Global hydrographic variability patterns during 2003-2008

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Outline:

1) Description of the global gridded hydrographic field

2) Long-term changes: A comparison to the World Ocean Atlas 2005 (WOA05, Locarnini et al., 2006; Antonov et al., 2006)

3) The annual cycle of temperature and salinity at depth

4) Interannual hydrographic fluctuations during 2003-2008

5) Global changes of Heat Storage, Freshwater Content and Steric Height

6) Conclusion

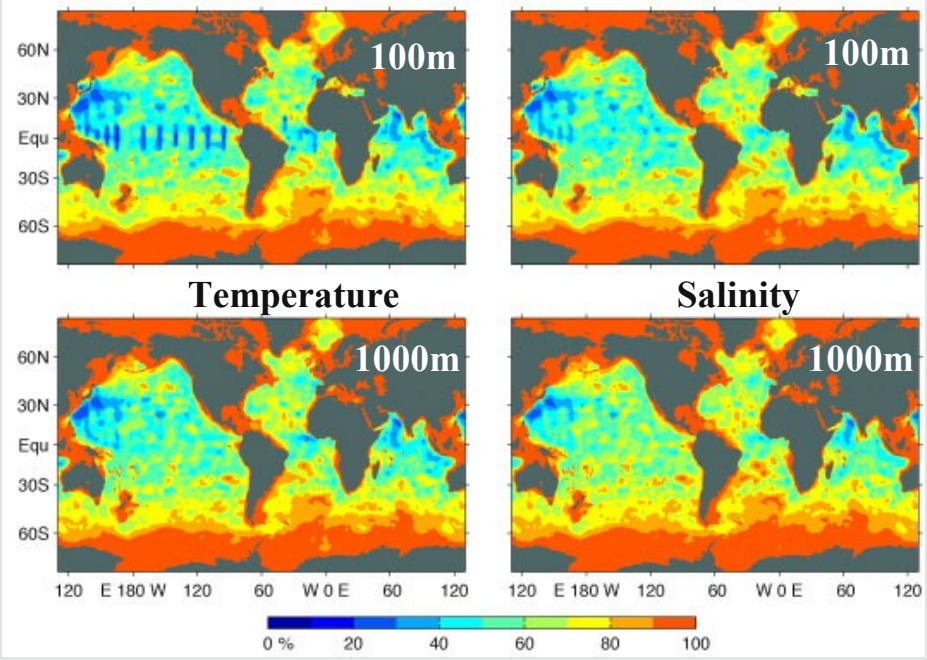
1) Description of the global gridded hydrographic field

The French project ARIVO (http://www.ifremer.fr/lpo/arivo/):

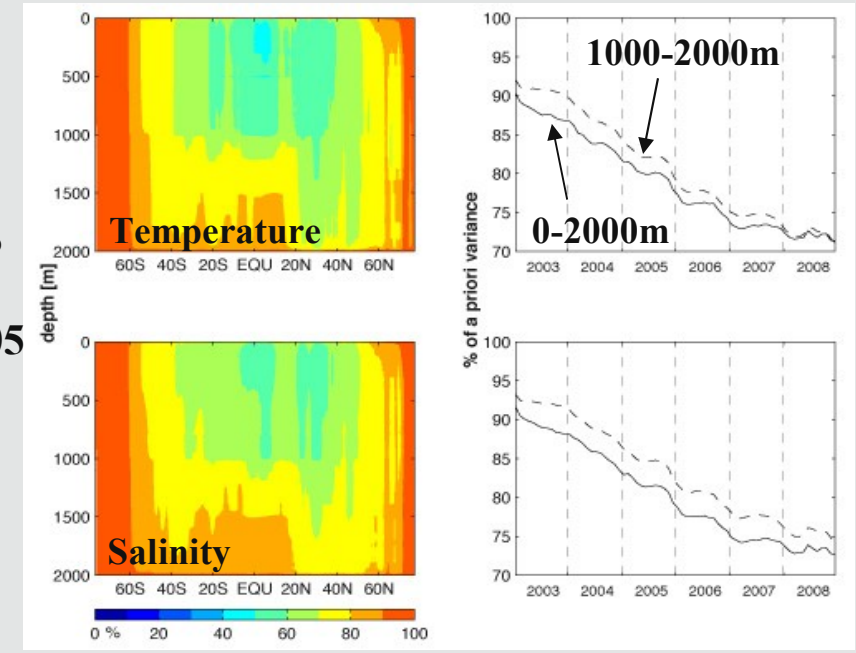
Monthly gridded fields of temperature and salinity are obtained by optimal analysis of in-situ data sets as Argo (95%), shipboard and mooring measurements (XBTs, XCTDs and SOLO floats are excluded)

Period: 2003-2008, ½° Mercator grid, 152 levels between the surface and 2000m

Reference: WOA05



100% = WOA05



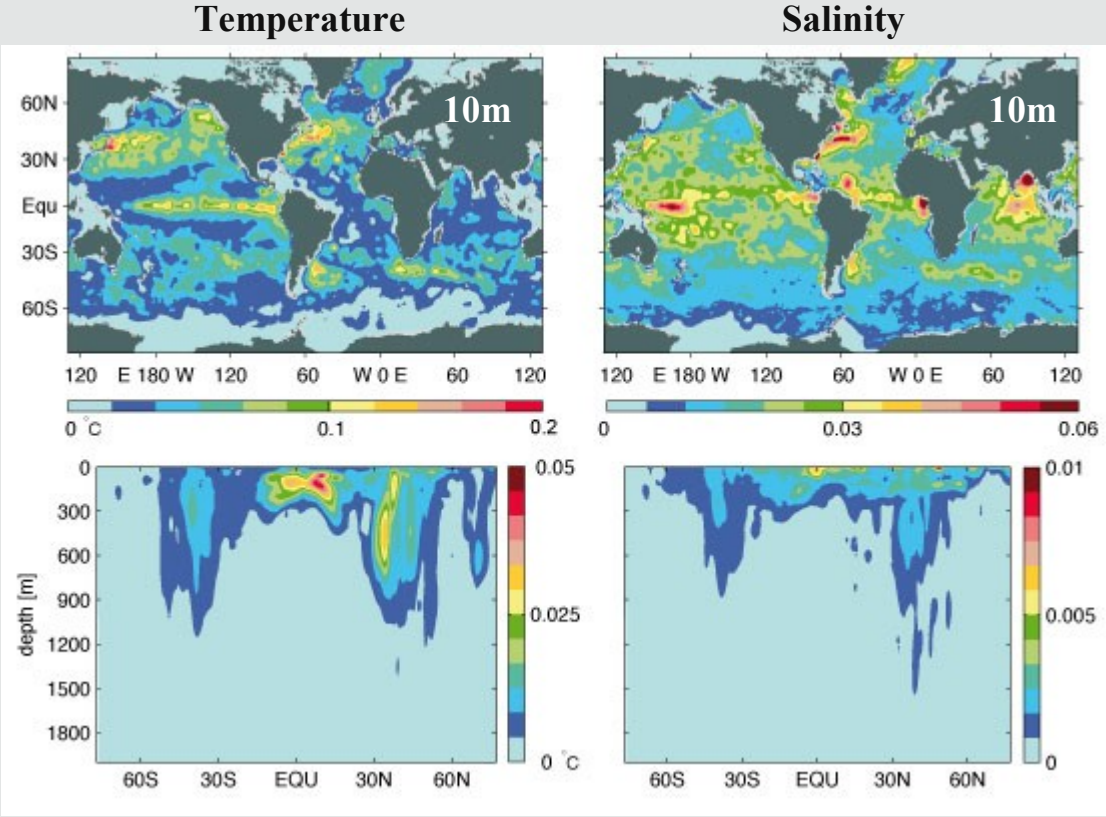
Data coverage information: Percentage of 'A Priori Variance'

