Diagnostics for variability on HYCOM 1/12º Atlantic data assimilative simulations

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Motivation

What is the Impact of data assimilation on the ocean circulation for NOWCAST and SHOM simulations?

The NOWCAST simulation shows skills and has been used extensively to provide boundary conditions to coastal/regional models. However, are integrated properties conserved?

We therefore look at

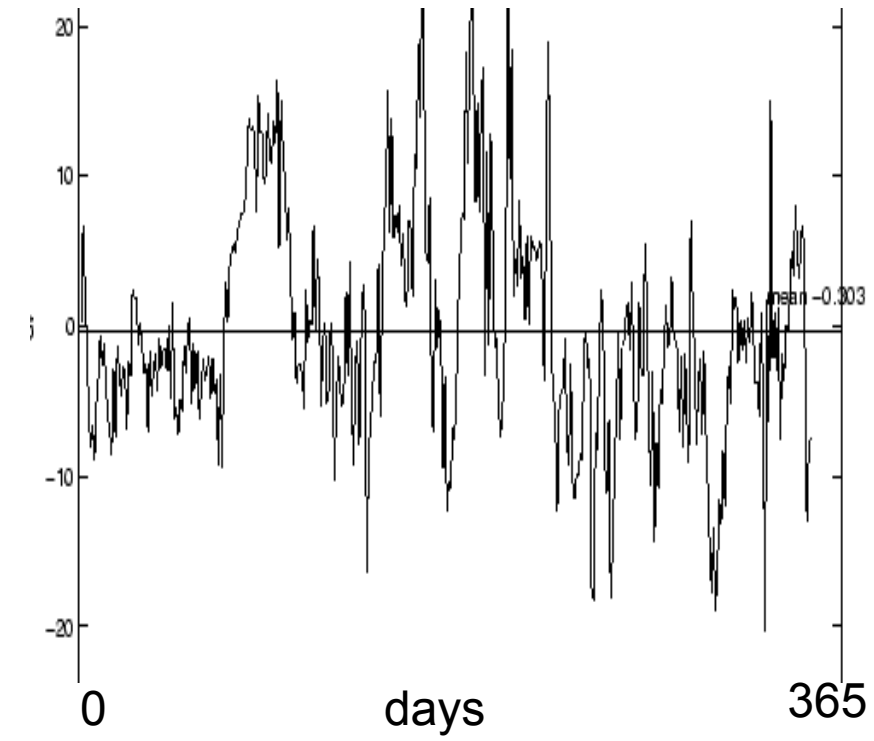
- Barotropic and layer transports
- Vertical structure for mean and variability
- Heat transport
- Overturning circulation

in

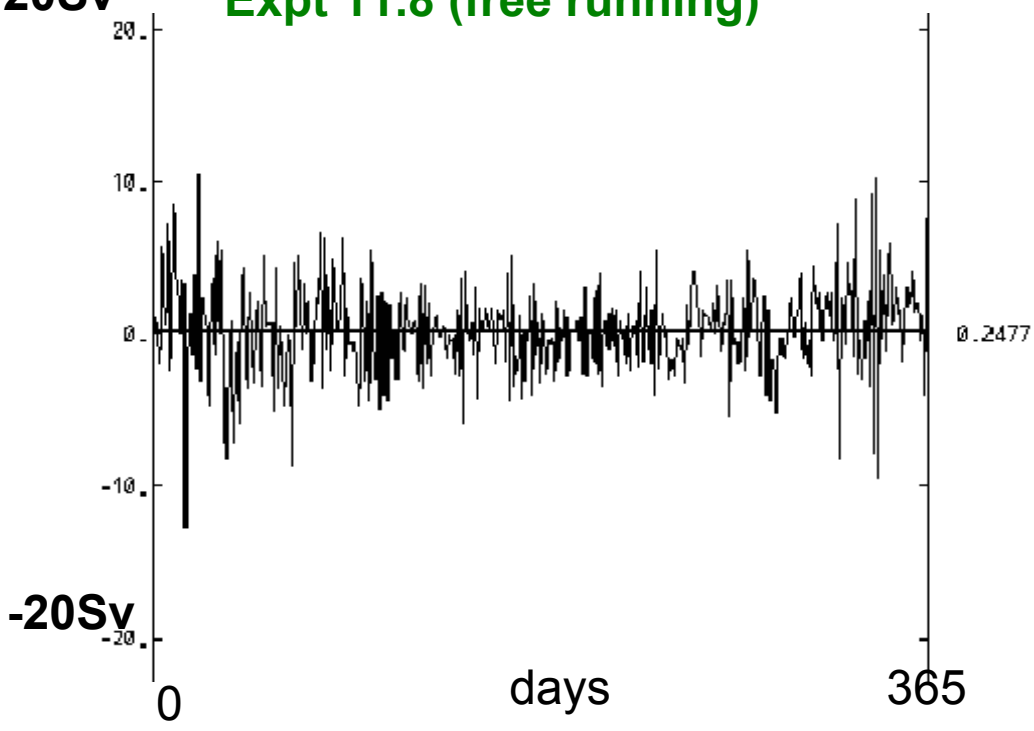
1. The NOWCAST simulation (σ_0), daily assimilation of MODAS SSH maps
2. The SHOM's σ_2^* simulation, based on NRL expt 11.8, data assimilation every 7 days

43°N, 1 year transport across Atlantic

NOWCAST



20Sv **Expt 11.8 (free running)**

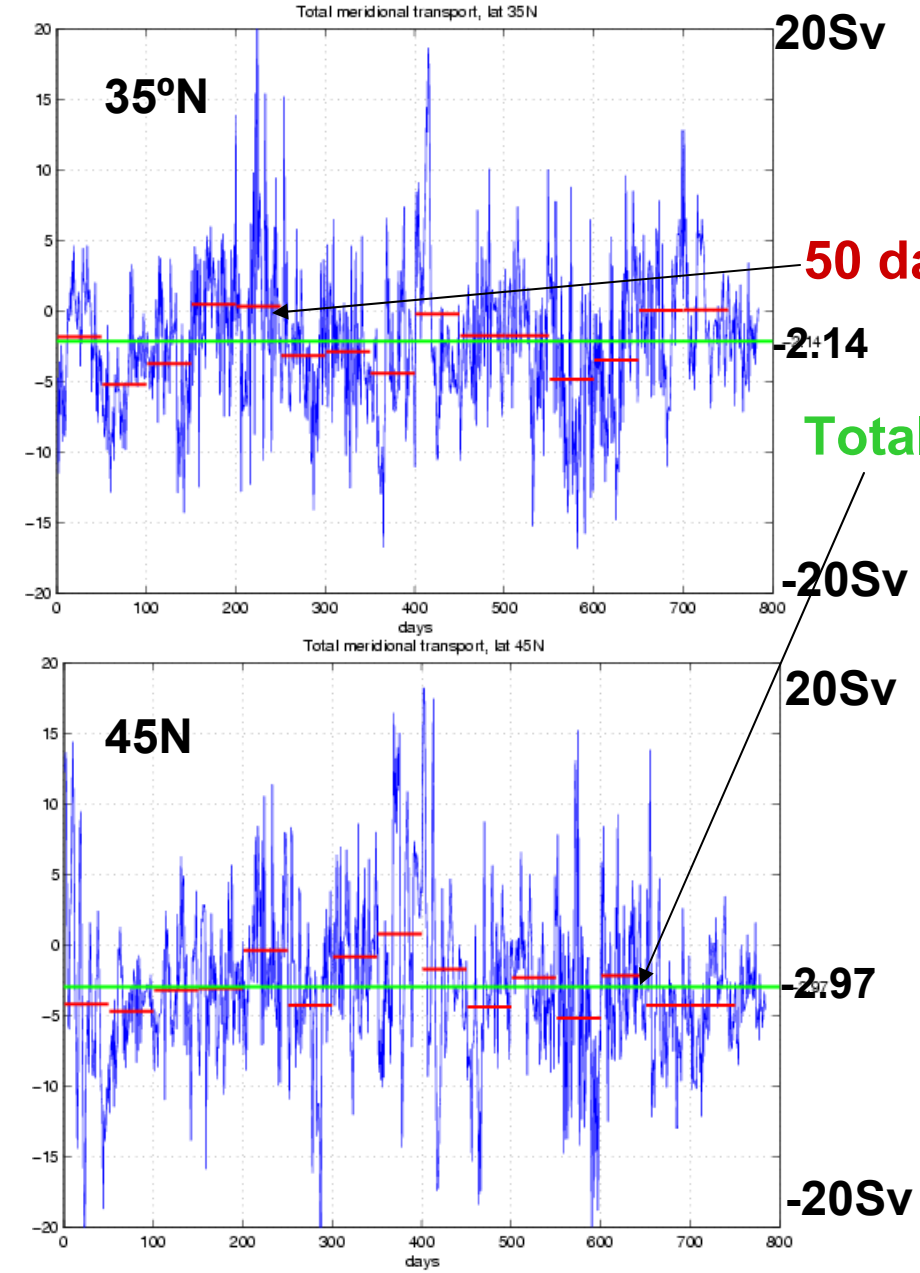


-20Sv

Large variability found in NOWCAST, with large values sustained over many days

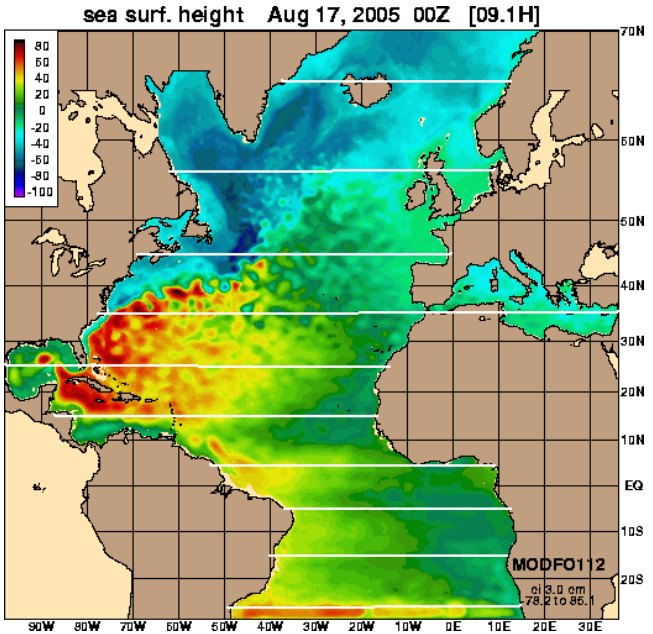
NOWCAST evaluation: Fritz Schott, L. Smith, Z. Garraffo

NOWCAST: 2003-2005 northward transport across Atlantic



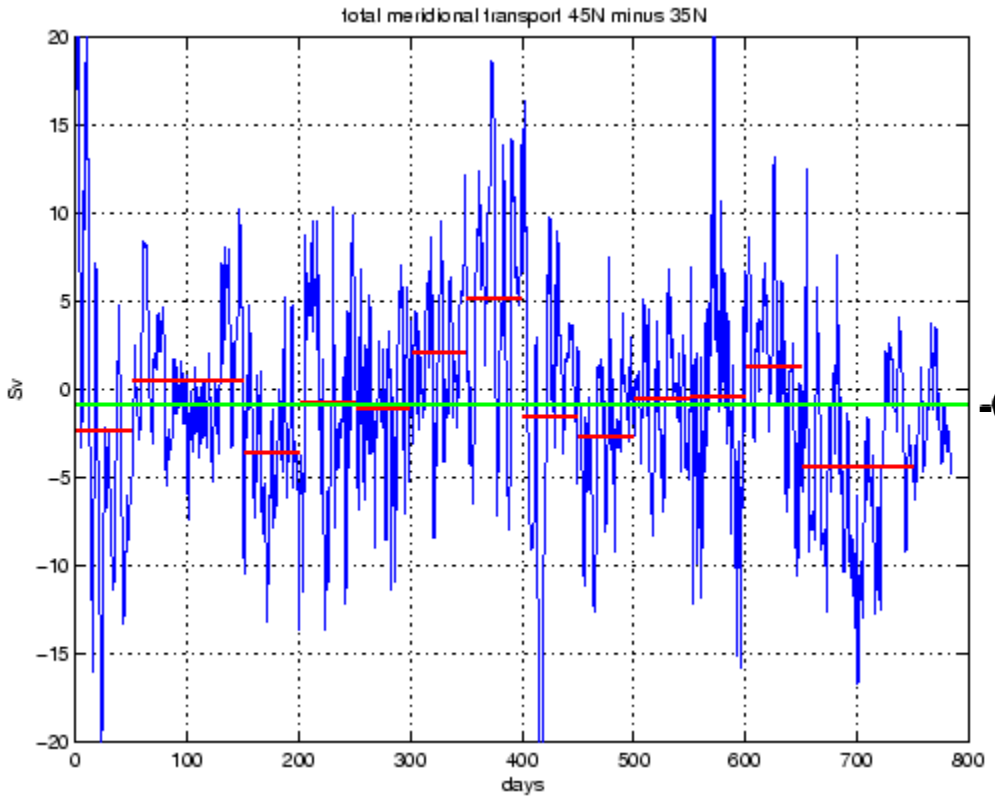
Motivated by the 43°N transports:

