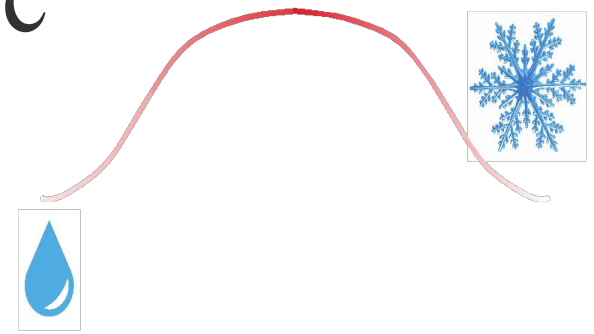
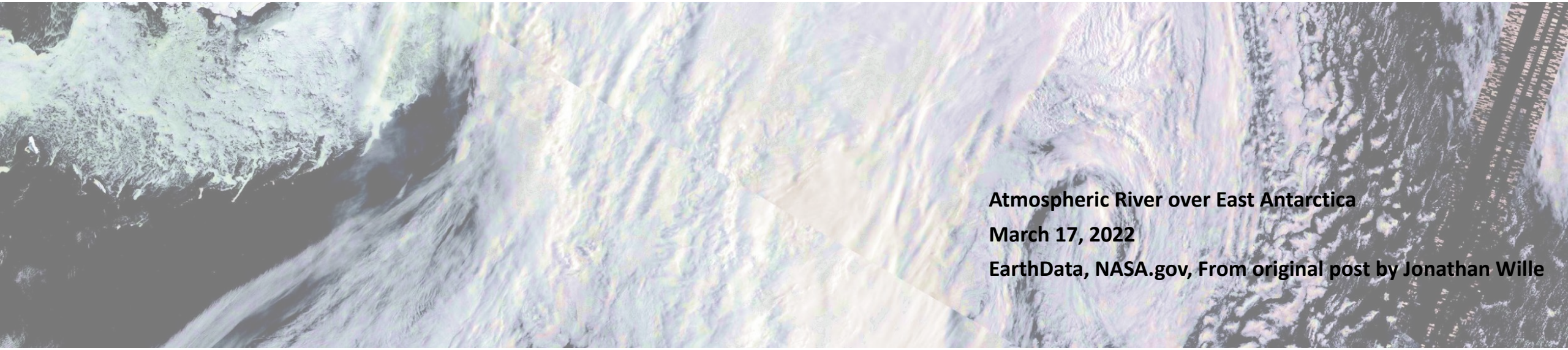
Global Sources of Moisture for Atmospheric Rivers over Antarctica



Using variable-resolution CESM2



Atmospheric River over East Antarctica
March 17, 2022
EarthData, NASA.gov, From original post by Jonathan Wille

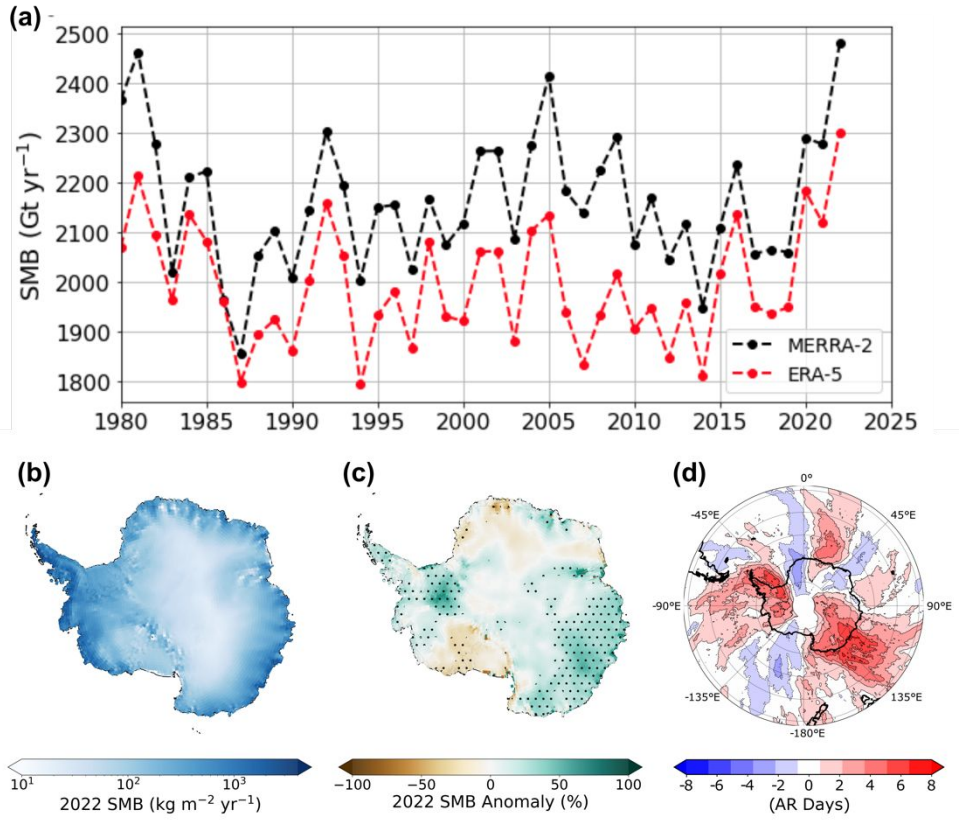
Rajashree (Tri) Datta

Adam Herrington, Luke Trusel, David Schneider, David Bonan, Jesse Nussbaumer, Ziqi Yin

Benjamin Pohl, Vincent Favier, Alice DuVivier, Cecile Agosta, David Bailey

ATOC, U. Colorado, Boulder

Record Surface Mass Balance this year

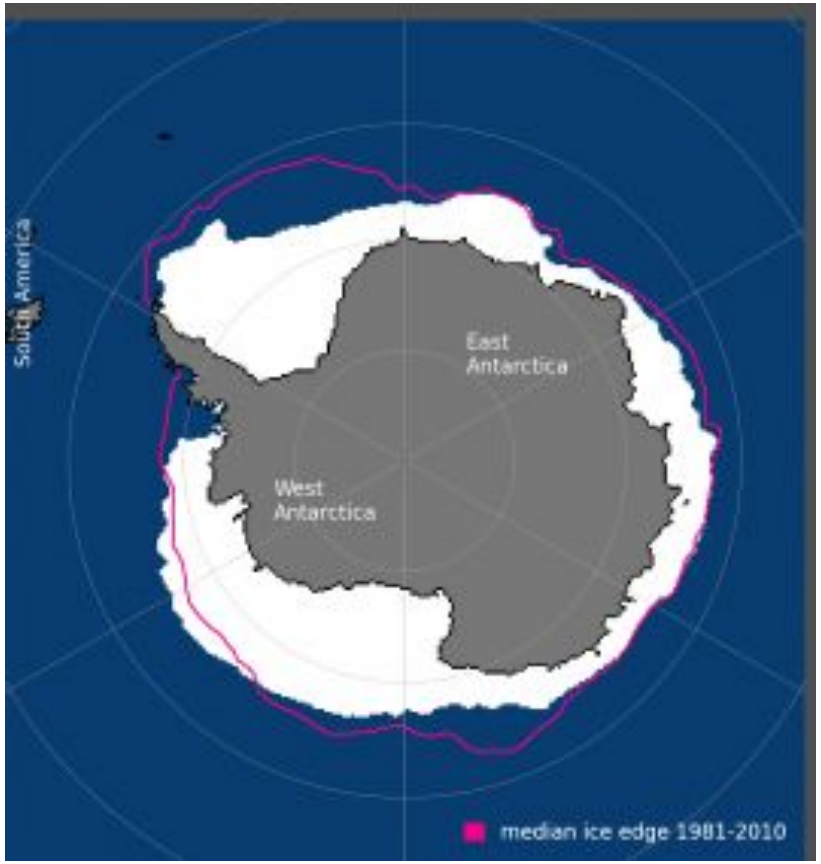


BAMS State of the Climate
Antarctica and the Southern Ocean
(in review). …Datta, R.T. …

