Evaluating AeroCom phase III TOA clear-sky flux using the CERES Energy Balanced and Filled (EBAF) product

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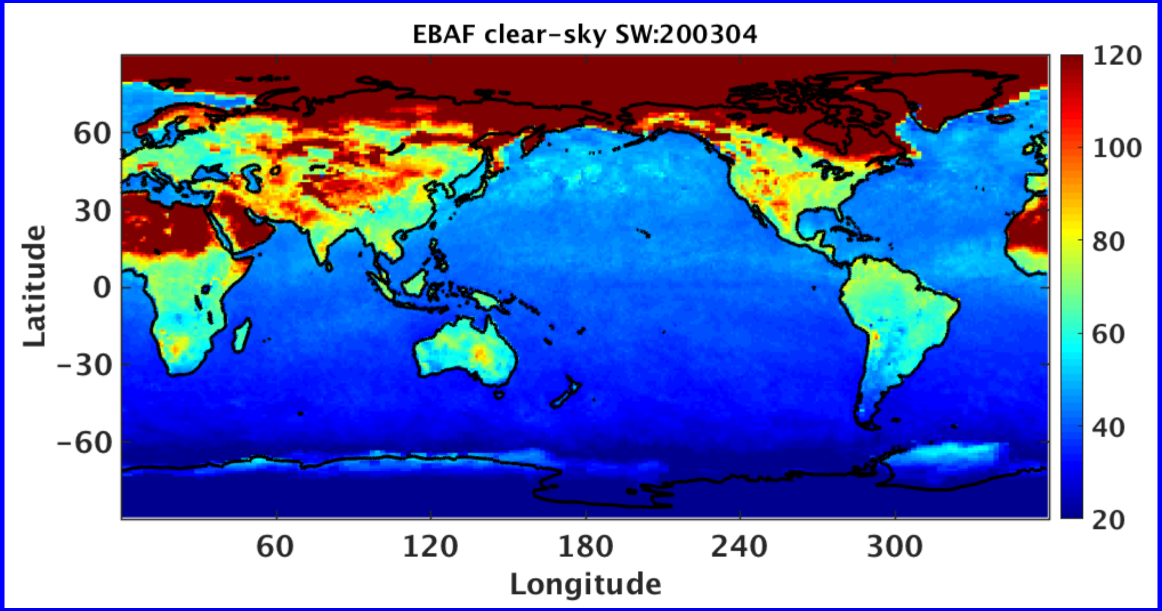
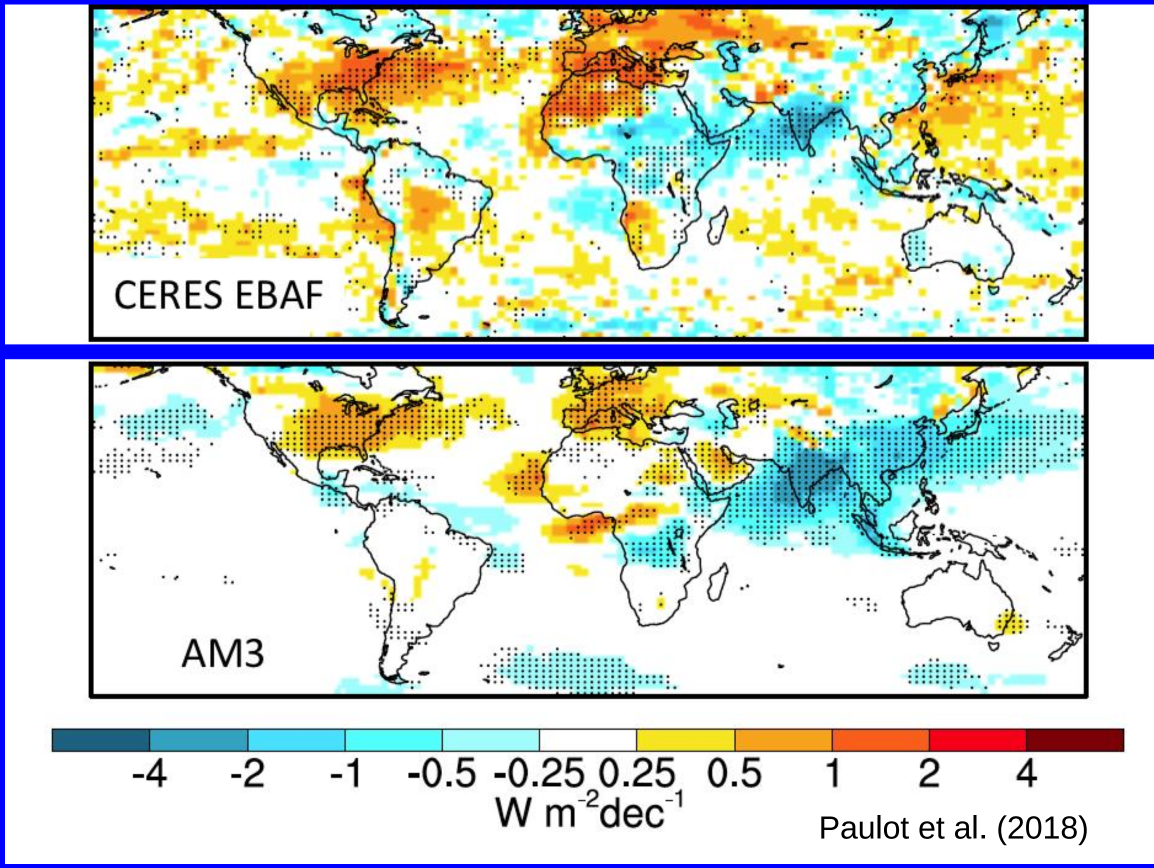


Details on Edition 4 TOA EBAF product are provided in Loeb et al. (2018).

The uncertainty of monthly mean clear-sky TOA SW flux in 1°x1° region is estimated to be 5 Wm^{-2}.

Clear-sky TOA SW direct aerosol radiative effect (DARE) trend from EBAF and from GFDL chemistry-climate model AM3

- An increase in DARE reflects a decrease in the amount of radiation scattered to space by aerosols;
- Both CERES and AM3 show increases in DARE over the US/Europe, and decreases over India;
- Over China and the Western Pacific, AM3 simulates a large decrease in DARE, which is inconsistent with the CERES results.
- Paulot et al. (2018) argue that this bias is partly due to the decline of SO2 emissions after 2007, which is not captured by the CMIP6 emissions, but are in MEIC*.



