3–D transport pathways of climatically important tracers in the Southern Ocean

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Motivation

The subduction of water masses, i.e. bottom water, mode water and intermediate water, is central to the sequestration and global redistribution of heat, carbon dioxide and other tracers[1][2].
The Southern Ocean has been identified as a key region for such subduction and in this study our aim is to identify export pathways of water masses from the Antarctic Circumpolar Current (ACC) into the subtropical gyres, using particle trajectories advected by the Southern Ocean State Estimate (SOSE). SOSE is an estimate of the time-evolving ocean circulation obtained through assimilation of observations into an ocean model.

Method

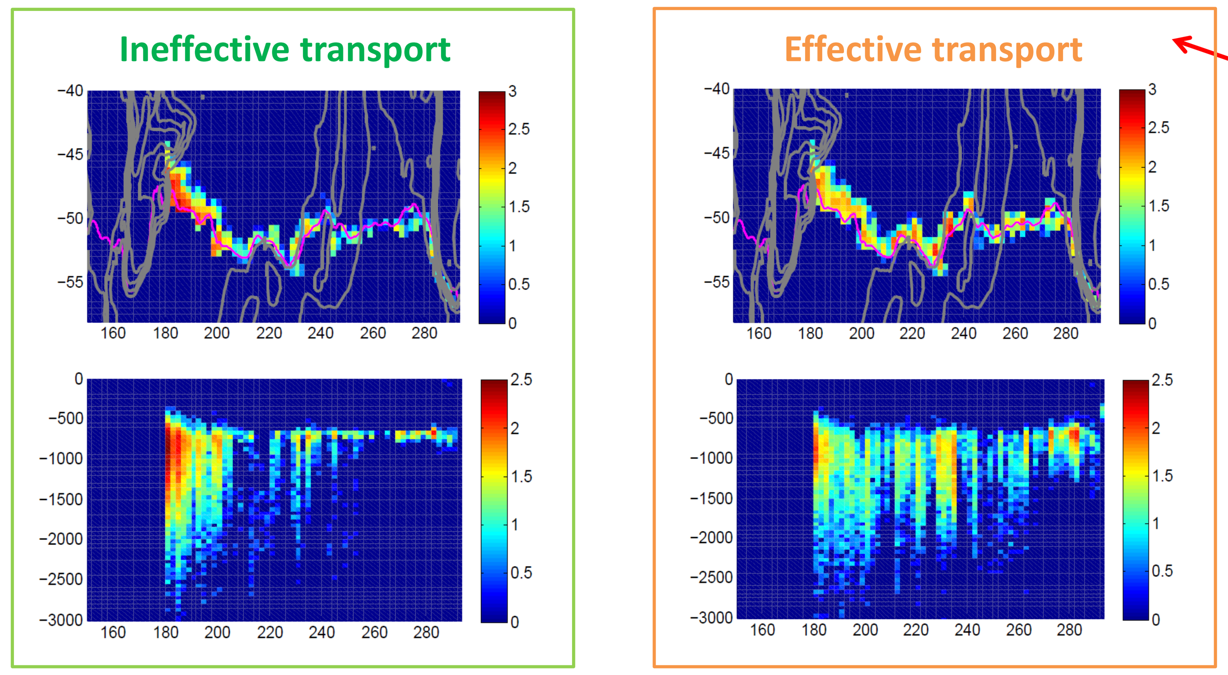
- Lagrangian particles advected in an annually repeating 3D velocity field from SOSE (2010) for 20 years
- 1/6 degree horizontal resolution
- 42 levels (varying thickness)
- MITgcm flt package with 2nd order Runge-Kutta integration scheme for the particle advection

Simulation

- 170 000 Lagrangian particles in the ACC
- Initialised at 700m (below mixed layer)
- Uniformly distributed in the horizontal plane
- Northern boundary of the ACC defined by the mean position of the northernmost SSH passing through Drake Passage

Results – Effective transport from the ACC

Fig. 1 Regions of the particles' last crossing of the ACC on their way to the Pacific, Atlantic and Indian Oceans – effective transport from the ACC.
Left: Blue dots show the hot spots for the effective transport.
Below: Comparison of the effective transport (last crossing) and ineffective transport (first crossing of the ACC with a possibility of going back to the ACC) for particles found in the Pacific sector (North of the ACC) at the end of the simulation.