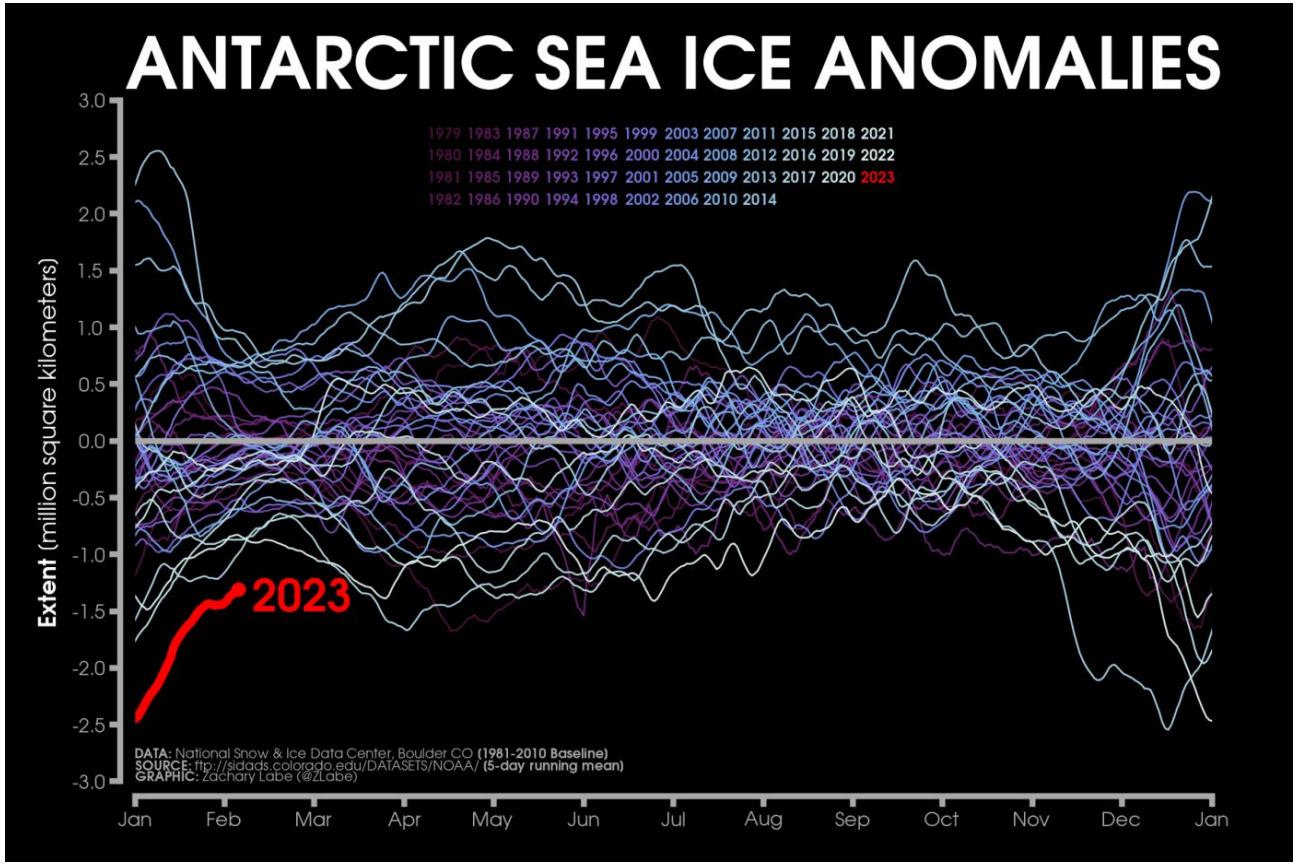
Record Surface Mass Balance
In 40 years

Driven primarily by two major atmospheric river events

Recent History

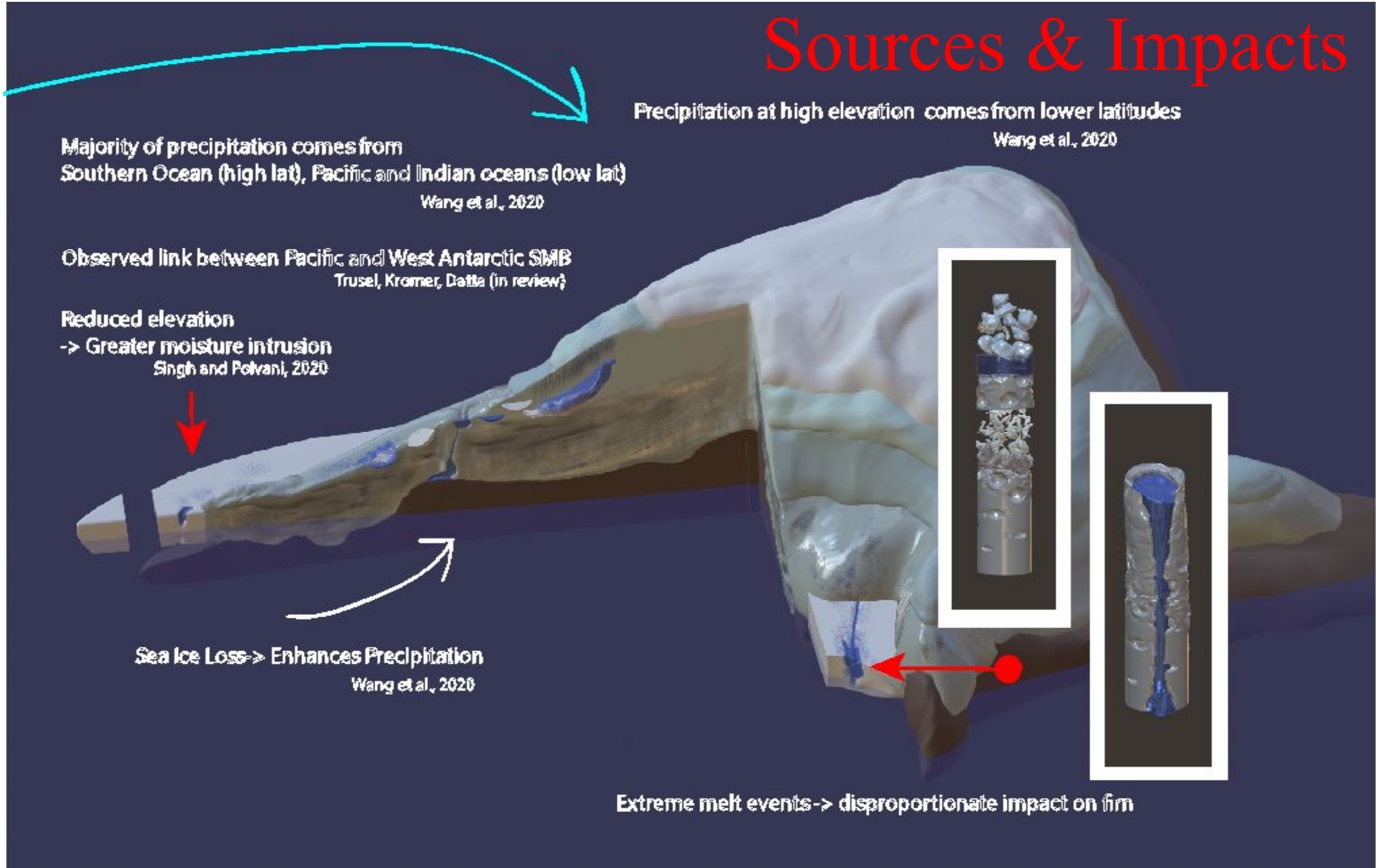


Courtesy NSIDC



Courtesy of Zack Labe @ZLabe

Sources & Impacts



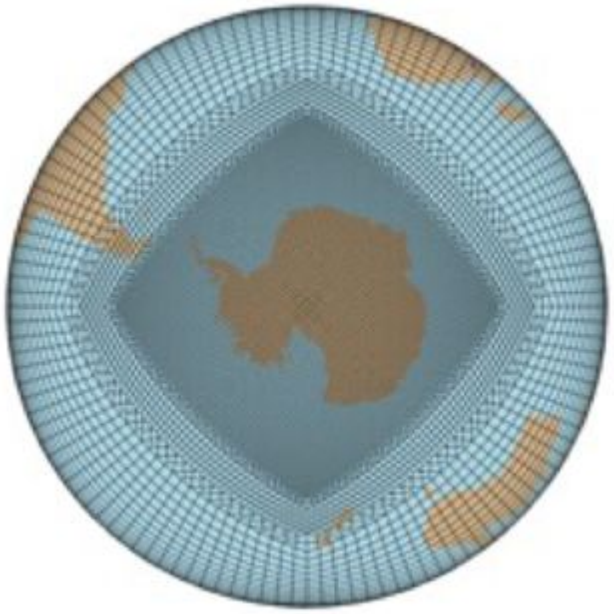
Main Questions

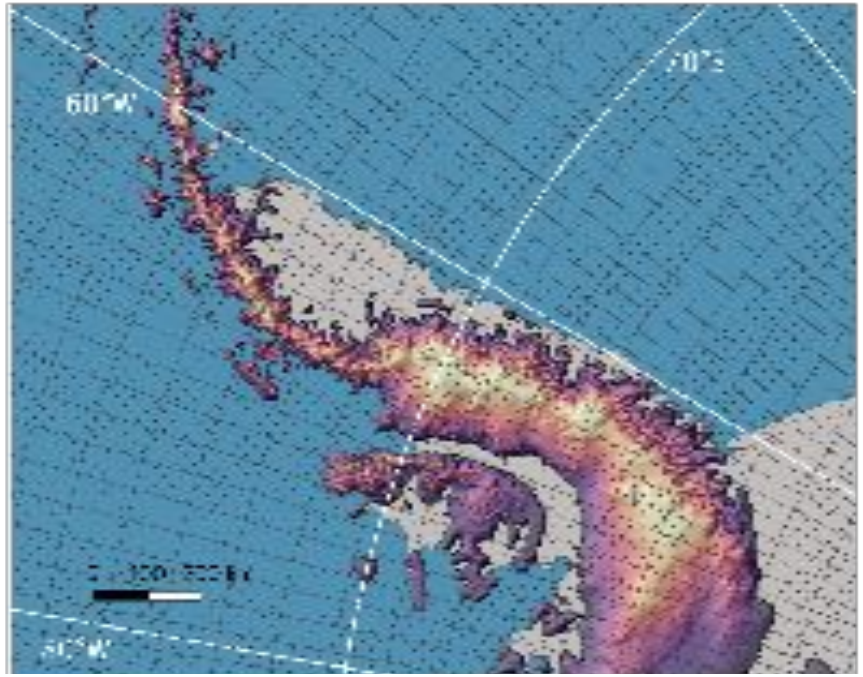
Differentiate ocean sources of **large-scale** precipitation from **extremes (e.g. atmospheric rivers)**

How do we attribute impacts (differences in extremes, moisture sources) to drivers (patterns of Sea Ice Concentration / Sea Surface Temperature)

Major Tool: Variable-Resolution CESM2

The refined mesh: 0.25° interior, 1° outside





Forced sea ice concentration and sea surface temperatures

1979-2020 for historical run
2000-2010 Moisture-tagging

3-hourly outputs
Atmosphere & ice sheet surface

