# Large-scale physical oceanography from ALPS

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ALPS-II
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What are the key scientific advances in physical oceanography enabled by ALPS over the past decade?

Focus on large-scale (global) questions

NOT

- Smaller scales
- Process studies
- Coastal regions or boundary currents
- Arctic or Antarctic
- Data assimilation

# What is the ocean’s role in the global climate system?

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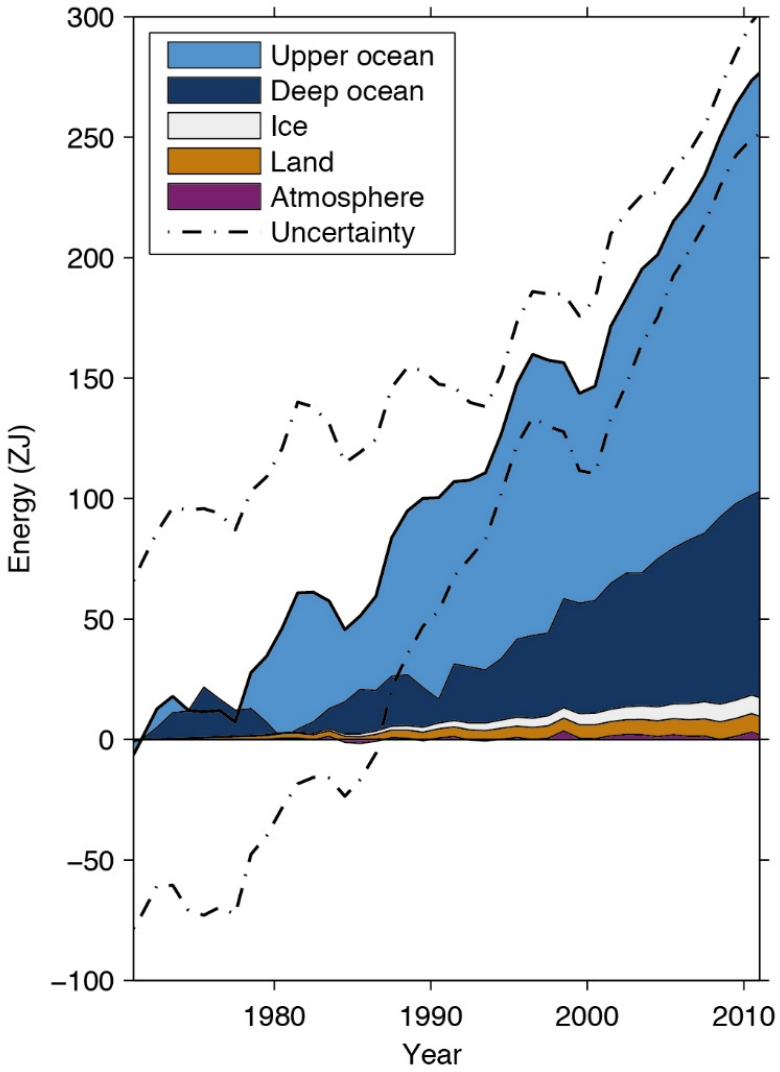
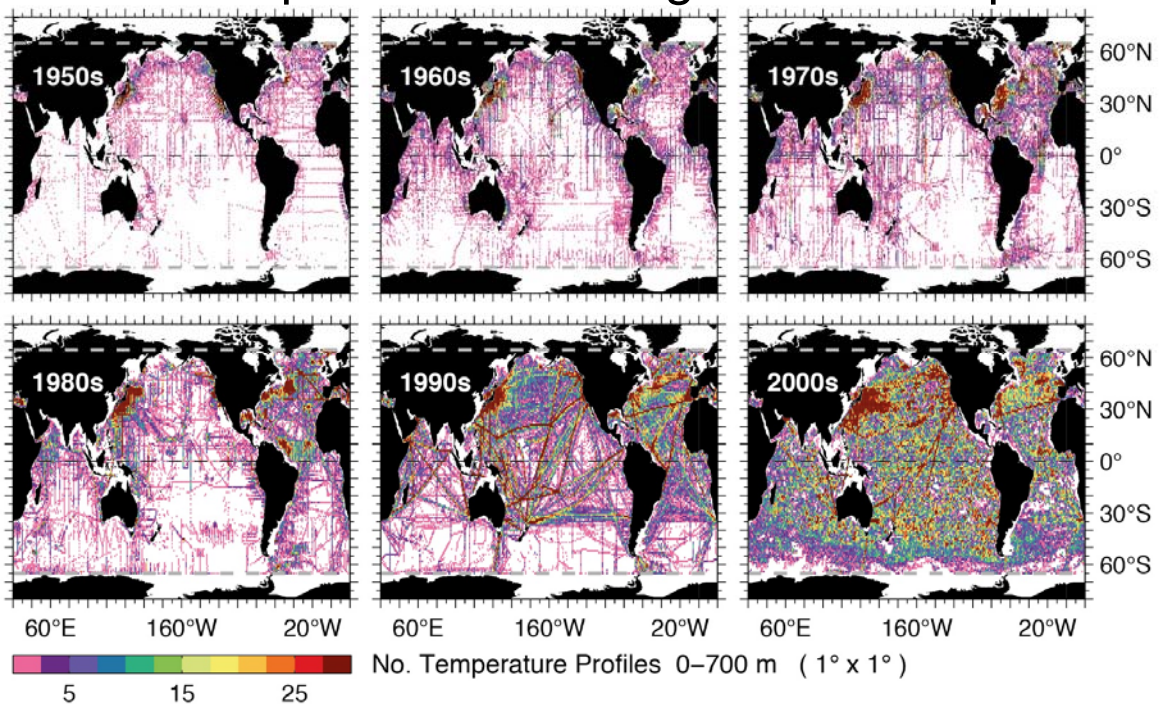
**"Global warming is ocean warming."**

