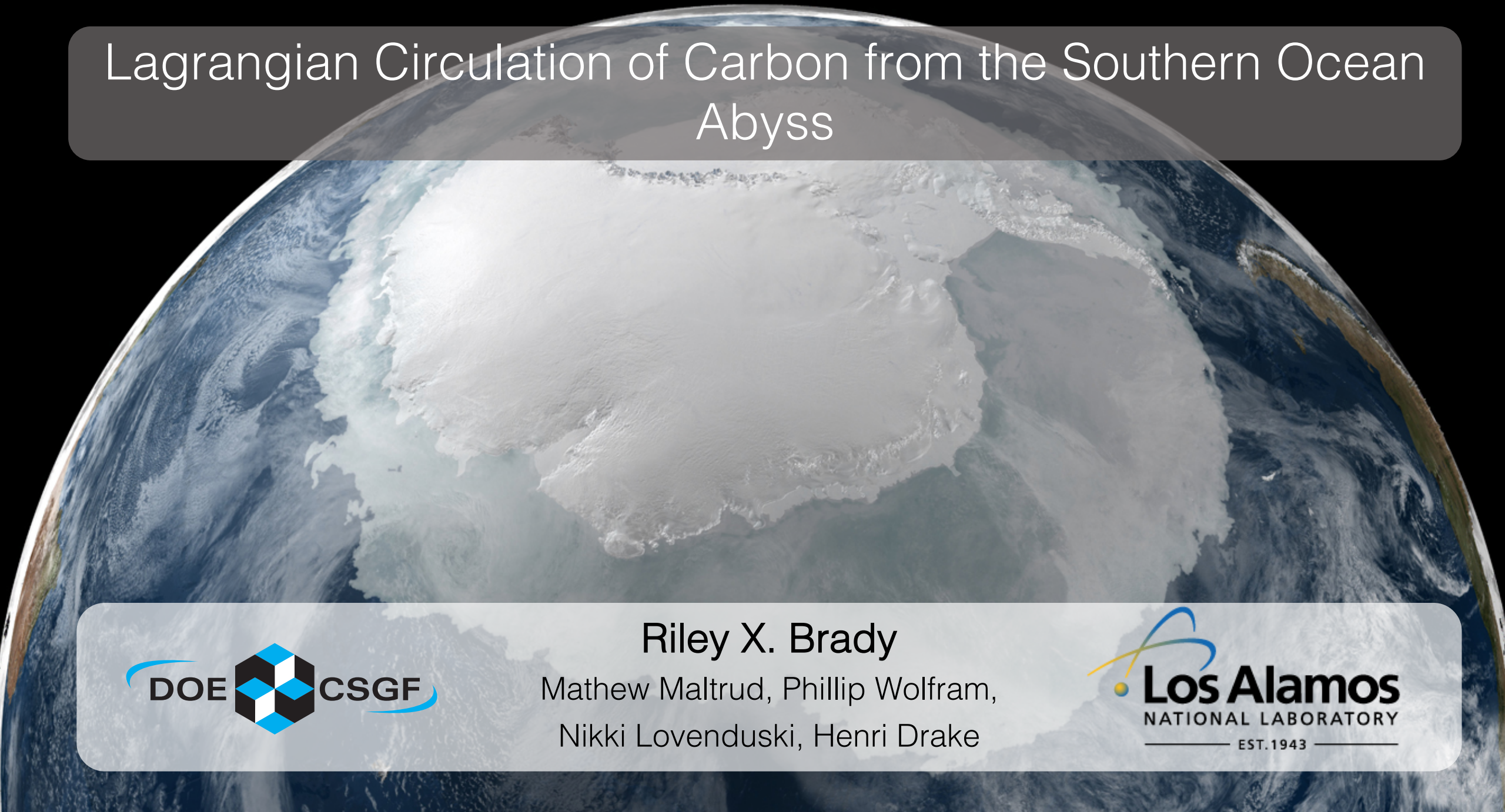
Lagrangian Circulation of Carbon from the Southern Ocean Abyss



Riley X. Brady

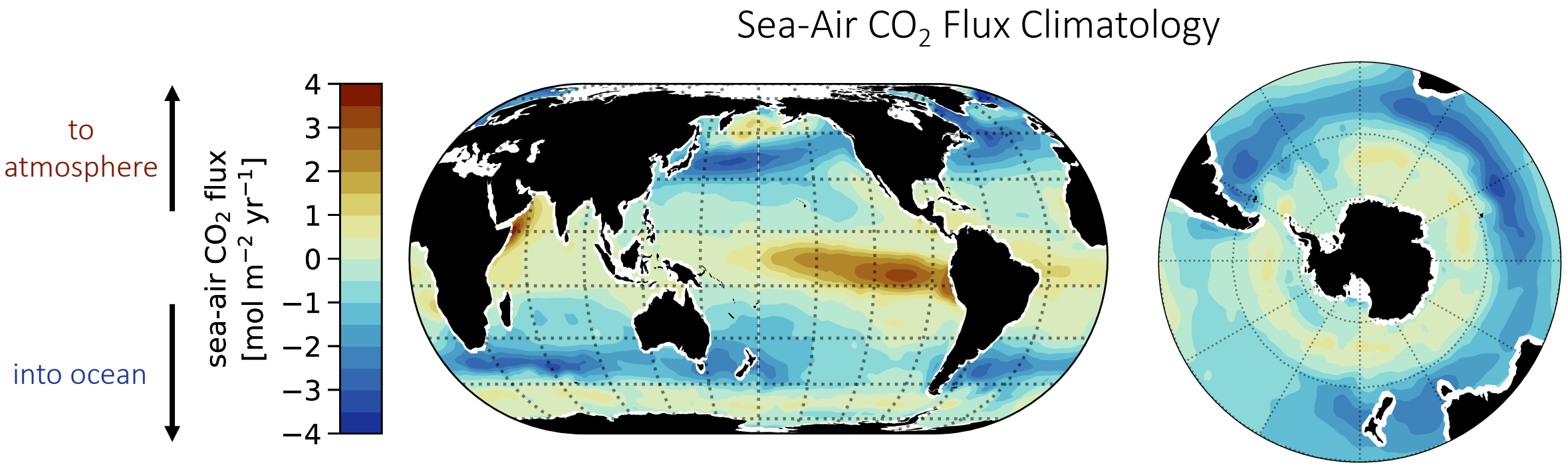
Mathew Maltrud, Phillip Wolfram,

Nikki Lovenduski, Henri Drake

DOE CSGF

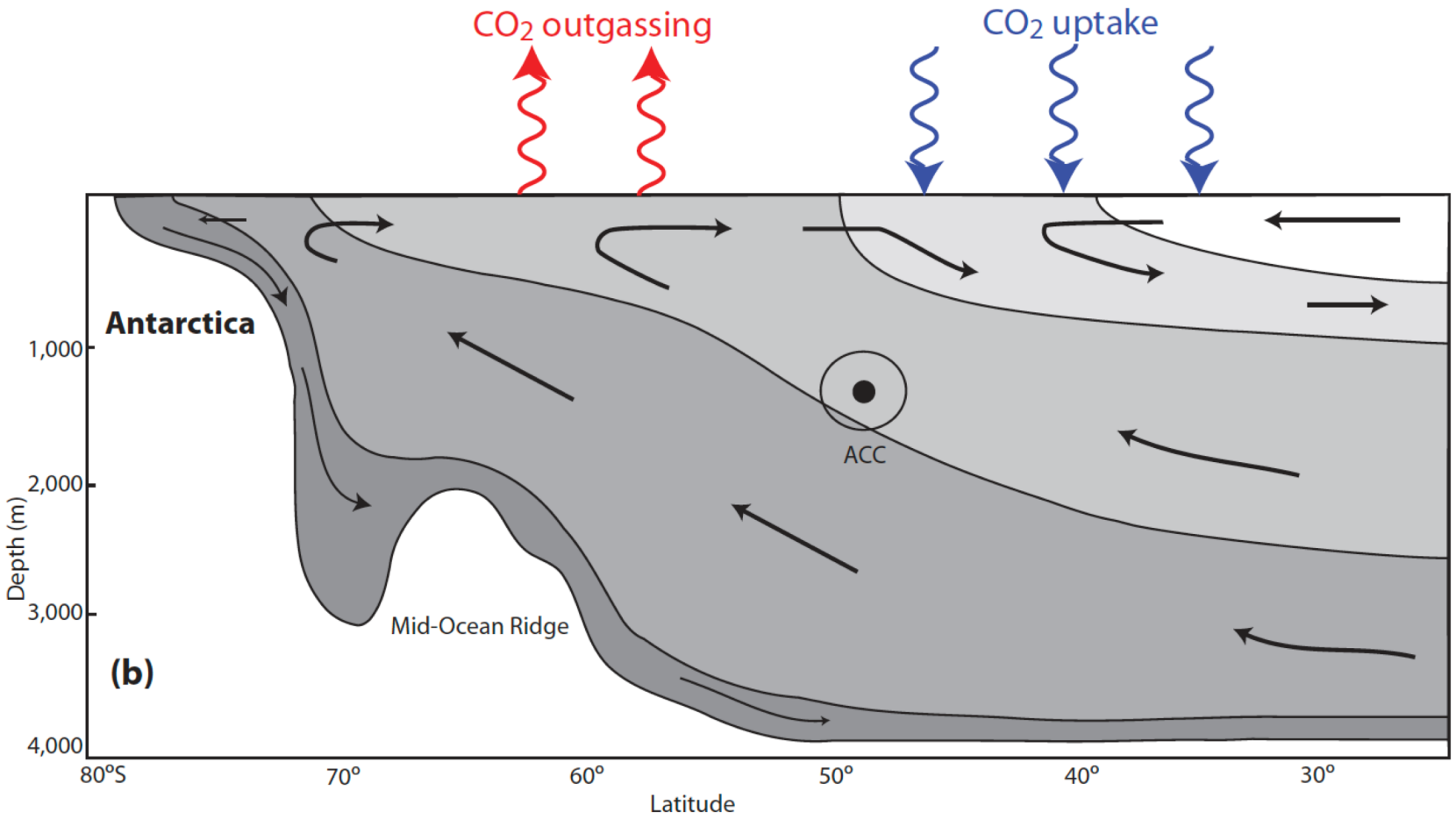
Los Alamos NATIONAL LABORATORY EST. 1943

The Southern Ocean has long been considered the major oceanic sink of atmospheric CO_2.



