# Surface Atmosphere Radiation Budget (SARB) working group update

Seiji Kato[1], Fred Rose[2], David Rutan[2], Alexander Radkevich[2], Thomas E. Caldwell[2], Seung Hee Ham[1], and David Fillmore[3]

[1]NASA Langley Research Center
[2]Science System & Applications Inc.
[3]Tech-X

# Outline

- Accomplishments since the last science team meeting
- SYN Ed4 update
- EBAF-surface update
- CRS Ed4 plan
- NPP plan

# Accomplishment since the last CERES science team meeting

- Evaluated the impact of V006 AIRS data to EBAF-surface (AIRS V005 versus V006 and GEOS-5.4.1, D. Rutan's presentation)
  - Extending EBAF-surface ed2.7 from October 2012 through March 2013
- Evaluated aerosol radiative effect in the SYN product
- Evaluated MATCH aerosols compared with CALIPSO (D. Fillmore's presentation)
- Developed snow BRDF to model broadband radiance over permanent snow (A. Radkevich's presentation)

# SYN Ed4

# SYNI Ed4 (in progress)

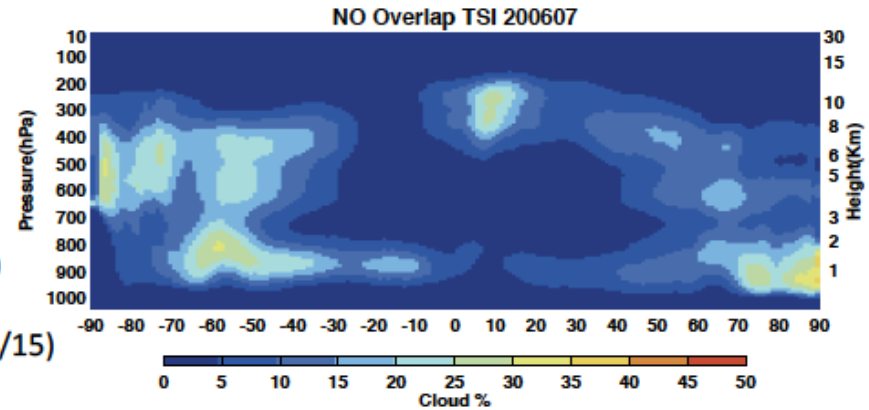
- Cloud
  - ✓ Use 4 significant cloud vertical profiles (combination of 4 cloud types)
  - ✓ Include cloud overlap (random overlap)
  - – Incorporate cloud group's lapse rate and consistent phase function.
- Aerosols
  - – Hourly MATCH (file size ~700 Mb/day) (test data month July 2010)
  - – Include tropospheric SO4, stratospheric SO4, Ammonium sulfate, and volcanic ash in addition to small dust, large dust, sulfate, sea salt, black carbon, soluble, and insoluble.
  - – MODIS aerosols (collection 5)
- Surface albedo
  - – Ed4 surface history map (include partly clear-sky albedo derived from MODIS radiances)
  - – new spectral shape (using MODIS MCD43C product) over land and snow
  - – Solar zenith angle dependent surface albedo look-up table
- Radiative transfer code
  - ✓ 18 SW bands
  - – SW, GWTSA (inhomogeneous scenes) /4-stream (homogeneous scenes) hybrid; homogeneous cloud SF >= 10 4-stream, inhomogeneous cloud (SF< 10, GWTSA), clear-sky 4-stream.
- Tuning
  - – Regional, seasonal, scene (cloud/clear) and surface type (land and ocean) dependent tuning
- TSI
  - – 5-channel GEO cloud properties (test data month Jan. 2010 no temp 4GEO, July 2004 Terra only + 4GEO, April 2008 Terra+Aqua +4GEO)
  - – Including MODIS and GEO retrieved skin temperature
  - – Improved NB-BB LW irradiance
  - – Include lapse rate retrieved by the cloud group (at least two heights of temperature and pressure)
- Snow/Ice map
  - – Use 1/16 mesh of EICE and ESNOW maps.
- New variables
  - – Aerosol radiative effect product from SYN pristine, clear-sky, all-sky, and all-sky no aerosol fluxes (proposed)
  - ✓ Entropy computations

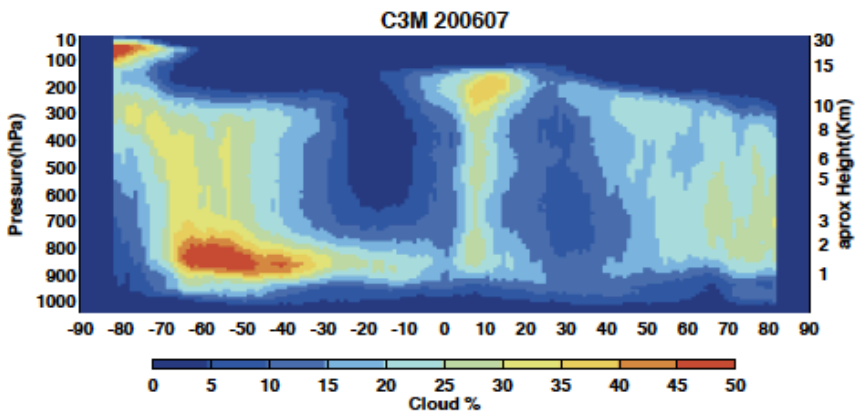
# cloud overlap in ed4 SYN

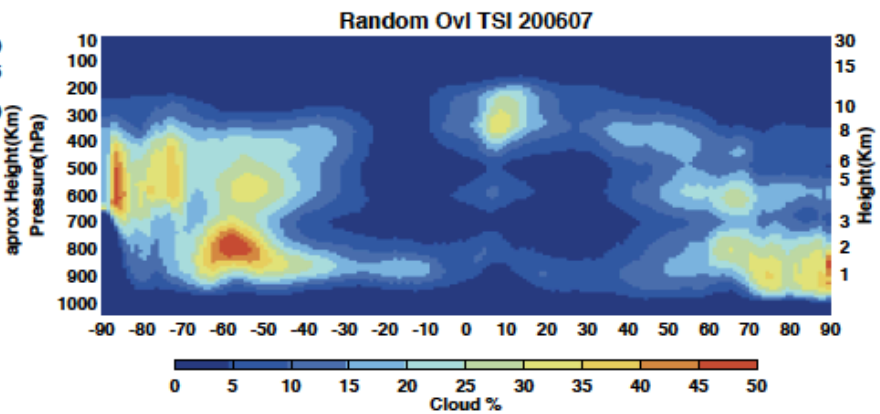
Monthly Mean Zonal /Pressure
Cloud Percentage July 2006

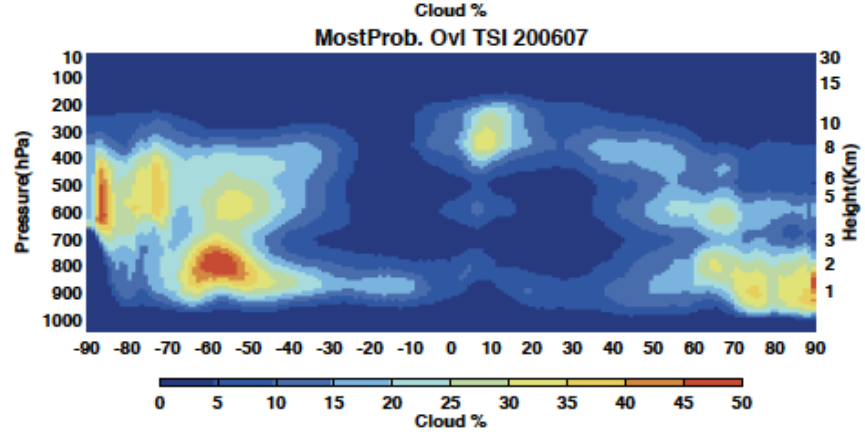
Left: C3M VFM Calipso/Cloudsat active sensor

Right Top: Ed3a TSI ( Modis/Geo) space viewed (No Overlap)
Right Middle: TSI ( Modis/Geo) w/Random Overlap (15case)
Right Bottom: TSI ( Modis/Geo) w/Most probable overlap (4/15)




Fifteen(15) possible cloud overlap conditions using TSI four (4) layer height information

| C | h1 | h2 | h3 | h4 | h5 | h6 | h7 | h8 | u1 | u2 | u3 | u4 | m1 | m2 | low |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F | T | T | T | T | T | T | T | T | F | F | F | F | F | F | F |
| F | T | T | T | T | F | F | F | F | T | T | T | T | F | F | F |
| F | T | T | F | F | T | T | F | F | T | T | F | F | T | T | F |
| F | T | F | T | F | T | F | T | F | T | F | T | F | T | F | T |

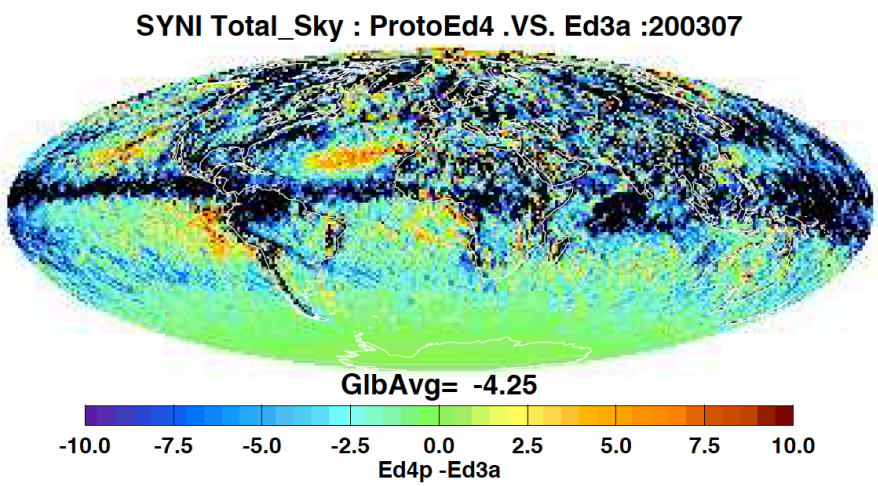
# Cloud overlap (with Ed2 clouds)

If everything else is the same, including cloud overlap (i.e. with fixed other cloud properties) gives

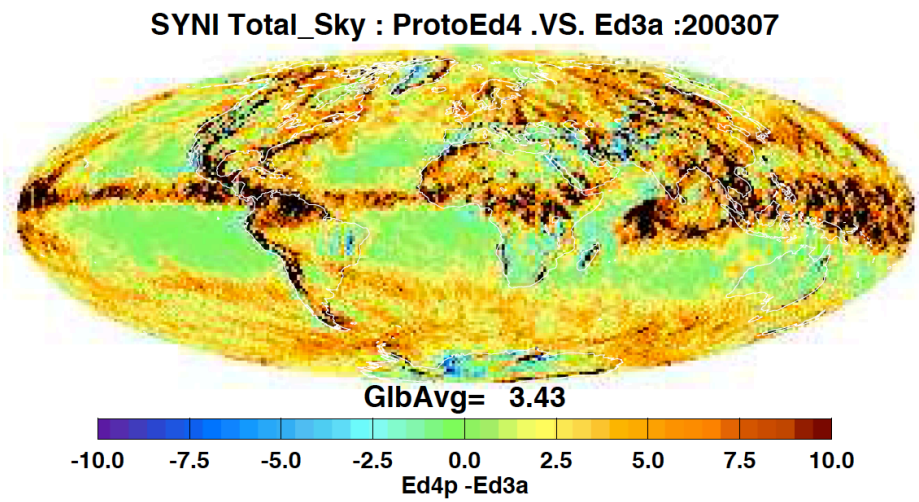
- a smaller TOA reflected shortwave
- a larger OLR

