Oceanic heat transport and recent sea level rise in the subpolar North Atlantic Ocean

Denis L. Volkov and Lee-Lueng Fu

Jet Propulsion Laboratory
California Institute of Technology

I. OVERVIEW

Nearly all atmospheric and oceanic motions are ultimately caused by uneven income of solar radiation. Overall, the Earth gains heat at low latitudes and it loses heat at high latitudes. To balance these gains and losses the heat is transported poleward by the atmosphere and the ocean in comparable proportions. The subpolar North Atlantic Ocean is the only basin through which the heat can be carried by the system of oceanic currents (**Figure 1**) towards the pole because of the open boundary between the Atlantic and the Arctic oceans. We use the high-resolution global-ocean data synthesis product provided by the **Estimating the Circulation and Climate of the Ocean, Phase II (ECCO2)** project *to show that the oceanic heat transport and fresh water fluxes were the major factors responsible for the observed sea level rise in the subpolar North Atlantic in 1992-2002.*

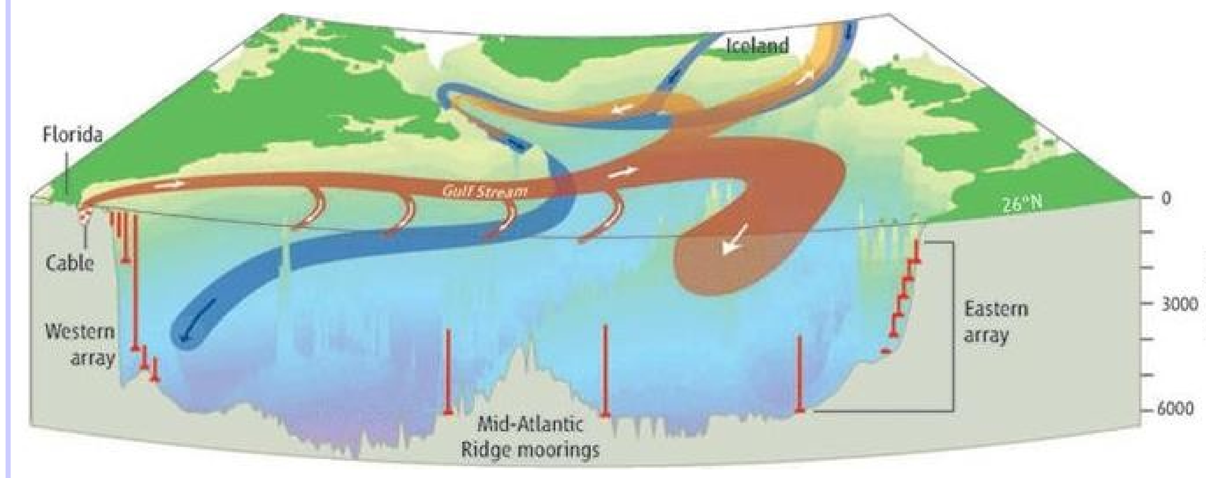


Figure 1: In the North Atlantic Ocean heat is transported northward by the Gulf Stream and the North Atlantic Current. Within the Subpolar Gyre the advected warm and saltier water loses heat and sinks forming deep water flowing south. This process is an essential part of the **Meridional Overturning Circulation**, which plays an important role in climate.

II. SEA LEVEL RISE IN THE SUBPOLAR NORTH ATLANTIC OCEAN

During the decade of 1992 - 2002 the subpolar North Atlantic experienced a sea level rise monitored by satellite altimetry missions (*TOPEX/Poseidon* and *ERS -1/2*). Despite some discrepancies this sea level rise is reasonably well simulated by ECCO2 model runs (**Figure 2**).

