

Surface Atmosphere Radiation Budget (SARB) working group update

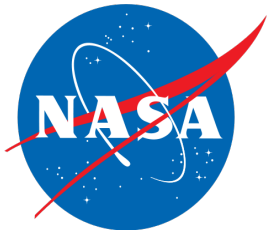
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²Science System & Applications Inc.

³NCAR

⁴University of Michigan



CERES Science Team Meeting
April 28-30, 2020



Outline of this talk

- CERES radiative transfer code update
- 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
- C3M revision.
- Edition 5 MATCH
- Longwave fingerprinting status
- Publications

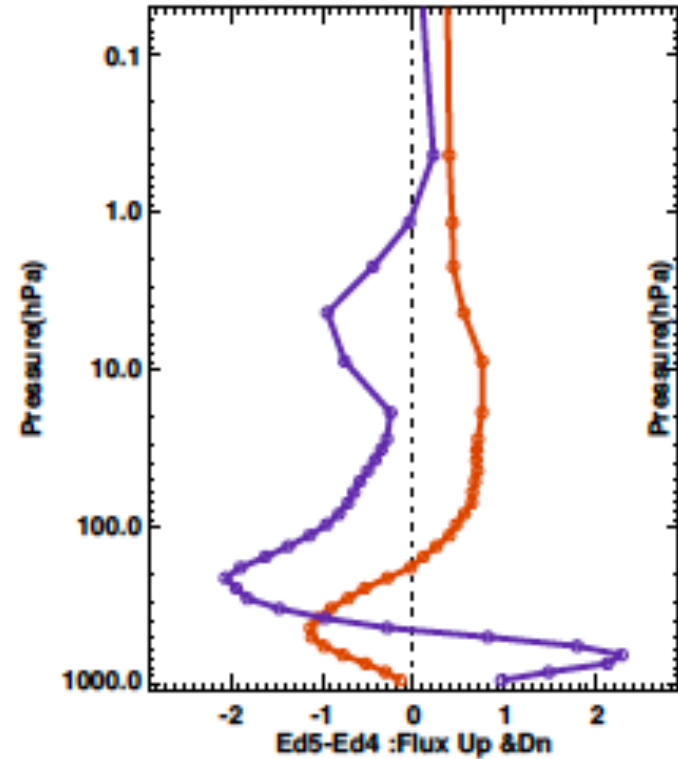
Edition 5 CERES radiative transfer code

- 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>

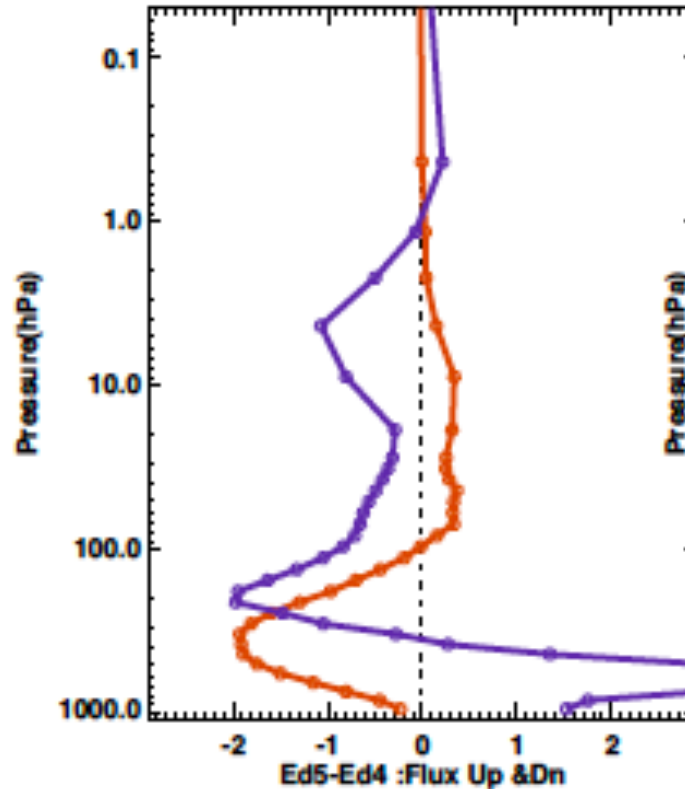
Edition 4 versus Edition 5: Clear-sky broadband Longwave

Edition 5 – Edition 4

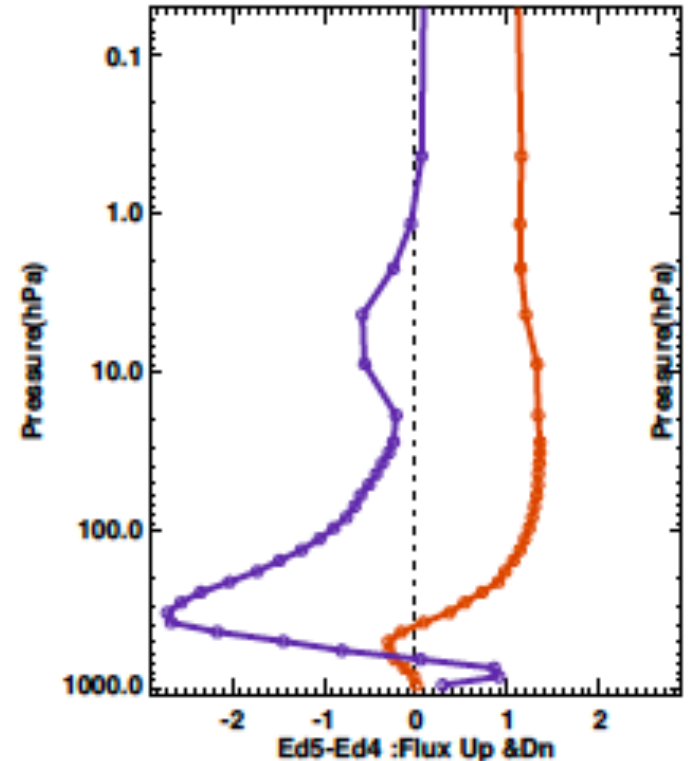
Mean of all 5 standard atmospheres



Tropical



Subarctic winter



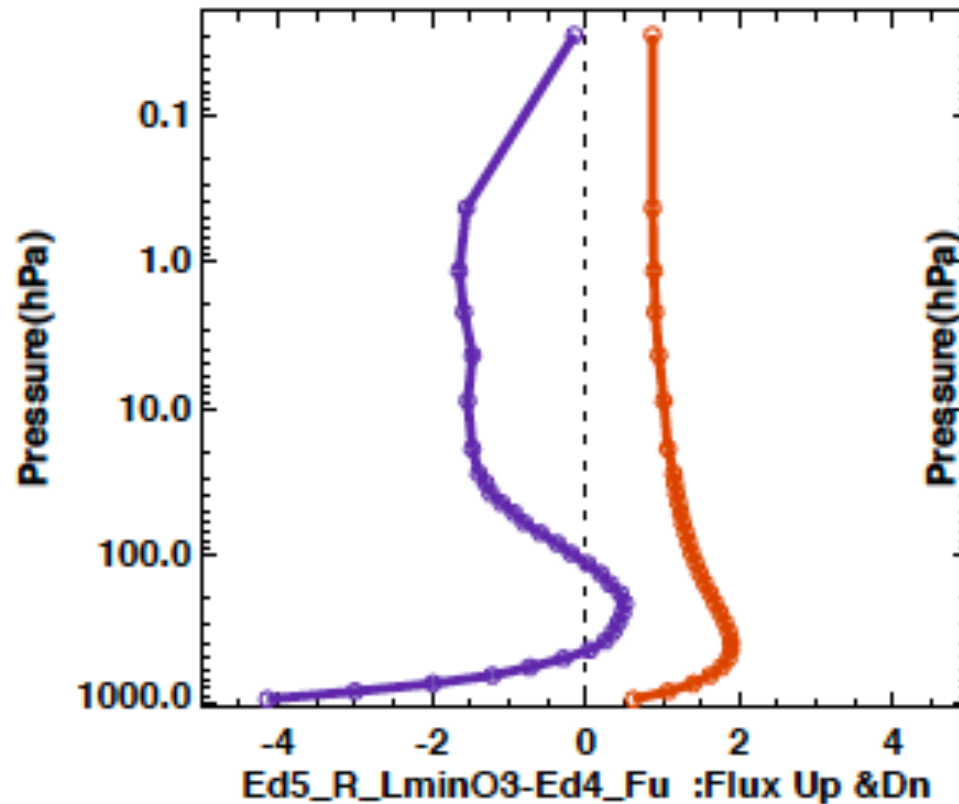
Mean Edition 5 – Edition 4 for 5 standard atmospheres upward TOA is $+0.4 \text{ Wm}^{-2}$ and downward surface is $+1.0 \text{ Wm}^{-2}$

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.



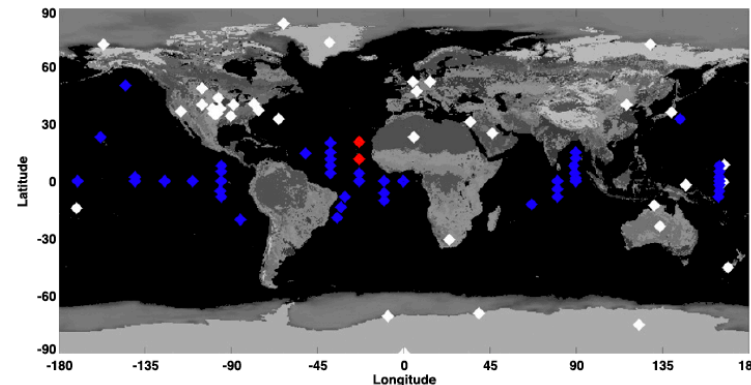
Mean Edition 5 – Edition 4 for 5 standard atmospheres upward TOA is $+1.0 \text{ Wm}^{-2}$ and downward surface is -4.0 Wm^{-2} (mean surface down is 660 Wm^{-2}).

