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Guide to the Science of Climate Change in the 21st Century

Chapter 8
Global Circulation of Water in the Ocean

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8.1 Introduction

The oceans contain 97 per cent of the water on the Earth. They cover 70 per cent of the Earth's surface. They interact with and significantly impact the global circulation of the atmosphere. Oceans are very important elements in the energy budget, carbon cycle and hydrologic cycle. The oceans are slow to warm and to cool and store considerable energy and dissolved greenhouse gases such as carbon dioxide.

8.2 Ocean currents

Circulation of water in the oceans is the result of a complex system of continuous directed movements of seawater known as ocean currents. Ocean currents mix ocean water, transport nutrients and influence the climates in the regions in which they travel.

There are two types of ocean currents, surface water currents and deep-water currents. Surface water currents are driven by winds and tides. Deep water currents are driven by differences in water density resulting from differences in temperature and salinity and are known as thermohaline circulation.

The combination of several surface water currents which also experience warming and changes in salinity due to evaporation and deep-water currents connect the oceans of the world in what is known as the global ocean conveyor belt as shown in Figure 8.1. Surface currents are shown in red and deep currents are shown in blue. Another name for the global ocean conveyor belt is the meridional overturning circulation or MOC.

The dynamics of the global ocean conveyor belt are illustrated in Figure 8.2 which identifies the Atlantic portion in greater detail. Sea water is warmed and evaporated near the equator in the vicinity of the Gulf of Mexico and the Caribbean Islands (See Figure 8.3). The resulting water is warmer and more saline but still less dense than adjacent water and remains a surface stream. A portion of this water, the Gulf Stream, flows north. As it nears Greenland it is cooled by the local air mass and some freezes. The remaining water is cold and has a higher salinity. It becomes denser than the adjacent water mass and sinks to form the North Atlantic Deep-Water Current in a process known as deep water formation. The sinking water is replaced by the warm water of the Gulf Stream. The flow of the Gulf Stream is determined by the rate of deep-water formation. See videos.

A full circulation of the global ocean conveyor belt, Figure 8.4, takes approximately 1000 years to complete.