Energy accumulation relative to 1971




Number of profiles extending to 700 m depth

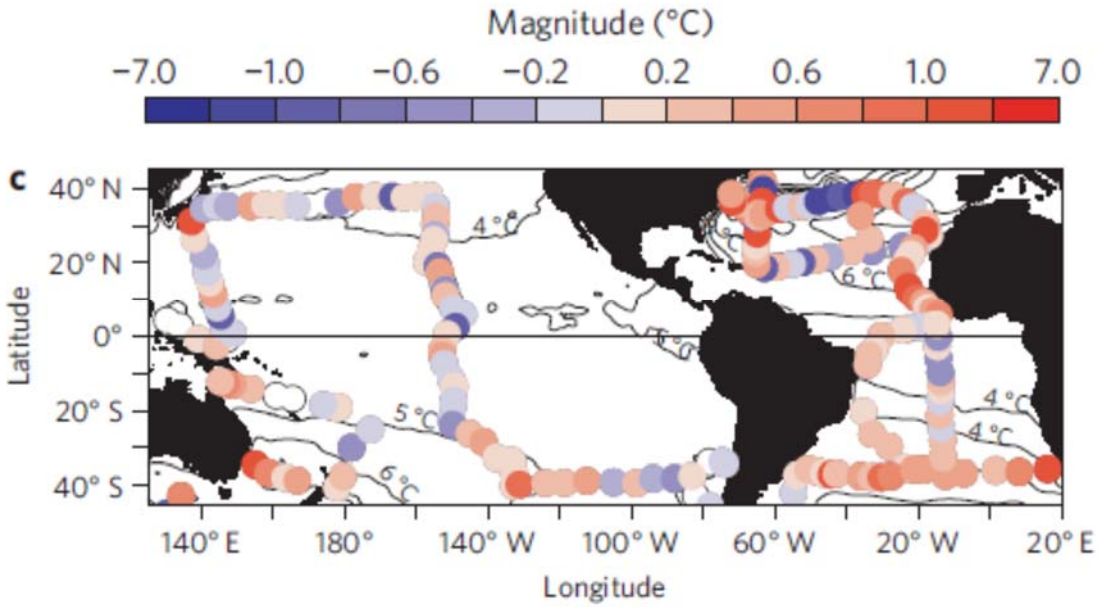



Ch. 3 of IPCC AR5, 2014

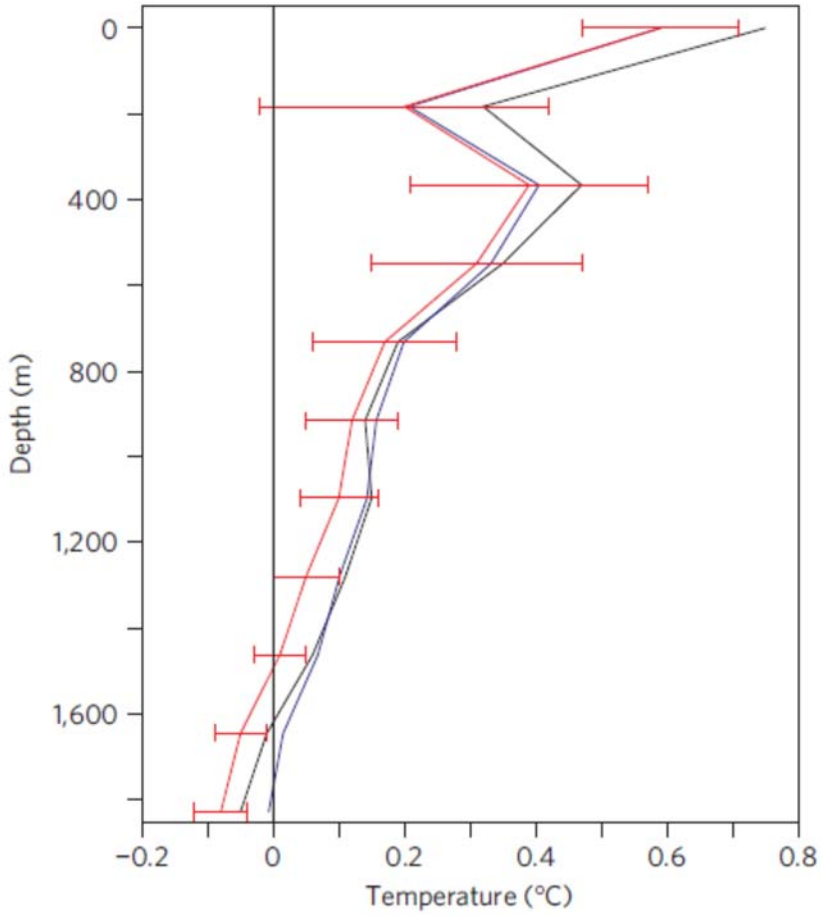
# What is the ocean's role in the global climate system?

## Ocean has been warming for at least a century.

Mean 2004-2010 Argo – *Challenger* temperatures at 914 m




Globally averaged difference between Argo and *Challenger*

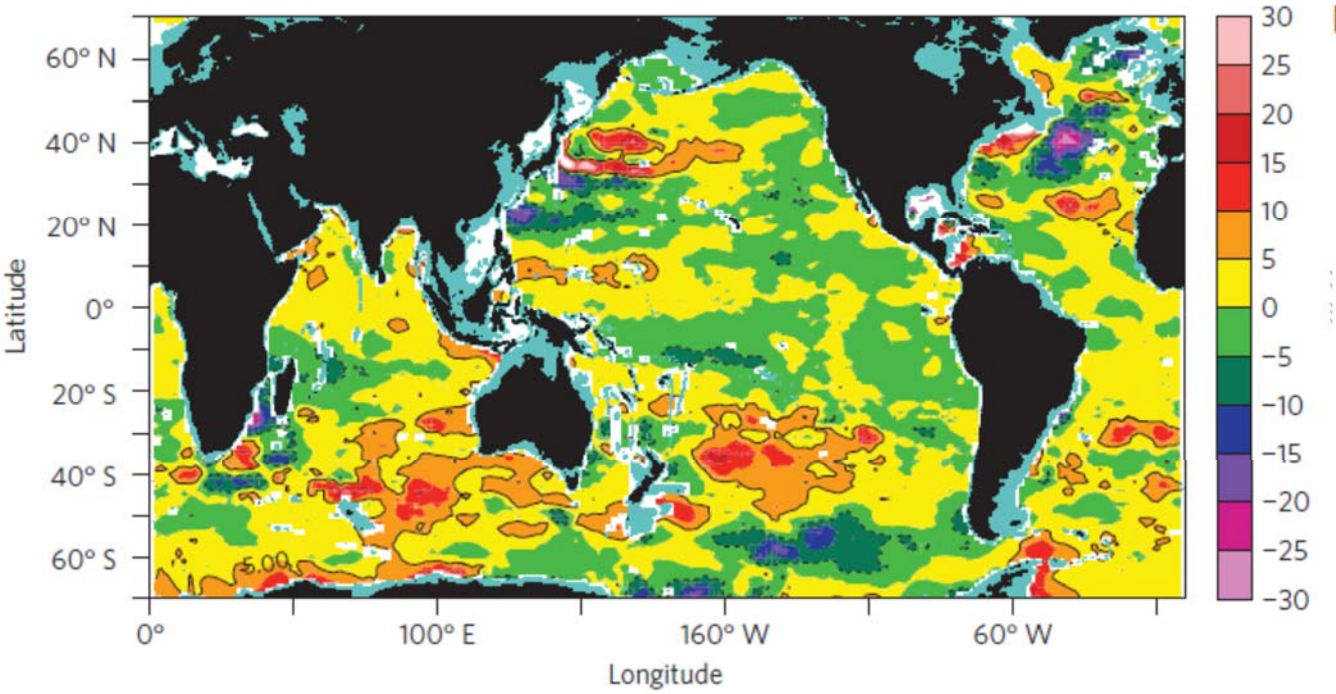



Roemmich et al., *Nat. Clim. Change* 2012

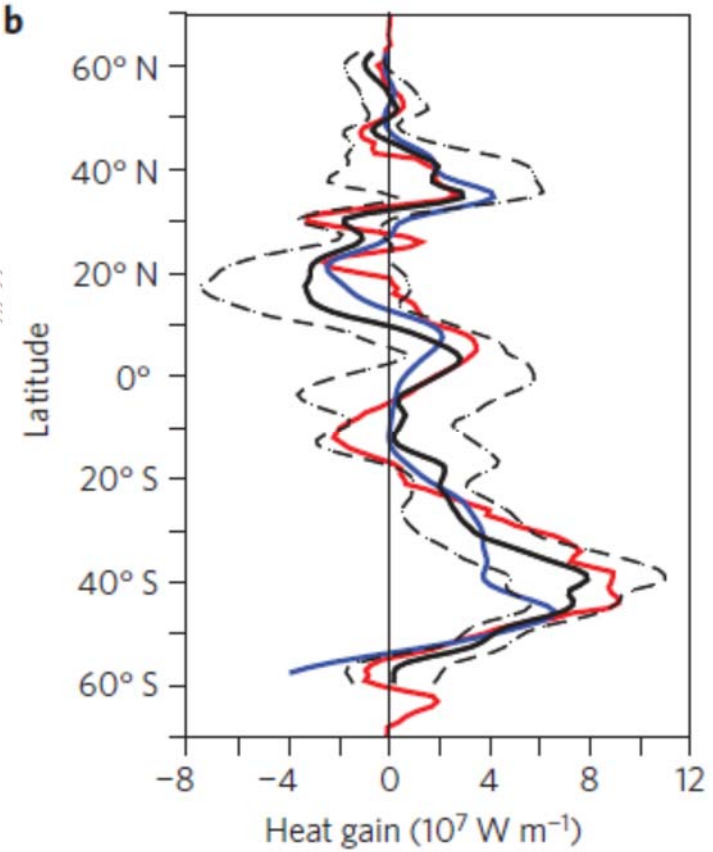
# What is the ocean's role in the global climate system?

