CERES MODIS & VIIRS Cloud Properties: Update Fall 2016

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Thanks to Dave Doelling and his calibration team!

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

Topics

- Publications
- Status
- MODIS Collection 6 vs 5
- Changes for Ed5
    - new ice models
    - multilayer
    - clouds over snow
- VIIRS: use CrIS?

Bill Smith

- GEO clouds

Update of CERES Cloud-related Papers since April 2016

Edition-4 related

Painemal, D., T. Greenwald, M. Cadeddu, and P. Minnis, 2016: First extended validation of satellite microwave liquid water path with ship-based observations of marine low clouds. *Geophys. Res. Lett.*, **43**, doi:10.1002/2016GL069061.

Dong, X., B. Xi, S. Qiu, P. Minnis, S. Sun-Mack, and F. Rose, 2016: A radiation closure study of Arctic cloud microphysical properties using the collocated satellite-surface data and Fu-Liou radaitive transfer model. *J. Geophys. Res.*, **121**, doi: 10.1002/2016JD025255.

Foster, M. J., S. A. Ackerman, K. Bedka, R. A. Frey, L. DiGirolamo, A. K. Heidinger, S. Sun-Mack, B. C. Maddux, W. P. Menzel, P. Minnis, M. Stengel, and G. Zhao, 2016: Cloudiness [in "State of the Climate 2015"]. *Bull. Amer. Meteorol. Soc.*, **97**, S28-S29.

Norris, P. M., A. M. da Silva, B. M. Auer, and P. Minnis, 2016: Monte Carlo Bayesian inference on a statistical model of sub-grid column moisture variability using high-resolution cloud observations: a radiative validation. *J. Adv. Mod. Earth Sys. (JAMES). Submitted.*

Zhang, Z., X. Dong, B. Xi, H. Song, P.-L. Ma, S. Ghan, S. Platnick, and P. Minnis,2016: Intercomparisons of marine boundary layer cloud properties from two MODIS products, ground-based retrievals, and a GCM over the ARM Azores site. *J. Geophys. Res.*, submitted.

Sun-Mack, P. Minnis, Y. Chen, D. R. Doelling, and B. Scarino, 2016: Calibration changes to Terra MODIS Collection-5 radiances for CERES Edition 4 cloud retrievals. *IEEE Trans. Geosci. Remote Sens.*, in preparation.

Tian, J., X. Dong, B. Xi, P. Minnis, S. Sun-Mack, and W. L. Smith, Jr., 2016: Comparisons of water path in deep convective systems among CERES-MODIS, GOES, and ground-based retrievals. In preparation, *J. Geophys. Res*.

Trepte, Q. Z., P. Minnis, C. R. Yost, S. Sun-Mack, and Y. Chen, 2016: Global cloud detection for CERES Edition 4 using Terra and Aqua MODIS data. *J. Atmos. Oceanic Technol.*, In preparation.

Chang, F.-L., P. Minnis, S. Sun-Mack, and Y. Chen, 2016: A CO_2 overlapping cloud property retrieval scheme applied to CERES-MODIS data. In preparation.

Minnis, P., S. Sun-Mack, C. R. Yost, Y. Chen, et al., 2016: Changes to CERES MODIS cloud product retrieval algorithms for Edition 4. *IEEE Trans. Geosci. Remote Sens.*, in preparation.

Edition-5 related

Minnis, P., G. Hong, S. Sun-Mack, W. L. Smith, Jr., and S. Miller, 2016: Estimation of nocturnal ice cloud optical depth and water path from MODIS multispectral infrared radiances using a neural network method. *J. Geophys. Res.*, **121**, doi: 10.1002/2015JD024456.

Scarino, B. R., P. Minnis, T. Chee, K. M. Bedka, C. R. Yost, and R. Palikonda, 2016: Global clear-sky surface skin temperature from multiple satellites using a single-channel algorithm with viewing zenith angle correction. *Atmos. Meas. Tech.*

CERES MODIS Status (Collection 5 Data)

- Ed2 processing
  - *Aqua: through May 2016, will continue until January 2017 (?)*
  - *Terra: through May 2016, will continue until January 2017 (?)*
- Ed4 Beta-2 processing
  - *Aqua: through April 2016 (~14 y)*
  - *Terra: through April 2016 (~16 y)*

CERES VIIRS Ed 1 Status

- Ed1 delivered, 4 years completed
  - *Jan 2012 – Dec 2015*

CERES Data Quality Summaries

- DQS clouds validation for Ed4 available
    - Full DQS available

https://eosweb.larc.nasa.gov/project/ceres/quality_summaries/CER_SSF_Terra-Aqua_Edition4A.pdf

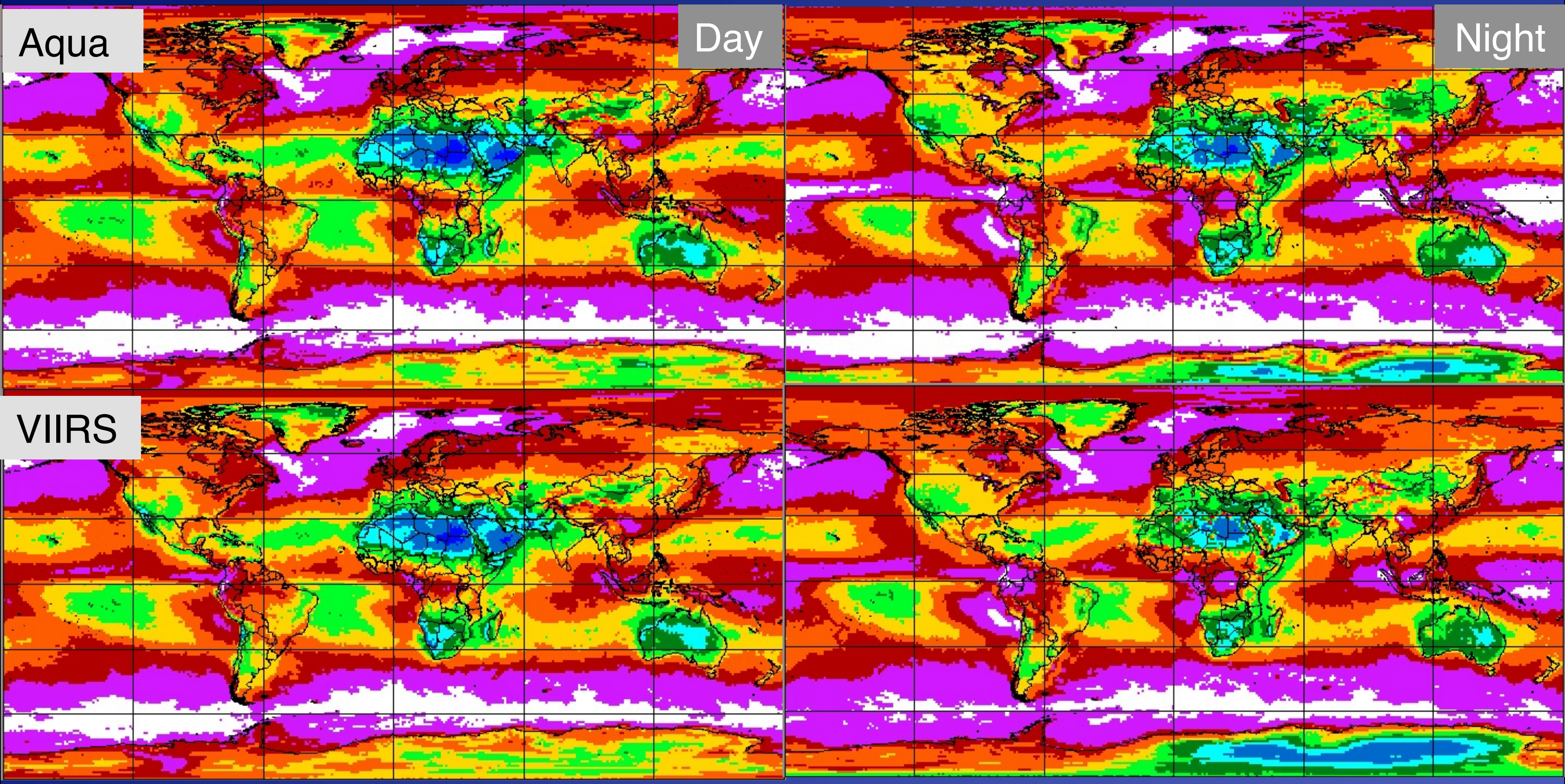
- DQS Validation started for VIIRS Ed1

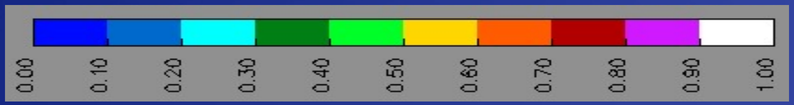
- DQS validation for GEOSat analyses next

Intersatellite Consistency

- VIIRS vs. Aqua MODIS: 2015

Aqua & VIIRS Daytime Mean Cloud Fraction, 2015





	Aqua	SNPP
Day	0.650	0.652
Night	0.684	0.672

- VIIRS & MODIS very similar in daytime
- Largest differences at night (tropics & polar regions)

- MODIS uses 6.7 and 13.4 μm channels not on VIIRS

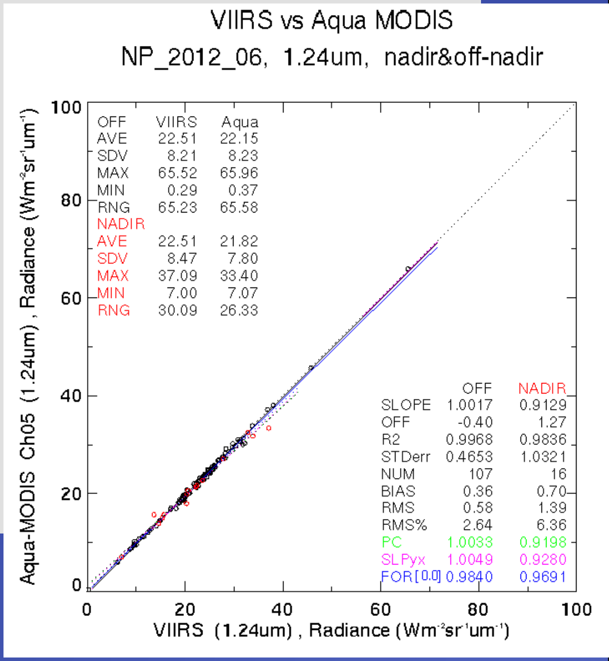
VIIRS – MODIS Consistency Summary

- 2015 VIIRS mostly as consistent as it was for 2013
  - mean cloud fractions very close
  - water cloud heights tend to be higher for VIIRS
  - VIIRS optical depths larger, greatest for liquid
    - *resolution effect larger for water clouds*
  - VIIRS water droplet radius 1 *μ*m smaller
    - *different reflectance model*

- Nocturnal cloud amounts differ regionally
  - bring in CrIS information?

- VIIRS tau over snow > MODIS, 1.24-*μ*m calibration?

- All VIIRS channels should be normalized to MODIS



Toward MODIS Edition 5 / VIIRS Edition 2

- Use MODIS Collection 6 calibrations
  - *additional results shown here*
- Merge SNPP CrIS and VIIRS footprints to recover WV and CO2 channels
  - *will improve consistency with MODIS record*
- Revised algorithms for 1.24, 1.6, and 2.1 μm retrievals
  - *optimal multi-channel algorithm for cloud/snow retrievals*
- Employ new 2-Habit model from P. Yang for ice clouds
  - *testing still underway*
- Nighttime ice cloud optical depths from neural network
  - *discussed previous STM*
  - *use same water reflectance model as VIIRS Ed1*
- Improving multi-layer algorithms
  - *will discuss in later presentation*
- Surface skin temperature
  - *discussed previous STM*

MODIS Collection 5 (C5) vs Collection 6 (C6)

C5 processing ends January 2017, what do we do?

- Continue processing Ed4? Expedite Ed5 code development?
- Either choice will require some adjustments

CERES Ed4 attempted to normalize all C5 Terra channels to Aqua

- No change in Aqua, degradation seen after 2008
- 3 segments for 0.65 μm
  - *no change in Terra prior to June 2002* ☹
- 3.8 μm: 0.5 K decrease in daytime, nonlinear change in low end at night
- Slight changes for 2.13 and 1.24 μm
- No changes for 11 and 12 μm

MODIS C6 calibration changes; no overt attempts to reconcile Aqua & Terra

- Minimal changes in Aqua, post-2008 degradation not taken into account
- Terra 3.8-μm low end corrected
- Terra 0.65-μm still < Aqua
- Some small changes in 1.24 and 2.13 μm
- < 0.2 K changes for low ends of 11 and 12 μm

Analysis of C5 vs C6 issues for CERES

Examine changes in reflectance/temperature differences

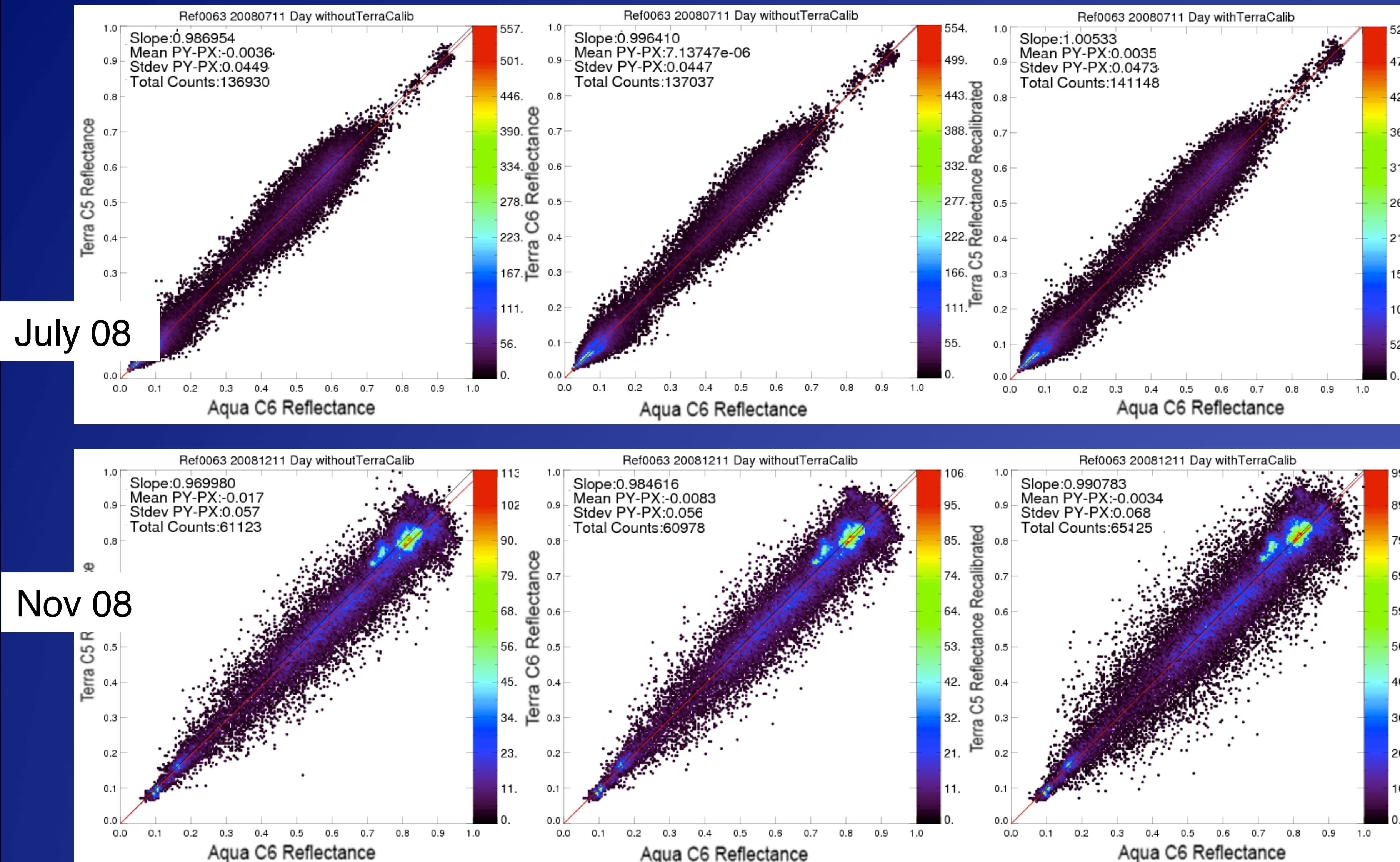
- Compute differences relative to Aqua C6
- Compute slope of forced linear regression (zero offset)
- Examine seasonal and annual variability: 9 days/ mo for 2003, 2008, 2013

Examine changes in cloud parameters from October

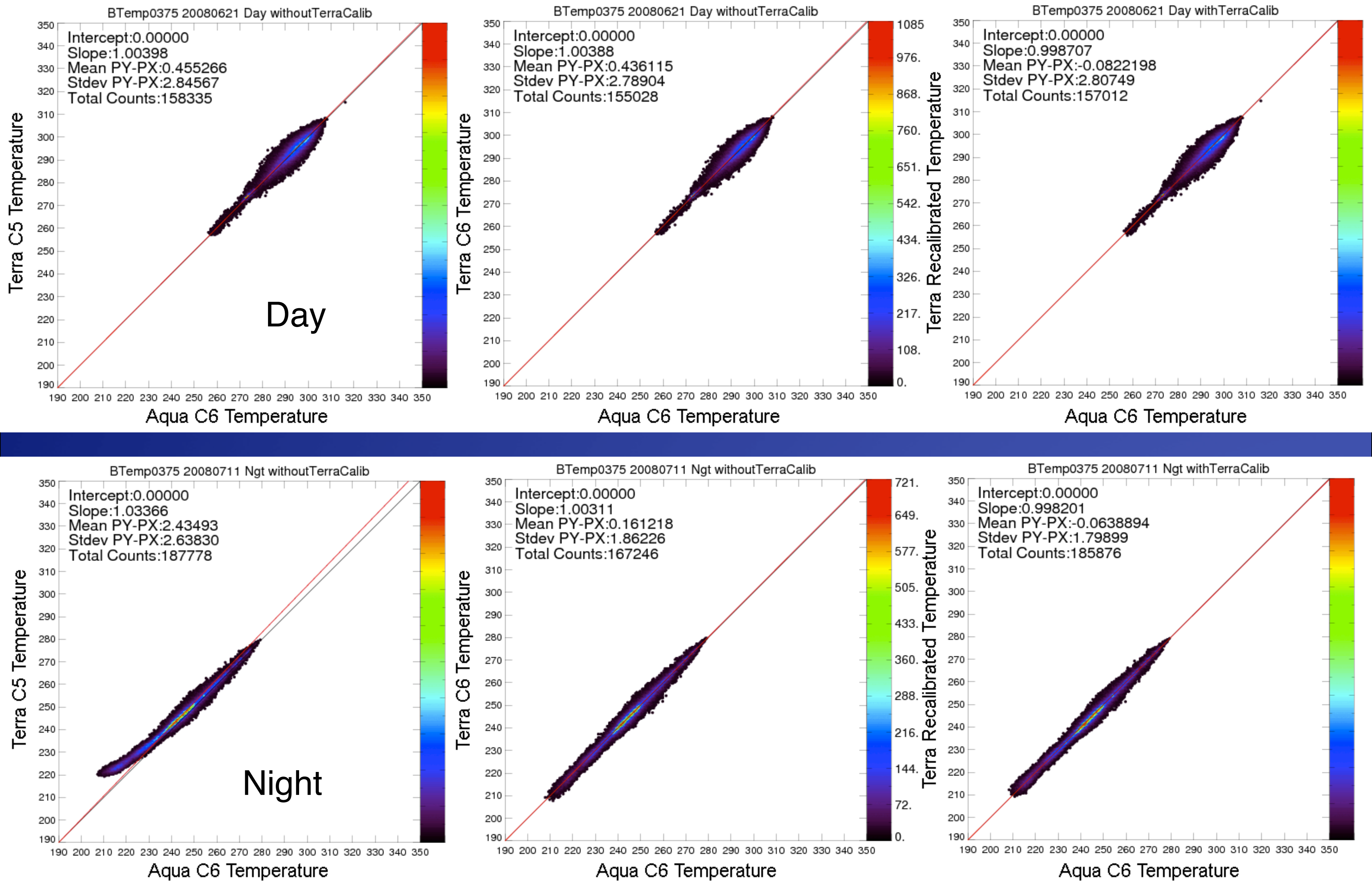
- Trends provided in Spring STM presentation
- Regional changes provided here