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

Upward longwave irradiance
Downward longwave irradiance

Validation of downward surface irradiance variability using surface observations

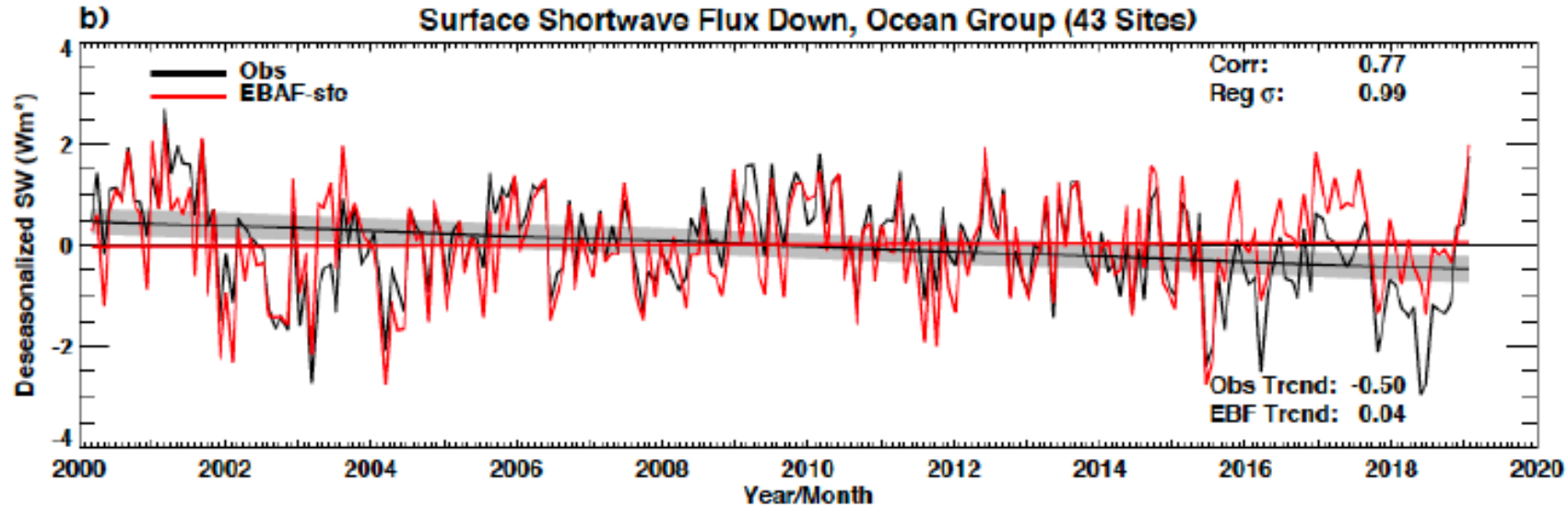
- Method to generate anomaly time series with surface observations.
 - Deseasonalize observed downward shortwave or longwave irradiances by site by subtracting climatological monthly mean irradiances.
 - Divide the anomaly time series at each site by their standard deviation.
 - For a given month, add 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.



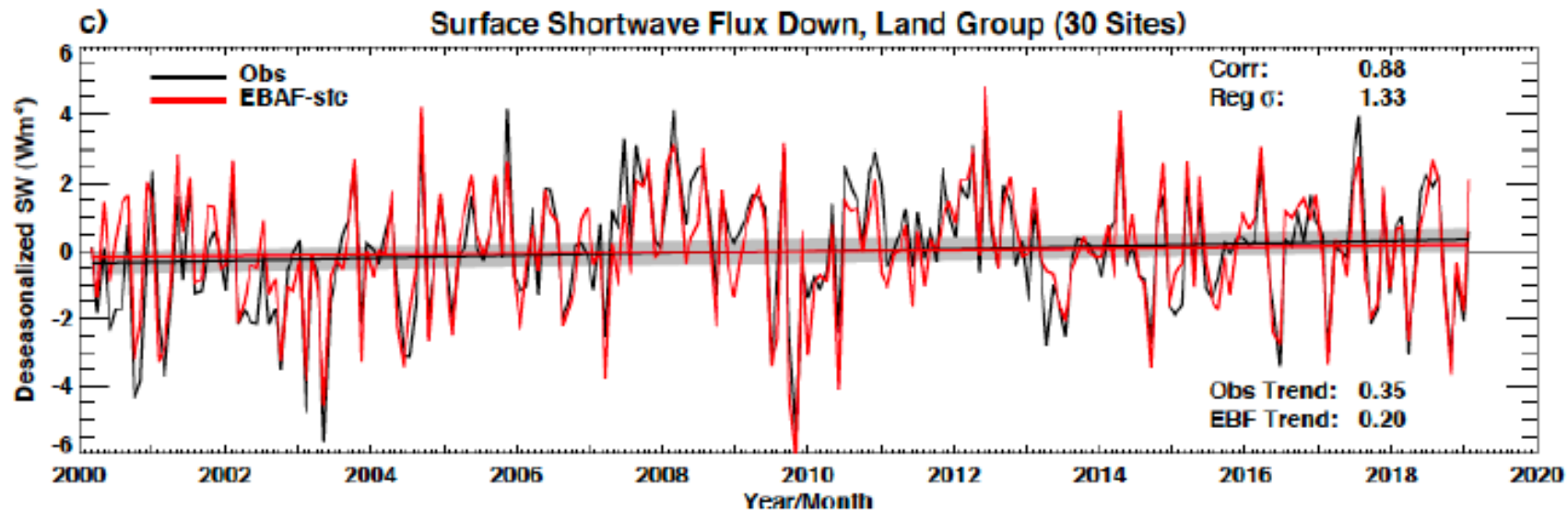
43 buoys and 30 land sites

Deseasonalized downward shortwave anomalies land and ocean

Ocean



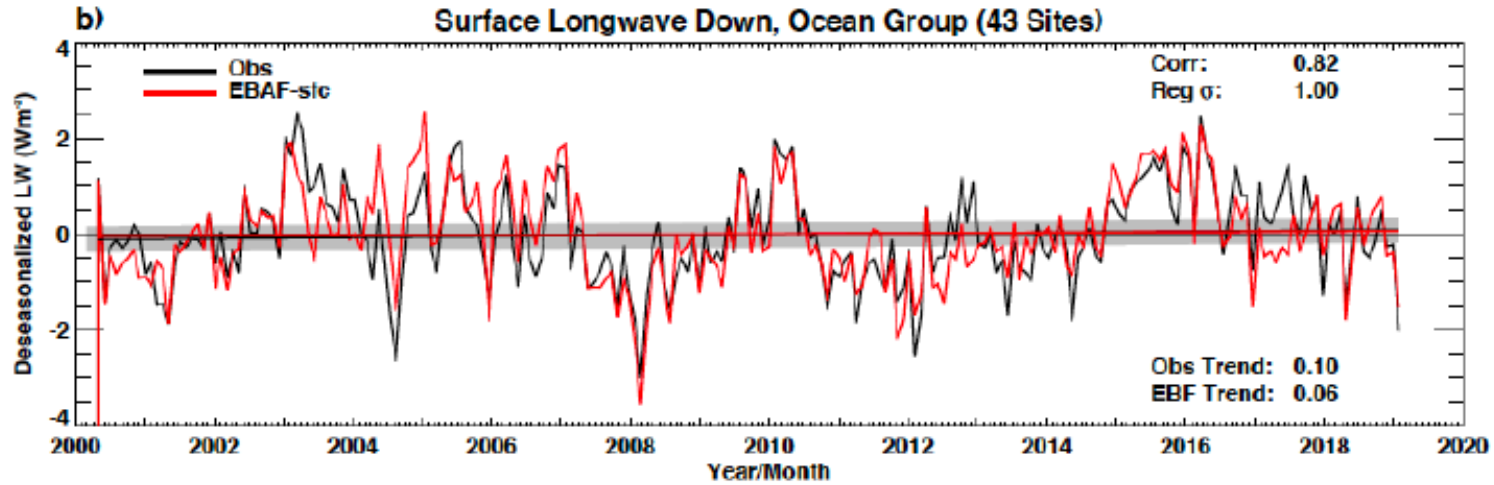
Land



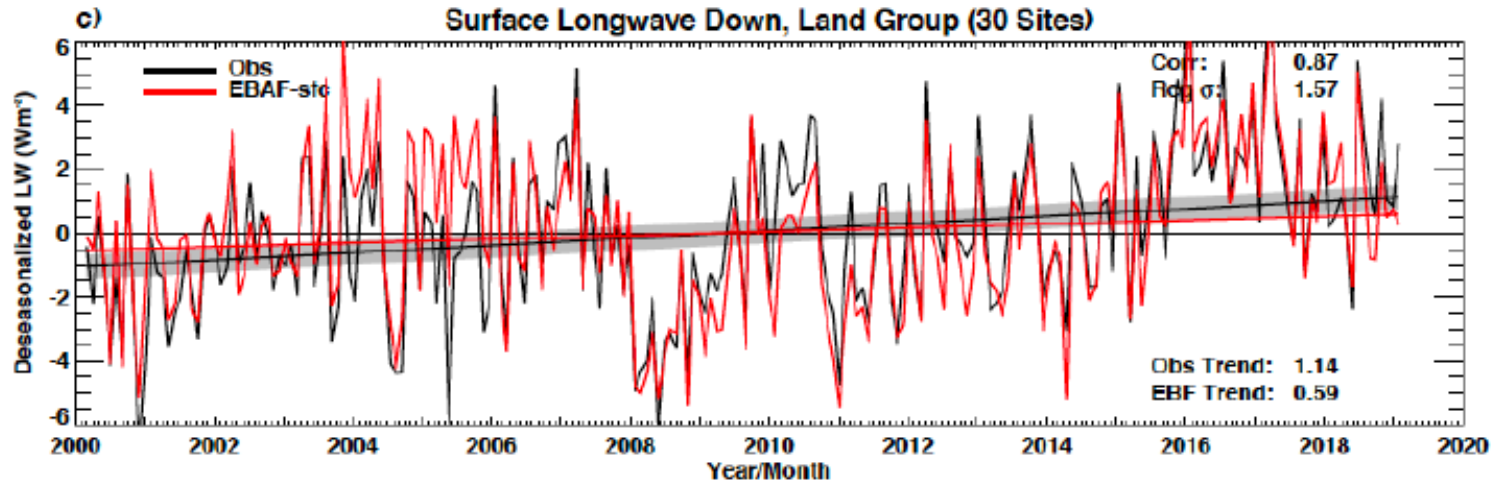
	Correlation coefficient
Ocean	0.77
Land	0.88

