Surface Atmospheric Radiation Budget (SARB) working group update

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16th CERES Science team meeting Oct. 4-6, 2011
At Lawrence Livermore National Laboratory, Livermore, CA

SARB working group

- Produces TOA and surface shortwave, longwave and window irradiances, as well as irradiances at 70, 200, and 500 hPa using radiative transfer models.
- The SARB working group contribution to CERES products
  - CRS Instantaneous CERES footprint base, Level 2
  - FSW Gridded instantaneous fluxes
  - CER_SYN1deg-3Hour, CER_SYN1deg-M3Hour, CER_SYN1deg-Month (produced with TISA working group)
  - Surface EBAF (produced with TISA and inversion working groups) Level 4 product, TOA irradiances match with TOA EBAF
  - CRS1deg-Month (Level 4 product, non-GEO surface; See Fred Rose's presentation in the SARB working group meeting)

Outline of this talk

- Surface EBAF
  - Global annual mean surface radiation budget and variability
  - Ed3 SYNI and AVG
  - CRS1deg-Month surface product
- Validation of SYNI and SYN1deg-Month using EOF (diurnal cycle) and surface sites (sampling).
- Ed4 proposal and changes from ed2
  - Better surface albedo map over polar region

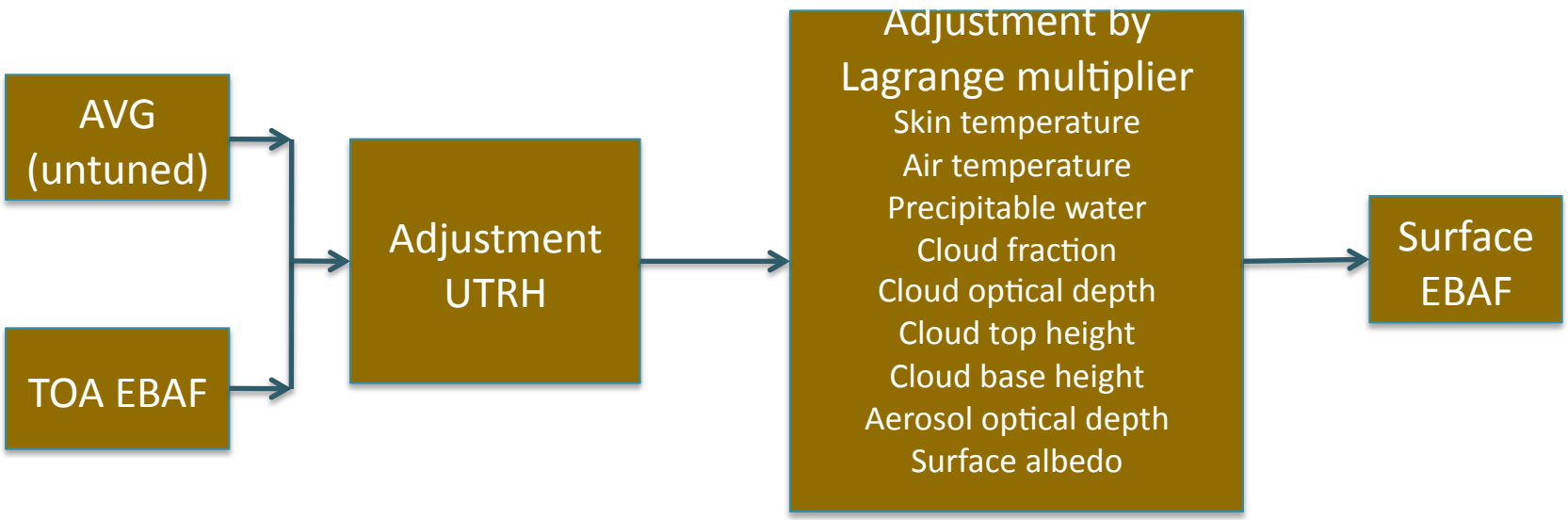
CERES AVG/SYN products (ed2)

- Contain 3-hourly(SYN) or monthly mean (AVG) TOA and surface irradiances
- Atmospheric properties (temperature and humidity) are from GEOS-4 (reanalysis)
- Cloud properties at Terra overpass time are derived from MODIS
- Non-terra overpass time cloud properties are from Geostationary satellites or interpolated values of MODIS-and GEO-derived cloud properties
- Aerosol properties are from MODIS and MATCH
- Aerosol types include small dust, large dust, sulfate, sea salt, soot, soluble particles, and insoluble particles. Optical properties are from Optical Properties of Aerosols and Clouds (OPAC [Hess et al. 1998]) and Tegen and Lacis [1996].

MATCH Aerosols: see David Fillmore's presentation in the SARB working group meeting

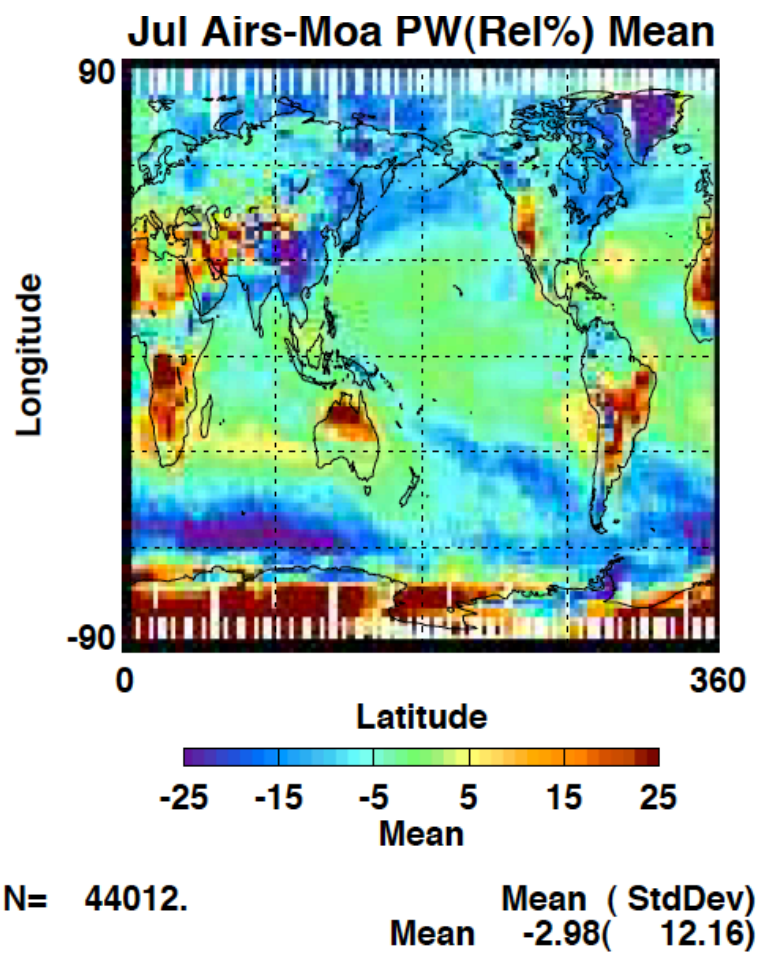
Surface EBAF product

- A Level 4 product that uses surface irradiances from the most integrated CERES product (AVG ed3).
- Using CALIPSO and CloudSat derived cloud properties, and AIRS derived atmospheric properties, monthly 1°×1°gridded mean cloud and atmospheric properties are perturbed to match TOA EBAF.

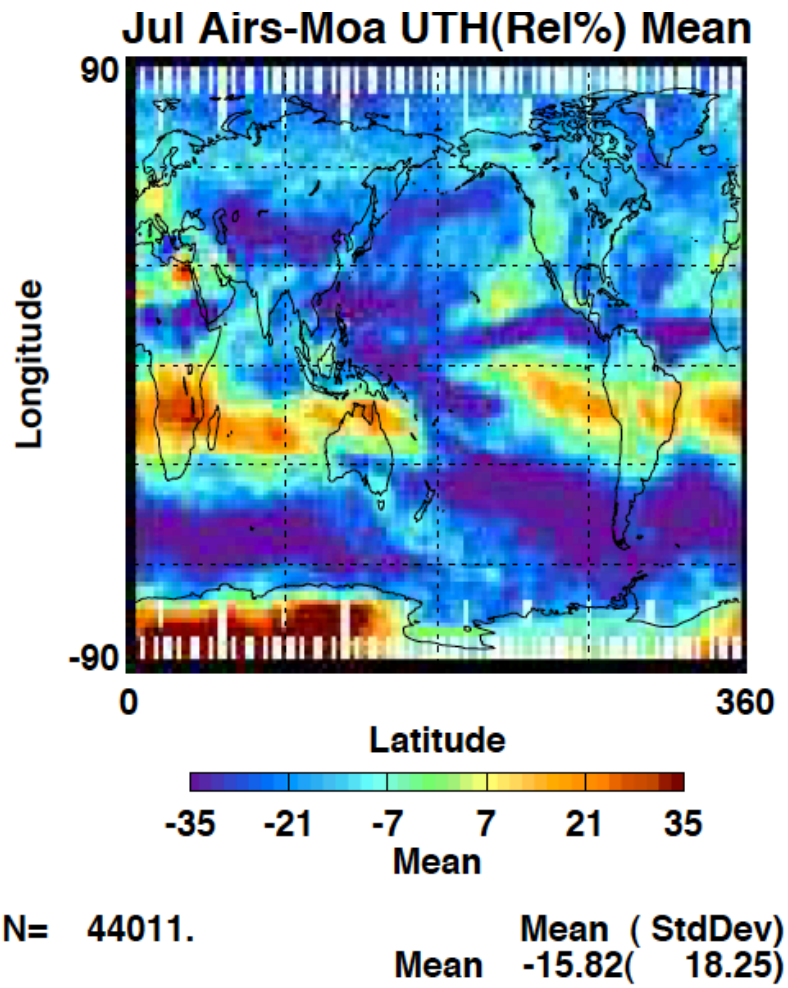


Water vapor adjustments are derived from AIRS vs. MOA comparison

Precipitable water



200 to 500 hPa relative humidity



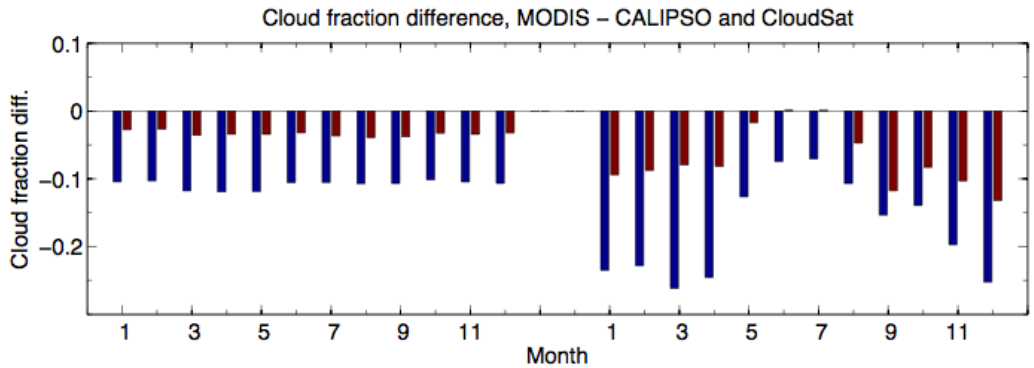
Cloud property uncertainty is based on MODIS, CALIPSO, CloudSat comparisons

