Exploring fresh water in global climate and high-latitude oceans
(short title: The Future of Water)

Peter Rhines
School of Oceanography and Department of Atmospheric Sciences
University of Washington

Fresh water moves through the Earth's climate system in many pathways. It is an essential ingredient in the biosphere, it transports heat though the atmosphere, affects the buoyancy of the ocean and hence its circulation, and in many ways controls human activity.

In these lectures we will explore the physics of fresh water and its role in the general circulation of atmosphere and ocean. We will also visit the problem of drought and 'deluge', in predictions of future climate. One of the most certain predictions for a warming world is that there will be more moisture in the lower atmosphere, and there are many consequences involving both the wet and dry regions of Earth.

While my experience is mostly in the northern Atlantic Ocean and the atmospheric circulation of the high northern latitudes, the circulation of the eastern South Pacific plays a key role in the global circulation. One of the most dramatic changes in global climate due to human activity is the acceleration of the polar vortex in the stratosphere above Antarctica, caused by ozone depletion and CO2 increase: this has affected the jet stream and surface winds, and the accelerating westerly winds are likely altering the ocean circulation and biological fields.

We will discuss how subpolar mode waters from the Southern Ocean invade the ocean along the Chilean coast, and the way the deep circulation responds as part of the global 'conveyor belt' circulation. Upwelling of nutrients provides a unique connection between physics and biology. Natural and anthropogenic chemical tracers are a key technique helps us to observe and understand the 'conveyor belt' circulation of the global ocean, while also determining the sites of the major ecosystems.

More locally, the dynamics of the coastal ocean are strongly affected by fresh-water inputs from land. Fjord dynamics and biological production are sensitive to the very buoyant surface layer created, in some cases the inflow of fresh water completely determines regions of intense primary production and the resulting growth of larger animals. We have found that in the Labrador Sea, the dominant spring phytoplankton bloom is controlled by such flow of fresh-water layers offshore from Greenland.

As a physical oceanographer, I must discuss the effects of Earth's rotation on ocean currents, upwelling and the atmospheric circulation above. We illustrate some of the most basic circulation patterns, Rossby waves and upwelling dynamics, with live laboratory experiments in these lectures.

We will complete the lectures with discussion of fresh water demands of the human population. An increasing number of countries are suffering from 'water stress', and

polluted waters are common in developing countries. Diseases like cholera experience Darwinian adaptation, becoming very virulent where rapid transmission occurs, yet very benign where public health conditions are good. Recent cholera outbreaks in South America and Bangladesh involve the coastal ocean and possibly global warming. Drought stress is widespread: in western Australia, where there has been extensive drought for at least 30 years, the population is responding with solar-equivalent powered desalination plant, groundwater extraction, water recycling and conservation.