Data from 2001-2015 are used to calculate the trend

*Multi-resolution Emission Inventory for China

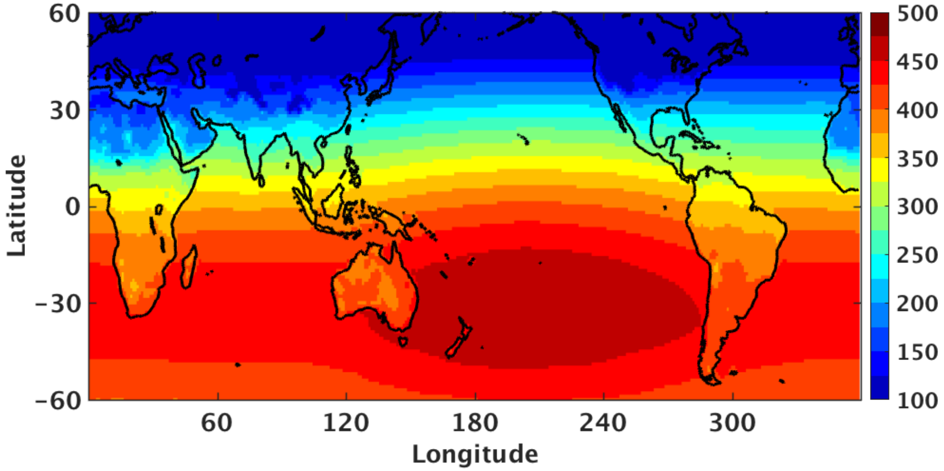
Evaluating AeroCom phase III experiments

- AeroCom phase III control experiment 2016 simulations for present day are used in this study;
- The following models provided top-of-atmosphere clear-sky flux output for 2010. They are interpolated to 1° latitude by 1° longitude to compare with the monthly gridded EBAF clear-sky upward SW fluxes;
- Combined MODIS dark target and deep blue AODs (collection 6.1) are used to compare with the model output (od550aer);
- Focus on comparisons between 60°S-60°N, separately over ocean and land.

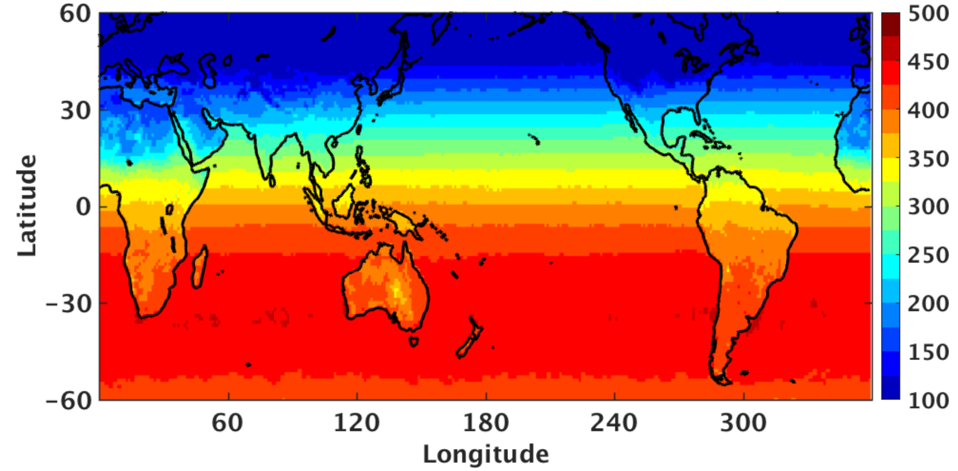
Model	Resolution	Name	Comment
CAM5.3-Oslo	192×288	rsutcs	upward SW flux
CNRM-AESM2	128×256	rsutcs	upward SW flux
CNRM-AESM2Nud	128×256	rsutcs	upward SW flux
ECHAM6-HAM2	96×192	swtoacsaer	total aerosol SW DRE
ECHAM6-SALSA	96×192	swtoacsaer	total aerosol SW DRE
ECMWF-IFS-CY42R1	256×512	swtoaclear	net downward SW flux
SPRINTARS-T106	160×320	rsutcs	net upward SW flux
SPRINTARS-T213	320×640	rsutcs	net upward SW flux