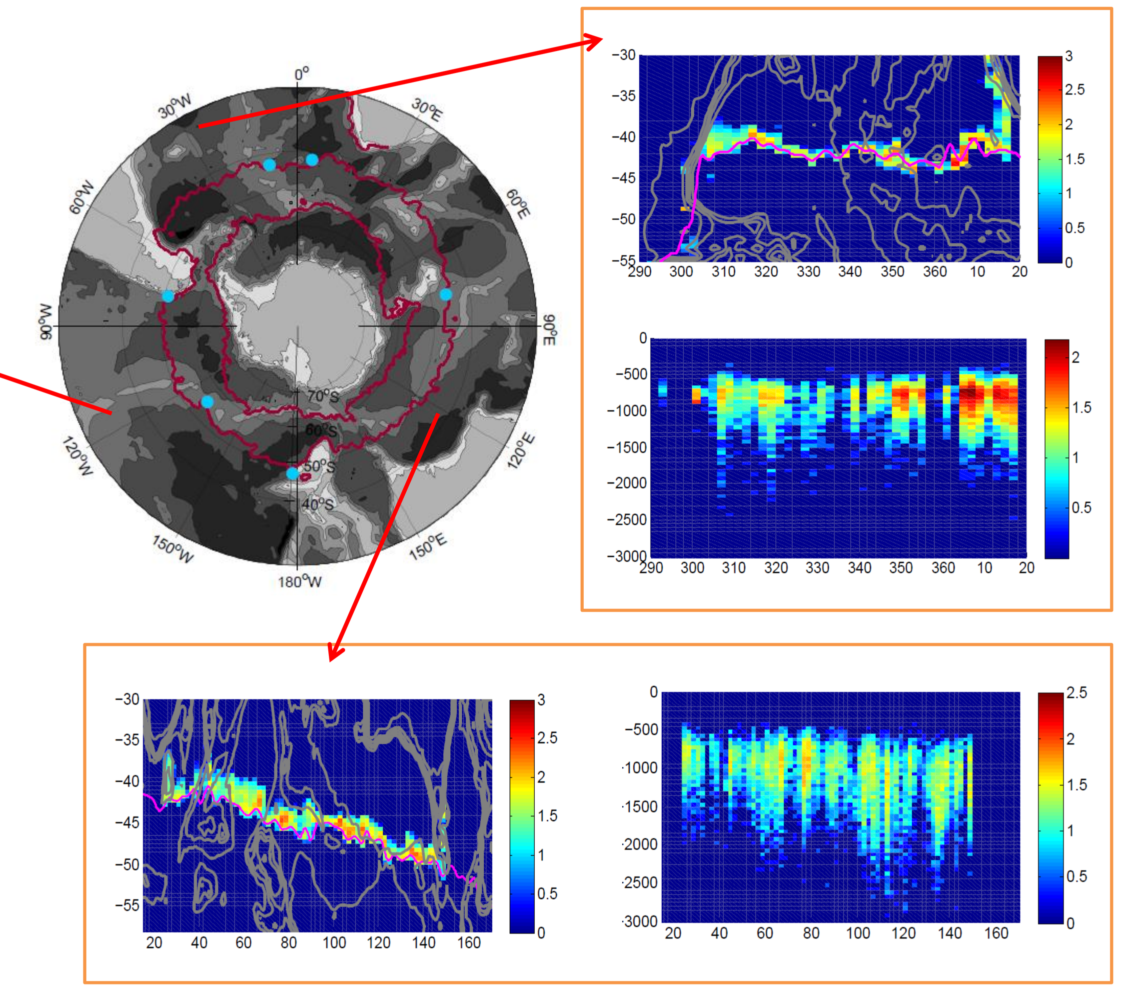
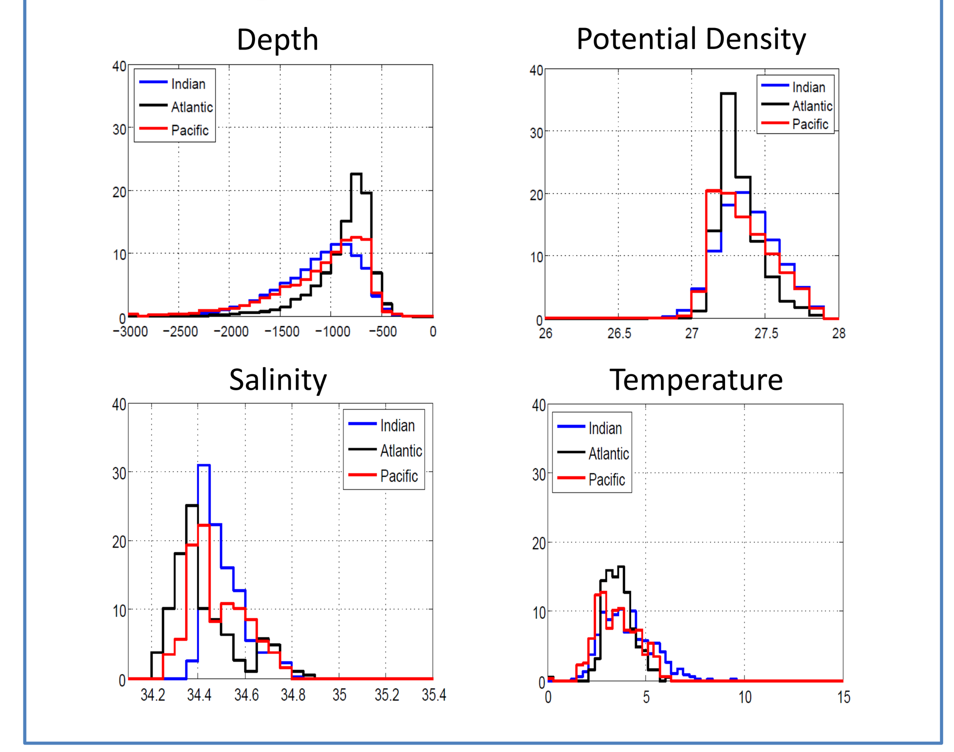
