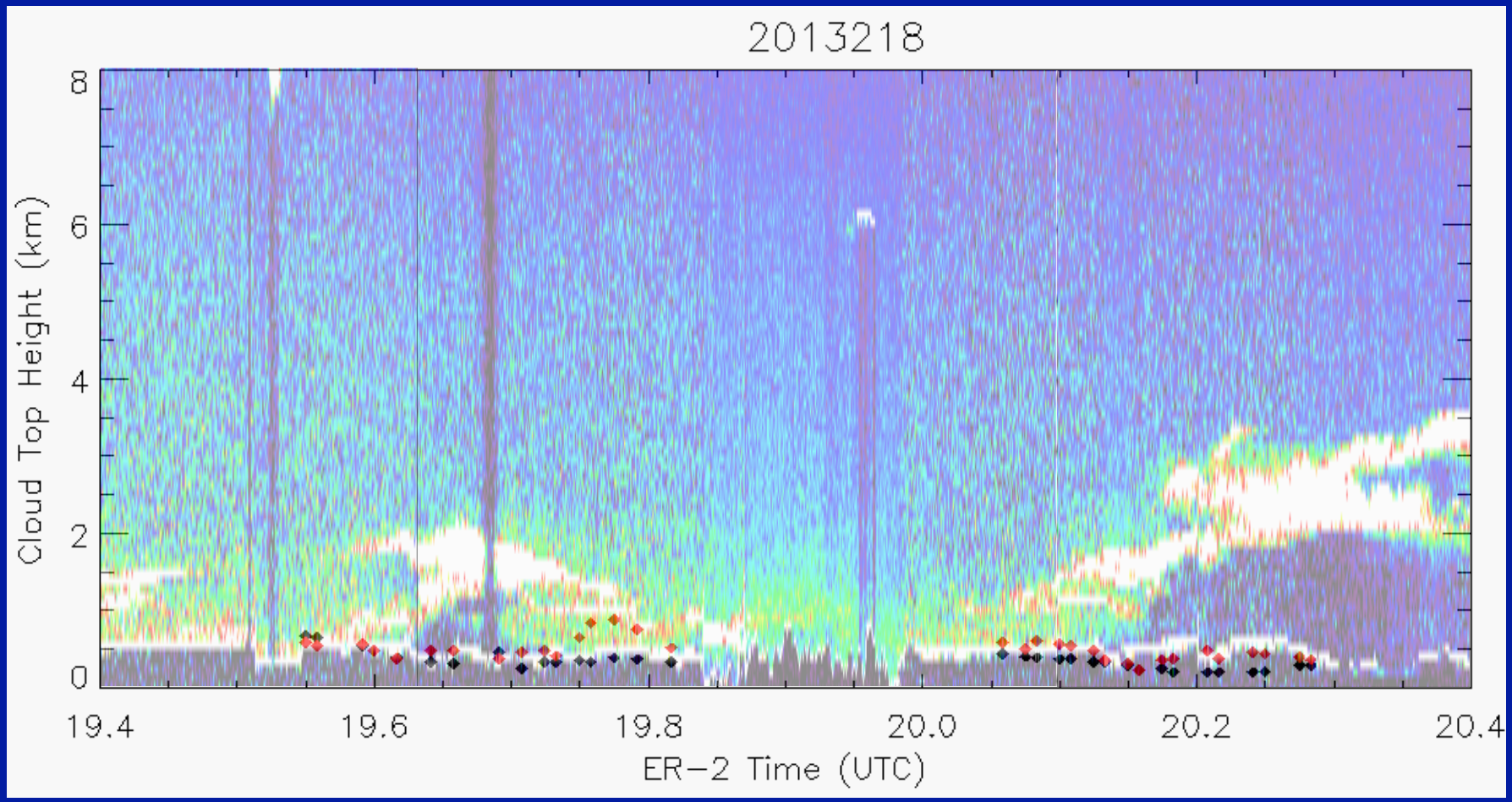
Cloud Heights: Imagers vs CPL, τ(CPL) > 0.5



- differences for GOES, MODIS, & VIIRS similar to that found with CC
- AVHRR a bit worse, uses MERRA surface temperatures, affects low clouds most
- scattered cumulus clouds likely responsible for low cloud biases
- some low & high cloud bias due to ML clouds

Detecting Stratus Height With Overlying Smoke

ER-2 CPL measured cloud & aerosol heights off California, 6 Aug 2013
- compared with two swaths from Terra MODIS (high angle views)



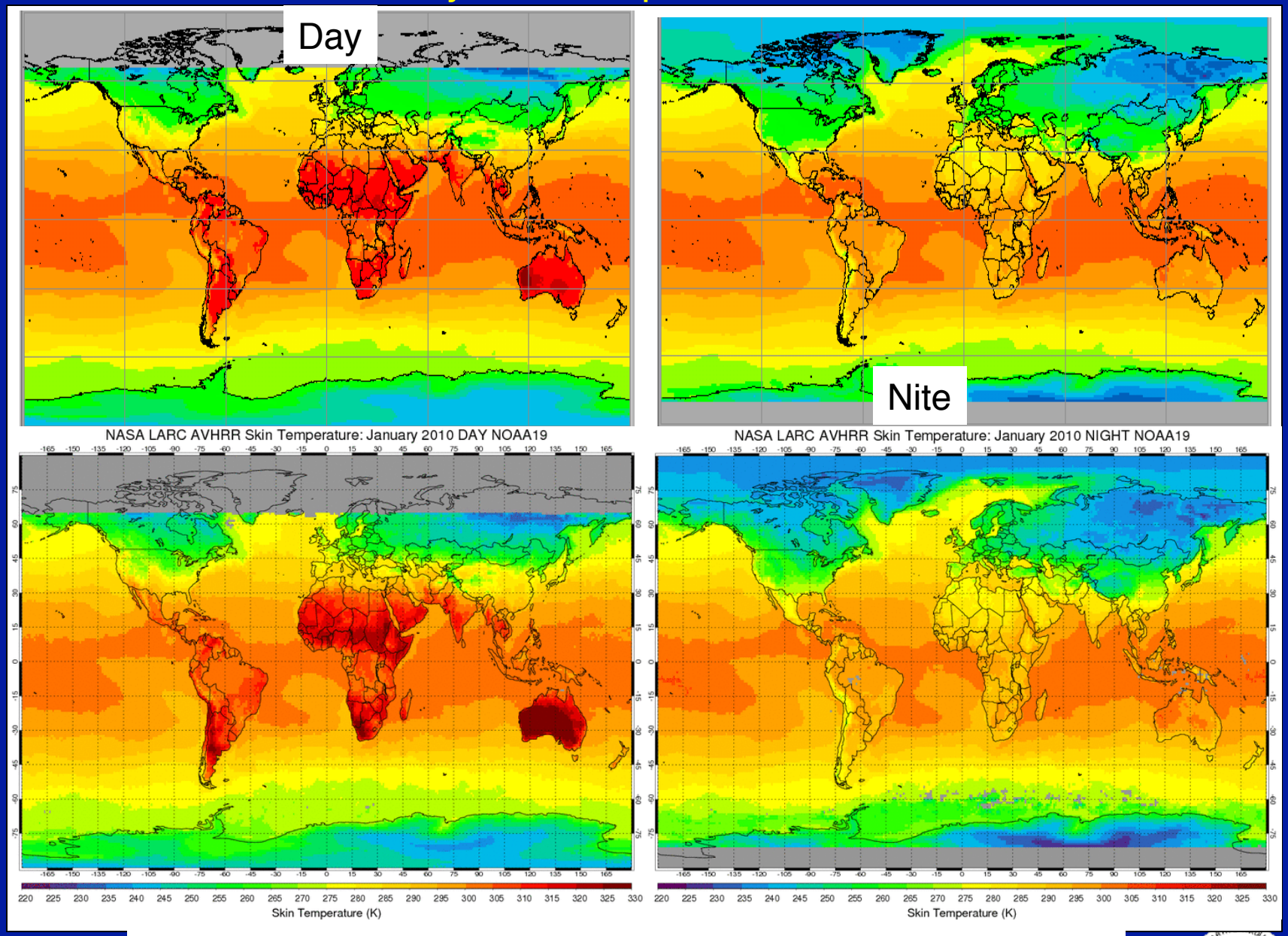
- Terra typically within 100 m except for 19.75 & 20.3 UTC
- 19.75, CPL calls aerosol cloud; 20.3, dense smoke increasing T11

Clear-sky Skin Temperature Bug

Mean Clear-Sky Skin Temperature, Jan 2010

MOA

N-19

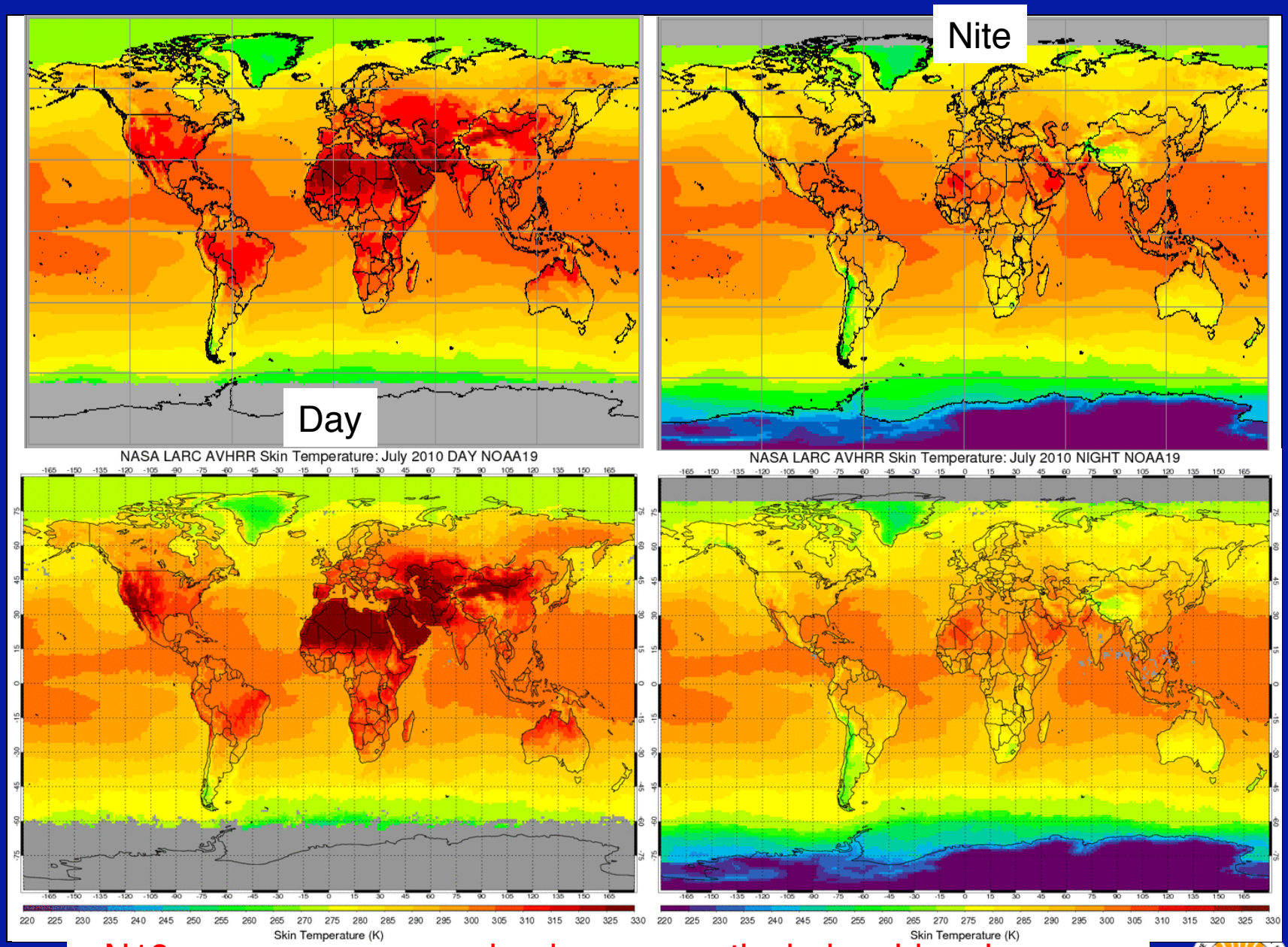


- N19 warmer over many land areas, particularly arid regions
- Dramatic day-night changes over land surfaces

