CRS, the CERES Footprint-scale Surface and Atmosphere Radiation Budget (SARB)

Clouds and the Earth's Radiant Energy System (CERES)
Science Team Meeting (GISS, New York City, 27-29 October 2008)

T. P. Charlock (NASA LaRC)
Fred G. Rose (SSAI) speaks later on SYNI, the "Synoptic" SARB
David A. Rutan (SSAI) Surface validation with CAVE
Zhonghai Jin (SSAI) Coupled Ocean Atmosphere Radiative Transfer (COART)
Wenying Su (SSAI) UV, PAR algorithms and comparison with GCMs
Seiji Kato (LaRC) Co-I talk on "super" SARB with Calipso/CloudSAT
Thomas E. Caldwell, Lisa H. Coleman (SSAI) - Data Management
David Fillmore (Boulder) provides MATCH aerosol assimilation

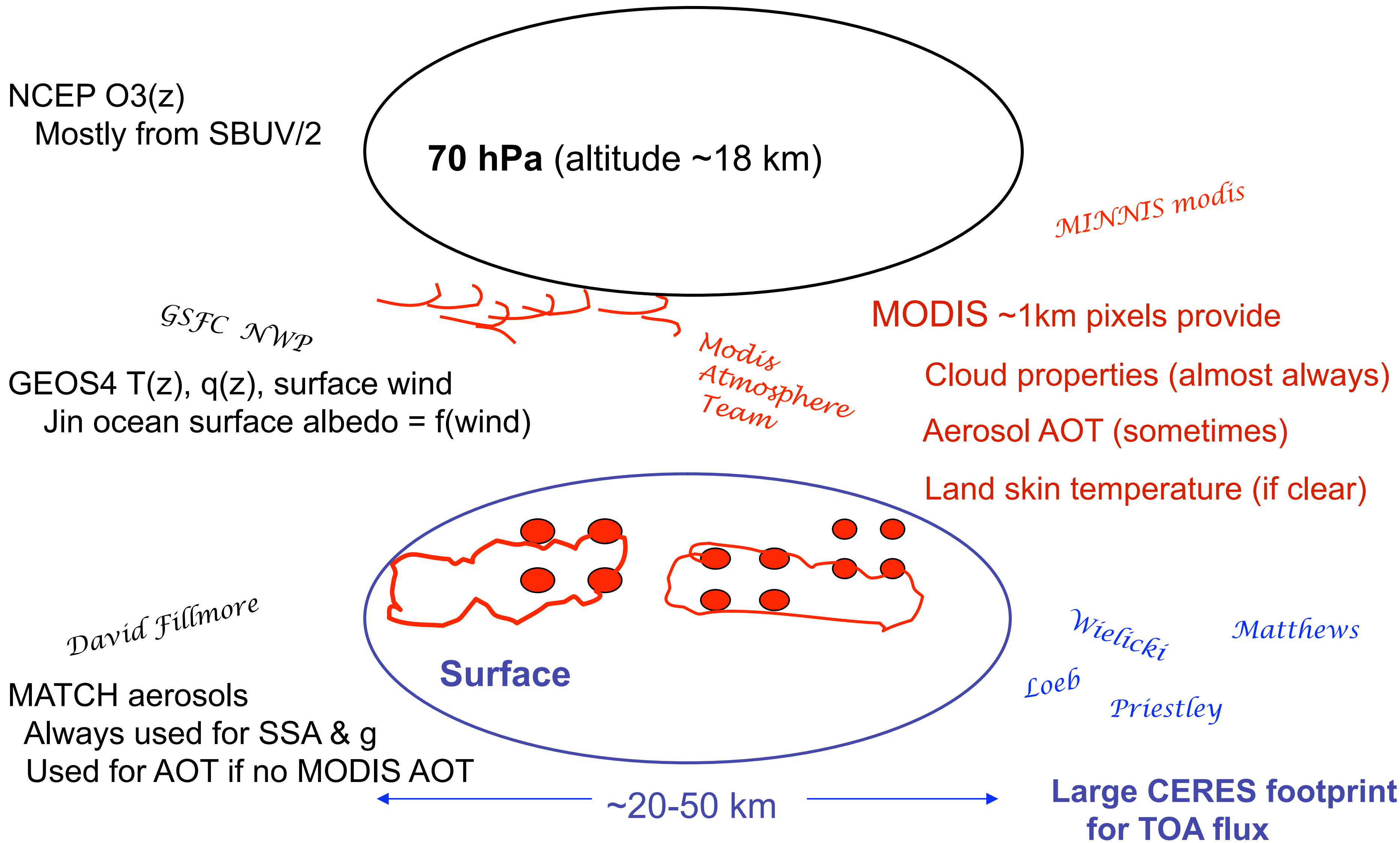
Bold font marks co-authors who could not attend meeting

SARB/SOFA Working Group Tuesday Morning:
Discussion/validation of SYN Beta4 (gridded & diurnal, CERES+geostationary)

www-cave.larc.nasa.gov/cave/ or google "CERES CAVE"
Easy to use subsets of data, on line radiative transfer, ocean albedo tables…

Ungridded SARB vertical profile at ~2,000,000 CRS footprints/day

Langley Fu-Liou radiative transfer: Kato 2005 SW upgrade, Kratz-Rose LW window



Aqua CRS Ed2B and Ed2C (Jul02-Dec06) within 25 km of ARM SGP sites

Daytime-Only analysis below

All rows in table have 71191 samples (mean cloudiness 48%)

	Observed (W/m**2)	Untuned Bias	Untuned RMS	Tuned Bias	Tuned RMS
TOA SW up	268	4	26	1	9
OLR	255	-2	9	-1	5
SW SFC down	589	8	101	15	102
SW SFC up	115	-20	48	-17	47
LW SFC down	345	-12	19	-12	19
LW SFC up	444	-8	30	-6	28

Google "CERES CAVE" for validation tool

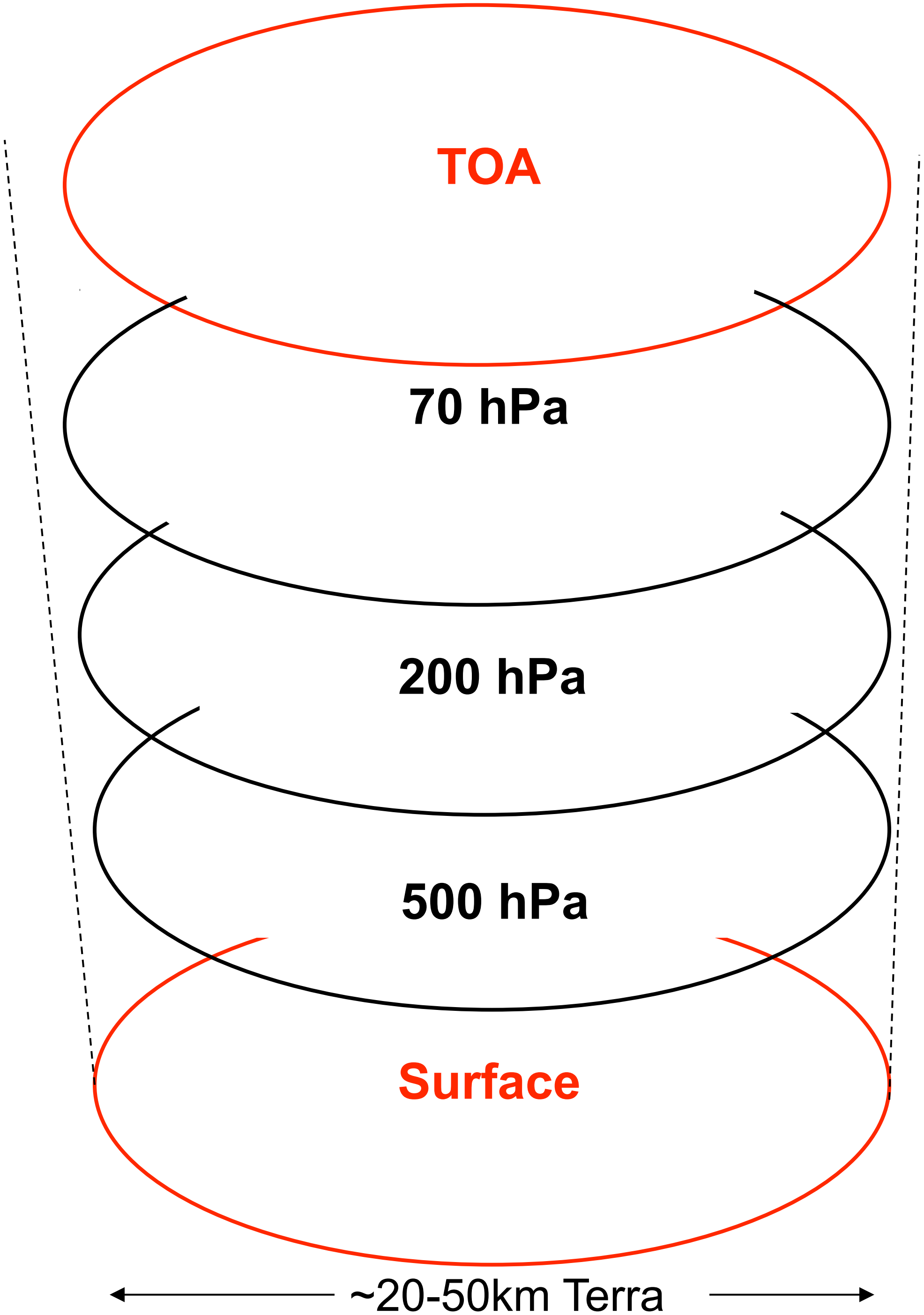
54639 samples report clouds (mean cloudiness then 63%).