**Ocean warming is spatially variable, with majority of heat uptake in Southern Hemisphere.**

2006-2013 trend in 0-2000 m heat content



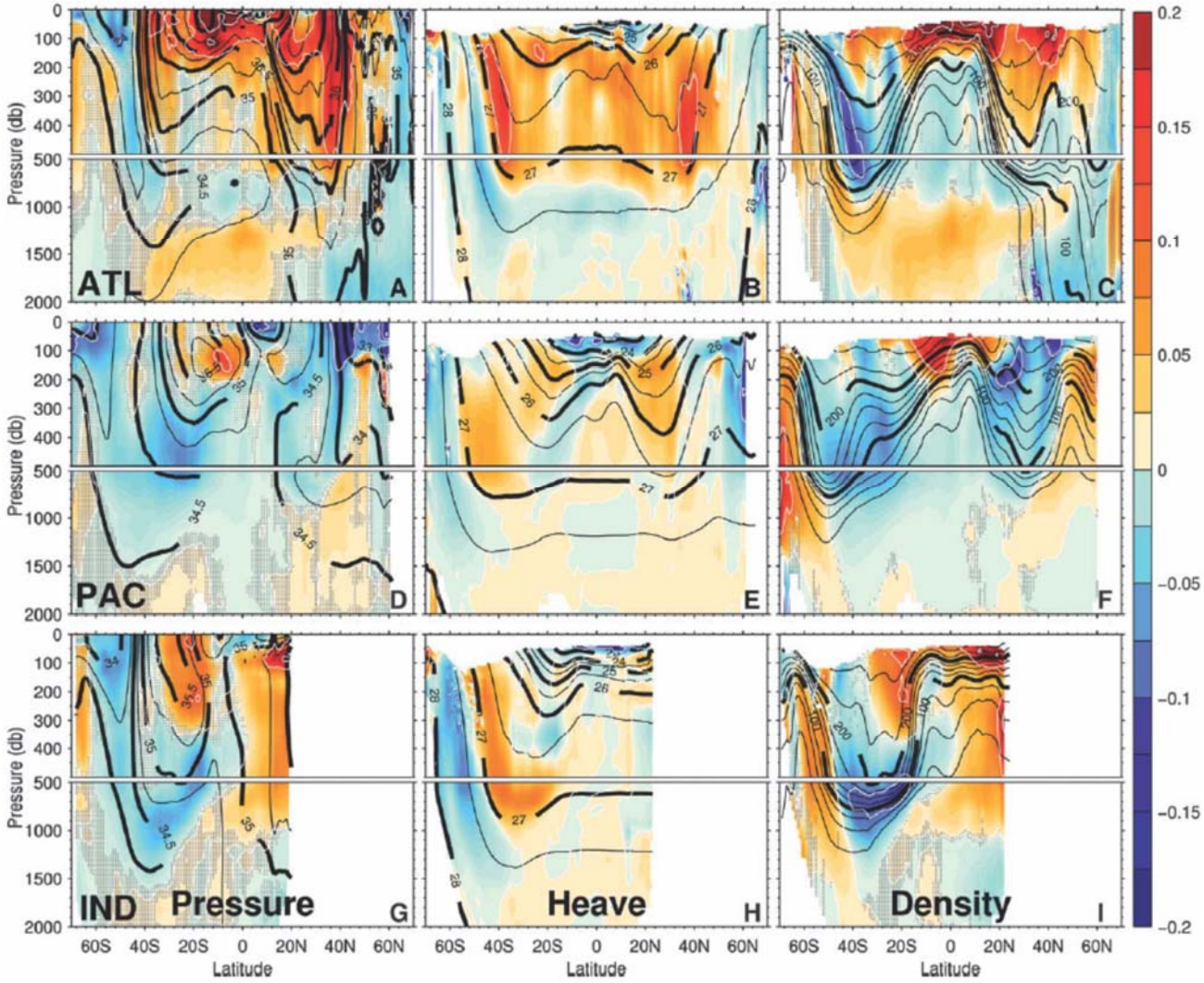

Zonally-integrated heat gain for 2006-2013




Roemmich et al., *Nat. Clim. Change* 2015

# What is the ocean's role in the global climate system?

**Large, robust multi-decadal salinity trends are due to both isopycnal heave and water-mass changes.**



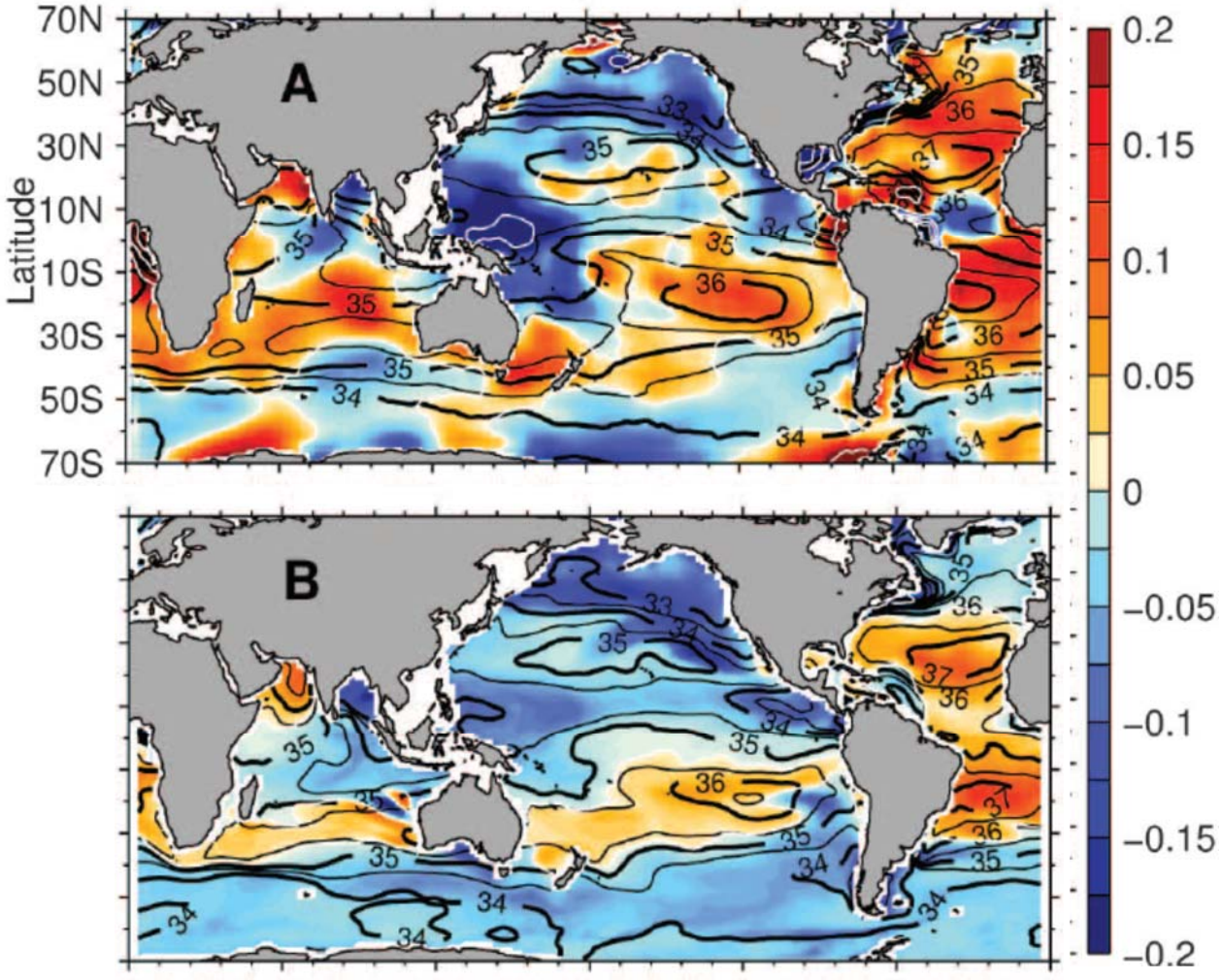

Zonally-averaged salinity trends for 1950-2008 in Atlantic, Pacific, and Indian basins; on pressure surfaces, due to heave, and on density surfaces.