We are in process of trying to understand the difference

TOA SW reflected SW difference
Ed4 – Ed2




TOA LW up difference
ED4 – Ed2




Global monthly mean surface irradiance difference in $Wm^{-2}$

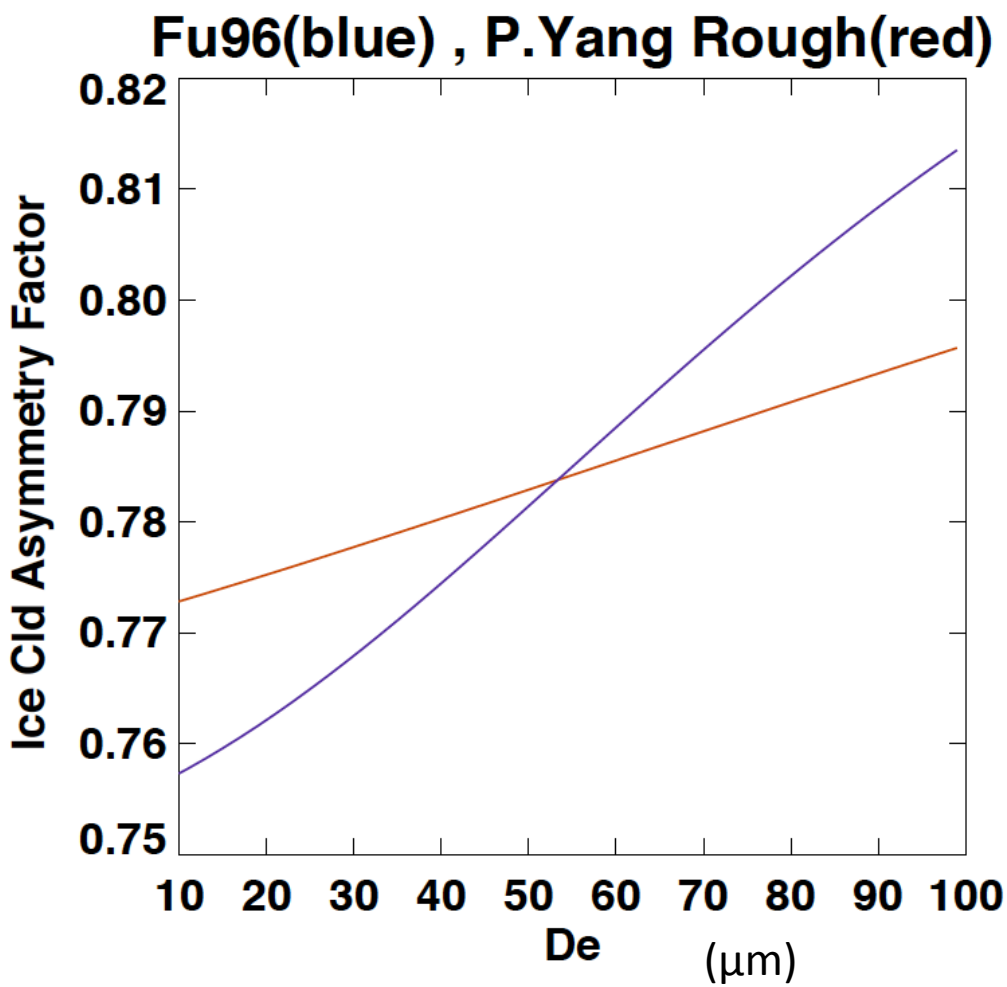
| Surface | SW up | SW down | LW up | LW down |
|---|---|---|---|---|
| Ed4 (with ed3 clouds) - EBAF | 0.6 | 6.8 | -0.2 | -1.6 (?) |

# Ice crystal optical property parameterization

- Langley Fu-liou code computes the asymmetry parameter g from the ice particle aspect ratio AR, i.e. g = f(AR).
- The ice particle phase function used in Ed4 cloud code is function of the effective diameter De, i.e. g = f(De).
- We determine the relationship between AS and De from g = f(AR) = f(De).
- This results in the relationship of

$$AR = 2.3 + 0.0159 * De.$$

# Asymmetry parameter difference




Fu 96: Ed2

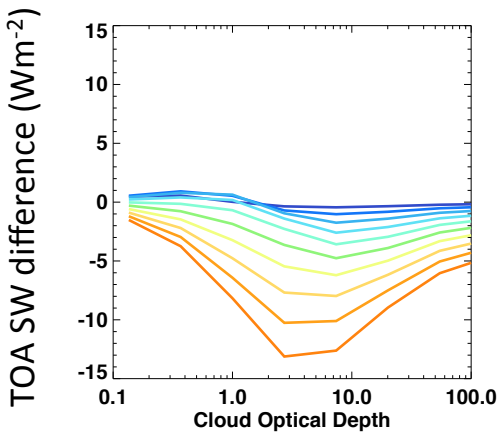
Yang Rough: Ed 4

Ed 4 SW TOA is darker De < 60µm
brighter De >60µm

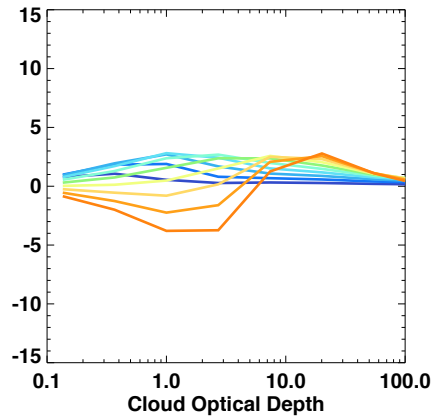
# Ed4 (Fu07) Rough minus Ed2 (Fu96)
# Using AR= 2.3 + 0.0159*De

Irradiance difference due to Ed4 – Ed2 parameterization
The difference is caused by the asymmetry parameter (g) difference for a given De

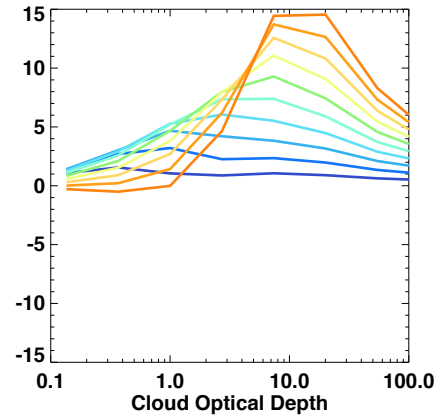
De =40 µm




De =60 µm




De =80 µm



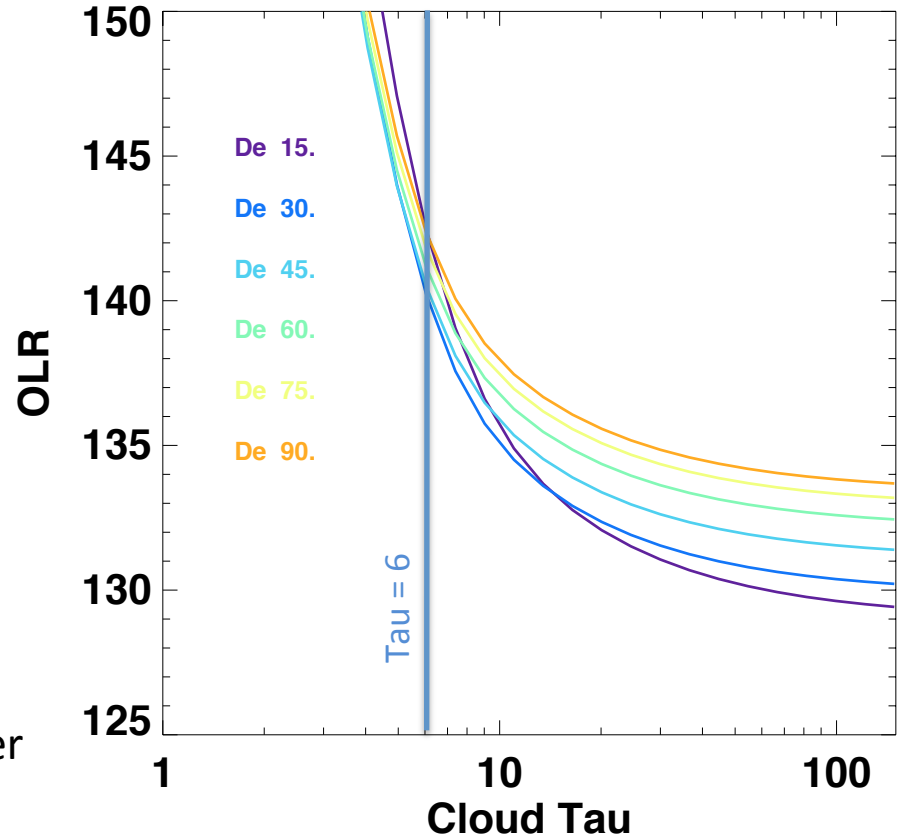

Fu07 for Roughened Ice Crystals needs and input of Aspect Ratio (AR)
The relationship AR= 2.3 + 0.0159*De is used to force consistency between P.Yang roughened Ice Crystals Asymmetry Parameter used for Cloud retrievals at 0.65µm. Fu96 was used in Ed3A SYNI

# High Cloud OLR vs Cloud Tau

About 25% of these daytime ice clouds have Tau > 6 (ln1.8) for latitude 10°N in July 2003.

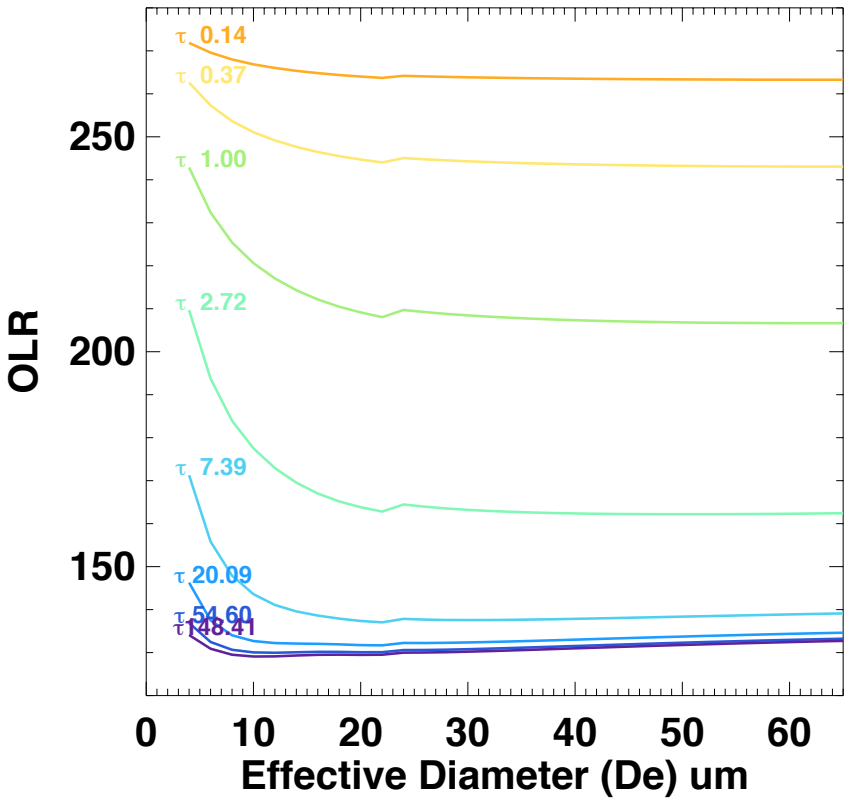
The emissivity of the cloud layer Very slowly approaches to 1 with tau.

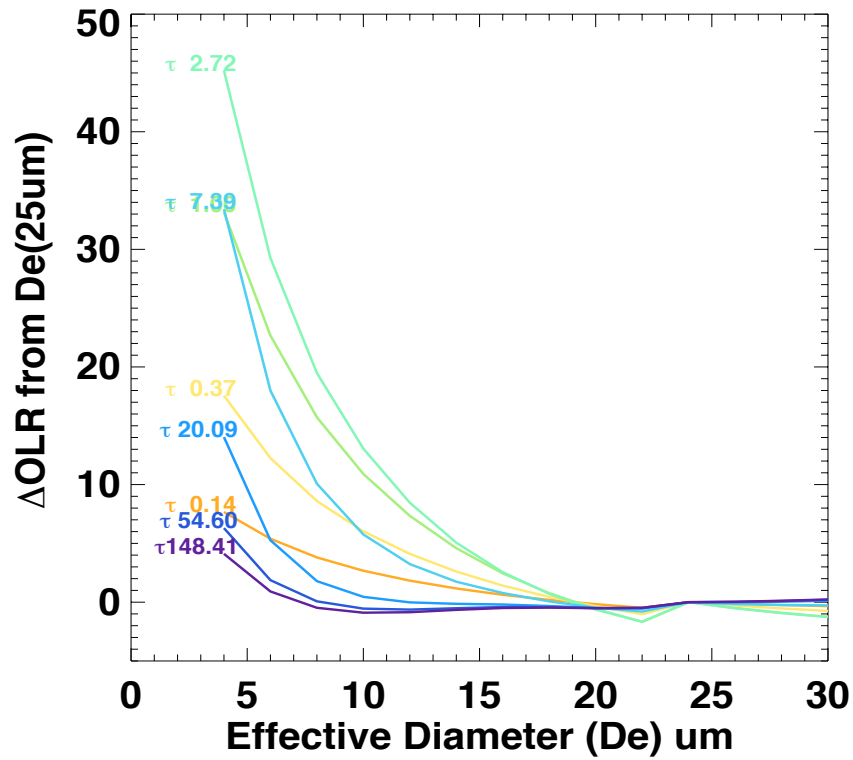
Our current overlap algorithm transfers optical depth to underlying clouds beginning at tau=6. The transfer of cloud optical depth from upper to lower layers causes an increase in OLR.



