Exploring the Local Atmospheric Response to Antarctic Sea Ice Loss

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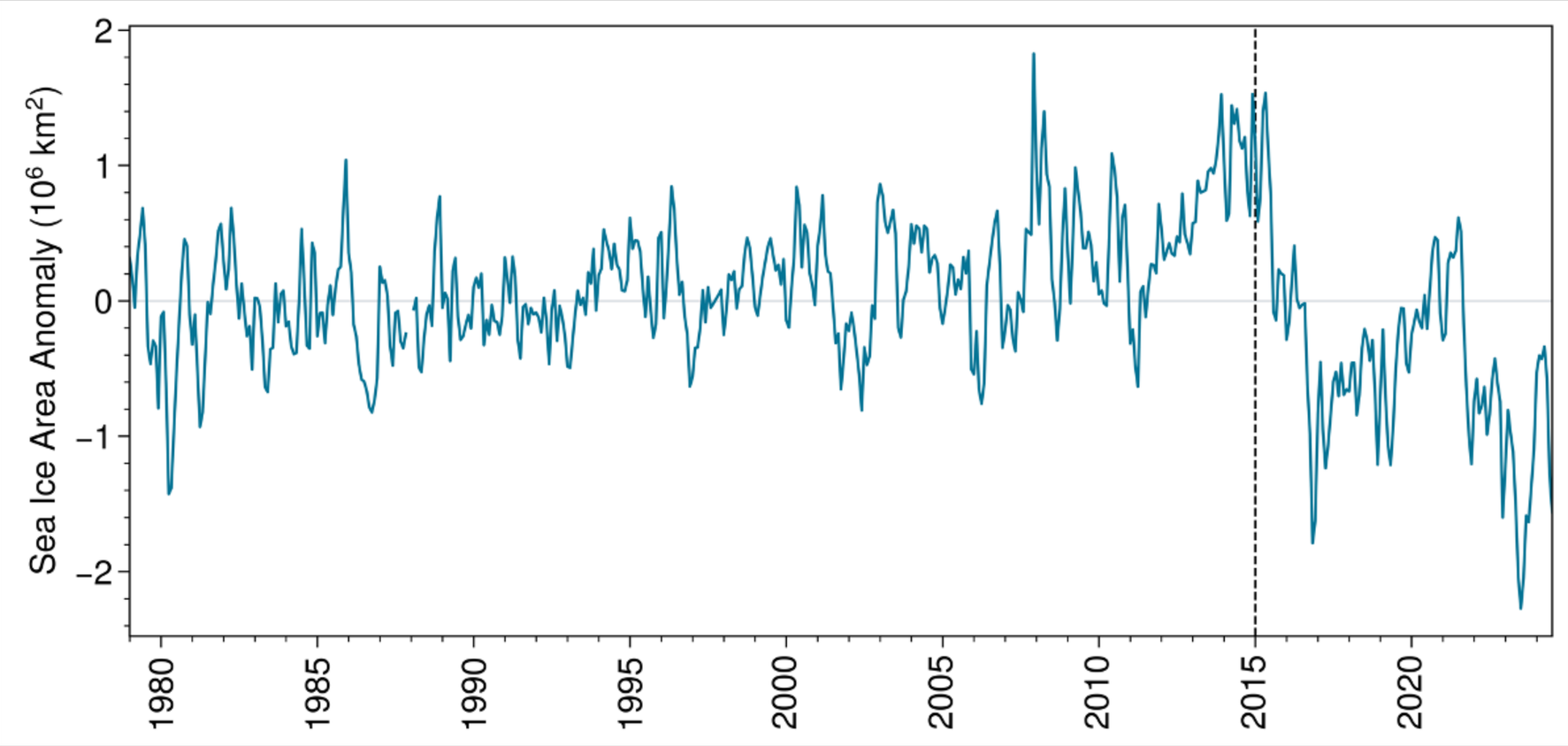
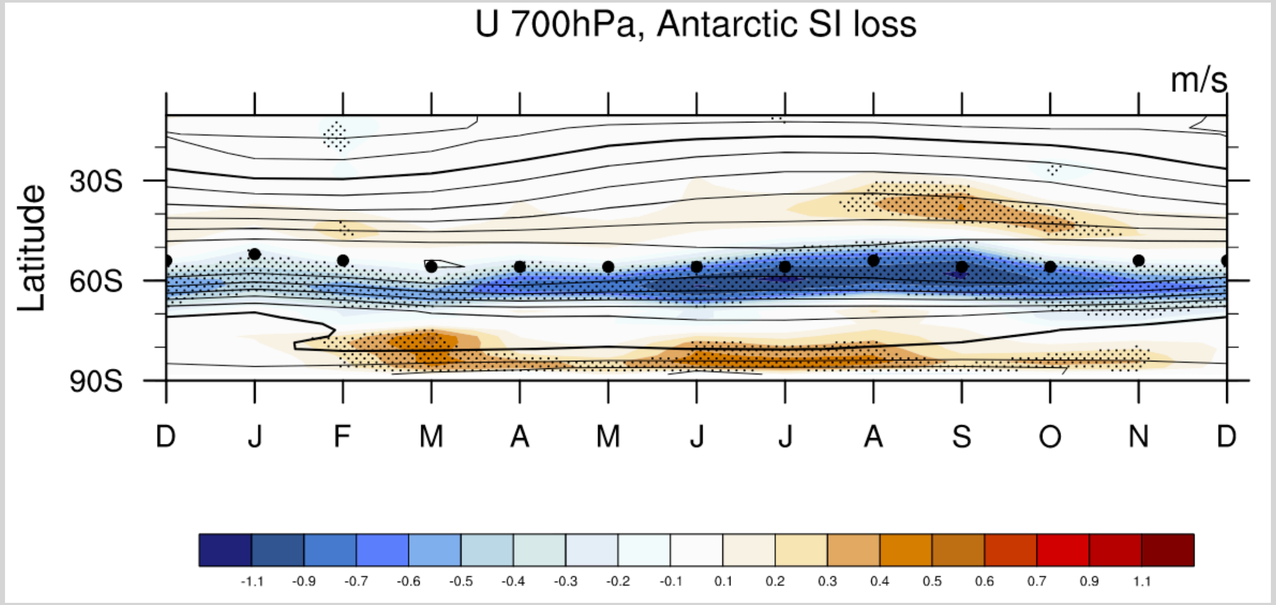
NSIDC