Scatterplots of C5 vs C6 for 0.65 μm reflectance

Ed2 | C6 | Ed4



C5 vs C6 for 3.78-μm Brightness Temperatures (K), June 2008

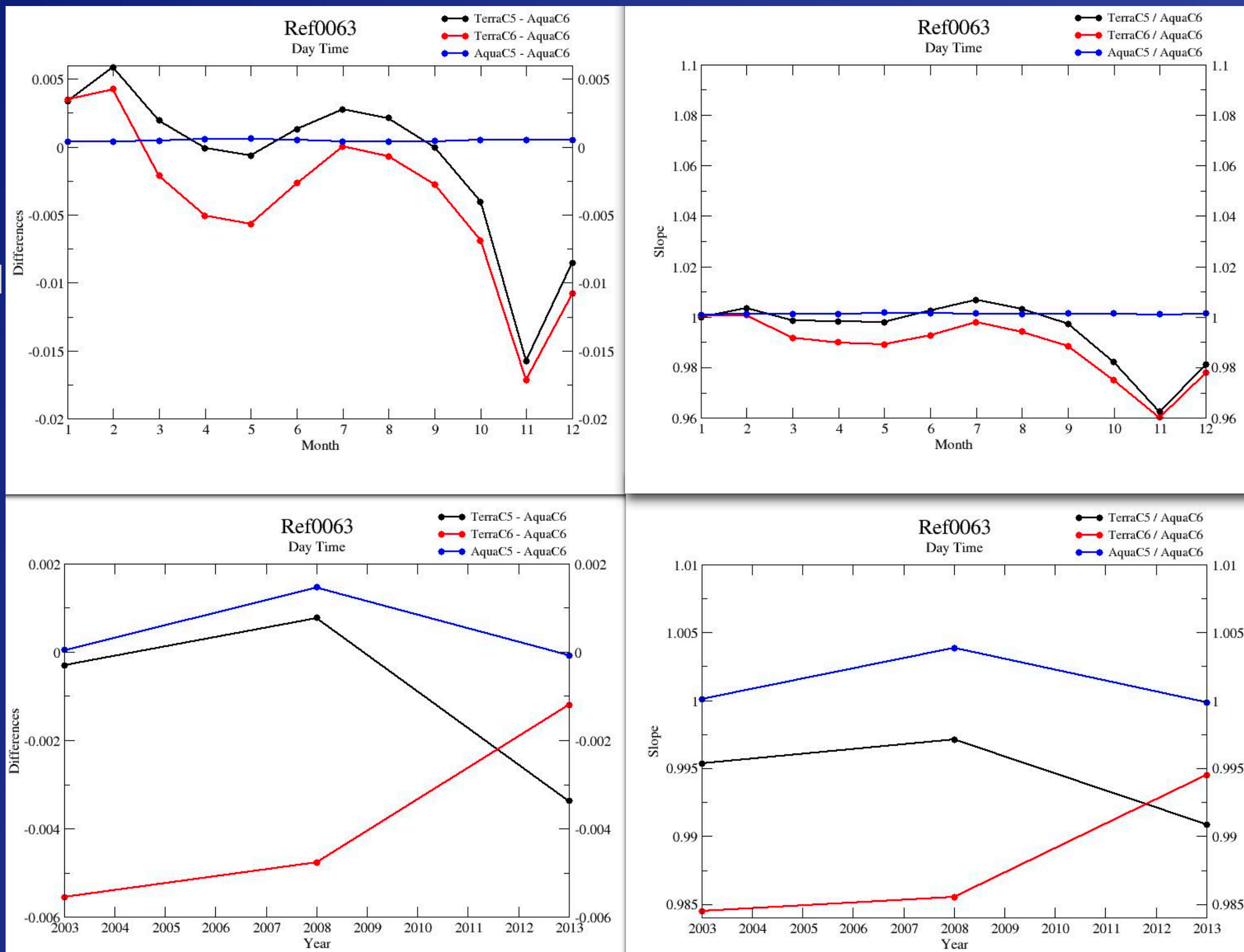


Visible channel (0.65 μm) C5-C6 changes

mean difference | slope of regression

seasonal

annual



Oct, Nov, Dec are oddball months: Antarctic is target, all bright, no balance of darker scenes

Aqua C6 rises by 0.4% in 2008, then drops

Terra C5 and C6 reverse after 2008

- Terra C5 closer (0.5% vs 1.5% differences) to Aqua, < 2008
- Aqua degradation brings Terra C6 closer in 2013

Channel Summary

- 0.65 μm: C5 Terra 0.2% < Aqua
  C6 0.3% > Aqua

- 1.24 μm: C5 Terra 0.2% < Aqua
  C6 3% > Aqua

- 1.38 μm: C5 Terra 5% < Aqua
  C6 10% < Aqua

- 2.13 μm: C5 Terra 2% < Aqua
  C6 1% < Aqua

- 3.78 μm: day: C5 ± 0.05 K night: C5 ± 0.05 K
  C6 + 0.25 K C6 + 0.20 K

- 6.7 μm: C5 Terra differs by -1 K after 2008
  C6 -0.5 K in 2003, -3.5 K in 2013

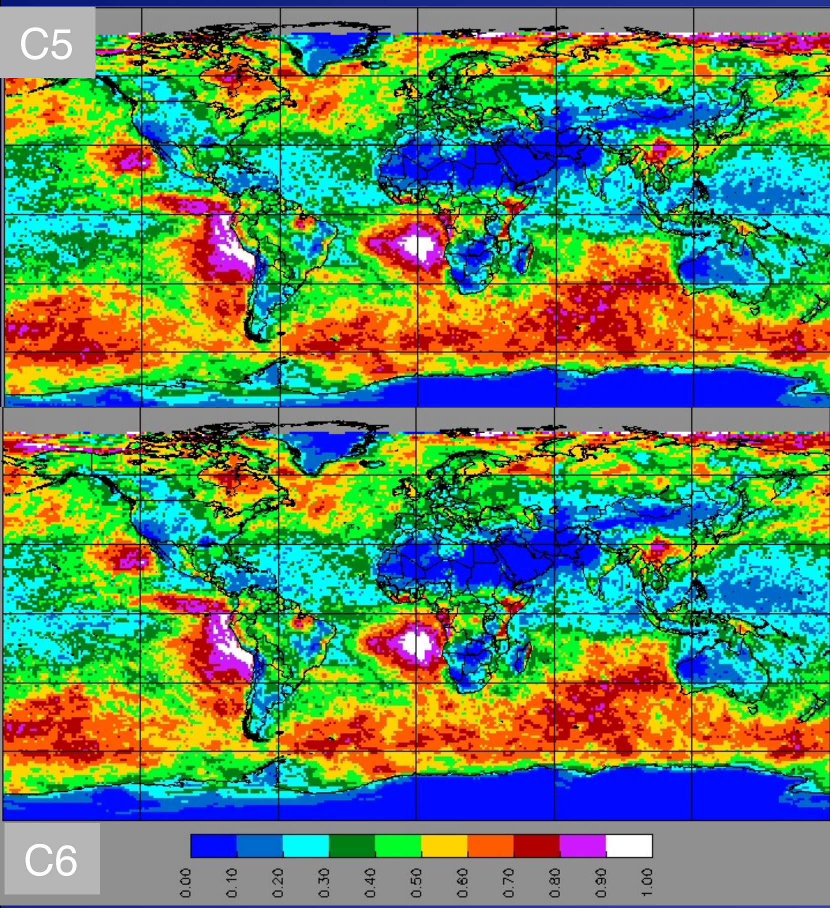
* 11 μm: C5 ± 0.1 K
  C6 ± 0.03K

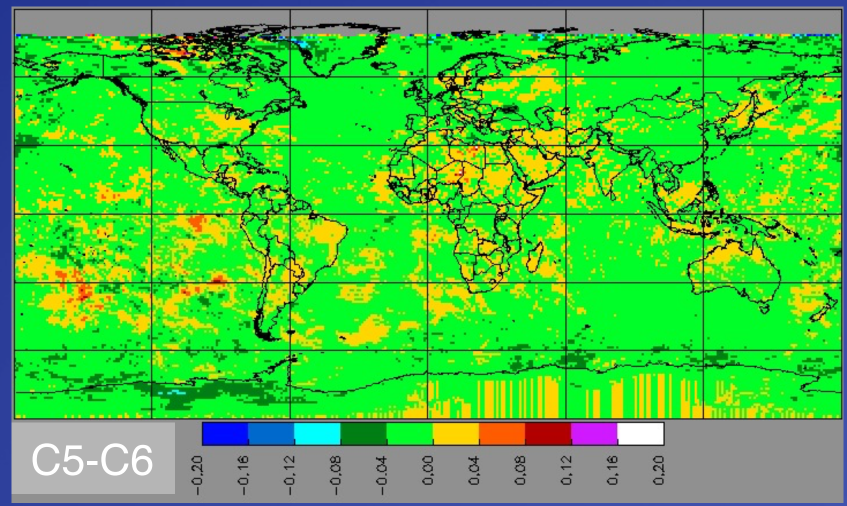
- 12 μm: C5 ± 0.1 K
  C6 ± 0.03K

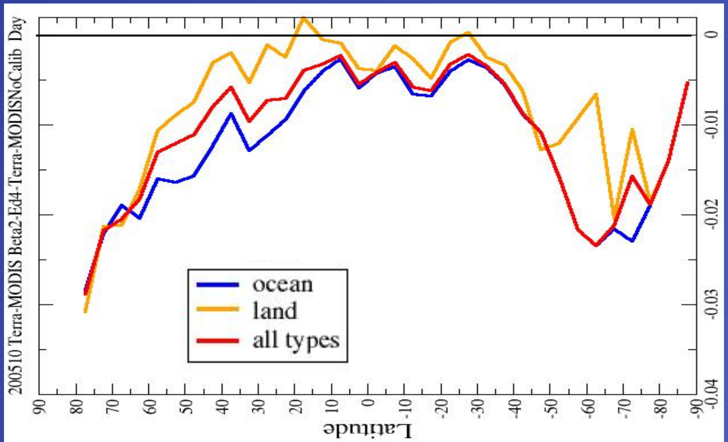
Cloud Fraction Using Terra C5 vs C6 Using Ed4 Code

Oct, 2005 Daytime

- C5 adjusted with LaRC calibrations, C6 nominal calibrations used







- Cloud amount changes mostly < 0.04
- C6 yields average increase of ~ 0.02 in polar, ~0.005 in tropics

C5-C6 Summary & Future

- Changes caused by C6 calibrations not enormous, but significant
- Most impactful problem is degradation of Aqua calibration
  - induces artificial trends in C5 Aqua and Terra

For Ed5, using C6, we will need to

- Rely on C6 infrared channel calibrations
  - apply daytime Aqua normalization for Reff for Terra
- Account for Aqua VIS channel degradation after 2008?
  - apply constant normalization to Terra to insure Aqua/Terra consistency
- Utilize Aqua C6 calibrations for NIR channels
  - normalize Terra to Aqua
  - adjust clear-sky maps based on C5 calibrations

Do we do something similar continuing Ed4 with C6?

- Accounting for trend in Aqua will cause discontinuity
  - Terra will be an issue regardless

Restoring MODIS Complement to VIIRS: CrIS

- VIIRS lacks water vapor & CO_2 channels used in CERES MODIS clouds
  - working resolution: 750 m with VZA resolution enhancement
- CrIS: interferometer on NPP & JPSS: 14 km resolution
  - 9.13 - 15.38 μm
  - 5.71 - 8.26 μm
  - 3.92 - 4.64 μm
- MODIS channels can be created from CrIS wavelengths
  - integrate over spectral response functions
  - 6.7 & 7.3 μm bands
  - four CO_2 bands

Procedures for Mapping CrIS to VIIRS at Subsetted Resolution

VIIRS Subset VZA

Original software:

NWP-SAF, a software developed by NWP SAF for mapping VIIRS to CrIS.

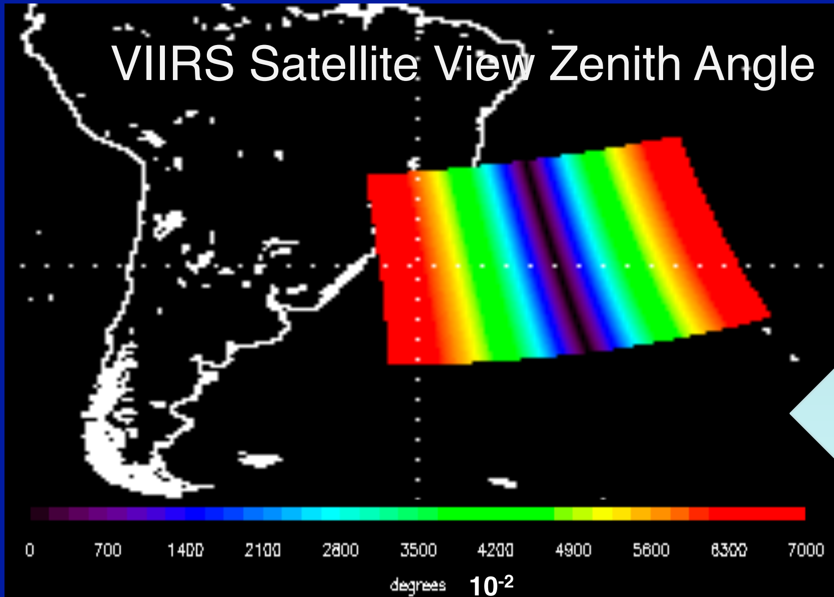
Work done at Langley:

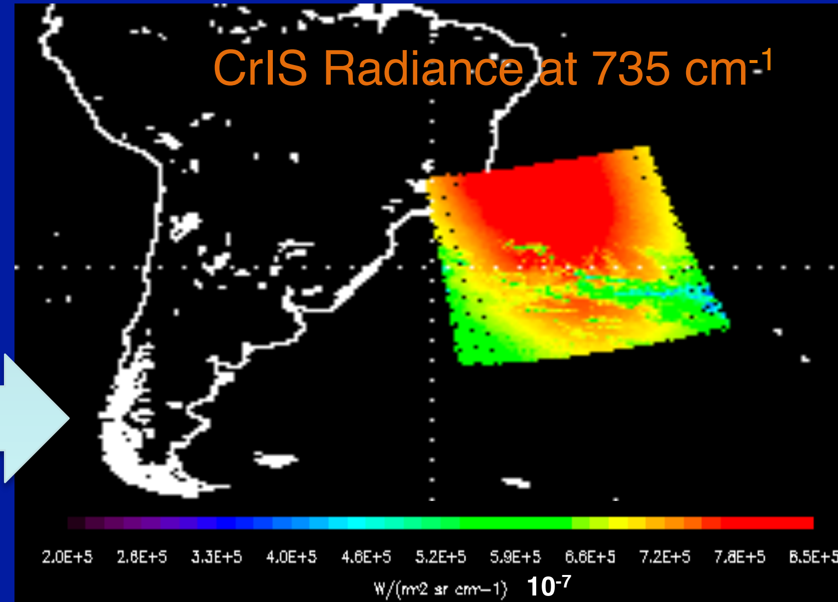
- Used subsetted resolution VIIRS (product VNP0203IMD received at Langley) instead of full resolution NOAA CLASS VIIRS (product GMODO-SVM16_npp) used in the original software.

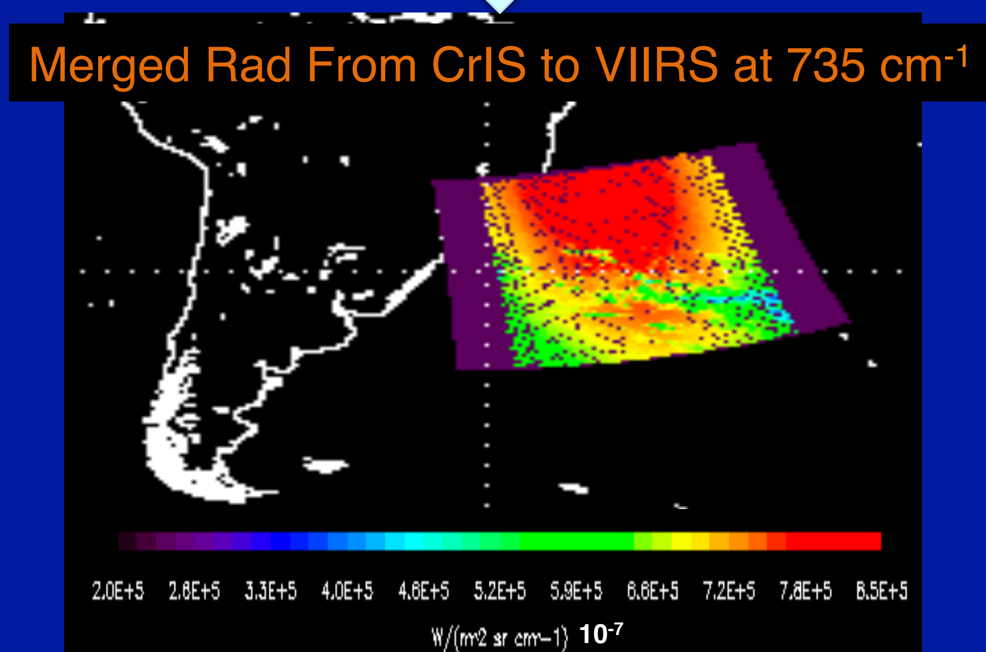
- Kept NOAA CLASS CrIS inputs unchanged, requiring two products: GCRSO_npp (Geolocation) and SCRIS_npp (SDR).

- Reversed the mapping instruments: merging CrIS to VIIRS, instead of VIIRS to CrIS. Finding VIIRS pixel indices inside CrIS footprints and transfering CrIS SDR at the specified band to VIIRS at the subsetted resolution.