60S – 60N

Arctic

Cloud fraction difference

Blue: all Red: $\tau > 0.3$

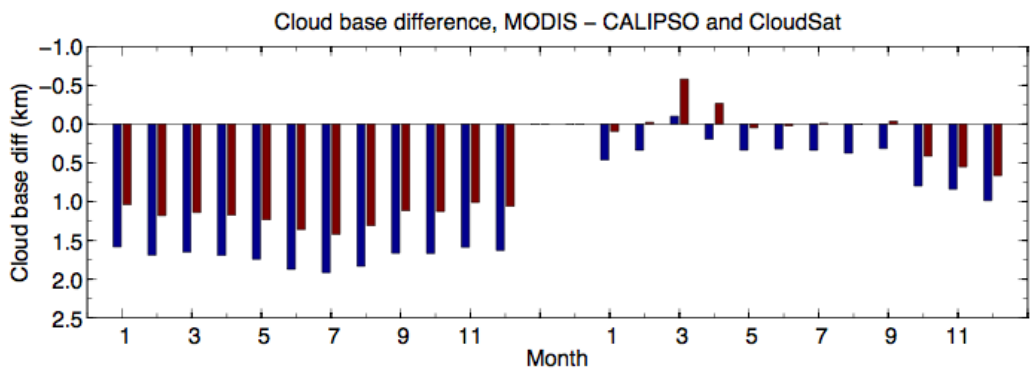


Cloud base

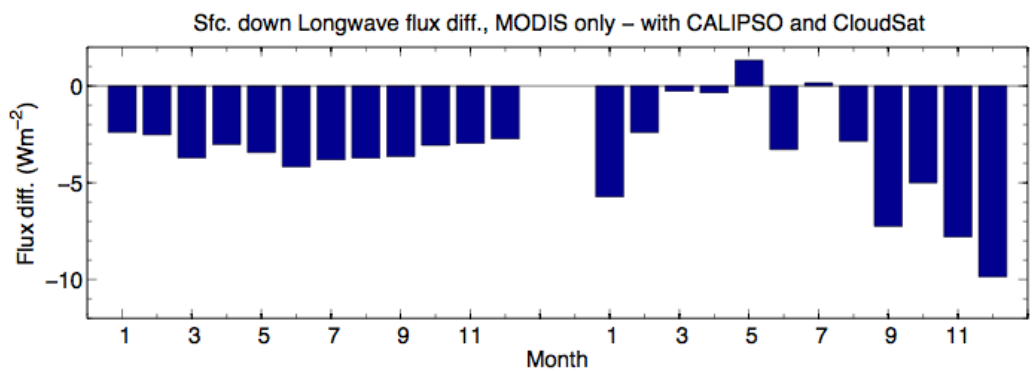
Blue: all

Red: non-precipitating clouds

Note: the y-axis sign is opposite, i.e. MODIS cloud base is higher



Downward longwave difference



Uncertainty table

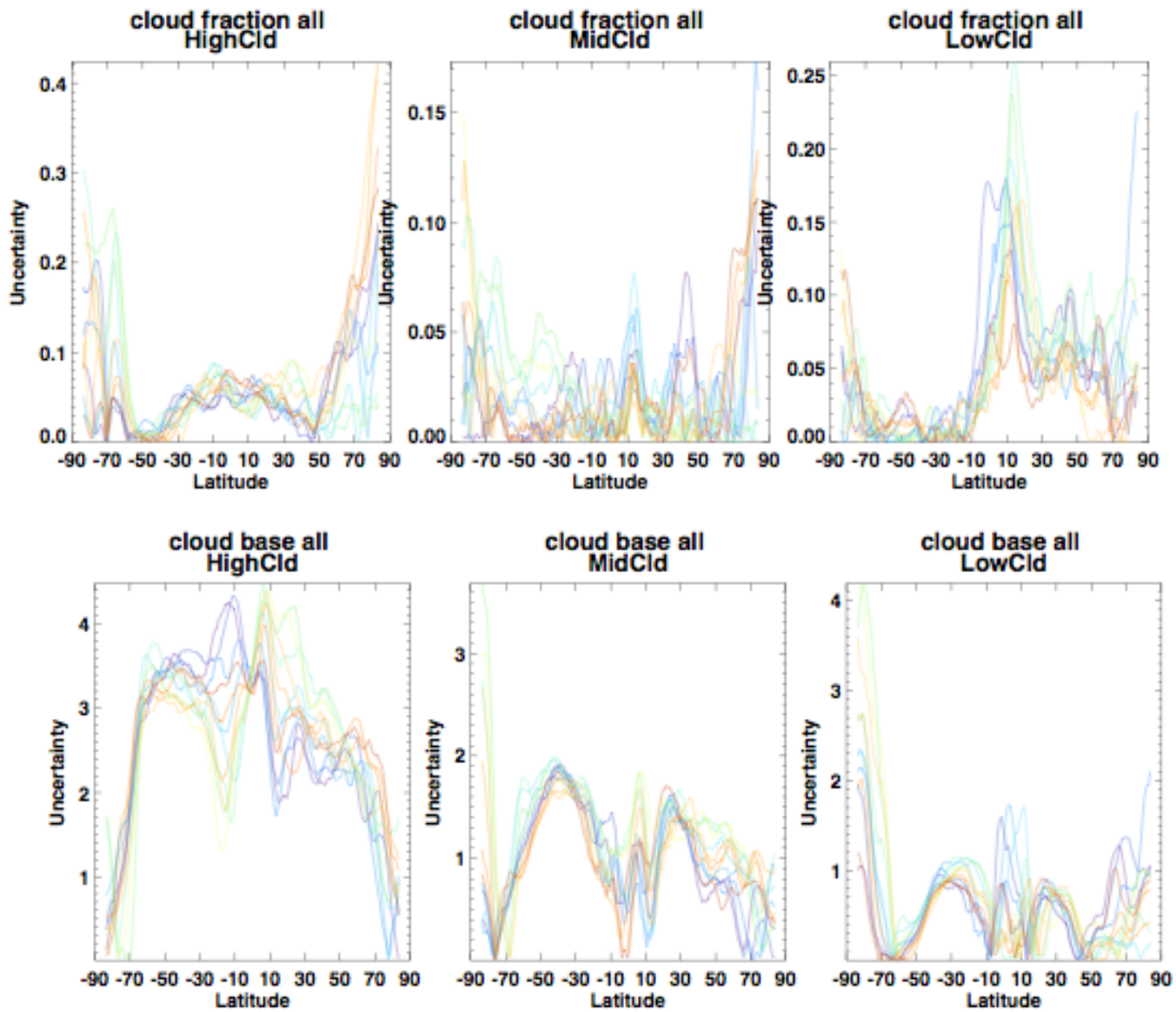
- Variables with a larger uncertainty are adjusted more than variables with a smaller uncertainty
- Cloud properties
  - Monthly 10 degree zonal cloud type (high, mid, and low) dependent uncertainty tables generated from MODIS - CALIPSO & CloudSat
- Temperature and humidity
  - Monthly 1°×1° climatology uncertainty table generated from MOA - AIRS

Uncertainty and systematic error

Monthly zonal cloud type-dependent uncertainty/passive sensor error

Cloud fraction

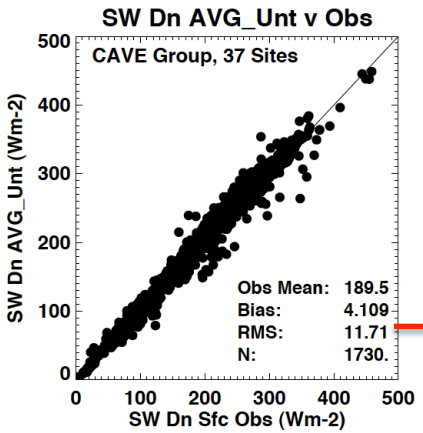
Cloud base



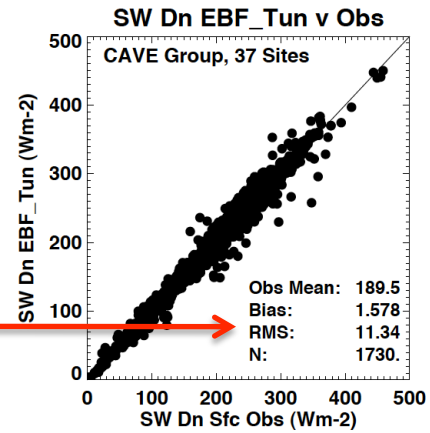
Monthly mean irradiance comparison with surface observations