Calculated ARs using algorithm by J. Wille
(adapted here for unstructured grid)

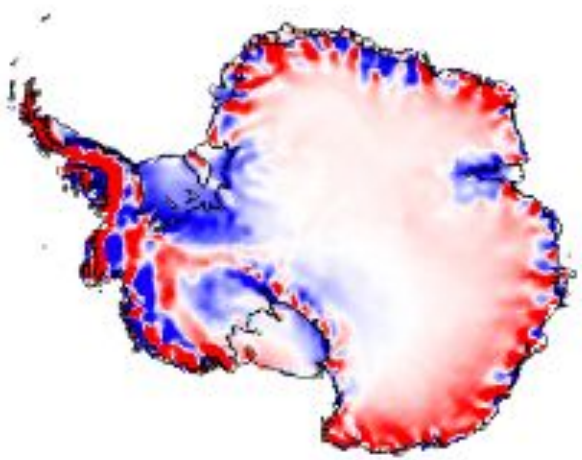
Datta, R. T., Herrington, A., Lenaerts, J. T. M., Schneider, D., Yin, Z., and Dunmire, D.: Evaluating the Impact of Enhanced Horizontal Resolution over the Antarctic Domain Using a Variable-Resolution Earth Systems Model, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2022-1311, 2022.

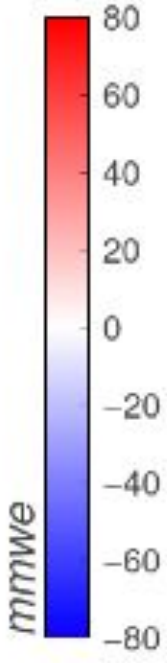
The Impacts of Enhanced Resolution:

Moisture Transport → Winter Precipitation → Increased SMB

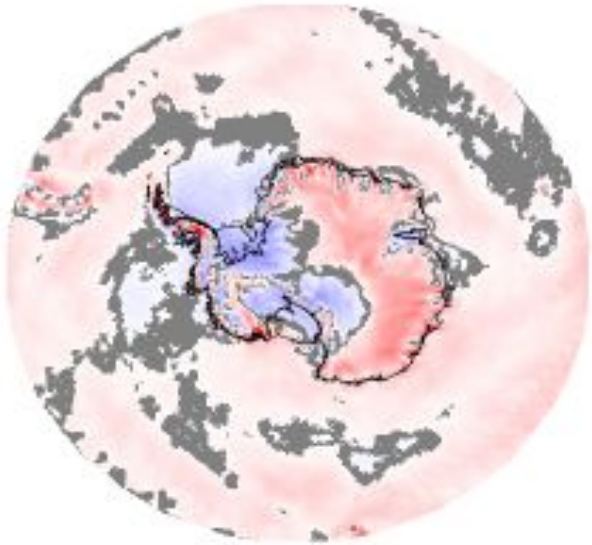
Winter

SMB

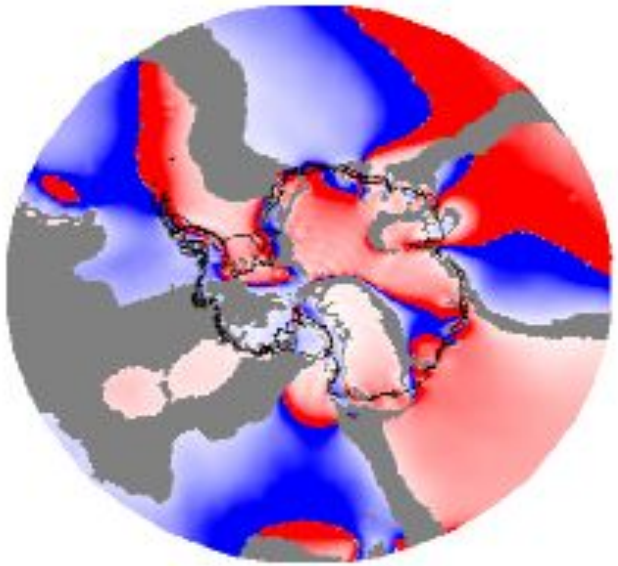


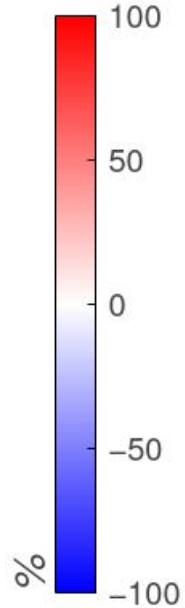


Large-scale precipitation



Integrated meridional vapor transport





*All showing ANTSI – AMIP, grey indicates where the 1std deviation in ANTSI (temporal) within 1std deviation of AMIP (ensemble)

