

The COMET Program

Our Climate: A Global Challenge

Academy of Lifelong Learning

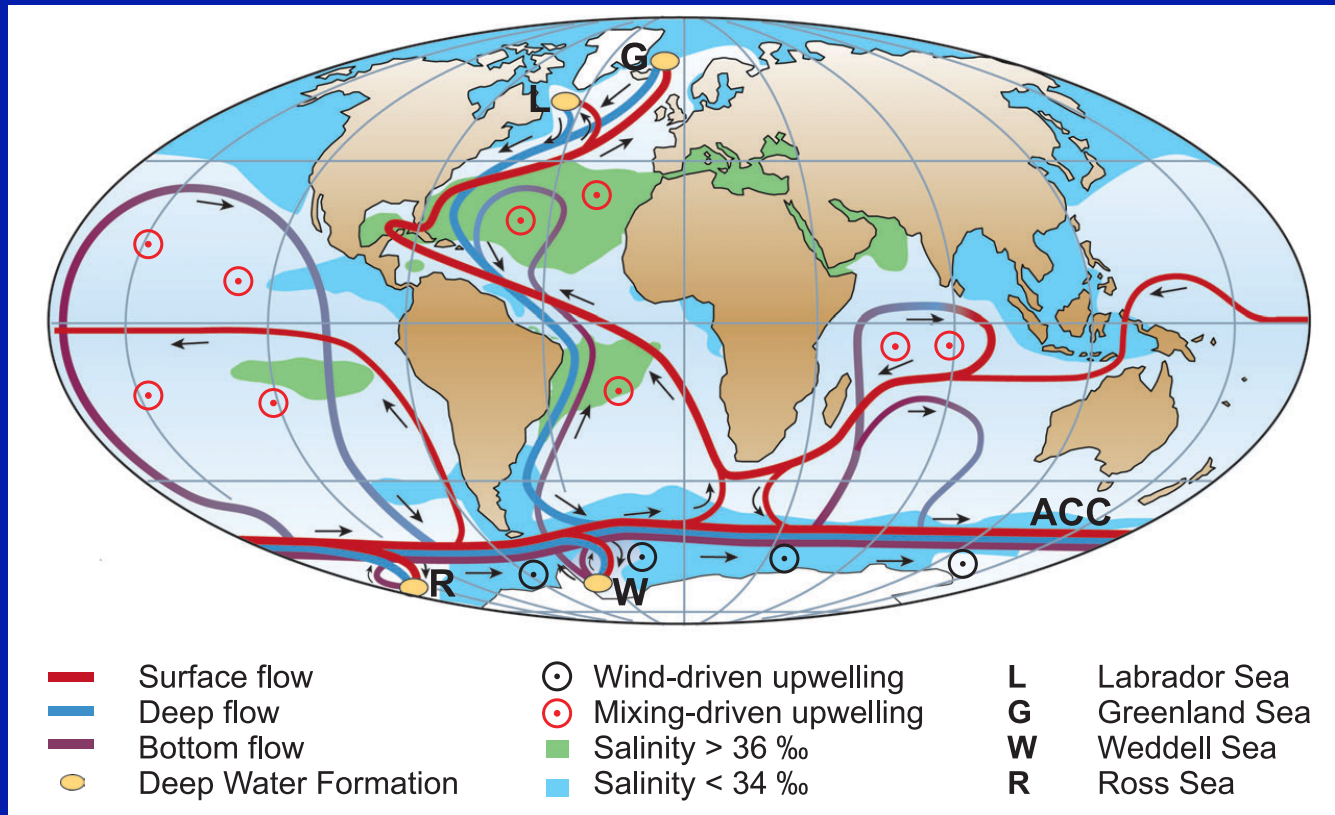
Denver, CO

April 9, 2015

Oceans

Thermohaline Circulation

It takes water 500 to 1000 years to go around the planet.