1) Description of the global gridded hydrographic field

Errors on the analyzed field

Error on the estimate of the mean: $E = \frac{1}{N^*}(\sigma_{x'}^2 + \sigma_e^2)$

$\sigma_{x'}^2$ is the variance of the samples around the mean
σ_e^2 is the variance of the error on each sample
N* is the number of independent samples

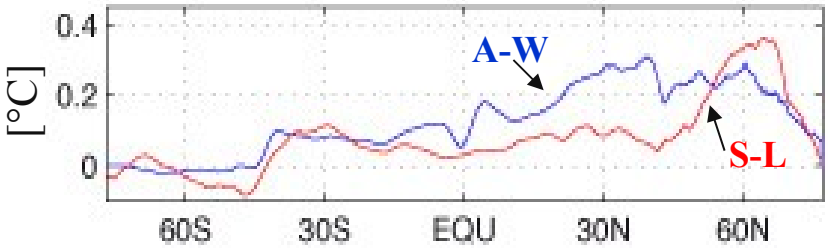


2) Long-term changes: A comparison to WOA05

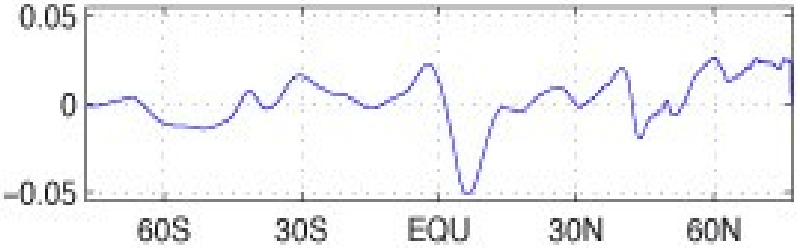
A-W: ARIVO (2003 to 2008 mean)-WOA05

S L

Temperature



Salinity



global zonal mean

Largest surface warming in the northern hemisphere: asymmetry in A-W and S-L

Both estimations show low amplitudes in the Southern Ocean, thus ruling out that low values in this part of the global ocean are due to insufficient sampling

Large surface freshening in the northern tropics

Areas of surface saltening in the southern tropics and subtropics and north of 15°N (except at 40°N)

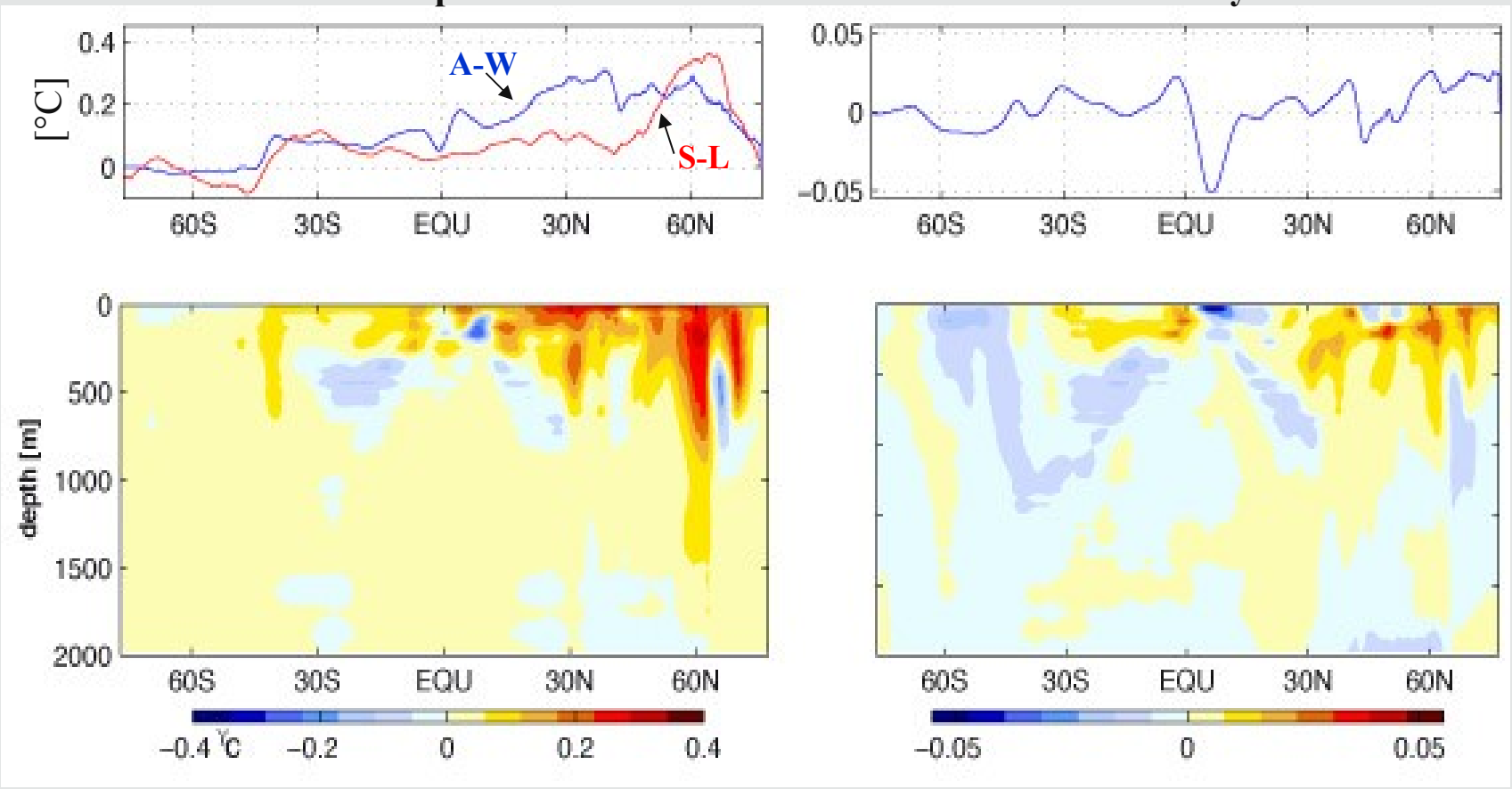
Surface freshening in the Southern Ocean between 40-60°S