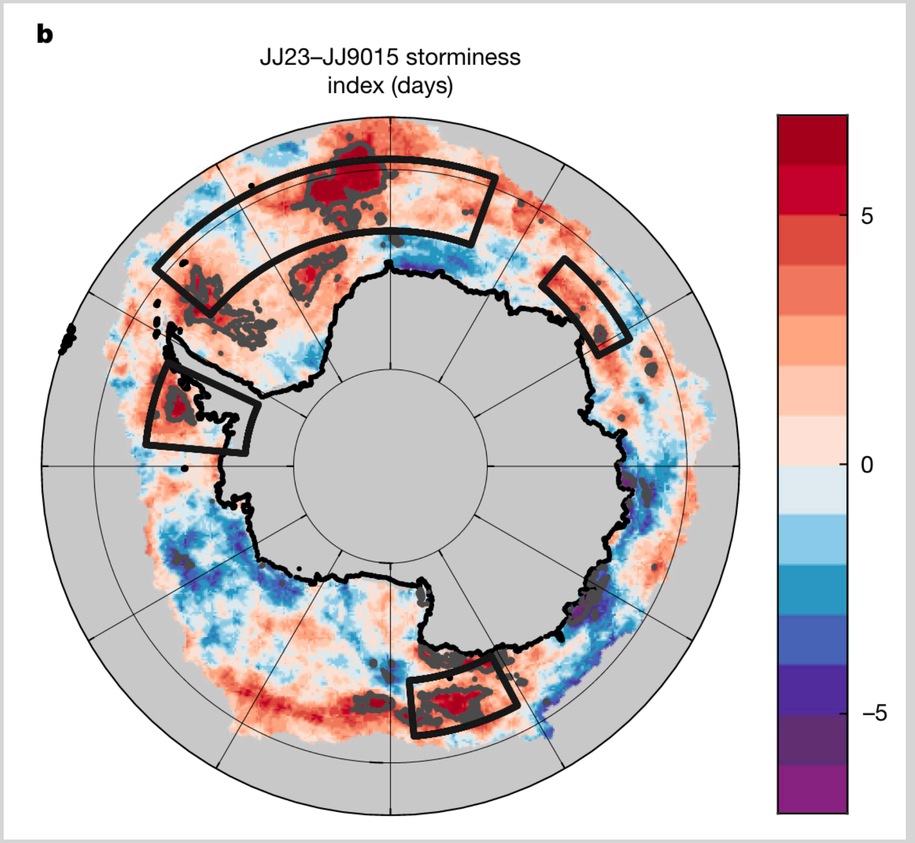
Annual-mean Antarctic sea ice extent has decreased roughly 2.5 million km^2 in the last decade.



There is still work to be done exploring potential impacts of Antarctic sea ice loss.



England et al. (2018)



Josey et al. (2024)

Can we use observationally-constrained data to explore impacts of Antarctic sea ice loss? How does it compare to modeled impacts?

Observationally-Constrained Data

- Monthly gridded sea ice concentration (SIC) data from NSIDC
- Monthly gridded atmospheric variables from ERA5 reanalysis
- Monthly gridded cloud fraction from CERES EBAF 4.2
- Data covers period January 1979 – September 2024
  - Detrended and Deseasonlized

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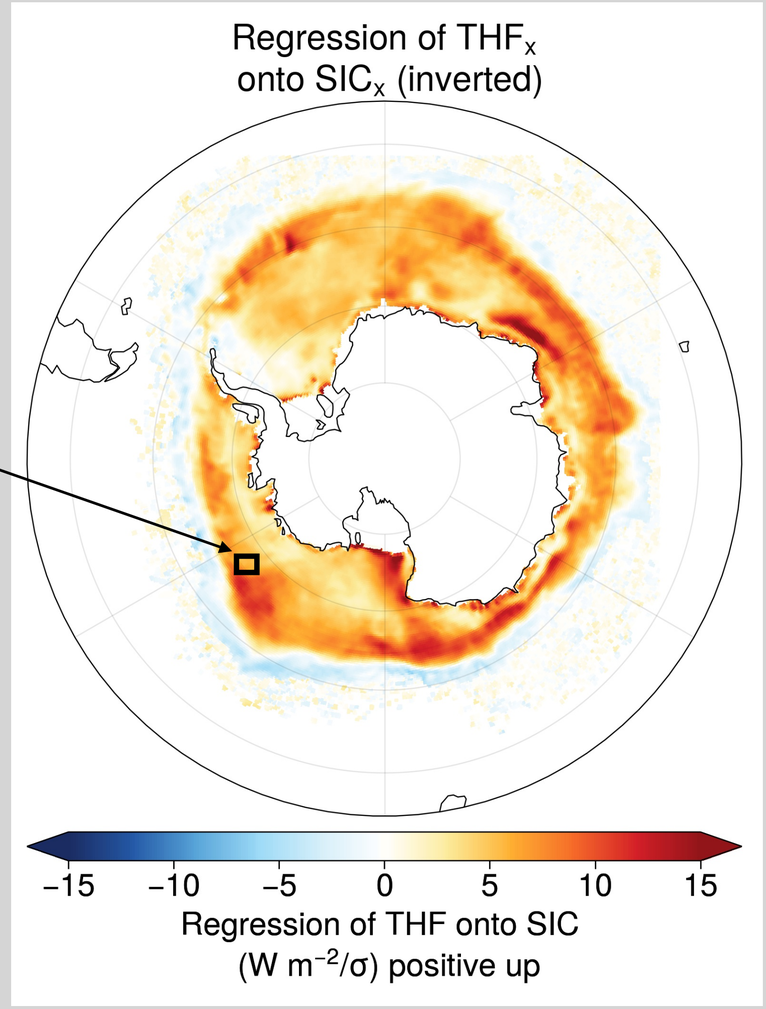
Model Output

- PAMIP experiments with CESM2
  - Atmosphere-only time slice experiments, 100 ensemble members
  - Experiments start on 1 April, 2000 and run for 14 months, first 2 months are discarded for model spin up
  - Monthly output from 1) present-day SSTs with **future** Antarctic sea ice and 2) present-day SSTs with **preindustrial** Antarctic sea ice

Local-local regression methodology isolates local response and allows exploration of the regionality of relationships

