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Recent strengthening of snow and ice albedo feedback driven by Antarctic sea ice loss

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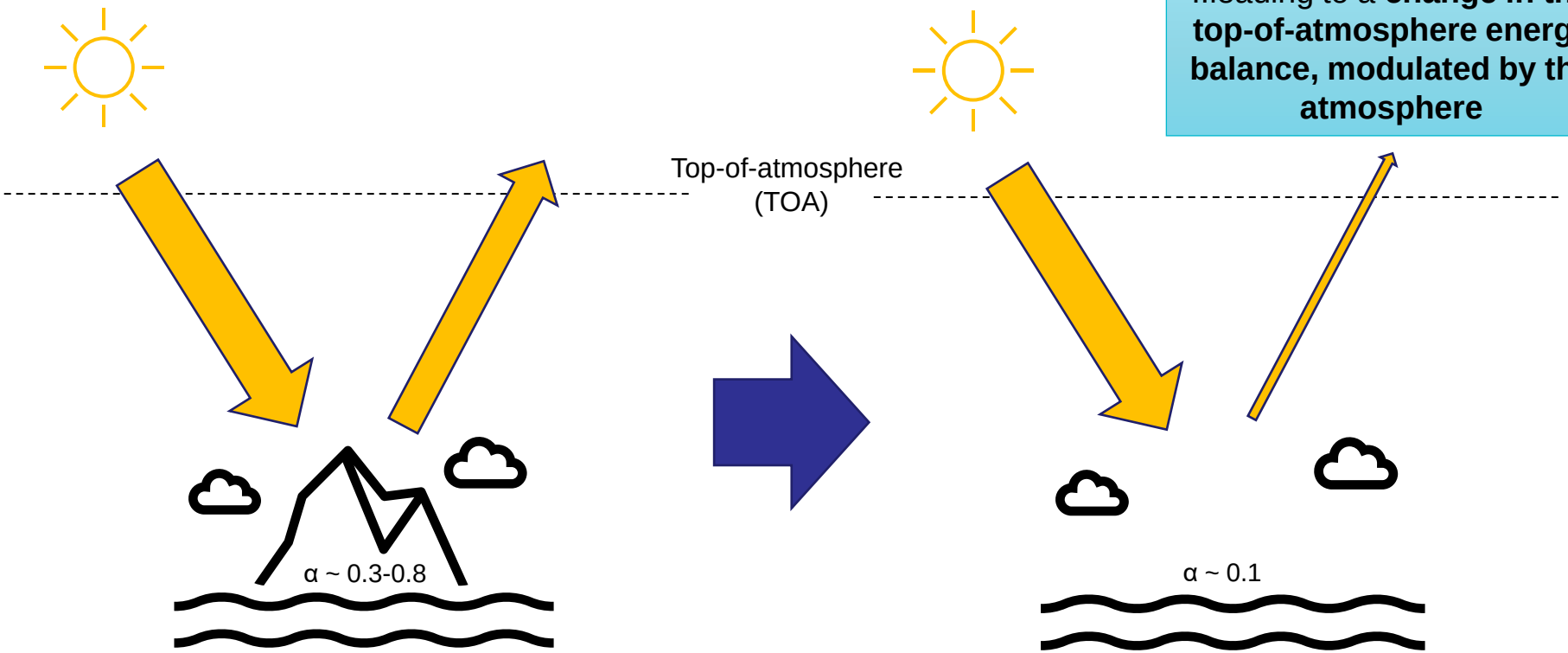
3.2.2022 **AR**

Snow and ice albedo feedback (SIAF)

Visualization by NASA/Goddard Space Flight Center Conceptual Image Lab, https://svs.gsfc.nasa.gov/20022

What is the snow and ice albedo feedback (SIAF)?



..leading to a **change in the top-of-atmosphere energy balance, modulated by the atmosphere**