Shortwave surface downward irradiance improvement

Before

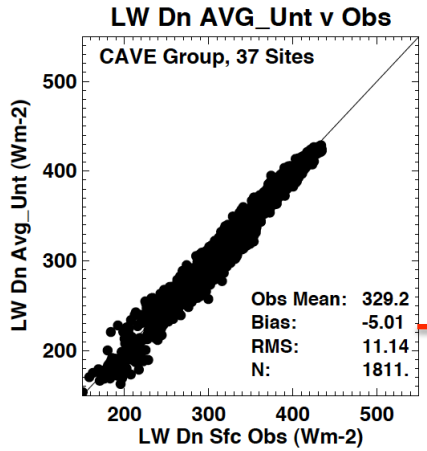


After

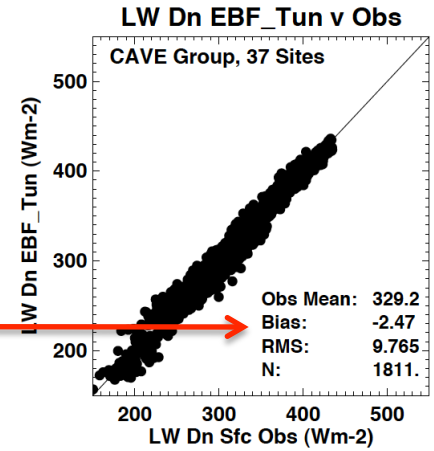


Longwave surface downward irradiance improvement

Before



After



Data from 37 sites and March 2000 through October 2005

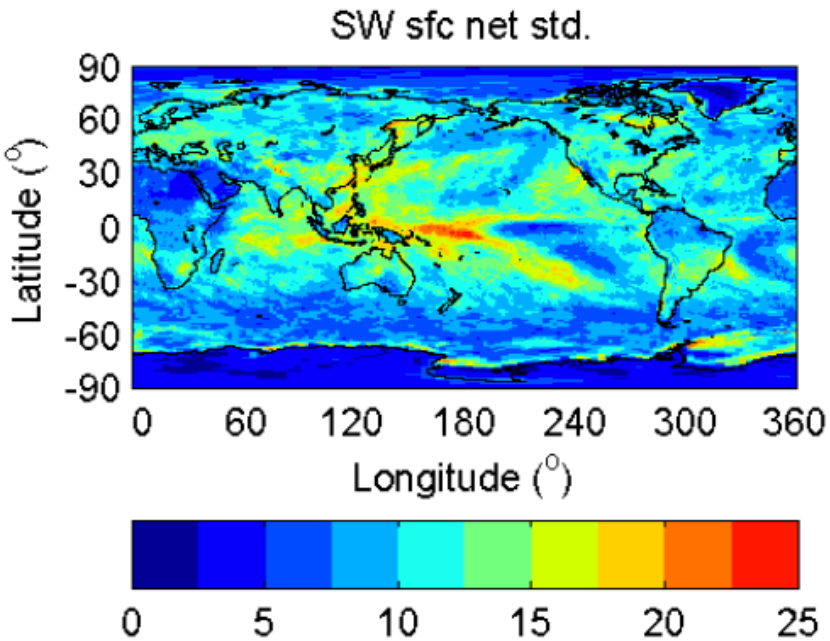
	Before [bias(RMS)] AVG	After [bias(RMS)] Surface EBAF
Longwave down (Wm-2)	-5.01(11.14)	-2.47 (9.77)
Shortwave down (Wm-2)	4.11 (11.71)	1.58 (11.34)

Global annual mean surface downward longwave irradiance (Surface EBAF is preliminary)

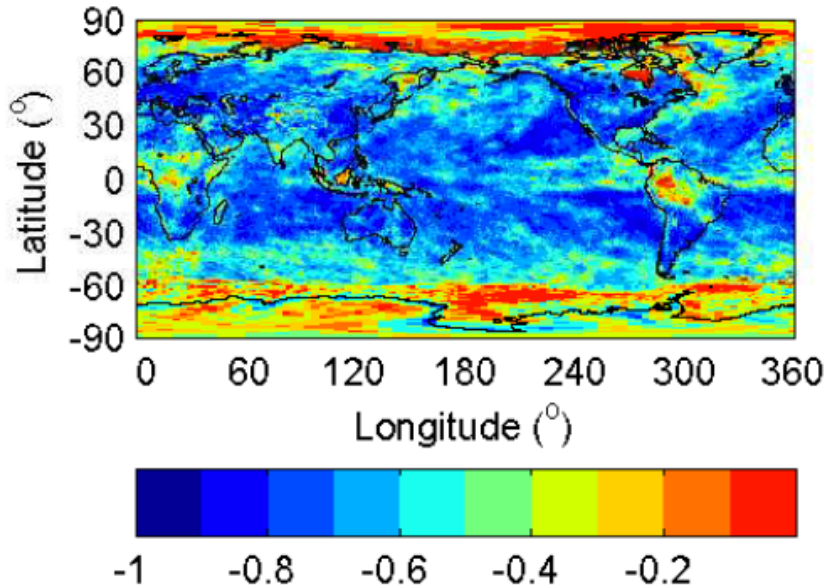
Surface	CERES AVG	Surface EBAF
LW down (W m^{-2})	342.0	343.8
LW up (W m^{-2})	398.0	398.5
SW down (W m^{-2})	188.9	187.4
SW up (W m^{-2})	23.1	24.0
TOA		**tuned to TOA EBAF**
LW up (W m^{-2})	237.8	240.7
SW down (W m^{-2})	340.3	340.3
SW up (Wm^{-2})	97.9	99.8

- Global average of 5 years of data from March 2000 through Feb. 2005
- Atmospheric shortwave net is 77.1 Wm^{-2}
- Uncertainty of all irradiances is estimate by validation

Surface SW net versus LW net



Correlation between
Δ surface SW net and Δ surface LW net



$$\Delta F_{SW}^{net}(sfc) = c_p \rho_w h_e \frac{d\Delta T}{dt} + \Delta F_L + \Delta F_s + \Delta F_{LW}^{net}(sfc) + c_p \rho_w h_e \mathbf{v} \cdot \nabla \Delta T$$

Energy deposited by shortwave anomalies are used for
Surface temperature change
Latent heat flux
Sensible heat flux
Longwave emission
Horizontal advection by ocean currents

Negative correlation
More SW net gives
Less LW net
Where positive net
Is downward net flux

Surface irradiance validation with ground sites

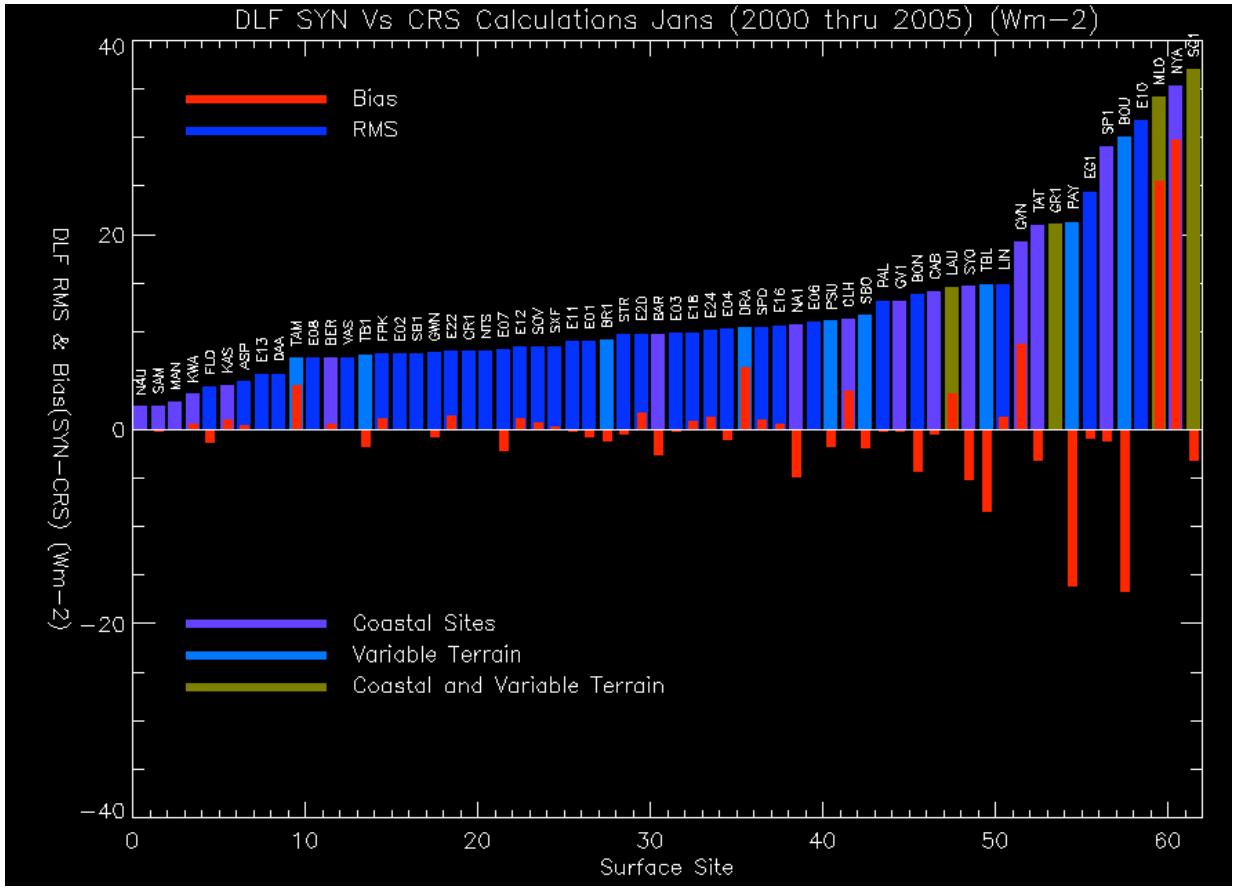
Surface variation error components

Total RMS^2 = spatial sampling RMS^2
+ temporal sampling RMS^2
+ modeling input RMS^2

Total bias = spatial sampling bias
+ temporal sampling bias
+ modeling input bias

Spatial sampling error:
Temporal sampling error: Diurnal cycle comparison
Modeling input error: AIRS vs. GEOS5, MODIS vs. CALIPSO CloudSat, CRS validation

Site versus grid box (spatial sampling error)



RMS difference and Bias between a grid box monthly mean irradiance in an hour box and mean of instantaneous irradiance within 25 km from a surface surface site