September 19, 2015, Hour: 15, Min: 54-60







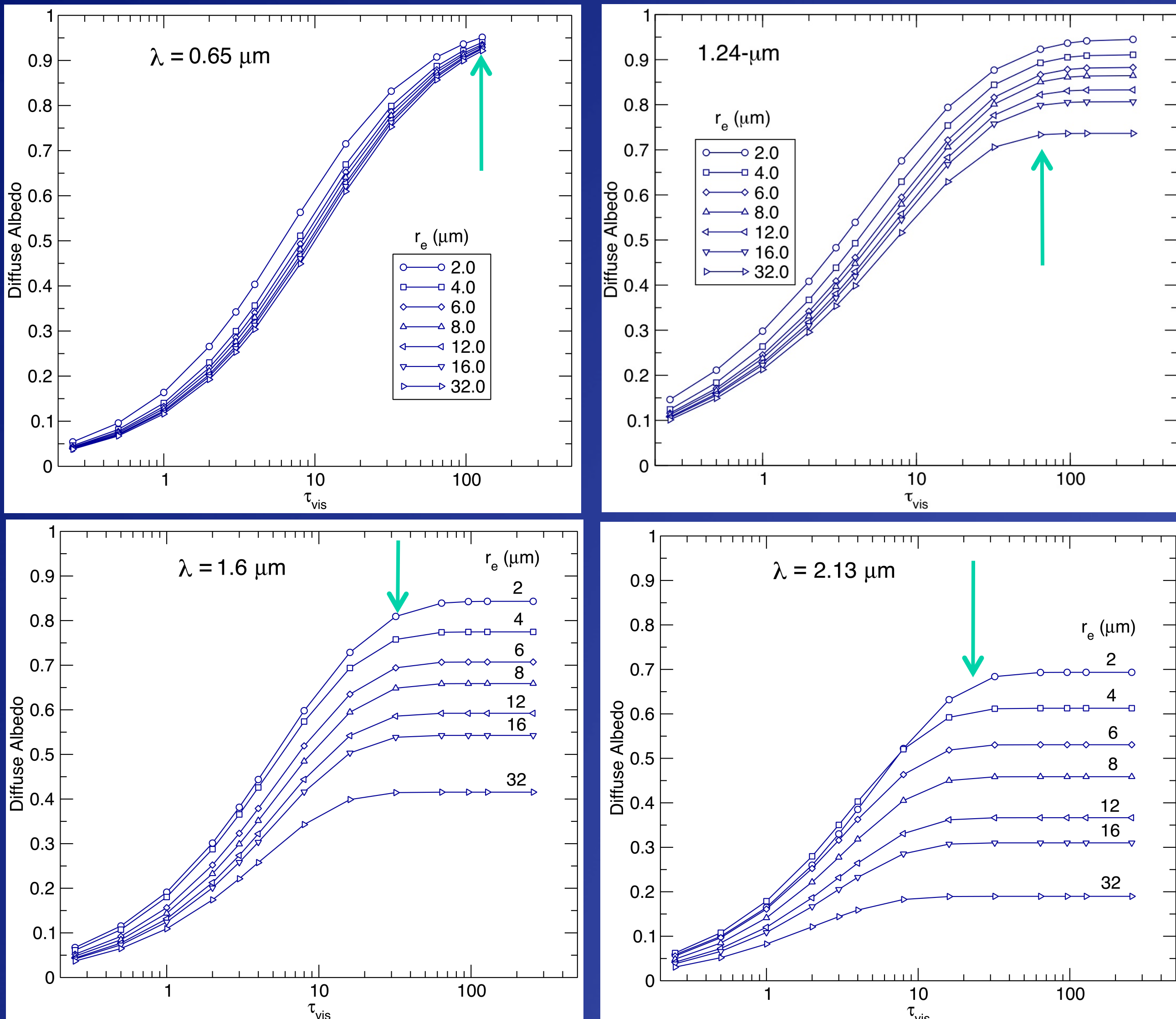
Using CrIS with VIIRS

- having CrIS would allow consistency with MODIS mask/retrievals
  - polar regions would benefit, especially at night
  - CO2-slicing could be used for cirrus cloud heights
  - nocturnal neural net tau algorithm could be used
  - NN ML algorithm could be employed
- Challenges
  - CrIS does not cover full VIIRS swath width
  - CrIS resolution is 19 x VIIRS
    - deconvolve the fat pixels?
- will the gain from the effort be worth it?
  - TBD
  - process has begun

Optimal Retrievals over Ice and Snow

- 1.24 µm used in place of 0.65 µm over ice and snow surfaces
  - *yields reasonable optical depths (COD) for thick stratus*
    Dong et al. (JGR, 2016)
  - *other validation minimal*
  - *suspect overestimates for thinner clouds*
    - *possible impact of surface albedo uncertainty*
- 1.6 and 2.13 µm channels have potential over snow
  - *yields reasonable optical depths up to a limit* *Minnis et al. (2011)*
  - *minimal surface albedo impact, may be better for optically thin clouds*
- Infrared approach may be needed for thinnest clouds
  - *use 11 and 12 µm channels only*
- Perform validations for each
  - *develop logic based on optimal criteria for each channel*
- Initial runs using 1.6 and 1.24 µm during ARISE period (some in situ data)

Diffuse Liquid Cloud Albedos from Adding-Doubling Computations



Cloud model

- modified Γ dist
- σ = 0.10
- Mie scattering
- sfc albedo = 0

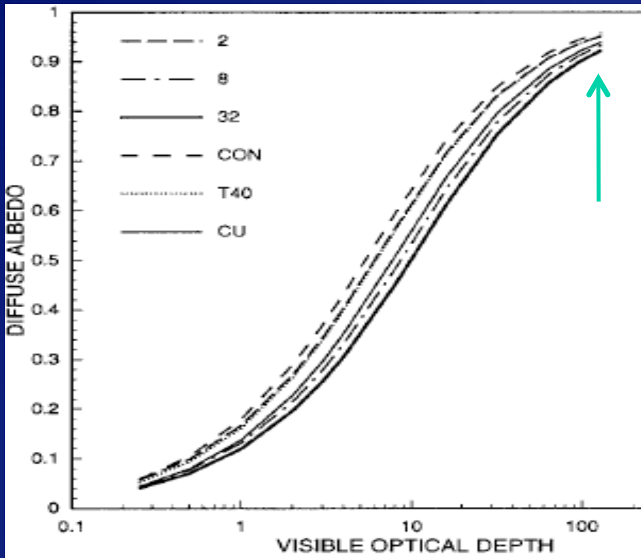
Minnis et al. JAS, 1998

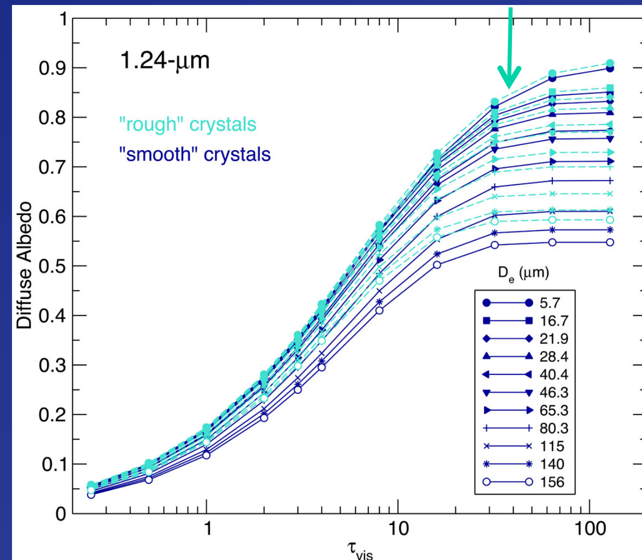
λ (µm)	τ Limits
0.65	> 128
1.24	64 - 96
1.62	10 - 30
2.13	6 - 10

Actual limits depend on viewing & illumination angles & sfc albedo

1.24 µm channel has promise for getting most of full range of τ

Diffuse Ice Cloud Albedos from Adding-Doubling Computations

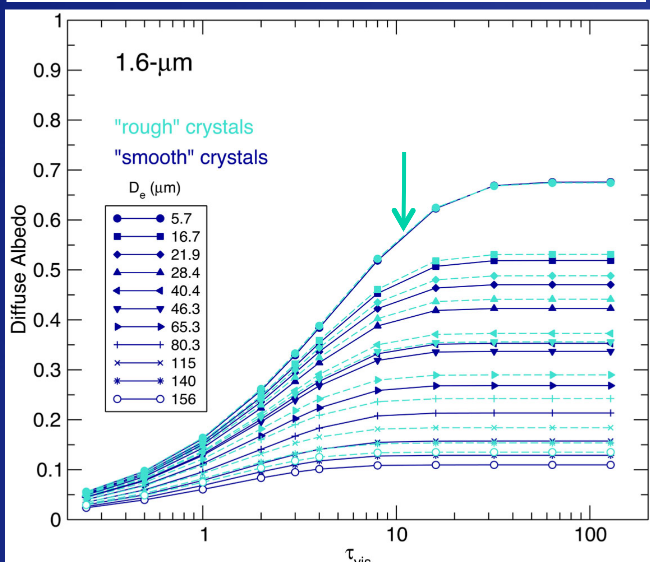


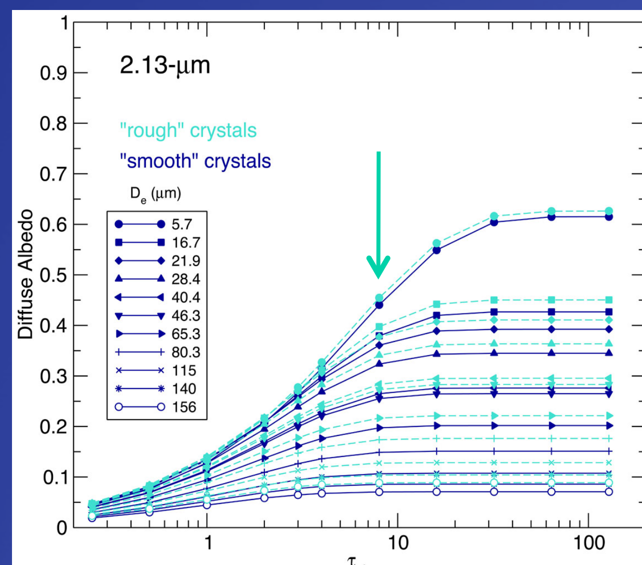


Ice model based on hex column dist

Minnis et al. JAS, 1998

<u>λ (μm)</u>	<u>τ Limits</u>
0.65	> 128
1.24	32 - 60
1.62	2 - 8
2.13	1 - 3



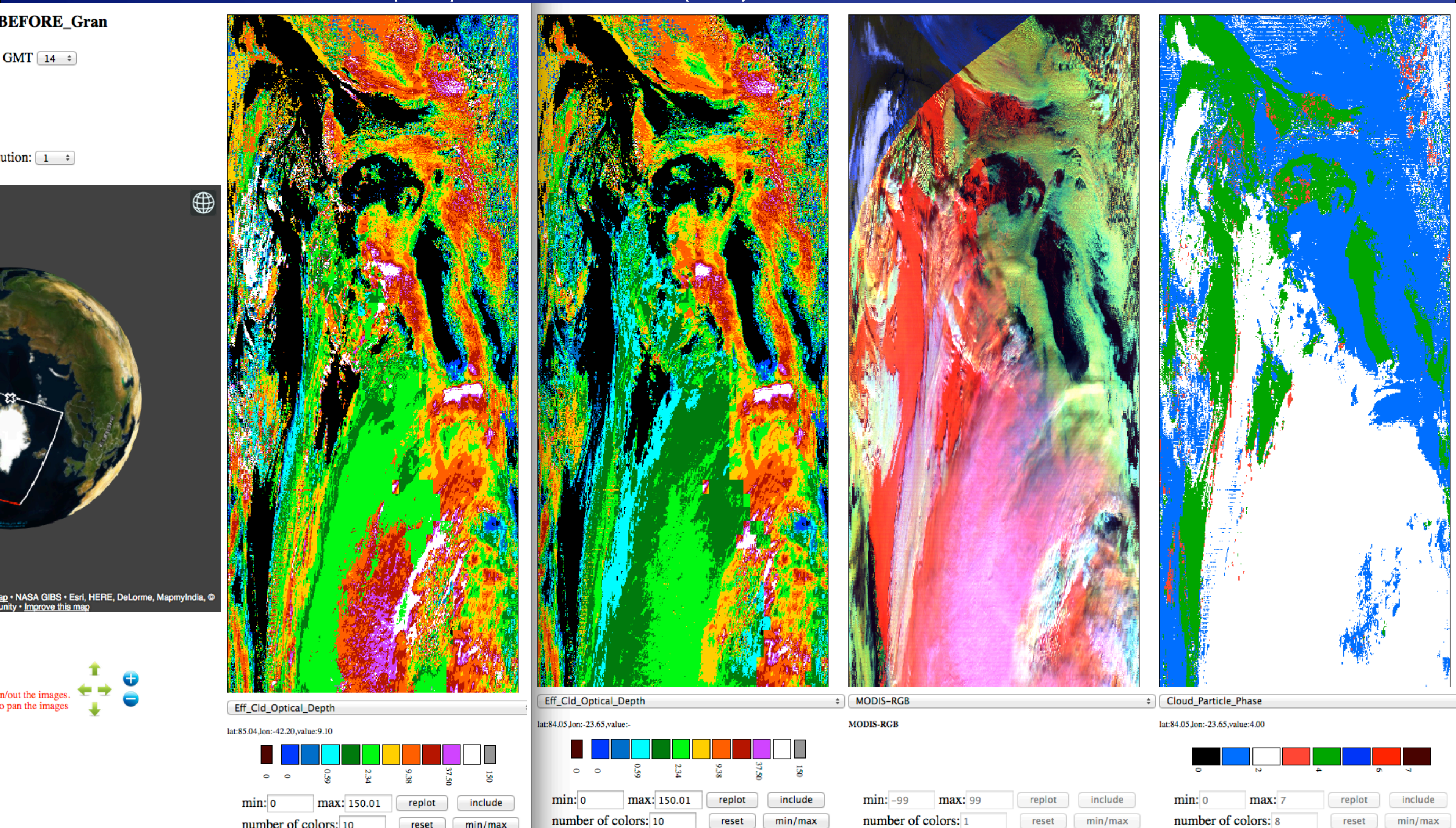


Actual limits depend on viewing & illumination angles & sfc albedo

1.24 μm channel has more promise for getting most of full range of τ

Ex: Optical Depth Retrievals Using Terra 1.2 and 1.6 μm data

COD(1.2) COD(1.6) RGB Phase



- Snow-free areas use 0.65 μm, COD(1.6) < COD(1.2)

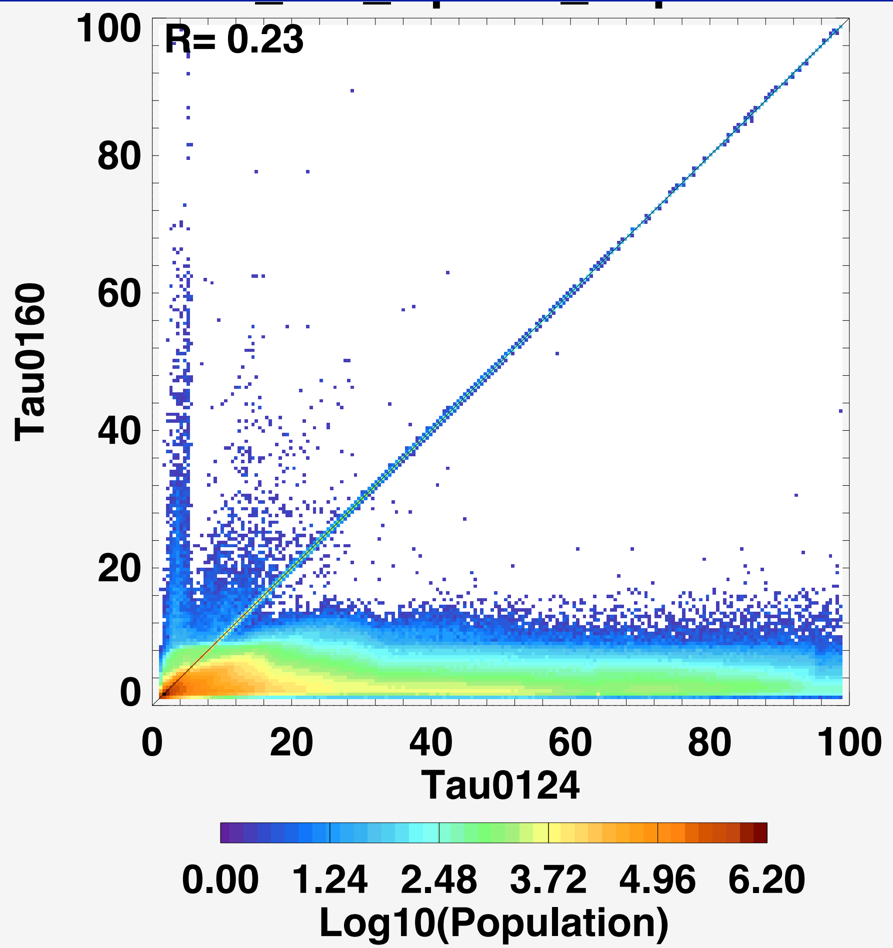
Terra-MODIS, September 2014, all ARISE Overpasses

Condition to run snow tau retrieval is
either permanent snow
or snow map says snow
or Ice map % > 20 %

	1.6 Snow Retrieval		
1.24 Snow Retrieval		Ice	Water
	Ice	25.5×10^6 37.0 %	1.5×10^6 2.15 %
	Water	2.1×10^6 2.98 %	39.8×10^6 57.87 %

Cloud phase agreement = 37.0 % + 57.87 % ~ 95 %

1.24 vs 1.6 μm optical depth comparison, September 2014 : both ice

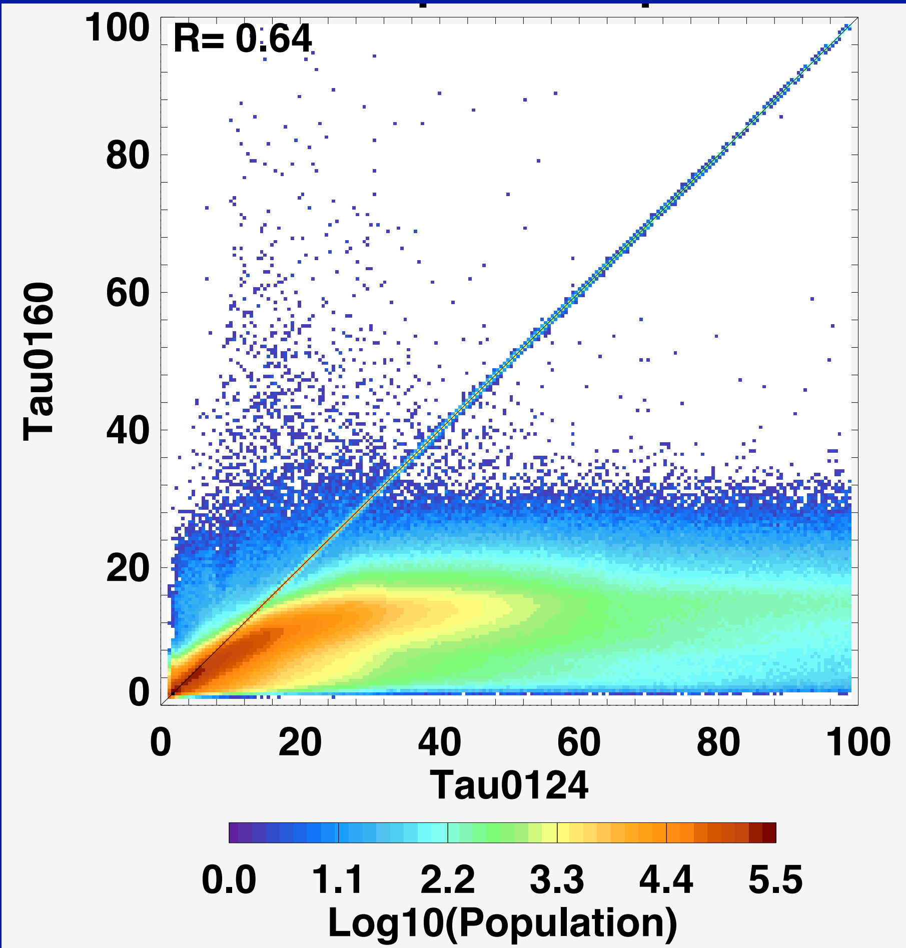


N= 25477938.

	Mean	(StdDev)
Tau0124	8.23(	13.78)
Tau0160	2.00(	2.42)
Y-X	-6.23(	13.44)
RMS(	14.81)...............	

- COD(1.6) < 10
  - *most < 7, mean = 2*
  - *hides low clouds*
- COD(1.2) much higher
  - *gets reflective effect from low clouds*
  - *some impact from surface albedo uncertainty*
- need to separate overlap from bad surface albedo
  - *combination of neural net and COD(1.6)?*

1.24 vs 1.6 μm optical depth comparison, September 2014 : both liquid

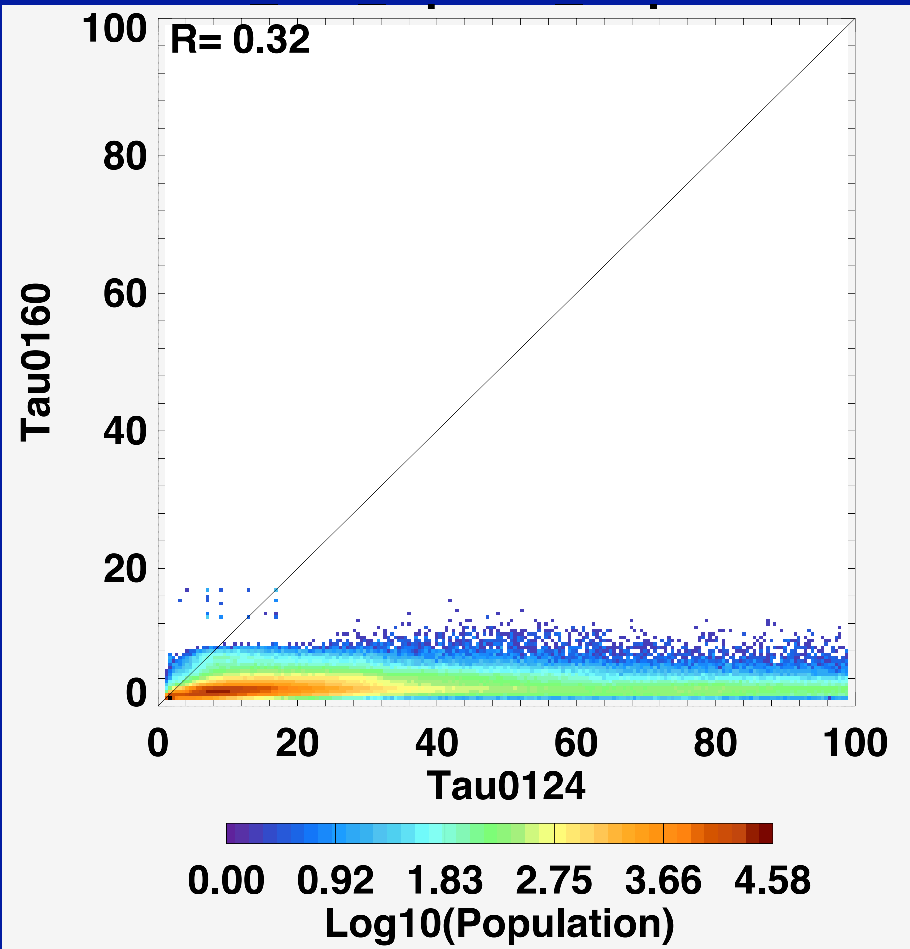


N= 39844102.

