Surface Atmosphere Radiation Budget (SARB) working group update

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CERES Science Team Meeting
May 7-9, 2019

Work done after the fall 2018 CERES meeting

- Revision of SYN1deg products (Edition 4.0 to Edition 4.1).
- Producing Edition 4.1 EBAF-surface
- Producing the difference of TOA and surface irradiances between clear-sky cloud removed and clear-sky observation sampled (Loeb's talk).
- MATCH aerosol optical thickness evaluation under partly cloudy conditions.
- Evaluation of MERRA2 and new GMAO skin temperatures, temperature profiles, and humidity profiles.
- Analysis of sea ice albedo depending on age of ice
- Comparison of deep blue and dark target aerosol optical thickness (Rutan's talk)
- Evaluation of daily mean computed TOA and surface irradiances by 2- and 4-steram models (Ham's talk)
- Changing MOA format (binary to HDF)

Outline of this talk

- Edition 4.1 SYN1deg and EBAF flux, aerosol, and cloud changes from Edition 4.0
- MATCH aerosol validation under partly cloudy conditions
- Evaluation of GMAO products, GEOS-5.4.1, MERRA, MERRA2, FP
  - How skin temperature bias affects surface flux computations
- Sea ice albedo
- Working in progress
  - Revision of Fu-Liou code k-distribution (with a help from Lusheng Liang)
  - C3M with Ed4 clouds and new versions of CALIPSO and CloudSat products

Edition 4.1 SYN1deg

- Edition 4.1 SYN1deg has been processed from March 2000 through September 2018 with
  - MATCH with Collection 6.1 Terra and Aqua (from July 2002)
  - Revised Himawari-8 cloud code
  - Tuning TOA fluxes to the latest TSI
  - Collection 5 MODIS from March 2000 through February 2016
  - Collection 6.1 MODIS after March 2016
  - New surface albedo history map with Collection 6 (not 6.1) MODIS BRDF product

Edition 4.1 EBAF-surface

- March 2018 is the final month of Edition 4.0
- Edition 4.1 EBAF-surface from March 2000 through September 2018 will be released soon.

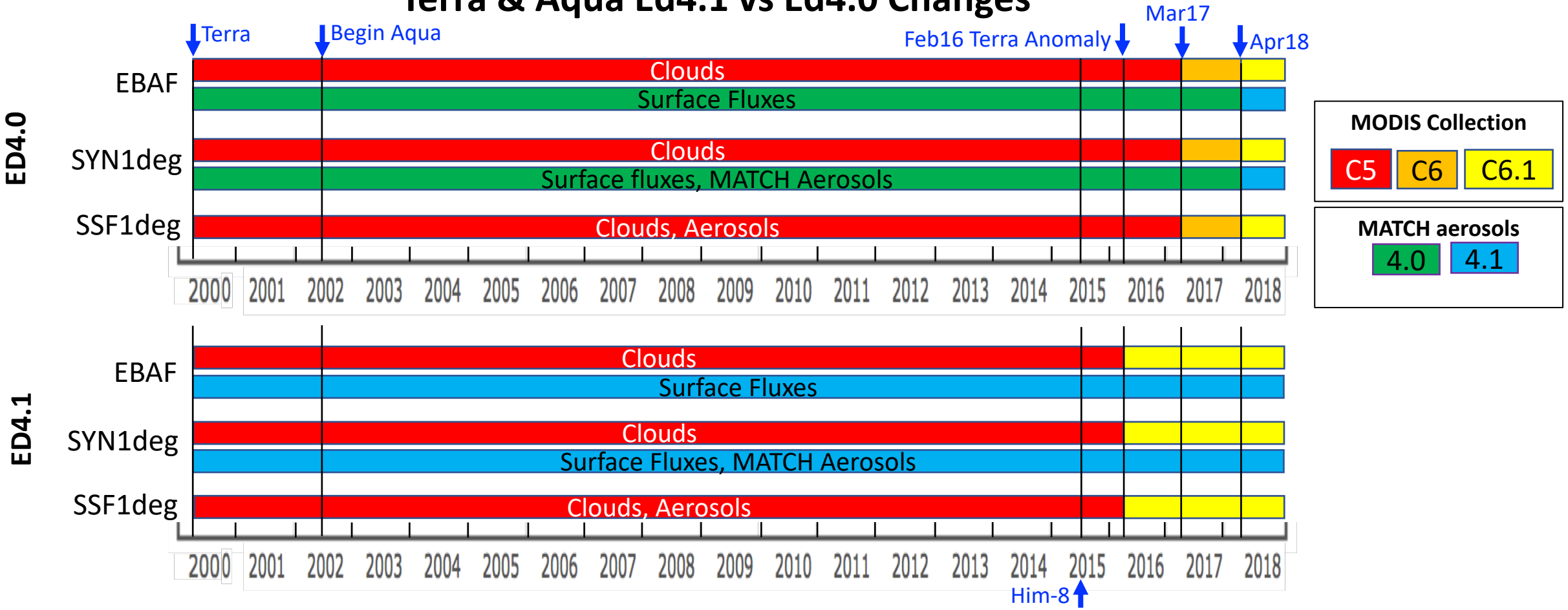
Issues affecting edition 4.0 EBAF-surface

- Large changes occur in polar night cloud fraction after March 2016 due to MOIDS instrument issues
- A bug in the MODIS aerosol algorithm (Terra and Aqua dark target and deep blue) causes large differences in the aerosol optical thickness over land between collection 5 and collection 6.1.
- These problems do not affect observed TOA irradiances, but affect computed surface irradiances.
  - The effect of small compared with clear-sky adjustment but significant enough to introduce a discontinuity in clear-sky surface downward shortwave fluxes.
- Edition 4.0 EBAF-surface is available from march 2000 through March 2018.
- Edition 4.1 EBAF-surface will replace Ed4.0 for the entire record.

Edition 4.1 EBAF-surface

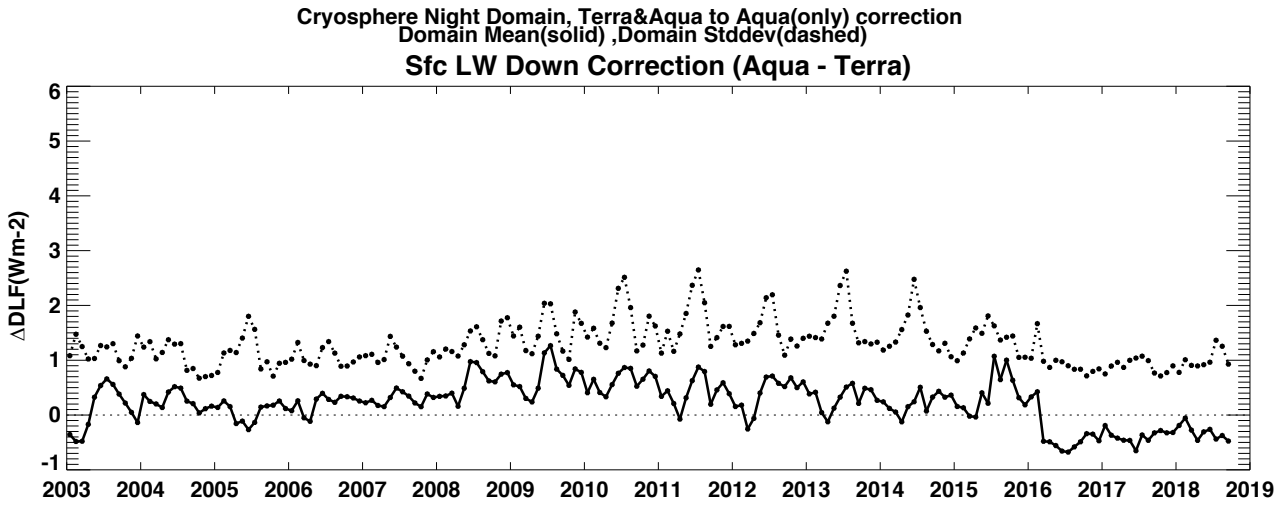
- Nighttime polar cloud fraction bias correction (60˚ to poleward) is applied from July 2003 through the end of the record to correct Terra cloud fraction.
  - Terra polar nighttime cloud fraction is adjusted to match Aqua nighttime cloud fraction.
- New Himawari 8 clouds is processed with correct input including corrected collocation of IR and VIS from July 2015.
  - Himawari-8, GOES-16, and GOES-17 are processed with the same cloud code.
- MODIS collection 6.1 aerosol optical thickness (and new surface albedo history map) is used for the entire time period.

Terra & Aqua Ed4.1 vs Ed4.0 Changes



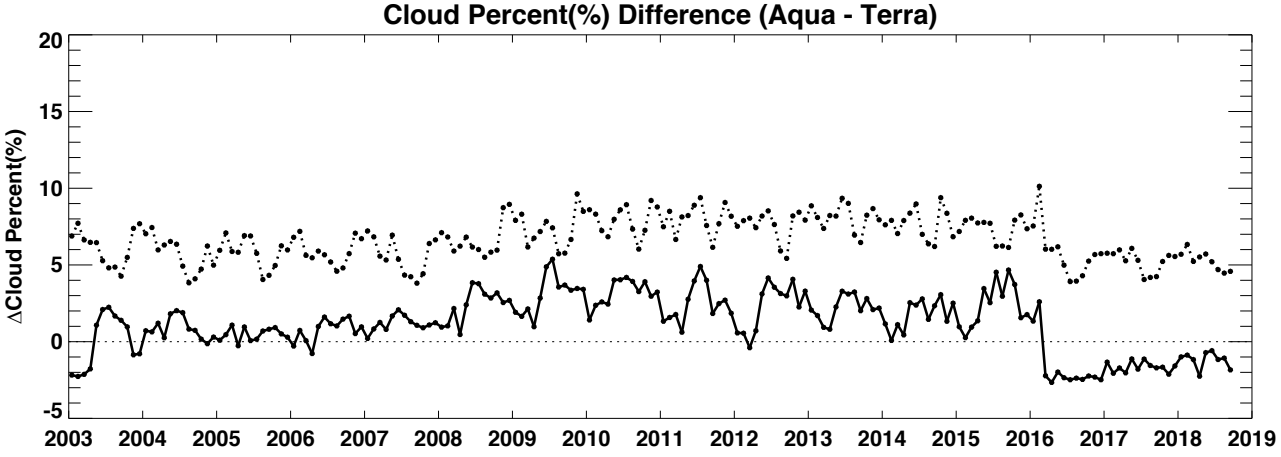
Parameter	ED4.0	ED4.1
MODIS-collection	Terra-MODIS 6.7, 8.6 µm striping, March 2016 to March 2018	MODIS C6.1 resolved the Terra-MODIS 6.7, 8.6 µm striping
MATCH-Edition	Large discontinuity between MODIS C5 & C6.1 AOD inputs	Uses MODIS C6.1 AODs as input for entire CERES record
MODIS Clouds	Impacted Terra cloud properties	Terra cloud properties corrected beginning in Feb 2016
GEO Clouds	Him-8, GOES-16,17, Met-8,11 cloud codes with bugs	Consistent cloud code using MATCH Ed4.1, begin July 2015
Surface fluxes	The clear-sky SW down surface flux was impacted by MODIS C5 & C6.1 AOD discontinuity	SYN surface fluxes, computed using consistent GEO cloud code with MATCH Ed4.1 and tuned fluxes to correct GEO TOA flux

Ed 4.1 Sfc EBAF : Correction applied back to 2003



Time series of nighttime LW down bias correction averaged over nighttime Arctic and Antarctic

Actual bias correction is applied at a 1˚×1˚ grid resolution



Correction is based on the nighttime cloud fraction correction applied to Terra cloud fraction correction

Assumption: nighttime monthly mean Terra cloud fraction over cryosphere is equal to the monthly mean nighttime Aqua cloud fraction

