Southern Ocean clear-sky brightening from sea spray aerosol increase drives departure from hemispheric albedo symmetry

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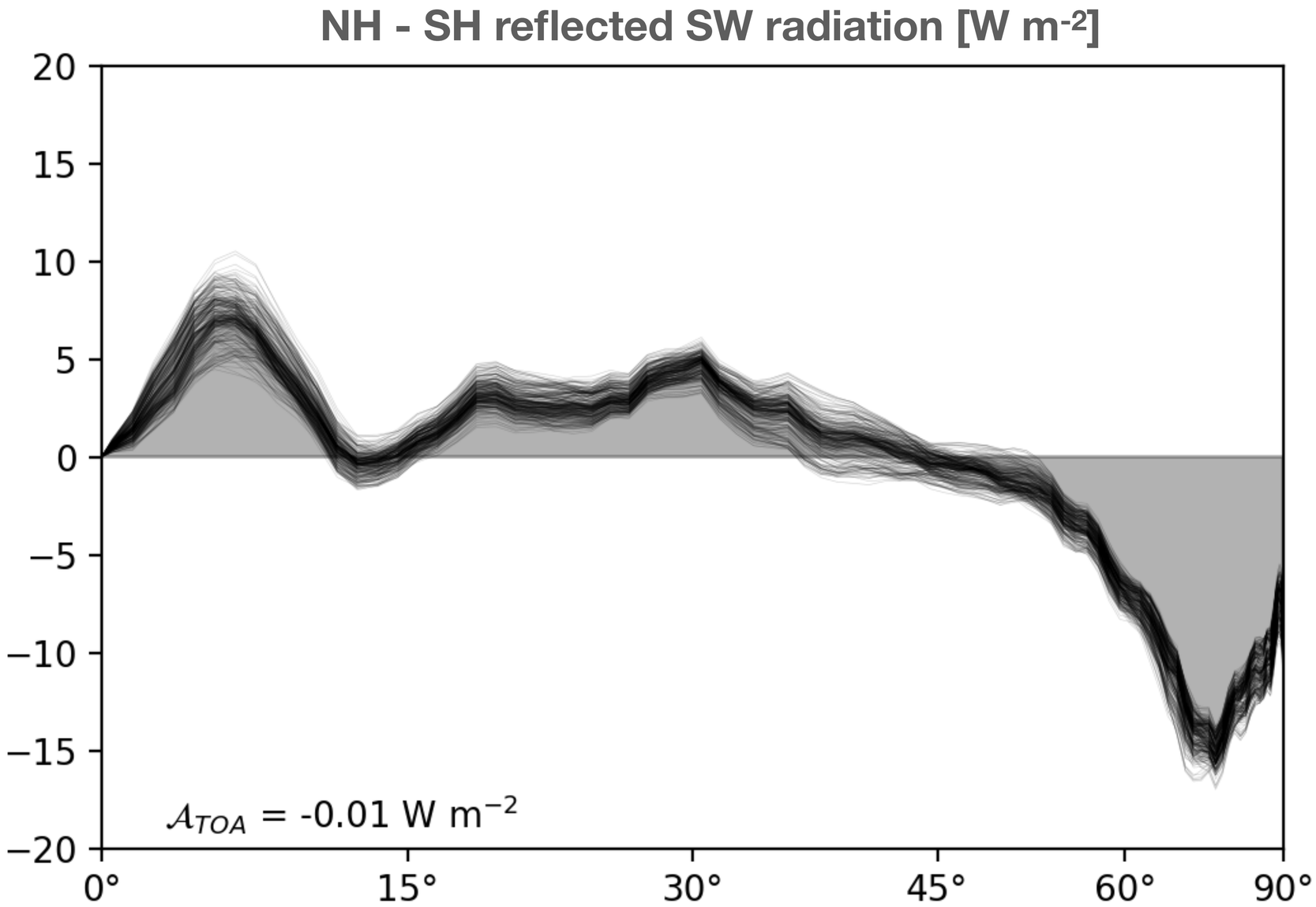
44th CERES Science Team Meeting
May 13, 2026

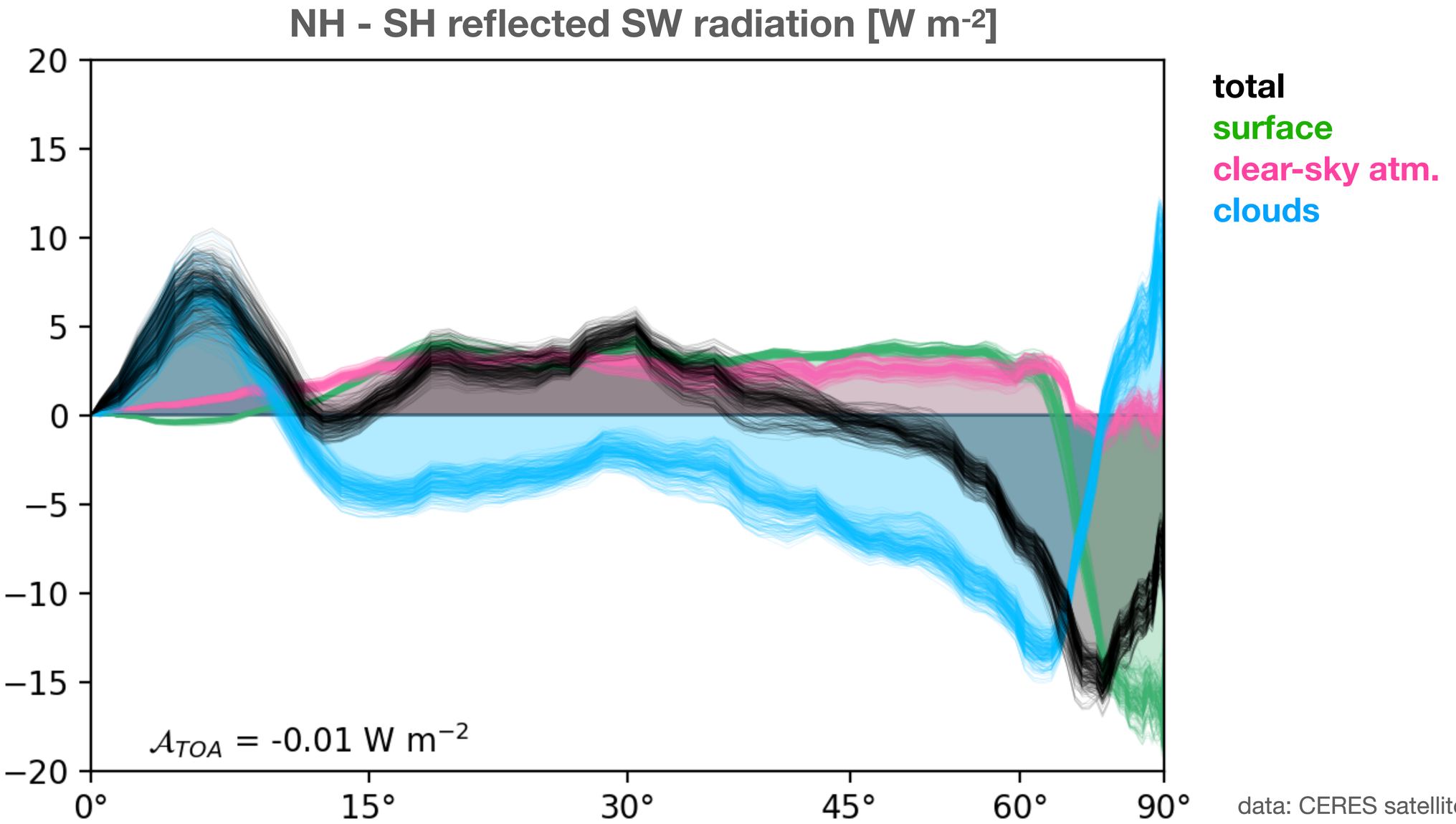
Many thanks to Robert Pincus and Columbia/LDEO for hosting me and NOAA C&GC for funding this work

NH albedo = SH albedo



data: CERES satellite

Clouds + clear-sky reflection asymmetry perfectly compensate



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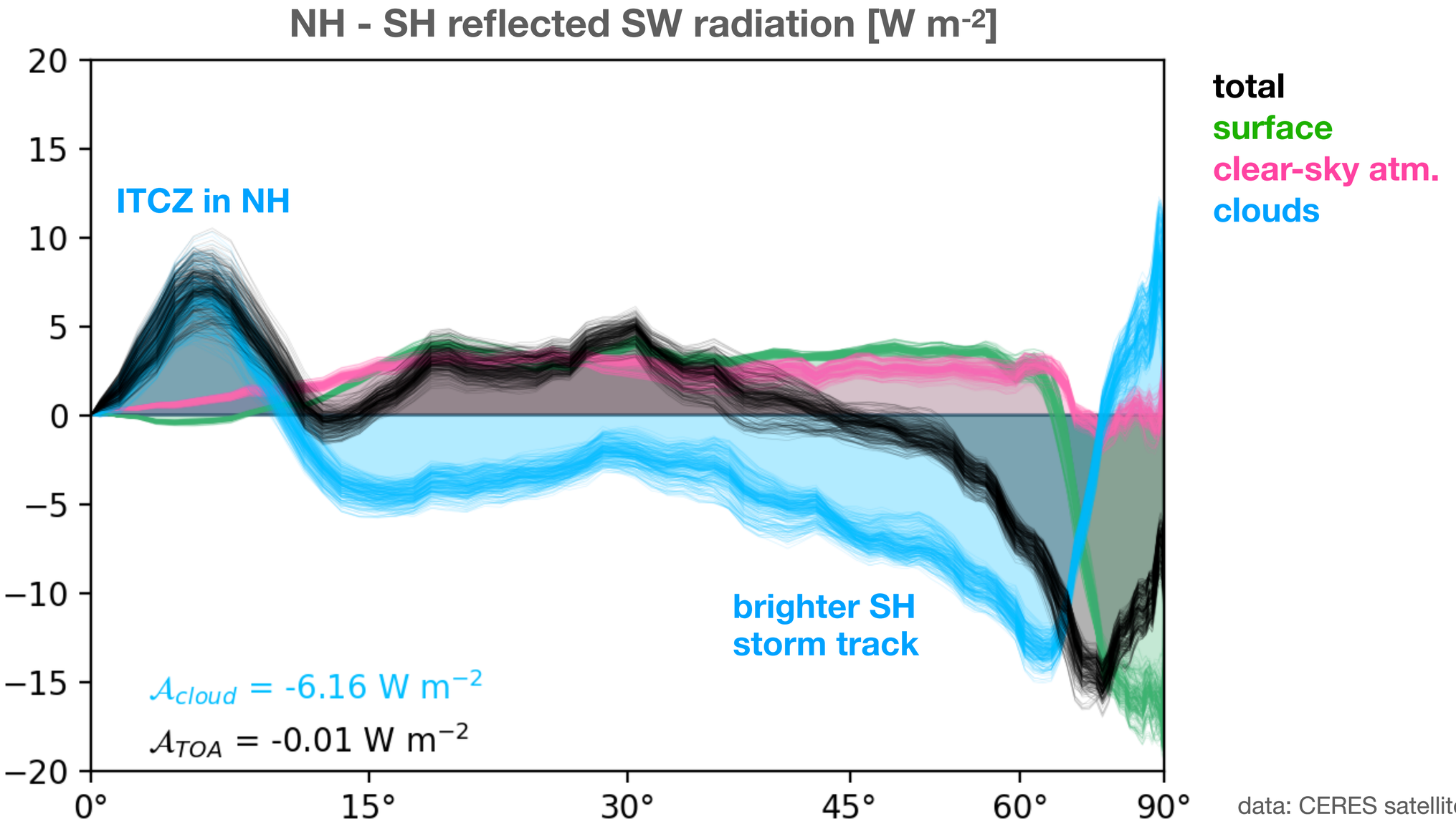

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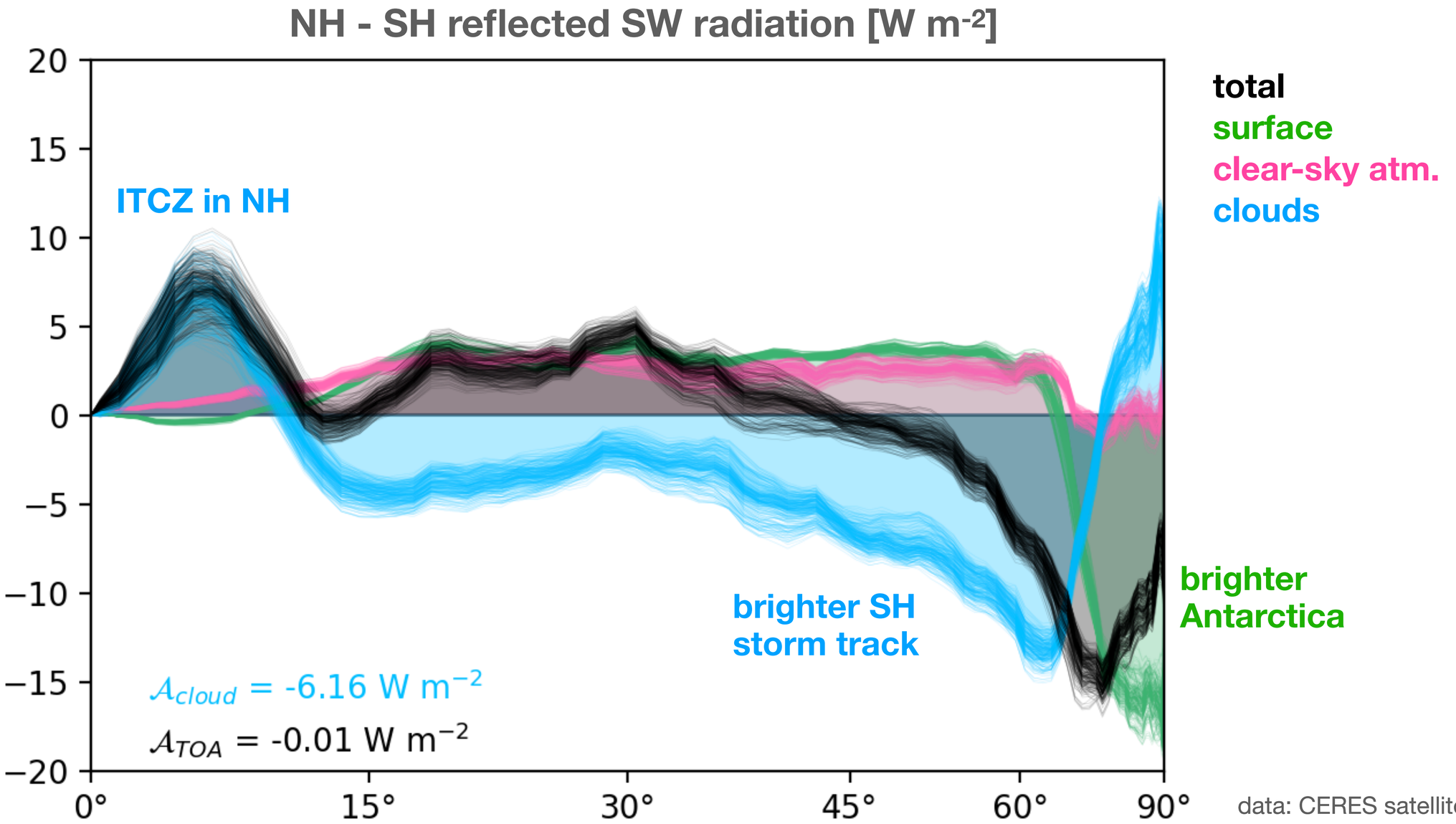