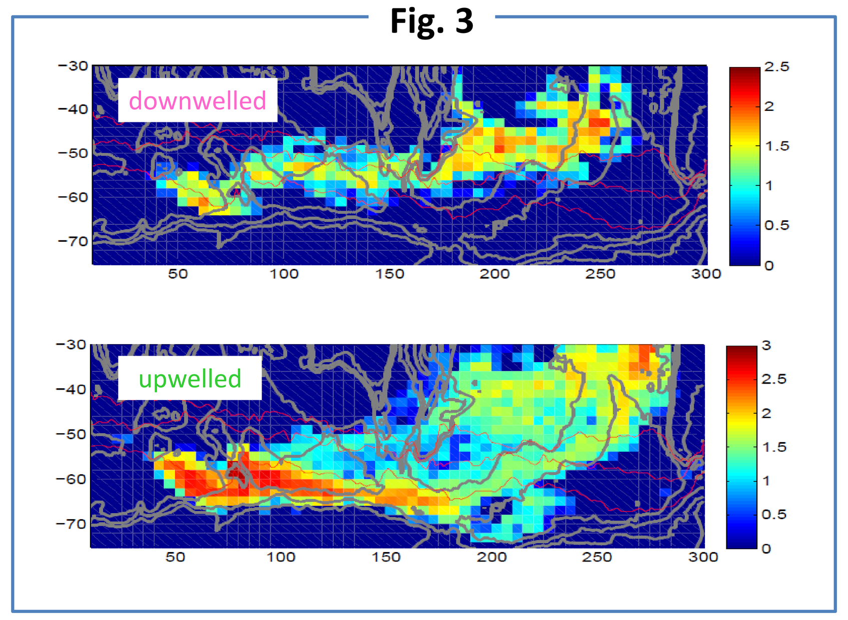