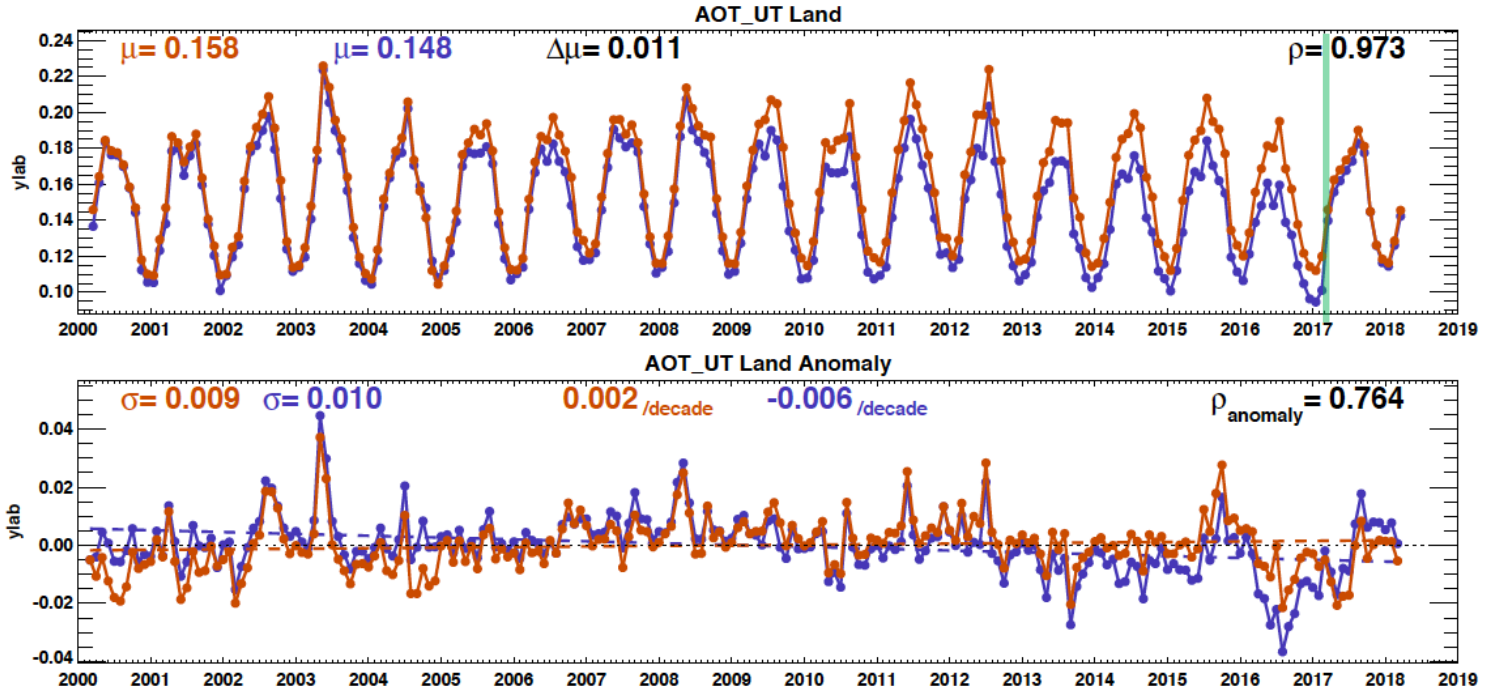
Summary of downward longwave flux bias correction

- Correction for monthly 1˚×1˚gridded all-sky and clear-sky surface and TOA LW fluxes due to the difference in temperature and specific humidity between AIRS and GEOS-5.4.1, using radiative kernels of Thorsen et al. (2018).
- Correction for monthly 1˚×1˚gridded all-sky surface LW fluxes for regions between 60˚ and 90˚ due to the difference in nighttime cloud fraction between Terra and Aqua, using radiative kernels of Thorsen et al. (2018).
- Correction for monthly 1˚ zonal all-sky LW fluxes based on the cloud fraction viewed from the surface derived from CALIPSO and CloudSat and MODIS and GEO-derived low-level cloud fraction, using radiative kernels of Thorsen et al. (2018).

Ed4.1 and Ed4.0 SYN1deg and EBAF-surface comparison

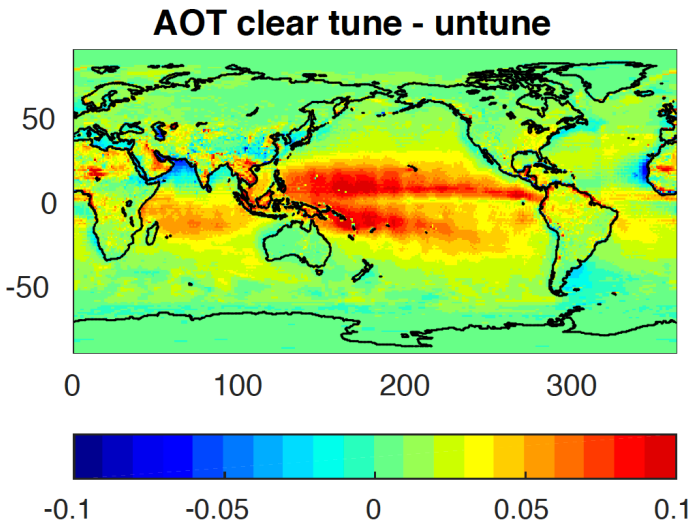
Aerosol optical thickness change

Aerosol optical thickness over land

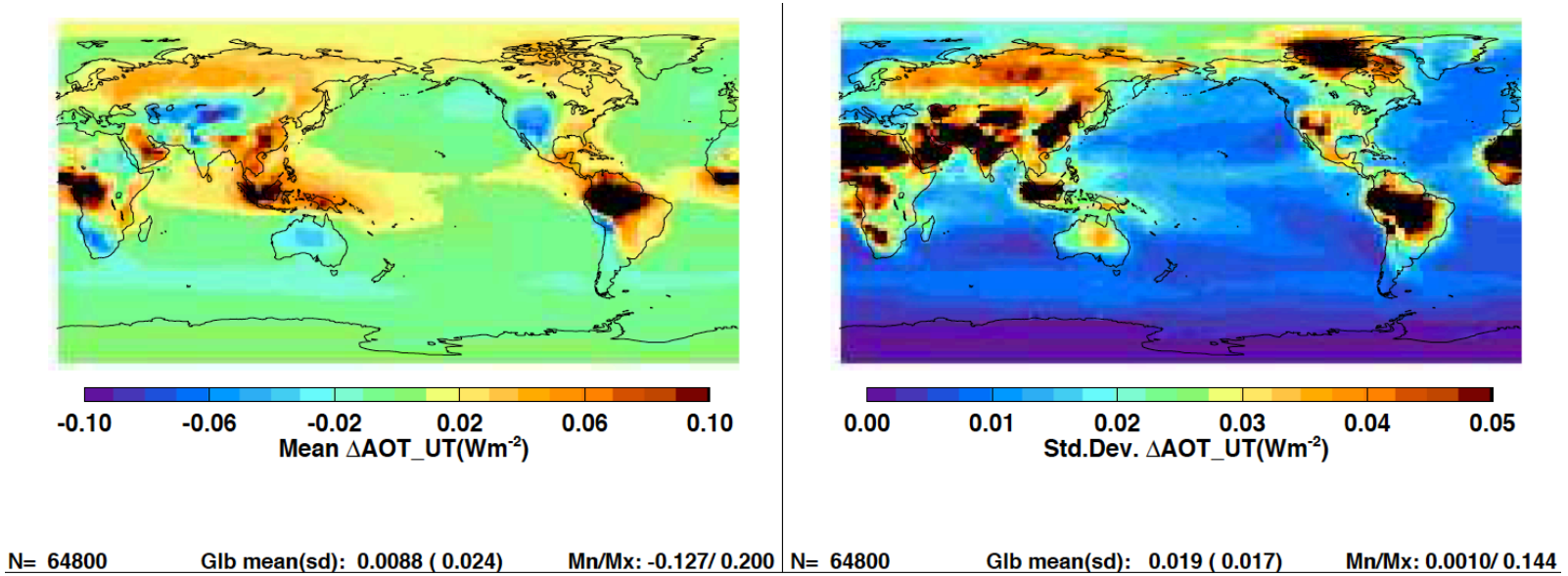


SfcEbaf Ed4.0
SfcEbaf Ed4.1y

Ed 4.0

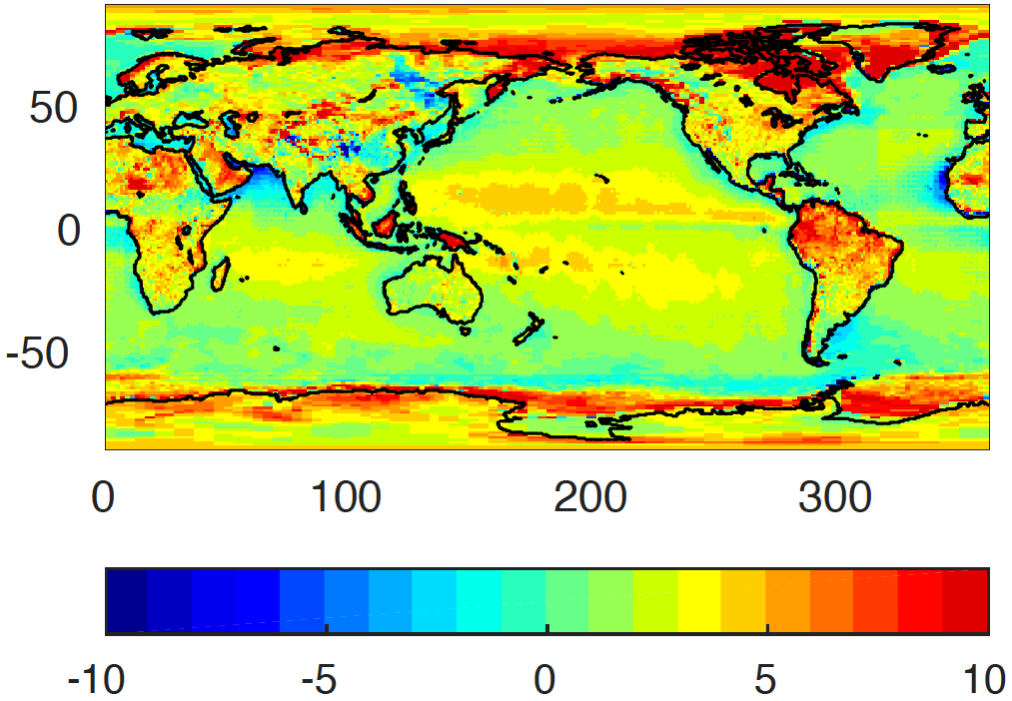


Ed4.1 – Ed4.0

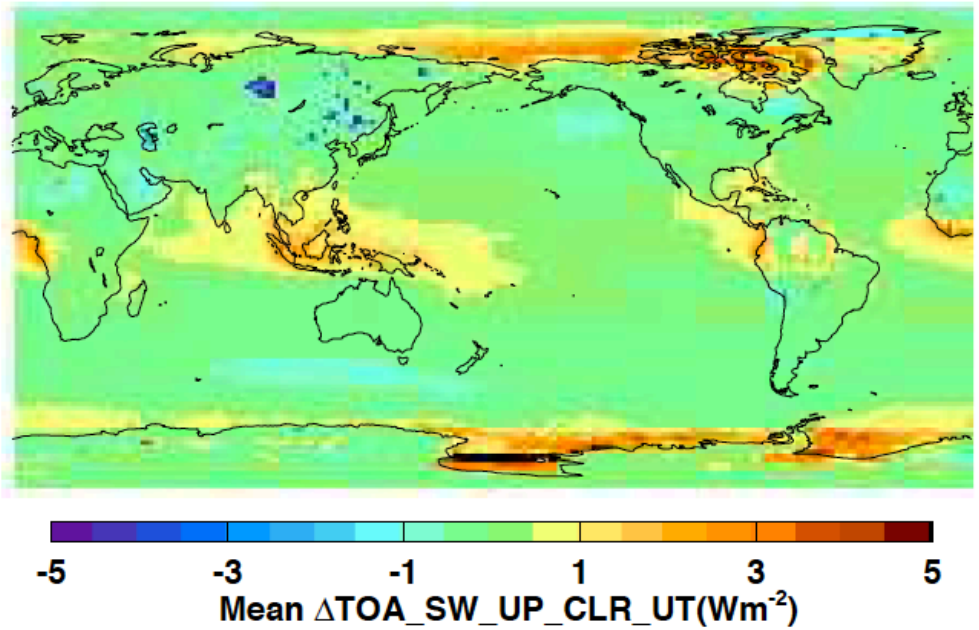


Clear-sky adjustment vs. SW difference due to aerosol difference

TOA clear-sky reflected shortwave irradiance
EBAF-TOA – computed



Difference in TOA clear-sky reflected shortwave irradiance
Ed4.1 – Ed4.0

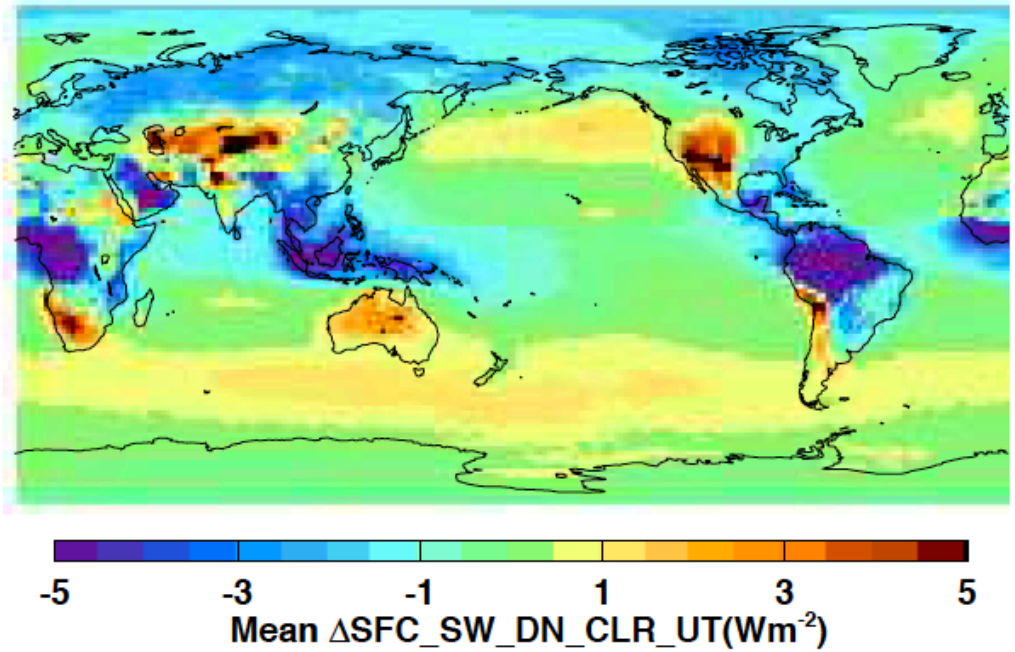


N= 64800 Glb mean(sd): 0.095 (0.805) Mn/Mx: -9.77/ 8.38

Adjustment is much larger than the TOA shortwave difference due to aerosol optical thickness difference
Difference over land is very small because clear-sky surface albedo is derived from CERES observations