Meridional transport time series, every 10º latitude



Found large variations (~15Sv), and large 50-day averages (+/- 5Sv), especially at 35°N-45°N

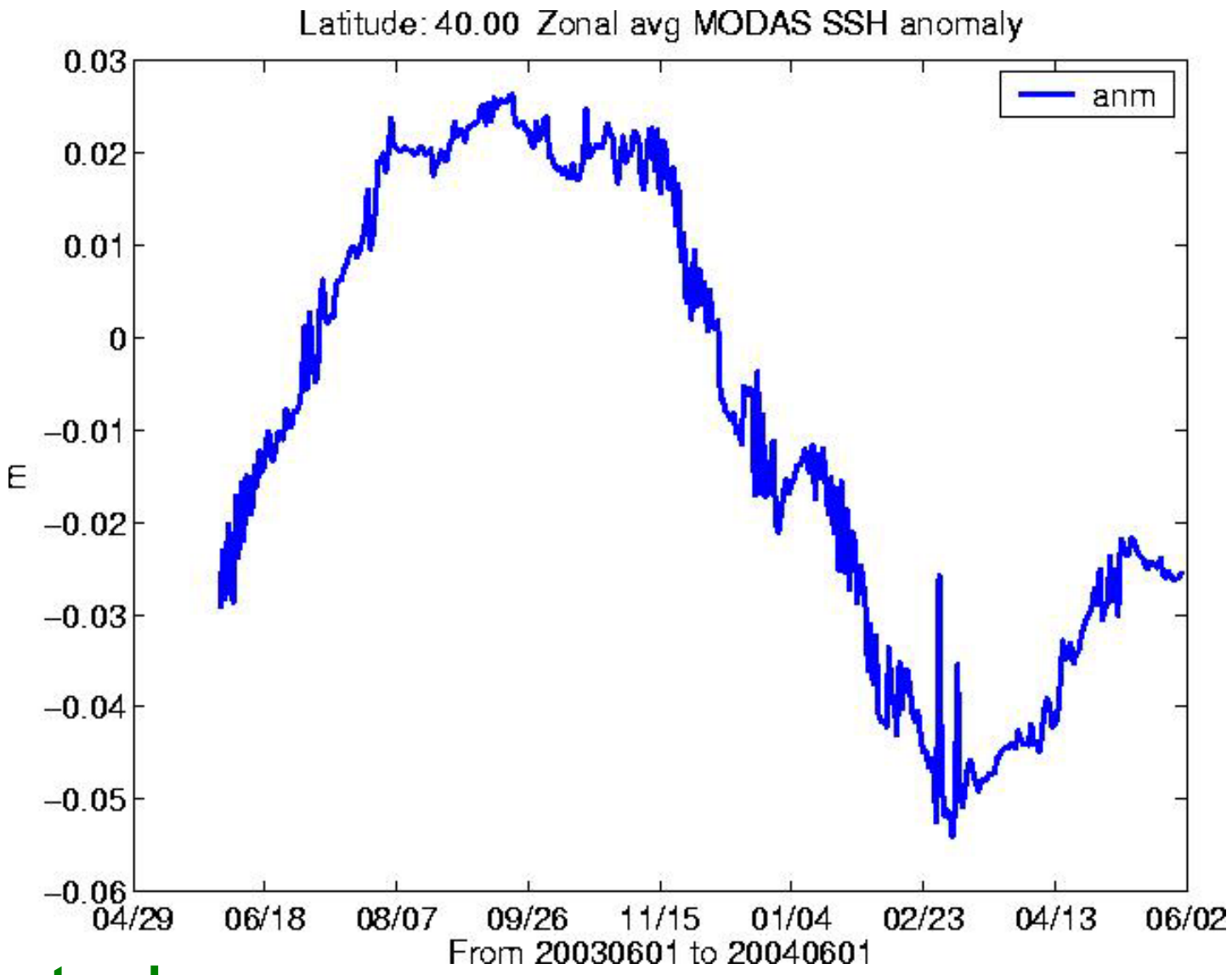
Net transport across Atlantic, box 35N-45N



— 50-day mean

— total mean

Example: 5 Sv during 50 days on 10 degree Atlantic latitudinal band→ Δ SSH = 3 meters!

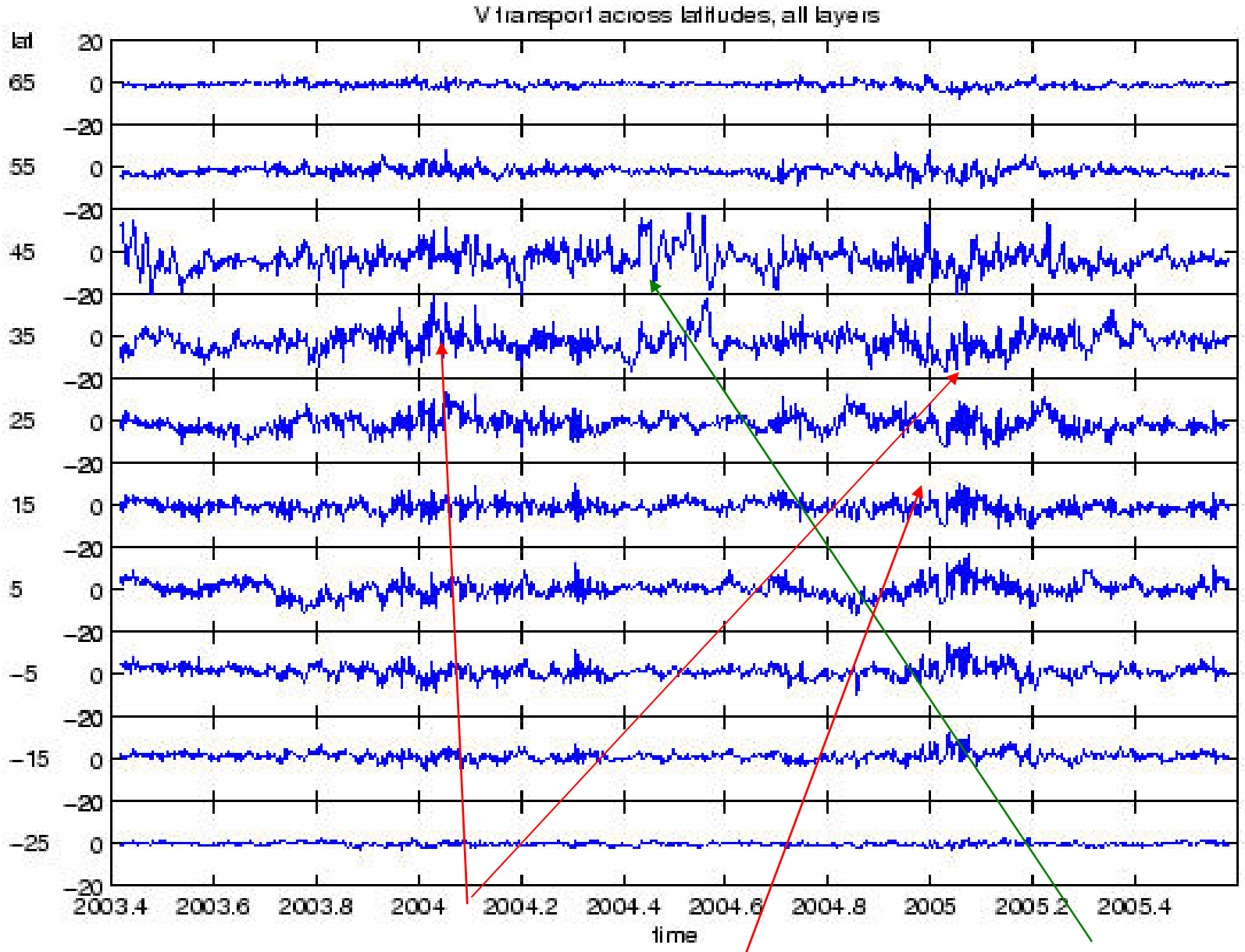


Instead:

SSH anomaly from MODAS assimilated daily → 2 cm

The 3m transport-implied Δ SSH is ~ 100 times bigger than what is assimilated

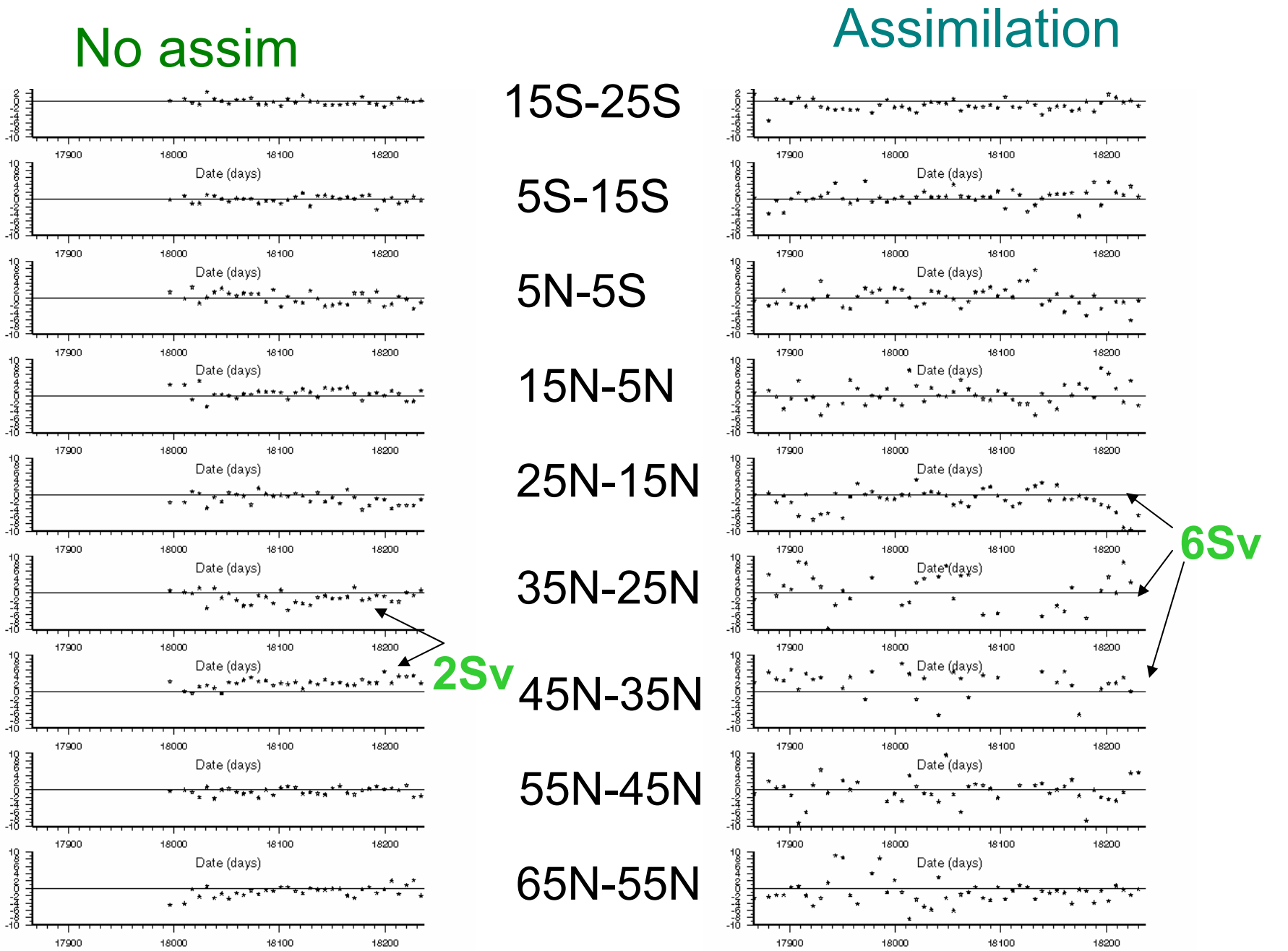
Large transport variations in the 5ºS - 45ºN band