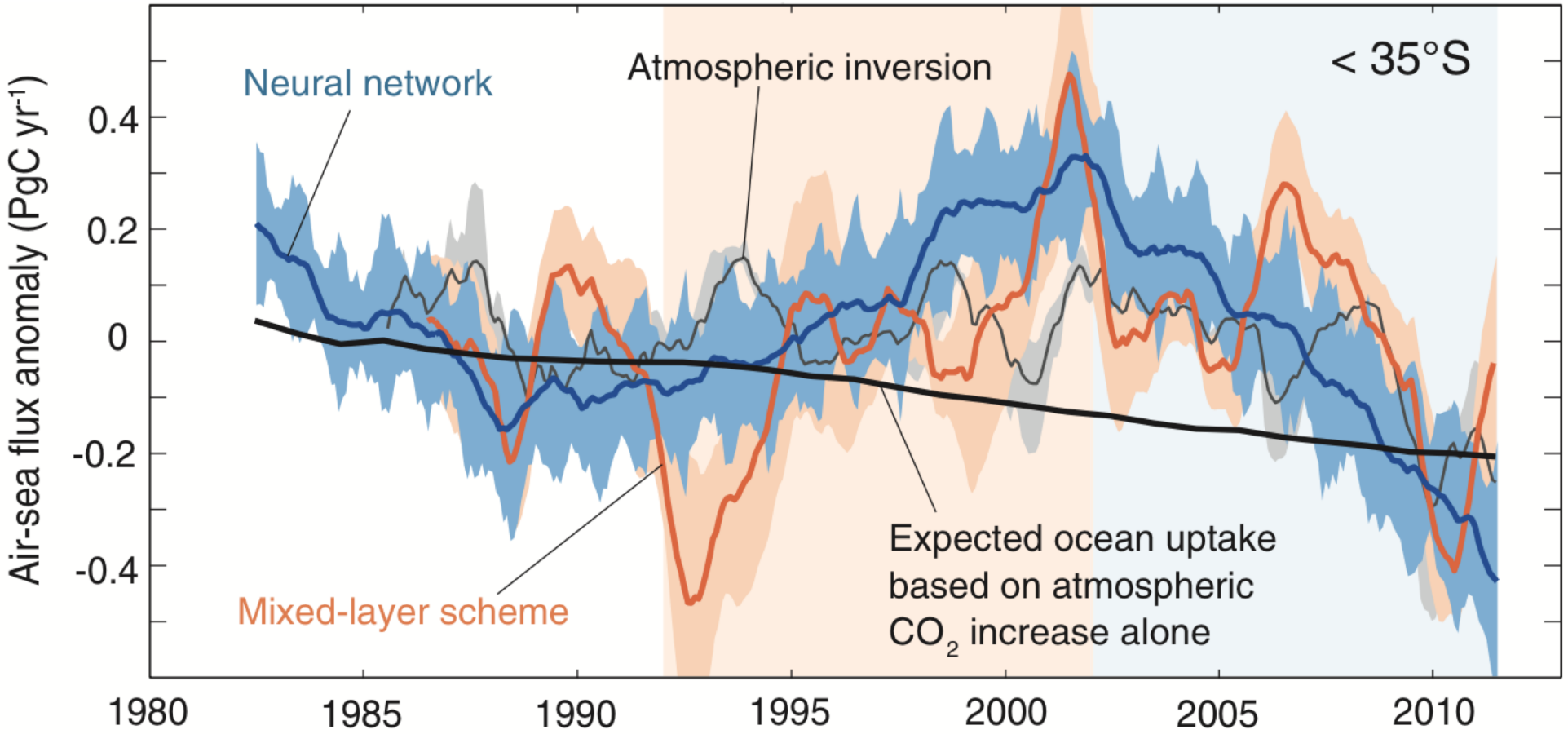
Data from Landschützer et al. (2016)

Air-sea CO_2 exchange in the Southern Ocean is mediated by its overturning circulation.



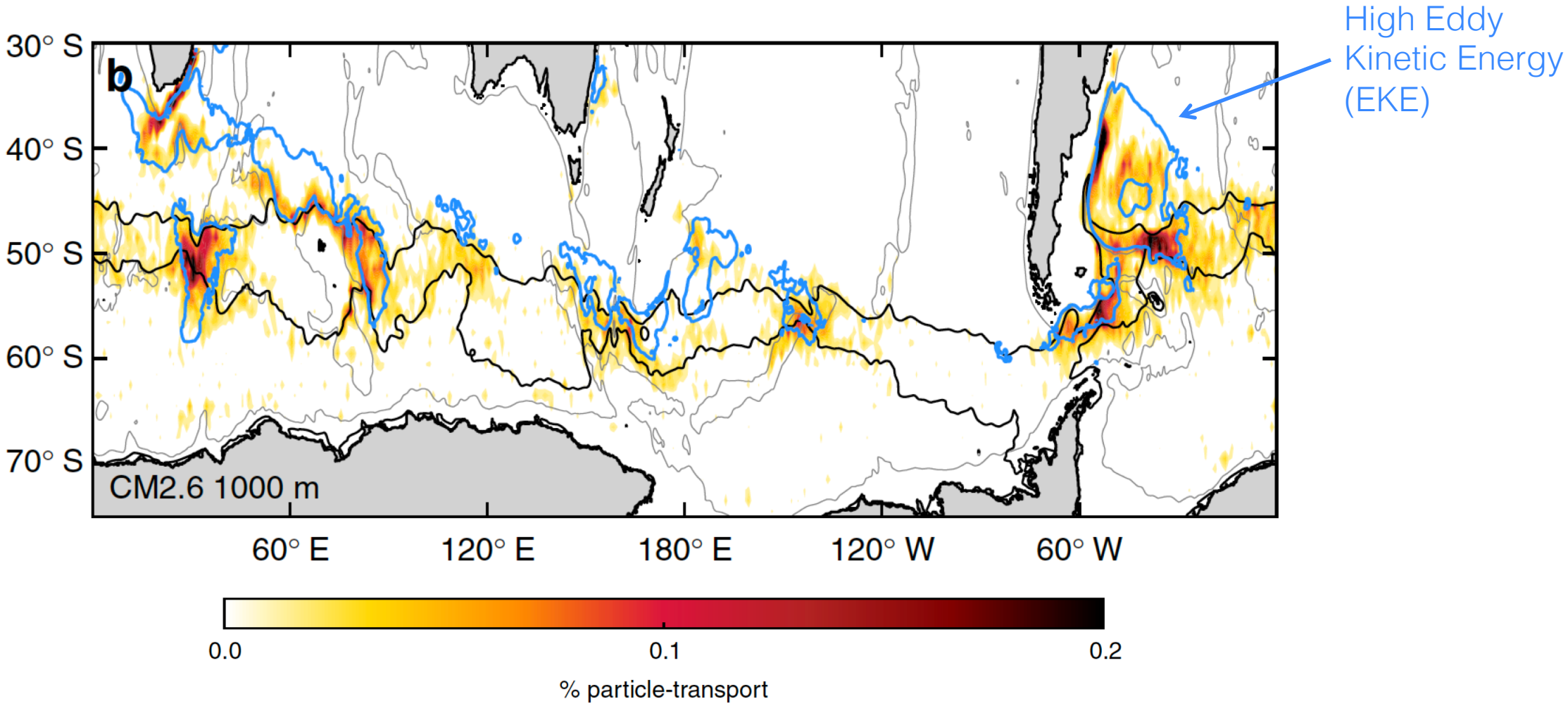
from Nikki Lovenduski

The Southern Ocean CO_2 sink exhibits substantial decadal variability.



Landschützer et al. (2015)

Studies have shown the development of upwelling “hotspots” in high-resolution models, but have stopped at their physical description.



Tamsitt et al. (2017)

Questions

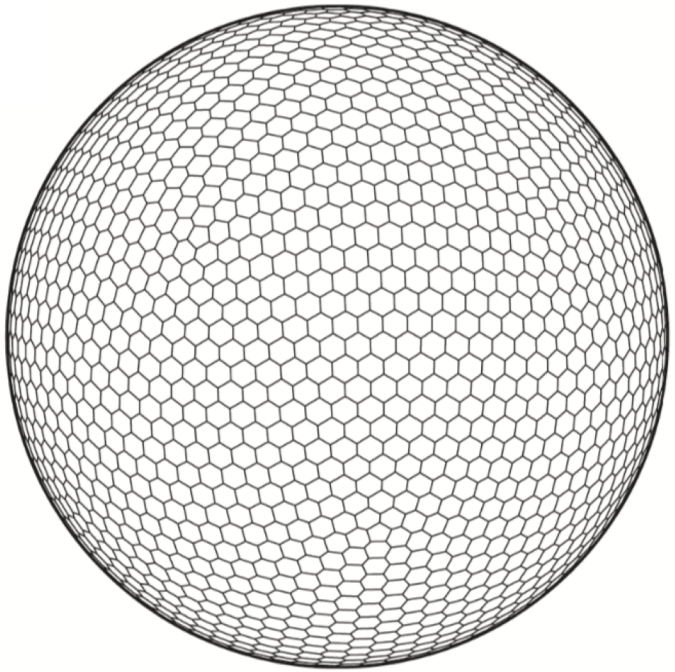
1. Are these hot spots associated with enriched carbon?

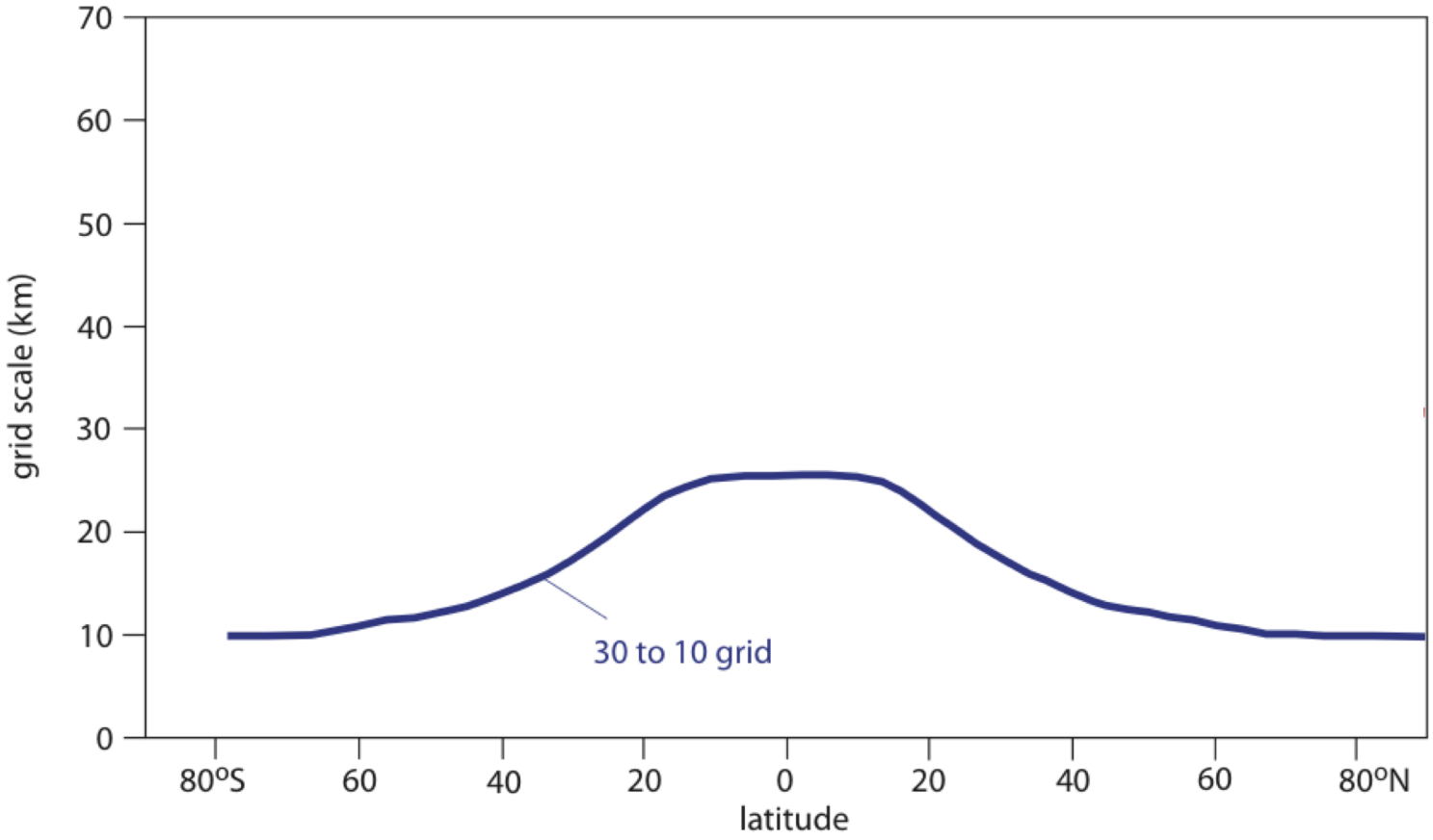
2. What is the origin of this carbon-enriched water?

