How does ocean circulation work?
Could changes in ocean circulation cause abrupt climate change?

The Climate Context
The oceans as well as the atmosphere, glacier ice, land surfaces, vegetation, and freshwater are all important components of the climate system. These components respond to external factors, such as the sun and the Earth’s orbit. In addition, extensive and complex interactions between these components produce all the different climates that exist around the world. Could a change to one part of the climate system, the ocean, result in abrupt climate change?

A. Orientation to ocean circulation

Figure 1. The ocean conveyor belt. White ribbon represents the movement of surface water. Blue ribbon represents the movement of deep ocean water. (Illustration by Jayne Doucette, WHOI Graphic Services).
http://www.whoi.edu/institutes/oaggi/currenttopics/climatechange_wef_en1.html
The map (Figure 1) above is a rough sketch of the ocean “conveyor belt” that Alley describes. The conveyor belt is driven by thermohaline (thermo= temperature, haline = salt) circulation. At a basic level, the oceans have two layers of water, surface water and deep water. Except for in a few special places, deep water is so dense that surface water floats on top of it without mixing with the deeper layer. Both layers are involved in thermohaline circulation. The next few questions are designed to help you orient to the basic features of this global ocean system.

1. Where is the North Atlantic on this map? Mark it on the map.

2. Briefly describe (write down) the overall flow of both surface and deep water illustrated by this map, through the entire cycle. Start with the warm tropical surface waters between South American and Africa. Refer to specific locations at which water changes from surface to deep water and vice versa.

B. What makes ocean water dense enough to sink?

As the map (Figure 1) above shows, surface water sinks in the north Atlantic ocean and becomes deep water. This sinking is driven by density effects. The density of ocean water is controlled by both its temperature and salinity (salt content). To help you explore the relationships between density, temperature, and salinity, your instructor will help you perform (or demo) two hands-on activities.

**Temperature-density activity.** In this activity you will layer hot and cold water to see how temperature and density are related. Begin by predicting and explaining what will happen when ice-cold water meets hot water in a glass.

3. When you put a layer of hot water underneath a layer of cold water, what occurred?

4. When the cold water was underneath the hot water, what occurred?
5. Why did the layers mix in one situation and not mix in the other situation?

6. What do the results of this activity imply about what happens to the density of water as it changes temperature?

Another way to do this experiment: Put a few drops of blue food coloring into ice-cold water and slowly pour it into a glass of room temperature water. What does it do? Was your prediction right? Now mix a few drops of red food coloring into hot tap water and slowly pour it into another glass of room temperature water. Did it do the same as the cold?

Salinity-density activity
http://www.erionline.co.uk/experiment_10.htm
Your teacher has two glasses of water, each with about 1 cup of water. One is pure water (like fresh water) and the other has ¼ cup of salt added (like salty ocean water). Watch as the egg is placed into each glass.

7. What did the egg do in the two glasses?

8. Rank the density of the egg, the freshwater, and the saltwater.

9. What have you learned about water’s salinity-density relationship from this activity?
C. What have we learned about ocean circulation and its ability to change?

10. When ocean salinity increases, what happens to density?

11. When ocean temperature decreases, what happens to density?

12. Based on your knowledge of the relationship between density, temperature, and salinity, what conditions allow surface ocean water in the North Atlantic to sink and become deep ocean water?

D. How does ocean circulation affect climate?

As Alley discusses, the Earth is unevenly heated by the sun. Earth is warmer near the Equator and colder near the poles because the angle at which the sun’s rays hit Earth varies with latitude. At low latitudes, the sun’s rays hit the earth at a more direct (90 degree) angle, focusing a lot of radiation over a small area. At higher latitudes, the sun’s rays approach Earth at an indirect angle and are spread over a wide area. Hence, the tropics receive more radiation per unit area and are warmer than the high latitudes. Ocean circulation is one earth system that helps to redistribute heat from the tropics to the poles.

Flashlight demo. Your teacher will do a flashlight demonstration to help you understand why the Earth is unevenly heated. She will point a flashlight directly at the wall and at an angle to the wall to illustrate how the angle of light affects the area it covers.

13. What will the flashlight’s circle of light look like when pointed directly at the wall?

14. How will the flashlight’s circle of light change when it is held at a wider angle?
15. Relate what you have learned about light at different angles to why Earth is unevenly heated by the sun.

**Ocean current and air temperature.** Ocean currents can change the climate of a region because water can exchange large amounts of heat with the air. Thus, thermohaline circulation of the ocean water is also said to be a “conveyor belt” of heat. Because of its high heat capacity, ocean water picks up lots of energy from the sun as it travels through the tropics, while resisting a large rise in temperature. The water continues toward the poles, carrying tropical heat along with it. As the water moves into regions in which air-temperature is cooler than water-temperature, heat is transferred from the oceans to the atmosphere. In the Atlantic Ocean, for example, water that has been warmed in the Gulf of Mexico travels north, heating air over the North Atlantic Ocean. Since the prevailing winds of the region blow from west to east, air warmed by the ocean then is carried to Europe.

[Image: Mean Surface Air Temperature, AIRS data, January 2003]

[Link](http://www-airs.jpl.nasa.gov/features/features_newglobalmaps.html)
16. Look at the map above. Locate the north Atlantic ocean and Europe. Compare the surface air temperature over Europe to that over similar latitudes in North America. Briefly explain why these surface temperatures are different.

E. Summing up

Using what you have learned here, what kinds of abrupt changes in the north Atlantic Ocean might alter the climate in Europe?