Surface Atmosphere Radiation Budget (SARB) working group update

Seiji Kato[1], Fred G. Rose[2], David A. Rutan[2],

Alexander Radkevich[2], Seung Hee Ham[2], Tyler J. Thorsen[1]

Thomas E. Caldwell[2], Antonio Viudez-Mora[2],

David Fillmore[3], and Xianglei Huang[4]

[1]NASA Langley Research Center

[2]Science System & Applications Inc.

[3]NCAR

[4]University of Michigan

CERES Science Team Meeting
April 28-30, 2020

Outline of this talk

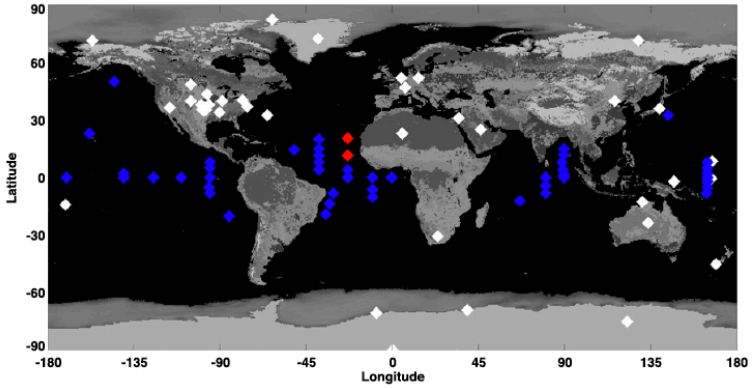
- EBAF-surface and Surface irradiance variability validation and the uncertainty in the trend
- Effect of Himawari-8 and GOES-16 switches on the surface downward longwave irradiance
- Surface albedo trend
- CERES radiative transfer code (Edition 5) update
- Edition 5 MATCH
- C3M revision.
- Longwave fingerprinting status (Edition 5)
- Publications

Data products with surface irradiances

- EBAF: March 2000 through November 2019
- SYN1deg: March 2000 through November 2019

Validation of Edition 4.1 EBAF downward surface irradiance variability using surface observations

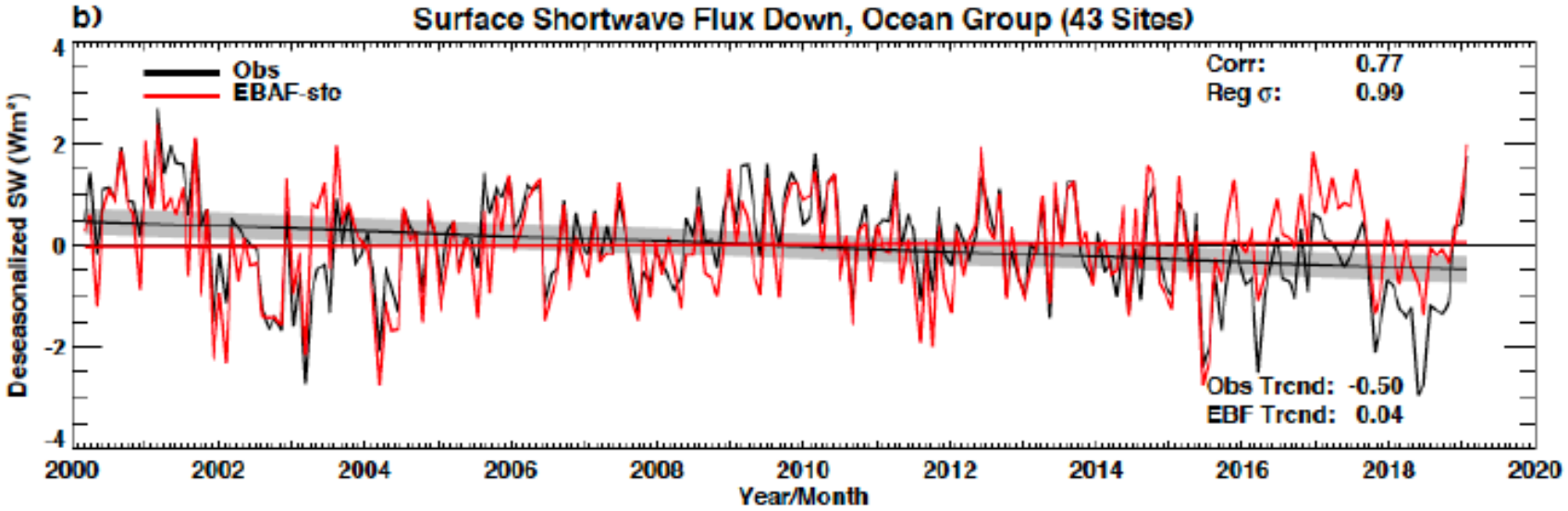
- Method to generate anomaly time series with surface observations.
  - Deseasonalize observed downward shortwave or longwave irradiances by site by subtracting climatological monthly mean irradiances.
  - Divide the anomaly time series at each site by their standard deviation.
  - For a given month, add all available anomalies and divide by the square root of the number of available sites.
  - Divide resulting anomalies by their standard deviation and multiply by the standard deviation of monthly anomalies over global land, ocean or land+ocean computed with the EBAF-surface product.