Mean Clear-Sky Skin Temperature, Example July 2010

MOA

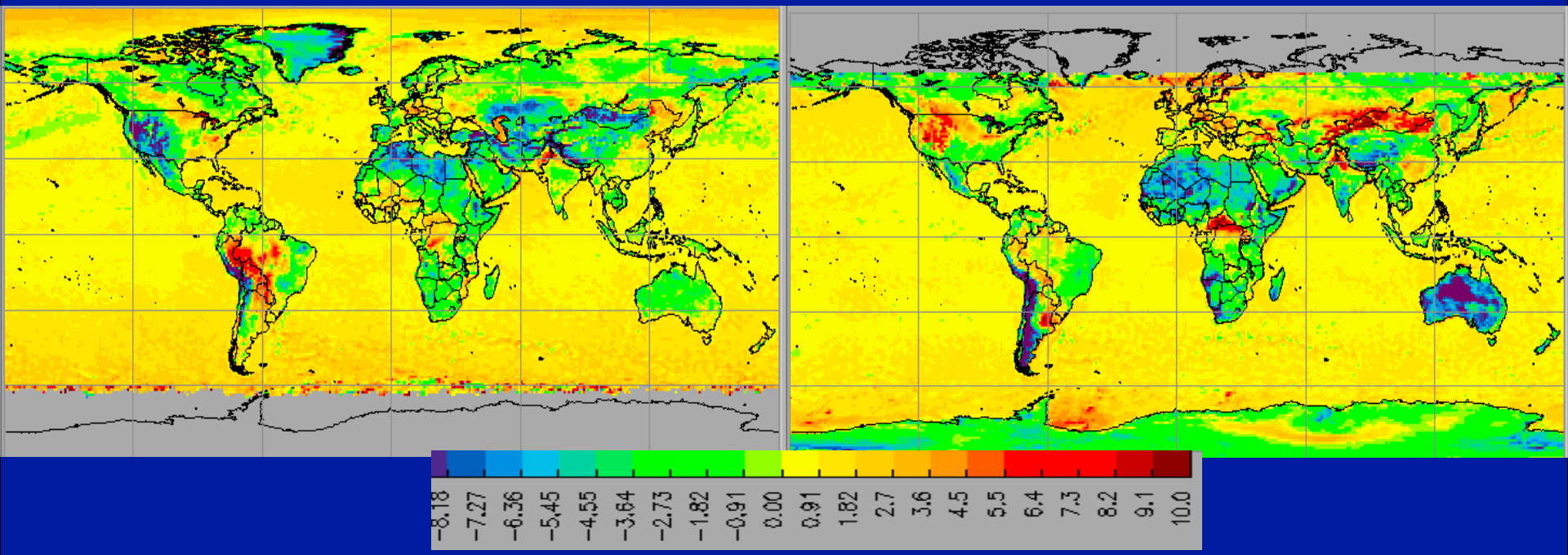
N-19



- N19 warmer over many land areas, particularly arid regions
- Dramatic day-night changes over land surfaces

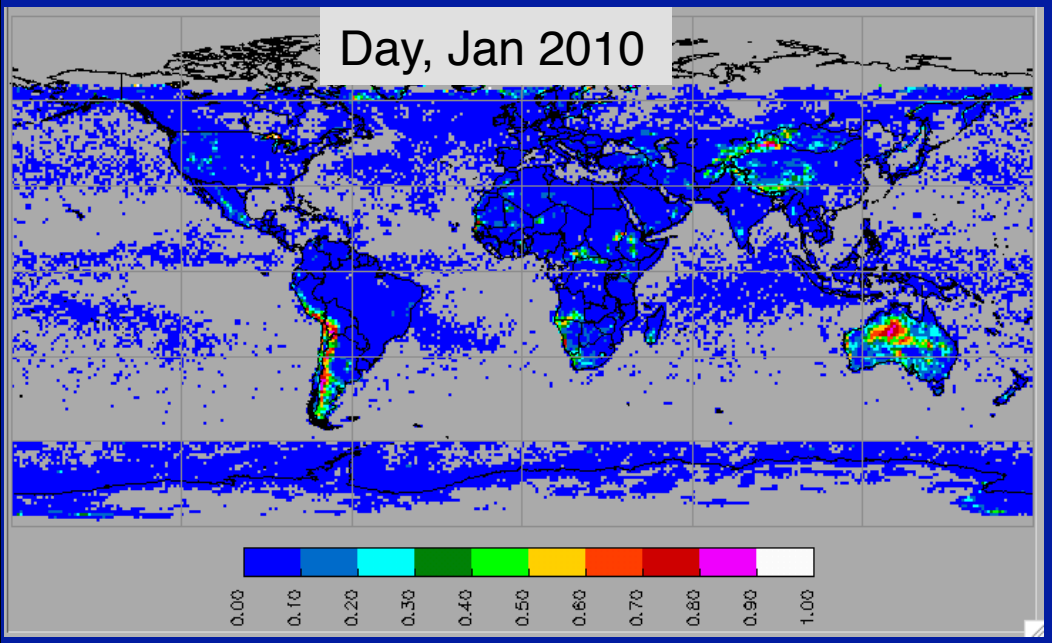
Aqua Mean MOA Clear-sky Temperature – Observed, Day

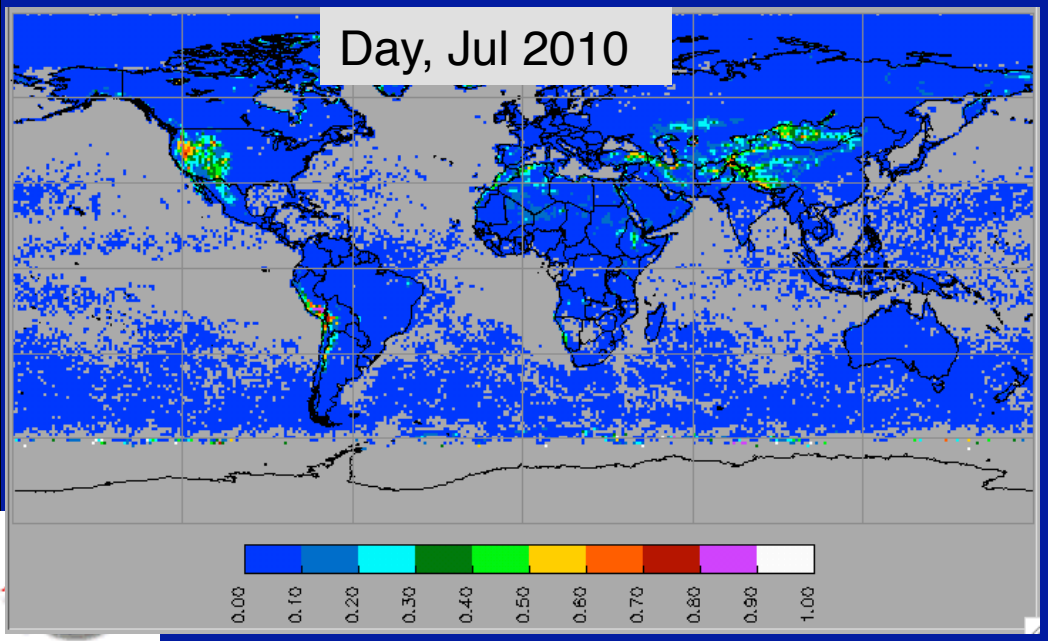
- Temporary statement left in Ed4 & Ed1 code to prevent core dumps
  - If |Tclr(MOA) – Tclr(OBS)| > 10, then Tskin = Tskin(MOA)



- In arid mountainous regions, Tclr(MOA) averages often colder than observed
  - indicates no actual Tskin computed for many samples in this area

Frequency of Replacing Aqua Tskin with MOA



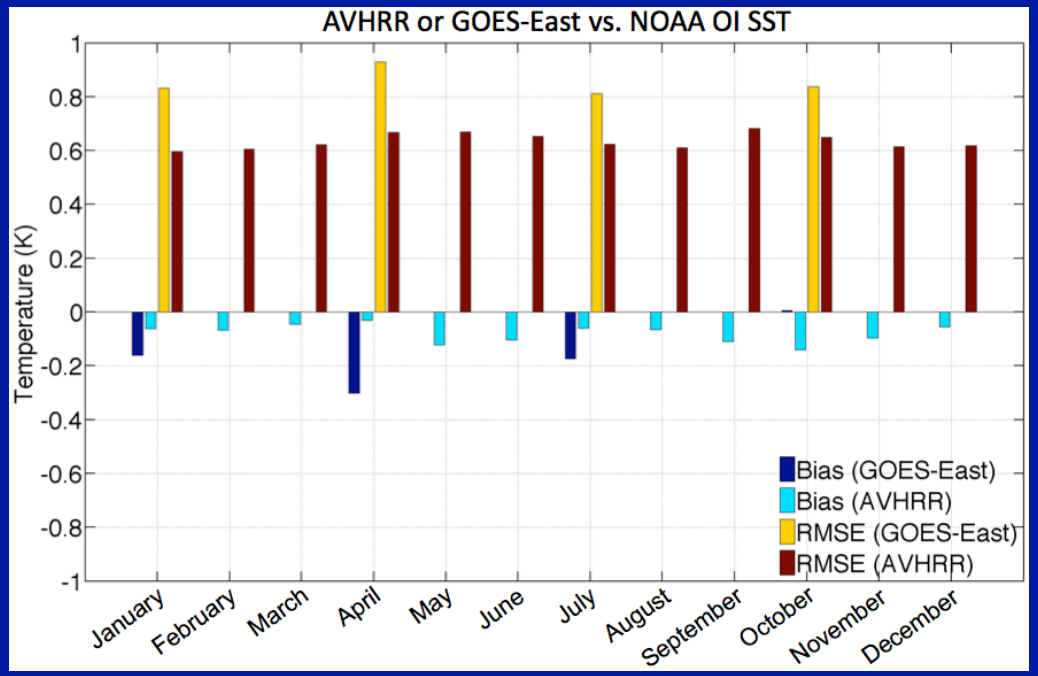


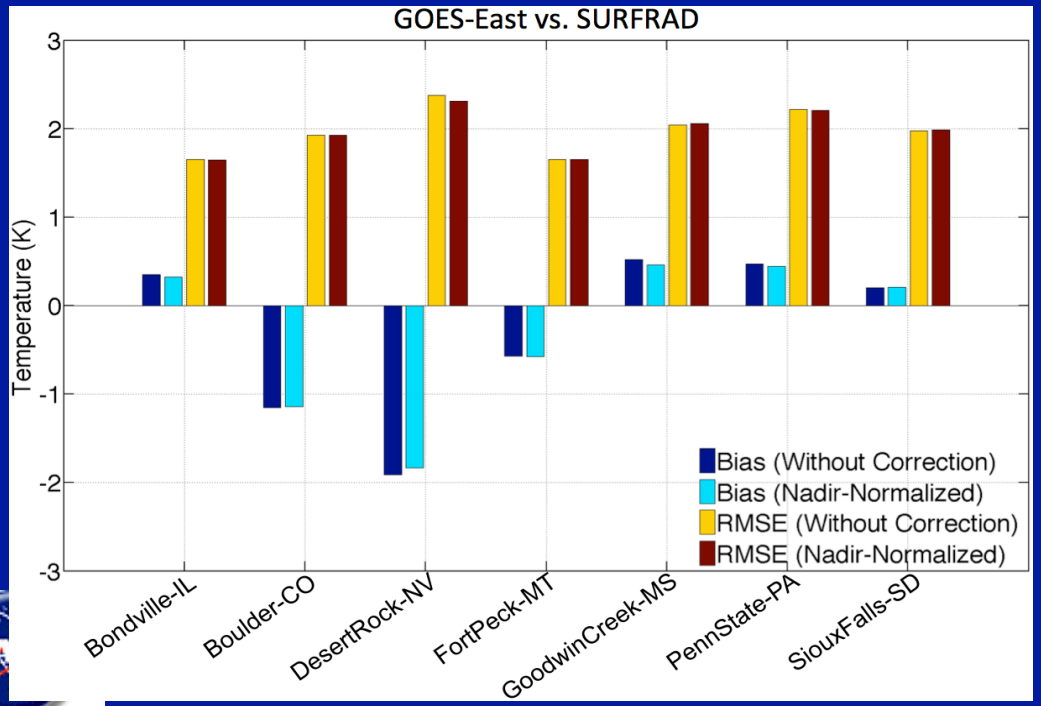
- Tskin not retrieved over hot desert areas in up to 80% of cases over SH
- Smaller substitution rate over NH
- Affects computation of OLR downstream

- Should be easy to replace these “bad” Tskin values with some post-processing of the Ed4 SSF
- Add Tskin to QC for next Eds

Validation of Tskin

2013, AVHRR & GOES



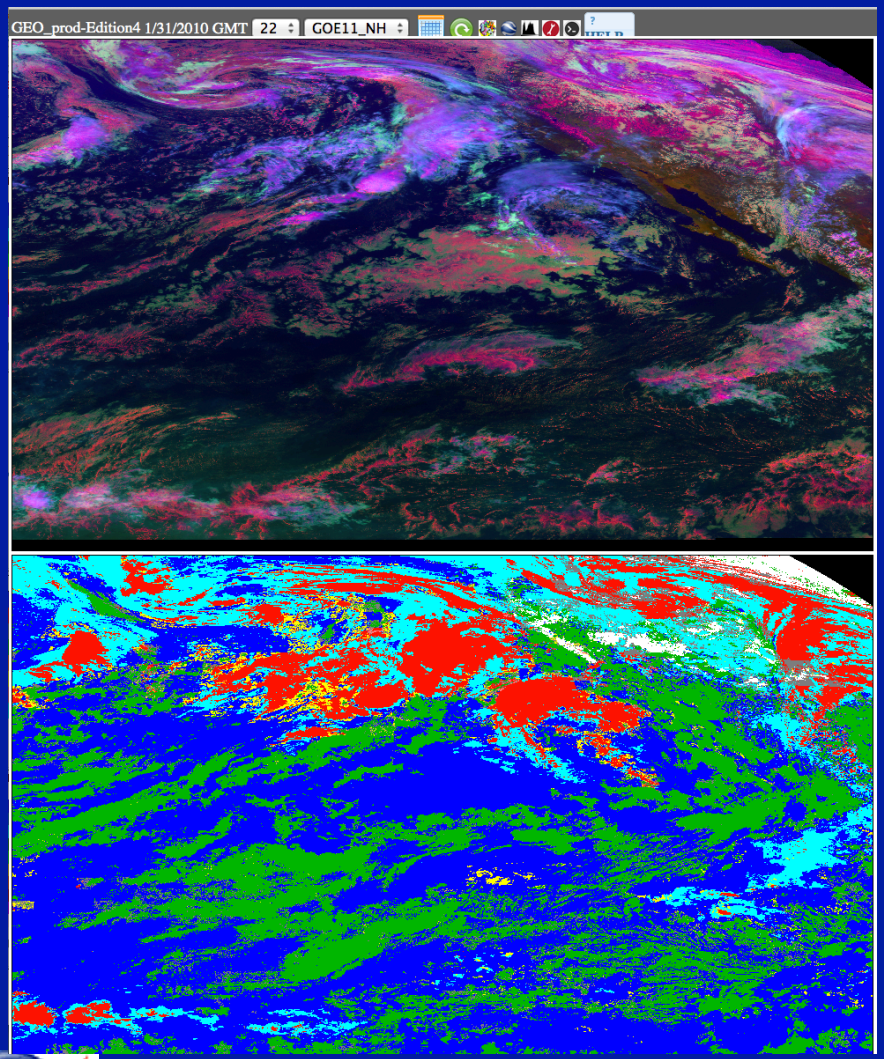


- SST generally biased by < 0.1 ±0.7K compared to OI SST
- LST generally biased by < 1.5 ±2.2 K
- Results as good as any methods available
- Expect similar results for Ed4/ Ed1