A change in snow and ice cover alters the surface radiative energy balance…

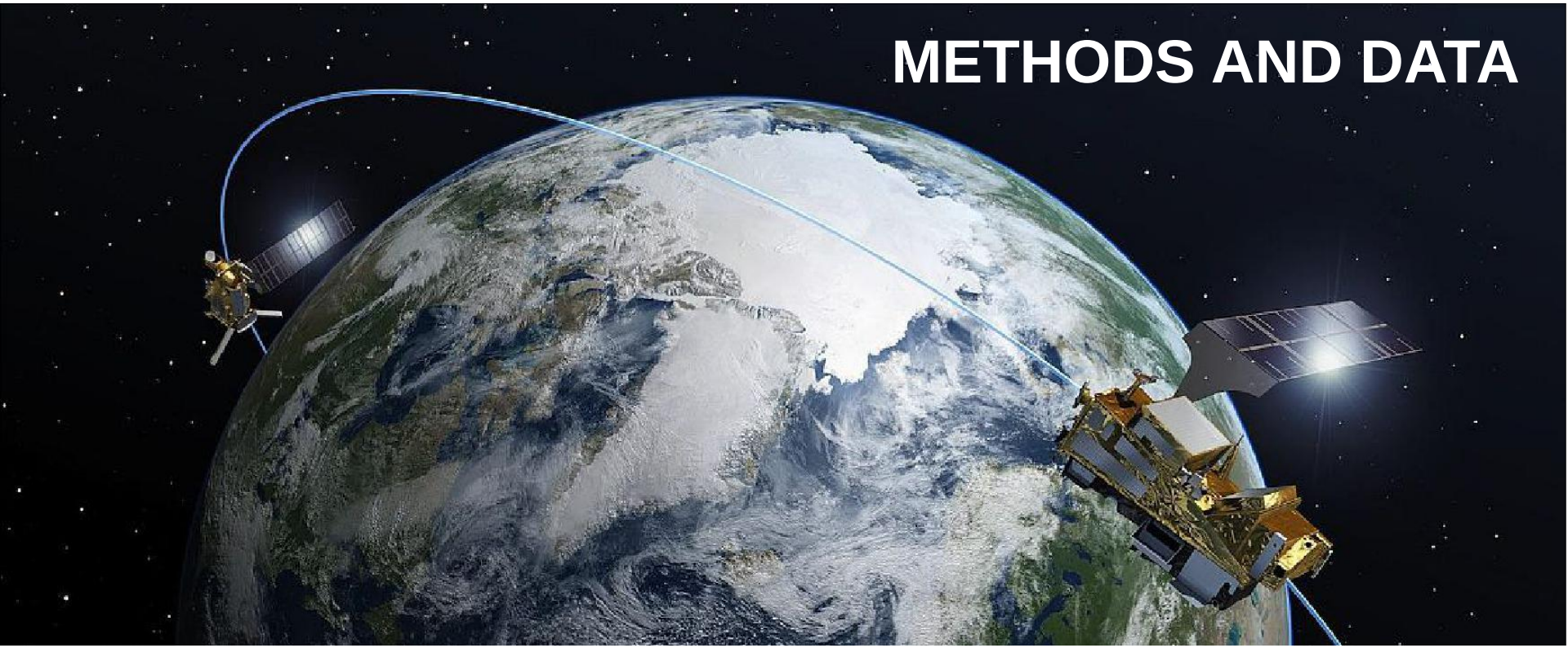
The question(s)

Can we estimate SIAF from an observational basis to serve as an independent counterpoint to climate models?

What is the Antarctic contribution to global SIAF?

What is the current magnitude of global SIAF over both polar cryospheres?

METHODS AND DATA



So we need to quantify surface albedo changes and the modulating effect of the atmosphere…

- Enter the radiative kernel technique:

$$SIAF = \sum k * \Delta\alpha \qquad [W\ m^{-2}]$$

Summed over all grid cells in the study area (over the year), and usually projected against the full surface area of the Earth

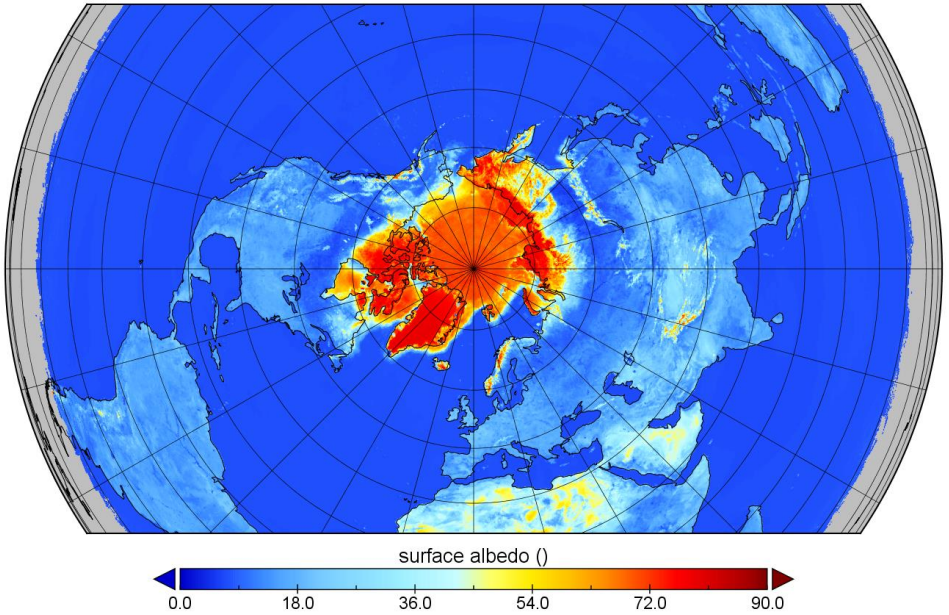
Disturbance in TOA SW radiative energy balance per unit change (0.01) in surface albedo

✖

Change in surface albedo (relative to some reference/baseline condition)