Model Simulation

Virtual floats in a high-resolution ocean biogeochemistry simulation

We ran a global 30-to-10 km simulation of MPAS-O with ocean biogeochemistry.





Petersen et al. (2019); Personal Comm. from N. Lovenduski (2020)

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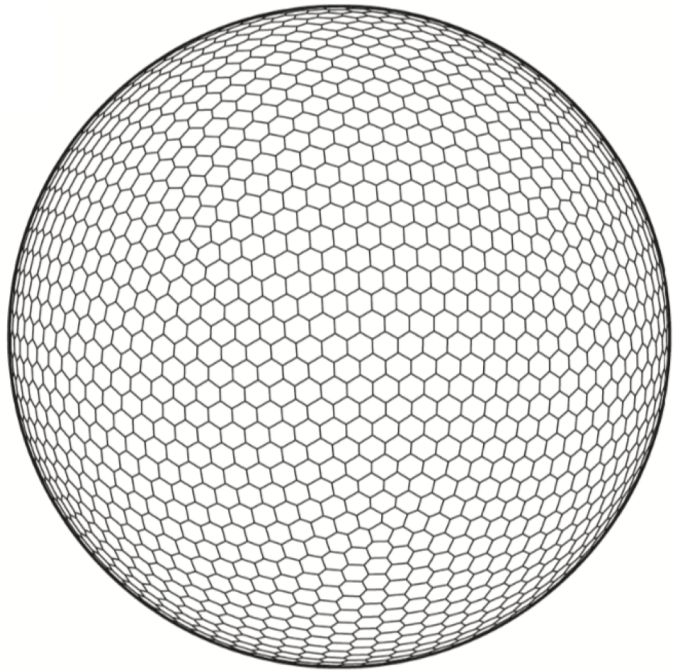
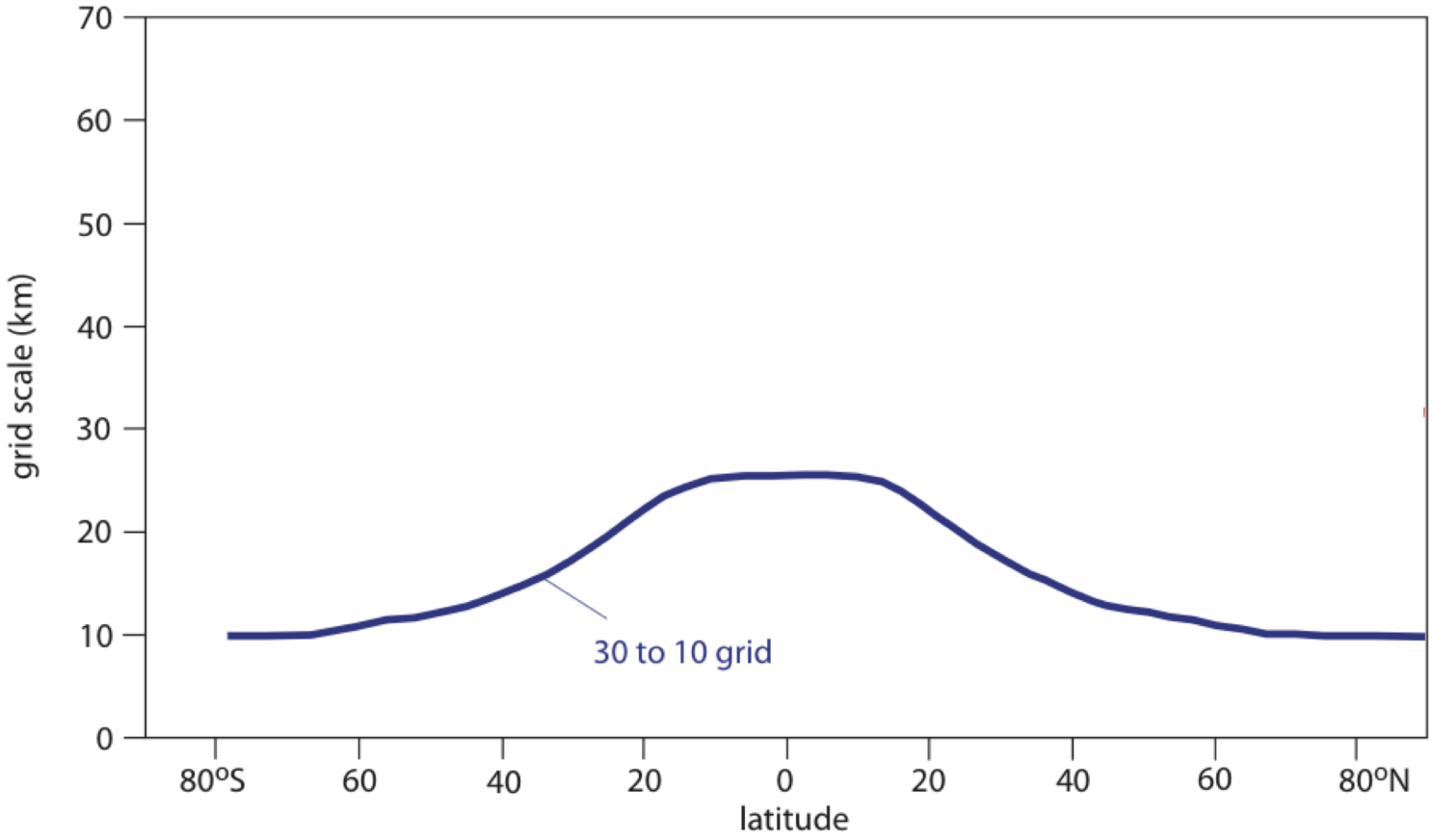
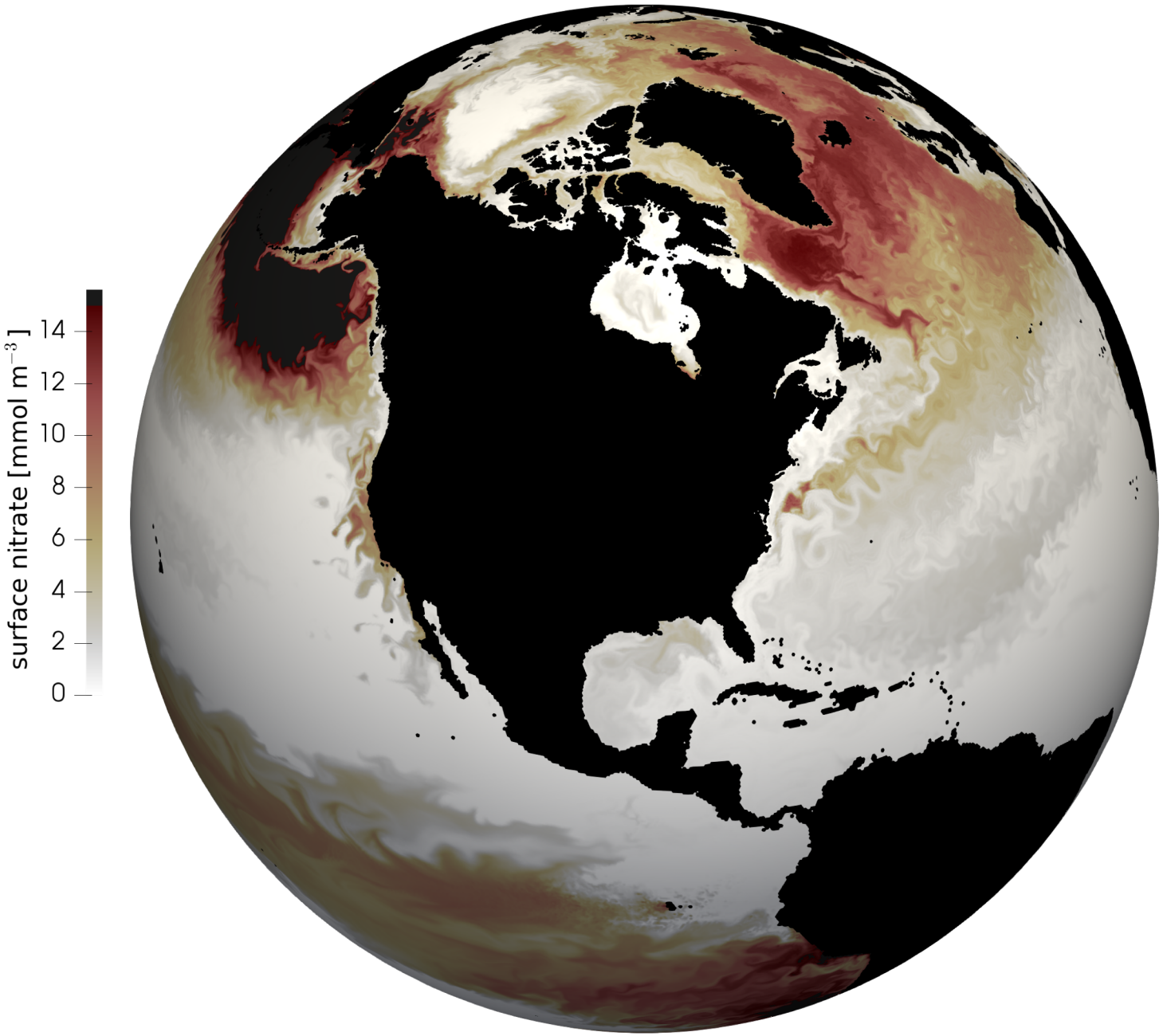