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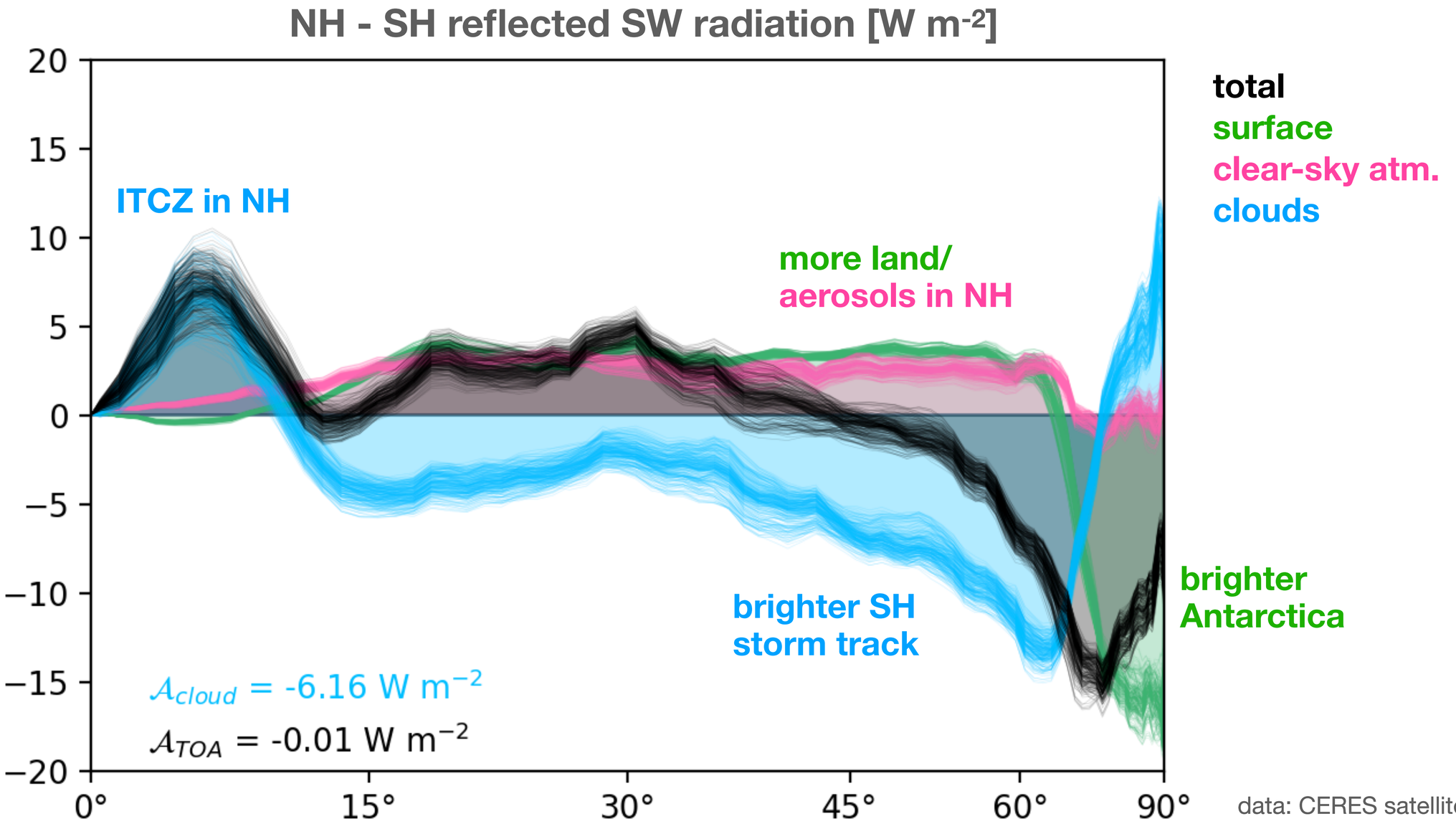
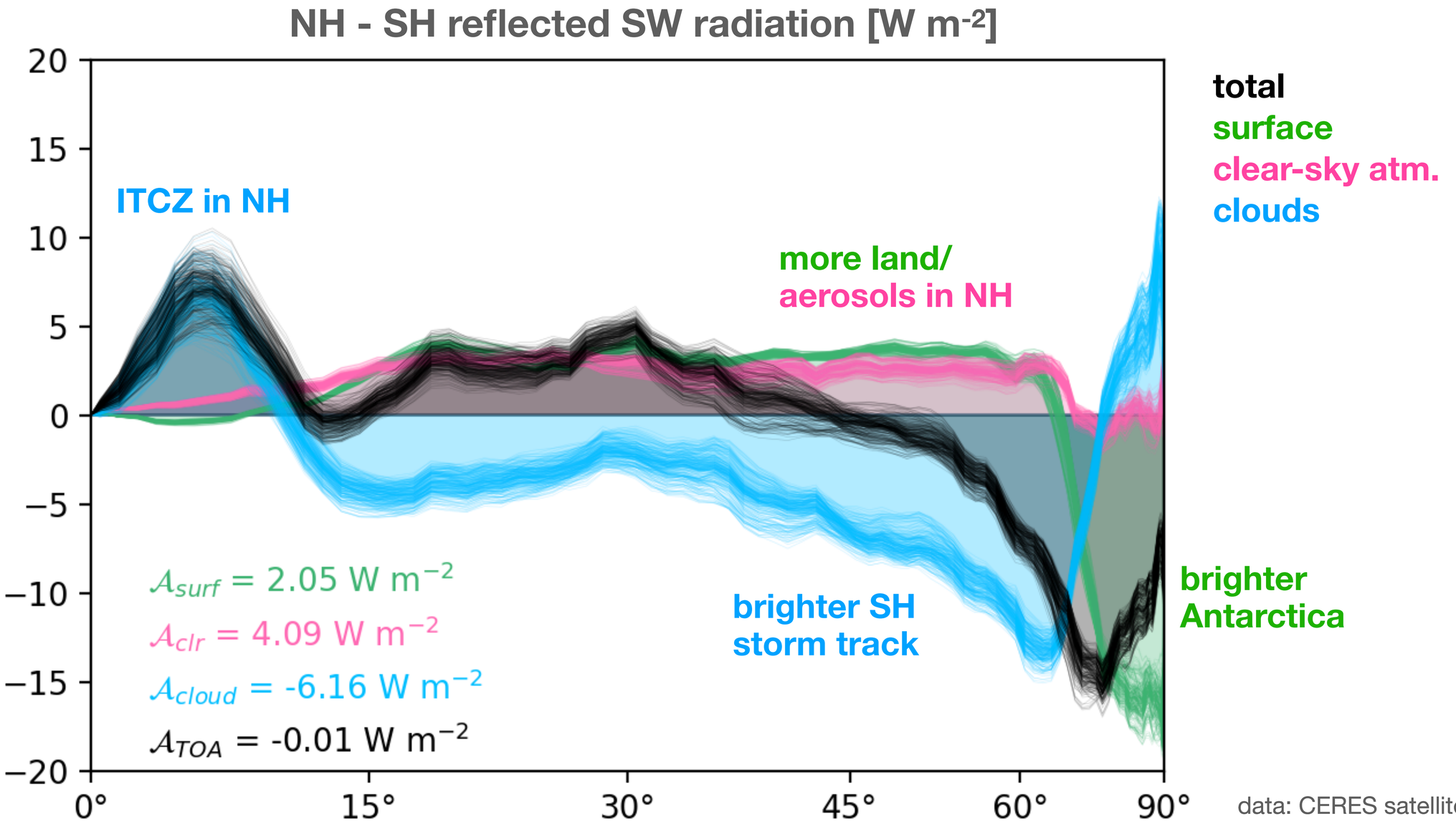
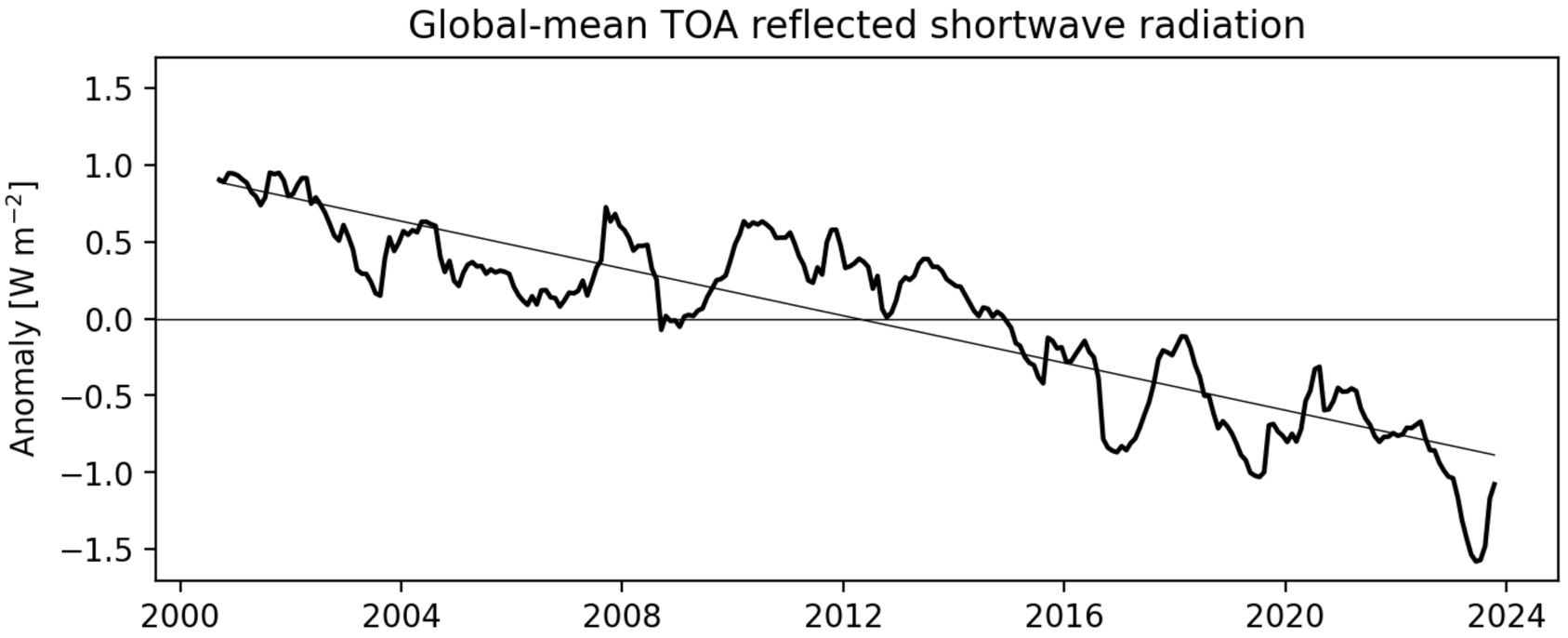