Tuning assigns a priori uncertainties to cloud parameters and TOA fluxes, then solves for minimum least squares adjustment. Similar for clear sky.

Observed cloud parameters from Minnis MODIS SSF:

MODIS	Tuned	RMS	(N = 54639)
63.8	63.8	~0	Cloudiness (%)
264	264	3	Cloud top temperature (K)
12.1	11.5	5.7	Cloud optical depth

CERES CRS: Surface and Atmosphere Radiation Budget (SARB) Product



Tuned fluxes at all 5 levels
All-sky & Clear-sky, Up & Down,
SW and LW

Surface & TOA also have Untuned fluxes
Fluxes with aerosols
Pristine fluxes (no aerosols)

Aerosol forcing for all-sky & clear-sky

Tuning does NOT yield a perfect match to TOA observations.

Parameters adjusted when clear:
Skin temperature, aerosol AOT, precipitable water (PW)

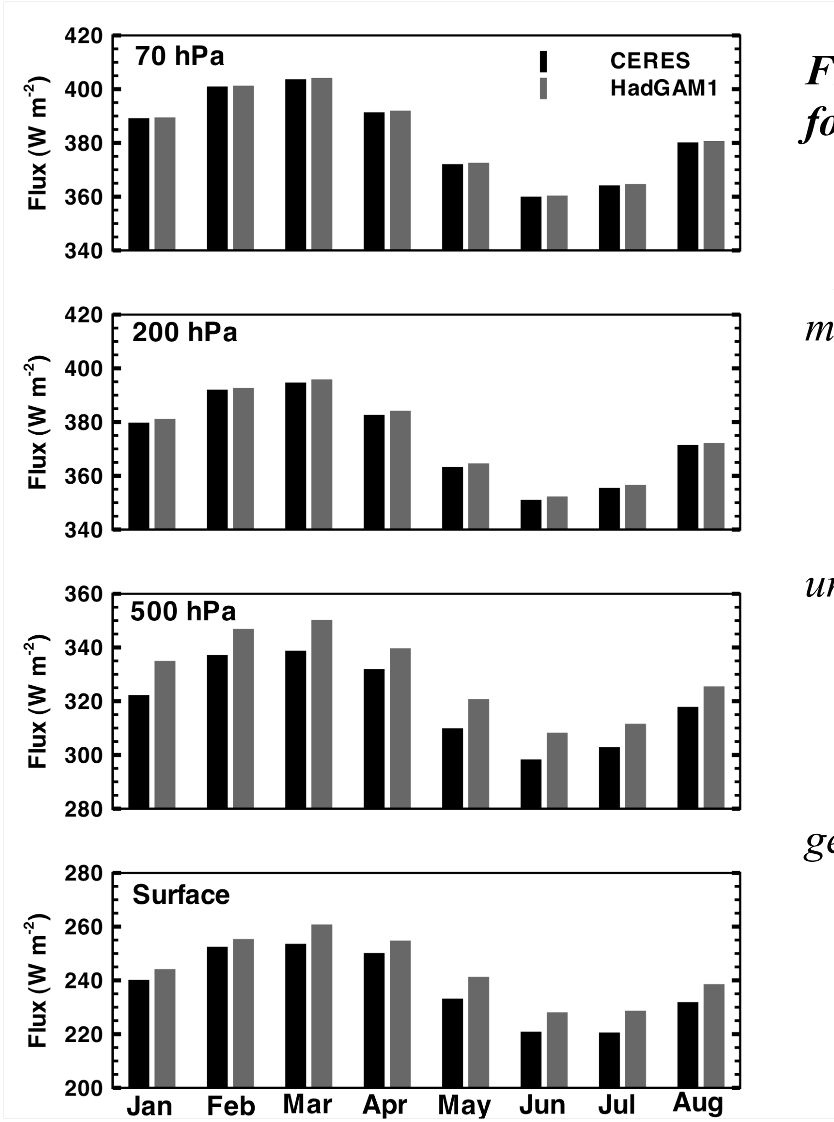
Parameters adjusted when cloudy:
LWP/IWP, cloud top temperature, cloud fractional area within footprint

Evaluation of Cloud Effect Profile in HadGAM1 GCM with TRMM SARB

Profiles of All-sky SW Downwelling

Black = CERES SARB

Grey = HadGAM1



From analysis of SW and LW profiles for all-sky and clear-sky fluxes…

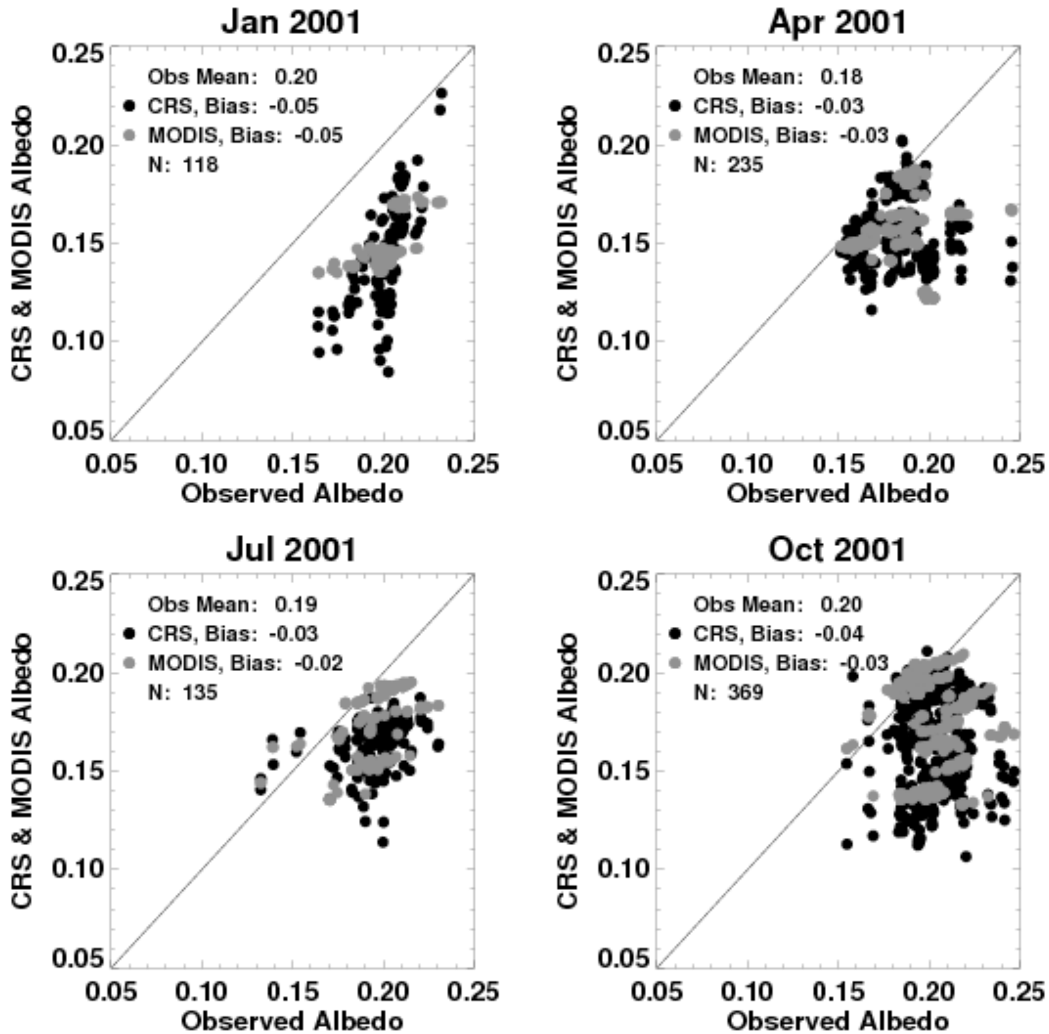
Above 200 hPa: HadGAM1 produces more clouds than CERES

From 200-500 hPa: HadGAM1 underestimates average cloud height

Below 500 hPa: HadGAM1 and CERES generally agree for cloud effects

Su, W., A. Bodas-Salcedo, K.-M. Xu, and T. P. Charlock, 2008: Evaluation of the radiative flux and cloud effect profiles in a climate model with the Clouds and Earth Radiant Energy System (CERES) data. Submitted to *J. Geophys. Res.*

SURFACE ALBEDO
Terra CRS Edition 2B and MODIS 5km MCD32C2 versus Measurements
at 14 land surface sites during four months in 2001



