Global all-sky direct radiative forcing of anthropogenic aerosols from combined satellite observations and GOCART simulations

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Natural/Pre-Industrial Aerosols

Total/Present Day Aerosol

- Anthropogenic = Total – Natural (Present Day – Pre Industrial)

Direct aerosol radiative effect/forcing

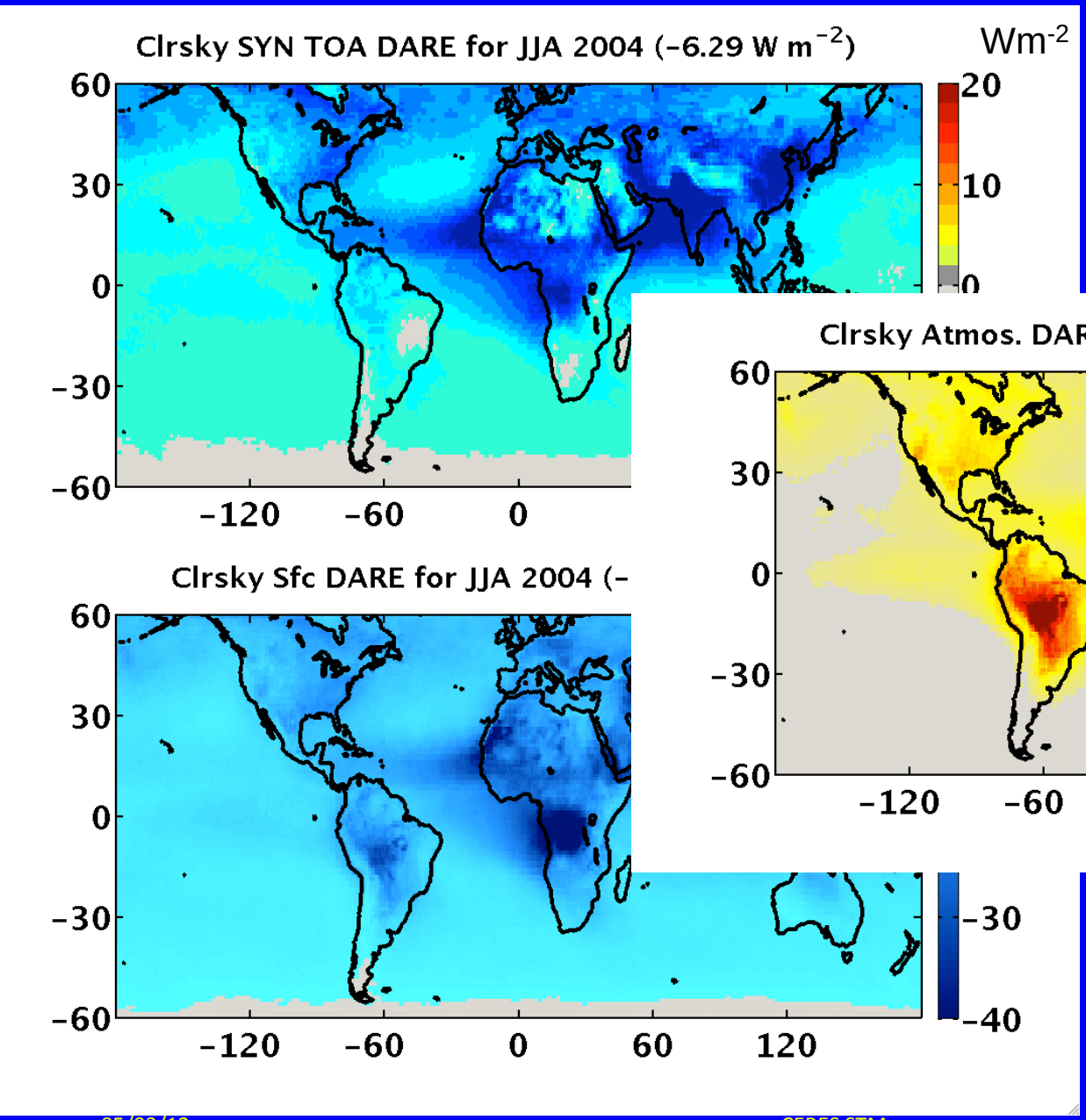
- Direct aerosol radiative effect (DARE) is the mean radiative flux perturbation due to the presence of aerosols (both natural and anthropogenic)
- Direct aerosol radiative forcing (DARF) is the anthropogenic component of DARE
- DARE has been estimated from satellite measurements, but mostly for clear-sky
- Estimating DARF from satellite measurements is more challenging
- We combine cloud properties and TOA fluxes in CERES product with natural and anthropogenic aerosols in GOCART to derive all-sky DARF.

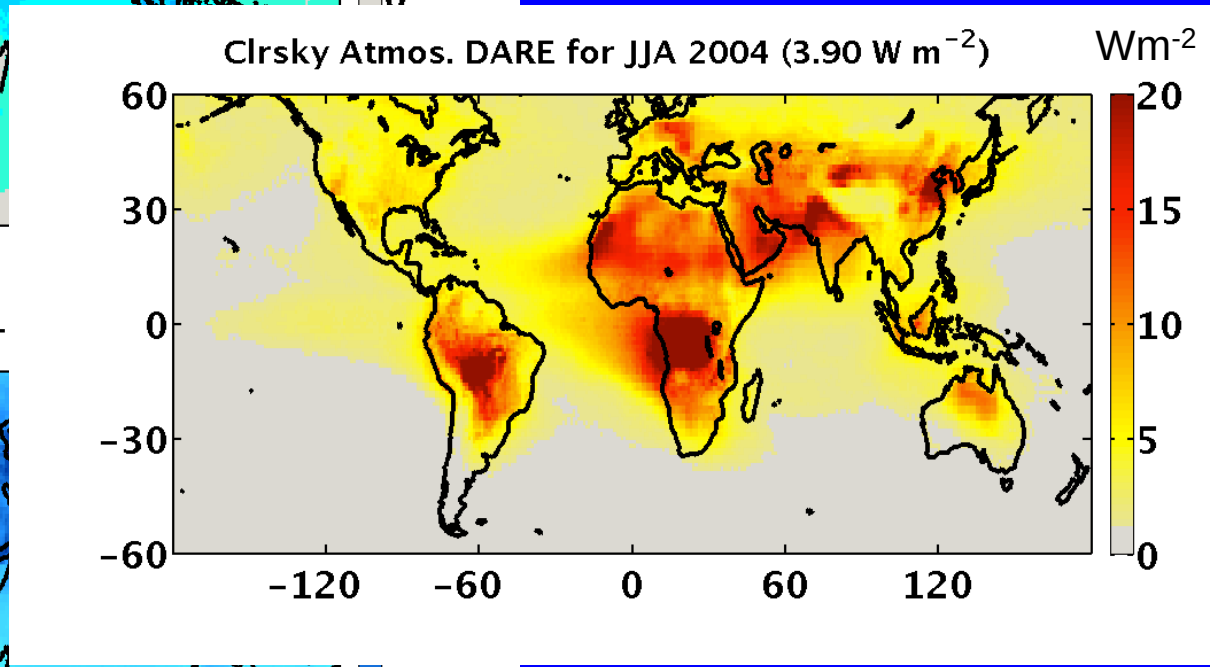
CERES synoptic radiative fluxes and clouds product

- Cloud properties (3-hourly)
  - MODIS and geostationary satellite retrievals
- Aerosol optical depths
  - MODIS and MATCH aerosol assimilation model
- Aerosol composition and profile
  - MATCH model
- Radiative transfer calculations provide fluxes at the TOA and surface
  - 3-hourly radiative fluxes
    - Pristine: $F_{c,p}$
    - clear-sky: $F_{c,t}$
    - all-sky: $F_{a,t}$
    - all-sky no-aerosol: $F_{a,p}$