Clouds + clear-sky reflection asymmetry perfectly compensate



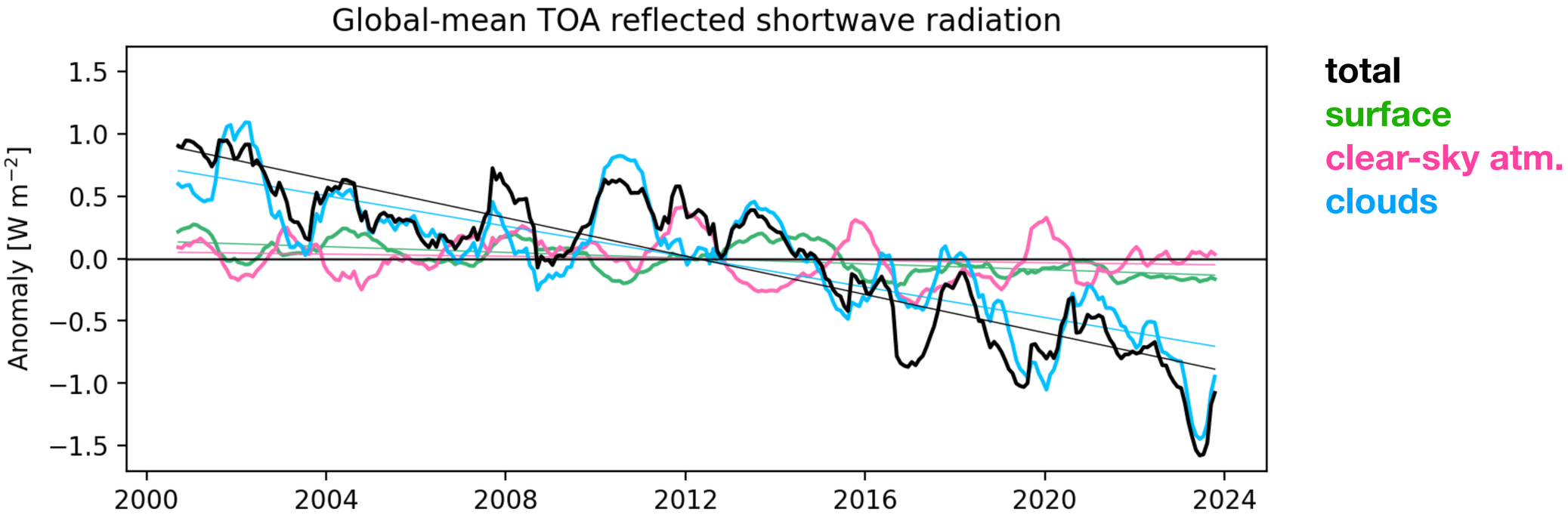
Observed global mean dimming



total

data: CERES satellite

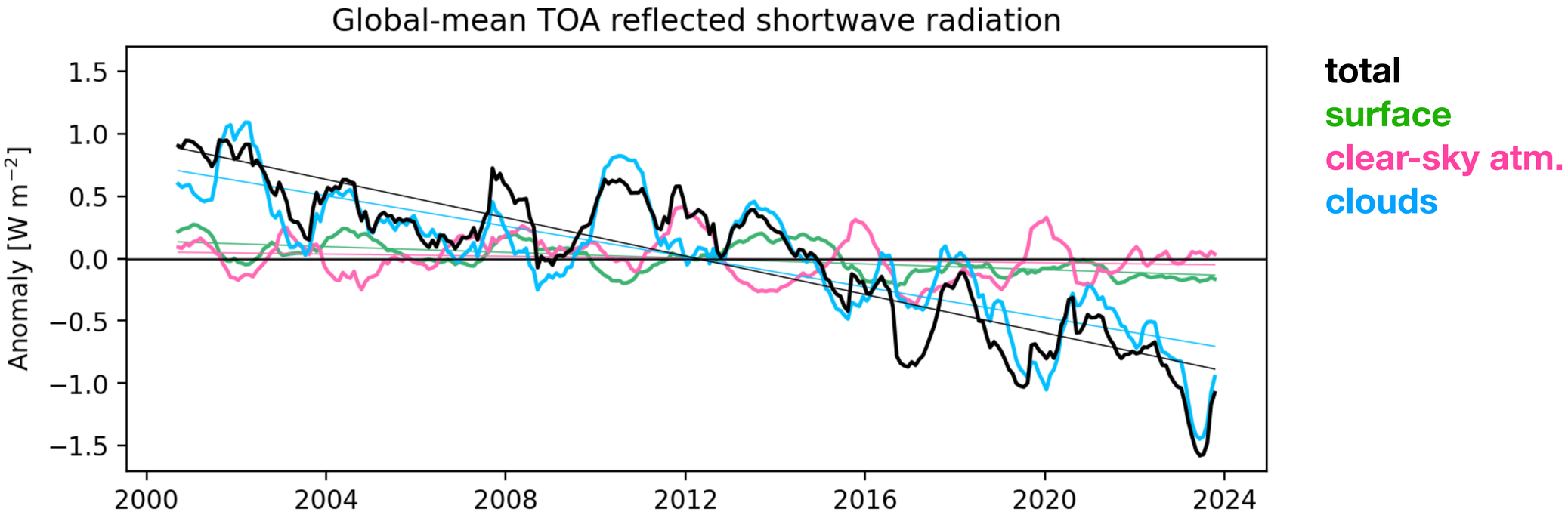
Observed global mean dimming is controlled by clouds



total
surface
clear-sky atm.
clouds

data: CERES satellite

Observed global mean dimming is controlled by clouds

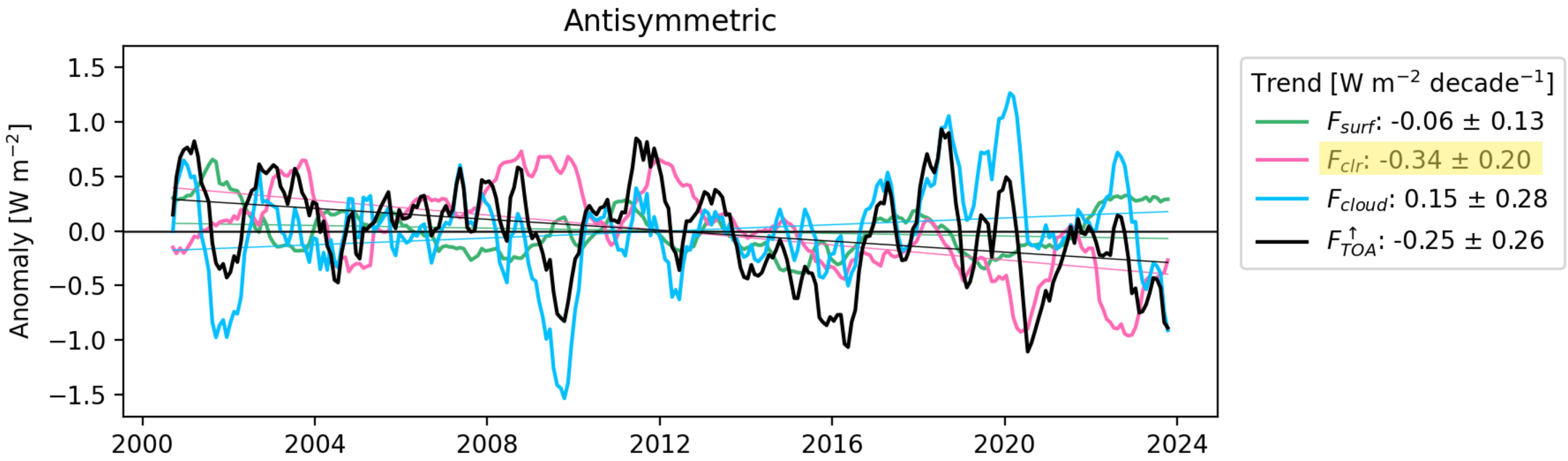


- The dimming is *mostly* symmetric between the hemispheres

data: CERES satellite

The asymmetry is not stagnant

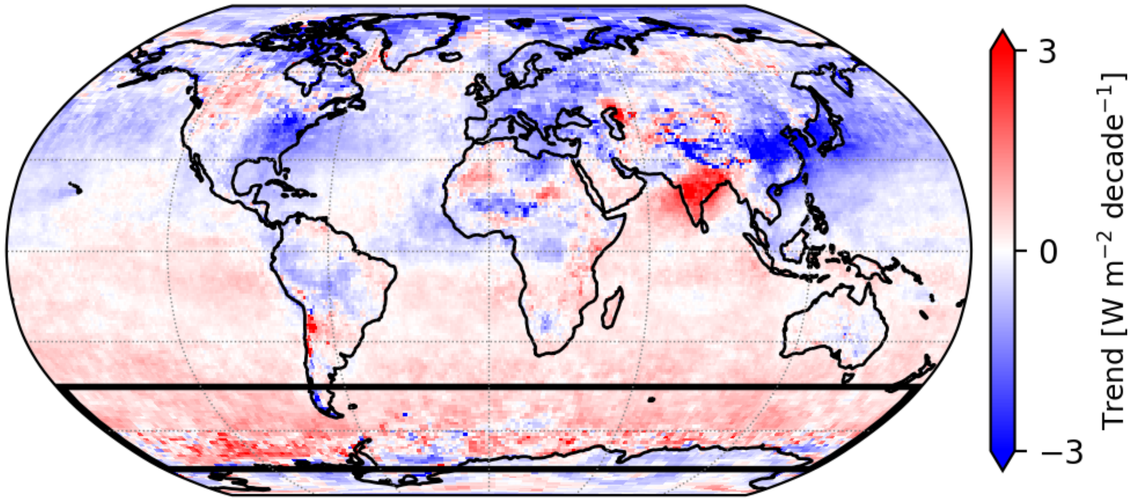
- It is trending negative: overall the NH is dimming faster than the SH
- This asymmetric trend is driven entirely by the clear-sky atmosphere



data: CERES satellite

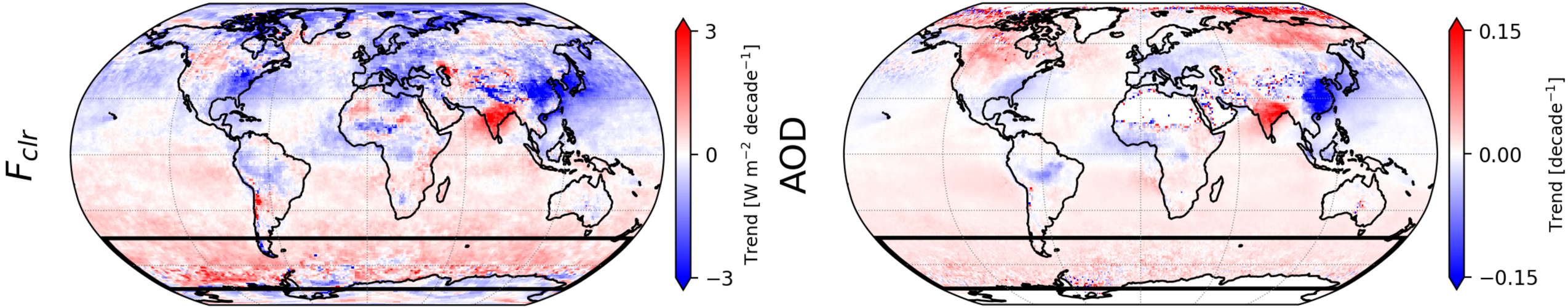
In the clear-sky, the NH is dimming, but the SH is actually brightening

F_{clr}



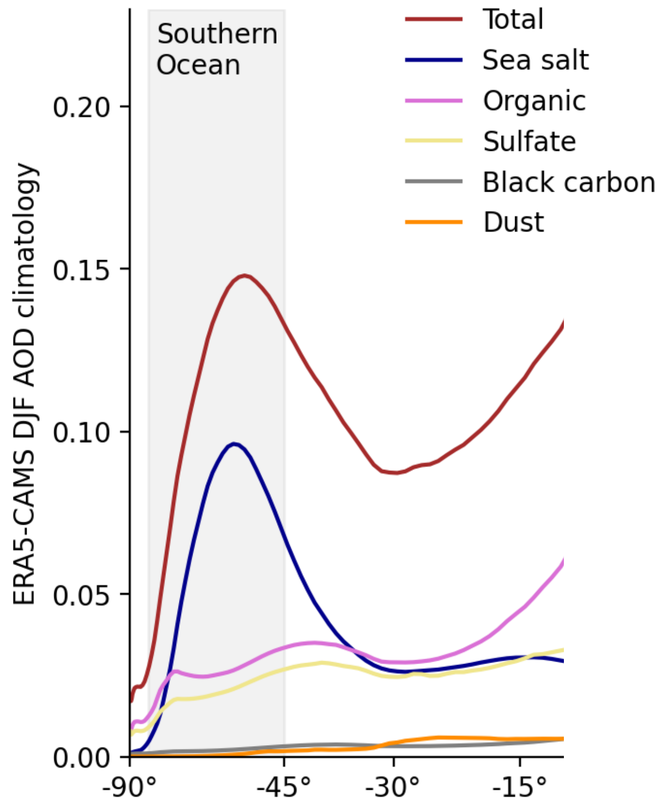
data: CERES satellite

Atmospheric clear-sky albedo trends are driven by aerosols



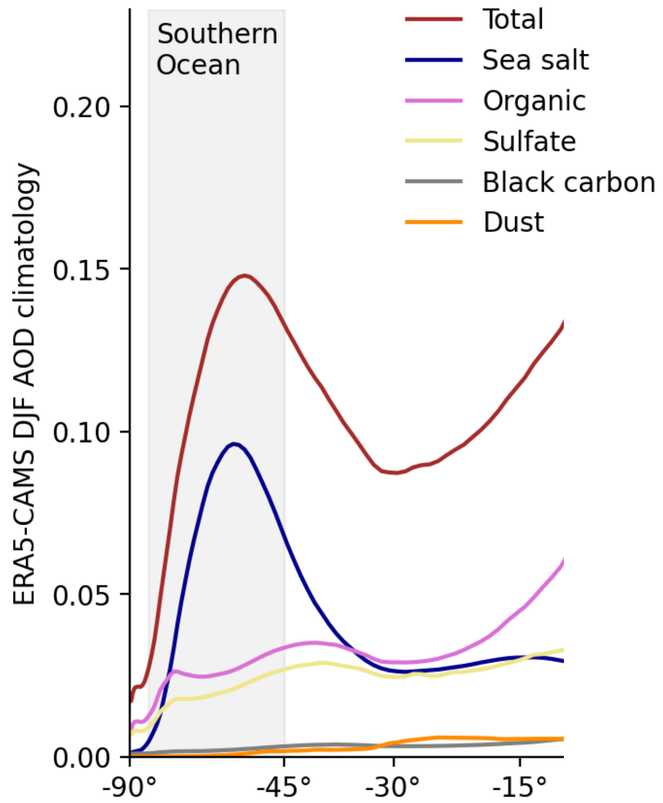
data: MODIS satellite

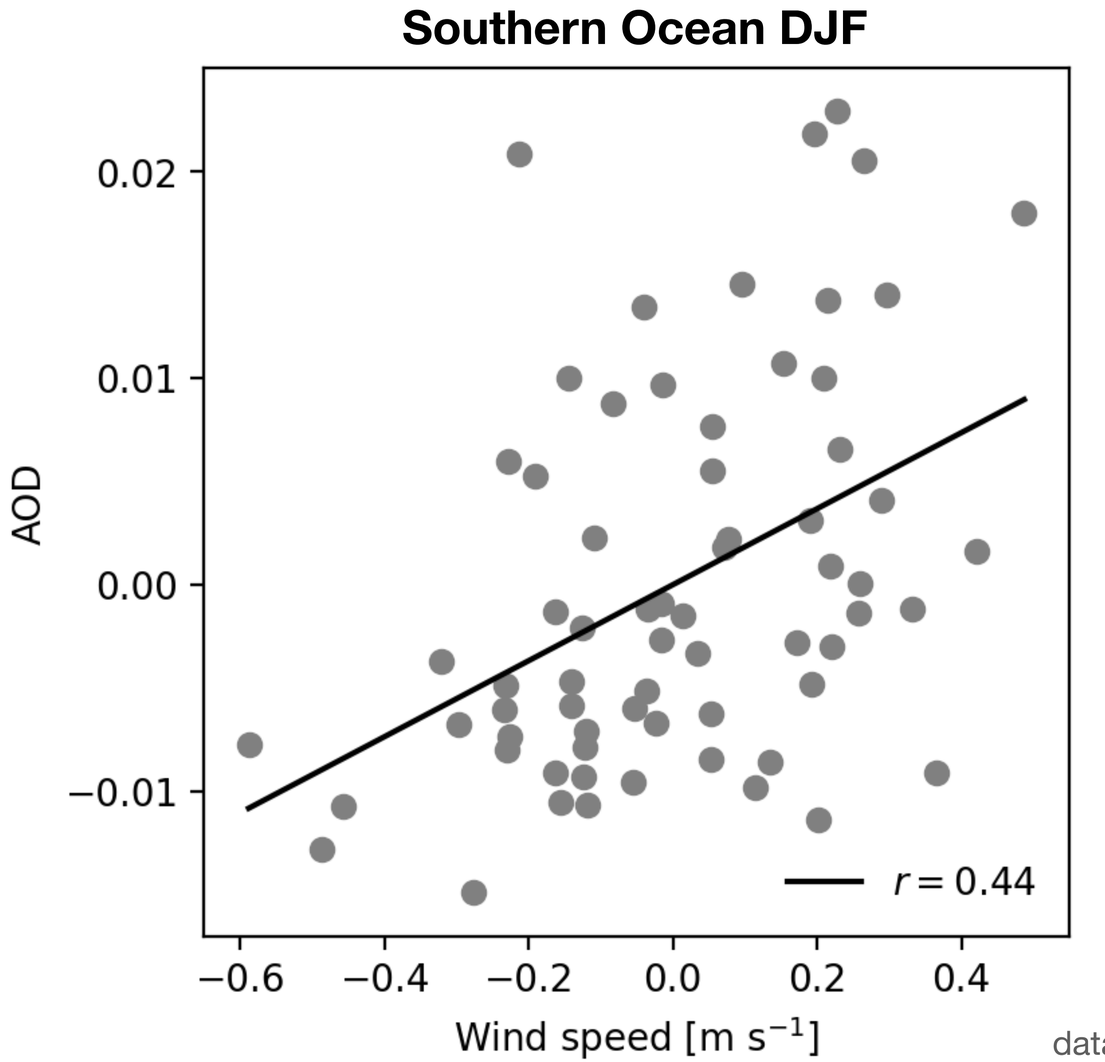
Southern Ocean aerosols come from oceanic sources, emissions are tied to wind speed