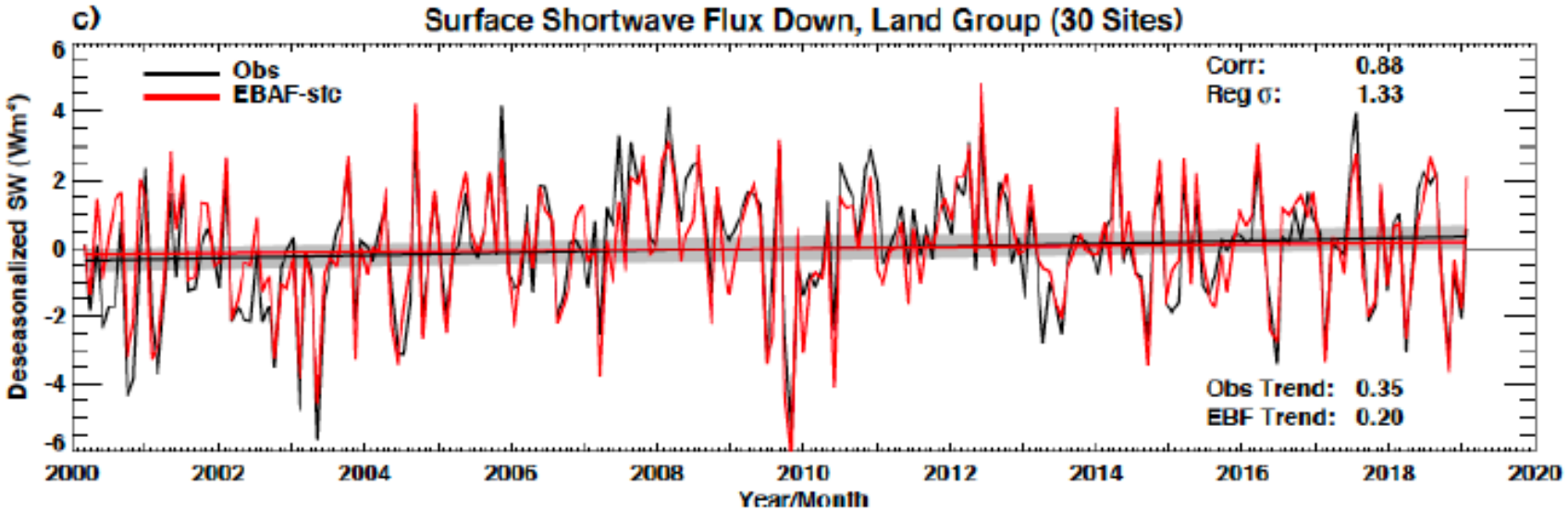
43 buoys and 30 land sites

Deseasonalized downward shortwave anomalies land and ocean

Ocean



Land

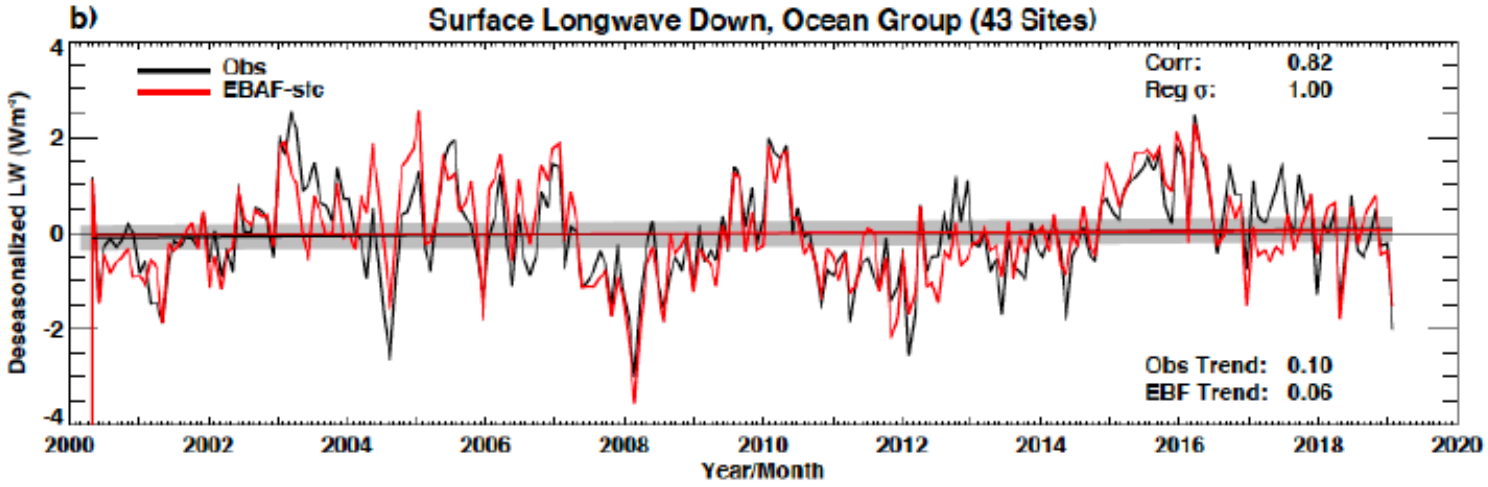


	Correlation coefficient
Ocean	0.77
Land	0.88

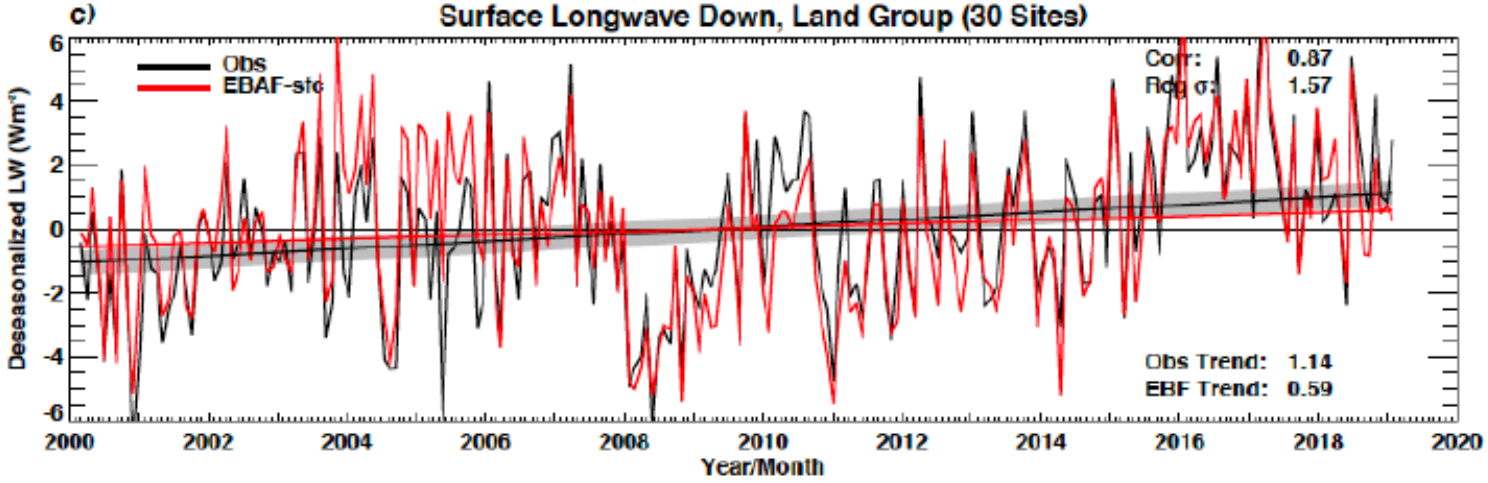
The trend derived from combined anomaly time series depends on the length of time record at each site. But a simplest case when all n sites have the record over the entire time with the trend x, then the trend derived from time combined time series is x time sqrt(n).

Deseasonalized downward longwave anomalies land and ocean

Ocean

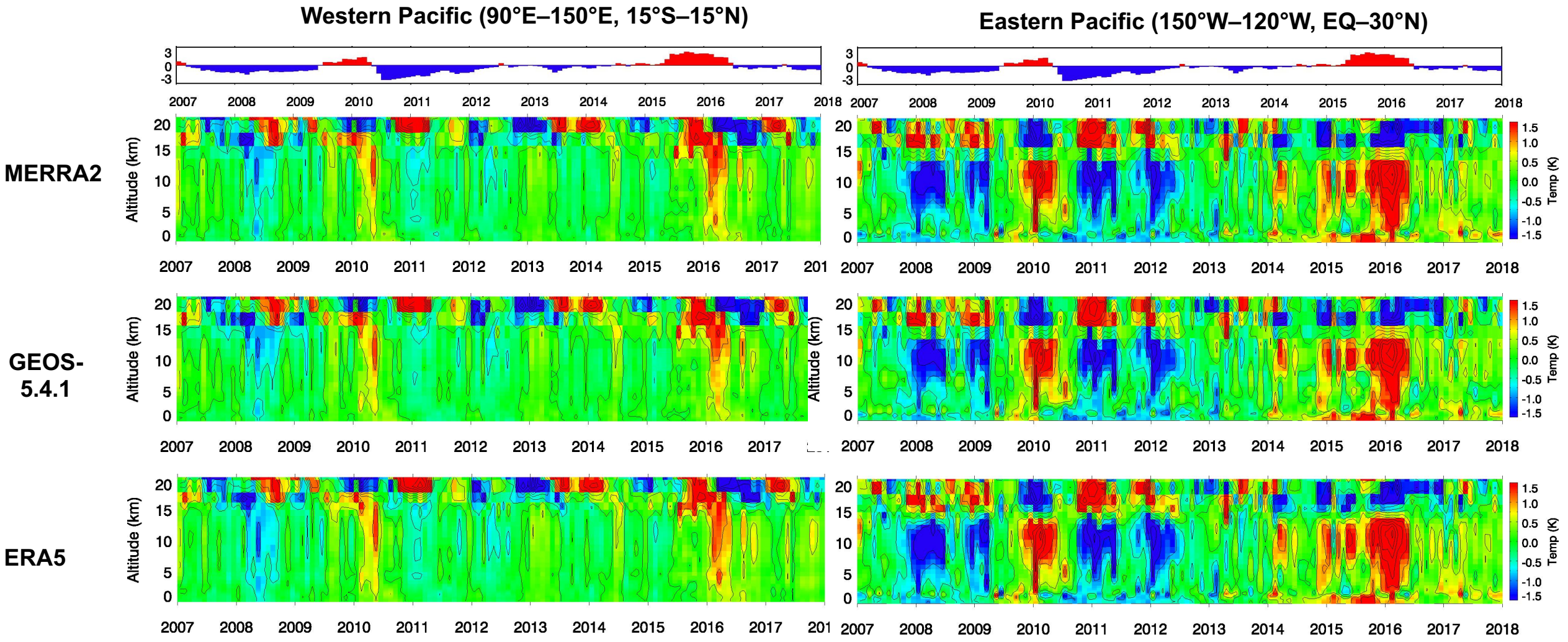


Land

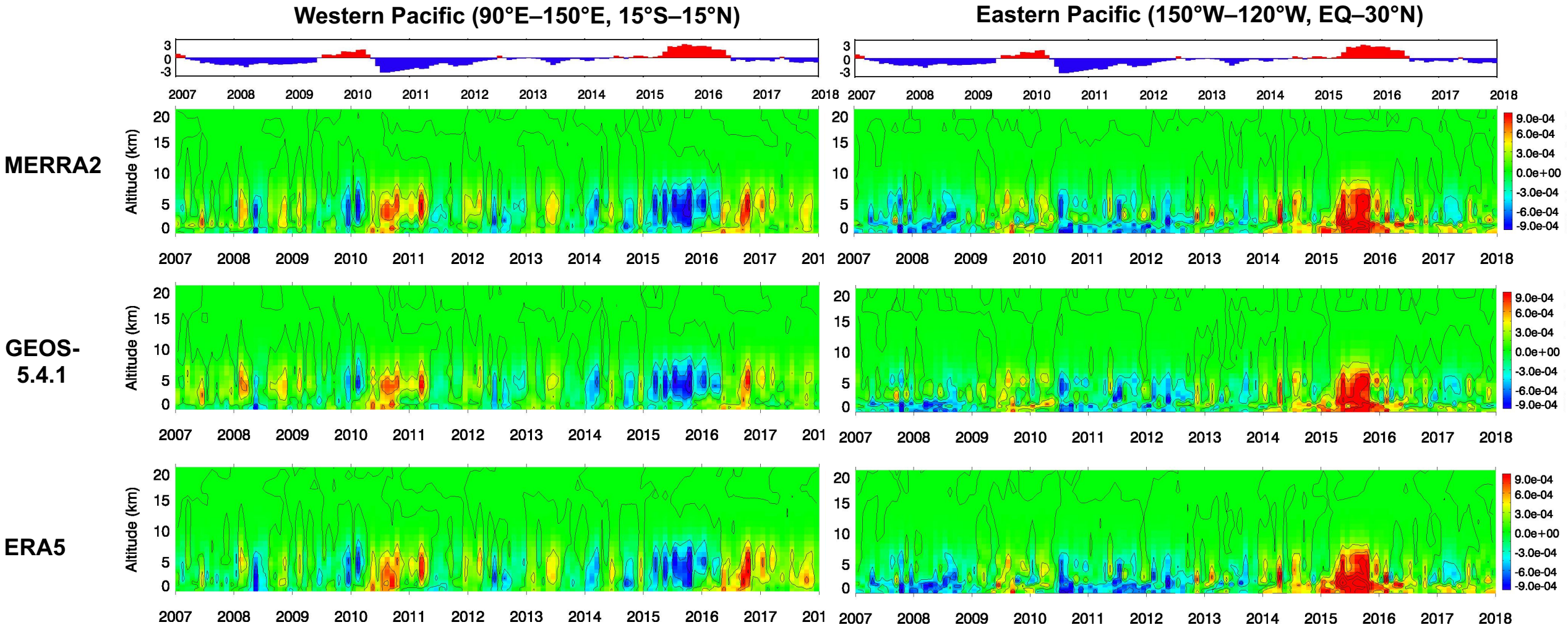


	Correlation coefficient
Ocean	0.82
land	0.87

Temperature (K) anomalies in MERRA2, GEOS-5.4.1, and ERA5



Specific humidity (g/g) anomalies in MERRA2, GEOS-5.4.1, and ERA5



Uncertainty in the slope in Wm^{-2} $decade^{-1}$

$$U(b_{x,EBAF}) = \left[(b_{x,EBAF} - b_{x,obs})^2 + \sigma^2_{b_{x,EBAF}} + \sigma^2_{b_{x,obs}}\right]^{1/2}$$

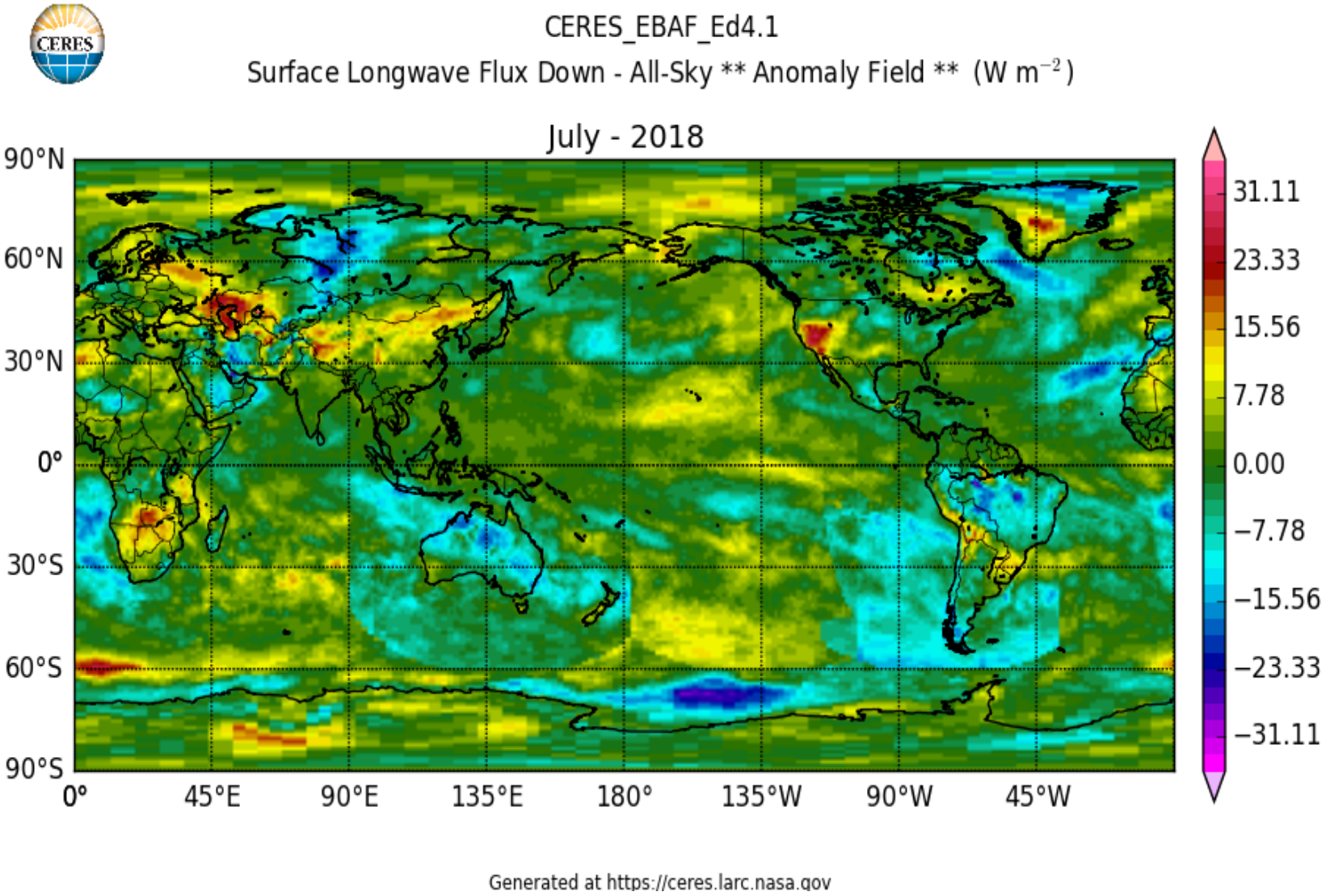
$$\sigma^2_{b_x} = \frac{\frac{1}{n-2}\sum_{i=1}^{n}\left[F_{i,x,anom} - \hat{F}_{x,anom}(t_i)\right]^2}{\sum_{i=1}^{n}(t_i - \bar{t})^2}$$