ECMWF: TOA net downward clear-sky SW flux for January

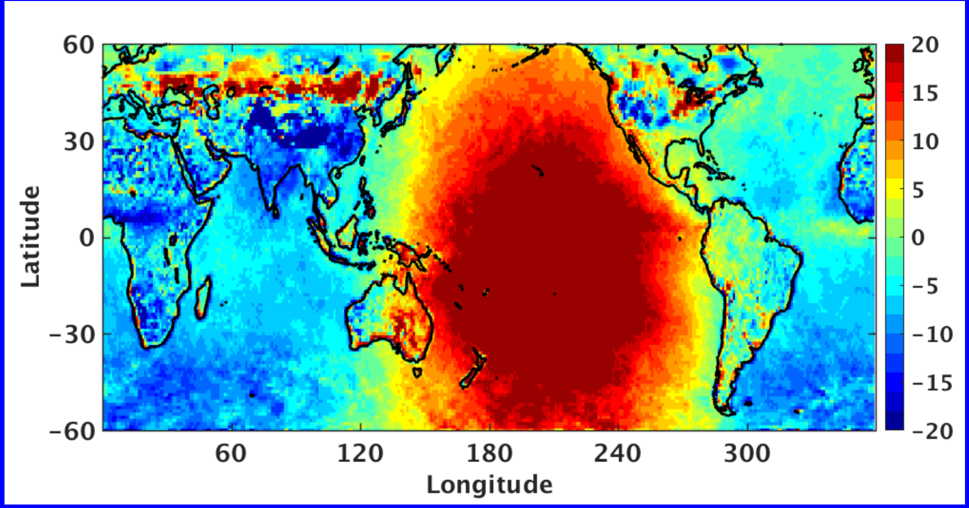
ECMWF



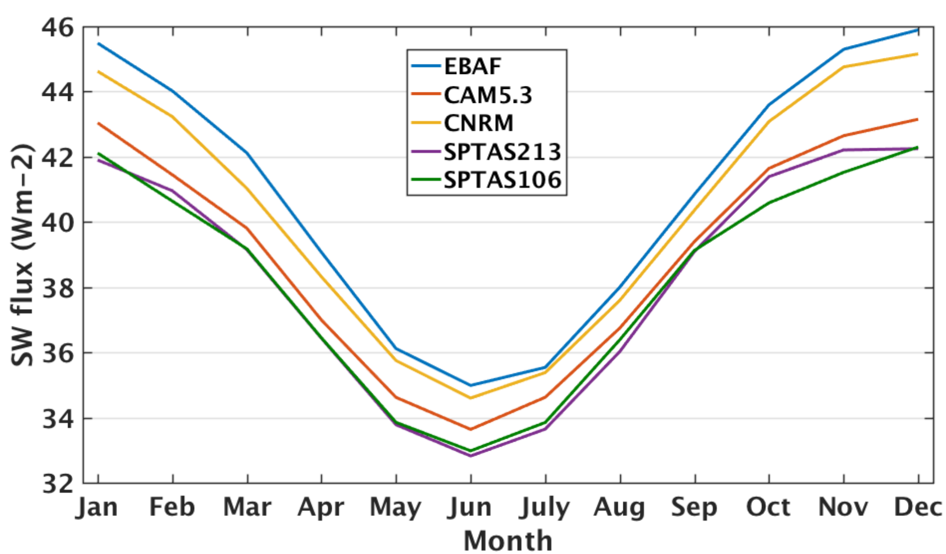
EBAF

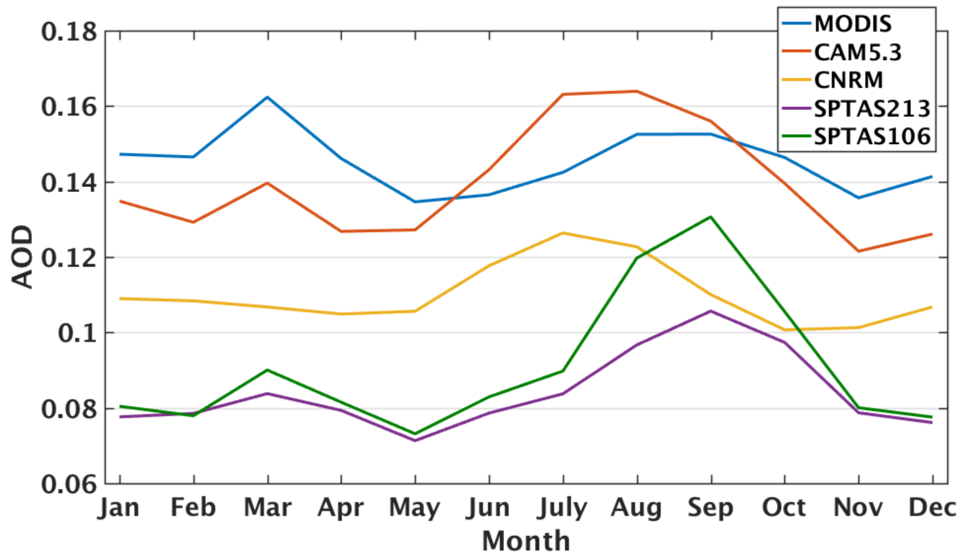


ECMWF-EBAF



Monthly mean clear-sky flux and AOD comparison: over ocean

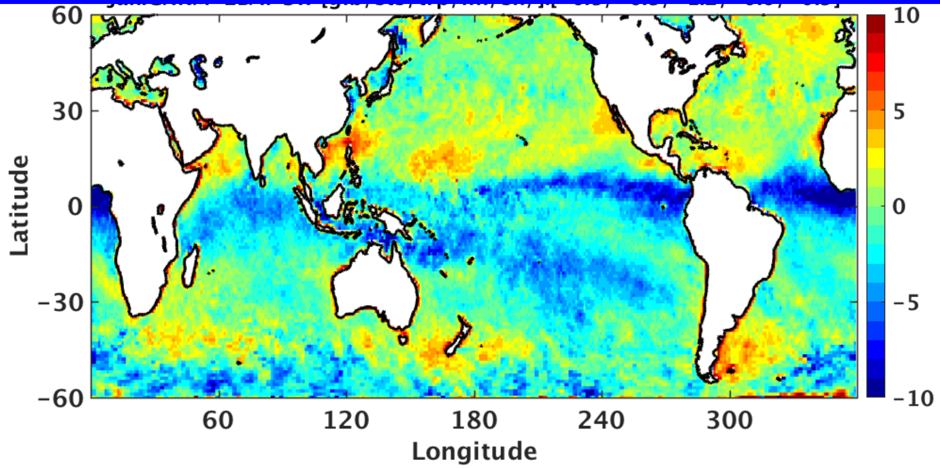




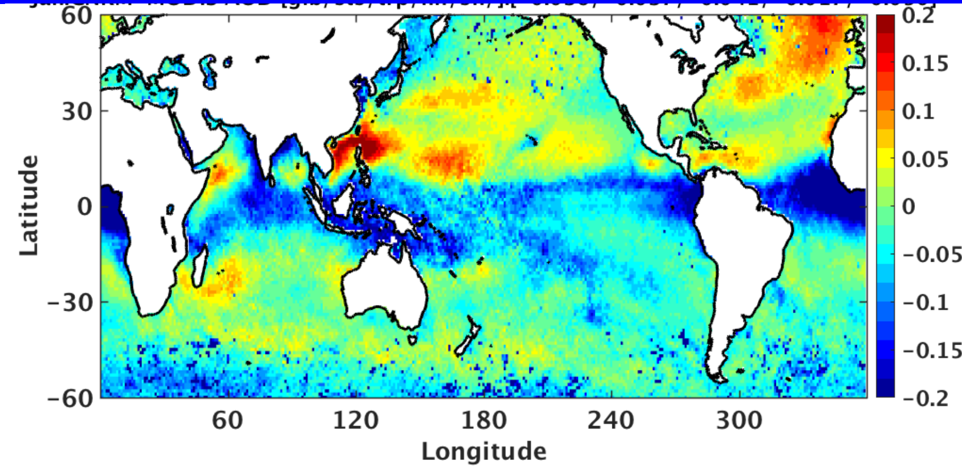
- The annual variation of clear-sky SW flux from models tracks that from EBAF well.
- Models underestimate the clear-sky SW flux by up to 3.5 Wm^{-2} during the boreal winter months, and by up to 2 Wm^{-2} during the boreal summer months;
- All models, except CAM5.3 during the summer months, underestimate the AODs over ocean.
- Assuming clear-sky aerosol radiative efficiency of 30-40 Wm^{-2}/τ, most of the flux differences can be explained by the AOD differences.

Regional clear-sky SW flux differences between CNRM and EBAF and aerosol optical depth differences between CNRM and MODIS

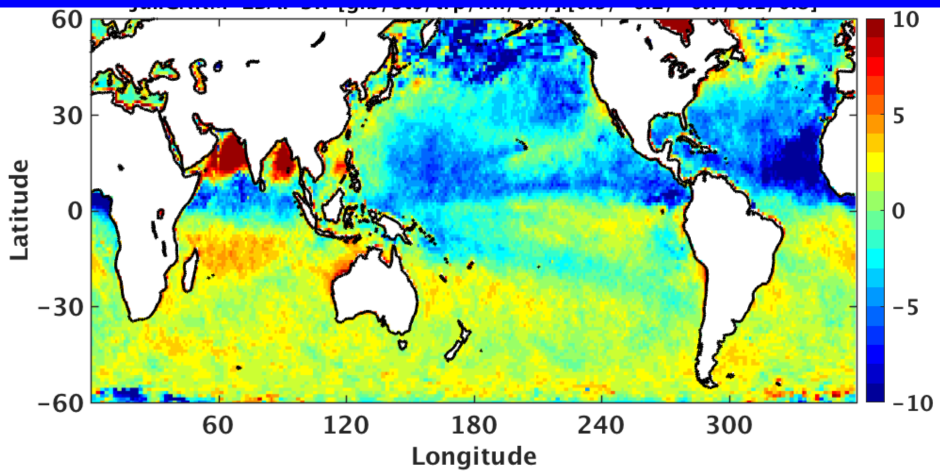
January flux difference (CNRM-EBAF): $-0.9 Wm^{-2}$