# New OLR Ice cloud parameterization for De < 20

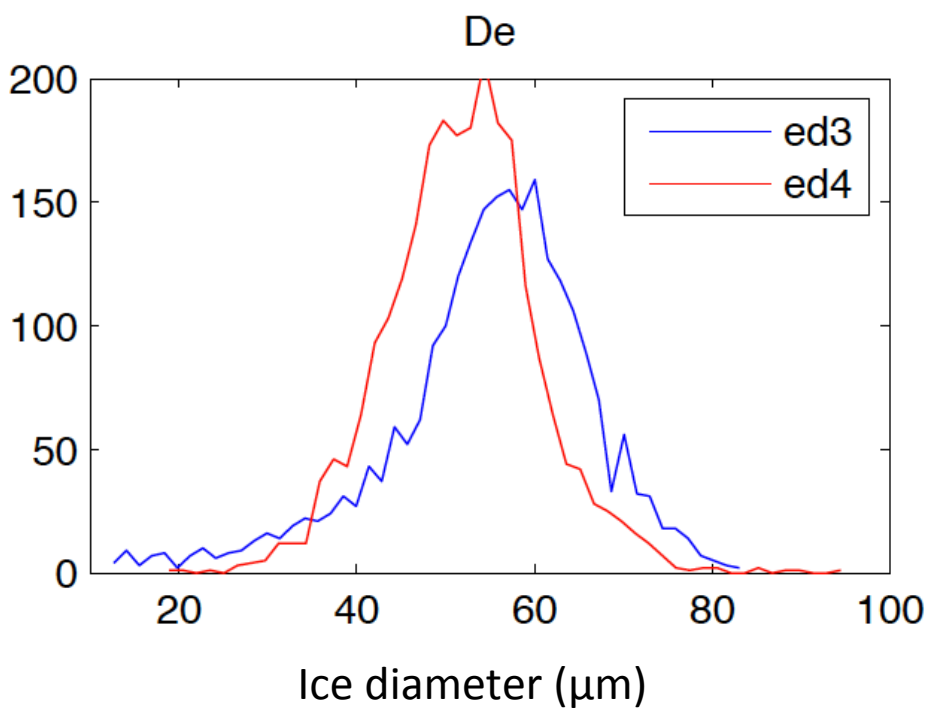
A small population of very small De <20 and moderate optical depth contribute to a warmer OLR due to a new optical property parameterization in the ED4 Fu_Liou for small De that were set to De=20 in Ed3 Fu Liou.

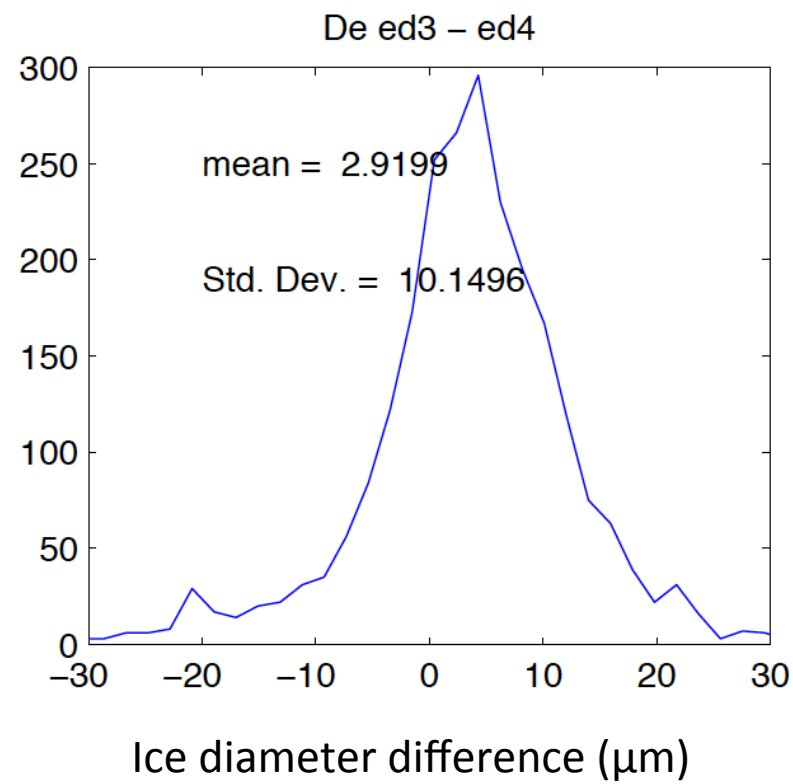


# Ed4 ice particle size

**January 2010 (Nadir view only)**




Ed4 gives smaller De.

# ED4 boundary layer clouds

- Cloud group
  - Seasonal and surface type (land, ocean, and snow) dependent lapse rate derived from CALIPSO.
  - Modify GEOS lapse rate to the CALIPSO-derived lapse rate below 780 hPa and place the cloud based on the retrieved cloud top temperature.
  - Temperature profile goes back to GEOS at 680 hPa
- SARB gets temperature and pressure at the cloud top and base T(top), p(top), T(base), and p(base) through Ed4 TSI. z(top) and z(base) are optional.

# SARB temperature and WV modification

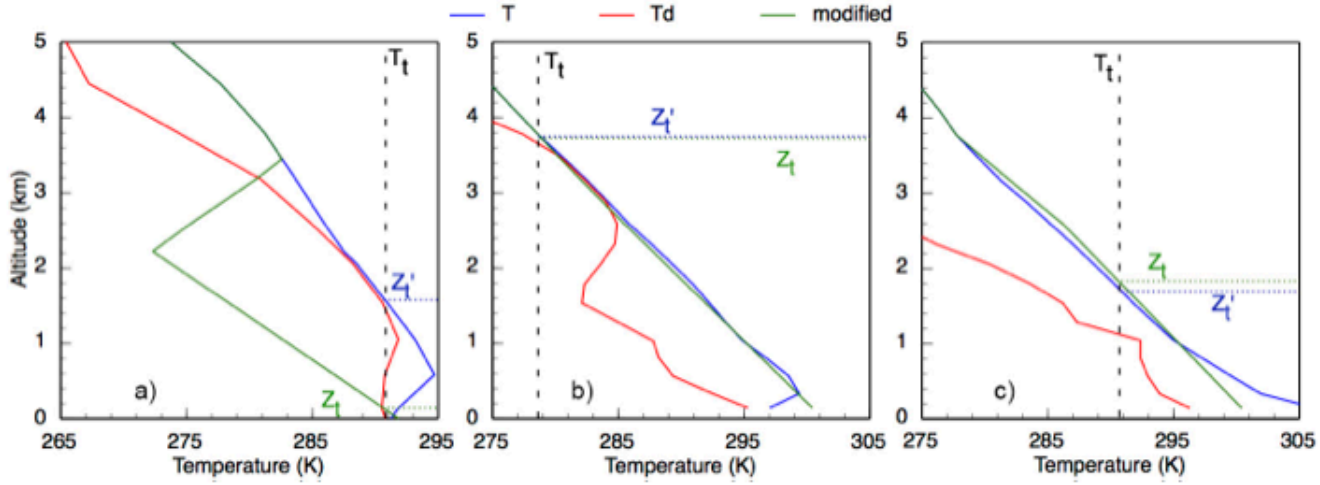
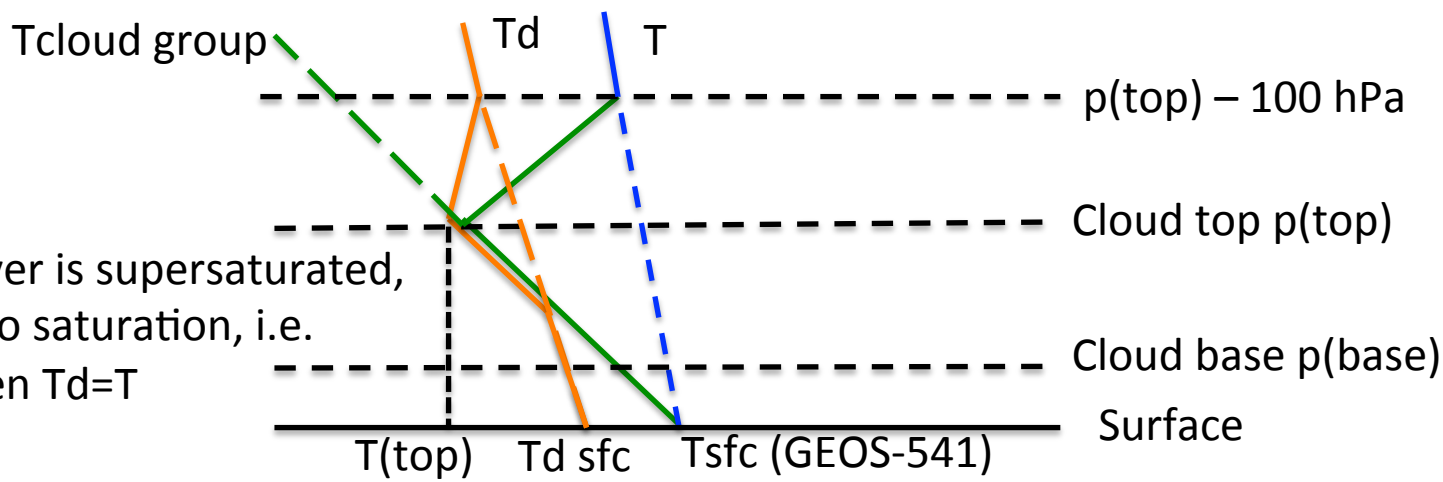



FIG. 4. Temperature (T), dewpoint temperature (Td), and lapse rate modified T profiles from Rapid Refresh analyses. Also indicated are cloud-top temperatures $T_t$ retrieved from GOES images and cloud-top heights $Z_t'$ and $Z_t$ retrieved from $T_t$ using original and modified Rapid Refresh analyses, respectively. (a) marine stratus at 31.2°N, 119°W, 21:30 UTC, 31 August 2013; (b) convective remnant at 31.9°N, 85.9°W 0400 UTC, 1 September 2013; and (c) developing cumulus at 31.9°N, 85.9°W 1700 UTC, 1 September 2013.

Sun-Mack et al. 2013
submitted to
J. Applied Meteorol. Clim.