	Mean	(StdDev)
Tau0124	13.51(	12.79)
Tau0160	6.97(	4.76)
Y-X	-6.54(	10.43)
RMS(	12.31)...............	

- COD(1.6) < 20
  - *most < 15*
  - *hides low clouds*
- COD(1.2) much higher
  - *more sensitive to surface albedo uncertainty*
- need to determine when to use 1.6 μm
  - *use 1.6 asymptote as guide*

1.24 vs 1.6 μm optical depth comparison, September 2014 : 1.6 μm ice, 1.2 μm liquid

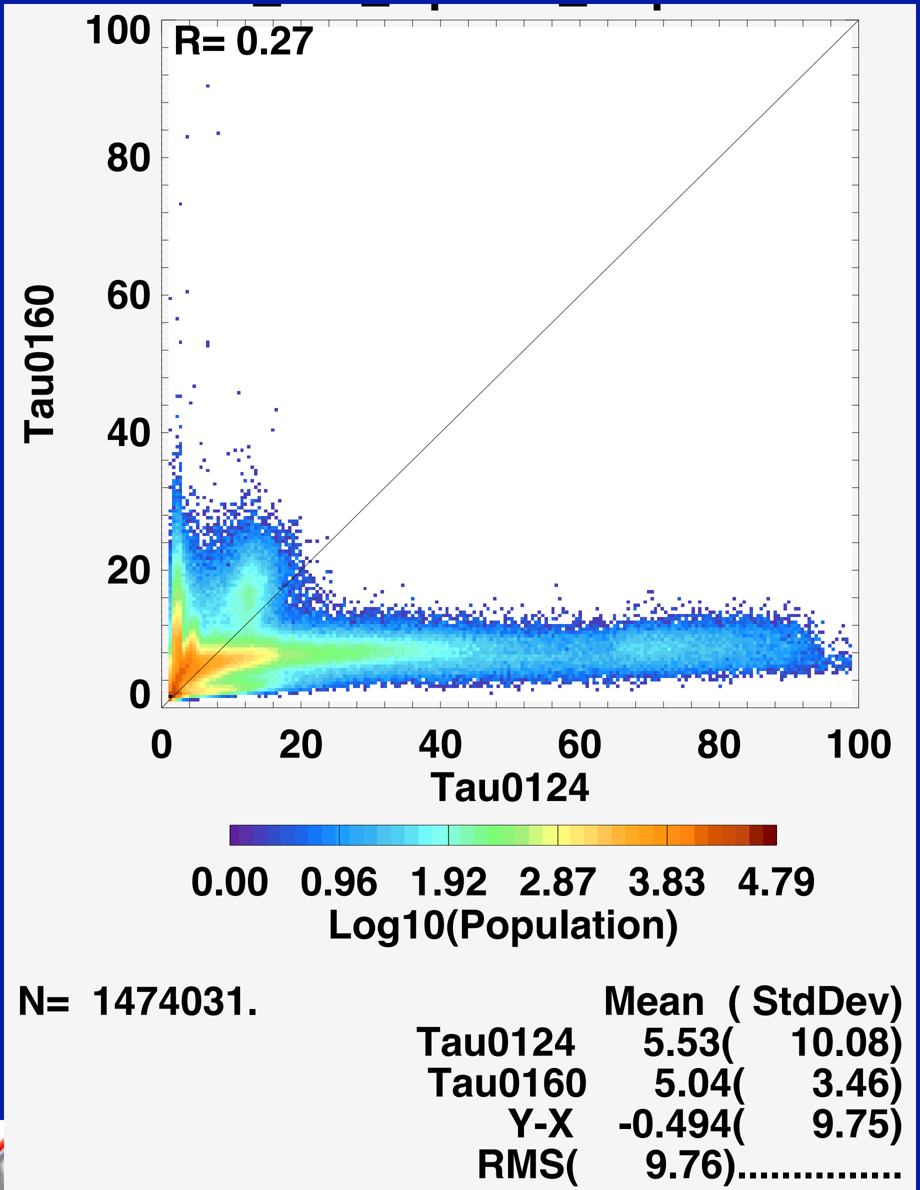


N= 2054848.

	Mean	(StdDev)
Tau0124	14.81(	15.59)
Tau0160	1.51(	0.930)
Y-X	-13.30(	15.32)
RMS(	20.28)...............	

- COD(1.6) < 8
  - *most < 4, mean = 1.5*
  - *may hide low clouds*
- COD(1.2) much higher
  - *gets reflective effect from low clouds*
  - *some impact from surface albedo uncertainty*
  - *probably chooses liquid because ice cloud very thin*
- need to separate overlap from bad surface albedo
  - *combination of neural net and COD(1.6)*

1.24 vs 1.6 μm optical depth comparison, September 2014 : 1.6 μm liquid, 1.2 μm ice



- COD(1.6) < 20
  - *most < 12*
  - *some values > 15*
- COD(1.2) much lower for most
  - *phase error makes it lower than COD(1.6) in most cases*
  - *> COD(1.6), it exceeds ~10*
  - *means equal*
- need further analysis of phase algorithm

Clouds over snow algorithms remarks

- 1.6 and 2.1 μm channels can be useful for water cloud optical depth retrievals, but need to be used carefully
  - only use for non-asymptotic conditions
    - replace 1.24 μm value
  - perform validations for a variety of conditions

- 1.6 and 2.1 μm channels might be useful for thin cirrus retrievals
  - need other indicators that no lower clouds are present

- 1.6 and 2.1 μm channels may be helpful for multilayered cloud detection/retrieval
  - used in conjunction with 0.65, 1.24, 11, 12, and 6.7 μm

- which to use?
  - 2.1 on both Terra & Aqua, not VIIRS
  - 1.6 on VIIRS & Terra, bad on Aqua
    - recovery possible on Aqua, only at full 0.5 km res

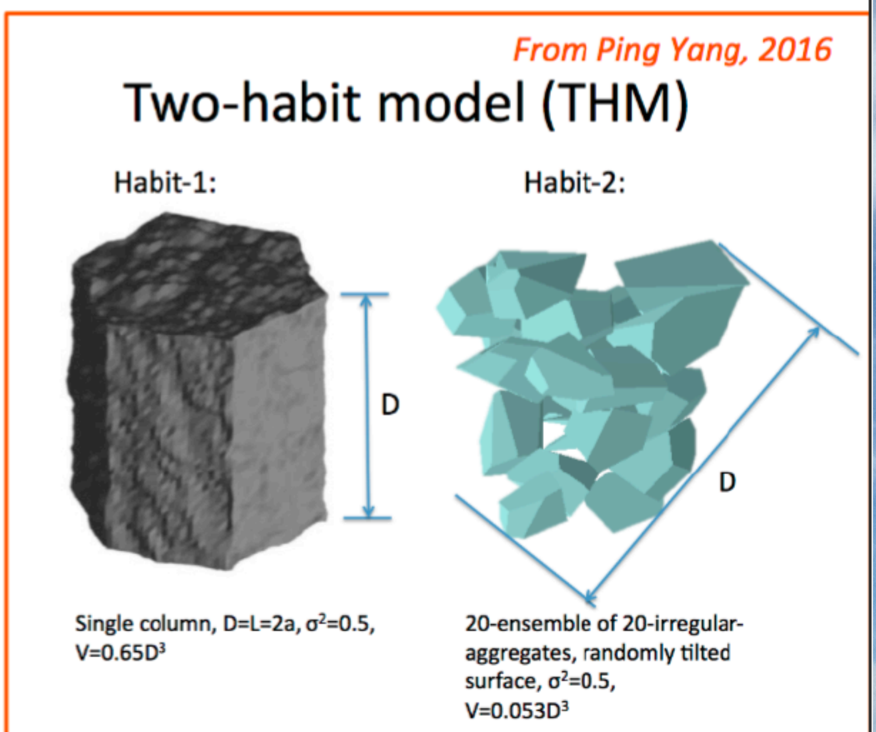
- need to be determined from multiple validation studies

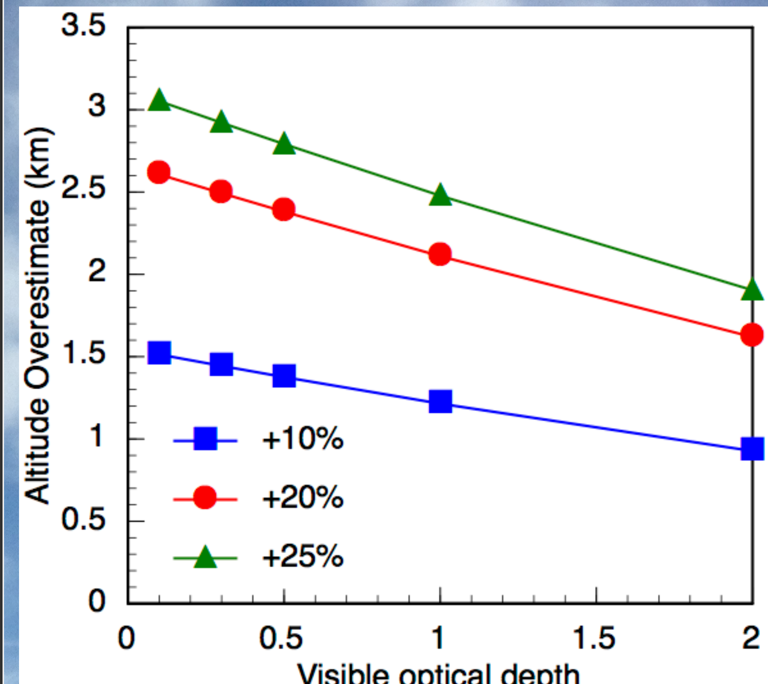
Ice Particle Models

- Current 1-habit (1-H) model yields COD ~ 2 COD(CALIPSO)
  - causes ~2-km underestimate of height relative to CALIPSO
- New 2-habit model delivered recently from Yang group
  - initial tests performed

Compact particles, smaller *g*
hollow to solid, smaller *g*

hence smaller tau





Theory indicates 15% decrease at nadir in COD produces 2 km rise Zeff for this configuration (Ts = 290K, Tc = 220K

Comparisons Between 1HM and THM

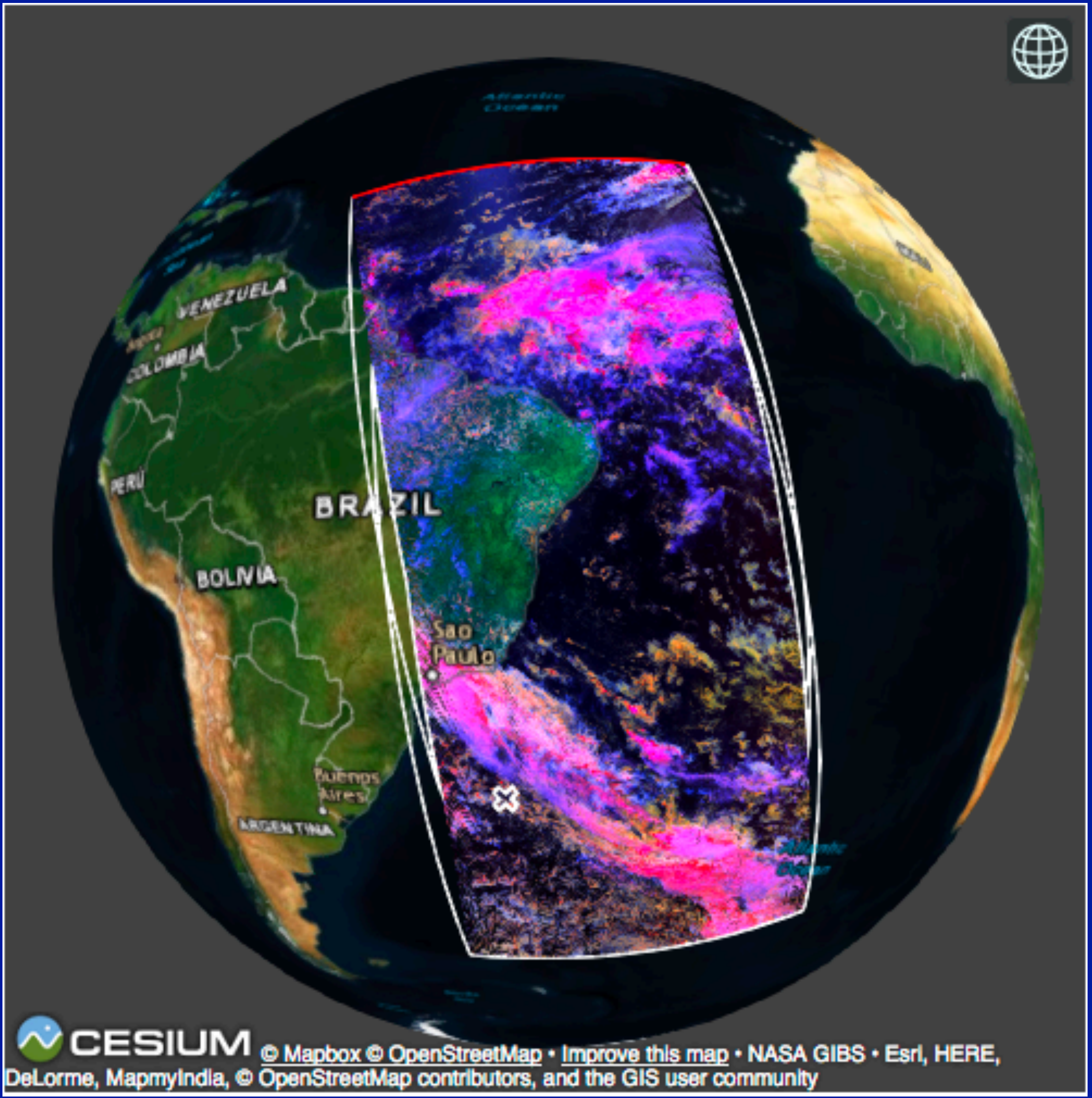
1HM: One Habit Model with Rough Single Hexagonal Column used for CERES Ed4 (CERES4)

THM: Two Habit Model with 20 Irregular Aggregates Randomly Tilted

- Initial run: All Aqua data for March 2008
  - over snow/ice areas: 1.24 μm for tau
  - over snow-free areas: 0.65 μm for tau

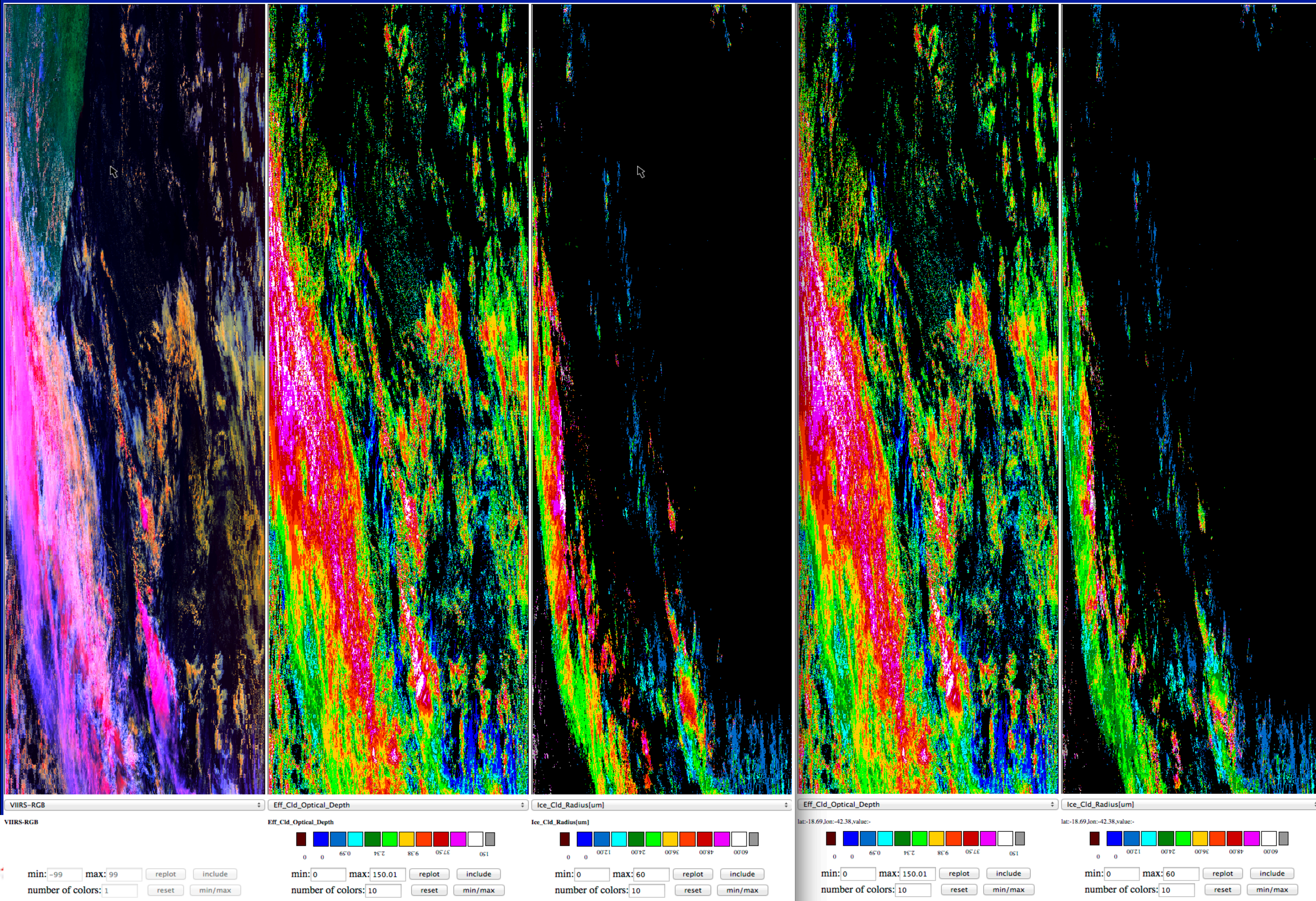
Testing Data

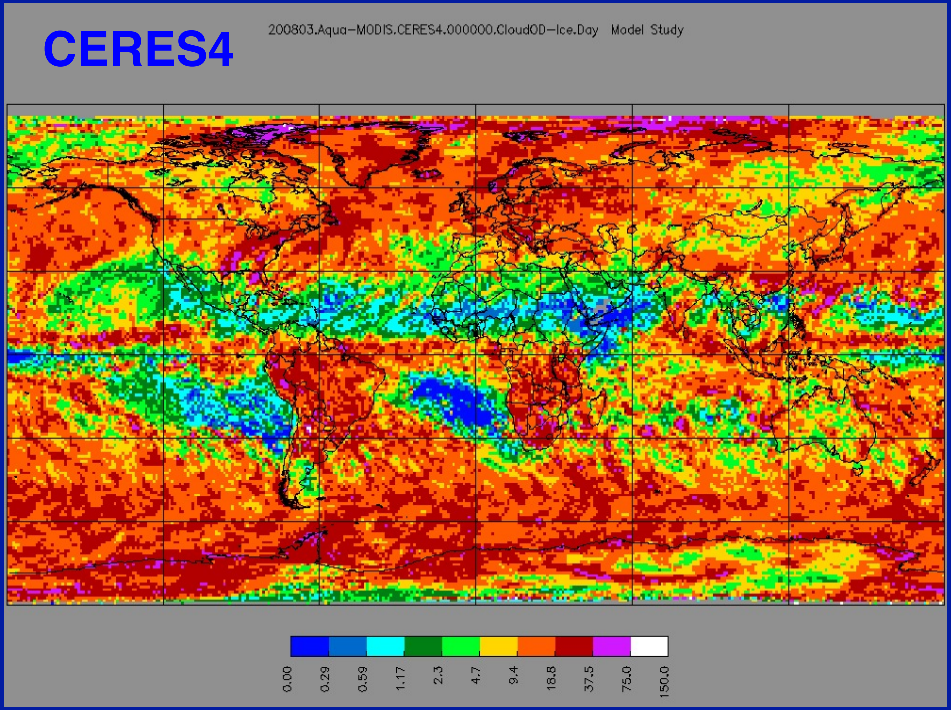
NPP-VIIRS: April 30, 2016. Hour 15, 4 Granules