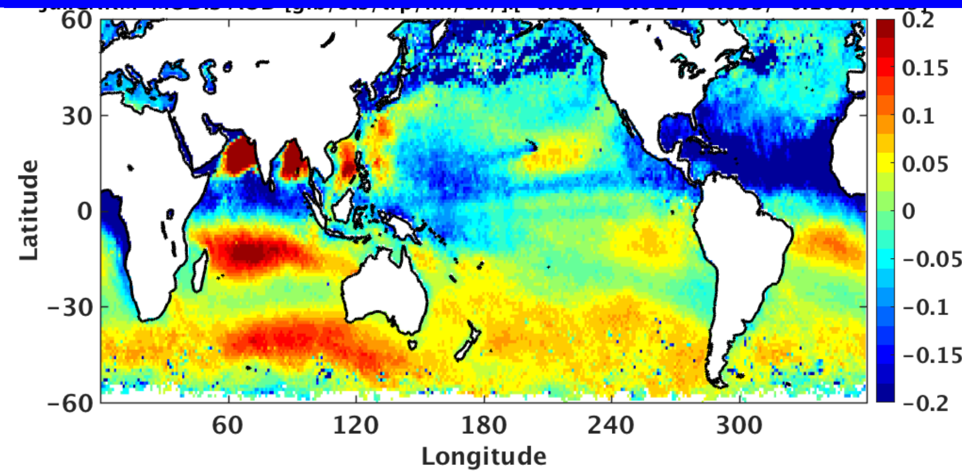
January AOD difference (CNRM-MODIS): -0.037



July flux difference: -0.2Wm-2

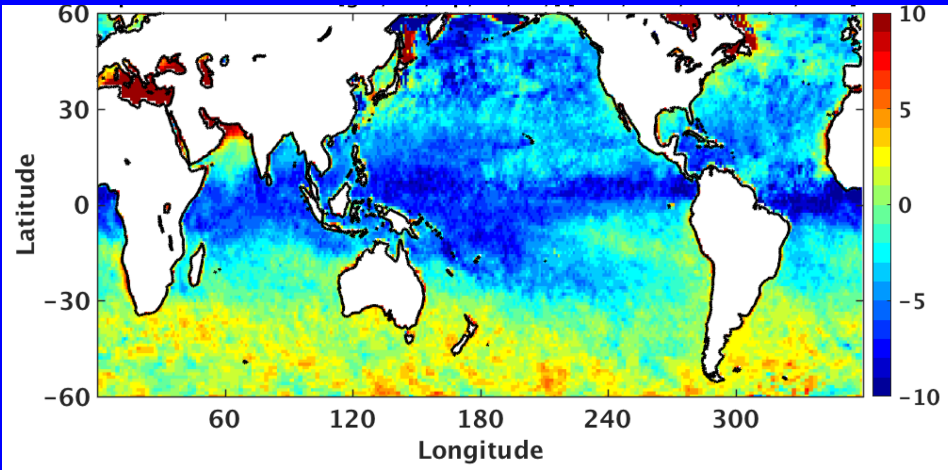


July AOD difference: -0.012

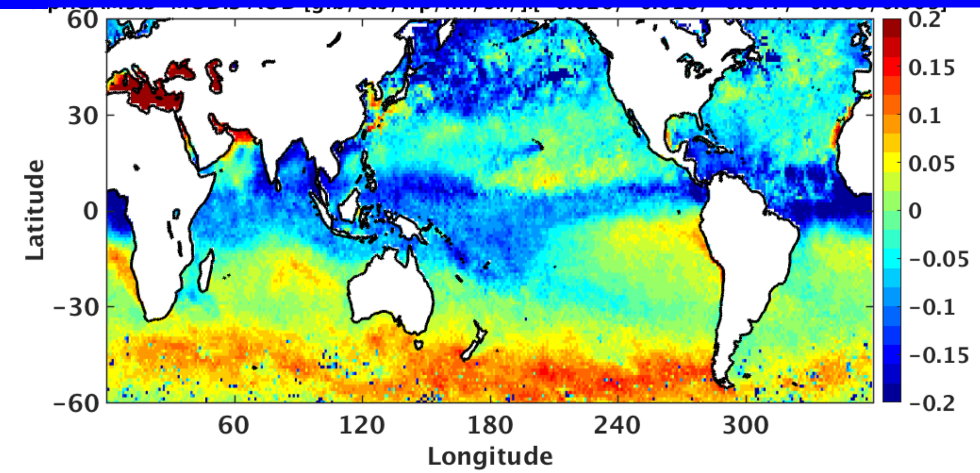


Regional clear-sky SW flux differences between CAM5.3 and EBAF and aerosol optical depth differences between CAM5.3 and MODIS