data: MODIS + ERA5

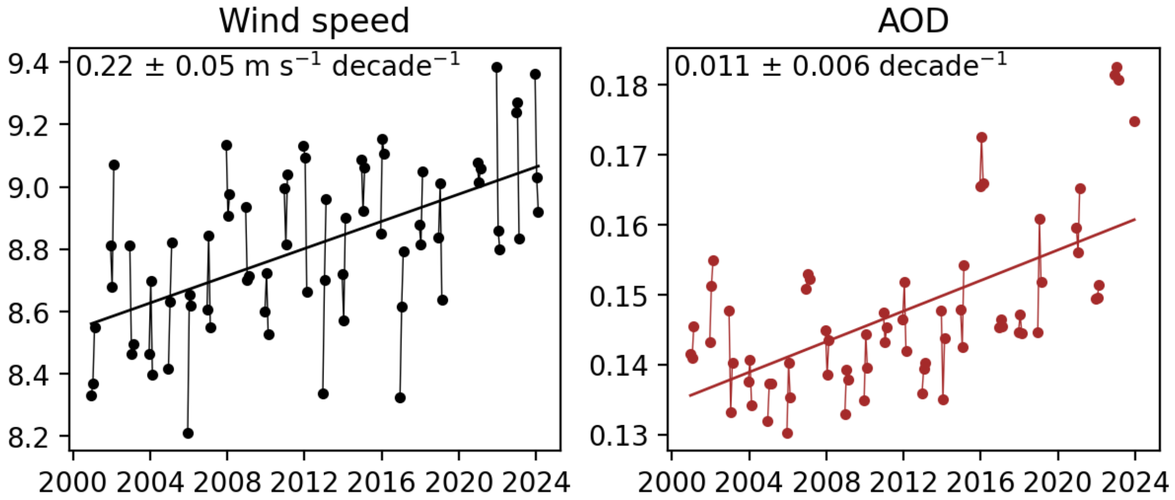
Southern Ocean aerosols come from oceanic sources, emissions are tied to wind speed

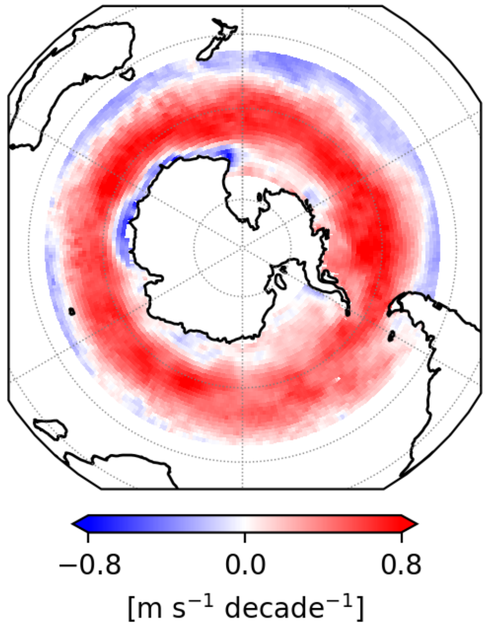


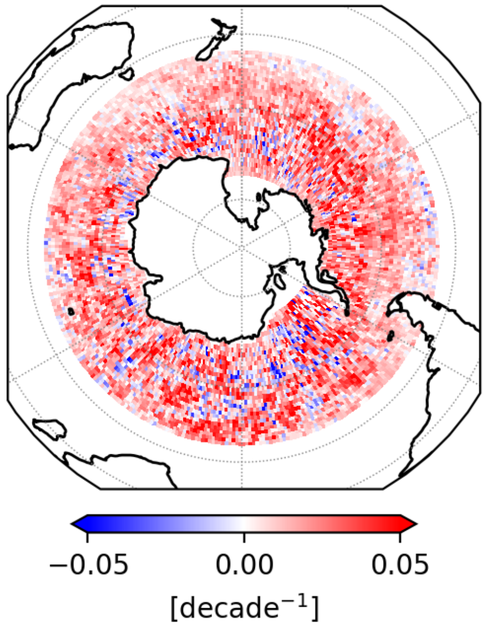


data: MODIS + ERA5

More wind —> more aerosol

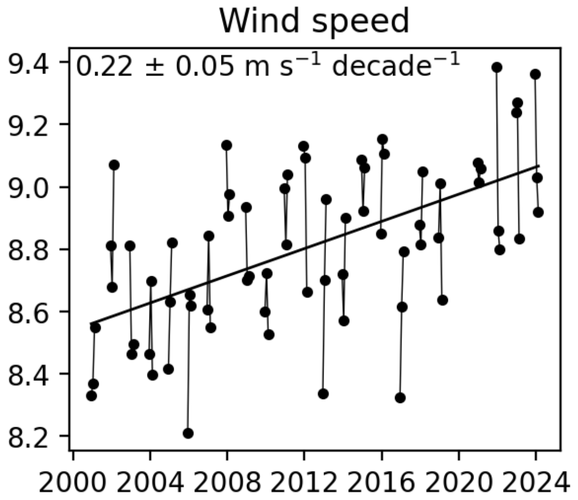


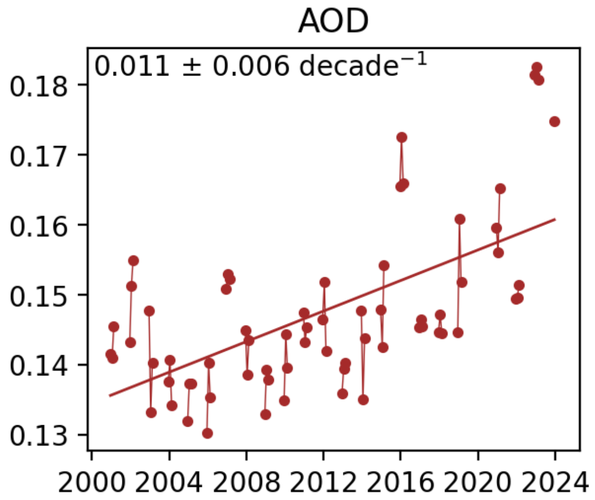


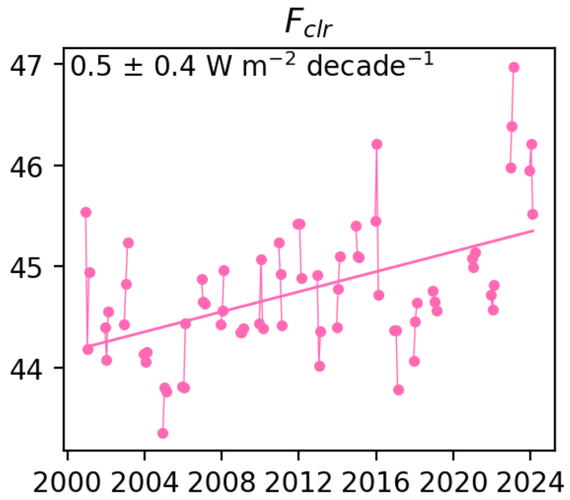


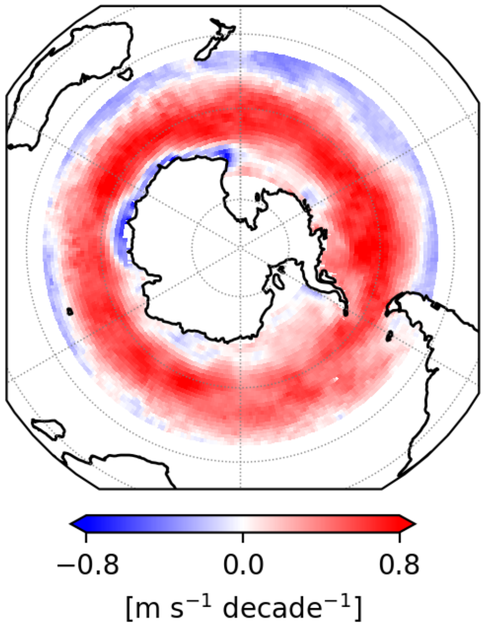
data:
ERA5 +
MODIS

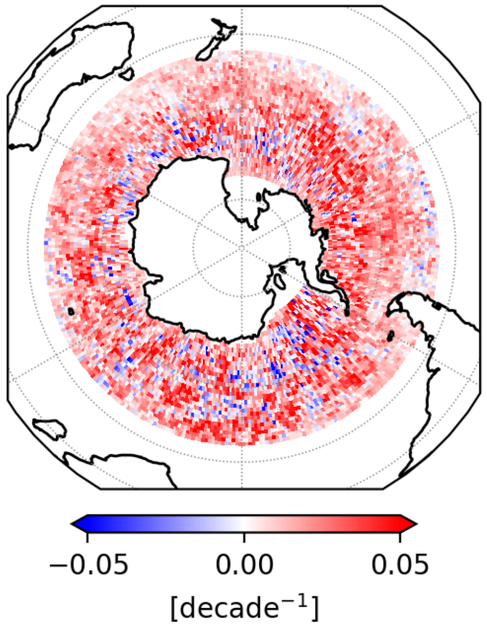
More wind —> more aerosol —> higher clear-sky albedo