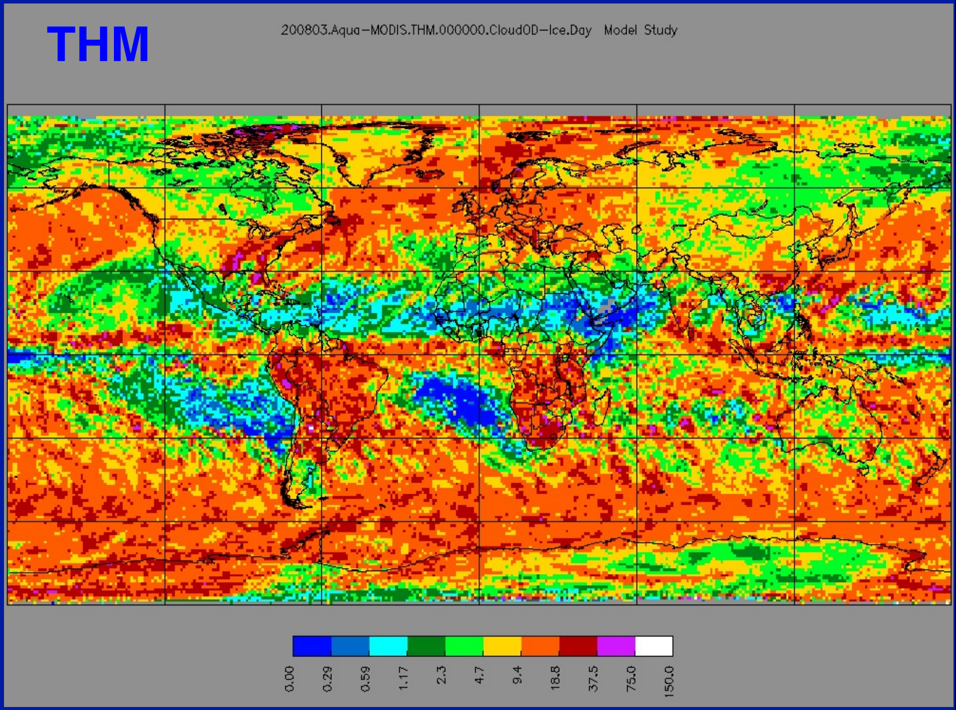


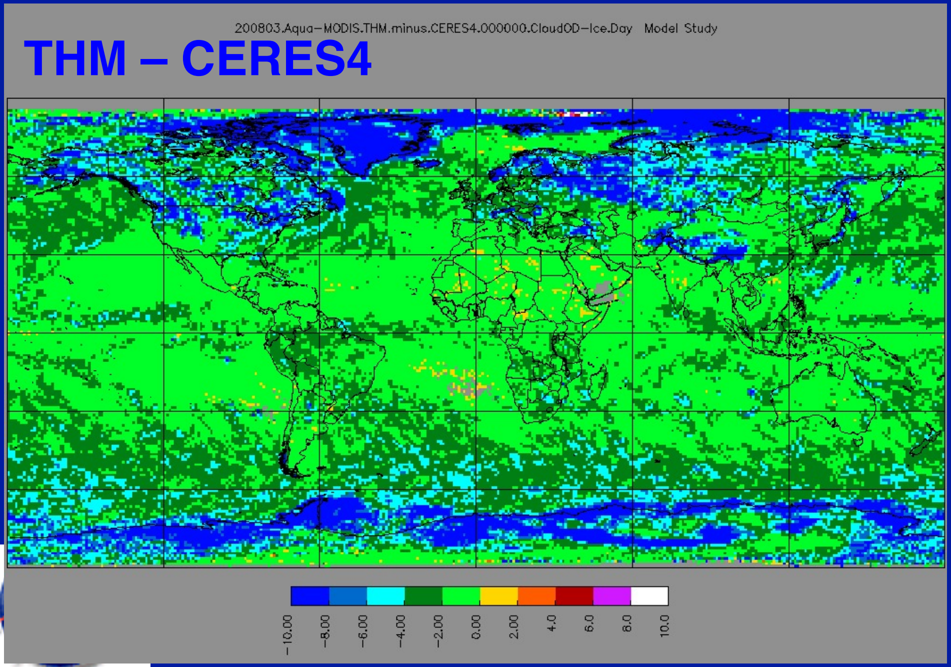
OHM-Rough THM-20IrregAgg

Tau Re Tau Re

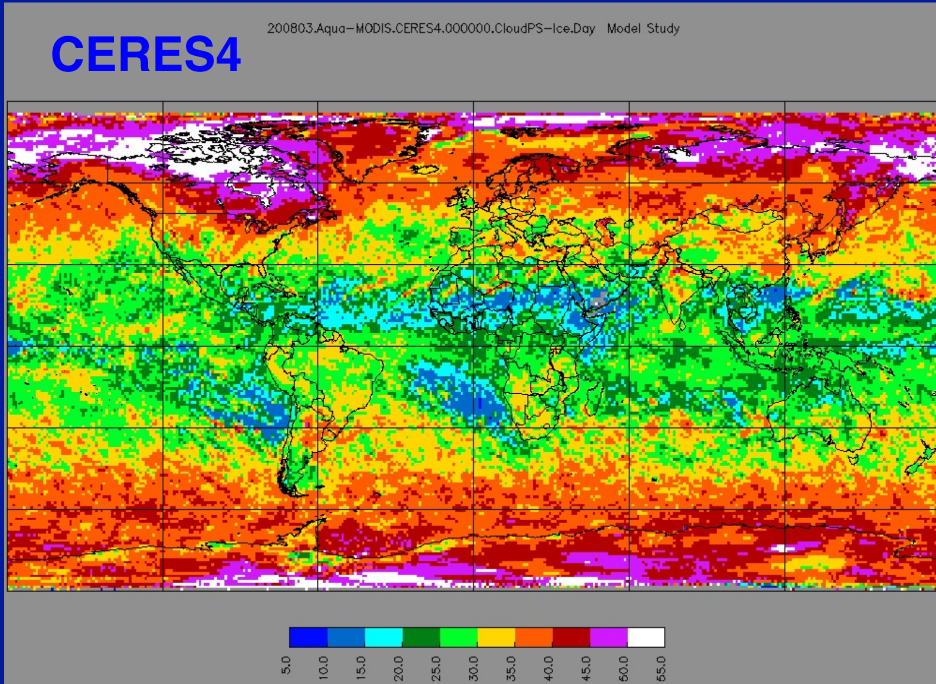


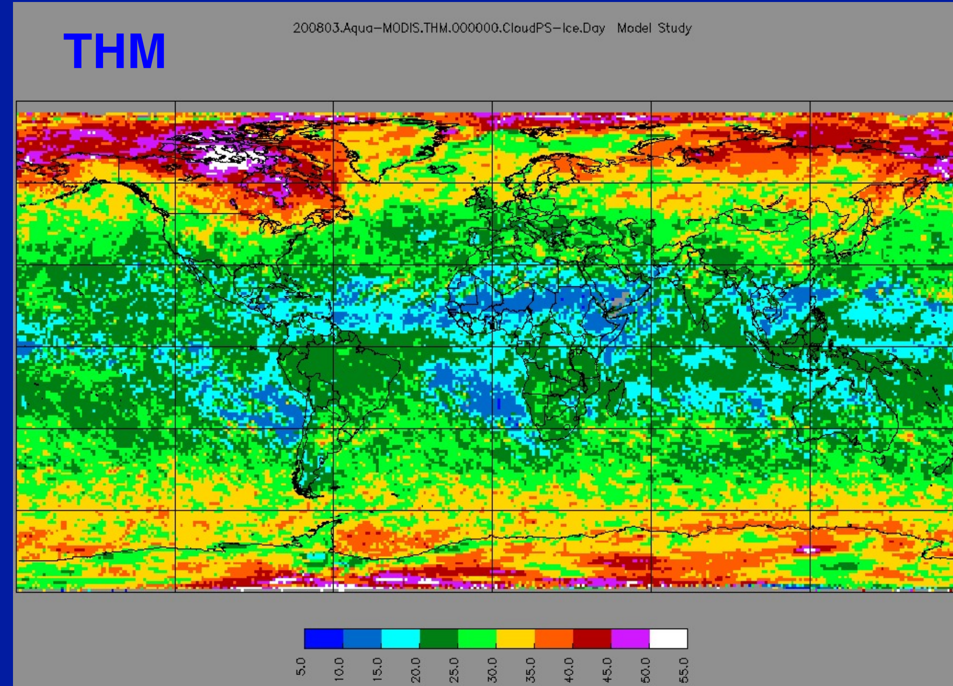


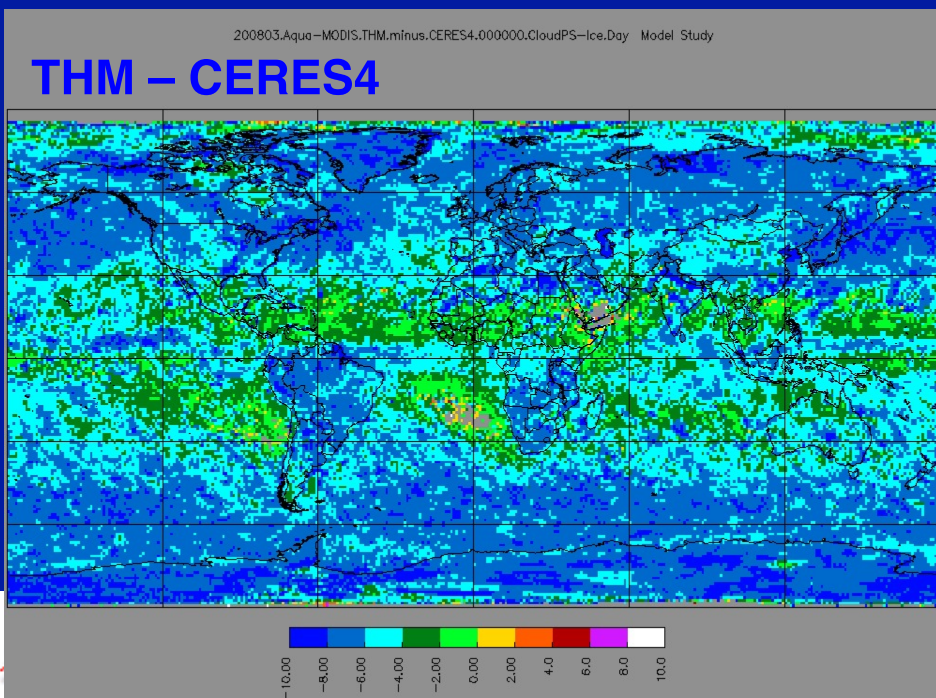




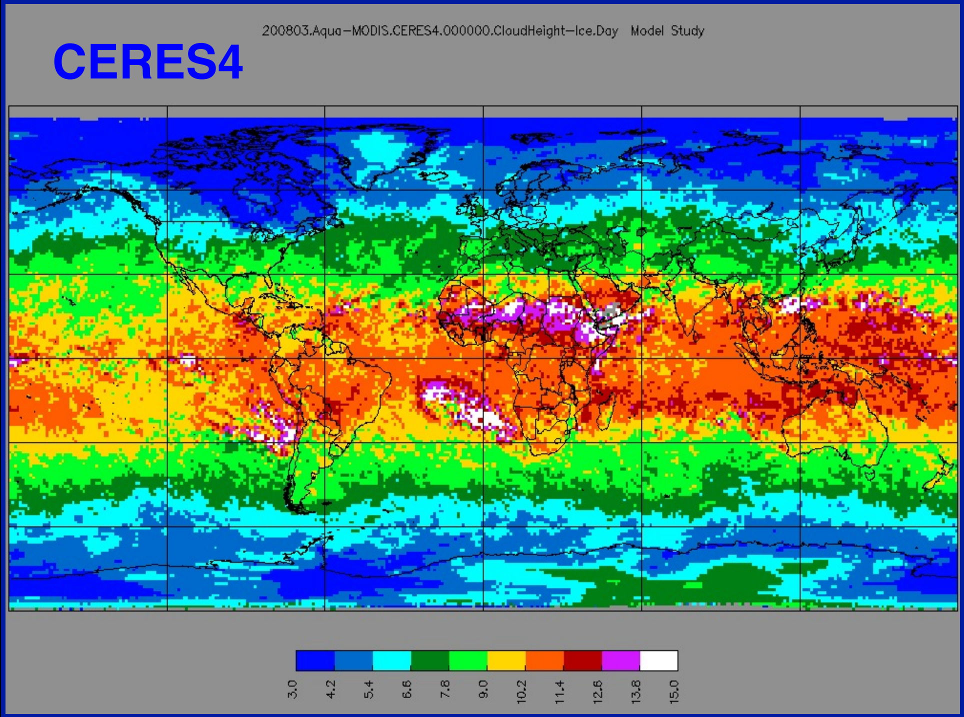
Aqua MODIS, March 2008
Optical Depth, Ice Phase, Day Time

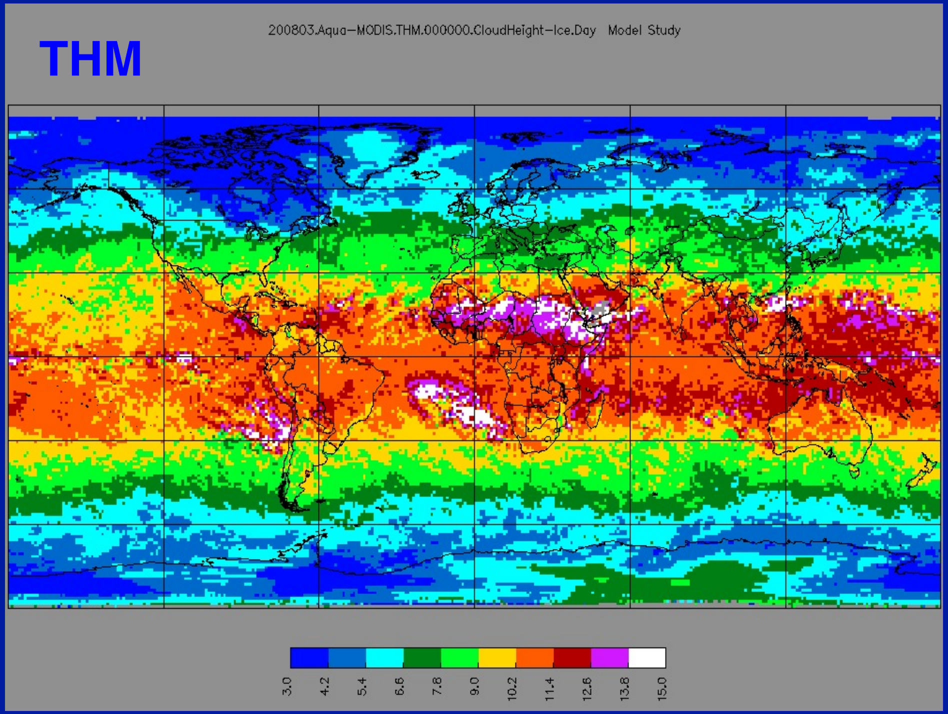


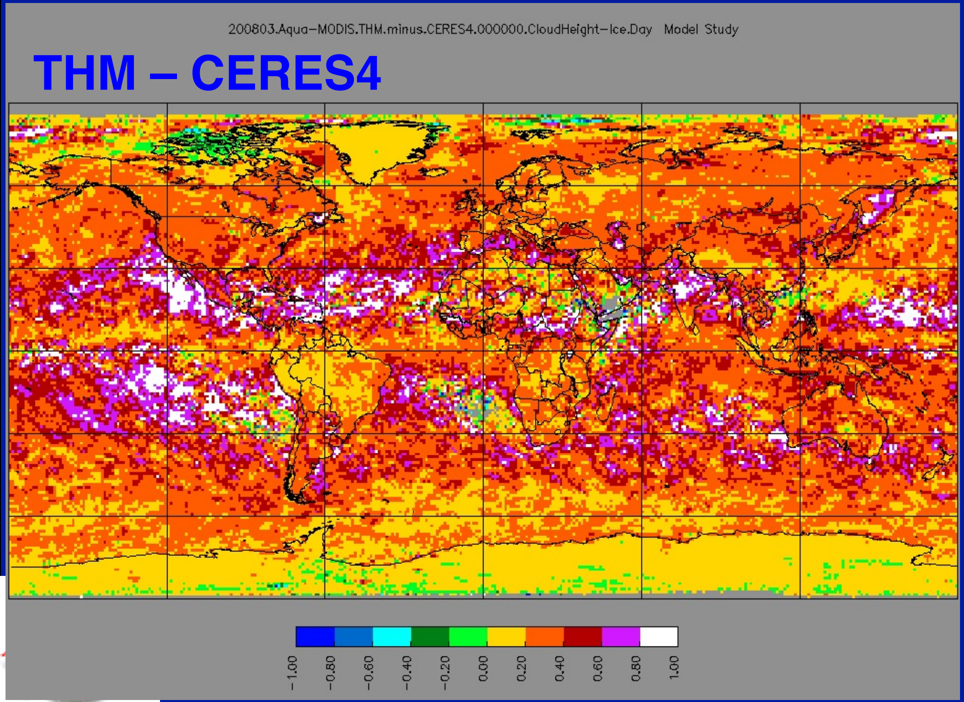




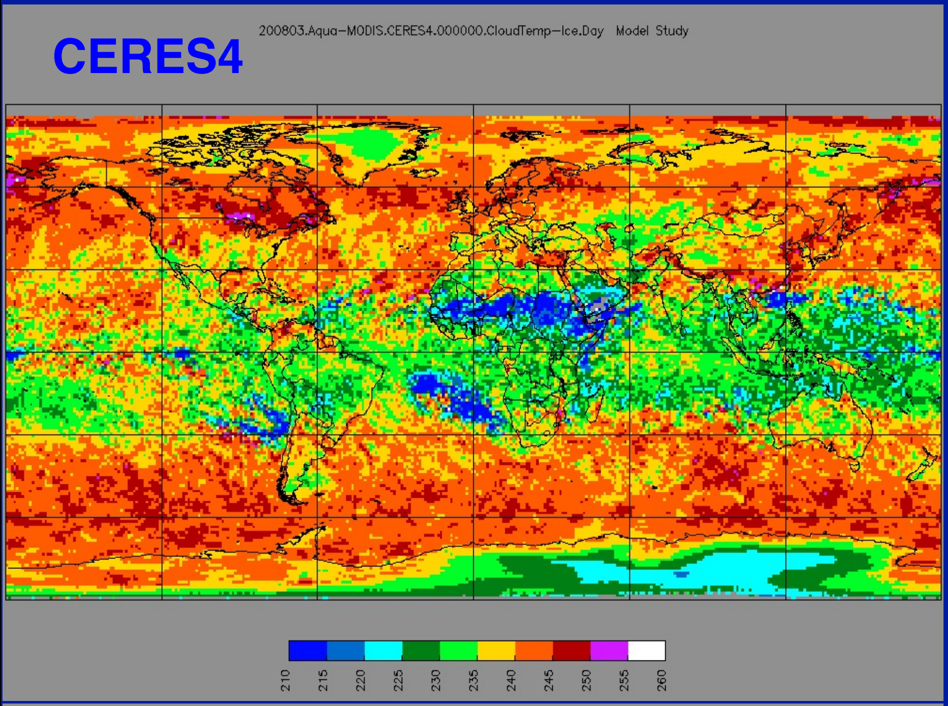
Aqua MODIS, March 2008
Ice Effective Radius, Day Time