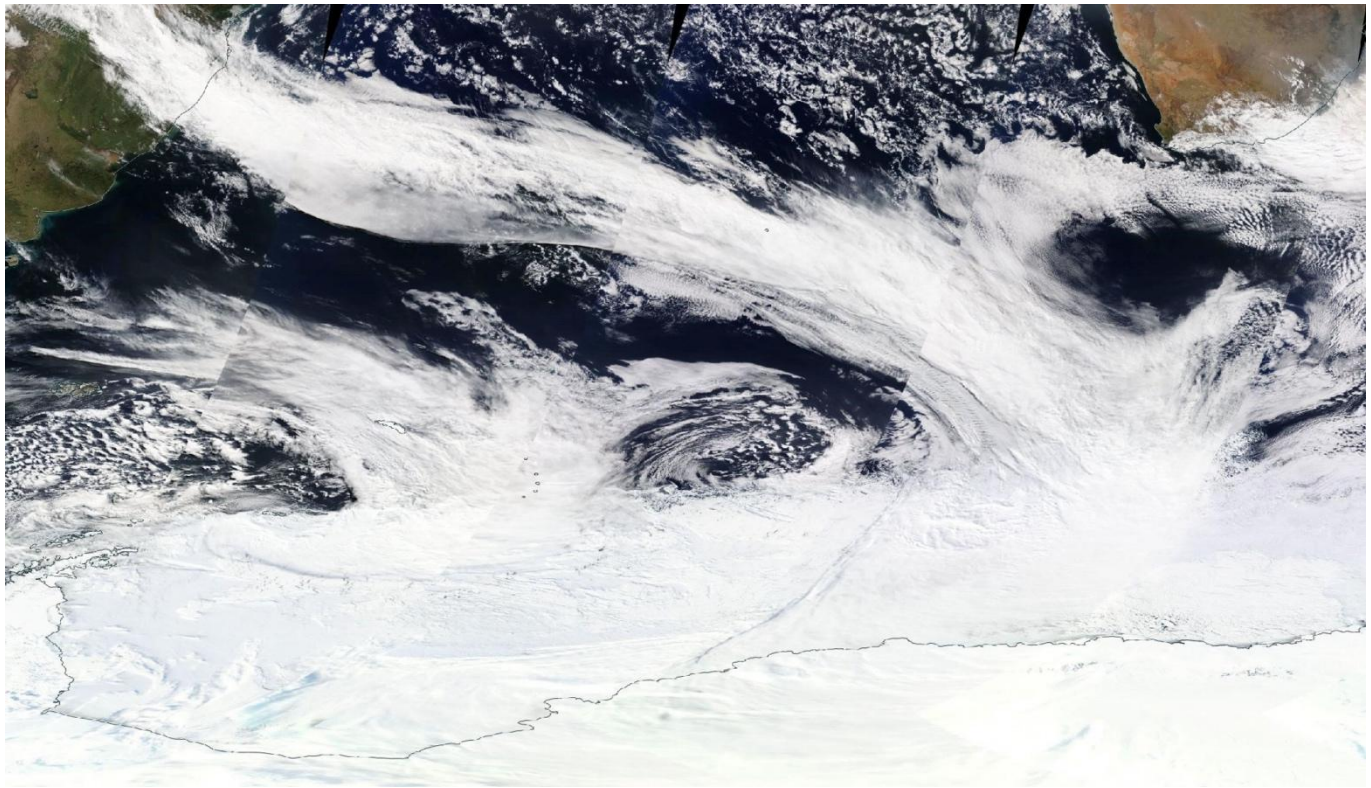
Atmospheric Rivers
How we measure them

$$\mathrm{vIVT} = -\frac{1}{g}\int_{\text{surface}}^{\text{top}} qv\,dp,$$

vIVT in kg m^{-1} s^{-1}

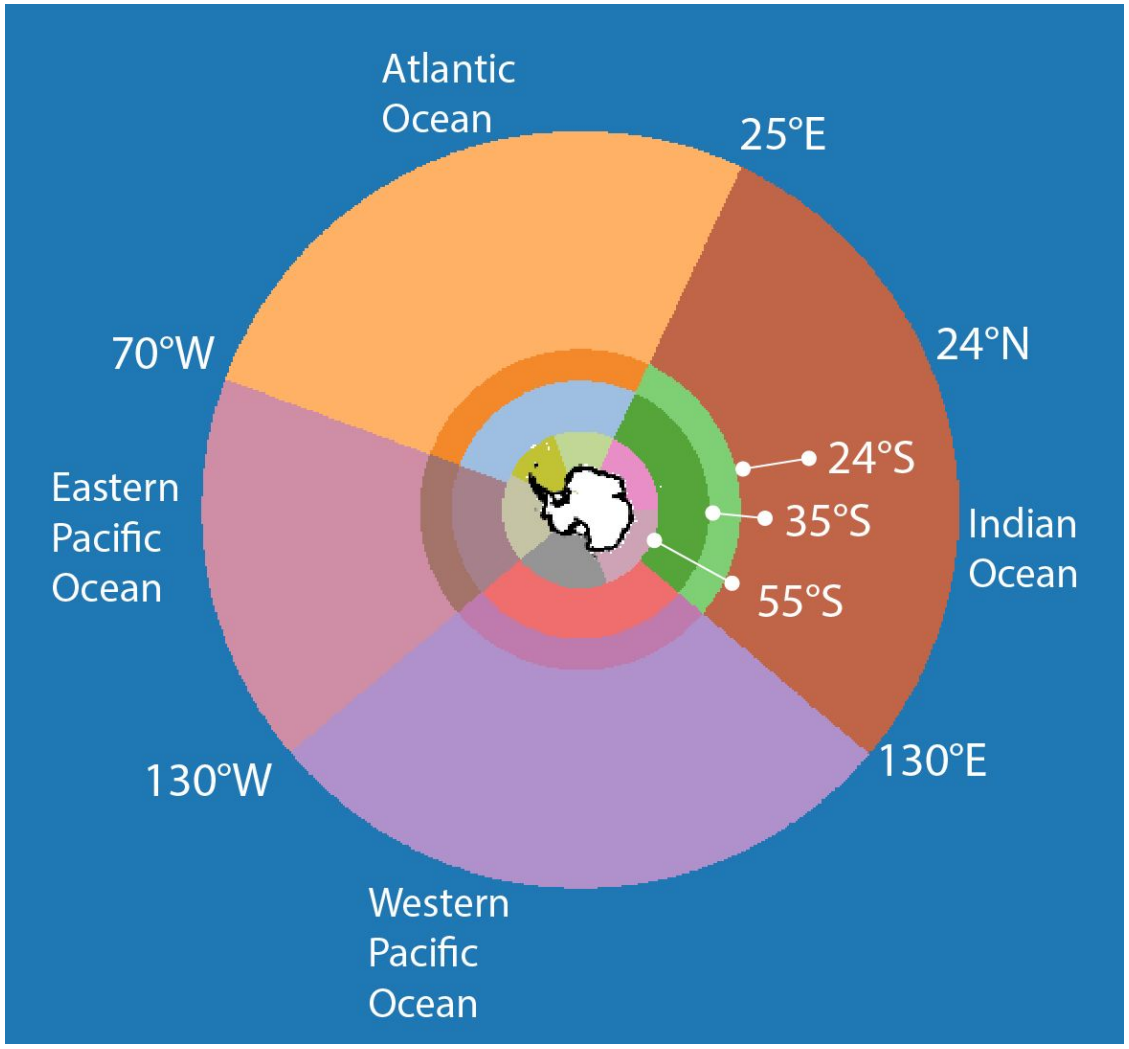
q (kg kg−1) is the specific humidity
v is the meridional wind velocity (m s−1),
g (m s−2) is the gravitational acceleration
p is the atmospheric pressure (hPa).