Durack and Wijffels, *J. Clim*. 2010

# What is the ocean's role in the global climate system?

## Surface salinity changes indicate substantial intensification of global hydrological cycle

Patterns in surface salinity trends for 1950-2000.




Observed trend (50 year$^{-1}$)

OGCM with 5% increase in E-P (50 year$^{-1}$)

Durack et al., *Science*, 2012

# What is the large-scale circulation?

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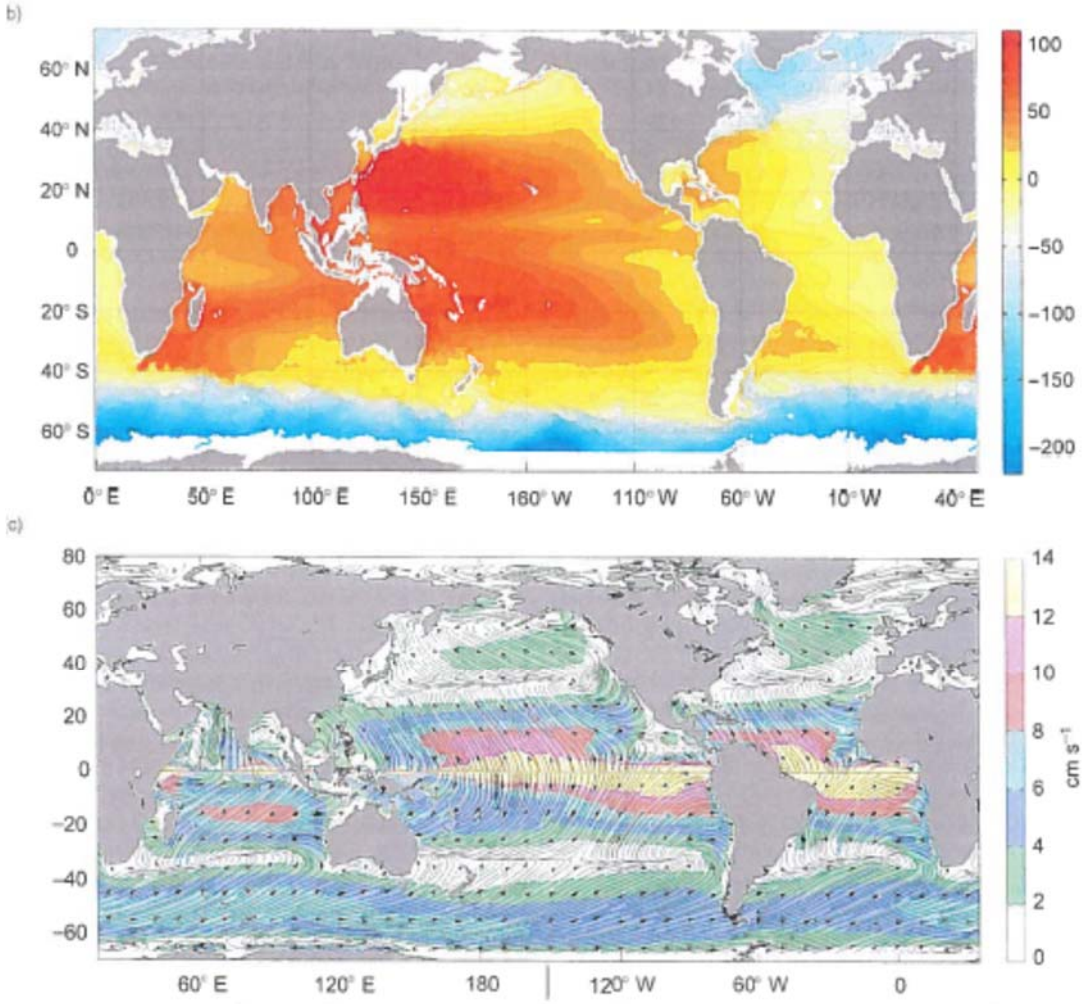
## Surface circulation determined from drifters