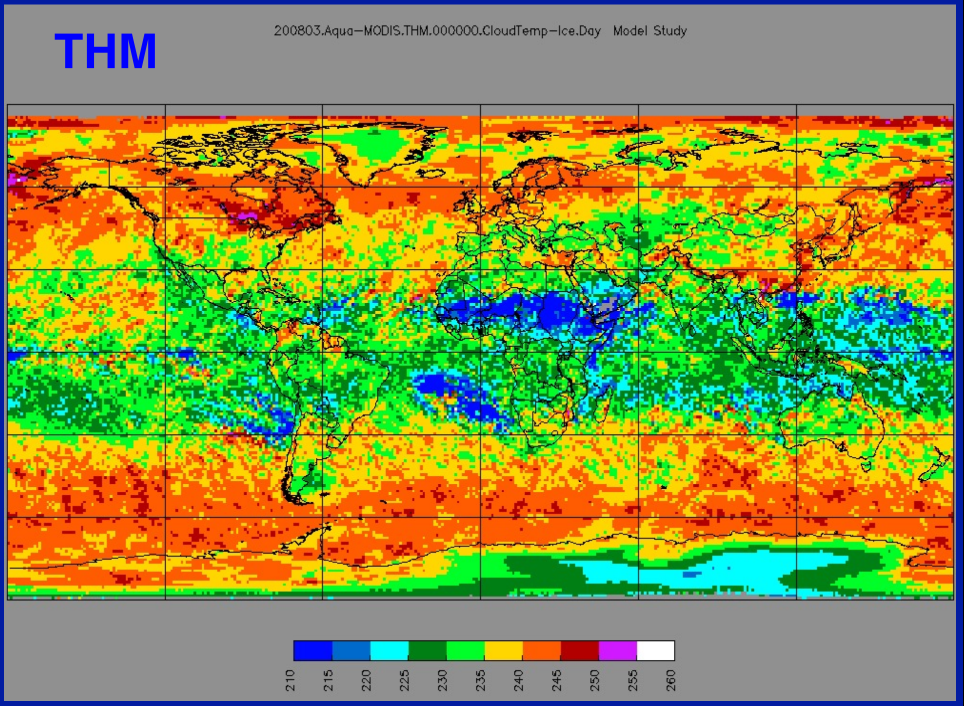


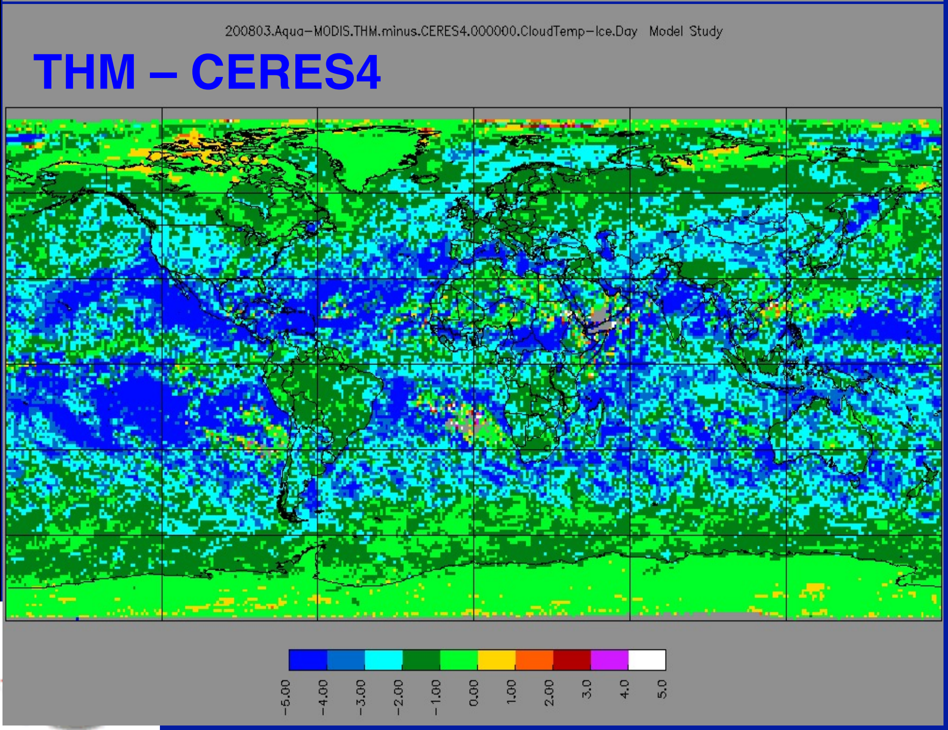




Aqua MODIS, March 2008
Eff Height, Ice Phase, Day Time







Aqua MODIS, March 2008
Cloud Temp, Ice Phase, Day Time

Cloud Phase Agreement for THM & 1HM Results
Aqua-MODIS, March 2008

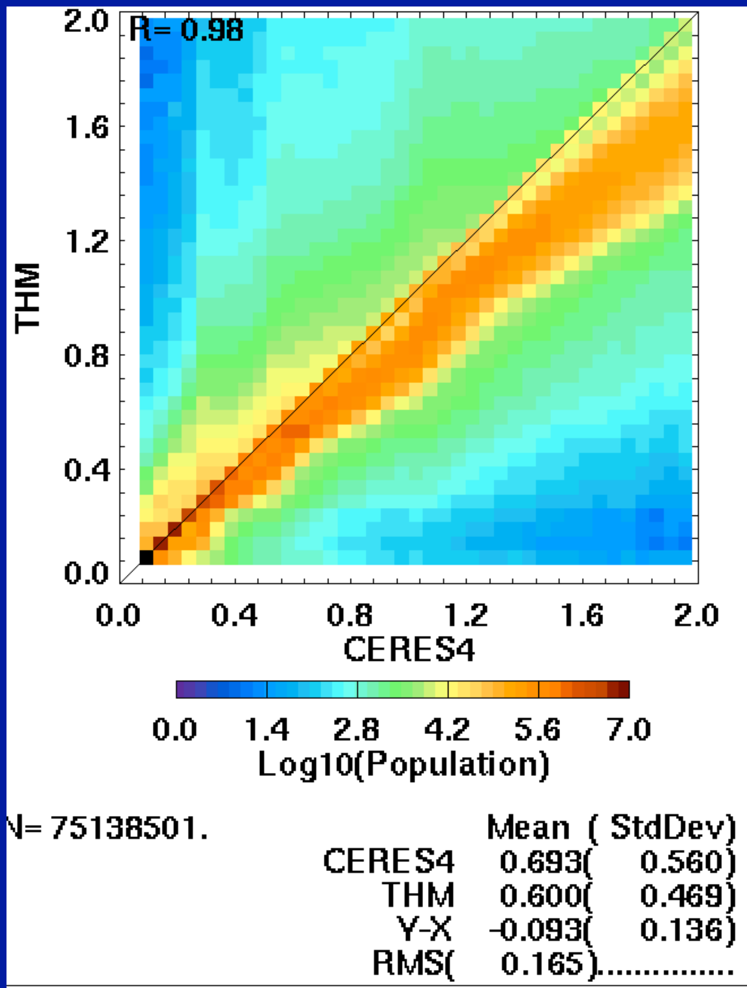
		THM	
CERES4		Ice	Water
	Ice	0.91×10^9 46.0 %	7.9×10^6 0.4 %
	Water	3.3×10^6 0.2 %	1.06×10^9 53.4 %