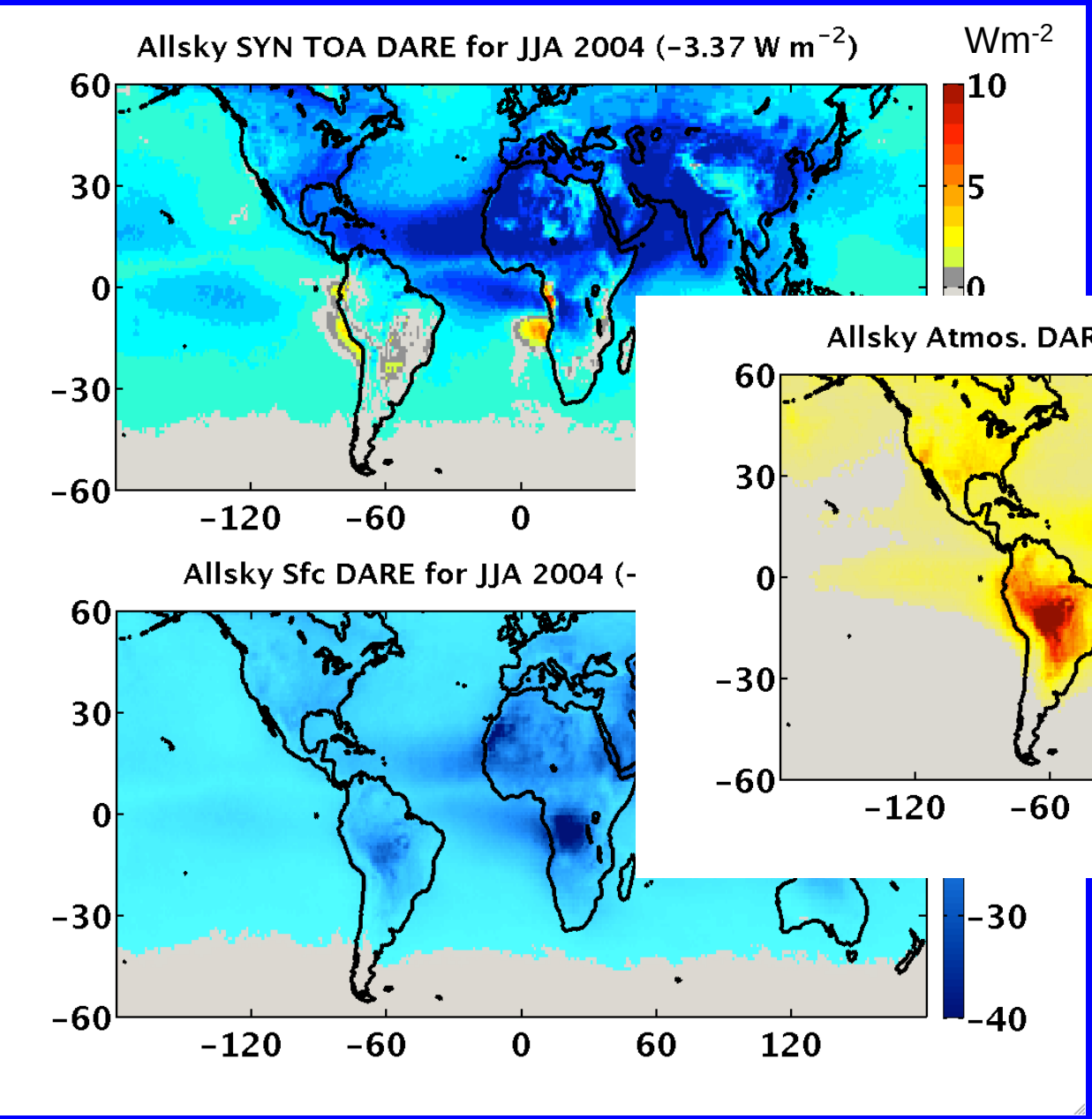
$$\left.\begin{array}{l} F_{c,p} \\ F_{c,t} \\ F_{a,t} \\ F_{a,p} \end{array}\right\} \Longrightarrow \begin{array}{l} DARE_c = F_{c,t} - F_{c,p} \\ DARE_a = F_{a,t} - F_{a,p} \end{array}$$