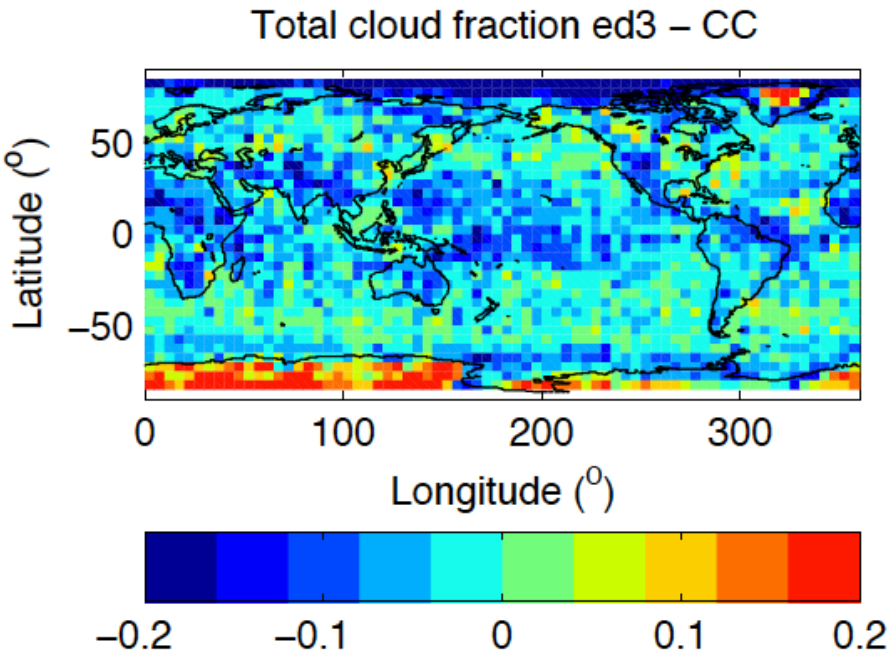


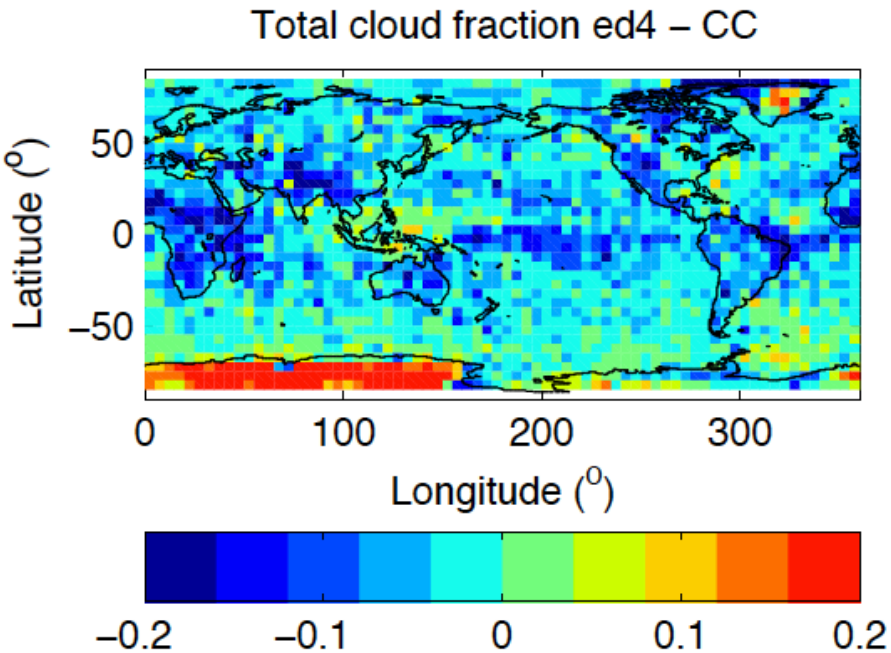

If the layer is supersaturated, reduce to saturation, i.e. Td>T then Td=T

# Cloud fraction (tau > 0.3)

## Comparison with CALIPSO & CloudSat

**October 2010 (Nadir view only)**



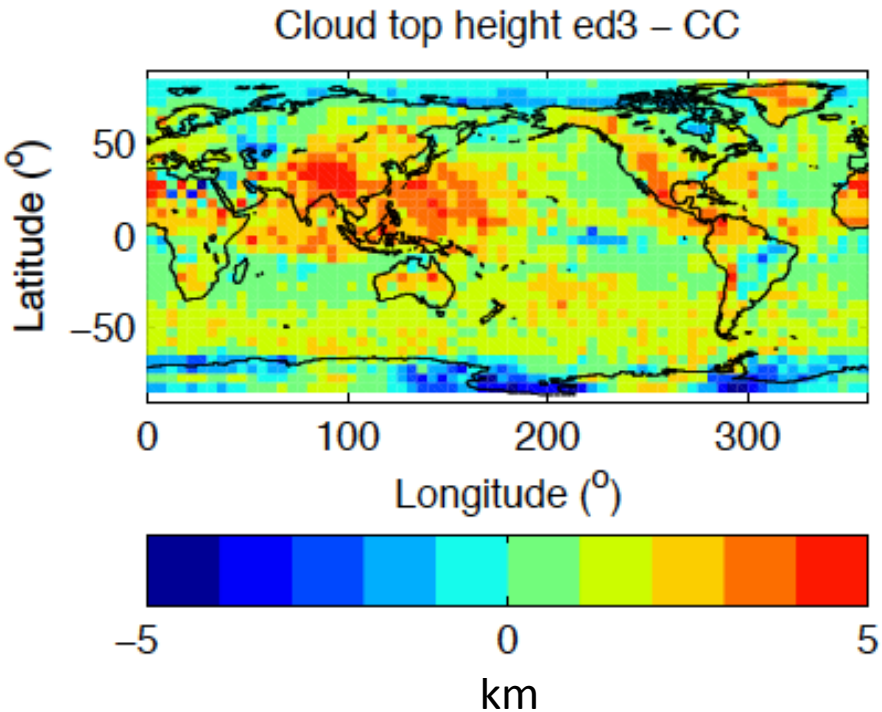



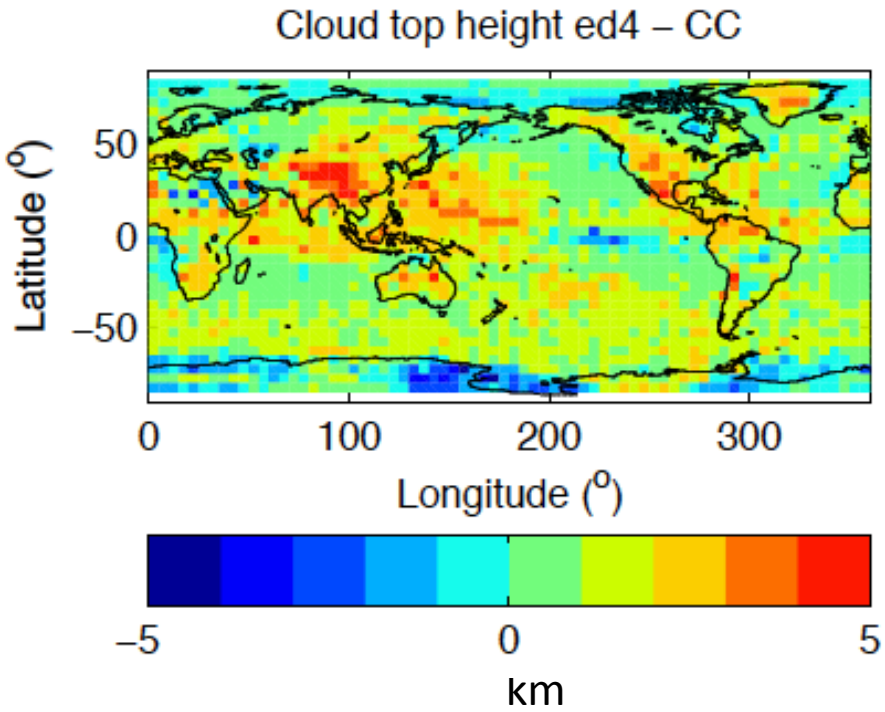

Cloud fraction over the Arctic is improved

# Cloud top height (tau > 0.3)

## Comparison with CALIPSO & CloudSat

**July 2010 (Nadir view only)**

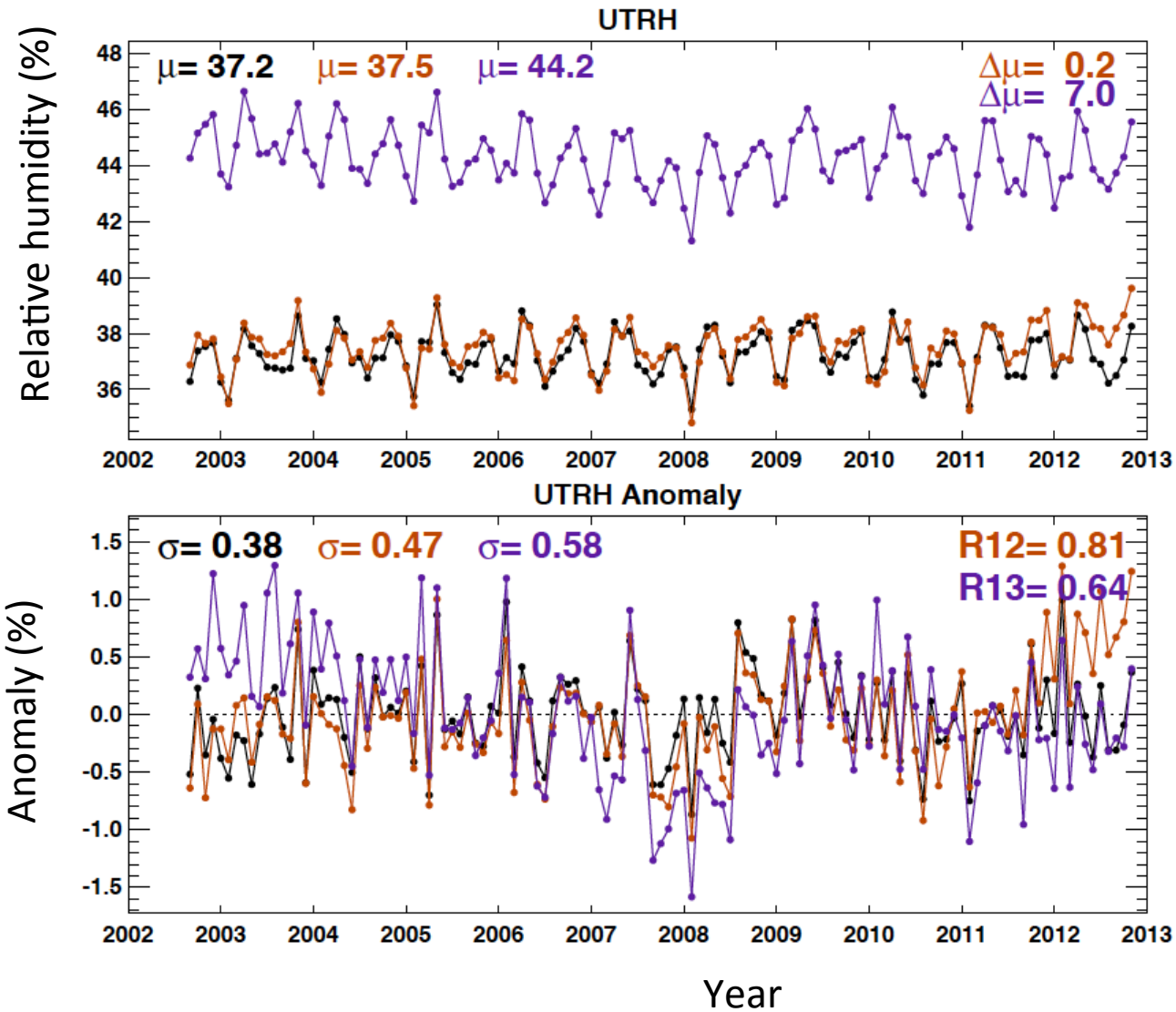



Cloud height is improved

# EBAF-surface

# AIRS V005, 006 GEOS5.4.1
# Global mean UTRH comparison

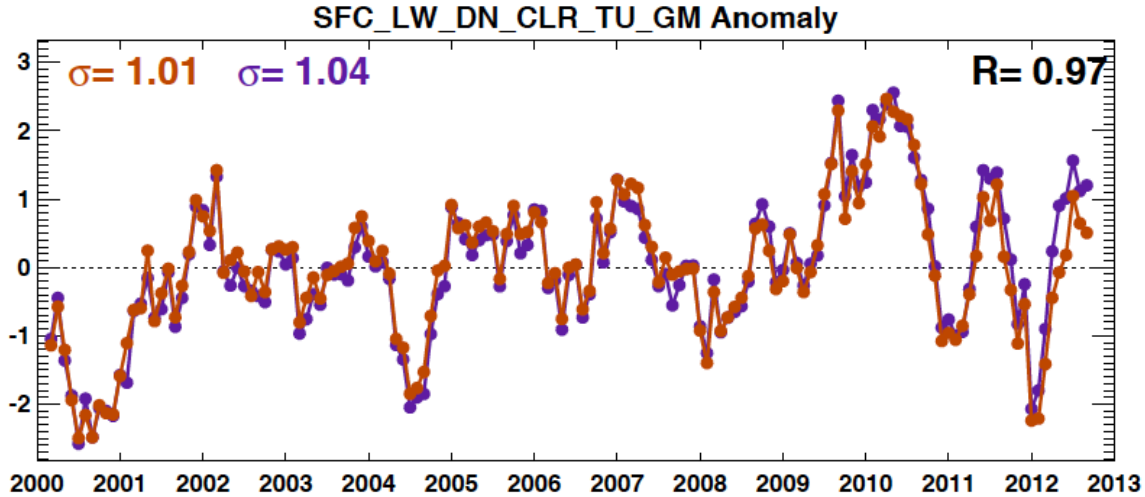



GEOS5.4.1 has a positive WV bias at upper troposphere

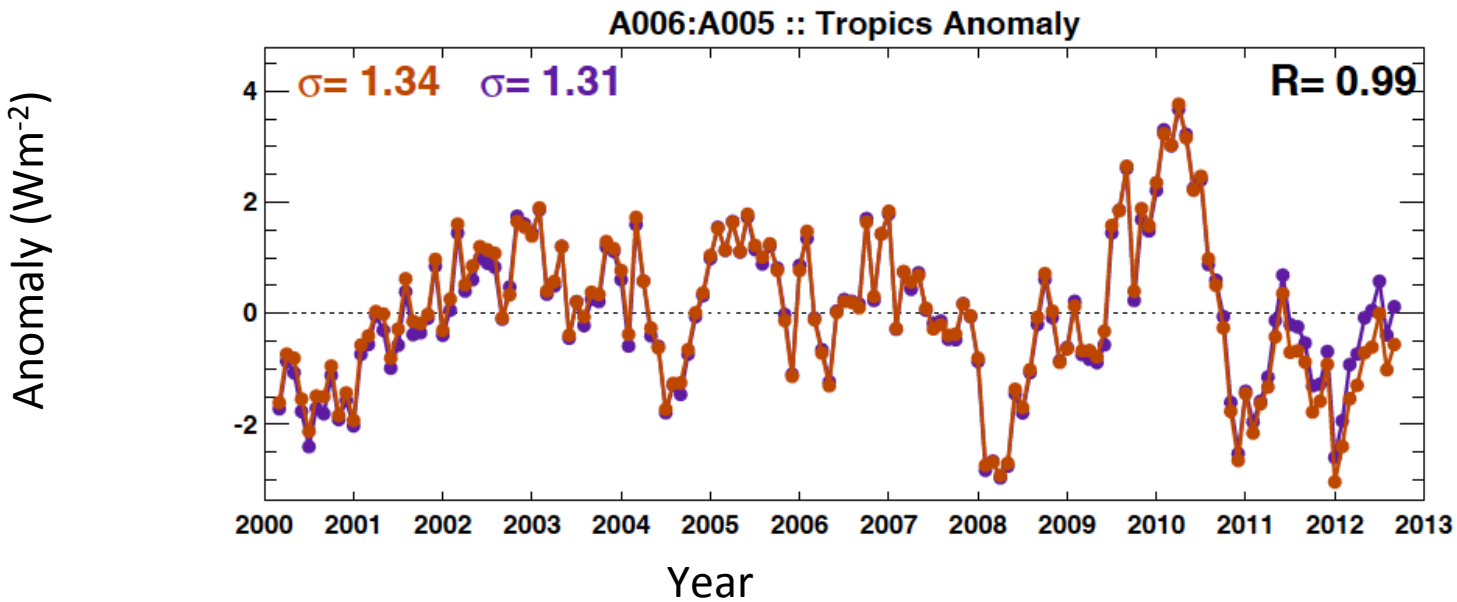
V005 starts drifting after middle of 2011 due in part to the degradation of AMSU-A channel 5

# Impact of AIRS V006 on downward LW surface irradiance

Red: V006
Blue: V005




Global clear-sky



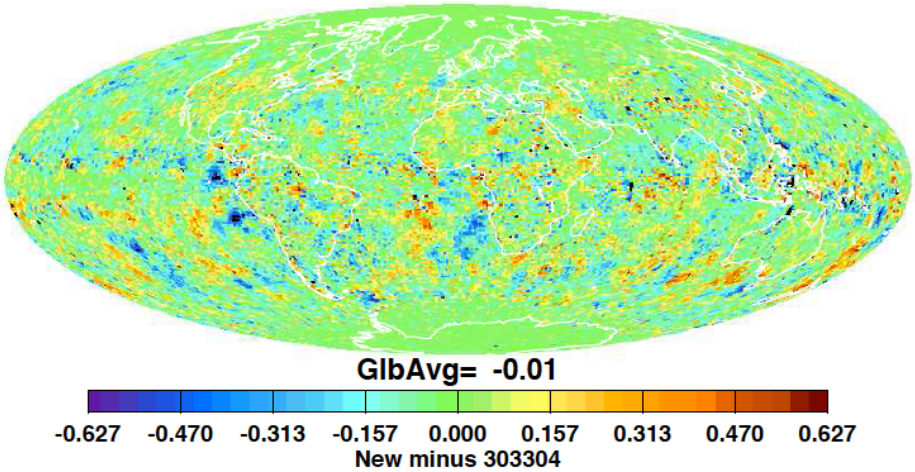

Global mean difference is even smaller
σ = 0.86 with V005 compared to 0.87 with V006.

# Conclusion on AIRS V005 vs. V006

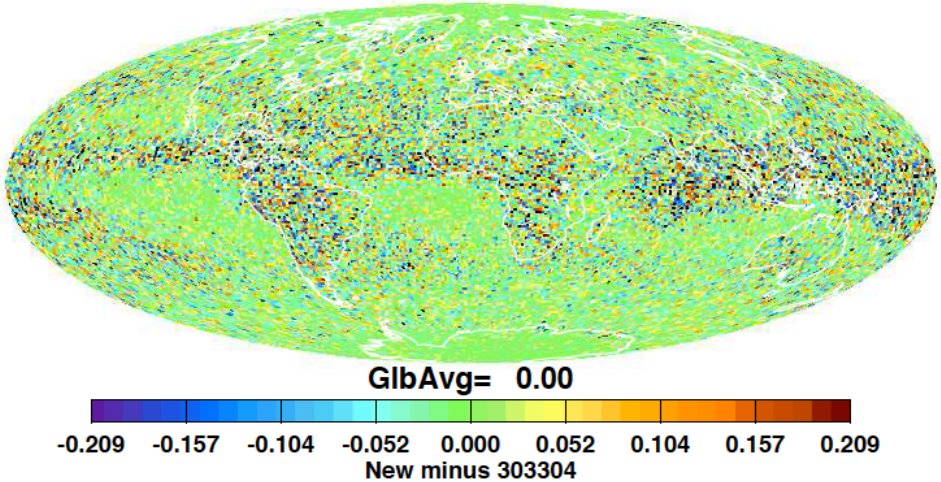
- The largest impact is on the LW down anomaly at about 0.5 $Wm^{-2}$ for all-sky and about 1 $Wm^{-2}$ for global clear-sky. If A005 is switched to A006, the jump is about 0.5 $Wm^{-2}$ for both all-sky and clear-sky. A 0.5 $Wm^{-2}$ change is not unusual in the time series and do not introduce a significant discontinuity.