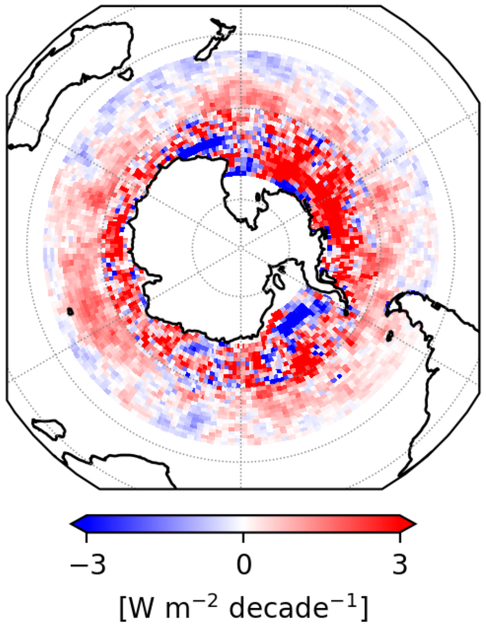








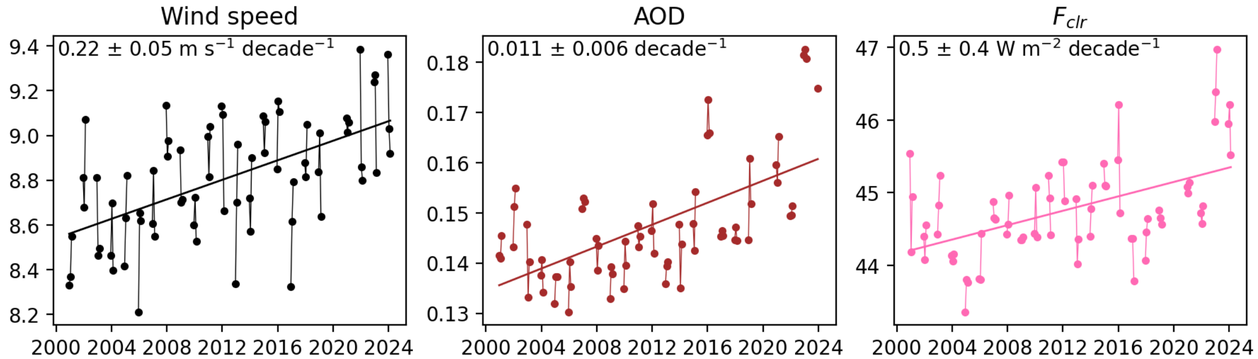


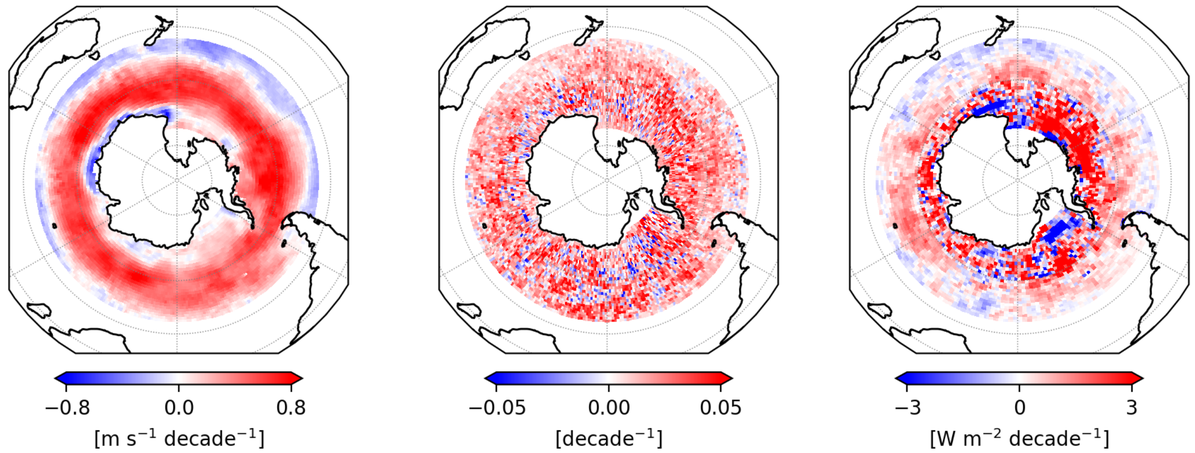


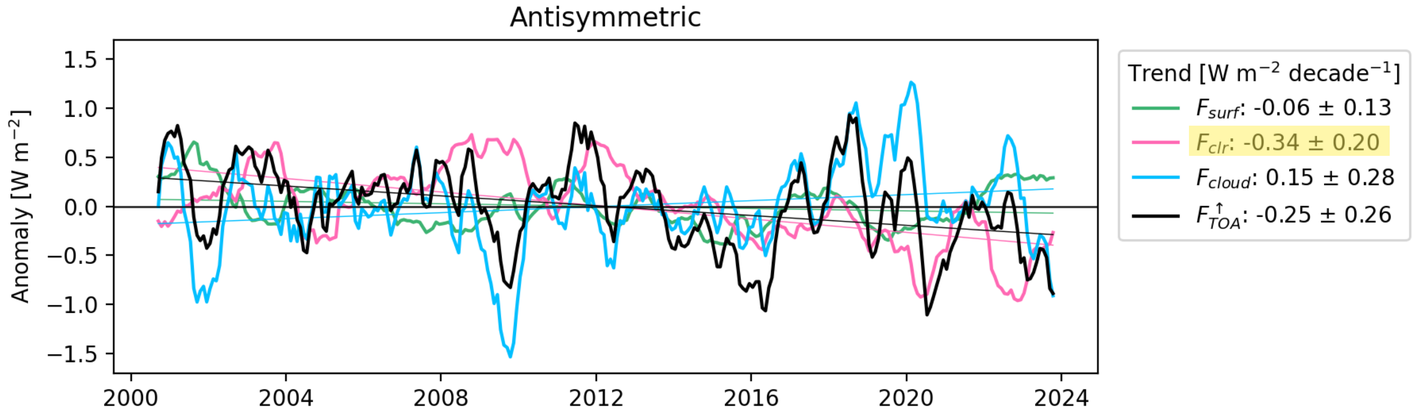
data:
ERA5 +
MODIS +
CERES

Summary

- Wind speeds over the Southern Ocean have been increasing (especially during summer)
- This has increased the emissions of sea spray aerosol into the atmosphere
- The atmosphere has gotten more reflective
- This is an important contribution to the total trend away from hemispheric albedo symmetry

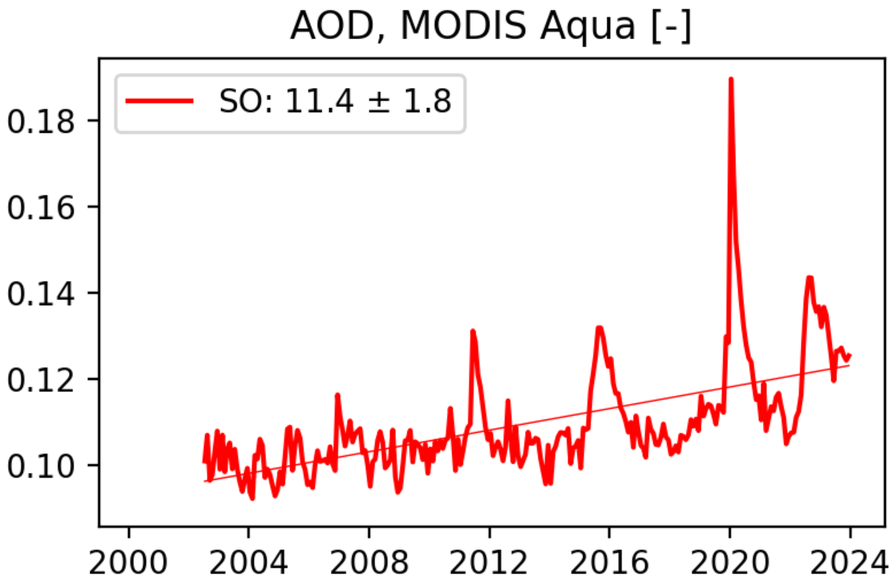


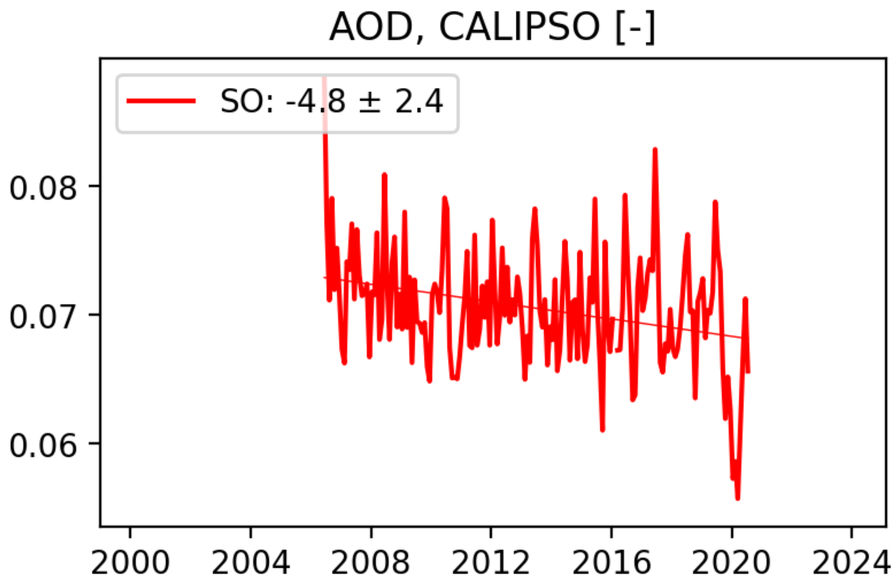




A bit of an aside… but an important reminder about observational limitations

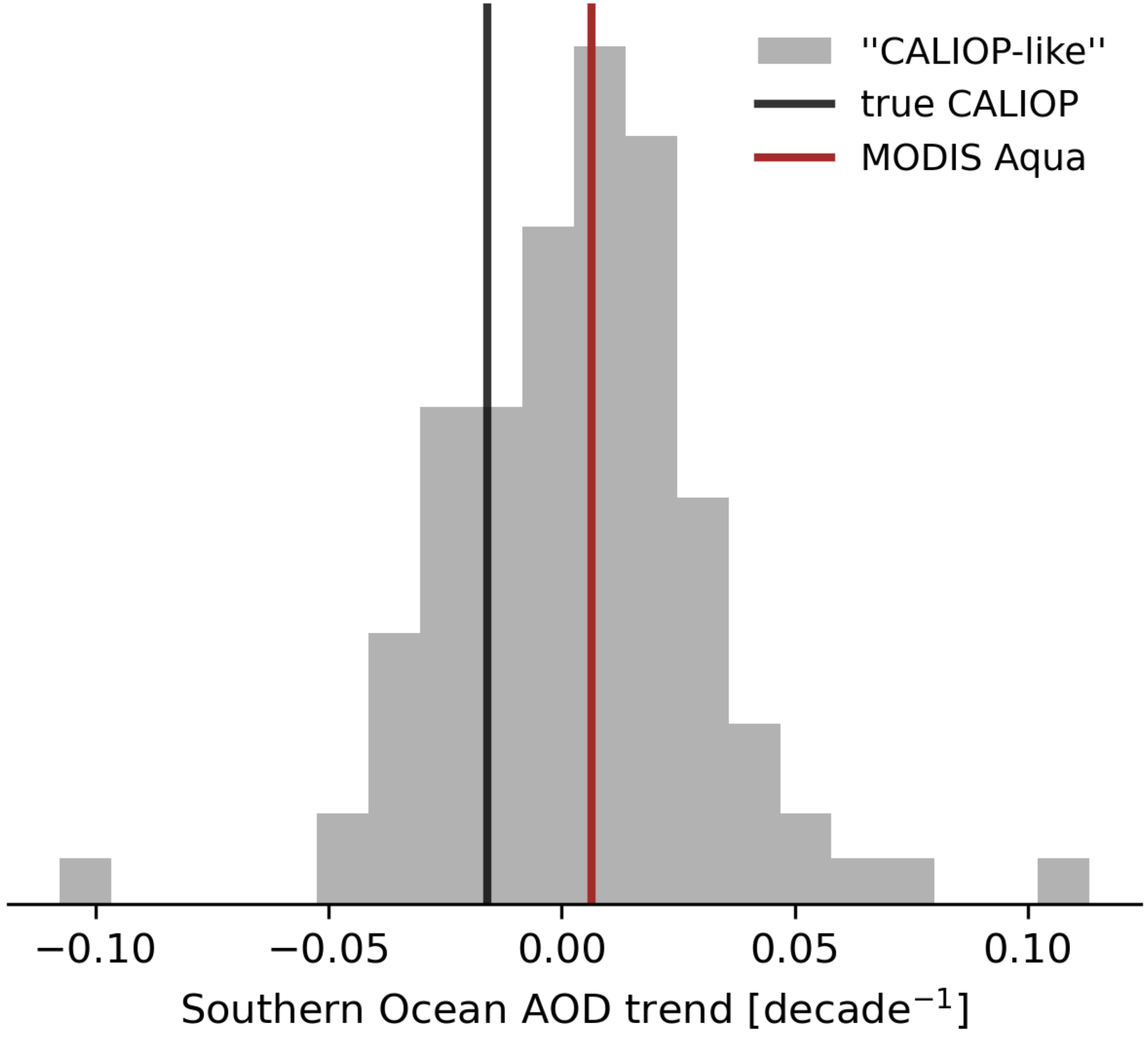
MODIS vs. CALIOP





- CALIOP is known for making high-precision aerosol observations
- Limitations:
  - Known low bias for total-column AOD in “clean” conditions
  - Missing obvious events like 2019-2020 Australian wildfires
  - Small measurement footprint

Negative AOD trends observed by CALIOP are perfectly consistent with MODIS given the very sparse sampling



- Given the very sparse spatiotemporal sampling of CALIOP, we do not expect it to be able to detect a small increase in AOD on top of the highly variable background in the Southern Ocean
- Histogram shows 100 random samples of an AOD trend that could be detected by an instrument with “CALIOP-like” sampling rates given the AOD observed by MODIS

Summary

Geophysical Research Letters

Research Letter | Open Access

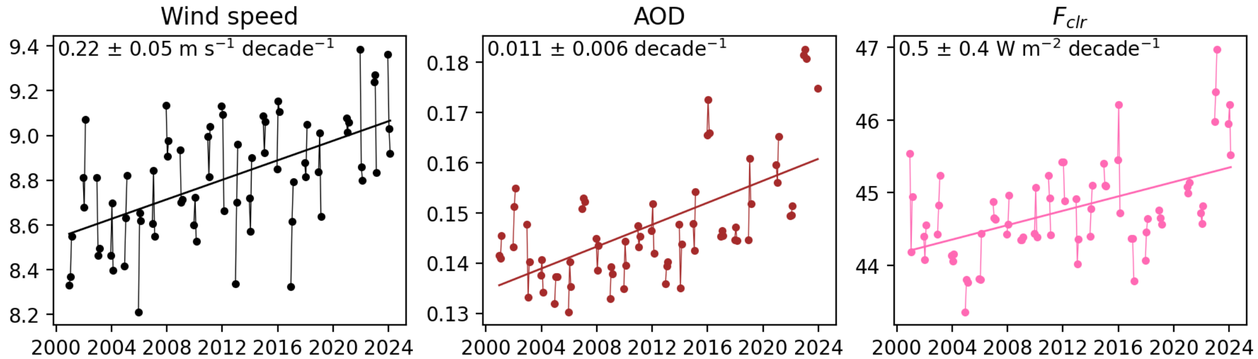
Southern Ocean Clear-Sky Brightening From Sea Spray Aerosol Increase Drives Departure From Hemispheric Albedo Symmetry

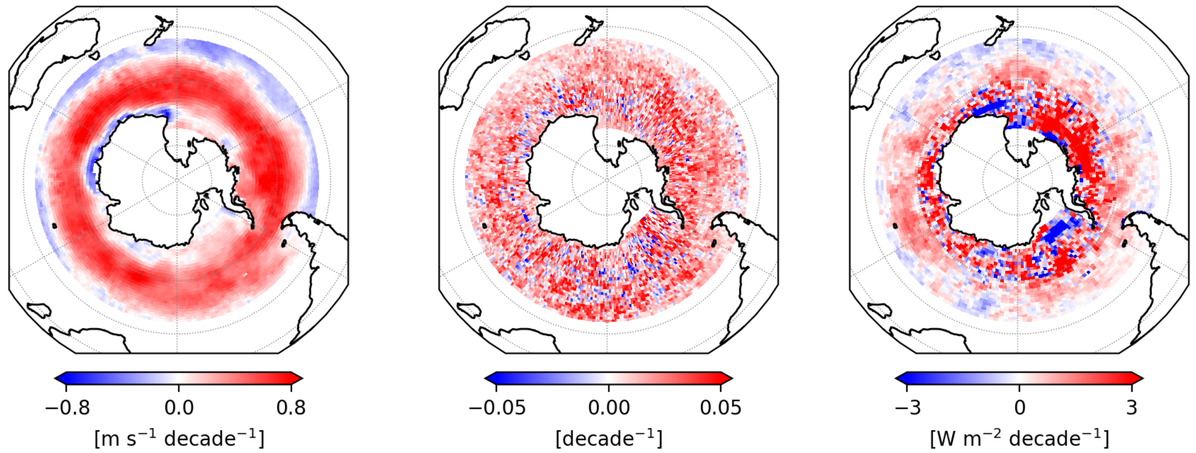
Clare E. Singer, Robert Pincus

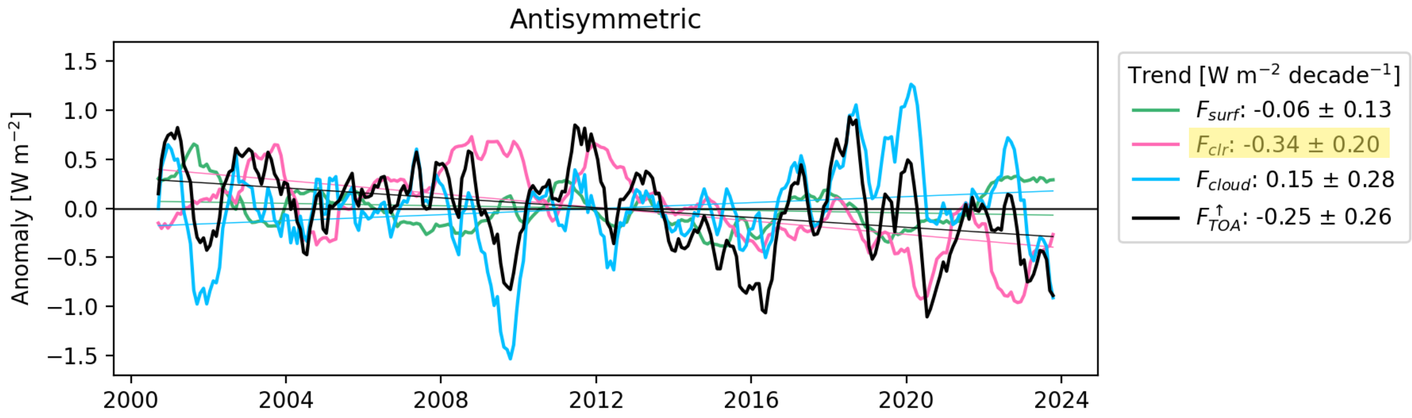
First published: 26 December 2025 | https://doi.org/10.1029/2025GL119637 | VIEW METRICS