Regression of Turbulent heat flux at grid point point **x** regressed onto standardized values of sea ice *loss* at point **x**

$$\beta = \frac{\overline{x_i' y_i'}}{x_i'^2}$$

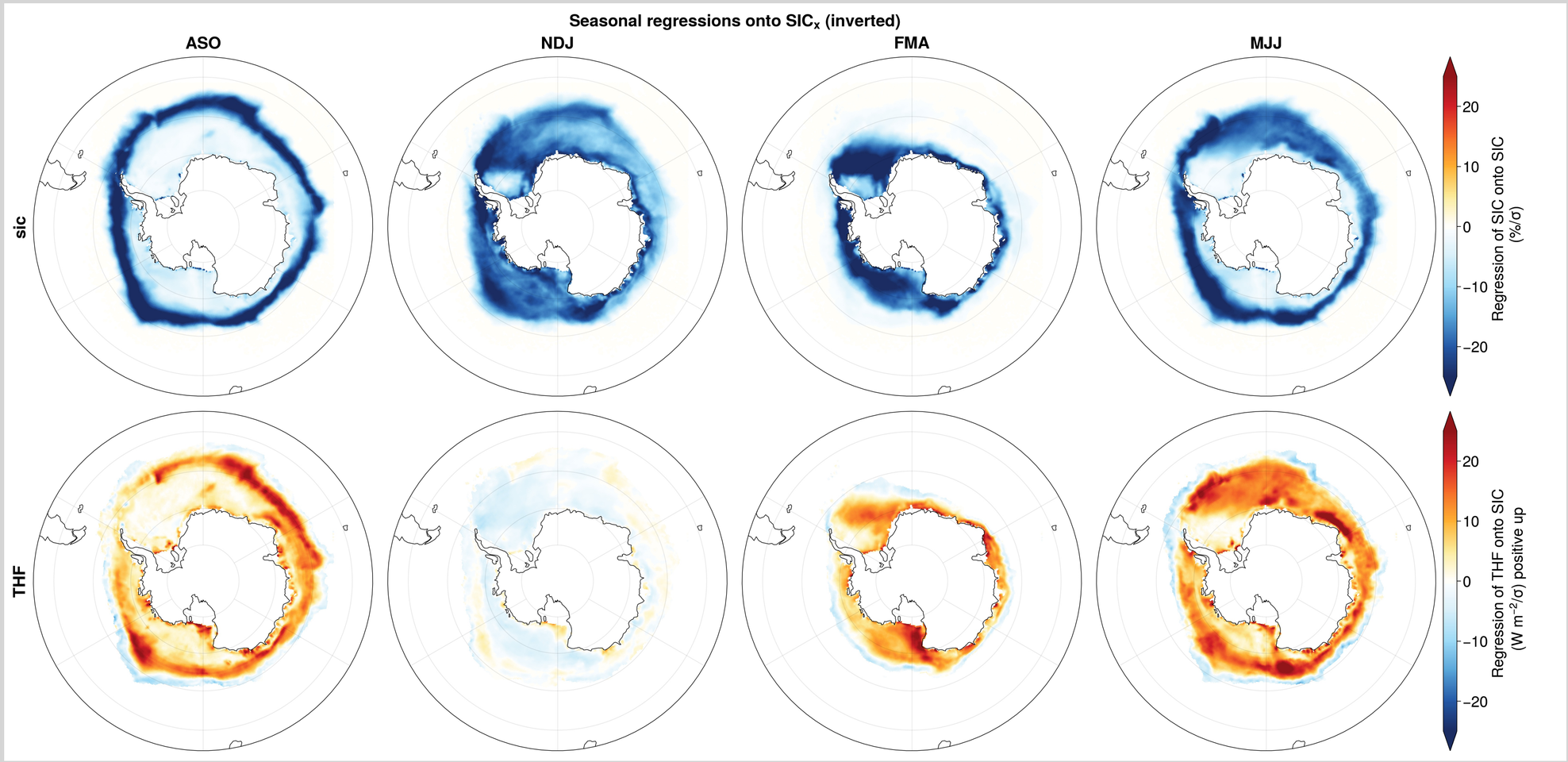


Areas of sea ice loss are correlated with increased net turbulent heat flux into the atmosphere, strongest in the winter.

Aug,Sep,Oct | Nov,Dec,Jan | Feb,Mar,Apr | May,Jun,Jul

Sea Ice Concentration ($\%/\sigma$)

