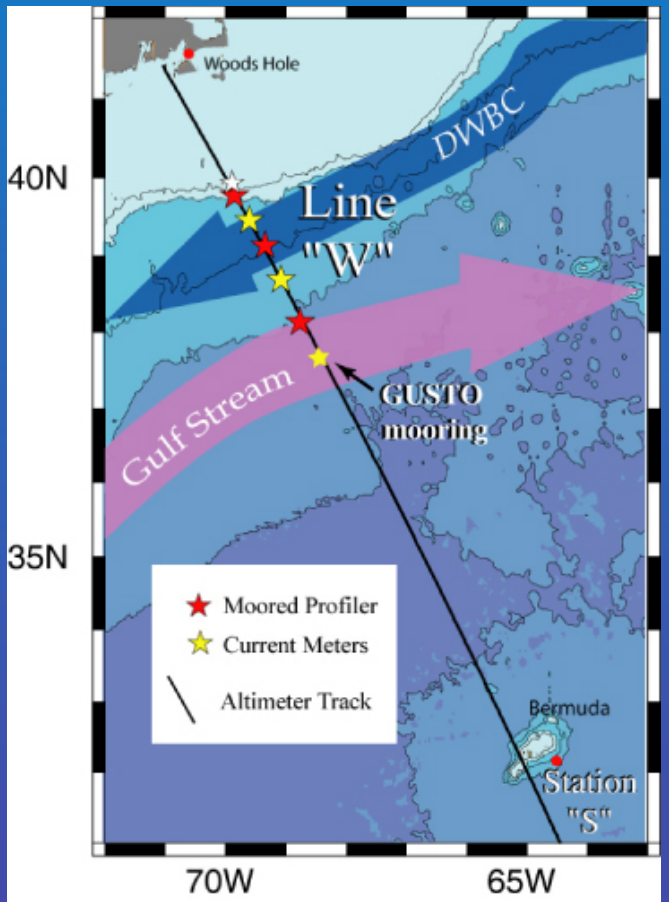
Line W:
A sustained measurement program sampling the North Atlantic Deep Western Boundary Current and Gulf Stream about 39°N 70°W

John Toole, Ruth Curry, Terry Joyce, Beatriz Peña-Molino (WHOI)

Bill Smethie (LDEO) and John Smith (BIO)

Field program consists of a moored array spanning the continental slope southeast of New England and repeated hydrographic sampling by ship.

Planned measurement period: 2004-2014



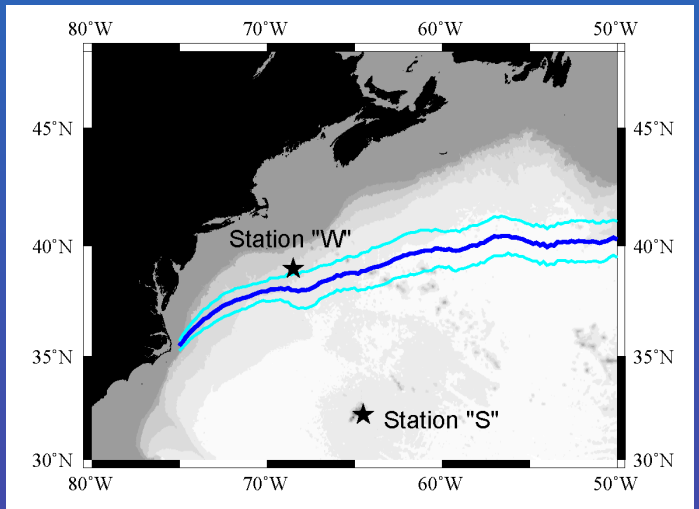
Scientific goals include documenting and characterizing velocity (transport) and water property changes to build understanding of boundary current variability and its role in Atlantic Circulation change.

