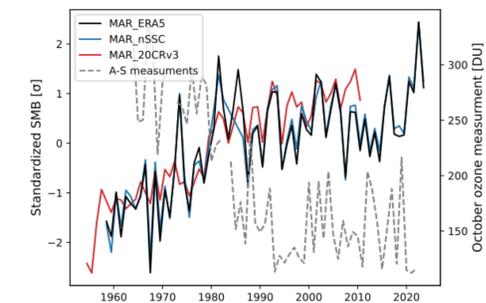


# Tracing Antarctic Surface Mass Balance Since 1958: Signal or Artifact?

## SUMMARY

Understanding long-term changes in Antarctica's surface mass balance (SMB) is critical for constraining past and future sea level rise. We used the regional climate model MAR (v3.14)<sup>1</sup> at 25 km resolution, to reconstruct Antarctic SMB from 1940 to the present. Previous studies suggested that reanalysis-forced RCMs exhibit an artificial SMB increase around 1979<sup>2,3</sup>—coinciding with the assimilation of satellite data—due to spurious signals in Southern Ocean sea surface conditions (SSCs).

By replacing ERA5 SSCs with a debiased reconstruction<sup>4</sup>, we found no significant change in the reconstructed SMB, challenging this assumption. However, forcing MAR with the satellite-free 20CRv3 reanalysis still produced a clear SMB increase in the 1970s. Through information transfer analysis, we demonstrate that this discontinuity is partially driven by a real shift in atmospheric regime over the South Pole, linked to the early development of the ozone hole.

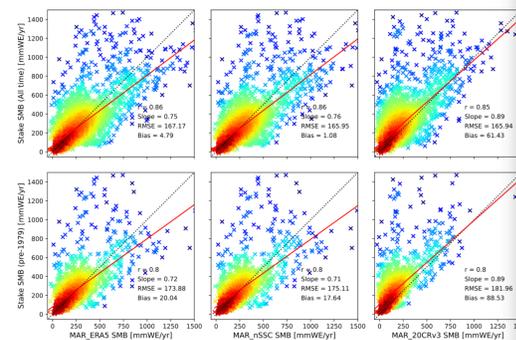


Standardized annual SMB evolution reconstructed by MAR\_ERA5, MAR\_nSSC and MAR\_20CRv3 against September averaged total column ozone measurements at Amundsen-Scott