NOWCAST

High variability occurs over wide latitude band **or localized (35ºN-45ºN)**

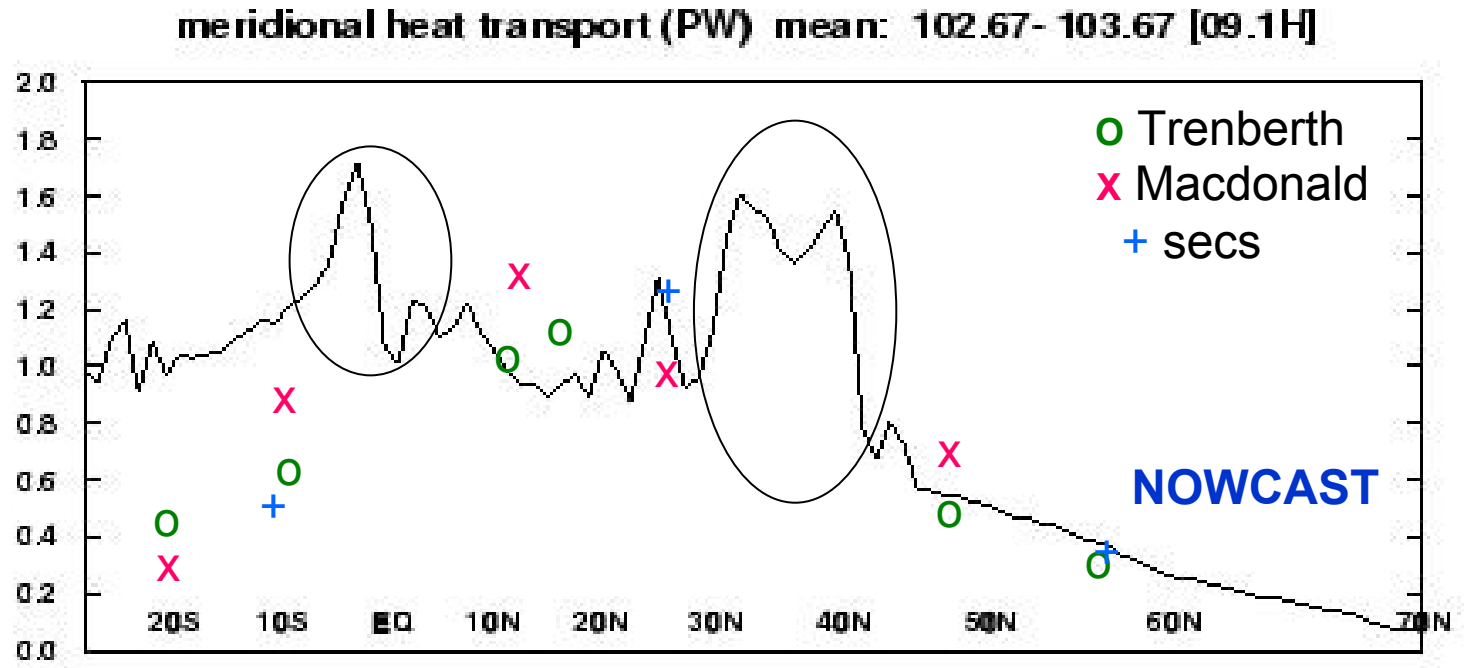
SHOM simulation: net transport across Atlantic

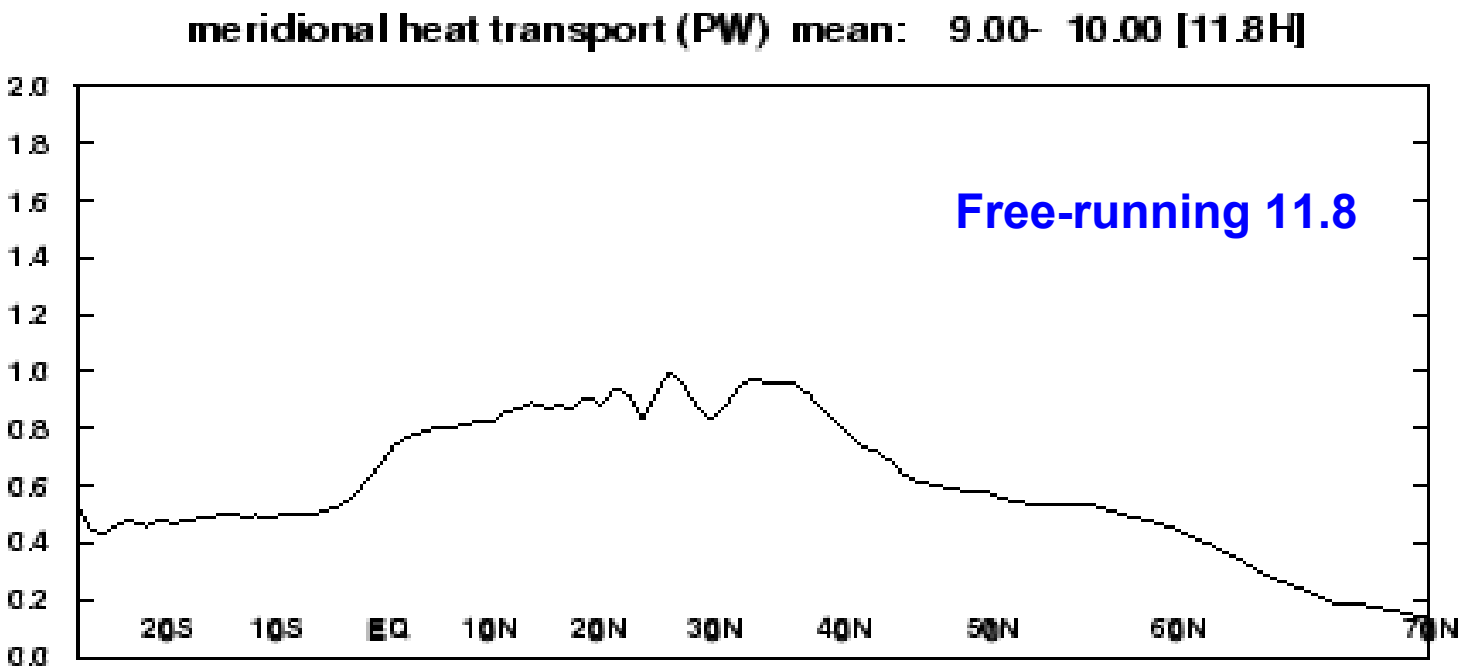


Summary mass transport

Transports are not consistent with mass conservation. The SSH information is propagated downward via potential vorticity conservation (Cooper-Haines) => does not guarantee mass conservation and balanced transport.

