Edition 4.2 EBAF Surface product update

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CERES Science team meeting

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Difference of Edition 4.2 EBAF (released in 2023) from the previous version (Ed. 4.1)

- MERRA-2 temperature and humidity profiles were used for irradiance computations.
  - Clouds are retrieved using GEOS-5.4.1
- Only MODIS and VIIRS retrieved cloud properties were used
  - No geostationary satellite derived cloud properties were used.
- Uncertainty in surface irradiance trends is much smaller than the uncertainty derived from the previous version.

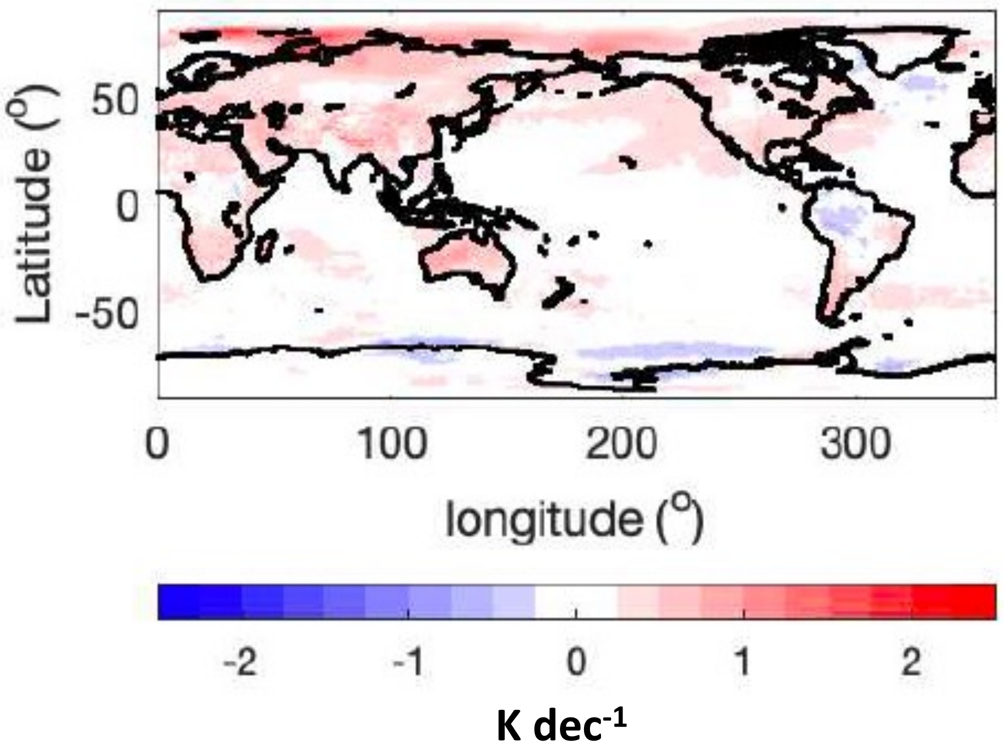
Outline of this talk

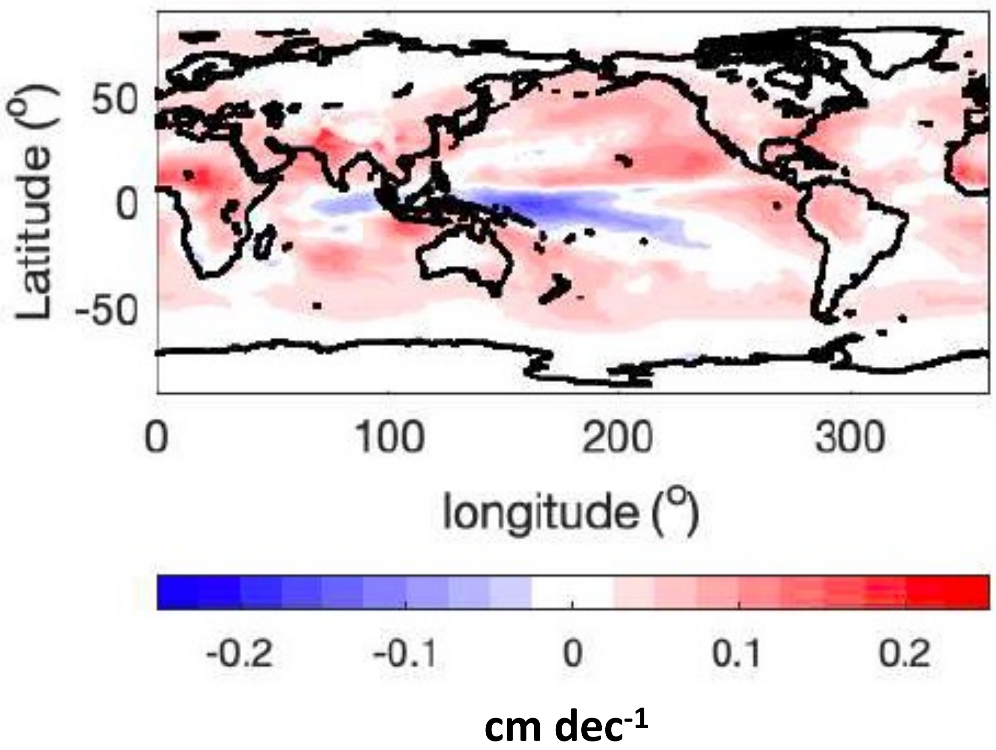
- Key input variables (skin temperature and water vapor)
- Trend of absorbed shortwave and emitted longwave irradiances by the atmosphere
- Aerosol optical thickness and direct aerosol radiative effect (DARE)
- Known issues

Skin temperature and water vapor trend

Skin temperature (K dec-1)
Global mean trend: 0.22 K dec^{-1}
Trend over land is larger than the trend over ocean

Precipitable water
Global mean trend
1.5% dec^{-1}
1.5% dec^{-1} / 0.22 K dec^{-1} = 6.8% K^{-1}

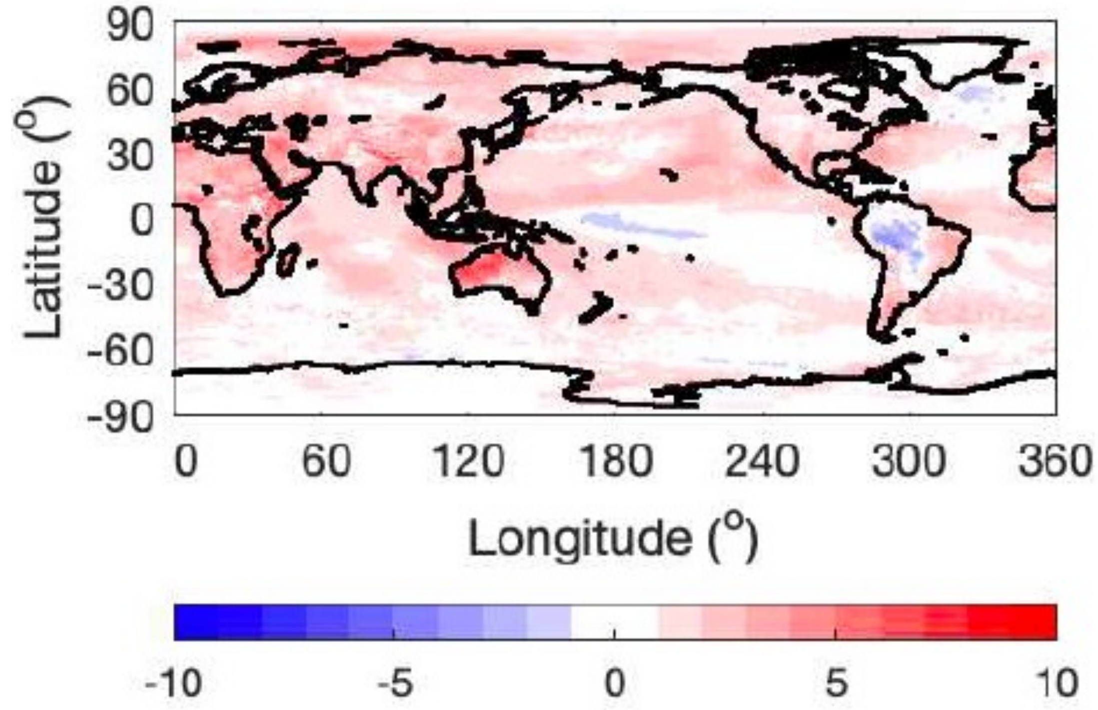




Skin temperatures are hybrid of GEOS-5.4.1 and those retrieved by the cloud group
Precipitable water is from MERRA-2