- Read the paper:

- Contact me: clare.singer@colorado.edu

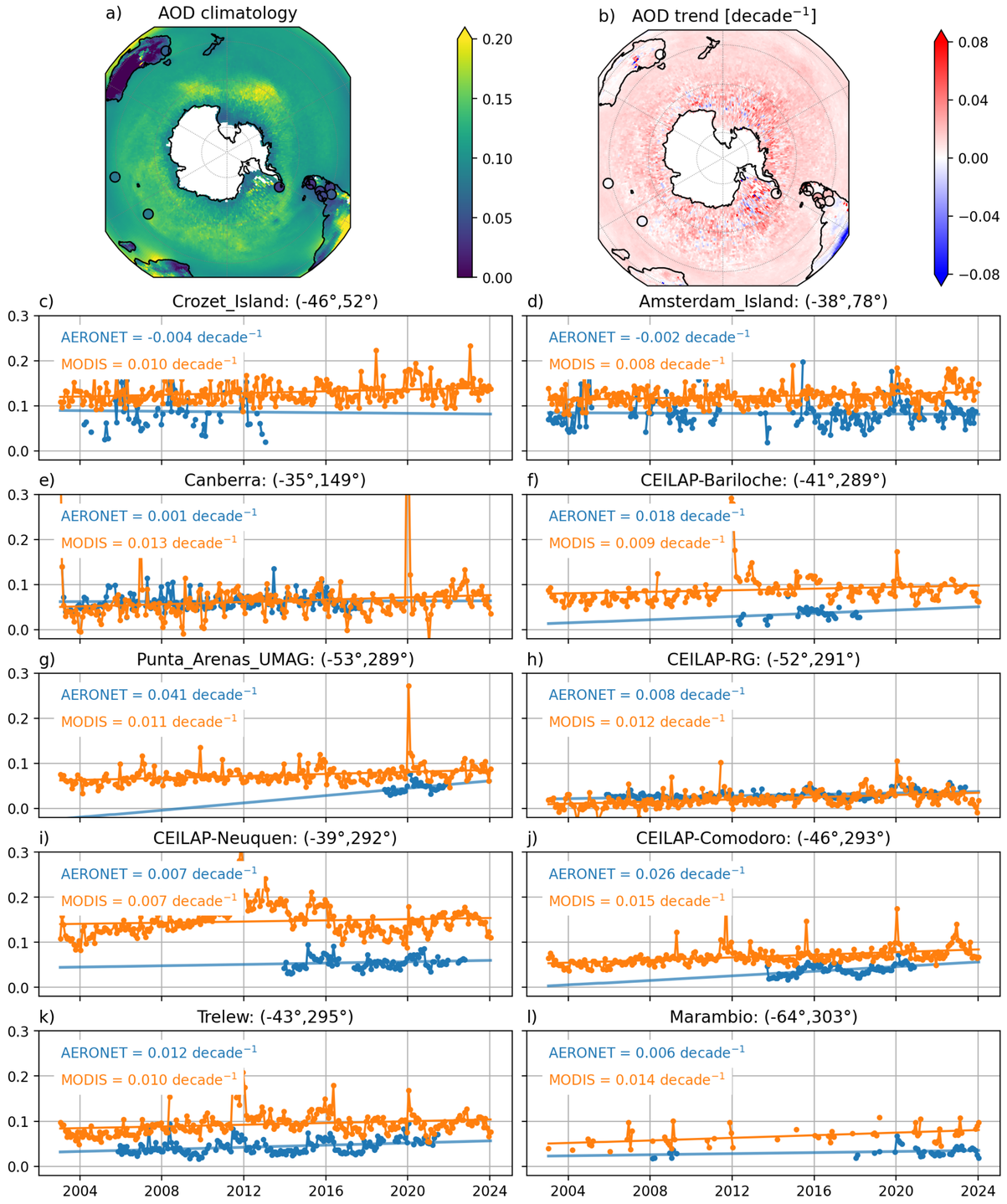




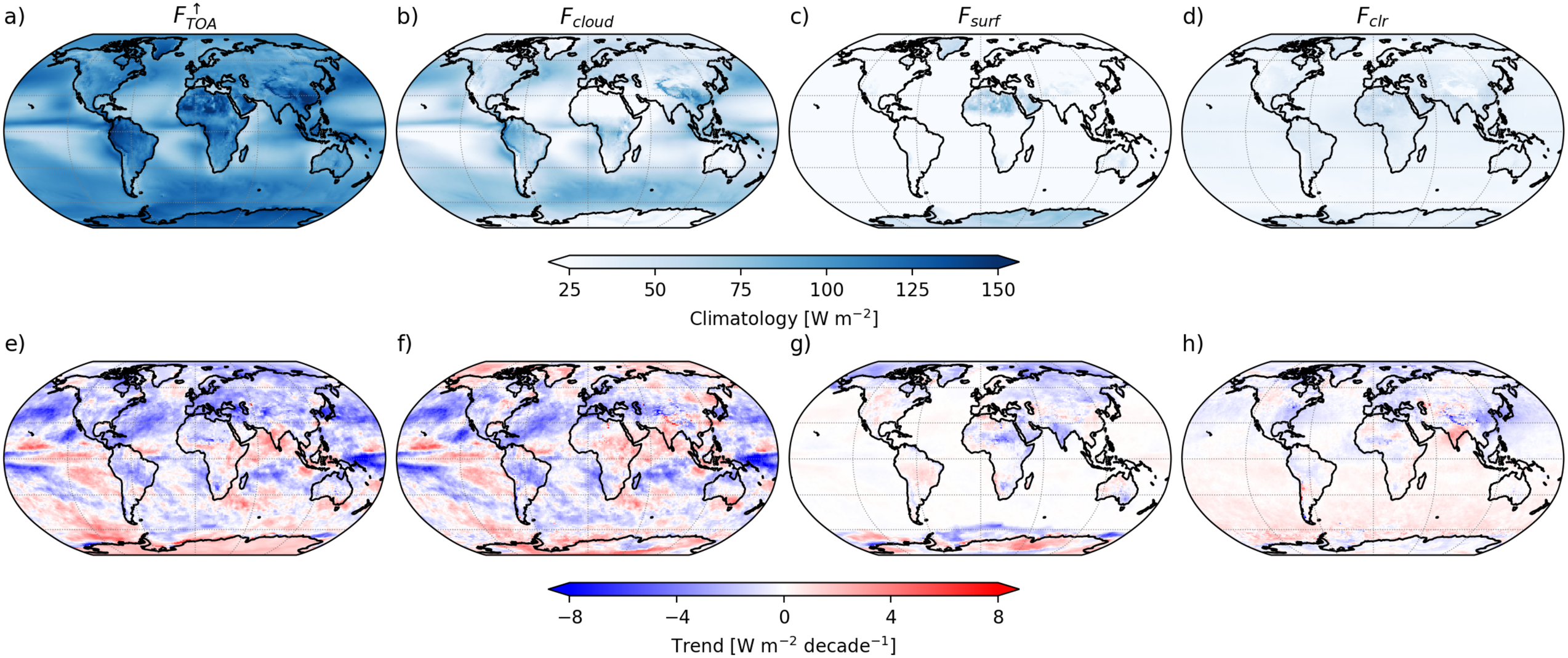


Extra slides

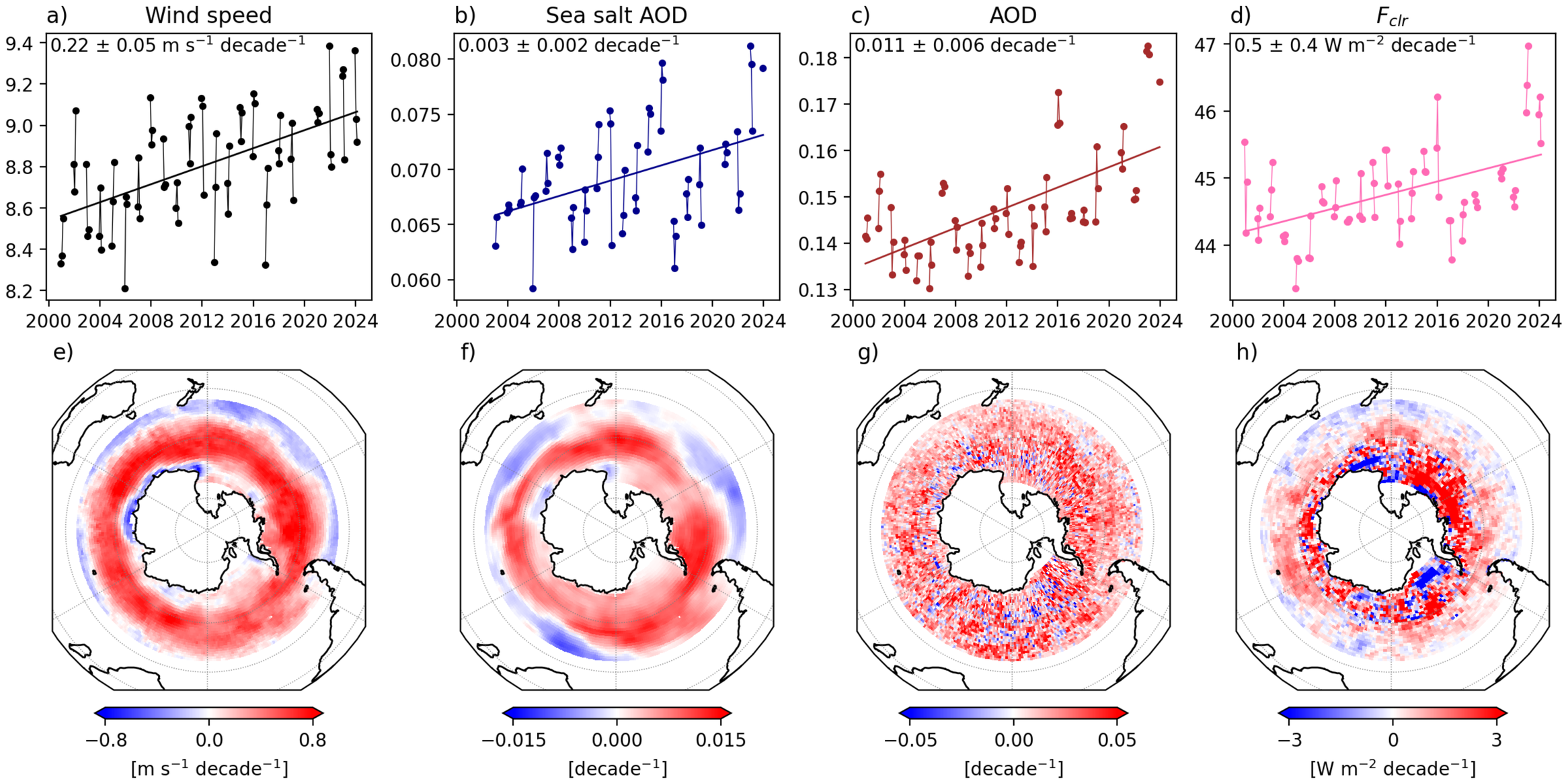
AERONET cannot tightly constrain MODIS AOD observations