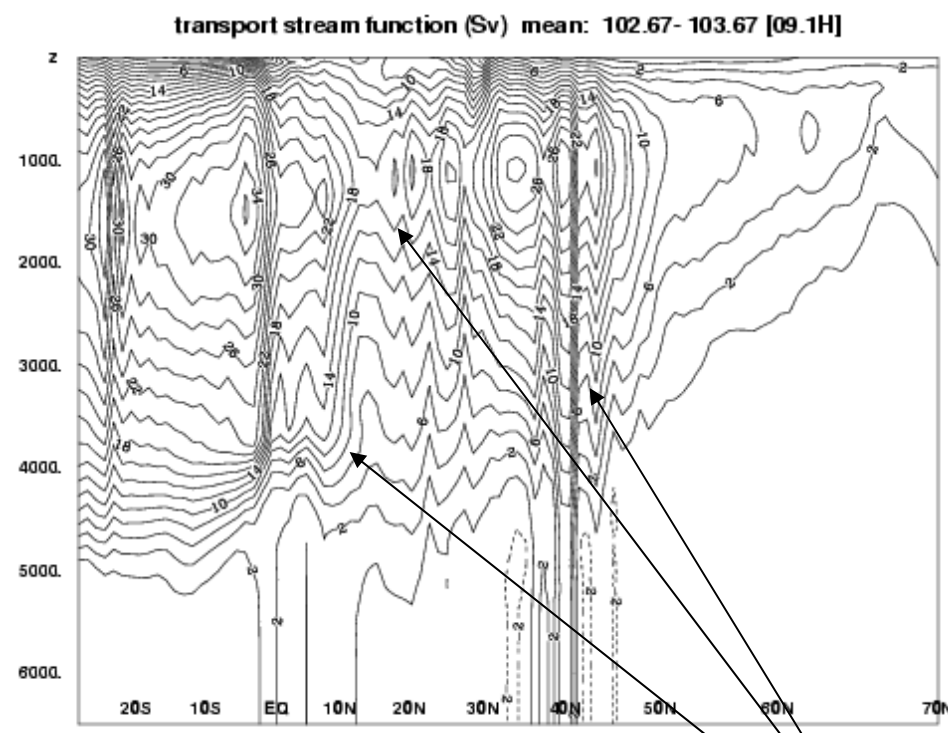
Now look at : HEAT TRANSPORT



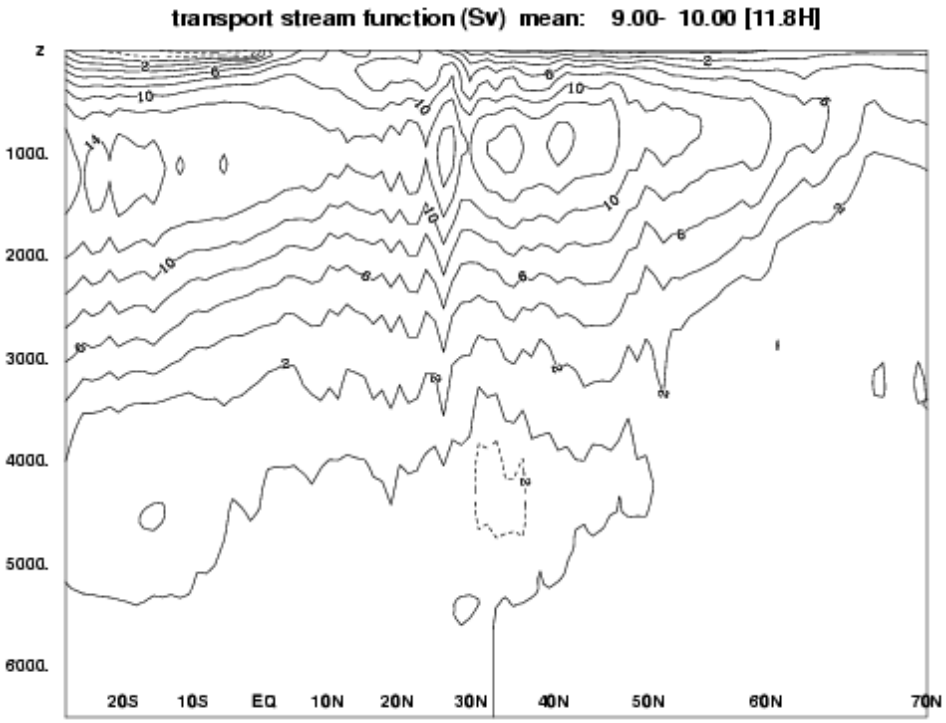


And also look at:
Meridional Overturning Ciculation

NOWCAST



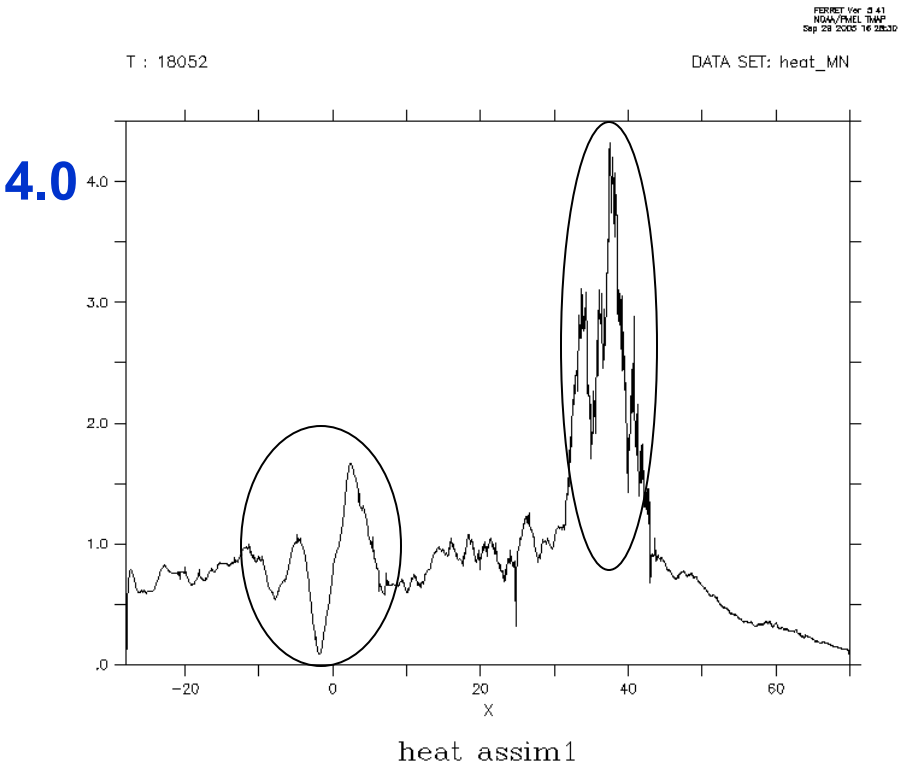
Free running 11.8



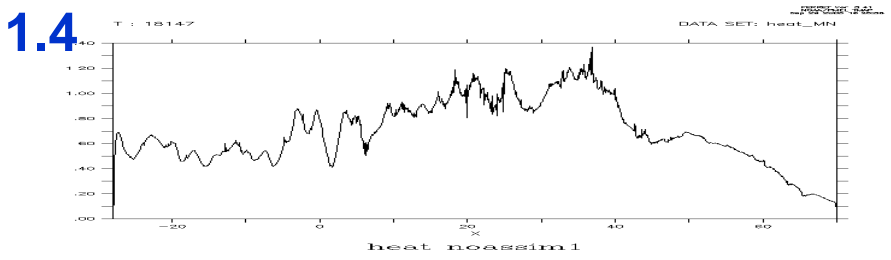
Unrealistic vertical motions and water mass transformations not present in free running case

SHOM simulation: Heat transport

Assim



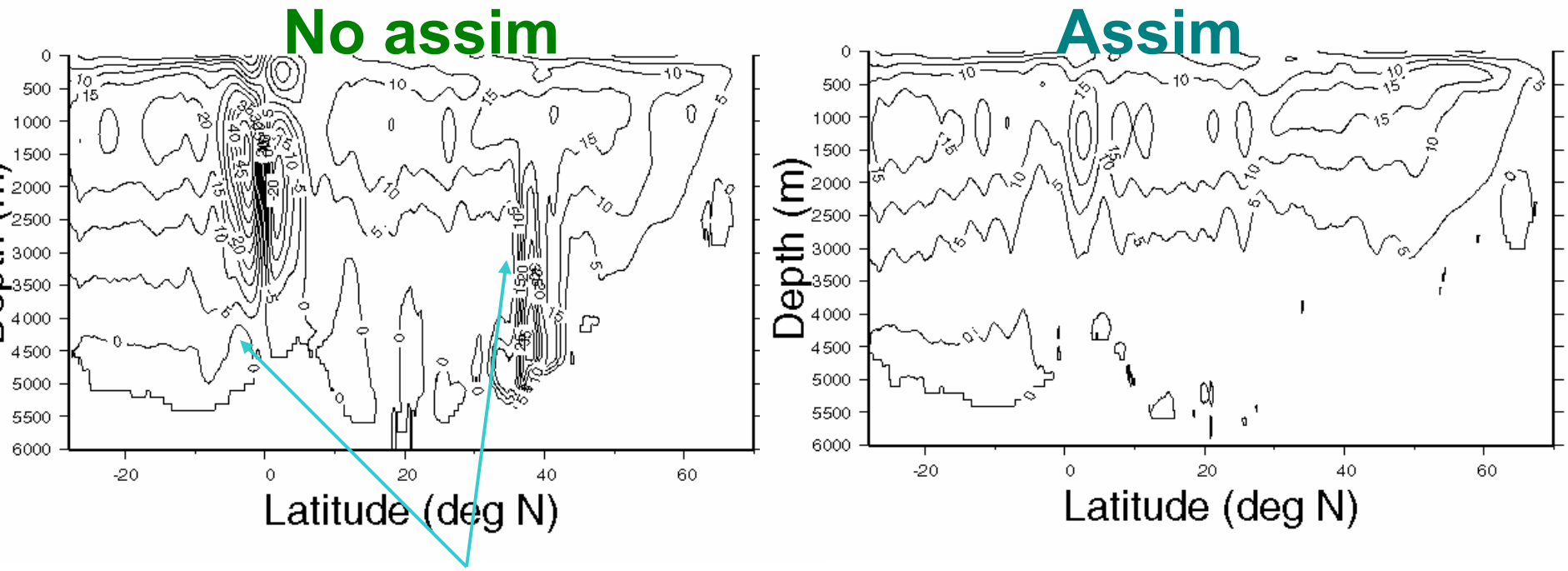
No assim



Unrealistic peak, 32-40°N, 4pw

And variations at equator

Overturning stream function in z coordinates



Unrealistic cells at 40°N (deep cell) and equator

~38°N: problem seems related to interaction of data assimilation and topography

Equatorial problem: in the region of transition from no data assimilation to data assimilation (with no data assimilation in SHOM)

SHOM simulation

Summary heat transport and MOC

Heat content is not conserved via data assimilation. Unrealistic vertical motions and water mass transformation are also present.

The southward branch of MOC appears to be too deep at most latitudes in the data assimilative run.

Question on vertical structure:

The Cooper Haines scheme is active to the top of layer 22, which is the bottom layer in most of the Atlantic configuration.

However, mesoscale corrections should mostly operate in the upper ocean. Would it not be better to have the scheme acting to shallower depths?

Conclusions

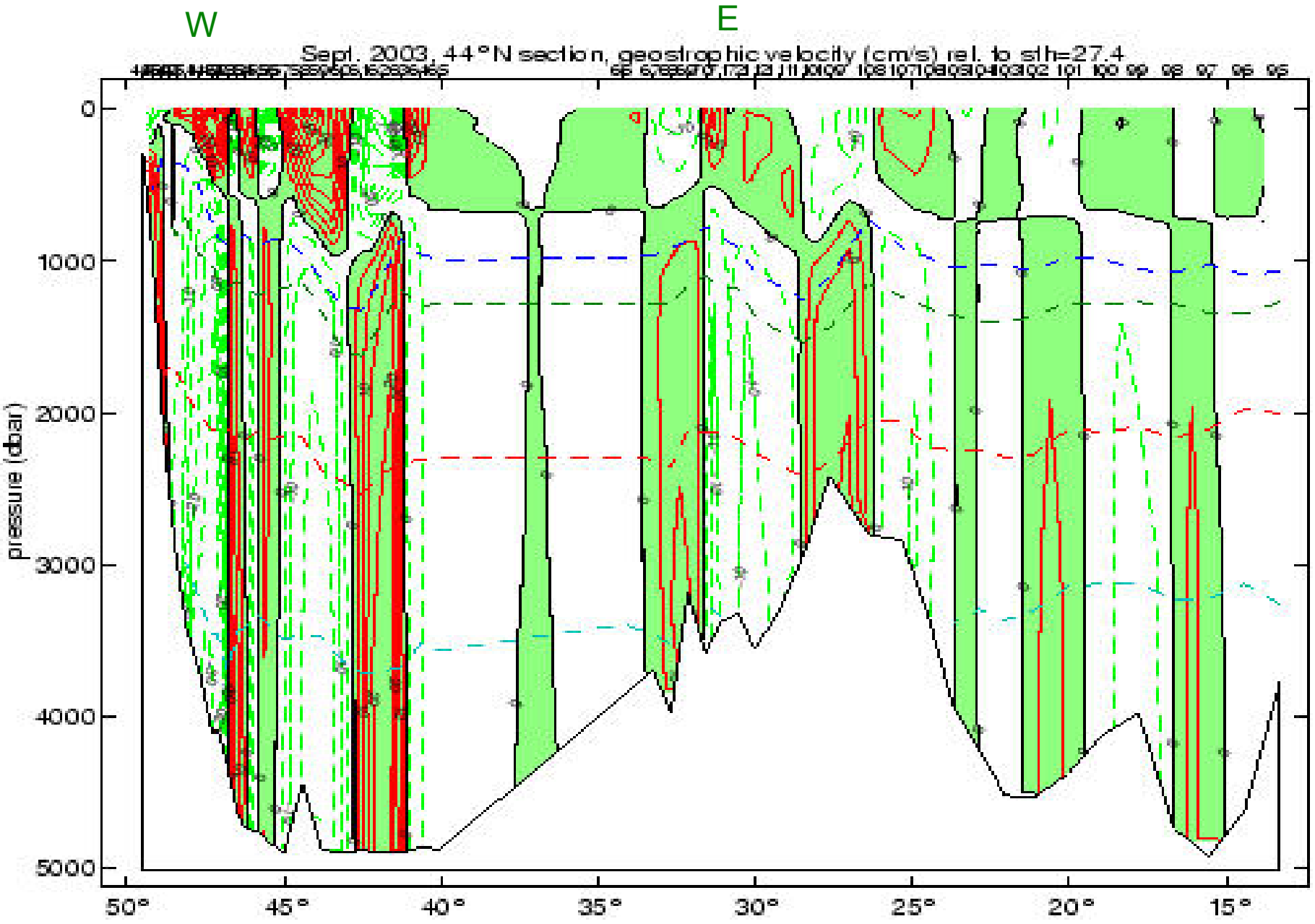
- Diagnostics was implemented for NOWCAST simulation to detect realistic and unrealistic features of the interior circulation, to find areas for improvement
- Mass and heat are not conserved by the Cooper-Haines data assimilation
- As data assimilation methods are improved, the above needs to be taken into account

