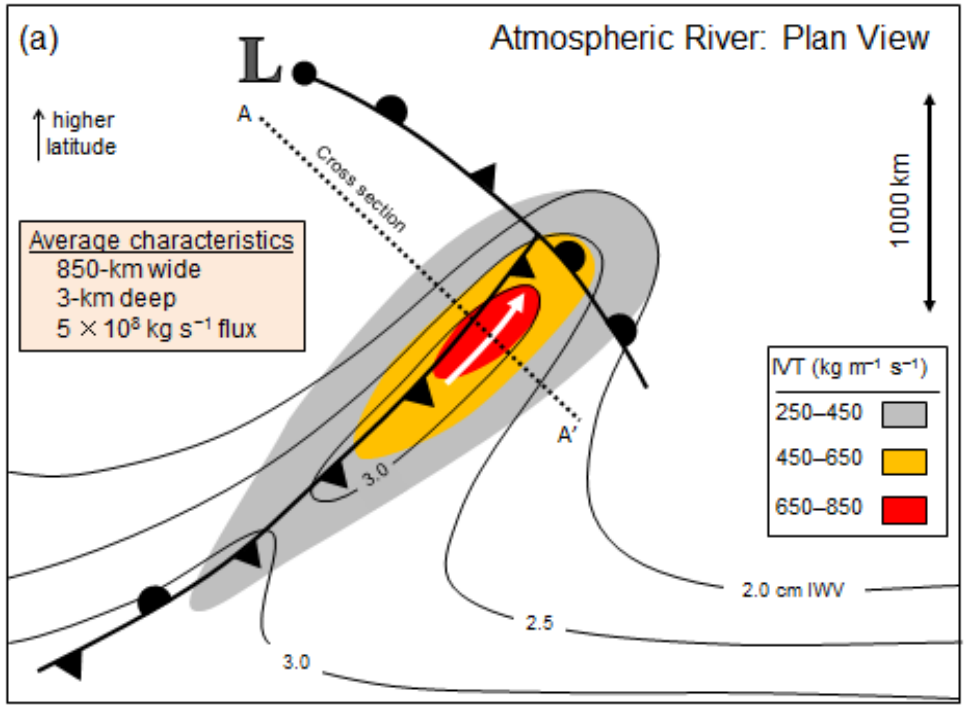
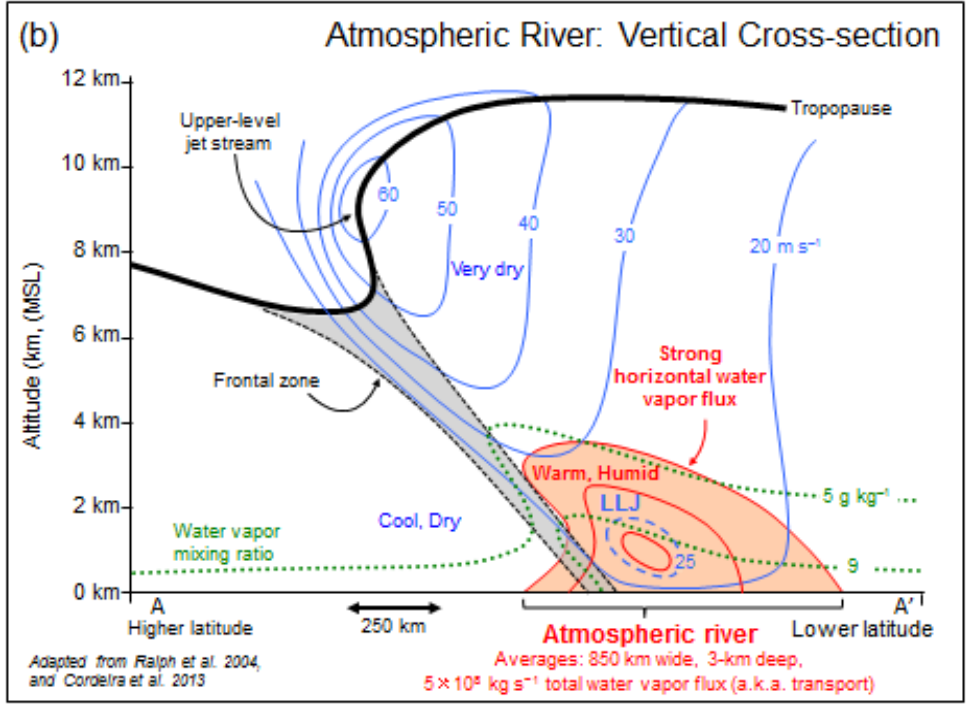
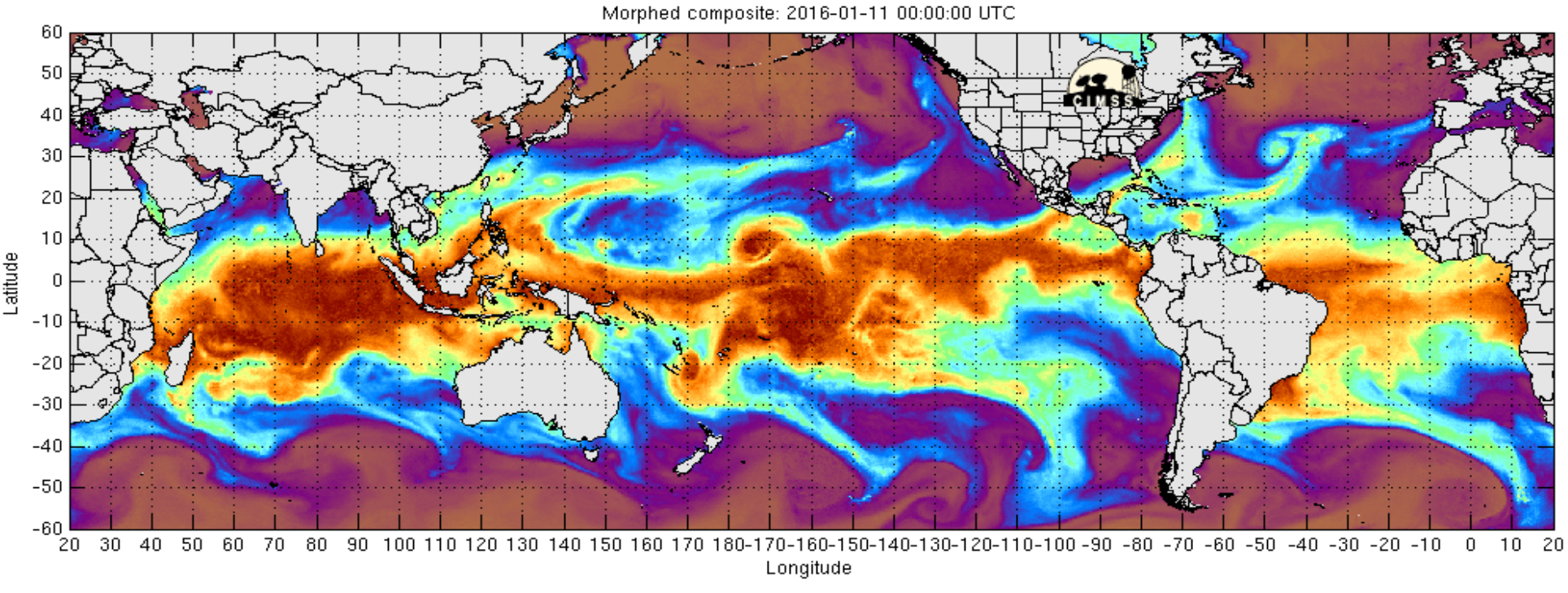
Antarctic Atmospheric River Climatology and Impacts

Jonathan D. Wille, Vincent Favier, Irina V. Gorodetskaya, Cécile Agosta, Jai Chowdhry Beeman, Ambroise Dufour, Nicolas Jourdain, Tessa Vance, Francis Codron, John Turner

Photo: WAIS Divide, January 10th, 2016


(a)
Atmospheric River: Plan View
L
A
A′
Cross section
↑ higher latitude
1000 km
Average characteristics
850-km wide
3-km deep
5 × 10⁸ kg s⁻¹ flux
IVT (kg m⁻¹ s⁻¹)
250–450
450–650
650–850
3.0
2.0 cm IWV
2.5
3.0