Deseasonalized downward longwave anomalies land and ocean

Ocean



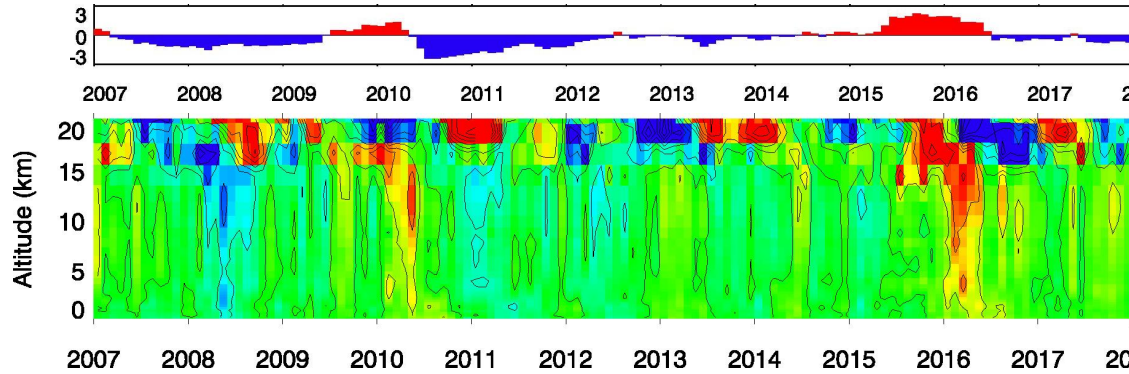
Land



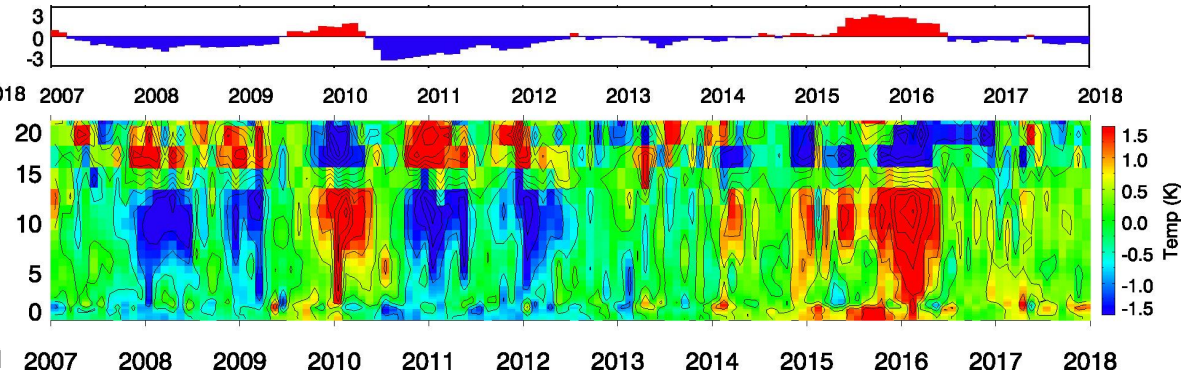
	Correlation coefficient
Ocean	0.82
land	0.87

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

Western Pacific (90°E–150°E, 15°S–15°N)

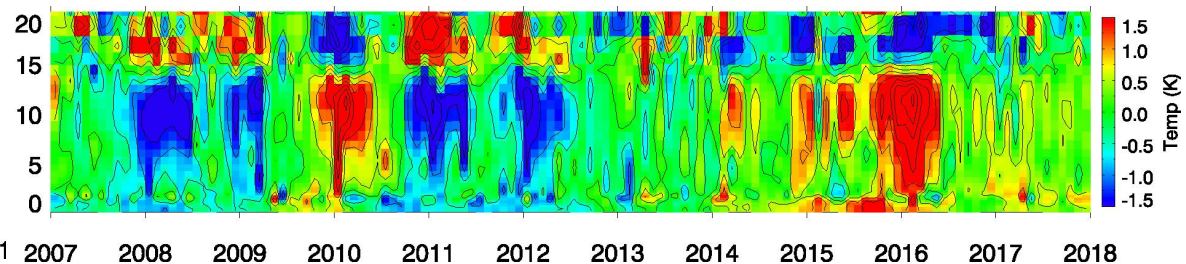
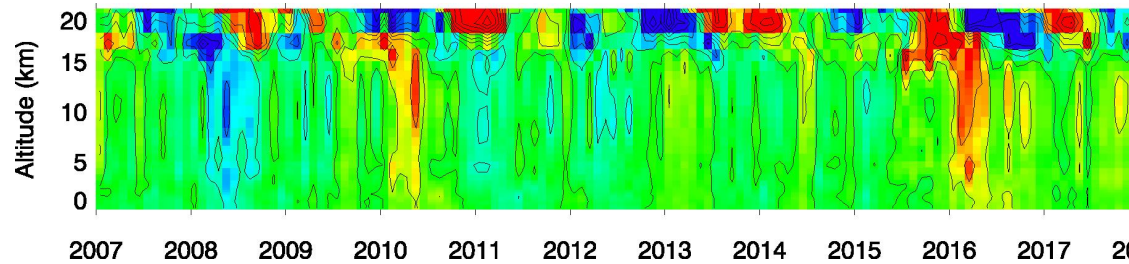
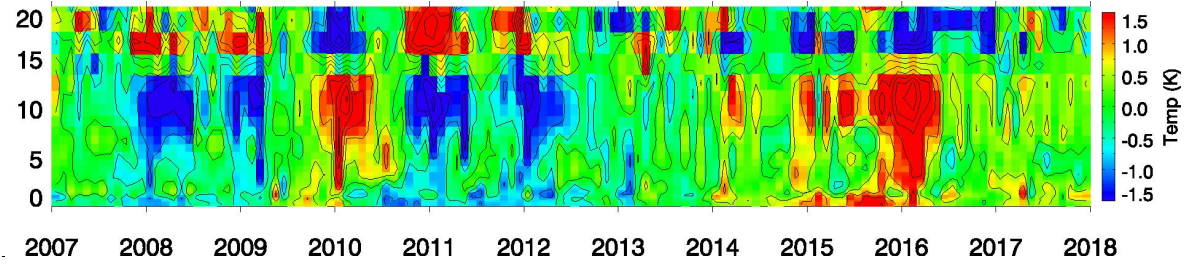
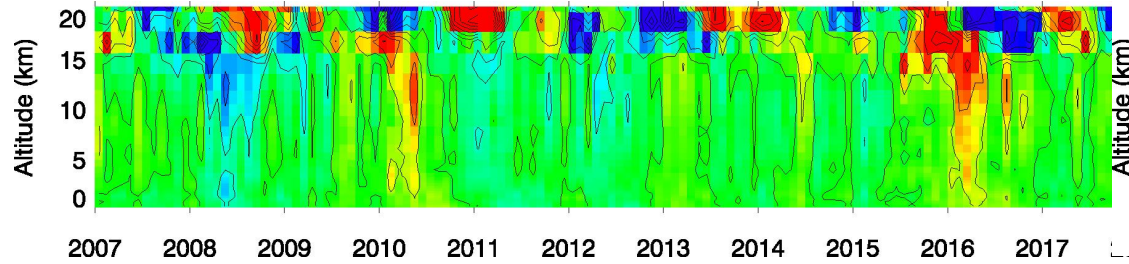


Eastern Pacific (150°W–120°W, EQ–30°N)



MERRA2

GEOS-5.4.1

ERA5

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

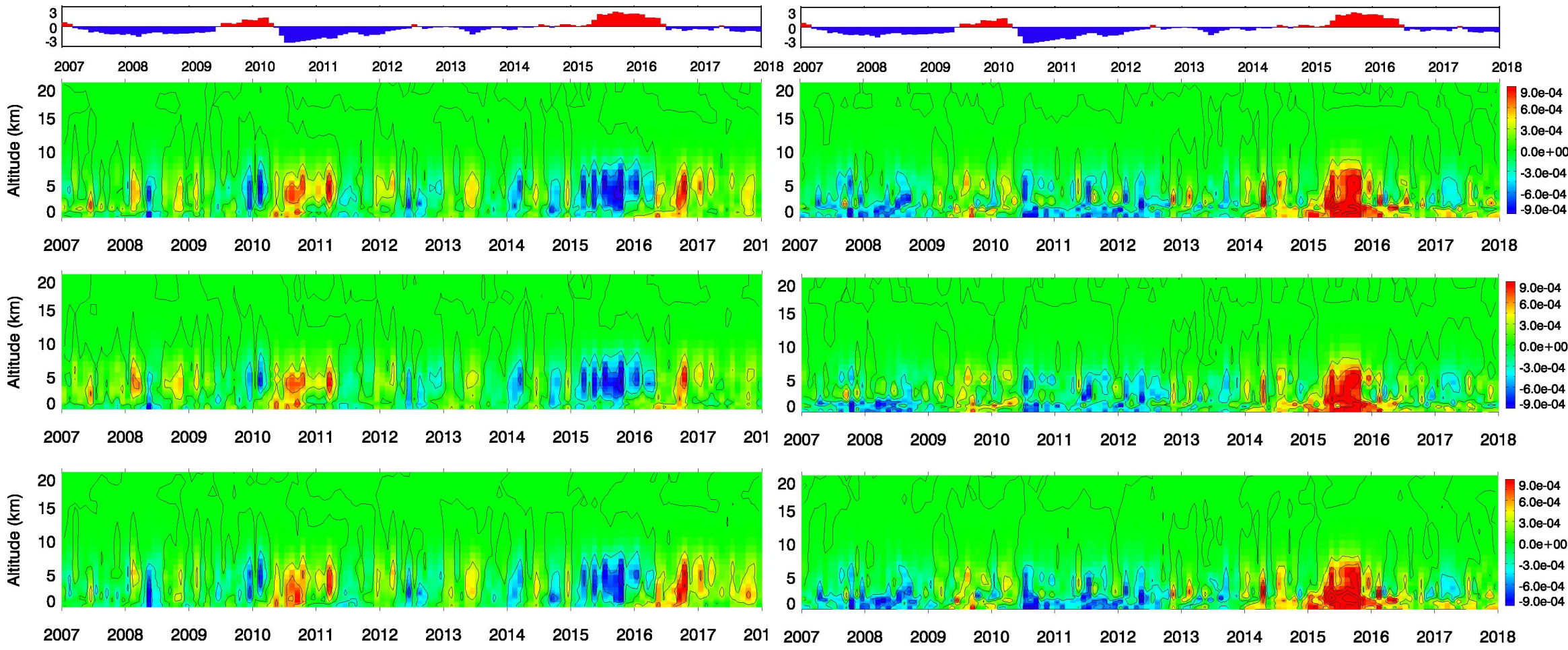
Western Pacific (90°E–150°E, 15°S–15°N)

Eastern Pacific (150°W–120°W, EQ–30°N)