- Let’s now examine the vertical structure

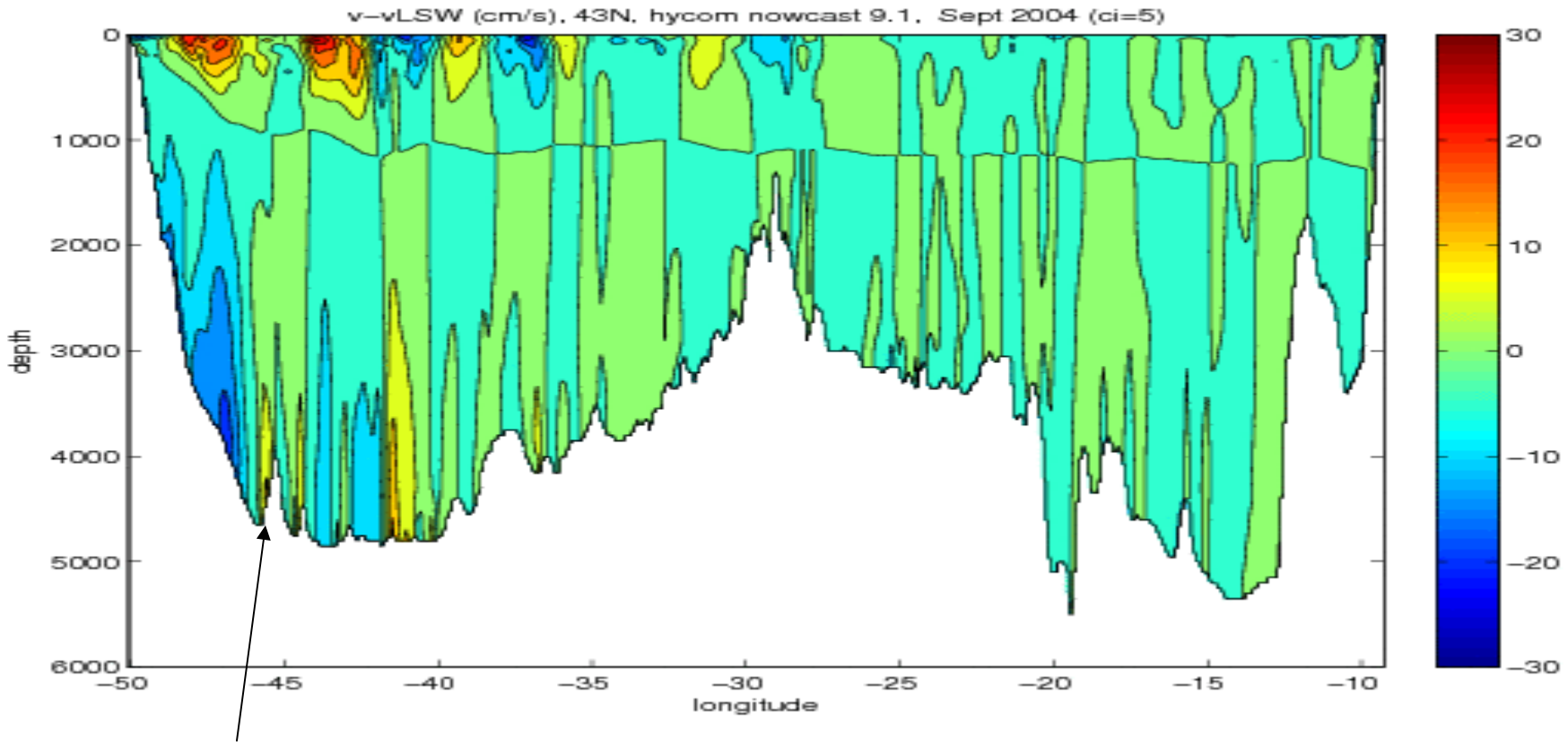
- 43ºN section, in observations and NOWCAST

(with Fritz Schott and Linda Smith)

Geostrophic velocity, example of observed (Sep 2003) 43ºN section (Schott)



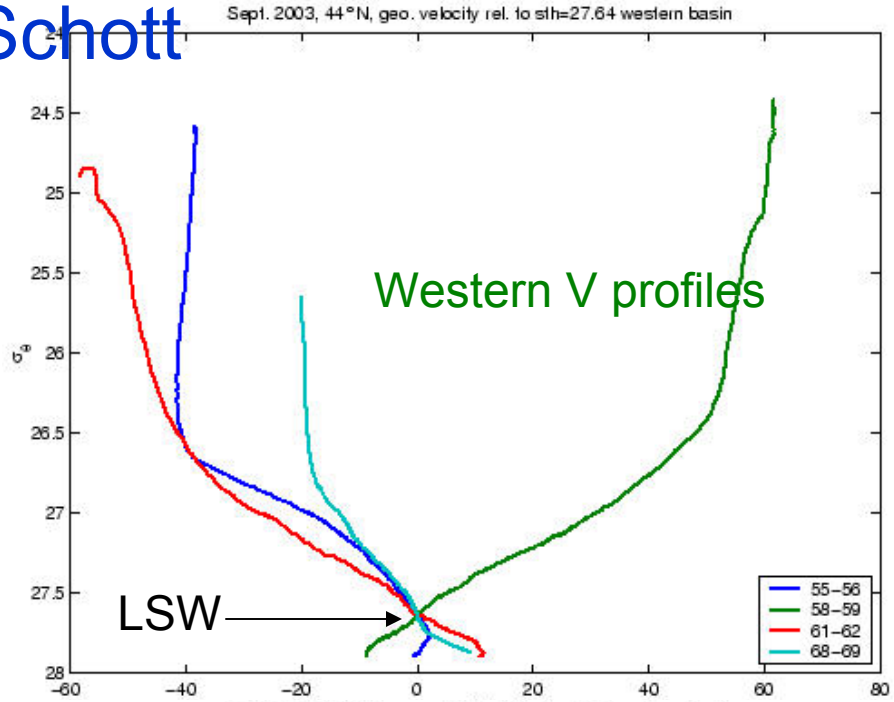
NOWCAST September 2004 section, V-V Lab sea water

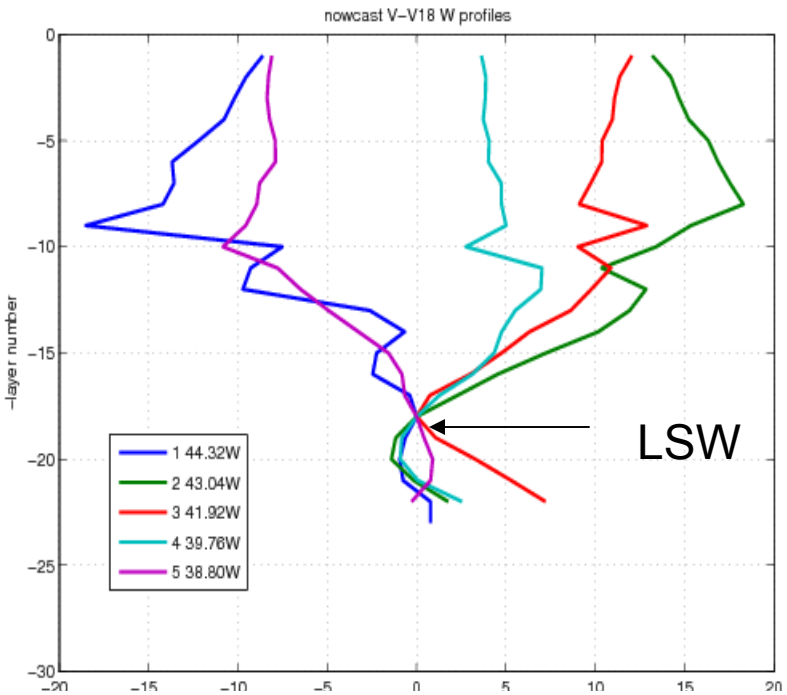


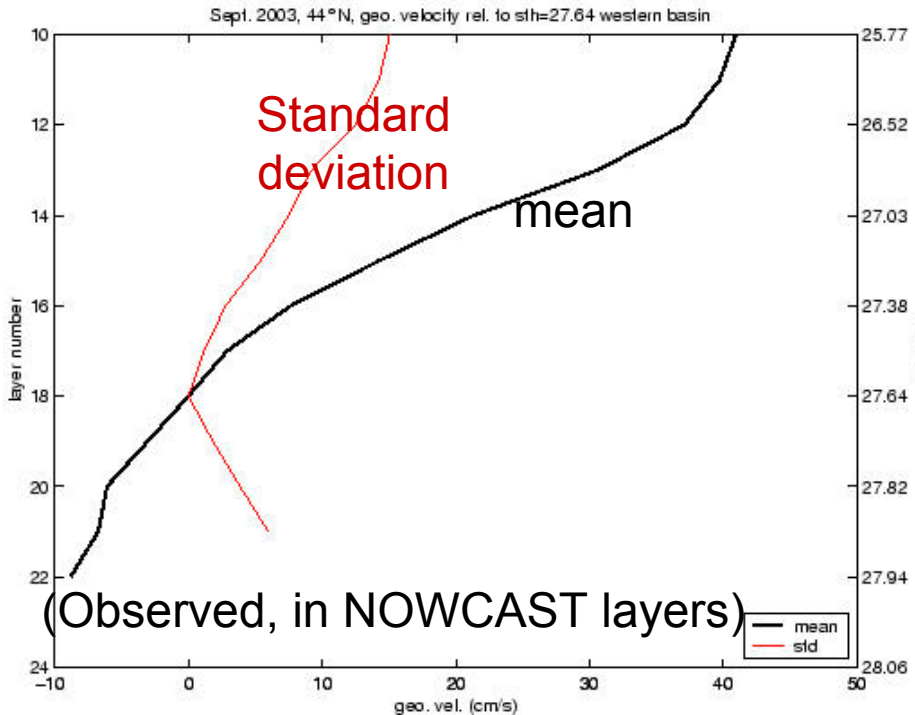
Western Eastern →

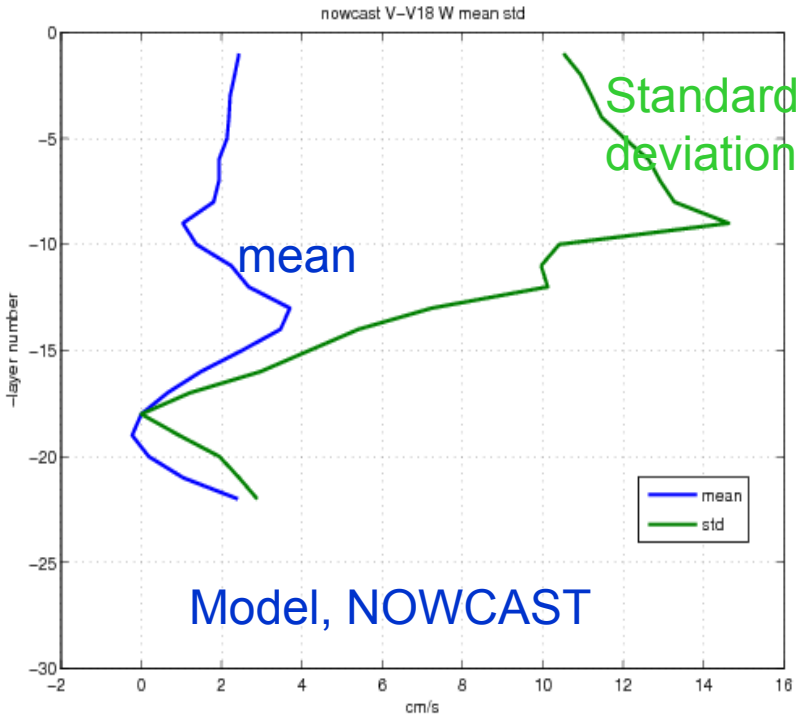
Generally clear baroclinic structure, but in some places, top and bottom same sign

Schott


Sept. 2003, 44°N, geo. velocity rel. to sth=27.64 western basin
Western V profiles
LSW
55–56
58–59
61–62
68–69


nowcast V–V18 W profiles
layer number
LSW
1 44.32W
2 43.04W
3 41.92W
4 39.76W
5 38.80W