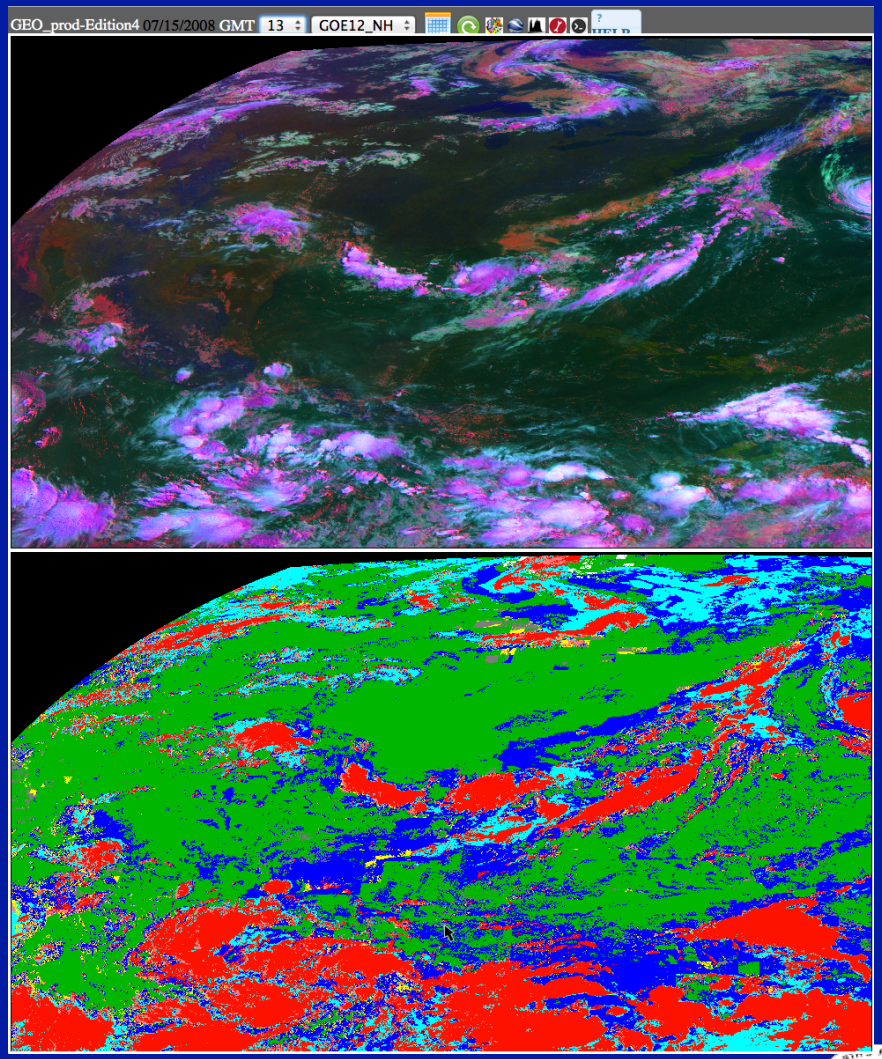
Geosats

Edition 4 GEO Scene Identification

GOES-11 Jan 31, 2010, UTC 2200
Daytime Pacific Ocean and U.S.



GOES-12 Jul 15, 2008, UTC 1300
Daytime U.S. and Atlantic Ocean



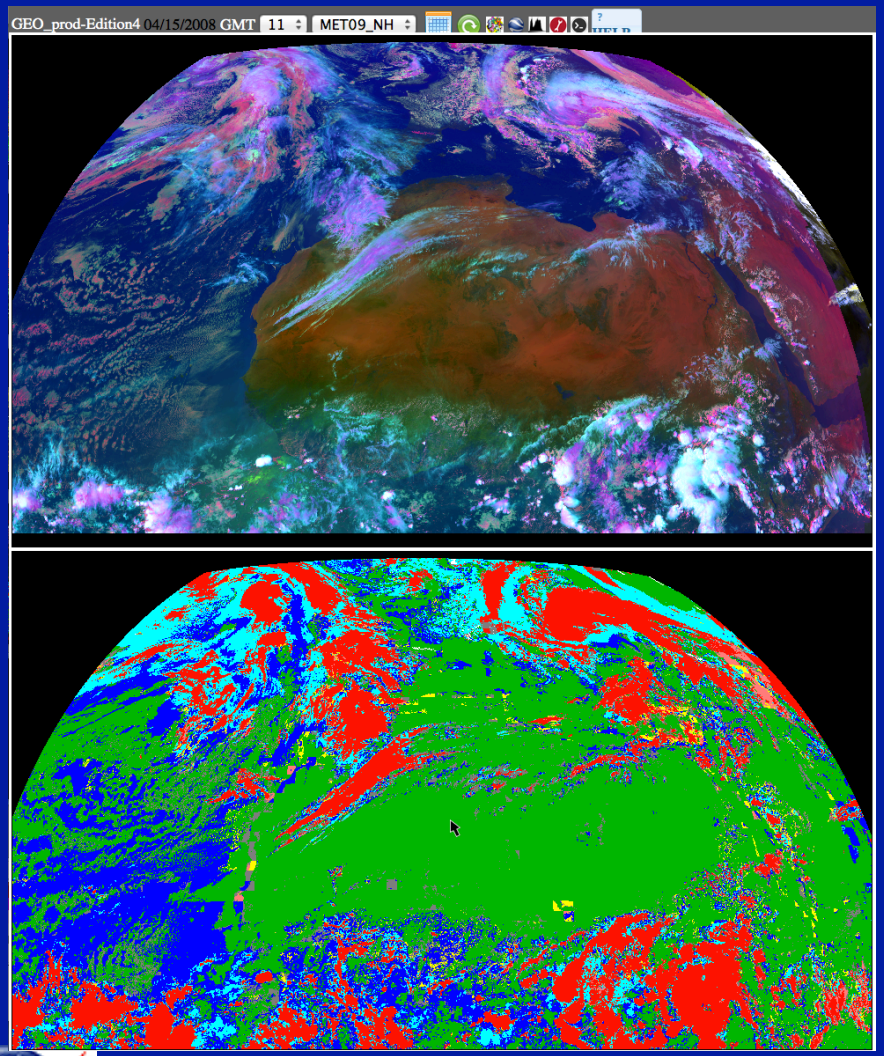
Cloud Phase

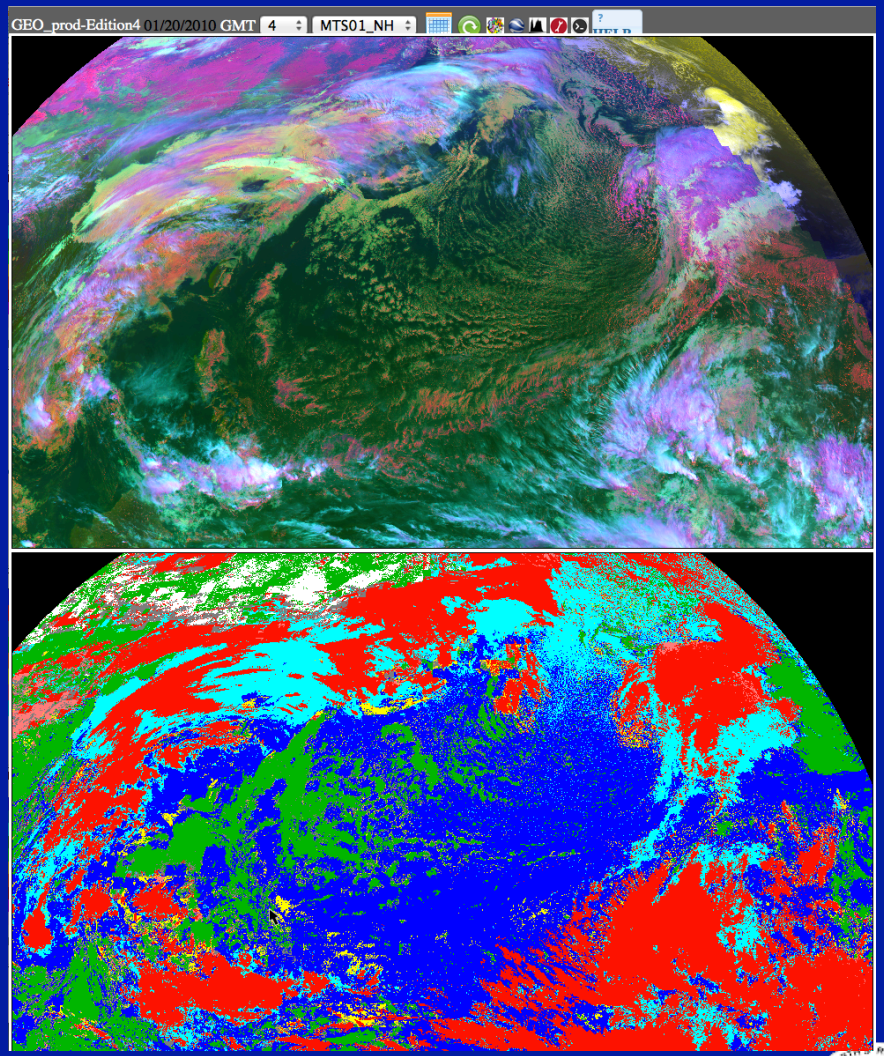
Liq cld T>273	Liq cld T<273	Liq cld weak	Ice cld	ice cld weak	clear	no retrvl	bad data	snow ice

