What is the thermohaline circulation?

There are three main processes that make the oceans circulate: tidal forces, wind stress, and density differences. The density of sea water is controlled by its temperature (thermo) and its salinity (haline), and the circulation driven by density differences is thus called the thermohaline circulation. The animation and list below describes the key features of the global-scale thermohaline circulation.

1. The Gulf Stream (and its extension, the North Atlantic Drift) bring warm, salty water to the NE Atlantic, warming western Europe.
2. The water cools, mixes with cold water coming from the Arctic Ocean, and becomes so dense that it sinks, both to the south and east of Greenland.
3. If we zoom out, we see that this current is part of a larger system, connecting the North Atlantic...
4. ...the tropical Atlantic...
5. ...the South Atlantic...
6. ...the Indian and Pacific Oceans...
7. ...and the Southern Ocean. Further sinking of dense water occurs near to Antarctica.

8. If we look below the surface, water from the two main sinking regions spreads out in the subsurface ocean...
9. ...affecting almost all the world's oceans at depths from 1000m and below...
10. The cold, dense water gradually warms and returns to the surface, throughout the world's oceans.
11. The surface and subsurface currents, the sinking regions, and the return of water to the surface form a closed loop, the thermohaline circulation or global thermohaline conveyor belt
Will the thermohaline circulation collapse?

The critical part of the thermohaline circulation (THC) is the sinking in the North Atlantic Ocean. This occurs here (and not in the North Pacific) because the Atlantic is much more saline (and hence, denser). It is more saline because it is warmer (more evaporation of fresh water increases the salinity of the sea water). It is warmer in the North Atlantic because warm water is brought by the thermohaline circulation from the tropical and South Atlantic. To some extent, therefore, the THC appears to be self-sustaining. And if some event occurs to break this self-sustaining chain of processes, then there is the potential for the circulation to break down rapidly (i.e., over several decades) and to remain in a reduced-circulation state for several centuries.

Some fairly simple models of the world's oceans do simulate a rapid break down of the THC, when the density of the water in the North Atlantic Ocean is lowered by adding fresh water (rain) and/or by warming. Increased rainfall and warming over the North Atlantic are both expected as a result of increased greenhouse gas concentrations, and so it can be argued that global warming may cause a rapid collapse of the thermohaline circulation. The self-sustaining system described above is, however, much more complex in reality, and the more complete climate models, that take some of these complexities into account, generally simulate only a gradual weakening of the THC in response to global warming. Nevertheless, observations and palaeoclimate evidence both indicate that the THC has fluctuated both recently and in the distant past.

A recent intercomparison of changes in the North Atlantic THC simulated by a number of different General Circulation Models as a response to global warming (Gregory et al. 2005) showed that the THC weakens gradually in all of the climate models that were investigated, but it collapses in none of them.

The majority of climate scientists believe that a critical change in the THC is unlikely to occur during this century, but the question cannot be answered with certainty at present. Due to the potentially serious impact on our climate of a collapse of the THC, it must be regarded as a low-risk, high-impact event that cannot be ignored.

What would happen to our climate if the thermohaline circulation collapsed?

Due to the interactions between many components of the climate system, it is not a simple matter to estimate how different our climate would be without the current thermohaline circulation. Certainly the biggest impact would be on the temperature over the North Atlantic and Europe. The northern North Atlantic and NW Europe have annual temperatures that are about 9 degrees C above the average for their latitude, but this cannot all be attributed to the THC, since the wind driven ocean circulation helps to transport heat to these regions too. This represents an upper bound on the cooling that would occur following a collapse of the THC.

Simulations with a complex climate model (see figure below, figure from Wood, Vellinga and Thorpe(2003)), whose thermohaline circulation is artificially forced to collapse in the year 2050, show cooling of up to 12 degrees C north of Norway, and cooling of 1 to 3 degrees in the UK and Scandinavia. In Central Europe a warming due to the greenhouse effect dominates over the cooling due to the collapsed thermohaline circulation, and a slight net warming occurs. All areas away from the North Atlantic ocean show the warming effect of the enhanced greenhouse effect
In the unlikely event that the Atlantic thermohaline circulation were to completely stop due to the effects of greenhouse warming, therefore, most areas would still warm, but much of the North Atlantic, as well as the UK and parts of Scandinavia, might actually become colder than they were before global warming started.

There might also be a general decrease in precipitation over the northern hemisphere, with precipitation in high latitudes decreasing more strongly than any increases due to global warming (Vellinga and Wood, 2007).

**Change in annual temperature resulting from a combination of greenhouse warming and an artificially imposed collapse of the thermohaline circulation. The map shows differences in temperatures simulated for the 2050s and those that occurred prior to industrialisation (i.e. in those areas with values close to zero, the collapse of the thermohaline circulation has offset all of the warming due to increased greenhouse gases and has returned temperatures to their pre-industrial conditions)**

![THC collapse under GHG control](image-url)

*Figure courtesy of Michael Vellinga, UK MetOffice, published in Wood, Vellinga and Thorpe (2003).*

**Literature**