2) Long-term changes: A comparison to WOA05

A-W: ARIVO (2003 to 2008 mean)-WOA05

S L

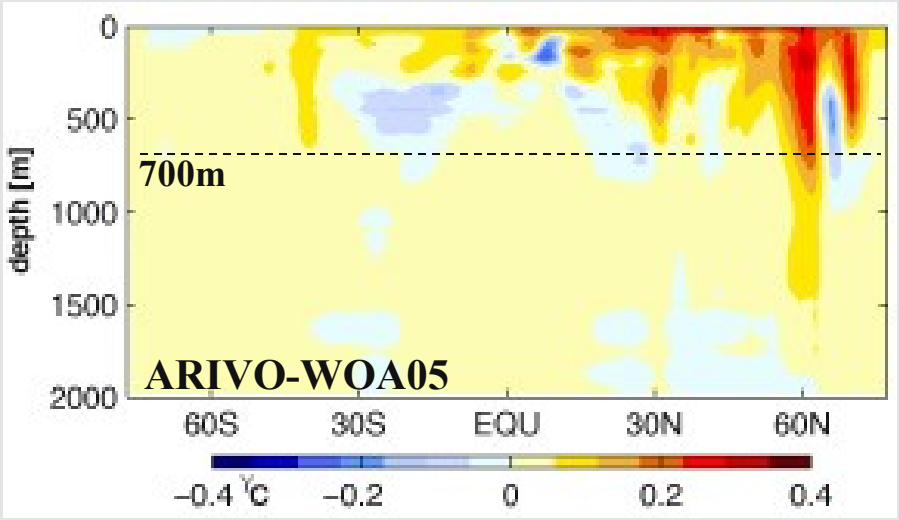
Temperature **Salinity**



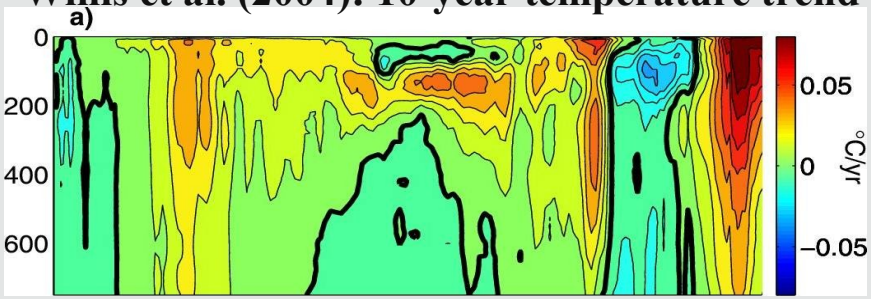
global zonal mean

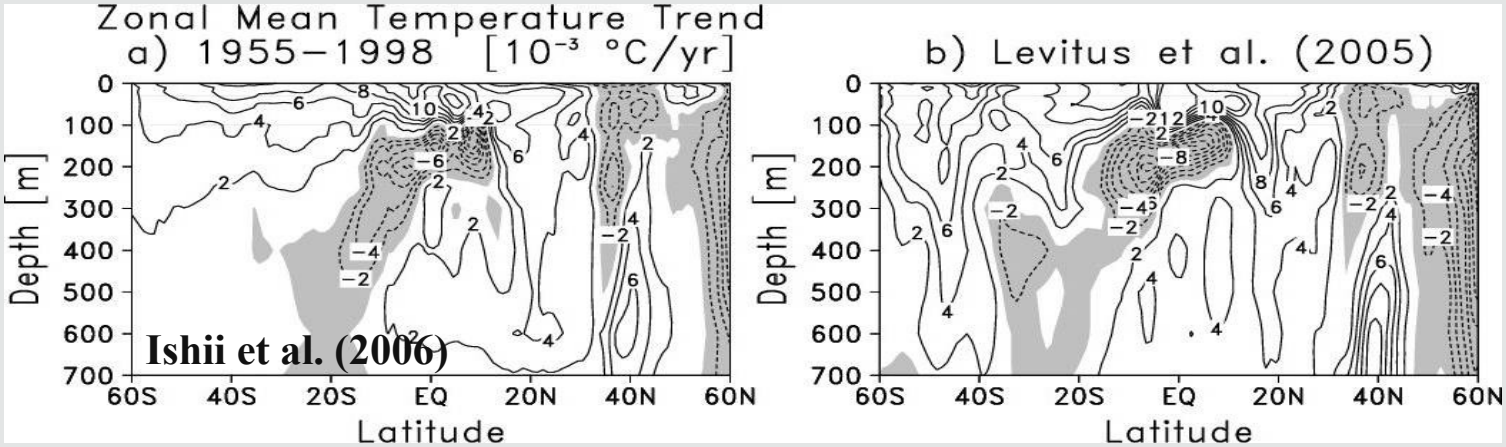
Long term changes in the upper layer reach down to greater depth.