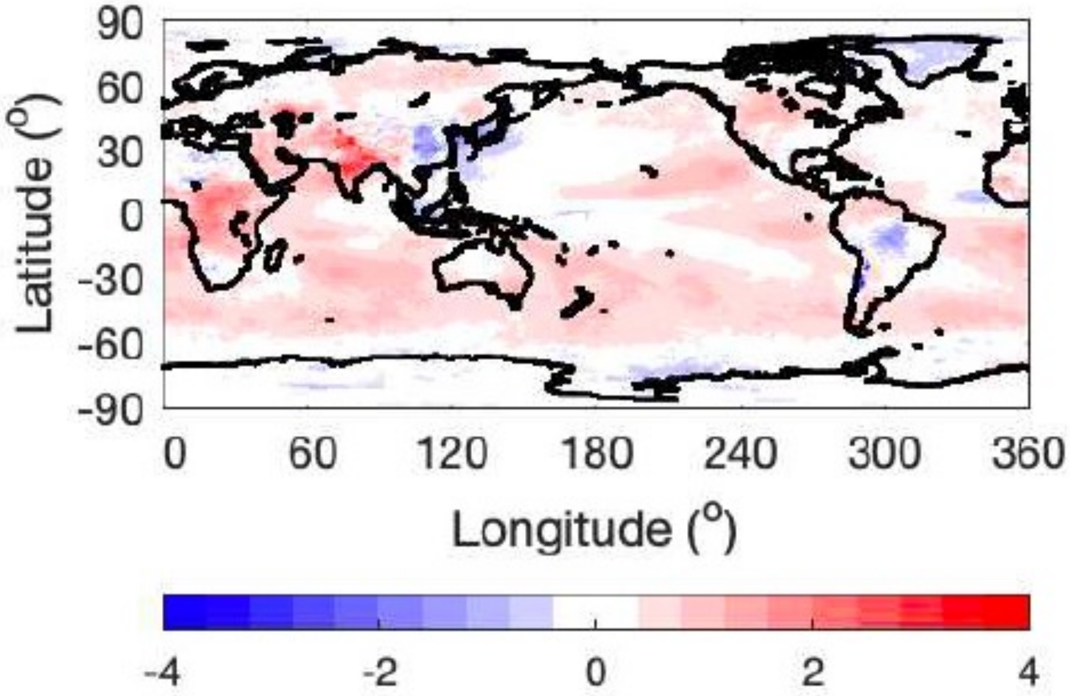
Clear-sky irradiance trends

G = surface upward longwave – TOA upward longwave (Raval and Ramanathan 1989)



Wm^{-2} dec^{-1}

Shortwave absorbed irradiance by the atmosphere
Net TOA shortwave – net surface shortwave