Wille et al., 2021

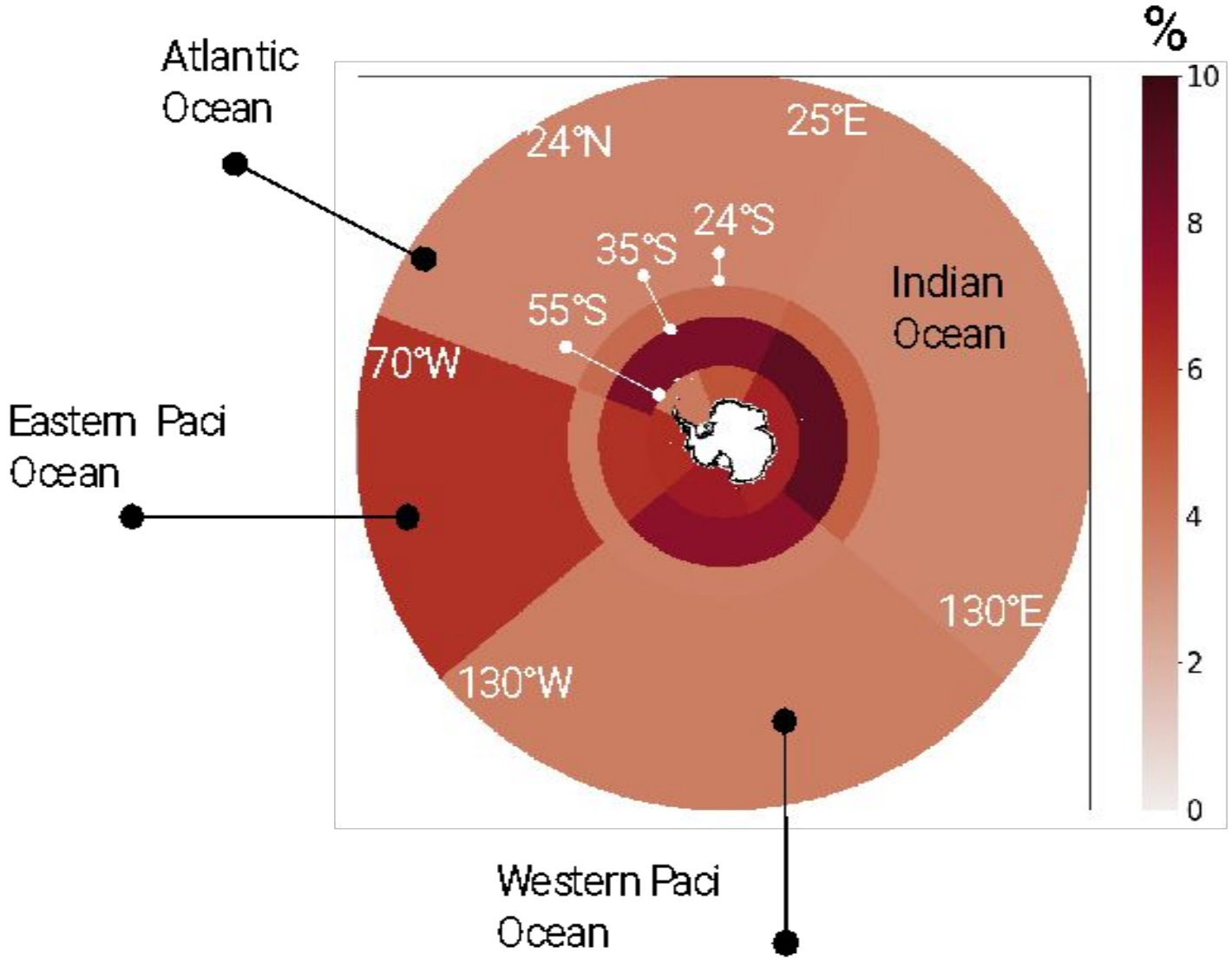


A band of clouds in an atmospheric river extending from South America to the Antarctic sea ice zone on Sept. 16, 2017. Image: NASA

Moisture Tagging Map

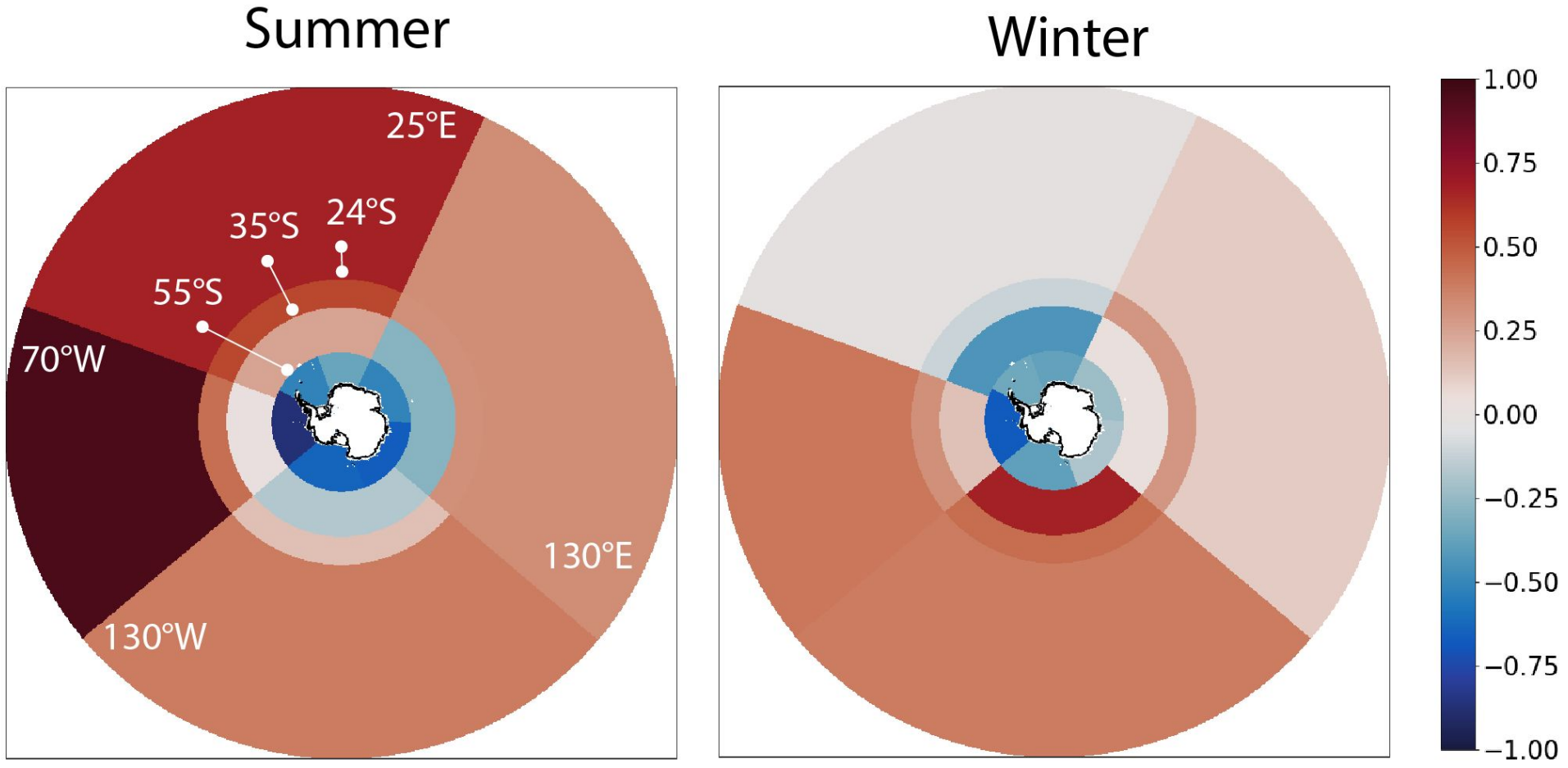


Sources for Precip over Antarctica 2000-2010
(Fall Season Shown)