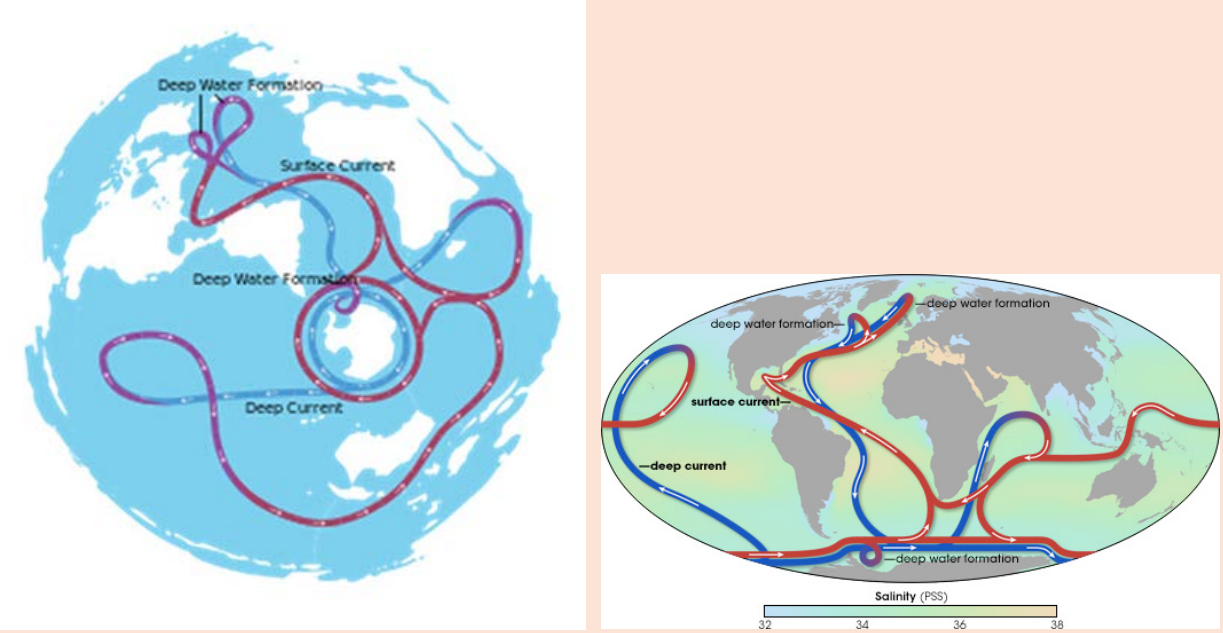

Figure 8.1 Two views of the thermohaline circulation or 'global ocean conveyor belt'.

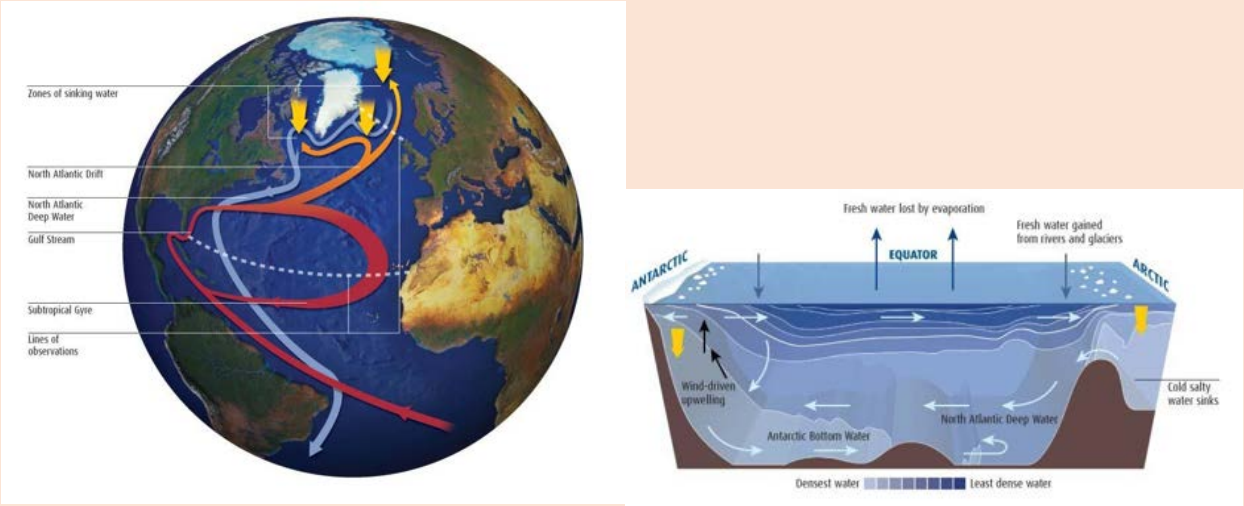

Figure 8.2 Atlantic portion of the global conveyor belt.