- The effect on tropical anomalies is similar. The difference in the all-sky downward LW is about 0.6 $Wm^{-2}$. A 0.6 $Wm^{-2}$ change in the tropical anomaly time series is not unusual. In addition, it does not look like a trend is introduced by switching AIRS data starting October 2012.

# Impact of loosing footprints in SSF

TOA all-sky SW
All - missing




TOA all-sky LW
All - missing



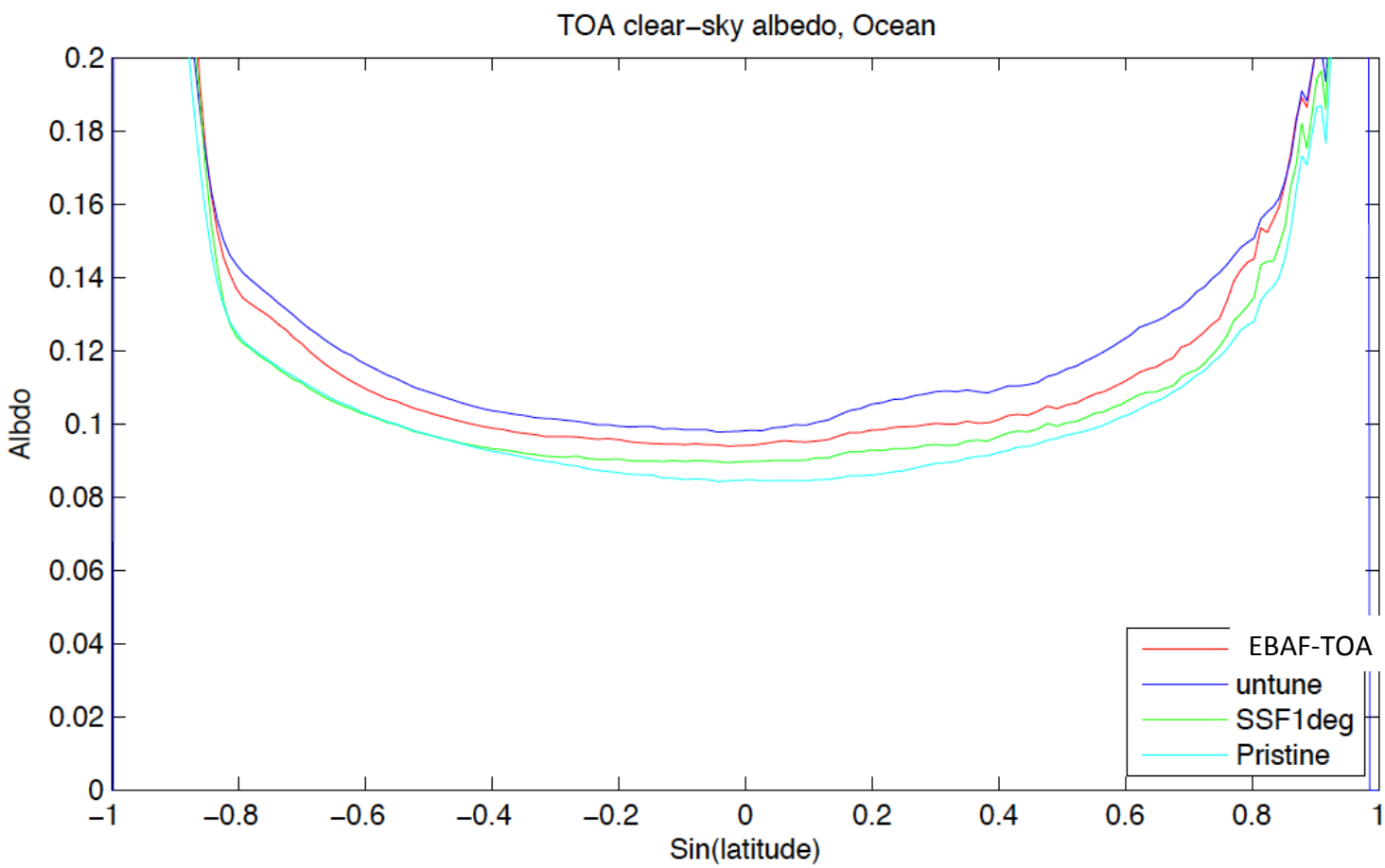

Differences are negligible

# EBAF-surface

- Propose to switch from AIRS V5 to V6 starting Oct. 2012 instead of reprocess Ed2.7 with AIRS v6 from the beginning of the data period (i.e. March 2000).

# Aerosol radiative effects from EBAF

# Comparison with pristine albedo
# Zonal aerosol effect over ocean



# Clear-sky aerosol direct radiative effect

- Pristine albedo is the lower than EBAF and SSF1deg is in between. At high latitudes in the southern hemisphere, SSF1deg is very close to or even slightly lower than pristine value. Perhaps a large clear-sky area happens under a very clean condition there.
- Global mean aerosol radiative effect computed by subtracting pristine value
  - EBAF – pristine = 4.1 Wm-2
  - Untune – pristine = 5.3 Wm-2.

  approximately a 20% reduction
- The global mean aerosol optical thickness over ocean is 0.138 for untune and 0.120 for adjusted values. The adjustment reduces the aerosol optical thickness by 15%.