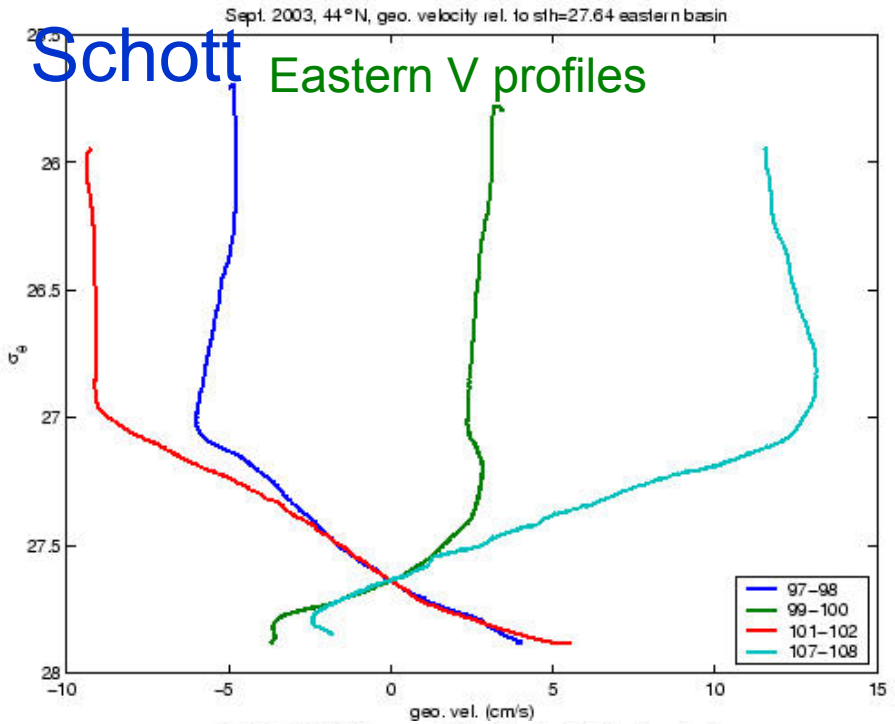

Sept. 2003, 44°N, geo. velocity rel. to sth=27.64 western basin
Standard deviation
mean
(Observed, in NOWCAST layers)
layer number
density
geo. vel. (cm/s)
mean
std

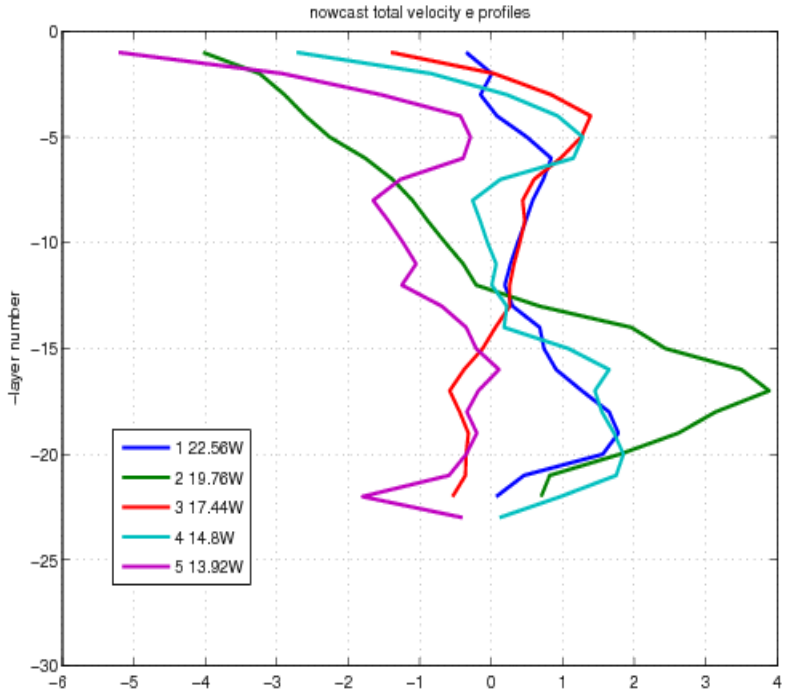

nowcast V–V18 W mean std
Standard deviation
mean
Model, NOWCAST
layer number
cm/s
mean
std

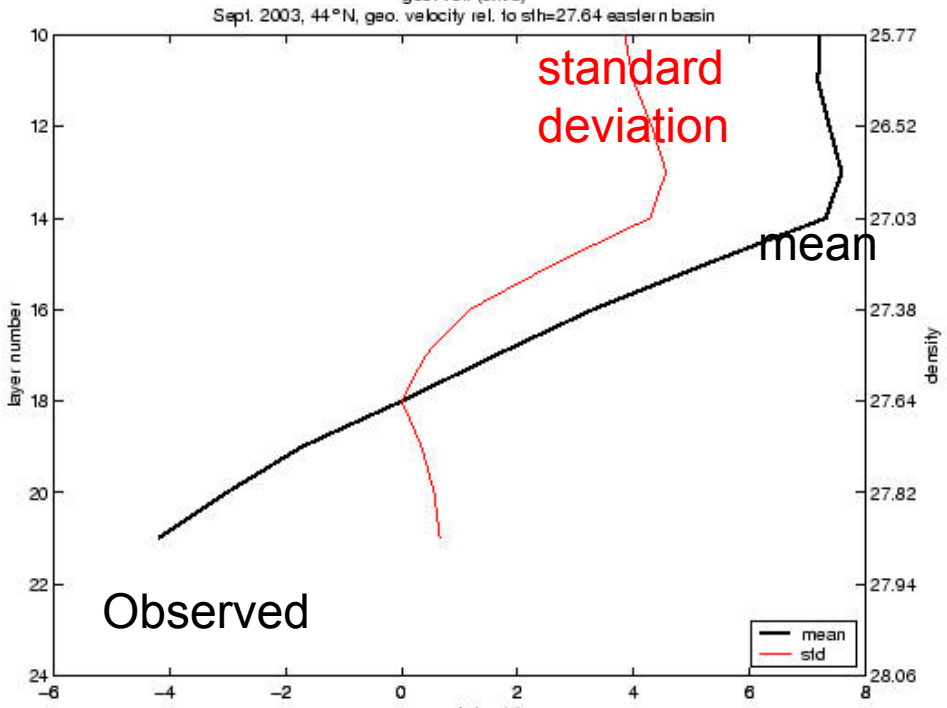
Schott

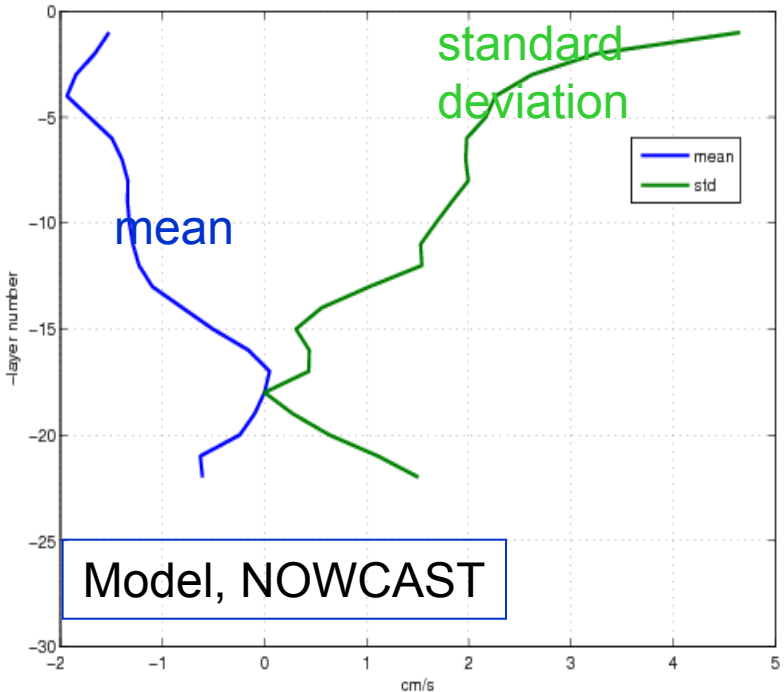
Eastern V profiles

43N

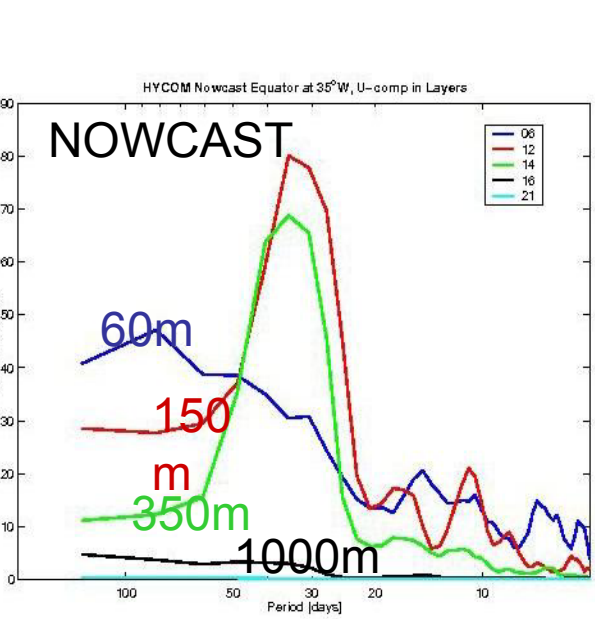


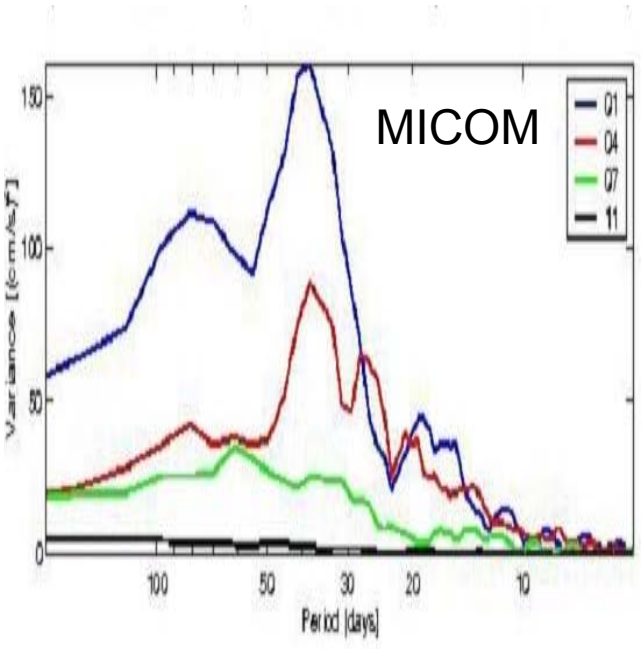


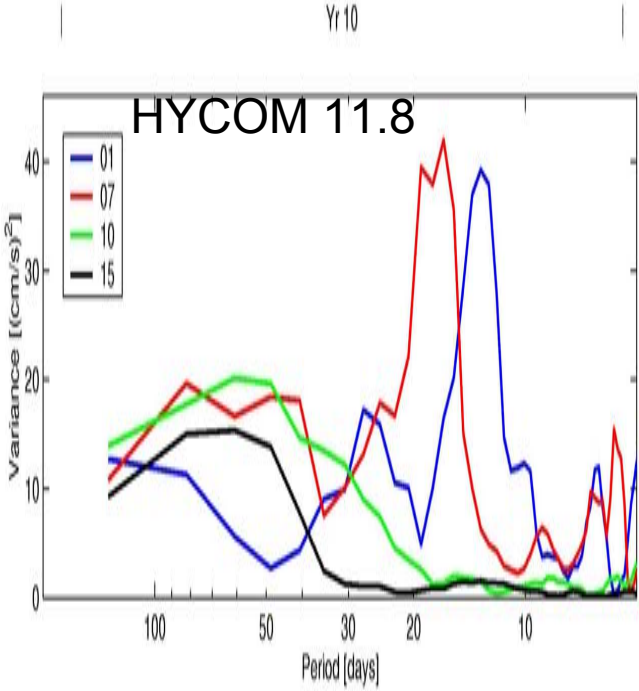




35W NOWCAST variability (with Schott)