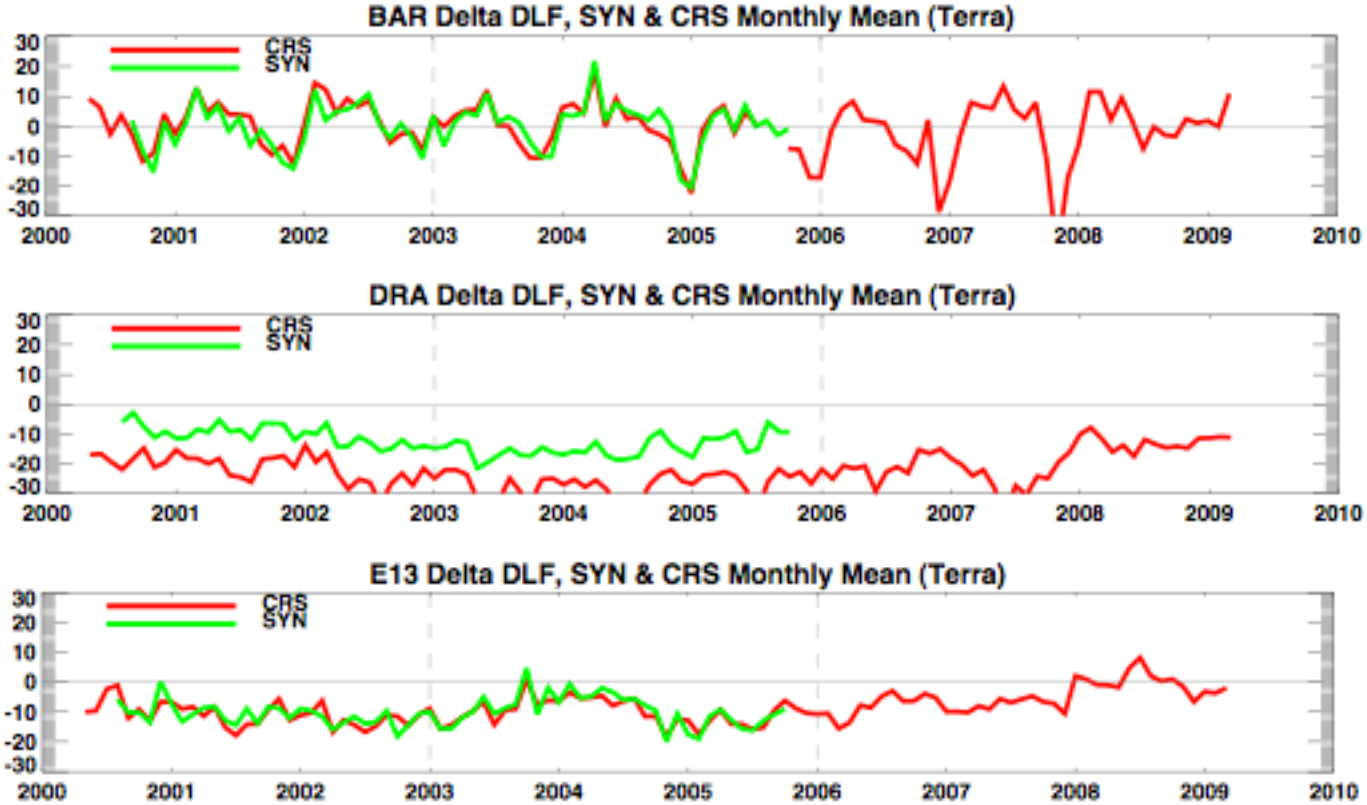
SYN Spatial Error Estimates

	Land & Ocean	Coastal	Variable Terrain	Coastal & Variable Terrain
	33 Sites	16 Sites	9 Sites	4 Sites
LW down (12 months)				
Bias	-0.1	2.1	-3.9	3.6
RMS	1.3	8.1	9.4	18.3
SW down (12 months)				
Bias	-2.4	-6.3	-1.8	-18.3
RMS	4.2	12.7	8.5	18.3

Differences computed between all hour boxes across months for SYNI calculated downward surface flux minus average of CRS untuned calculation for that grid box/ hour box.

CRS footprints are within 25km of surface site (grid box center where there is no surface site) whereas grid box is approximate equal area 1 degree.

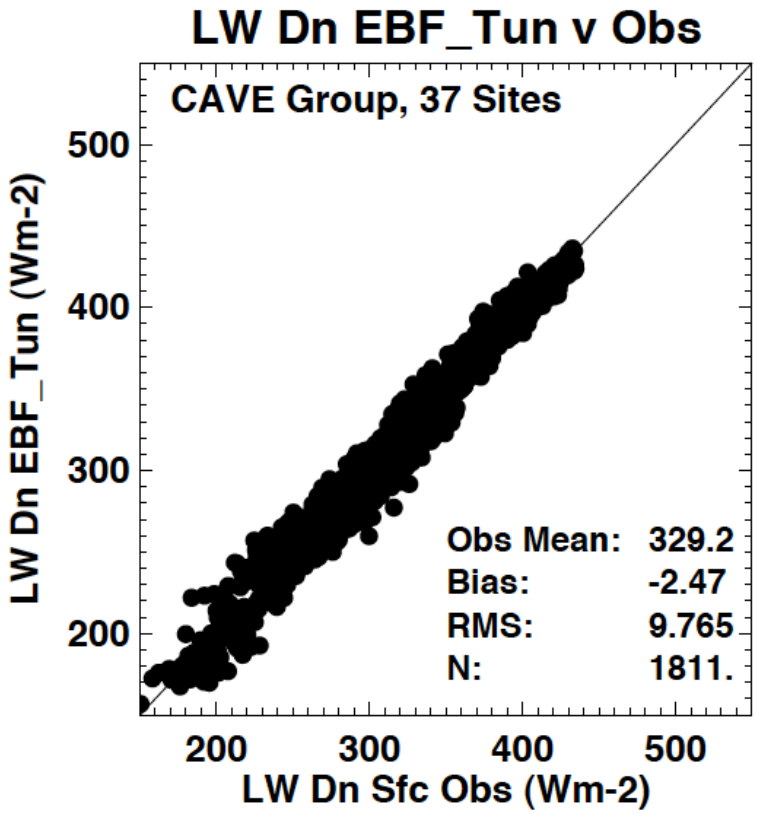
Spatial and temporal sampling errors

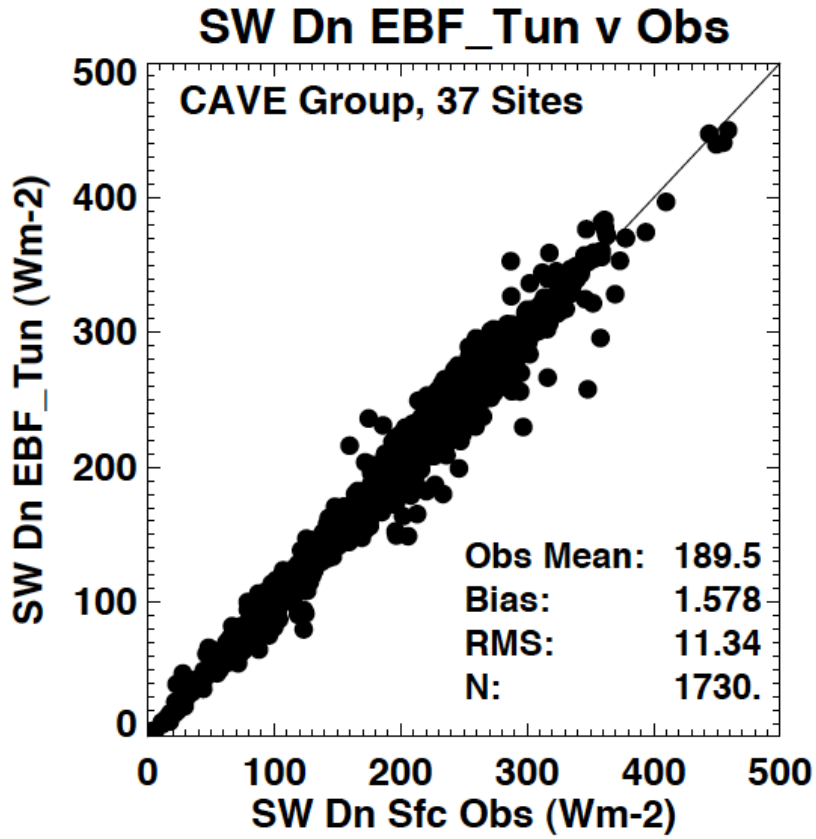


	LW down (Wm-2)	SW down (Wm-2)
Bias	0.5	-4.8
Bias (CRS vs. Obs)	-6.7	9.8

Comparison of SYN (gridded + diurnal correction) and CRS (within 25 km from ground sites and average of irradiances at terra overpass time)

Uncertainty of gridded monthly mean irradiances





sqrt(RMS^2 – spatial sampling $noise^2$) gives the gridded monthly mean irradiance uncertainty, i.e. there is 68% probability a monthly gridded mean lies in the interval.

	LW down (Wm-2)	SW down (Wm-2)
Bias (RMS) [EBAF – spatial error]	-3.4 (7.6)	1.9 (6.5)
Bias [CRS & SYNI]	-6.1	7.4

Surface irradiance uncertainty

Table 3: Summary of uncertainties in the irradiance computed with satellite-derived cloud and aerosol properties

			Estimated uncertainty			
		Mean value	Monthly gridded	Monthly zonal	Monthly global	Annual global
Downward longwave	Ocean+land	345	13	12	11	7
	Ocean	354	14	13	11	7
	Land	329	15	14	11	7
Upward longwave	Ocean+Land	398	14	10	5	4
	Ocean	402	14	10	5	5
	Land	394	20	16	6	3
Downward shortwave	Ocean+Land	192	8	6	5	5
	Ocean	190	8	6	5	5
	Land	203	8	7	5	5
Upward shortwave	Ocean+Land	23	11	5	3	3
	Ocean	12	11	3	2	2
	Land	53	12	8	6	5

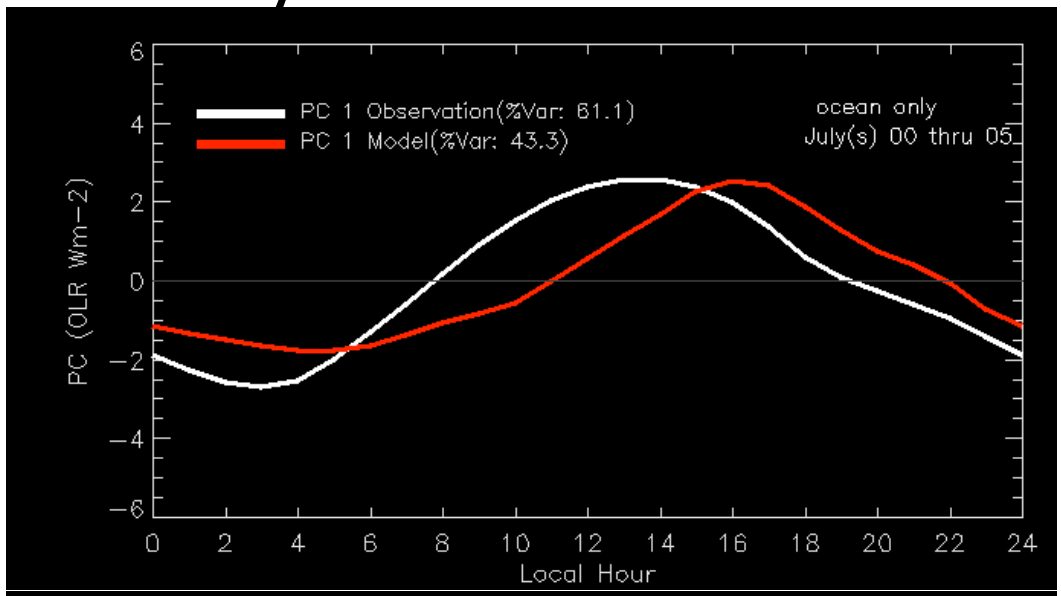
Global annual mean SW Atm irradiance: 77.1±6.2Wm^{-2}