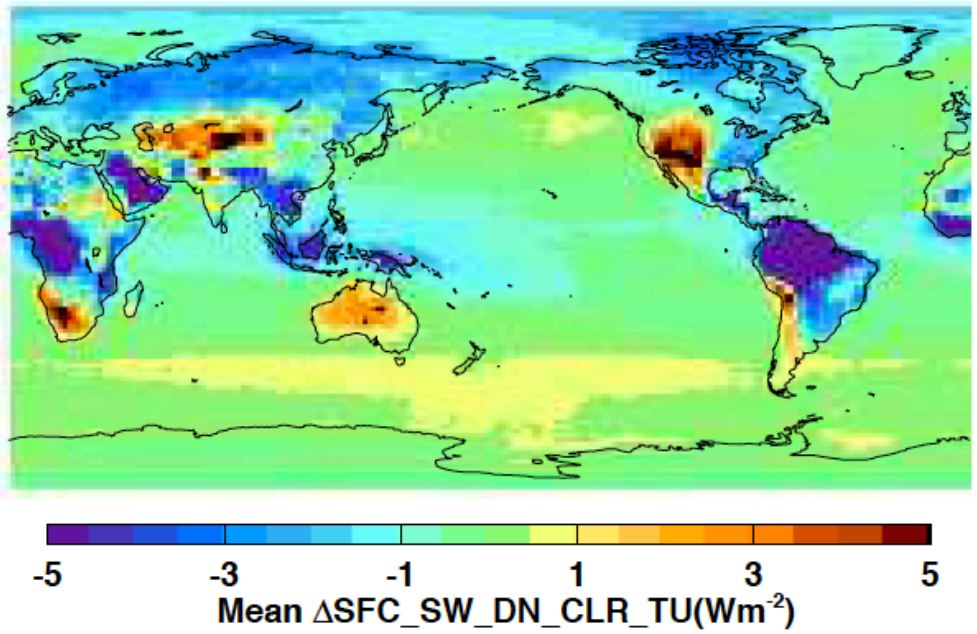
Clear-sky downward surface shortwave flux difference

Ed4.1 – Ed4.0 (SYN)



N= 64800 Glb mean(sd): -0.448 (1.57) Mn/Mx: -12.33/ 8.47

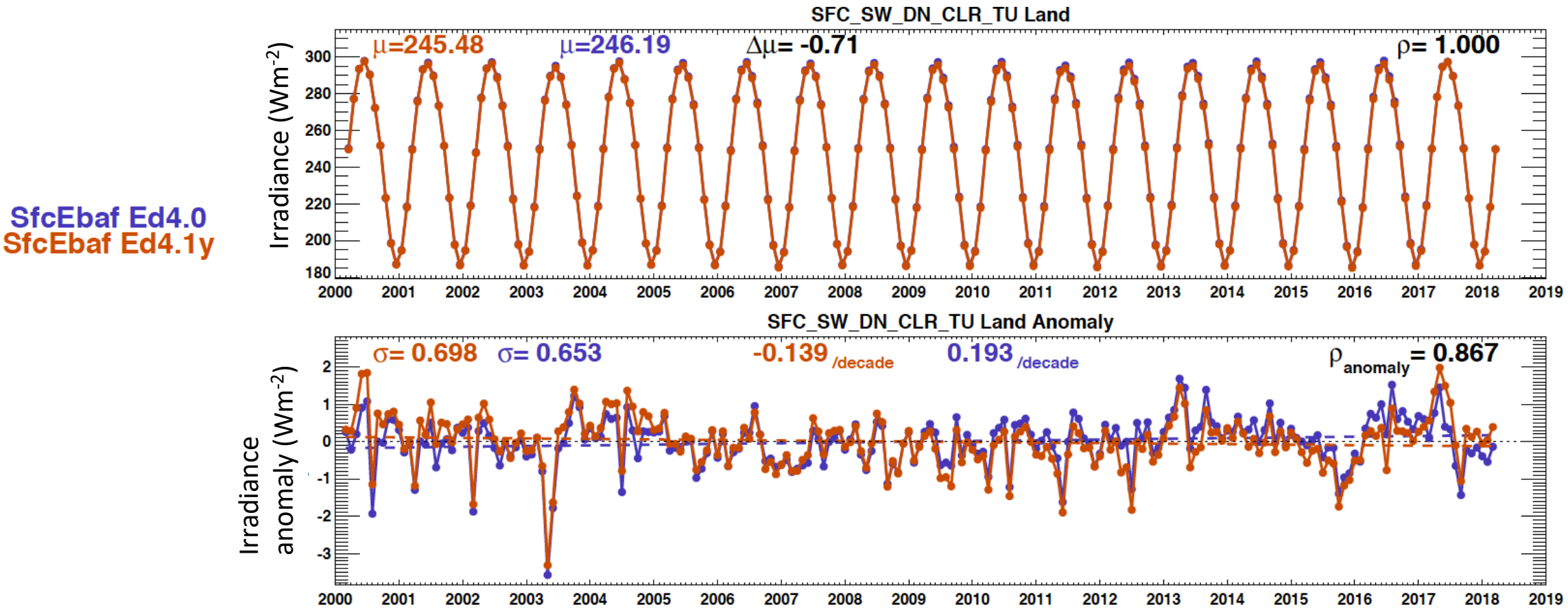
Ed4.1 – Ed4.0 (EBAF)



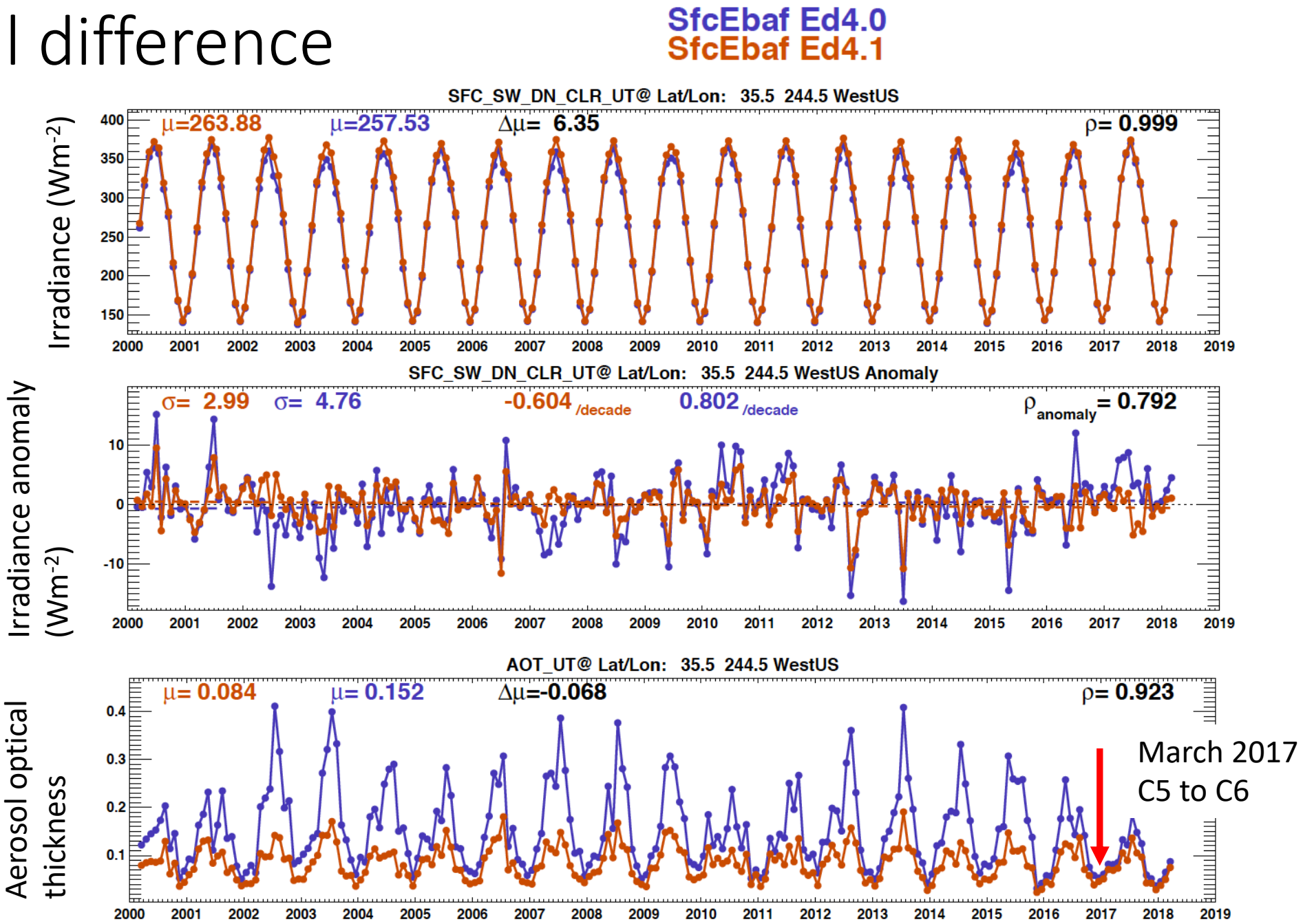
N= 64800 Glb mean(sd): -0.604 (1.56) Mn/Mx: -14.35/ 8.94

EBAF Ed4.0 and Ed4.1 flux difference over land is largely due to aerosols

Clear-sky downward shortwave flux change over land



Regional difference



Ed4.0 and Ed4.1 global mean irradiances

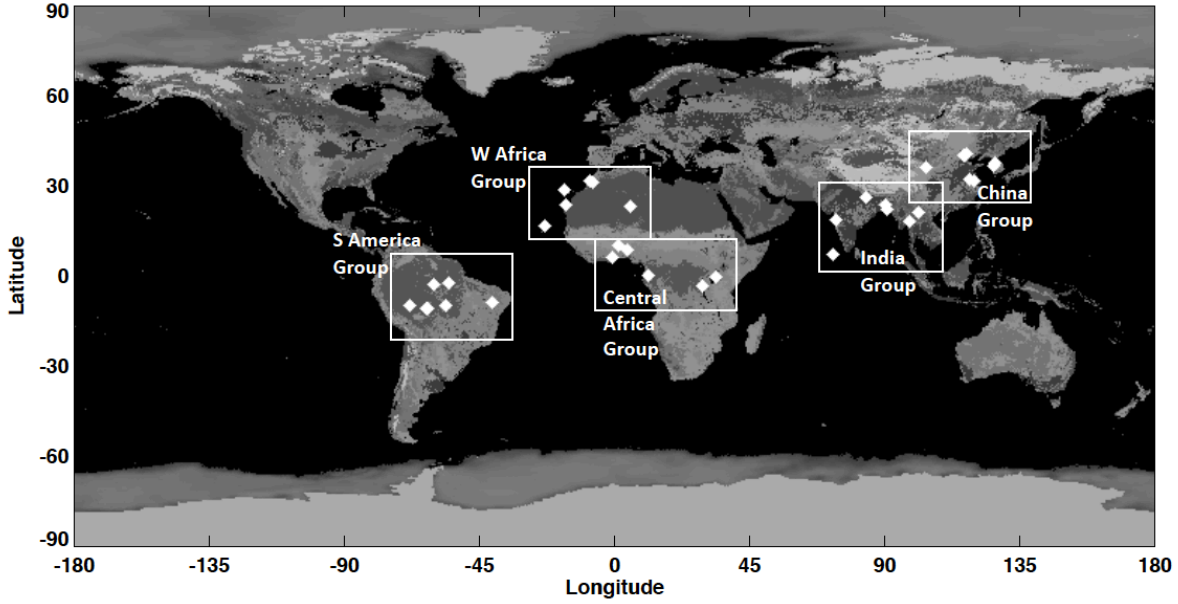
	All-sky			Clear-sky		
	Ed4.1	Ed4.0	Ed4.1-Ed4.0	Ed4.1	Ed4.0	Ed4.1-Ed4.0
TOA SW insolation	340.0	340.0	0.0	340.0	340.0	0.0
SW down	186.6	187.0	-0.4	243.1	243.7	-0.6
SW up	23.3	23.4	-0.1	29.6	29.8	-0.2
SW net[1]	163.3	163.7	-0.4	213.5	213.9	-0.4
LW down	345.0	345.0	0.0	313.8	314.1	-0.3
LW up	398.3	398.3	0.0	397.5	397.6	-0.1
LW net[1]	-53.4	-53.4	0.0	-83.7	-83.5	0.2
SW+LW net	110.0	110.3	-0.3	129.8	130.4	-0.6