2) Long-term changes: A comparison to WOA05



Willis et al. (2004): 10-year temperature trend





Temperature

Long-term changes are constistent with previous results, but some differences occur:

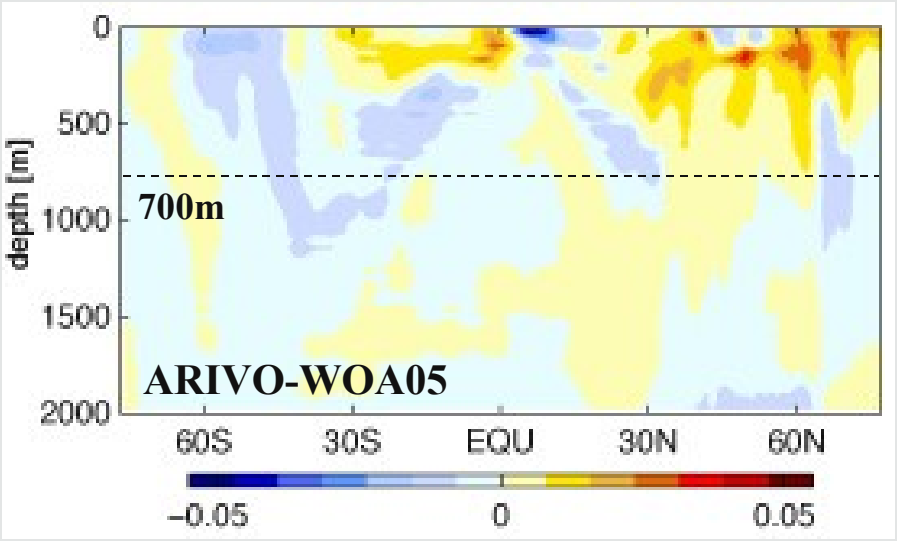
Intermediate subsurface cooling occurs also in the northern hemisphere

Large interannual and decadal fluctuation at northern mid-latitudes

Our results show weak Southern Ocean warming

2) Long-term changes: A comparison to WOA05

Salinity

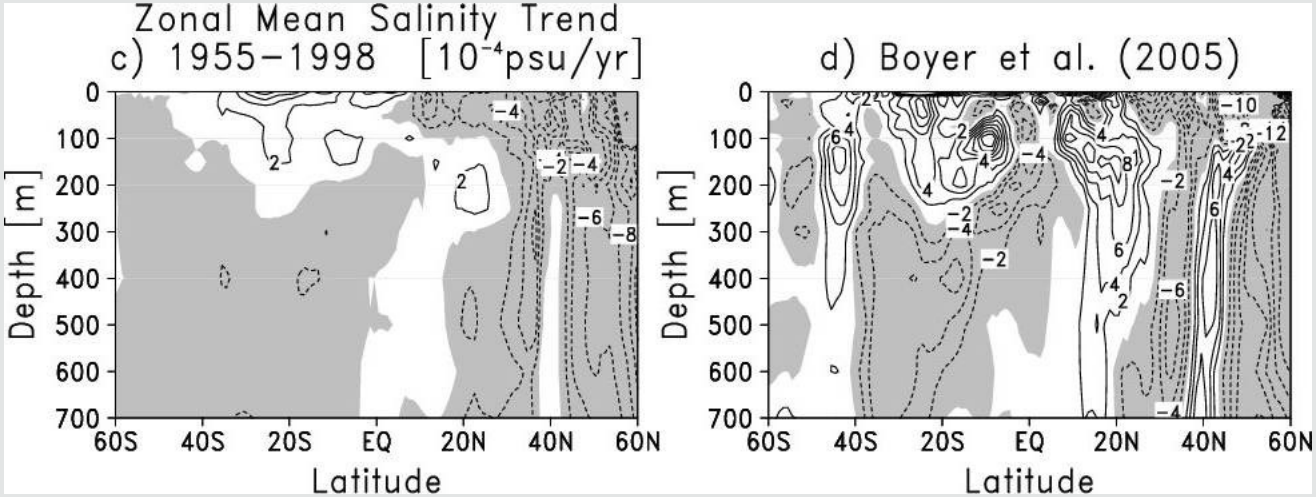


Differences occur between the estimations:

Large differences in the upper tropics and in the northern hemisphere, reflecting the sensitivity of long-term means to strong interannual changes.

Our results also show intermediate freshening in northern tropics and subtropics

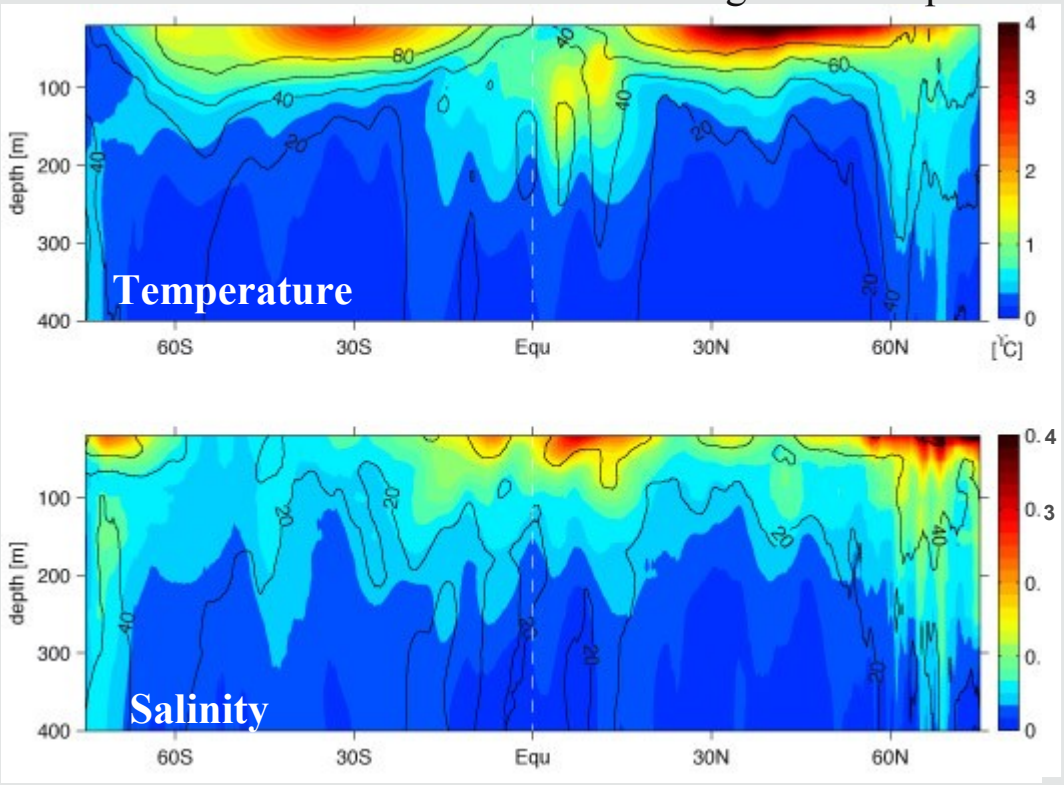
Freshening in the Southern Ocean is stronger in our estimation.