$b_{x,EBAF}$ and $b_{x,obs}$ are the slope of linear regression line

Downward irradiance	$b_{x,EBAF} - b_{x,obs}$	$\sigma_{x,EBAF}$	$\sigma_{x,obs}$	$U(b_{x,EBAF})$
Land + ocean				
Longwave	-0.33	0.12	0.11	0.37
Shortwave	0.29	0.09	0.09	0.32
Ocean				
Longwave	-0.03	0.12	0.12	0.17
Shortwave	-0.55	0.12	0.11	0.57
Land				
Longwave	-0.55	0.18	0.17	0.60
Shortwave	-0.15	0.16	0.16	0.27

Effect of new generation geostationary satellites on surface irradiance

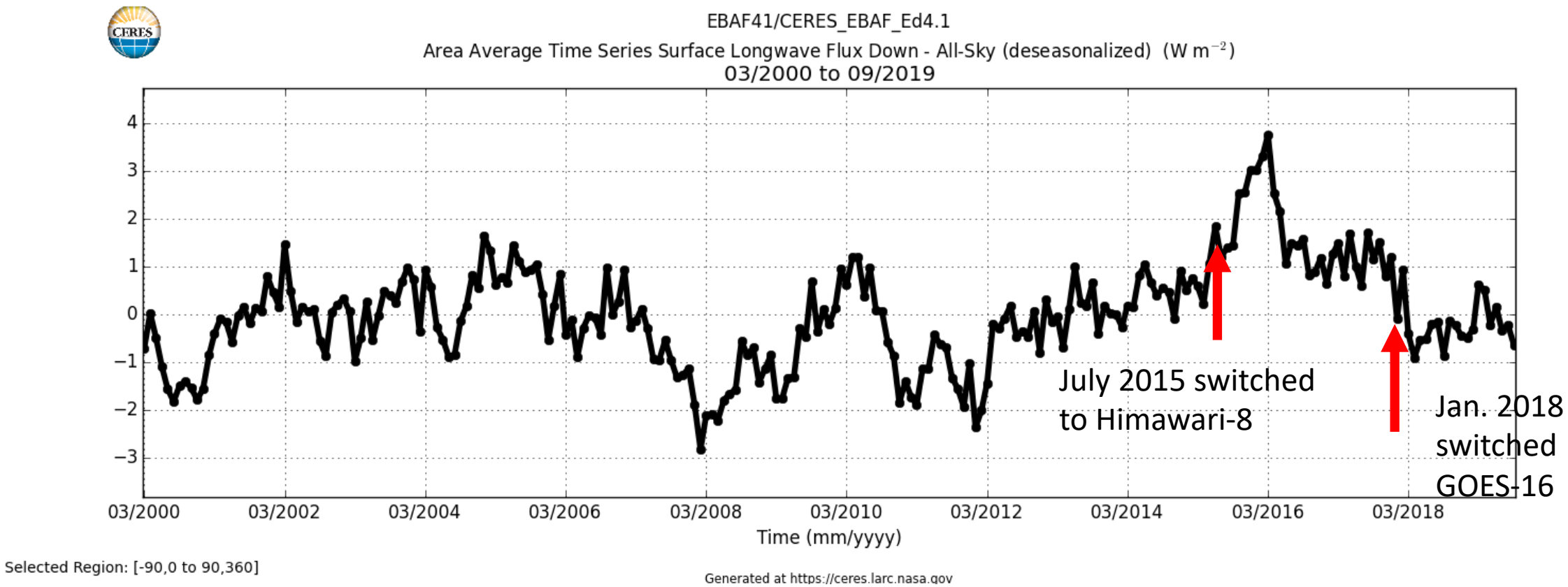
Downward longwave issue



Himawari-8 replaced MTSAT-2 on July 6 2015.

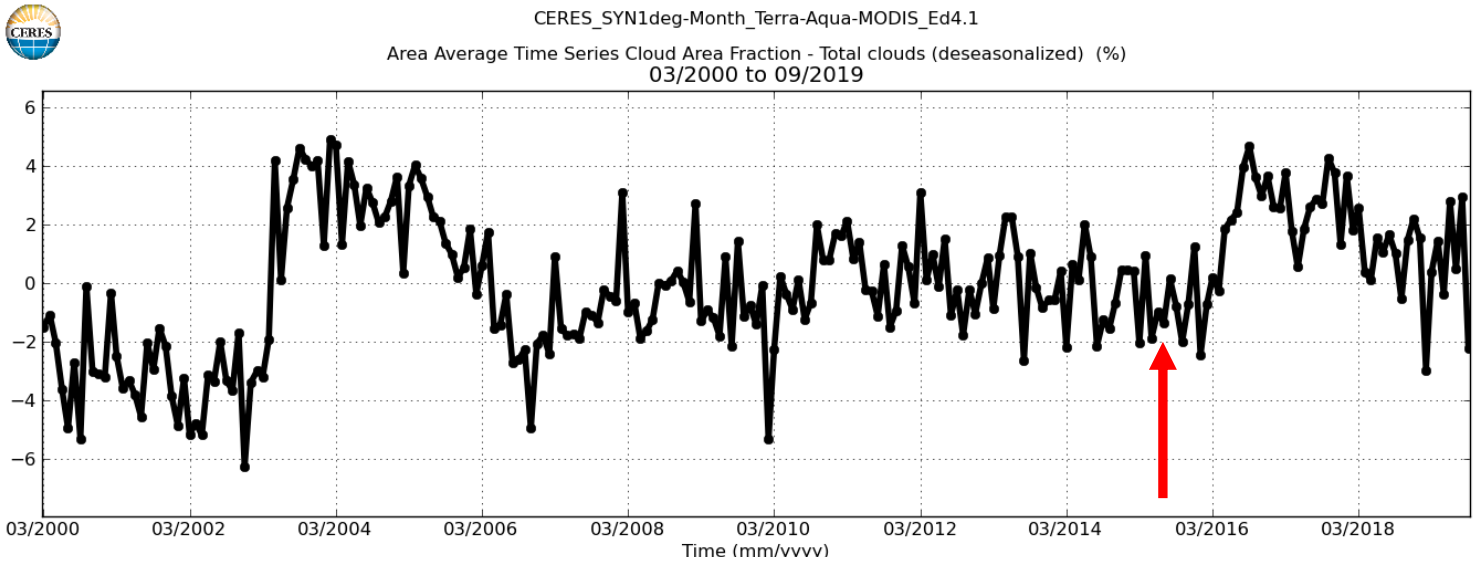
GOES-16 replacedGOES-14 on January 1 2018.

