



The North Atlantic's mild climate has nurtured succeeding civilisations, but what dictates the flow of the all-important Gulf Stream in delivering what for centuries has been a benign environment for life in this part of the world? Associate Professor Matthew England is an oceanographer and climate scientist who, together with PhD student Willem Sijp and the rest of his research team, has been using global climate models to solve some of the planet's more persistent climate riddles.

"The Gulf Stream's climate dominance over Europe relies on events some 30 million years ago, when Antarctica started to freeze following the final break-up of Gondwana, the great southern continent. As the great land masses of what are now South America, Australia, India, Africa and Antarctica drifted apart, Antarctica became isolated by the Southern Ocean which surrounds it. When you arrange the land masses to match past climate states in a model, you can see the role they played in the climate system by leaving Antarctica isolated to the south," said Matthew England.

Density-driven or thermohaline circulation (THC) is central to climate research. As opposed to wind-driven currents and tides, THC is that part of ocean circulation that's driven by density differences in seawater. These density differences are determined by temperature (thermo) and salinity (haline), with the densest seawater being cold and salty. At polar regions, evaporation, ice formation and heat loss to the atmosphere cause seawater to become extremely dense. The present-day THC has deep dense water forming in the North Atlantic and off the Antarctic continent. The production of these water masses plays a key role in moderating the world's climate because as the dense water 'sinks', it draws in warmer water from the tropics, driving a global overturning circulation.

"With Antarctica so much colder than the North Atlantic, the southern polar waters should dominate this process. But we found that the very strong east-west current that circles the Southern Ocean effectively isolates Antarctica. In doing

the Norwegian and Greenland Seas, to replace the sinking water. In doing so, the Gulf Stream pushes a lot of heat towards Europe. Without North Atlantic Deep Water sinking, the heat would stop moving towards Europe in such vast quantities, and the Gulf Stream would simply recirculate over a smaller area – making Europe a much colder place.

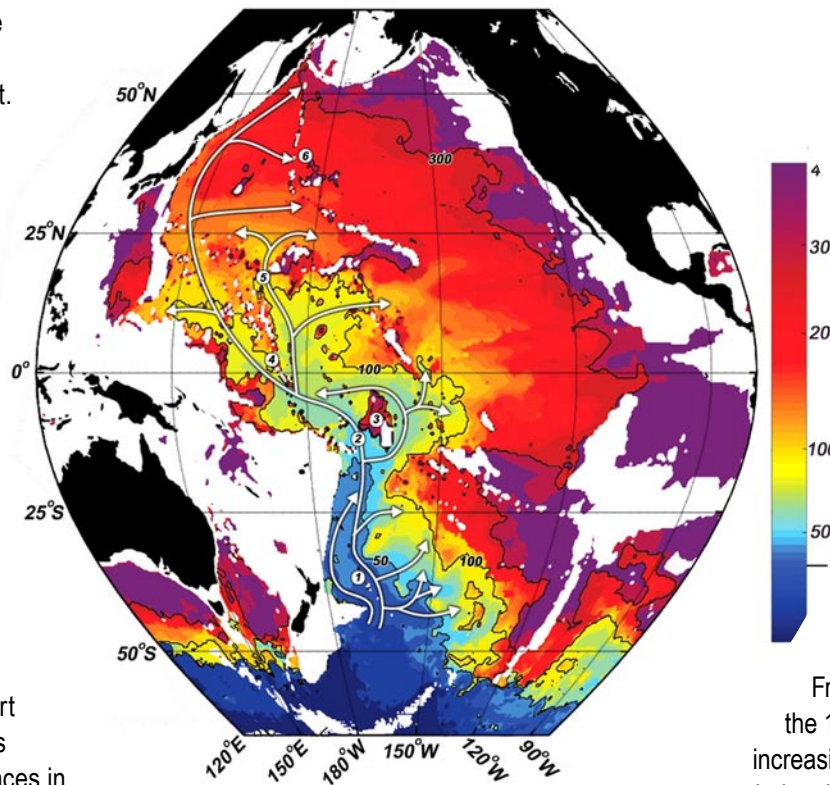
"The work we've done in establishing a connection between the Southern Ocean and the North Atlantic has implications for interpreting past climates. The fact that the Southern

Ocean controls the North Atlantic also plays a big role in either limiting or exacerbating climate change, as increasing greenhouse gases will undoubtedly alter water-mass properties in these two regions. The coming decade is an important time for global ocean research."

Matthew England was the first oceanographer to use chlorofluorocarbons (CFCs) to assess global climate models, resulting in last year's Australian Academy of Sciences

Frederick White Prize. "Since the 1930s, CFCs have been increasing in the atmosphere due to our industrial production of these gases. They are absorbed by the ocean in small but detectable quantities, from where they are overturned in deep-ocean sinking. This provides a uniquely clear view of the movement of these water masses, and a new stringent benchmark against which to test climate models."

## The climate trail



so, the circumpolar current significantly reduces the capacity of the Antarctic oceans to draw warm tropical waters southward. It's a little counterintuitive: even though Antarctica has the densest surface waters, it has a comparatively weak rate of overturning. This is what contributes to Antarctica's glacial climate.

"This reduced overturning of Antarctic Bottom Water allows 'sinking' in the North Atlantic to dominate in drawing warm water away from the tropics. This occurs as the balmy Gulf Stream flows up past Florida and eventually towards

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