The surface albedo dataset: CM SAF CLARA-A2.1

- Global annual coverage between 1982-2018 from intercalibrated AVHRR imager data
- Broadband black-sky surface albedo (DHR) estimates for all surfaces on Earth
- Retrieval accuracy evaluated as 5-10% (relative) over snow and ice

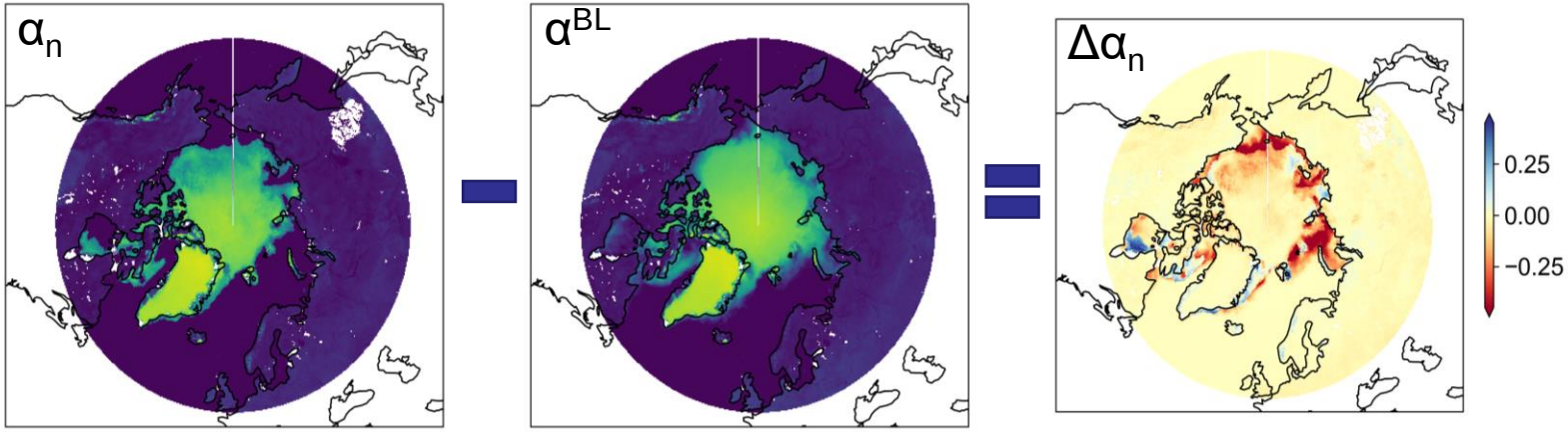


Here, all albedo estimates converted from black- to white-sky albedo (isotropic illumination) for analysis.

Δα from internal baseline comparison

- For any month in the study period, $\Delta\alpha = \alpha_n - \alpha_n^{BL}$
- The baseline period is defined as the 1982-1991 mean
- **Therefore, all SIAF estimates equate to a SW radiative feedback against mean snow/ice conditions of 1982-1991**

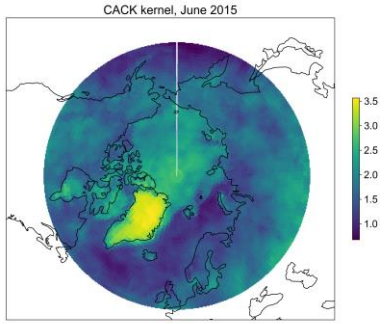
Example of WSA albedo changes vs. baseline, July 2015

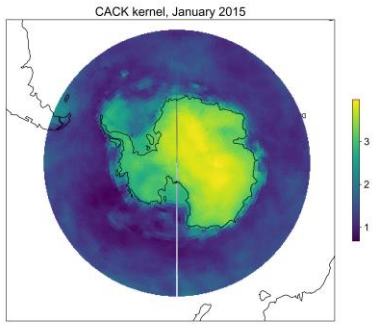


Advantages – eliminate/diminish albedo estimation biases (WSA over sea ice), no need to prescribe snow/ice/vegetation albedos.

Disadvantages – sacrifice a part of data record length

The radiative kernels – CloudSat-CALIPSO (CC) & CERES Albedo Change Kernel (CACK)





CACK

From CERES radiative flux observations

Spatiotemporally resolved between 2001-2016, filled to cover study period

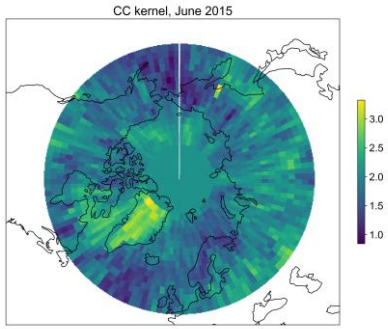
Bright & O'Halloran (2019)