Ed4.1 EBAF global monthly surface downward longwave irradiance anomalies



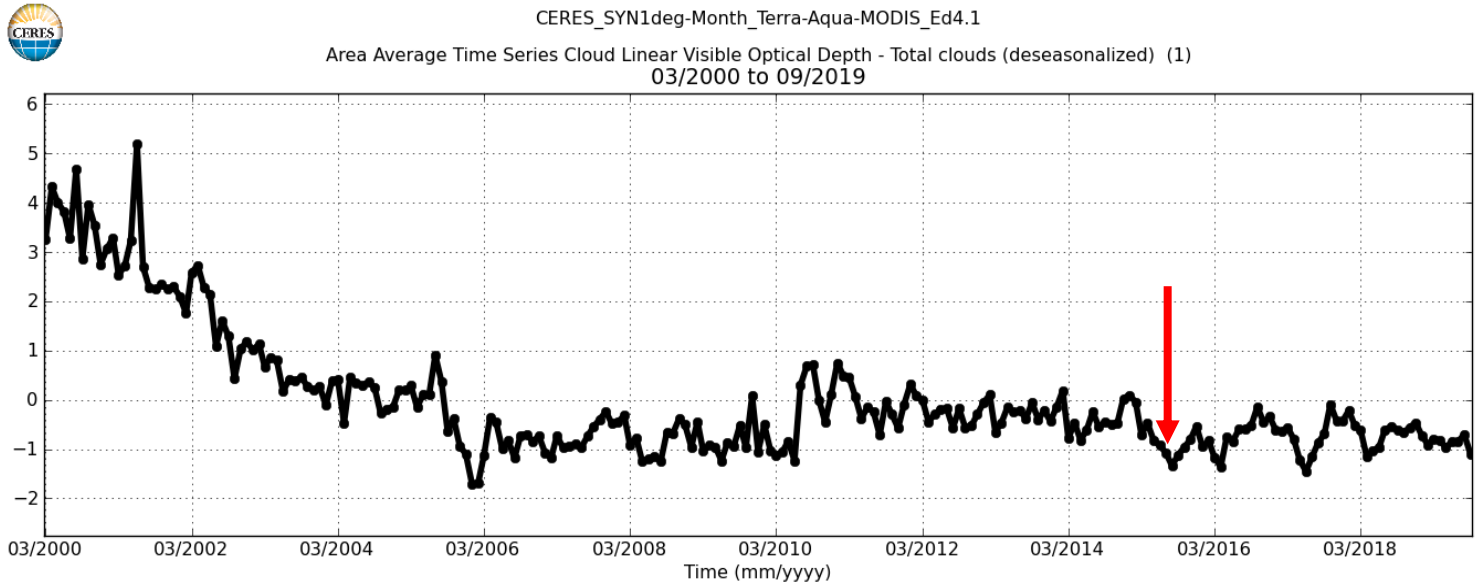
Cloud properties over Western Pacific

Cloud fraction



A larger cloud fraction is compensated by a slightly smaller optical thickness

Cloud optical thickness

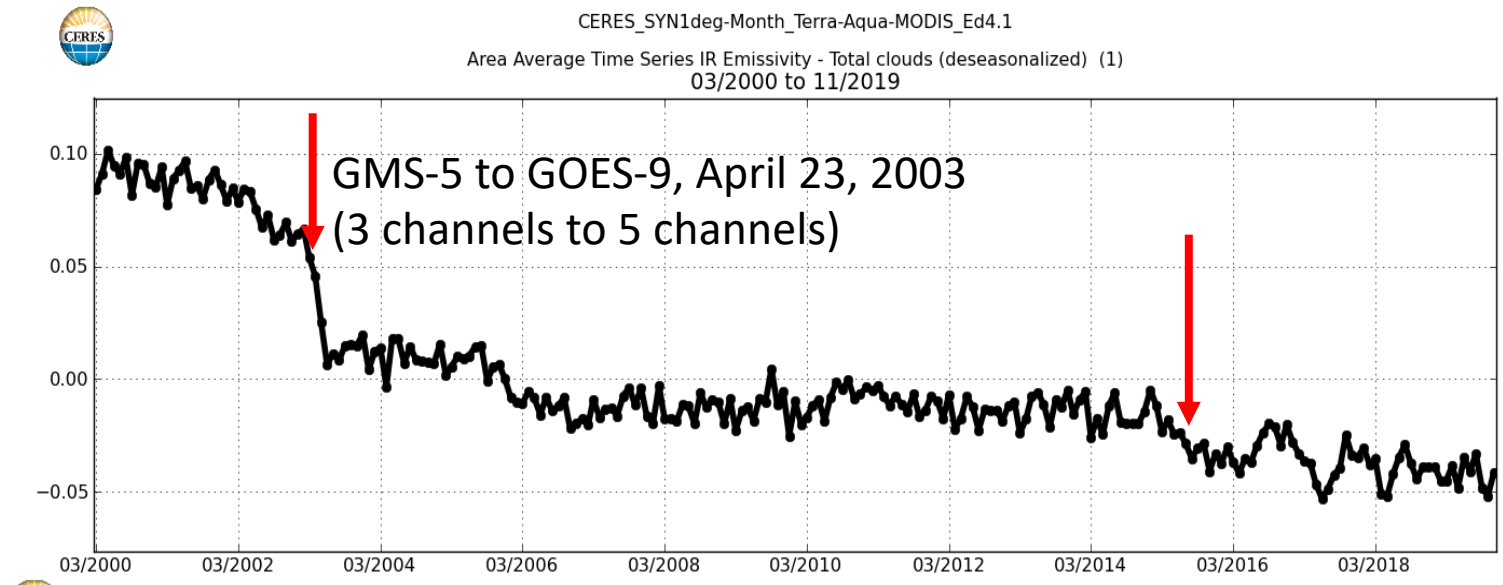


Selected Region: [-60,90 to 60,180]

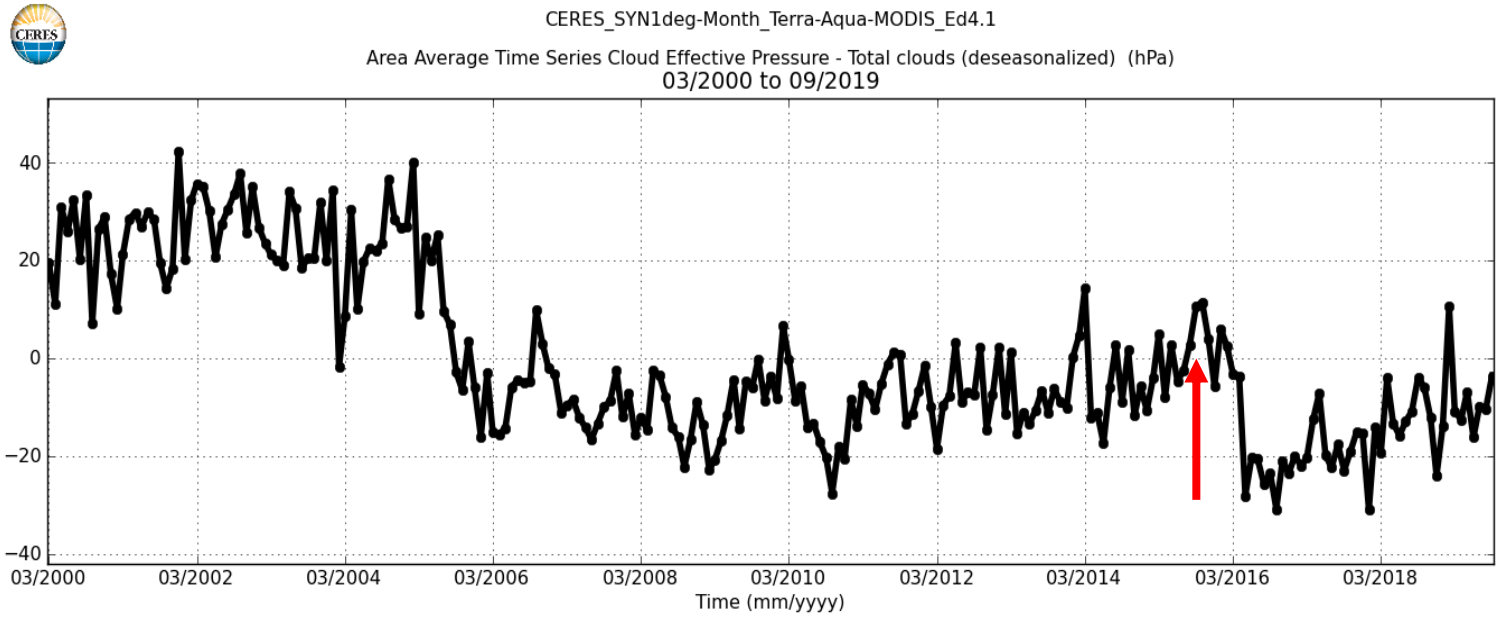
Generated at https://ceres.larc.nasa.gov

Cloud Emissivity and effective pressure

Emissivity



Cloud effective pressure



Selected Region: [-60,90 to 60,180]

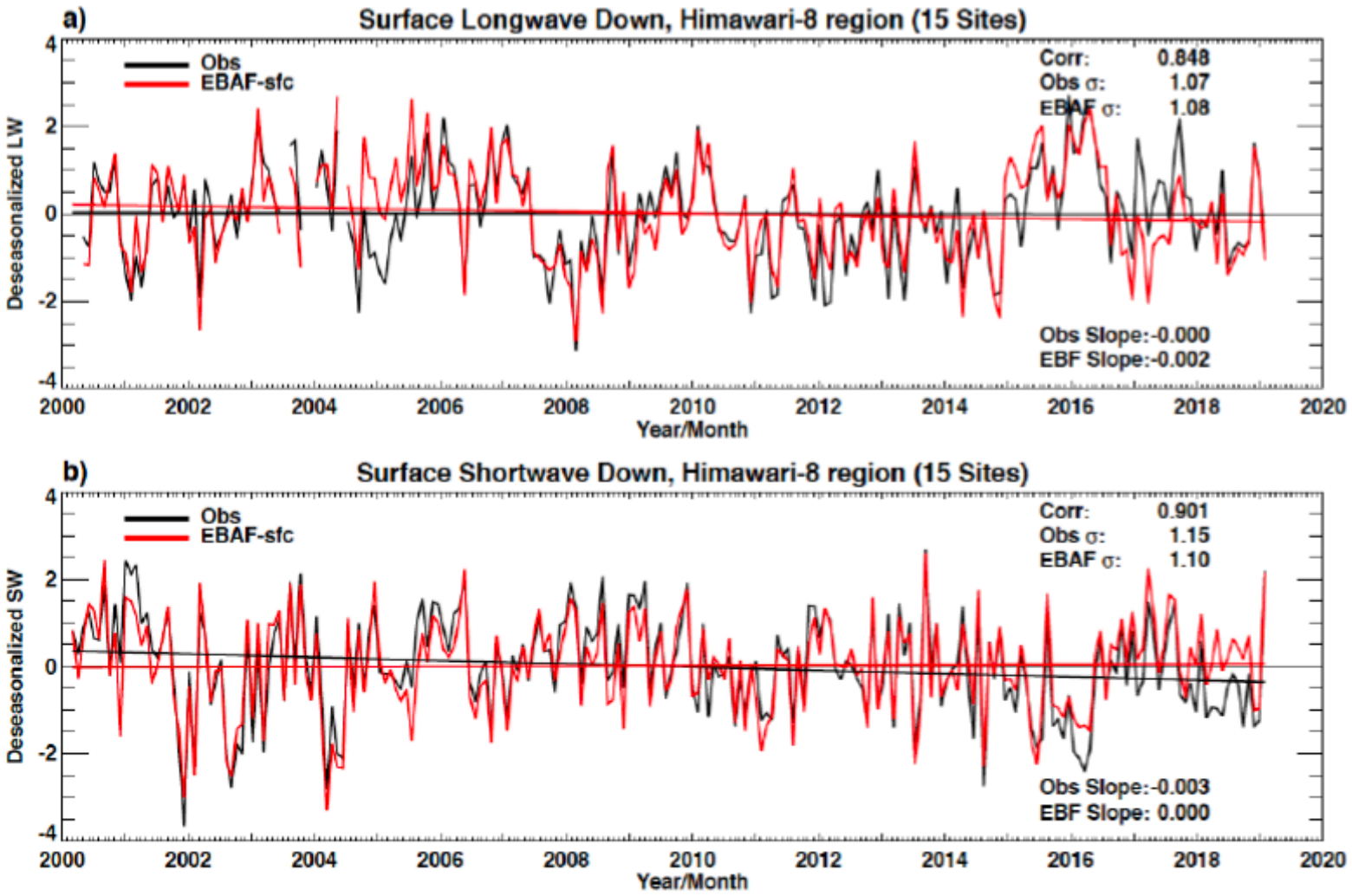
Generated at https://ceres.larc.nasa.gov

A thinner optical thickness (emissivity) and a higher cloud top height lead to a higher cloud base height

The effect of GMS-5 to GOES-9 probably exists but hard to quantify

We will use perturbation analysis to try to quantify the effects

Downward longwave and shortwave irradiance anomaly time series over the Himawari-8 region



Effects on the time series are not apparent because

1) the variability is large compared with the downward longwave anomaly discontinuity.