Turbulent Heat Flux (Wm^{-2}/σ) Positive up



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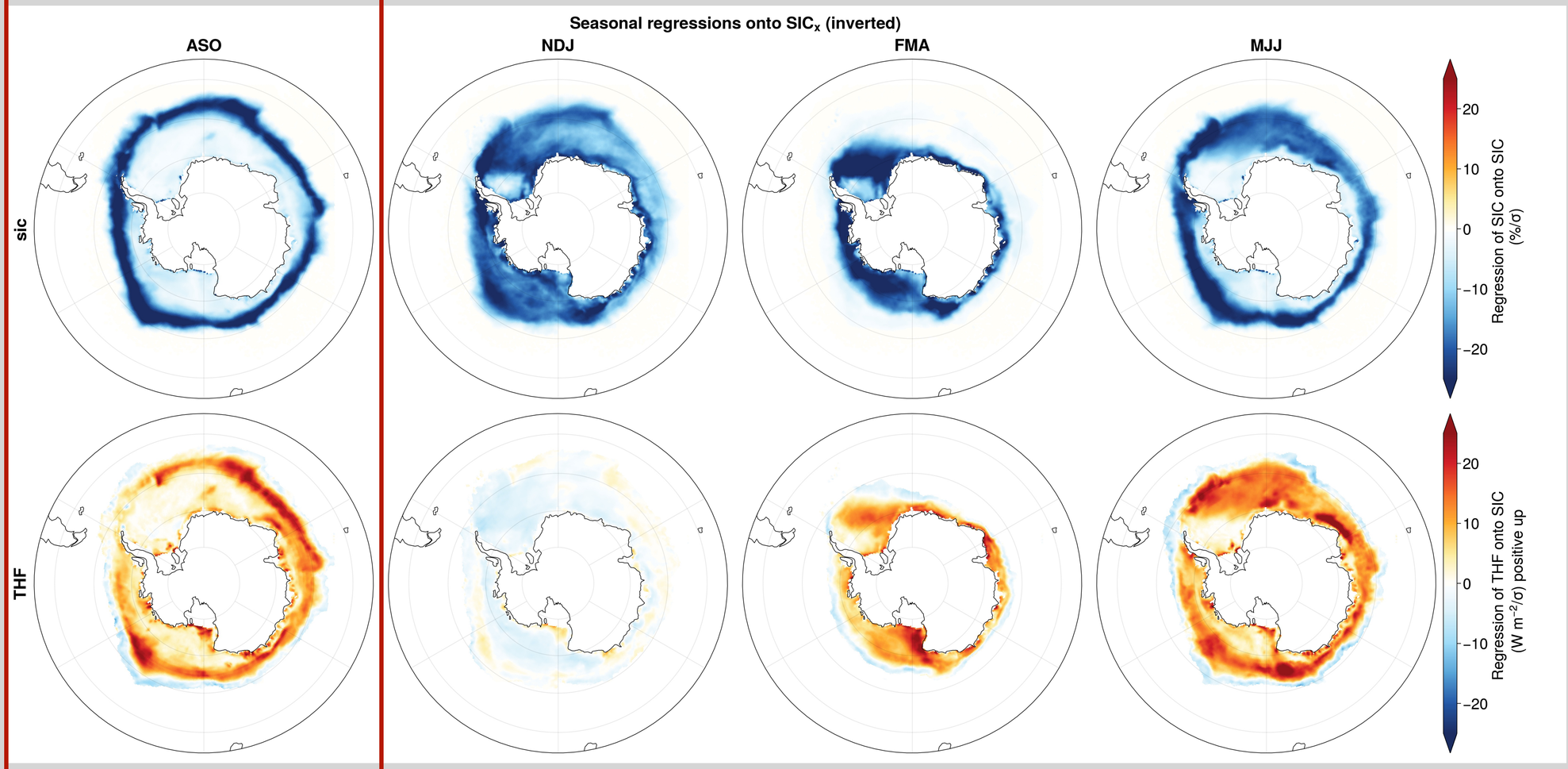
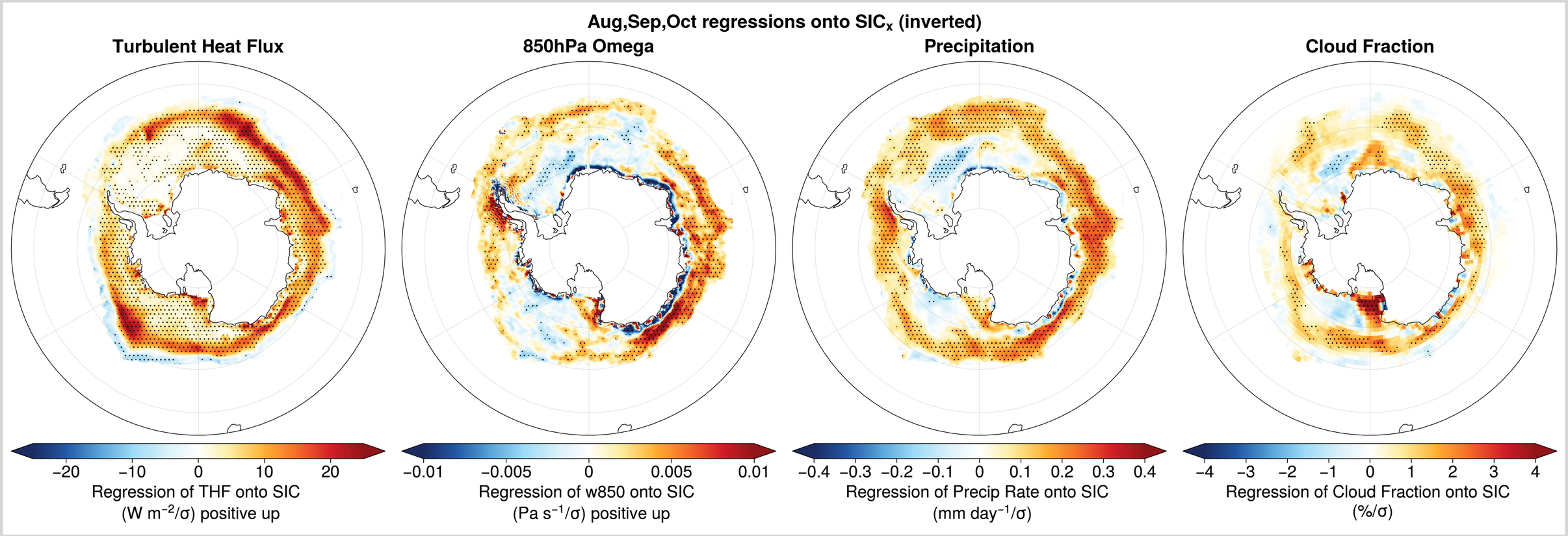
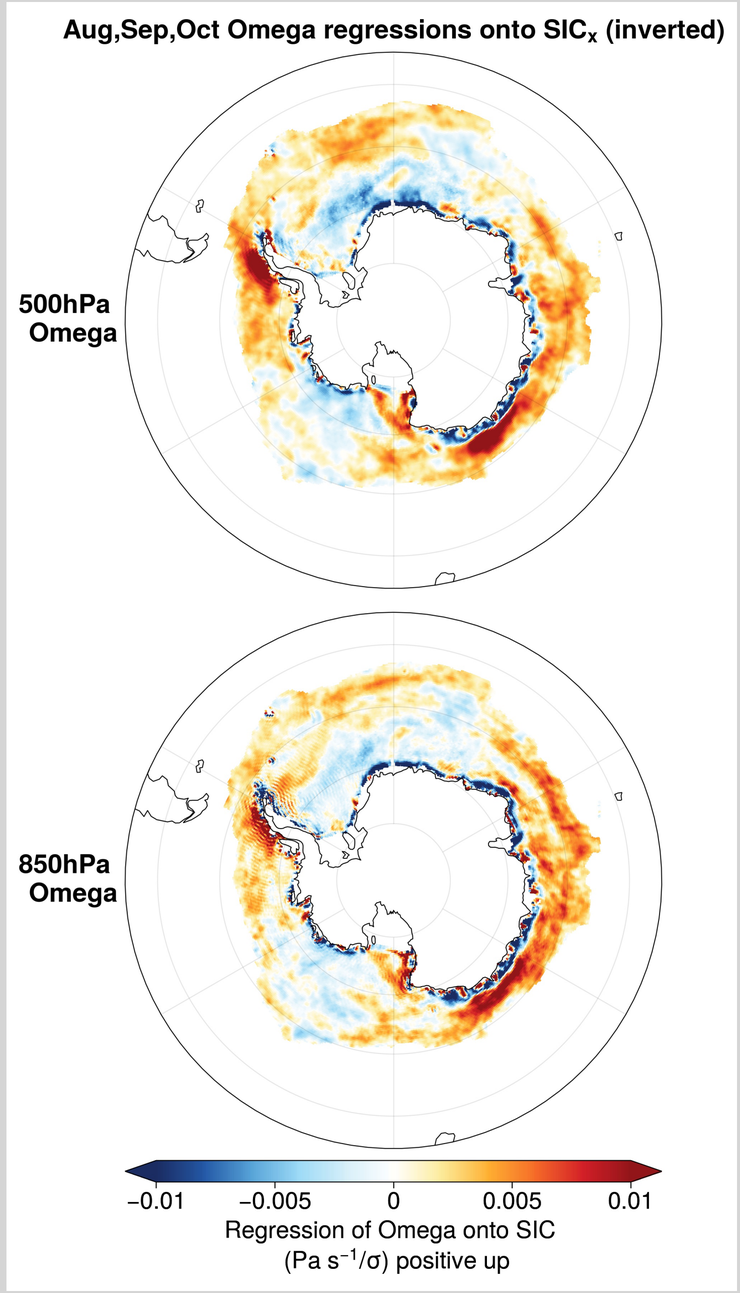