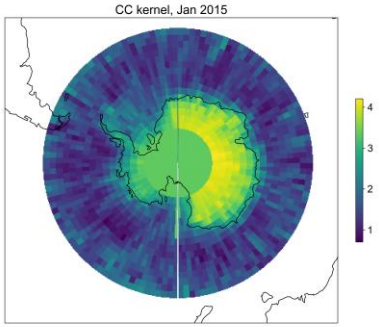
CC

From CloudSat and CALIPSO radar/lidar observations

Data from 2008/2009, filled to cover study period (also near-pole data gap filled)

Kramer et al. (2019)





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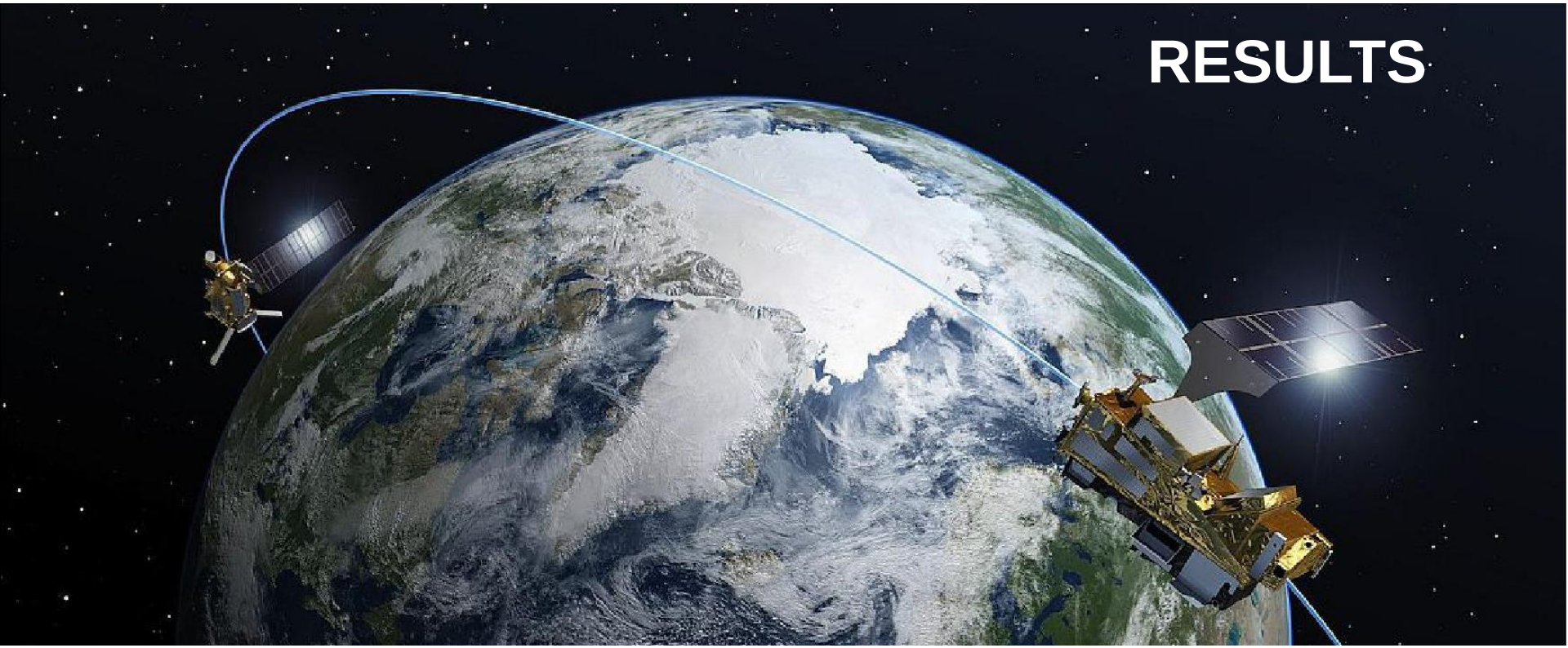
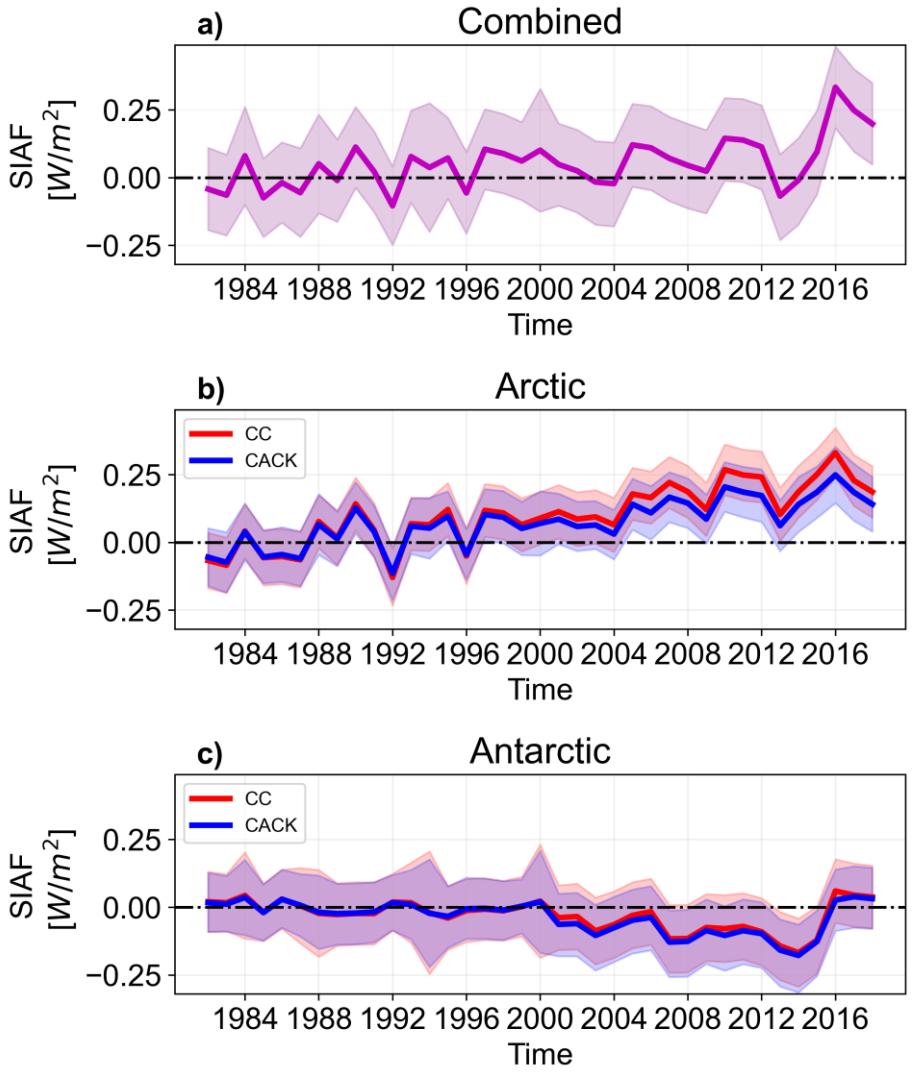
Very recent advances, observation-based and independent from each other and the surface albedo record!