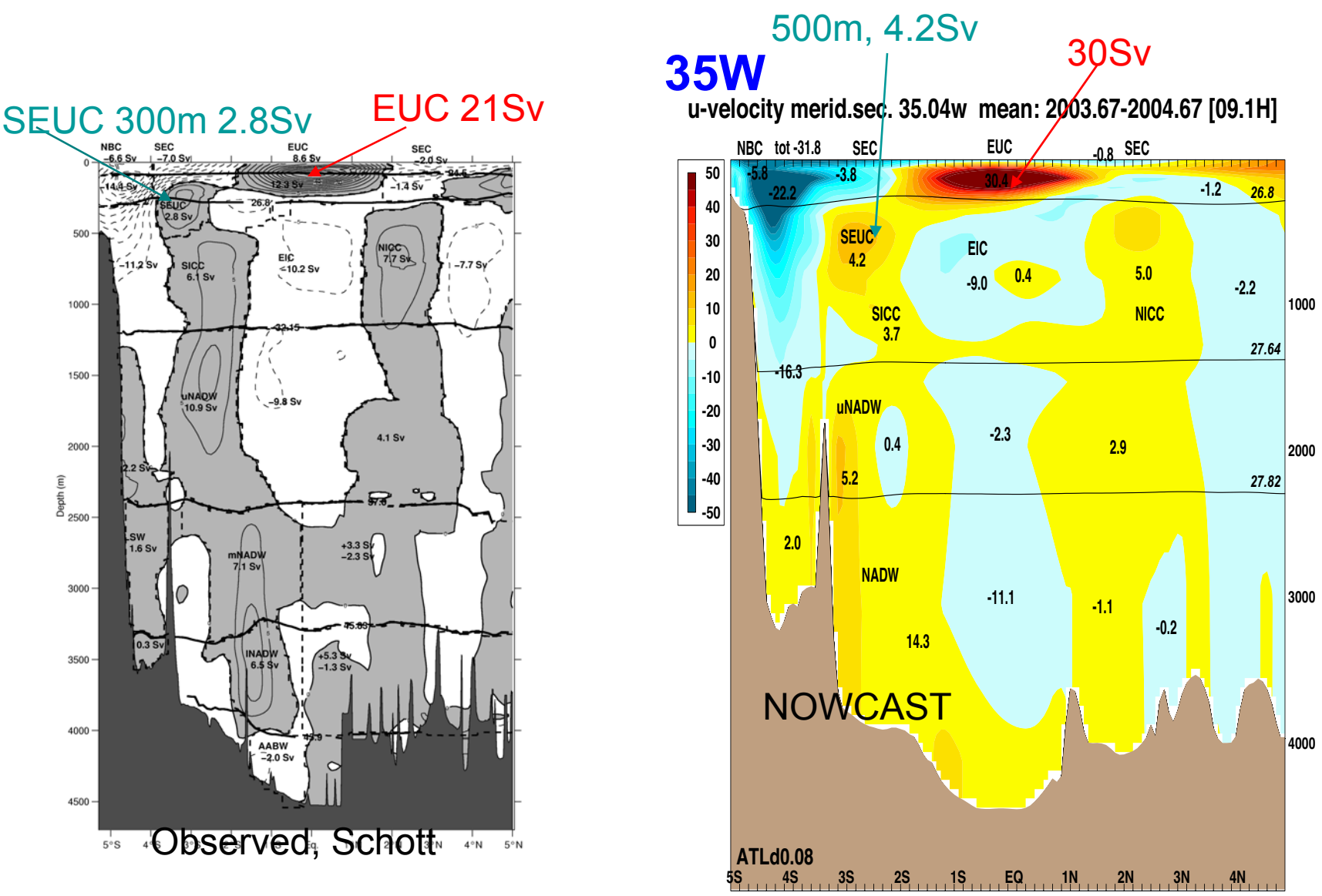




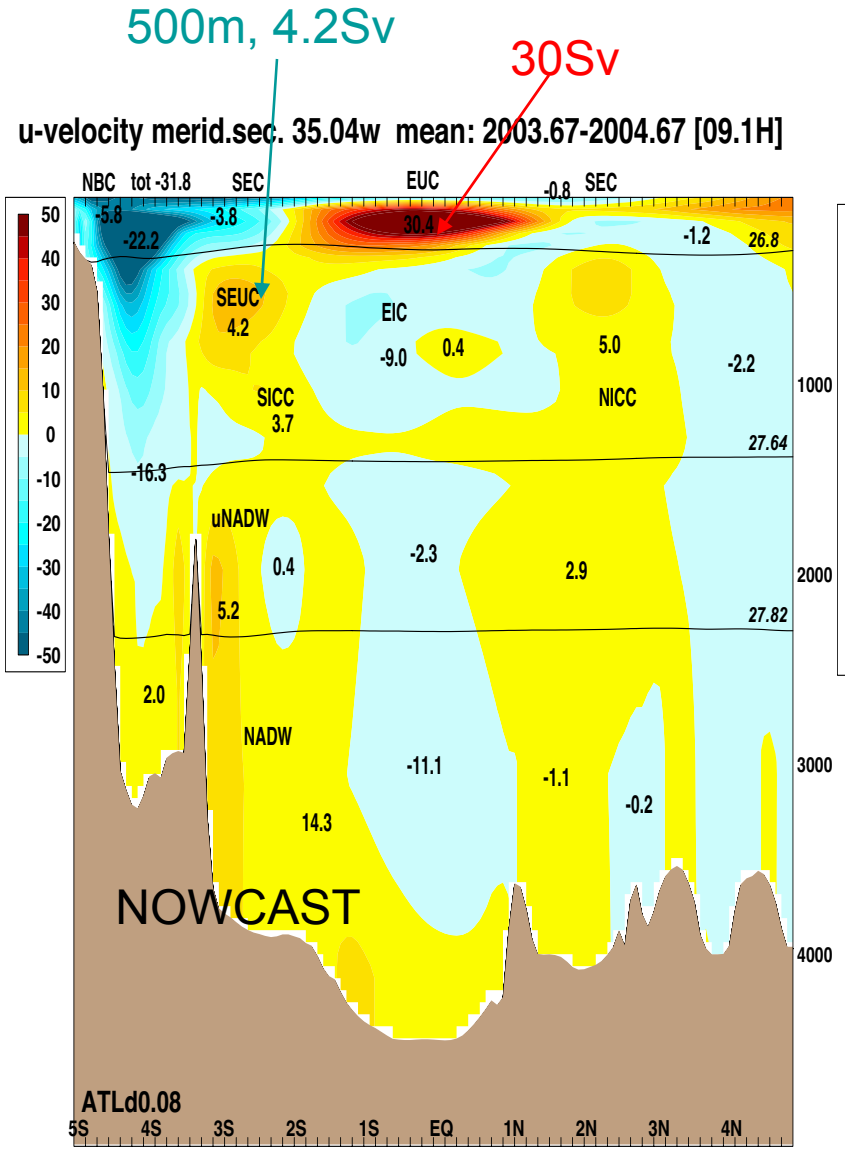


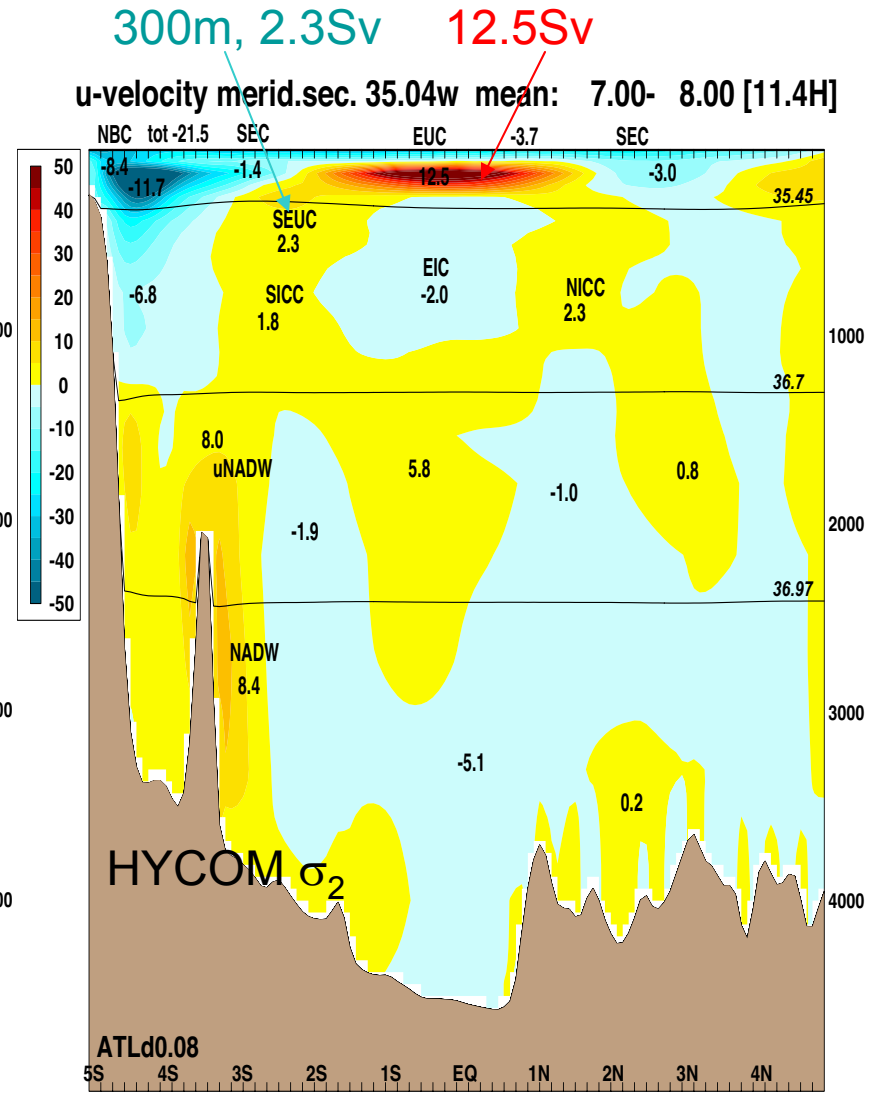
Is it a realistic feature?
~30 day peak at 150-350m, but not present above and below

In free running simulations a similar peak has maximum variance at the surface



NOWCAST: SEUC deeper than observed, EUC stronger than observed





Hycom σ_2
Very similar results from other σ_0 and σ_2 simulations

At the 35W equatorial section, in NOWCAST:

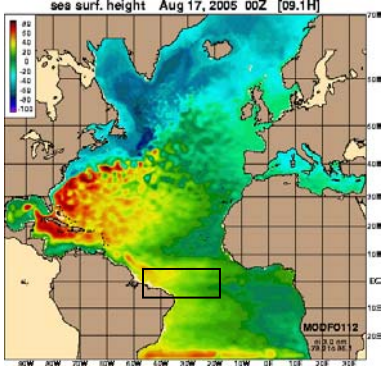
Is it unrealistic the vertical structure of variability?