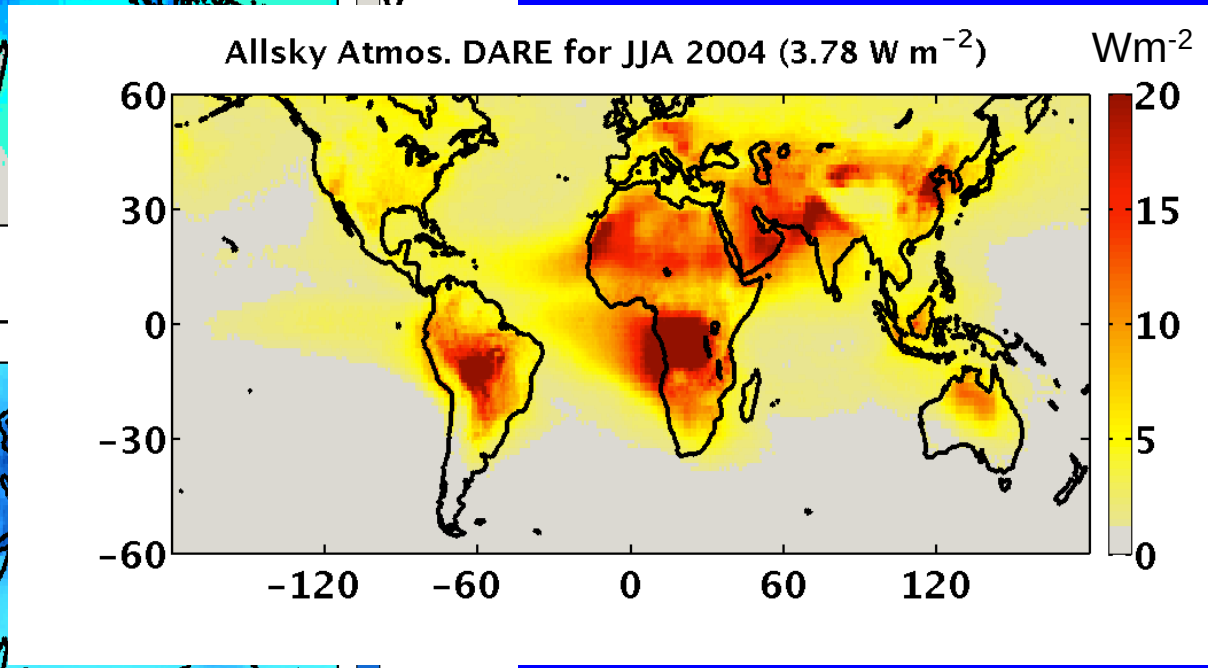
Clear-sky DARE from CERES SYN





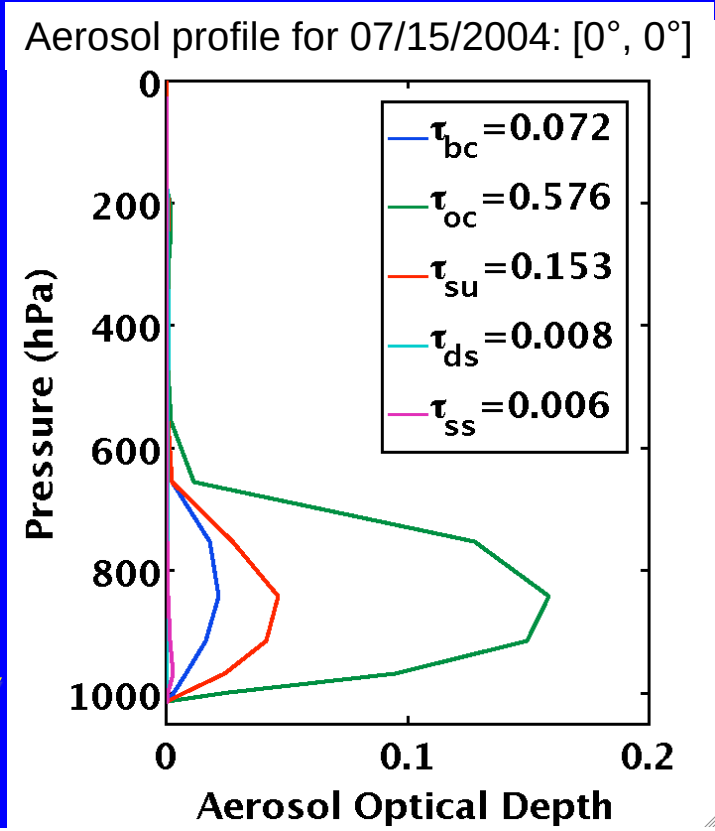
All-sky DARE from CERES SYN



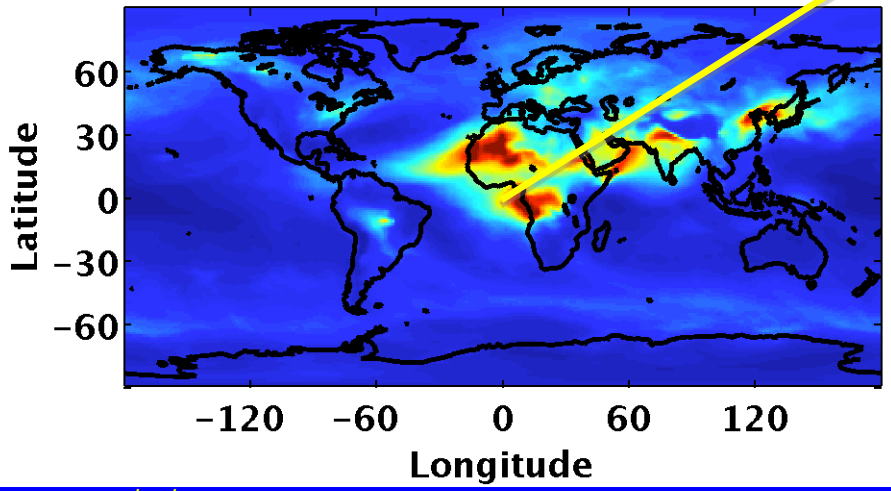


GOCART model

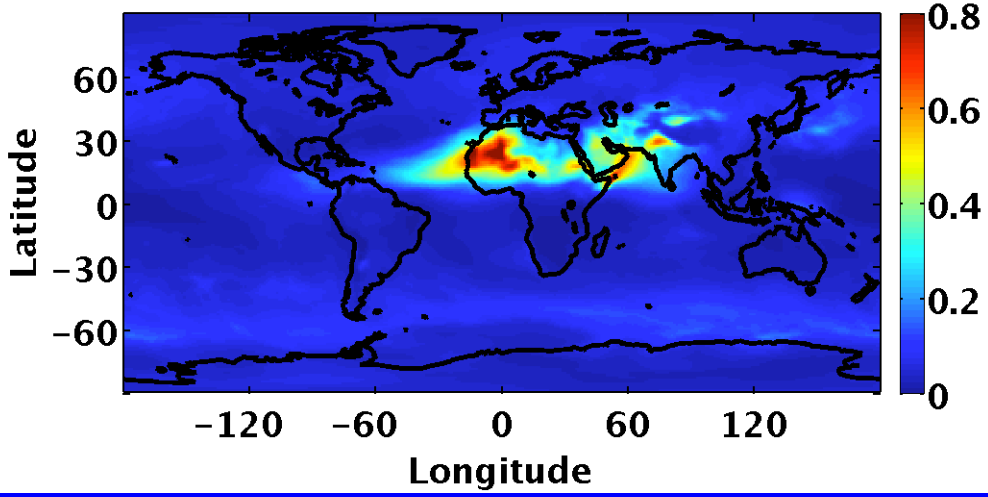
- Daily 1°X1.25° GOCART output contains:
  - AOD of total organic carbon, black carbon, sea salt, dust, and sulfate; and their vertical profiles
  - AOD of natural organic carbon, black carbon, and sulfate; and their vertical profiles