(b)
Atmospheric River: Vertical Cross-section
12 km
10 km
8 km
6 km
4 km
2 km
0 km
Altitude (km, (MSL)
Upper-level jet stream
Tropopause
60
50
40
30
20 m s⁻¹
Very dry
Frontal zone
Strong horizontal water vapor flux
Warm, Humid
LLJ
25
5 g kg⁻¹
9
Water vapor mixing ratio
Cool, Dry
A
Higher latitude
250 km
A′
Lower latitude
Atmospheric river
Averages: 850 km wide, 3-km deep,
5 × 10⁸ kg s⁻¹ total water vapor flux (a.k.a. transport)
Adapted from Ralph et al. 2004, and Cordeira et al. 2013


Morphed composite: 2016-01-11 00:00:00 UTC
CIMSS
Latitude
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
Longitude
20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 -170 -160 -150 -140 -130 -120 -110 -100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20

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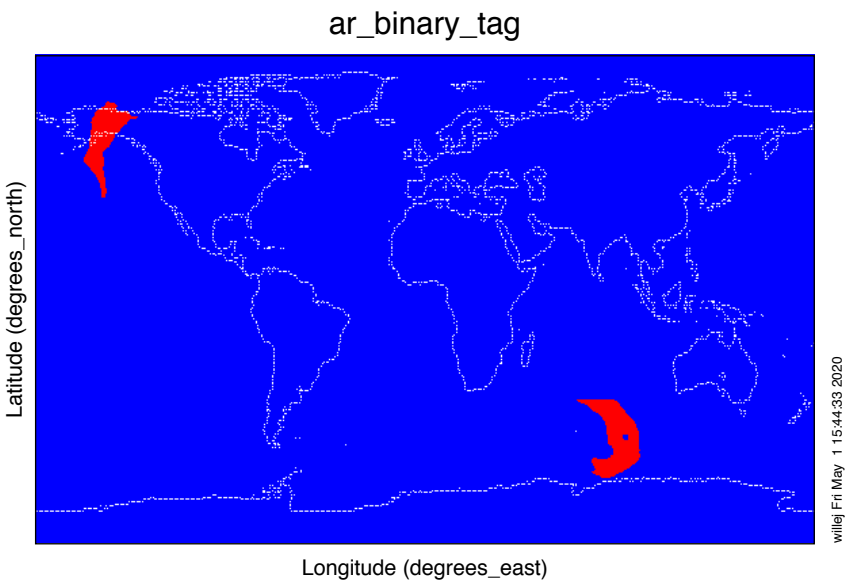
Atmospheric river detection algorithm

28-Nov-2019 09UTC



Range of ar_binary_tag: 0 to 1 (null)
Range of Longitude: -180 to 179.375 degrees_east
Range of Latitude: -90 to 90 degrees_north
Current time: 1.05109e+06 hours since 1900-01-01 00:00:00.0
Frame 2652 in File MERRA2.ar_tag.Wille_v2.3_vIVT.3hourly.20190101-20191231.nc4

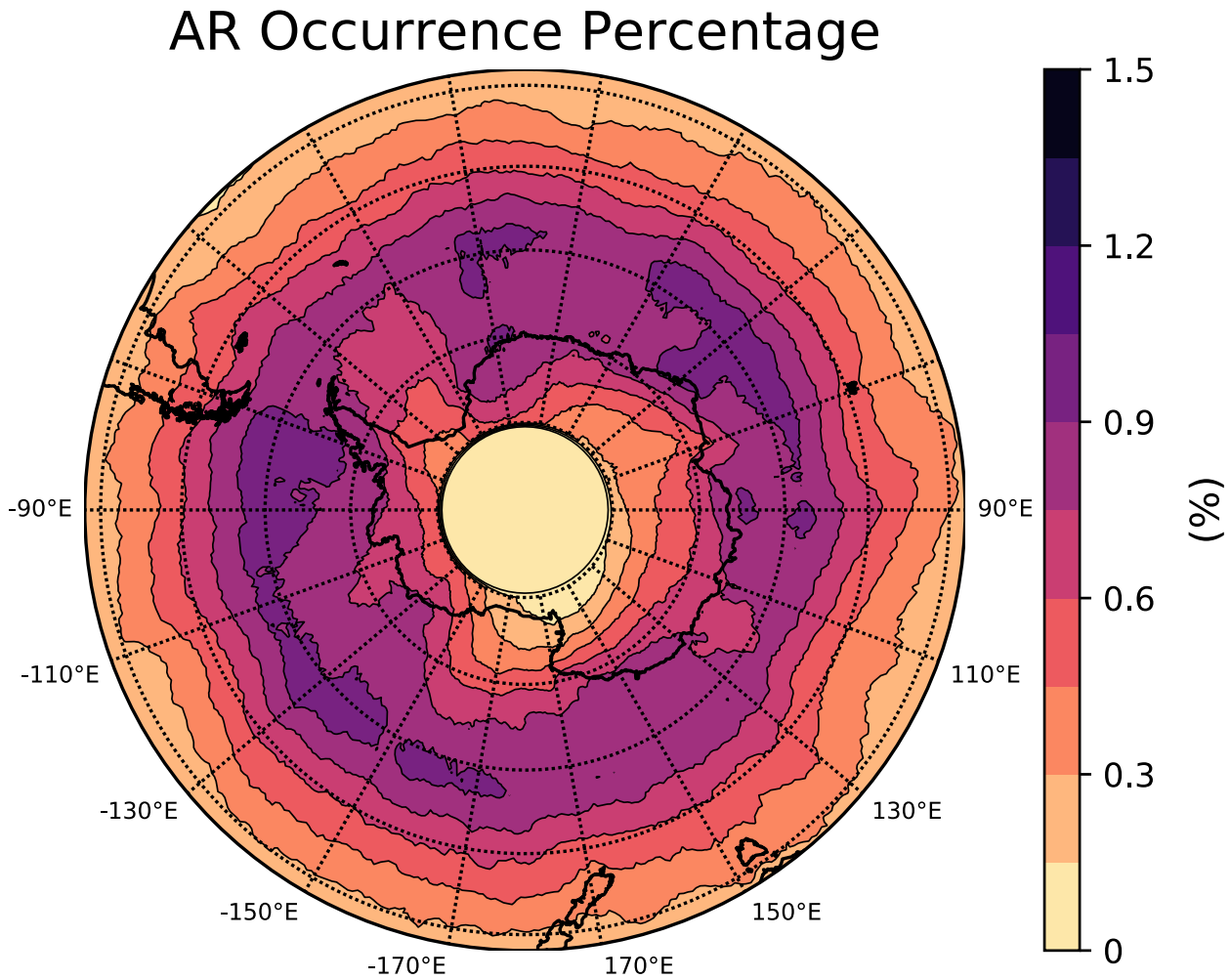
Detection criteria

- 98th percentile of vIVT
- Continuous in the meridional direction
- Extends for at least 20° latitude
- Use MERRA2 reanalysis data