Mean dynamic topography

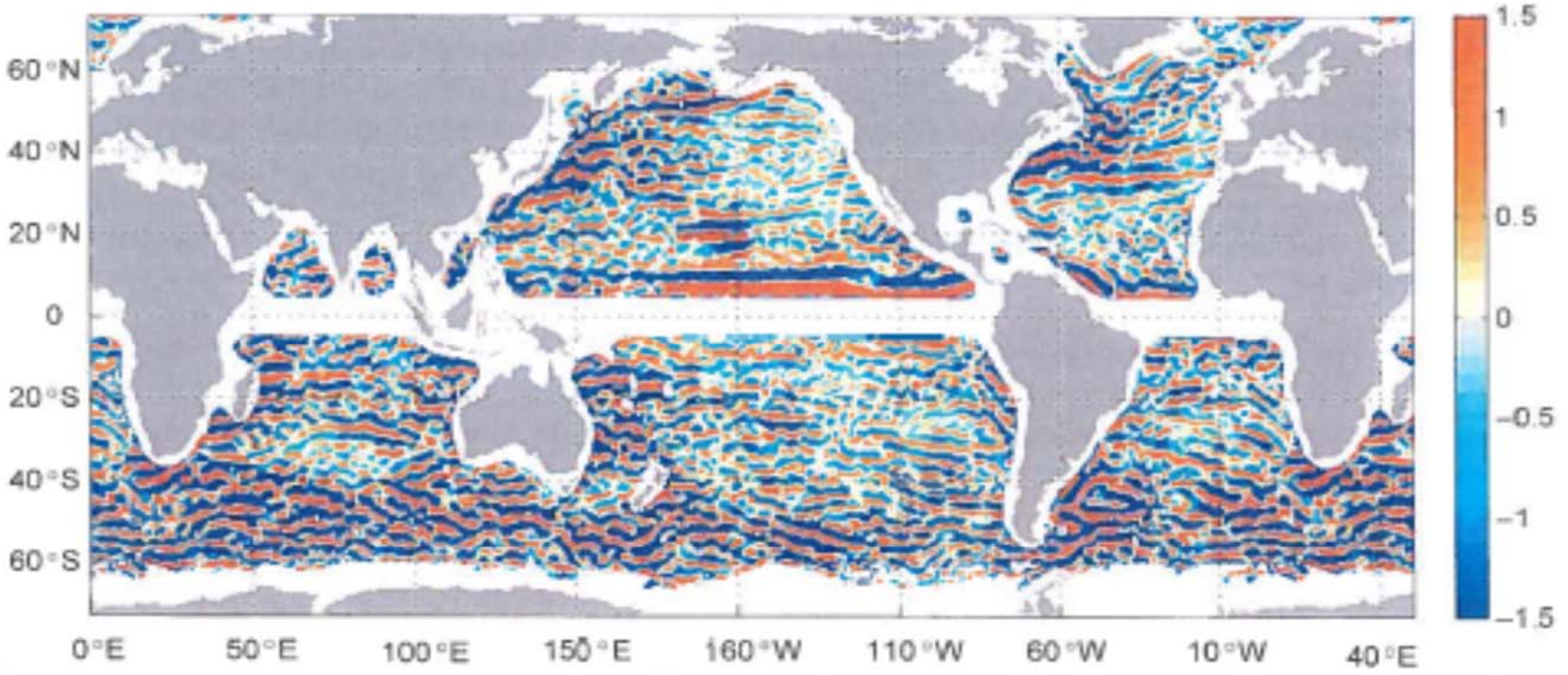
Mean Ekman currents at 15 m

Maximenko et al. 2013

# What is the large-scale circulation?

## Surface circulation determined from drifters

High-pass filtered 1993-2002 zonal surface geostrophic velocity




IGURE 12.3 1993–2002 mean zonal surface geostrophic velocity calculated from the MDOT of Maximenko and Niiler (2005) high-pass filtered with a o-dimensional Hanning filter of 4° half-width. Units are cm s⁻¹. *Reproduced from Maximenko et al. (2008).*

Maximenko et al. 2013

# What is the large-scale circulation?

## Subsurface circulation determined from floats

Geopotential height at 1000 dbar

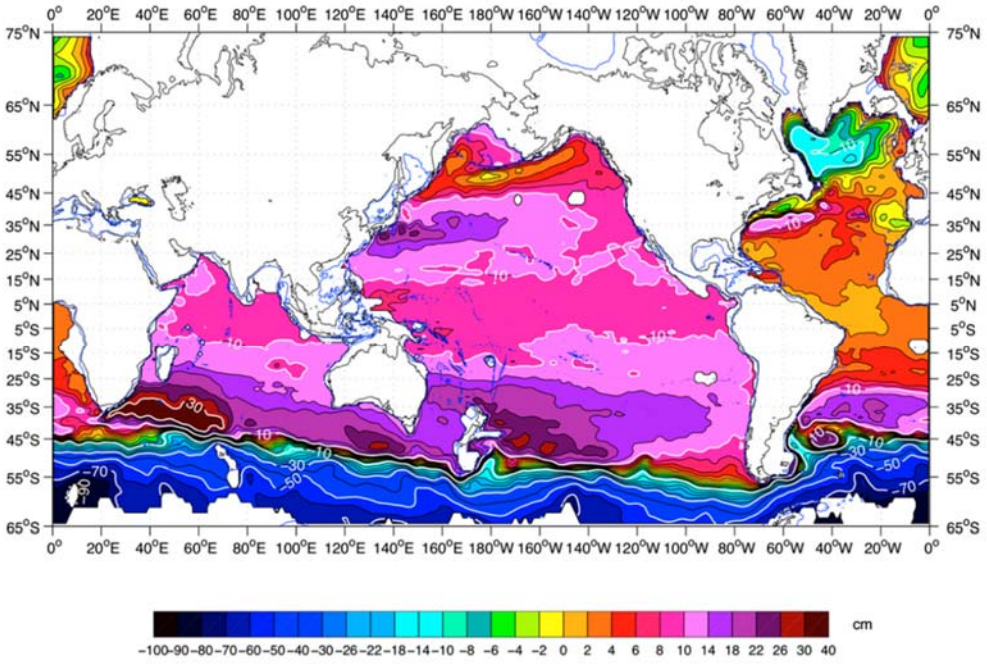
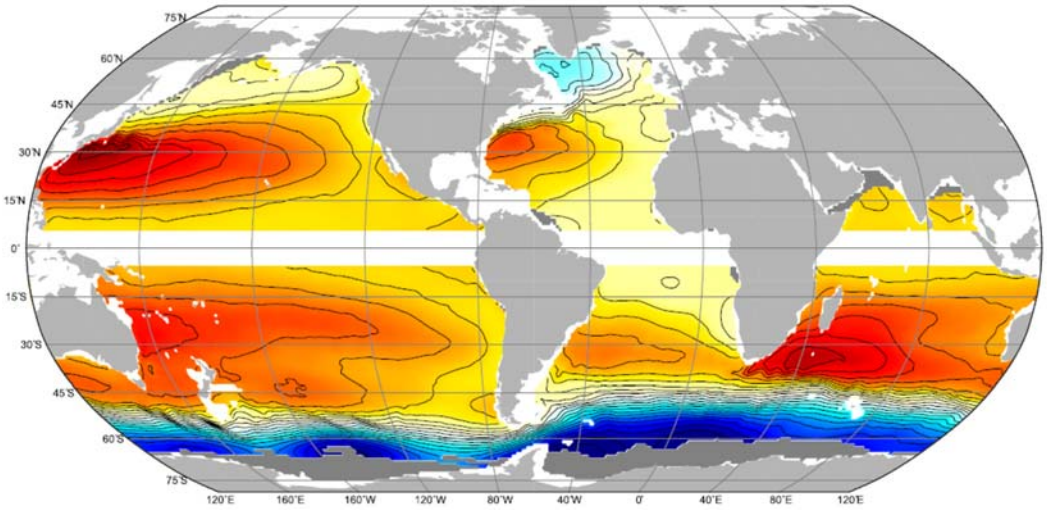



FIG. 16. Geopotential height field near 1000 dbar [given as $100\Phi/g_e$ in (cm) height].