Contribution to
Atlantic Meridional Overturning Circulation Study
In collaboration with the U.K. Rapid Programme

Research supported by the U.S. National Science Foundation

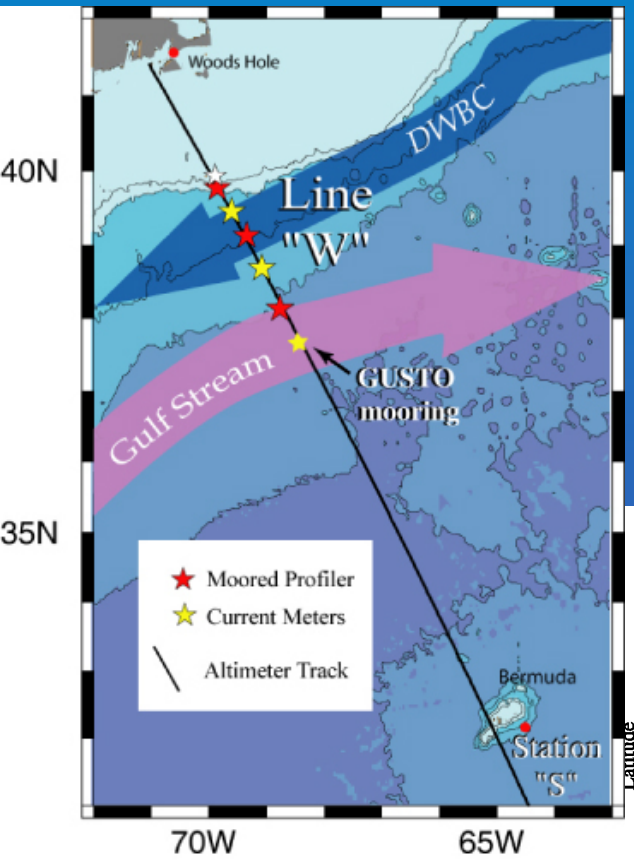
- Introduce the Line W program
  where, what and when
- Highlight some initial results
- Invite others to work with us -
  particularly interested in collaborating with modelers
  to use Line W data for validation or input to state estimation

Line W focus:
Cold limb of the MOC
between
Cape Hatteras
and
Grand Banks

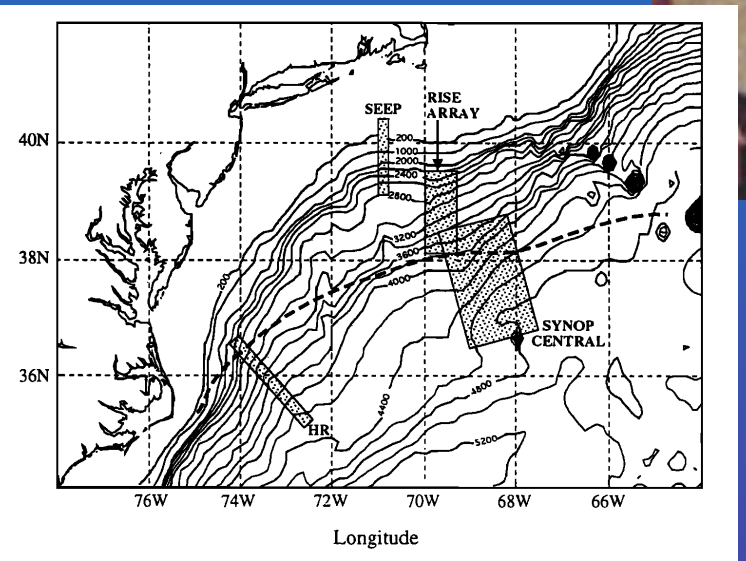


sustained measurement program consists of a moored array and repeated hydrographic sampling

Line W is named in memory of Val Worthington, a WHOI physical oceanographer who, together with John Swallow, conducted seminal research on the Atlantic DWBC