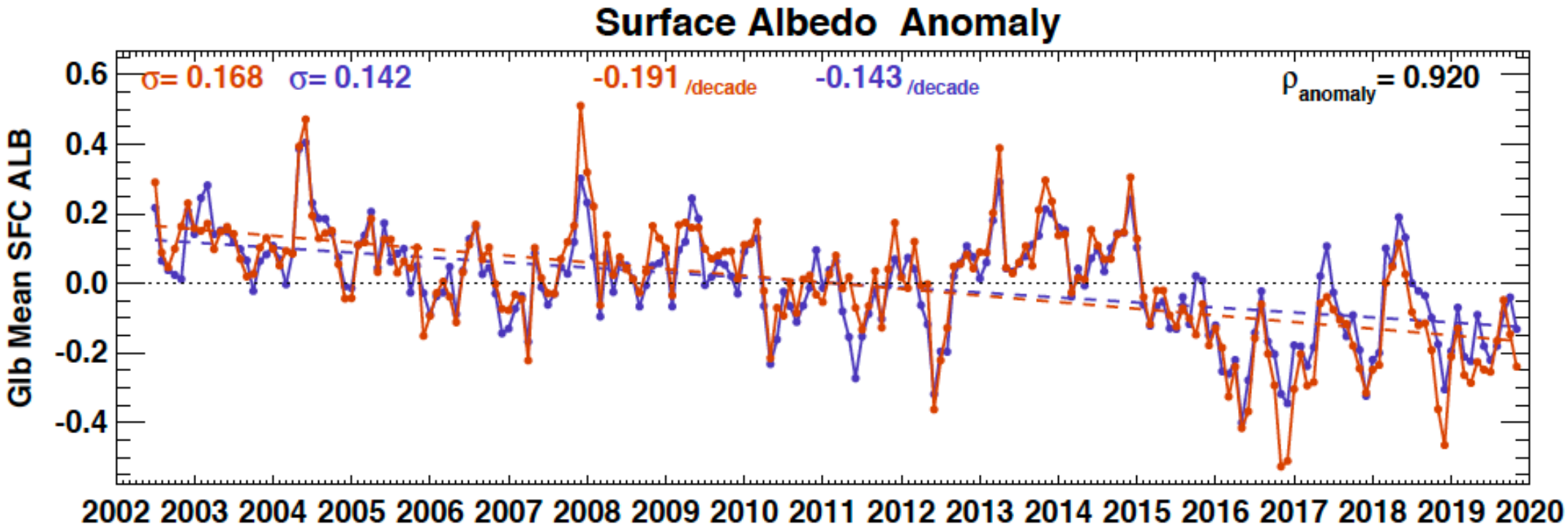
2) the systematic differences occur predominately in mid-latitude to 60S over ocean where surface sites are absent.

Surface albedo trend

Surface albedo time series (not averaging albedo)

Clear-sky

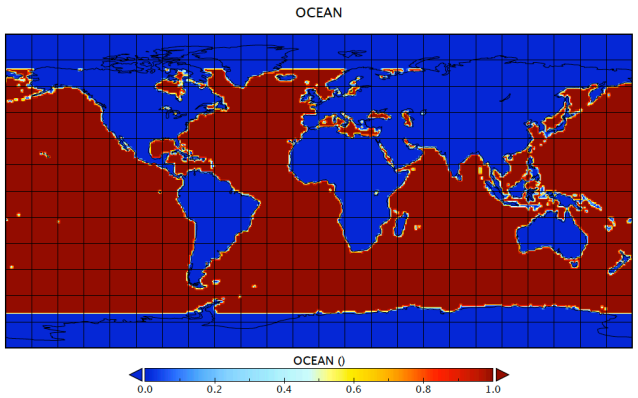
All-sky



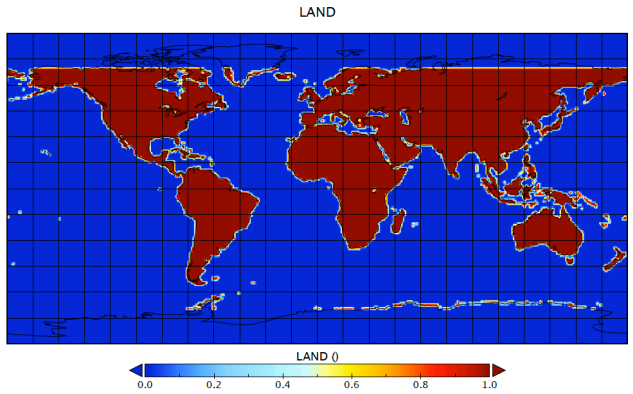
Global mean surface (SW down / SW up)
Albedo range 0 to 100.
Global mean downward shortwave irradiance = 187 Wm^{-2}
-0.191 $decade^{-1}$ is 0.36 Wm^{-2} $decade^{-1}$

Albedo trend

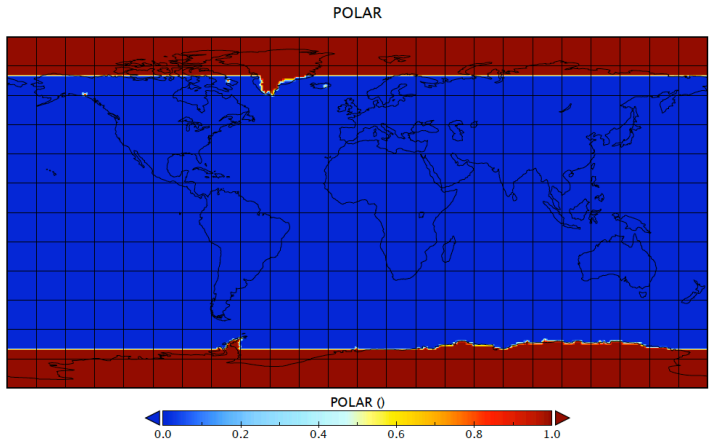
Ocean

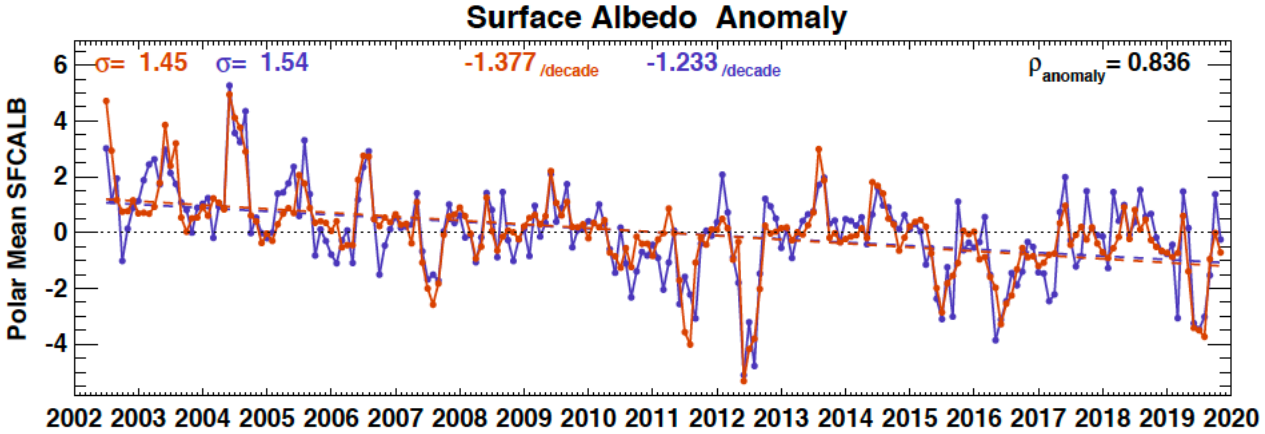


Land



Polar

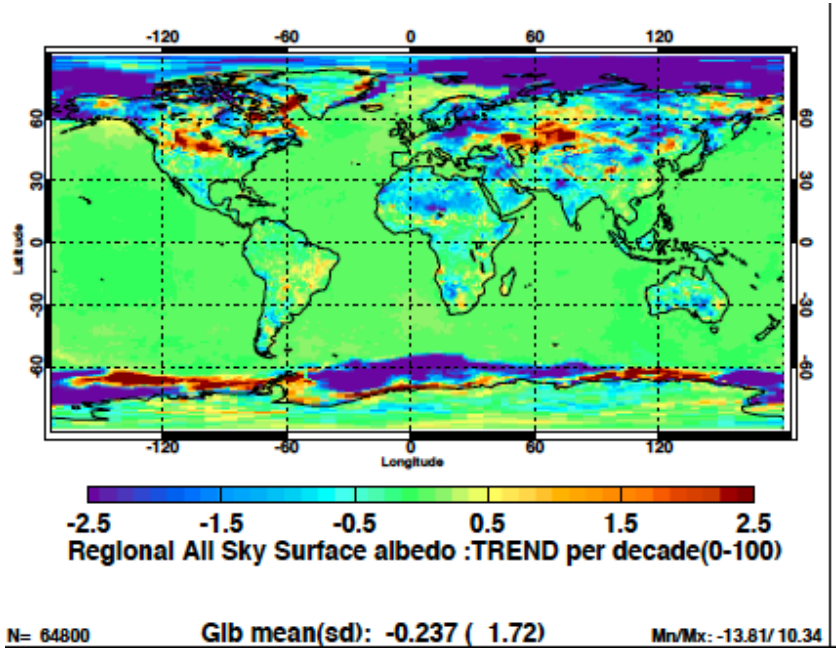


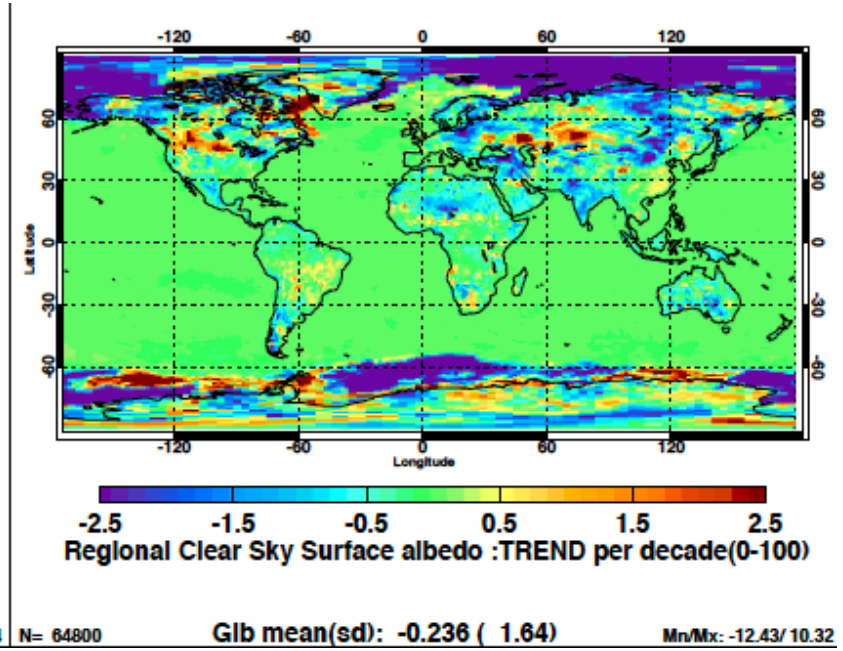


Region	All-sky	Clear-sky
Ocean	-0.137	-0.117
Land	-0.090	-0.051
Polar	-1.377	-1.233