[1] Net is defined as downward – upward

MATCH aerosols

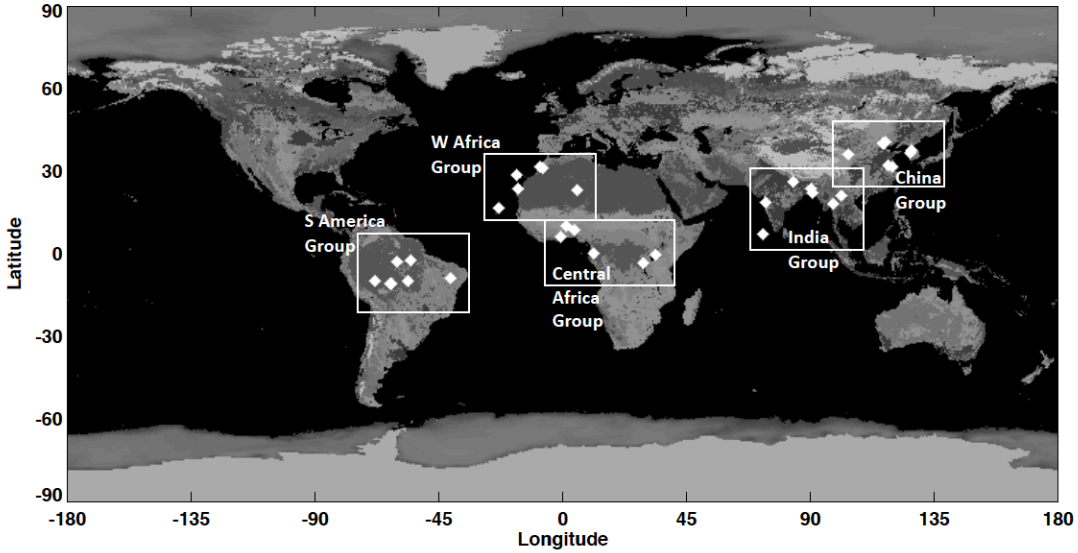
- Evaluate MATCH aerosols under partly cloudy conditions
  - When MODIS-derived aerosols are not available, temporally and spatially interpolated MODIS-derived aerosols are used in flux computations.
  - Water up-take as a function of relative humidity for hygroscopic aerosols (sulfate, sea salt, and soluble) is included.
- Interpolated aerosols affect EBAF clear-sky flux corrections

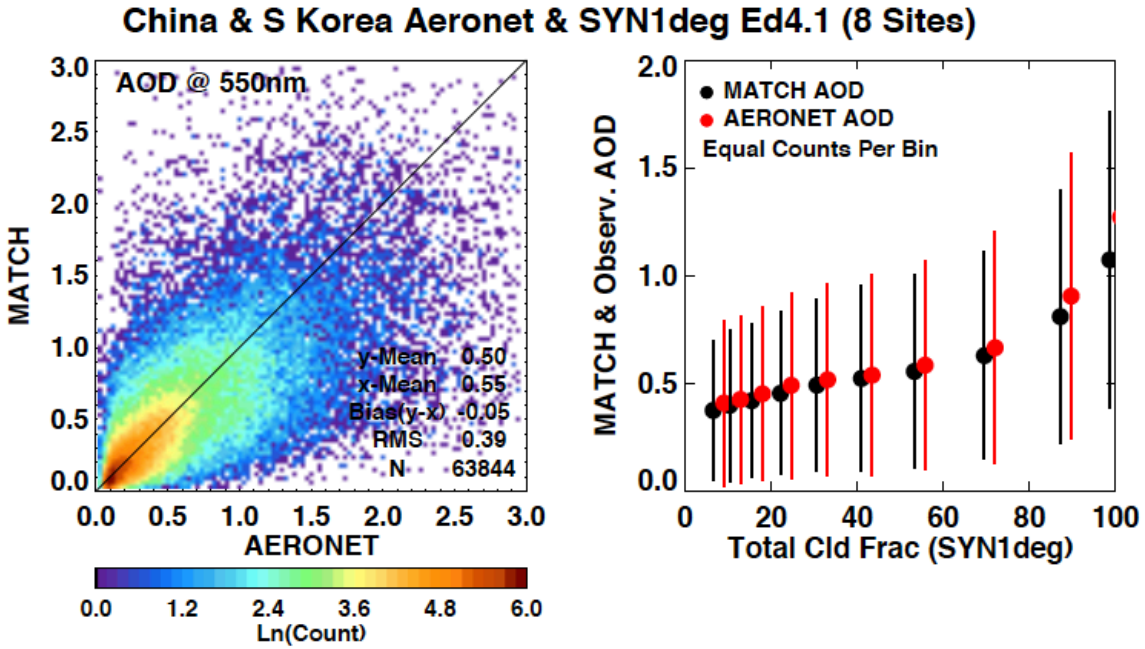
Map shows AERONET sites grouped for validation.

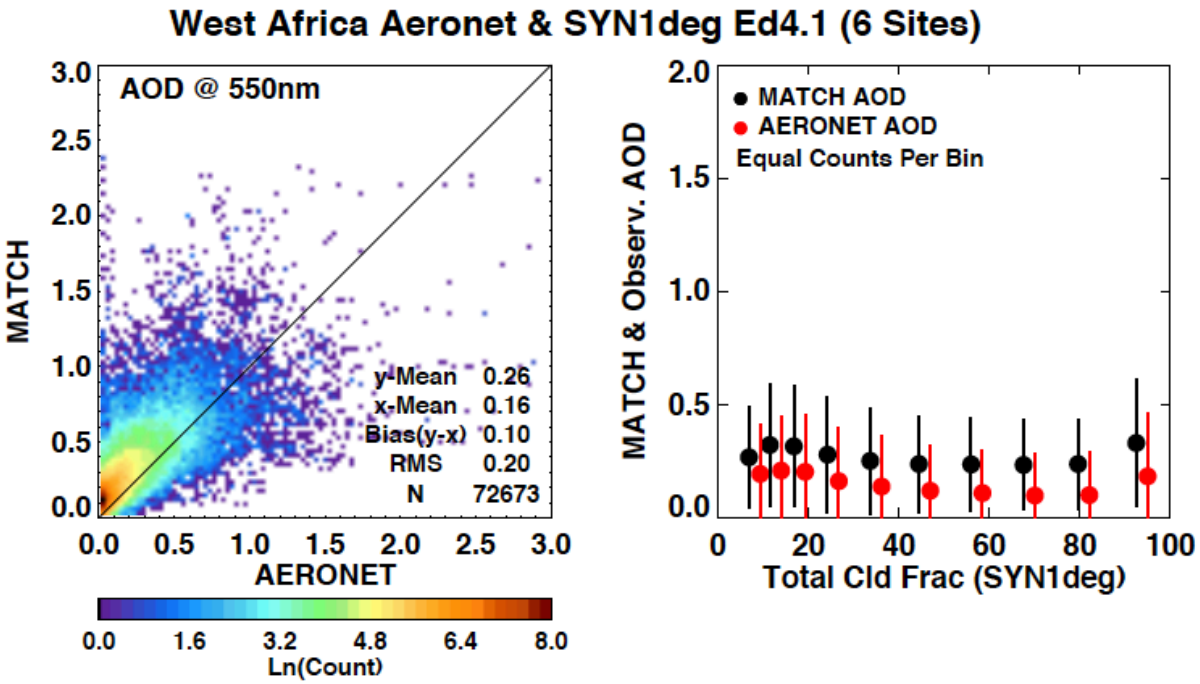


AOD comparison with AERONET

Map shows AERONET sites grouped for validation.







AOD comparison

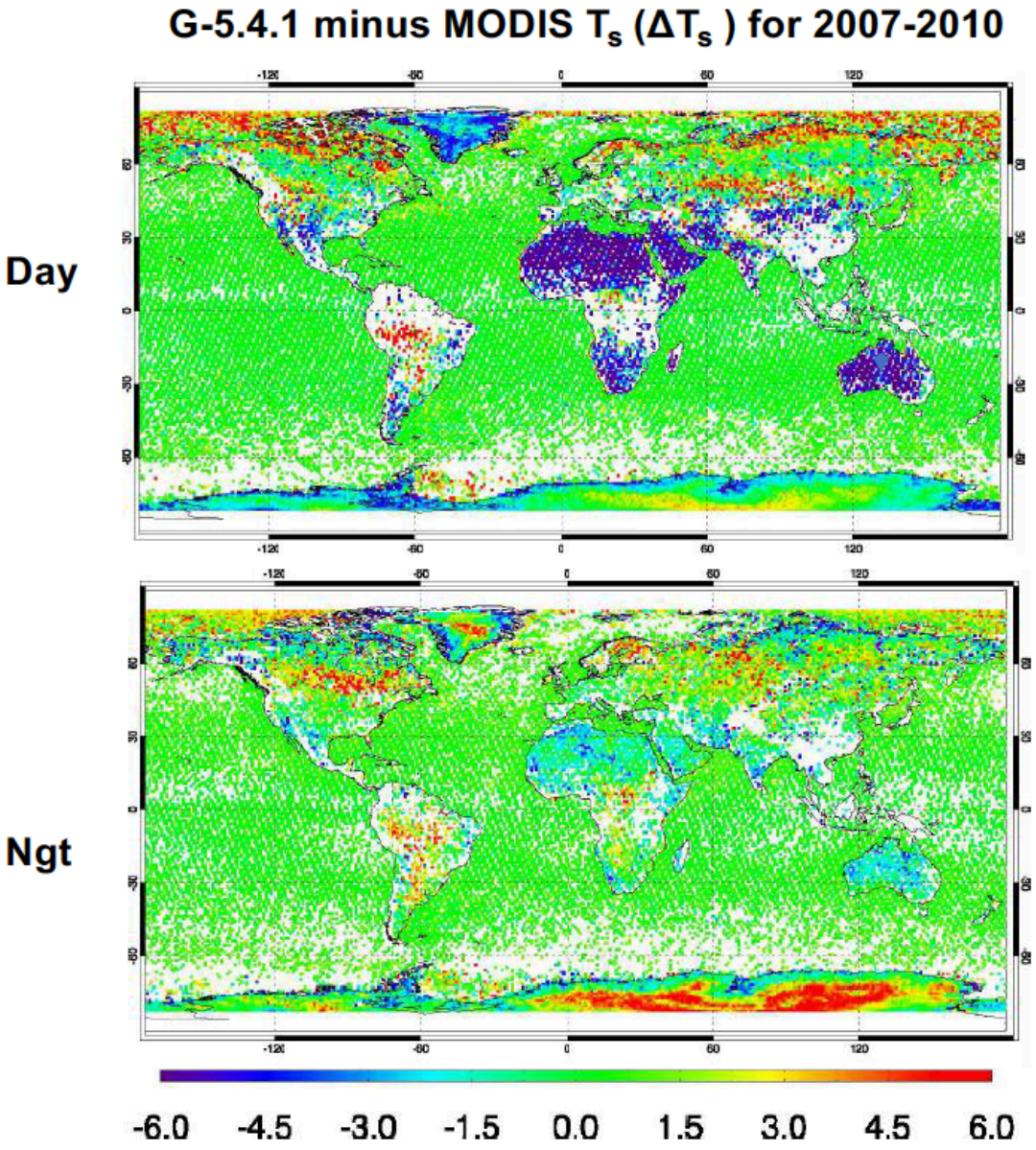
Group	MATCH mean	AERONET mean	Bias	RMS difference	Number of hours
China & S. Korea (8 sites)	0.50	0.55	0.05	0.39	63844
Central Africa (6 sites)	0.46	0.54	-0.07	0.26	35820
West Africa (6 sites)	0.26	0.26	0.10	0.20	72673
Brazil (7 sites)	0.29	0.26	0.03	0.24	67706
India & Bangladesh (8 sites)	0.47	0.52	-0.05	0.29	48584