Edition 4 GEO Scene Identification

METEO-9 Apr 15,2008 UTC 1100
Daytime Sahara

MTSAT-1R Jan 20, 2010, UTC 0400
Daytime China and Pacific Ocean





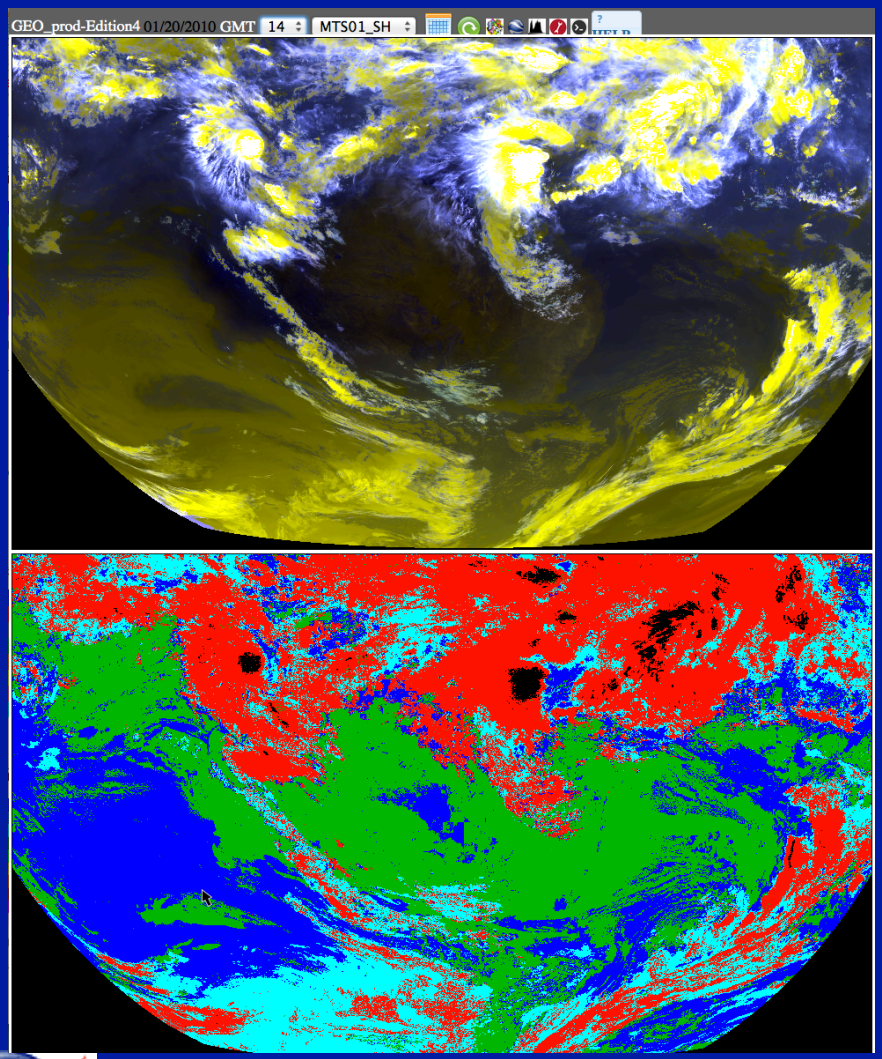
Cloud Phase

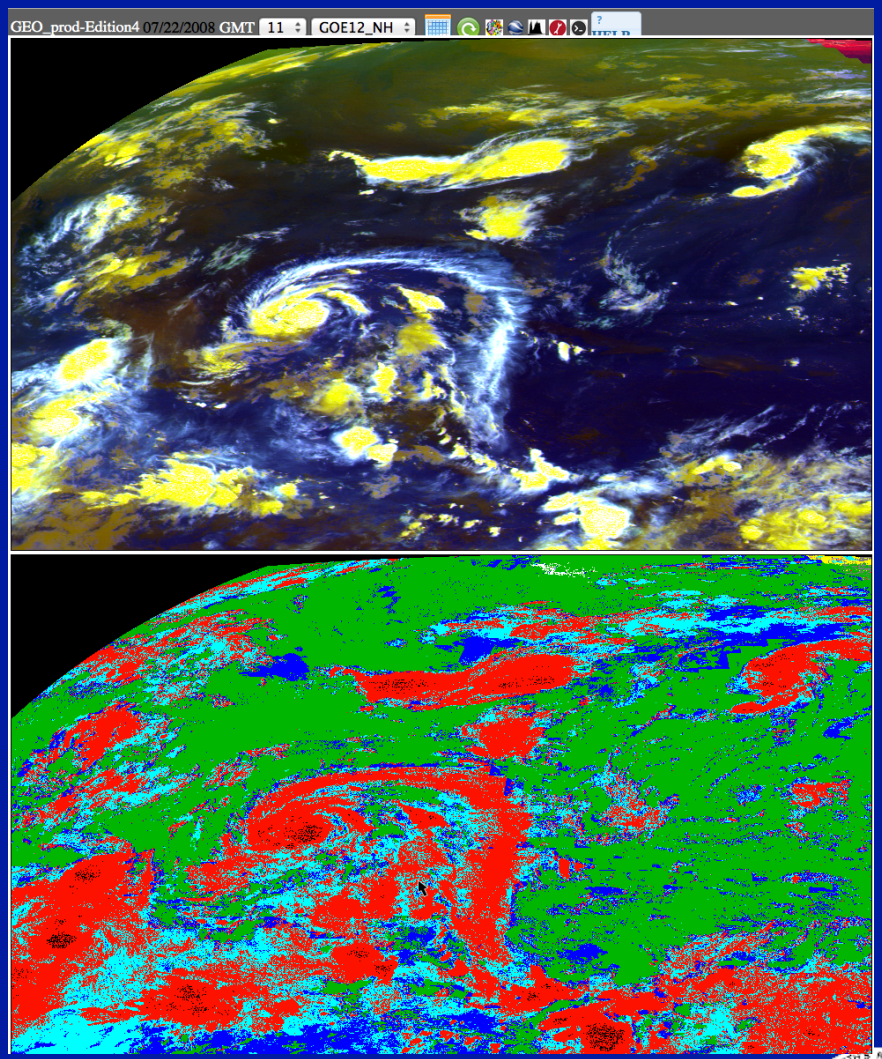
Liq cld T>273	Liq cld T<273	Liq cld weak	Ice cld	ice cld weak	clear	no retrvl	bad data	snow ice

Edition 4 GEO Scene Identification

MTSAT-1R Jan 20, 2010 UTC 1400
Nighttime Australia

GOES12 Jul 22, 2008, UTC 1100
Nighttime U.S.





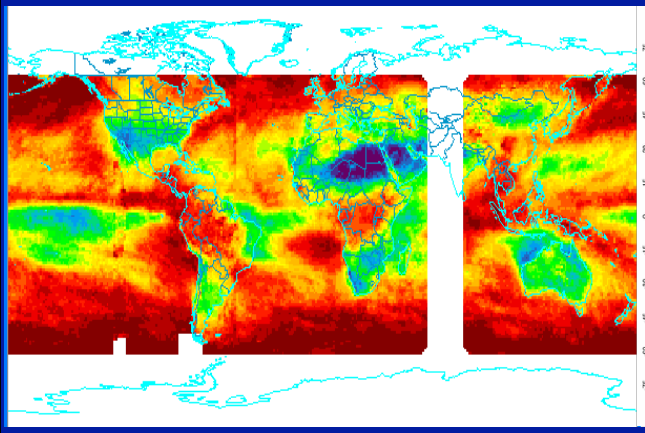
Cloud Phase

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

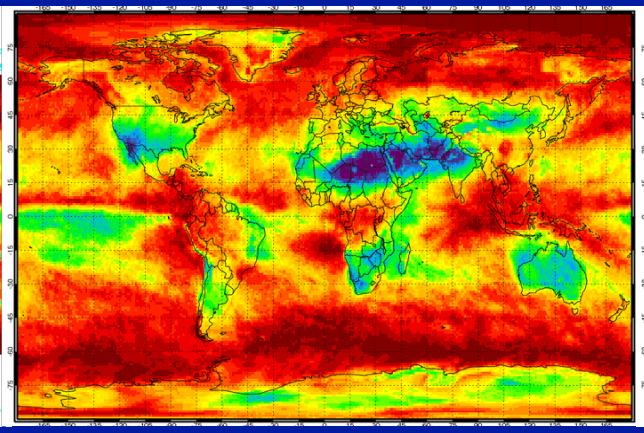
Global Monthly Cloud Fraction Comparison