- Overall agreement: 46.0% + 53.4% ~ 99%

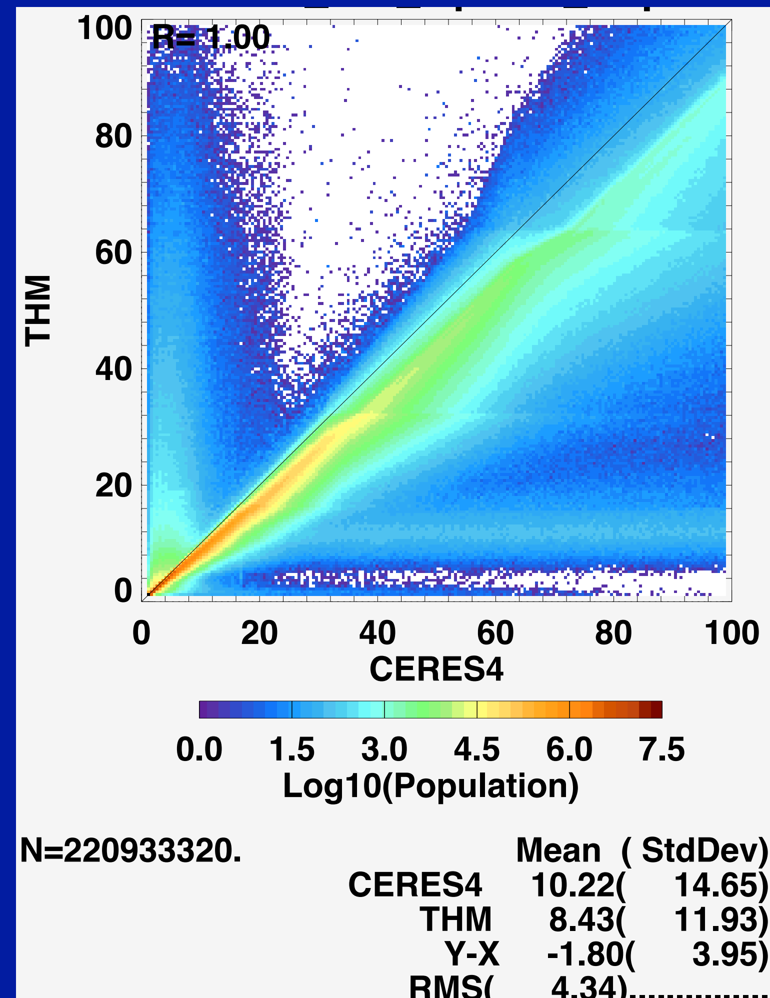
Optical Depth Comparisons, Snow Free

Y-axis: THM; X-axis: 1-H-Rough

tau < 2

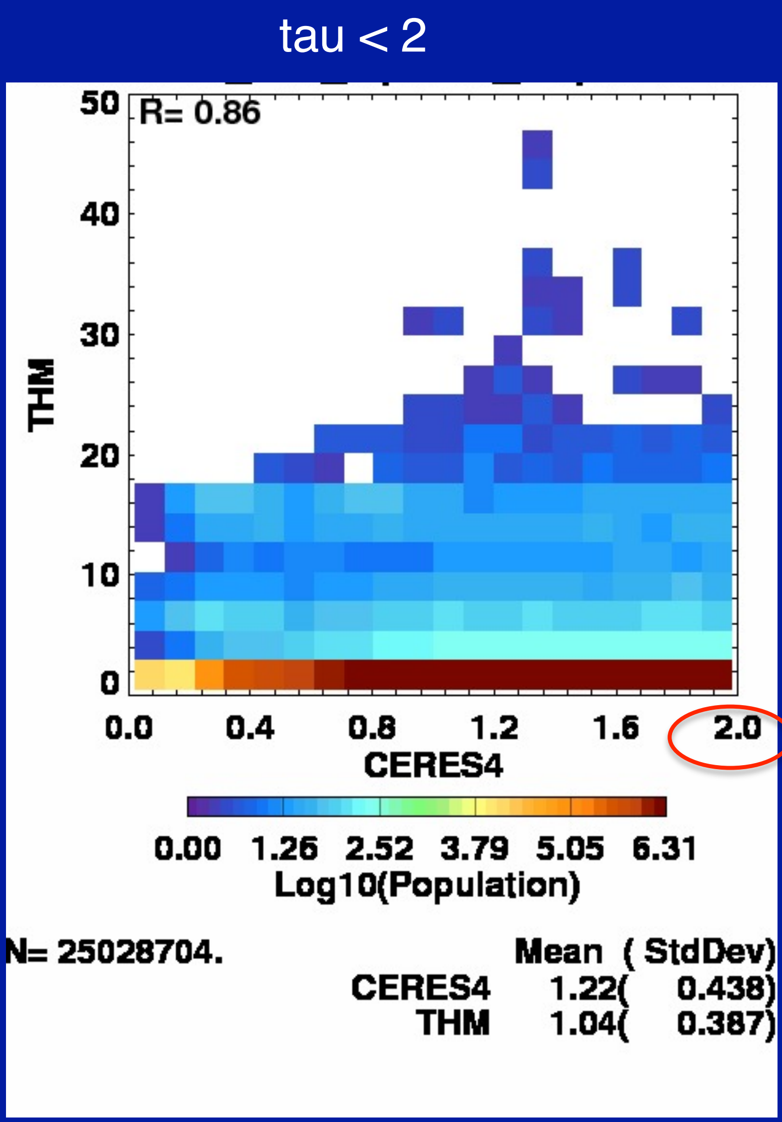


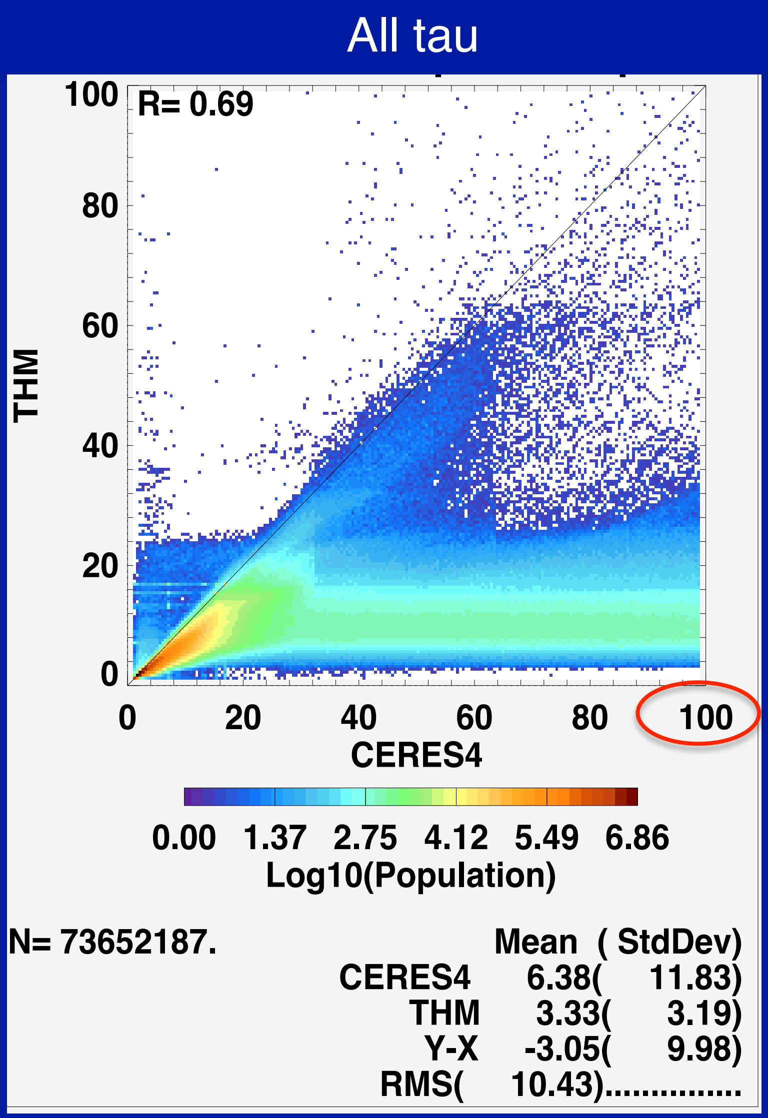
All tau



- 13% decrease for COD < 2; 18% overall
- Odd artifacts being examined

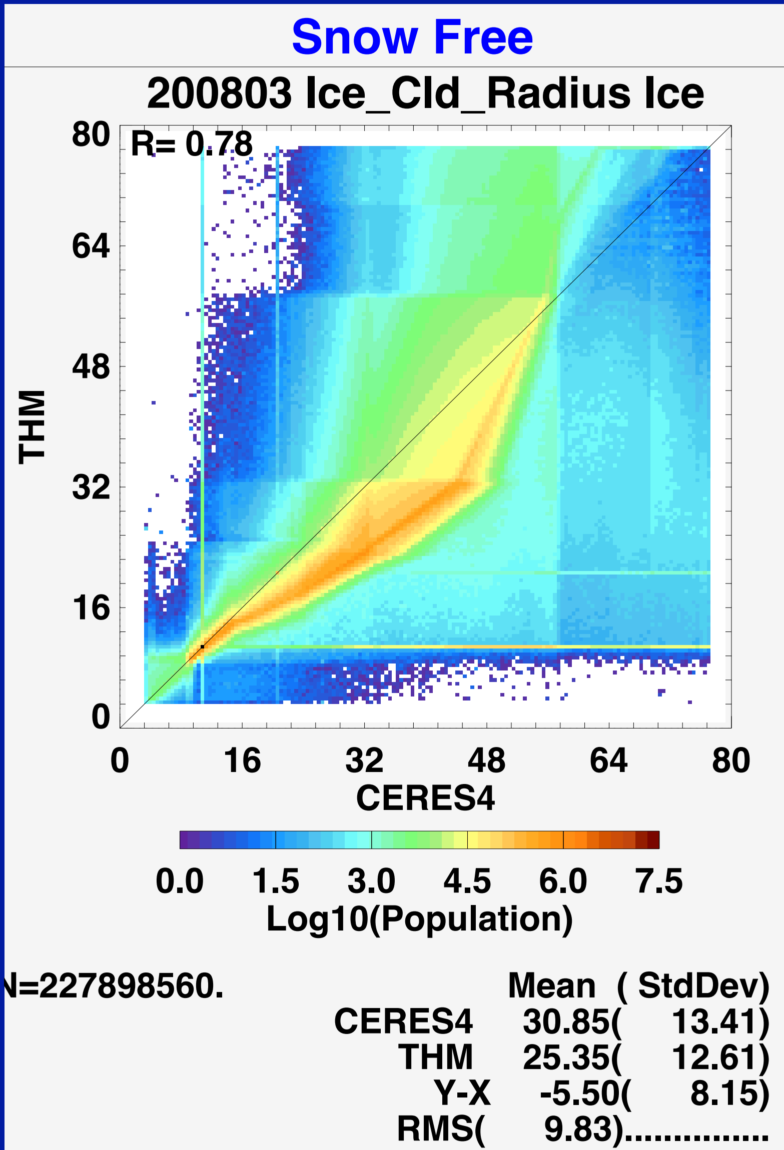
Optical Depth Comparisons, Snow Cover

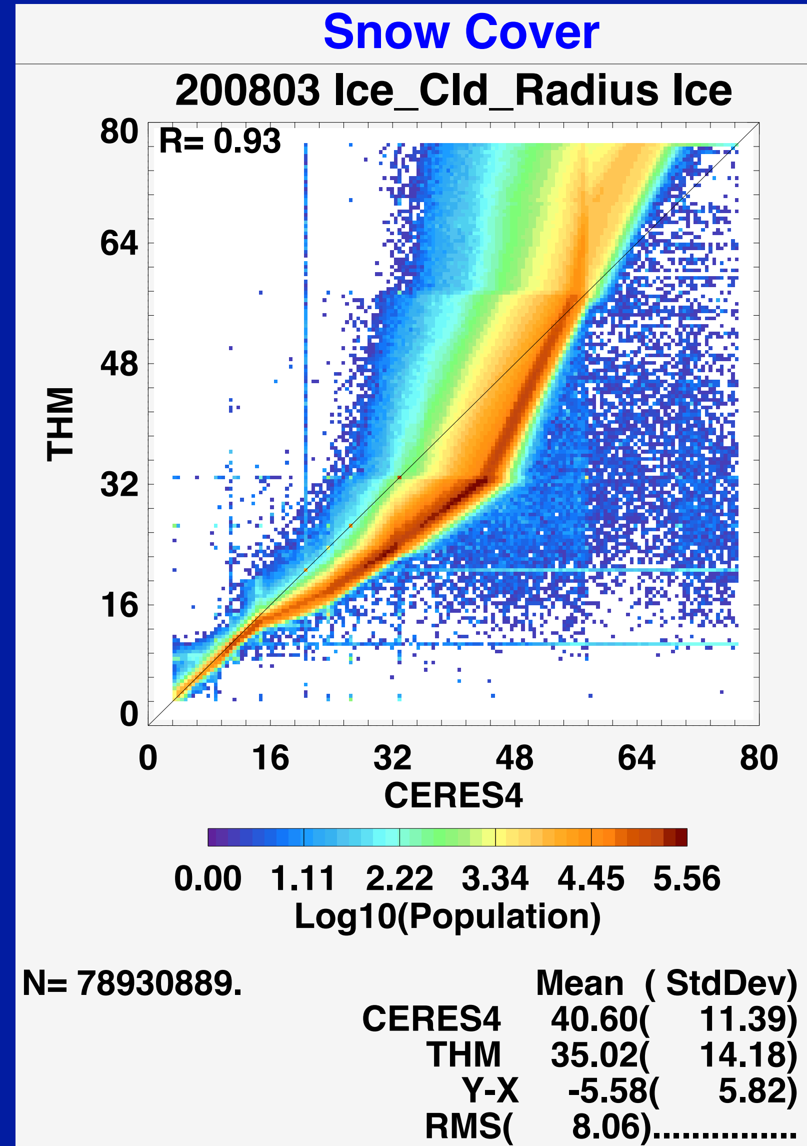




- 15% decrease for COD < 2; nearly 50% overall
- Odd artifacts being examined

Cloud Particle Size (Re, μm), Both Ice Phase

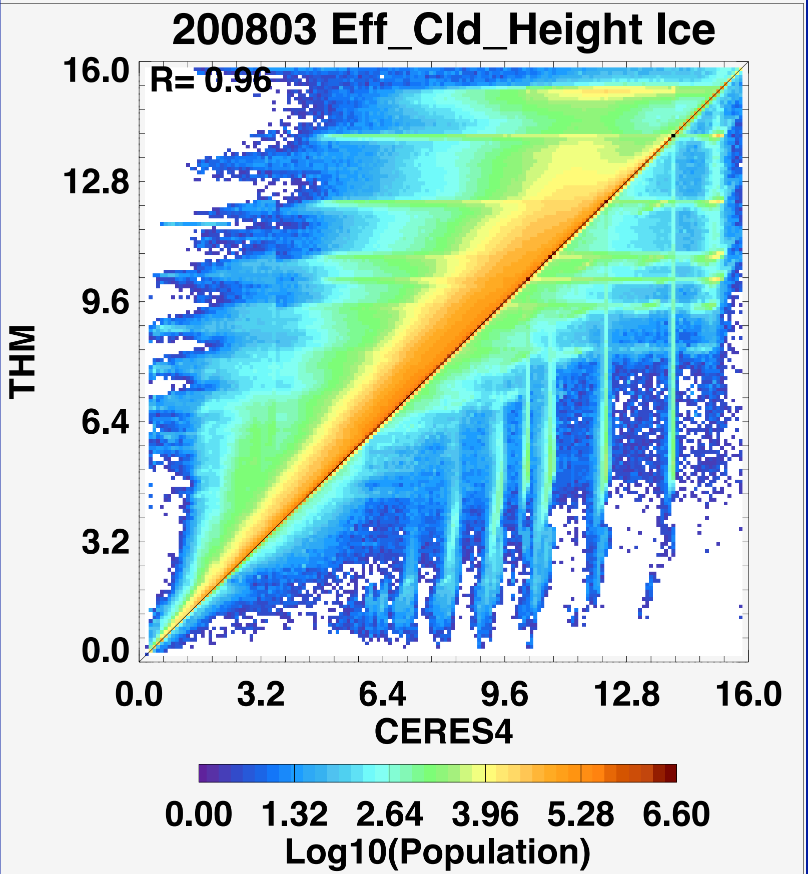




- Mean Re will go down by~18% with THM

Cloud Eff Height, Both Ice Phase, Snow Free

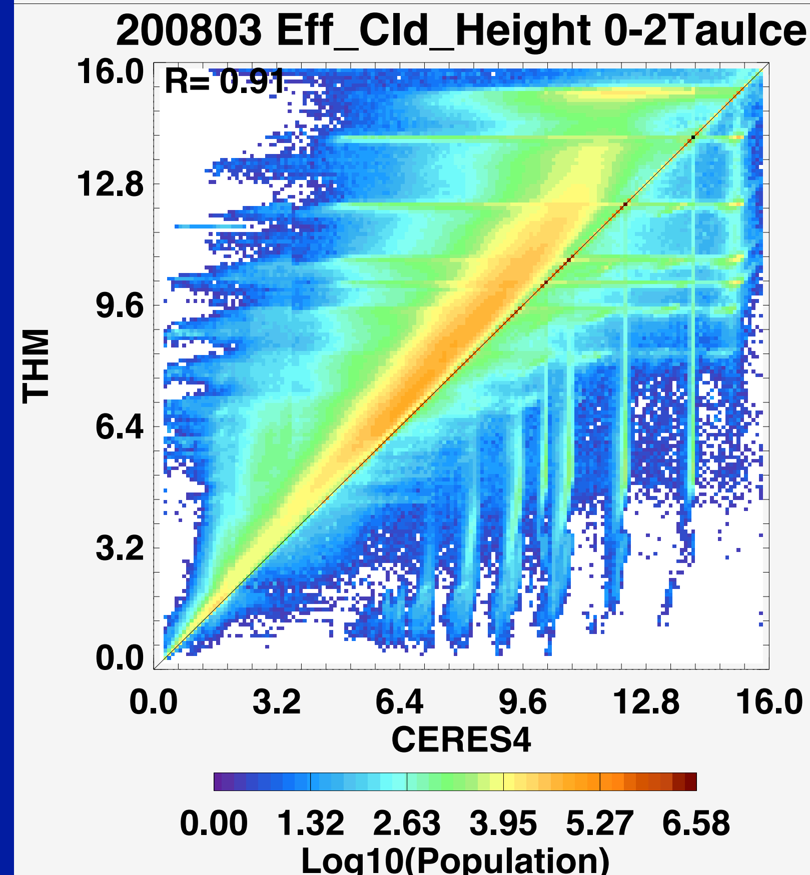
For All Tau



N=224171112.

	Mean	(StdDev)
CERES4	8.51(	2.80)
THM	8.84(	2.83)
Y-X	0.330(	0.768)
RMS(	0.836)...............	

For Tau < 2

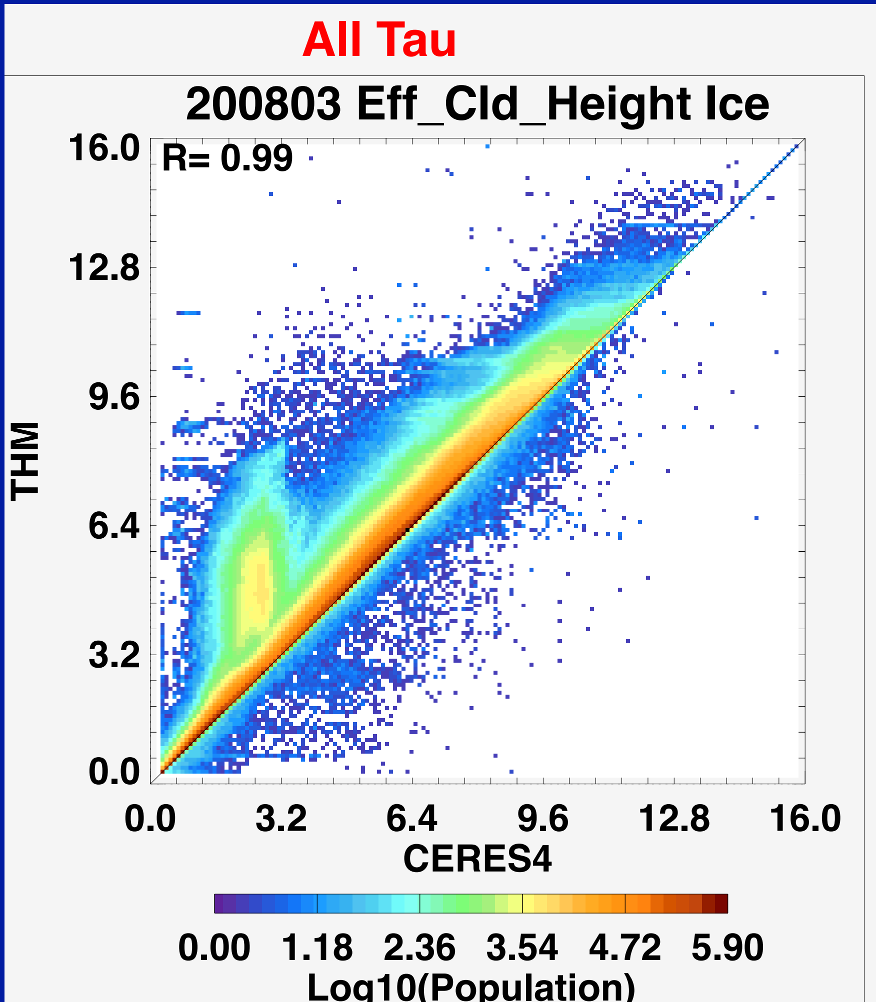


N= 72004415.

	Mean	(StdDev)
CERES4	9.03(	2.86)
THM	9.72(	2.79)
Y-X	0.688(	1.18)
RMS(	1.37)...............	

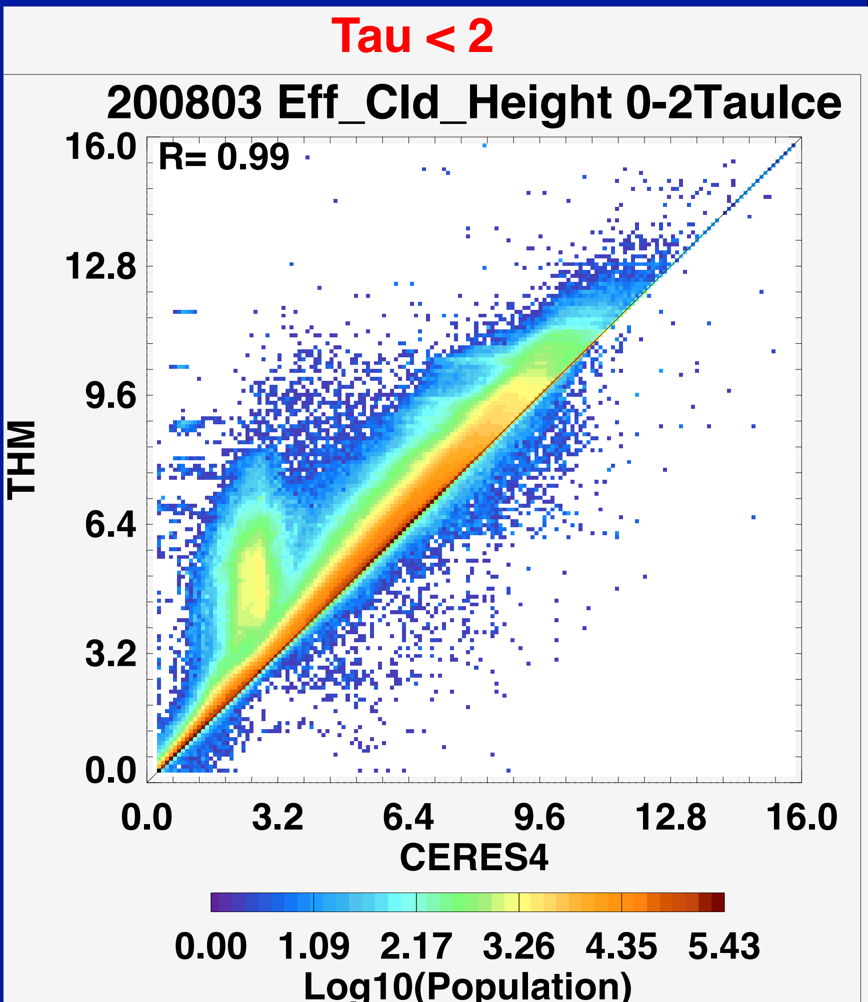
- 0.3 km increase overall, 0.7 km increase for thin clouds

Cloud Eff Height, Both Ice Phase, Snow Cover



N= 78930761.

	Mean	(StdDev)
CERES4	4.91(	2.32)
THM	5.08(	2.35)
Y-X	0.170(	0.354)
RMS(	0.393)...............	



N= 25028605.

	Mean	(StdDev)
CERES4	4.63(	2.37)
THM	4.83(	2.44)
Y-X	0.203(	0.397)
RMS(	0.446)...............	

Remarks on Initial THM Retrievals

- THM reduces ice cloud optical depth by
  - snow-free:18% for all; 15% for thin (< 2) ice clouds
  - snow: 48% for all; 15% for thin (< 2) ice clouds

- On average, THM reduces ice Re by 18%
  - IWP will drop
    - *need Re profile to obtain accurate IWP*

- THM ice cloud Zeff increased by
  - snow-free: 0.33 km for all; 0.69 km for thin (< 2) ice clouds
  - snow: 0.17 km for all; 0.23 for thin (< 2) ice clouds

- THM will bring CERES IR and VIS ice cloud retrievals closer

- CALIPSO: Version 4 out soon with reduced tau, so CERES and CALIPSO optical depths should have better agreement

Multilayer Clouds

- Many single layer ice or ice/water clouds being classified as multilayer
  - new approach uses neural network
  - talk on Thursday morning

Addressing thick ice cloud systems

- NN provides information about ice cloud COD

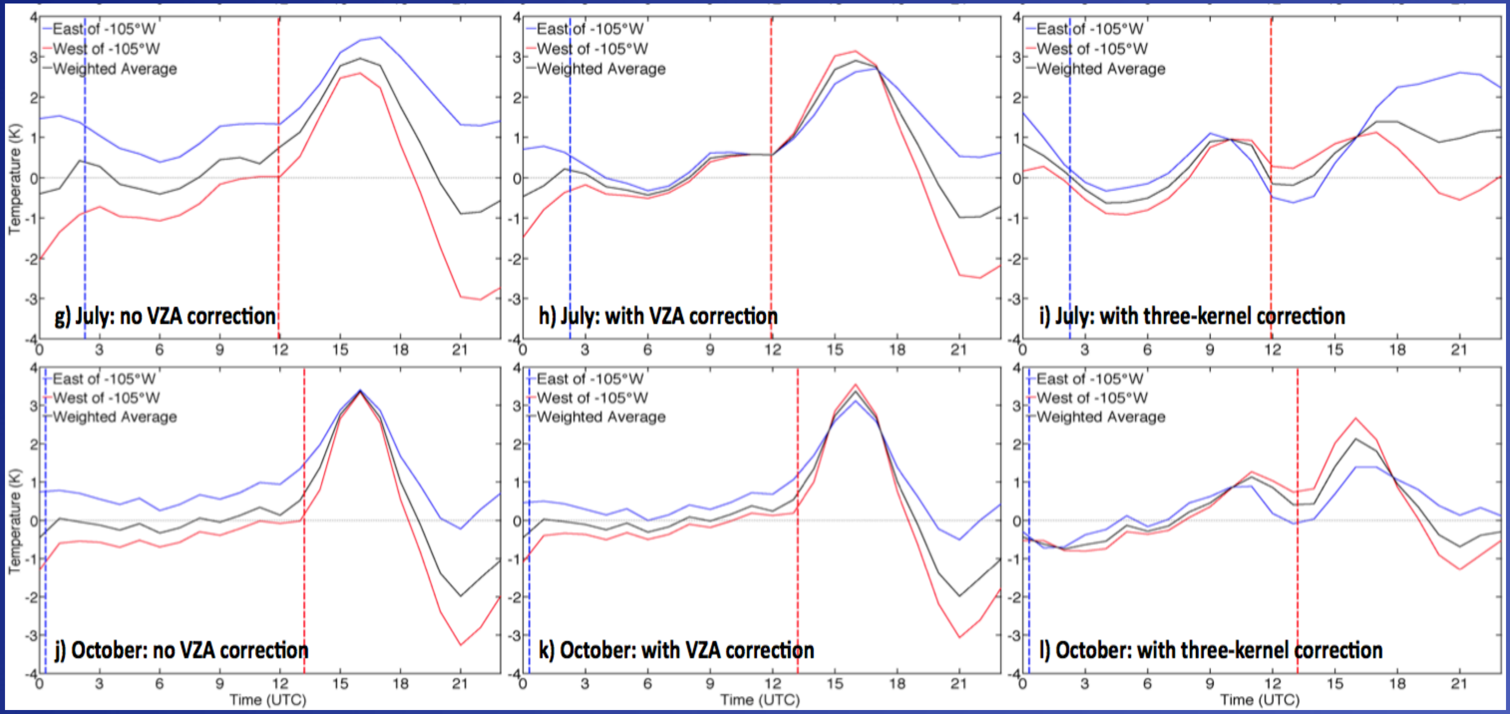
- Develop a different NN system to separately identify thick cloud systems
  - examine signals from various channels
    - *use C3M CC profiles of COD and layering*

Welcome Bill Smith

Accounting for LST anisotropy

- Developed approach to account for VZA dependence
- A variant of Vinnikov model could help account for all angle dependencies
  - use multiple matched data with terrain & vegetation information

LST(GOES-E) – LST(GOES-W) over N. America, 2013, 1° regional means



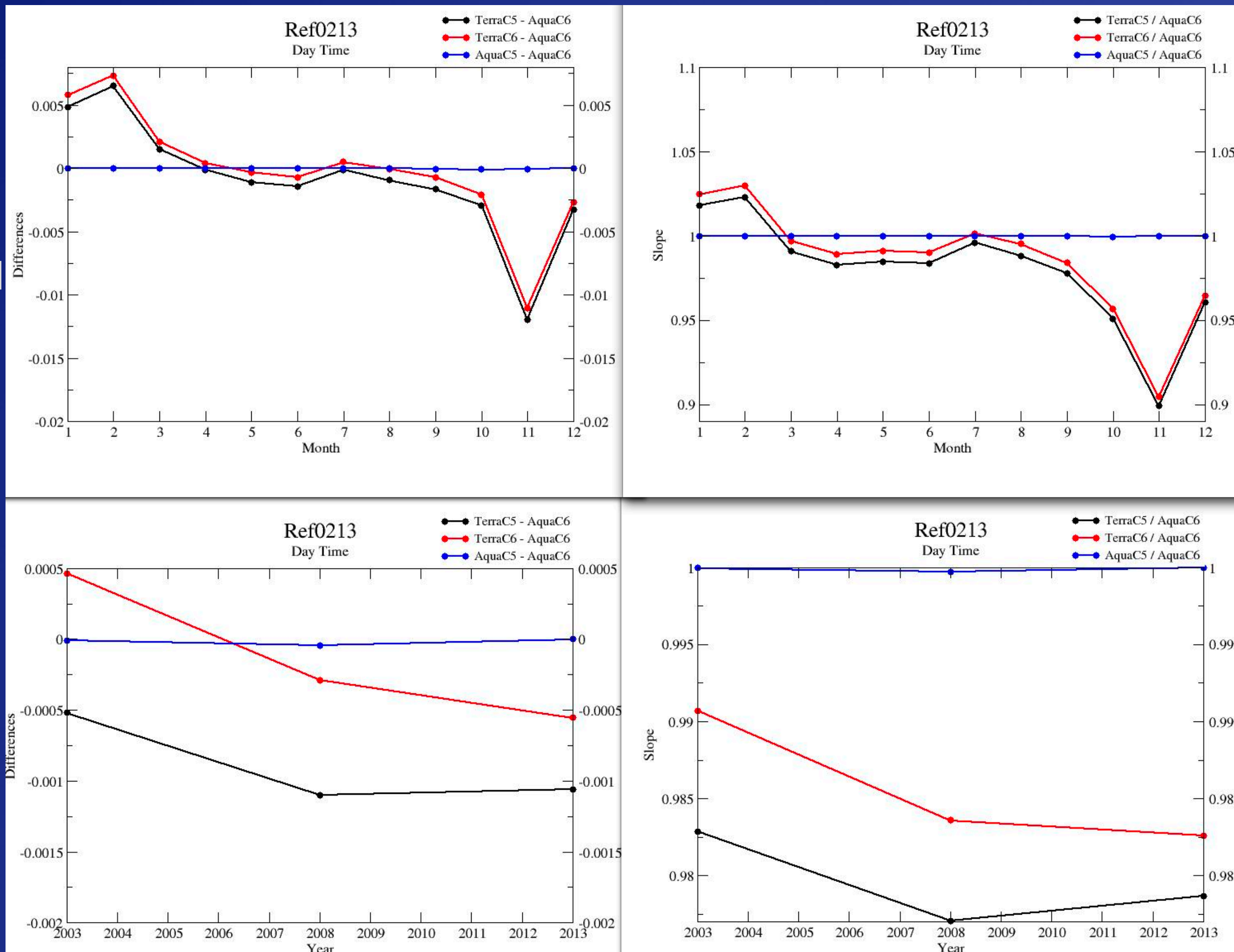
- Mean biases up to 3.5° (day), 1.2° (night) with no correction
- Single VZA correction reduces day to 3° and night to 0.5°
- Universal Vinnikov model reduces night to 1° and day to 2.5°