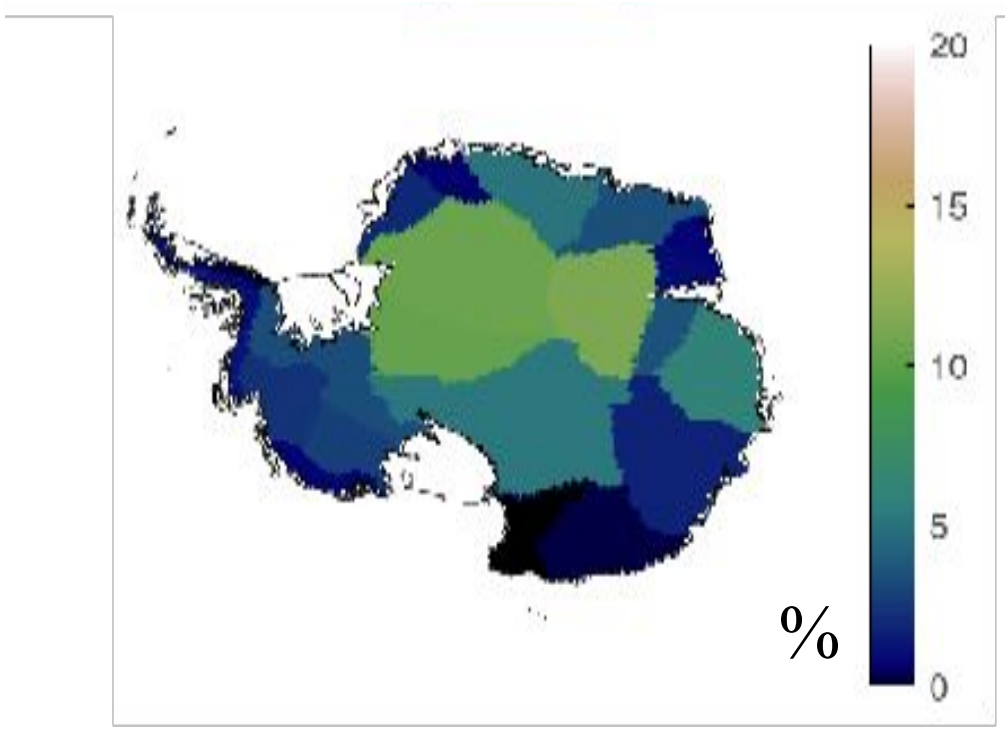
Moisture Sources of ARs (2000-2010)

Moisture Δ%

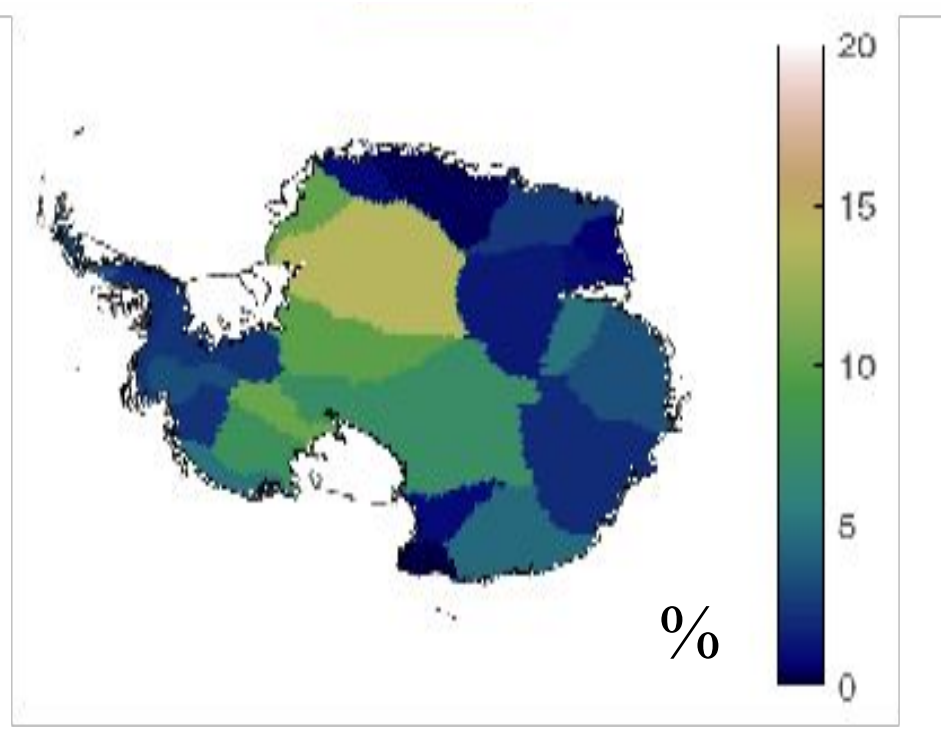


The Relative Importance of ARs (2000-2010)

Summer



Winter



Experiment:
Attributing Extremes to SIC/SST Patterns

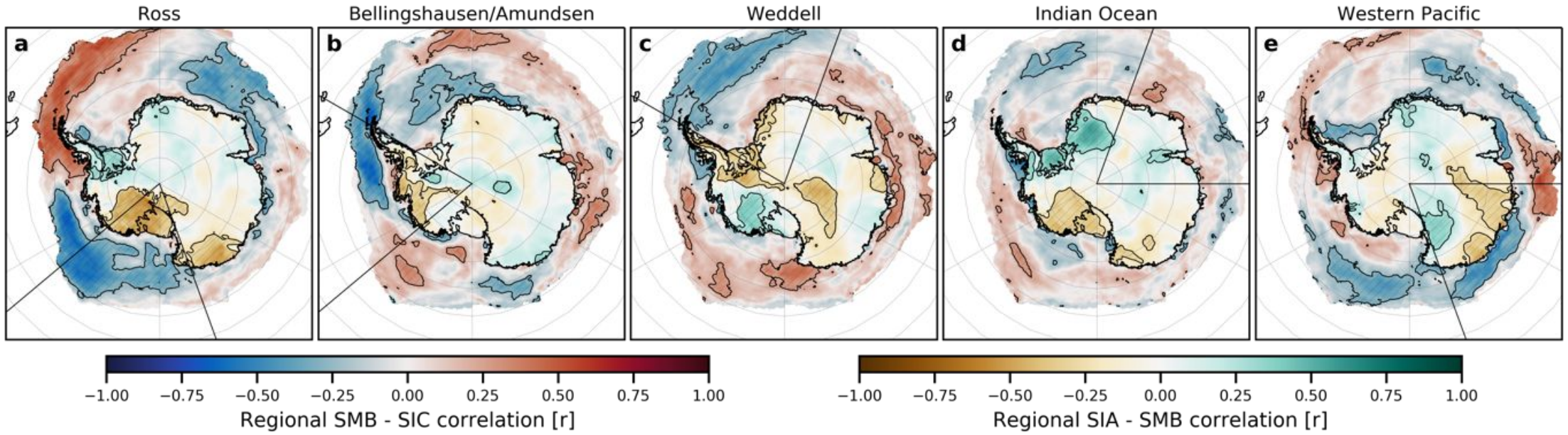
What is the impact of a recurrent anomaly pattern of reduced sea ice?