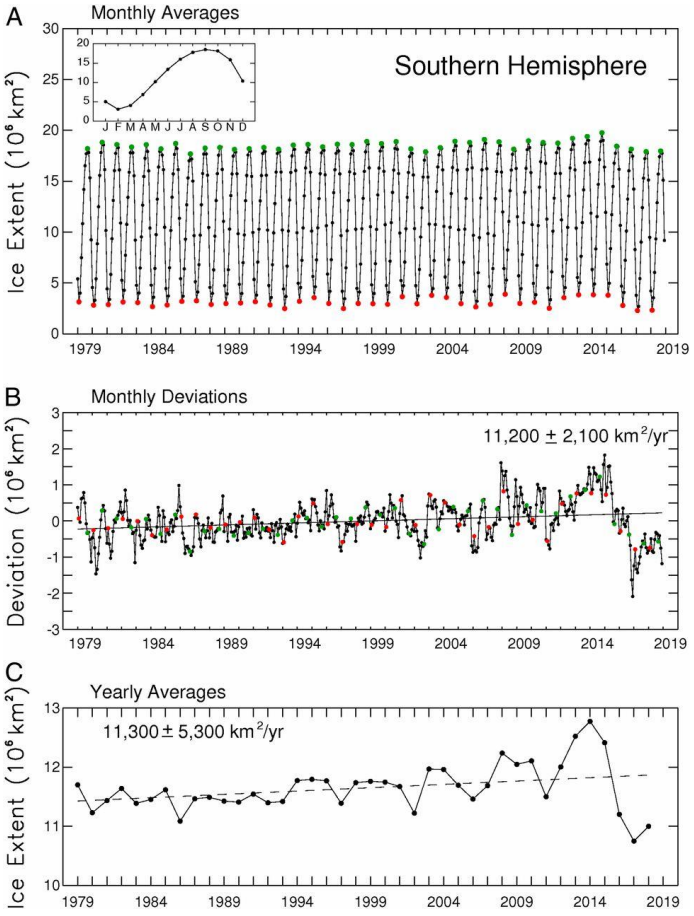
Annual global mean SIAF



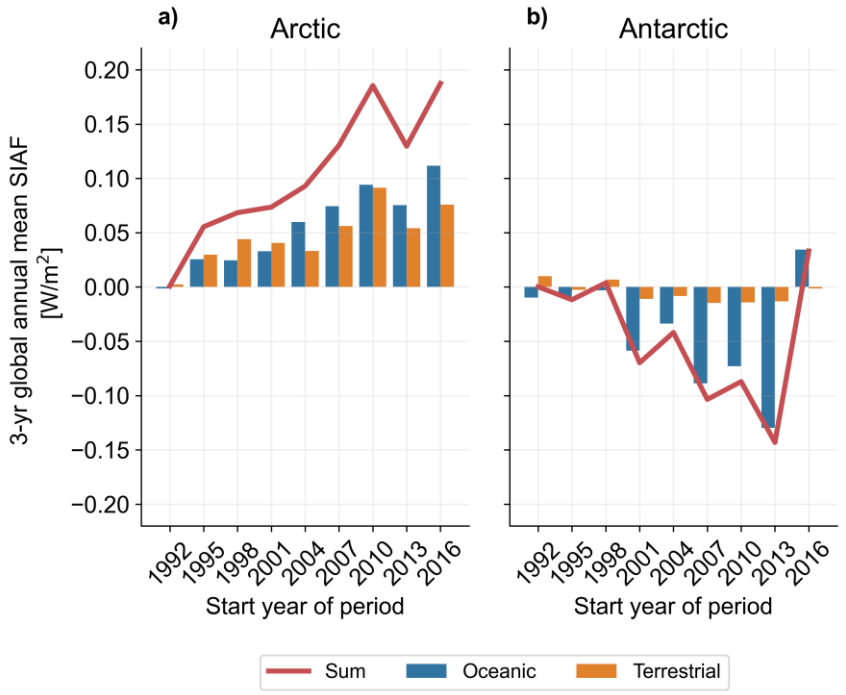
>50 °N

<-50 °N

Antarctic reversal?



Parkinson (2019): **A 40-y record reveals gradual Antarctic sea ice increases followed by decreases at rates far exceeding the rates seen in the Arctic. Proceedings of the National Academy of Sciences.**



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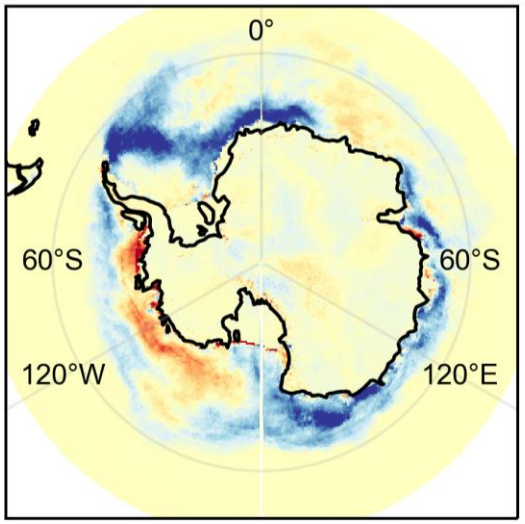
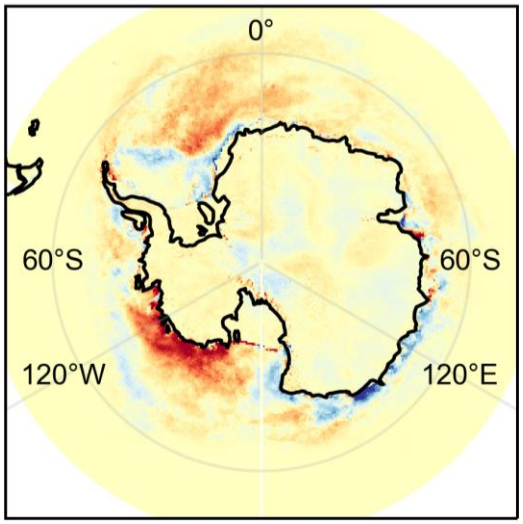
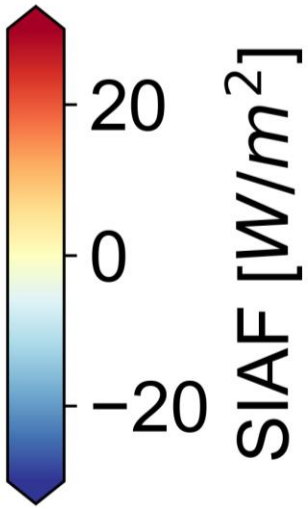
Antarctic reversal, confirmed.