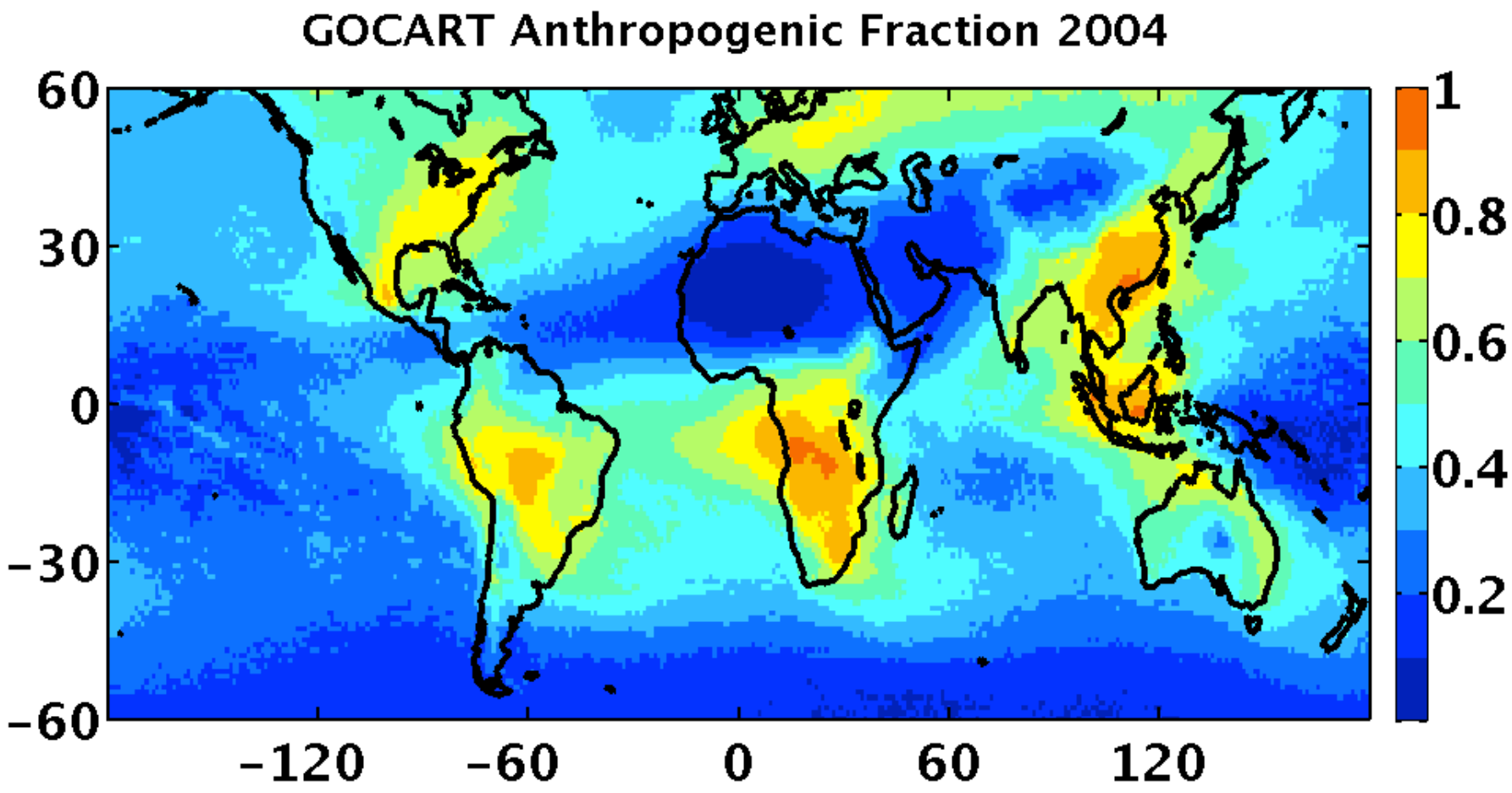
July 2004 GOCART Total AOD



GOCART natural AOD

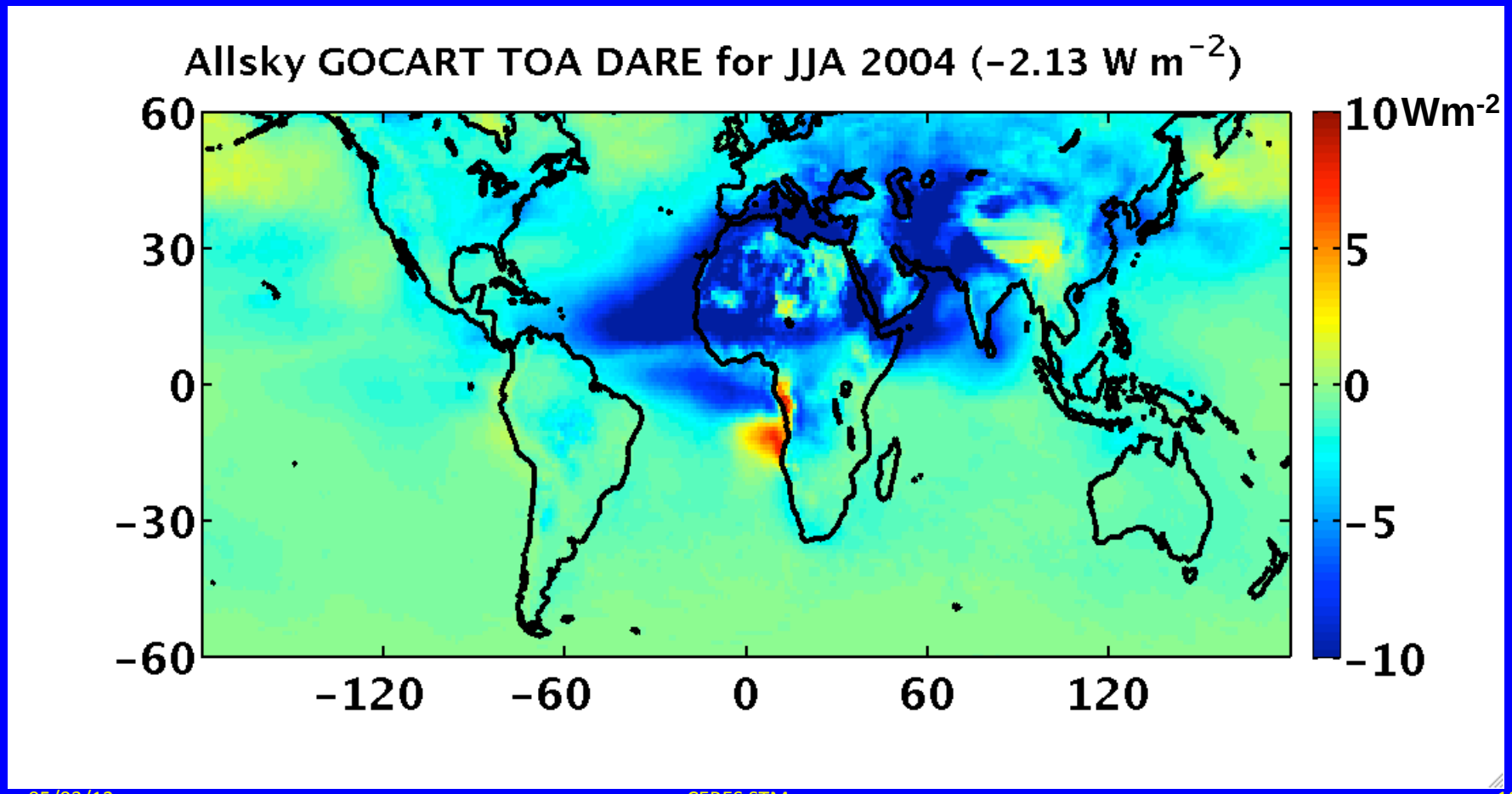


Anthropogenic fraction (τ_a/τ) from GOCART



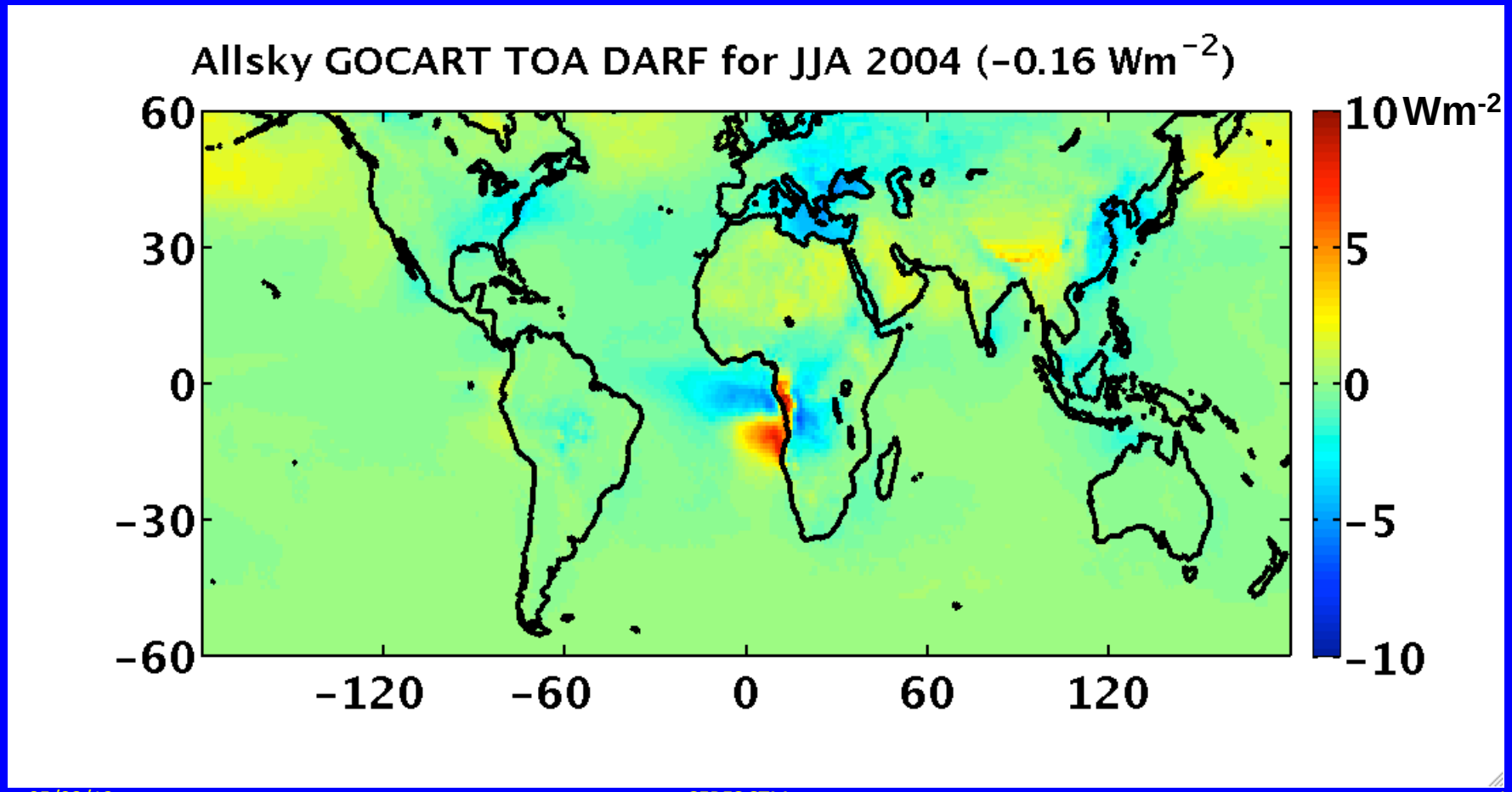
Combine CERES SYN and GOCART to derive all-sky DARF

- First run radiative transfer model with inputs of
  - 3-hourly cloud properties and surface albedo from CERES SYN
  - Daily-mean TOTAL aerosol optical depth and vertical distribution from GOCART