Adjacent to SYNOP, Rise and SEEP arrays; Downstream from Halkin & Rossby



Field Program

Shipboard sampling

2004-2008:
spring and fall cruises
CTD/O_2,
LADCP, SADCP,
CFCs, ^{129}I

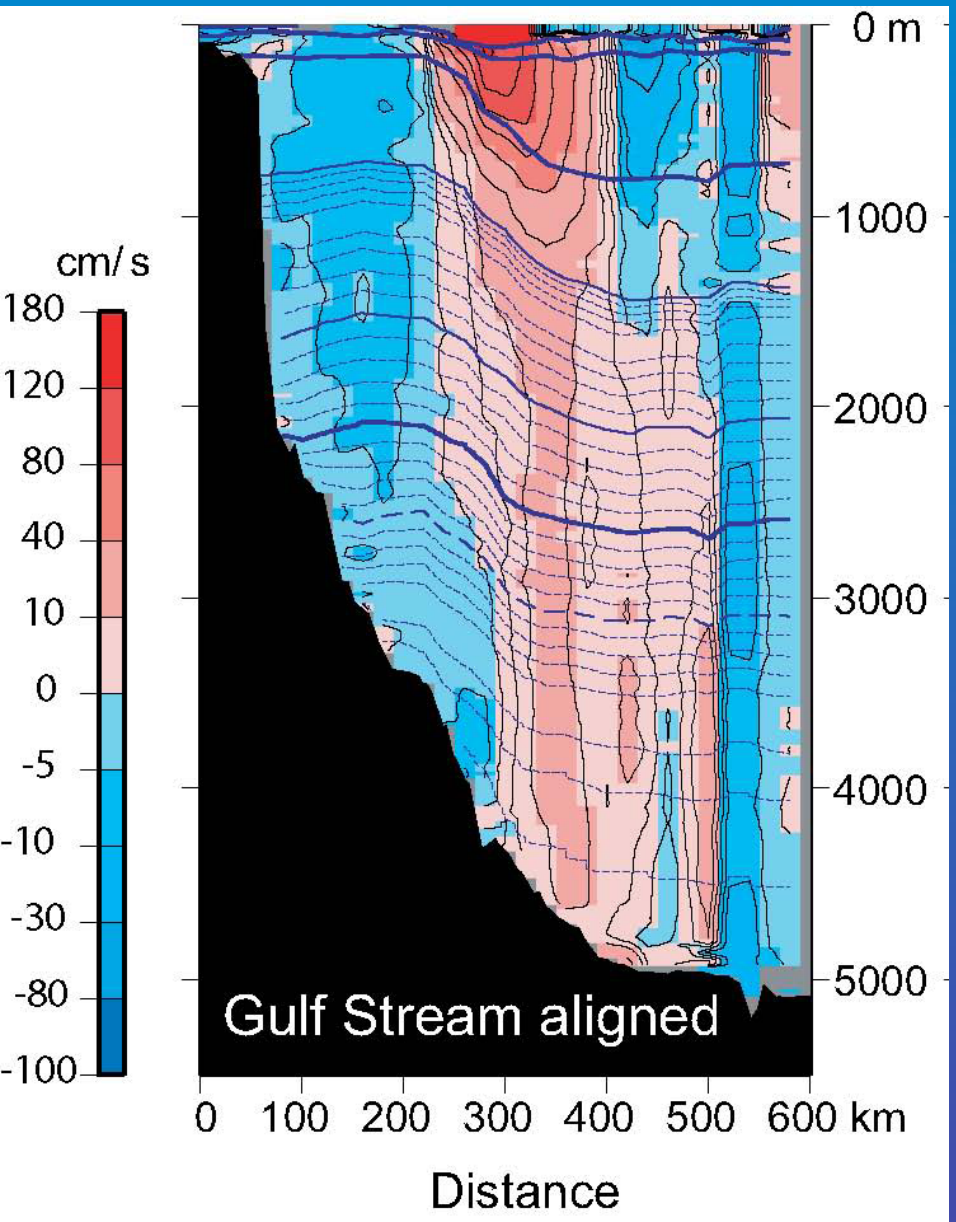
2008-2013:
one cruise/year