2013-2015

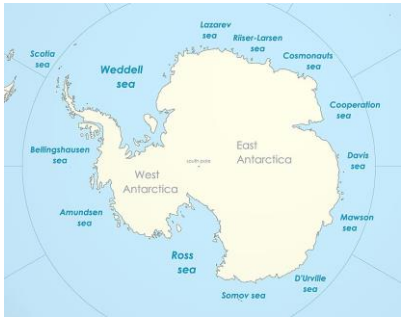


2016-2018

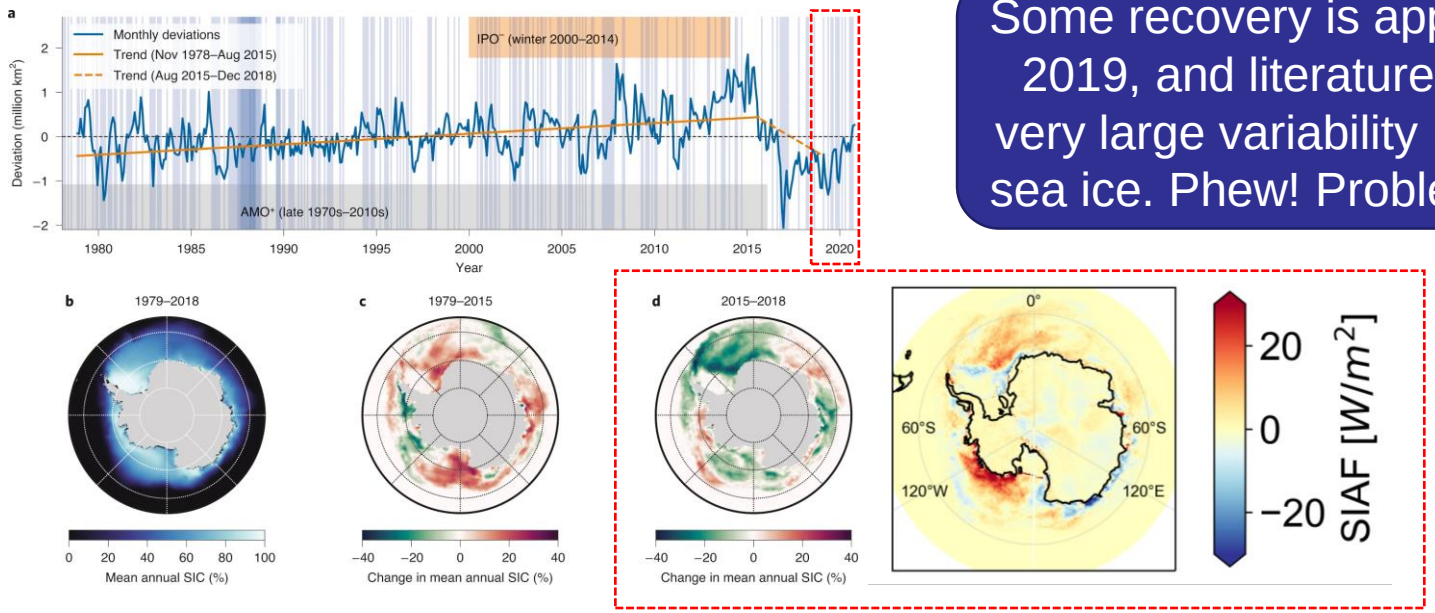




(keep in mind, SIAF is calculated against 1982-1991 baseline)



Annual variability writ large or regime shift?