Thermohaline Circulation, 2006, Stefan Ramstorf, Encyclopedia of Quaternary Science

http://www.pik-potsdam.de/~stefan/Publications/Book_chapters/rahmstorf_eqs_2006.pdf

http://education.nationalgeographic.com/education/encyclopedia/ocean-conveyor-belt/?ar_a=1

What drive ocean currents

- Wind and tides drive surface currents
 - Winds drive upwelling of cold, nutrient filled waters; good fishing off west coast of South America
- Temperature and salinity drive deep ocean currents; hence “thermohaline”
 - cold water is denser and sinks
 - salt water is denser than fresh
 - freezing water squeezes the salt out making a flow of salty water towards the deeper ocean
 - huge underwater “waterfall” off Antarctica

- The cold water flows down in underwater rivers that move around in the deep ocean following the topography of the ocean floor
- The water near the equator rises slowly over a larger area in the tropical and sub tropical zones
- This flow draws warmer surface water towards the poles, carrying heat to the poles where climate change is most pronounced.

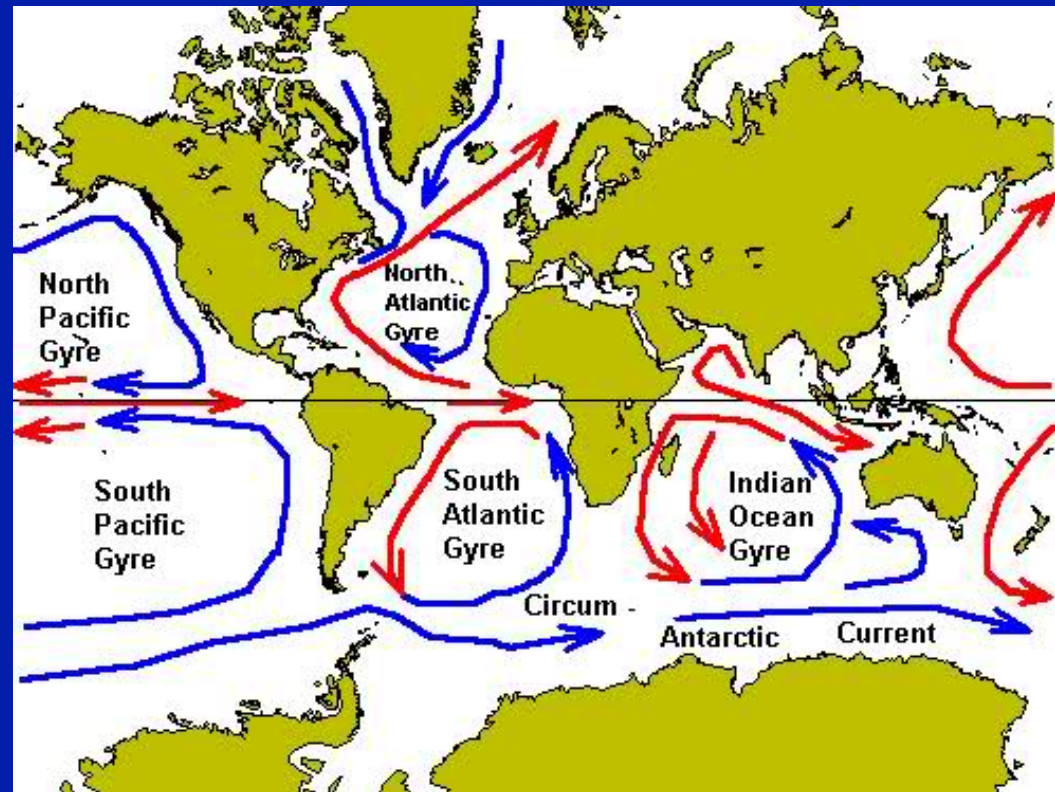
Gyres

A gyre: a large system of wind driven rotating ocean currents

Rotation caused by the Coriolis Effect.

Locations of the continents matter.

Gyres affect local climates.