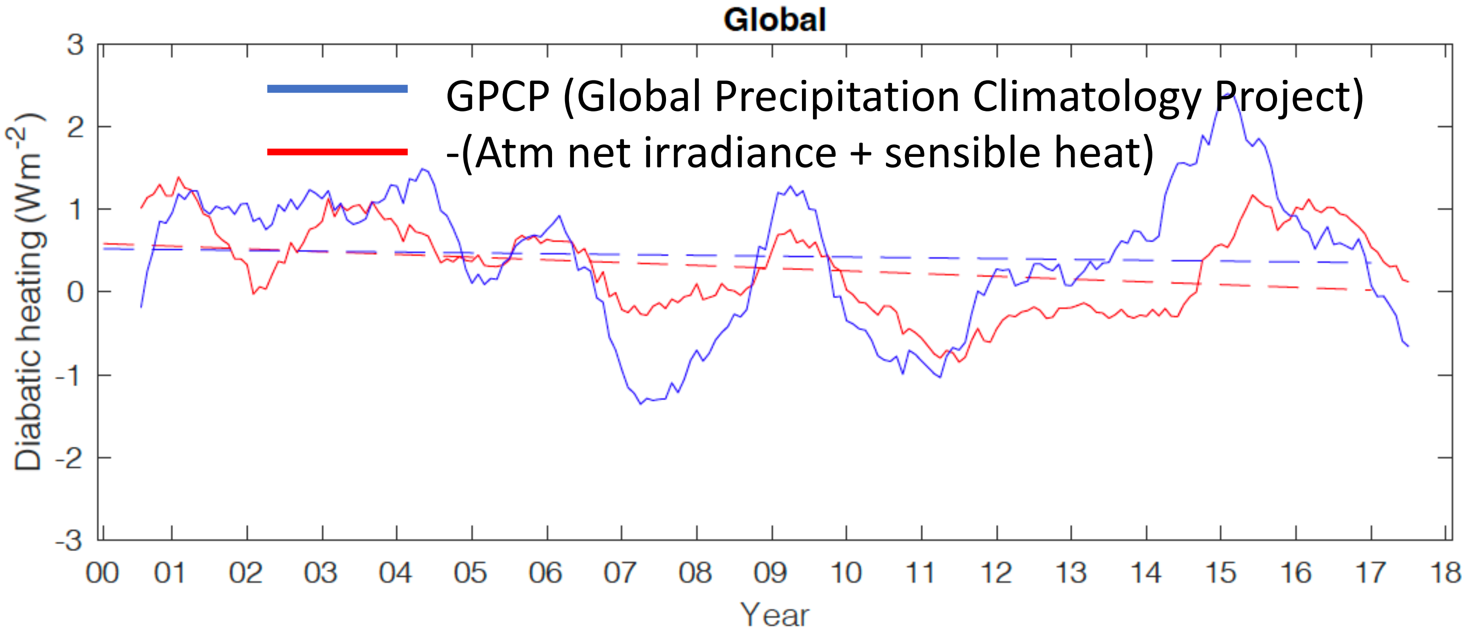


Wm^{-2} dec^{-1}

(minus) Net atmosphere irradiance and Precipitation trend

From January 2001 through December 2018

Net atmosphere = net TOA = net surface



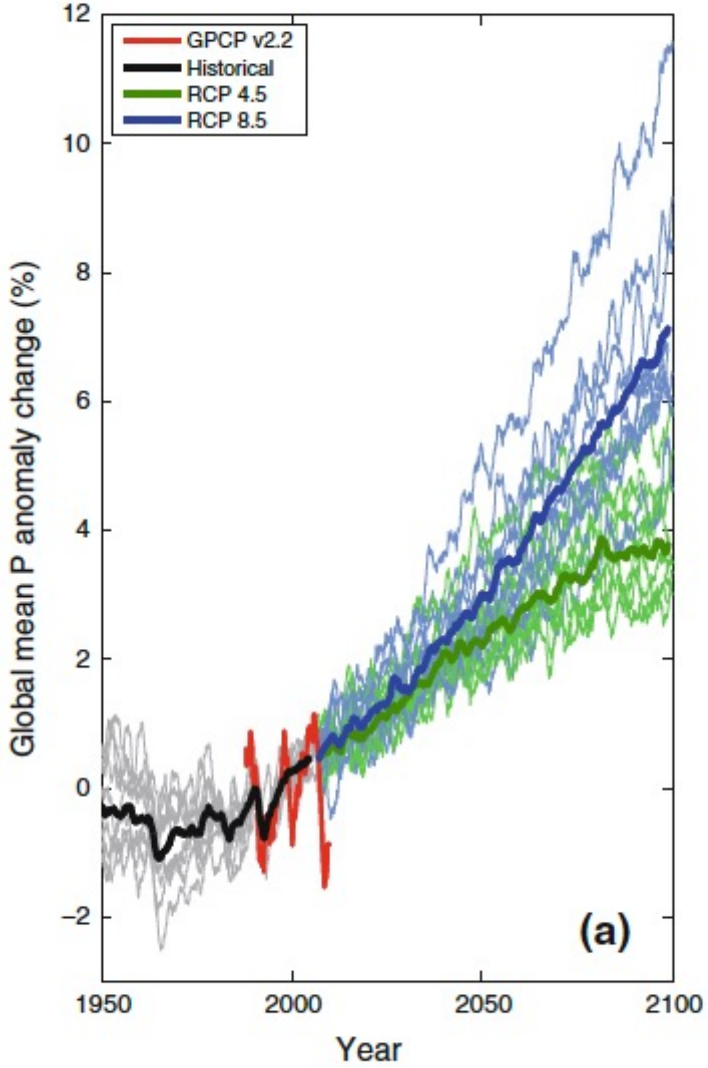
Trend

GPCP: -0.06±0.59 Wm^{-2} dec^{-1}

Ed4 EBAF + sensible flux: -0.33±0.37 Wm^{-2} dec^{-1}

Anomalies are computed relative to July 2005 – June 2015 climatology

Sensible heat flux: Seaflux V3 over ocean and ERA5 over land



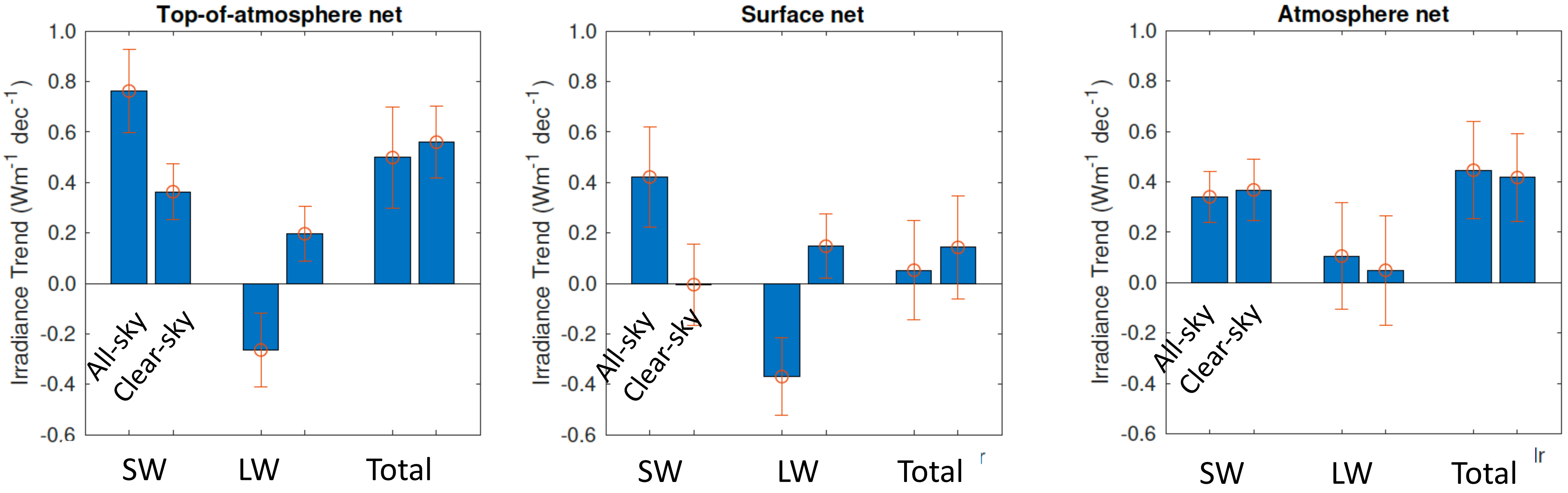
CMIP5 climate simulation

RCP4.5 and RCP8.5

Allan et al. 2014

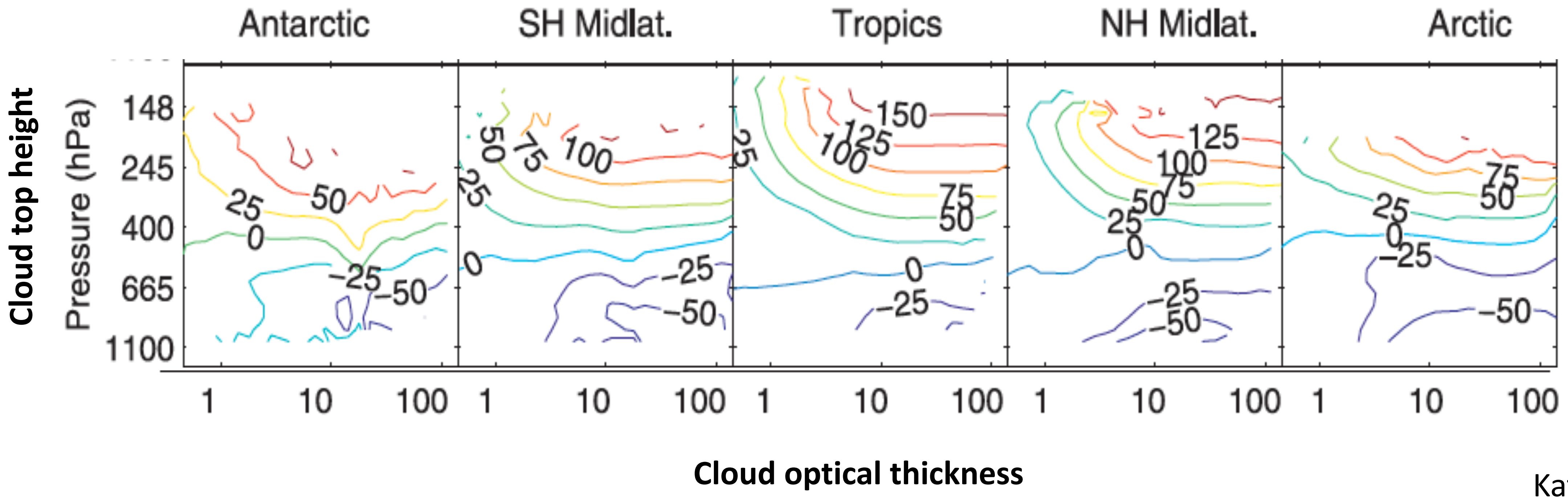
Global TOA, surface and atmosphere irradiance trends

from March 2000 through June 2023



- A positive trend indicates energy inputs at TOA or surface
- Difference between all-sky and clear-sky is due to clouds
- A positive trend of net atmospheric irradiance is driven by shortwave absorption

Cloud effect on net atmospheric longwave irradiance in Wm^{-2}



Kato 2009

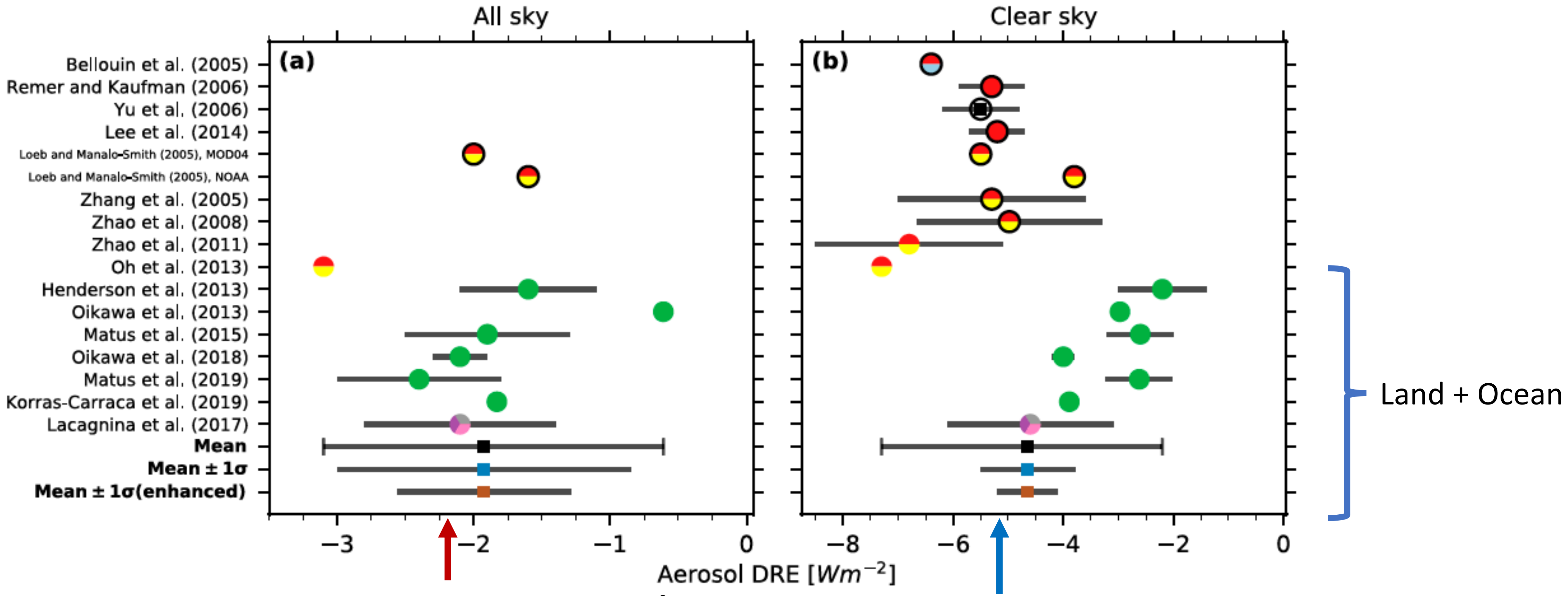
- High-level clouds have a warming effect and low-level clouds have a cooling effect to the atmosphere
- Increasing high-level clouds and reducing low-level clouds reduces longwave cooling in the atmosphere

Aerosol

- Importance of shortwave absorption in the atmosphere in estimating the trend of net atmospheric irradiance emphasizes the importance of aerosol
- We use MODIS-derived aerosol optical thickness (Dark-target and Deep blue, for clear-sky) and modeled aerosol optical thickness (cloudy-sky) by MATCH transport model

Global mean direct aerosol radiative effects

SYN1deg is used to produce EBAF



CERES SYN: -2.2 Wm^{-2}
Land + Ocean
200003 to 202306

CERES SYN: -5.2 Wm^{-2}
Land + Ocean
200003 to 202306

Thorsen et al. 2021

Trend of clear-sky TOA direct aerosol radiative effect derived from CERES observations