Other details

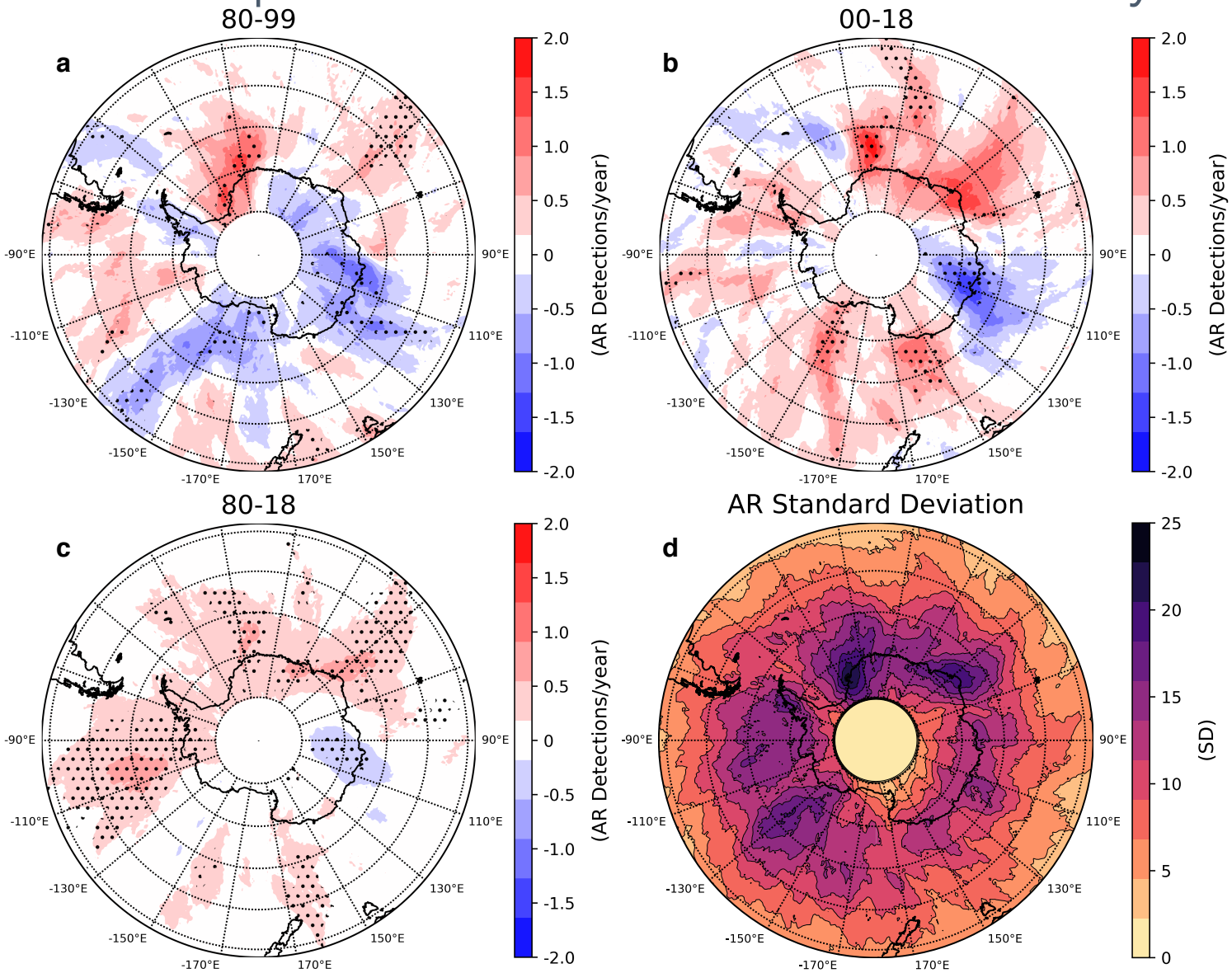
- Outputs the AR shapes using a binary index
- Scans the Arctic and Antarctic regions
- Member of the ARTMIP project and available upon request

Atmospheric river climatology



AR frequency from the AR detection algorithm for 1980-2018

Atmospheric river trends and variability



The trends in annual AR frequency measured by detections per year for **a** 1980-1999, **b** 2000-2018, and **c** 1980-2018. Black circles represent areas of significant trends (p-value < 0.025). **d** is the standard deviation within the annual AR frequency

The melty bit

Photo credit: Bruno Jourdain

nature geoscience

ARTICLES

https://doi.org/10.1038/s41561-019-0460-1

West Antarctic surface melt triggered by atmospheric rivers

Jonathan D. Wille[1*], Vincent Favier[1], Ambroise Dufour[1], Irina V. Gorodetskaya[2], John Turner[3], Cécile Agosta[4] and Francis Codron[5]

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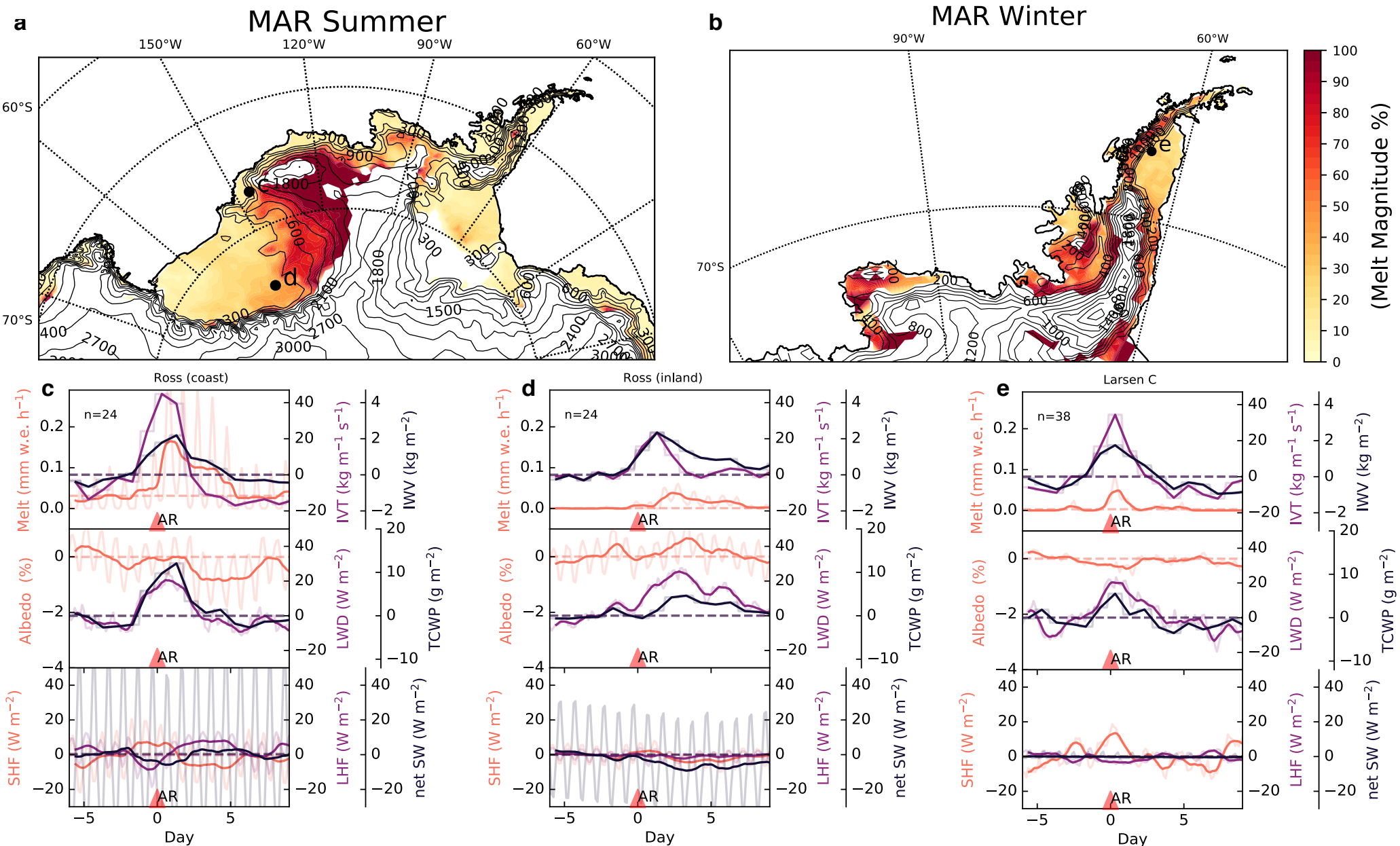
Percentage of surface melt attributed to atmospheric rivers and the life cycle of an average AR landfall