MERRA2

GEOS-5.4.1

ERA5



Uncertainty in the slope in Wm⁻² decade⁻¹

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

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

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

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

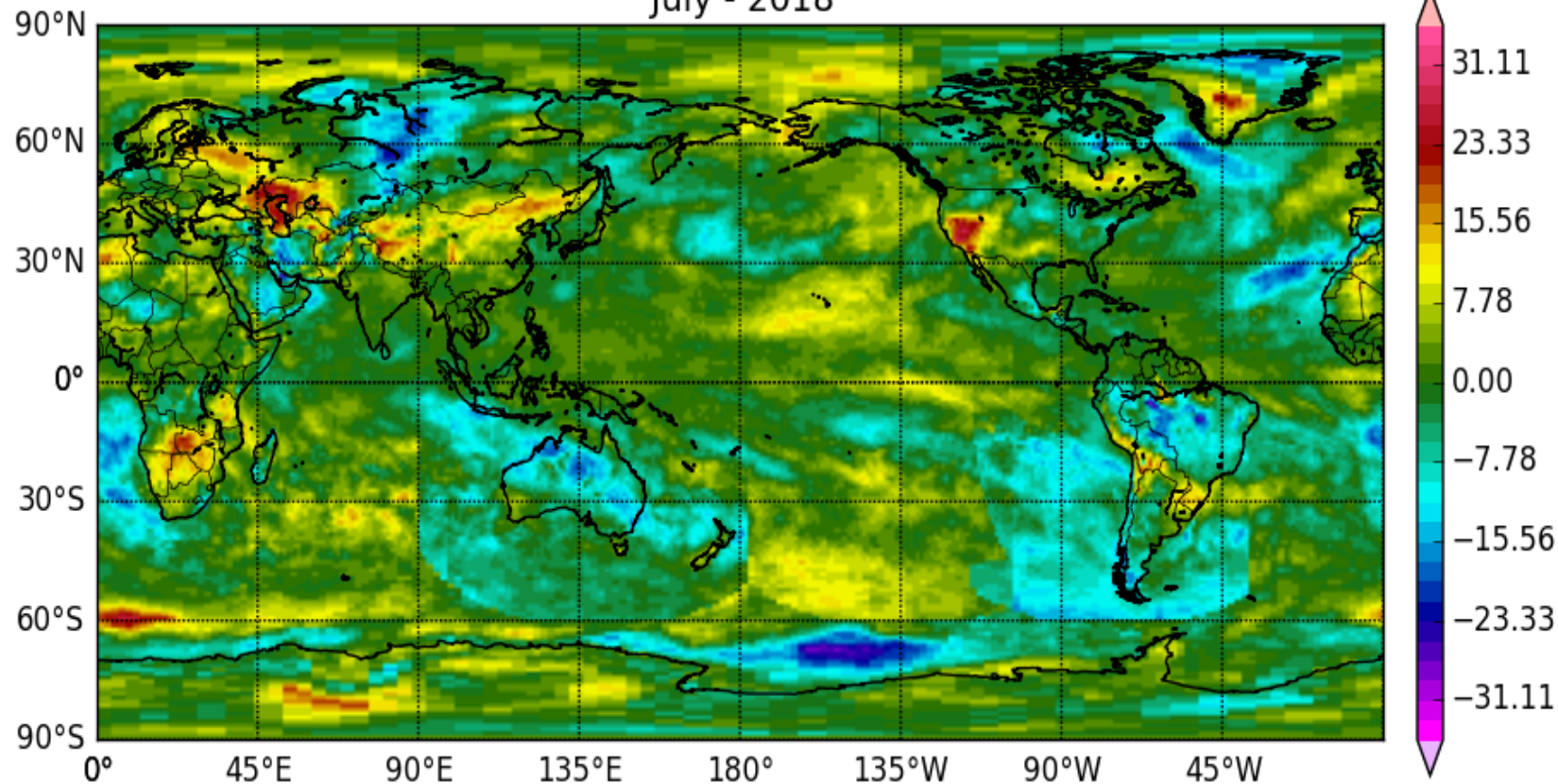
Downward longwave issue



CERES_EBAF_Ed4.1

Surface Longwave Flux Down - All-Sky ** Anomaly Field ** (W m^{-2})

July - 2018



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

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

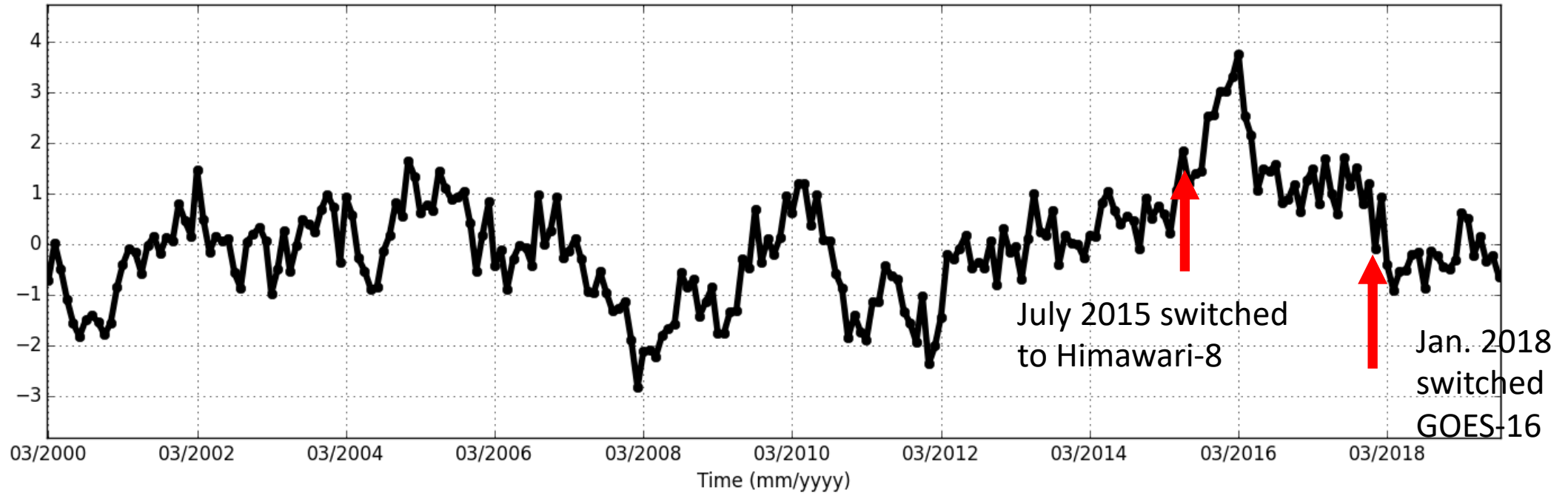
GOES-16
replaced GOES-14 on
January 1 2018.

Ed4.1 EBAF global monthly surface downward longwave irradiance anomalies



EBAF41/CERES_EBAF_Ed4.1

Area Average Time Series Surface Longwave Flux Down - All-Sky (deseasonalized) (W m^{-2})
03/2000 to 09/2019

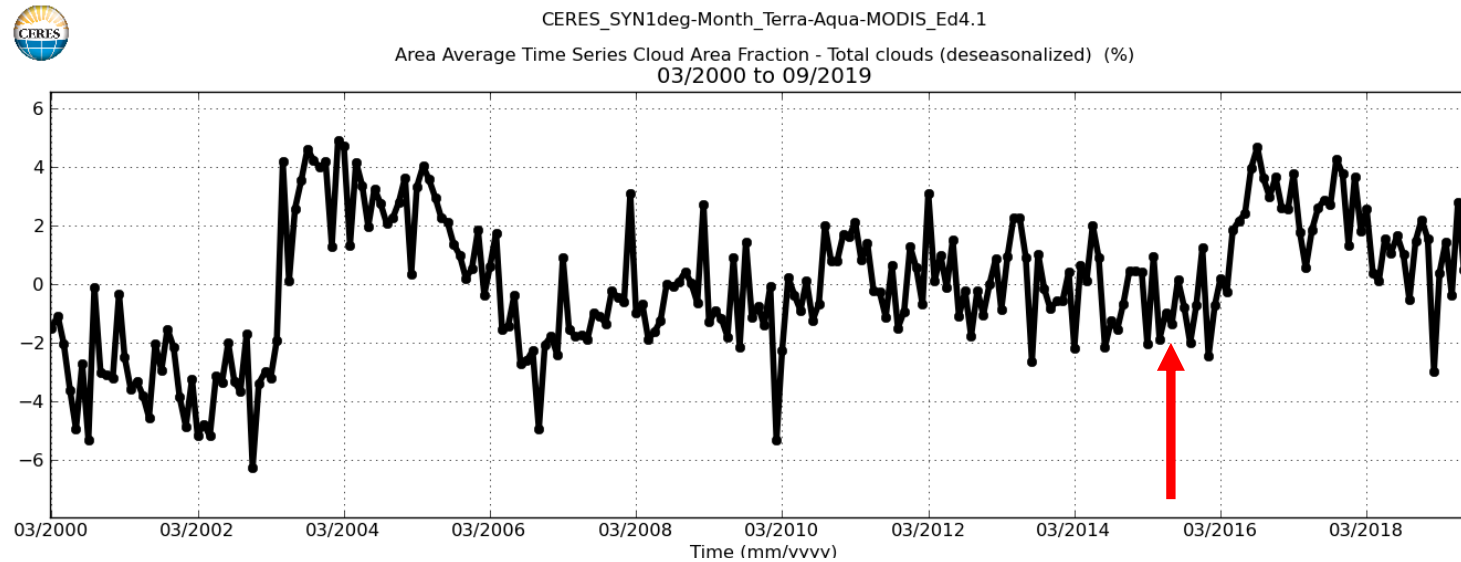


Selected Region: [-90,0 to 90,360]