CERES footprint ~ 30km

MODIS product 5km

Ground tower ~ 10m

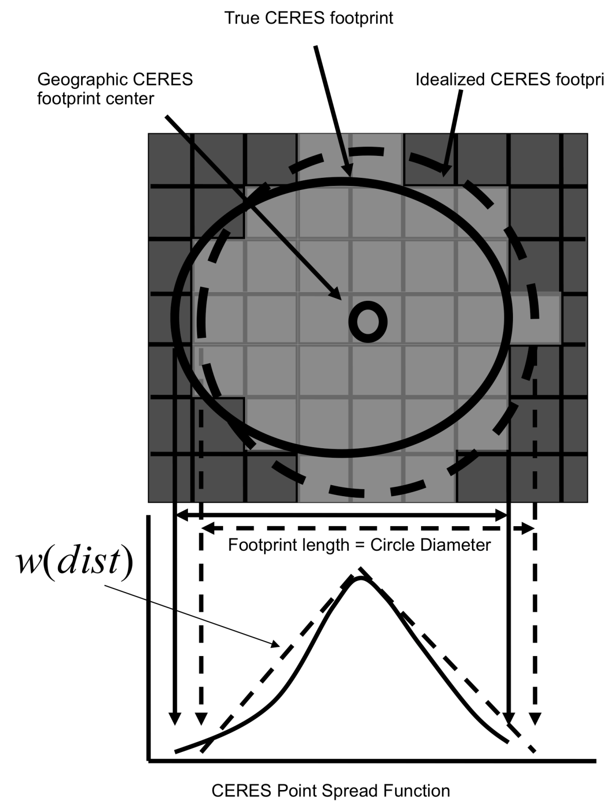
Rutan, D., F. Rose, M. Roman, N. Manalo-Smith, C. Schaaf, and T. Charlock, 2008: Development and assessment of broadband clear-sky surface albedo from CERES clouds and radiation swath data product. Revised version submitted to *J. Geophys. Res.*

	Jan	Apr	Jul	Oct	All Months
CRS Mean	0.145	0.150	0.154	0.161	0.154
MODIS Mean	0.153	0.153	0.158	0.165	0.158
Absolute Bias	-0.008	-0.003	-0.003	-0.003	-0.004
Absolute RMS	0.020	0.018	0.013	0.015	
Relative Bias	-5.2%	-2.0%	-2.0%	-1.8%	-2.4%

Monthly mean albedo differences between CRS albedo and MODIS albedo integrated within CERES Terra FM1 for land footprints for four months in 2001.

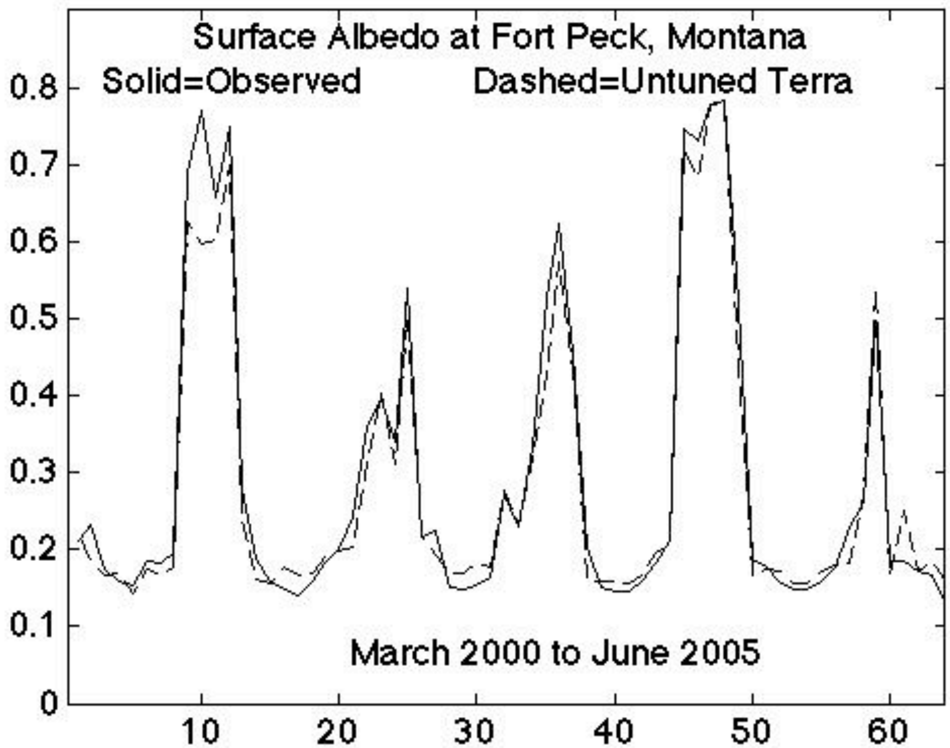
Here MODIS product is scaled up to approximate CERES footprint.

SARB surface albedo is then ~2% darker than MODIS.



Schematic of placement of MODIS gridded 'pixels' inside of larger CERES footprint and integration weights.

CERES retrieval of surface albedo catches the large interannual variability at Fort Peck:



Cloud forcing and aerosol forcing are useful diagnostic quantities.

What about Surface Albedo Forcing in Edition 3?

A tool to assess the causes of long-term variations to TOA albedo,
(i.e., in regions with seasonal snow cover).

GTSRT Calculation at Fort Peck, Montana

GTSRT is a test SW calculation with 18 SW bands.

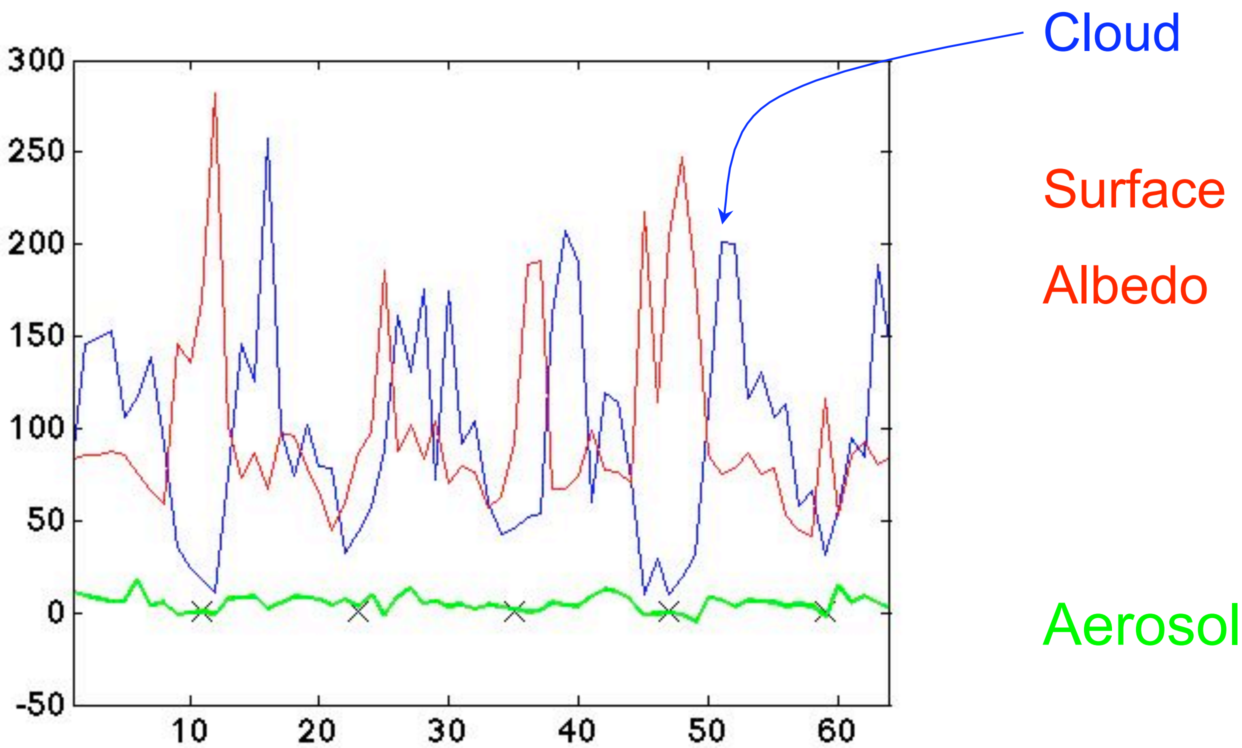
Forcing

to TOA

All-sky

Upwelling

(W/m**2)



March 2000 to June 2005

Surface Albedo Forcing = (Regular calculation)

- (Calculation with zero surface albedo)