Moored Array

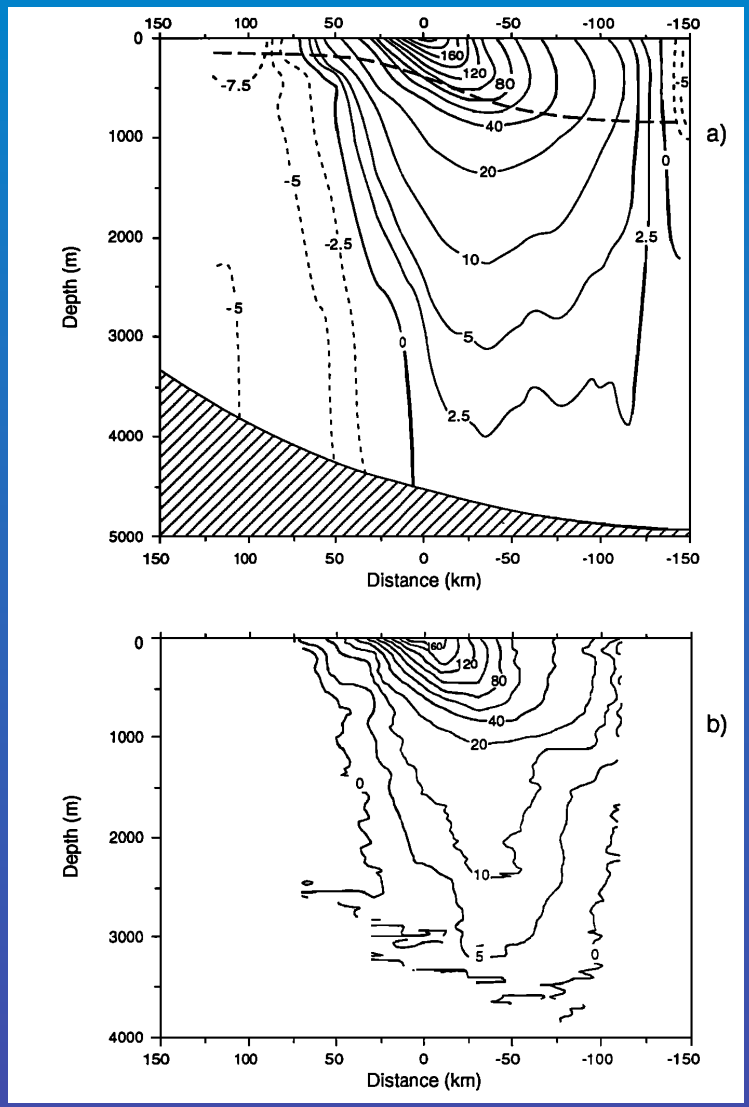
2004-2008:
2 conventional (2-yr endurance)
3 MMP (annual service)
1 conventional (2.5 yr)
+ POL BPRs

2008-2013:
4 conventional
2 hybrid MMP-CM
All on 2-year service schedule
+ POL BPRs