Regional surface albedo change

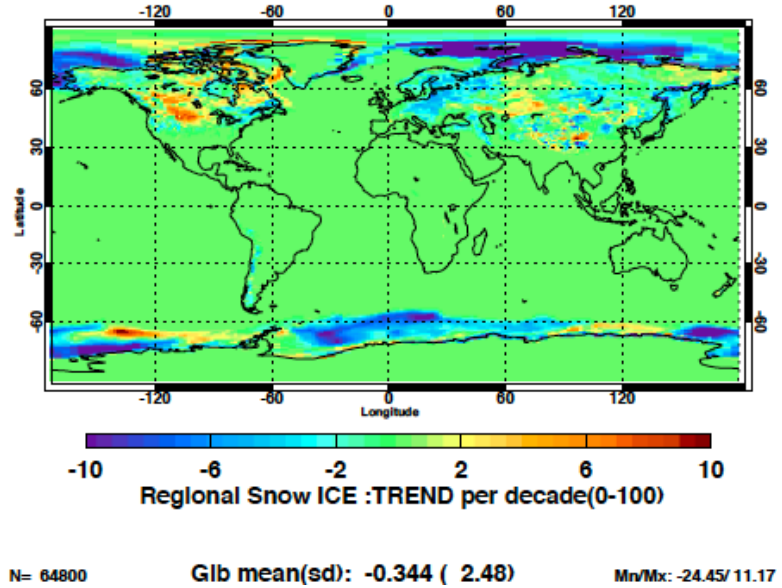
All-sky





Clear-sky

Snow and sea ice trend



- Decreasing albedo over polar region is due to decreasing sea ice cover
- Some of regional albedo trends over land can be explained by decreasing snow cover
- Decreasing albedo over Saharan desert, India, and Arabian peninsula needs further investigation. A possible explanation is an AOD trend difference between MATCH and MODIS

Edition 5

Edition 5 CERES radiative transfer code

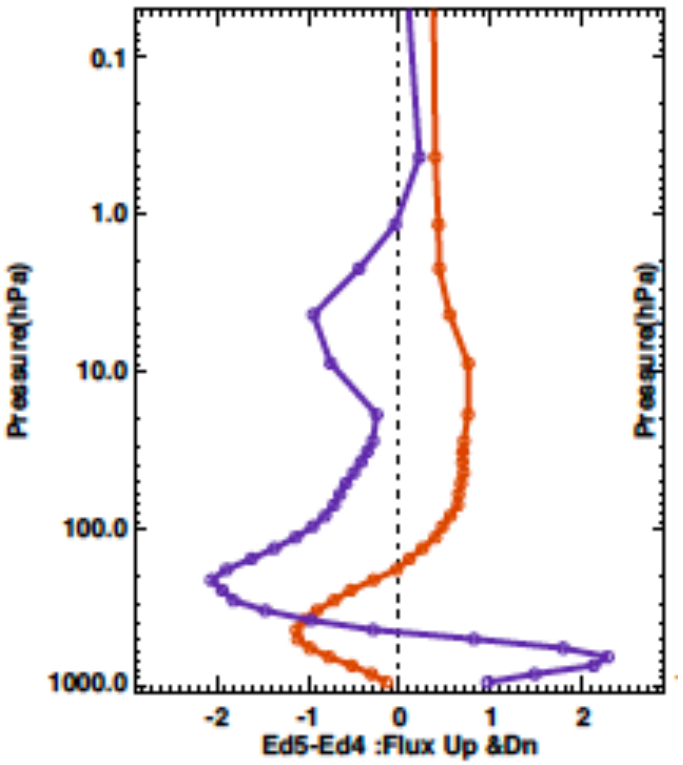
- New k-distributions were generated with HITRAN 2012 (line by line code lblrtm v12.8 outputs were made by Lusheng Liang)
- Includes absorption by H2O, CO2, O3, O2, and CH4
  - CO2 absorption with variable CO2 concentrations can be computed for both shortwave and longwave
- Same band structure as Edition 4 but the code can handle different band structures (k-distribution tables needs to be updated).
- Spectral loop-up-tables of extinction coefficients, asymmetry parameter, and single scatter albedo of water and ice clouds and aerosols
  - New aerosol types to be consistent with Edition 5 MATCH
- Molecular scattering coefficients and band solar constants
- All k-distribution, cloud and aerosol tables are inputs to the code so that they can be updated in the future
- Beta version was completed

- CERES on-line radiative transfer tool is available from [Edition 4, under “Resources” on the CERES home page]
  - https://cloudsgate2.larc.nasa.gov/cgi-bin/fuliou/runfl.cgi

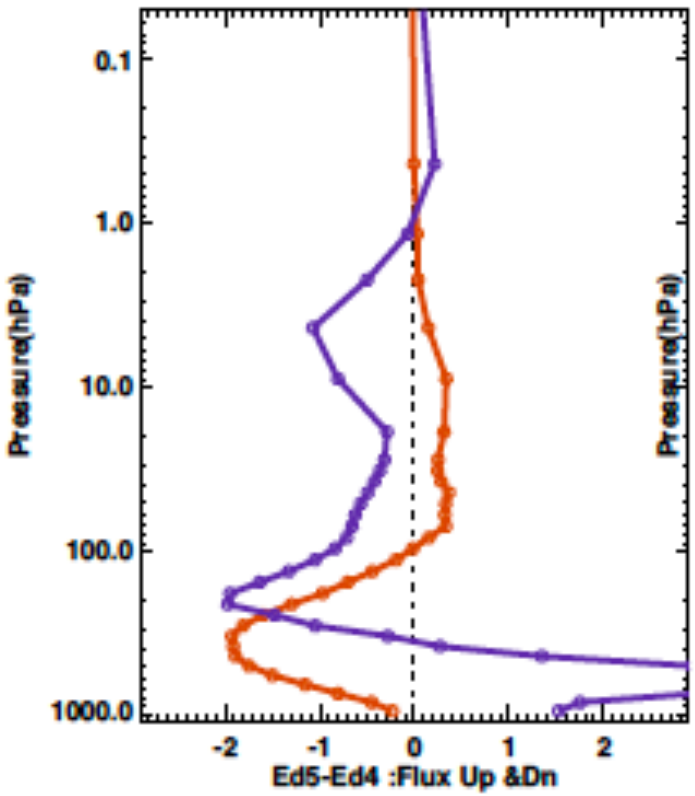
Edition 4 versus Edition 5: Clear-sky broadband Longwave

Edition 5 – Edition 4

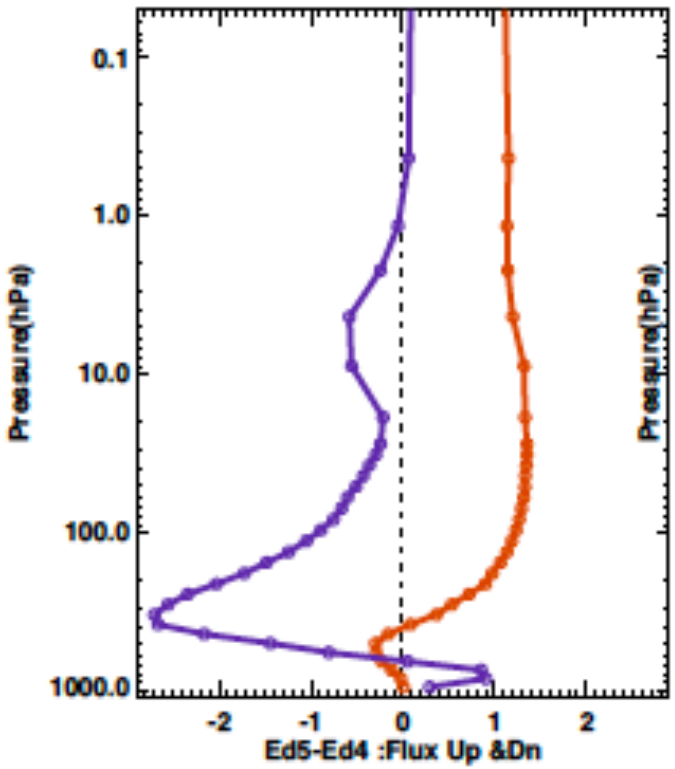
Mean of all 5 standard atmospheres



Tropical



Subarctic winter



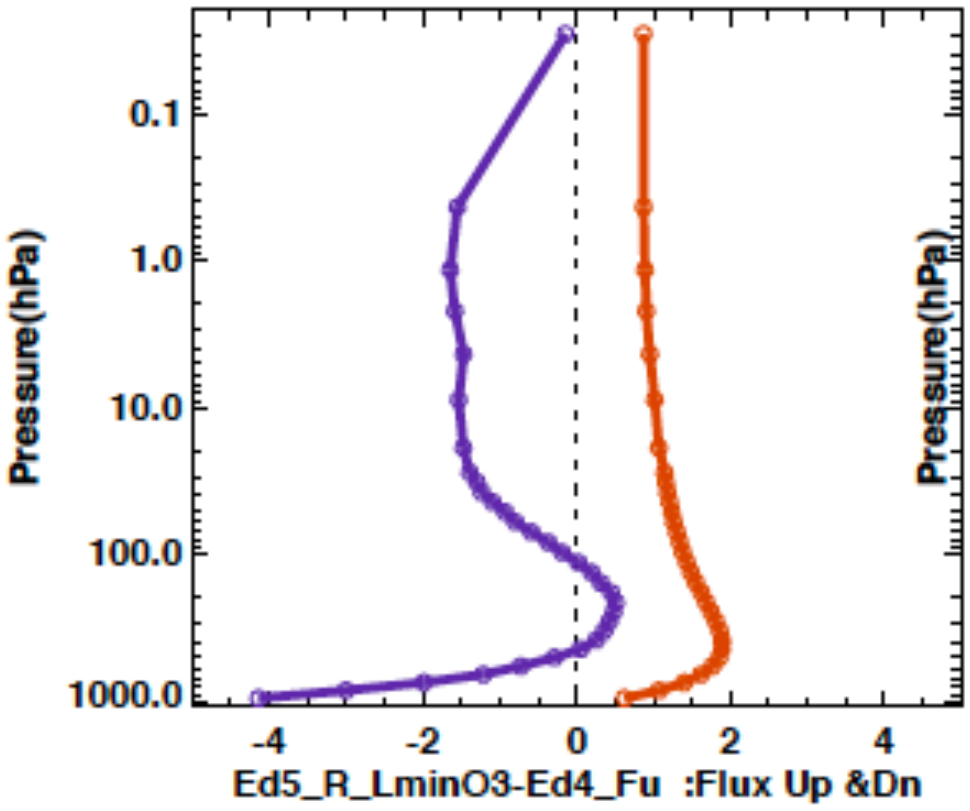
Mean Edition 5 – Edition 4 for 5 standard atmospheres upward TOA is +0.4 Wm^{-2} and downward surface is +1.0 Wm^{-2}

Upward longwave irradiance
Downward longwave irradiance

Edition 4 versus Edition 5: Clear-sky (no aerosol) broadband Shortwave

Edition 5 – Edition 4

Mean of 5 standard atmospheres and 4 solar zenith angles (0, 30, 60, and 80 degrees) with 0 surface albedo.



Mean Edition 5 – Edition 4 for 5 standard atmospheres upward TOA is +1.0 Wm^{-2} and downward surface is -4.0 Wm^{-2} (mean surface down is 660 Wm^{-2}).

Edition 5 has more absorption in the atmosphere due to water vapor.