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

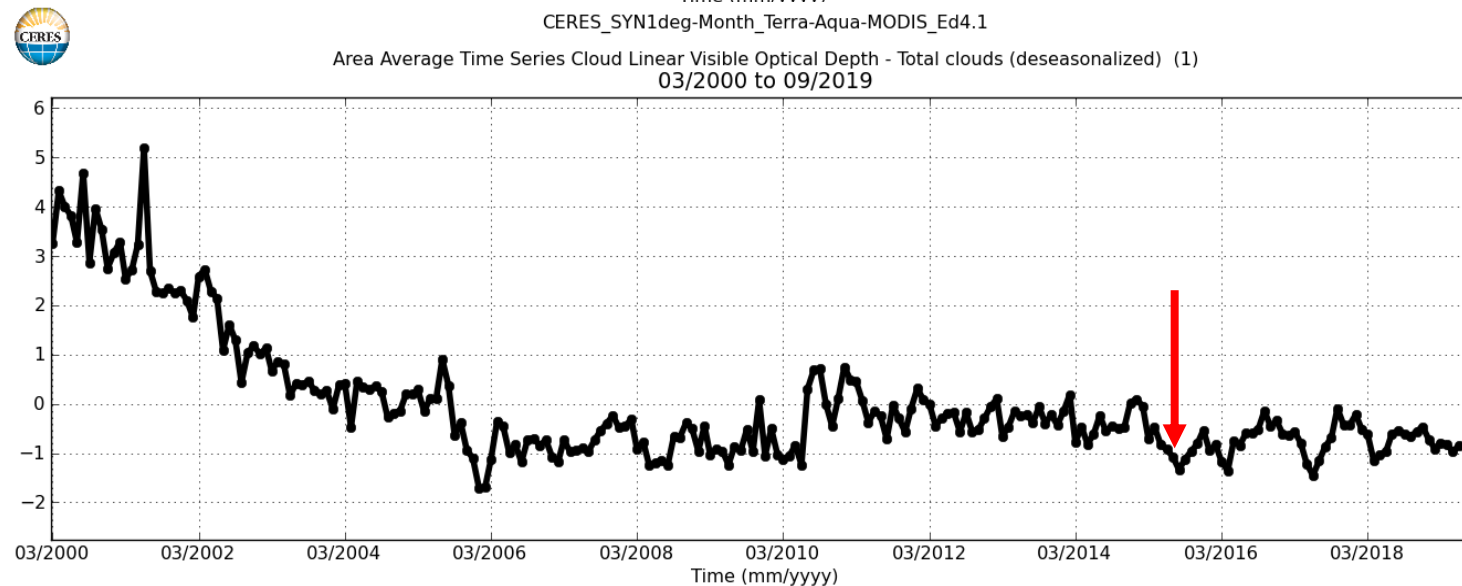
Cloud properties over Western Pacific

Cloud
fraction



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

Cloud
optical
thickness

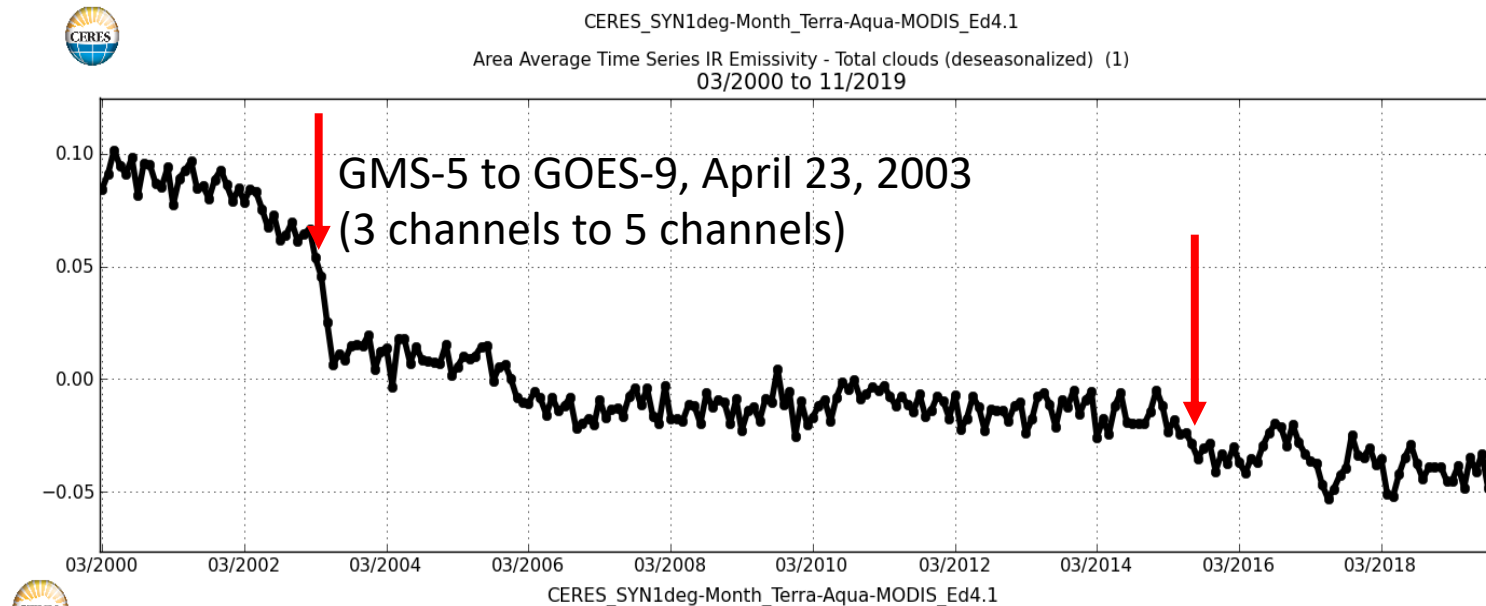


Selected Region: [-60,90 to 60,180]

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

Cloud Emissivity and effective pressure

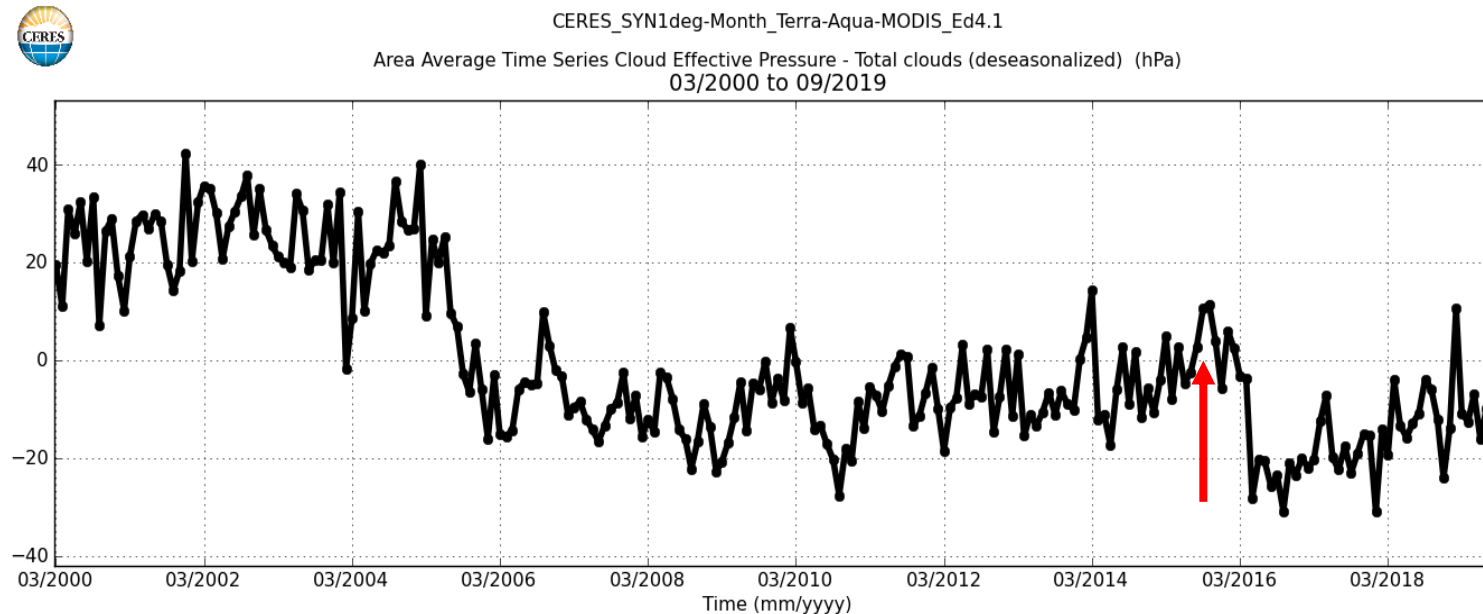
Emissivity



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

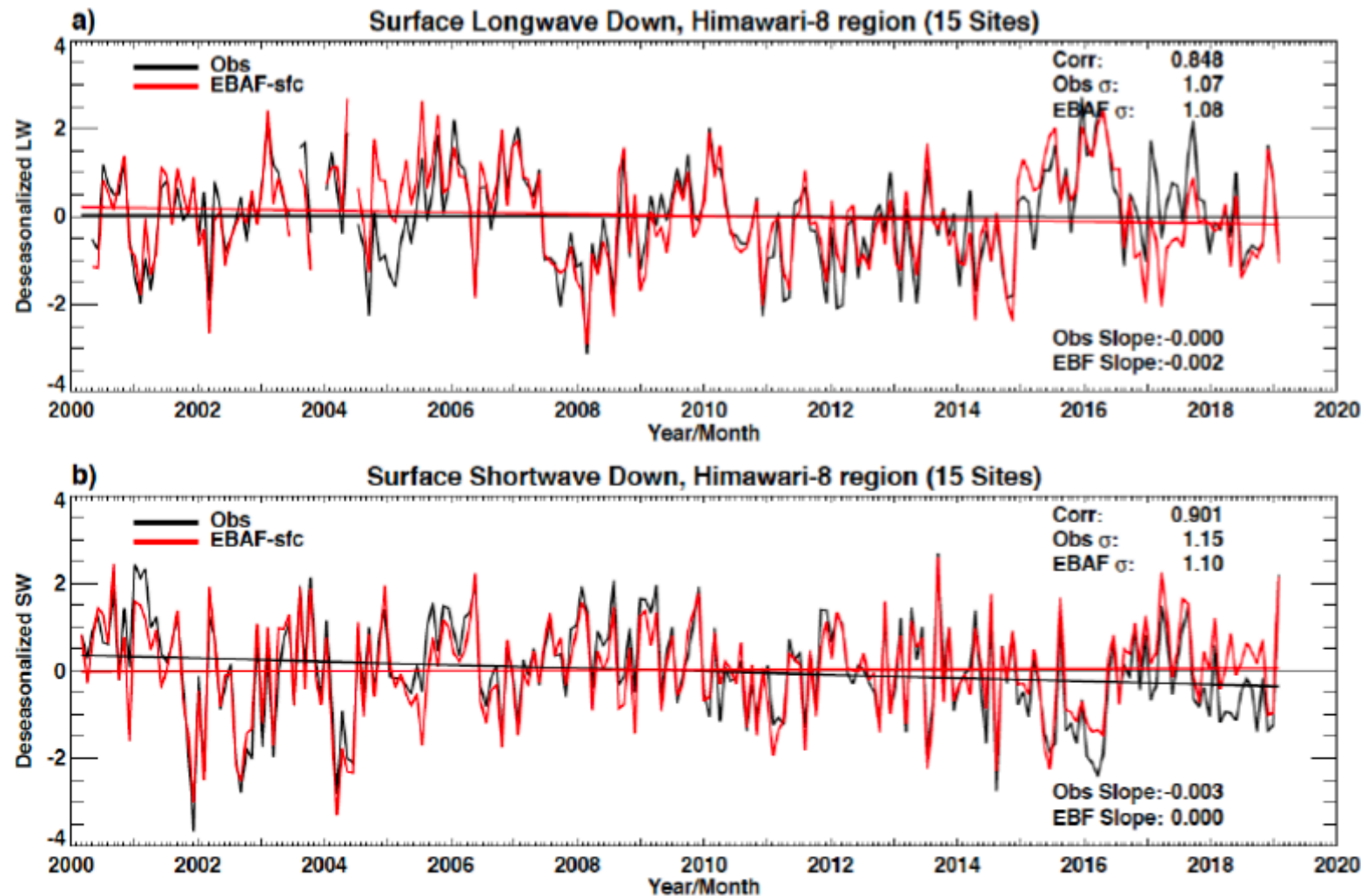
The effect of GMS-5 to GOES-9 probably exists but hard to quantify

Cloud effective pressure



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.