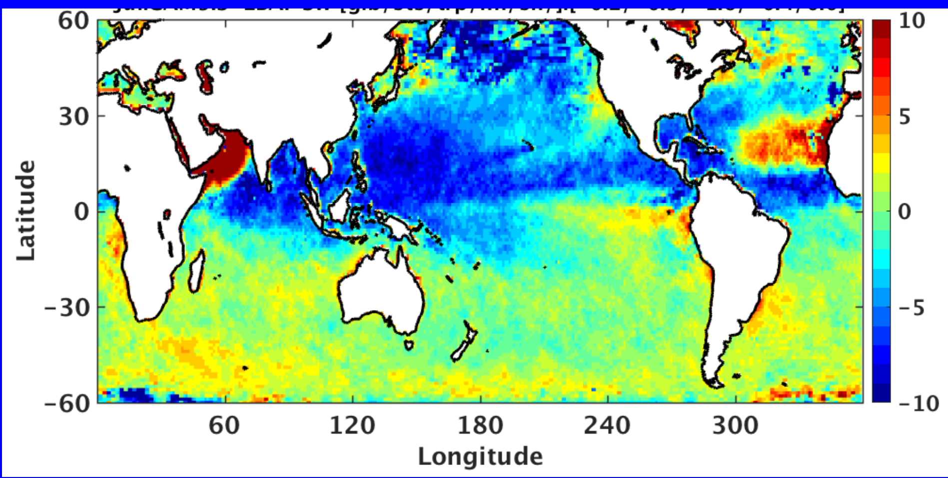
April flux difference: -2.1 Wm-2



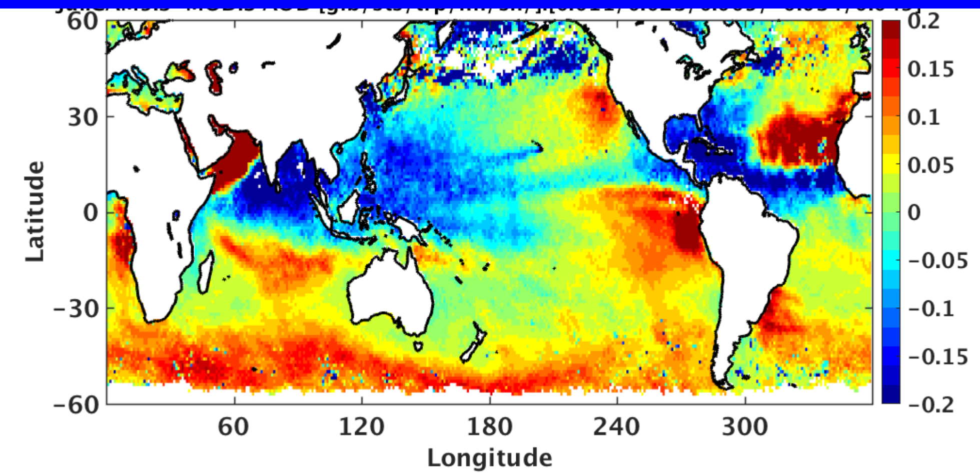
April AOD difference: -0.018



July flux difference: -0.9 Wm-2

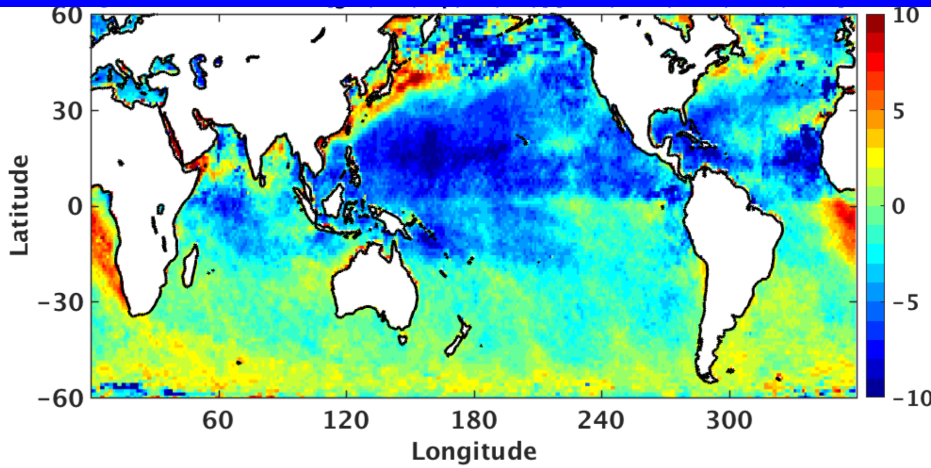


July AOD difference: 0.025

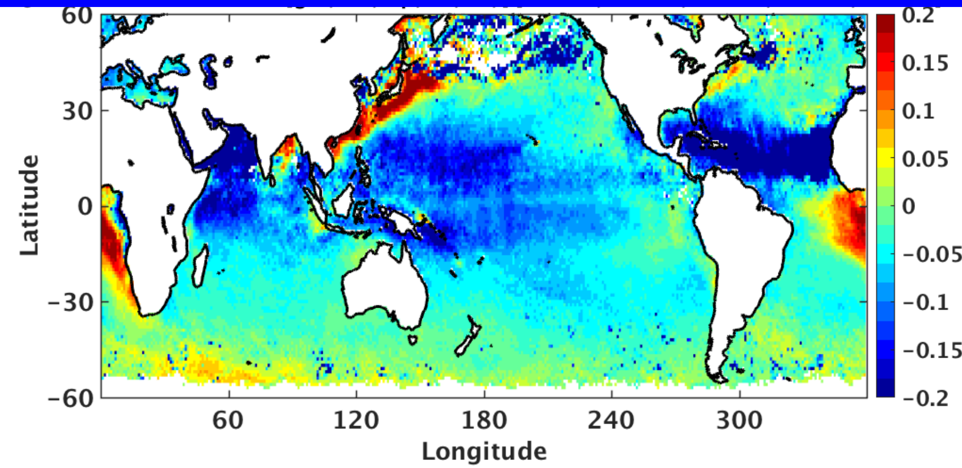


Regional clear-sky SW flux differences between SPRINTARS and EBAF and aerosol optical depth differences between SPRINTARS and MODIS