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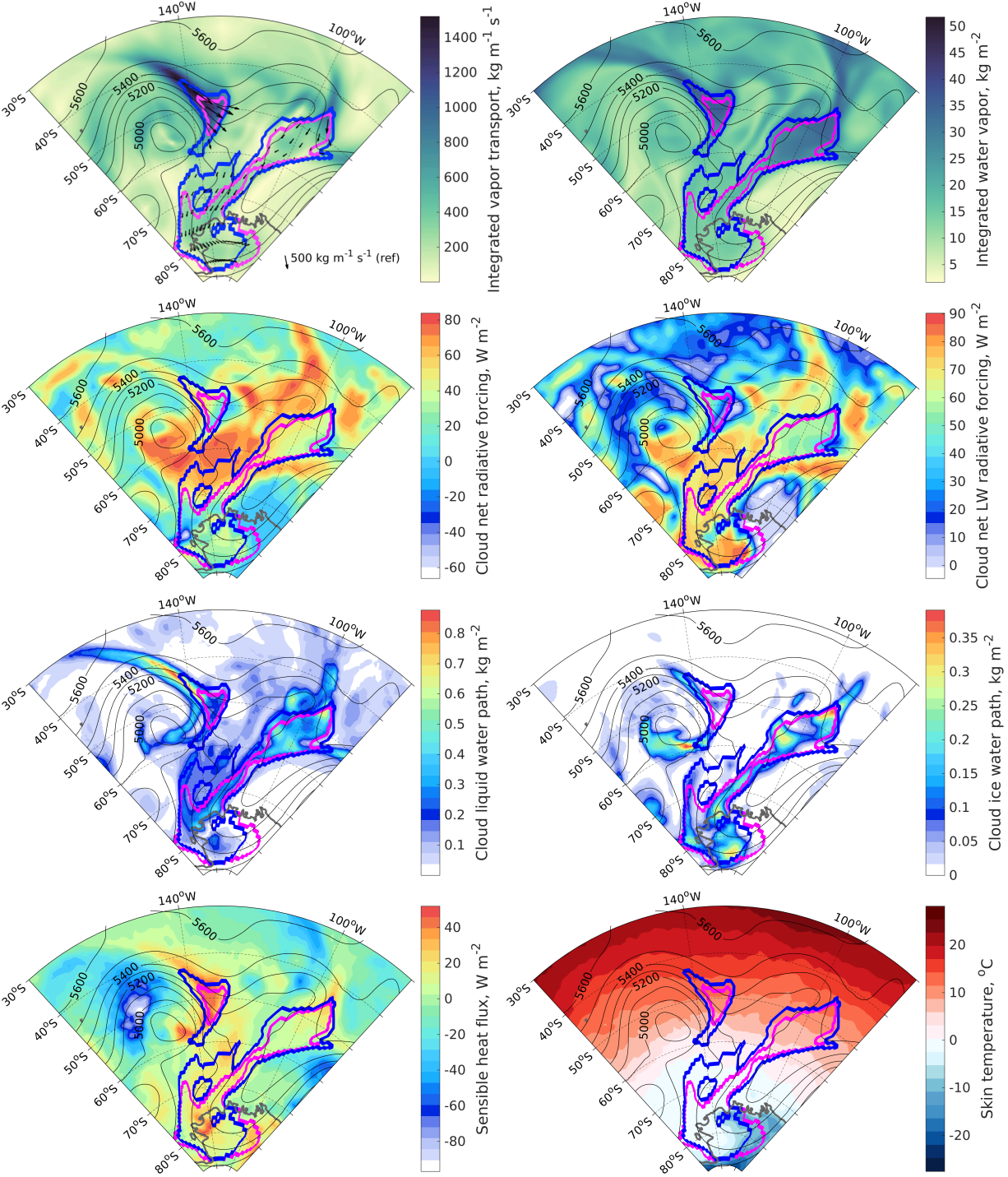
January 2016 Melt Event

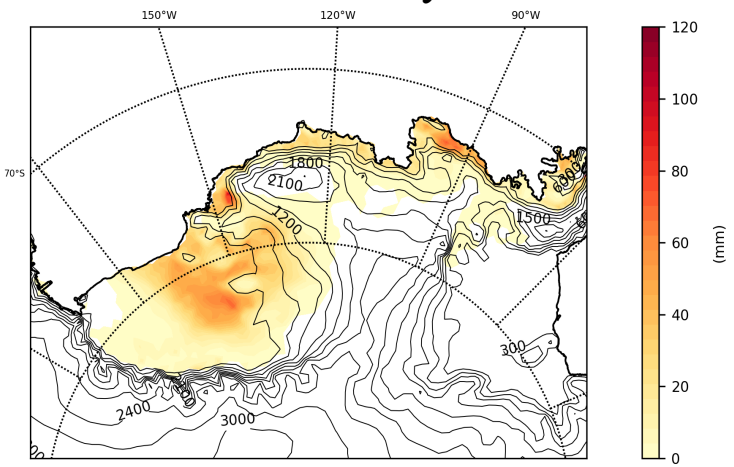


= Wille et al. 2019

= Gorodetskaya et al. 2014

- High cloud liquid and ice water dominates
- Lower sensible heat flux
- Downward longwave partially compensated by a negative shortwave radiation flux

Melt from 10/01/16 - 22/01/16 simulated by MAR



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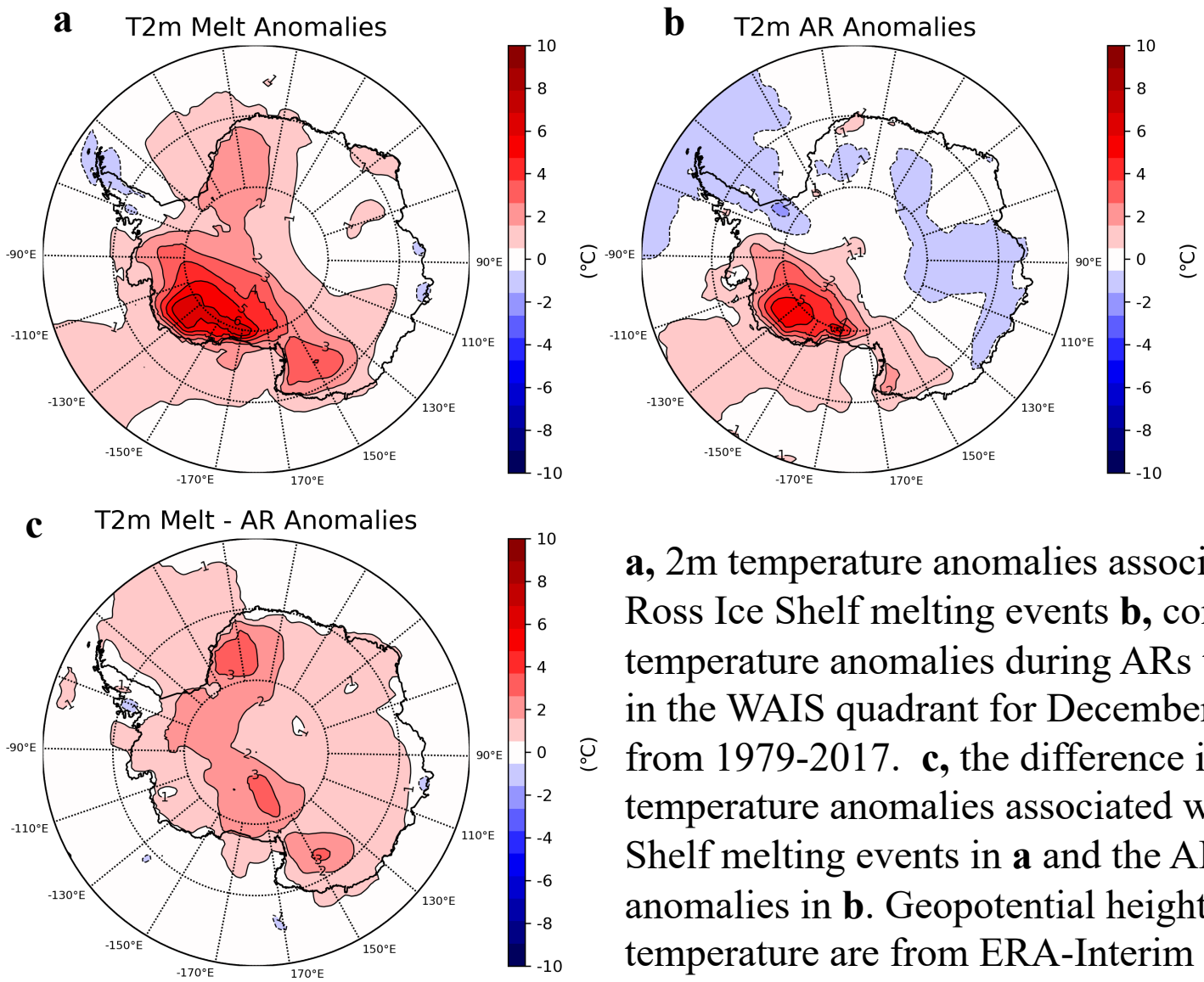
AR related melt is rare on the Ross Ice Shelf, but that might change



a, 2m temperature anomalies associated with five Ross Ice Shelf melting events **b,** composite 2 m temperature anomalies during ARs to make landfall in the WAIS quadrant for December and January from 1979-2017. **c,** the difference in 2 m temperature anomalies associated with the Ross Ice Shelf melting events in **a** and the AR temperature anomalies in **b**. Geopotential height and 2 m temperature are from ERA-Interim

