Shutdown of the great water conveyor belt? – Possible future changes in the Atlantic Meridional Overturning Circulation

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The Atlantic Meridional Overturning Circulation (AMOC) is a large-scale ocean circulation in the Atlantic: Warm waters flow northward at the surface – part of which is known as the Gulf Stream – cool and hence become denser, sink, and flow southward at depth. This circulation (Fig. 1) brings heat from the equator to higher latitudes, and its shutdown would have dramatic consequences for our climate in Europe and worldwide[1].

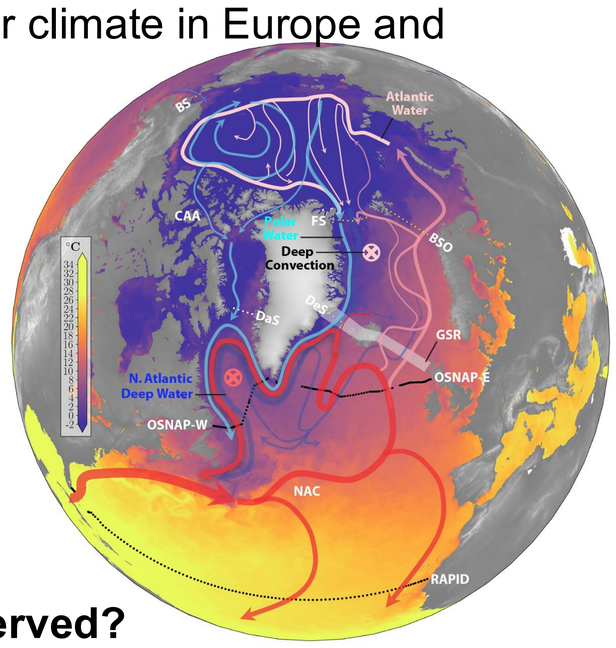

*Fig. 1: Schematic of currents constituting the AMOC, where red lines are warm surface currents and blue lines are cold currents at depth. B*Background color shows temperature.[2]

How can the AMOC be observed?

- The flow is monitored by three major mooring arrays: The RAPID-MOCHA at 26.5°N measuring since 2004 and OSNAP array two arrays around 59°N since 2014 (Fig. 2).
- Moorings are ropes anchored to the seafloor, carrying instruments that measure e.g. current strength, temperature and salinity, with a floating buoy at the top. From this data, oceanographers can calculate the volume transport through the mooring arrays.
- During the 20 years of measurements from the RAPID array, the AMOC has weakened by about 2.5 Sv after the first four years but has been steady since.[2,4] On long timescales, the observed mean transport had a value of about 17 Sv (=17.106 m^3/s) across all latitudes.[4]

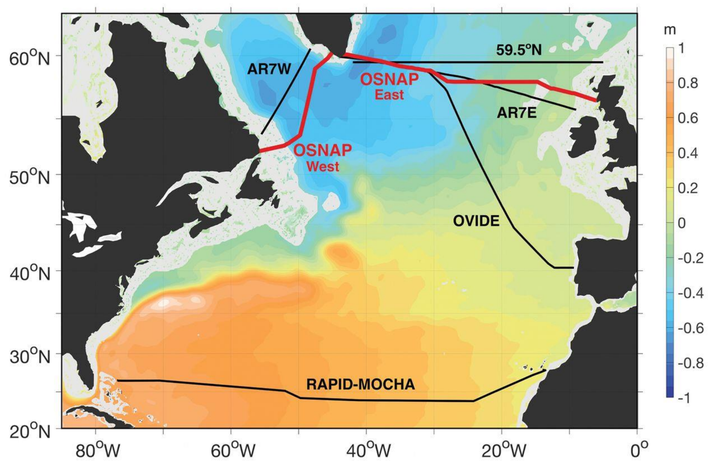

Fig. 2: Observational efforts monitoring the AMOC. Background color shows absolute dynamic height (surface height compared to reference).[3]

Typical model experiments

- Model experiments examining AMOC impact on future climate often add freshwater to the North Atlantic to simulate the effects of a weakened AMOC.[5, 6]
- Adding fresh water stimulates ice melting, makes the water lighter and inhibits the formation of deep water, thus reducing AMOC circulation.
- They first run a preindustrial control simulation to represent typical past AMOC conditions for comparison.[5, 6]
- Then, simulations with freshwater forcing to show the effects of a weakened AMOC are conducted.[5, 6]

Consequences for European Climate

- In Europe, a weakened AMOC results in reduced temperature, less precipitation, more snow cover, and higher albedo.[5]
- There will be more storms resulting in locally higher winter rainfall, whereas summer precipitation decreases in northern Europe and increases in southern Europe.[5]
- A weakened AMOC intensifies the meridional temperature gradient, which can strengthen the jet stream.[5]
- The stability of the jet stream can lead to less variability in weather patterns.[5]
- The frequency of extreme cold spells in Europe may therefore decline, even though the overall temperature decreases.[5]

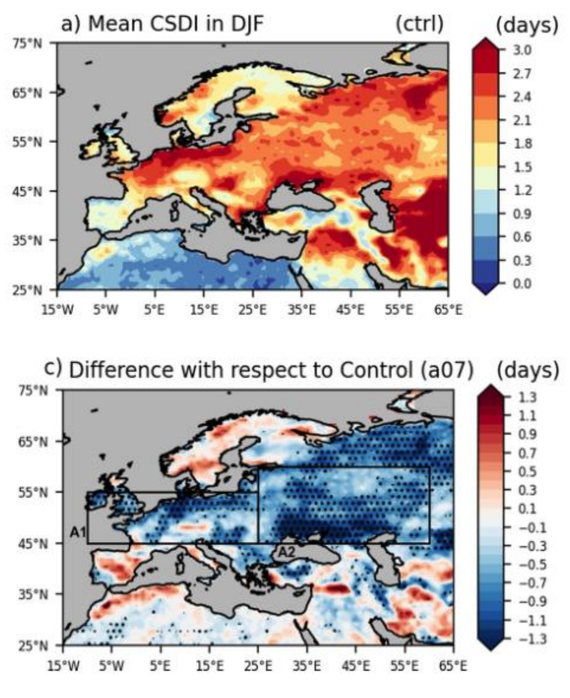

Fig. 3: Cold spell duration for boreal winter (DJF). (a) shows the ensemble mean of the mean number of days per boreal winter (DJF) belonging to a cold spell in control experiments (mean AMOC ≈ 17.5 Sv). (c) shows the differences to the control run, corresponding strong (≈ 7 Sv) AMOC reductions. Dots in (c) indicate regions where more than 75% of ensemble members have the same sign of difference as the ensemble mean.[5]

Future outlook

- The AMOC will likely be reduced in the future, but there is great uncertainty about how much. This creates uncertainty about the severity of the consequences.[5, 6]
- A weaker AMOC leads to a stronger and more stable jet stream over the Northern Hemisphere while the opposite happens in the Southern Hemisphere.[7]
- Changes in ocean temperatures and salinity can lead to disruptions in marine ecosystems.[7]
- Changes in precipitation patterns can severely impact crop yields and water supply.[7]
- Cities along the U.S. East Coast may face greater threats from rising sea levels and storm surges.[7]
- Arctic sea ice could see a vast expansion, while Antarctic sea ice may gradually retreat.[7]

Conclusions

- The AMOC is an integral part of our climate system, keeping climate in Northern Europe pleasant
- During the two decades that it has been directly observed, the AMOC was remarkably stable.
- If in a future climate, AMOC stability is violated, this might have severe consequences for our climate in Europe and worldwide.

References
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