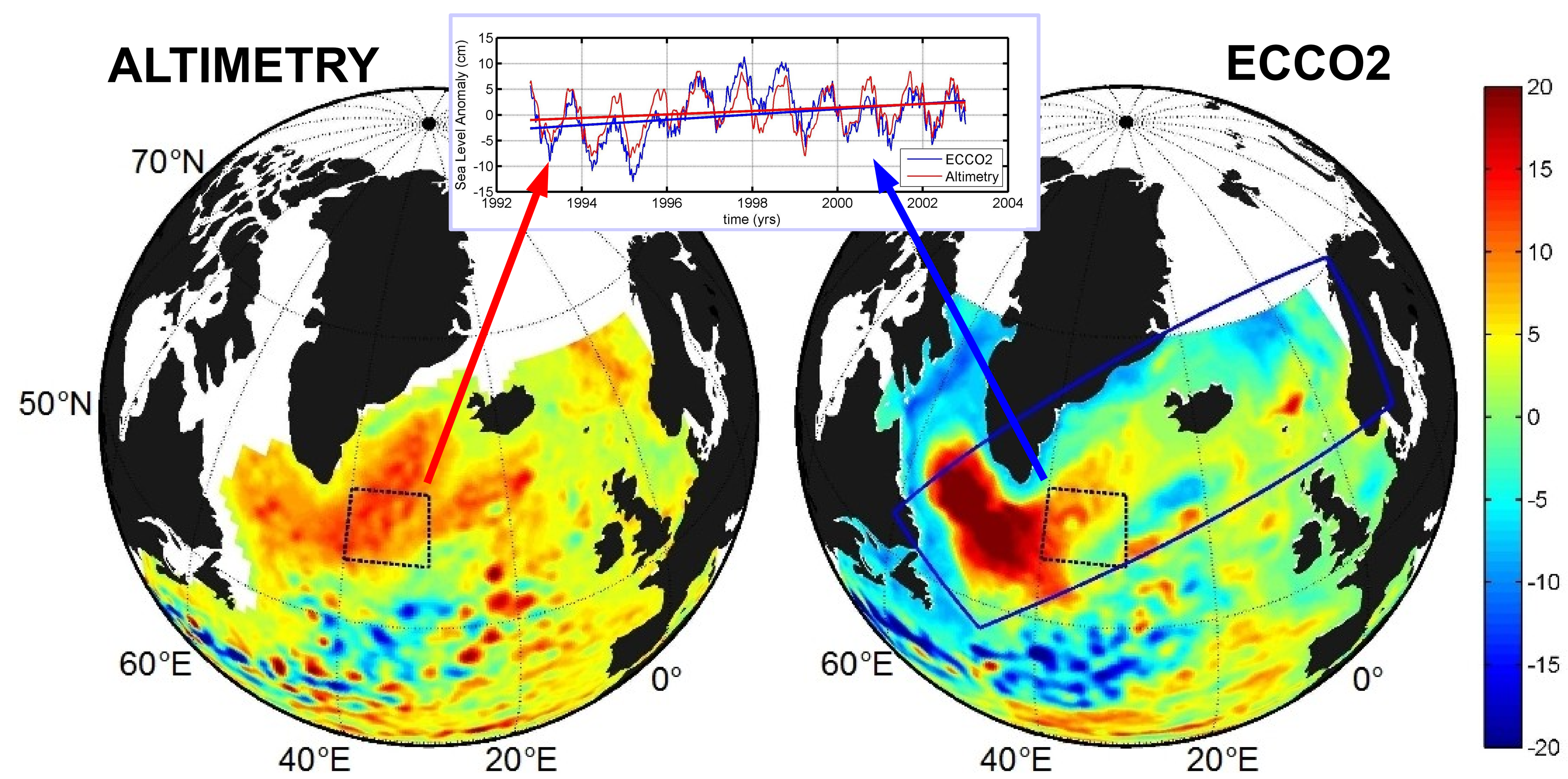


Figure 2: *The 1992 – 2002 sea level trend (cm) measured by satellite altimetry (left globe) and simulated by the ECCO2 model (right globe) and the time series of the sea level anomaly averaged over 30°W-40°W, 55°N-60°N (areas bounded by dashed contours). The domain of this study is bounded by the blue line (right globe).*

III. OCEANIC HEAT TRANSPORT

The zonally integrated oceanic heat transport across any given latitude y at time t is well approximated by

$$Q(y,t)=\iint \rho C_p \theta V dxdz=\iint \rho C_p \theta (\langle V\rangle + V')dxdz$$

where V is the meridional component of the absolute velocity across the latitude y, θ is potential temperature, ρ is the seawater density, C_p is the specific heat capacity of seawater, and z is depth. Heat is transported meridionally by the zonally-averaged flow $\langle V\rangle$, that is the *overturning circulation*, and by the residual *horizontal circulation* V'.