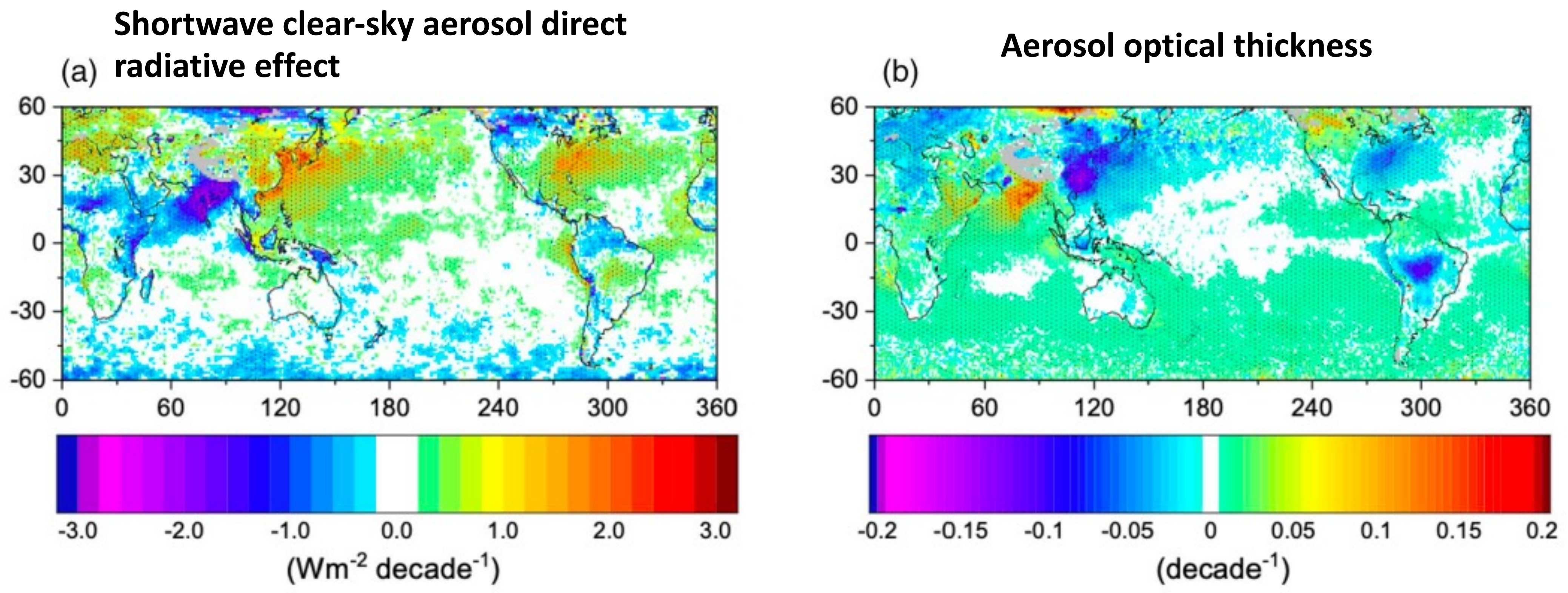
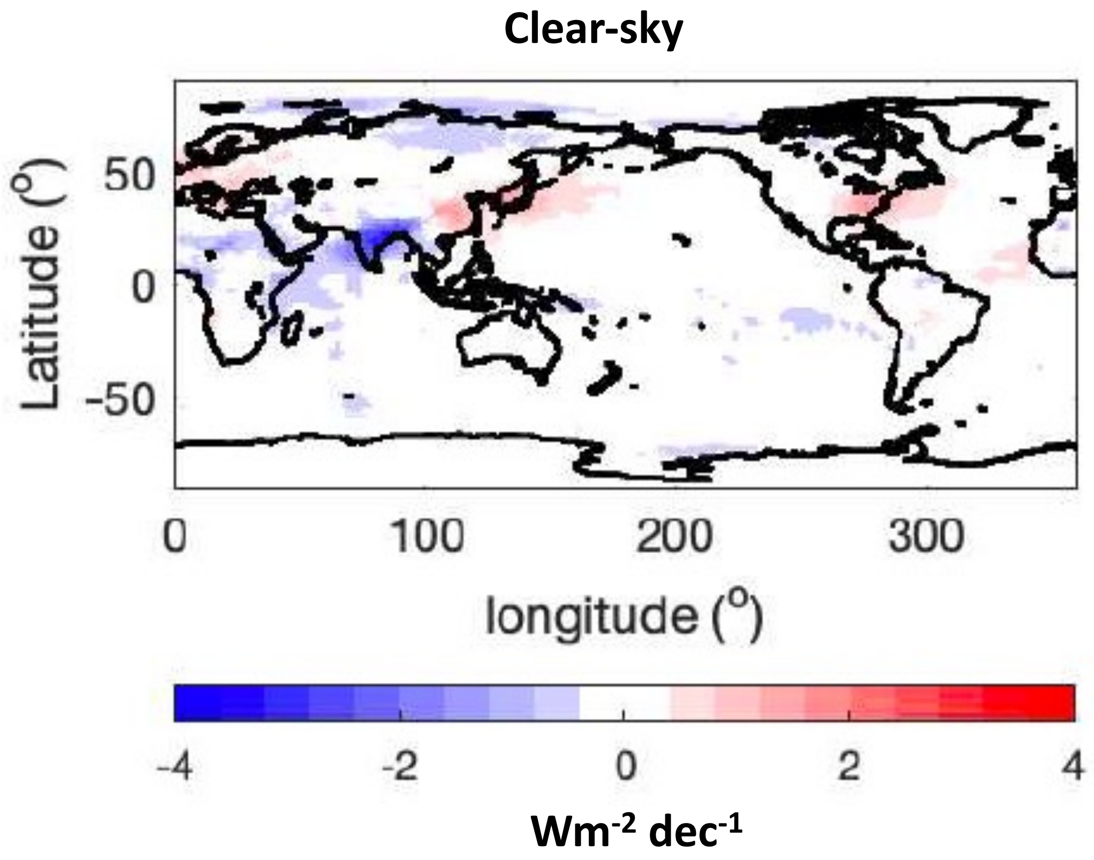


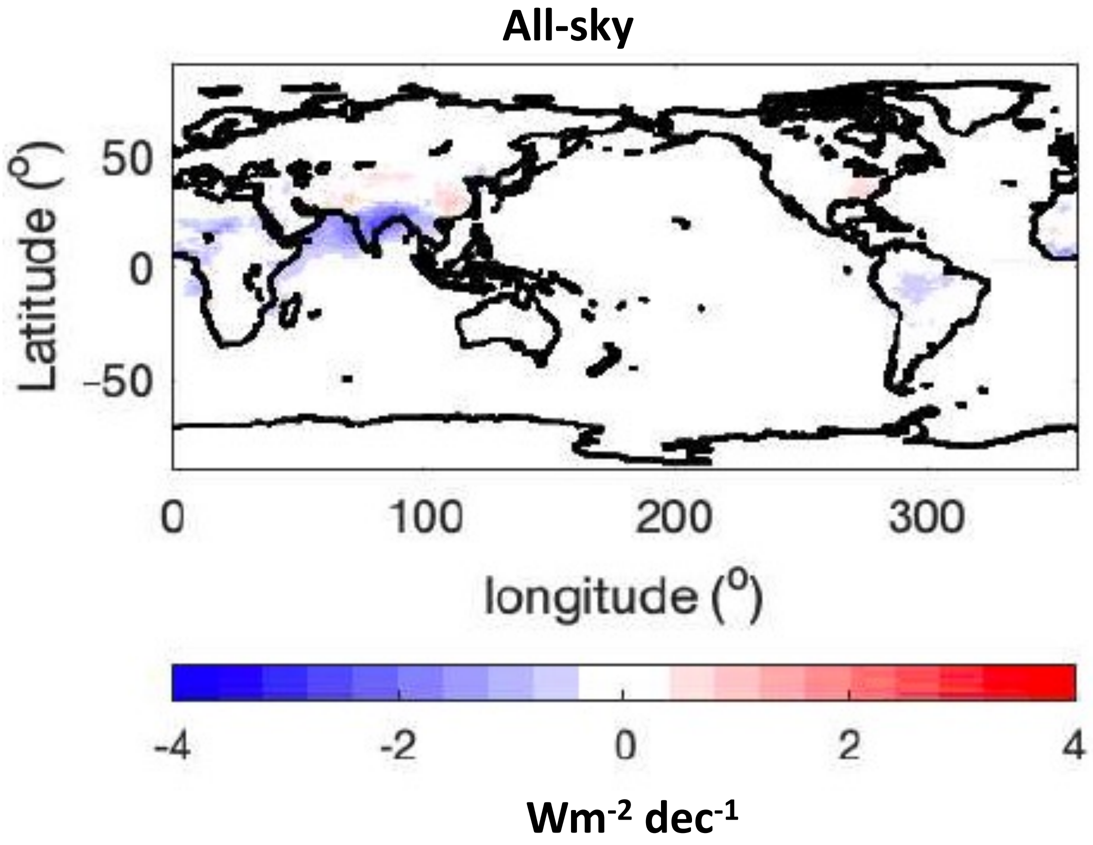
Figure 1. Trend in anomalies of (a) SW clear-sky ADRE and (b) AOD for 2002/07–2020/03. Stippled area exceeds 95% confidence interval. ADRE, aerosol direct radiative effects; AOD, aerosol optical depth.