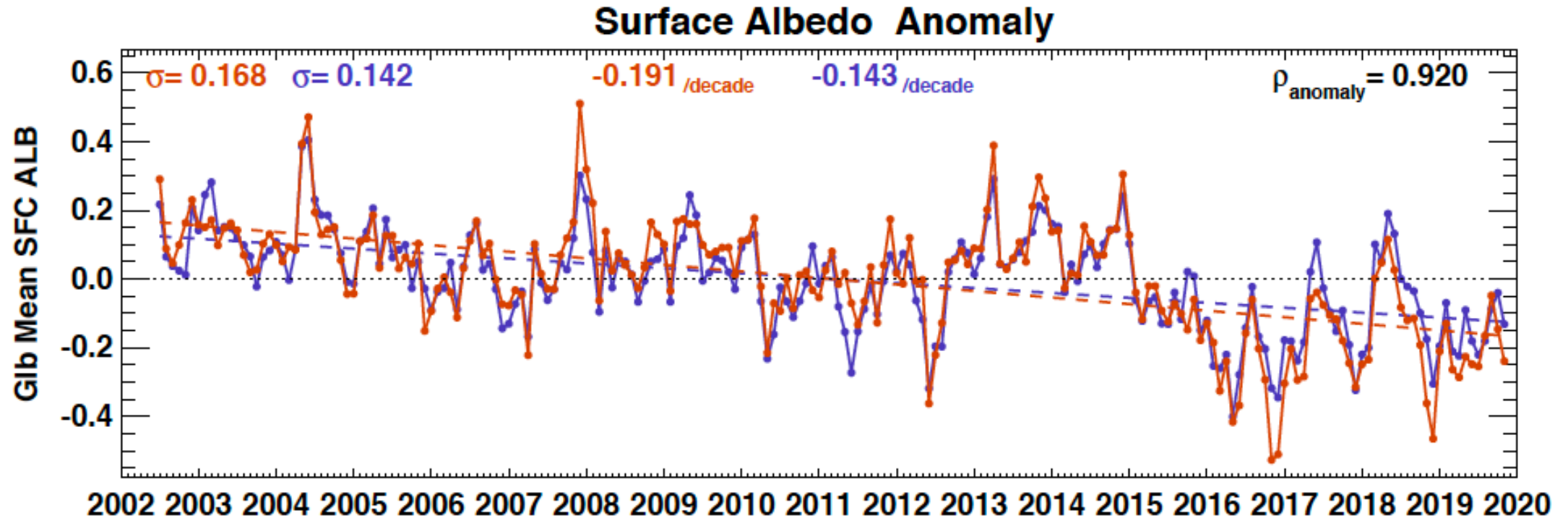
2) the systematic differences occur predominately in mid-latitude to 60S over ocean where surface sites are absent.

Surface albedo trend

Surface albedo time series (not averaging albedo)

Clear-sky

All-sky



Global mean surface (SW down / SW up)

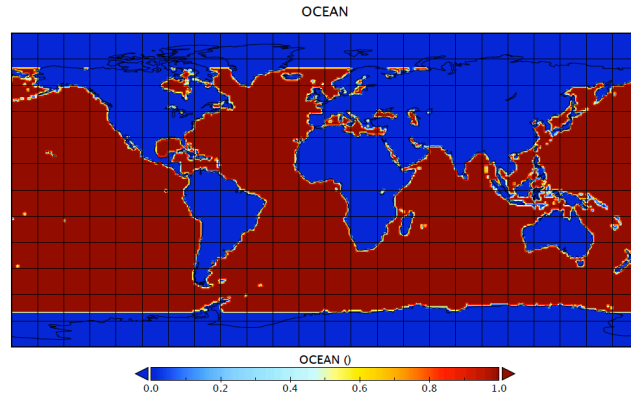
Albedo range 0 to 100.

Global mean downward shortwave irradiance = 187 Wm^{-2}

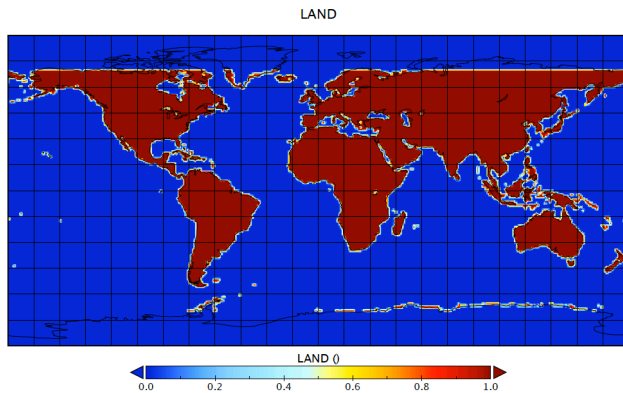
$-0.191 \text{ decade}^{-1}$ is $0.36 \text{ Wm}^{-2} \text{ decade}^{-1}$

Albedo trend

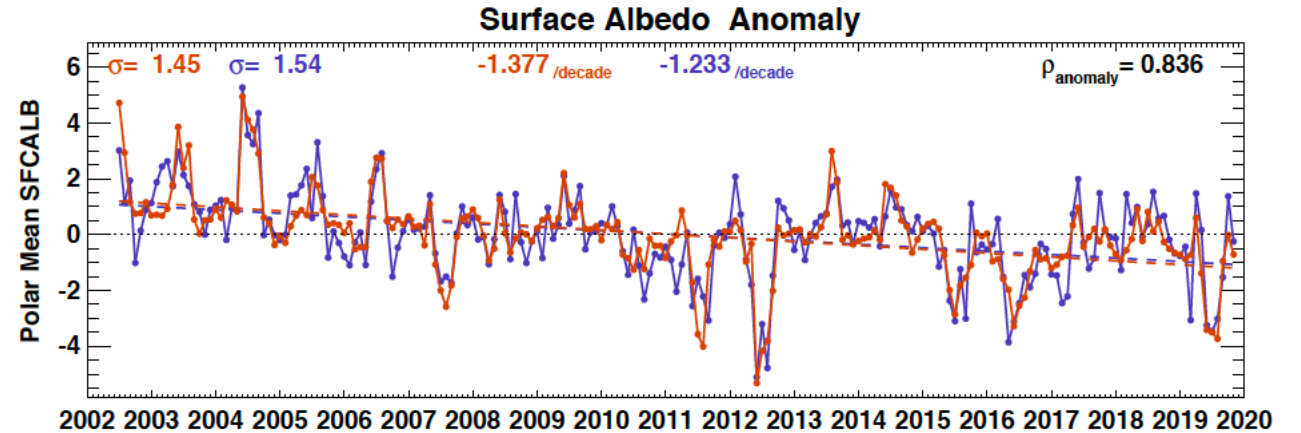
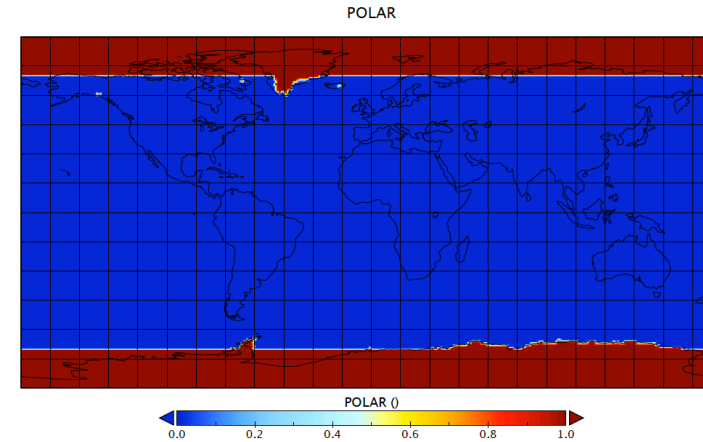
Ocean



Land



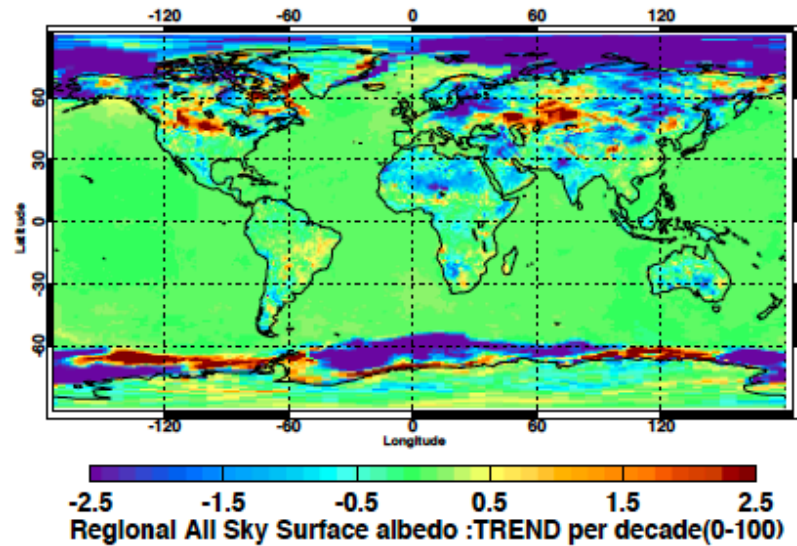
Polar



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

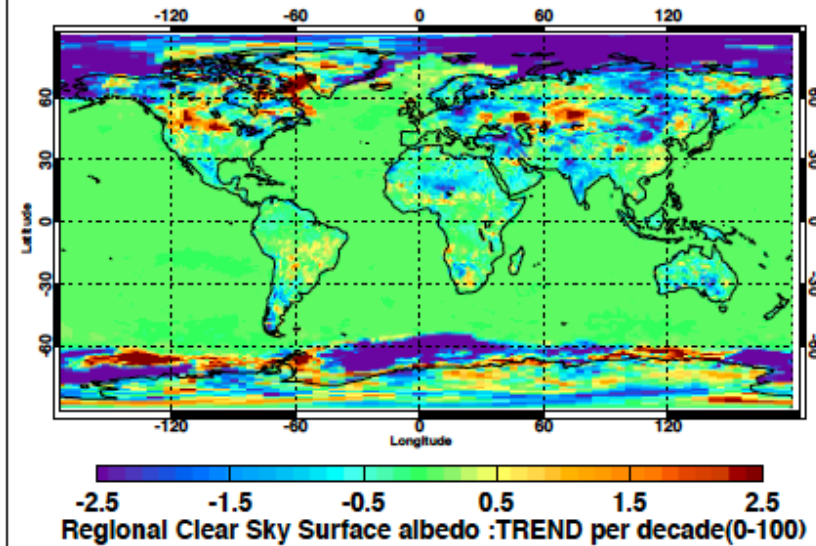


N= 64800

Glb mean(sd): -0.237 (1.72)