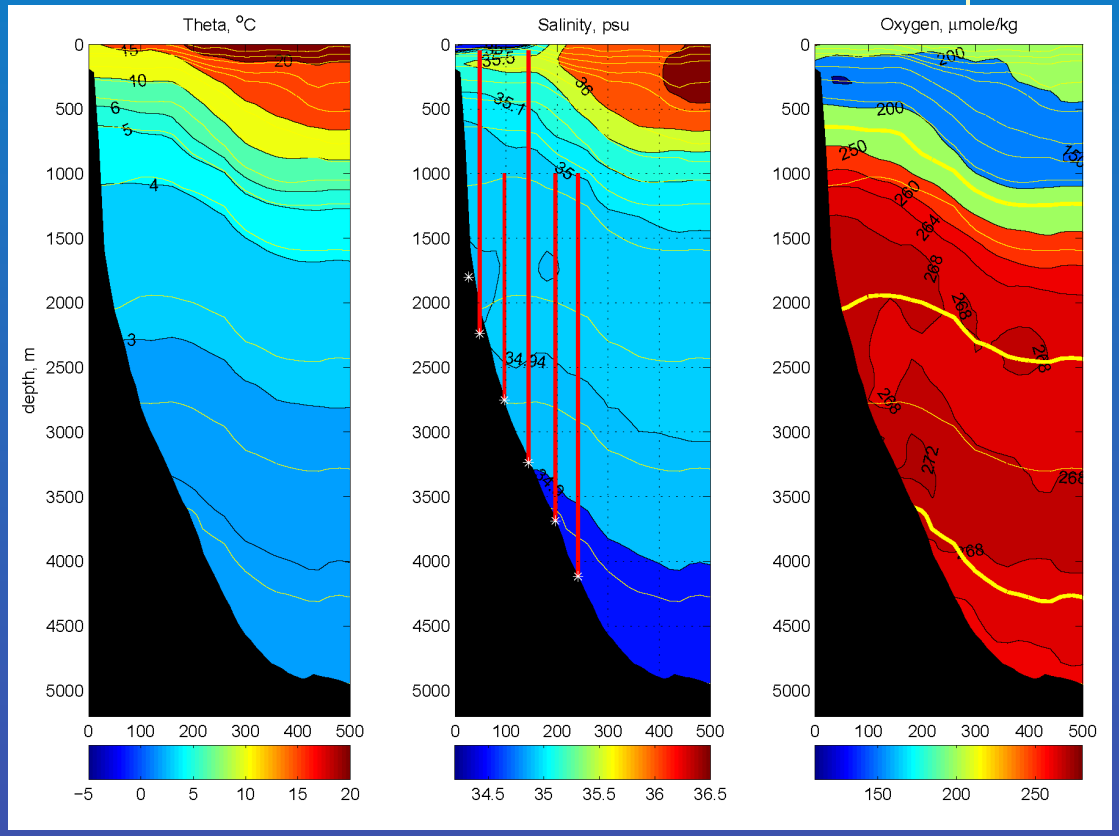
Average LADCP Velocity Section

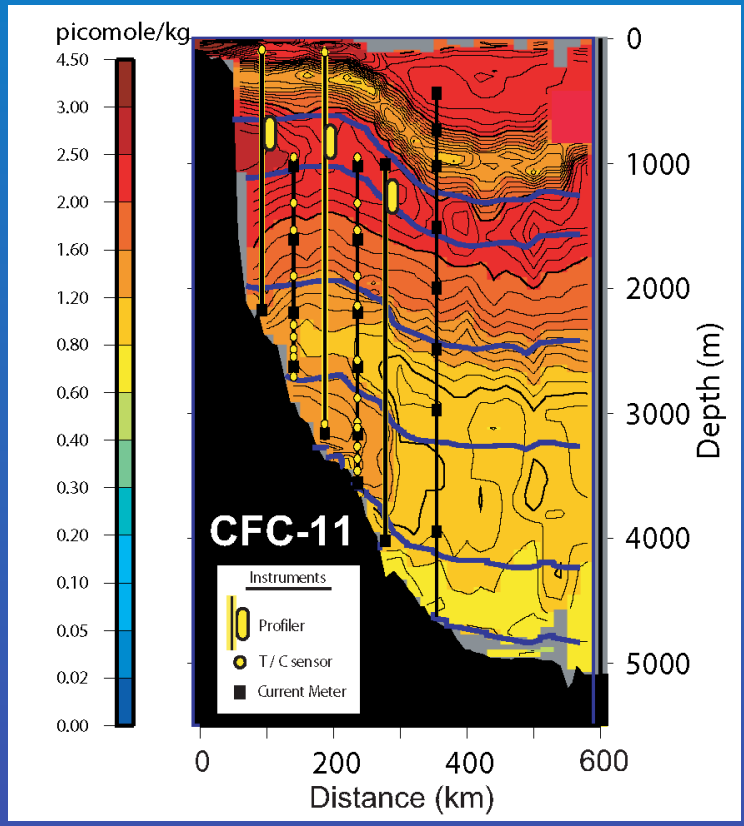


Johns et al. (1995) Halkin and Rossby (1985)