GTSRT Calculation at Fort Peck

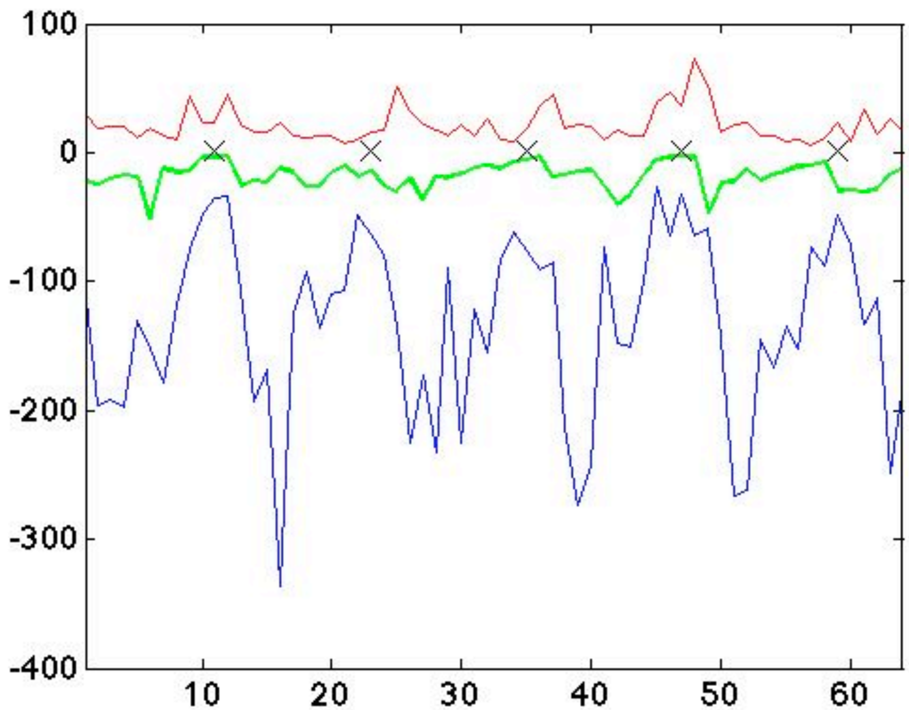
Forcing

to SFC

All-sky

Down

(W/m**2)



Surface Albedo

Aerosol

Cloud

March 2000 to June 2005

Surface Albedo Forcing = (Regular calculation)

- (Calculation with zero surface albedo)

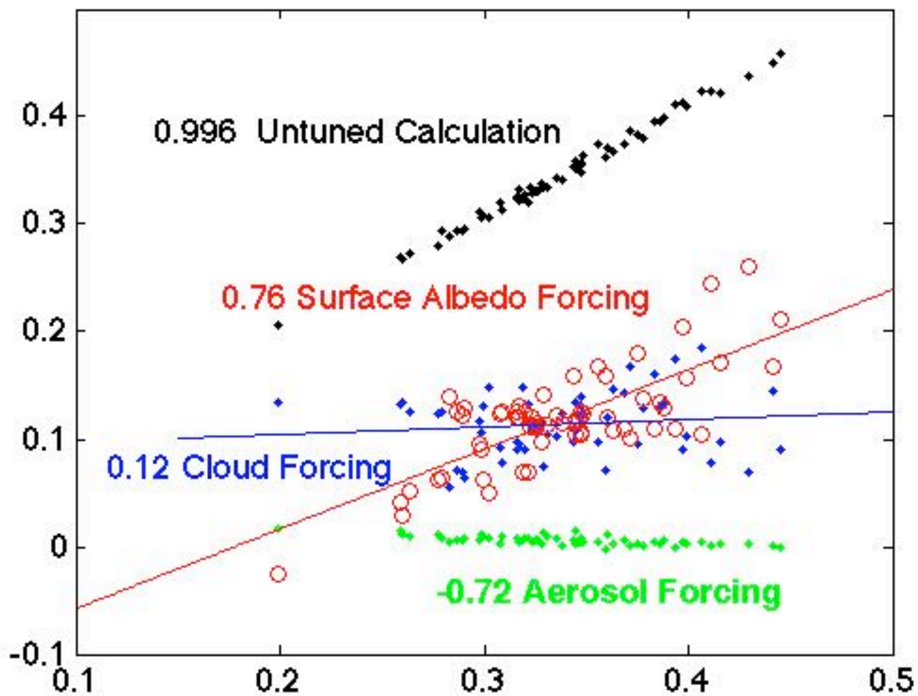
Correlation of Observed TOA Albedo

with Calculations (Deseasonalized)

Computed

All-sky

Parameter



Monthly TOA Albedo Terra SSF Ed2B

Surface albedo

explains

half of the

variance

at Fort Peck

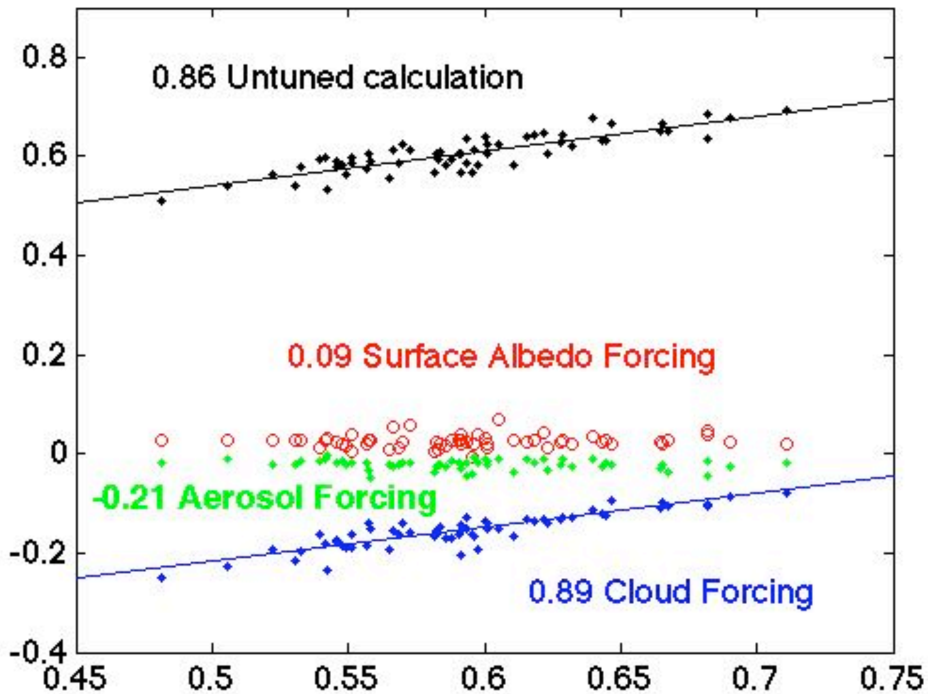
Surface Albedo Forcing = (Regular calculation)

- (Calculation with zero surface albedo)

Correlation of Observed Transmission

with Calculations (Deseasonalized)

Computed Trans- mission Parameter



Monthly Transmission (SURFRAD)

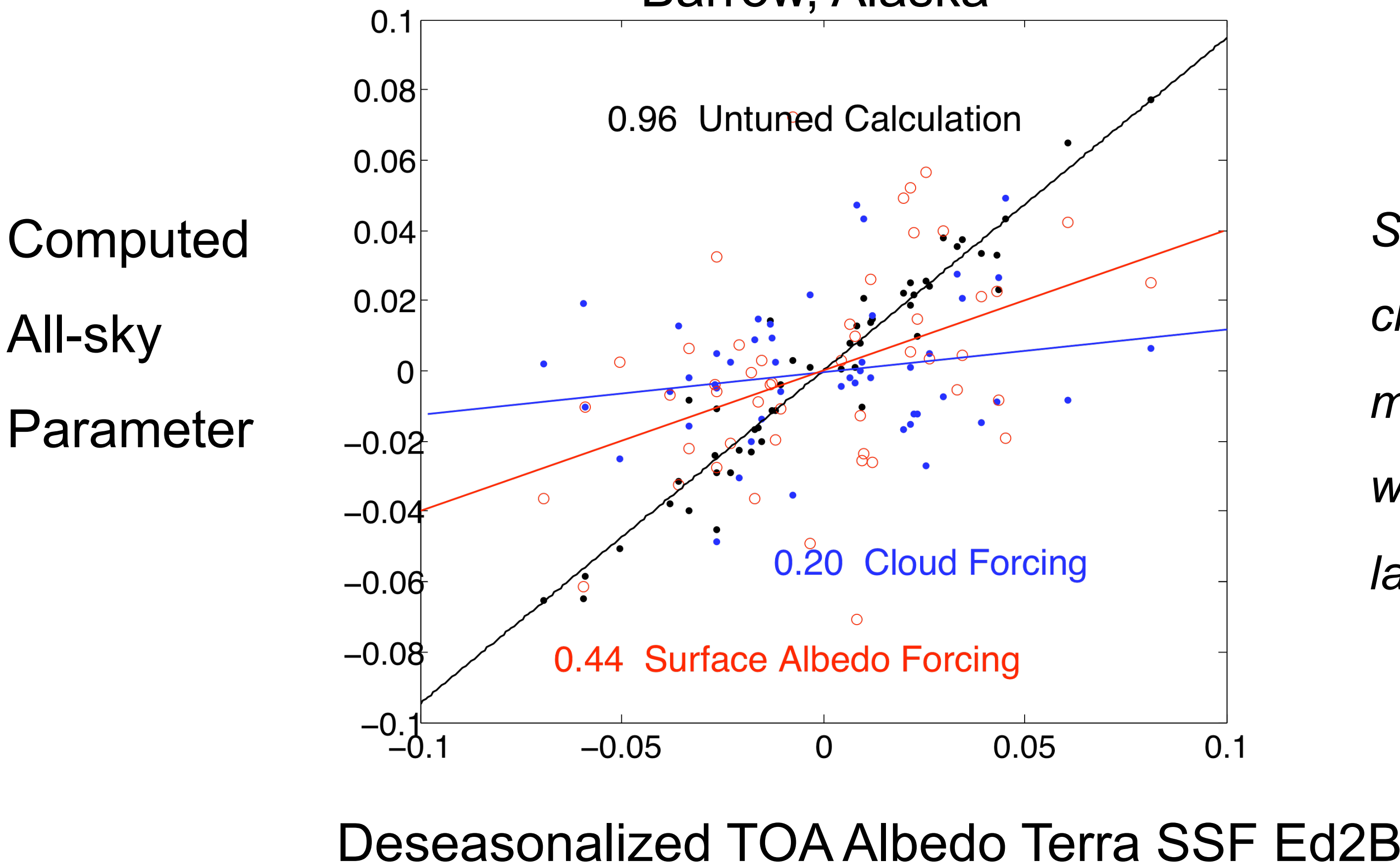
Cloud forcing explains most of the variance of transmission at Fort Peck