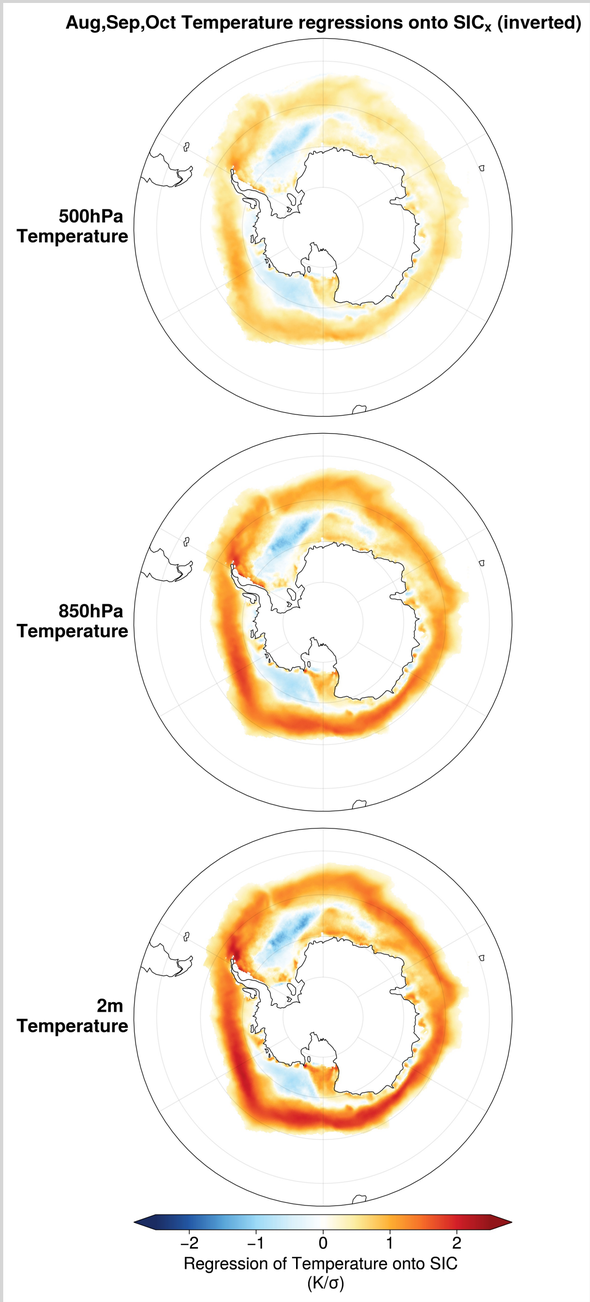
Sea ice loss during Aug,Sep,Oct is correlated with increased vertical motion, precipitation, and cloud cover



Stippling indicates statistical significance at the 95% confidence interval

Temperature and vertical velocity changes correlated with sea ice loss extend into the free troposphere.