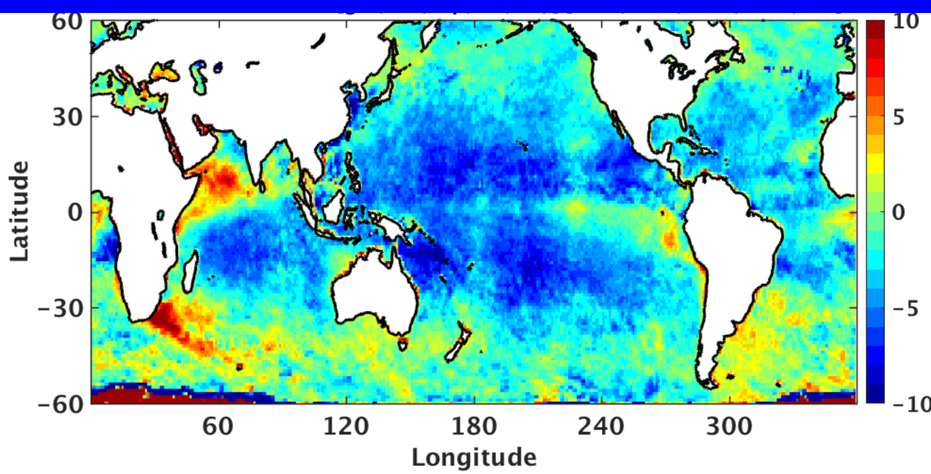
July flux difference: -1.9 Wm-2



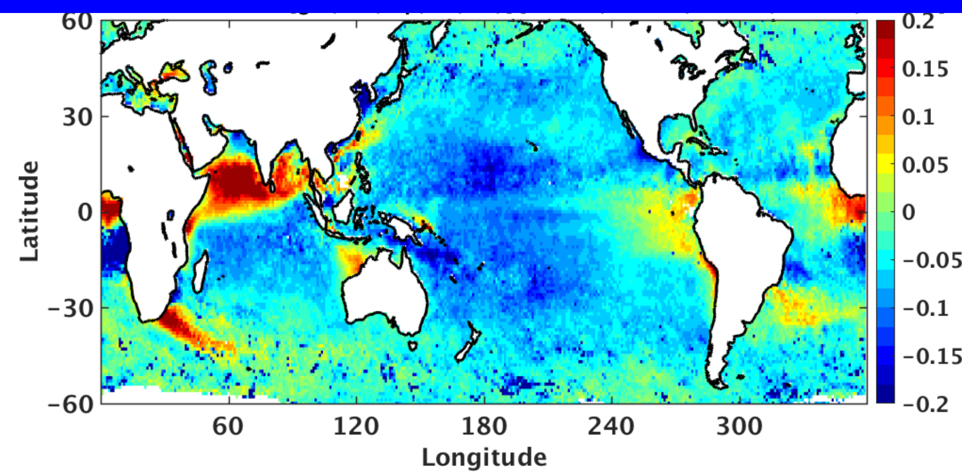
July AOD difference: -0.058



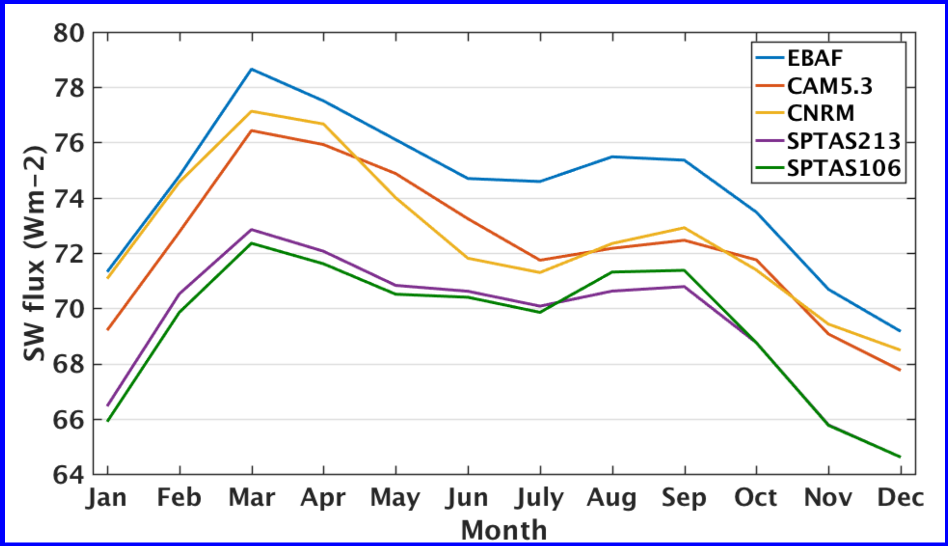
October flux difference: -2.2 Wm-2

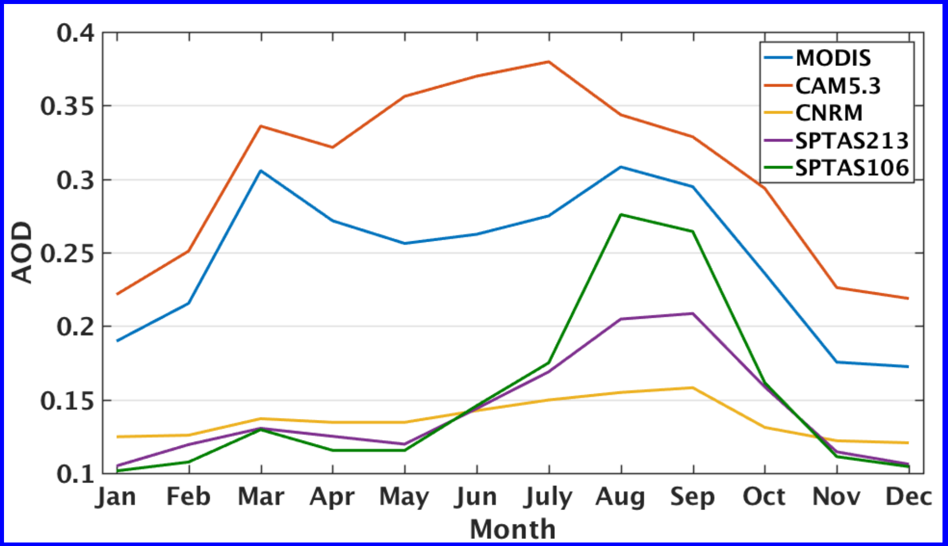


October AOD difference: -0.049



Monthly mean clear-sky flux and AOD comparison: over land

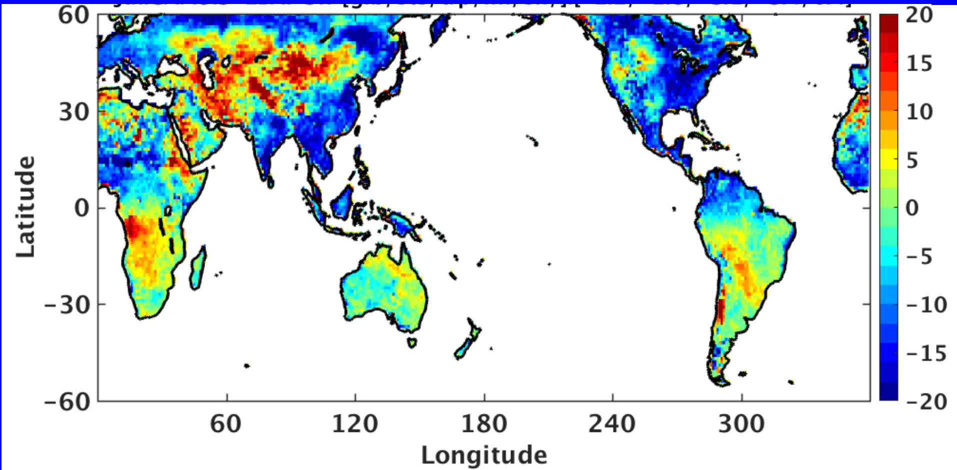




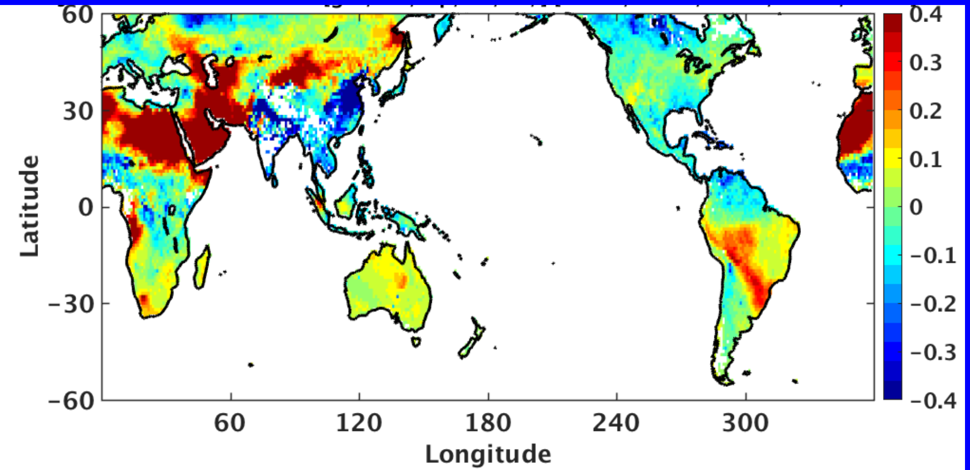
- All models underestimate the clear-sky TOA SW fluxes, with differences as large as 6 Wm^{-2};
- Comparing to the MODIS AOD, CAM5.3 overestimates the AOD over land, while all the other models underestimate the AOD;
- Clear-sky TOA SW fluxes from CNRM have the best agreement with EBAF, however, AODs from CNRM are the lowest among all the models;
- Surface albedo used in the models need to be evaluated.