Fig. 2 Distribution of depth, potential density, salinity and temperature at the crossing regions for all three basins: Pacific, Atlantic and Indian Oceans. The majority of particles are exported in the SAMW and AAIW depth ranges (~200-1000m; 26.5-27.4 kg m^{-3} [3][4]).



Results – Pathways from (30°-60°)E (55°-65°)S to the Pacific

Fig. 3



Particles initialised at (30°-60°)E (55°-65°)S which end in the Pacific

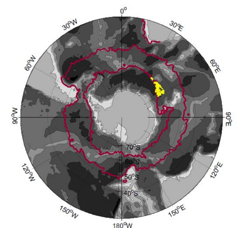
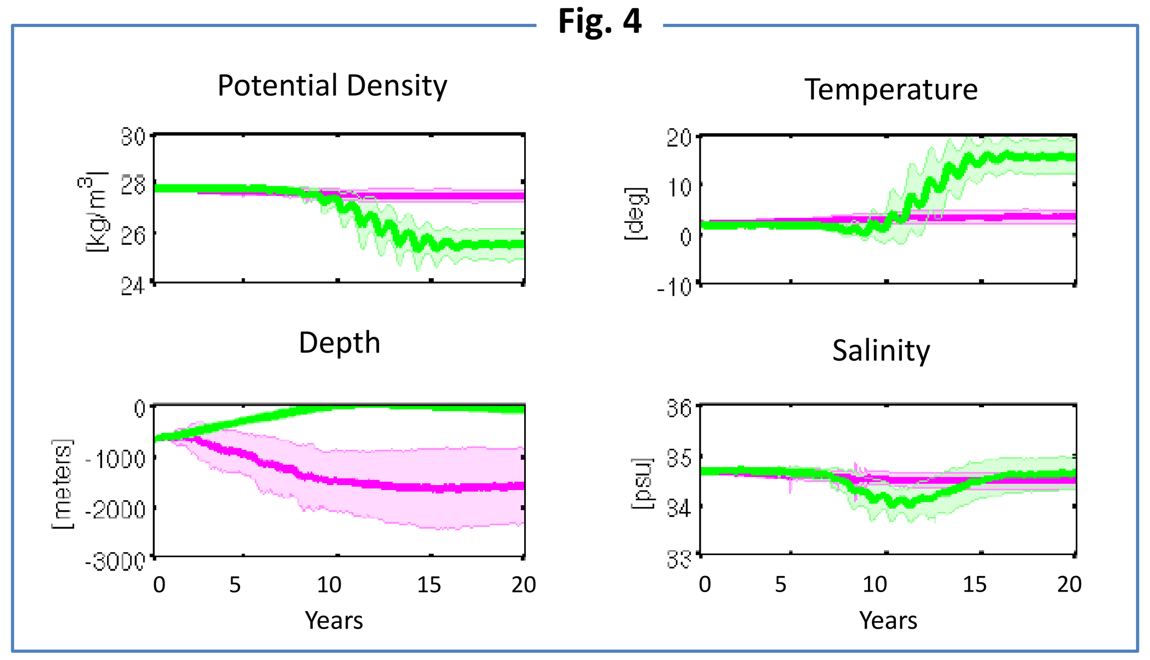


Fig. 3 Left: 20-year visitation measure – a relative amount of time over 20 years during which a bin (3°x1°) has been visited by particles in the chosen ensemble. Regions in red show the most visited regions (log scale).

Fig. 4 Right: Shows the time series of the mean values (solid lines) with standard deviation (shade) for temperature, salinity, potential density and depth. Anomalous salinity values were removed. Downwelled particles are shown in pink and upwelled in green.

Fig. 4



References

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Conclusions

- The trajectory calculations have shown that effective transport from the ACC into the ocean basins is concentrated into localised regions. Further analysis is needed to understand what processes influence the transport in these regions and to identify the pathways.
- Particles initialised at (30°-60°)E (55°-65°)S that end in the Pacific Ocean follow two distinct routes influenced by different processes. The downwelled particles cross the ACC fronts at distinct points associated with Kerguelen and Campbell plateaus, suggesting internal mixing/stirring, while the upwelled particles follow a broader path after leaving the ACC interior indicative of Ekman style processes. This interpretation of the vertical circulation is supported by the particles' different ranges in temperature, salinity, density and depth shown in fig. 4.
- Further integrations for different particle ensembles, both using SOSE and output from a high-resolution ocean model, will be utilised to identify and quantify the key transport pathways and the processes enabling these pathways in the 3-D Southern Ocean circulation.