Ollitrault and Colin de Verdiere, *JPO* 2014

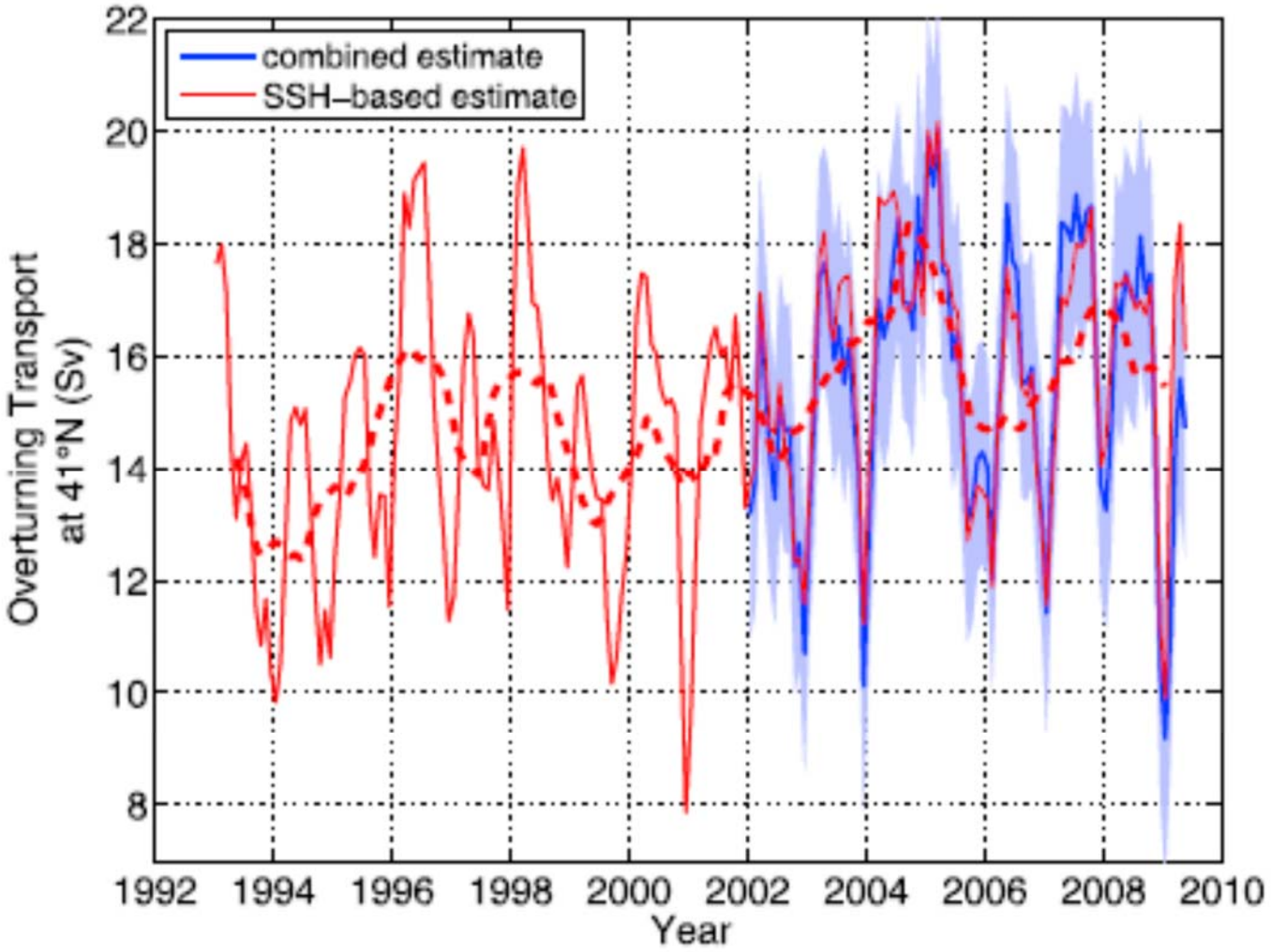
Geostrophic streamfunction at 200 dbar



Gray and Riser, *JPO* 2014

# What is the large-scale circulation?

## Atlantic MOC determined from floats and satellite altimetry

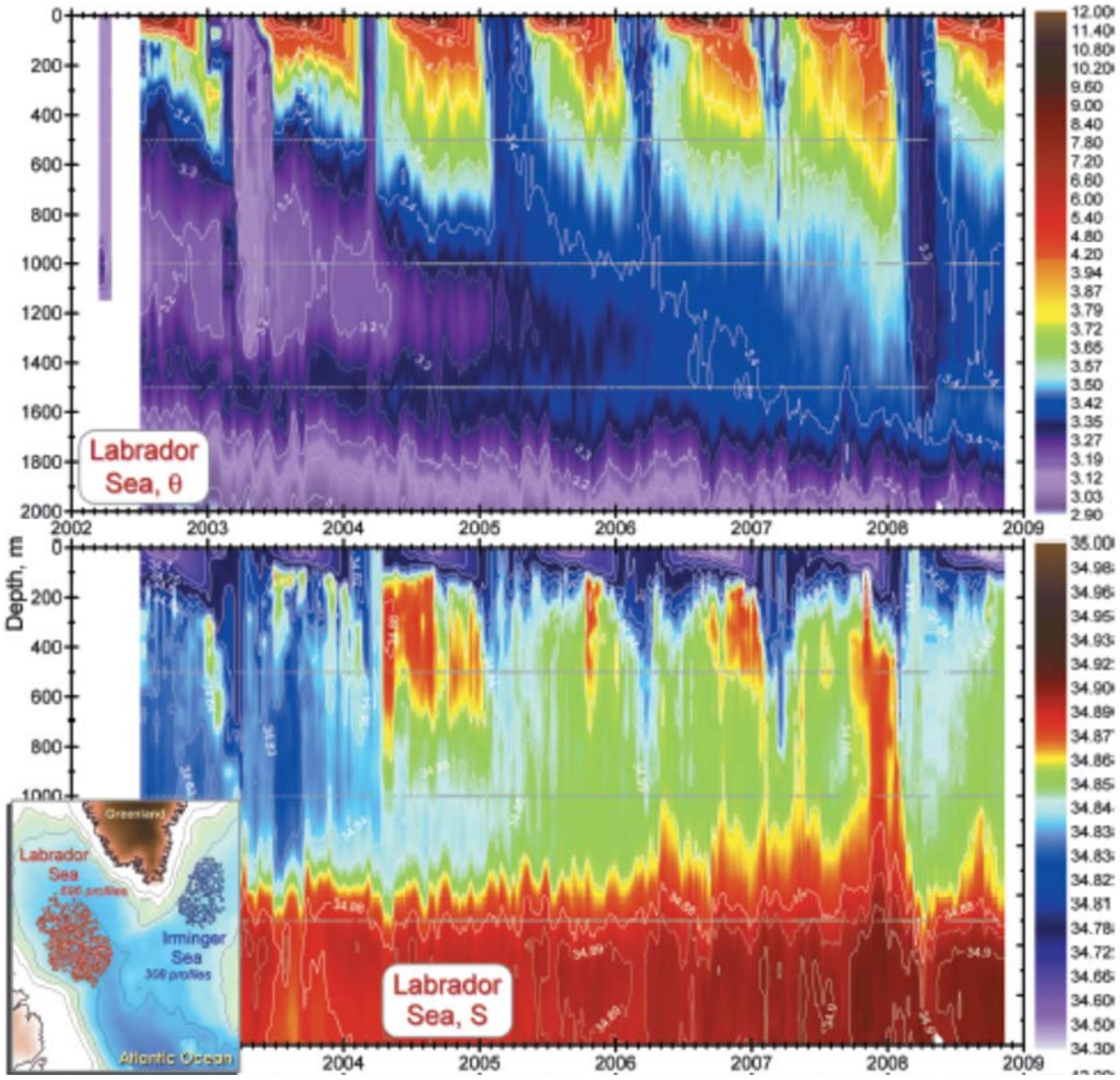



Variability in the AMOC at 41°N computed as the sum of Ekman and geostrophic transports between 0 and 1130 m

Willis, *GRL* 2010

# What is the large-scale circulation?

## Deep convection observed in the Labrador Sea

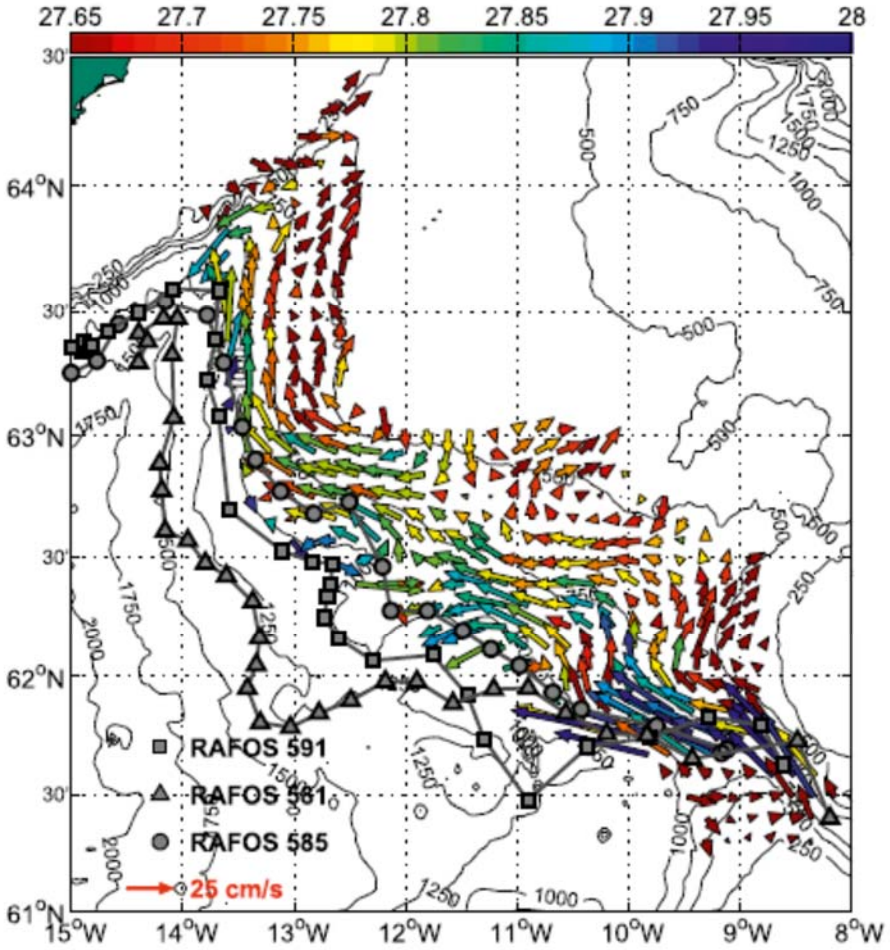



Seasonal-to-interannual development of potential temperature and salinity in the central Labrador Sea