# Clear-sky Aerosols radiative effects comparison with other studies

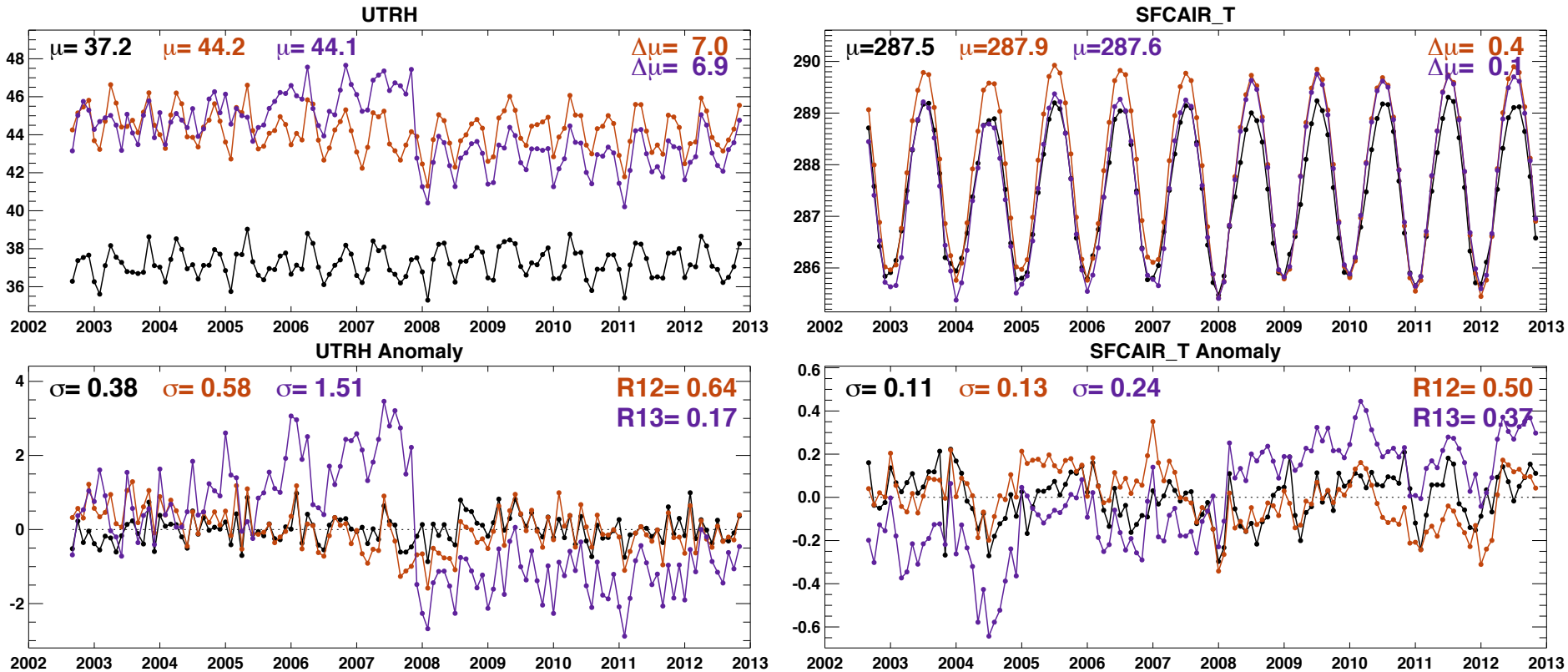
| | Untune-pristine (Ocean only) | Tune-Pristine (Ocean only) | SYN (Su et al. JGR Jan 2013 Table 2 , ocean only) | Kim and Ramanathan (2008, Table 5, ocean only) | CCCM (CALIPSO + CloudSat + MODIS) |
|---|---|---|---|---|---|
| Period | 200003-201202 | 200003-201202 | | 2000-2002 | 2008 |
| TOA ($Wm^{-2}$) | -5.3 | -4.1 | -5.2 | -5.5 | -3.3 |
| ATM ($Wm^{-2}$) | 2.6 | 1.8 | 2.0 | | |
| SFC ($Wm^{-2}$) | -7.3 | -5.7 | -7.2 | -9.0 | |

Tuning reduces the clear-sky aerosol direct effect at the surface by ~20% and to the atmosphere by 30%.

# GEOS-5.4.1

- Surface validation of downward LW irradiances indicates that GEOS-5.4.1 boundary layer temperature might be too warm over polar regions.
- We use GEOS-5.4.1 temperature and water vapor mixing ratio
  - Marine boundary layer to merge low-level clouds from the cloud group with GEOS-5.4.1.

# Global Monthly Mean Time Series

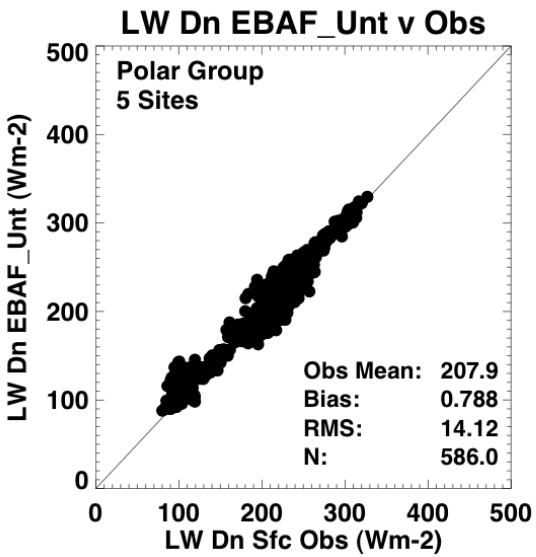


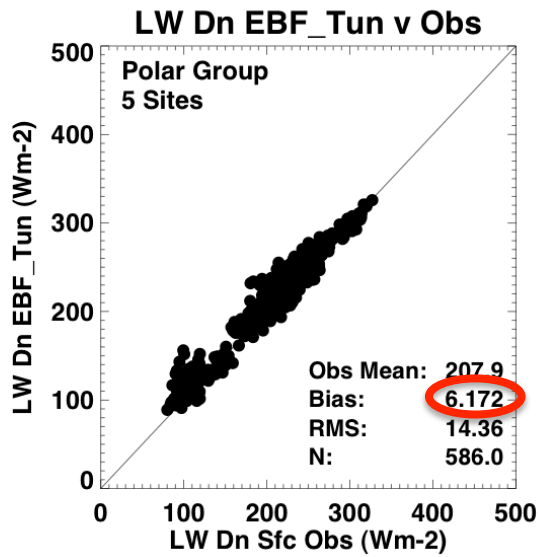

AIRS v006

GEOS 5.4.1

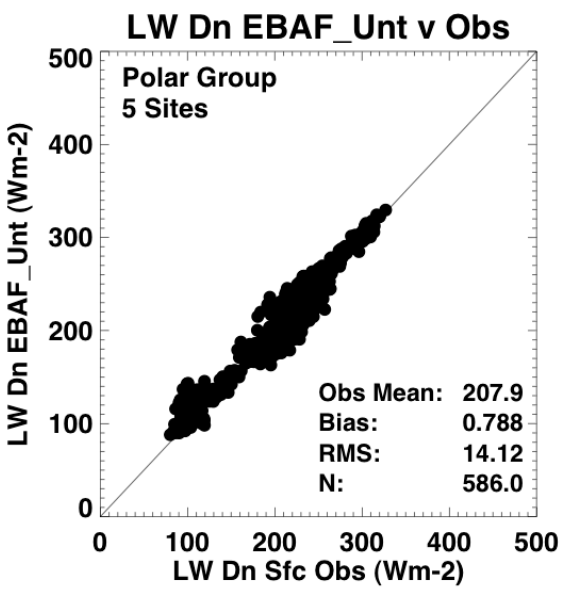
GEOS 4/5.2

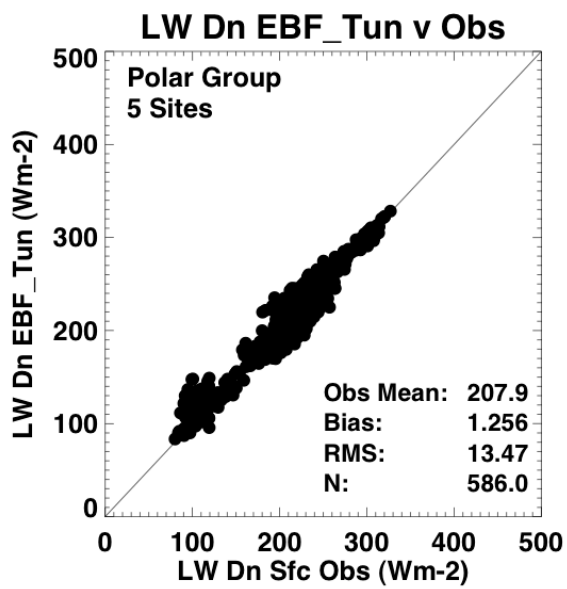
# GEOS-5.4.1 surface air temperature over the Arctic