The snowy bit

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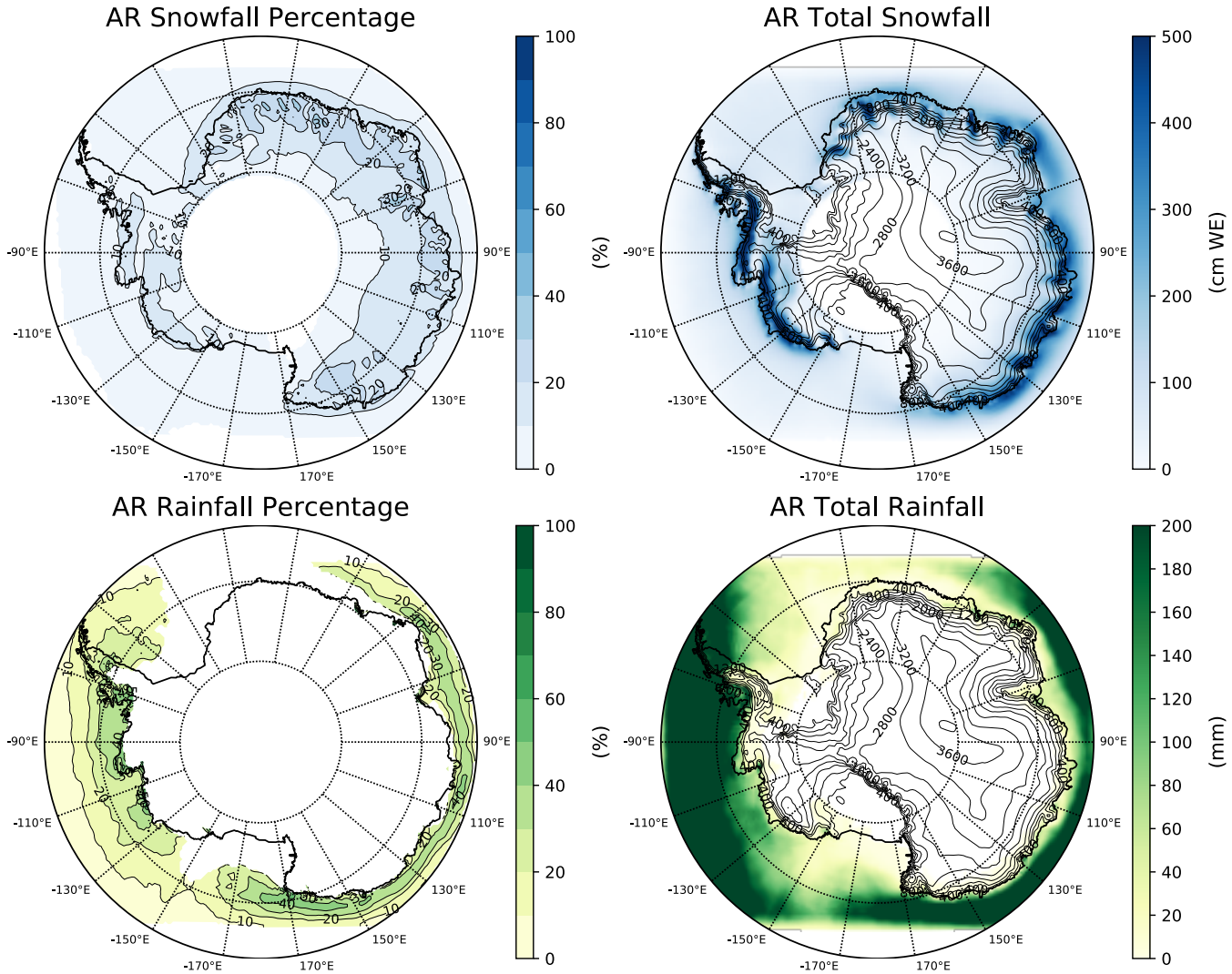
Photo credit: Mark Curran

Precipitation attributed to atmospheric river landfalls



- Precipitation data is from MARv3.11 @ 35 x 35 km^2 with ERA5 boundary conditions from 1980-2018
  - Results are verified against an AR detection algorithm run on ERA5 data

Certain areas of Antarctica receive a large percentage of their annual precipitation from a few high precipitation events (HPEs)

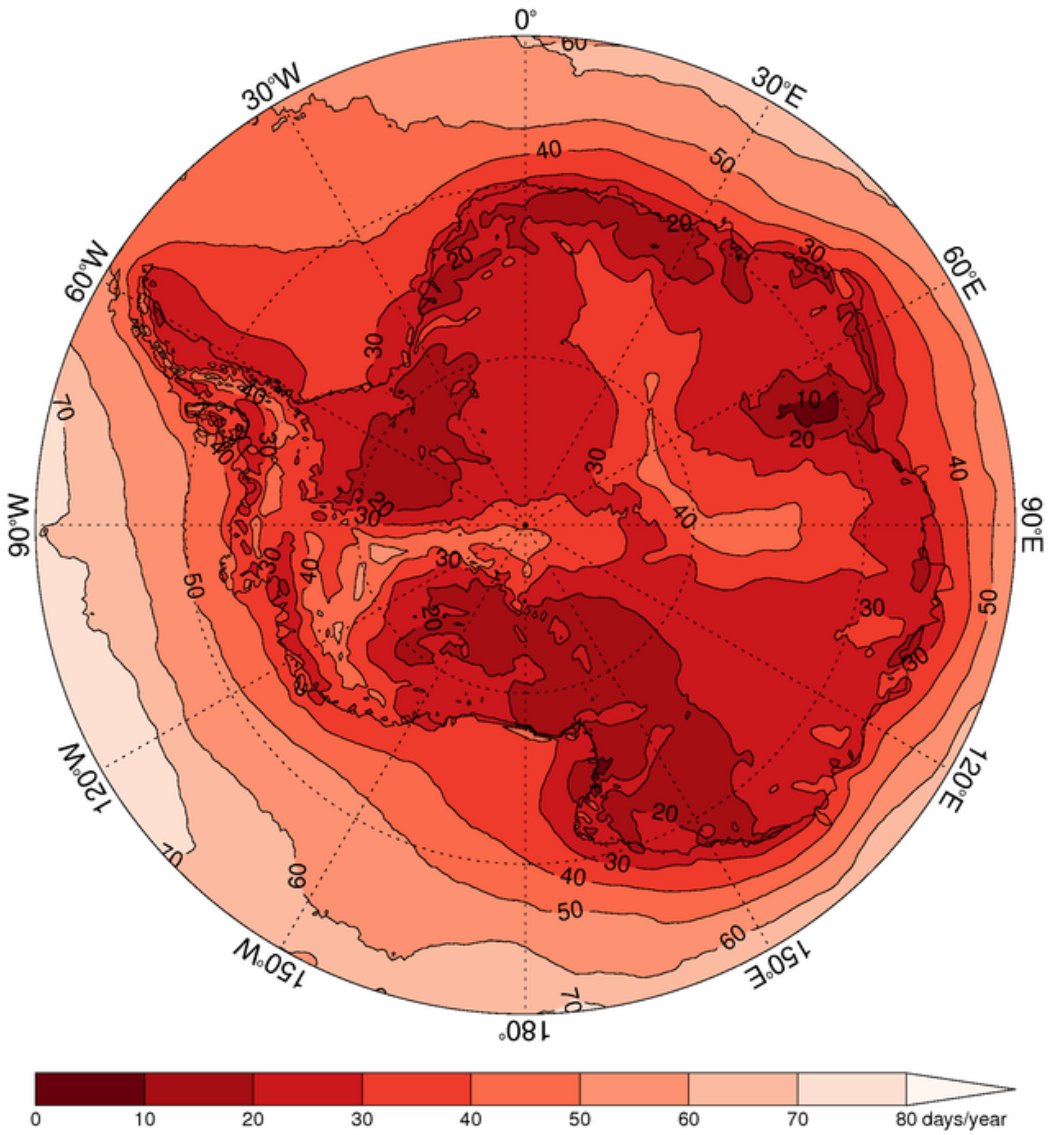
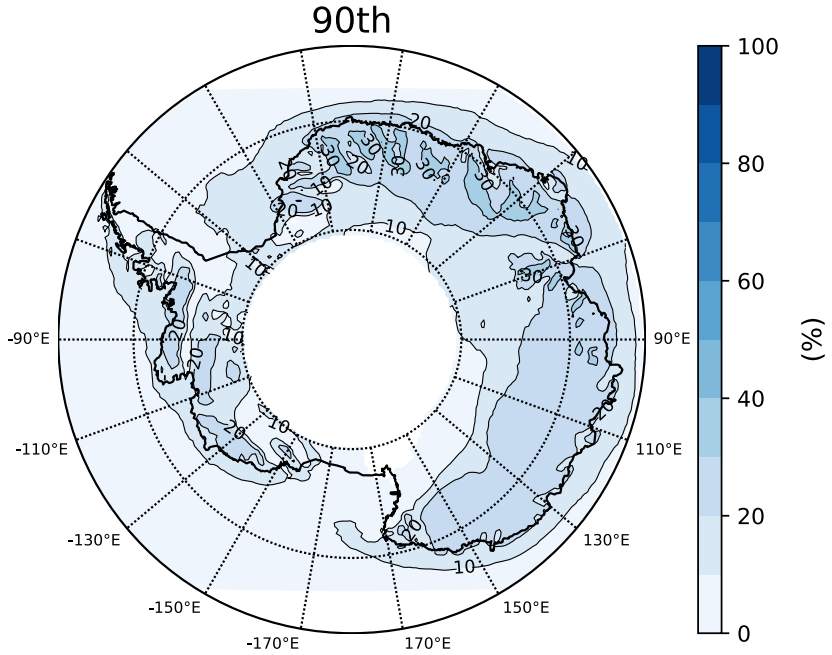


