Met Office

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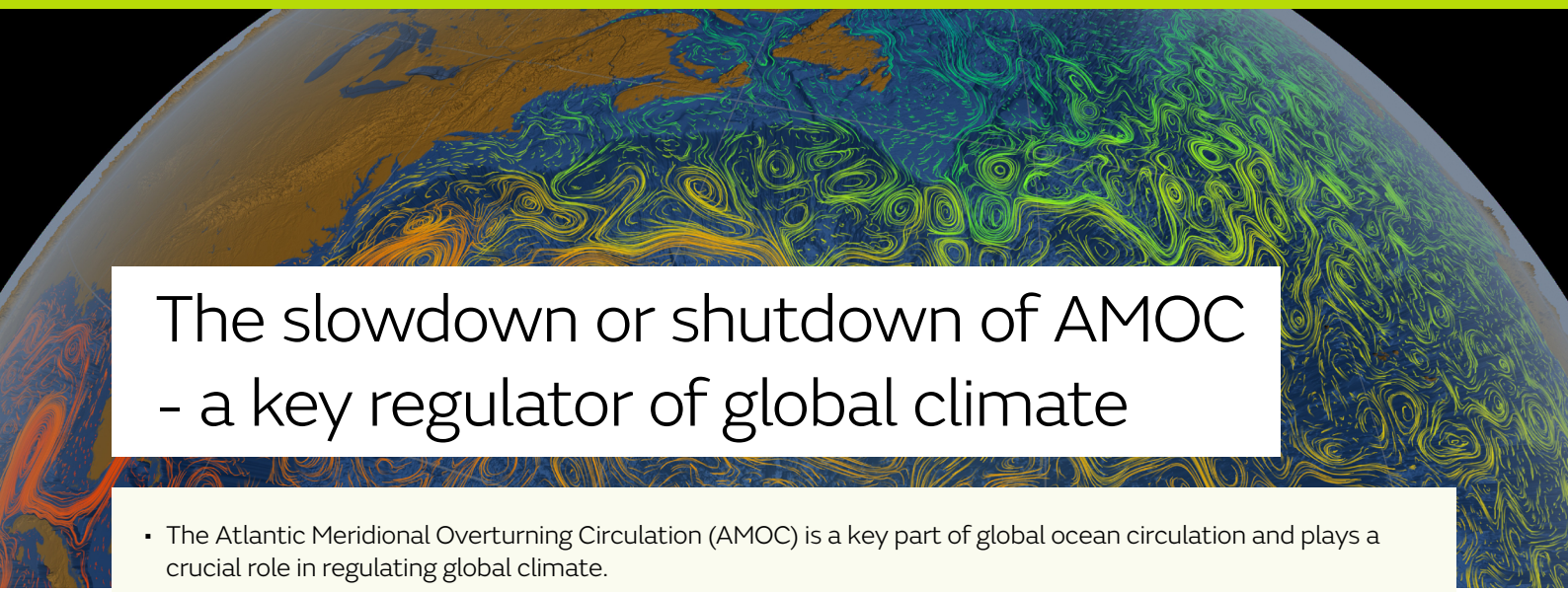
Met Office Hadley Centre Climate Briefing Note



The slowdown or shutdown of AMOC - a key regulator of global climate

- The Atlantic Meridional Overturning Circulation (AMOC) is a key part of global ocean circulation and plays a crucial role in regulating global climate.
- Over the 21st Century climate change will very likely weaken the AMOC, but a shutdown in the 21st Century is very unlikely - though still plausible.
- Understanding more about AMOC shutdown 'tipping points' could enable early warning, giving time to take action.
- Recent advances in monitoring and modelling are enabling more confident projections of future changes in the AMOC.

What is the AMOC & why is it important?

The 'Atlantic Meridional Overturning Circulation' (AMOC for short) is one of the main current systems of the global ocean circulation (Figure 1). It plays a crucial role in regulating global climate by transporting heat from the tropics northwards in the Atlantic, keeping Europe much warmer than it would be otherwise. If the AMOC slowed or stopped completely it would have widespread impacts[1], including substantial cooling of the Northern Hemisphere. There would also be large changes in tropical rainfall, increases in winter storms over Europe, and sea level around the North Atlantic basin could rise by up to half-a-metre more (on top of the sea level rise expected from other factors caused by global warming).

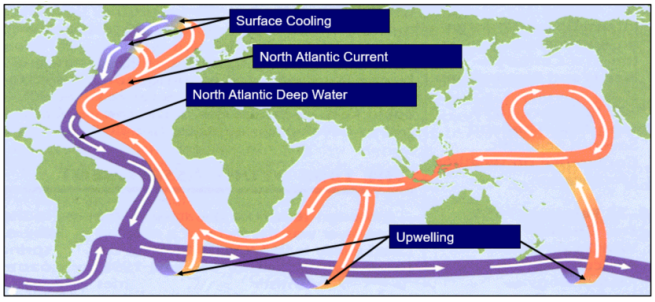


Figure 1: An illustration of the AMOC and its place within large-scale global ocean circulation.

How might global warming affect the AMOC?