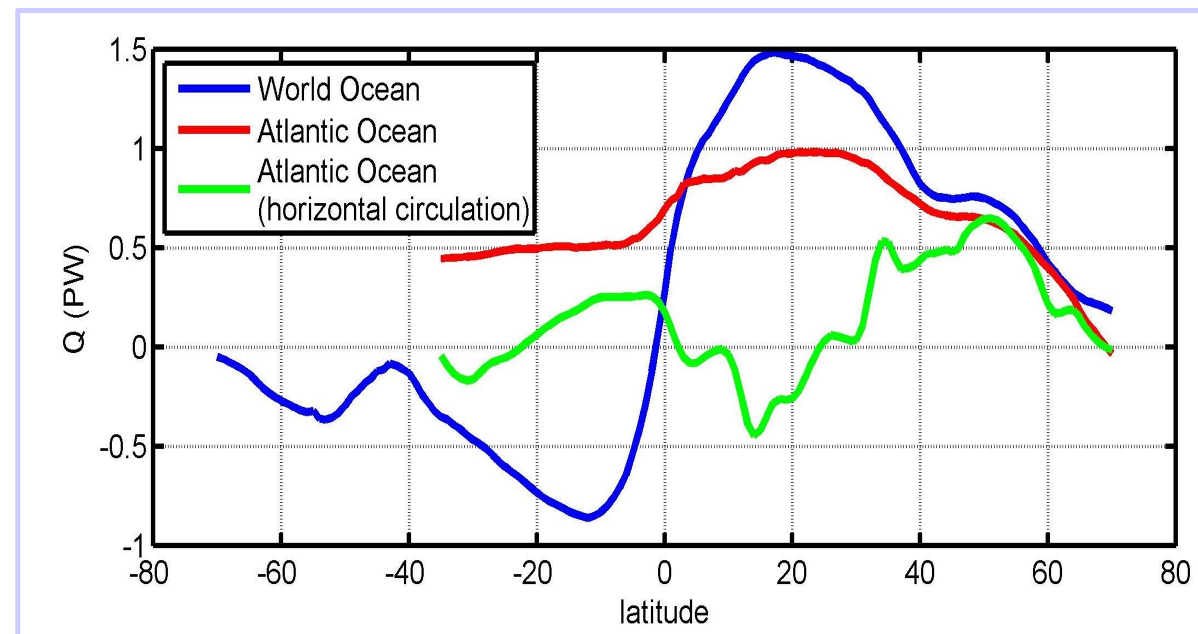
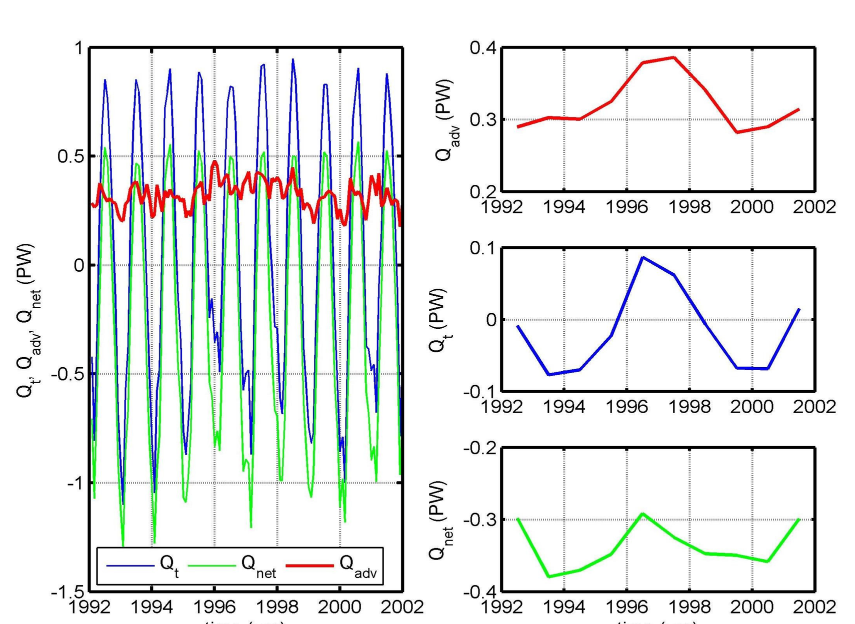


Figure 3: *Zonally-integrated meridional heat transport in the World Ocean and in the Atlantic Ocean.*

Most of the northward oceanic heat transport in the Northern Hemisphere is contributed by the North Atlantic Ocean; the remaining part is transported by the North Pacific Ocean. *In the subpolar North Atlantic (north of ~40°N) the northward heat transport is mainly due to the **horizontal**, and not overturning, circulation* (**Figure 3**). This means that the exisiting regular monitoring of the **Meridional Overturning Circulation** in the tropical North Atlantic to infer its impact on climate at mid- and high latitudes is not sufficient.