Mn/Mx: -13.81/ 10.34

Clear-sky

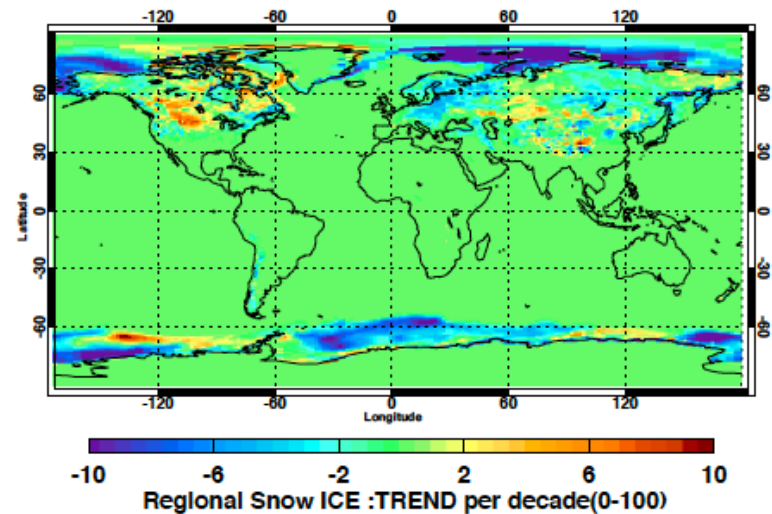


N= 64800

Glb mean(sd): -0.236 (1.64)

Mn/Mx: -12.43/ 10.32

Snow
and sea
ice
trend



N= 64800

Glb mean(sd): -0.344 (2.48)

Mn/Mx: -24.45/ 11.17

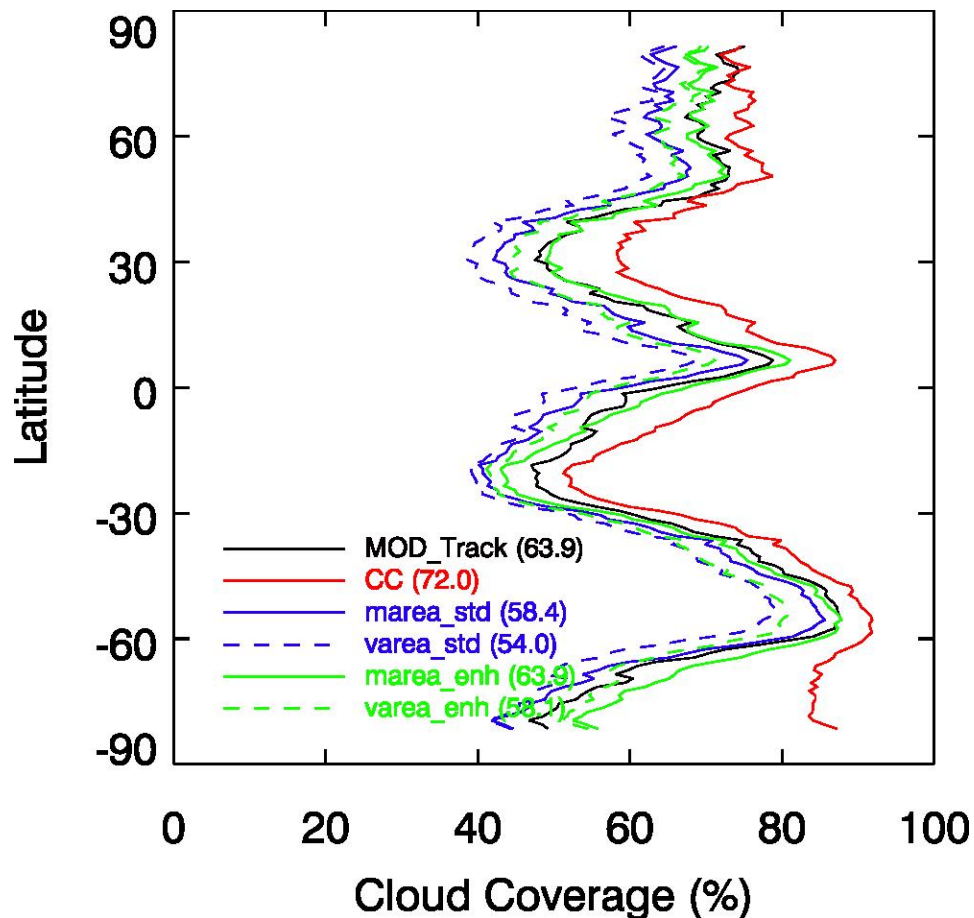
- Decreasing albedo over polar region is due to decreasing sea ice cover
- Some of regional albedo trends over land can be explained by decreasing snow cover
- Decreasing albedo over Saharan desert, India, and Arabian peninsula needs further investigation. A possible explanation is an AOD trend difference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

C3M update

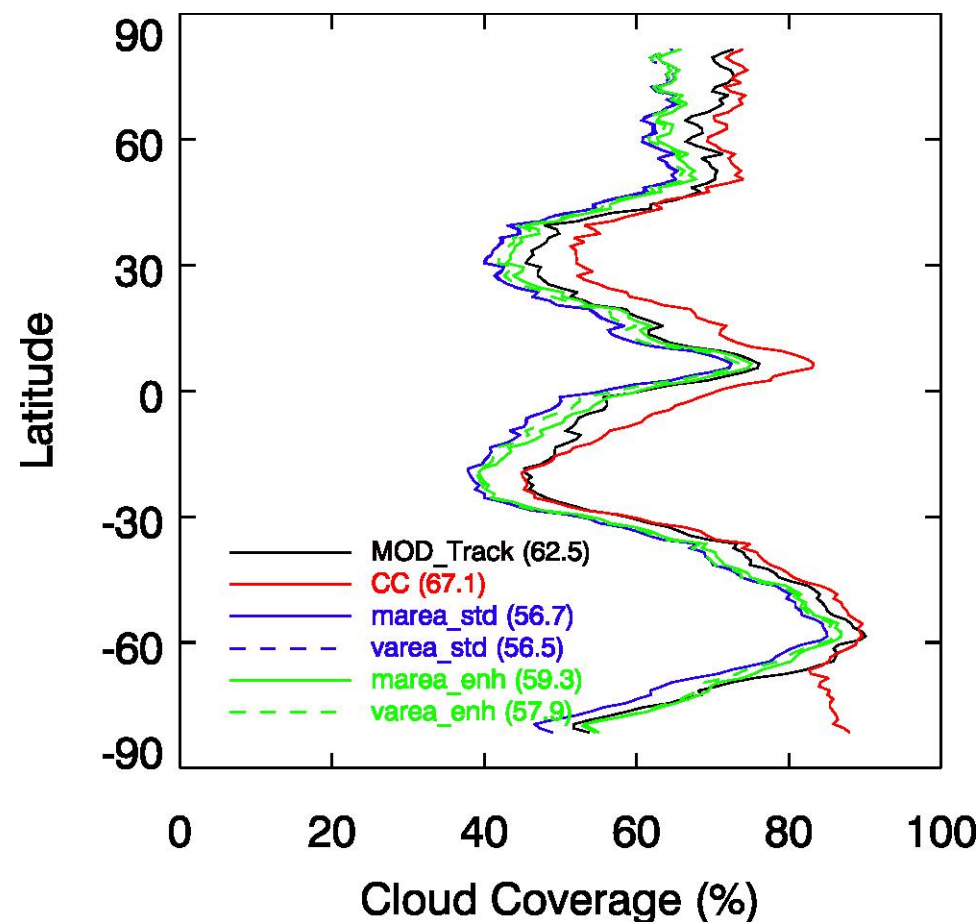
- Revising the C3M product (Edition D1) with R05 Cloudsat and version 4 CALIPSO data products.
- Resolving the cloud fraction difference between level 3 CALIPSO product and C3M (communicating with D. Winker and X. Cai).