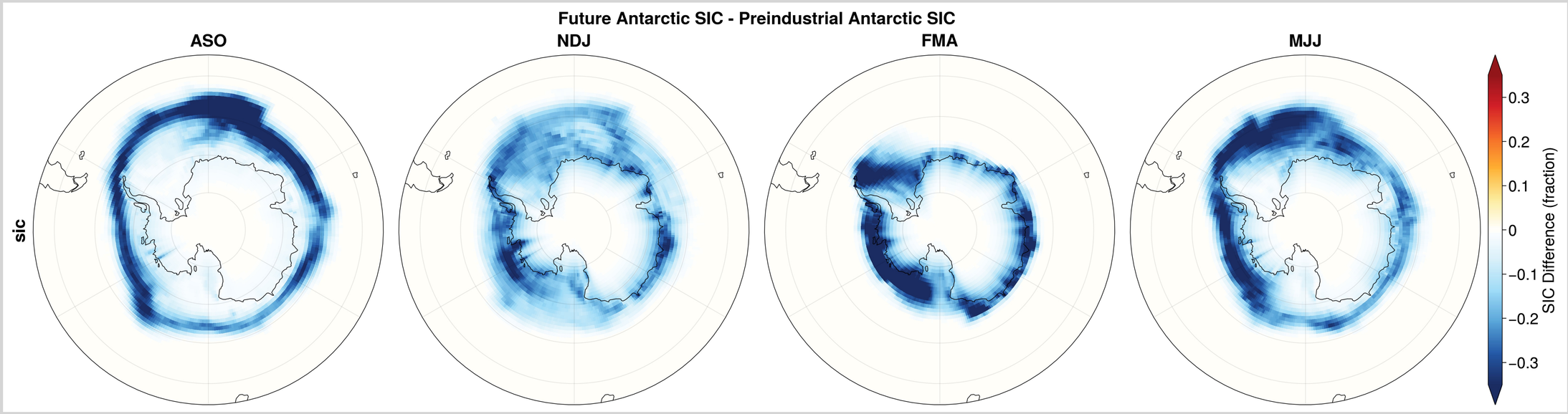




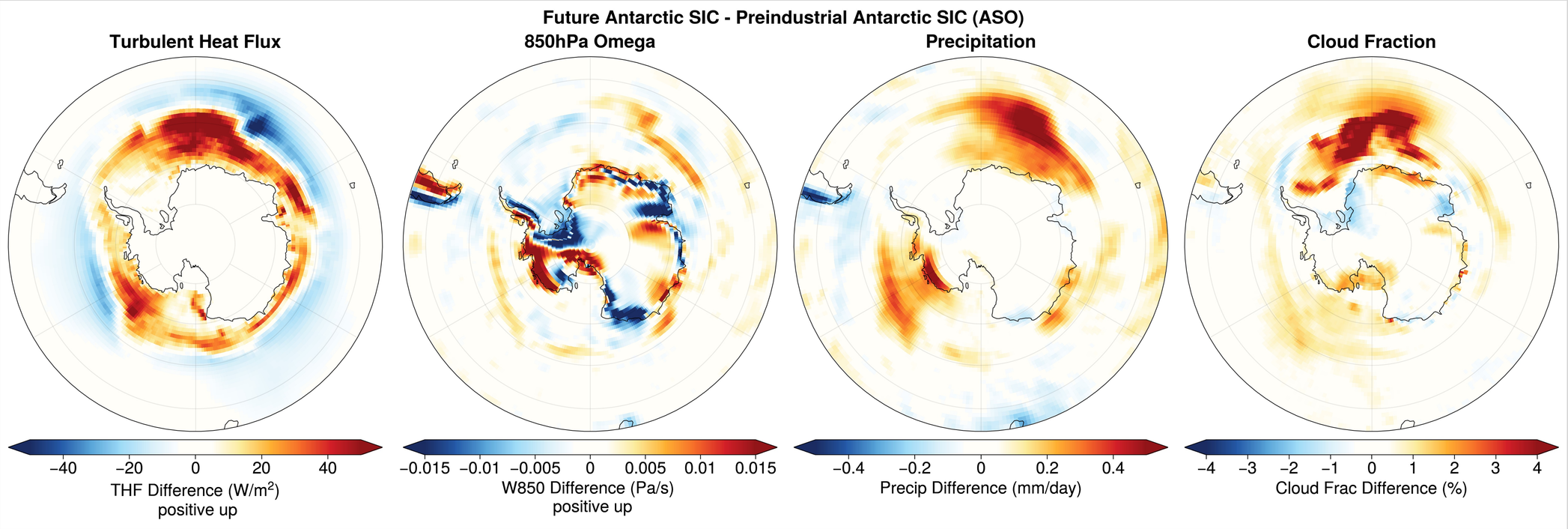
Sea ice loss in PAMIP experiments occurs in similar areas of large variability in observational data.

Sea Ice Concentration difference between Future Antarctic SIC experiment and Preindustrial Antarctic SIC experiment

Aug,Sep,Oct | Nov,Dec,Jan | Feb,Mar,Apr | May,Jun,Jul



Qualitatively, impacts from sea ice loss in PAMIP experiments are similar in magnitude to observational results



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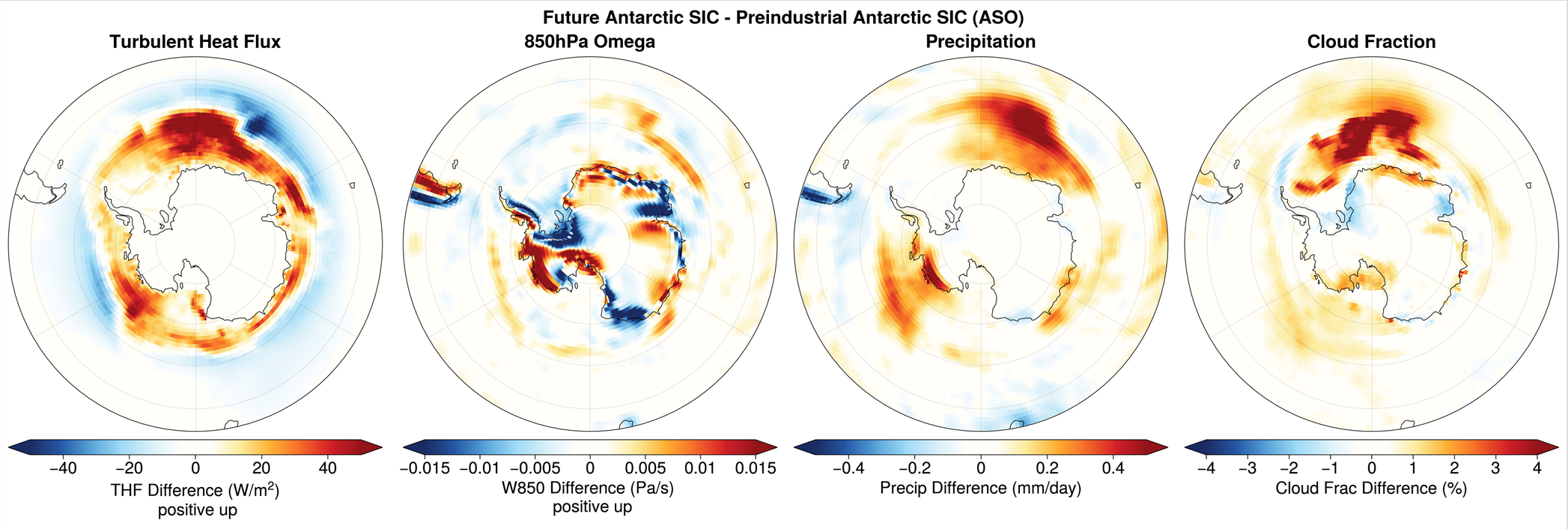