Kato et al. 2011 submitted

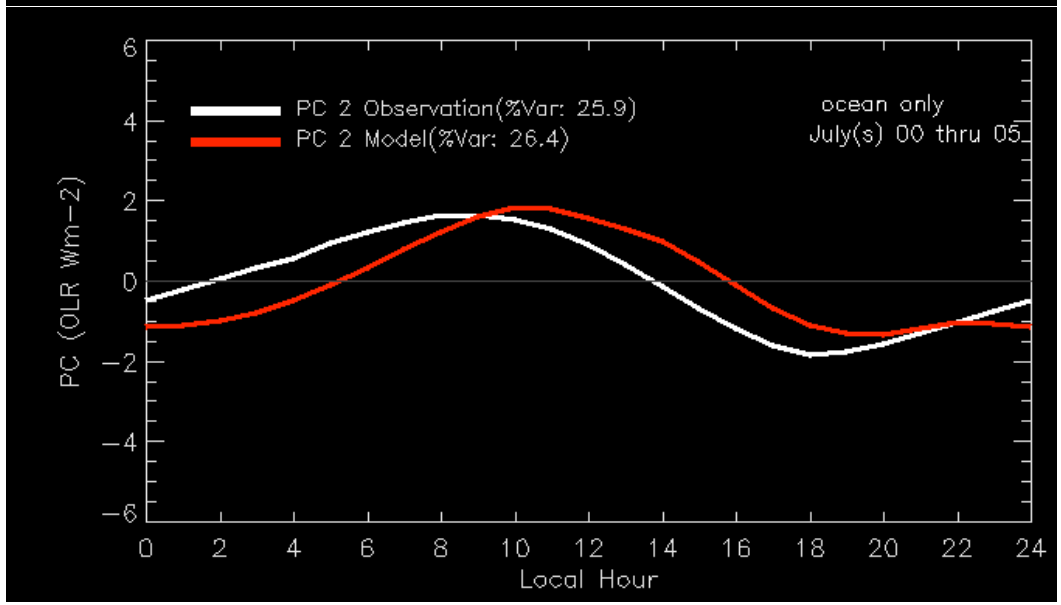
Diurnal cycle in SYNI

PC analysis applied to CERES and GEO derived TOA LW irradiances

PC1

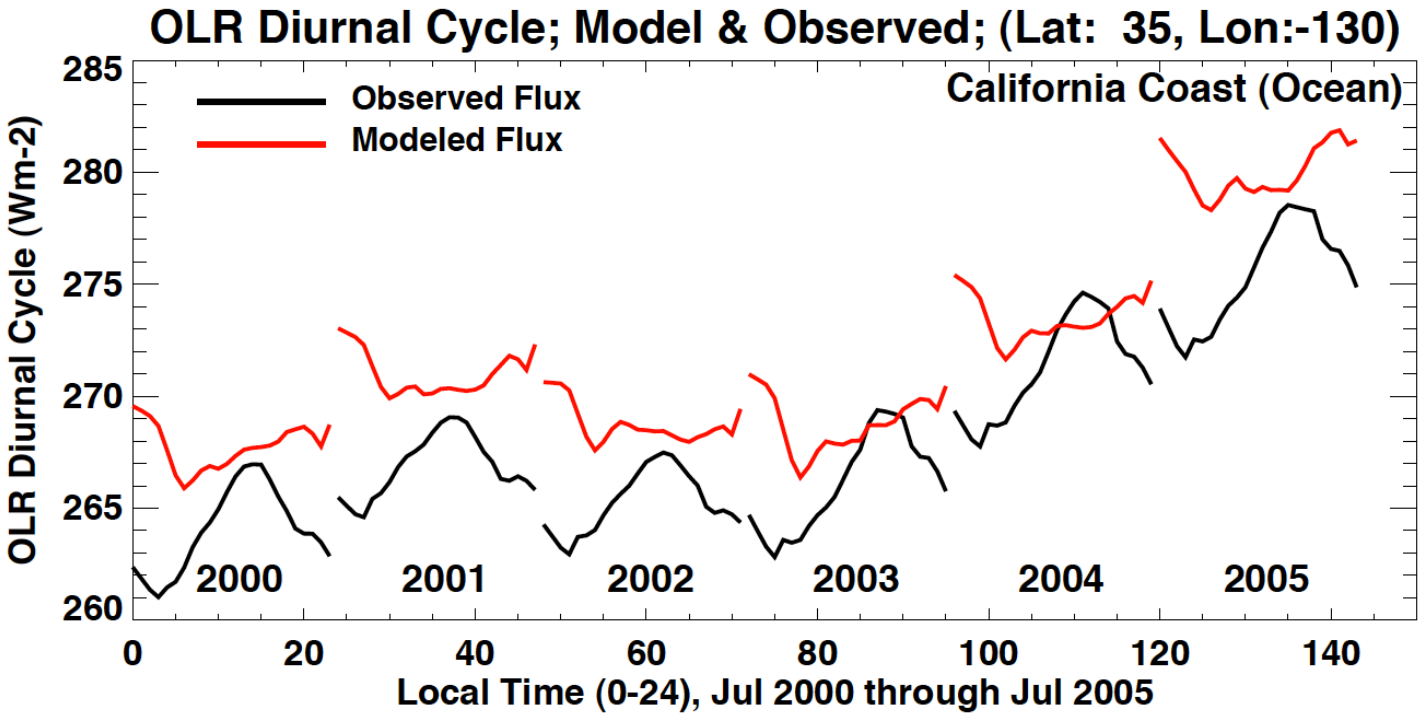


PC2



Derived from global mean 1 hourly TOA irradiances of 6 Julys (from 2000 through 2005)
It appears to be problem in the diurnal cycle of marine stratocumulus derived from GEO
Terra + Aqua (ed3 SYN1deg-Month) may mitigate this problem

TOA OLR comparison (regional)



Work in progress: Investigating regional cloud diurnal cycles

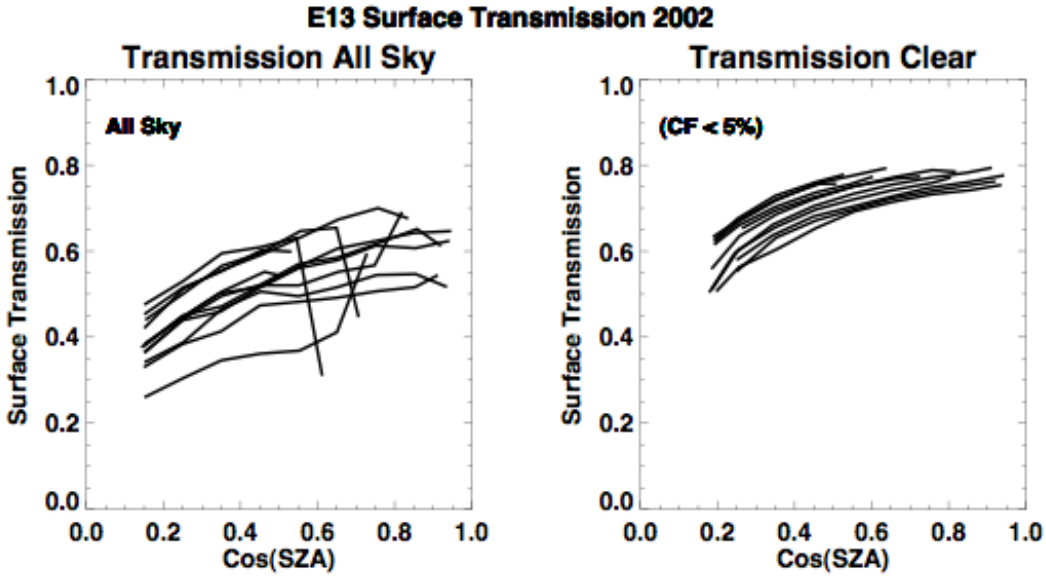
NON-Geo surface irradiance product (CRS 1degree)

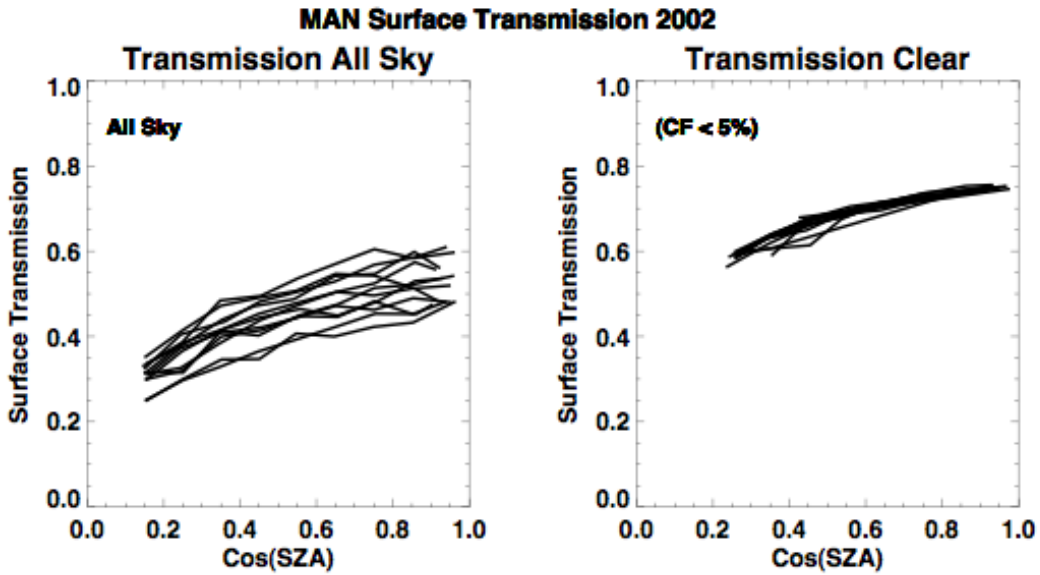
Non-Geo surface irradiance (CRS 1 degree)

- Shortwave only (with an assumption of constant cloud properties over the course of the day).
- Longwave is mean of instantaneous irradiances 2 per day (Terra or Aqua only) or 4 per day (Terra and Aqua combined) sampling.