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

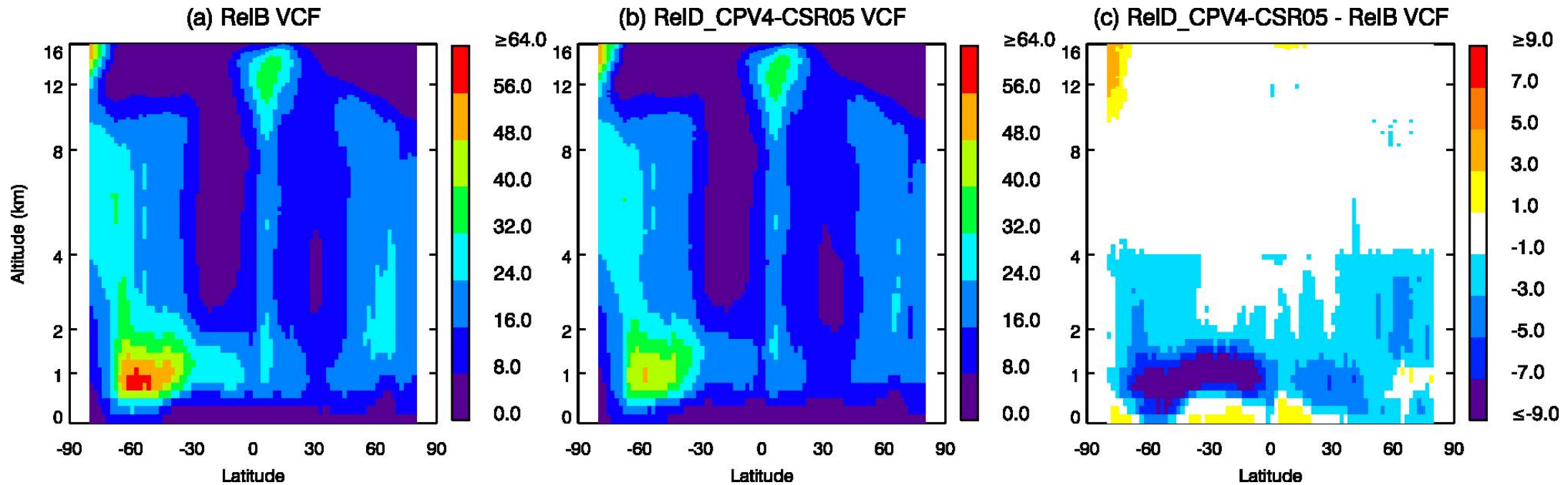
Cloud Volume Profiles in July 2008 (Day+Night)

CCCM Cloud Volume Profile Obtained at 160 m Vertical Resolution

Previous version (B1)

New version (D1)

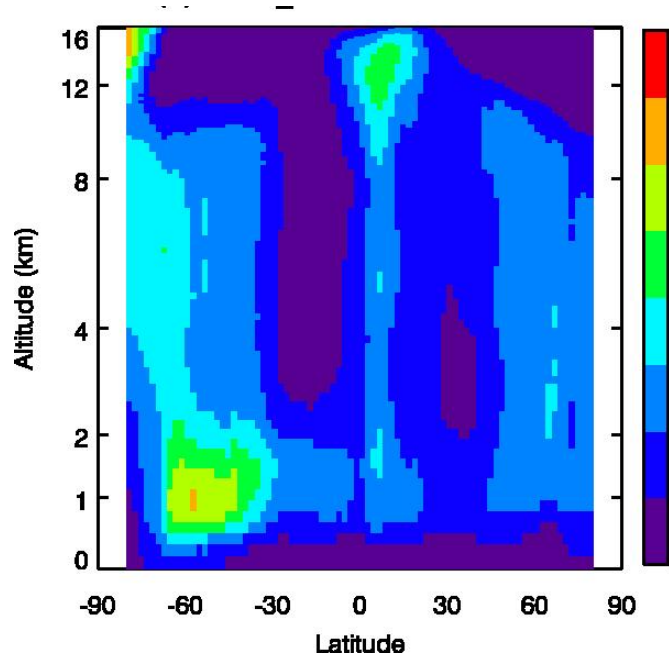
D1 – B1



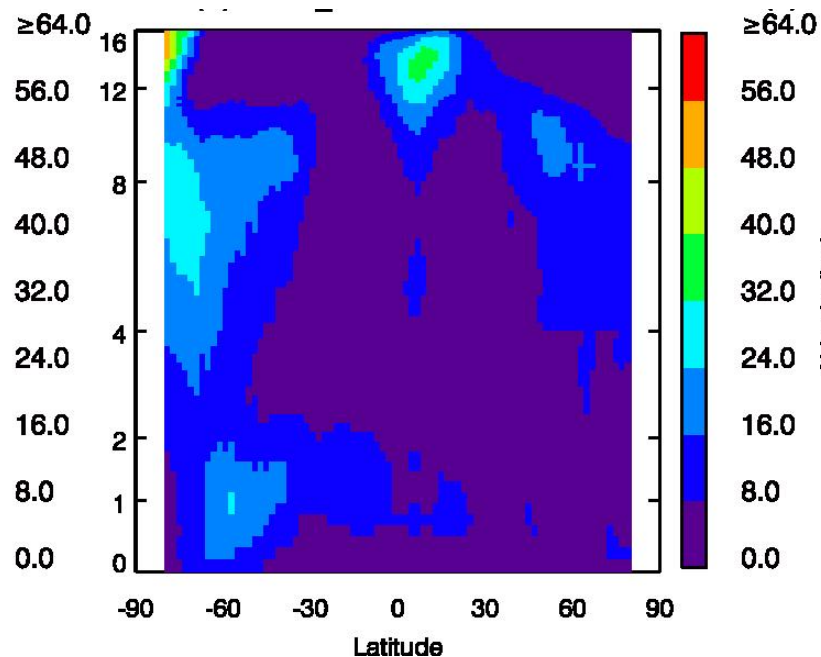
Cloud Volume Profiles in July 2008 (Day+Night)

C3M Rel D (new version)

CloudSat-CALIPSO

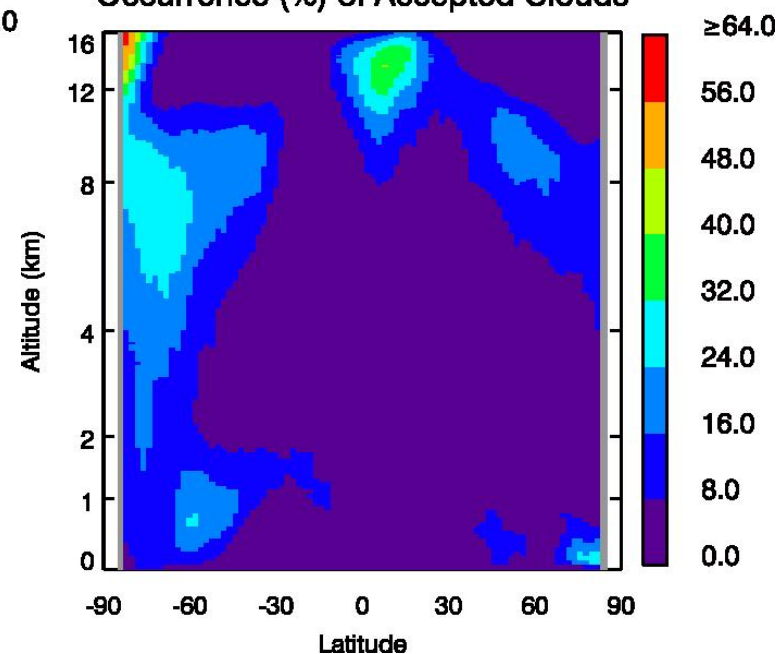


CALIPSO Only Clouds



CALIPSO Level 3 product

Occurrence (%) of Accepted Clouds



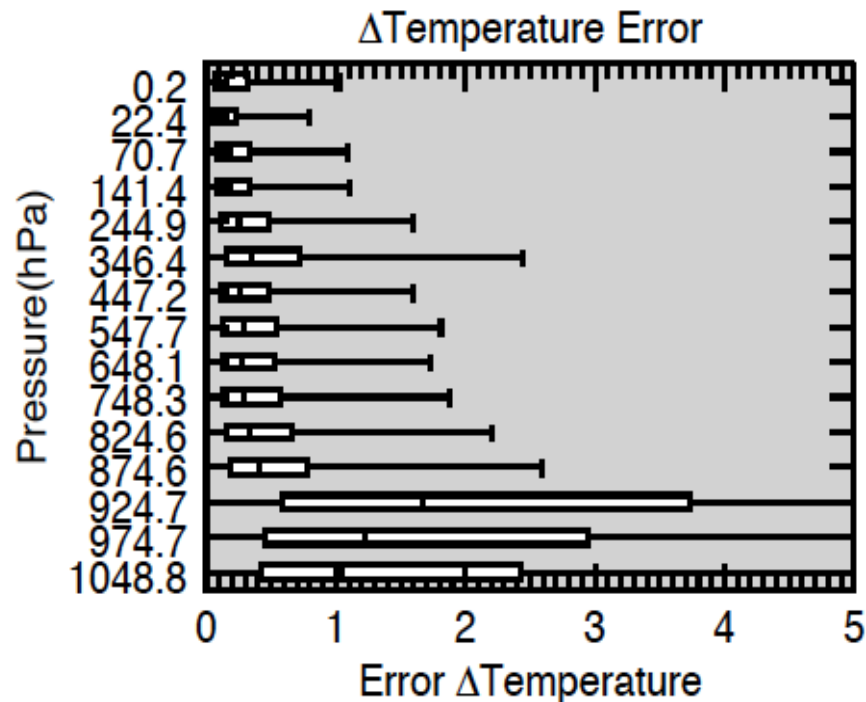
Cloud_Accepted_Samples/
(Cloud_Samples +
Cloud_Free_Samples)
x 100%

Edition 5 MATCH

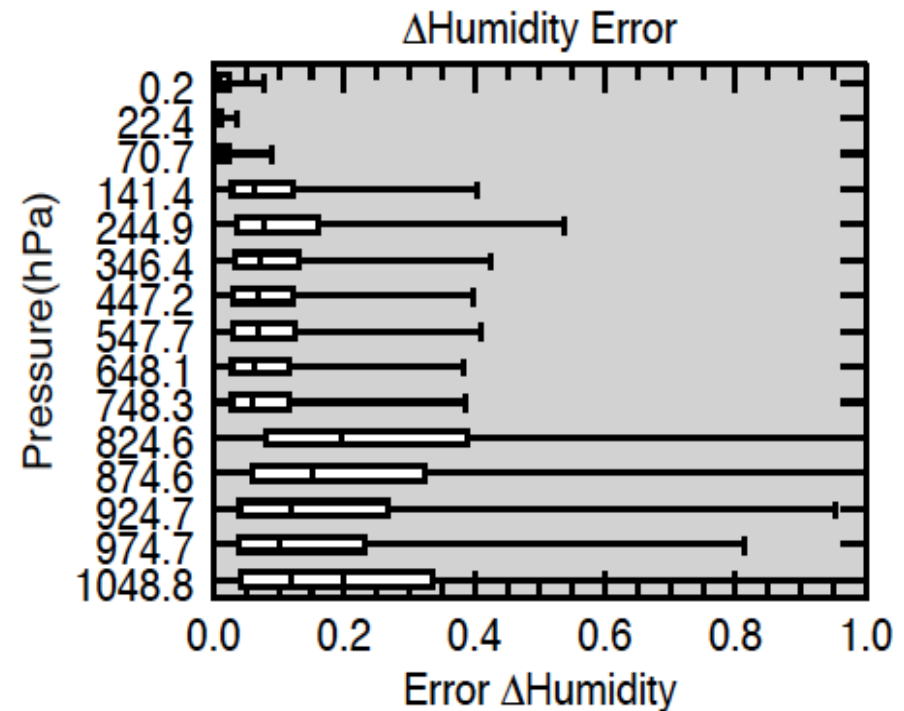
LW fingerprinting

- 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 due 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.*