The AMOC is vulnerable to climate change because it is driven by differences in temperature and salinity (the salt content of the water), both of which will be affected by climate change. Climate model projections of the 21st Century consistently point to a weakening of the AMOC, as the warming atmosphere makes it harder for the North Atlantic to lose heat from its surface. The most recent assessment of the Intergovernmental Panel on Climate Change (IPCC) in its Special Report on the Oceans, Cryosphere and Climate Change (SROCC) concluded the AMOC is very likely to weaken over the 21st Century. A slowdown would have a cooling effect around the North Atlantic region. However we expect that this effect would be smaller than the warming from greenhouse gases, leading to a reduced warming around the North Atlantic. Even more dramatic changes are theoretically possible as there may be a 'tipping point' beyond which the current strong AMOC becomes unsustainable. Furthermore, it's possible that if the AMOC were to shutdown it may not be able to recover.

[1] Jackson et al (2015), Climate Dynamics, Global and European climate impacts of a slowdown of the AMOC in a high resolution GCM

What is the likelihood of a shutdown?

A shutdown in the 21st Century is considered very unlikely (though plausible). The likelihood increases beyond 2100, at least for higher emissions scenarios (see IPCC SROCCC report). Climate model projections of the future of the AMOC range widely, and therefore climate scientists see understanding more about the potential future risks to this important system as a key priority.

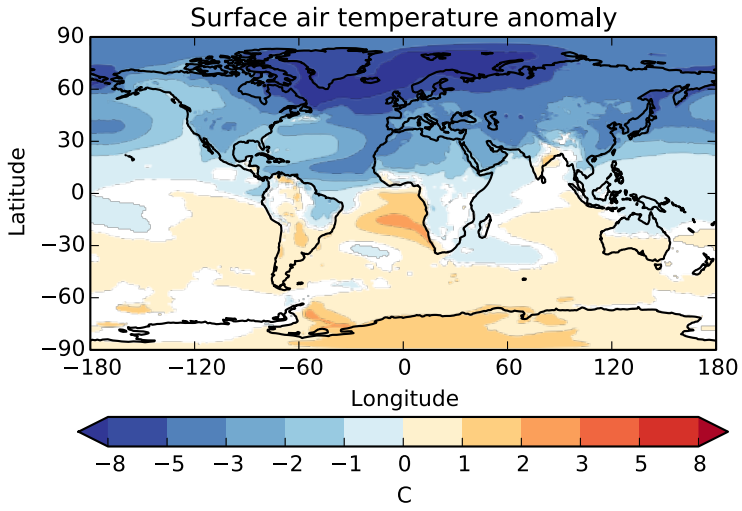


Figure 2: Shows the modelled change in surface temperature following an artificially-induced collapse of the AMOC in the Met Office climate model HadGEM3-GC2. This is an estimate of what the climate would be like if the AMOC were not there. It shows strong cooling around the North Atlantic, with warming in some parts of the Southern Hemisphere. Such an AMOC collapse is considered very unlikely in the 21st Century, but if it were to occur the cooling might more than counteract the warming effect of greenhouse gases leading to net cooling over parts of Europe and North America. A much more likely scenario is that the AMOC will weaken during the 21st Century, resulting in less warming around the North Atlantic than in some other parts of the world, but increasing precipitation changes and sea level rise in some regions. These milder effects of AMOC weakening are included in current model projections of climate change.

Can the AMOC be restarted if it does shut down?

It is thought that the AMOC may also exist in a collapsed state with very weak circulation. As long as the climate change we see is small or gradual enough, research suggests the current 'AMOC on' state will persist. A large or rapid climate change, however, might tip the AMOC to a collapsed state. In this case even by reversing the climate change we've seen, it may not be possible to restart the AMOC – a phenomenon known as 'hysteresis'.

Can we provide early warning of any shutdown or slowdown?

Because of the complexities of the modelling, climate scientists are currently not able to confidently define a level of global warming at which the AMOC would be at risk of crossing a tipping point. However it may be possible to manage the risk of AMOC collapse by developing an early warning system which could warn of an impending collapse.

Since 2004, the AMOC has been subject to monitoring which has helped to reveal more about its behaviour. Decadal prediction systems can also give insight as to how the AMOC and wider climate system may evolve in the near future. Research is also helping to identify possible thresholds in the way the AMOC operates that could be monitored to provide early warning that a tipping point was being approached[2].

In parallel with this research we are using the latest generation of CMIP6 climate models, which include improved simulation of many climate processes compared to the previous CMIP5 models, to understand how long we would have to respond to an early warning[3,4]. A response could either be restoring the climate system to a safer state for the AMOC before collapse became inevitable, or by preparing for the impacts before the collapse was complete.

Observing the AMOC

The RAPID-MOCHA system is a series of moorings across the Atlantic around the latitude of the Bahamas and the Canary Islands. In place since 2004, it has been monitoring the strength and structure of the AMOC. Recently this has been joined by a similar system called, O-SNAP, which has moorings between Canada, Greenland and Scotland – providing additional information on the behaviour of this vital ocean current.

[2] Alkhayuon et al (2019), Proc. Roy. Soc. A, Basin bifurcations, oscillatory instability and rate-induced thresholds for Atlantic meridional overturning circulation in a global oceanic box model

[3] Jackson and Wood (2017), Climate Dyn, Timescales of AMOC decline in response to fresh water forcing

[4] Jackson and Wood (2018), Geophys. Res. Lett, Stability of the Atlantic Meridional Overturning Circulation: A Review and Synthesis