See Fred Rose's presentation in the SARB working group meeting

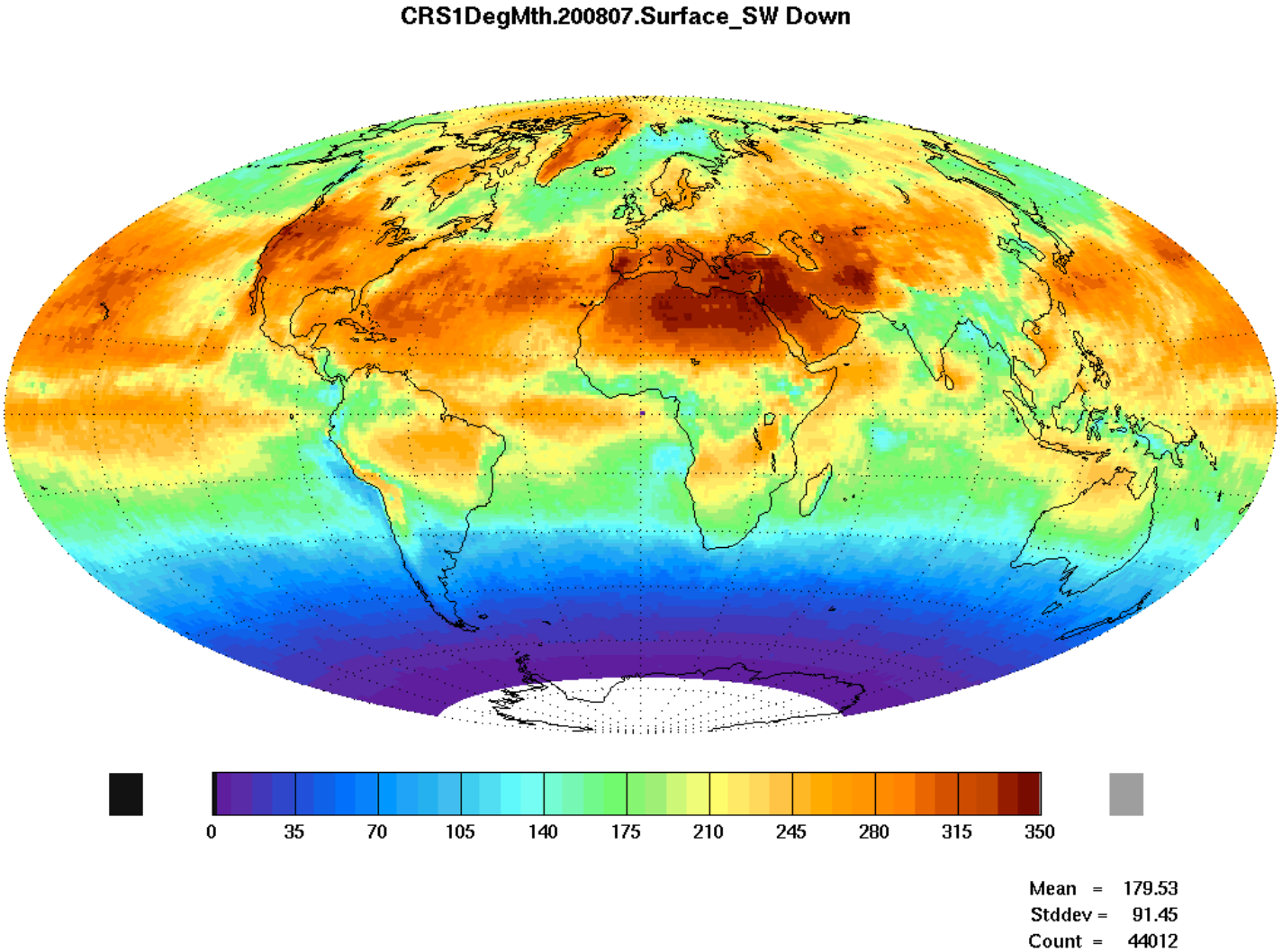
Transmission model





Surface observations show
that Monthly mean transmission
Is approximately
a simple monotonic
function of solar zenith angle

SW surface downward irradiance CRS1deg



Global mean surface shortwave downward for July = 179.9 Wm-2

Snow/ice surface albedo

Cryosphere Surface Albedo retrieval from NB to BB conversion

1. Scene identification:
   a) IGBP types 15 (permanent snow), 19 (fresh snow) and 20 (sea ice);
   b) full ice/snow cover over the clear-part (|SSF2-69 - SSF2-66|<1%)
   c) MODIS observations over clear area should meet empirical criterion:

$$NDSI + NDVI + TR > 0.62; \quad NDSI = \frac{(r_{0.86} - r_{1.64})}{(r_{0.86} + r_{1.64})} \quad NDVI = \frac{(r_{0.86} - r_{0.65})}{(r_{0.86} + r_{0.65})} \quad TR = \frac{T_{brightness,11}}{T_{surf,ra}} - 1$$

2. CERES BB radiance retrieval from MODIS radiance in bands 1, 2, 6 and 20 using regression-based parameterization.

$$L_{CERES}^{BB} = \Phi_{conv}(L_{0.65}, L_{0.86}, L_{1.64}, L_{3.79}, SZA, SCA, month, styp)$$

3. Retrieving CERES TOA SW flux by applying CERES ed2 snow/sea ice ADM:

$$L_{CERES}^{BB} \rightarrow F_{SW}^{TOA}$$

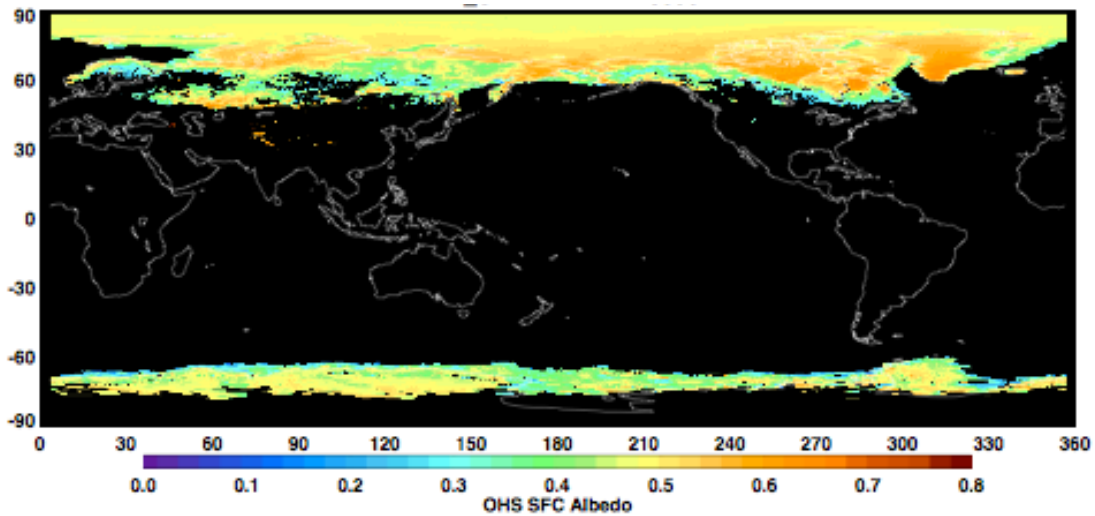
4. Clear sky atmospheric correction based on the Langley Fu-Liou model:

$$\rho_{surf}^{BB} = \Phi_{atm.corr}(F_{SW}^{TOA}, PWAT, AOD, P_{surf}, styp)$$

The results were used to update the Ed4 Surface Albedo History map increasing number of footprints used for albedo retrieval over cryosphere by a factor of 2.5.

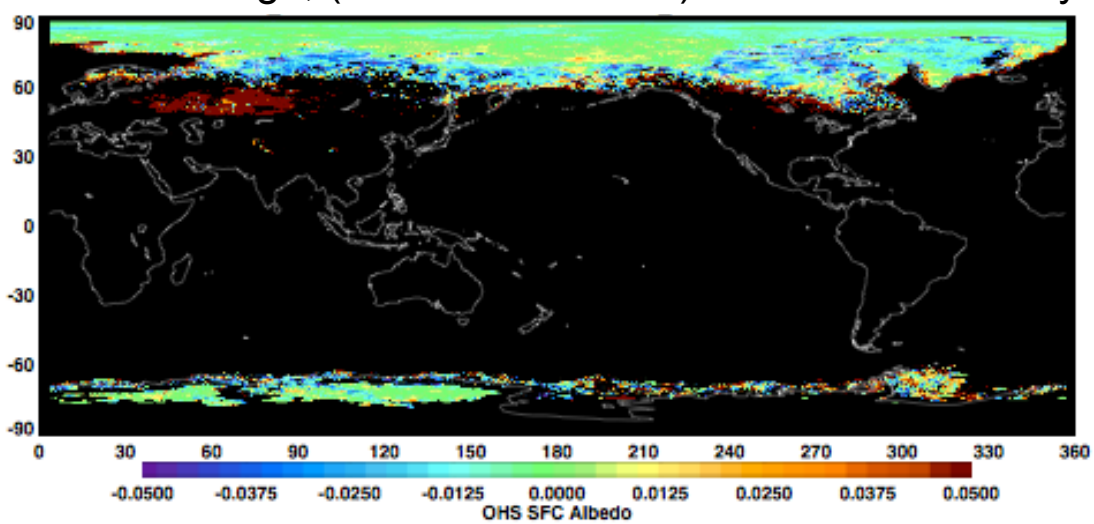
Surface albedo improvements

Cryosphere surface albedo derived from 100% clear (CERES) and partly clear (NB to BB conversion) over a CERES footprint



Surface albedo for
The solar zenith angle = 0°
For 200504

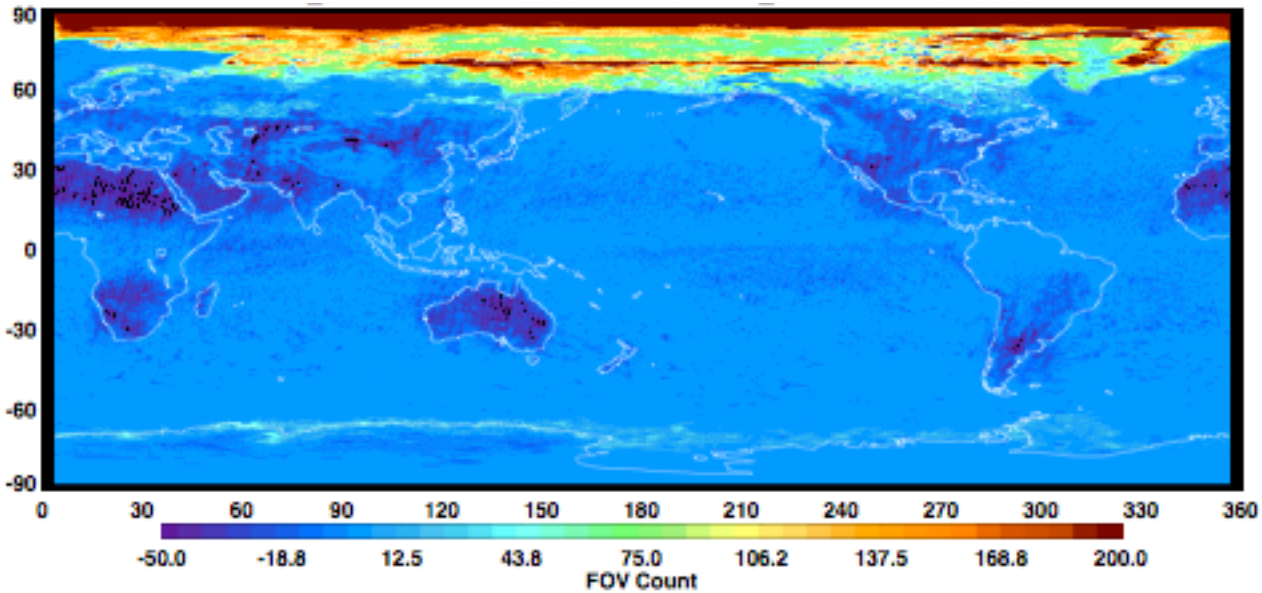
Albedo change, (CERES + NB+BB) minus CERES only