Loeb et al. 2020
0.18 ± 0.17 Wm^{-2} dec^{-1}

Trend of computed TOA Clear-sky and all-sky direct aerosol radiative effects



Clear-sky TOA shortwave direct aerosol radiative effect (clear-sky – pristine) from Ed. 4.1 SYN GEO



All-sky TOA shortwave direct aerosol radiative effect (all-sky – all-sky no aerosol) from Ed. 4.1 SYN GEO

Ed 4.2 Issues

- Negative total area clear-sky surface irradiances
  - These are caused using an older version of the SYNI code for March 2000 to January 2023.
- Positive cloud radiative effect on surface downward shortwave irradiances
- Negative cloud radiative effect on surface downward longwave irradiance
  - These cloud radiative effect anomalies occur throughout the Ed. 4.2 period (March 2000 through June 2023). The maximum occurrence is in February 2023
- Larger total area clear-sky surface upward shortwave irradiance anomalies in December 2000 and December 2001 (the cause is unknown).

Summary of Ed. 4.2 synopsis and plan

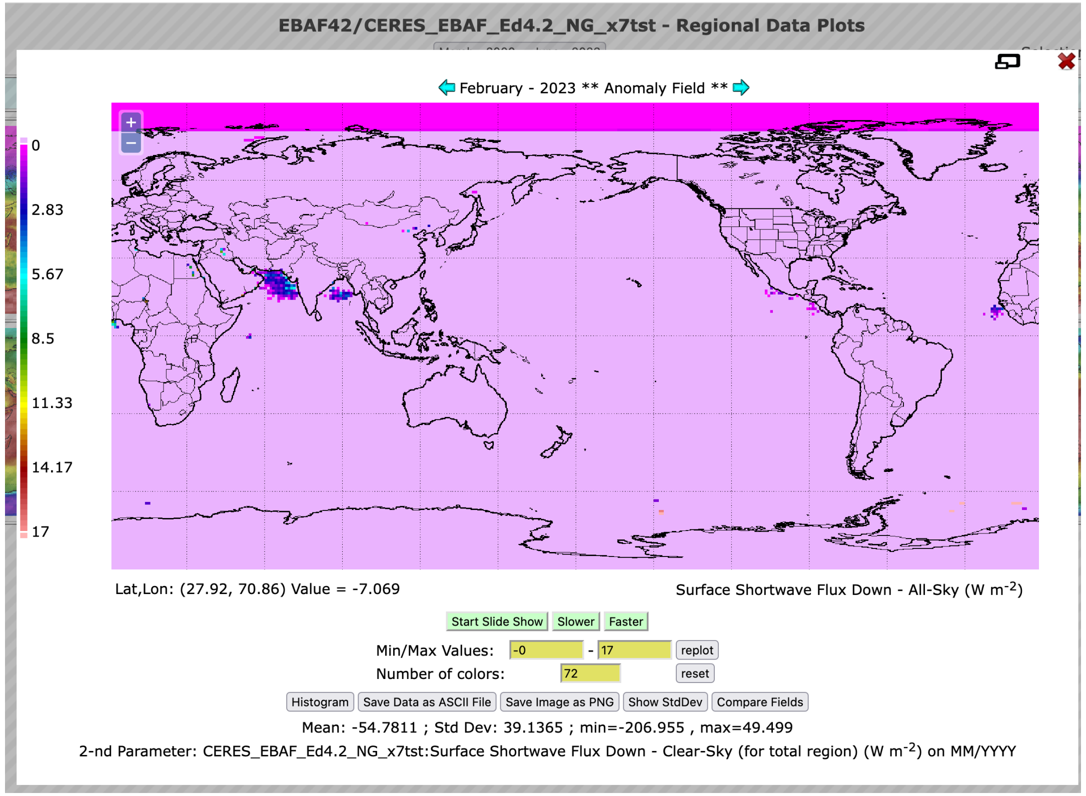
- Global mean skin temperature (a combination of GEOS-5.4.1 surface skin temperature and retrieved surface skin temperature) increases at a rate of 0.22 K dec^{-1}
    - Land skin temperature increases faster than sea surface temperature
- Precipitable water (MERRA-2) increases at a rate of 1.5 % dec^{-1} (6.8% K^{-1}).
- Trend of net total (SW+LW) atmospheric irradiance anomalies is qualitatively consistent with GPCP global precipitation trend.
    - Net atmospheric irradiance trend is largely driven by trend of shortwave absorption in the atmosphere.
- Aerosol optical depth (MODIS derived for clear-sky scenes and MATCH modeled aerosol for cloudy scenes)
    - Global mean direct aerosol radiative effect in SYN agrees with other observation-based estimates
    - Modeled aerosol radiative effect is consistent with that derived from TOA observations.
- Edition 4.3 EBAF will be released early 2024 (or earlier)
    - Due to some errors in Cloud radiative effects