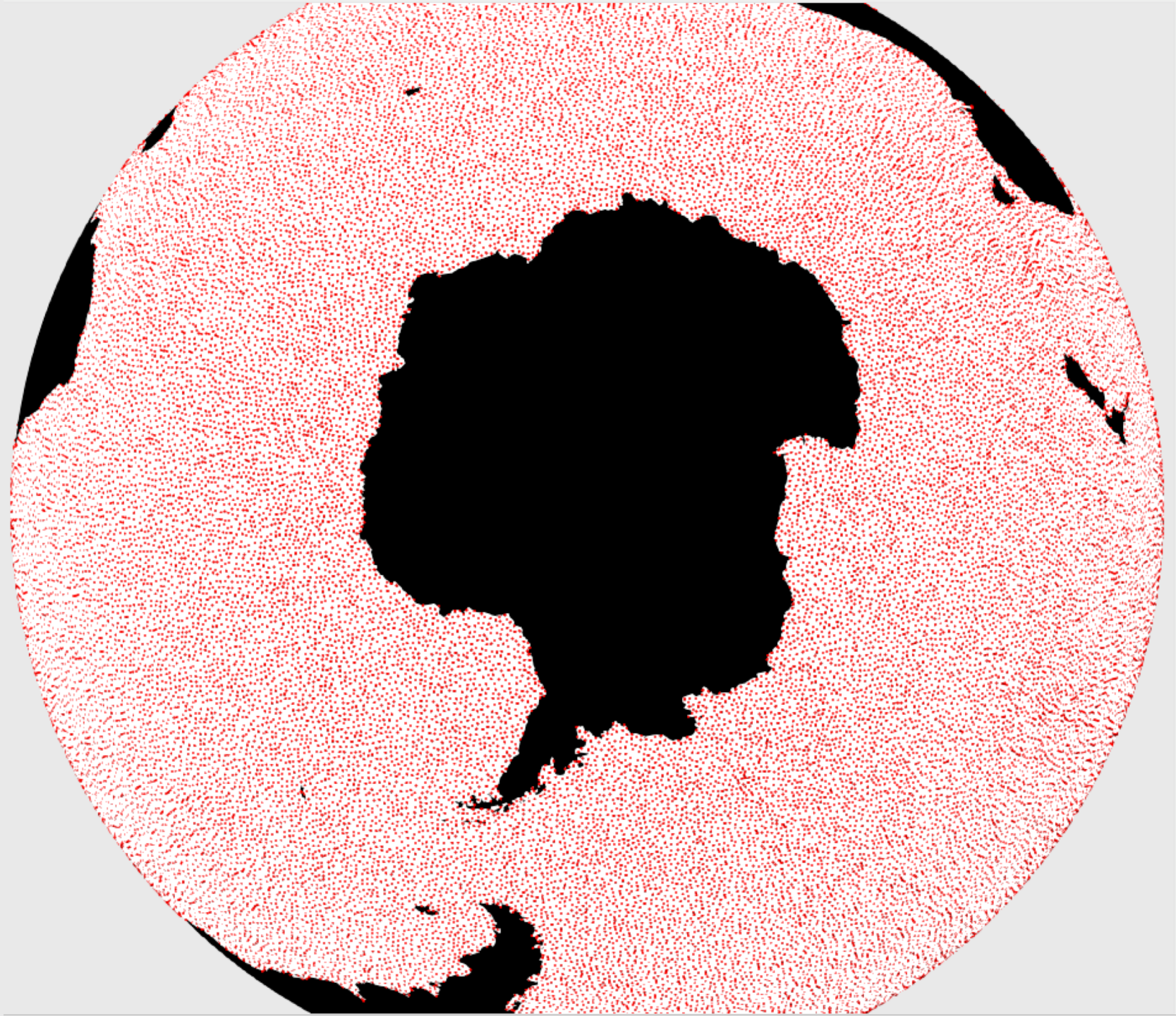


50 years of simulation
~10,000 CPU cores
~10 million CPU hours

Petersen et al. (2019); Personal Comm. from N. Lovenduski (2020)


surface nitrate [mmol m^{-3}]
14
12
10
8
6
4
2
0

We seeded the global ocean with ~1,000,000 Lagrangian particles.



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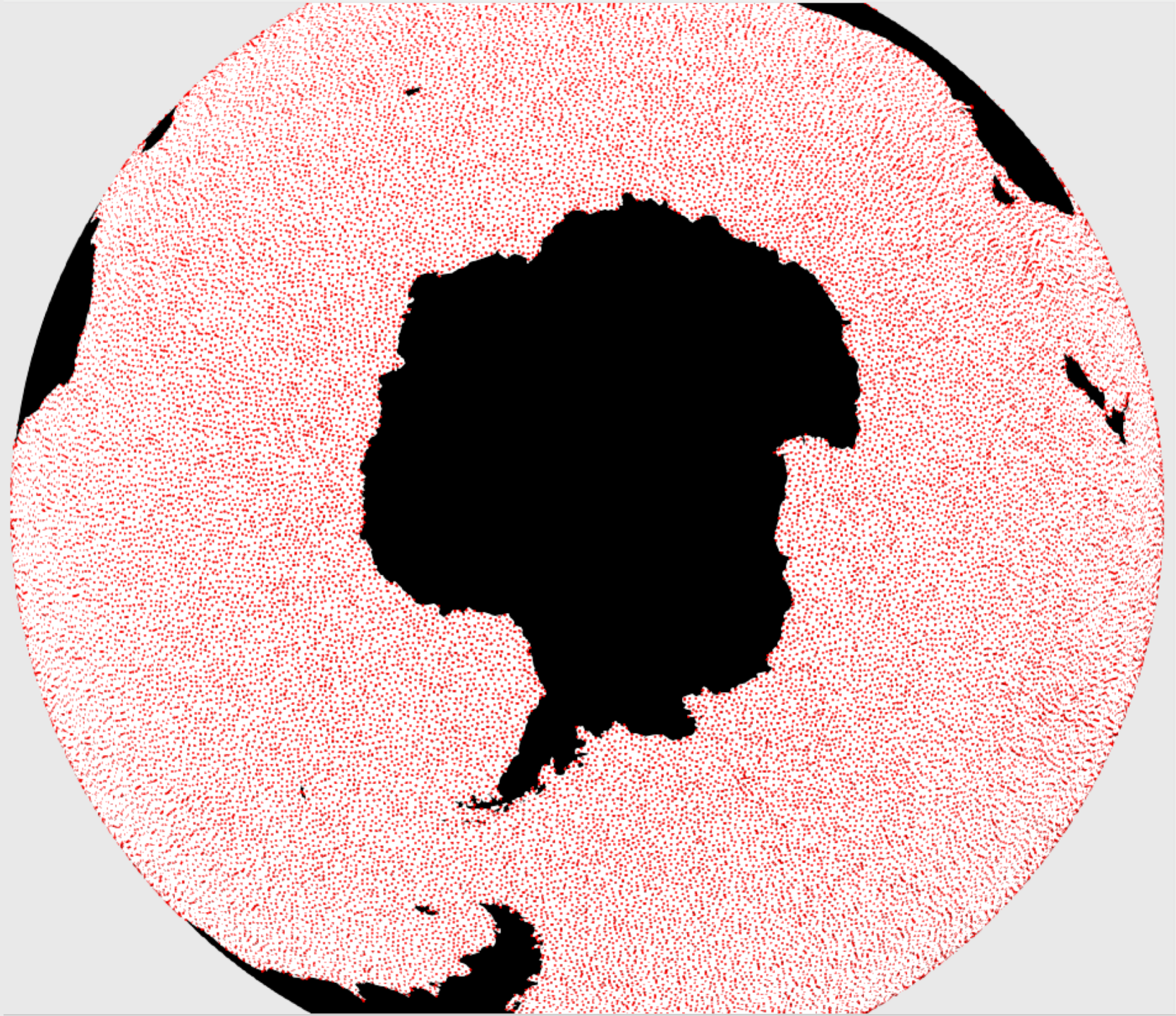
Passive 3D floats were initialized in 15 vertical layers after 50 years of model spinup.



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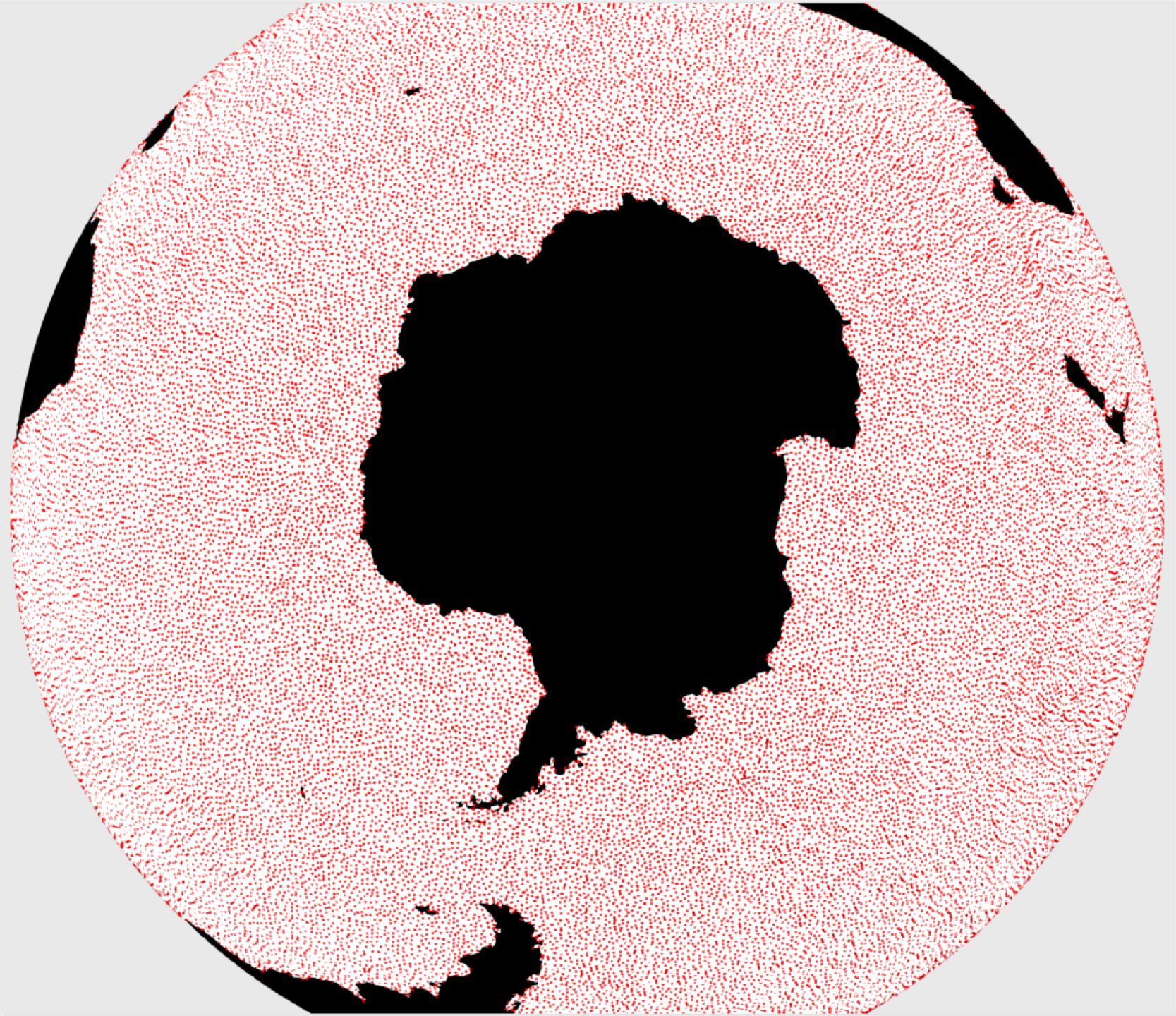
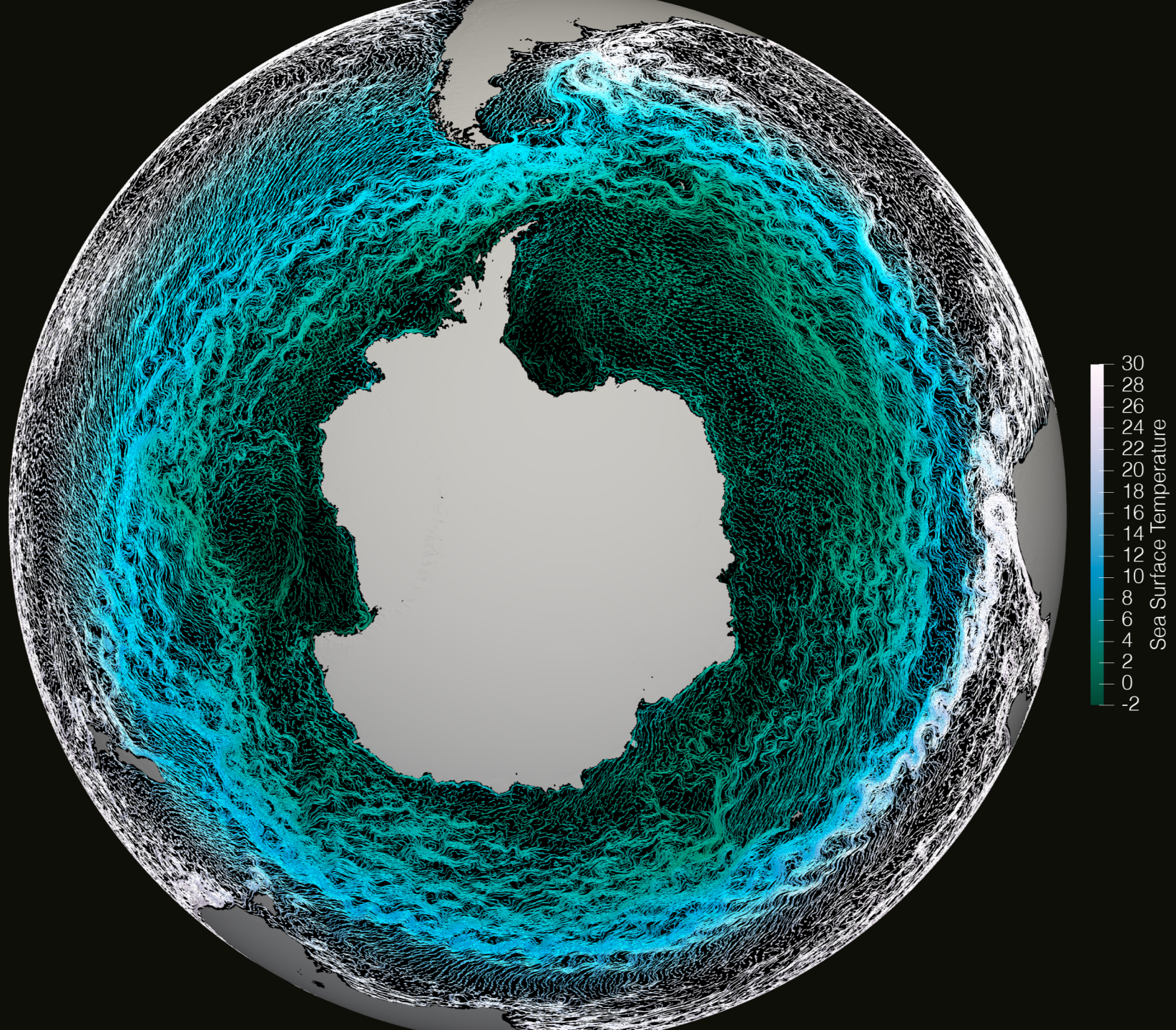
Passive 3D floats were initialized in 15 vertical layers after 50 years of model spinup.