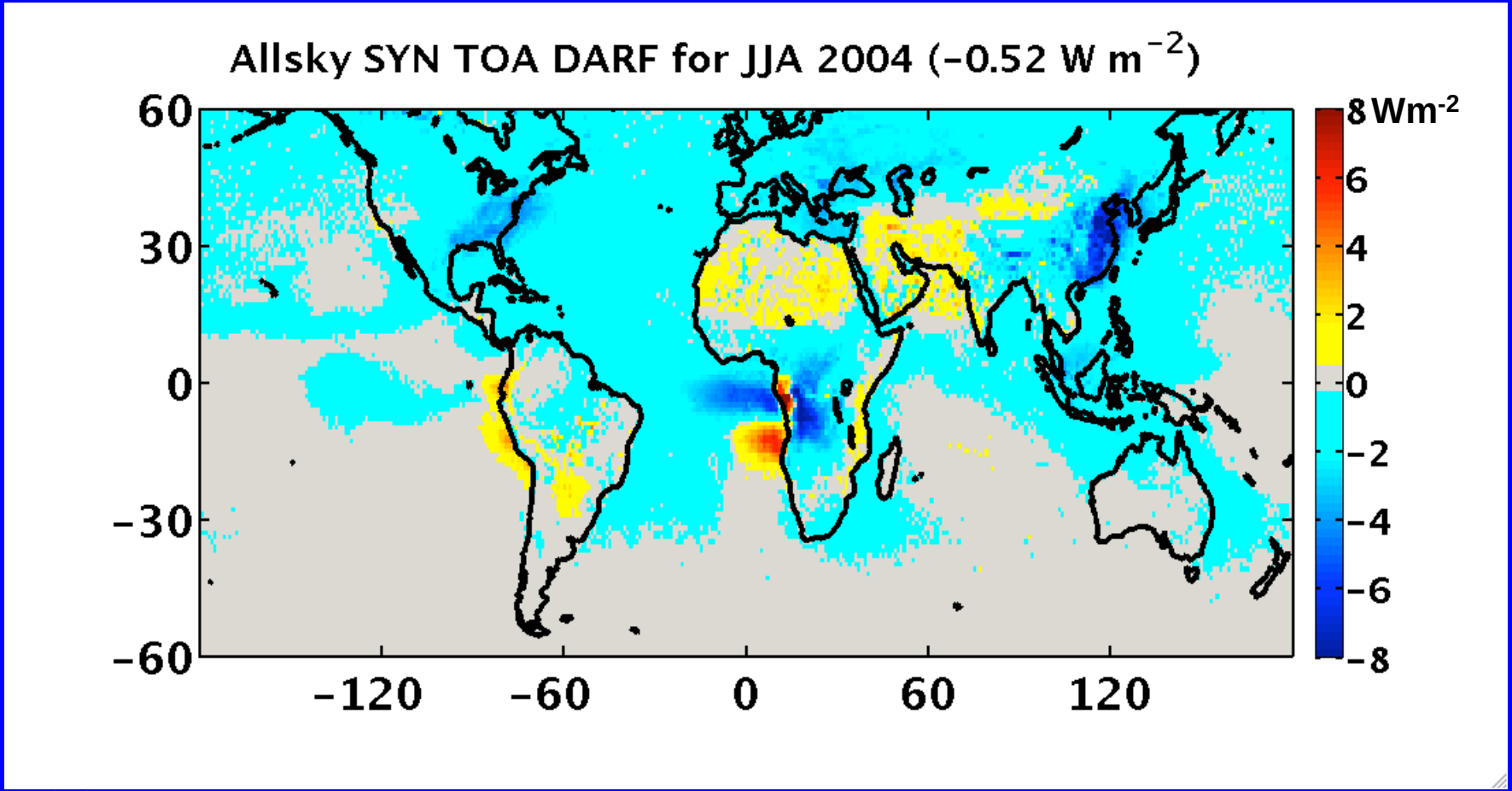
Combine CERES SYN and GOCART to derive all-sky DARF

- Then run radiative transfer model with inputs of
  - 3-hourly cloud properties and surface albedo from CERES SYN
  - Daily-mean NATURAL aerosol optical depth and vertical distribution from GOCART



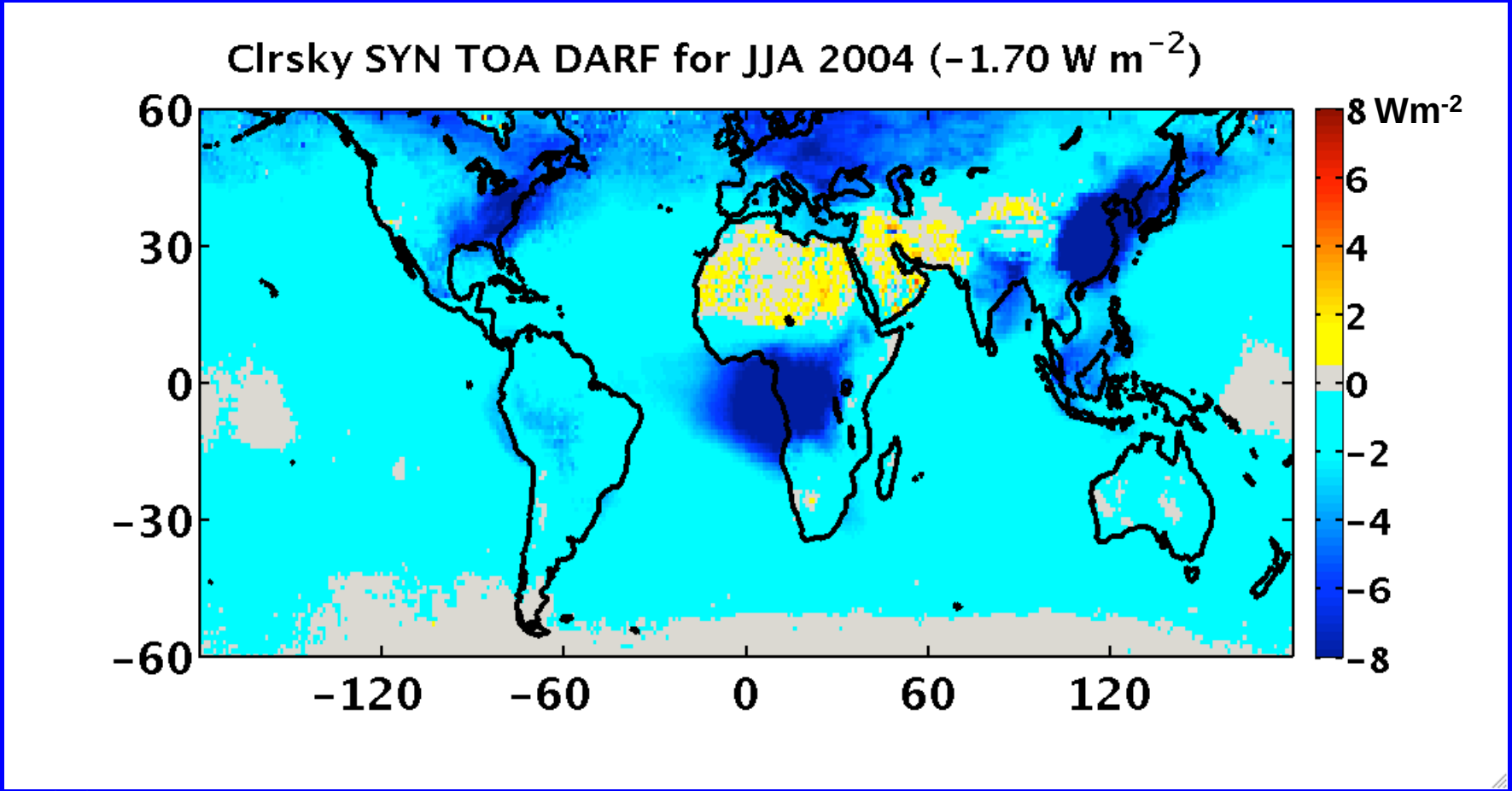
Combine CERES SYN and GOCART to derive all-sky DARF

$$DARF^{all}_{SYN} = DARE^{all}_{SYN} \times \frac{DARF^{all}_{GOCART}}{DARE^{all}_{GOCART}}$$