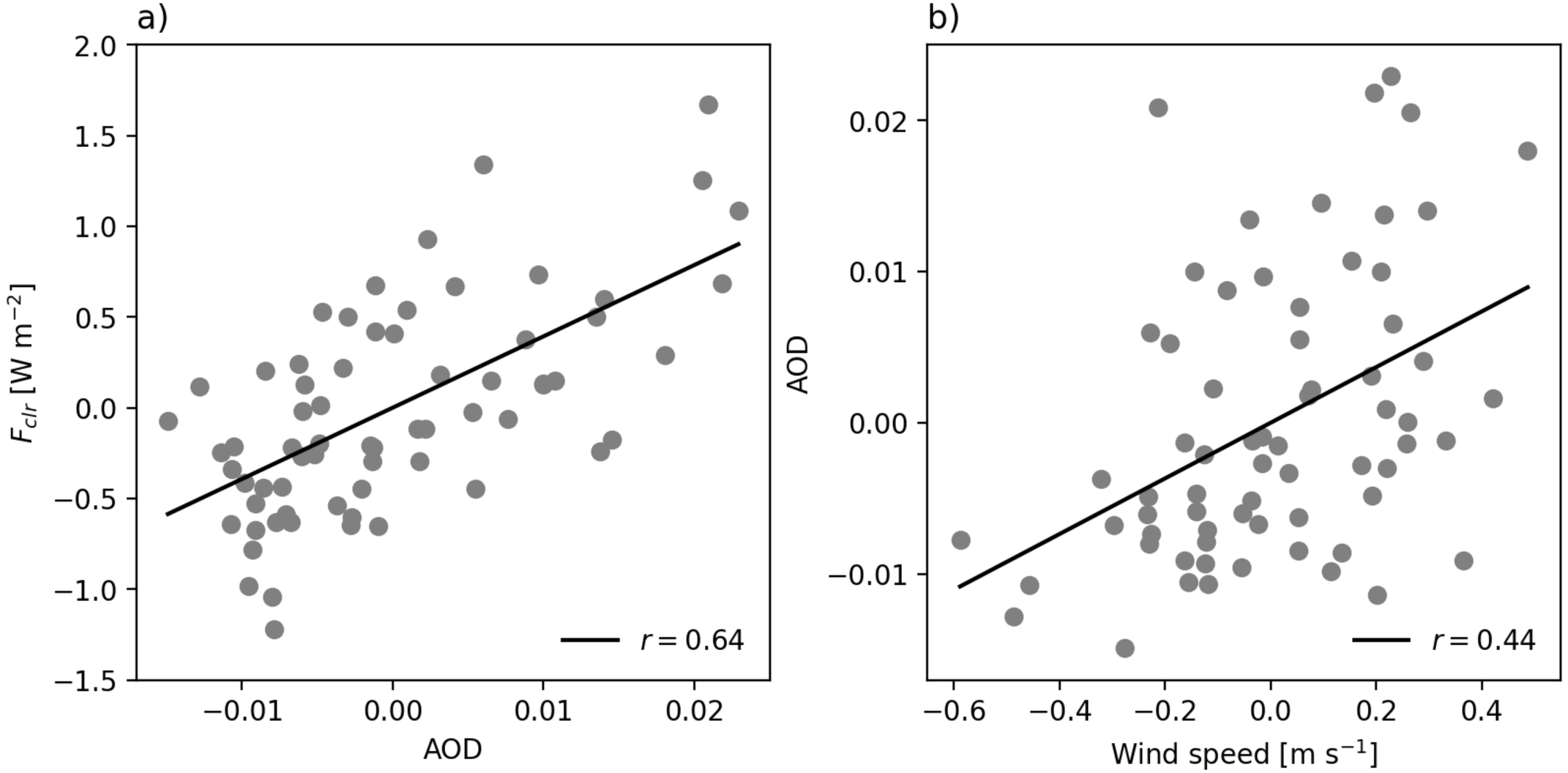
Climatology and trends of reflected shortwave radiation



Wind —> Sea spray aerosol —> Atmospheric clear-sky reflection



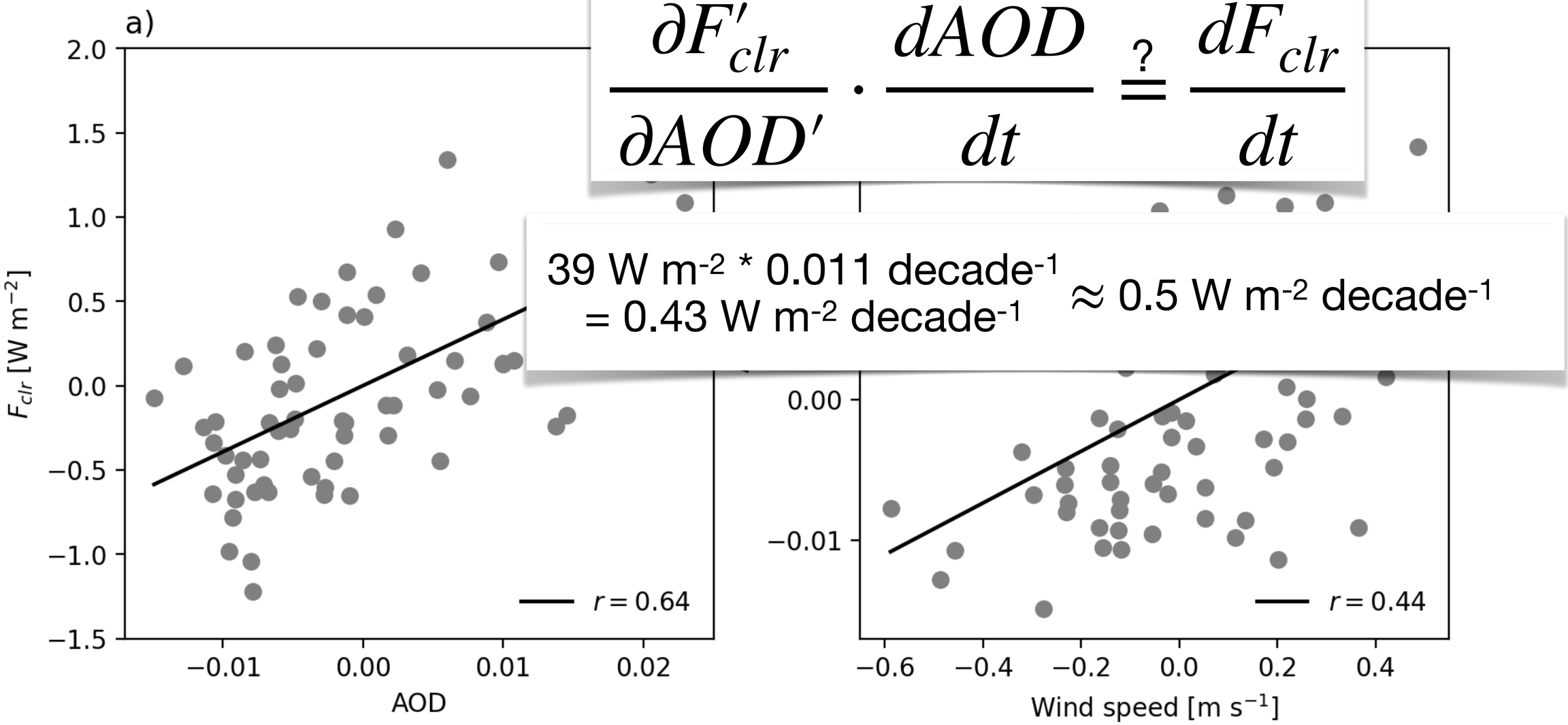
Correlation of *detrended* anomalies



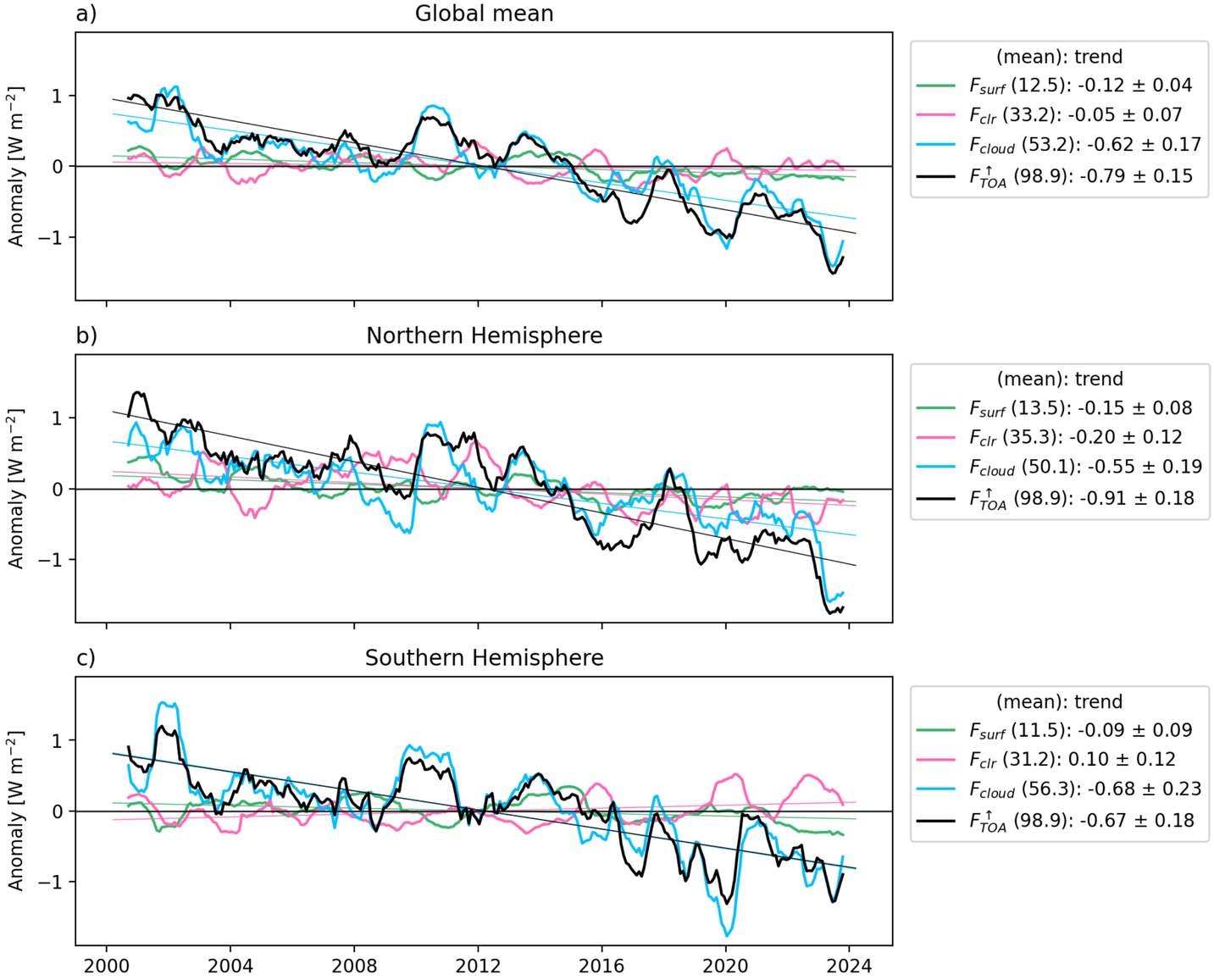
Correlation of *detrended* anomalies

$$\frac{\partial F'_{clr}}{\partial AOD'} \cdot \frac{dAOD}{dt} \stackrel{?}{=} \frac{dF_{clr}}{dt}$$

39 W m^{-2} * 0.011 decade^{-1}
= 0.43 W m^{-2} decade^{-1} $\approx$ 0.5 W m^{-2} decade^{-1}

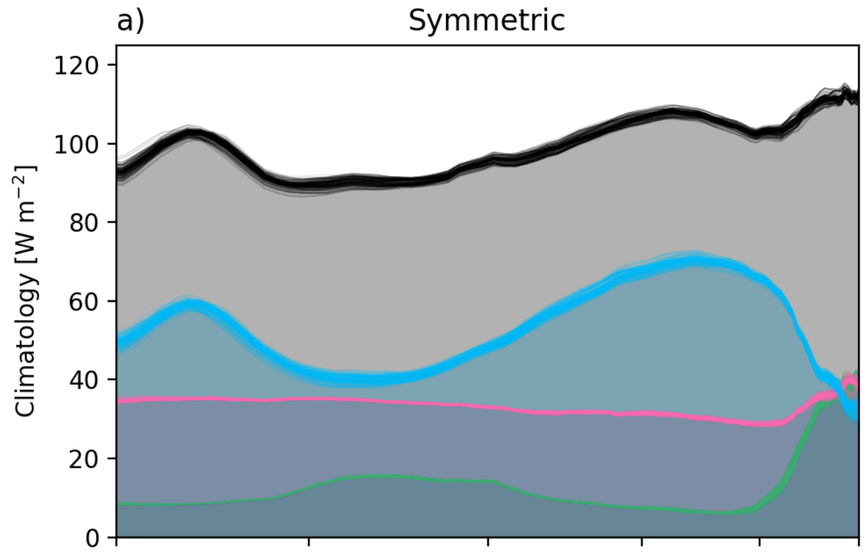


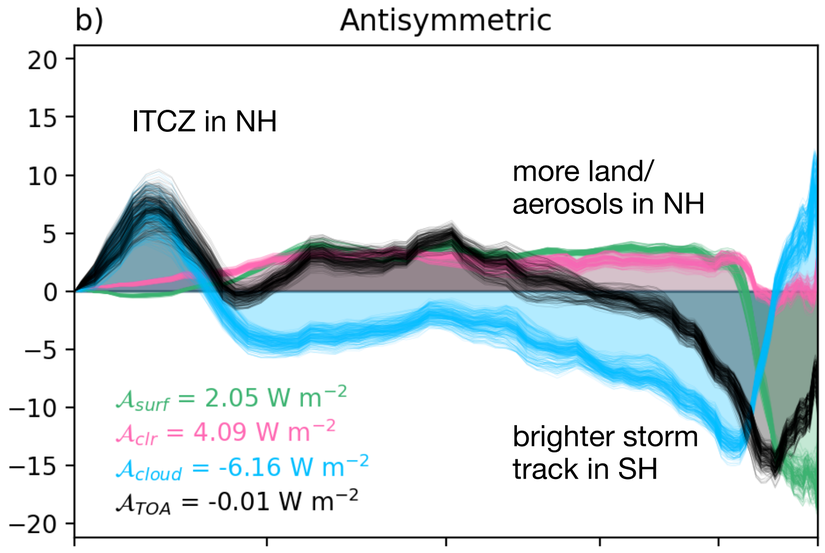
Trends of reflected shortwave radiation



- Global-mean dimming is driven by clouds and surface dimming
- NH has atmospheric clear-sky dimming
- SH has atmospheric clear-sky brightening

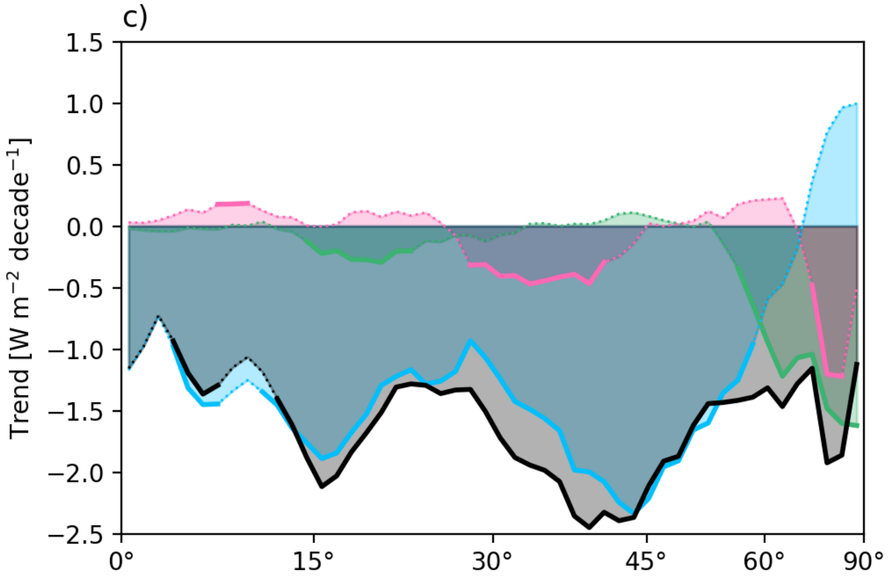
Symmetric and asymmetric components of reflected shortwave radiation