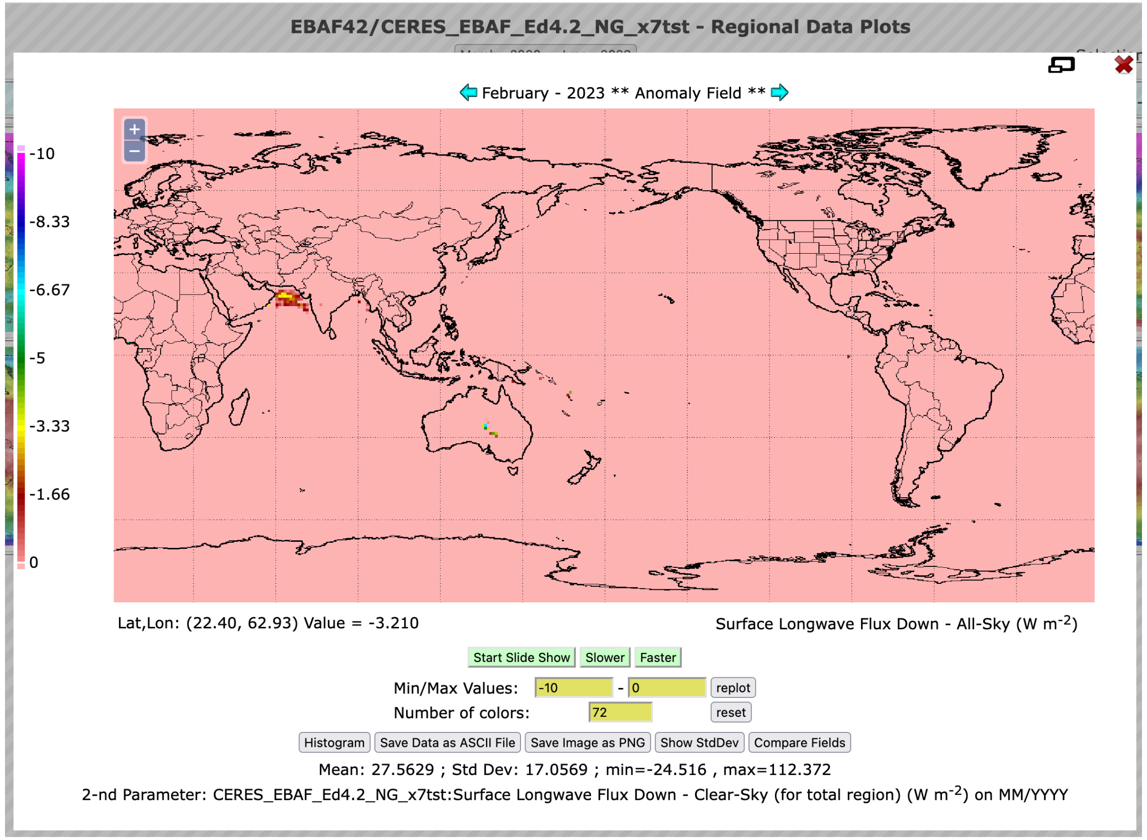
Backups

February 2023 case:
All-sky – Clear sky irradiances

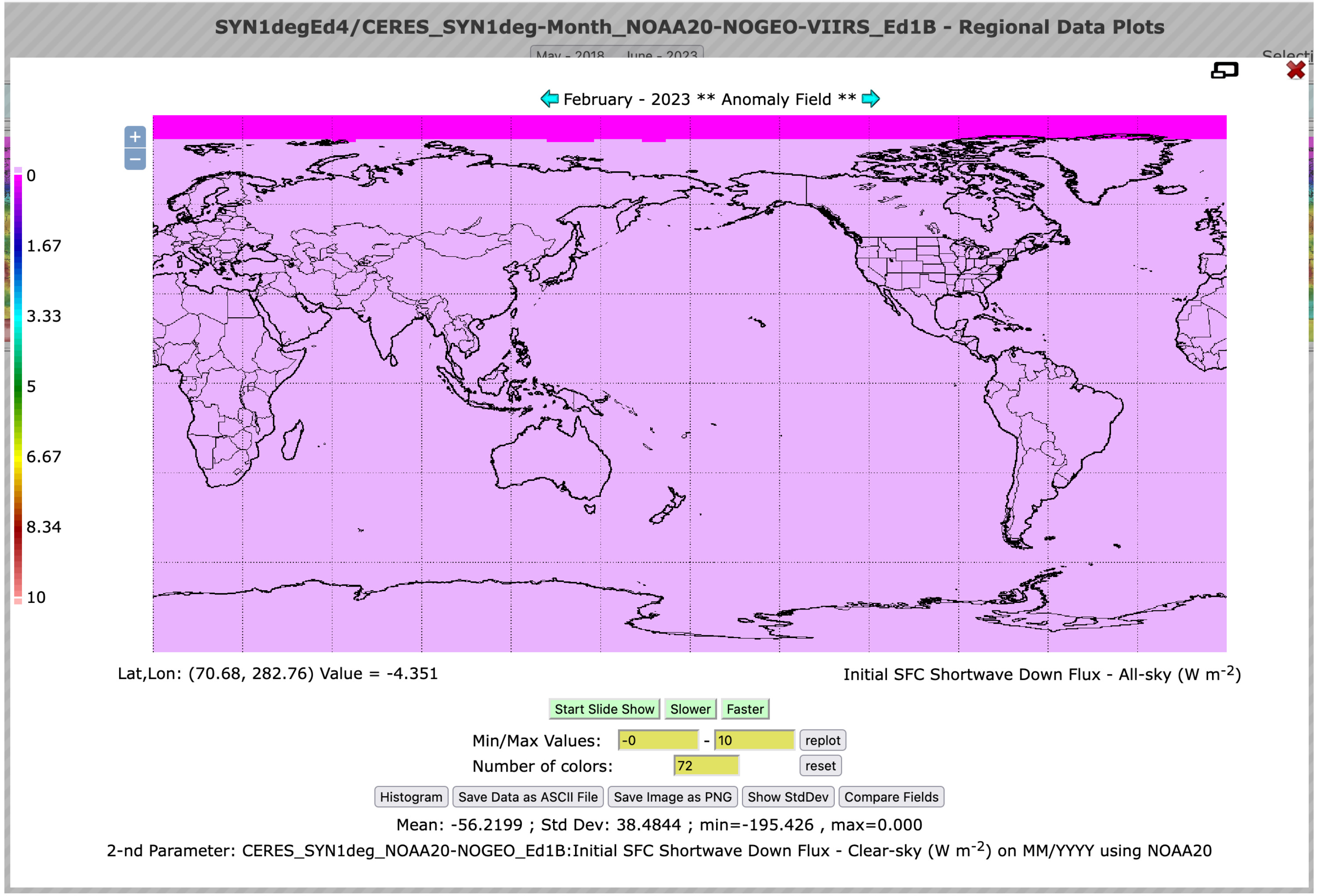
Downward shortwave irradiances

1. Downward longwave irradiances



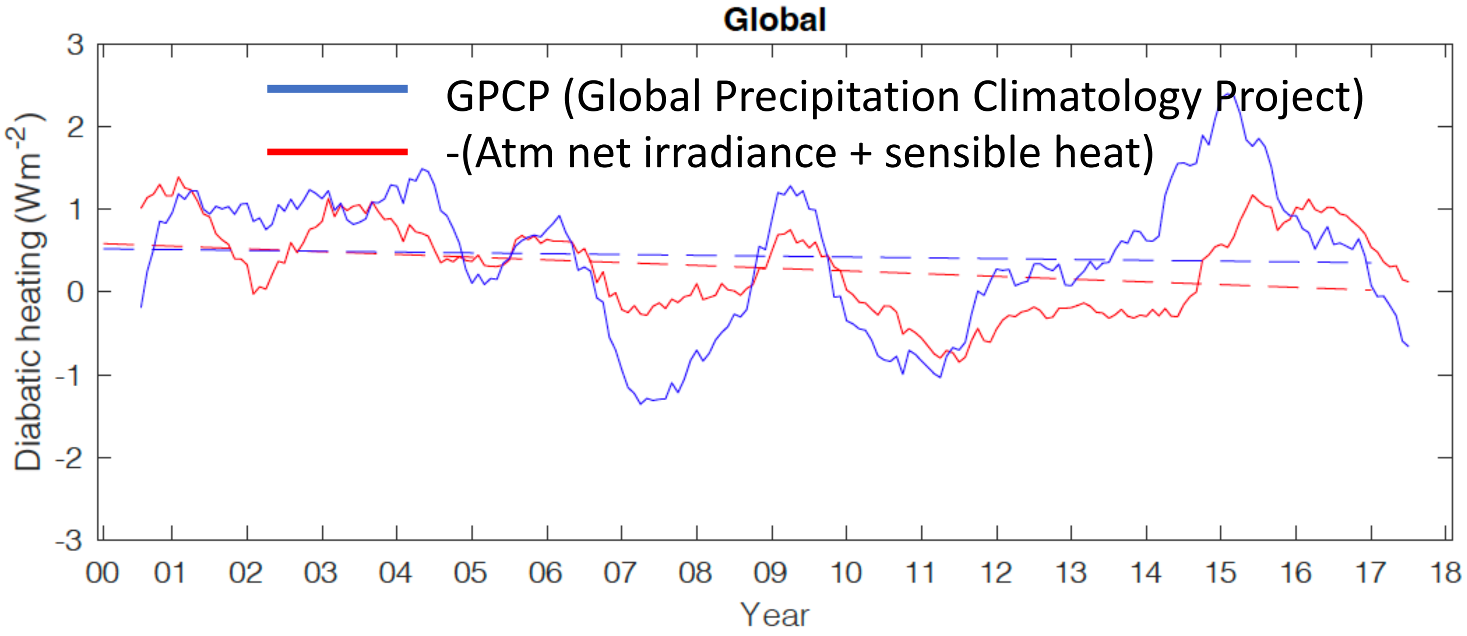


Positive shortwave cloud radiative effects do not occur in SYN noGEO

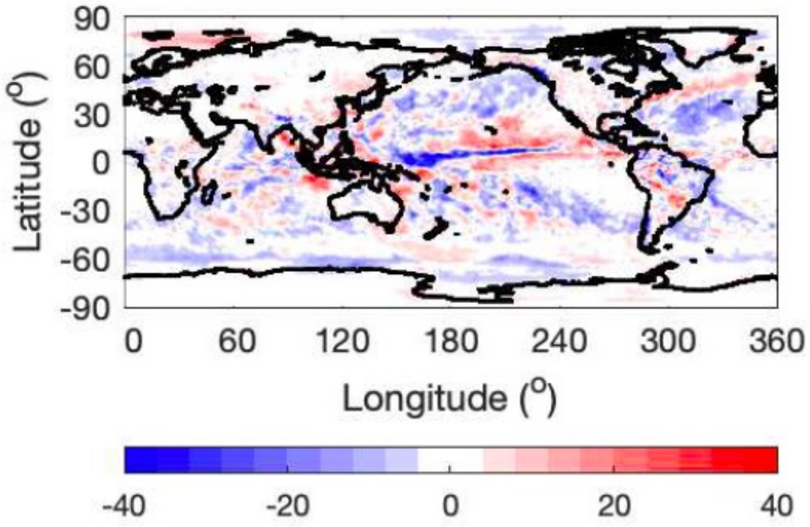


(minus) Net atmosphere irradiance and Precipitation trend

From January 2001 through December 2018



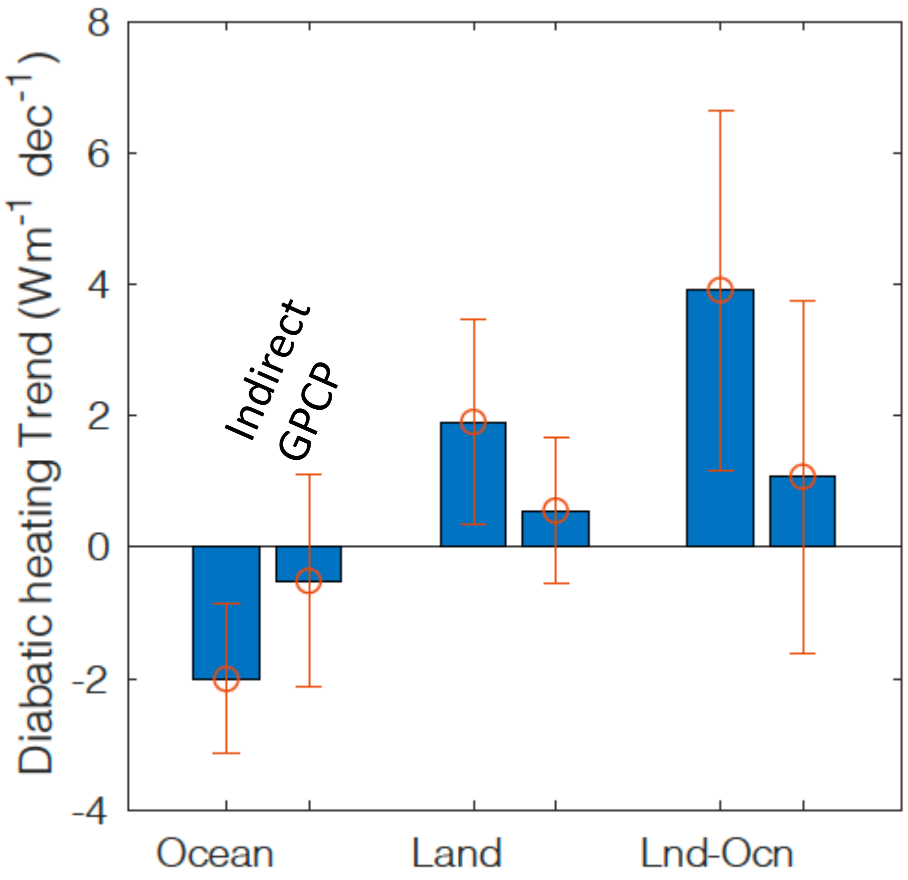
Regional trend from GPCP



Wm^{-2} dec^{-1}

Trend
GPCP: -0.06±0.59 Wm^{-2} dec^{-1}
Ed4 EBAF + sensible flux: -0.33±0.37 Wm^{-2} dec^{-1}