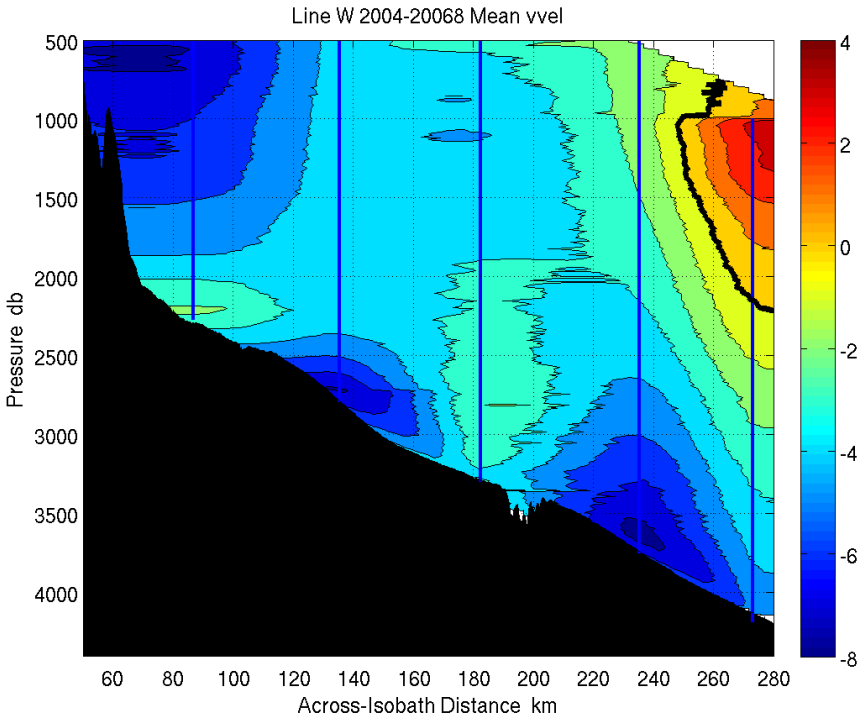
Mean Water Property Distributions

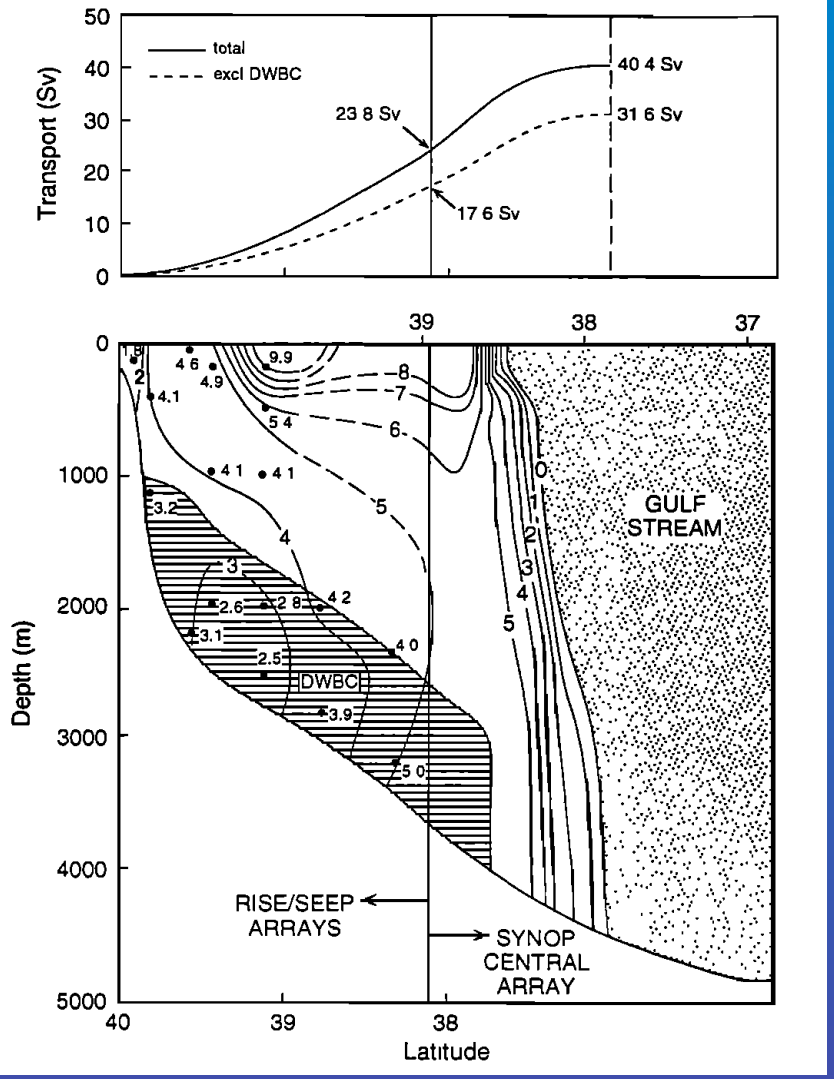




2004-2008
mean velocity section
along-isobath component

Johns et al. 1995
40 ± 10 Sv





Areal-integration of mean southward velocity (extrapolated up to z=0)
23.1 Sv

Line W mean transports

γ_n =27.8

ULSW: -3.07 +/- 0.3 Sv

γ_n =27.897

CLSW: -8.10 +/- 0.8 Sv

γ_n =27.983

ISOW: -6.15 +/- 0.8 Sv

γ_n =28.066

DSOW: -5.16 +/- 0.8 Sv

γ_n =28.125

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total mean : -22.5 +/- 2.3 Sv

each 5-day velocity estimate integrated horizontally in density layers to max southward streamfunction, then estimates averaged