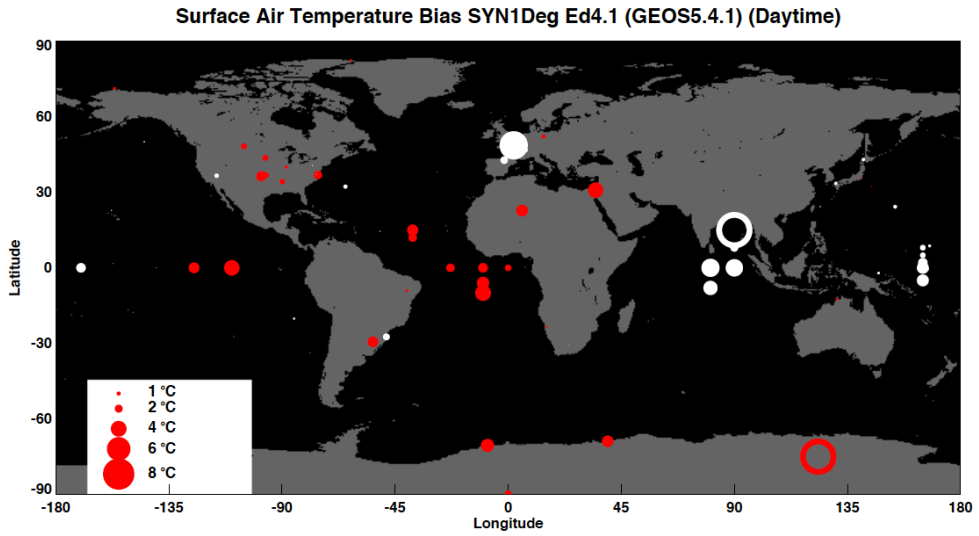
Evaluation of GMAO products

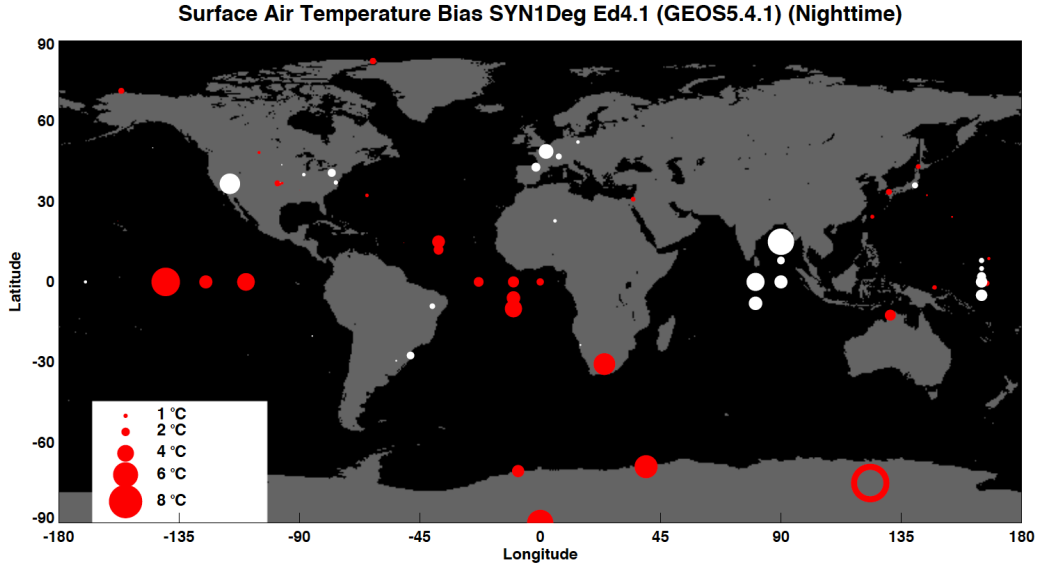
- Compare skin temperature from reanalysis products with skin temperature derived from MODIS when clear-sky is identified by CALIPSO and CloudSat
  - CERES footprint and GMAO grids selection criteria
  - Ground track within CERES footprints is clear
  - No clouds are reported in collocated GMAO grids
- Understand how skin temperature biases affect surface irradiance computations

Evaluation of skin temperature

Near surface air temperature validation

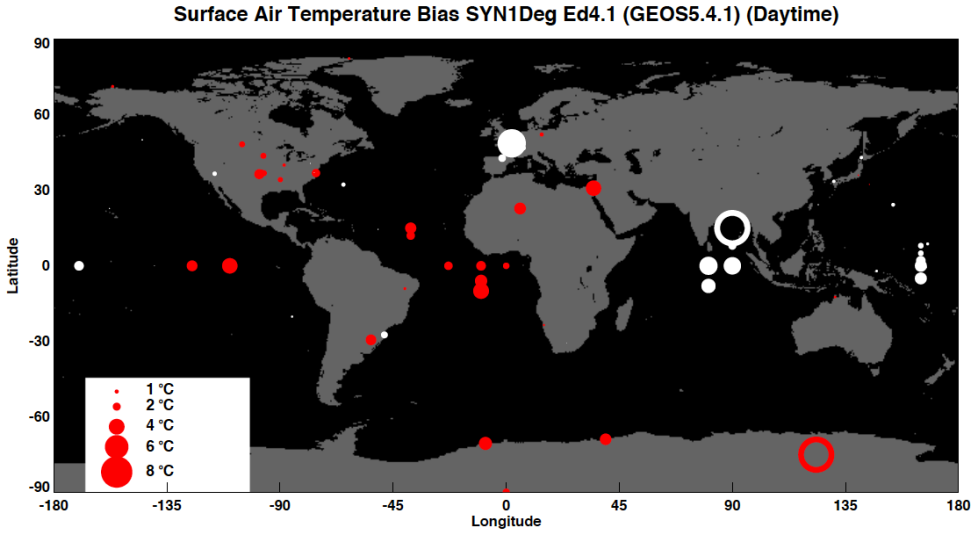


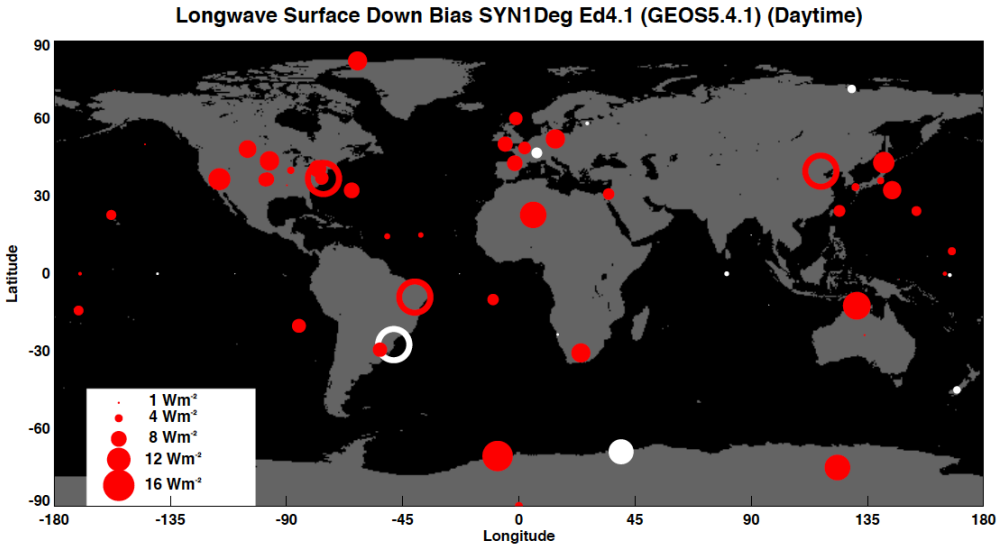


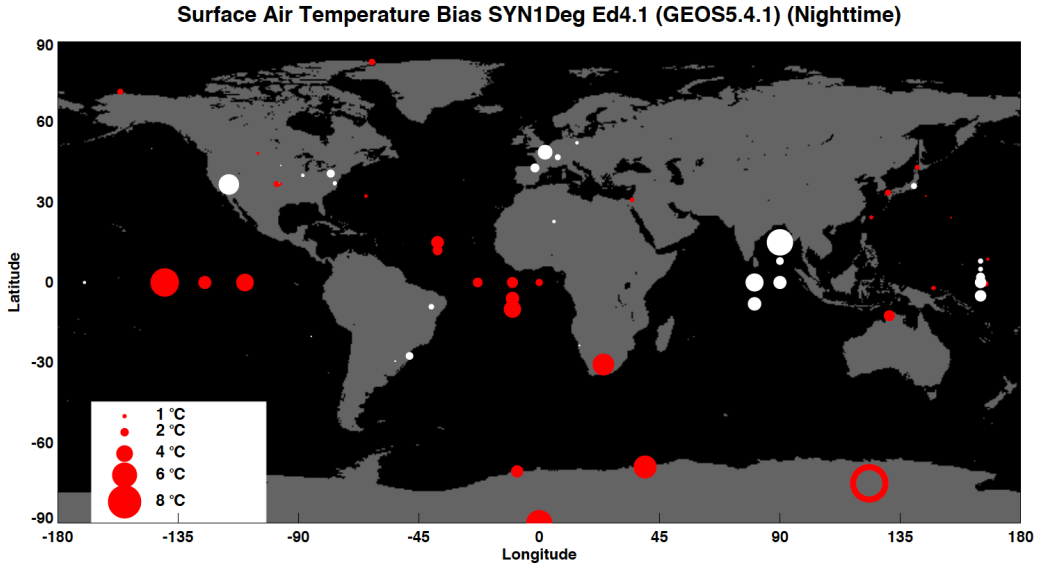


Circles are scaled to Max bias: 7.8 °C
Red -> Positive Bias
White -> Negative Bias
Open Circle -> Bias > Max on Scale