Surface Albedo Forcing = (Regular calculation)

- (Calculation with zero surface albedo)

Correlation of Observed TOA Albedo with Calculations (Deseasonalized)

Barrow, Alaska



Surface albedo and cloud forcing are more confused when footprint mixes land and ocean.

Surface Albedo Forcing = (Regular calculation)

- (Calculation with zero surface albedo)

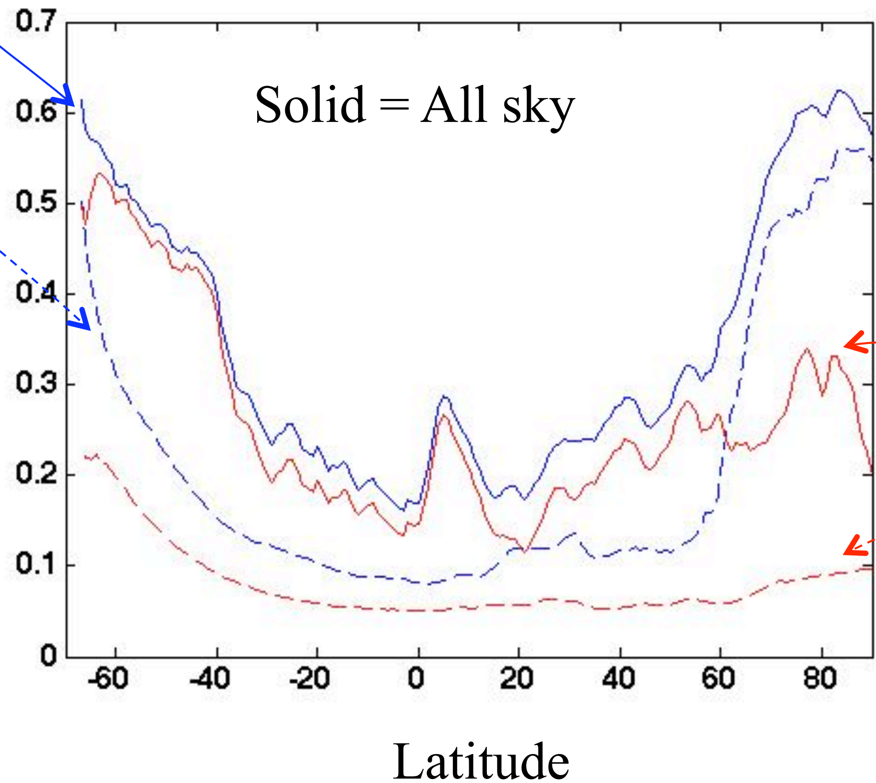
A Global Test for One Day…

Zonal Mean TOA Albedo at Aqua Overpass (20060513)

Untuned SARB calculations done two ways

CRS Ed 2C (production run)

Zero Surface Albedo (run with surface albedo = 0.001)



Dashed
= Clear sky

Forcing to Zonal Mean TOA Albedo at Aqua Overpass (20060513)

Untuned SARB Calculations

Cloud Forcing in CRS Ed 2C (production run)

Cloud Forcing in Zero Surface Albedo (run with surface albedo = 0.001)

Surface Albedo Forcing = (All sky Ed 2C) - (All sky Zero Surface Albedo)

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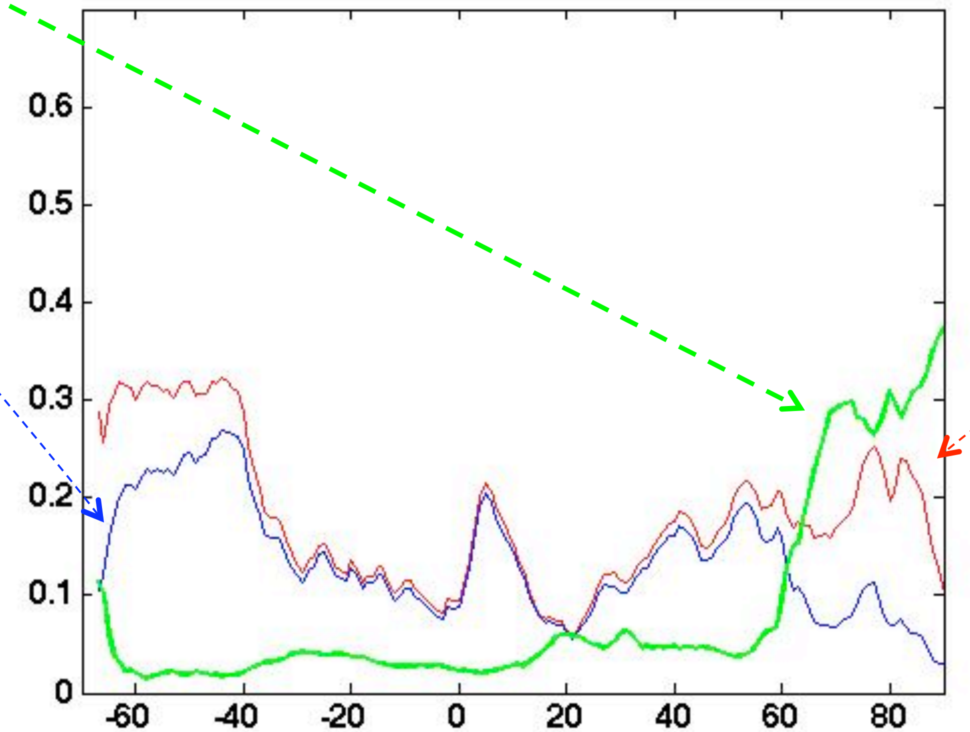


Latitude

Introduce Surface Albedo Forcing in Edition 3

Tool to assess the causes of long-term variations to TOA albedo, (i.e., in regions with seasonal snow cover).

Complement to aerosol forcing in areas with substantial surface albedo.

Easy: just compute for zero surface albedo.

And related to surface albedo forcing (a broadband quantity):

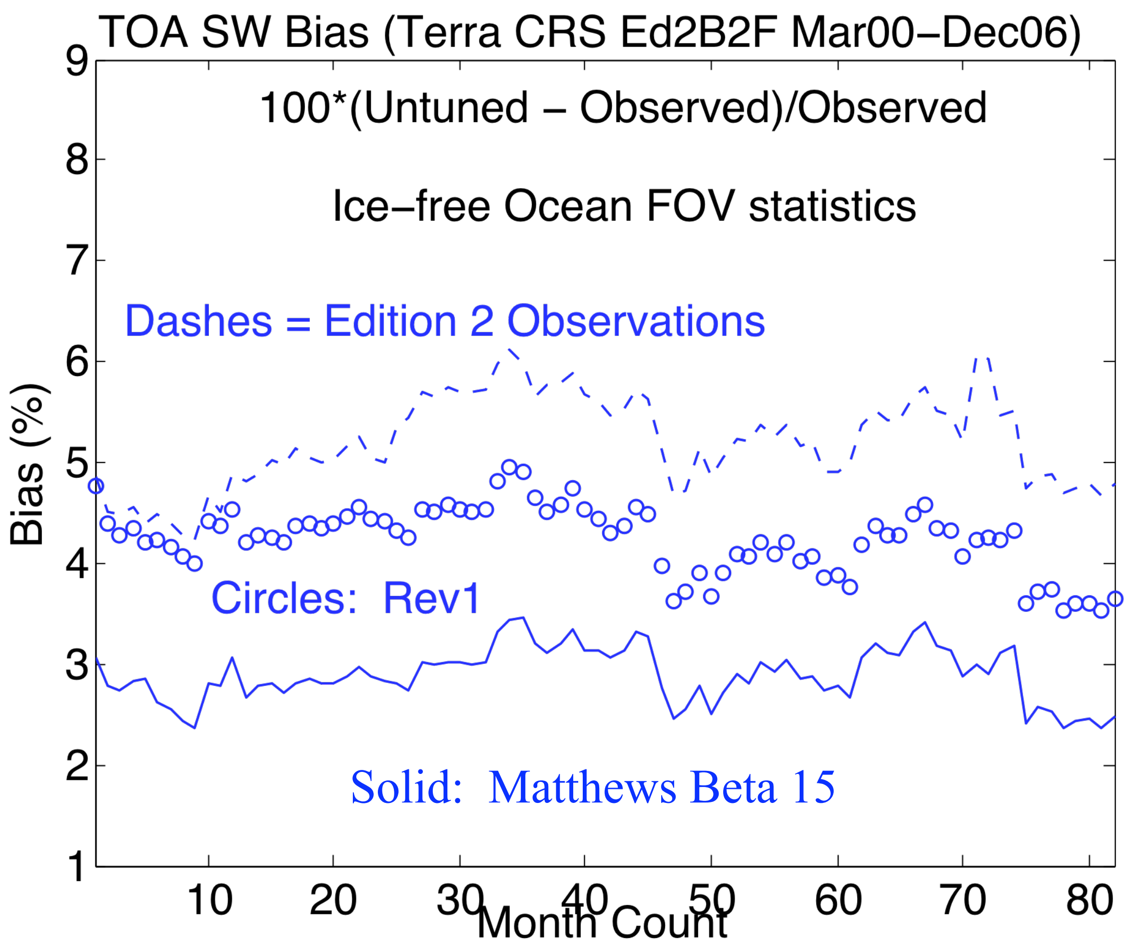
We are also considering to retrieve Antarctic snow grain sizes with MODIS in Edition 3 (Jin et al.).