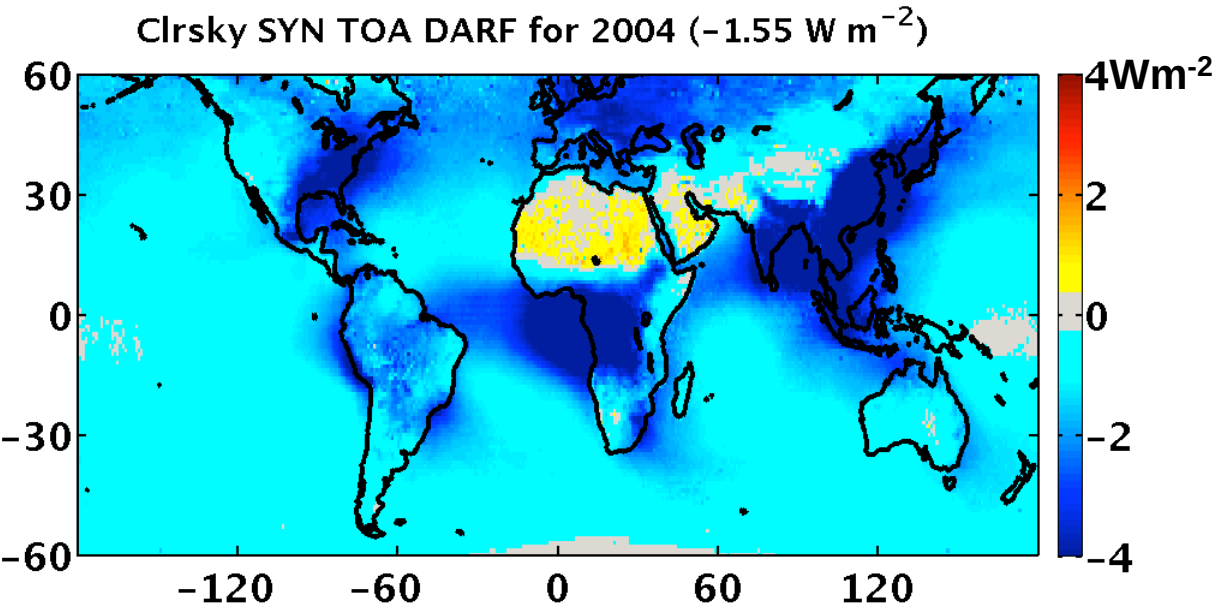


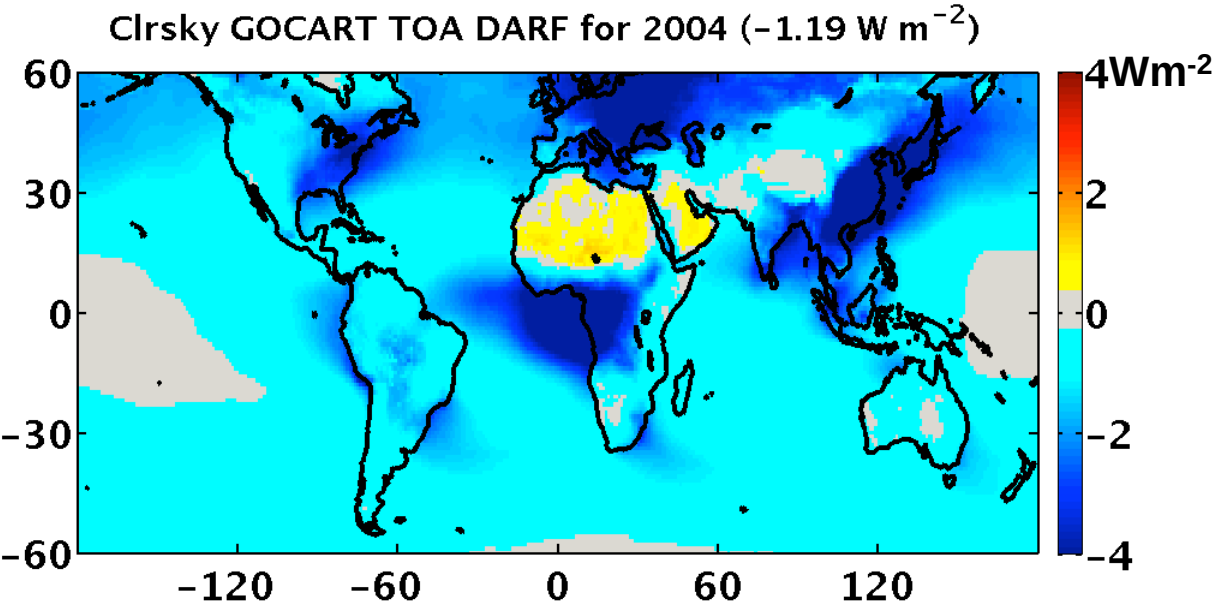
Clear-sky DARF is derived using the same method

$$DARF^{clr}_{SYN} = DARE^{clr}_{SYN} \times \frac{DARF^{clr}_{GOCART}}{DARE^{clr}_{GOCART}}$$



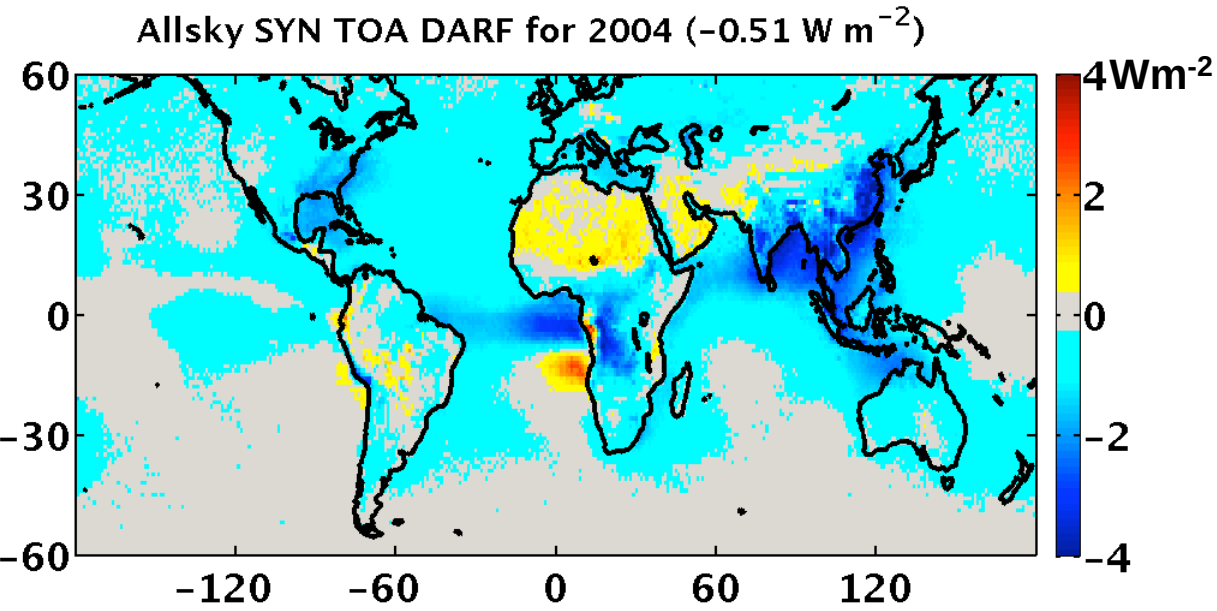
GOCART underestimates clear-sky DARF by 23%

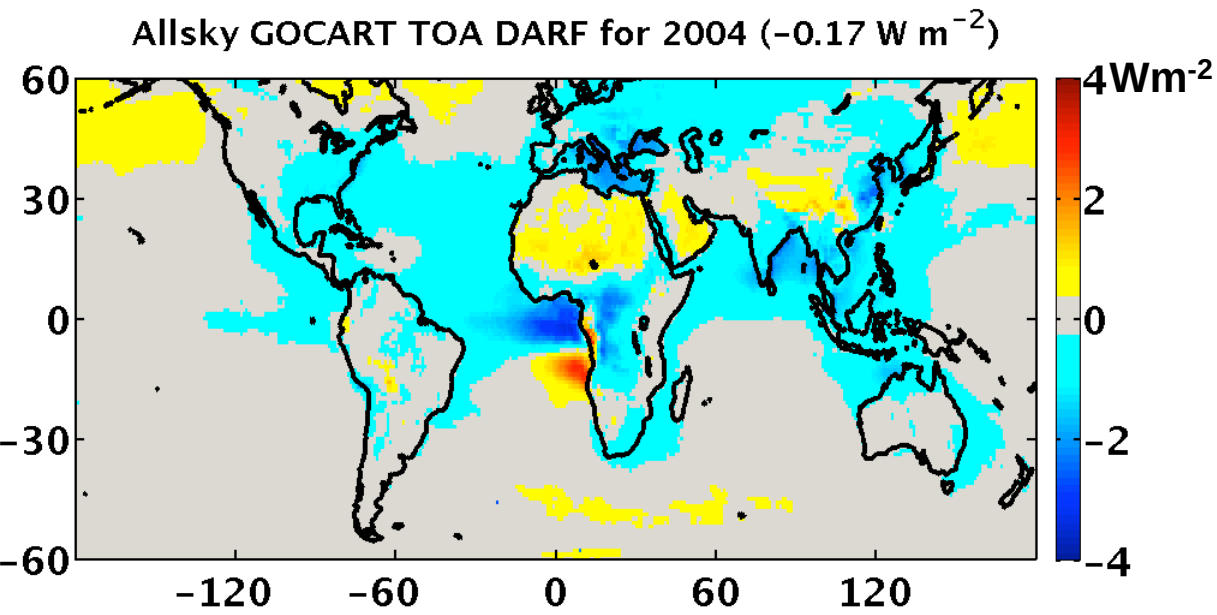




DARF (Wm^{-2})	SYN	GOCART
60S~60N	-1.55	-1.19
Ocean	-1.39	-1.08
Land	-1.98	-1.50
NH	-1.86	-1.53
SH	-1.25	-0.86