Ishii et al., 2006

3) The annual cycle of temperature and salinity at depth

First annual harmonic: Global zonal average of its amplitude



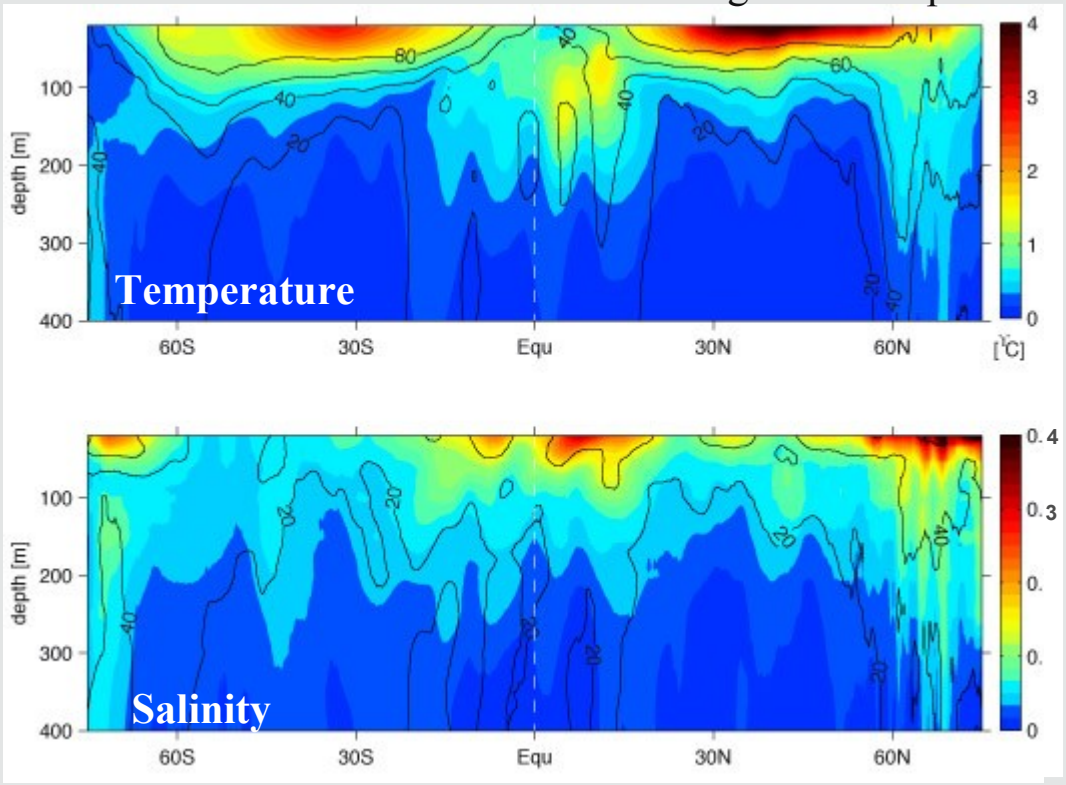
Regions of strong seasonal temperature changes differ from those of the salinity field

The depth penetration of the seasonal cycle increases with decreasing distance to the poles

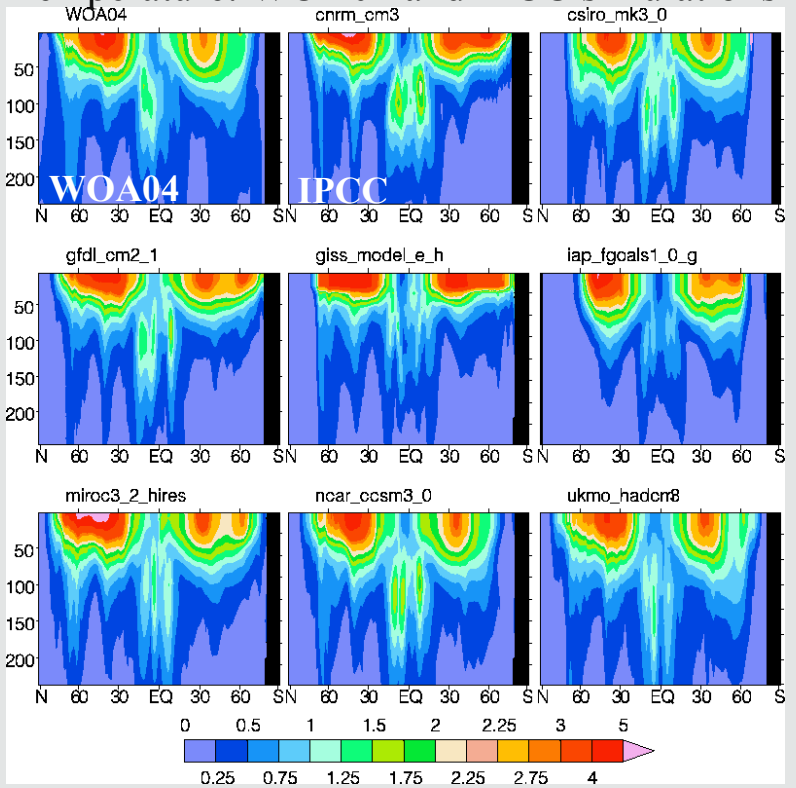
Seasonal amplitudes of both parameters are stronger in the northern hemisphere.