Upward longwave irradiance
Downward longwave irradiance

Edition 5 MATCH

- Incorporate CAM 5.1 Bulk Aerosol Module physics module and aerosol package into existing MATCH MODIS/VIIRS AOD assimilation framework. 4 sea salt (SSLT) size bins will used, to replace existing MATCH SSLT scheme. Secondary Organic Carbon (SOA) is also available. Other existing MATCH species to be the same, with updated physics module (SO4, OC/BC, DUST with four size bins, VOLC). CAM modules are available at https://github.com/NCAR/CESM.
- Aerosol and chemical source inventories are to be determined, but likely to be static emissions as is currently the case for MATCH.
- Increased spatial resolution, ~ x 2 in horizontal (1 degree) and vertical (40 levels), temporal output to remain hourly.

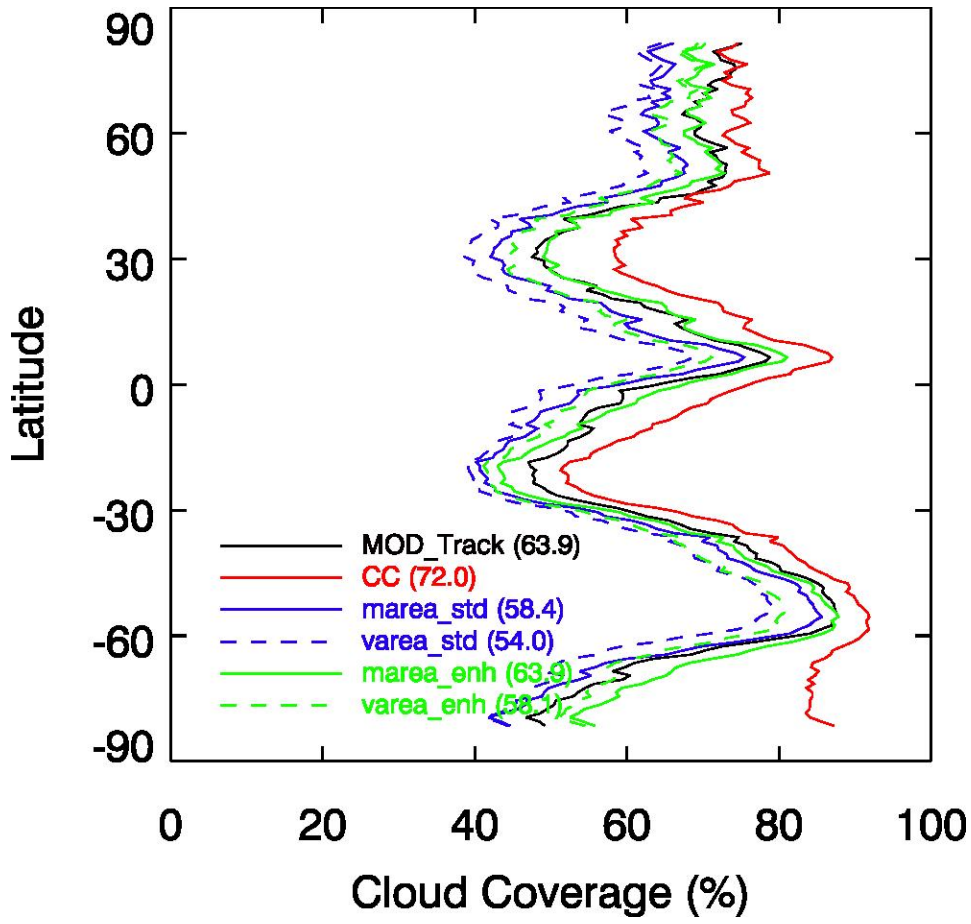
- Modeled Optical Properties of ensembles of Aerosol Particles (MOPSMAP), (Gasteiger and Wiegner, 2018, mopsmat.net) to replace Optical Properties of Clouds and Aerosols (OPAC 1998) package. Will be used to generate spectral optical properties of aerosol types for SARB radiative transfer.

C3M update

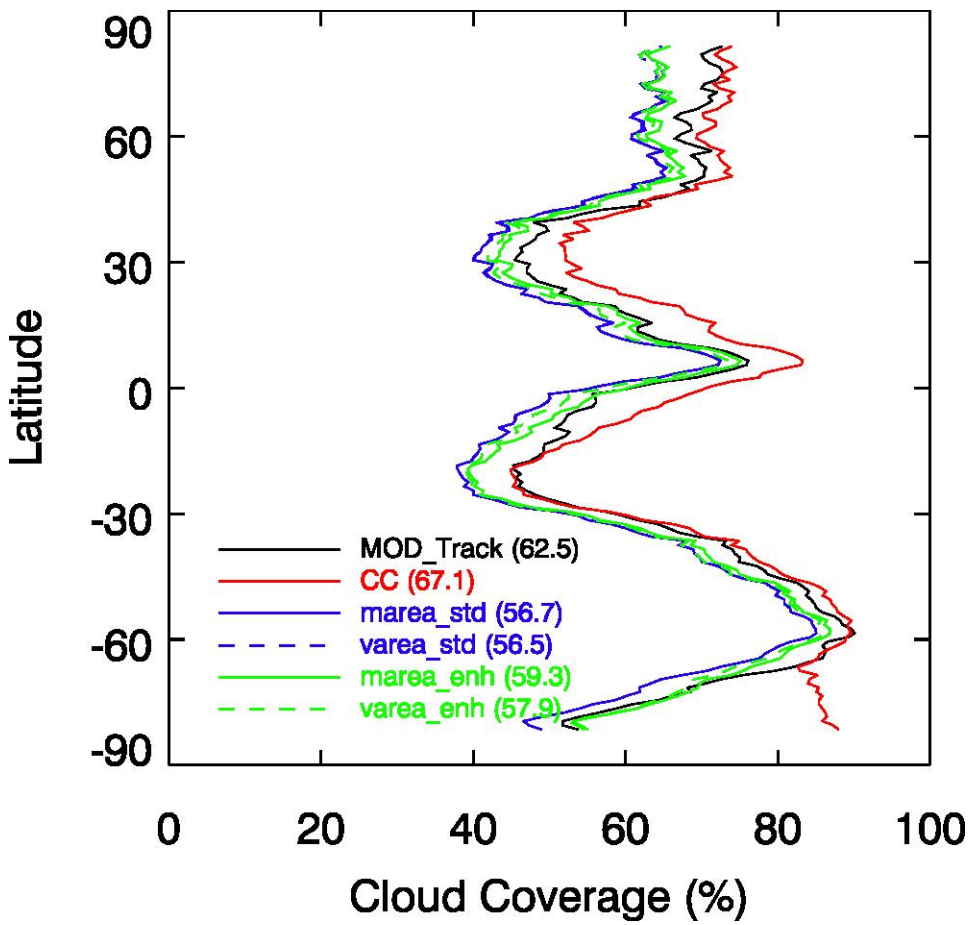
- Revising the C3M product (Edition D1) with R05 Cloudsat and version 4 CALIPSO data products.
- Resolving the cloud fraction difference between level 3 CALIPSO product and C3M (communicating with D. Winker and X. Cai).

July 2008

RelB1 (previous version)



RelD1CPV4-CSR05 (new version)



Global mean cloud cover from CALIPSO-CloudSat changes from 72% (B1) to 67% (D1).

The change is largely due to using single CALIPSO shots for water clouds below 4 km.

MOD_Track: MODIS cloud fraction over the CloudSat-CALIPSO (CC) track from SSFB dataset

CC: Cloud fraction according to CloudSat-CloudSat (sum of 16 cloud group areas, no screening of clouds)

marea_std: MODIS cloud coverage within the 16 CC groups when the standard algorithm is used

varea_std: MODIS cloud coverage that has valid MODIS cloud parameters within the 16 CC groups when the standard algorithm is used

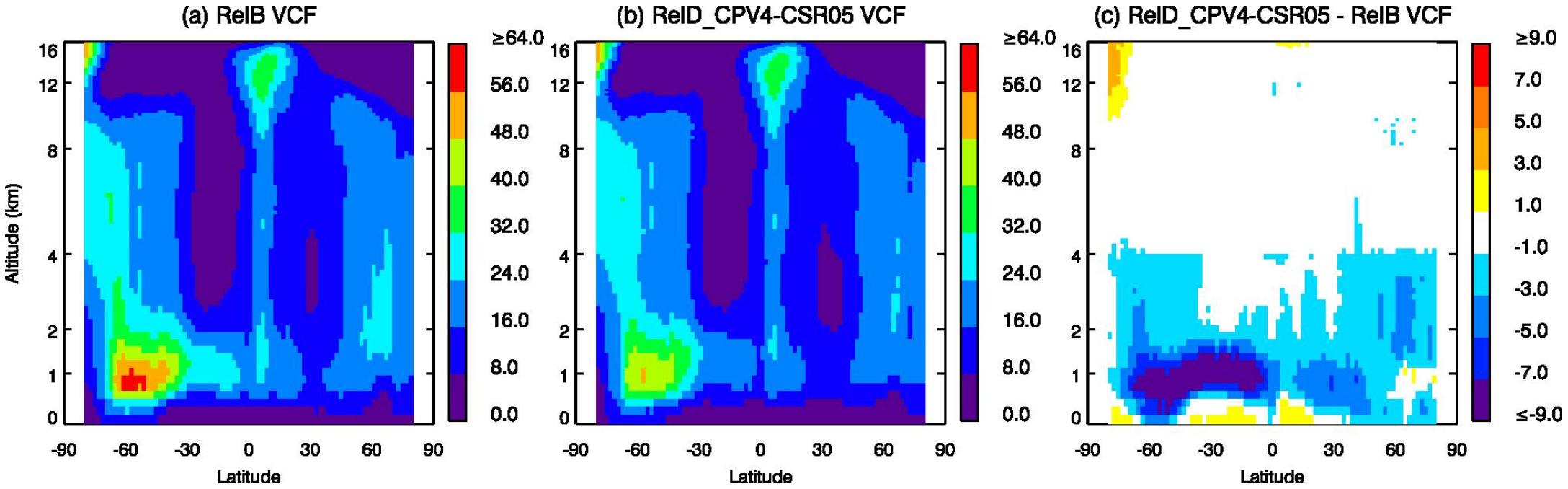
marea_enh: MODIS cloud coverage within the 16 CC groups when the enhanced algorithm is used

varea_enh: MODIS cloud coverage that has valid MODIS cloud parameters within the 16 CC groups when the enhanced algorithm is used

Cloud Volume Profiles in July 2008 (Day+Night)