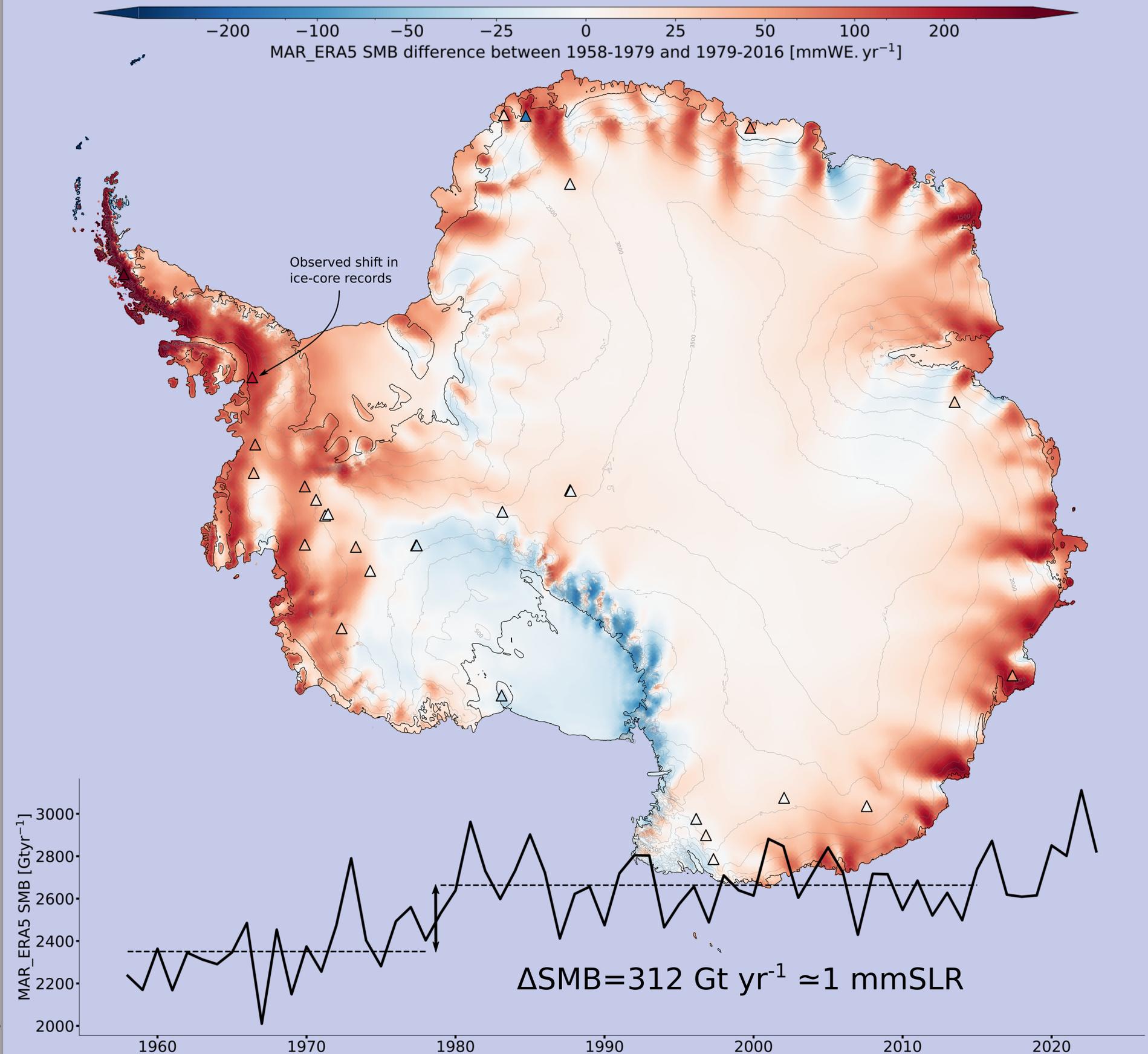
## METHODS

We use the regional climate model MARv314 at a 25 km resolution with a 326x326 grid (up to 40°S to encompass SSCs influence). ERA-5 and 20CRv3 are forced at the lateral and top boundaries, while new SSCs<sup>4</sup> are used in place of ERA-5 SSCs.

	Period	r	Bias	CRMSE
MAR_ERA	Presat	0.80	-13.5	6.17
	Postsat	0.94	-1.67	3.23
MAR_nSSC	Presat	0.81	-13.63	6.10
	Postsat	0.94	-1.88	3.25
MAR_20CRV3	Presat	0.85	-11.07	5.41
	Postsat	0.91	-3.19	4.08

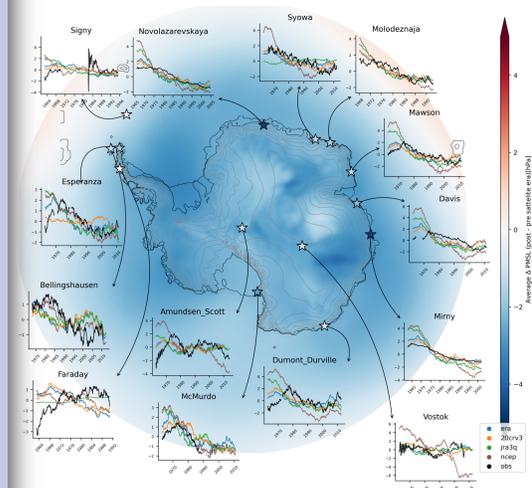


Surface Pressure (from AWS) and SMB (Stakes and ice-cores) evaluation



## CIRCULATION CHANGE

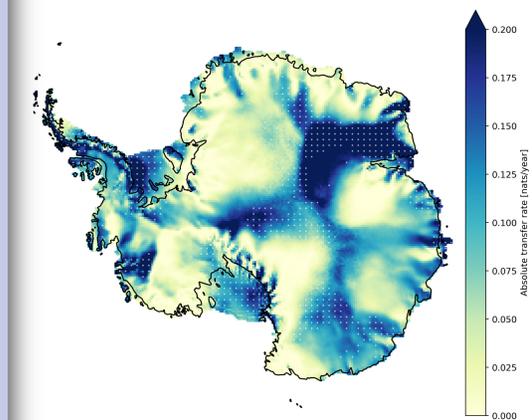
While the reliability of reanalysis products naturally decreases further back in time, several independent studies have highlighted substantial changes in atmospheric circulation over Antarctica since the mid-20th century<sup>5</sup>. These changes are not solely artifacts of data assimilation or reanalysis uncertainty. Observational records from Antarctic Automatic Weather Stations (AWSs) clearly document a long-term contraction of the polar vortex and a progressive decline in mean surface pressure along the coastal margins. These circulation shifts, particularly marked since the 70s, are reproduced in various reanalysis products.



Multi-reanalysis average surface pressure difference (background), and standardized evolution compared to obs. Star colors show the pre-post satellite era AWSs difference.

## OZONE HOLE

The role of stratospheric ozone depletion in driving Antarctic climate change has become increasingly evident. Recent studies<sup>6</sup> have demonstrated the changes in stratospheric ozone concentrations can directly influence SMB, accounting for up to 40% of the observed SMB increase during the latter half of the 20th century. Building on this, we applied information transfer analysis<sup>7</sup> to quantify direct causal links between September minimal ozone levels and annual SMB. Our results reveal a significant transfer of information across large regions of Antarctica, indicating that ozone variability is not only correlated with, but actively influencing SMB patterns.



Absolute information transfer rate between ERA5 October minimal stratospheric ozone below 60°S and annual SMB. White dots show significance.

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