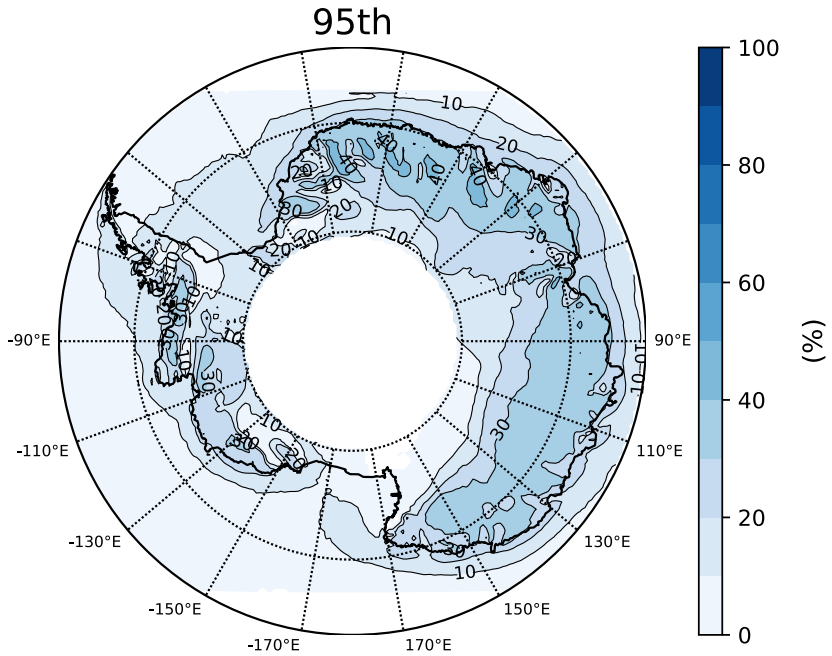
Fig. 1 The contribution of HPEs to the annual precipitation. The number of days of the highest, ranked precipitation that gives 50% of the annual total. Darker colours indicate where the HPEs are more important

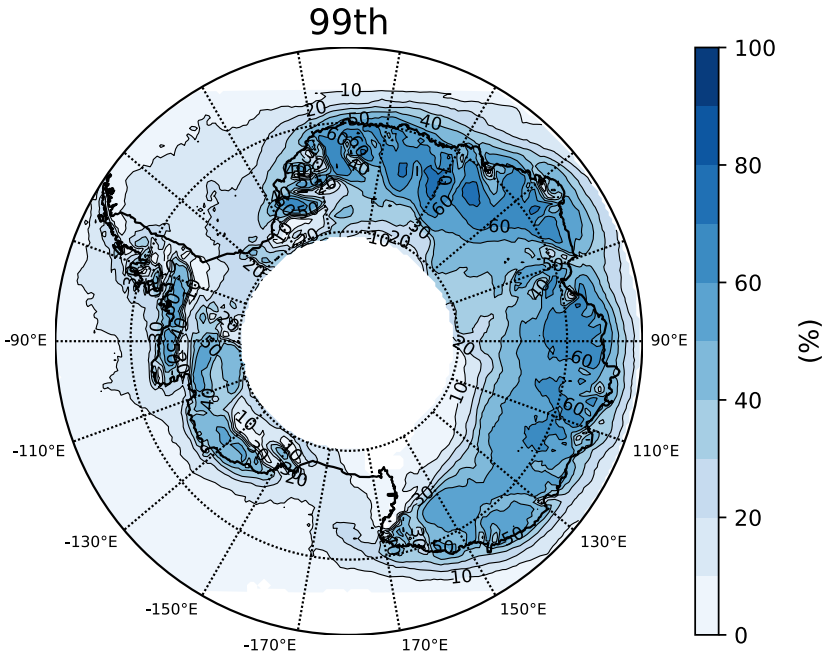
(From Turner et al. 2019)

Atmospheric rivers are responsible for many of these HPEs

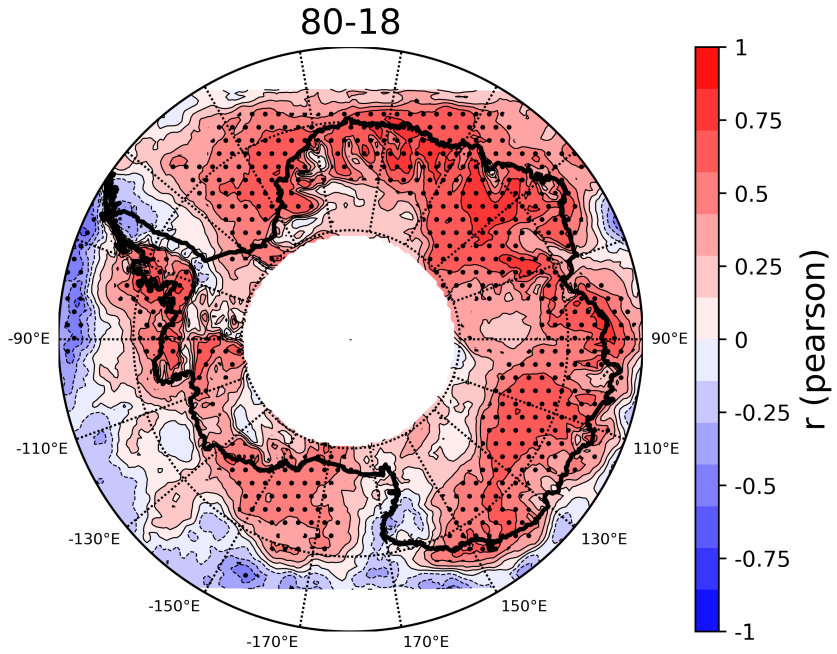


The percentage of precipitation that can be attributed to AR landfalls when all 3-hourly precipitation outside the 90th percentile, 95th percentile, and 99th percentile is removed from the precipitation total from 1980-2018