They are advected for 17 years and have onboard “sensors” to record their position and tracers every two days.



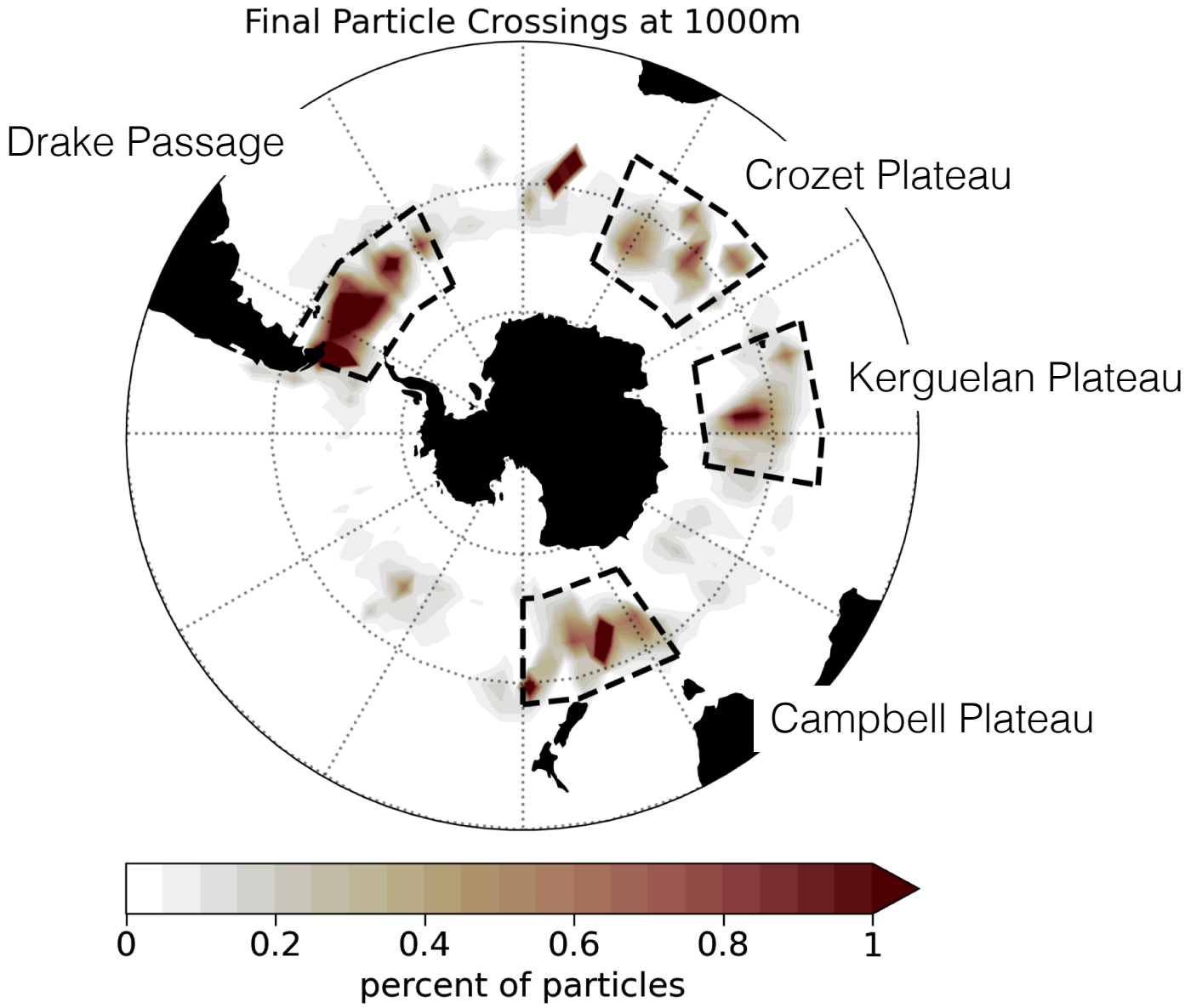
One month of surface flow in the Southern Ocean.