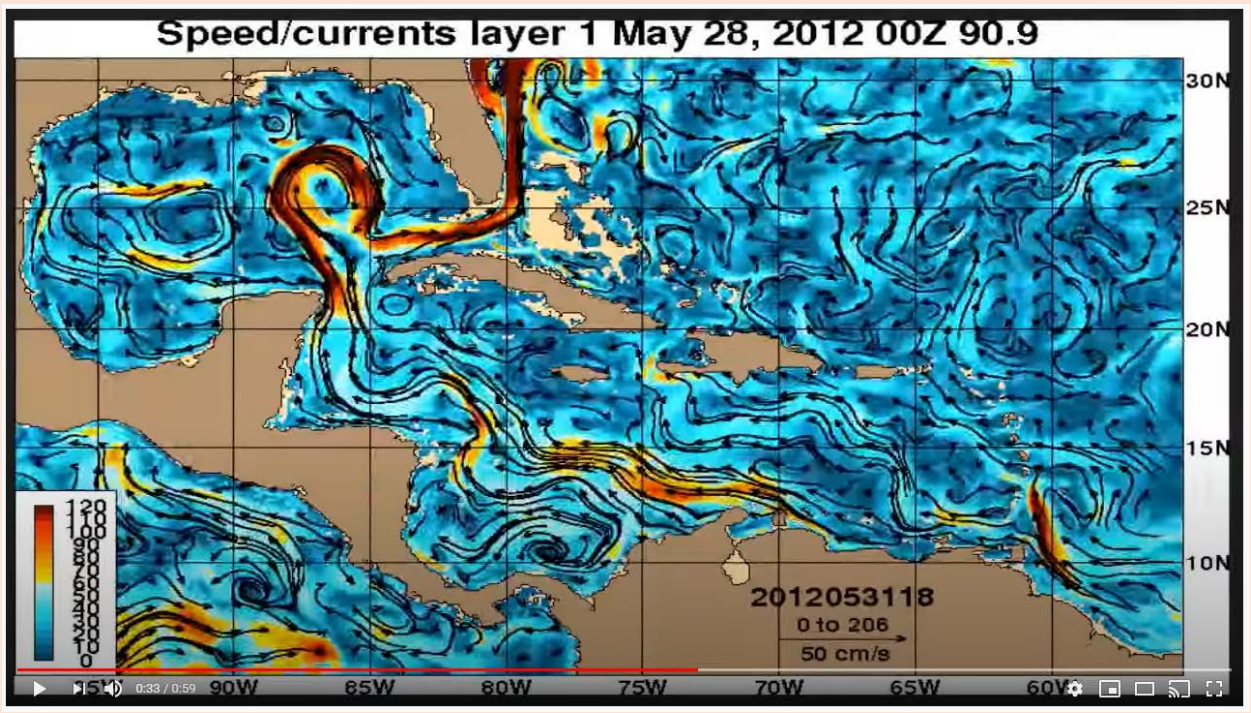

Figure 8.3 Ocean currents in the vicinity of the Gulf of Mexico and the Caribbean Islands.

Figure 8.4 illustrates global surface water ocean currents. Warm currents are shown in red and cold currents are shown in blue. The climate of regions adjacent to the currents will be significantly affected by their temperature.