October 2008 day and night combined

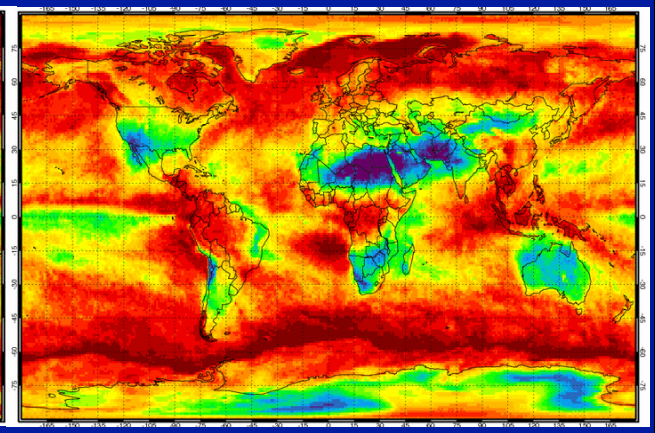
Merged GEO Ed4



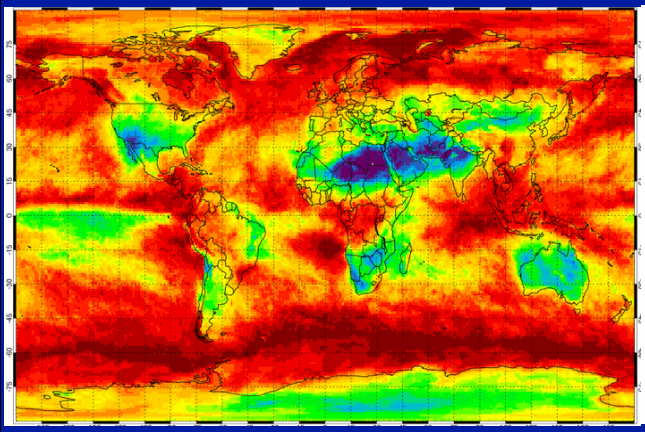
CERES Ed4 Aqua



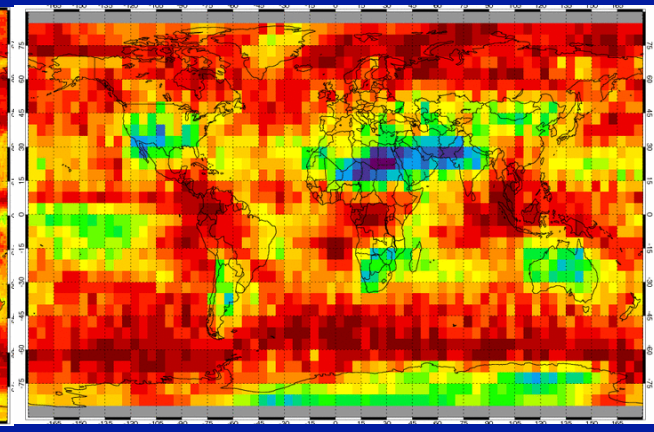
GSFC Aqua Col 6



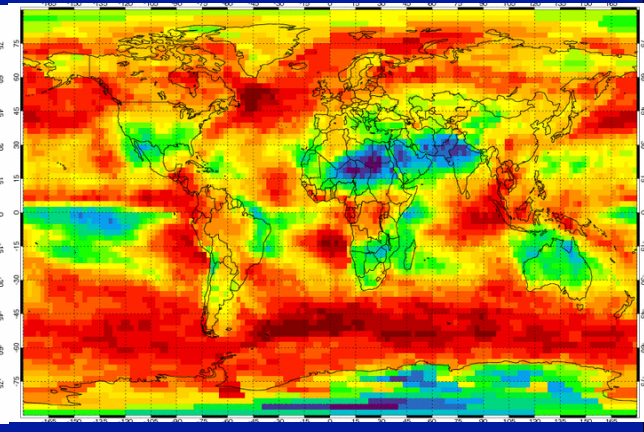
LaRC NOAA-18 AVHRR

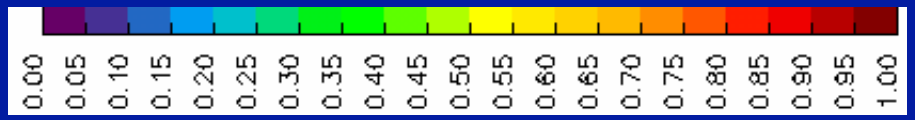


CALIPSO

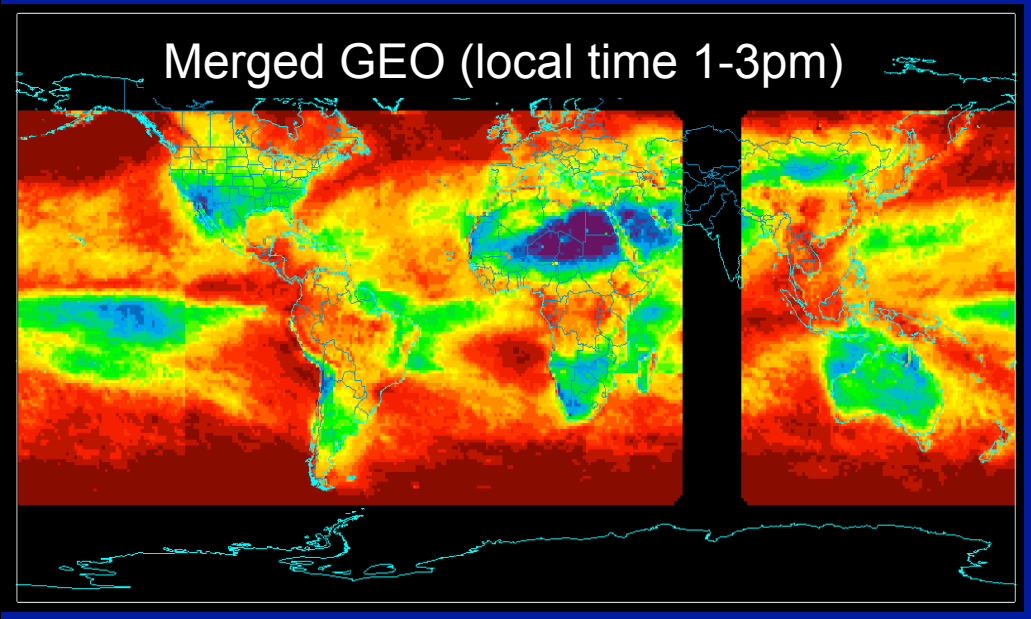


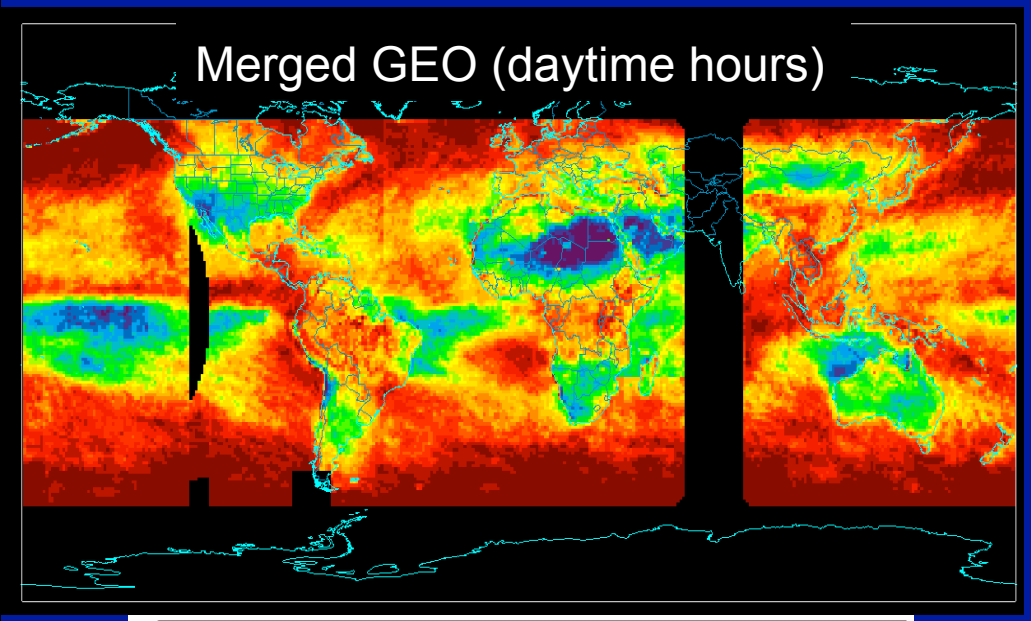
ISCCP

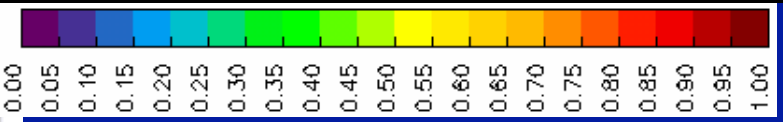




Mean Cloud Fraction, October 2008, day



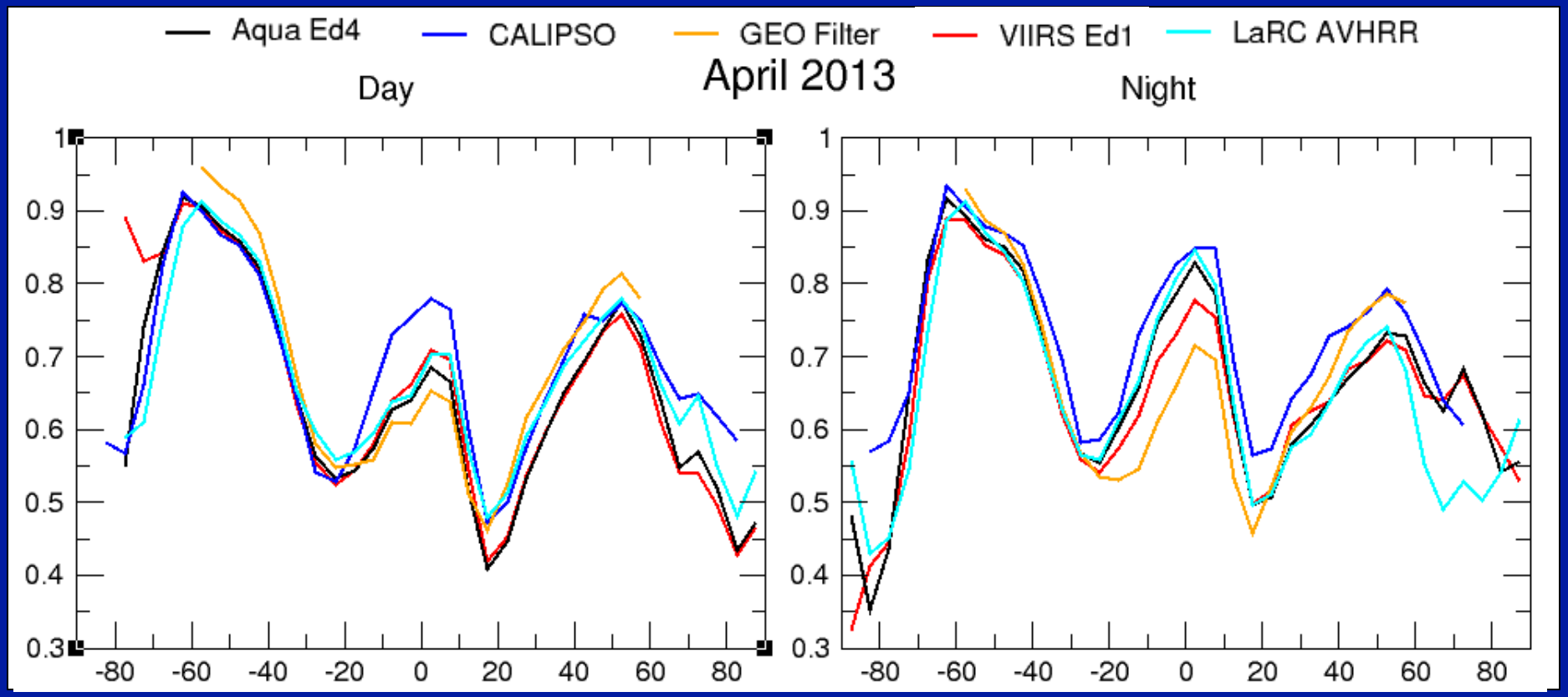




GEO day tropical underdetecting
Mid-lat ocean too large, VZA?

Zonal Monthly Cloud Amount Comparison

GEO Filter, CERES-Aqua, NPP-VIIRS, LaRC AVHRR, and CALIPSO



- Day: VIIRS & Aq consistent everywhere, good consistency < 20S, GEO too low in tropics, too high in extratropics

- Night: VIIRS & Aq close except tropics, GEO too low in tropics

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	

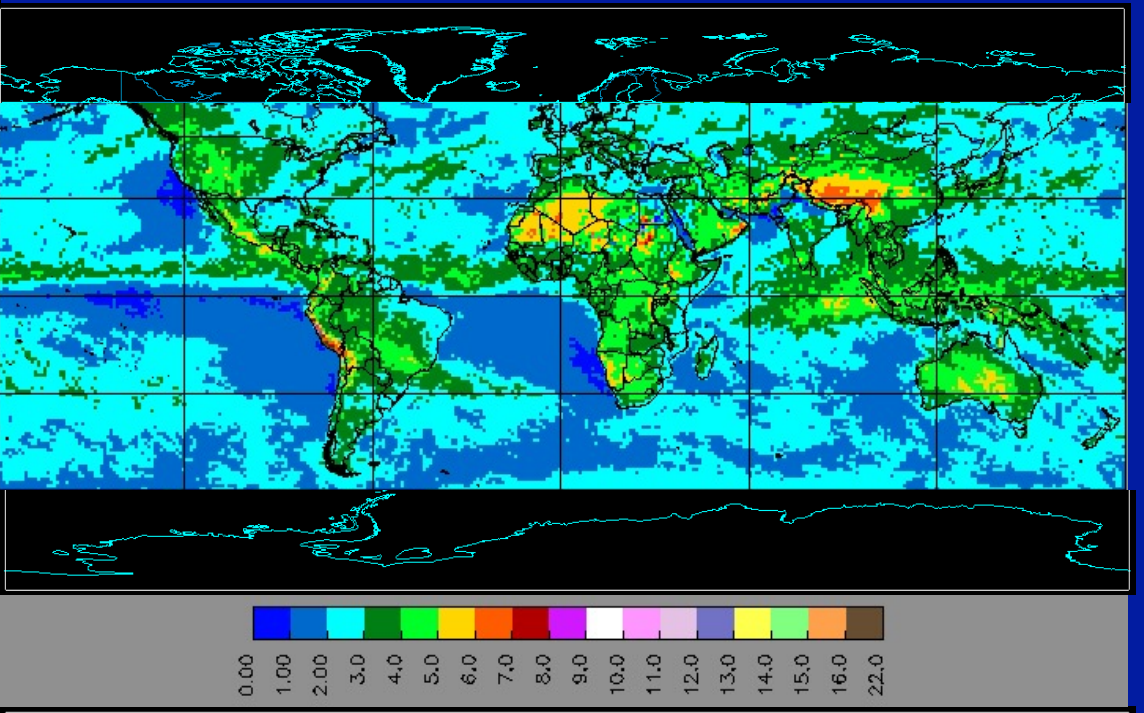
		Daytime (SZA<82)		Nighttime (SZA>=82)	
		CALIPSO		CALIPSO	
		clear	cloud	clear	cloud
MTSAT-1R MTSAT-2R	clear	18.0% 18.1%	6.8% 6.7%	16.5% 19.5%	10.8% 14.1%
	cloud	7.6% 8.0%	67.6% 67.2%	4.7% 3.0%	68.0% 63.4%
	Fraction Correct	FC = 0.856 FC = 0.853		FC = 0.845 FC = 0.829	

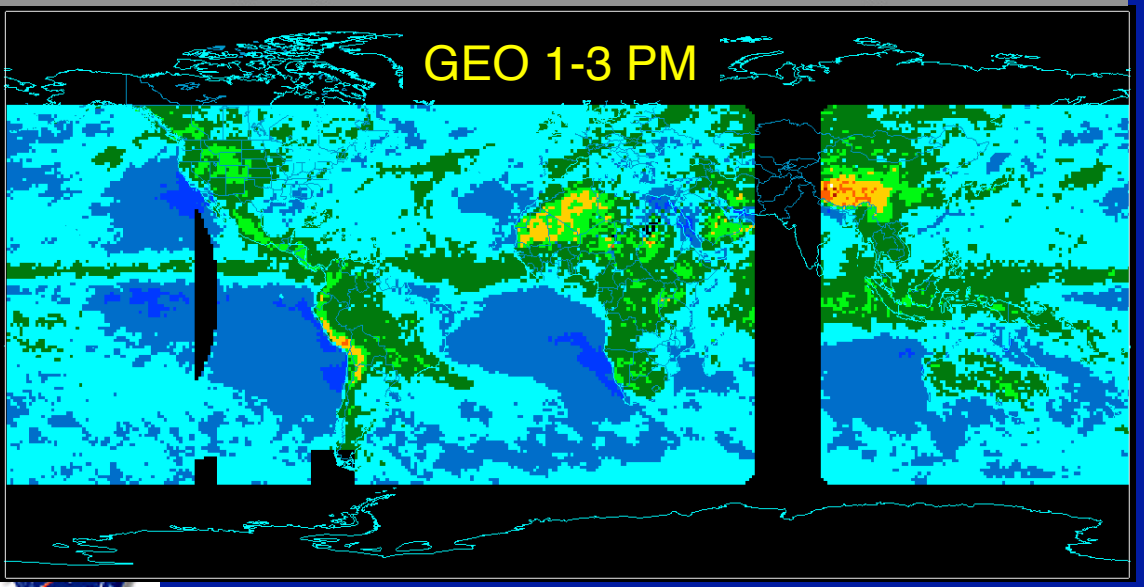
- Day, FC < than FC for Aqua (0.896); Night, FC < FC for Aqua (0.90)
  - expect smaller FC, off-nadir and lo-res data
- GOES-W best (most ocean?) Meteosat worst(desert coastline?)

Mean Liquid Cloud Top Heights

October 2008

CERES Aqua



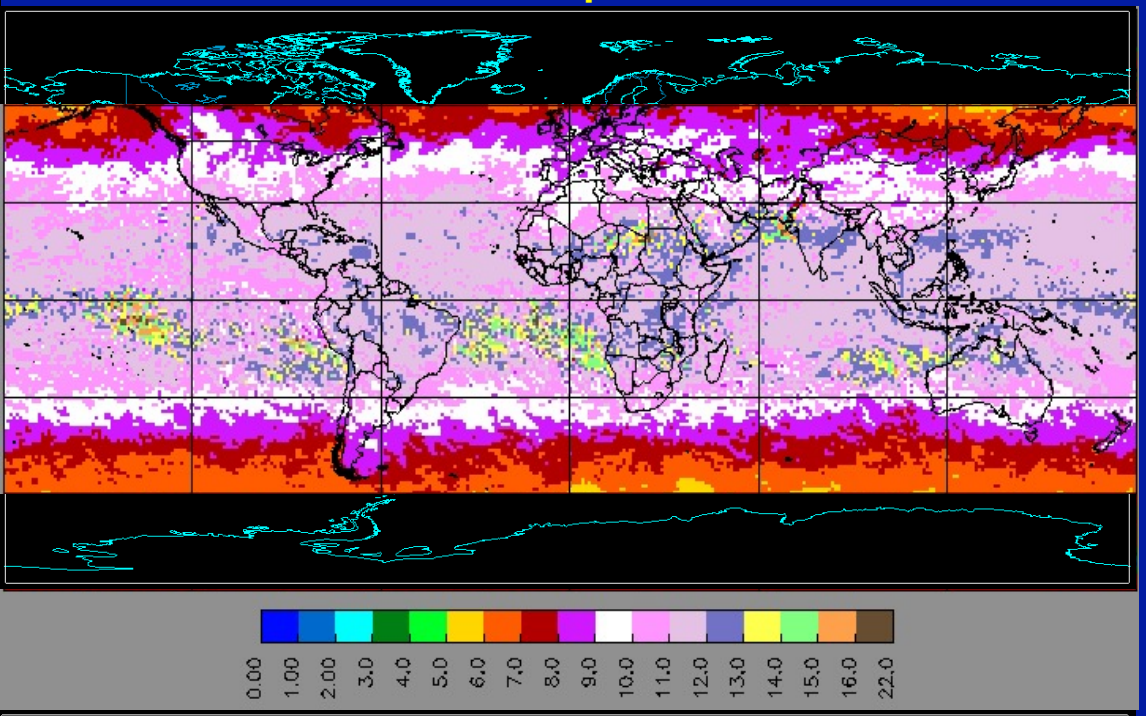


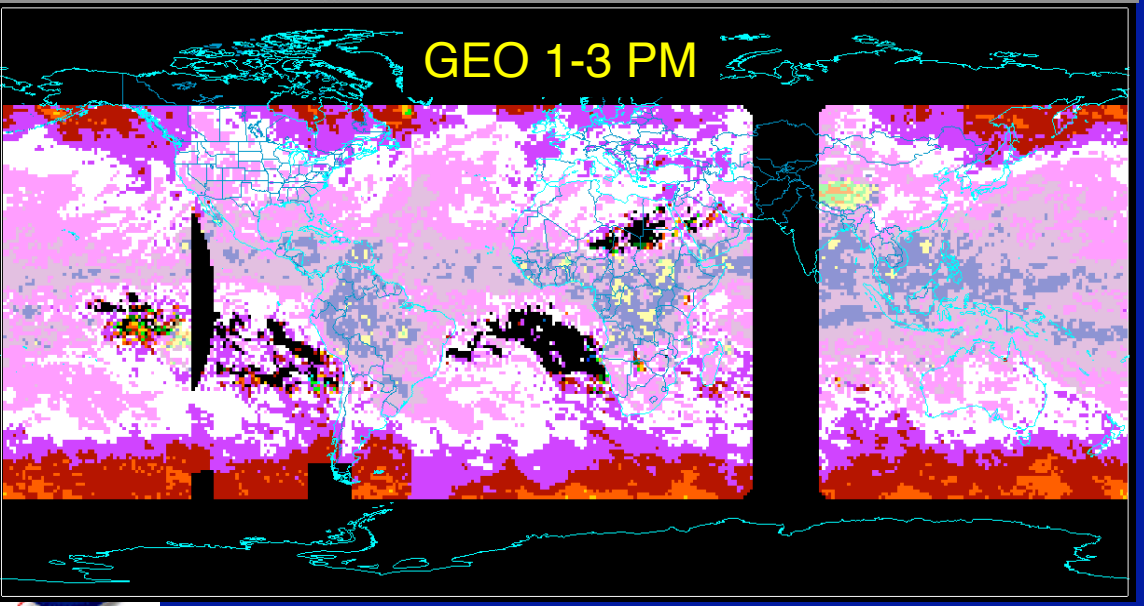
- GEO Zt patterns very close to Aqua
- GEO Zt within < 0.2 km in most places
- GEO biases likely due to lower resolution, VZA effects