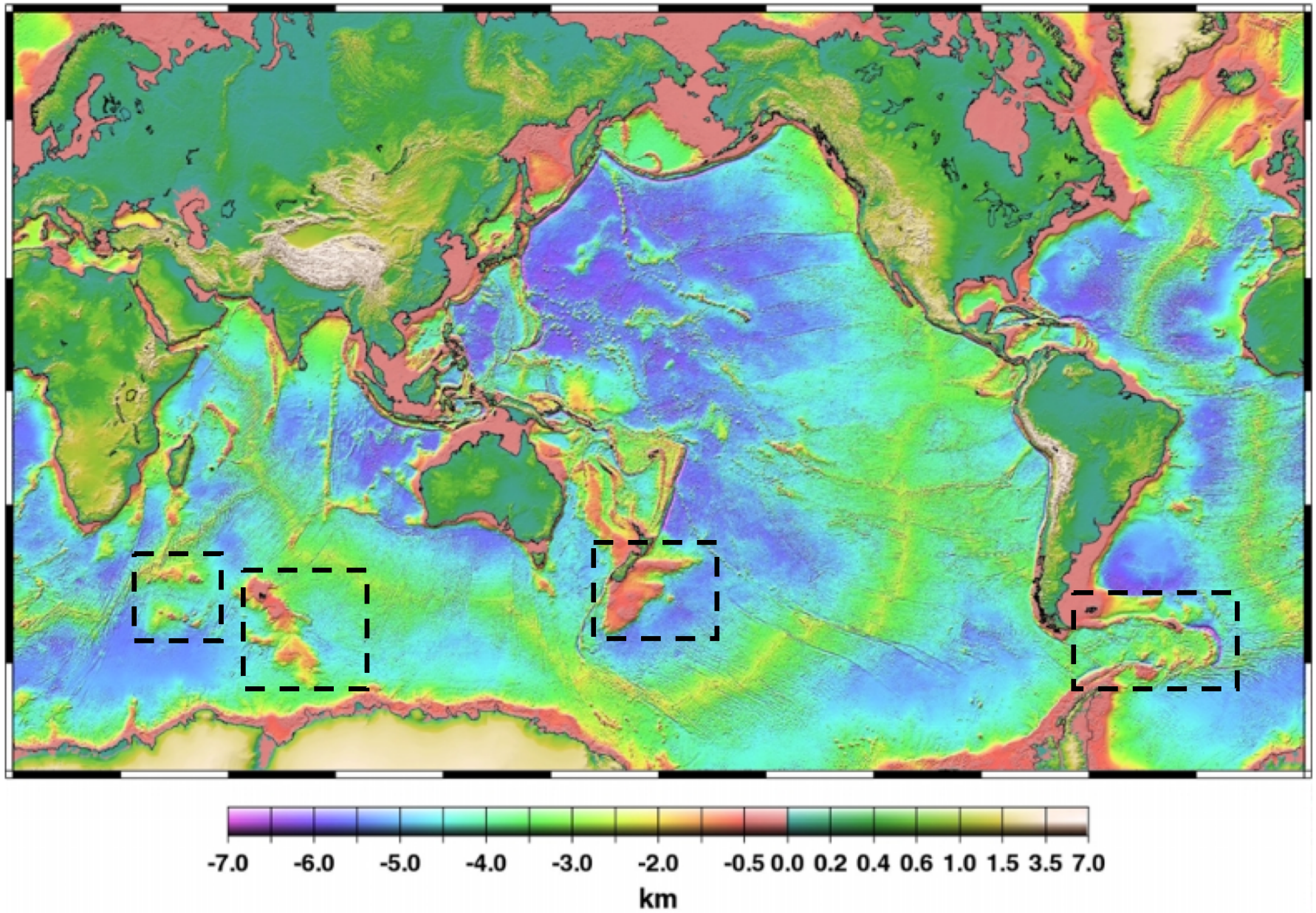
Upwelling Hotspots

Let's hope we have them…

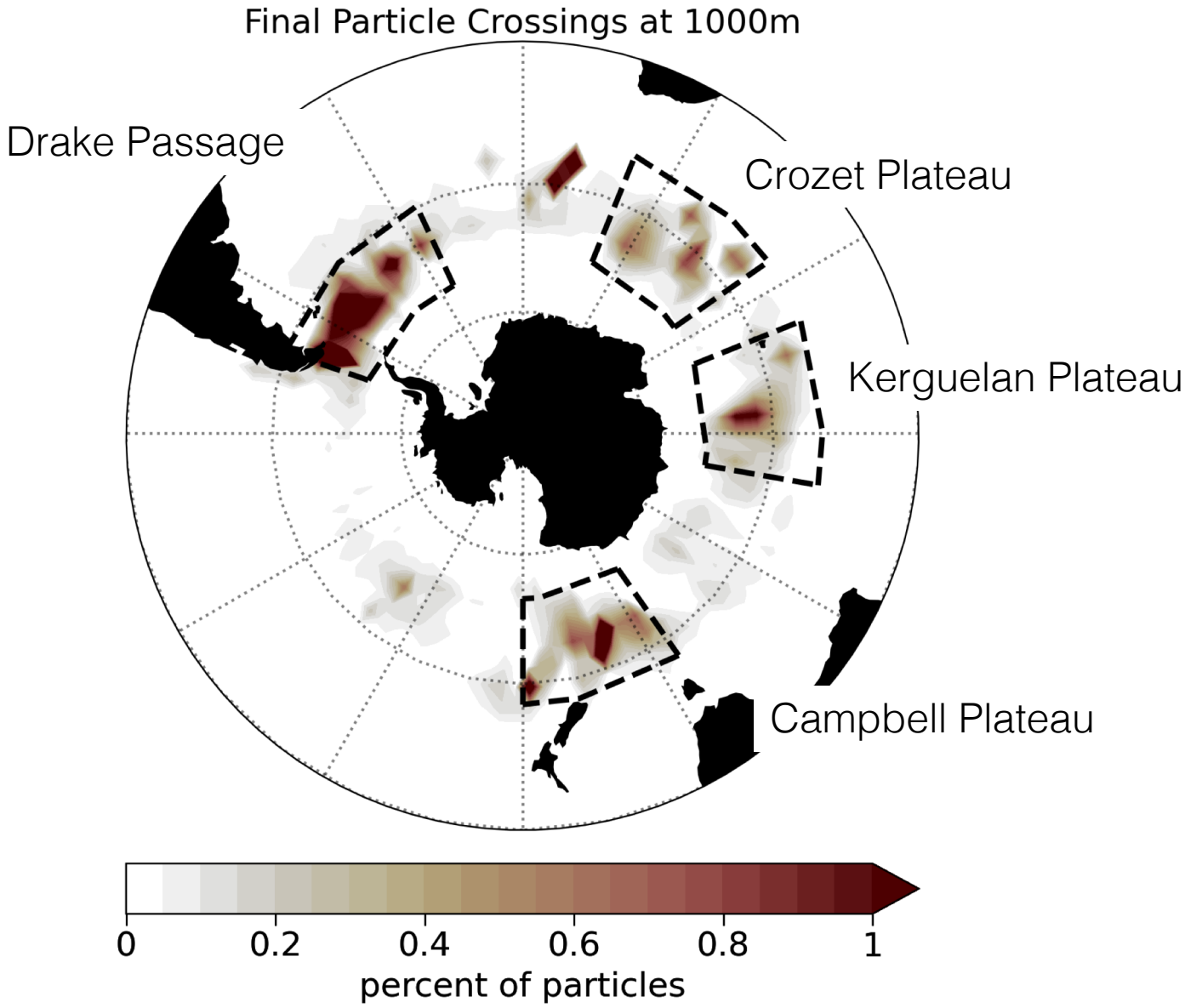
Particle upwelling is organized into a few dense regions.



These regions are associated with topographic features.



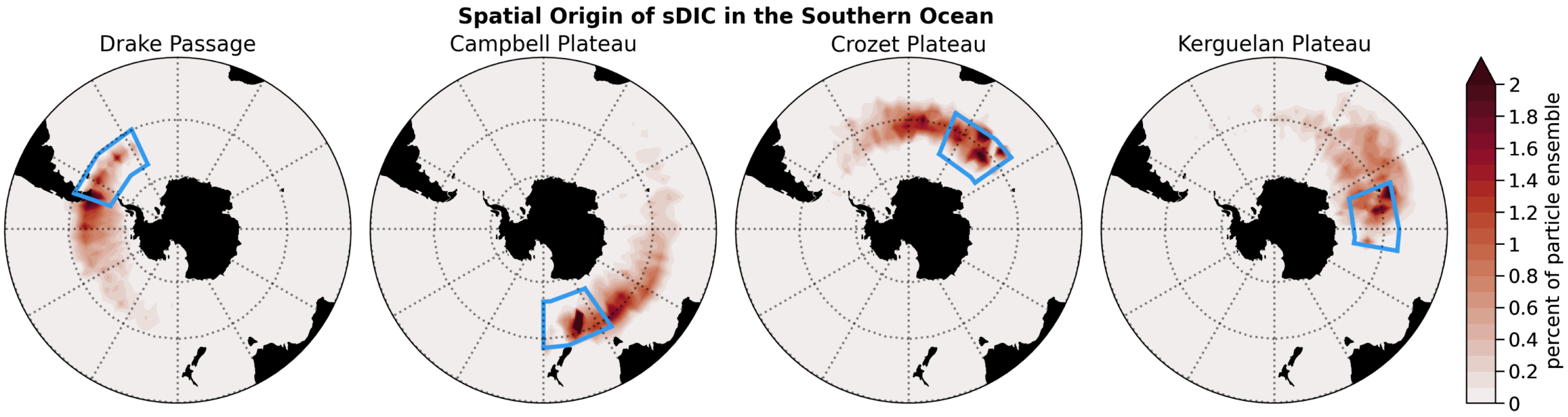
These four regions are associated with 72% of the total upwelling.