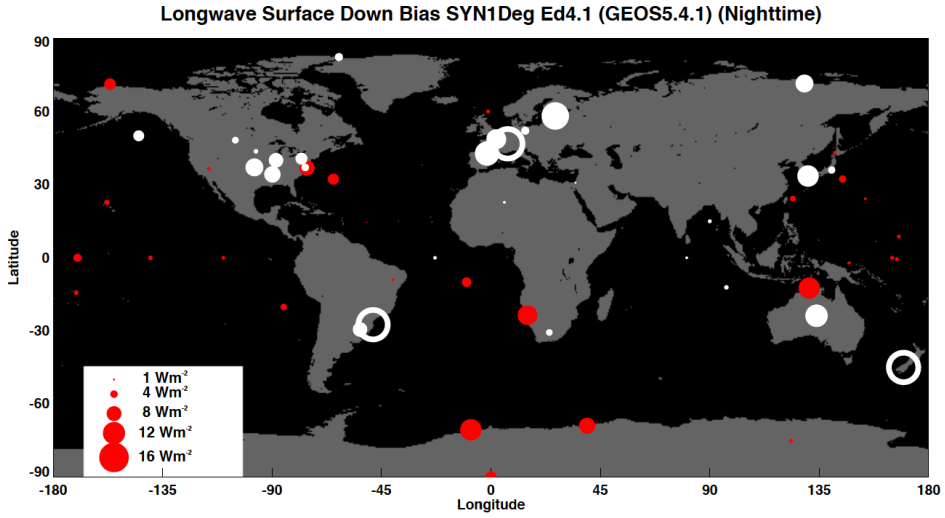
Effect on downward longwave irradiance







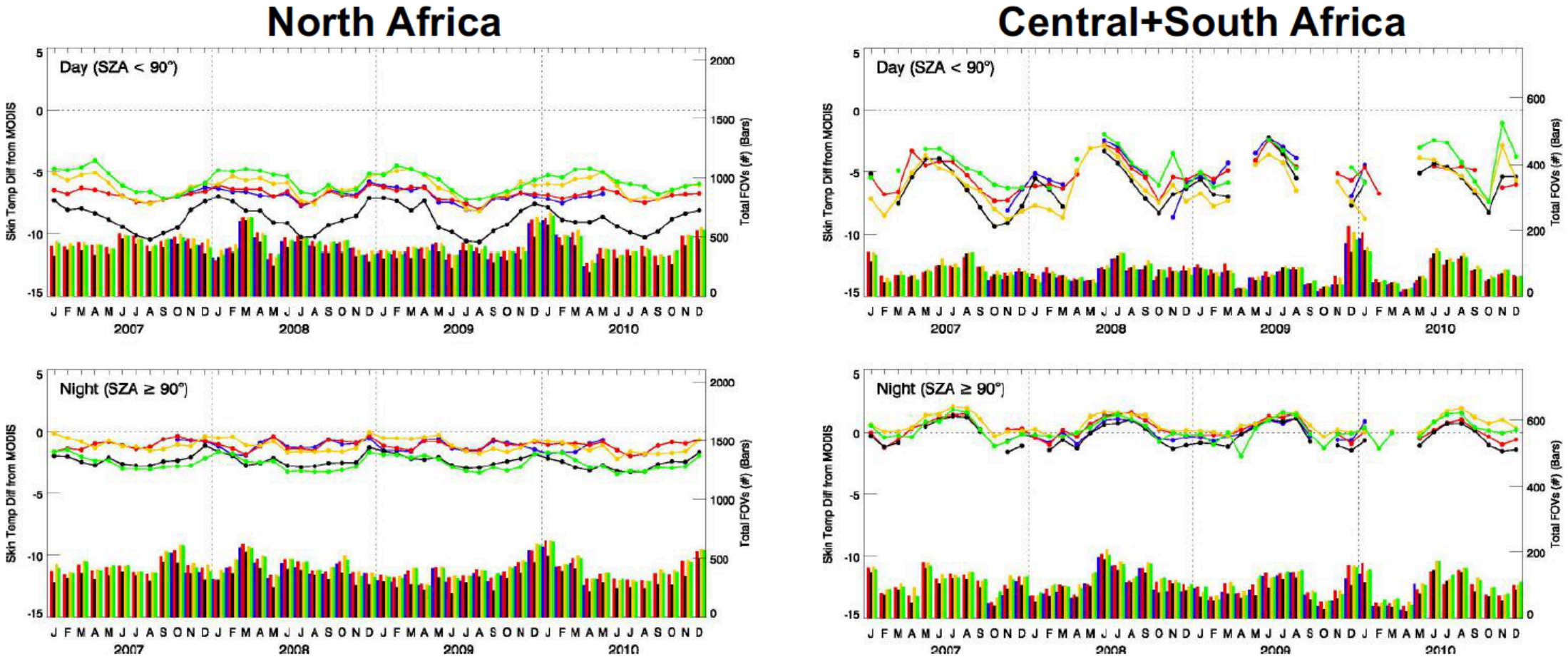
Circles are scaled to Max bias: 7.8 °C
Red -> Positive Bias
White -> Negative Bias
Open Circle -> Bias > Max on Scale



Circles are scaled to Max bias: 16.0 Wm⁻²
Red -> Positive Bias
White -> Negative Bias
Open Circle -> Bias > Max on Scale

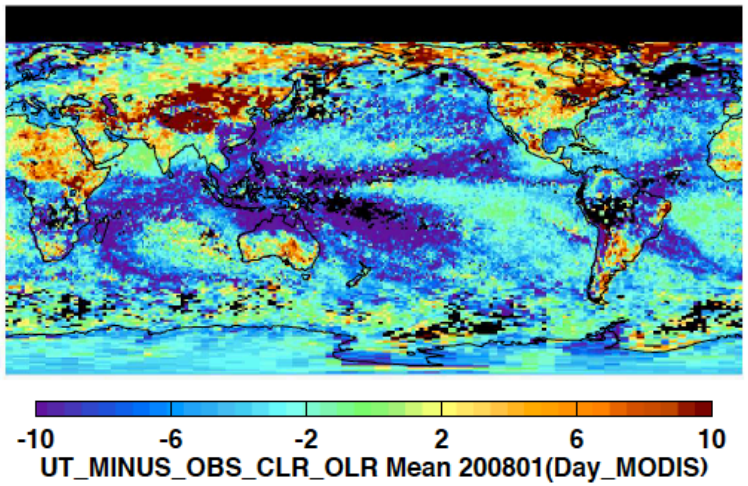
Day night skin temperature comparison

Time Series of {Reanalysis – MODIS T_{skin}} over Africa

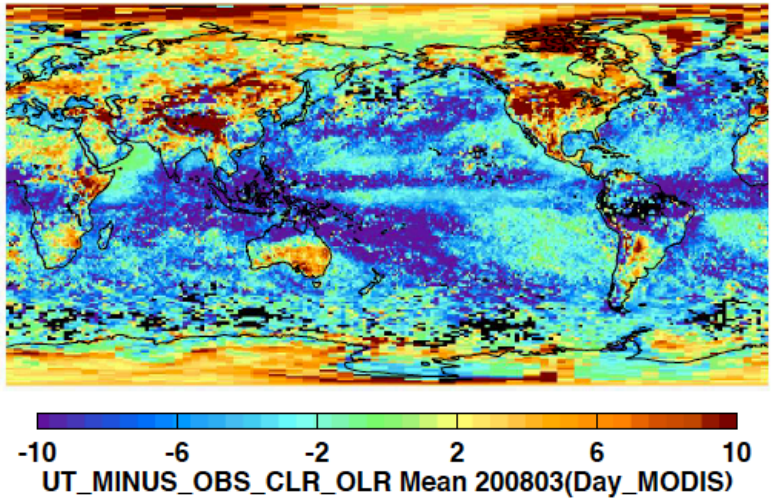


G520–MODIS G541–MODIS MERRA2–MODIS ERAI–MODIS ERA5–MODIS

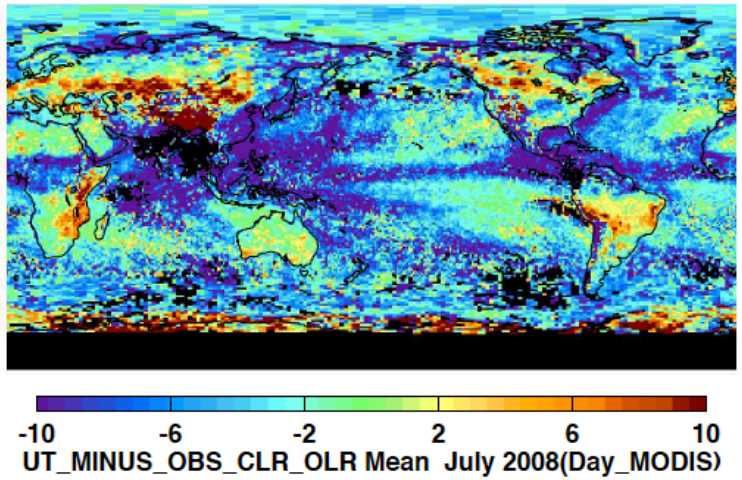
Clear-sky daytime OLR comparison, Jan., March, and July 2008



N= 55437 Glb mean(sd): * -3.75 (6.17) Mn/Mx: -45.14/ 52.94

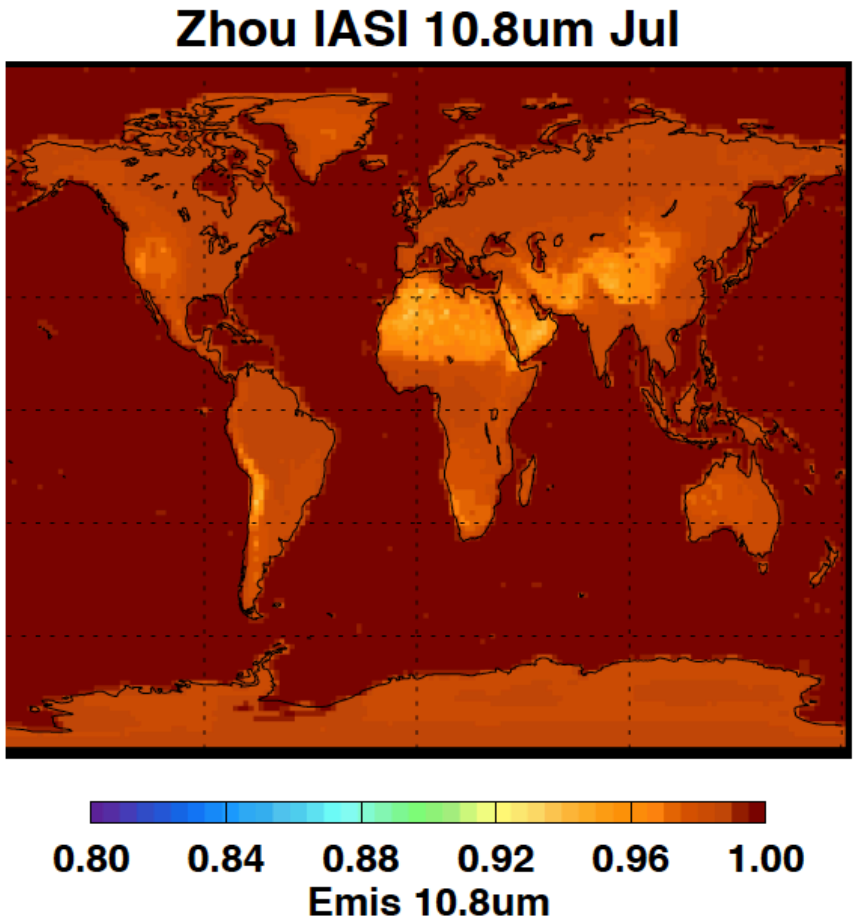


N= 62464 Glb mean(sd): * -3.21 (6.64) Mn/Mx: -38.85/ 68.26



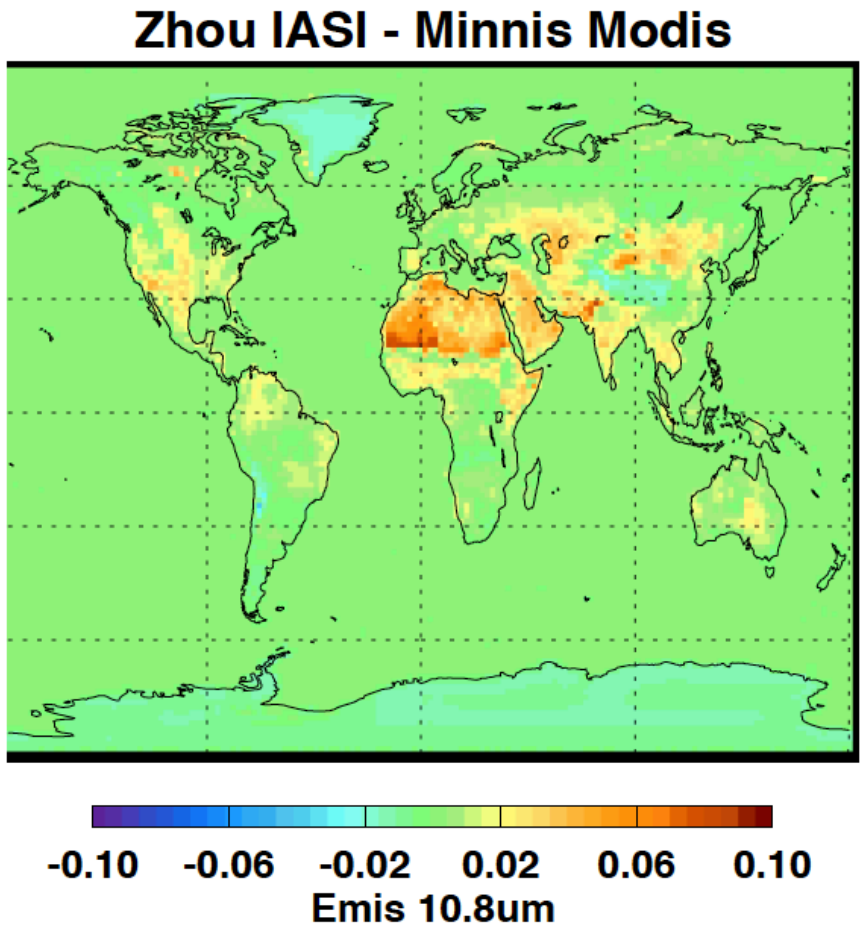
N= 54666 Glb mean(sd): * -4.11 (6.12) Mn/Mx: -39.64/ 60.46

Land surface emissivity



N= 259200.