Anomalies are computed relative to July 2005 – June 2015 climatology
Sensible heat flux: Seaflux V3 over ocean and ERA5 over land

Trend of diabatic heating by precipitation over land and ocean (from January 2001 through December 2018)



Left: indirect
Right: GPCP

Indirect approach
TOA and surface irradiance: Edition 4.2 EBAF
Dry static, kinetic energy divergence and tendency: ERA5
Sensible heat flux: Seaflux3.0 (ocean), ERA5 (land)

Precipitation
GPCP V3.2

Error bars are 5-95% confidence intervals.

Effect of clouds on net longwave atmospheric irradiance

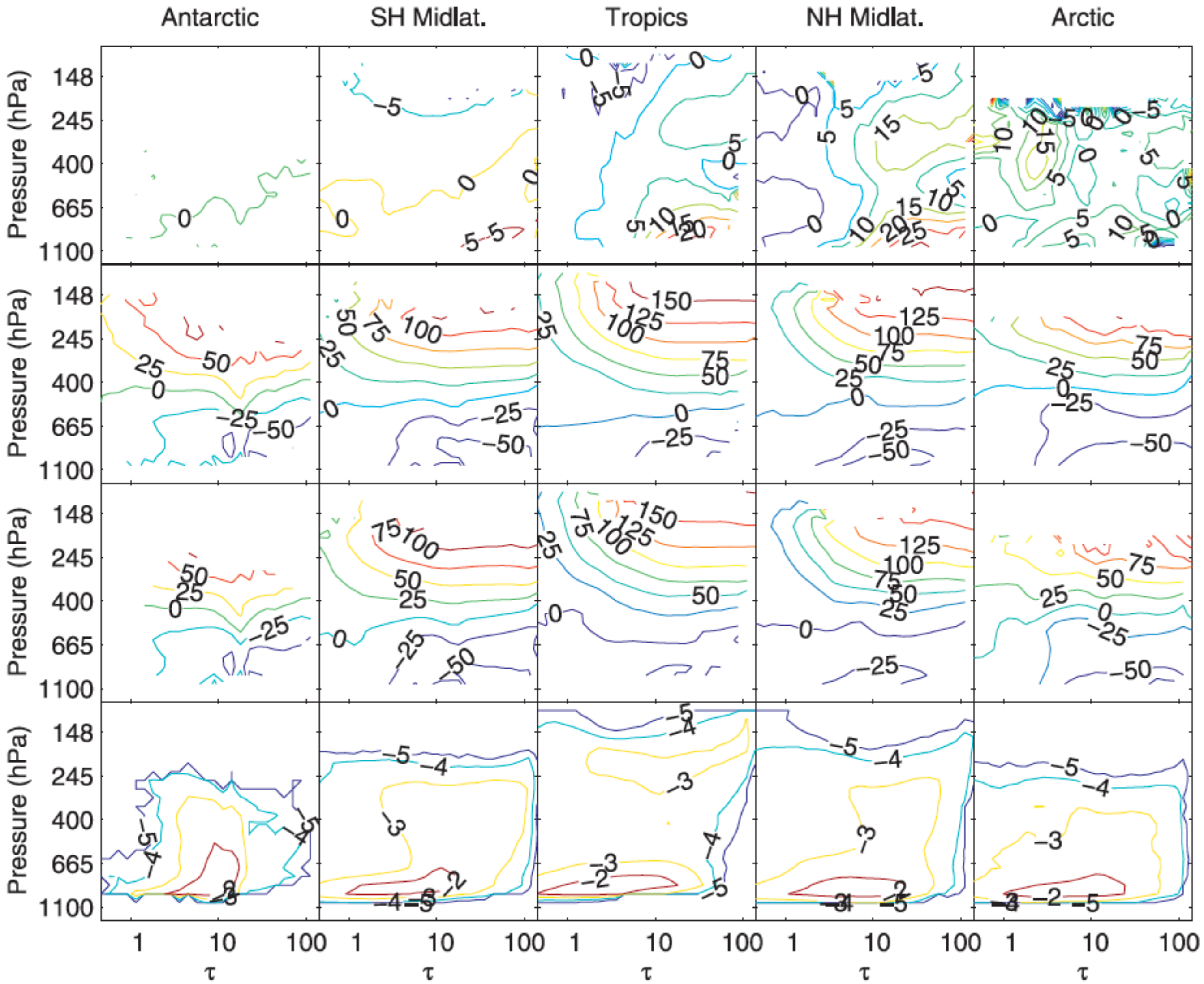
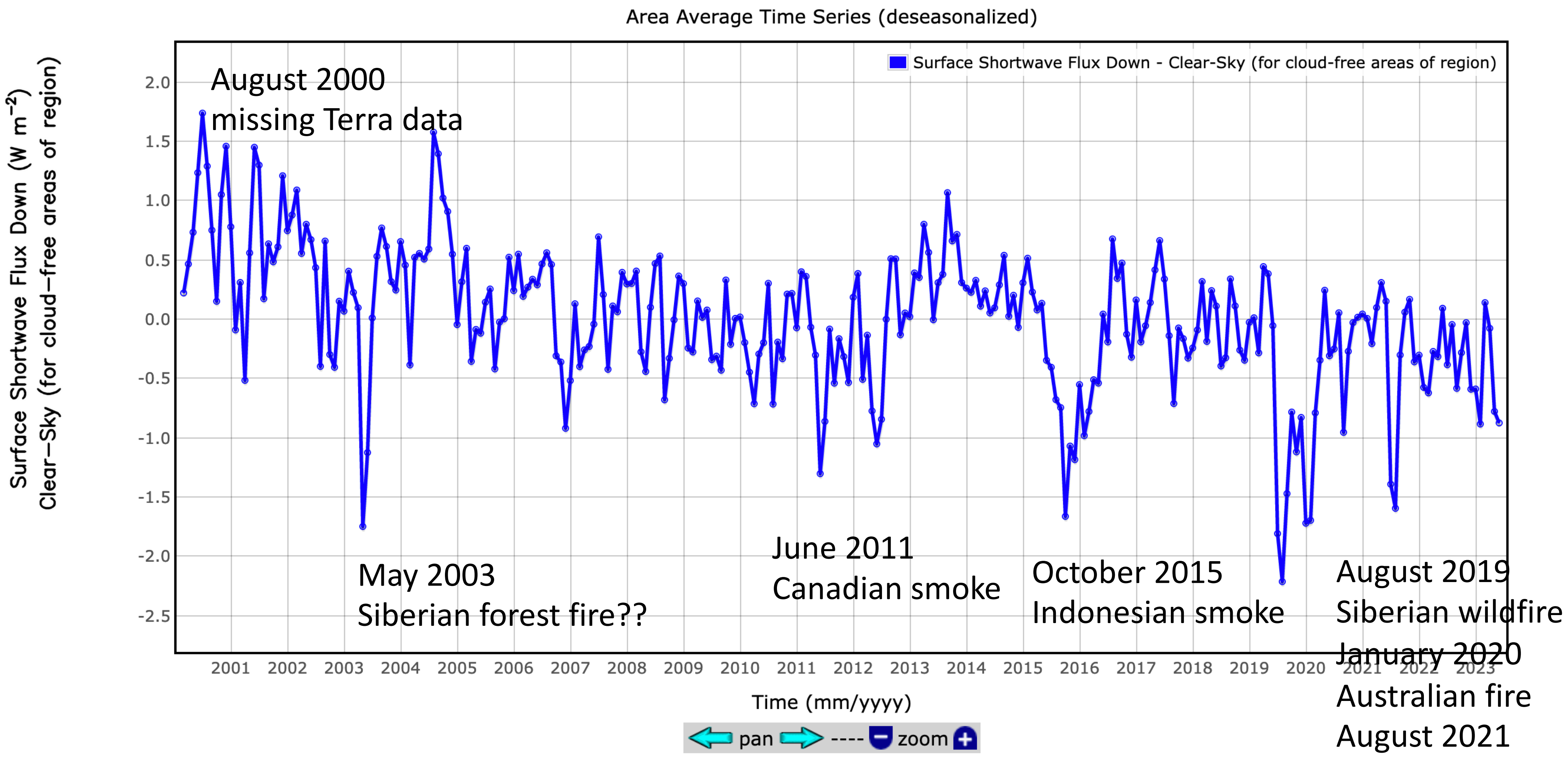