Shortwave-IR channel (2.13 μm) C5-C6 changes, day

mean difference | slope of regression

seasonal

annual



Oct - Feb oddball months

0.02 K rise in Aqua after 2008

Terra C5 and C6 reverse after 2008

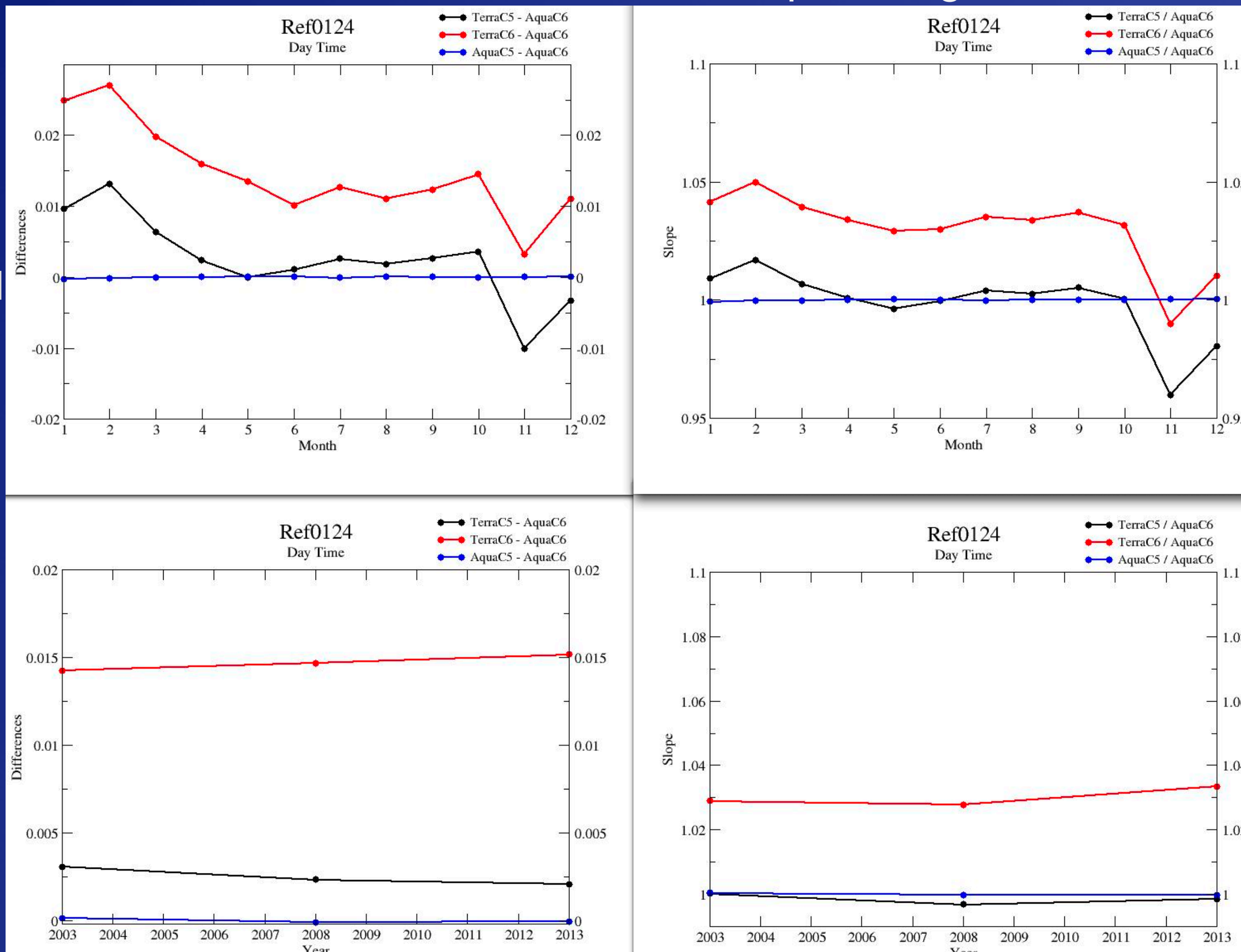
- Terra C5 (-0.10 to -0.02 K vs 0.14 to 0.25) closer to Aqua
- Terra C5 within 0.1% and C6 within 0.4% of Aqua

Near-IR channel (1.24 μm) C5-C6 changes

mean difference slope of regression

seasonal

annual



Nov-Feb oddball months

0.02 K rise in Aqua after 2008

Terra C5 and C6 reverse after 2008

- Terra C5 (-0.10 to -0.02 K vs 0.14 to 0.25) closer to Aqua
- Terra C5 within 0.1% and C6 3.0% > Aqua

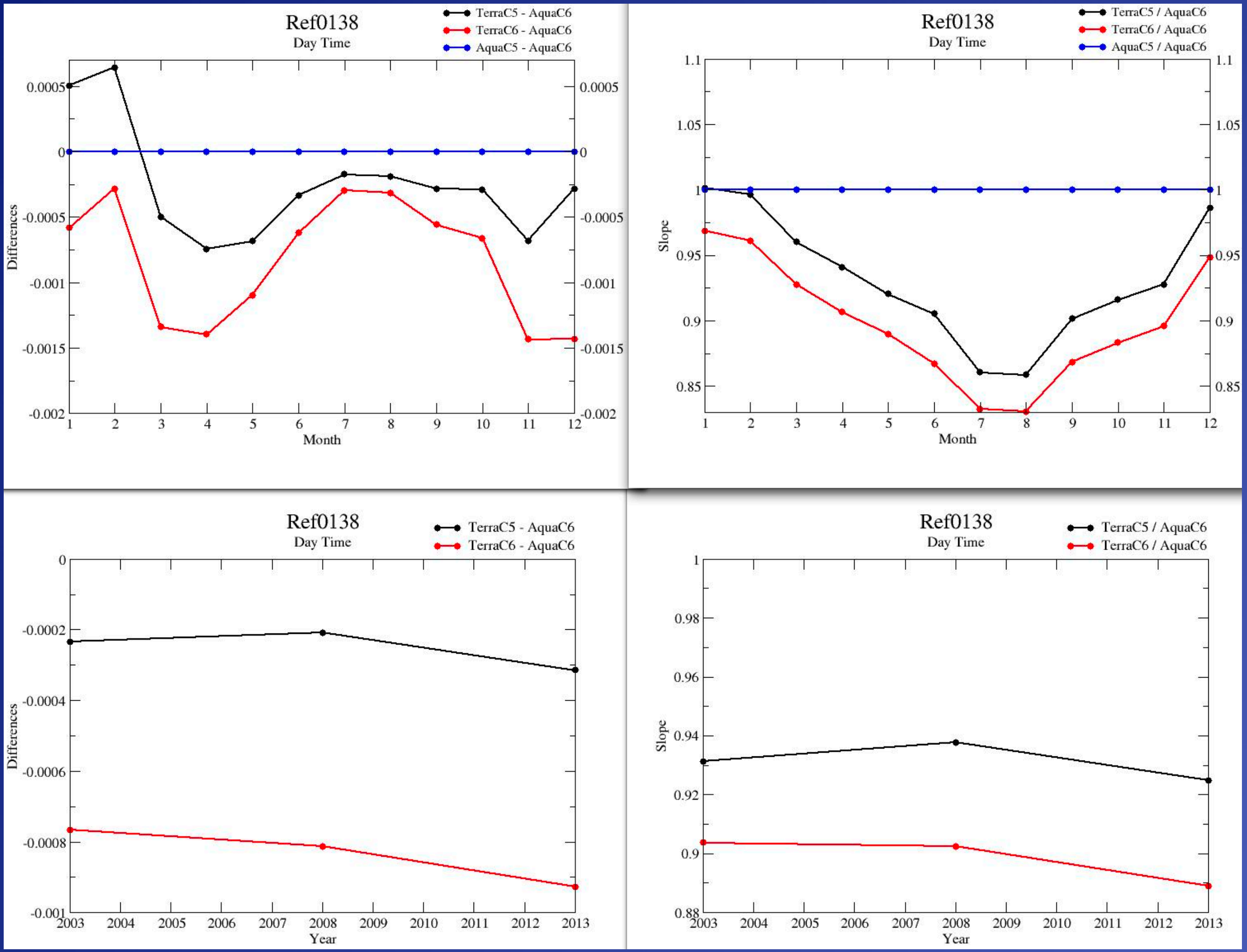
Near-IR channel (1.38 μm) C5-C6 changes

mean difference

slope of regression

seasonal

annual



Nov-Feb oddball months

0.02 K rise in Aqua after 2008

Terra C5 and C6 reverse after 2008

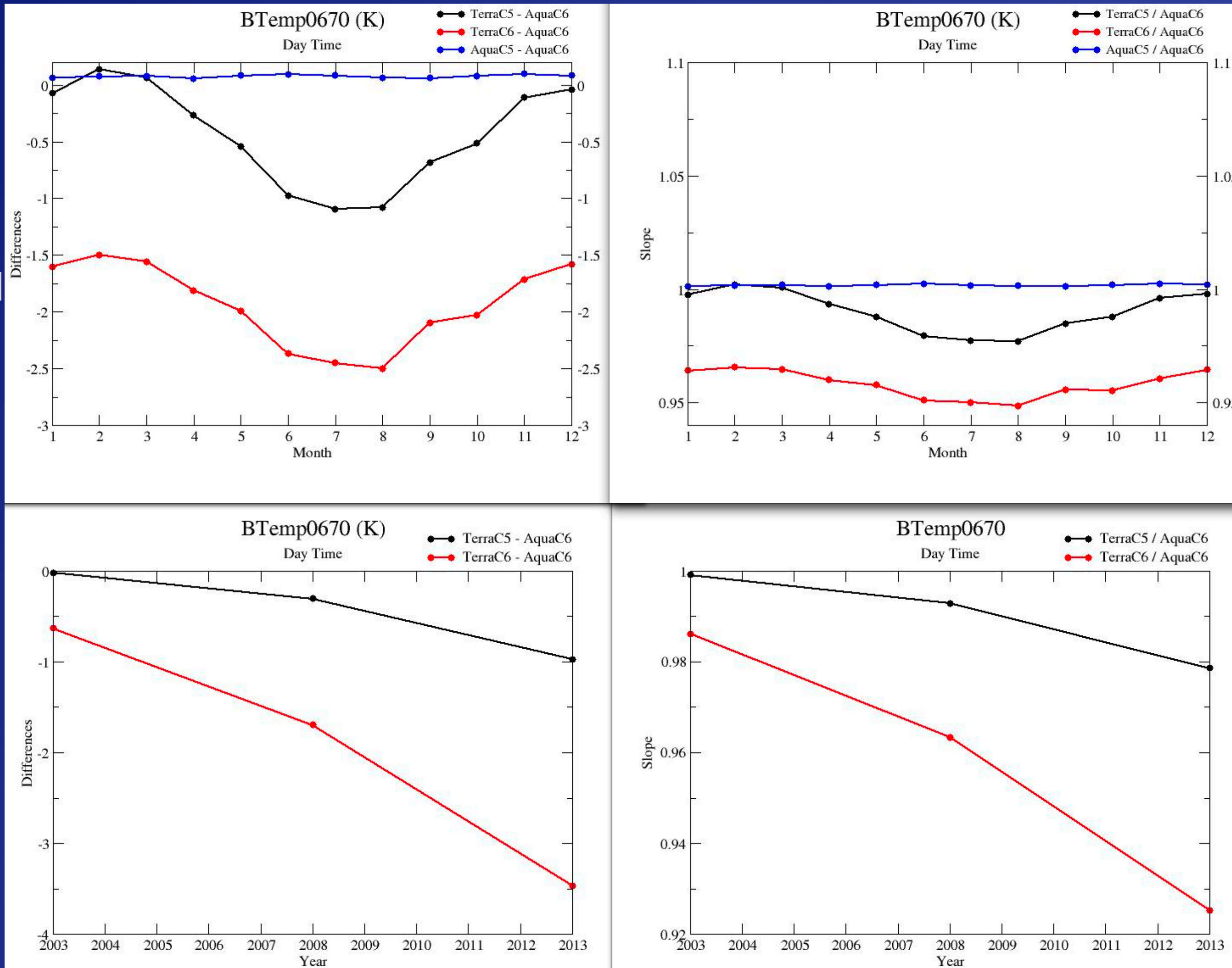
- Terra C5 (-0.10 to -0.02 K vs 0.14 to 0.25) closer to Aqua
- Terra C5 within 0.1% and C6 3.0% > Aqua

Water-vapor channel (6.7 μm) C5-C6 changes

mean difference — slope of regression

seasonal

annual



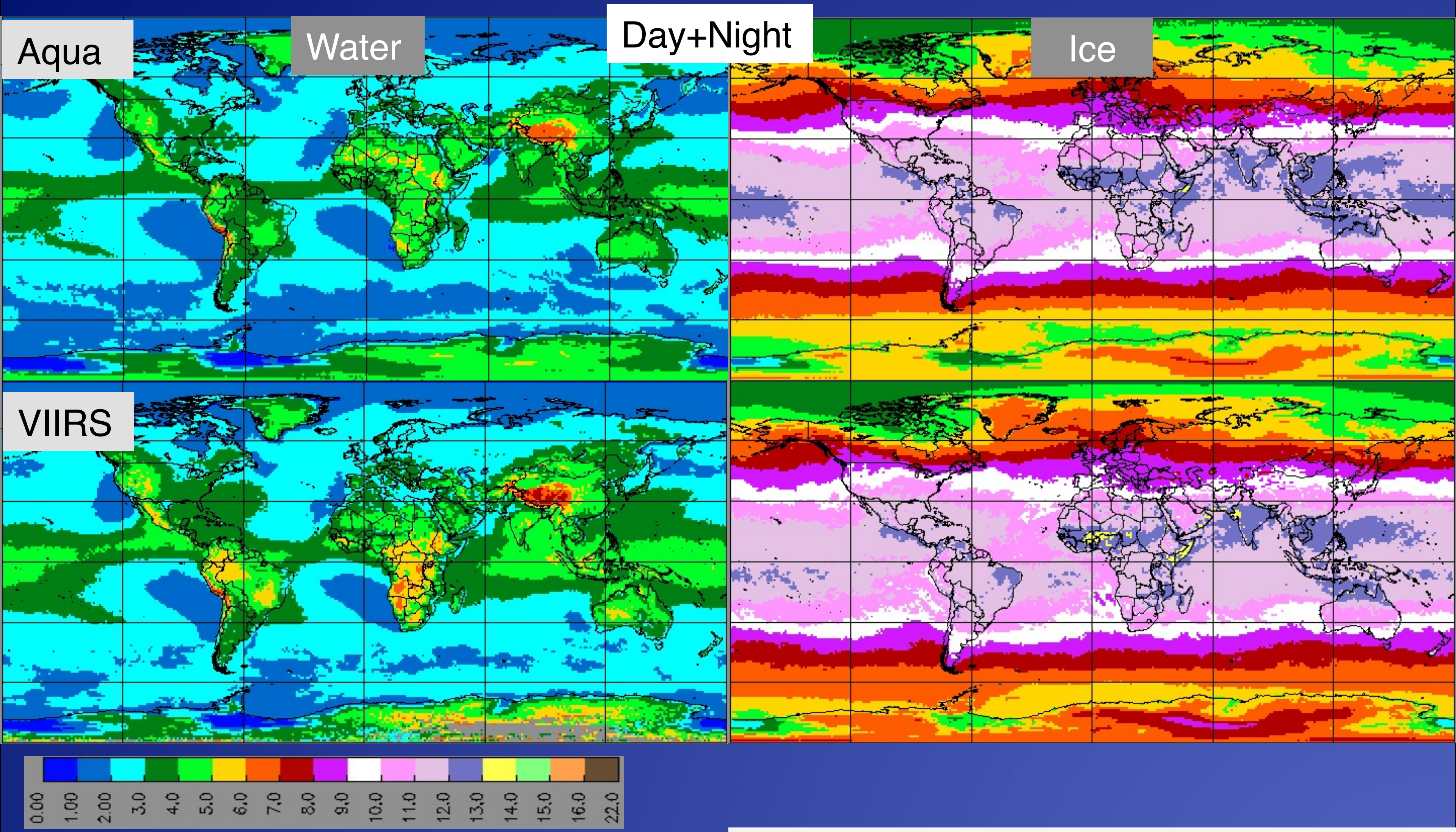
Nov-Feb oddball months

0.02 K rise in Aqua after 2008

Terra C5 and C6 reverse after 2008

- Terra C5 (-0.10 to -0.02 K vs 0.14 to 0.25) closer to Aqua
- Terra C5 within 0.1% and C6 3.0% > Aqua

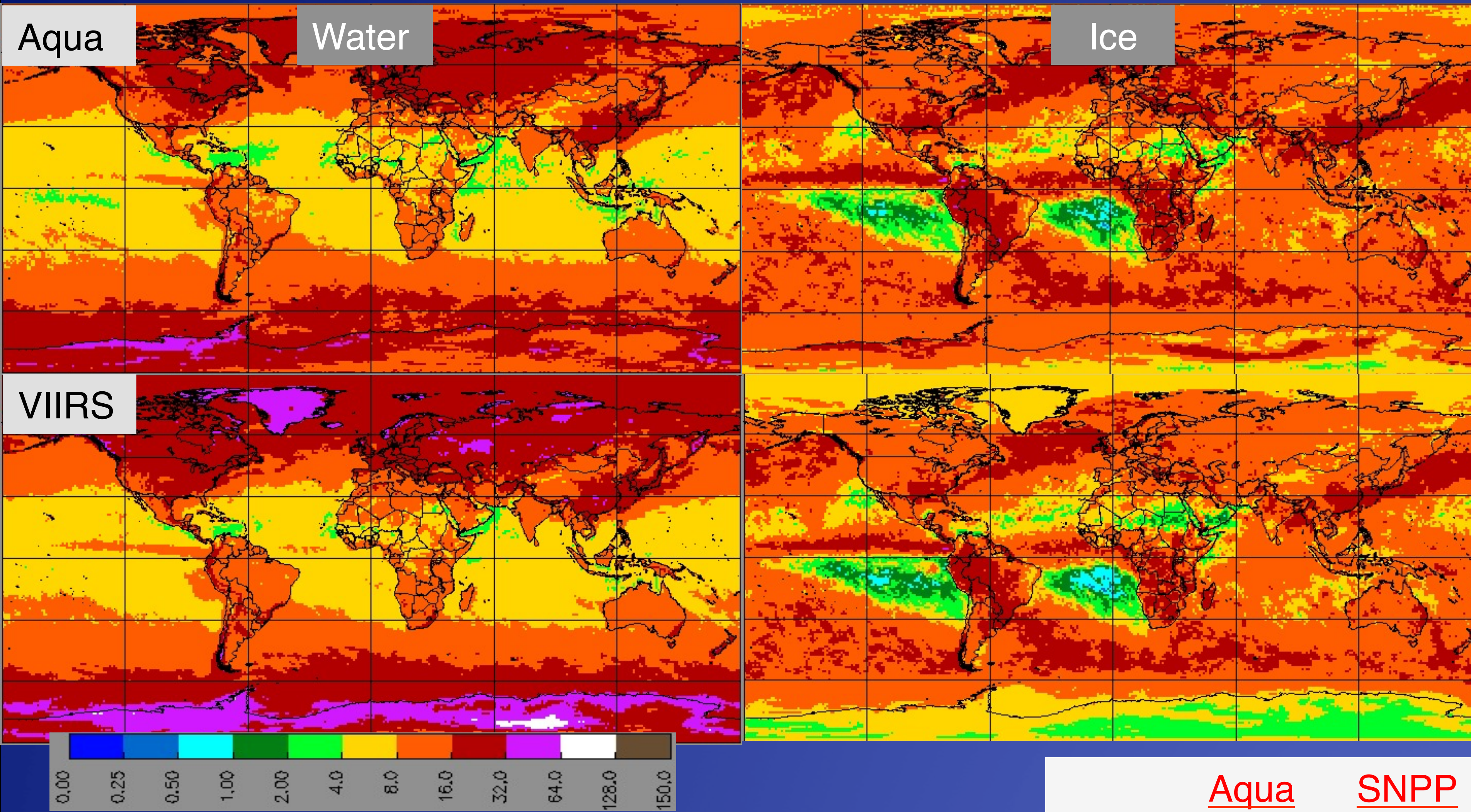
Aqua & VIIRS Mean Cloud Effective Heights (km), 2015



	Water		Ice	
	Aqua	SNPP	Aqua	SNPP
Day	2.68	2.86	8.85	9.19
Night	2.94	3.03	9.48	9.50

- VIIRS slightly higher than MODIS during the daytime

Aqua & VIIRS Mean Cloud Optical Depths, Day 2015



	Aqua	SNPP
Water	10.8	11.3
Ice	12.7	11.5

- VIIRS larger for water:
  - Aqua degradation, resolution effect?
- VIIRS ice both smaller & larger, 9% less in mean
  - polar regions biggest difference, calibration?

C5 vs C6 for 3.78-μm Brightness Temperatures (K), Day 2008

Ed2 | C6 | Ed4