Darker at the edge of snow/sea ice

Sampling improvements

Number of samples change, (CERES + NB+BB) minus CERES only



Using partly cloudy CERES footprint improves
59.8 FOVs/ month to 155 FOVs/month
i.e. ~2FOVs/day to ~5 FOVs/day

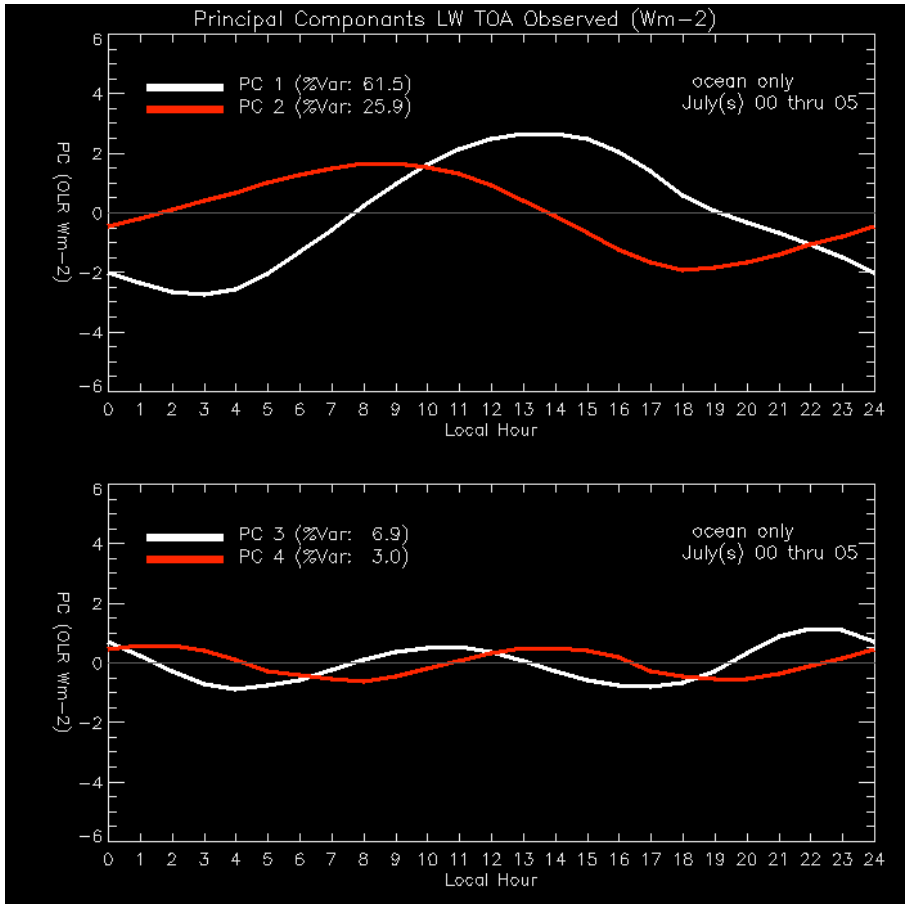
Summary and future work

- 10 years of Surface EBAF product that is consistent with TOA EBAF and integrates information from CALIPSO, CloudSat, and AIRS, will be produced (soon i.e. in 2012).
- Surface validation sites provide useful verification and surface irradiance uncertainty estimates.
- Cryosphere surface albedo improvements will be extend to other surface type and will be implemented in Ed4 CRS.
- CRS1degree (a non-geo surface product) product is for surface irradiance trend analysis
- Determine revisions for Edition 4 CRS

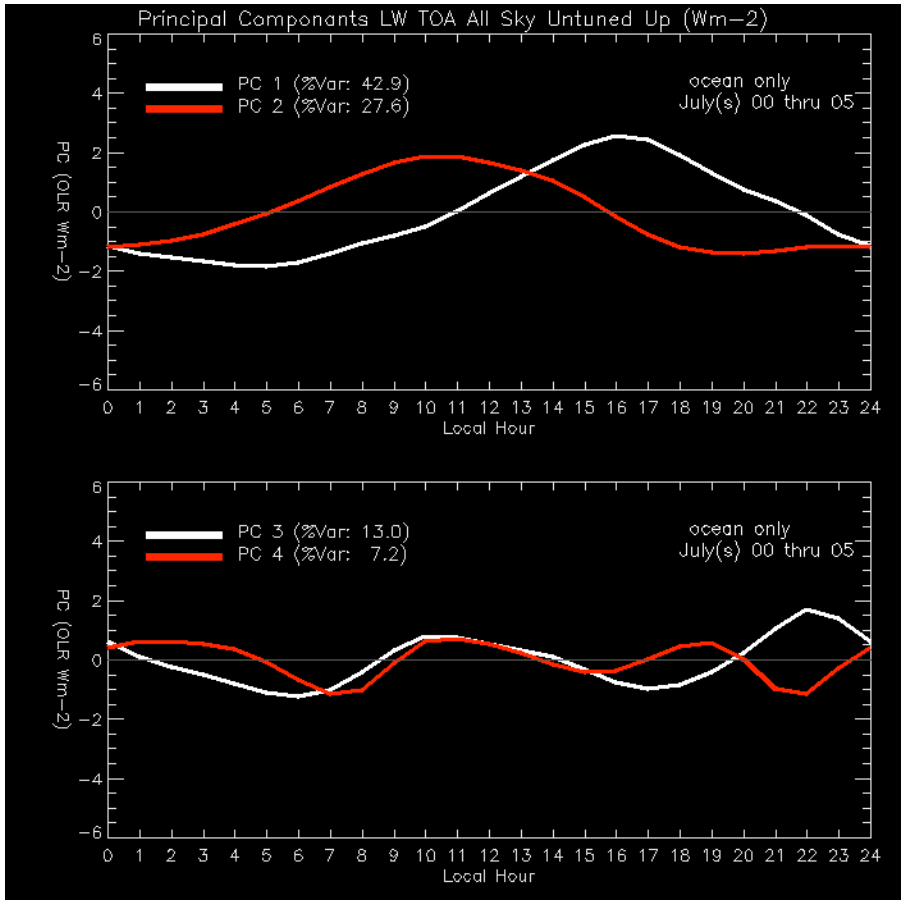
Back-ups

Diurnal cycle in AVG/SYNI

PC analysis applied to CERES and GEO Derived TPA LW irradiances



PC analysis applied to modeled TOA irradiances with MODIS and GEO derived clouds



Derived from global mean 1 hourly TOA irradiances of 6 Julys (from 2000 through 2005)
It appears to be problem in the diurnal cycle of marine stratocumulus derived from GEO
Terra + Aqua (ed3 AVG) may mitigate this problem

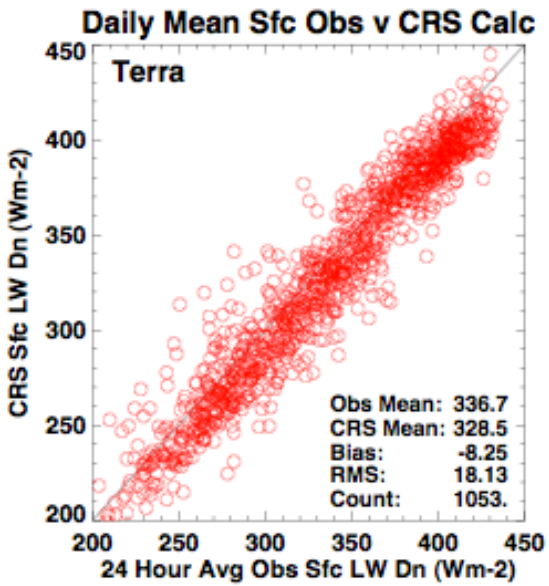
SYN Spatial Error Estimates

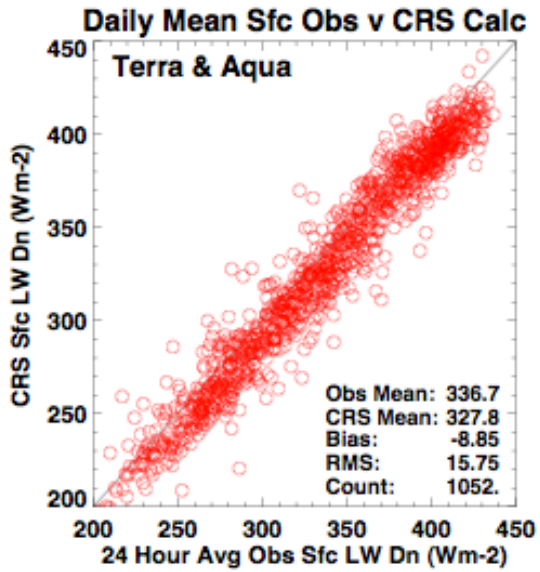
	Land & Ocean	Coastal	Variable Terrain	Coastal & Variable Terrain
	33 Sites	16 Sites	9 Sites	4 Sites
LW down (Bias/RMS)				
January	+0.0(11.4)	+1.7(15.8)	-4.1(15.5)	+6.6(28.4)
July	-0.0(5.8)	+0.5(10.5)	-3.5(13.9)	+5.5(22.5)
SW down (Bias/RMS)				
January	+0.0(35.7)	-5.2(44.0)	+1.6(35.7)	-14.4(53.5)
July	-2.6(45.5)	-4.4(50.1)	-4.9(50.9)	-11.2(48.5)

Differences computed between all hour boxes across 6 Januarys (Julys) for SYNI calculated downward surface flux minus average of CRS untuned calculation for that grid box/hour box.

CRS footprints are within 25km of surface site (grid box center where there is no surface site) whereas grid box is approximate equal area 1 degree.