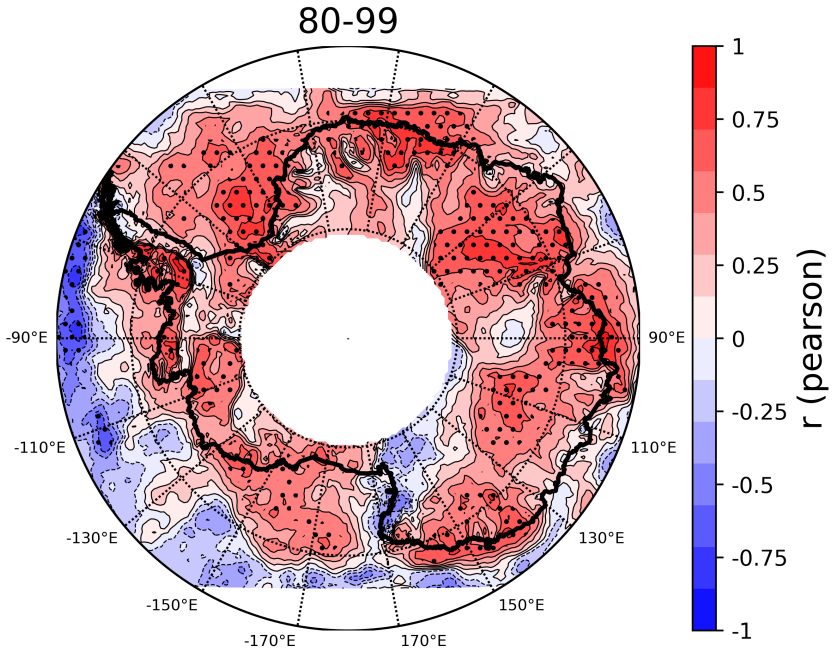


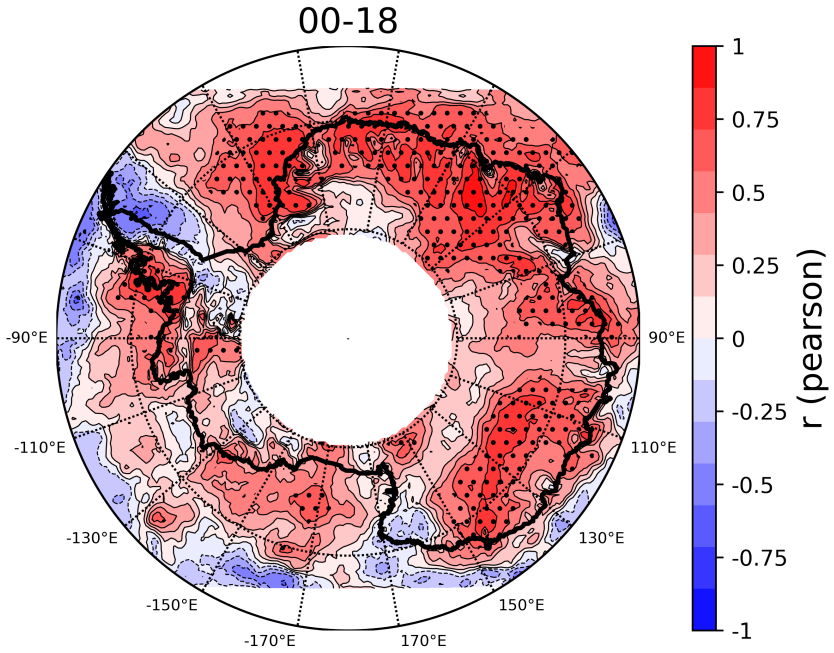


Atmospheric rivers control snowfall interannual variability

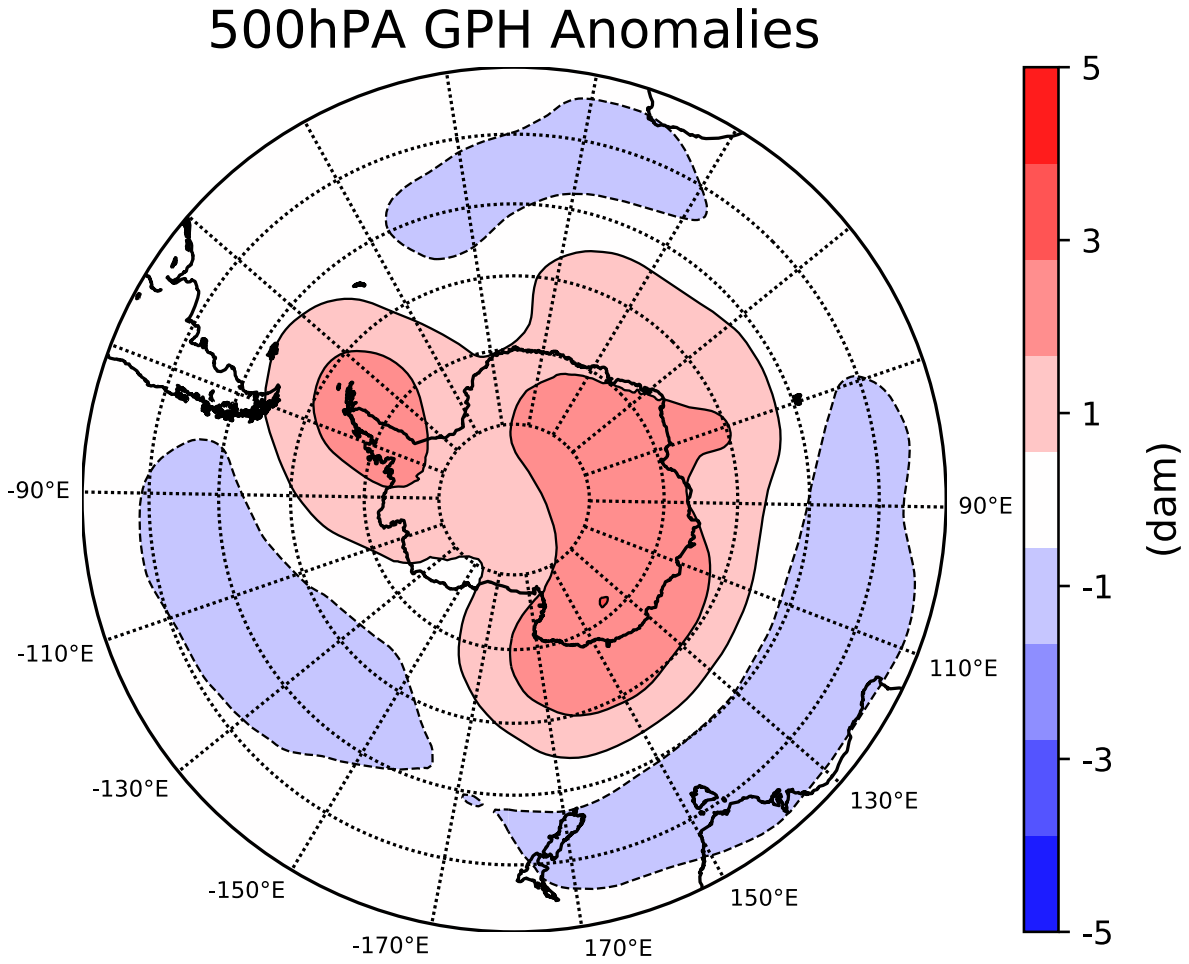


The Pearson's correlation coefficent (r-values) between annual AR frequency and annual snowfall accumulation from MAR. Black circles represent areas of significant corrolations (p-value < 0.025)