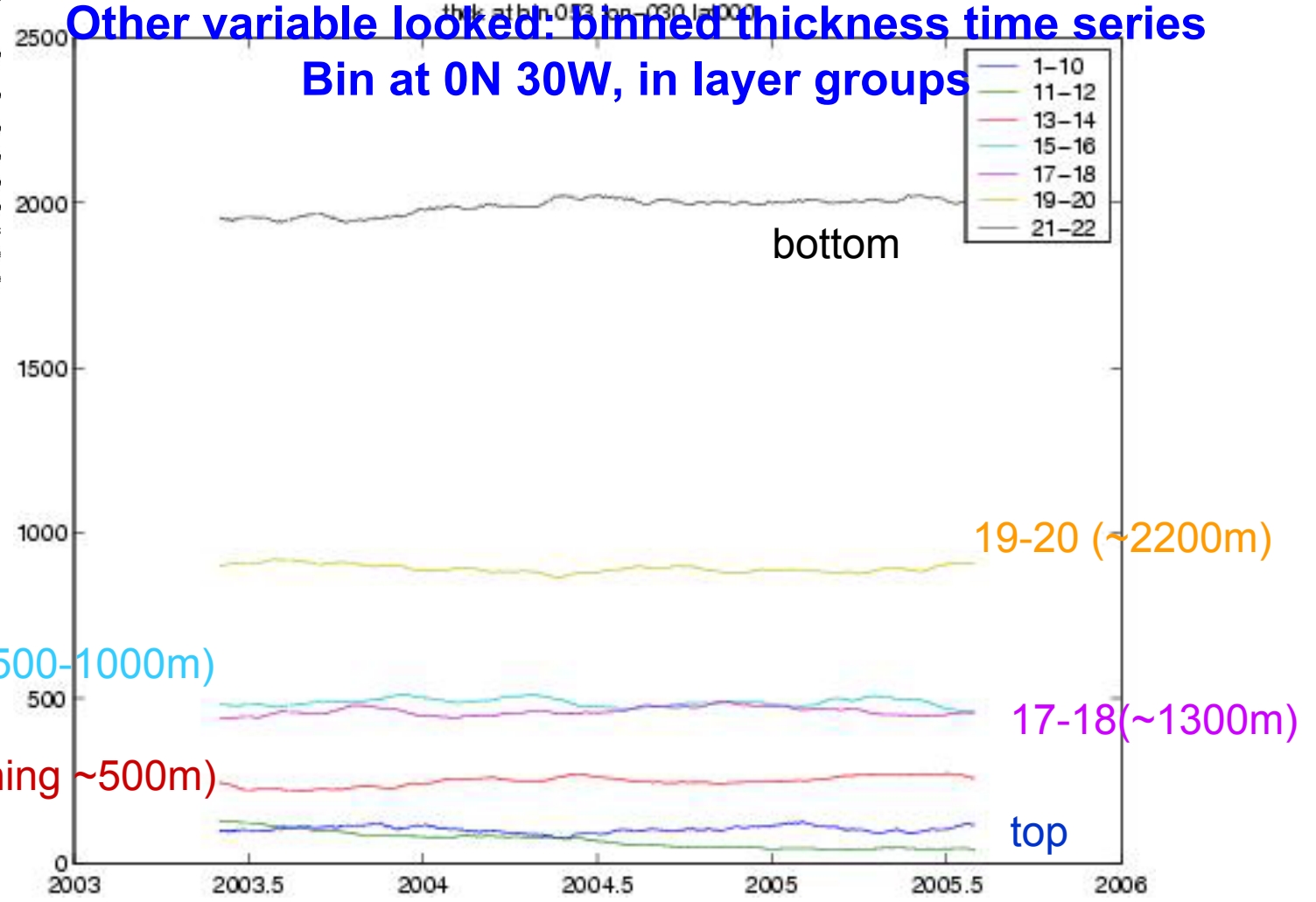
SEUC is at deeper depth than in free running solutions

(checked that initial state for NOWCAST is similar to free running solutions)

Other variable looked: binned thickness time series

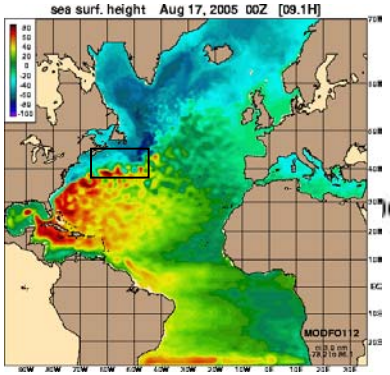
Bin at 0N 30W, in layer groups





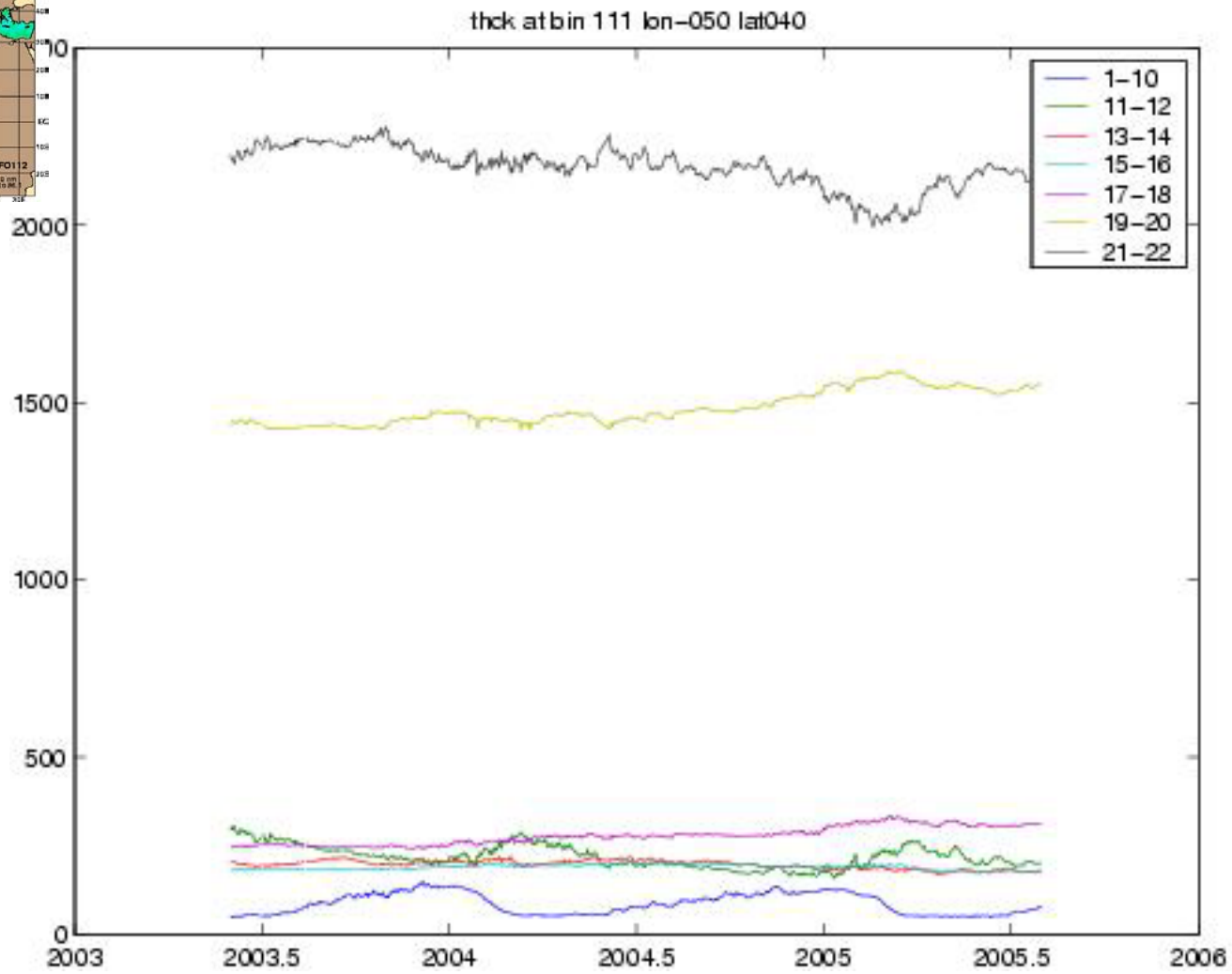
Not important variations in the thickness time series (but the SEUC is 200m in NOWCAST compared with free running)

Layer 13-14 thickness, above SEUC, increases in less than 100m, but layer 11-12 decreases in similar amount

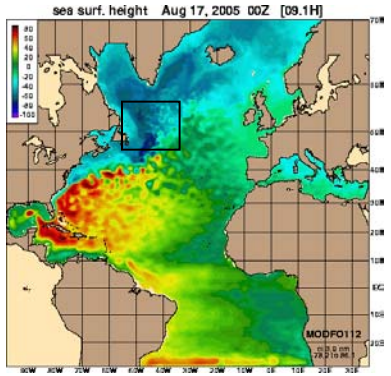


Layer depth timeseries

Western Atlantic 40N

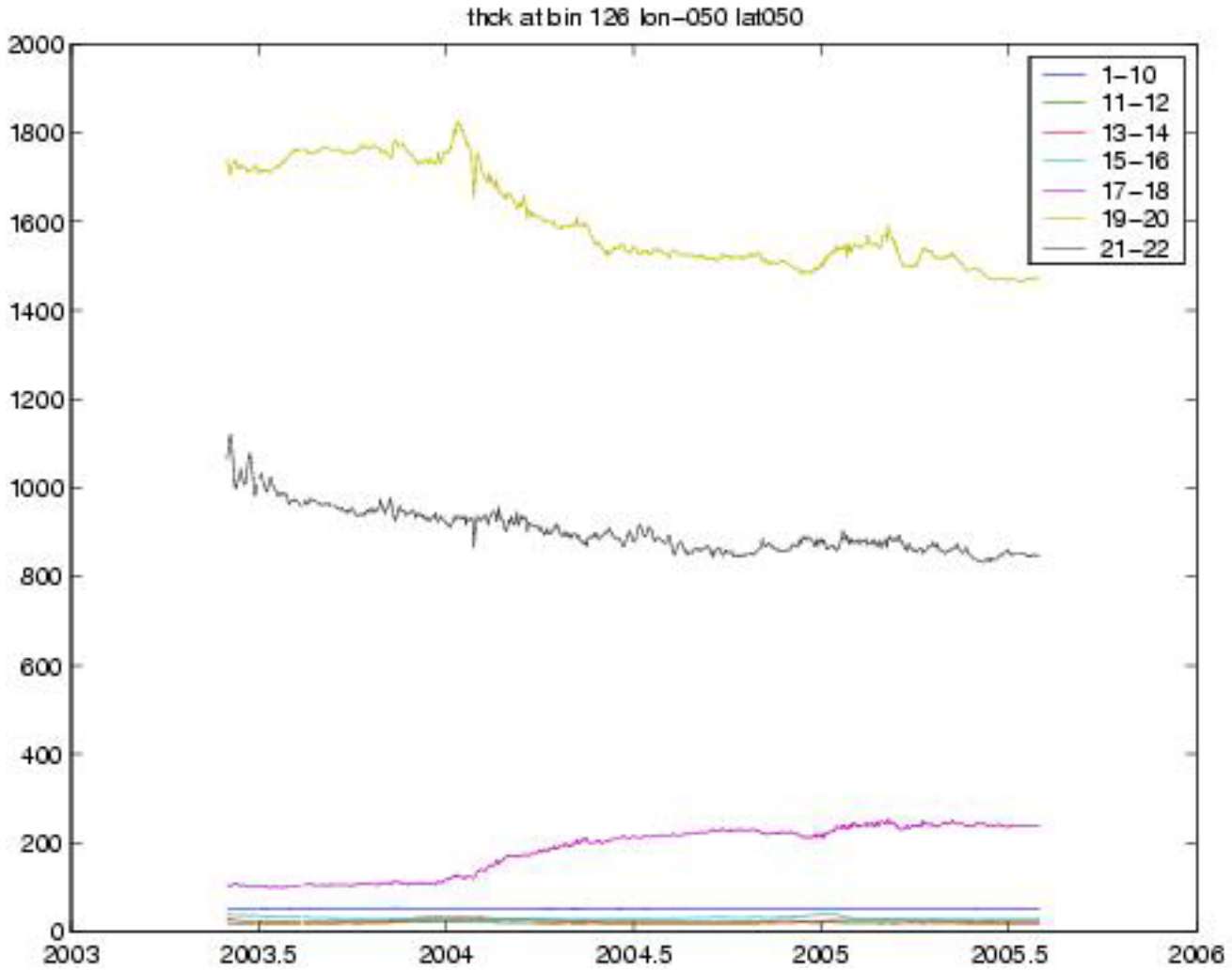


layer below LSW thickens in 300m, layers below get thinner



Layer depth timeseries

Western Atlantic 50N



50°N: LSW gets thicker (200m), and layers 19-22 thinner (500m)