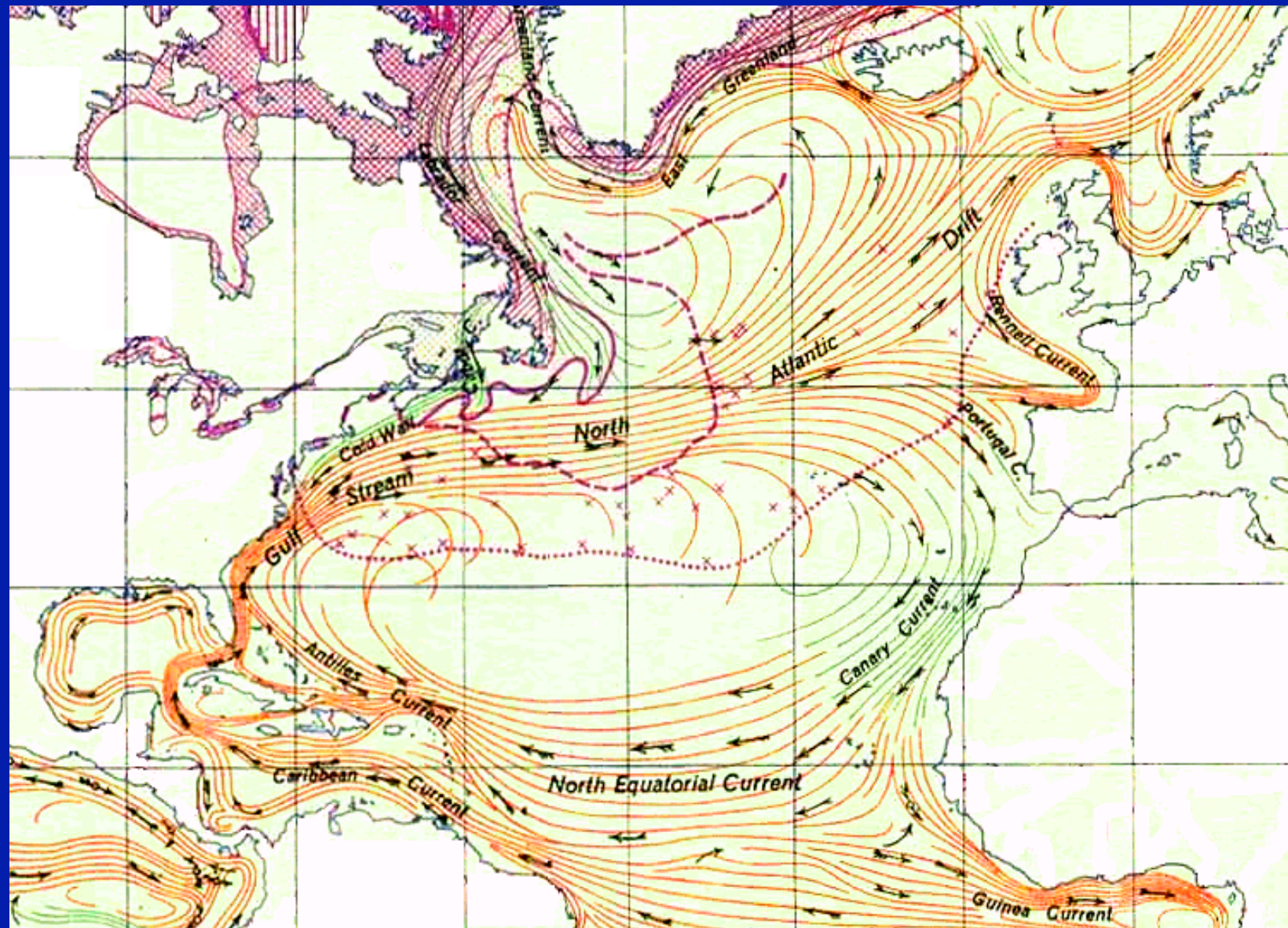


North Pacific gyre and garbage patch

Result: an enormous trash buildup that's killing birds and sea life



North Atlantic Gyre



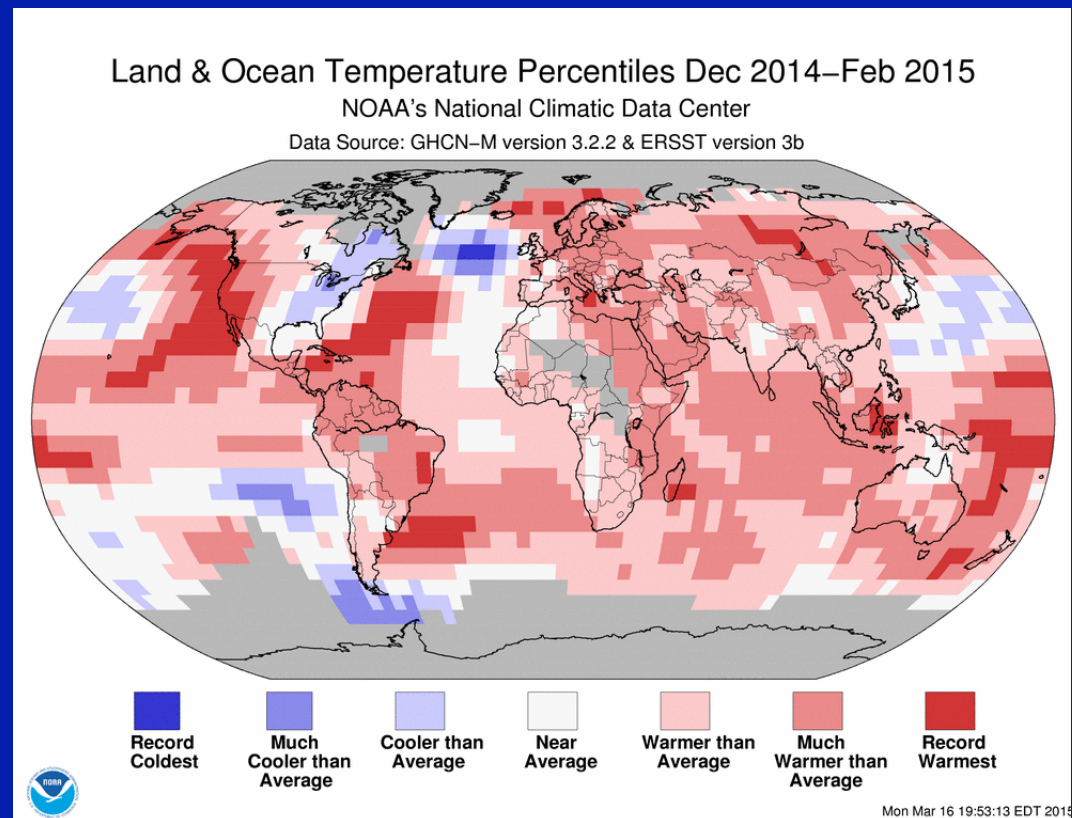
Gulf Stream

- Discovery credit goes to Anton de Alaminos, a pilot for Ponce de Leon (both sailed with Columbus) 1519
- Northern leg was charted by Benjamin Franklin and his cousin Folger in the 18th century; Spanish treasure ships used the stream to return to Europe throughout the 16th.
- British Admiralty wanted to know why American ships sailed to England 2 weeks faster than theirs. Franklin was called to testify. They ignored the testimony.
- More than 20 times all the great land rivers and glacier melt combined.
- One hundred thousand million (10^{11}) tons of warm salt water flow between Florida and the Bahamas every hour. At 235 gallons per ton, we have 235×10^{11} gallons per hour flowing between two and five miles per hour northward.

Slowing of the Ocean currents

Freshwater melt from Greenland and other North Atlantic ice caps is causing a cold spot in the North Atlantic which has slowed the Gulf Stream by 15-20%.

Rahmstorf, S., Box, J., Feulner, G., Mann, M., Robinson, A., Rutherford, S., Schaffernicht, E. (2015): Exceptional twentieth-Century slowdown in Atlantic Ocean overturning circulation. *Nature Climate Change* (online)