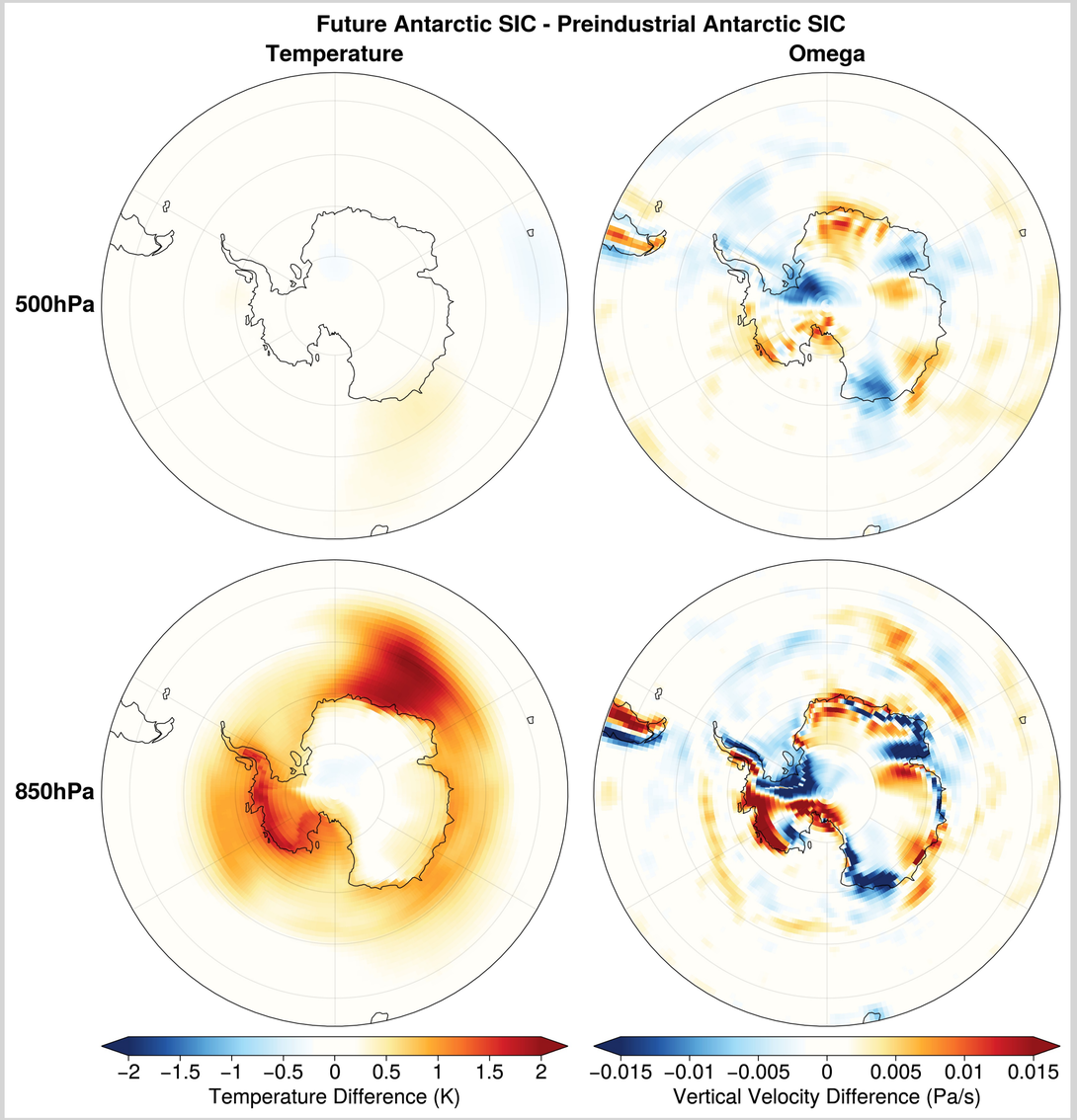
In **observational** results, given 20-25% decline in sea ice:

- THF increases by ~ 25 W/m^2
- Vertical velocity @ 850hPa increases by ~ 0.01 Pa/s
- Precipitation increases by ~ 0.3 mm/day
- Cloud fraction increases by ~3%

In **PAMIP** results, given 35-40% decline in sea ice:

- THF increases by ~ 45 W/m^2
- Vertical velocity @ 850hPa changes by ~ 0.01 Pa/s
- Precipitation increases by ~ 0.4 mm/day
- Cloud fraction increases by ~4%

One notable difference between the model and observational results is the vertical extent of the impacts.



Key Points

- Using this local-local regression analysis, we can explore impacts of Antarctic sea ice loss using observationally-constrained data
- Results are qualitatively similar to PAMIP experiments with CESM2
- Results from observations show impacts higher into the atmosphere than in model results