More general algorithm for larger grain sizes in NH would require re-tooling and experimentation.

Jin, Z., T. P. Charlock, P. Yang, Y. Xie, and W. Miller, 2008: Snow optical properties for different particle shapes with application to snow grain size retrieval and MODIS/CERES radiance comparison over Antarctic. *Remote Sensing of Environment*, **112**, 3563-3581.

Bias of Calculated SW at TOA (all-sky, ice-free ocean)

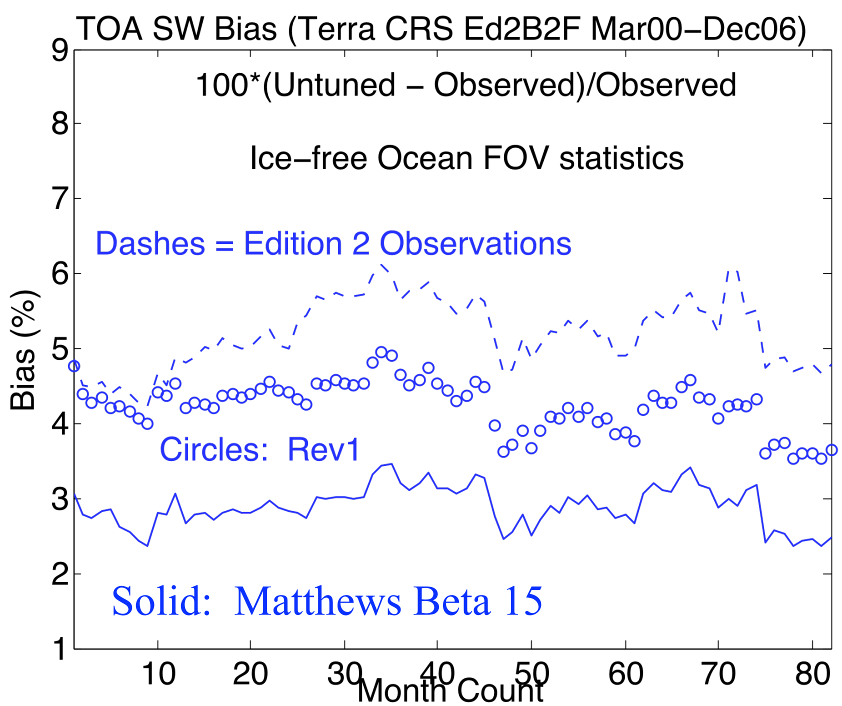
For each field, compute monthly average, deseasonalize, then form bias.

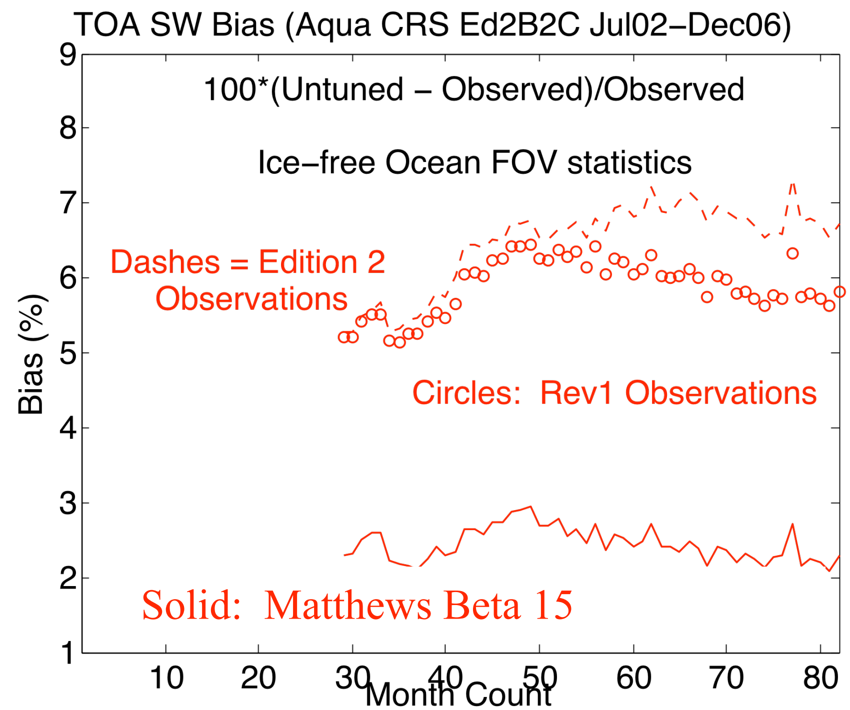


Untuned SW calculation uses no CERES broadband data over ice-free ocean. This compares the original calculations (Ed2) to original observations (Ed2), to official revised observations (Rev1), and to further test modifications to observations (Beta15).

Bias of Calculated SW at TOA (all-sky, ice-free ocean)

For each field, compute monthly average, deseasonalize, then form bias.

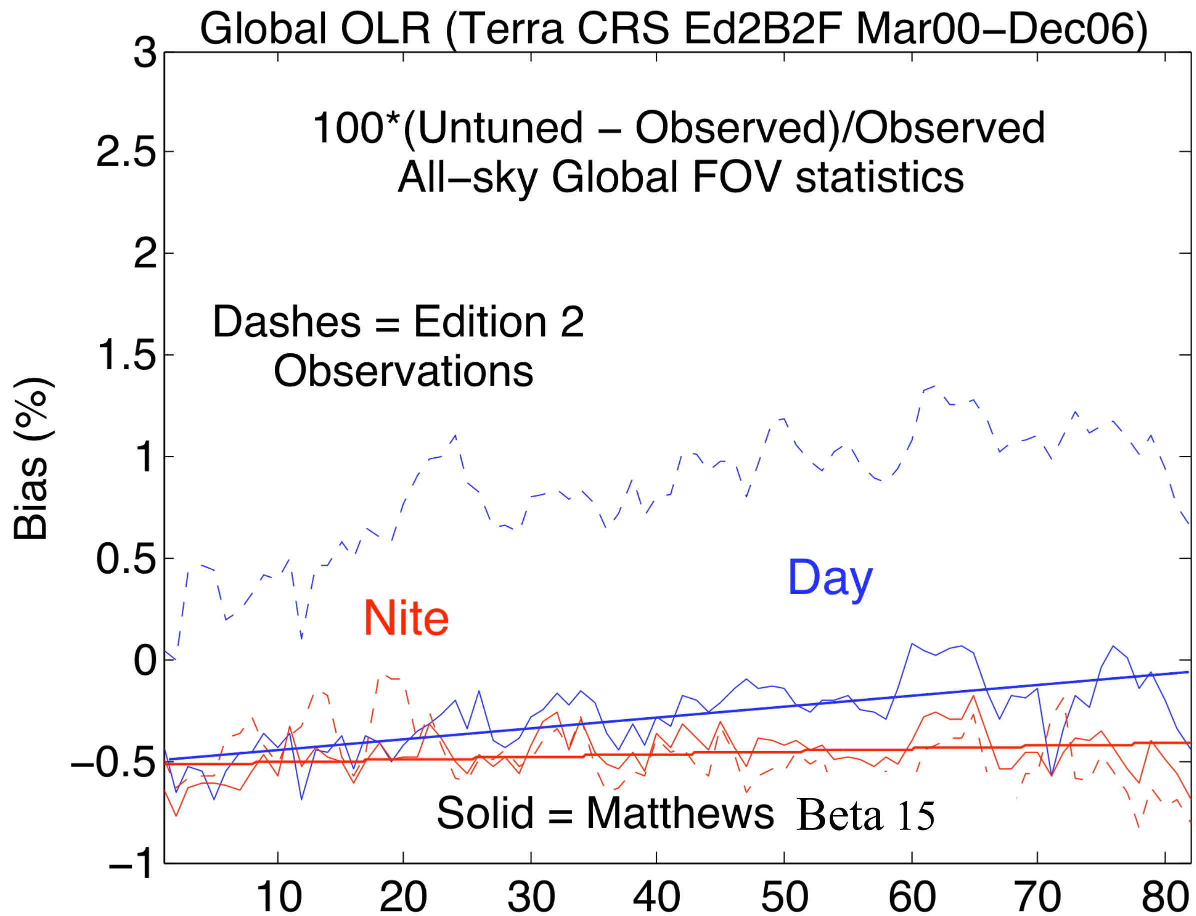




Untuned SW calculation uses no CERES broadband data over ice-free ocean.