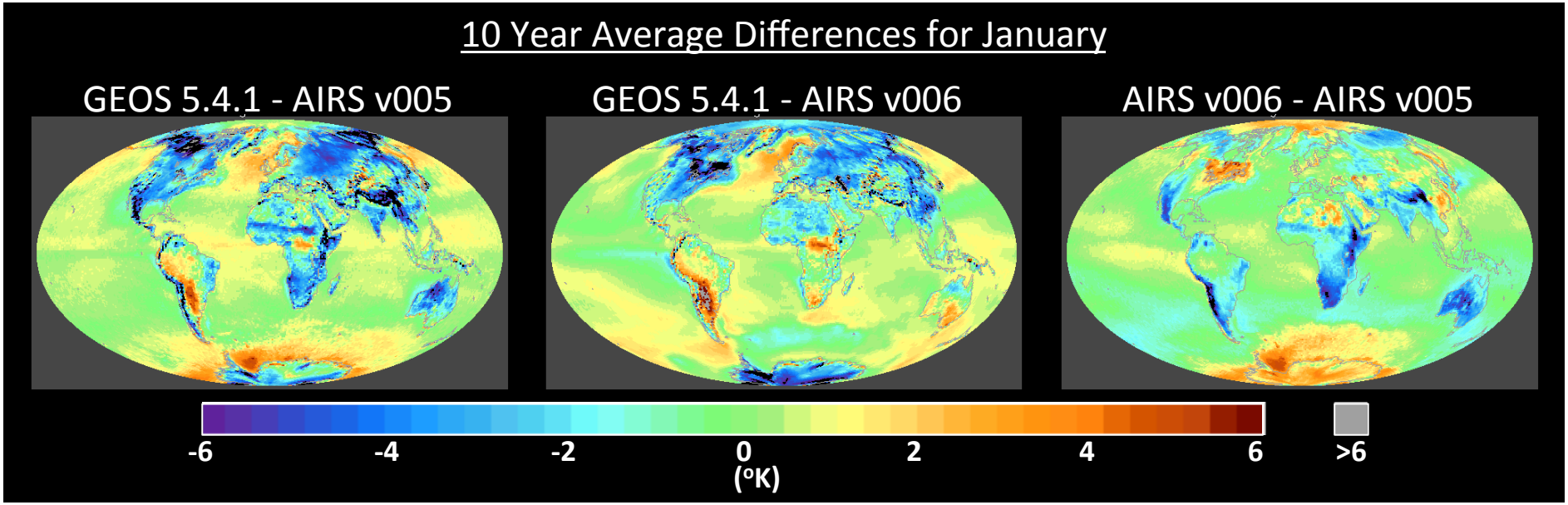

EBAF-surface
With GEOS-5.4.1
correction

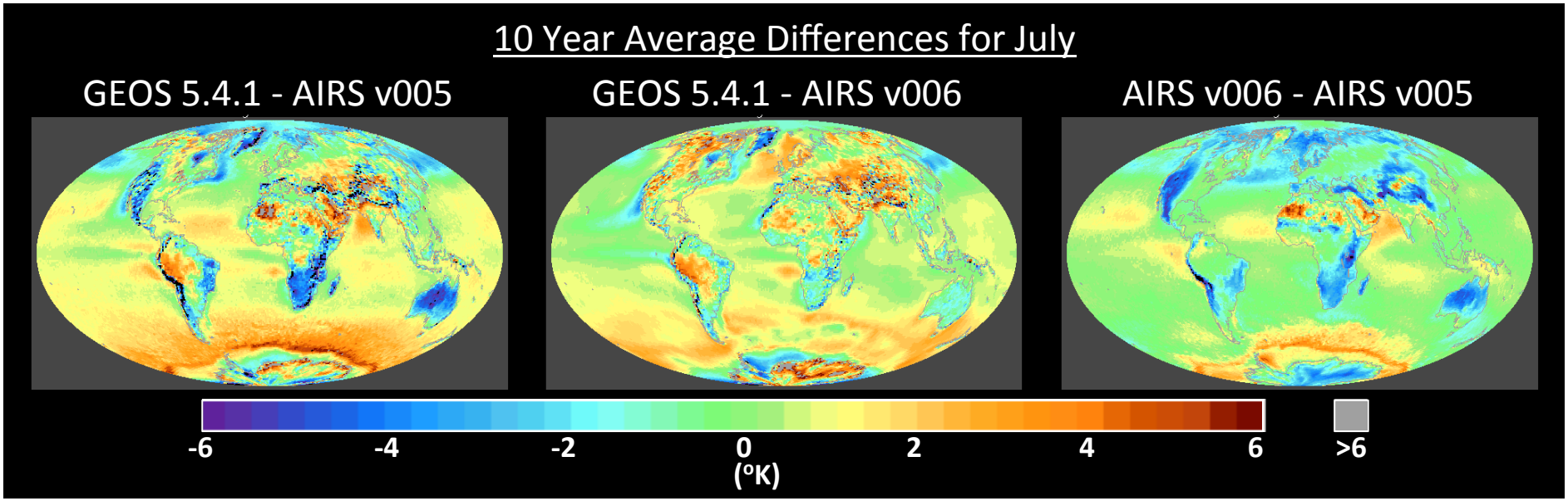


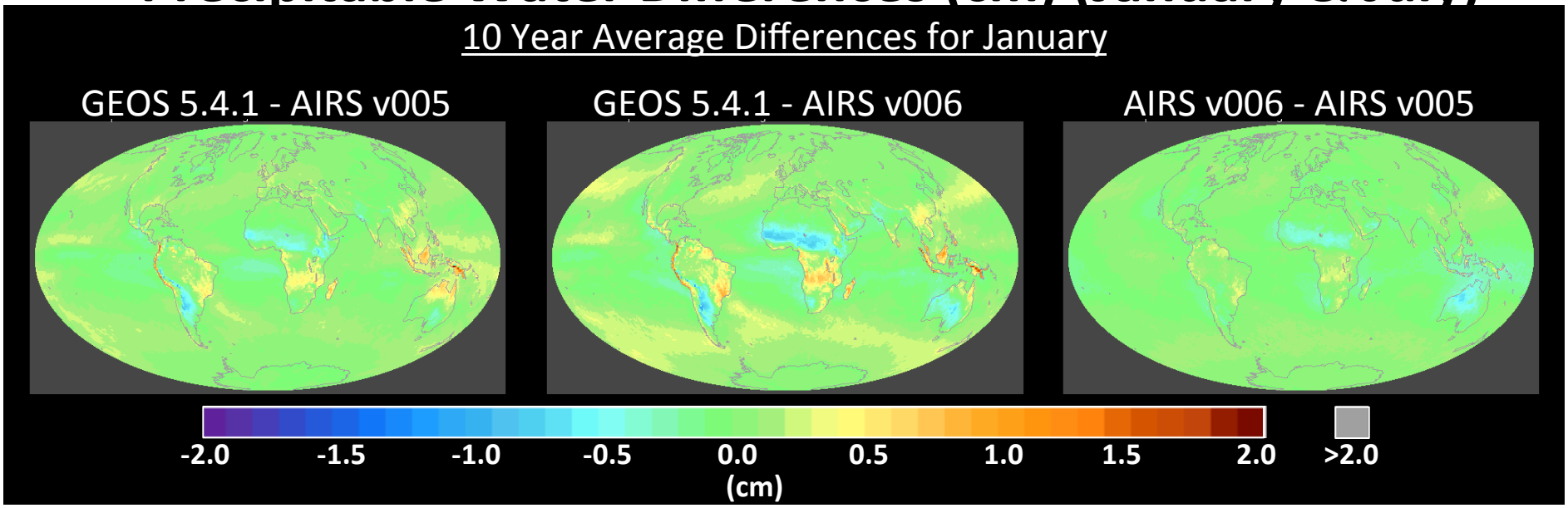

EBAF-surface
without GEOS-5.4.1
correction

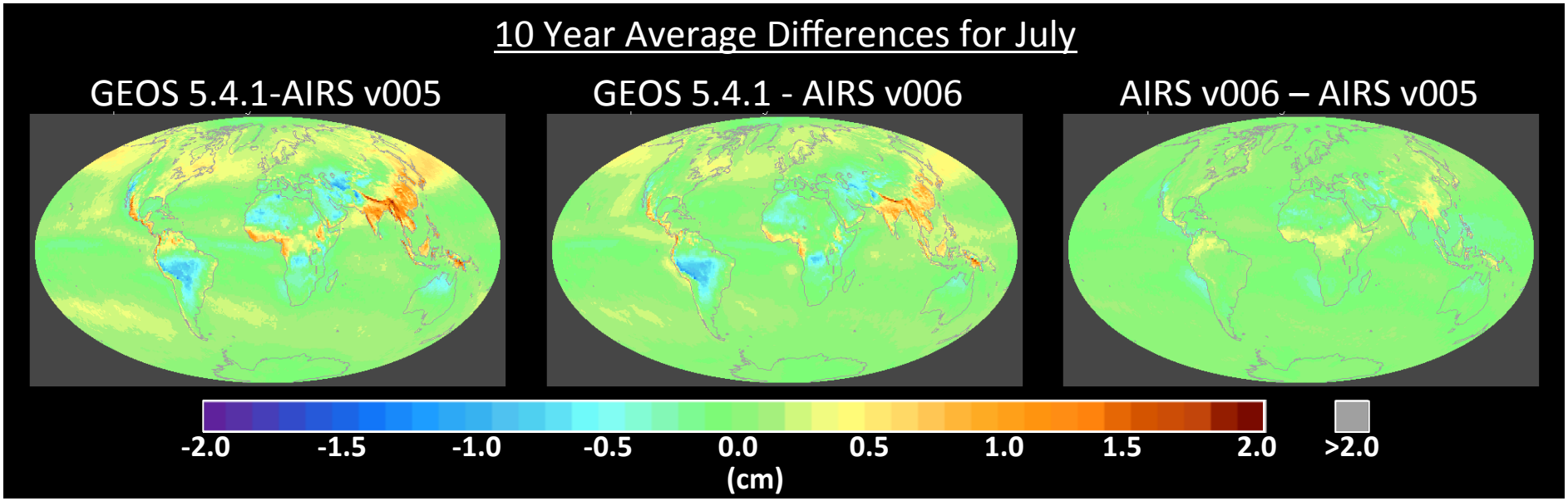
# Surface Air Temperature Differences (K) (January & July)



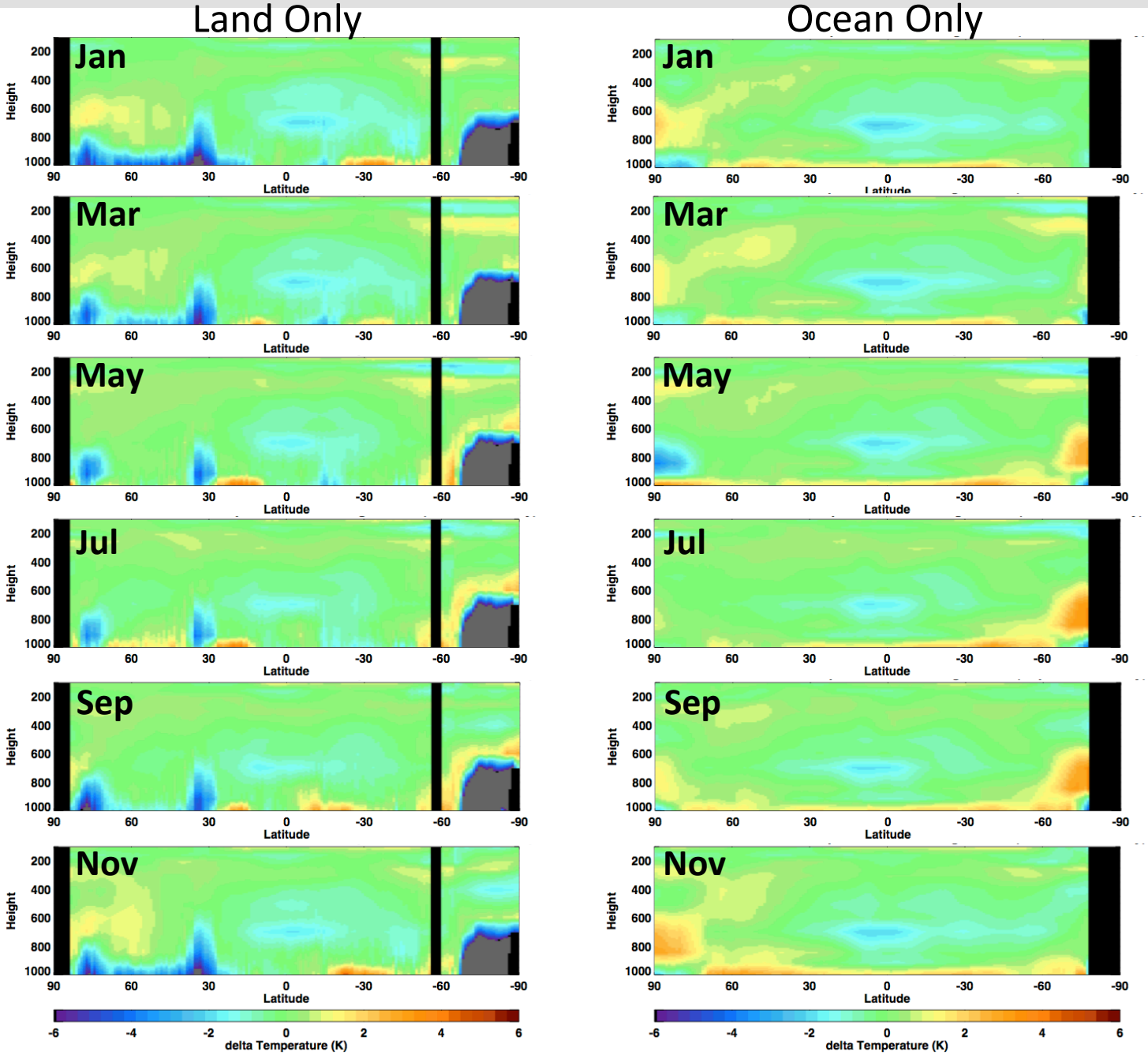



# Precipitable Water Differences (cm) (January & July)



# Zonal Mean Temperature (MOA/GEOS-AIRv006) 10 Year Average



# 3D – 1D difference of TOA radiance (ΔI), surface downward irradiance (ΔT), and absorbed irradiance by the atmosphere (ΔA) by cloud type in $Wm^{-2}$

Table 3. Mean and standard deviation of $\pi\Delta I$, $\Delta A$, and $\Delta T$ for a 17,500-km long by 71-km wide domain observed on 1 November 2010 02 UTC. $\theta_0$ is set as 0° and 60°. Mean and standard deviation are given as (mean)±(one standard deviation).

| | $\theta_0 = 0°$ | | | $\theta_0 = 60°$ | | |
|---|---|---|---|---|---|---|
| Scene Type | $\pi\Delta I$ | $\Delta A$ | $\Delta T$ | $\pi\Delta I$ | $\Delta A$ | $\Delta T$ |
| All | −4.9±50.8 | 0.4±21.3 | 1.7±94.2 | −0.3±30.4 | 1.1±26.9 | −1.8±92.9 |
| Clear | 1.7±3.6 | 3.7±9.5 | 29.5±60.6 | −0.2±5.4 | −0.1±15.3 | −14.0±76.1 |
| Ci | 2.0±34.7 | −5.1±24.9 | −18.5±121.5 | 3.9±21.6 | 3.7±28.6 | −4.7±111.9 |
| As | −4.4±46.6 | −1.9±19.2 | −15.8±94.5 | 0.8±25.3 | 2.5±25.6 | 10.3±101.6 |
| Ac | 20.2±76.5 | 12.5±22.5 | 24.0±93.0 | −17.2±79.6 | −12.2±38.5 | 8.3±95.1 |
| St | 3.3±33.2 | 4.8±16.4 | −3.3±101.0 | −4.5±23.8 | −4.6±21.1 | 3.2±107.2 |
| Sc | −7.1±51.7 | 1.9±17.4 | −21.0±110.3 | −4.7±33.8 | −2.8±23.9 | 13.3±116.0 |
| Cu | −31.8±87.1 | −4.7±22.2 | −33.8±108.5 | −3.2±44.2 | 2.2±30.9 | 23.2±124.2 |
| Ns | 11.6±86.8 | 4.5±27.2 | 2.2±60.8 | −7.7±58.0 | −5.8±37.0 | −1.4±41.2 |
| Dc | −33.9±102.1 | 3.7±39.7 | −7.1±44.3 | 10.2±66.1 | 13.9±49.5 | 22.5±63.1 |

# Ed4 CRS

- 18 band SW code
- New ice cloud properties (consistent with cloud group)
- Time varying CO2, CH4, N2O
- Boundary layer temperature profile consistent with cloud group
- Surface albedo history map including retrieval from partly cloudy CERES footprints
- Snow spectral albedo is modeled by snow grain size as a parameter
- Use MODIS derived surface albedo spectral shape
- Solar zenith angle dependent all-sky surface albedo
- Revised tuning algorithm

# SARB:NPP

- Currently testing Ed1 code
- Analyze CRS with ed1 clouds
- Deliver Ed1 CRS (Ed2 CRS Terra/Aqua code) with Ed4 typdef.
- Deliver SYNI Ed1 code in Spring 2014 (with TISA WG).