Flux differences and AOD differences over land for July

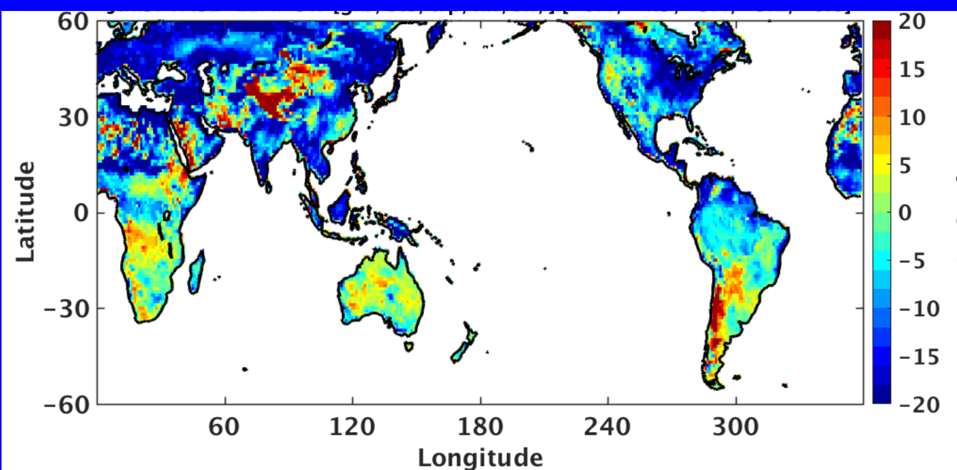
July flux difference: CAM5.3-EBAF=-2.8 Wm-2



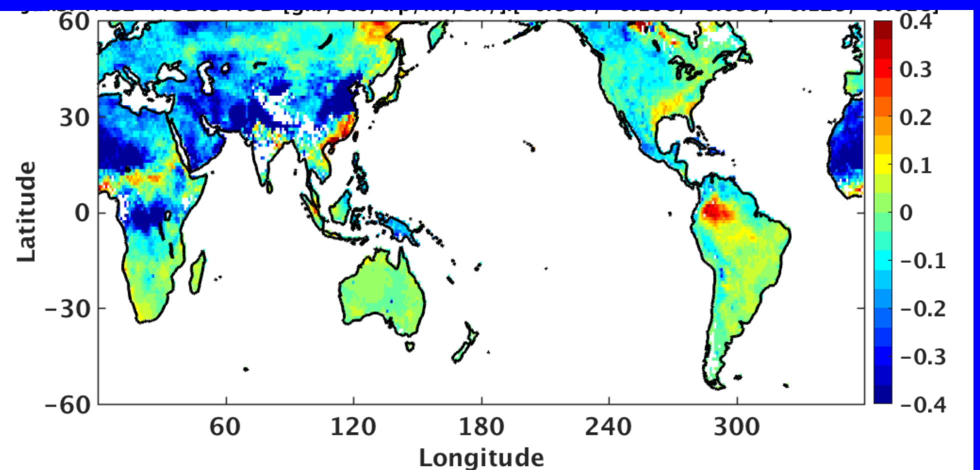
July AOD difference: CAM5.3-EBAF=0.113



July flux difference: SPTAS-EBAF=-4.5 Wm-2

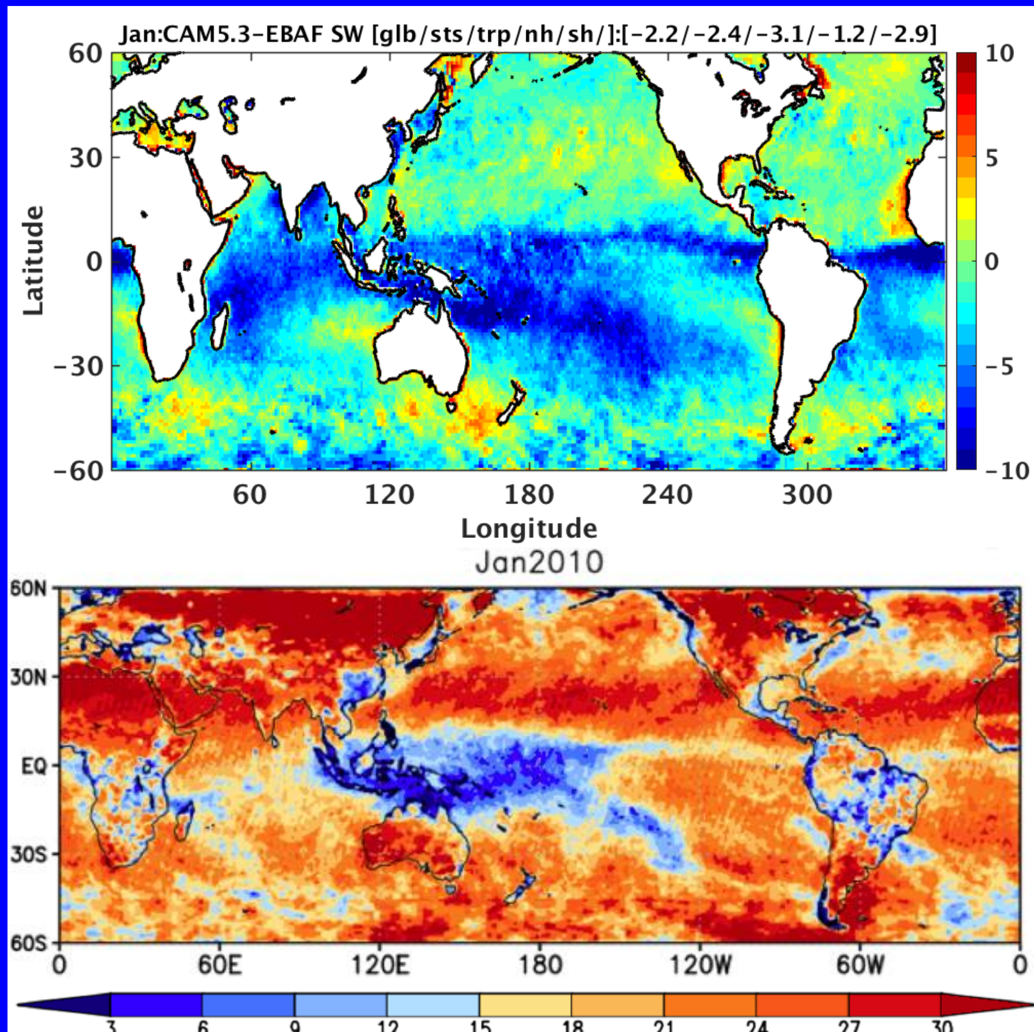


July AOD difference: SPTAS-EBAF=-0.106



Causes for the SW flux differences

- Biases in aerosol properties and surface albedo;
- Radiative transfer calculation biases (Randles et al., 2013);
- Uncertainty in the observations: cloud contamination, sampling issues.