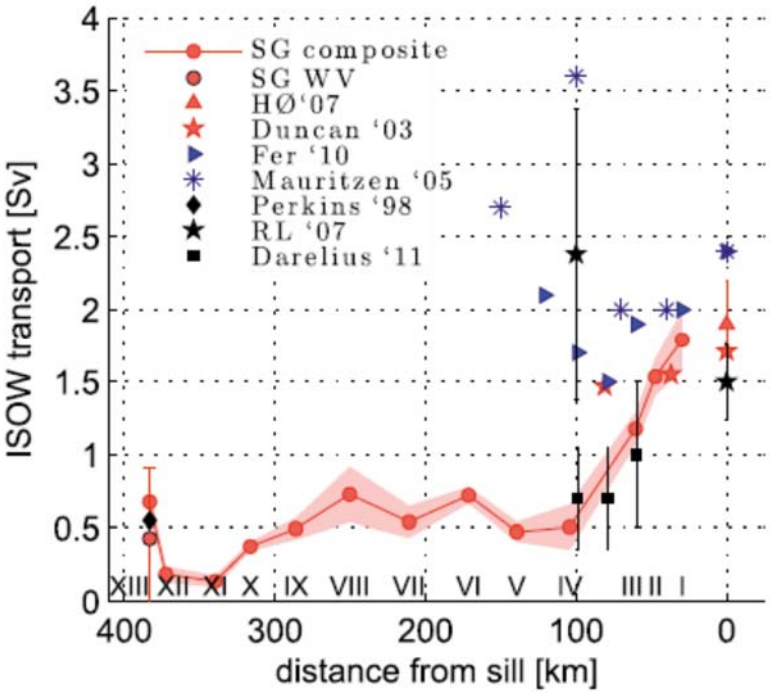
Yashayaev and Loder, *GRL* 2009

# What is the large-scale circulation?

## Part of the deep limb of the Atlantic MOC observed with gliders




Near-bottom velocities and transport of ISOW across Iceland-Faroe Ridge




Beaird et al., *JPO* 2013

# What is the global distribution of small-scale physical processes?

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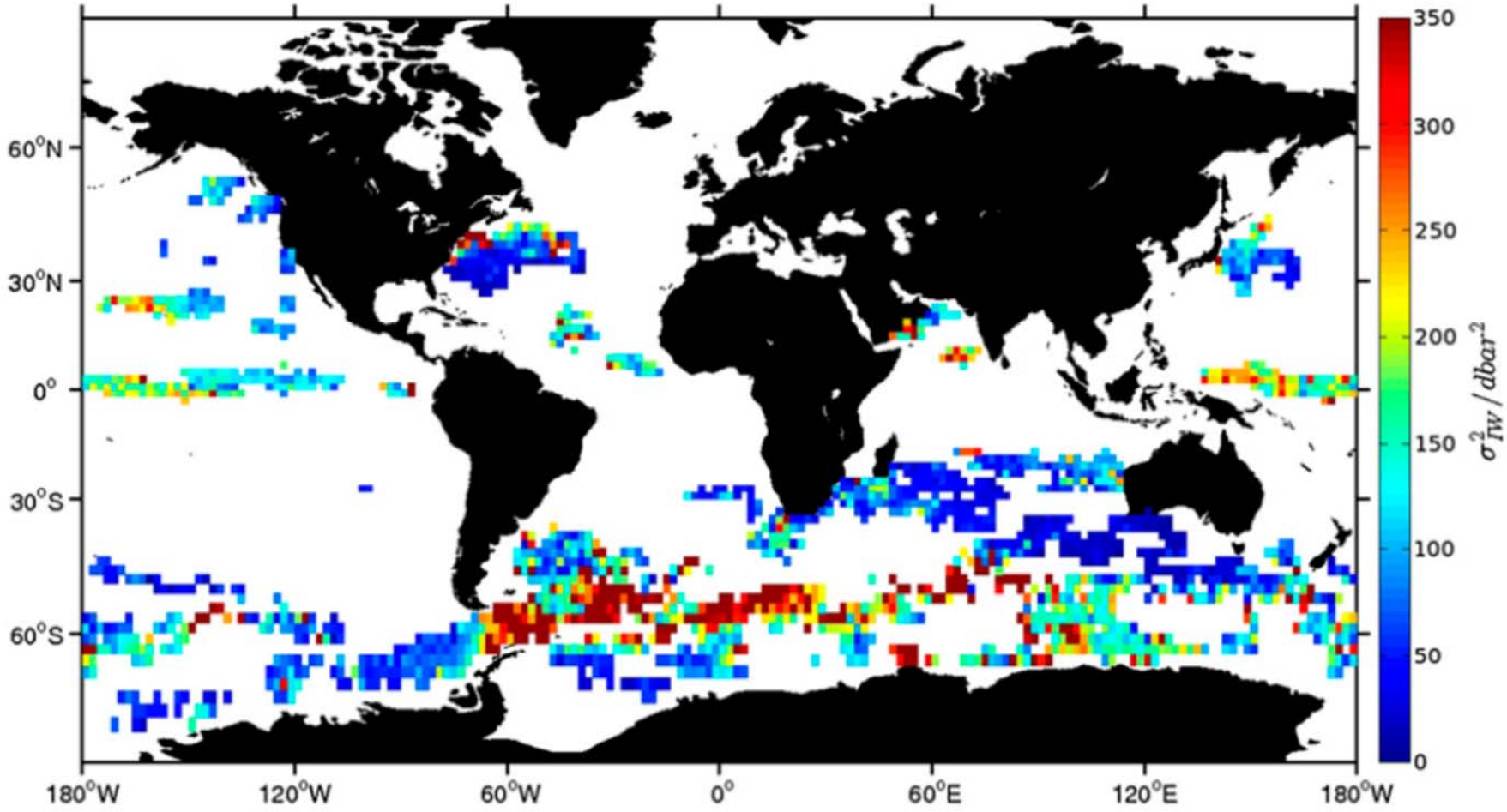
## Internal wave intensity correlated with seafloor roughness and proximity, and local barotropic velocity