# Publications and documentations

- Published
  - Rose, F., D. A. Rutan, T. P. Charlock, G. L. Smith, and S. Kato, 2013; An algorithm for the constraining of radiative transfer calculations to CERES observed broadband top of atmosphere irradiance, *J. Ocean. Atmos. Technol.* DOI: 10.1175/JTECH-D-12-00058.1.
  - Radkevich, A., K. Khlopenkov, D. Rutan, S. Kato, 2013, A Supplementary Clear-Sky Snow and Ice Recognition Technique for CERES Level 2 Products, *J. Atmos. Oceanic Technol.*
  - Radkevich, A, 2013; A new look at decoupling of atmospheric and surface radiative transfer*, JQSRT*.
  - Ham, S.-H., B. J. Sohn, S. Kato, and M. Satoh 2013; Vertical structure of ice cloud layers from CloudSat and CALIPSO measurements and comparison to NICAM simulations, *J. Geophys. Res*.

- Submitted
  - Rutan, D., G. L. Smith, and T. Wong, 2013; Diurnal Variations of Albedo,,submitted to *J. App Met. Clim.*
  - Ham, S.-H., S. Kato, H. W. Barker, F. G. Rose, and S. Sun-Mack, 2013; Effects of 3D clouds on atmospheric transmission of solar radiation: Cloud type dependencies inferred from A-train satellite data, submitted to *J. Geophys. Res*.

Documentation

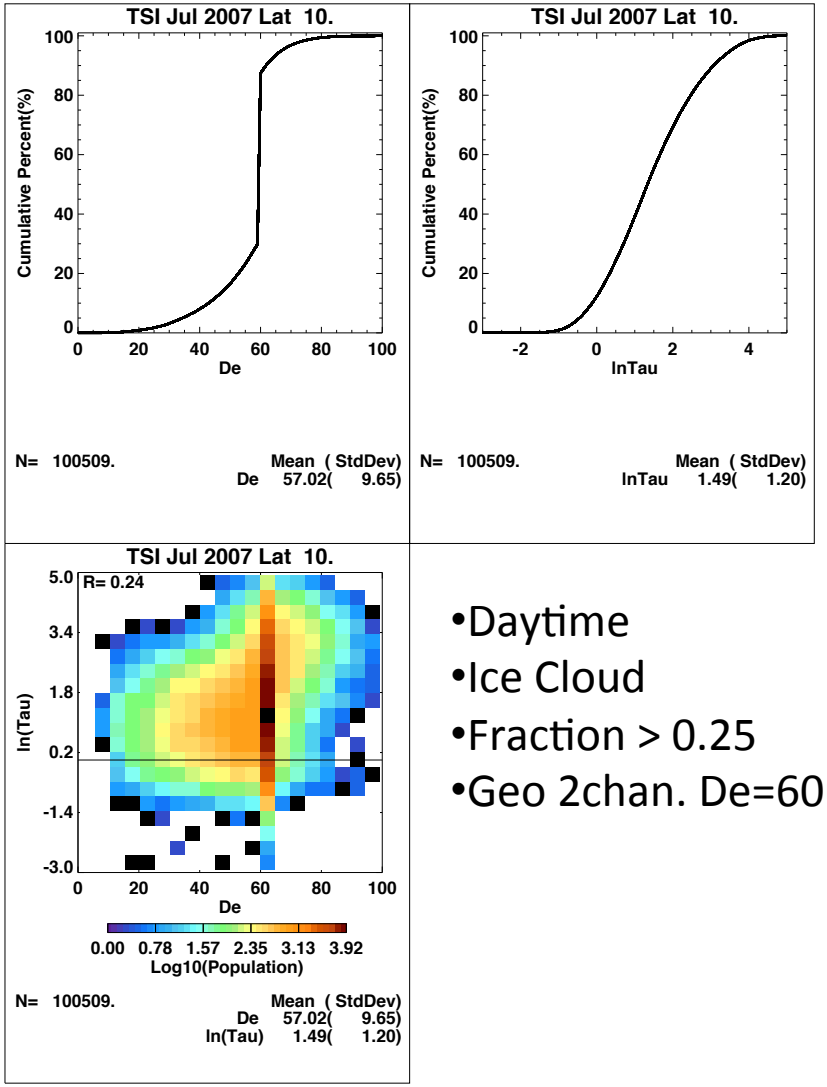
- Ed2 CRS collection guide (in progress)

# Back ups

# Ice Cloud De / lnTau histogram

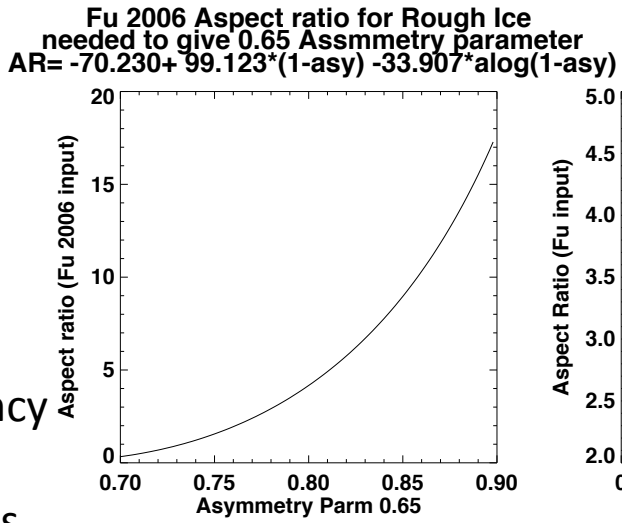
For the latitude zone 10N where proto-Ed4 was much darker than Ed3a
A significant population of grid-hr boxes had thin ice clouds Tau <10 (ln2.3), De < 60.
Of these the majority of non-geo had De < 60.

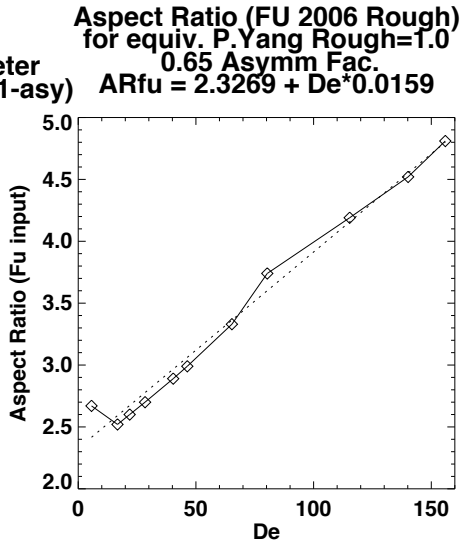
This contributes to proto_Ed4 having darker TOA SW. A similar story at other latitudes.

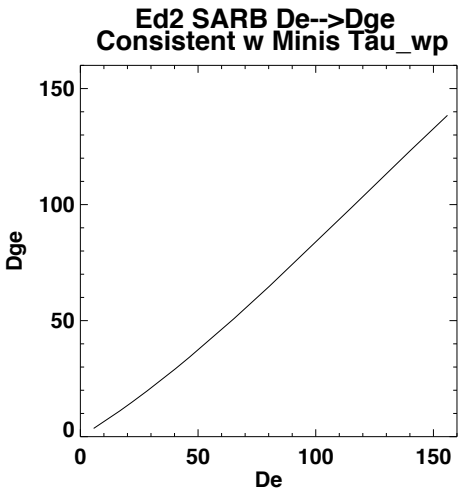


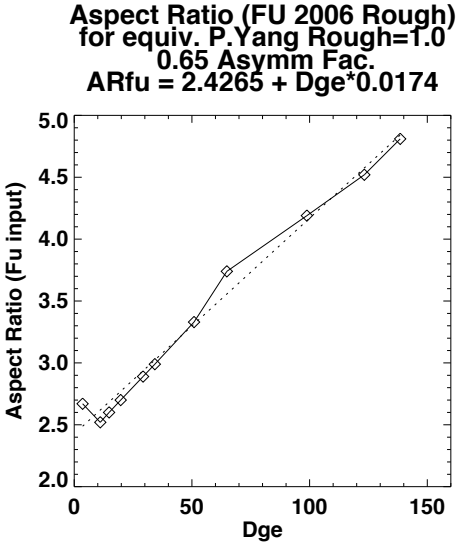

- Daytime
- Ice Cloud
- Fraction > 0.25
- Geo 2chan. De=60um

These relationships were derived for the implementation of Fu2007 several year ago to force consistency with visible Asymmetry Factor from P.Yang Roughened Ice Crystals which were solely dependent on De



# MATCH/MODIS aerosols versus CALIPSO aerosols

# 1D - 3D RMS differences for different horizontal averaging scales

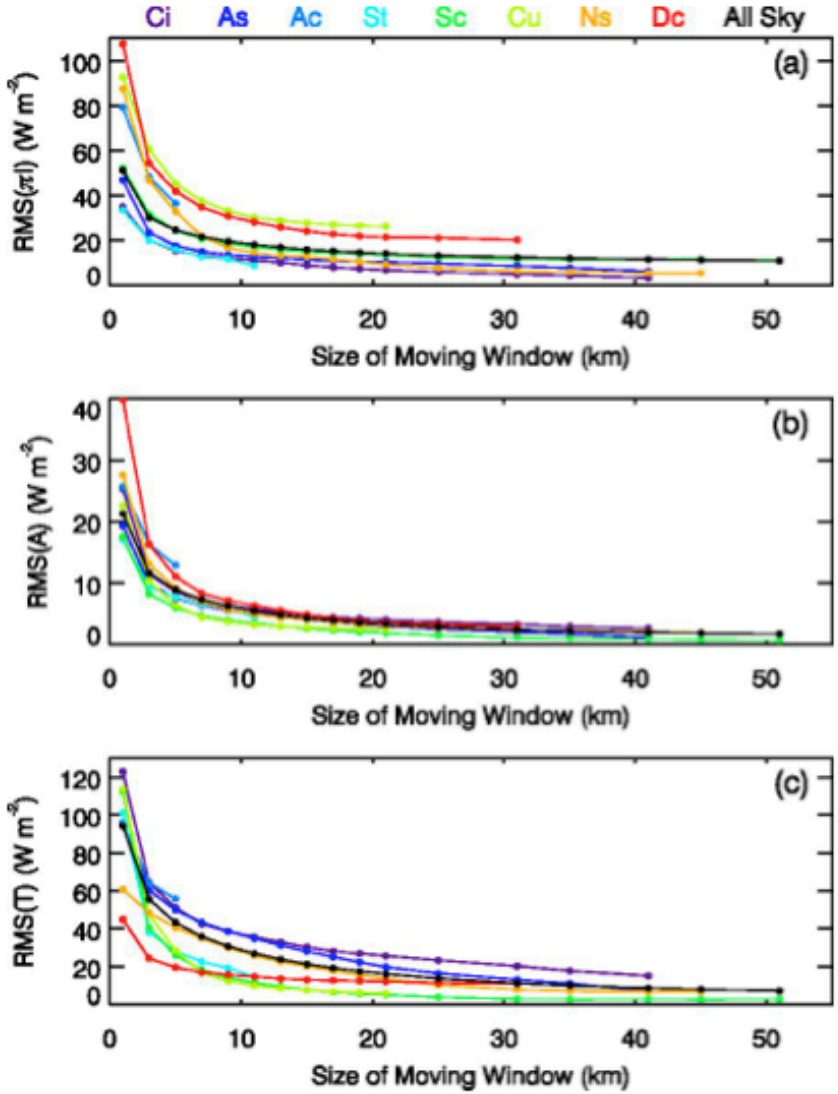



Figure 14. Same as Fig. 13 but for $\theta_0 = 0°$.

# Surface Air Temperature Hovmoller Diagrams (Land & Ocean )
# GEOS v541 & AIRS v5 & v6
# Latitude vs Time (Jan 2003 through Dec 2012) Zonal Profile Differences
# (Axes/scales need work)