3) The annual cycle of temperature and salinity at depth

First annual harmonic: Global zonal average of its amplitude



Temperature: WOA04 and IPCC simulations



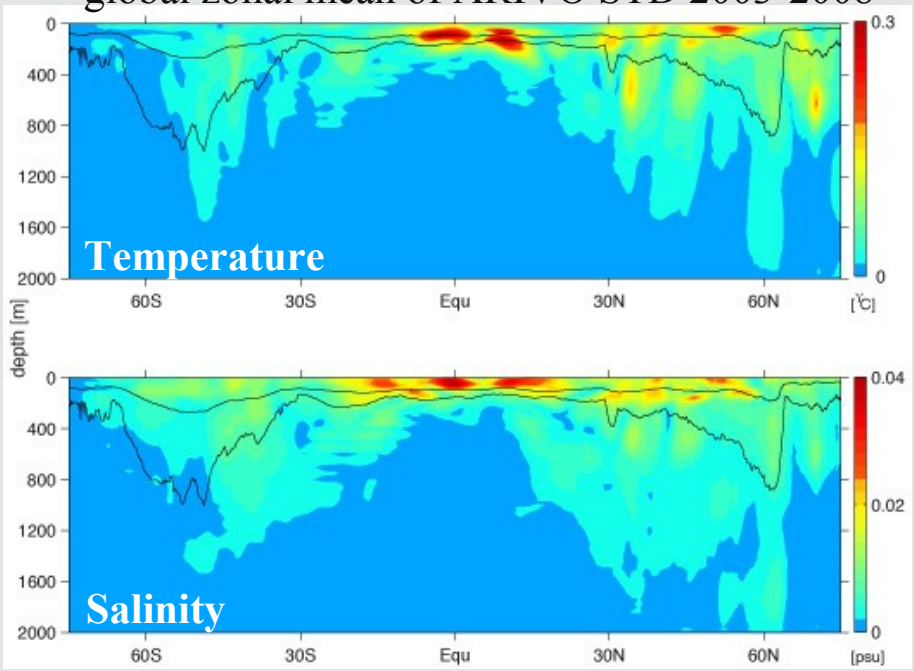
Gleckler et al., 2006

Problems of simulating the annual cycle, especially in the tropical basin

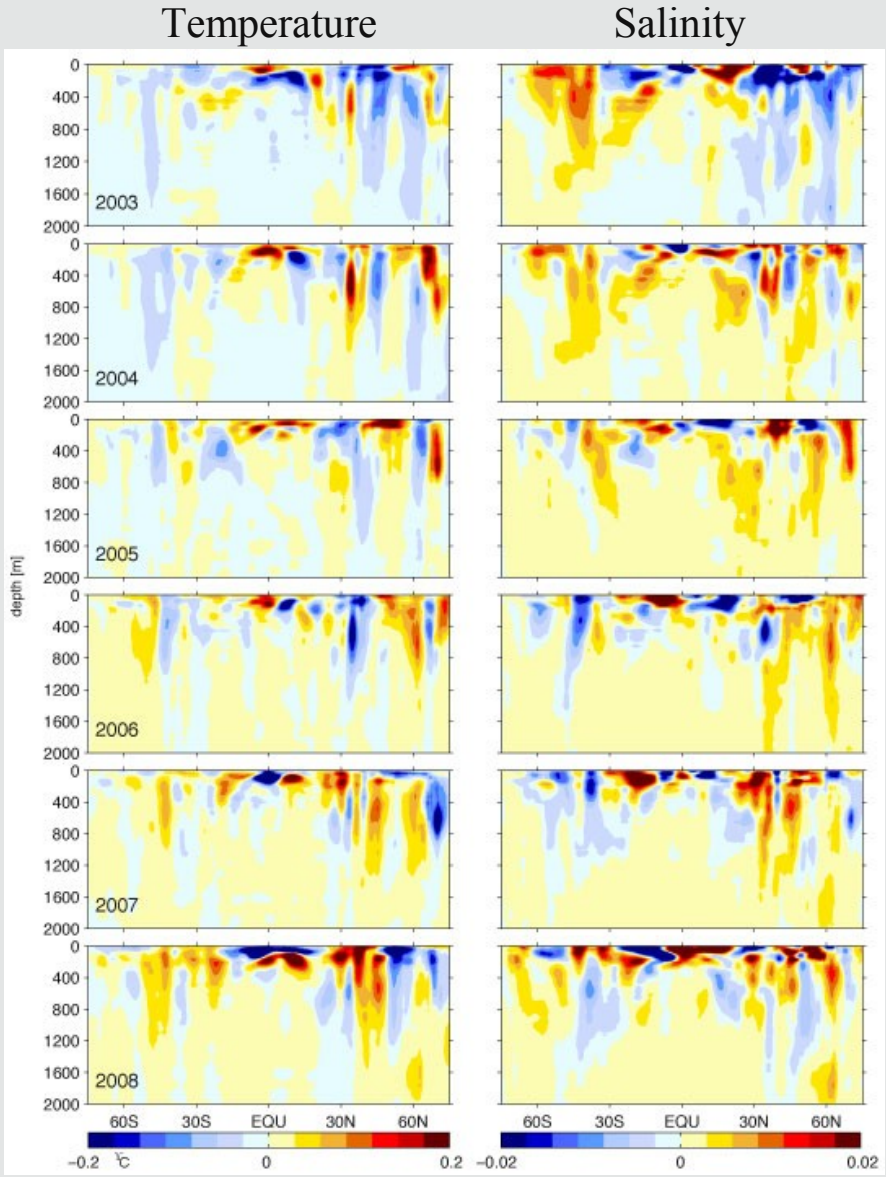
With the growing data density in time and space, Argo will become a robust reference

4) Interannual hydrographic fluctuations during 2003-2008

global zonal mean of ARIVO STD 2003-2008



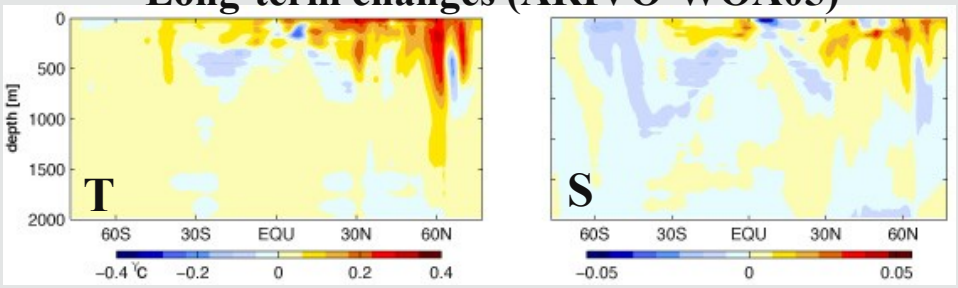
Forget and Wunsch, 2007:
" Variability of temperature and salinity is strongly correlated below the upper 100m and the vertical maximum of variability is associated with the equatorial and ventilated thermocline."