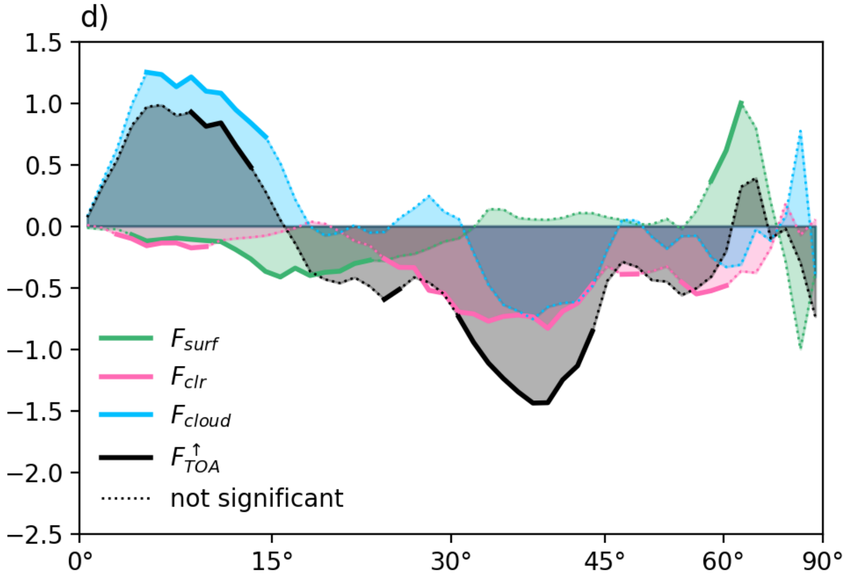


Hemispheric reflection is nearly perfectly symmetric (A=0.04 W m^{-2}) due to compensation between clouds and clear-skies

brighter Antarctica

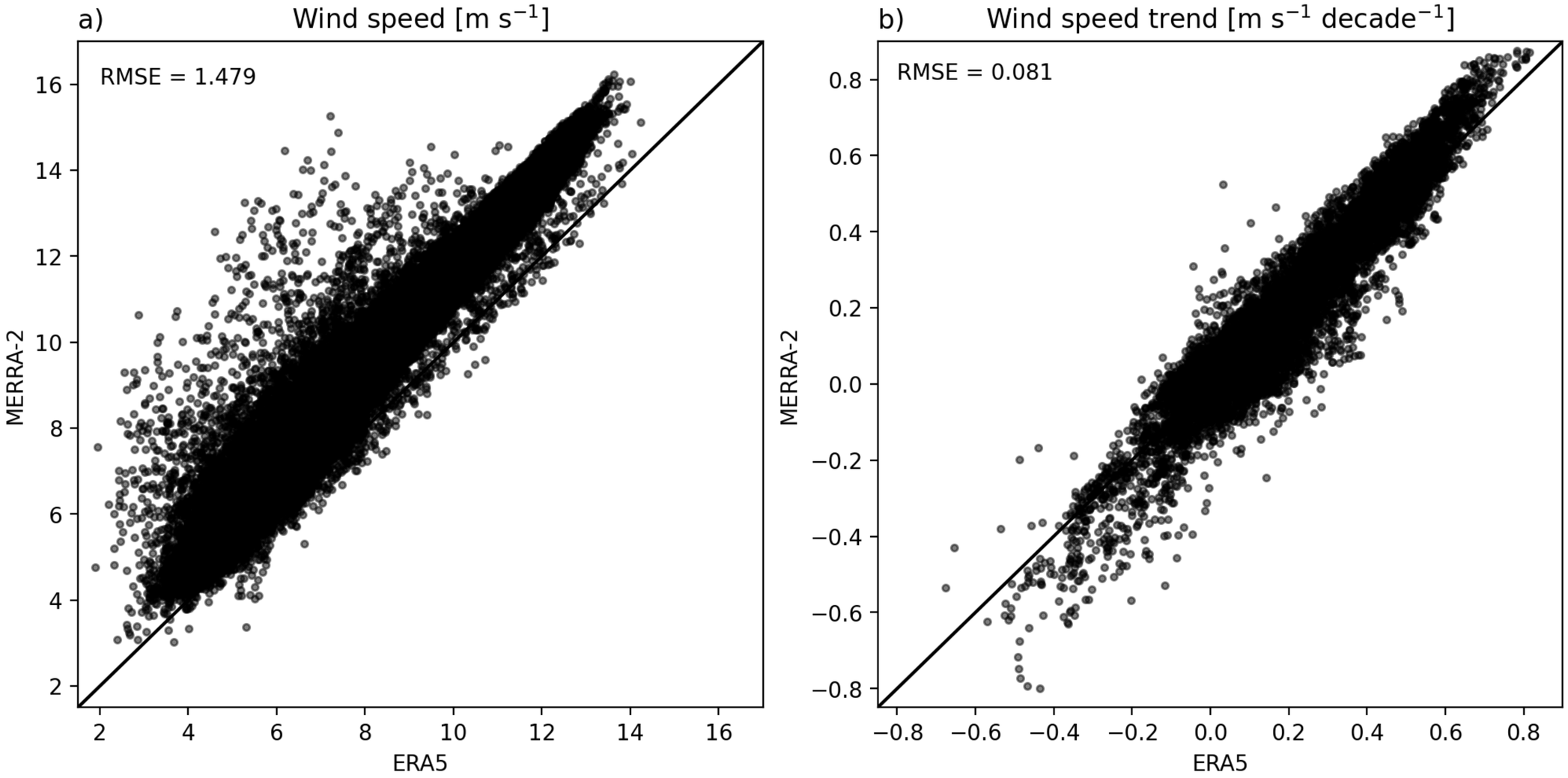


Global dimming driven by clouds, except at high latitudes where it is driven by surface

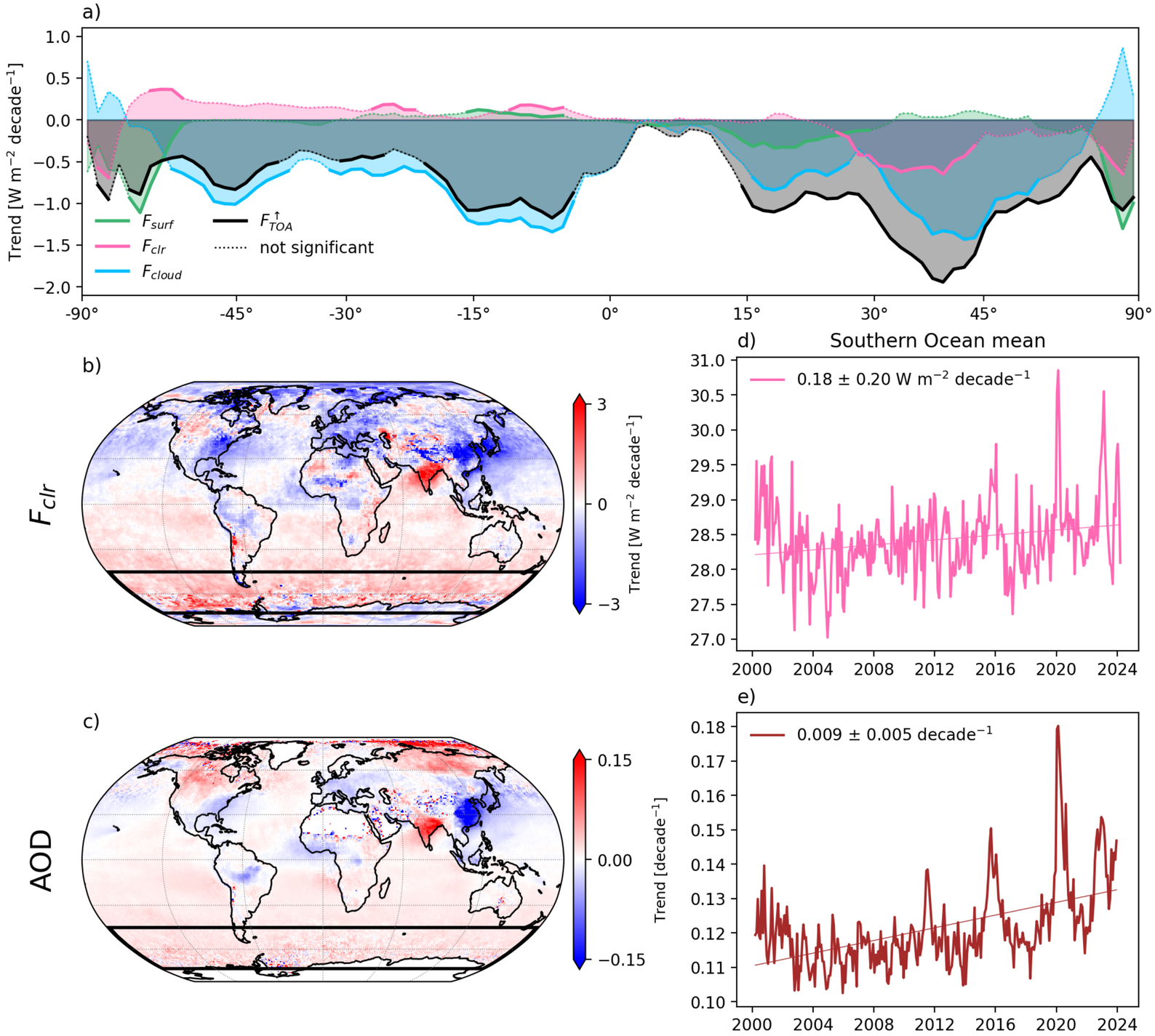


Only significant trends in midlatitude atmospheric clear-sky — equally driven by NH anthropogenic and SH natural aerosol changes

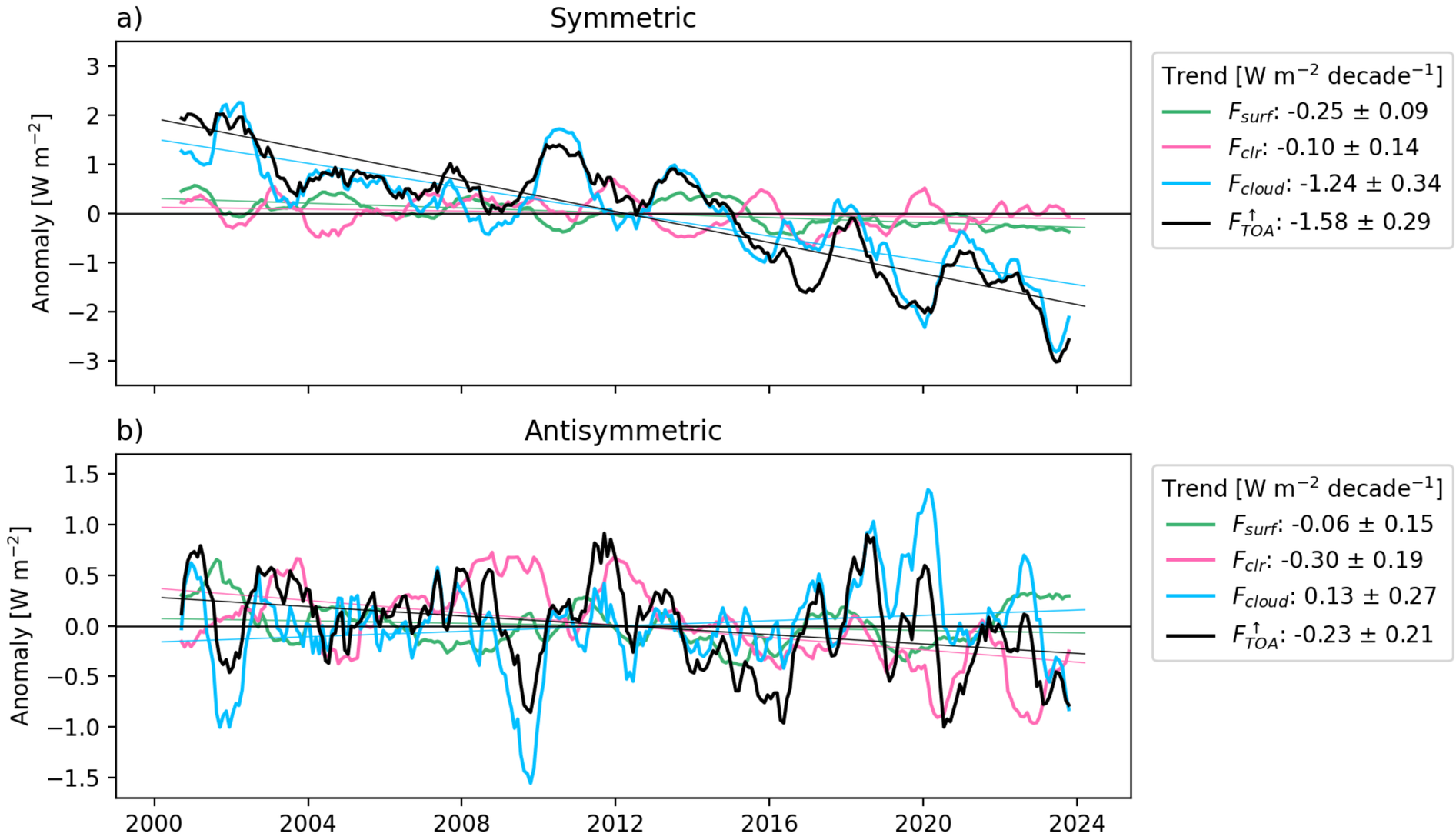
Wind speed trends are consistent between reanalyses, even if mean wind speeds have a slight bias (MERRA-2 winds are faster than ERA5)



Clouds drive dimming at all latitudes; aerosols drive brightening in SH and dimming in NH mid-latitudes



Albedo trends are mostly symmetric between hemispheres (clouds); antisymmetric trends are driven by atmospheric clear-sky



1) SST and boundary layer RH are not consistent with being drivers of increasing AOD
2) ERA5-CAMS indicates that sea salt aerosol are most correlated with wind speeds