	Mean	(StdDev)
Emis 10.8um	0.990(	0.008)

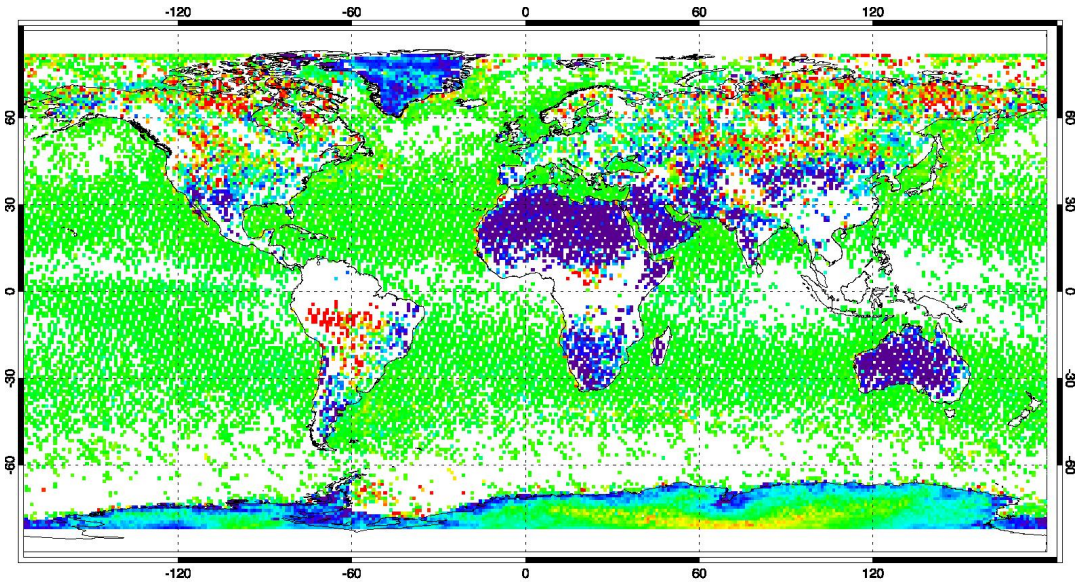


N= 259200.

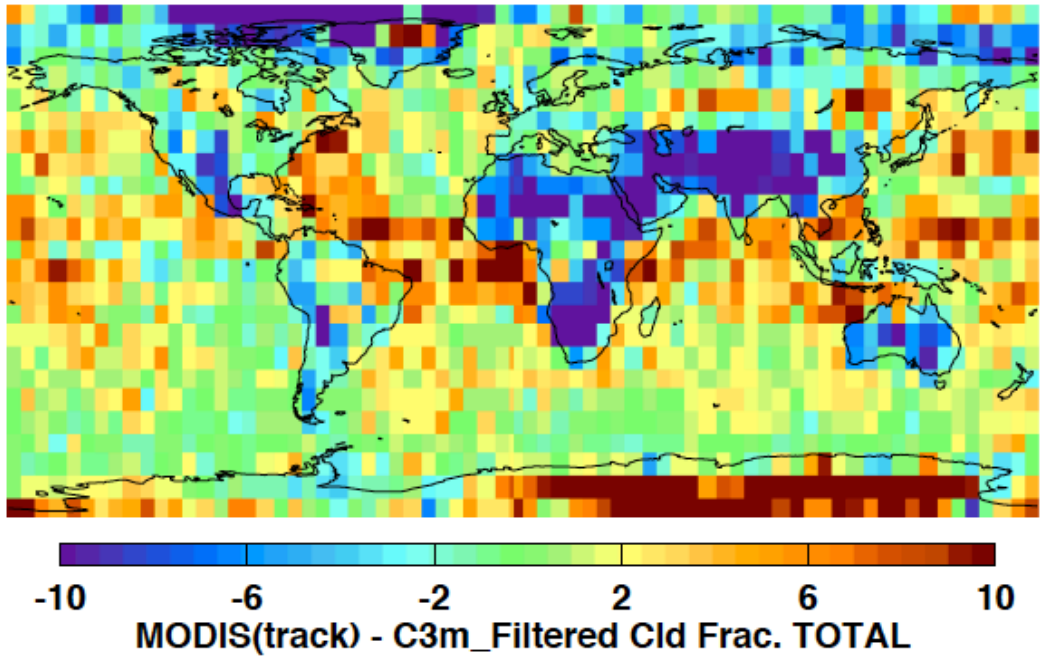
	Mean	(StdDev)
Emis 10.8um	0.001(	0.009)

Skin temperature bias

G-5.4.1 minus MODIS T_s (ΔT_s) for 2007-2010



January, April, and October 2010 daytime cloud fraction bias
Edition 4.0 MODIS – (CALIPSO+CloudSat)



N= 2448 Glb mean(sd): ^ 0.586 (5.95) Mn/Mx: -31.96/ 35.44

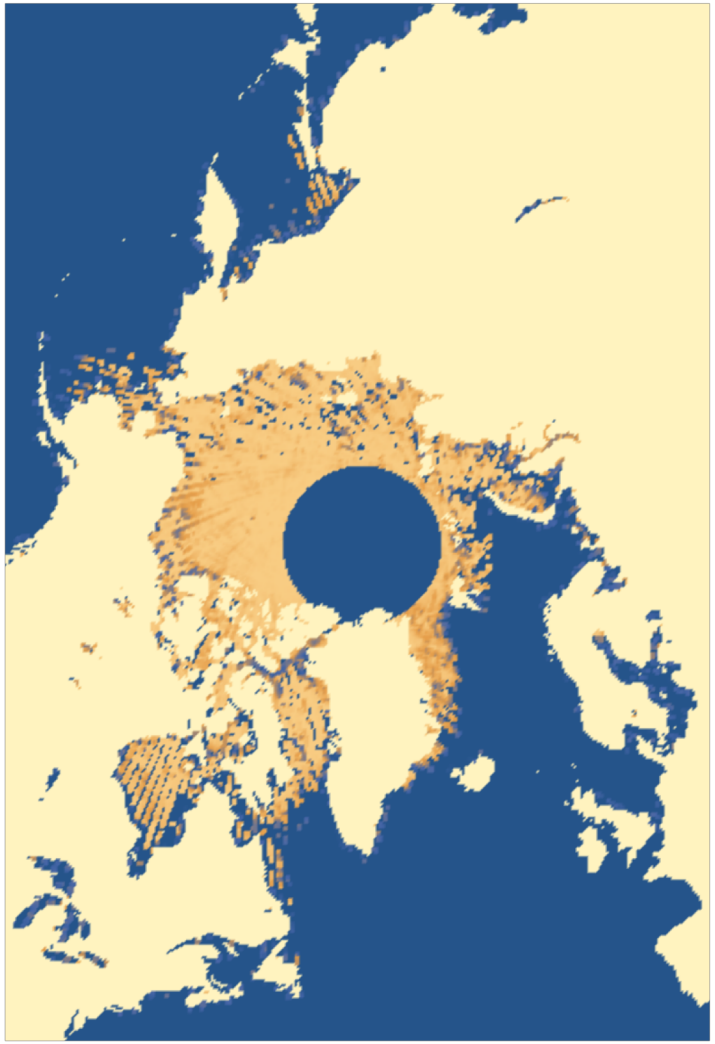
Update on sea ice map

- http://nsidc.org/data/nsidc-0051, Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data
- IGBP = NISE (used in Ed4 production)
- CWG sea ice map from cloud working group
- Comparison using 2017 data

Difference between Sea Ice Concentrations (SICs) from NSIDC-51, IGBP, and CWG

SIC Maps

NSIDC-51



IGBP

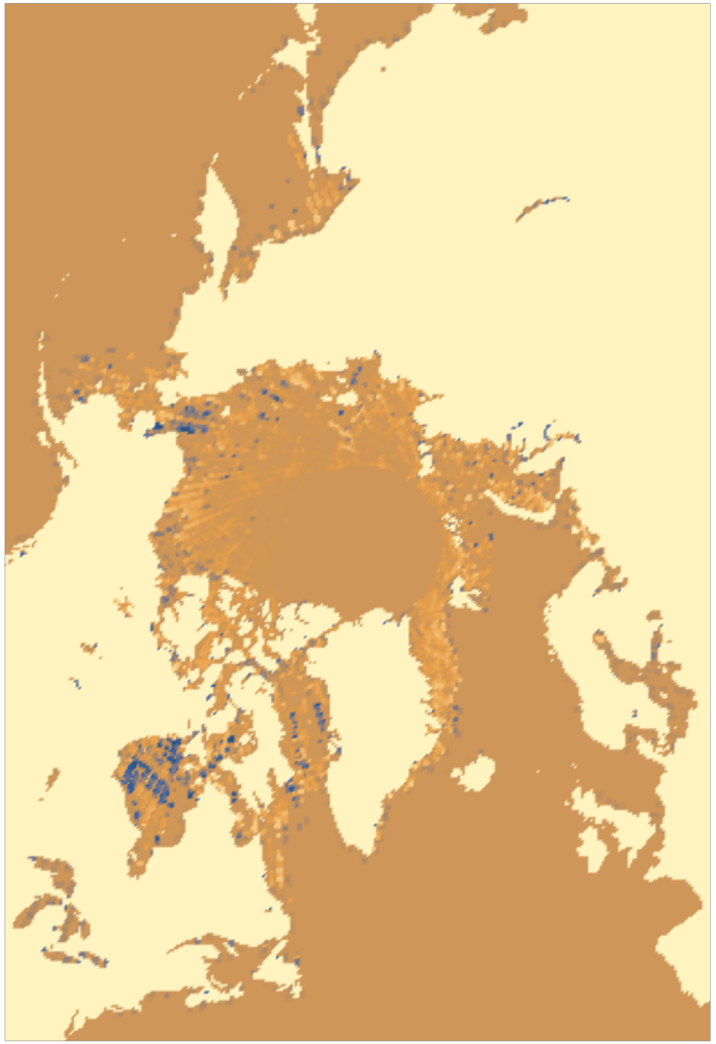
CWG

Difference between Sea Ice Concentrations (SICs) from NSIDC-51, IGBP, and CWG

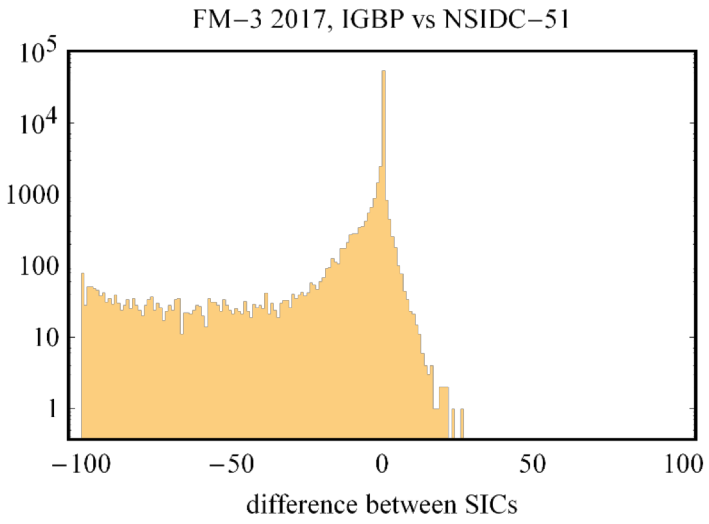
SIC Difference Maps and Distributions

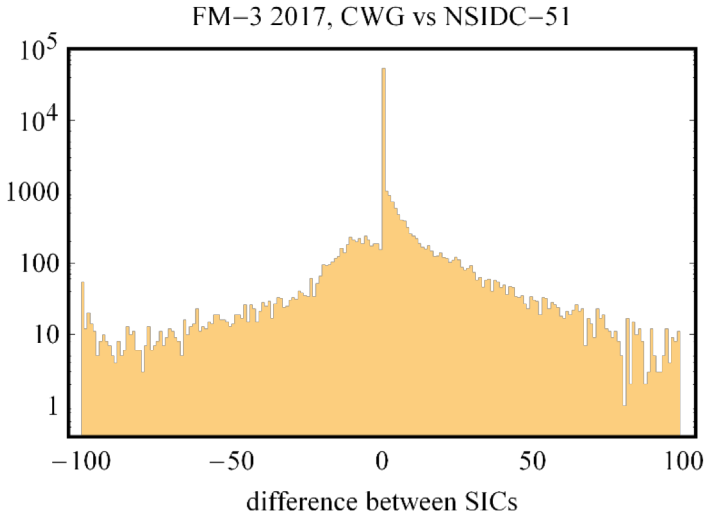
IGBP - NSIDC-51

CWG - NSIDC-51



Distributions of difference





Summary

- Edition 4.1 EBAF-surface from march 2000 through September 2018 is produced and evaluated.
  - Significant change in shortwave surface fluxes over land especially for clear-sky conditions due to changes in the aerosol optical thickness. The difference is larger before February 2017.
  - Change in nighttime surface longwave fluxes over polar regions due to changes in polar cloud mask. Minor changes occur through February 2016 and significant changes occur from March 2016 onward.
  - Significant surface shortwave and longwave flux changes occur after July 2015 over western Pacific due to changes in cloud properties derived from Himawari-8.