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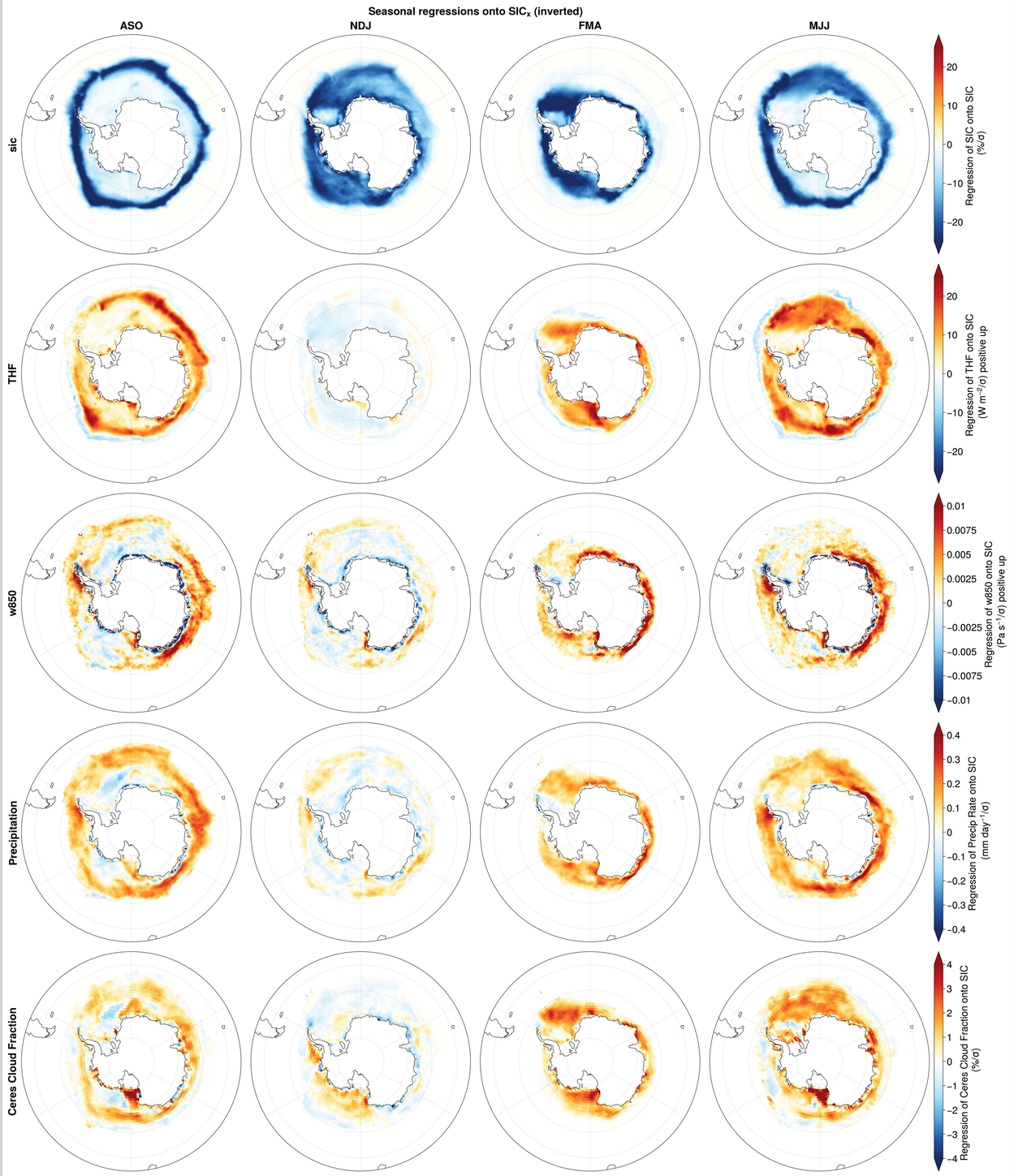
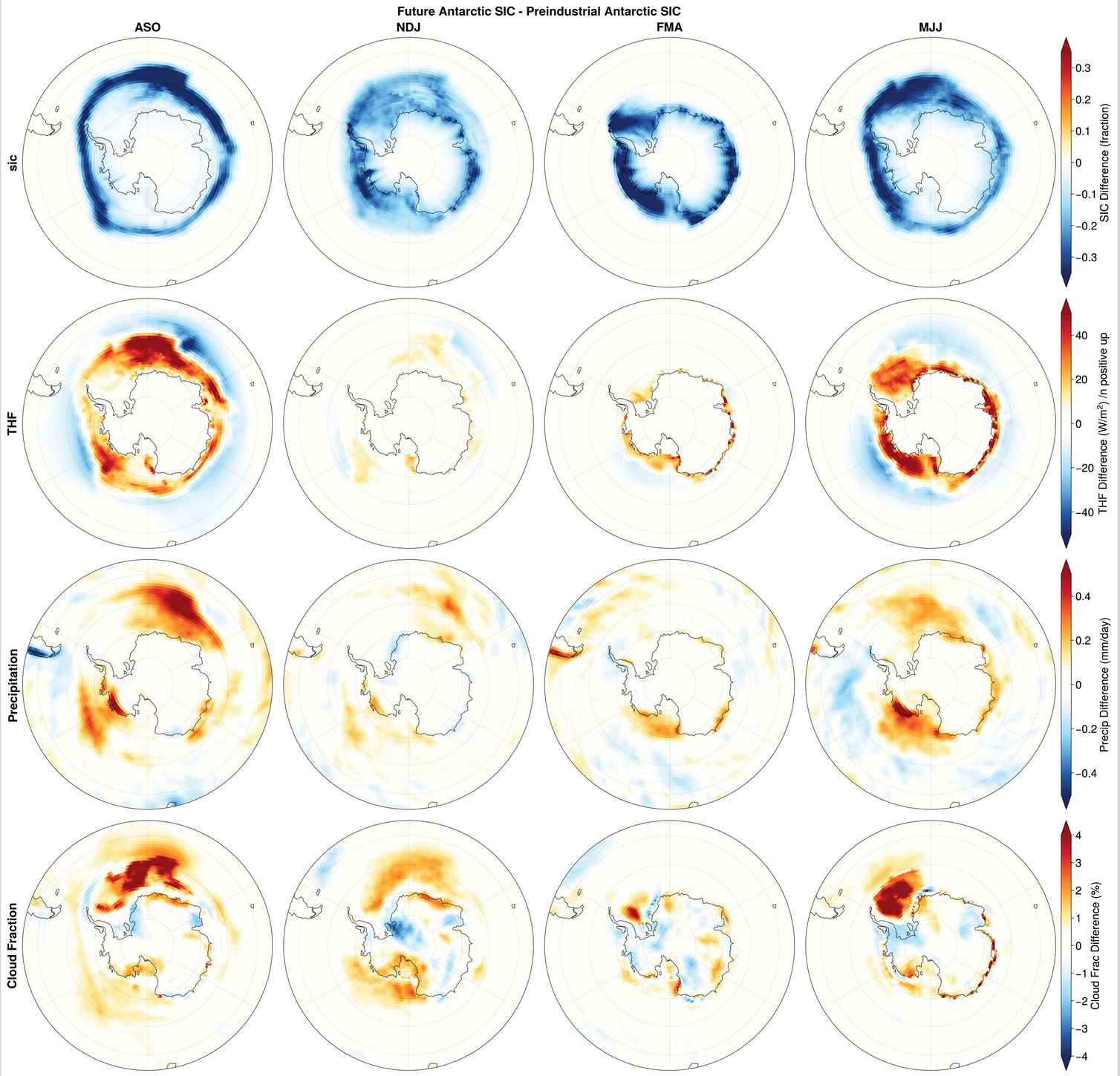

Seasonal regressions onto SIC$_x$ (inverted)
ASO
NDJ
FMA
MJJ
sic
THF
w850
Precipitation
Ceres Cloud Fraction
Regression of SIC onto SIC (%/σ)
Regression of THF onto SIC (W m^{-2}/σ) positive up
Regression of w850 onto SIC (Pa s^{-1}/σ) positive up
Regression of Precip Rate onto SIC (mm day^{-1}/σ)
Regression of Ceres Cloud Fraction onto SIC (%/σ)


Future Antarctic SIC - Preindustrial Antarctic SIC
ASO
NDJ
FMA
MJJ
sic
THF
Precipitation
Cloud Fraction
SIC Difference (fraction)
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
THF Difference (W/m2) /n positive up
40
20
0
−20
−40
Precip Difference (mm/day)
0.4
0.2
0
−0.2
−0.4
Cloud Frac Difference (%)
4
3
2
1
0
−1
−2
−3
−4