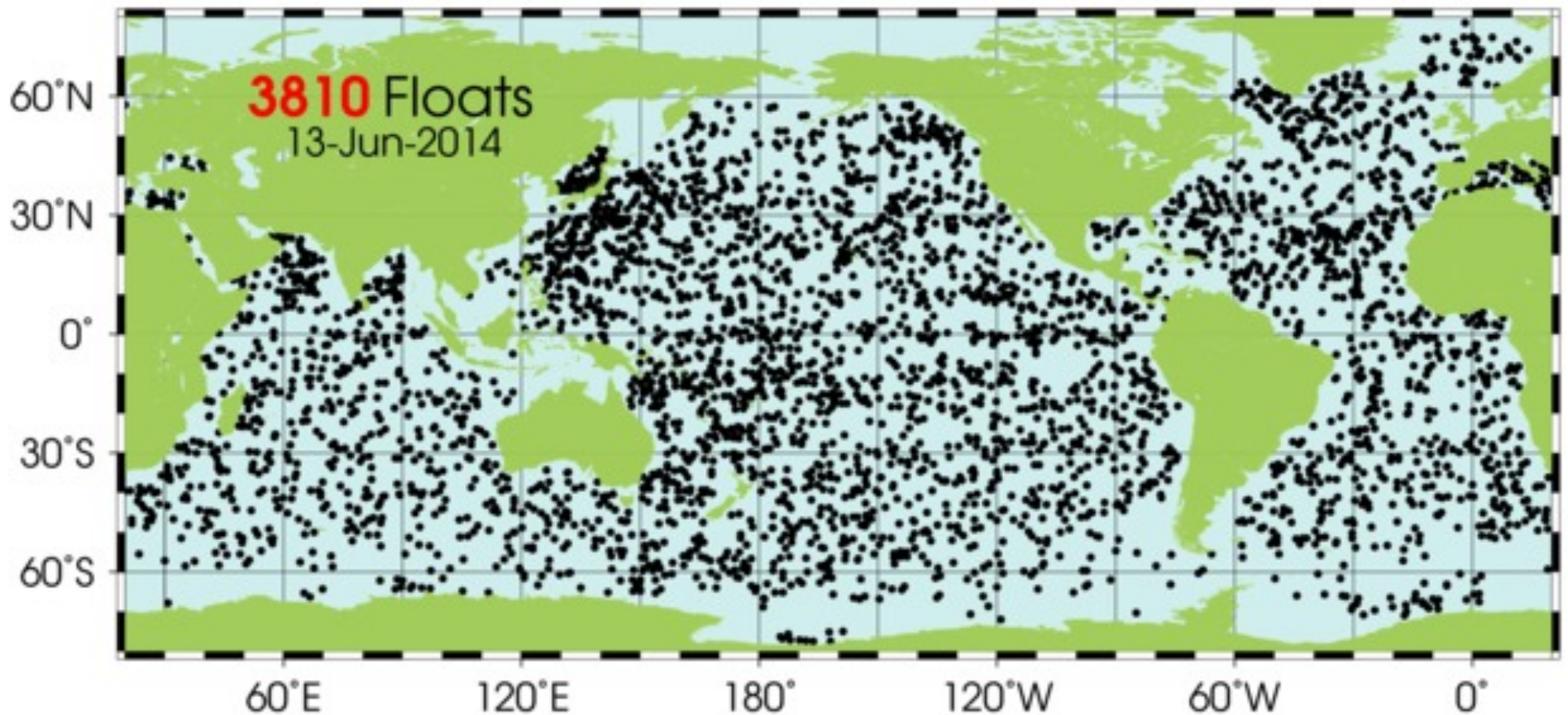


Affects sea level on the east coast

- Gulf stream draws water away from the coastal areas; faster stream, more draw.
- Sea level there has been about 1 meter lower than average sea level due to this effect.
- As the Gulf stream slows, this trough is filling, so sea level is rising faster there than the global average rise.

Argo float distribution, June 2014

measure temperature & salinity of the upper 2000 m of the ocean



Seiche

- Standing waves in a partially bounded body of water
- Waves stimulated by tidal surges, winds, earthquakes, or even children
- Natural frequency $T = \frac{2L}{\sqrt{gh}}$
 - T: period of oscillation, L: length, h: height, g: accel. of gravity
 - Swimming pool: $2 \times 50\text{m} / \sqrt{(9.8\text{m/s}^2 \times 3\text{m})} = 18\text{s}$
 - Bay of Fundy: $2 \times 235\text{ km} / \sqrt{(9.8\text{m/s}^2 \times 10\text{m})} = 13\text{ hrs}$
 - Pacific Ocean: 2 days
- Known in freshman physics as a simple harmonic oscillator

Bay of Fundy

Spring tides can reach above 14 meters.

Be careful how you tie up your boat.



[Click here.](#)



<https://www.youtube.com/watch?v=UEYLfLL3c>

Natural cycles (quasi-periodic)

- El Niño, La Niña: both part of the El Niño Southern Oscillation (ENSO)
- North Atlantic Oscillation (NAO)
- Atlantic Multidecadal Oscillation (AMDO)
- Indian Ocean Dipole
- Pacific Decadal Oscillation (PDO)
- Maybe a oscillations, including ~60 year oscillation in the Arctic
- There may be undiscovered longer period oscillations; our baseline is limited.

Heat enters and leaves the ocean during these oscillations.

Conclusion

Modeling of the ocean circulations is probably underestimating the effects of climate change. A more advanced ARGO system is being prepared for deployment to improve the ocean data.