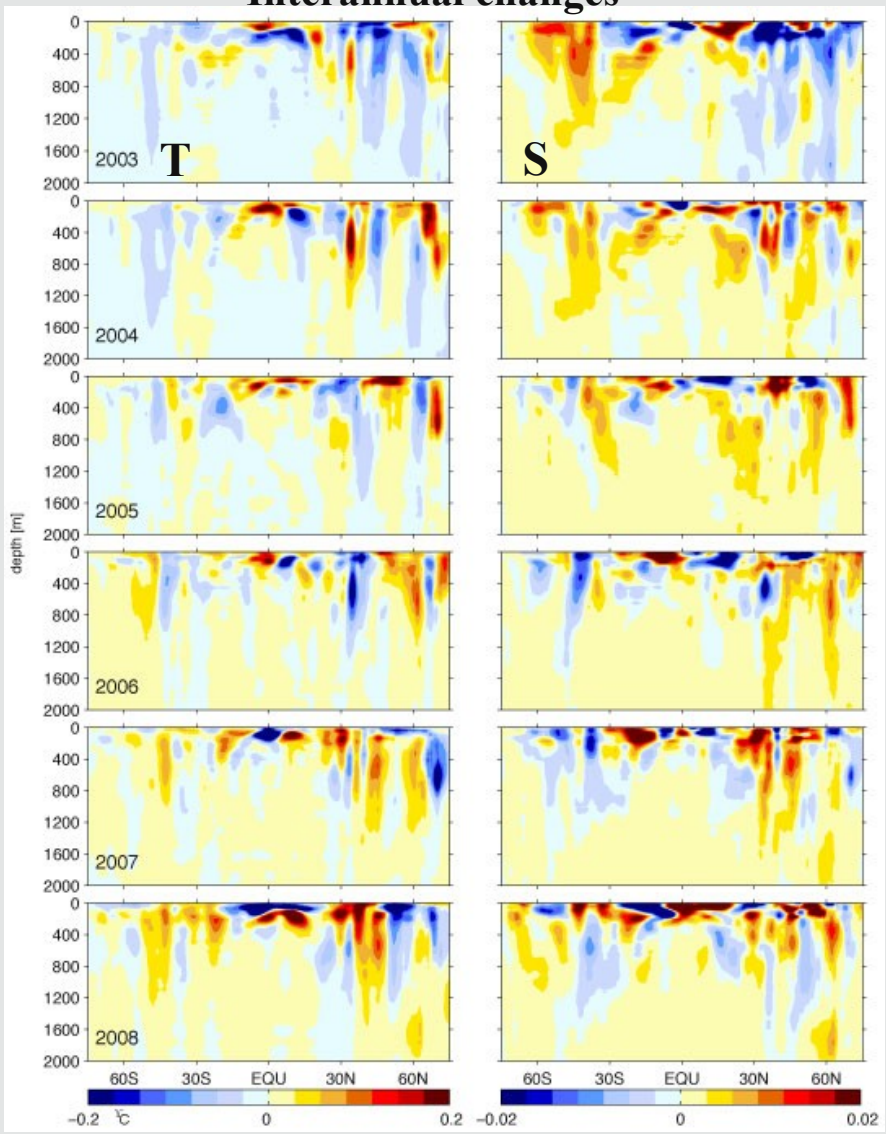
global zonal mean of the annual averages

4) Interannual hydrographic fluctuations during 2003-2008

Long-term changes (ARIVO-WOA05)



Interannual changes

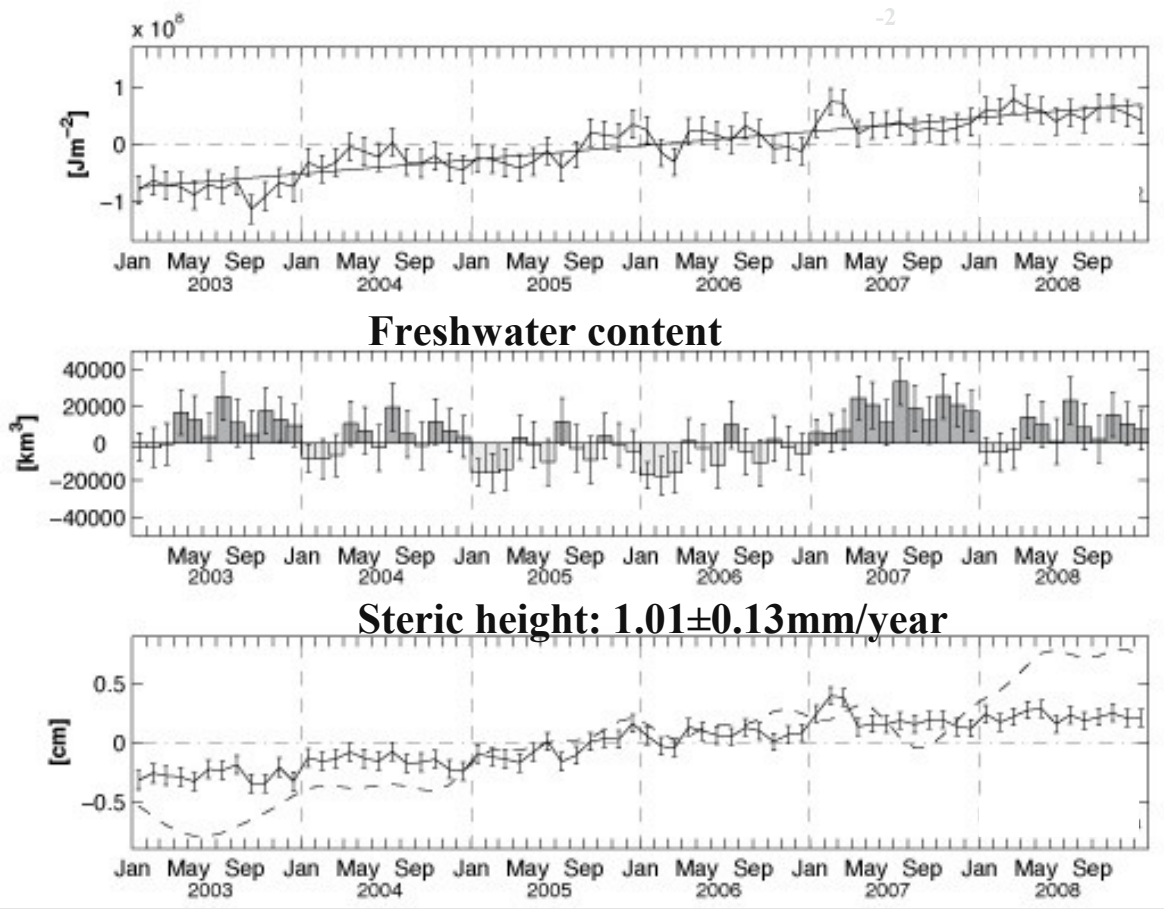


Large interannual fluctuations superimpose deep warming and increase in salinity in the northern hemisphere.