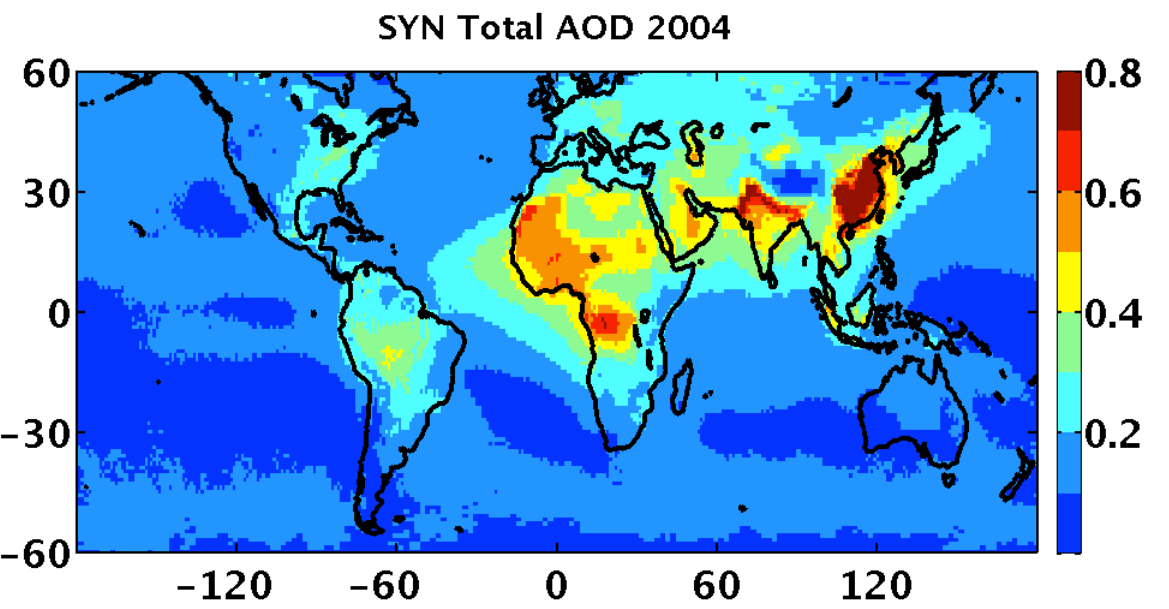
GOCART underestimates all-sky DARF by 67%

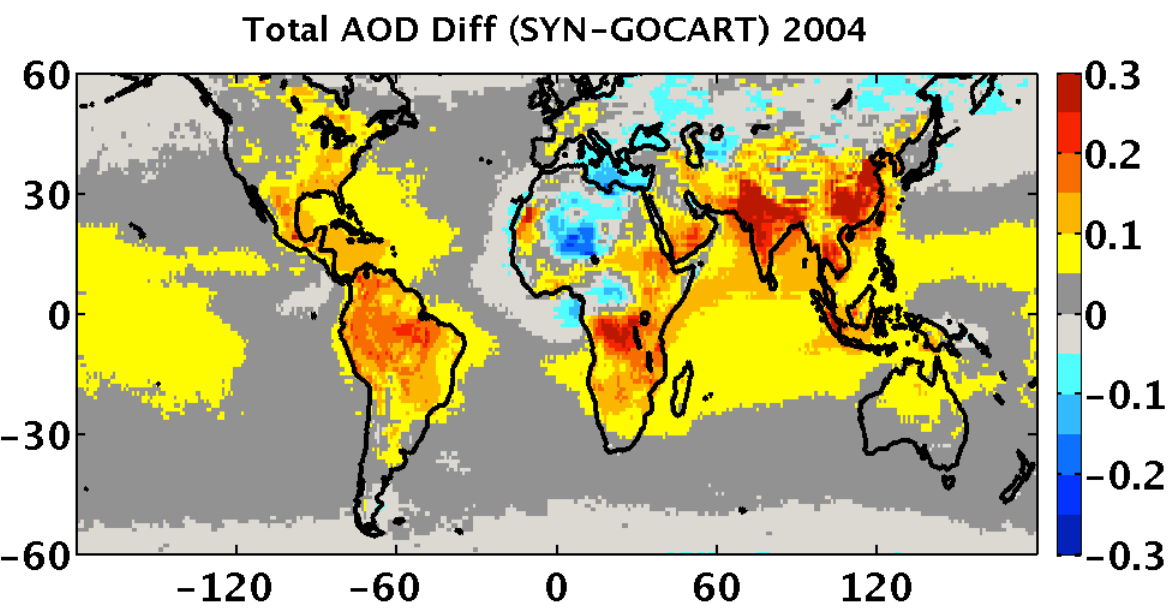




DARF (Wm^{-2})	SYN	GOCART
60S~60N	-0.51	-0.17
Ocean	-0.49	-0.15
Land	-0.57	-0.23
NH	-0.67	-0.29
SH	-0.35	-0.06

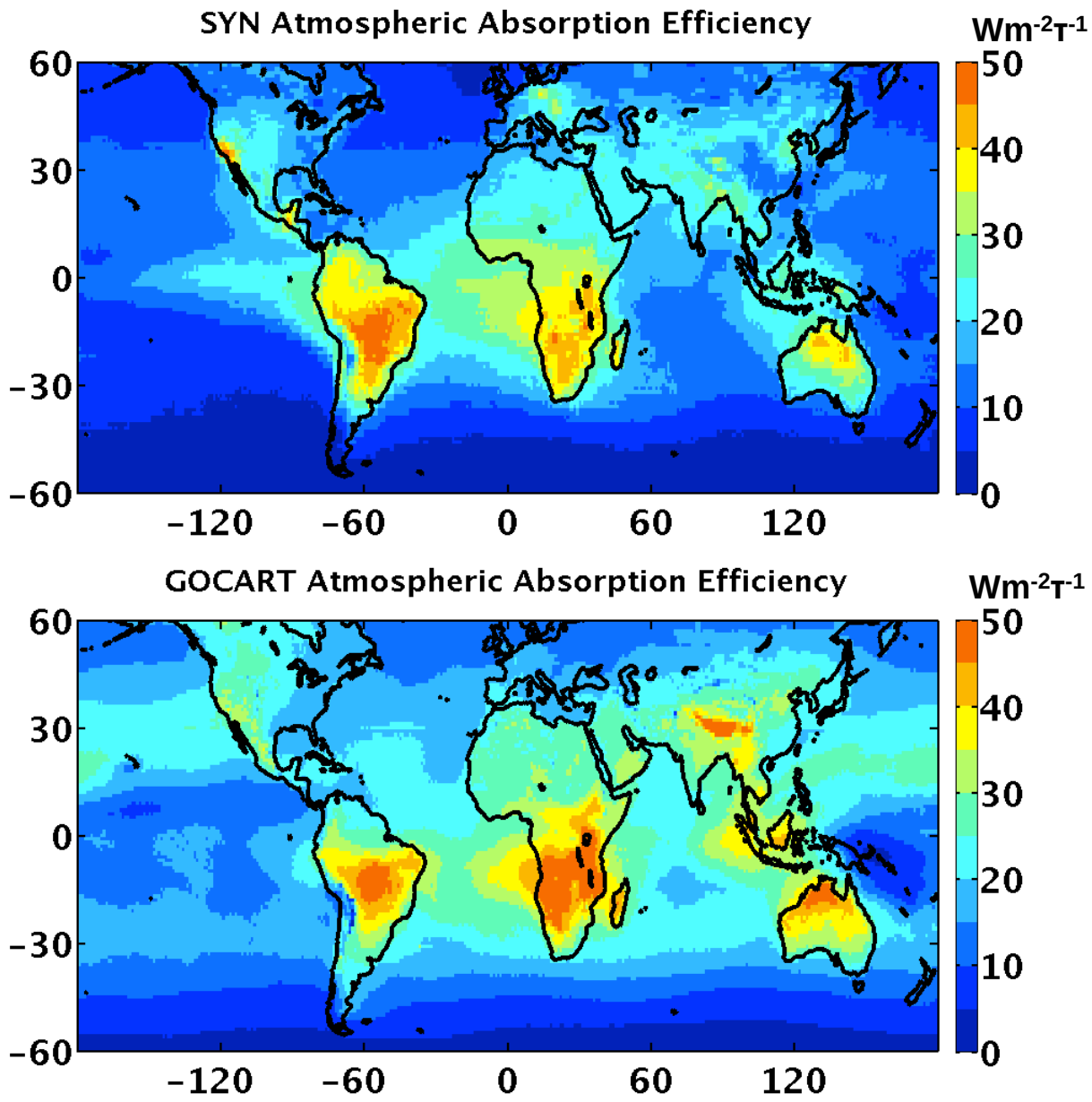
Aerosol optical depth in SYN is larger than in GOCART