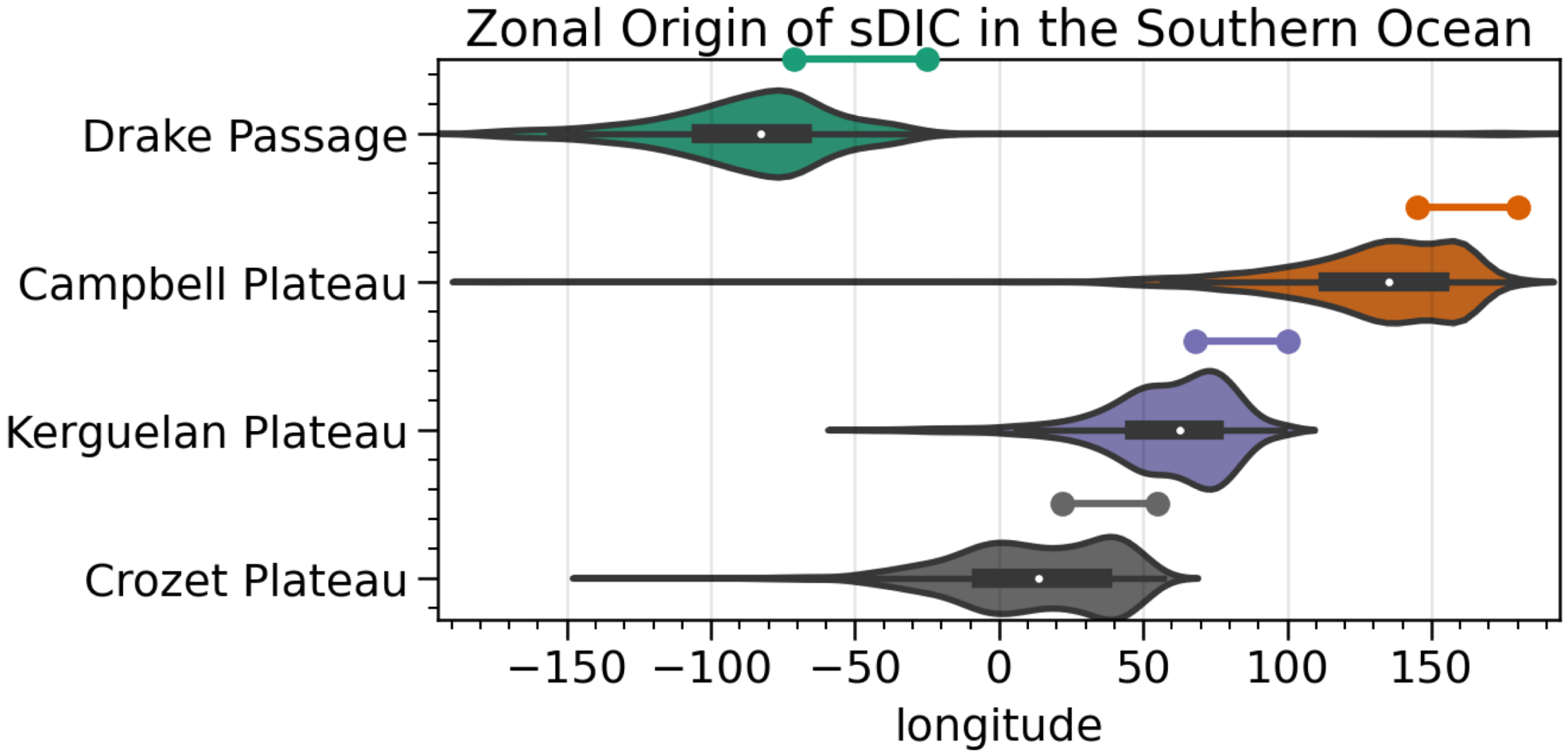
Memory Time

Finding the origin of dissolved inorganic carbon

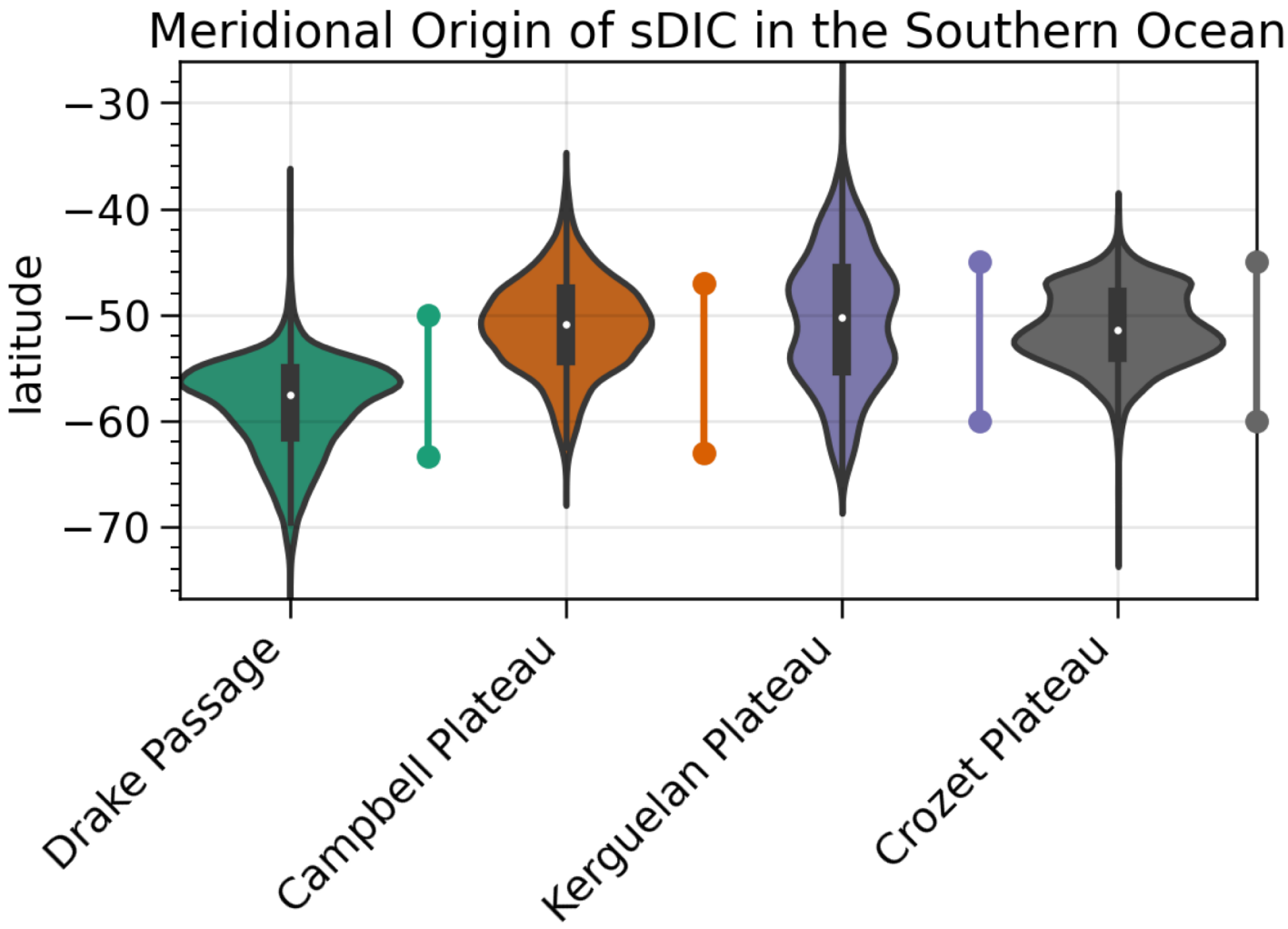
The zonal and meridional range of source waters varies for each region.



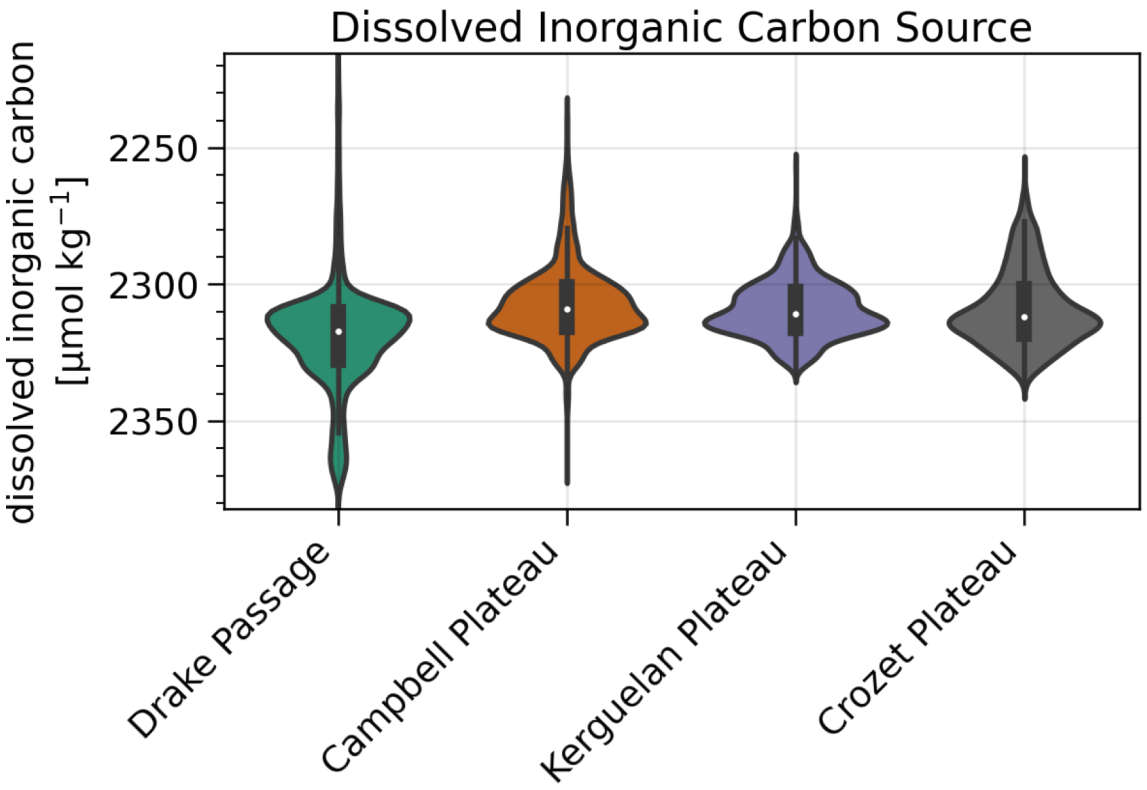
The Drake Passage and Campbell Plateau are fueled by the most zonally distant waters.

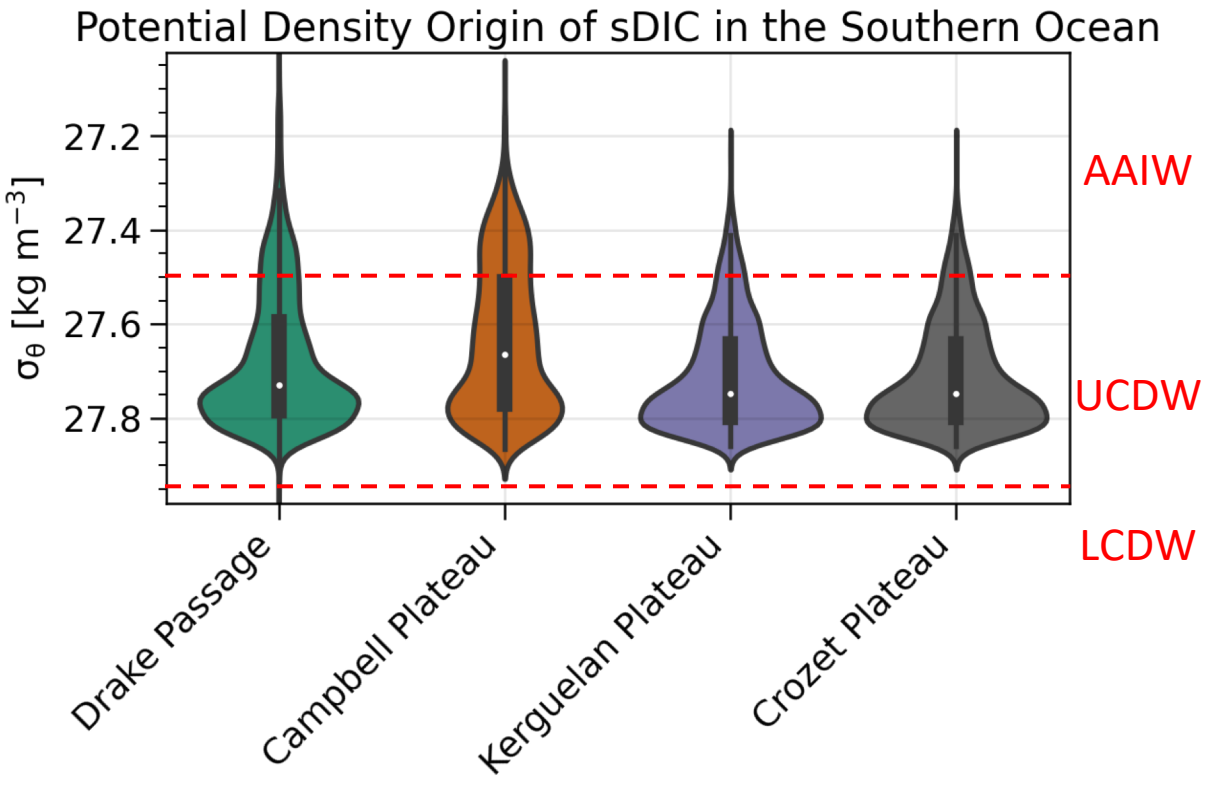


The Kerguelan Plateau sources carbon from a large range of latitudes.

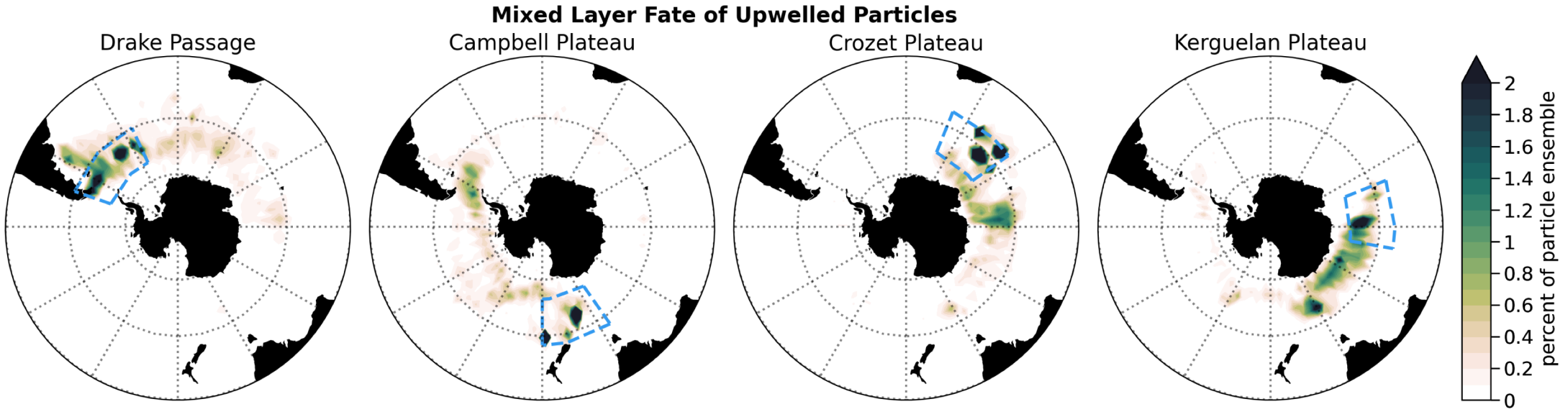


Regions have variable source carbon contents despite drawing from similar water masses.