Upper layer of the tropical basin is dominated by large interannual changes.

Interannual temperature fluctuations are large in the Southern Ocean, whereas salinity changes can be observed on longer time scales.

5) Global changes of Heat Storage, Freshwater Content and Steric Height



mean total sea level from altimetry: www.aviso.oceanobs.com, rate 2003-2008: 2.34±0.24 mm/year.

Significant positive 6-year trend in heat storage superimposed by weak interannual variability.

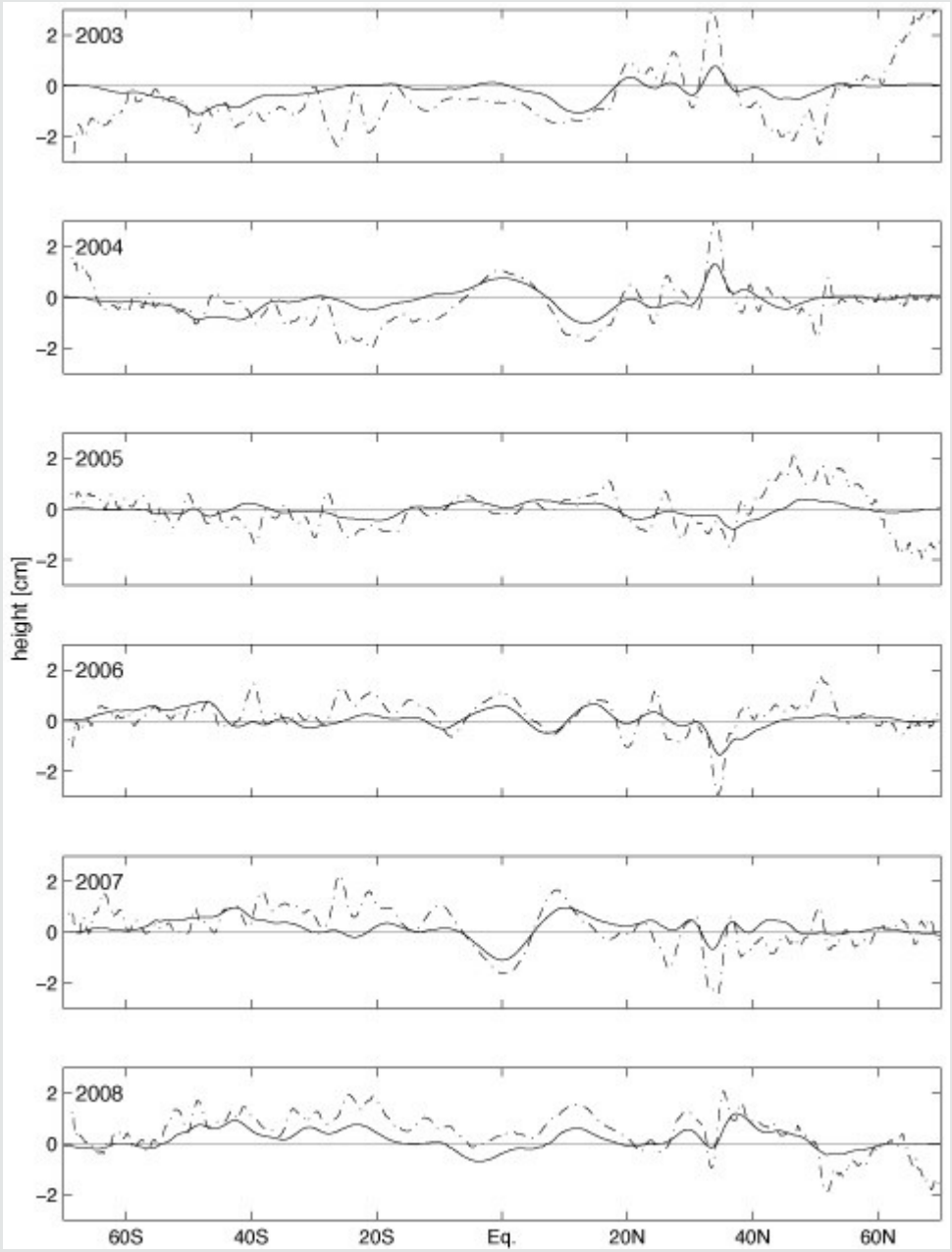
Freshwater content is dominated by interannual variability and a weak positive trend is not significant.

Significant positive 6-year trend in steric sea level is superimposed by weak interannual variability. Steric height contributes about 40% to the 2003 to 2008 increase of total sea level from altimetry.

Conclusion

During 2003-2008, an oceanic warming can be observed in the upper 2000m

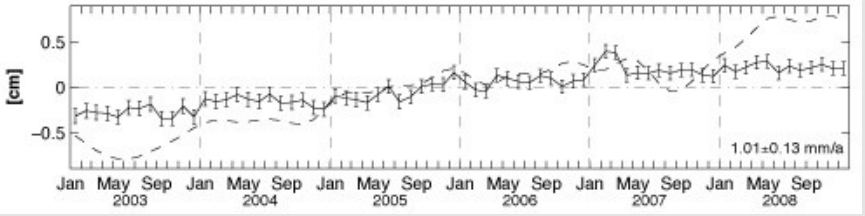
6) Conclusion



Steric height and sea level from altimetry are in good agreement during 2005-2007, but diverge from 2003 through 2004 and in 2008. During the same time, regional biases are large in the tropical basin.

Differences are due to ?

- mass changes (Cazenave et al., 2009)
- barotropic response
- changes in the deep ocean
- remaining errors in one or more of the global observing systems (Willis et al., 2008)
- …



Conclusion

During 2003-2008, an oceanic warming can be observed in the upper 2000m