CCCM Cloud Volume Profile Obtained at 160 m Vertical Resolution

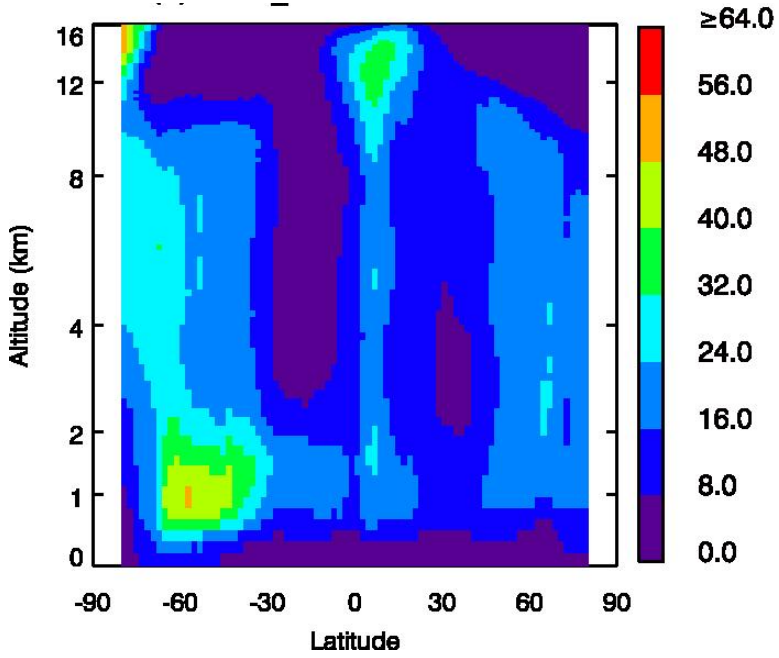
Previous version (B1) | New version (D1) | D1 – B1



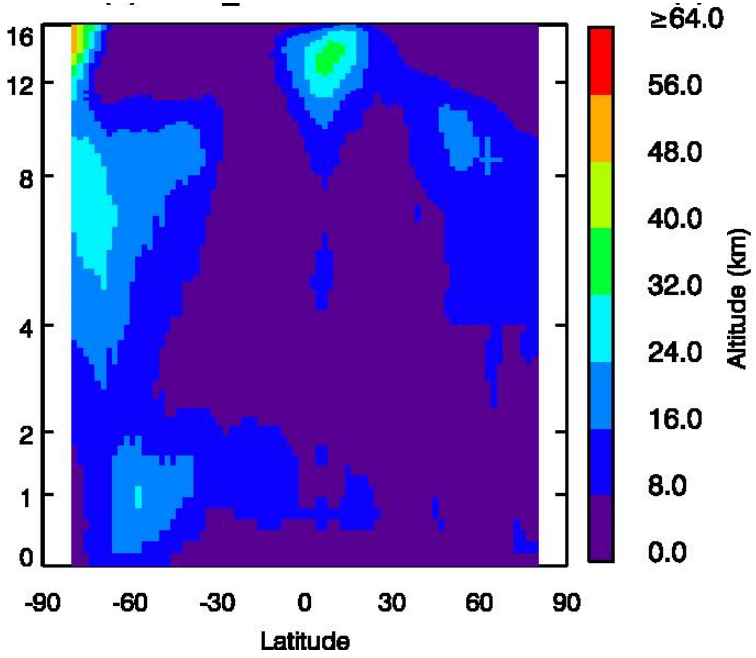
Cloud Volume Profiles in July 2008 (Day+Night)

C3M Rel D (new version)

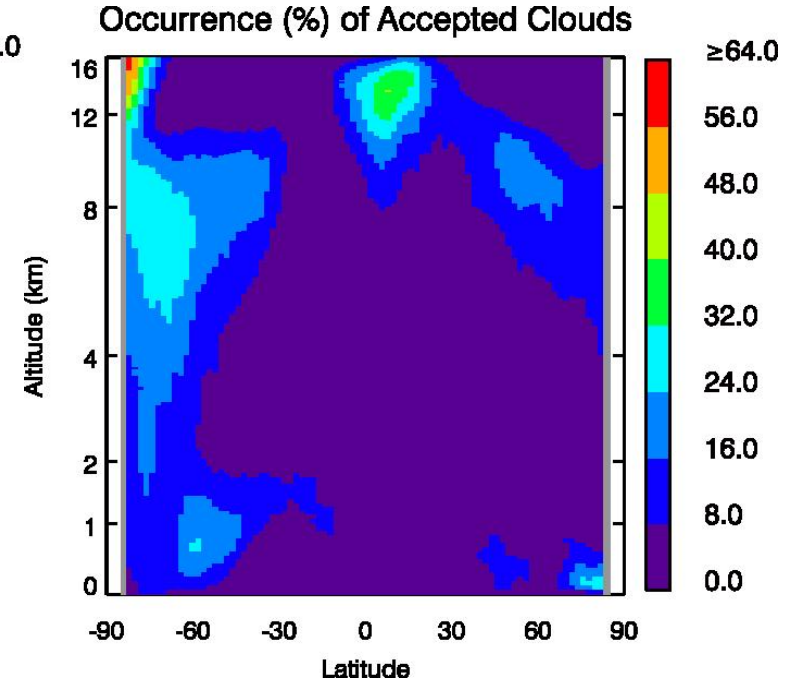
CloudSat-CALIPSO



CALPSO Only Clouds



CALIPSO Level 3 product

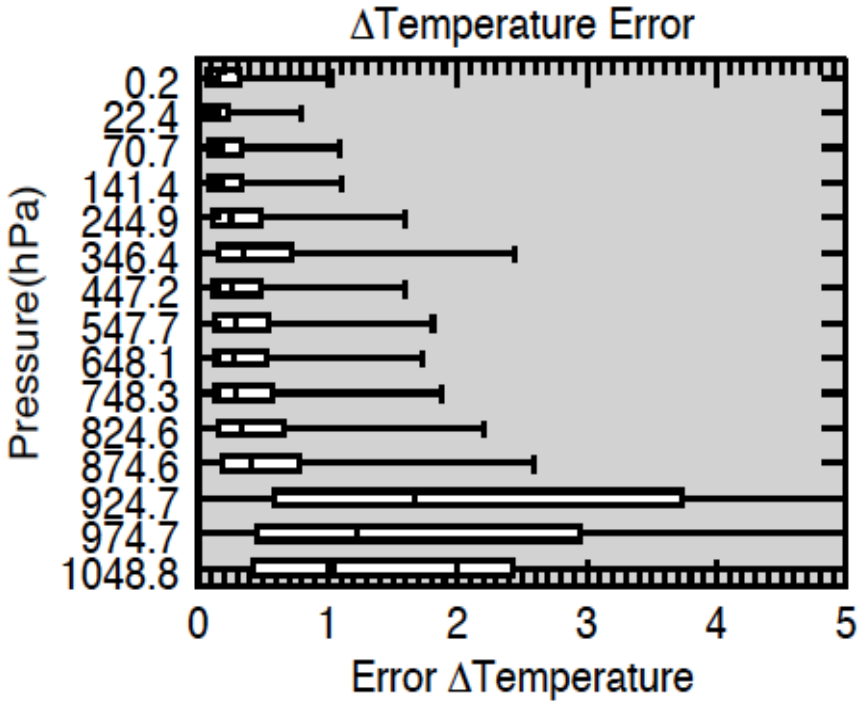


Cloud_Accepted_Samples/
(Cloud_Samples +
Cloud_Free_Samples)
x 100%

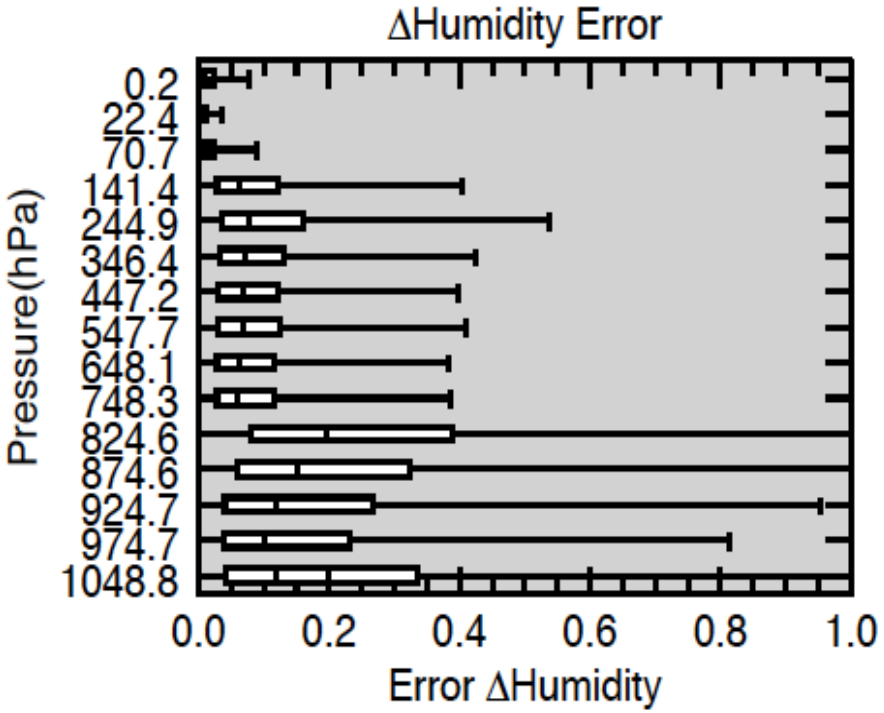
LW fingerprinting

- An algorithm using AIRS spectral radiance to correct monthly mean temperature and specific humidity in upper troposphere is under development.

Absolute value of temperature error



Absolute value of specific humidity retrieval error



Publications

- Ham, S.-H., S. Kato, and F. G. Rose, 2019: Examining biases in diurnally-integrated shortwave irradiances dur to two- and four-stream approximations in cloudy atmosphere, J. Atmos. Sci. 72, 551-581, DOI:10.1175/JAS-D-19-0215.1.
- Kato, S. and F. G. Rose, 2019: Global and regional entropy production by radiation estimated from satellite observations, *J. Climate*, 33, 2985-3000, DOI: 10.1175/JCLI-D-19-0596.1
- Thorsen, T. J., R. A. Ferrare, S. Kato, and D. M. Winker, 2020: Aerosol direct radiative effect sensitivity analysis, *J. Climate*, in press.
- Pan, F., S. Kato, F. G. Rose, A. Radkevich, and X. Liu, 2019: An algorithm to derive temperature and humidity profile changes from highly spatially and temporally averaged spectral radiance differences, submitted to *J. Atmos. Ocean. Technol*.
- Kato, S., N. G. Loeb, D. A. Rutan, and F. G. Rose, 2019: Effects of electromagnetic wave interference on observations of Earth radiation budget, submitted to *J. Quant. Spec. Radiant. Trans.*
- Kato1, S., D A. Rutan, F. G. Rose, T. E. Caldwell, S.-H. Ham, A. Radkevich, T. J. Thorsen, A. Viudez-mora, D. Fillmore, and X. Huang, 2020: Uncertainty in satellite-derived surface irradiances and challenges in producing surface radiation budget climate data record, *Remote Sensing*, in preparation.

Summary and near future work

- EBAF
  - Surface irradiance variability agrees well with observed variability, but we need to work on consistency of cloud properties from different geostationary satellites.
  - GOES-17 (work with cloud and TISA working groups)
  - Investigate albedo trend might be caused by MATCH aerosols over deserts
- Edition 5
  - the CERES radiative transfer code
  - MATCH
  - CCCM (work with the CALIPSO group)
  - LW fingerprinting (work with the Huang's group)
  - MOA