For both Terra and Aqua, these original SARB CRS Edition 2 calculations have less bias and less trend with Rev1 modifications to SSF Edition 2 observations, and even less when compared with Beta 15 modifications to observations.

Bias of Computed All-sky OLR
Deseasonalized Monthly Footprint Means over Full Globe



Terra SSF Ed2 daytime OLR drifts. There is still some drift in daytime OLR with Beta 15.

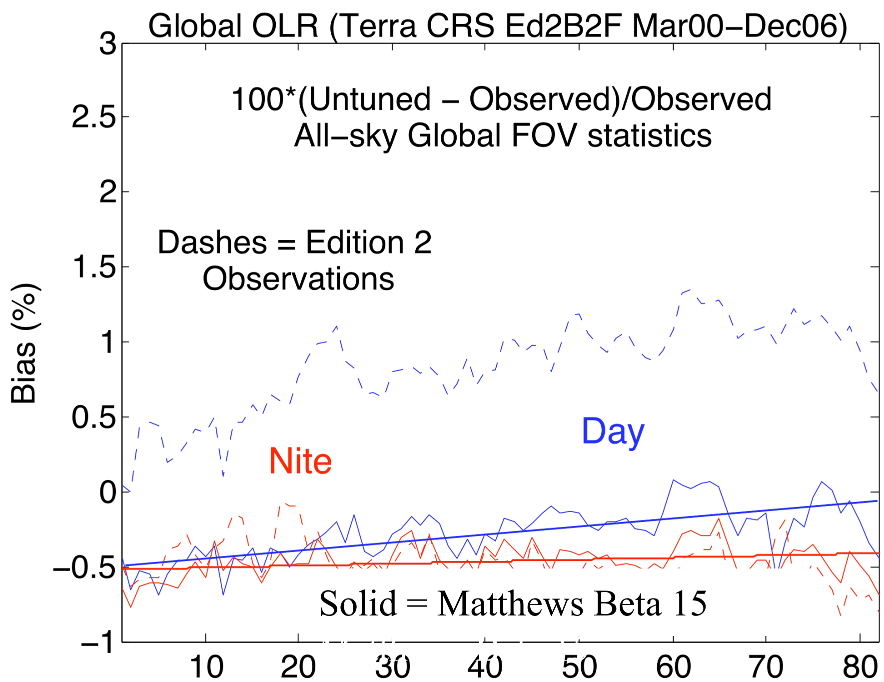
*Bias of 0.4% is ~1 W/m**2*

Untuned calculations for OLR and window (WN) use no CERES data.

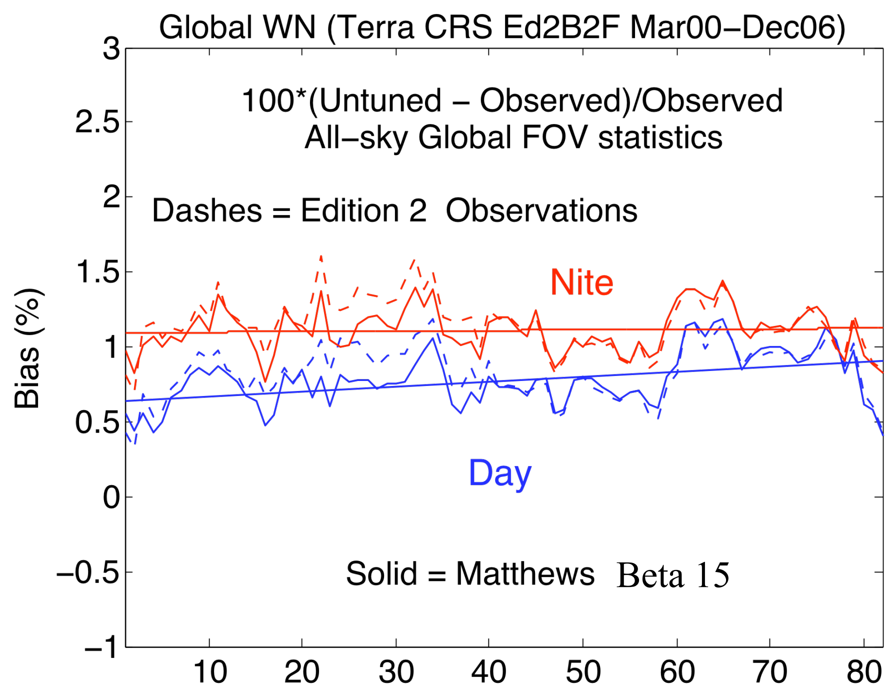
Beta 15 modifications to observed OLR use 11 scene types, differ for day and night.

Bias of Simulated Terra OLR and Window (WN)

OLR (previous slide)



CERES Window

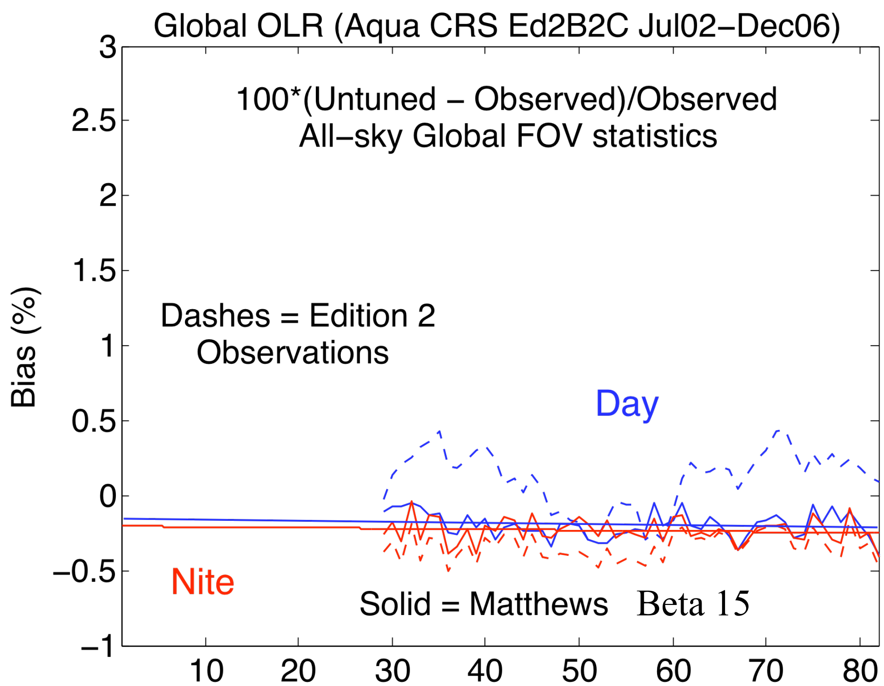


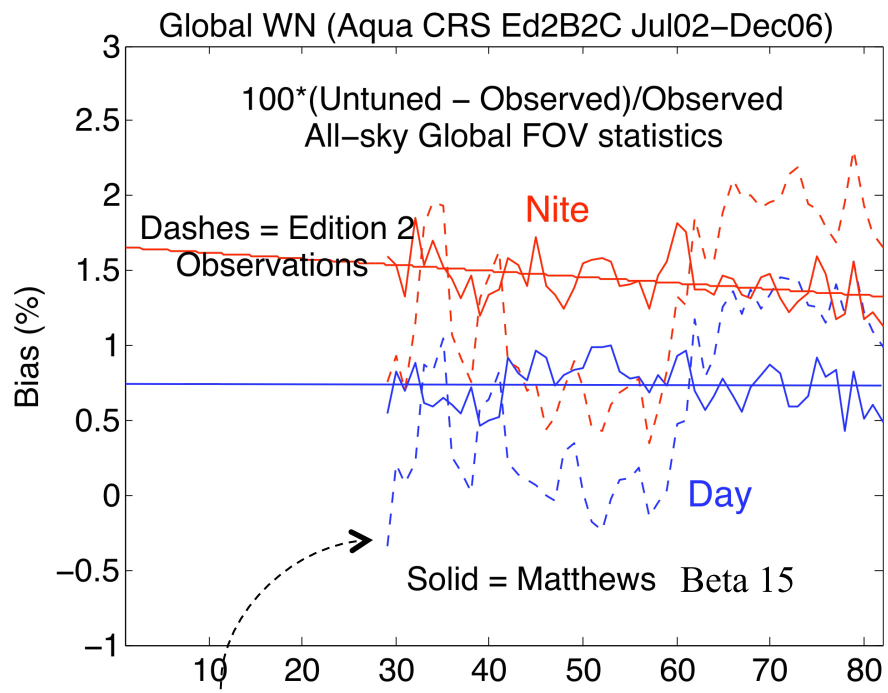
"Trend" in Terra daytime OLR bias is less in daytime WN.