Mean Ice Cloud Top Heights

October 2008

CERES Aqua

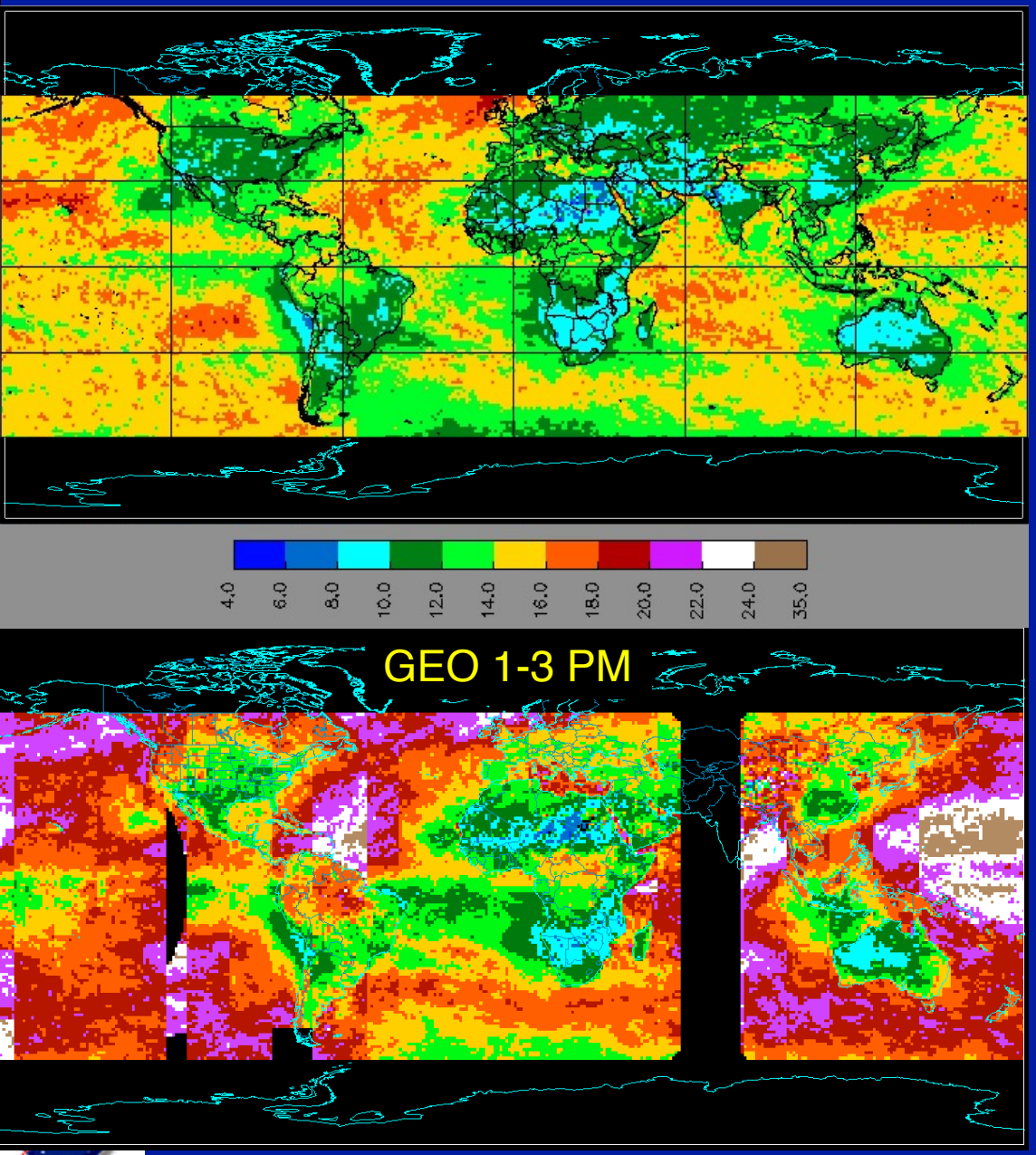




- GEO Zt patterns mostly like the Aqua values
- GEO means are generally within 1 km of Aqua
- GEO biases likely due to lower resolution, VZA effects

Mean Liquid Cloud Re Comparison

October 2008

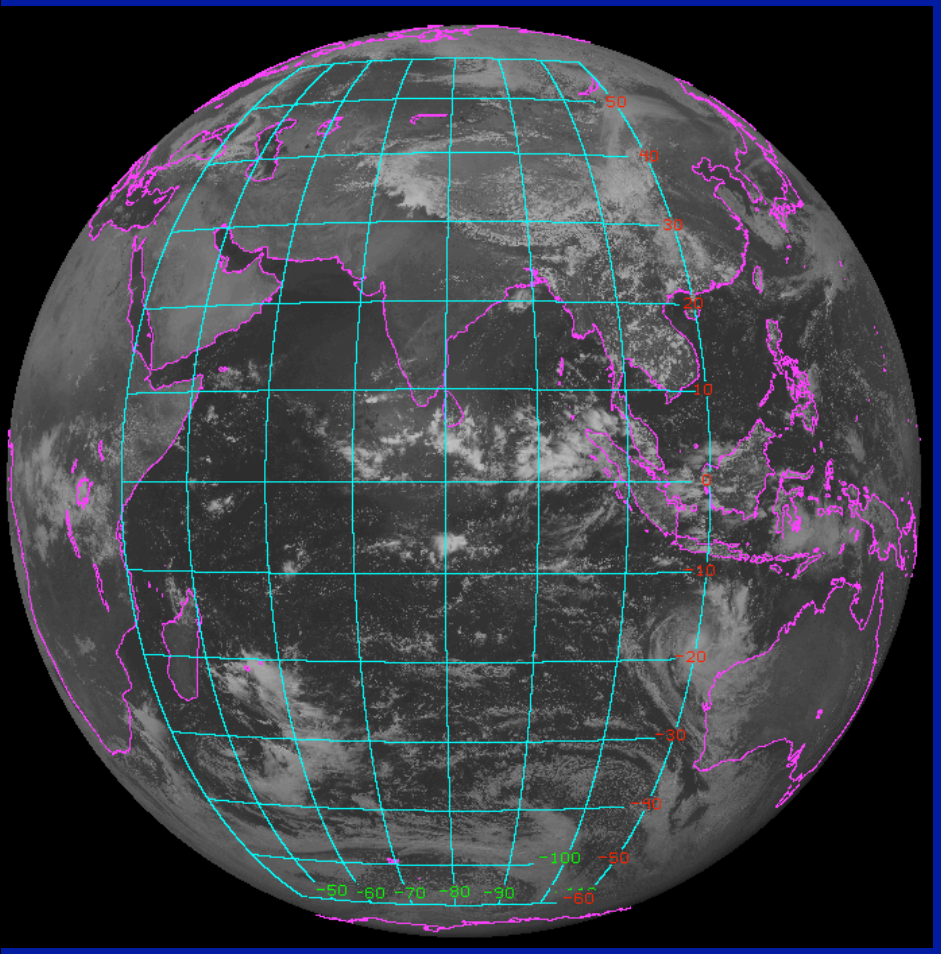


- GEO Re patterns mostly like the Aqua values
- GEO Re 3-4 μm greater than Aqua, except MSG, less bias for smaller values
- GEO biases likely due to crude atmo corrections, lower resolution and VZA effects
- GOES- East sampling not great

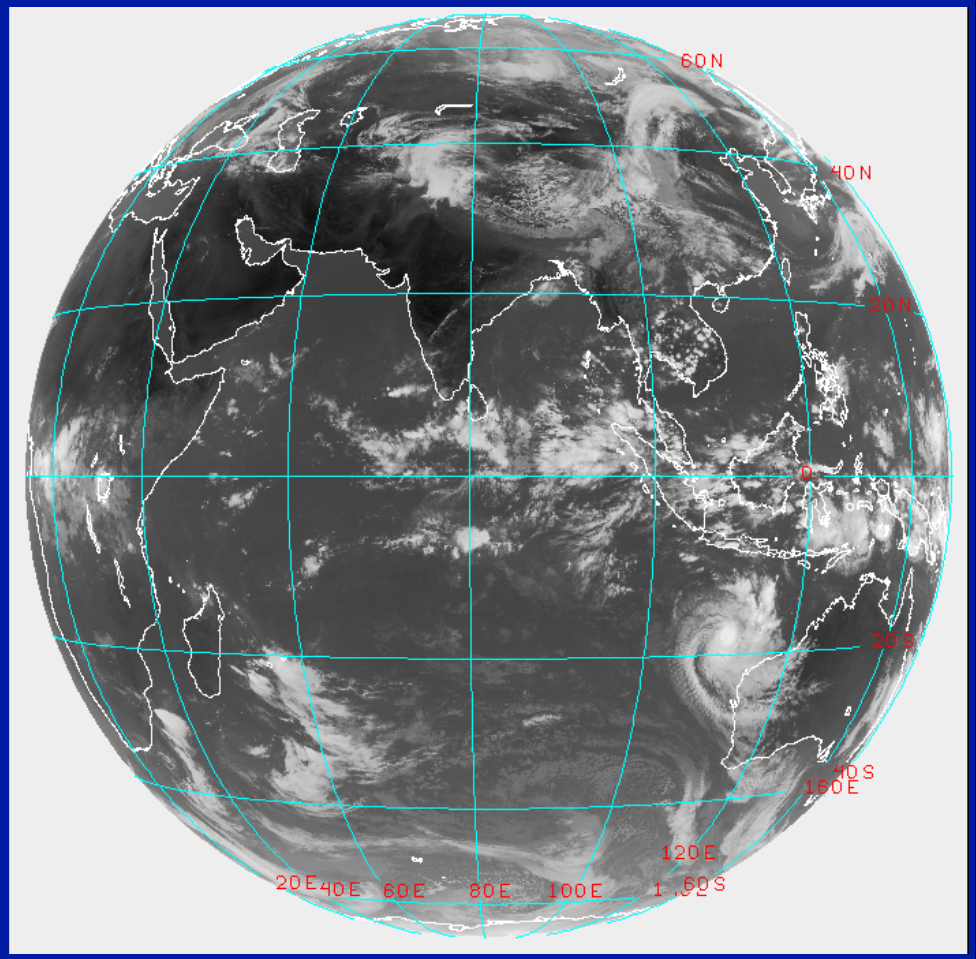
INSAT-3D Geostationary Satellite

April 30, 2015, UTC 0700 UTC

VIS



IR

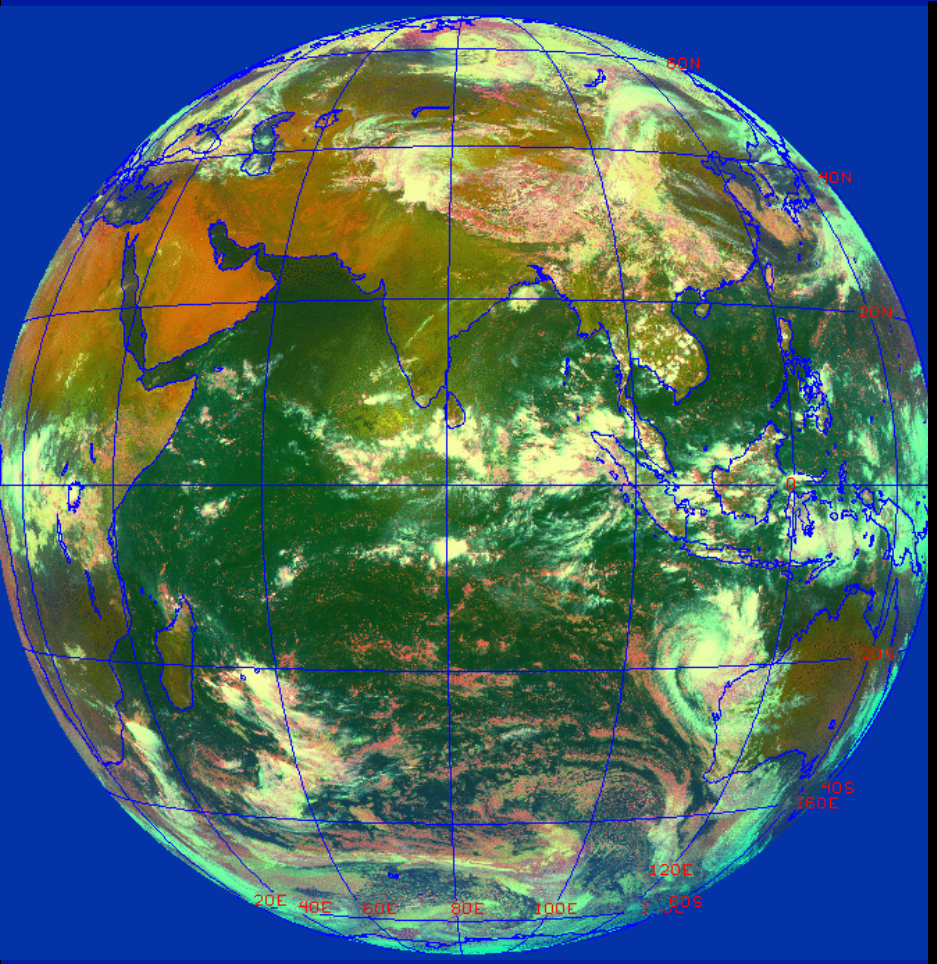


- This is equivalent to the Meteosat-7
  - *old LBTM code applied for cloud analysis*