*enhanced sea ice loss since 2016

Observed Relationship between Sea Ice Concentration & Surface Mass Balance

Blue
SIC decrease
&
SMB increase

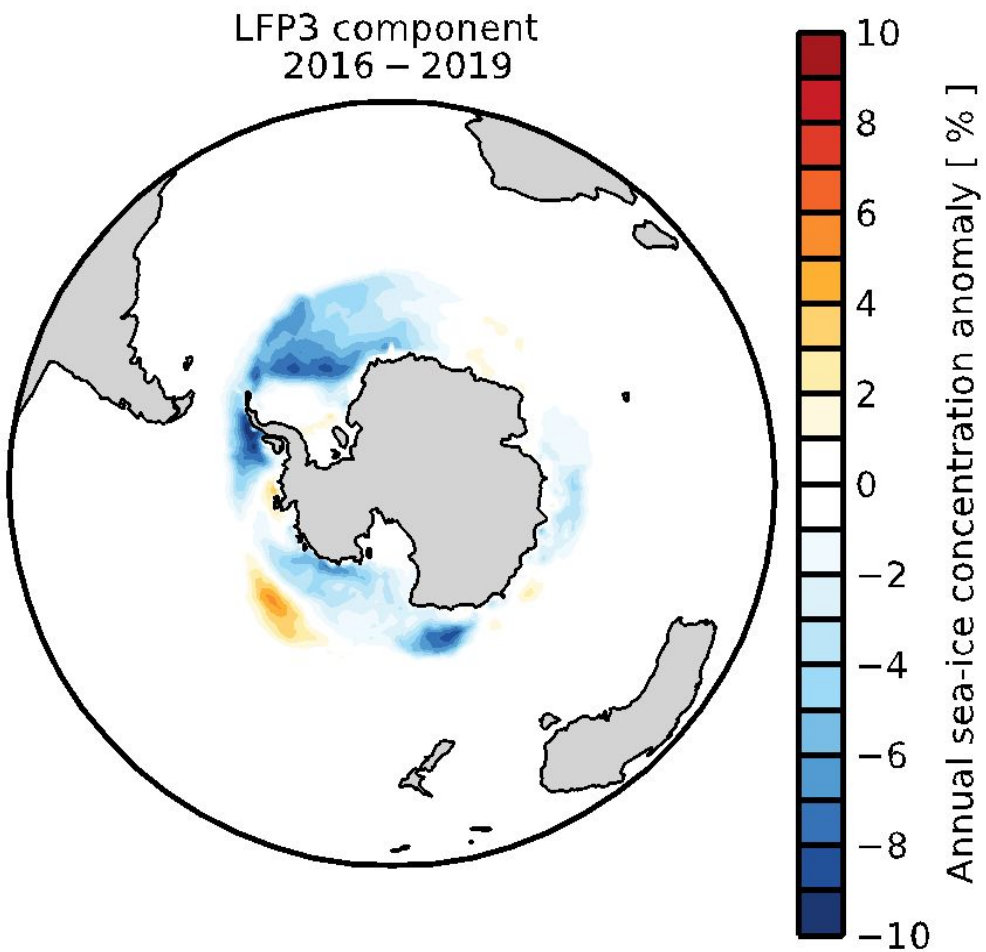
Brown
SMB decrease
&
SIC increase



Trusel, L., Kromer, J., **Datta, R**, *in review*

The Experiment: Pattern of Recent Sea Ice Decline

created a 5 year ensemble of a **synthetic** year from the **observed** pattern

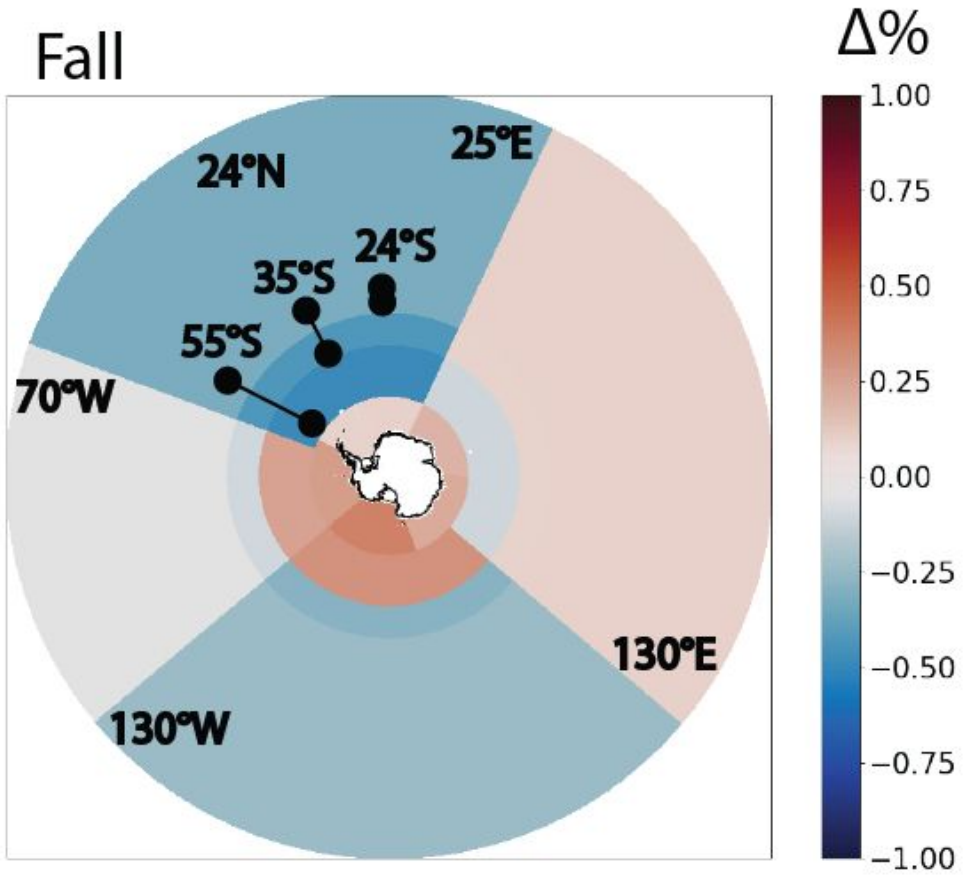


Sources of low-frequency variability in observed Antarctic sea ice

David Bonan et al. (submitted to TC)

The Impact of Sea Ice Decline in Fall (MAM)

Moisture Sources for ARs



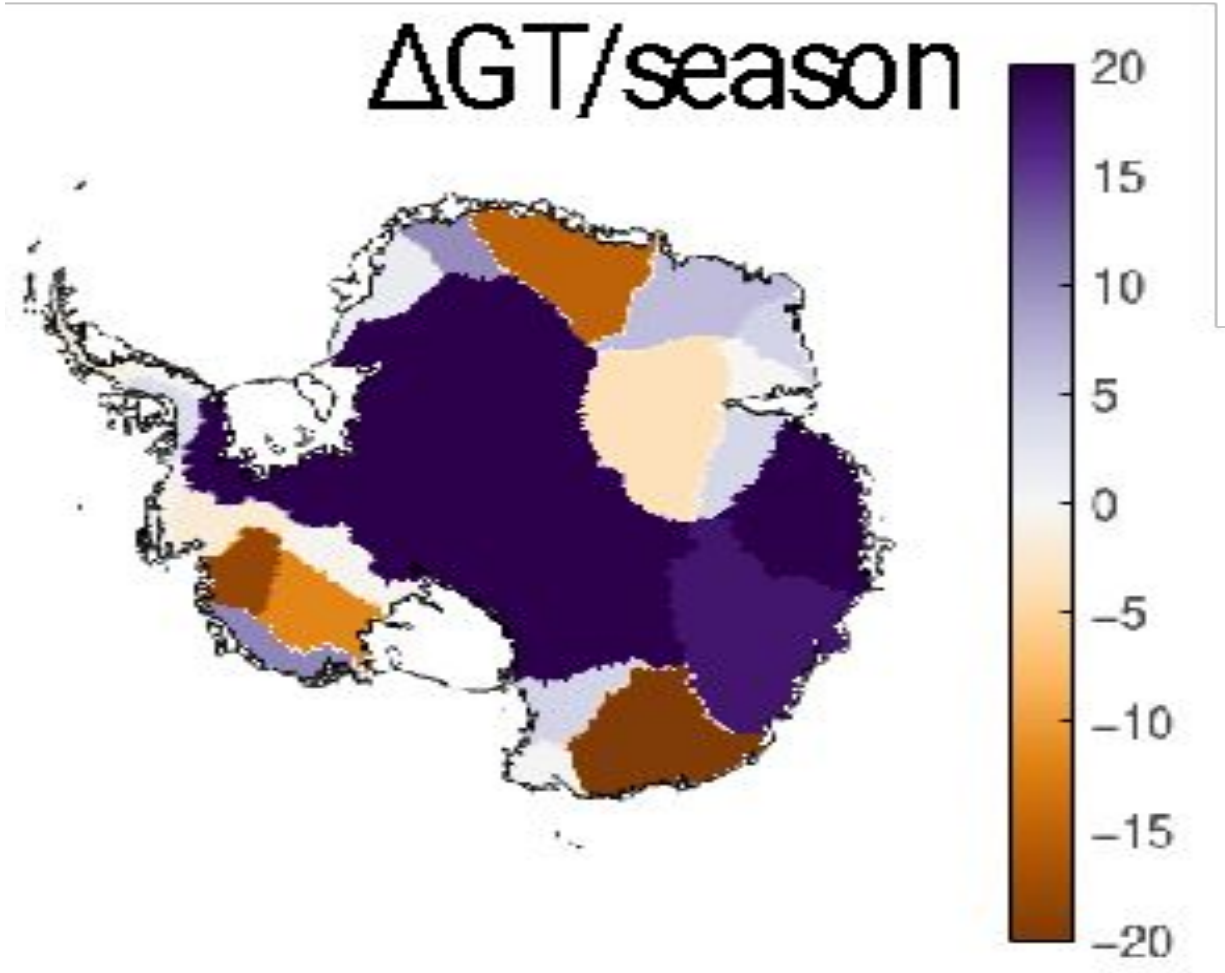
ARs occurring with reduced sea ice

- Retrieve more relative moisture below 55°S
- Retrieve more relative moisture between -35°S and 55°S in the Pacific (beyond the margin of sea ice
- Retrieve more relative moisture from the Indian Ocean