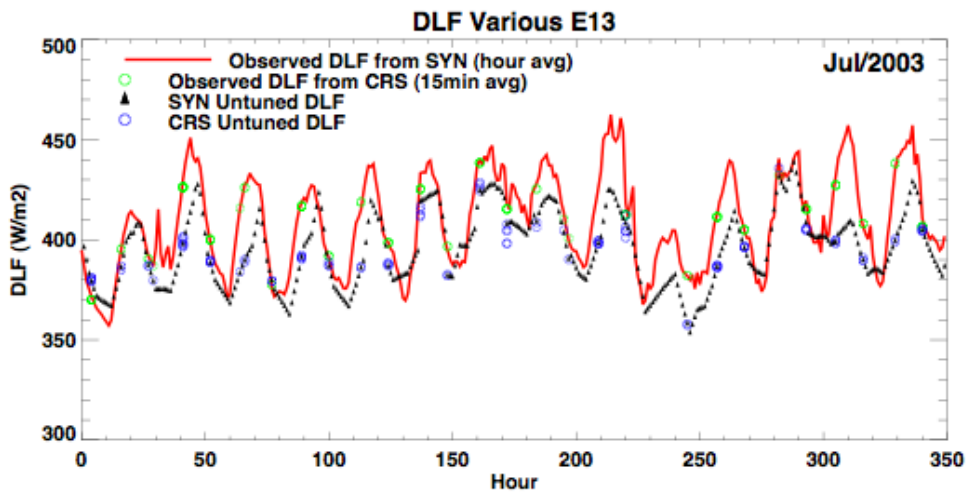
2/day + GEO, 2/day sampling, and 4/day sampling (Temporal sampling error)

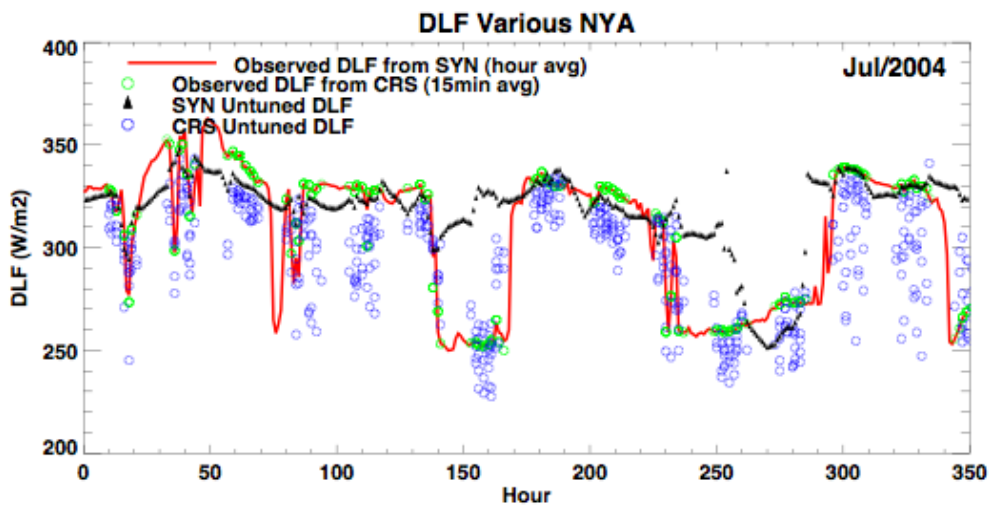




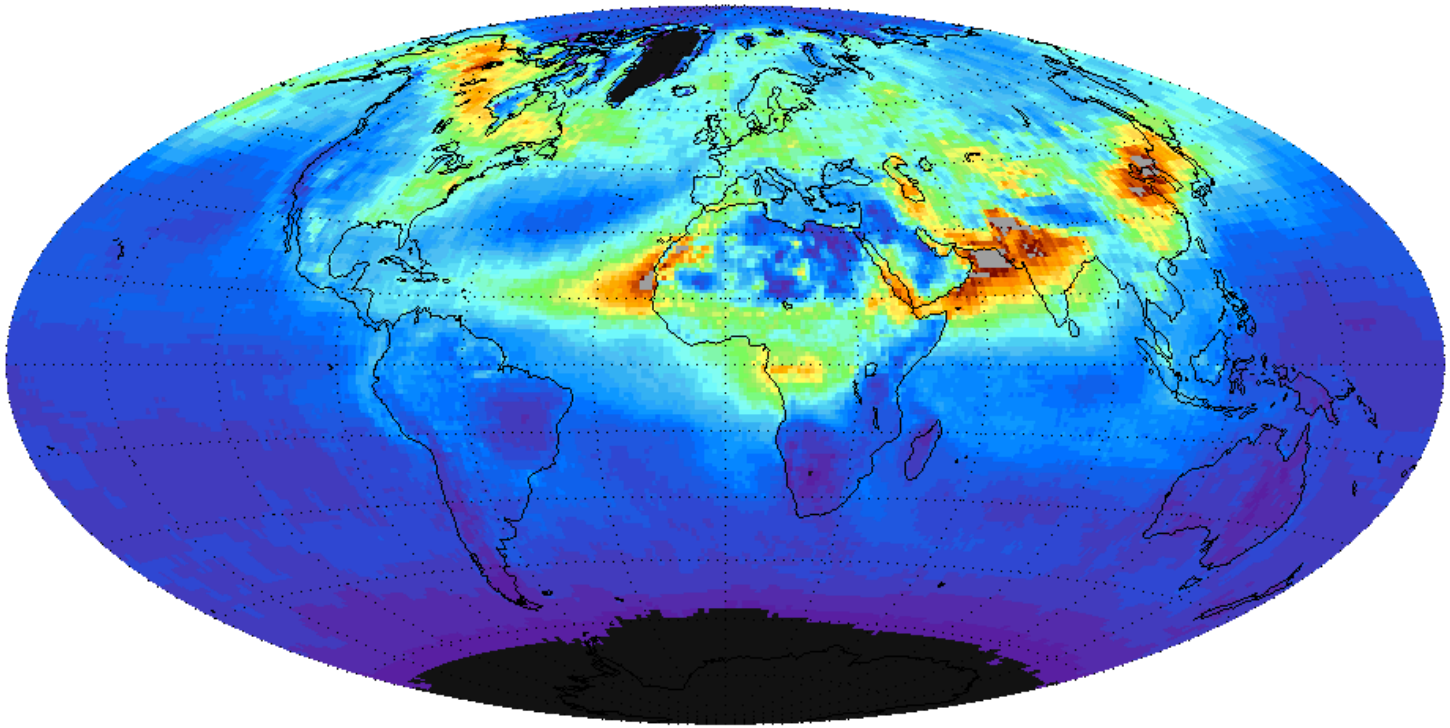
	SYN LW down bias (RMS)	Terra	Aqua	Terra+Aqua
E13	-10.2 (15.0)	-8.3 (18.1)	-9.5 (17.1)	-8.9(15.6)
MAN	-2.2 (6.1)	-1.9 (7.7)	-3.2 (7.5)	-2.6(7.1)
TAM	3.6 (12.1)	-6.1 (15.9)	-1.0 (17.9)	-3.6 (13.8)

Total error

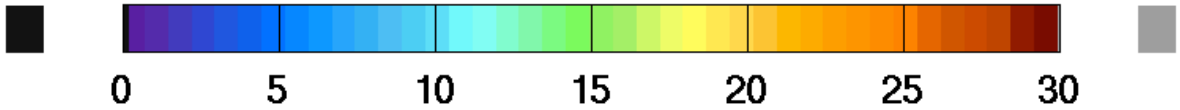

DLF Various E13
Observed DLF from SYN (hour avg)
Observed DLF from CRS (15min avg)
SYN Untuned DLF
CRS Untuned DLF
Jul/2003
DLF (W/m2)
Hour
500
450
400
350
300
0
50
100
150
200
250
300
350


DLF Various NYA
Observed DLF from SYN (hour avg)
Observed DLF from CRS (15min avg)
SYN Untuned DLF
CRS Untuned DLF
Jul/2004
DLF (W/m2)
Hour
400
350
300
250
200
0
50
100
150
200
250
300
350

SYNI 200407 TOA SW Aerosol Forcing
Clear Sky Monthly Mean

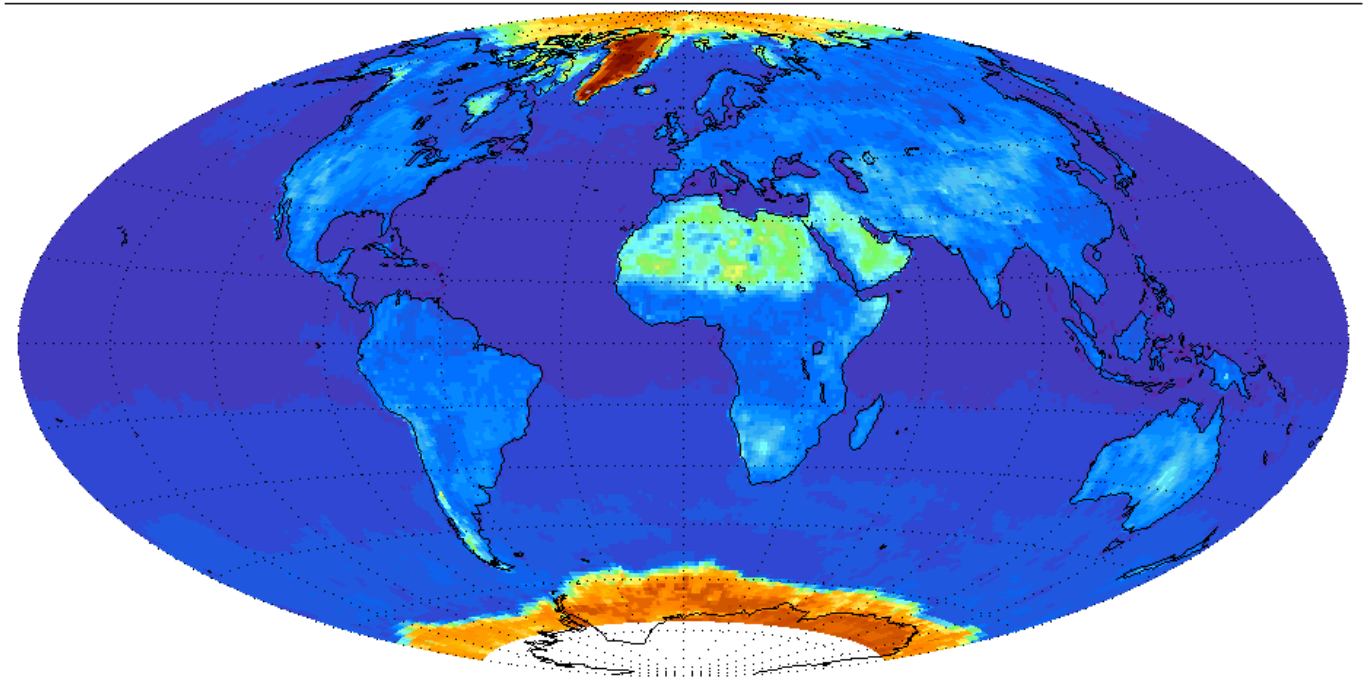


Mean= 5.92

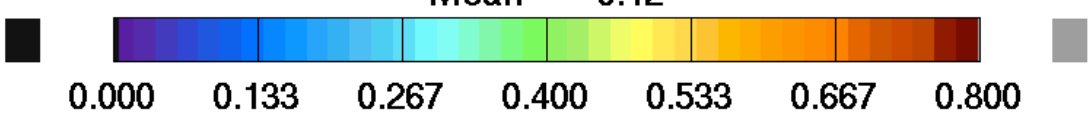


Stddev = 5.45
Count = 44012

SYNI 200407 UNTuned Surface Albedo



Mean= 0.12



Stddev = 0.14
Count = 42886