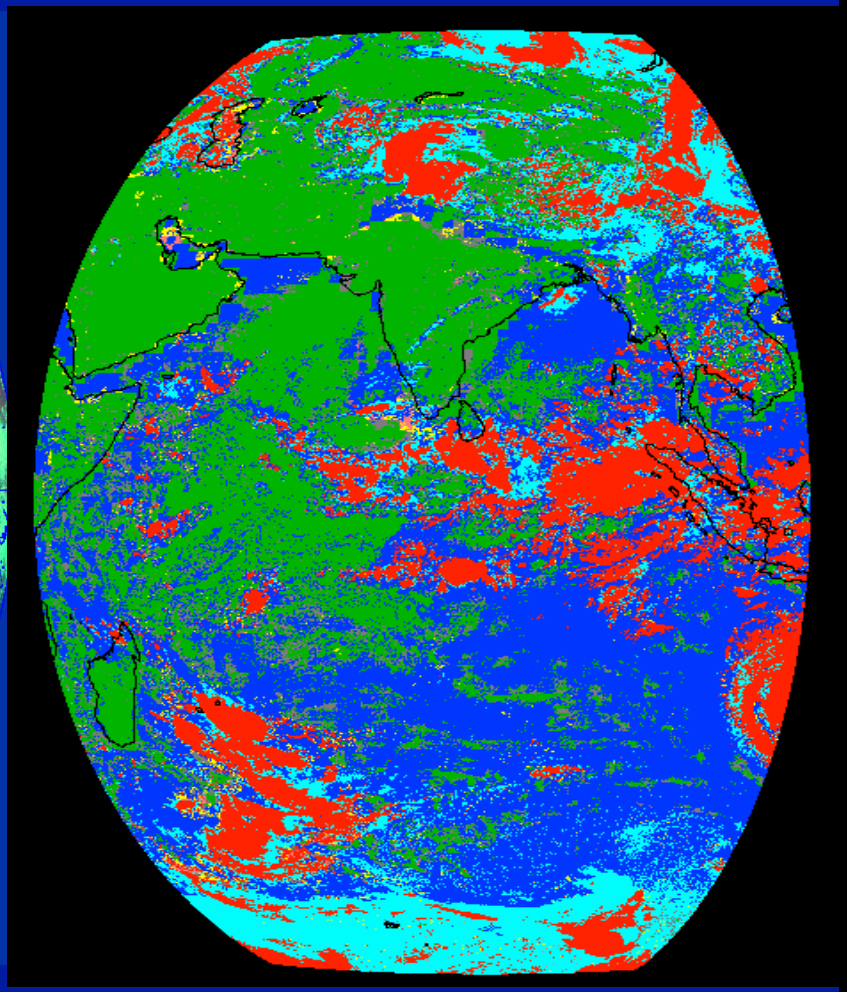
INSAT-3D Geostationary Satellite

April 30, 2015, UTC 0700 UTC

RGB



Cloud Phase



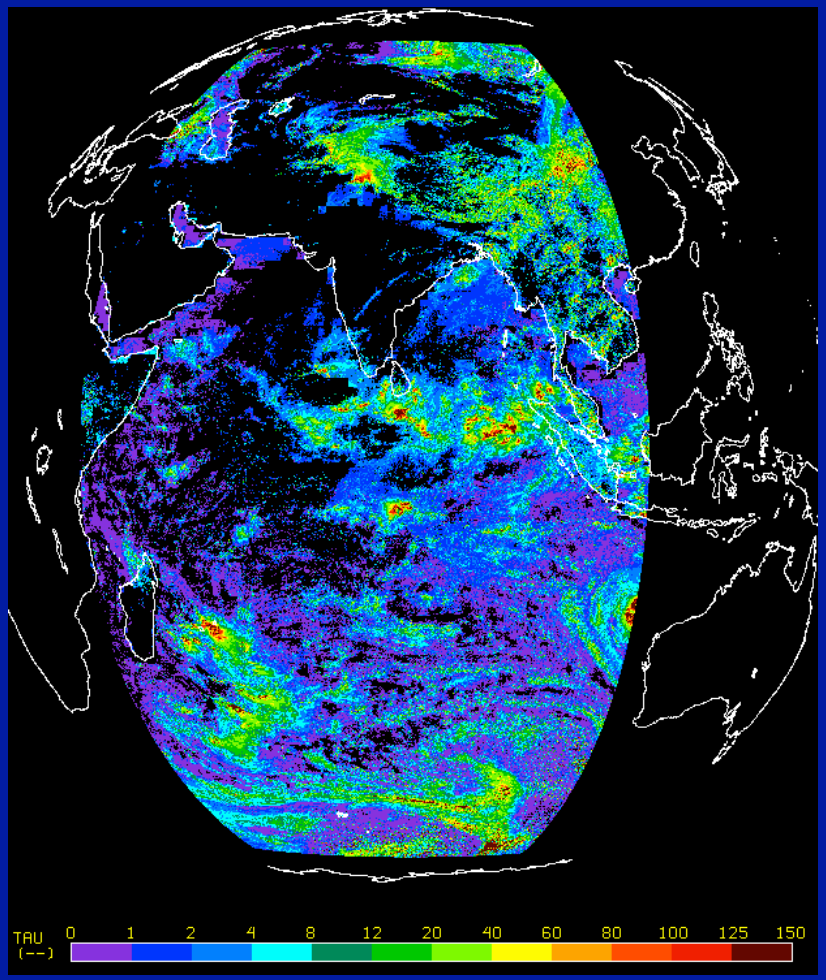
PHASE
SNOW/ ICE
NO/BAD DATA
NO CLD RETRVL
CLEAR
ICE CLD WEAK
ICE CLD
LIQ CLD WEAK
LIQ CLD T<273K
LIQ CLD T>273K

- But has additional channels (1.6, 3.8, 12 μm)
  - *initial VISST analysis performed*
  - *need some tweaking of mask (aerosols & snow)*

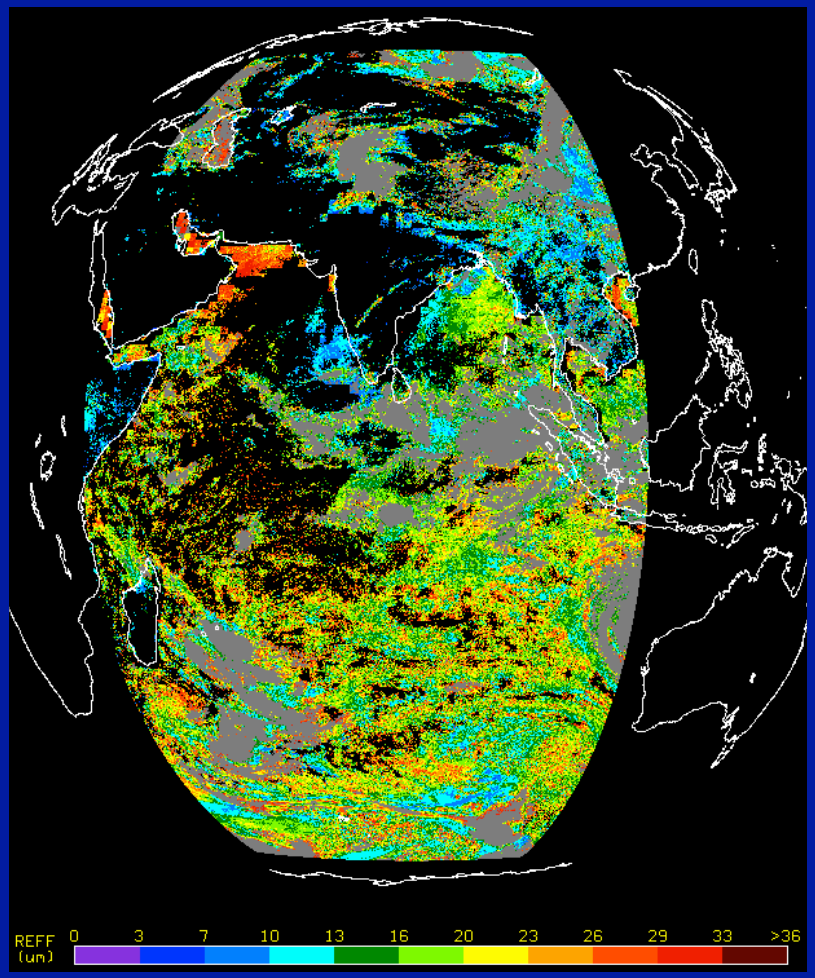
INSAT-3D Geostationary Satellite

April 30, 2015, UTC 0700 UTC

Cloud Optical Depth



Re (µm)



- Initial retrievals
  - *COD looks about right (well done, Conor!)*
  - *Re maybe a little large (need spectral response function)*

Multi-layer Detection by 3 CERES Methods: CO2, BTD, & Pavolonis ML

Computed fraction of correctly identified ML scenes (hit rate H) and number of scenes falsely identified as ML (FAR). CALIPSO VFM is the reference. VFM ML was defined two different ways:

1) Strict ML definition: typical ice-over-water scenes mostly, VFM ID = 6 or 7
2) Loose ML definition: just about anything that could be construed as ML, including deep convective clouds (DCC), VFM ID = 2 (if opaque), 4, 5, 6, 7

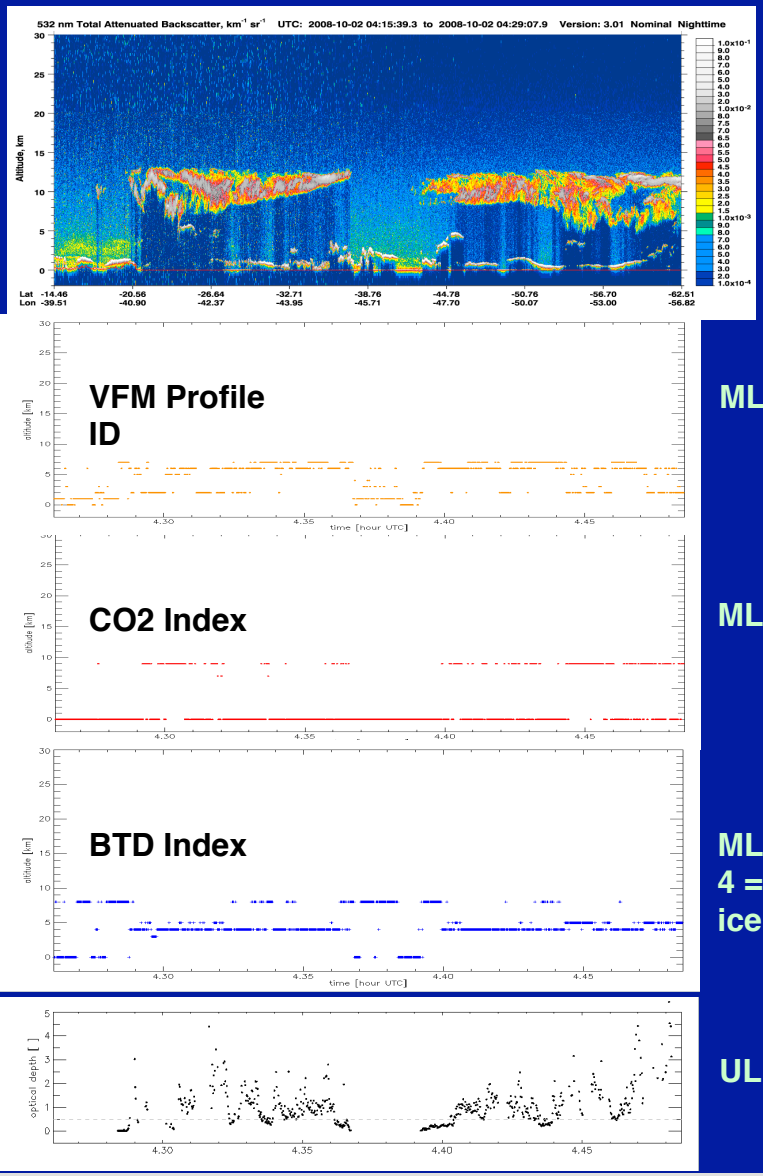
H = (# CO2/BTD/Pavolonis ML) / (# VFM ML)
FAR = (# CO2/BTD/Pavolonis ML) / (# VFM NOT ML)

1) Strict ML

	CO2	BTD	Pavolonis
H	0.17	0.15	0.25
FAR	0.07	0.07	0.13

2) Loose ML

	CO2	BTD	Pavolonis
H	0.22	0.18	0.31
FAR	0.03	0.03	0.07

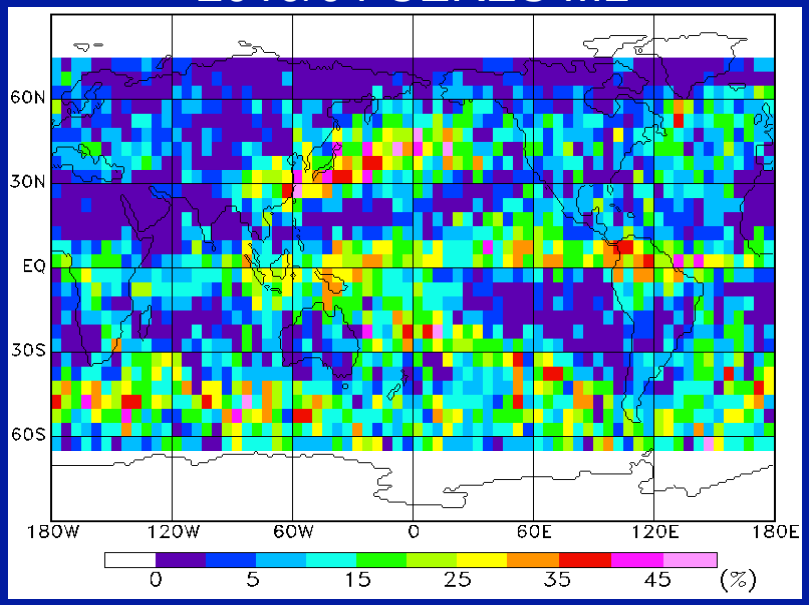


In both cases, BTD has the smallest H and Pavolonis has the largest.