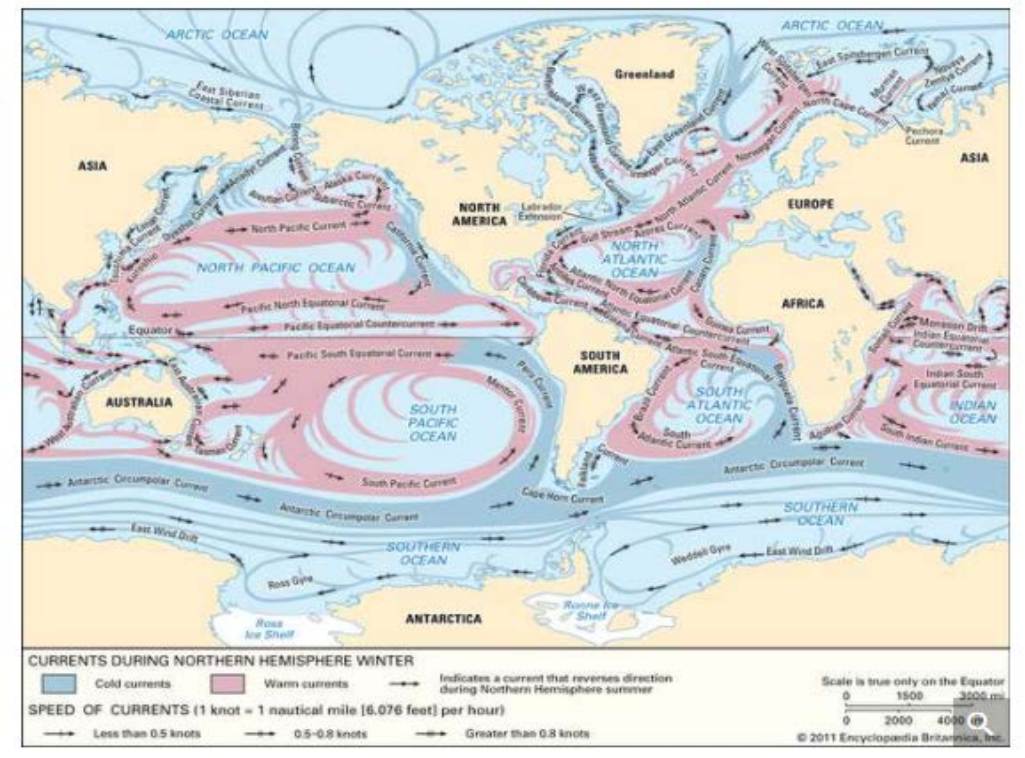

Figure 8.4 Global surface water ocean currents during northern hemisphere winter.

8.3 Gulf Stream

A very good description of the Gulf Stream may be found in https://scijinks.gov/gulf-stream/ . This web site is supported by NOAA and is provided as an educational resource. Excellent information on a variety of water, weather, climate related topics can be found using their search feature.

A recent study of the Gulf Stream and the larger Atlantic Ocean circulation known as the Atlantic Meridional Ocean Current or AMOC suggests that there is evidence (approximately 1500 years of proxy data) that the circulation is weakening https://www.pik-potsdam.de/en/news/latest-news/gulf-stream-system-at-its-weakest-in-over-a-millennium . A very good description of the AMOC, with animation, was recently published by the New York Times, https://www.nytimes.com/interactive/2021/03/02/climate/atlantic-ocean-climate-change.html?utm_campaign=Carbon%20Brief%20Daily%20Briefing&utm_content=20210303&utm_medium=email&utm_source=Revue%20Daily . The complexity of the circulation and how little is actually known about it is emphasized. It is suggested that the melting of the Greenland Ice Sheet is a likely cause for the weakening, if it is in fact weakening. A weakening AMOC would change the climate of northern Europe, cause warming of southern regions of the Atlantic with the result of drier conditions in the Sahel region of Africa and more frequent severe hurricanes. Because the AMOC is a large part of the 'ocean conveyor' the effects of its weakening would be global.

8.3 Information support

Key web sites:

1. Ocean currents. https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-currents

2. The global conveyor belt. https://oceanservice.noaa.gov/education/tutorial_currents/05conveyor2.html

3. Ocean current. https://en.wikipedia.org/wiki/Ocean_current

4. Surface currents in the Atlantic Ocean. https://oceancurrents.rsmas.miami.edu/atlantic/gulf-stream.html#:~:text=The%20Gulf%20Stream%20transports%20significant,%2Fs%20(5%20knots).

5. Gulf Stream, NOAA. https://scijinks.gov/gulf-stream/

6. Atlantic Meridional Ocean Circulation, AMOC. https://www.pik-potsdam.de/en/news/latest-news/gulf-stream-system-at-its-weakest-in-over-a-millennium

7. Atlantic Meridional Ocean Circulation, AMOC. https://www.nytimes.com/interactive/2021/03/02/climate/atlantic-ocean-climate-change.html?utm_campaign=Carbon%20Brief%20Daily%20Briefing&utm_content=20210303&utm_medium=email&utm_source=Revue%20Daily

8. Thermohaline circulation. https://en.wikipedia.org/wiki/Thermohaline_circulation

Videos:

1. Fresh water in the Arctic. https://www.youtube.com/watch?v=FxXaT7yO4TQ