Trend is probably not explained by constant CO2, CH4, N2O, and CFC in SARB Edition 2 radiative transfer.

Edition 3 code will account for changes in CO2 for LW.

Bias of Simulated Aqua OLR and Window (WN)





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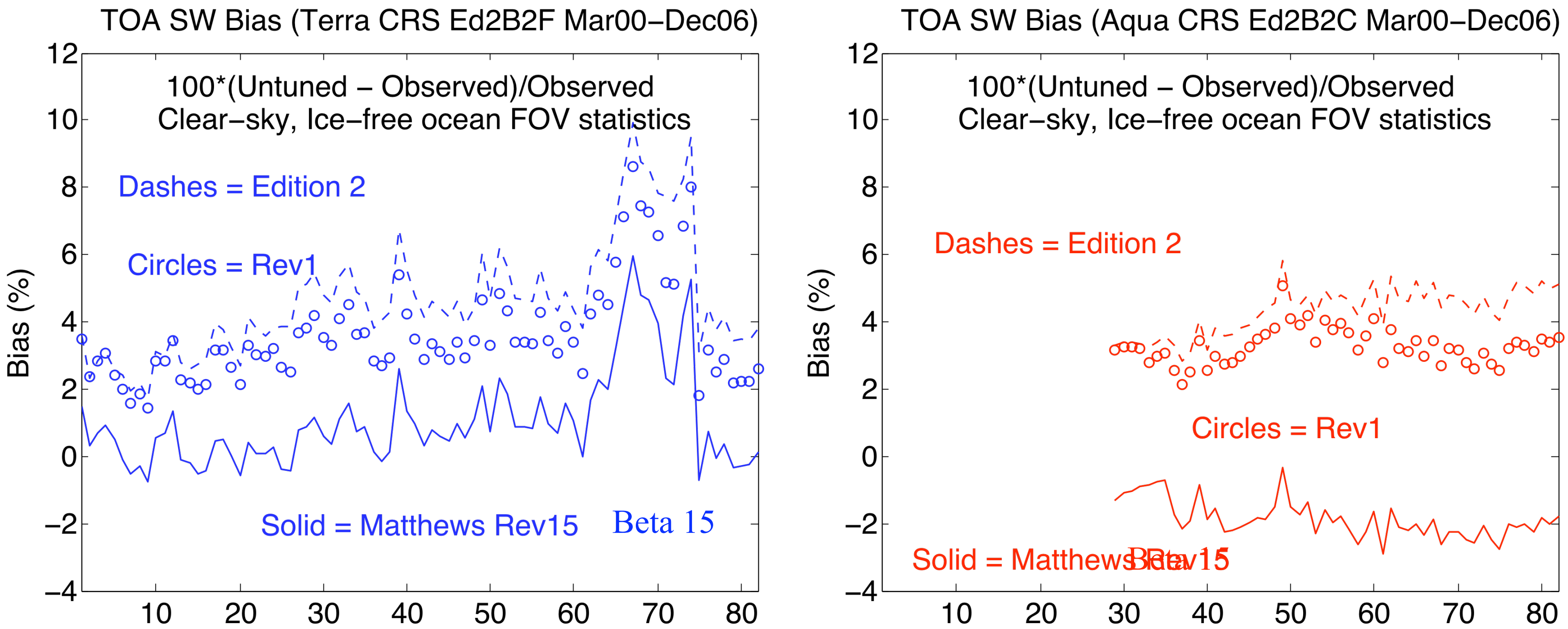
Aqua WN biases with Edition 2 SSF are erratic.

Aqua biases for day OLR and day WN are both flat with Beta 15.
Terra (previous slide) biases for day OLR and day WN still increase with Beta 15.
Aqua and Terra relative biases (%) for WN are larger than for OLR.

Bias of Calculated SW at TOA (CLEAR-sky, ice-free ocean)

Clear ocean SW is the toughest field to observe.
For Beta 15, bias are ~ 0% for most of Terra versus ~ -2% for Aqua.



NH winter of 2005-2006 has large Terra bias for SW over clear ocean. It is due to an input error: Aerosol Optical Thickness (AOT) is too high. Terra CRS Ed2B (but not Terra Ed2F or Aqua 2B2C) allows MODIS Daily Average AOT as a source; we've interpolated that field incorrectly earlier in Aqua CRS Ed2A.

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How do we validate Aqua CRS Edition 2C, the 2006 successor to Edition 2B?

Compare CRS Ed2B vs surface data and CRS Ed2C vs. surface data
for a common “season” (May to December) .

CRS Ed2C starts in May 2006.

Use 2006 for Ed2C and 2002-2005 for Ed2B.

Surface and Satellite Data (<25km from 17 CAVE sites) having
fairly consistent reporting in this period:

Barrow, AK (GMD)   Boulder Tower, CO (GMD)   Chesapeake Light (LaRC)   Desert Rock, NV (SURFRAD)
E01-Larned (ARM) E03-LeRoy (ARM) E13-Central Facility (ARM) E20-Meeker (ARM) E22-Cordell (ARM)
Fort Peck, MT (SURFRAD)   Kwajalein (GMD)   Manus Island/TWP (ARM)   Nauru Island/TWP (ARM)
Penn State, PA (SURFRAD)   Samoa (GMD)   South Pole (GMD)   Table Mountain, Boulder, CO (SURFRAD)

Compare CRS Ed2B vs surface data and CRS Ed2C vs. surface data for a common “season” (May to December) . CRS Ed2C starts in May 2006. Use 2006 for Ed2C and 2002-2005 for Ed2B.

Table 2 CRS Biases at 17 CAVE sites (calculation-observation in Wm-2)

	All sky		Clear sky		
	Ed2B	Ed2B-Ed2C	Ed2B	Ed2B-Ed2C	
Untuned SW up TOA	7.86	-0.92	-0.28	0.60	
Tuned SW up TOA	1.55	-0.18	0.25	0.06	
Untuned SW down SFC	9.73	-0.99	6.83	-0.79	
Tuned SW down SFC	18.24	-1.80	7.93	0.93	
Untuned SW up SFC	-26.18	-5.40	-33.76	1.83	**
Tuned SW up SFC	-24.44	-5.43	-33.38	1.85	**
Untuned OLR	-1.53	-0.24	-1.95	-0.26	
Tuned OLR	-0.42	-0.16	-1.47	0.12	
Untuned LW down SFC	-8.09	-0.07	-7.37	0.91	
Tuned LW down SFC	-8.36	-0.07	-8.55	0.80	
Untuned LW up SFC	-5.84	-0.80	1.21	1.30	**
Tuned LW up SFC	-4.75	-0.27	0.69	2.52	**

** 2 of 17 sites lack surface measurements of upwelling radiation

Compare CRS Ed2B vs surface data and CRS Ed2C vs. surface data for a common "season" (May to December) . CRS Ed2C starts in May 2006. Use 2006 for Ed2C and 2002-2005 for Ed2B.

Table 3 CRS RMS at 17 CAVE sites (calculation vs observation in Wm-2)

	All sky		Clear sky		
	Ed2B	Ed2B-Ed2C	Ed2B	Ed2B-Ed2C	
Untuned SW up TOA	26.06	-1.79	4.69	0.18	
Tuned SW up TOA	8.20	-1.08	1.45	-0.15	
Untuned SW down SFC	126.15	-0.38	28.52	0.33	
Tuned SW down SFC	126.45	-0.40	28.80	-0.30	**
Untuned SW up SFC	56.73	4.08	46.87	-3.48	**
Tuned SW up SFC	56.24	3.68	46.50	-3.80	
Untuned OLR	8.41	-0.46	5.61	-0.11	
Tuned OLR	4.65	-0.22	3.06	-0.12	
Untuned LW down SFC	19.01	0.09	15.64	0.89	
Tuned LW down SFC	19.23	-0.03	16.32	0.19	
Untuned LW up SFC	26.56	-0.26	20.24	-1.26	**
Tuned LW up SFC	25.00	-0.36	20.05	-0.71	**

** 2 of 17 sites lack surface measurements of upwelling radiation

Significant error in Terra CRS Ed2B during NH winter for clear-sky ocean SW

Caused by software that Ed2F leap frogs

Aqua CRS Edition 2C and Terra CRS Edition 2F are satisfactory

(Collection 5 MODIS, starting in May 2006)

Climatological aerosol profiles in Terra CRS Ed2F for May-Dec06

- cannot verify adverse impact to broadband

Comparison with successive global TOA observations (Ed2, Rev1, Beta15)

Beta 15 still gives ~2% bias of all-sky SW over oceans
in Terra and Aqua

Untuned bias drifts with daytime Beta 15 all-sky OLR
in Terra but not in Aqua

Surface albedo forcing product suggested for Edition 3