FIG. 7. Contour of the (first row) daily mean cloud shortwave radiative effect, (second row) longwave radiative effect, and (third row) shortwave plus longwave radiative effect (net) to the atmosphere for Antarctic latitudes (60°–90°S), Southern Hemisphere midlatitudes (30°S–60°N), the tropics (30°N–30°S), Northern Hemisphere midlatitudes (30°–60°N), and Arctic latitudes (60°–90°N) as a function of the cloud optical thickness (τ) and cloud-top height in the pressure coordinate estimated from July 2002 data. Only single-layer clouds are used. (fourth row) The logarithm (base 10) of the 2D normalized histogram of cloud occurrence. Shortwave effects are converted to daily values and daily mean longwave effects are computed by weighting daytime and nighttime longwave irradiances by the number of samples.

Global monthly surface clear-sky downward shortwave anomalies



Standard deviation = 0.59 Wm^{-2}

Mean=0.00000 ; StdDev=0.60415 (W m^{-2})

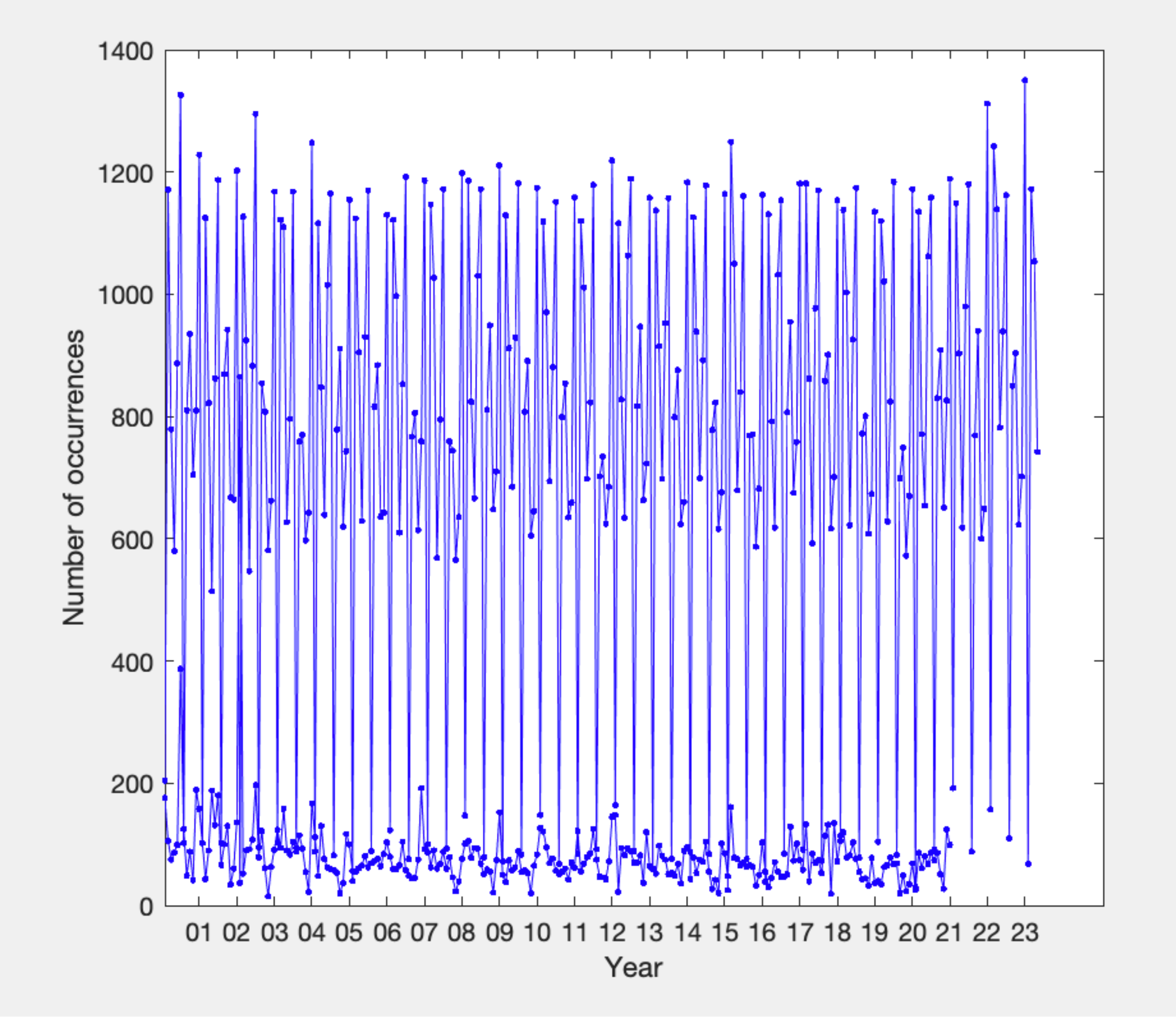
Using Time Range: 3/2000-6/2023

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

Number of month > 2σ: 14 (out of 261)

8 occurred after 2010   5 occurred after 2019

Number of occurrences of positive cloud radiative effect on downward shortwave fluxes

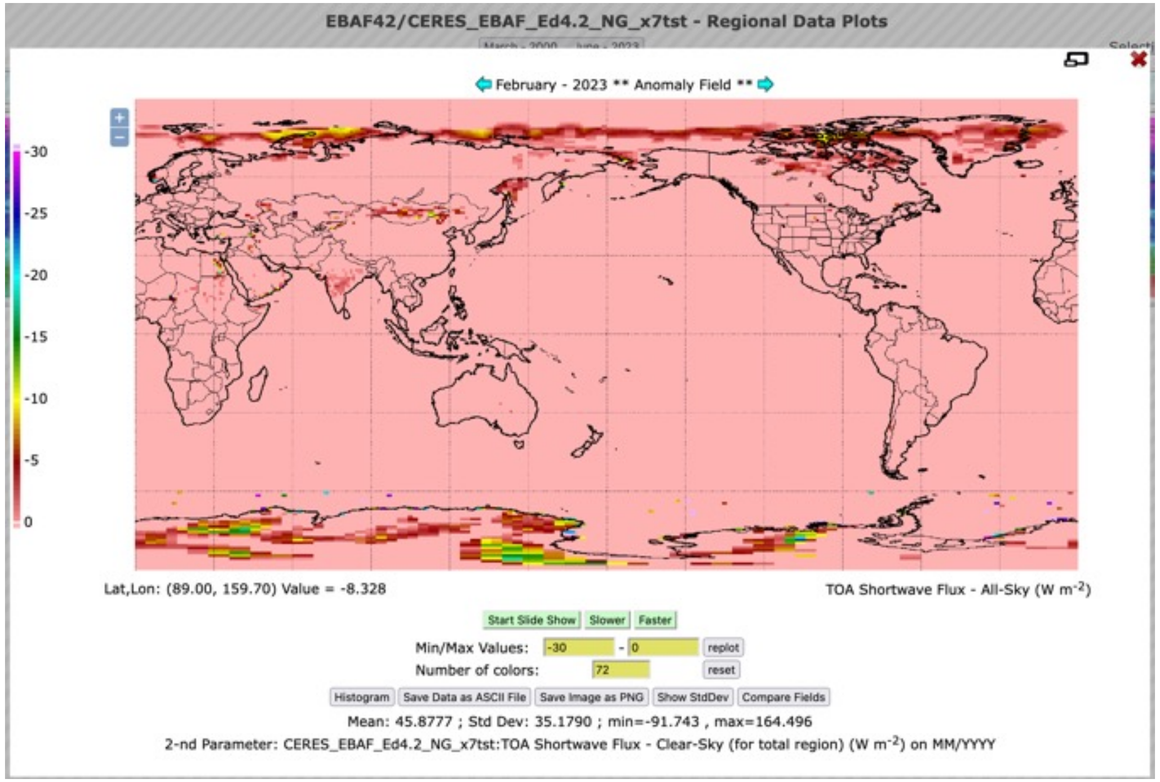


Edition 4.2

Edition 4.1

Shortwave cloud radiative effect anomalies at TOA

All-sky minus clear-sky (total area)



All-sky minus clear-sky (cloud free area)