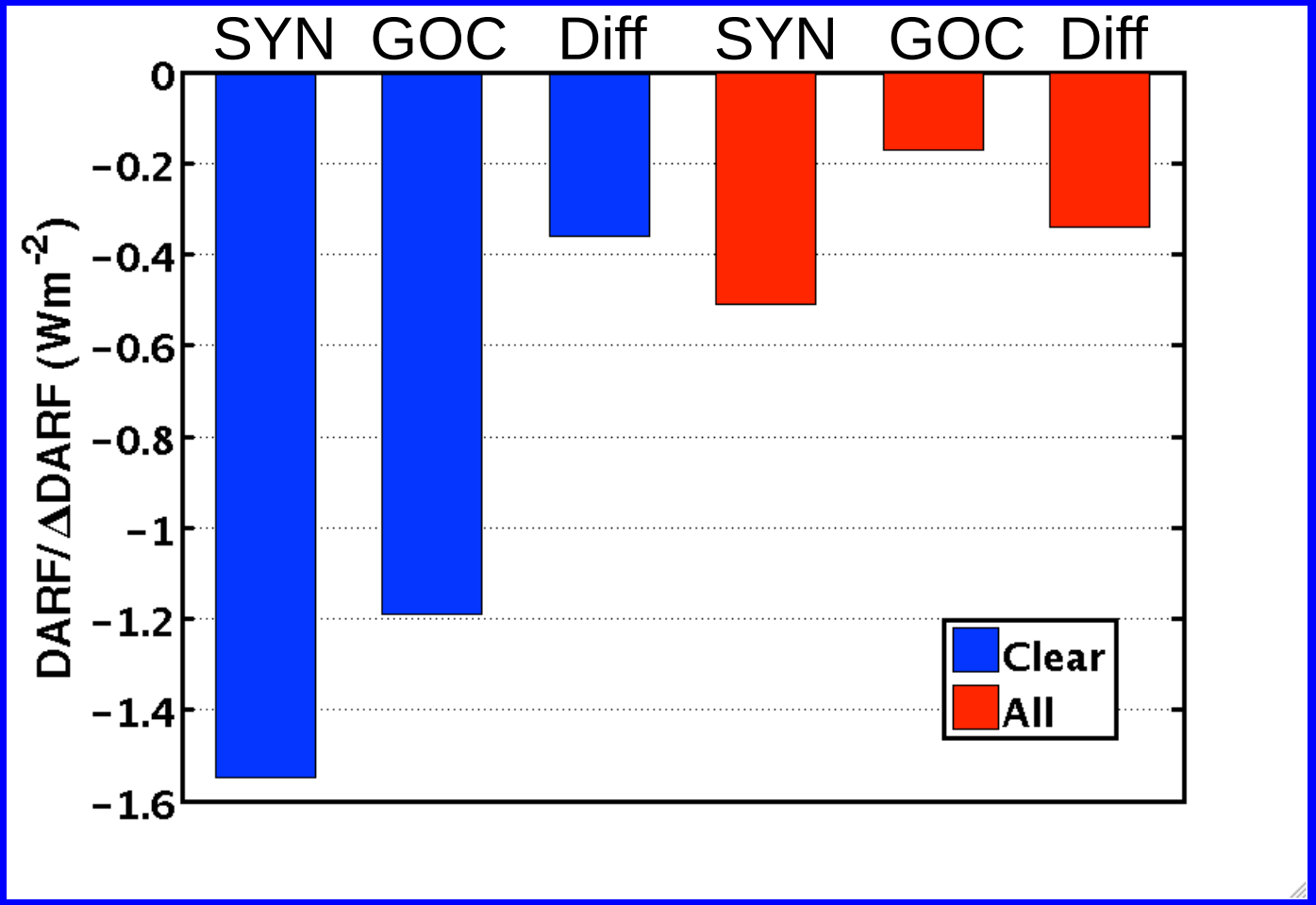
AOD	SYN	GOCART
60S~60N	0.18	0.14
Ocean	0.14	0.11
Land	0.28	0.22
NH	0.23	0.19
SH	0.13	0.09

Aerosols in GOCART are more absorbing than in SYN

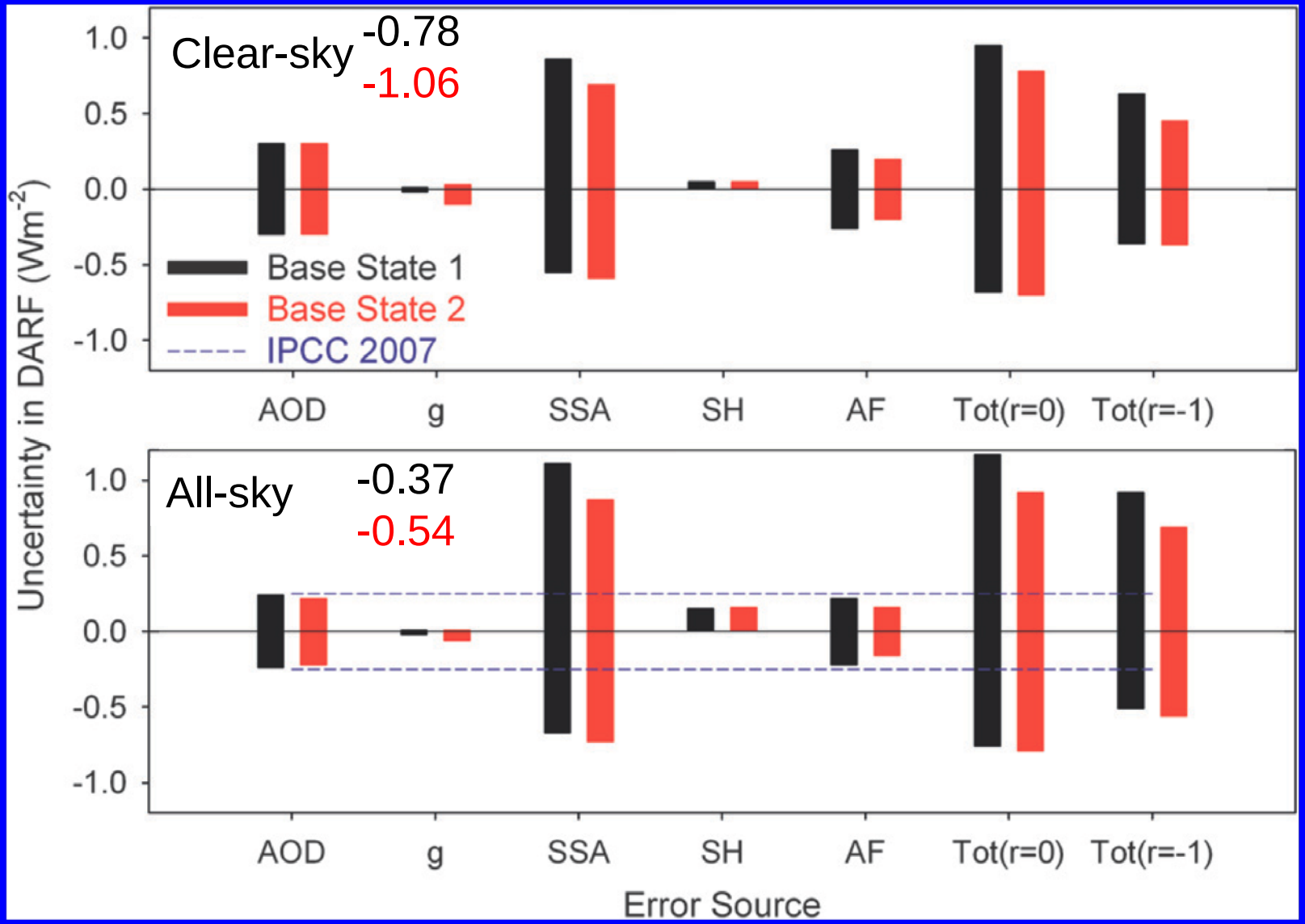


$$\frac{\text{Atmospheric Absorption}}{\text{Total } AOD}$$

Clouds reduce DARF, but not the difference



DARF is more sensitive to aerosol absorption and vertical distribution under all-sky conditions



Loeb and Su (2010)

Summary

- Clear-sky and all-sky DARF are computed from two methods
  - Observational based: CERES SYN
  - Model based: GOCART
- Global (60°N-60°S) mean CLEAR-sky DARF from CERES SYN is -1.55 Wm^{-2}, and is -1.19 Wm^{-2} from GOCART
- Global (60°N-60°S) mean ALL-sky DARF from CERES SYN is -0.51 Wm^{-2}, and is -0.17 Wm^{-2} from GOCART
- The presence of clouds amplifies the sensitivity of DARF to aerosol single scattering albedo and aerosol vertical distribution.