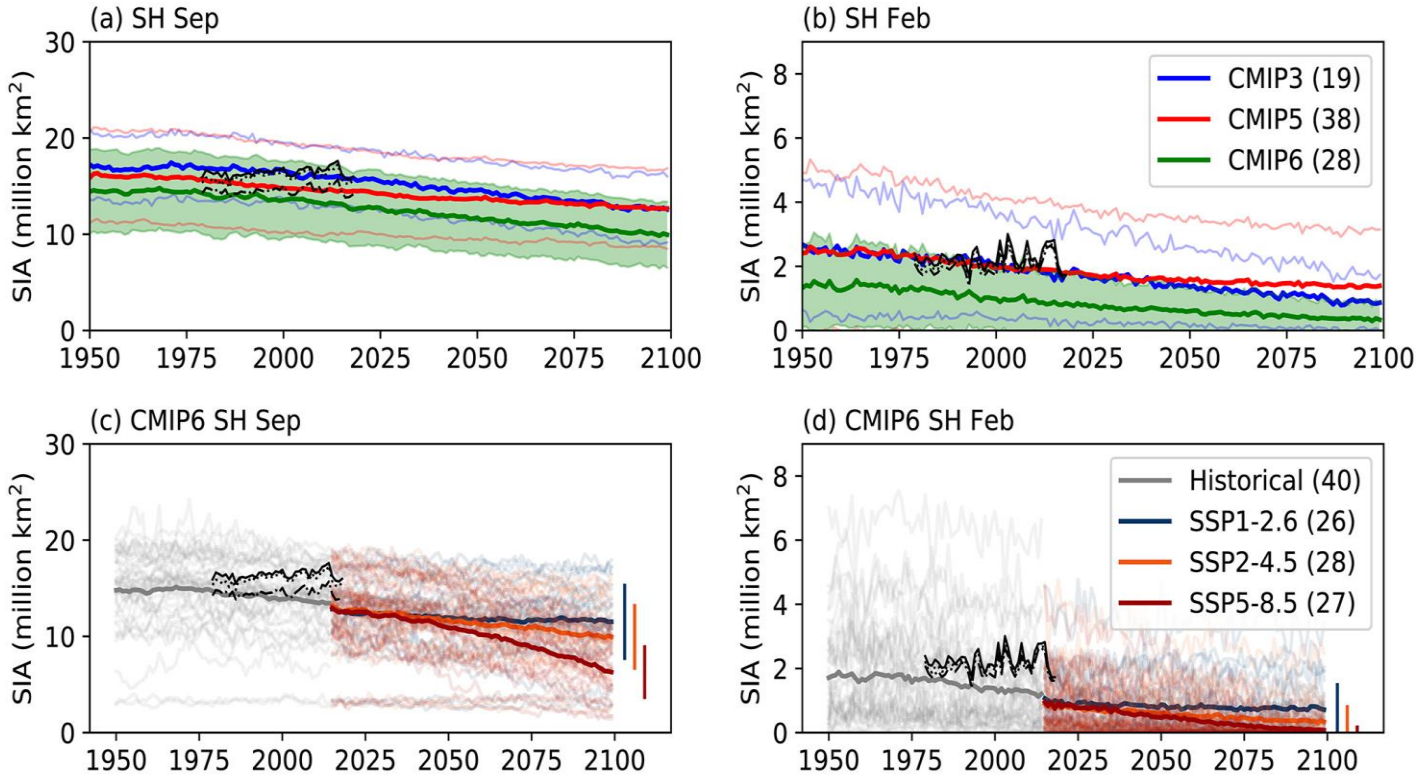


Some recovery is apparent after 2019, and literature suggests very large variability in Antarctic sea ice. Phew! Problem solved?

a, Monthly mean SIE anomalies since 1979 with respect to the 1979–2018 climatology (blue line); trend lines (orange; dashed orange) calculated through the monthly anomalies[53]. Orange shading shows the IPO⁻ and grey shading shows the AMO⁺. Blue shading shows months with weakened westerlies (SAM⁻ (ref. [55])). **b**, Mean annual SIC 1979–2018. **c**, Mean annual SIC changes from 1979 to 2015. **d**, Mean annual SIC changes from 2015 to 2018[54].

Eayrs et al. (2021): Rapid decline in Antarctic sea ice in recent years hints at future change. *Nature Geoscience*

Antarctic sea ice has proven to be challenging to track in CMIP3-6

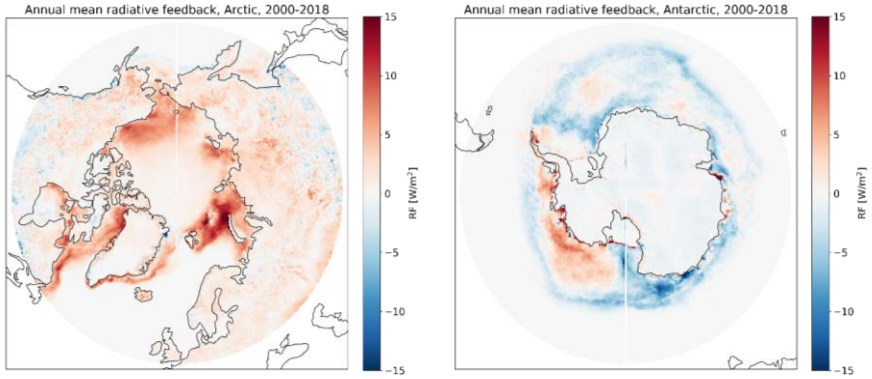


Roach, L. A., Dörr, J., Holmes, C. R., Massonnet, F., Blockley, E. W., Notz, D., et al. (2020). Antarctic sea ice area in CMIP6. *Geophysical Research Letters*, 47, e2019GL086729. https://doi.org/10.1029/2019GL086729

SIAF magnitudes in perspective

EESF: Emissions Equivalent Shortwave Forcing

$$EESF = \frac{SIAF}{kco2 * AF * 1e12 * 26}$$



The +0.08 W/m^2 mean SIAF of 1992 to 2018 yields ~3.8 $GtCO_2$-equivalent annual pulse emssions, or *roughly 10% of annual anthropogenic emissions* ***in the same period***.

But; significant simplifications are required for the airborne fraction of CO2 (AF), and true manifestation of SIAF onto the climate system may take decades to appear.

TAKE-HOME MESSAGE

- Combined Arctic + Antarctic SIAF saw a rapid rise in 2016, after a decade and a half of Arctic ice losses being mostly balanced by Antarctic increases

- Antarctic SIAF increase clearly a result of sea-ice losses
  - Not a singular regime shift of the Antarctic cryosphere, but our ability to forecast the future is hampered by some gaps in modeling
  - Recommend more attention be given to the Antarctic sea-ice and the cryosphere as a whole in the future

- Results are compatible with earlier results for the Arctic

- Nuts and bolts view:
  - https://www.nature.com/articles/s41561-021-00841-x
  - Riihelä, A., Bright, R.M., and Anttila, K. : Recent strengthening of snow and ice albedo feedback driven by Antarctic sea-ice loss. *Nature Geoscience,* 2021