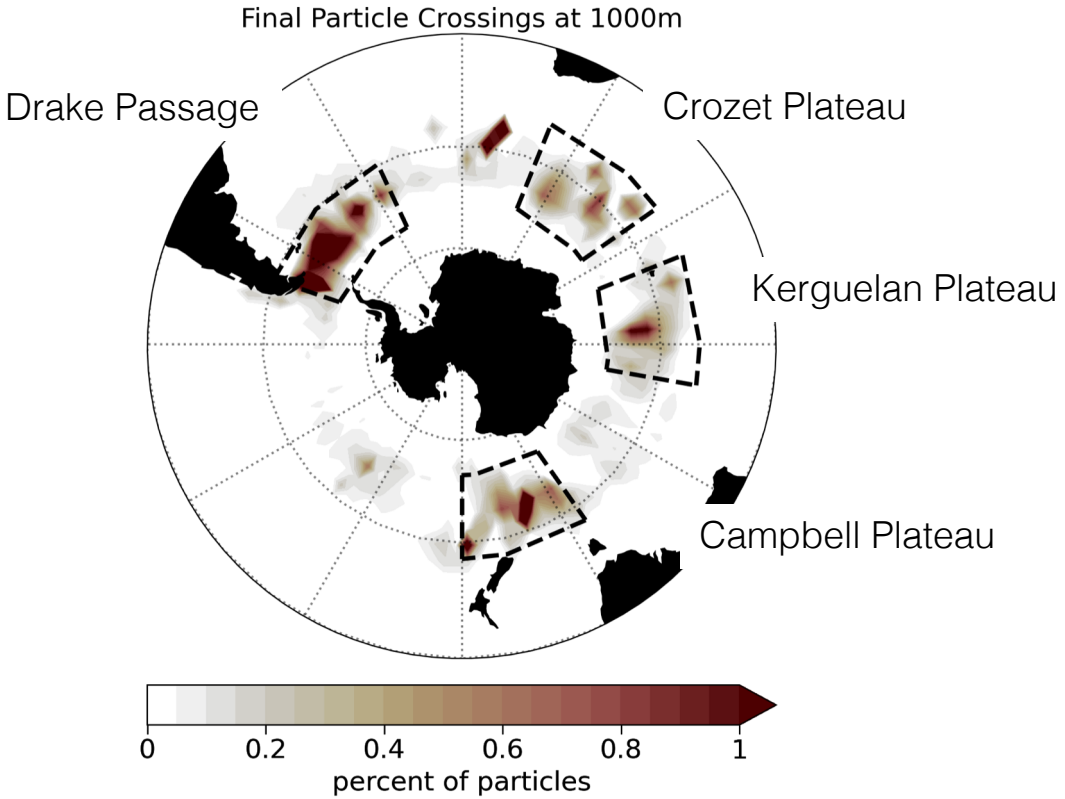


Deep waters upwelling in one region have a mixed layer influence on downstream regions.



Summary

We use a high-resolution Eulerian-Lagrangian simulation to identify hotspots of upwelling in the Southern Ocean.



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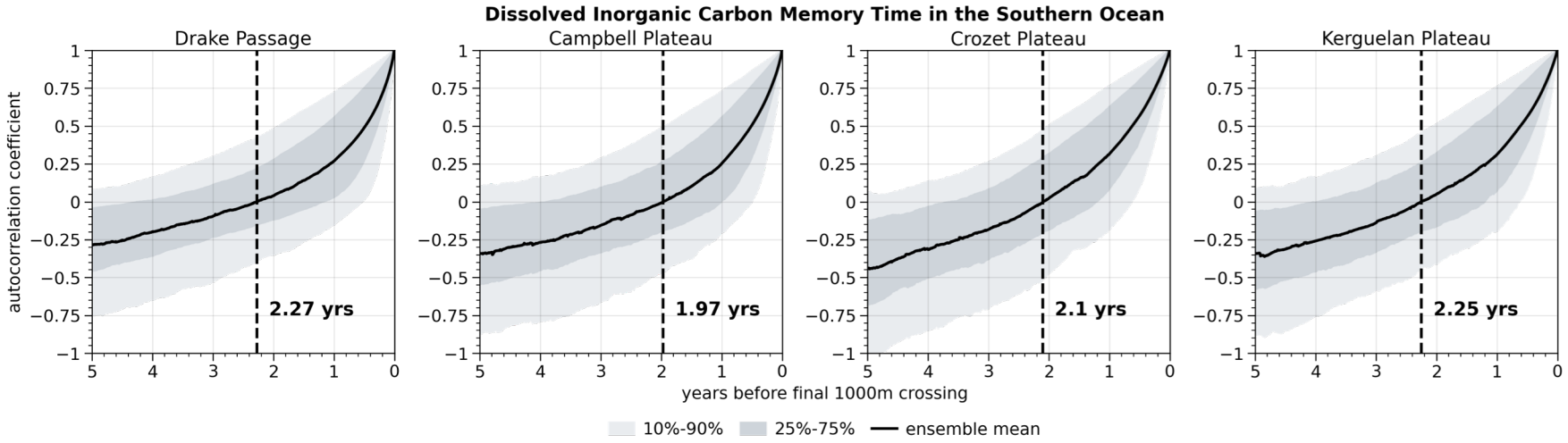

Summary

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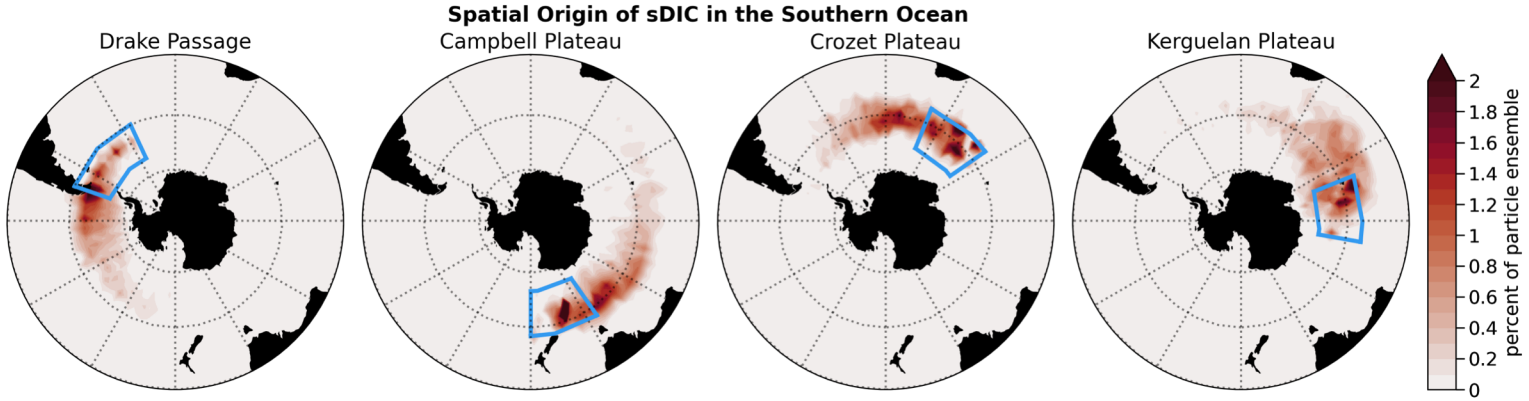
We identify the memory time of DIC in these regions to range from 2.0 – 2.3 years.

We further investigate the origin of DIC for these regions.



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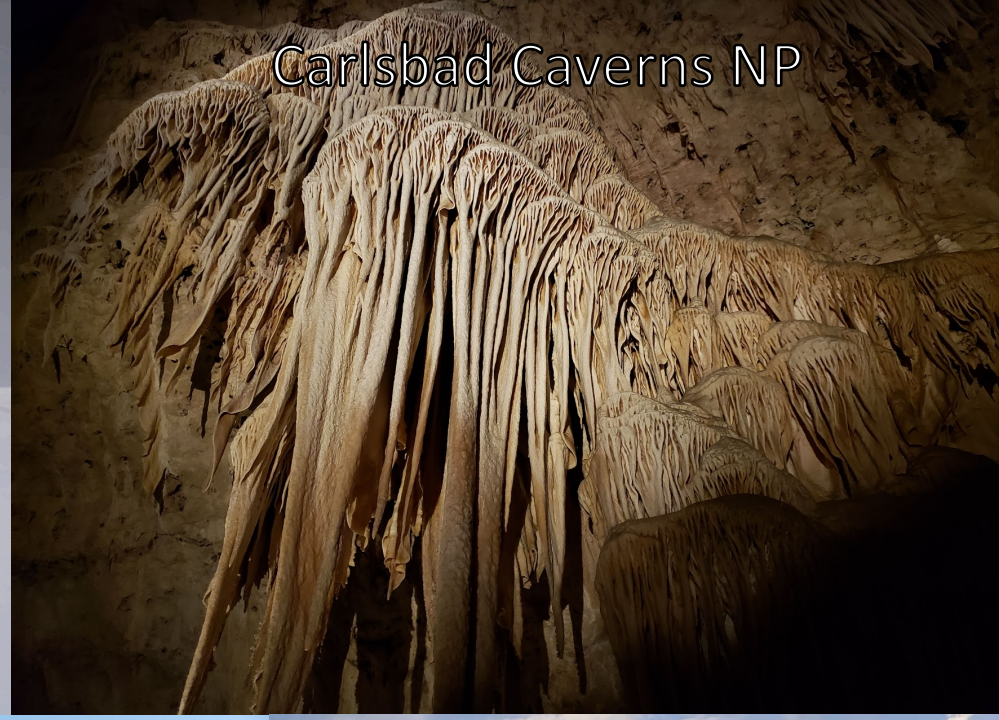
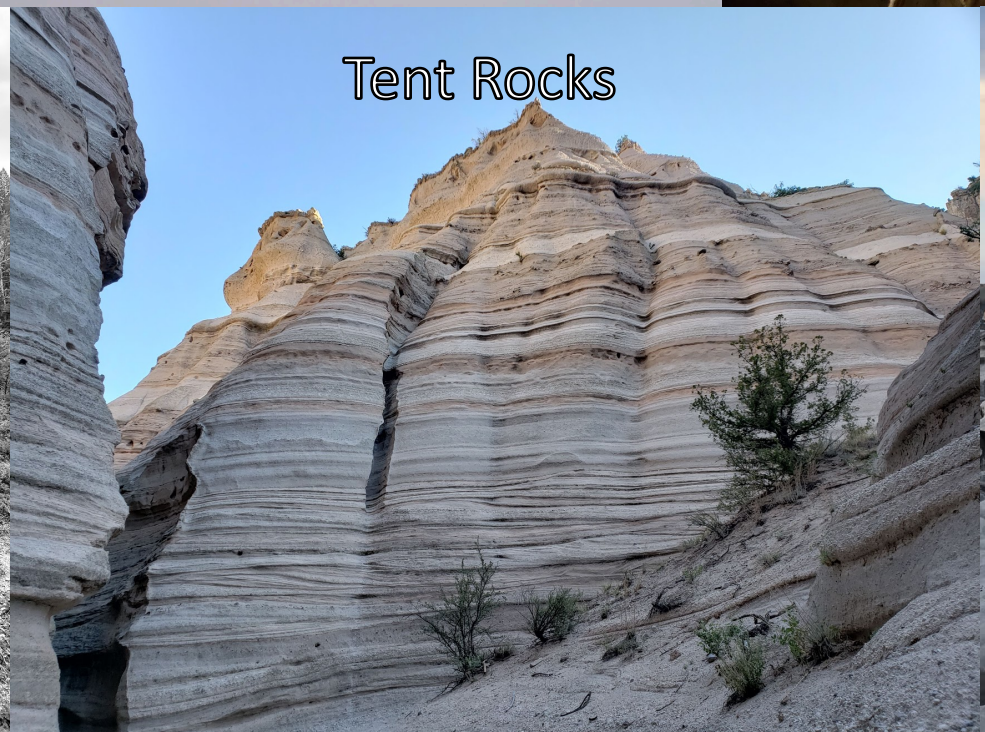
5. New Mexico is a hidden gem.


Chaco Canyon NHS


White Sands NP


Carlsbad Caverns NP


Cloudcroft, NM


Tent Rocks


Bisti Badlands