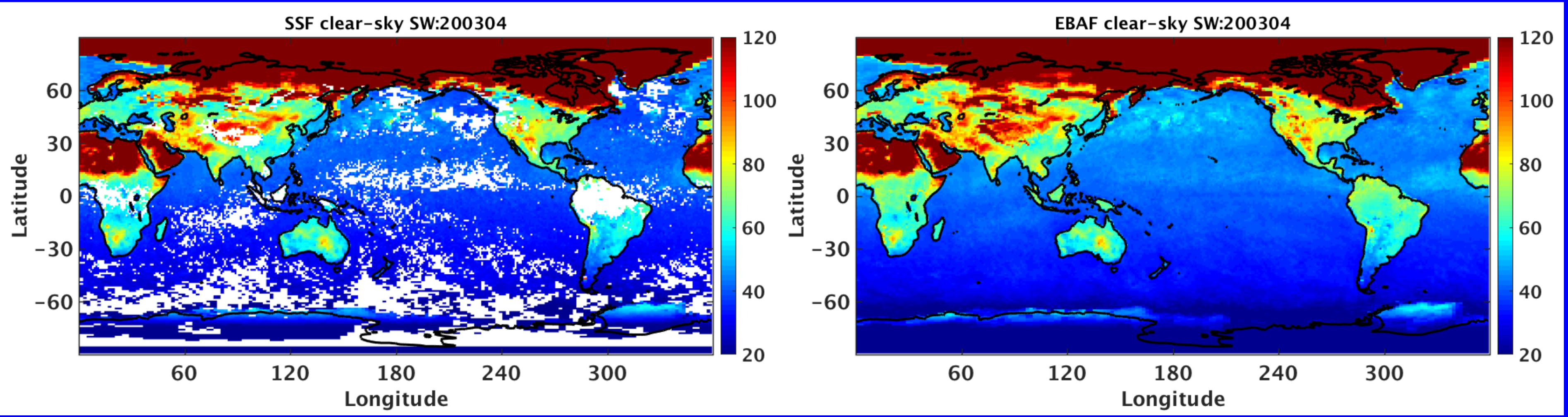
Summary

- TOA clear-sky fluxes from CERES EBAF offer an independent dataset for model evaluation;
- EBAF clear-sky SW fluxes are determined independently of MODIS AODs, thus consistency in their regional difference patterns against models over ocean suggests the differences are robust;
- To better understand the differences over land, surface albedo used in the AeroCom models need to be evaluated with observations (i.e. MODIS);
- Only five models provided the TOA clear-sky flux output;
- Simulations cover 2000-2020 will enable decadal trend evaluation against CERES EBAF, MODIS AOD, and many other datasets. This will offer new insights on AeroCom model simulation of aerosol changes;
- Daily outputs are needed to better address the sampling issues between observations and simulations.

Back up

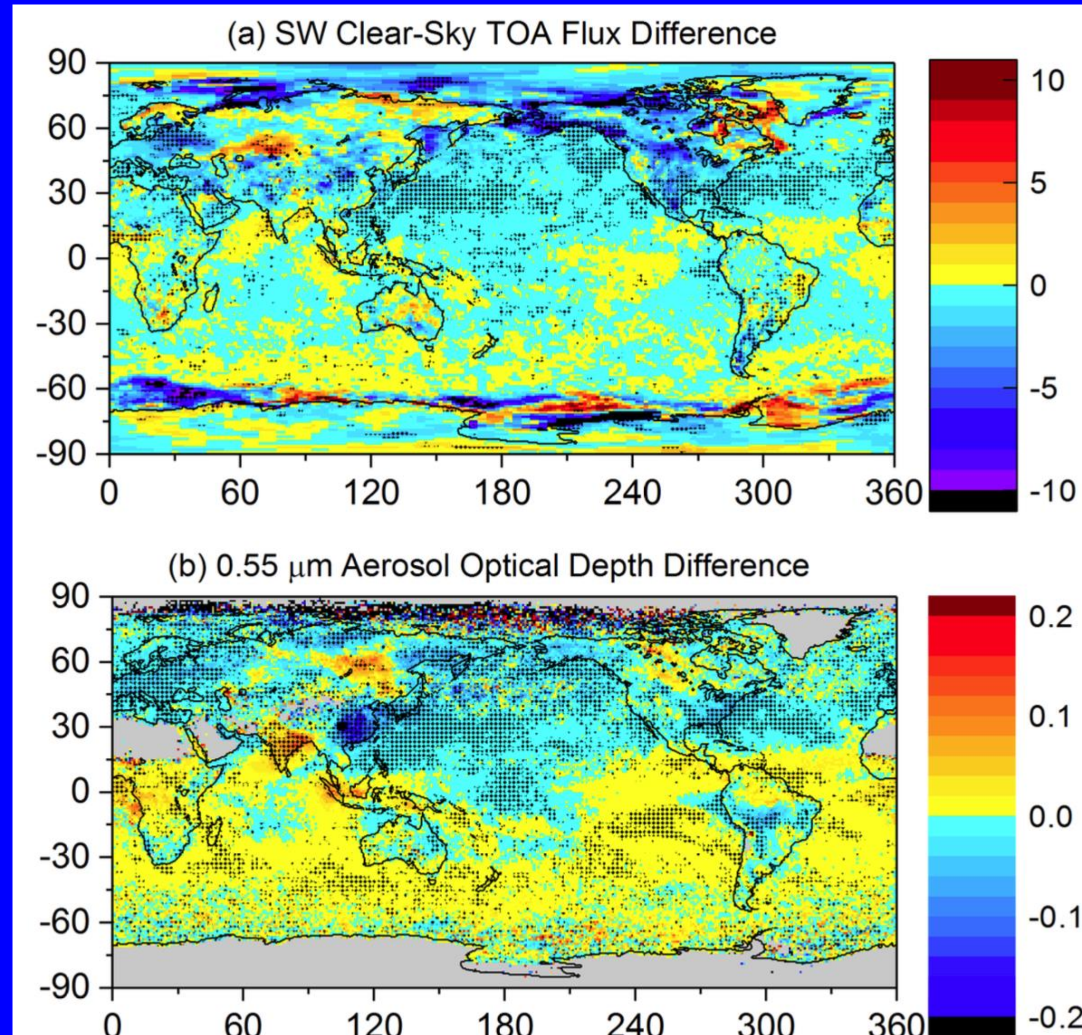
Clear-sky fluxes in EBAF are gap free

- Clear-sky fluxes in EBAF include clear-sky fluxes from cloud-free CERES footprints and from clear portions of partly cloudy (f<95%) CERES footprints;
- Clear-sky fluxes in partly cloudy CERES footprints are determined from MODIS narrowband radiances averaged over the clear portions of a footprint using MODIS–CERES narrowband-to-broadband regressions ;
- The narrowband-to-broadband regressions are developed from cloud-free CERES footprints for each calendar month;
- Monthly mean clear-sky fluxes are derived by weighting the daily mean SW fluxes with the grid box clear-area fraction to minimize the contamination of subpixel-scale clouds;
- The uncertainty of monthly mean clear-sky TOA SW flux in 1°x1° region is estimated to be 5 Wm^{-2} (Loeb et al. 2018).



Regional mean differences in clear-sky TOA SW and AOD (07/2014-06/2017) minus (07/2002-06/2014)

- Large reductions in clear-sky SW TOA flux are found over much of the Pacific and Atlantic Oceans in the northern hemisphere.
- These are associated with a reduction in aerosol optical depth consistent with stricter pollution controls in China and North America.
- EBAF clear-sky SW fluxes are determined independently of MODIS AODs, thus consistency in their regional patterns suggests the differences for this two periods are robust.



Loeb et al. (2018)