1000 m internal wave vertical displacement variance




Hennon et al., *JPO* 2014

# What is the global distribution of small-scale physical processes?

## Horizontal diffusivity varies over two orders of magnitude with depth, latitude, and longitude

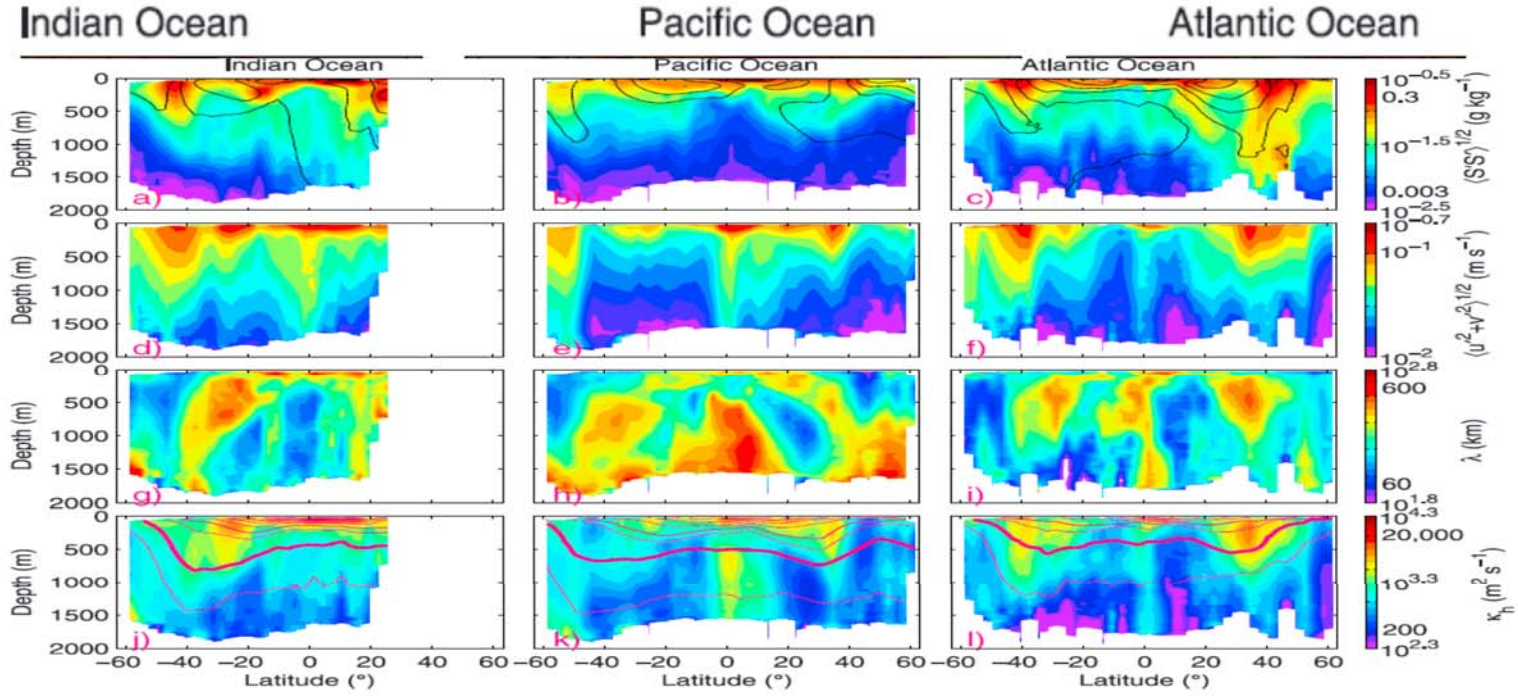



**Figure 4.** Zonally averaged (a–c) salinity standard deviation with average salinity (black contours), (d–f) ECCO2 velocity fluctuations, (g–i) mixing length, and (j–l) horizontal diffusivity with average density (magenta contours; 27.0 kg m$^{-3}$ in bold) in the (a, d, g, and j) Indian Ocean, (b, e, h, and k) Pacific Ocean, and (c, f, i, and l) Atlantic Ocean.

Cole et al., *GRL* 2015

# What is the global distribution of small-scale physical processes?

## Increased dissipation linked to regions with rough topography and areas of high eddy kinetic energy

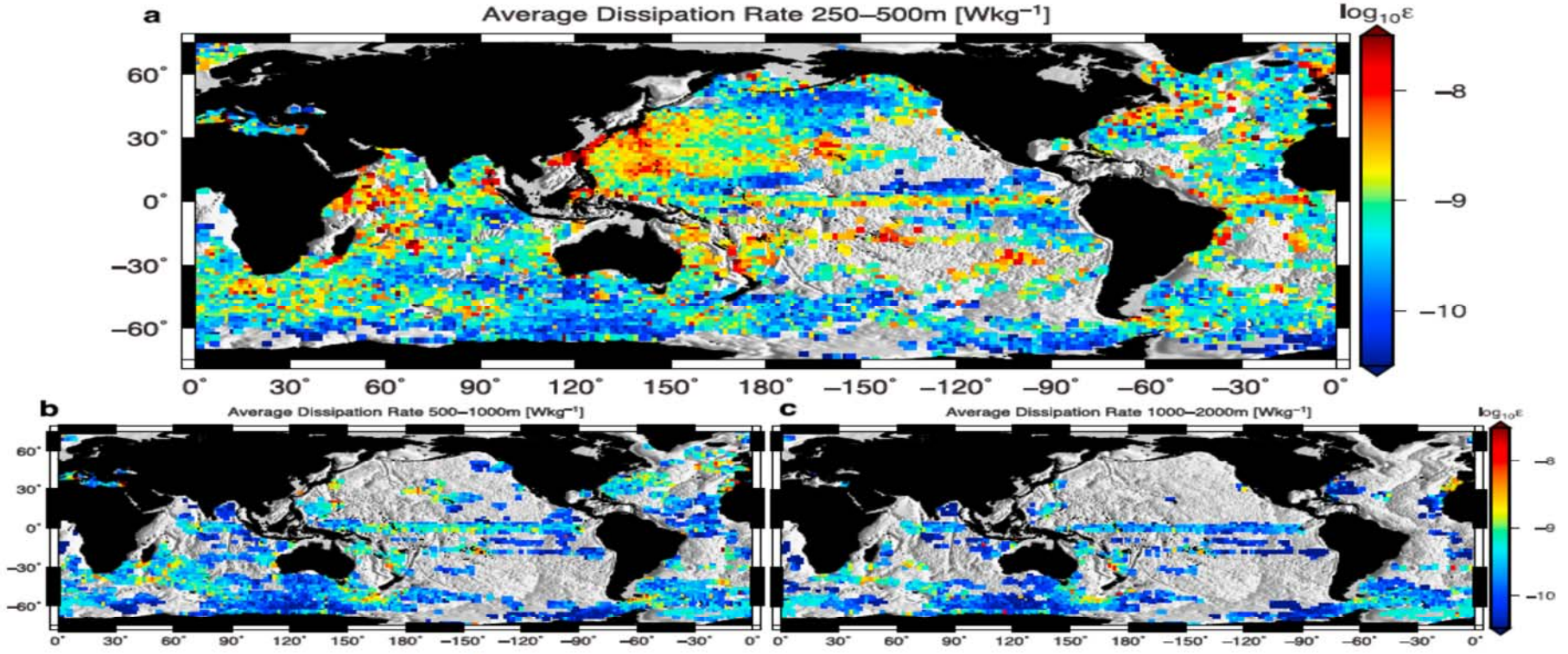



**Figure 1.** Dissipation rate $\epsilon$ (W kg$^{-1}$) estimated from over five years (2006–2011) of Argo data. Estimates from high vertical resolution data centered between (a) 250–500 m, (b) 500–1,000 m, and (c) 1,000–2,000 m are averaged over 1.5° square bins and plotted if they contain more than three dissipation rate estimates. The underlying bathymetry is from the Smith and Sandwell dataset [*Smith and Sandwell*, 1997] version 14.1.

Whalen et al., *GRL* 2012

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- Integration of ALPS data into global ocean observing system is important.
- Data management and quality are key.
- Publicly available data enables great and more science.
- If you build it,

  they will come.