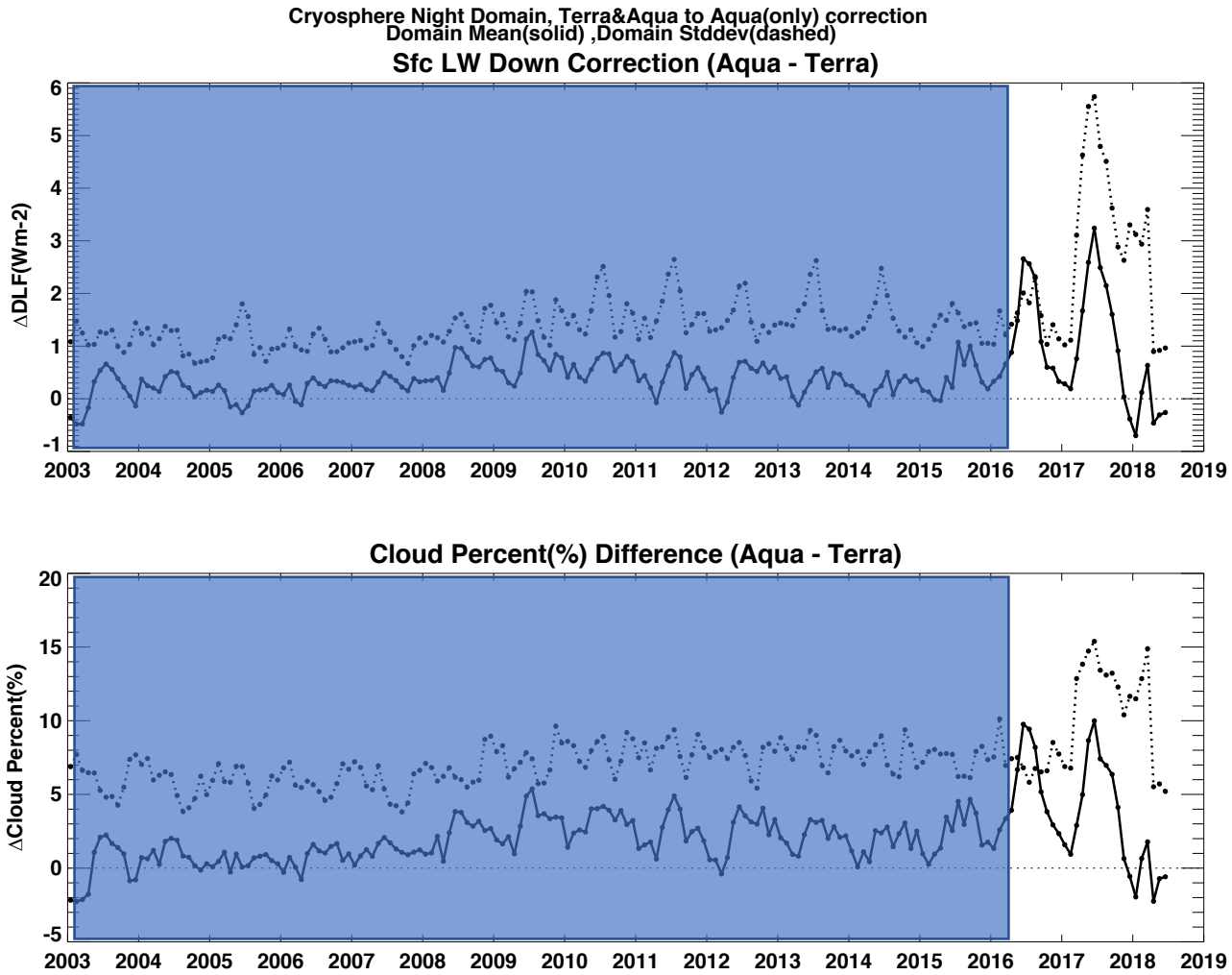
- Edition 4.1 SYN1deg is produced with MODIS collection 6.1 aerosols.
- Need to revise land emissivity data in order to retrieve skin temperature and compute upward surface longwave fluxes for Edition 5.

Publications

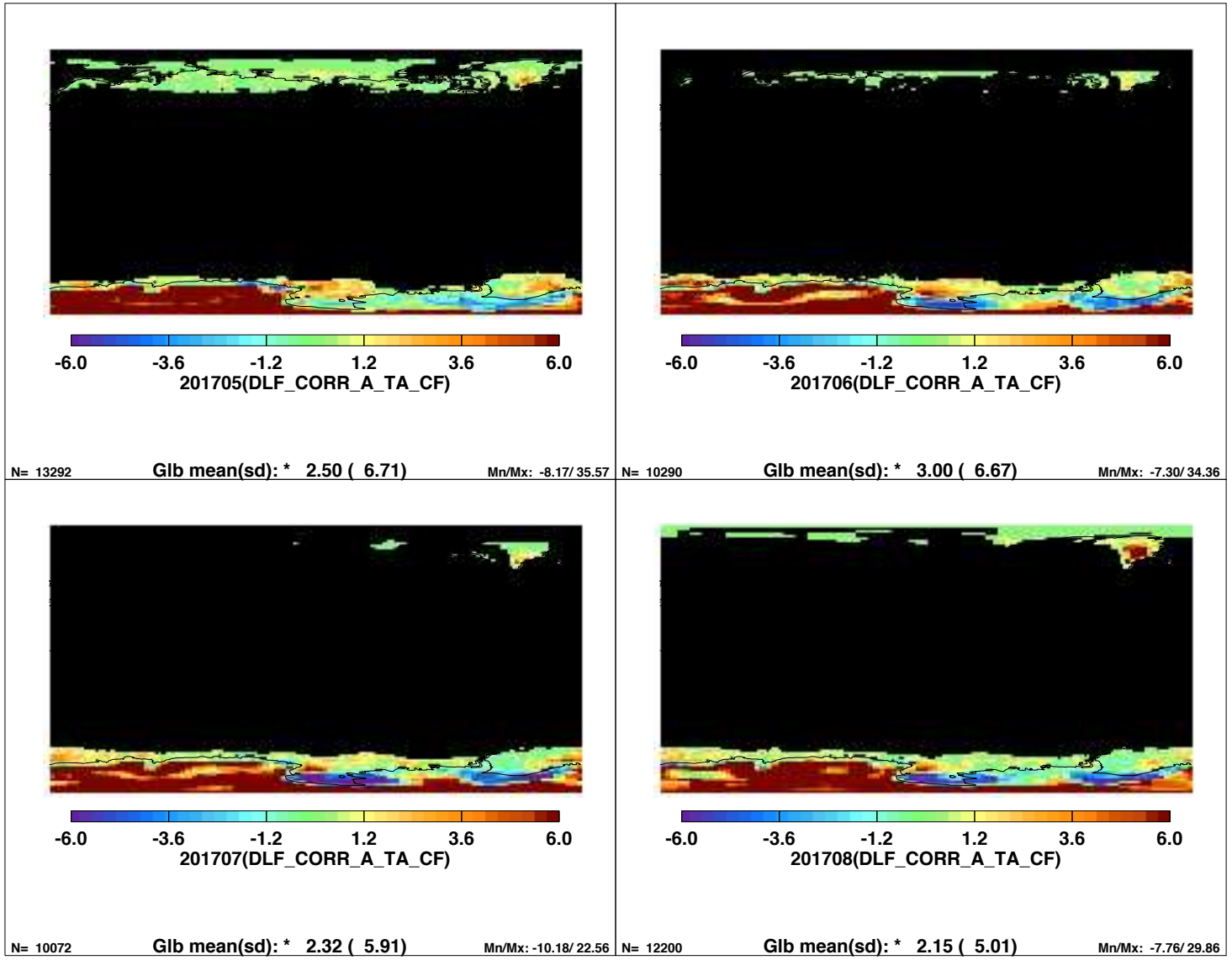
- Ham, S.-H., S. Kato, R. G. Rose, 2019: Impact of partly cloudy pixels on shortwave broadband irradiance computations, *Atmos. Ocean. Technol*. 36, doi: 10.1175/JTECH-D-18-0153.1.
- Kato, S., F. G. Rose, S.-H. Ham, D. A. Rutan, A. Radkevich, T. E. Caldwell, S. Sun-Mack, W. F. Miller, and Y. Chen, 2019: Radiative heating rates computed with clouds derived from satellite-based passive and active sensors and their effects on generation of available potential energy, *J. Geophysic. Res*. 124, 1720–1740. https://doi.org/10.1029/2018JD028878.
- Shrestha, A. K., S. Kato, T. Wong, P. Stackhouse, R. P. Loughman, 2019: New temporal and spectral unfiltering technique for ERBE/ERBS WFOV nonscanner instrument observations, *IEEE Trans. Geosci. and Remote Sens*., DOI: 0.1109/TGRS.2019.2891748.
- Hogikyan, A., M. F. Cronin, D. Zhang, and S. Kato, 2019: Commonly used surface albedo cause sizable differences in net ocean surface heat flux, submitted to J. Climate.
- Wong, T., G. L. Smith, S. Kato, N. G. Loeb, G. Kopp, and A. K. Shrestha, 2018: On the lessons learned from the operations of the ERBE nonscanner instrument in space and the production of the nonscanner TOA radiation budget data set, IEEE Trans., Geosci. Remote Sens., 10.1109/TGRS.2018.2828783.

backups

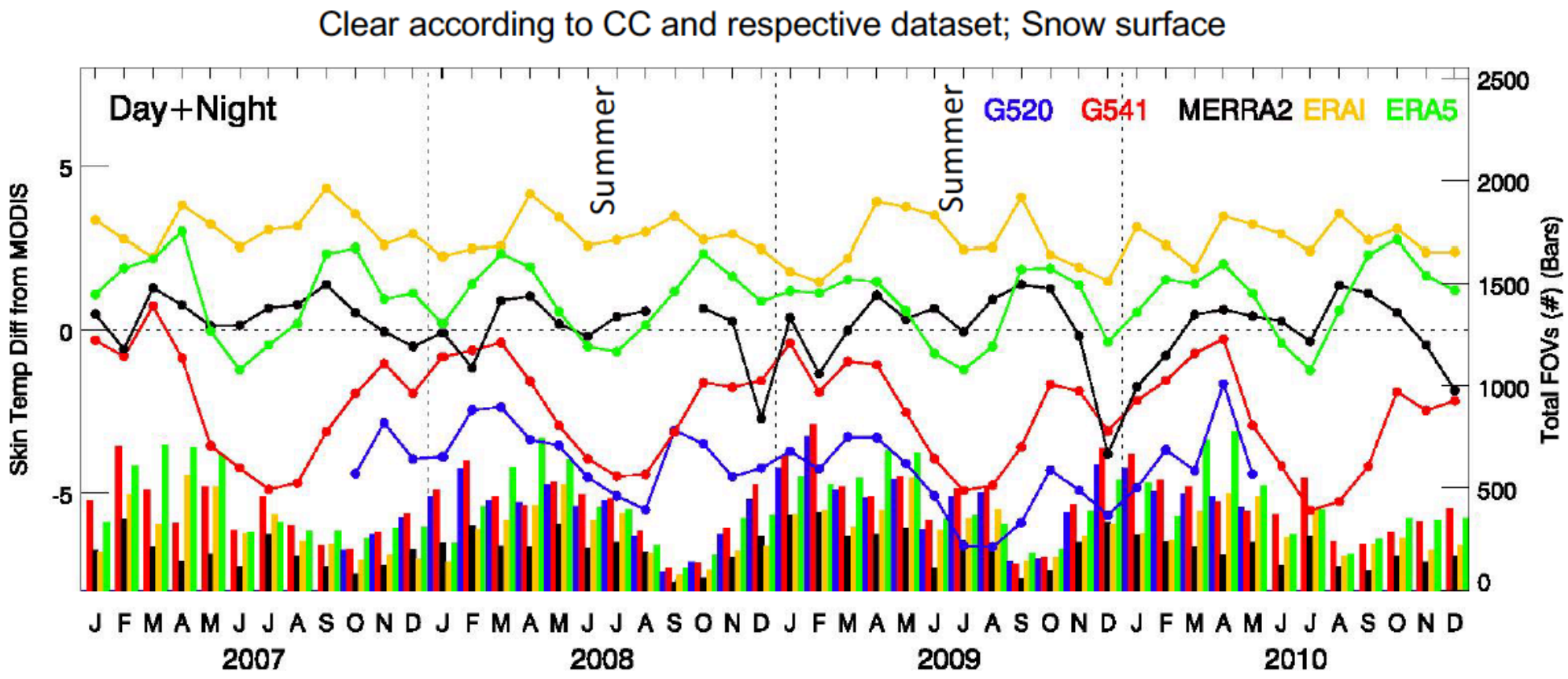
Ed 4.0 Sfc_Ebaf :No correction prior to March 2016



Maps of DLF Correction for 4 months of 2017 where magnitude of Aqua minus Terra Polar nighttime cloud fraction correction in Ed4.0 was at its peak.



Skin temperature comparison over the Arctic (Mostly over Greenland)



Skin temperature comparison over the Antarctica