*Caveat : no ensemble variability

The Impact of Sea Ice Decline in Fall

Impact on total precipitation



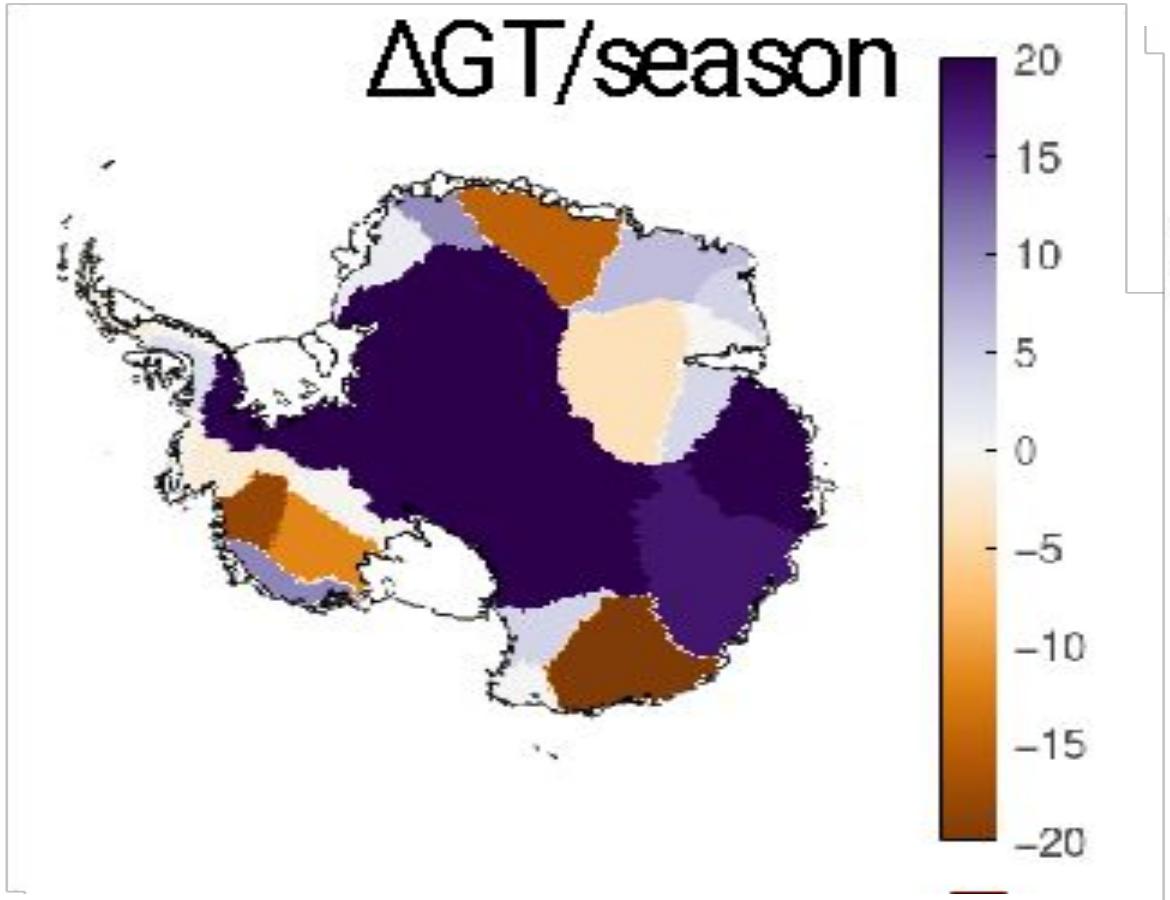
When sea ice is reduced

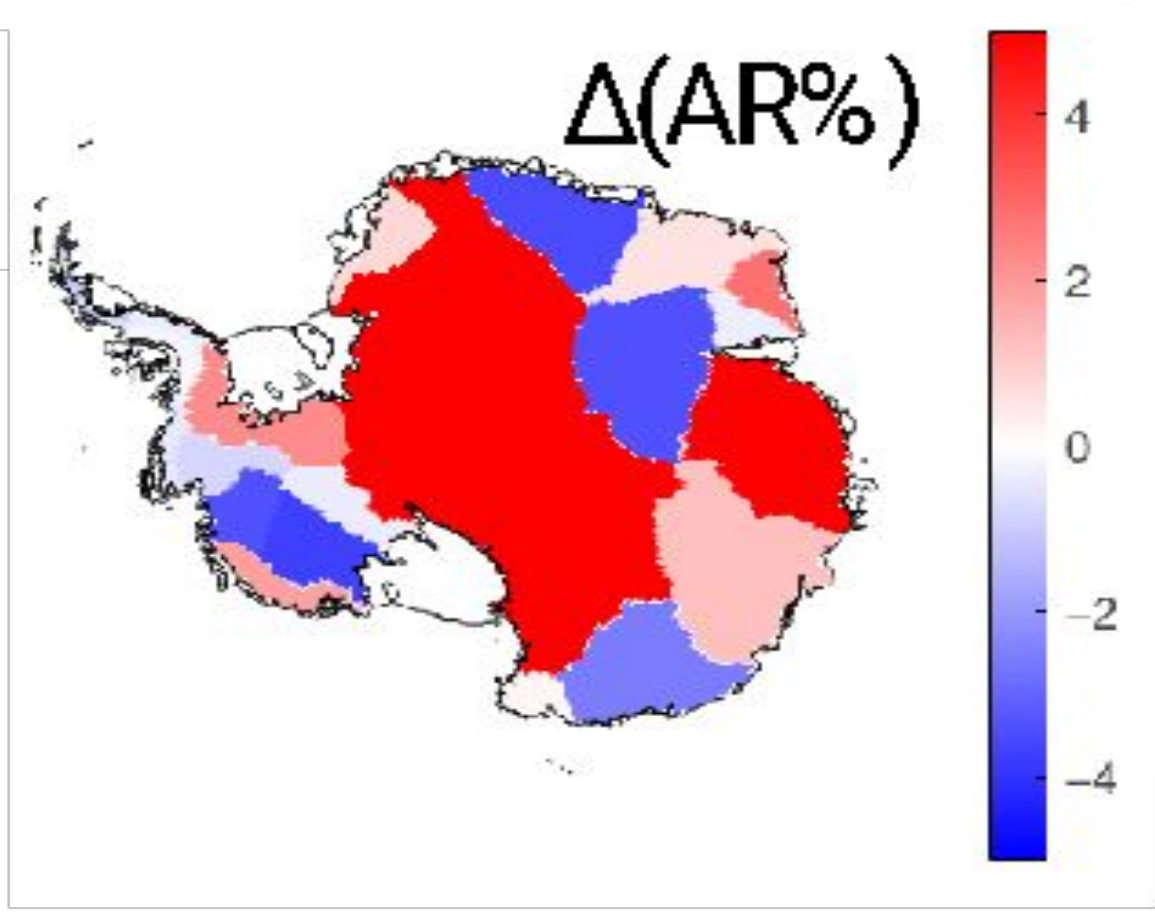
- Substantially higher precipitation in the center of the continent and portions of East Antarctica

*Caveat : no ensemble variability

The Impact of Sea Ice Decline in Fall

The relative importance of ARs driving total precipitation





Source

Ocean regions impacted by El Niño / La Niña

High-Latitude regions impacted by sea ice decline

Biases
Ensemble size?
Reference period?

Sink

LS Precipitation over the ocean

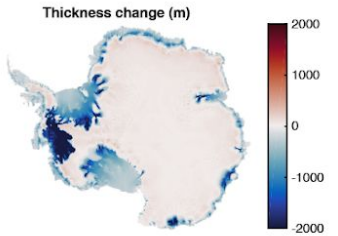
LS Precipitation over Antarctica

Atmospheric Rivers

Extremes at the surface

Shift in precipitation phase

Vulnerable Regions



ISSM at 2300 - courtesy Nicole Schlegel