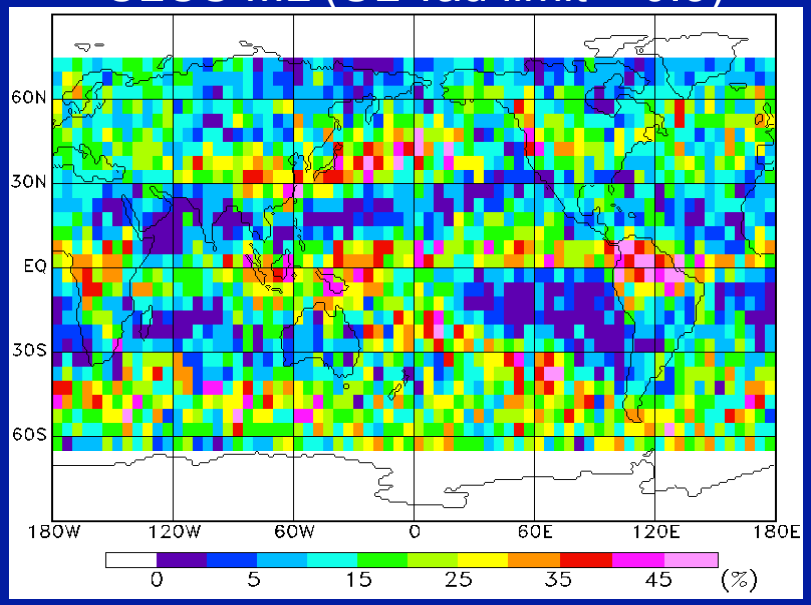
BTD classifies much ML seen here as SL ice, even the anvil portion. CO2 also misses a lot of the anvil too. BTD & CO2 seem to call thick ice ML for the most part.

Compare CERES and CLCS Multilayer Cloud Fractions

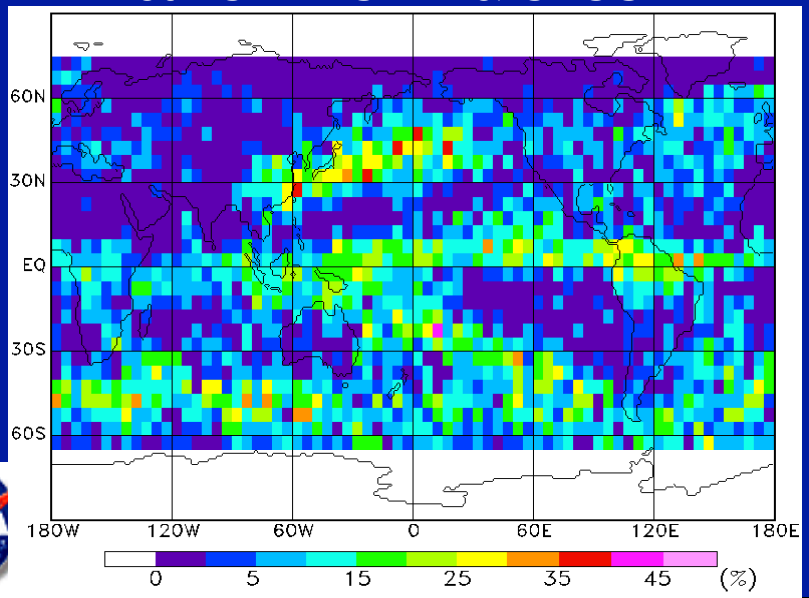
2010/04 CERES ML



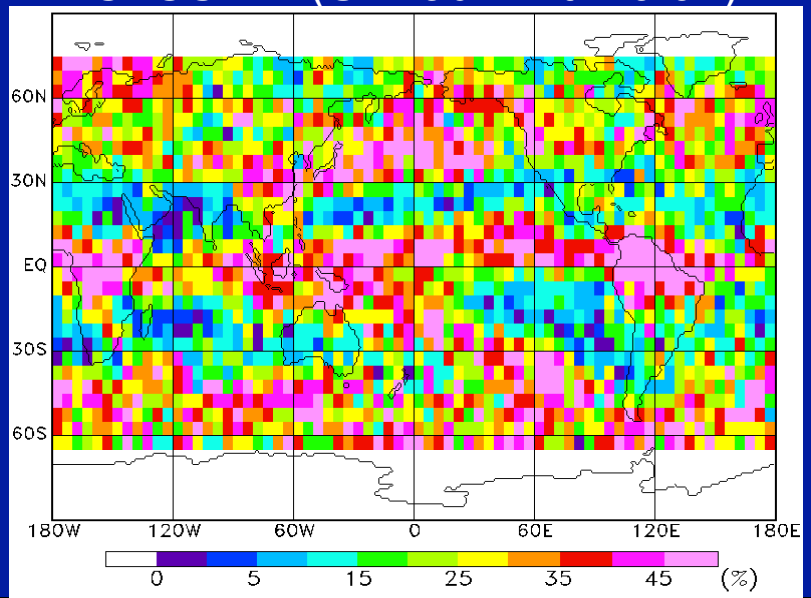
CLCS ML (UL Tau limit > 0.3)



Both CERES ML & CLCS ML



CLCS ML (UL Tau limit > 0.01)



Evaluate CERES and CLCS Upper-Layer and Multilayer Cloud Fractions

Daytime: 2010/04

%		CLCS UL Only	CLCS ML (H-H, H-M, H-L)
		17.3	26.5 (2.7, 5.4, 18.4)
CERES No CO_2 :	17.6	7.1	10.5 (0.3, 0.9, 9.3)
	15.3	6.3	9.0 (0.2, 0.6, 8.1)
*Red: Fractions that CLCS UL Tau < 0.3 (Ec < 0.15), CO_2 retrieval uncertain.			
CERES UL Only :	16.4	7.3	9.1 (1.2, 2.3, 5.6)
	6.9	3.0	3.9 (0.3, 1.1, 2.5)
	9.5	4.3	5.2 (0.9, 1.2, 3.1)
*Red: Fractions that CERES UL IR Ec > 0.80, ML retrieval uncertain. *Pink: Fractions that CERES LL Tau < 1.0+δ, ML retrieval uncertain.			
CERES ML :	9.8	2.9	6.9 (0.9, 2.1, 3.9)
	6.7	2.6	4.1 (0.8, 1.8, 1.4)
*Red: Fractions that CLCS ML decided by CS due to CL attenuation.			

Validation of CERES Ed4 Multilayer Cloud Properties

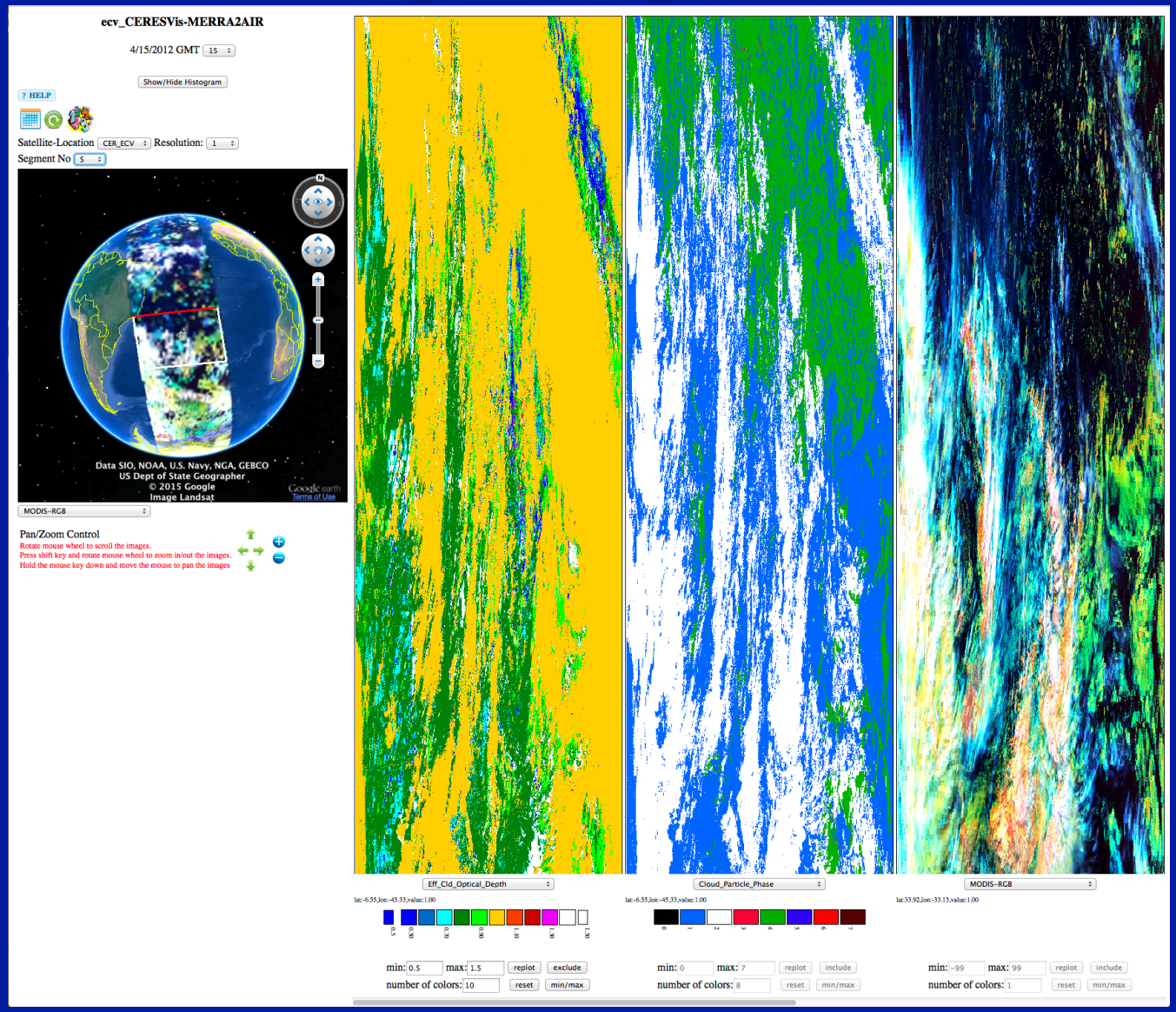
Summary

- In the C3M data, the global ML cloud overage was found to be ~0.10 for the CERES Ed4 and ~0.27 for the merged CALIPSO/CloudSat (CLCS).
- About 1/3 of the CLCS ML clouds had thin upper-layer cirrus optical depth < 0.3.
- About 15% of the CLCS ML clouds had near-opaque upper-layer emissivity > 0.8. For those, CERES ML was undecided.
- Another 20% of the CLCS ML clouds had thin lower cloud optical depth. For those, CERES ML retrieved them as single-layer clouds.
- About 70% of the CERES ML clouds agreed well with CLCS ML clouds while about 20% were vertically continuous clouds.
- About 26% of the CERES ML clouds had CLCS-UL only clouds, where CALIPSO were attenuated by the UL clouds and no lower cloud was detected by CloudSat.

Known Potential Errors

- The CERES-ML UL IR emissivity computations may contain errors due to a common block error in the data processing code.
- The CERES ML Lookup Table used for conversions from water-phase to ice-phase optical depths was not up-to-date.

Initial Testing of Yang 2-Habit Model



- τ_{ice} typically drops 15-25% with new model, further testing ahead

Summary

- Comparisons with C6 MODIS radiances
  - Aqua & Terra C5 with corrections very consistent with Ed4
    - Aqua VIS degrading in both
    - *C5' yields tighter Terra-Aqua 3.8-µm consistency than C6*
- VZA variations of cloud parameters quantified
  - *nothing too surprising*
  - *compensating CF, Re, and τ effects yield nearly flat CWP dependence*
- New comparisons with surface & airborne data
  - *adiabatic assumption should be used for LWP calculations (stratus +?)*
  - *Re(ice) represents top 0-3 opt depths; possible means for estimating Re(avg)*
  - *Zt errors consistent with CALIPSOs, main problems with Ci & Cu*
- Tskin from MODIS & VIIRS has a bug, but otherwise very accurate
  - *could be corrected post facto in SSF, or simply given a warning for users*
- GEO analyses underway, bug found in nocturnal DCC pixels
  - *cloud fractions low in tropics, high in midlats, Re too big*
  - *first analysis of INSAT-3D, will be part of suite from 2015 onward*
- ML cloud retrievals better understood => *know where & when they work*
- Evaluation of new 2-habit ice model underway
- AND MUCH MORE

Future

LEOsat

- Restore Tskin in SSF offline?
- Continue validation studies, e.g., ARISE, TC4, ARM
- Finalize new 1.24, 1.6, 2.1 models; complete testing of 2-Habit model
- Examine methods for improving Zt, nocturnal COD, ML detection/retrieval, retrievals over snow/ice, IWP/LWP based on profiles
- Continue DQS writing Ed4/Ed1, write up Ed4 code paper

GEOsat

- Repair DCC bug in GEO code
- Install high-res 3.9-µm spectral corrections to reduce Re
- Refine code for INSAT-3D, aerosols?
- Develop code to process Himawari-8 and GOES-R imagers
- Continue testing new P Yang 2-habit ice crystal model to reduce ice COD error
  - Ed5
- Document GEOsat retrievals

- MUCH MUCH MORE

Thanks