IV. HEAT BUDGET OF THE SUBPOLAR NORTH ATLANTIC OCEAN



The time-change of heat content in an oceanic basin (Q_t) is balanced by the net ocean-atmosphere heat flux (Q_{net}) and the advection of heat by oceanic currents or oceanic heat transport (Q_{adv}): $Q_t = Q_{net} + Q_{adv}$ (**Figure 4**).

Figure 4: *The monthly (left plot) and yearly (right plots) terms of the heat budget equation integrated over the area bounded by the blue line in Figure 2: Qt (blue curve), Qnet (green curve), and Qadv (red curve).*

V. THERMOSTERIC SEA LEVEL IN THE SUBPOLAR NORTH ATLANTIC OCEAN

The volume of a water column (sea level) varies because of changes in its mass or density. The density of a seawater column depends on its temperature and salinity that determine the *thermosteric* and the *halosteric* sea levels, respectively.

The *thermosteric* sea level $\langle\eta\rangle$ averaged over an area S is computed as follows: $\langle\eta\rangle=\frac{\alpha}{\rho C_p}\int (Q_{net}+Q_{adv})\,dt/S$,

where α is the thermal expansion coefficient, and t is time. The thermosteric sea level explains ~70% of the sea surface height variance in the domain of the study. *The oceanic heat transport appears to be the major contributor to the interannual variability of the thermosteric sea level in the Subpolar North Atlantic Ocean* (**Figure 5**).

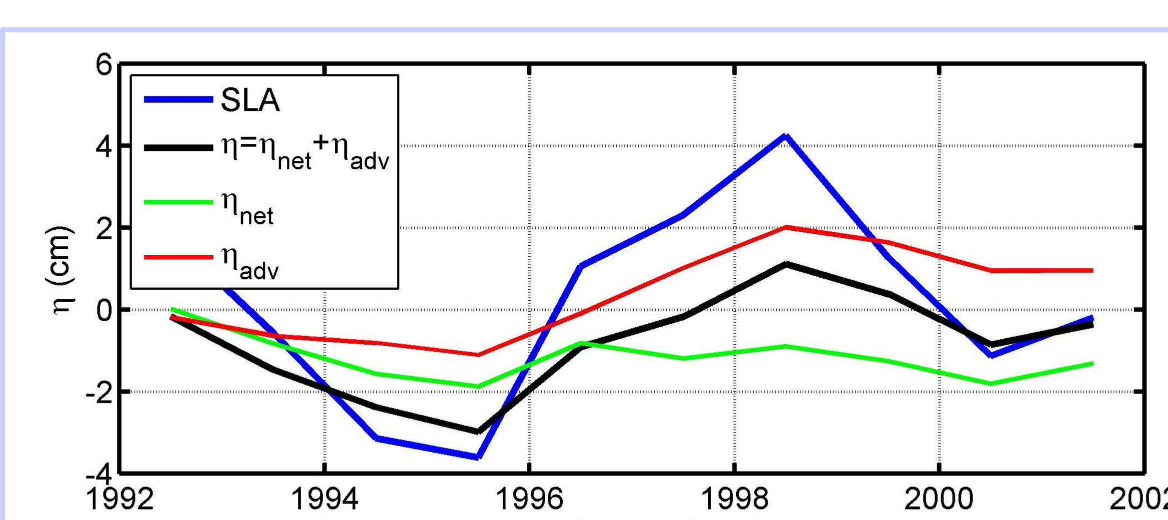


Figure 5: *Total (blue), thermosteric (black), thermosteric due to the net ocean-atmosphere heat flux (green), and thermosteric due to the oceanic heat transport (red) yearly sea level anomalies averaged over the domain of this study. The difference between the total and thermosteric sea levels is mainly explained by fresh water fluxes.*

SUMMARY:

- *The **oceanic heat transport** appears to be the major contributor to the year-to-year change of the Subpolar North Atlantic **heat content** and, therefore, has a strong impact on climate in the Northern Hemisphere.*
- *The sea level rise in 1992-2002 was predominantly caused by the **oceanic heat convergence** and **fresh water flux**.*
- *In the Subpolar North Atlantic heat is advected mainly by the **horizontal** circulation; the overturning circulation plays a minor role. This is important to take into account when interpreting data from existing observational arrays.*

Contact: denis.volkov@jpl.nasa.gov **26 August 2008, JPL Post-Doc Poster Session** Poster № **003**