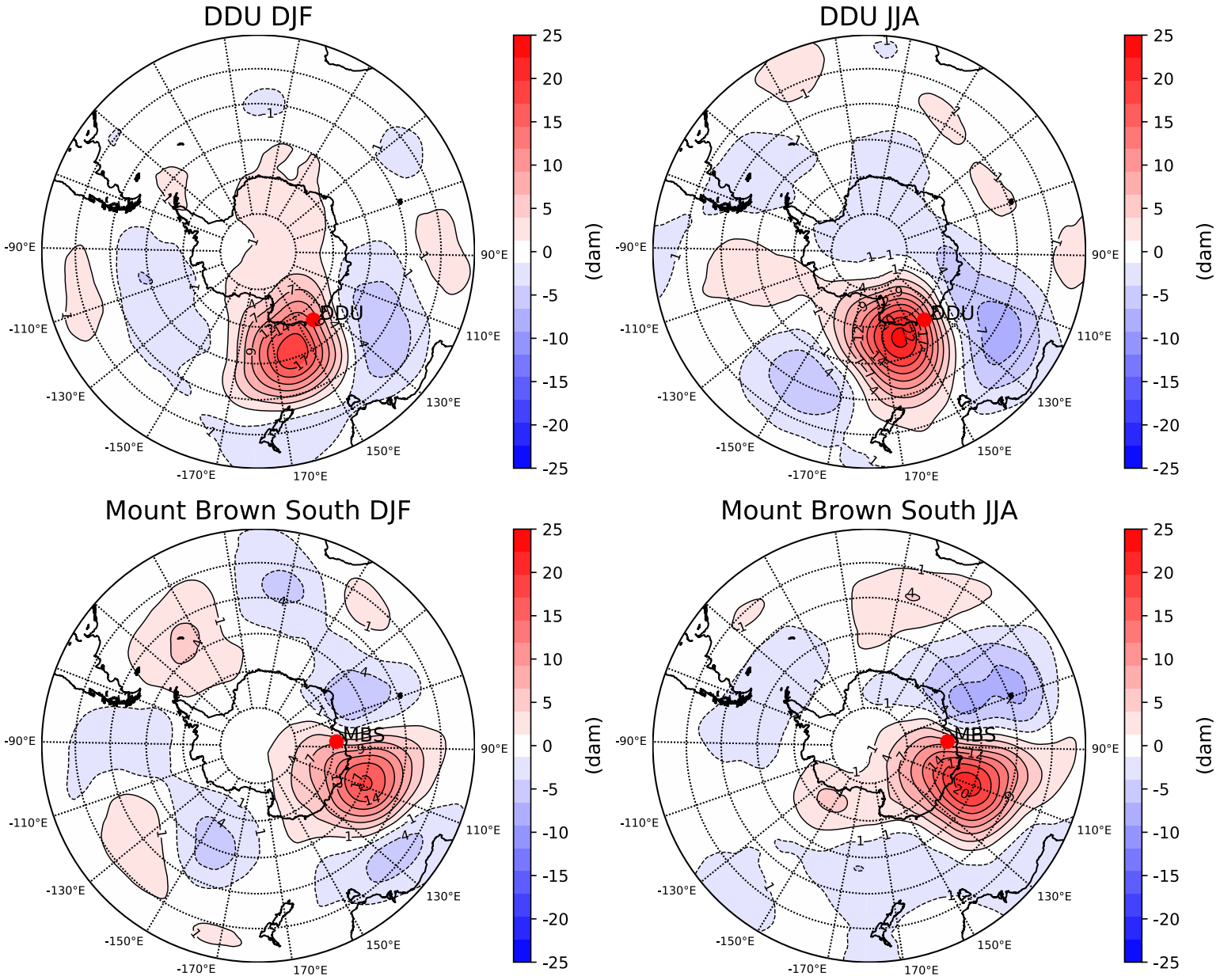




Atmospheric blocking around Antarctica is essential for an AR to reach the continent



Composite MERRA-2 500 hPa geopotential height anomalies for all AR landfalls from 1980-2018



Composite MERRA-2 500 hPa geopotential height anomalies for all AR landfalls at DDU and Mount Brown South 1980-2017

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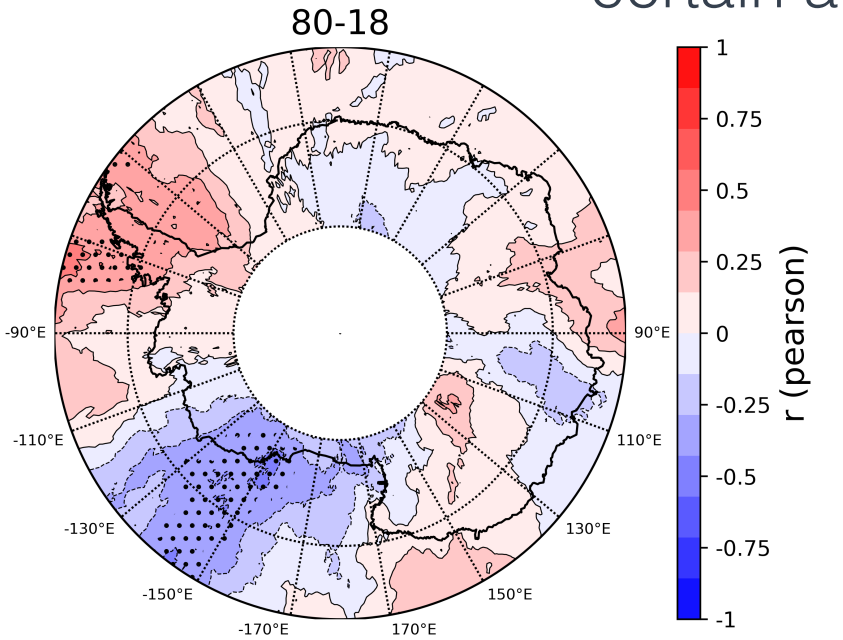
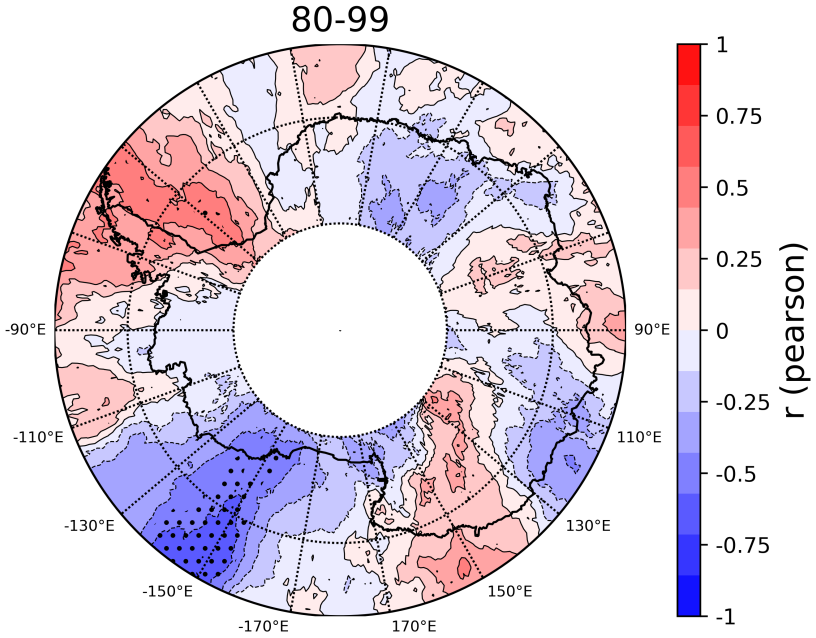
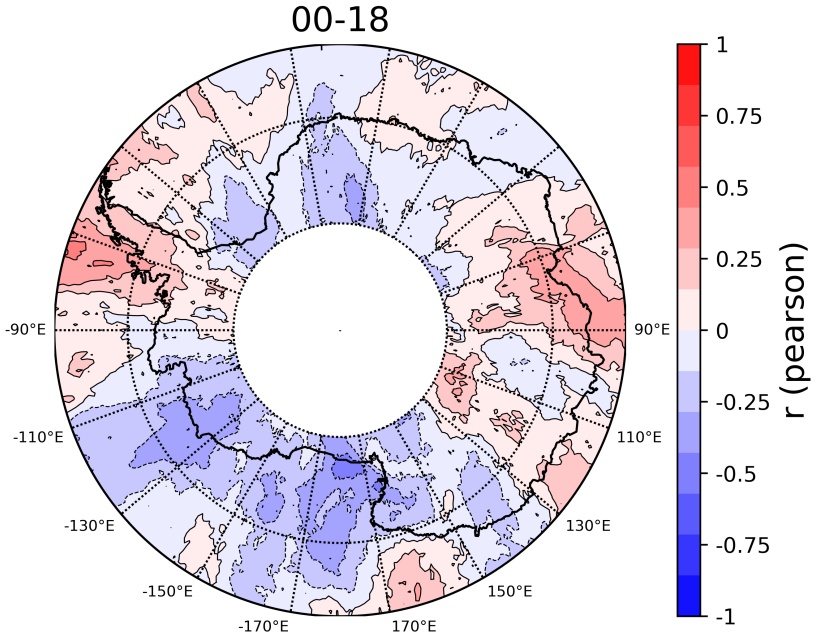
Atmospheric river frequency is correlated with SAM in certain areas



- The Pearson's correlation coefficent (r-values) between annual AR frequency and annually averaged Marshall SAM. Black circles represent areas of significant corrolations (p-value < 0.025)
- A stronger AR/SAM correlation appears on the Antarctic Peninsula during the non-summer months and in the ERA5 AR catalogue





Works Cited

- Wille, J. D., V. Favier, A. Dufour, I. V. Gorodetskaya, J. Turner, C. Agosta, and F. Codron, 2019: West Antarctic surface melt triggered by atmospheric rivers. *Nat. Geosci.*, **12**, 911–916, https://doi.org/10.1038/s41561-019-0460-1.
- Turner, J., Phillips, T., Thamban, M., Rahaman, W., Marshall, G. J., Wille, J. D., et al. The Dominant Role of Extreme Precipitation Events in Antarctic Snowfall Variability. *Geophysical Research Letters*., https://doi.org/10.1029/2018GL081517 (2019).
- Gorodetskaya, I. V., M. Tsukernik, K. Claes, M. F. Ralph, W. D. Neff, and N. P. M. Van Lipzig, 2014: The role of atmospheric rivers in anomalous snow accumulation in East Antarctica. *Geophysical Research Letters*, **41**, 6199–6206, doi:10.1002/2014GL060881.

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Questions?