95% confidence bounds based on 10-d decorrelation timescale

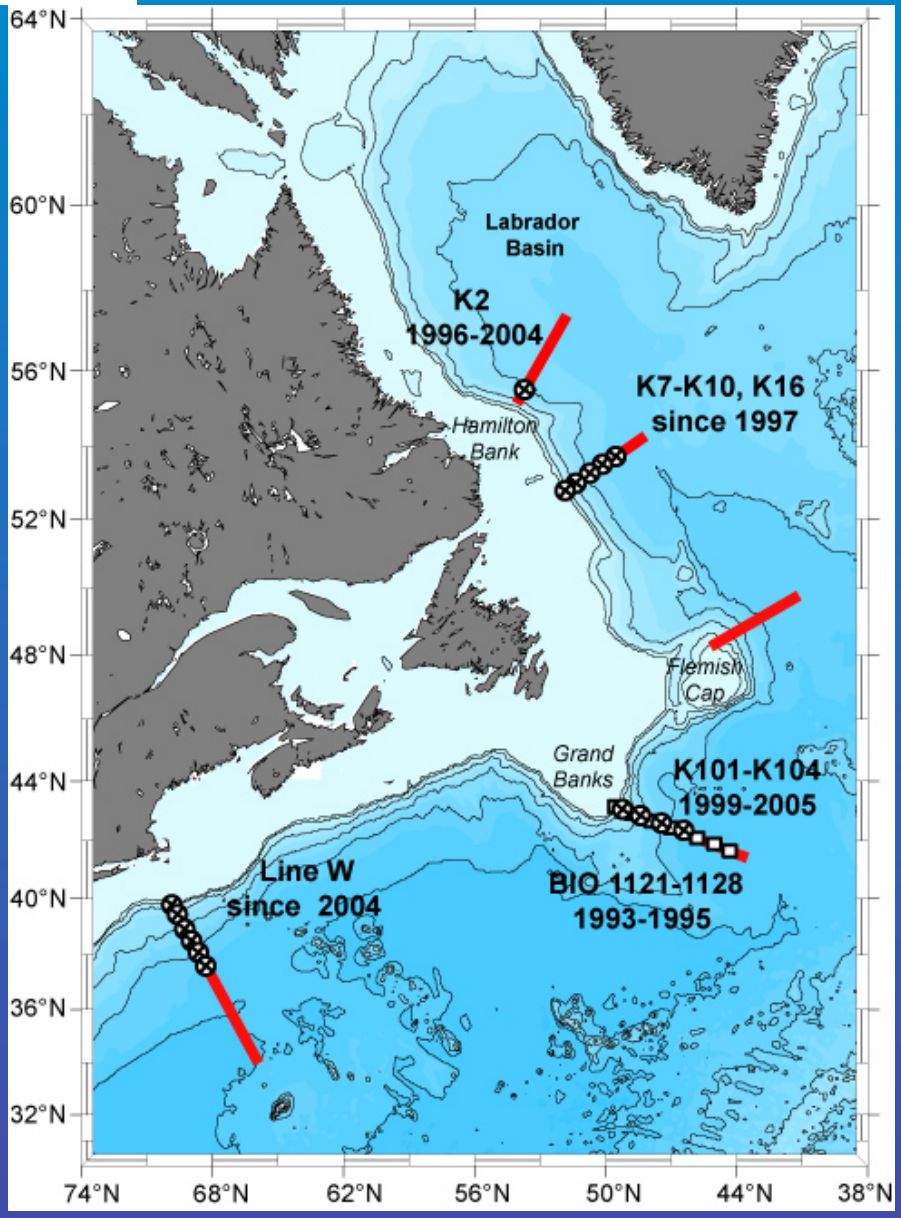
Direct velocity measurements of the subpolar western boundary current

Marcus Dengler
Leibniz-Institut für Meereswissenschaften, Kiel

In collaboration with:
Fritz Schott, Jürgen Fischer and Rainer Zantopp, IFM-GEOMAR

North Atlantic Subpolar Gyre Workshop, 20 March 2007, Kiel

Direct velocity observations SFB460/WHOI



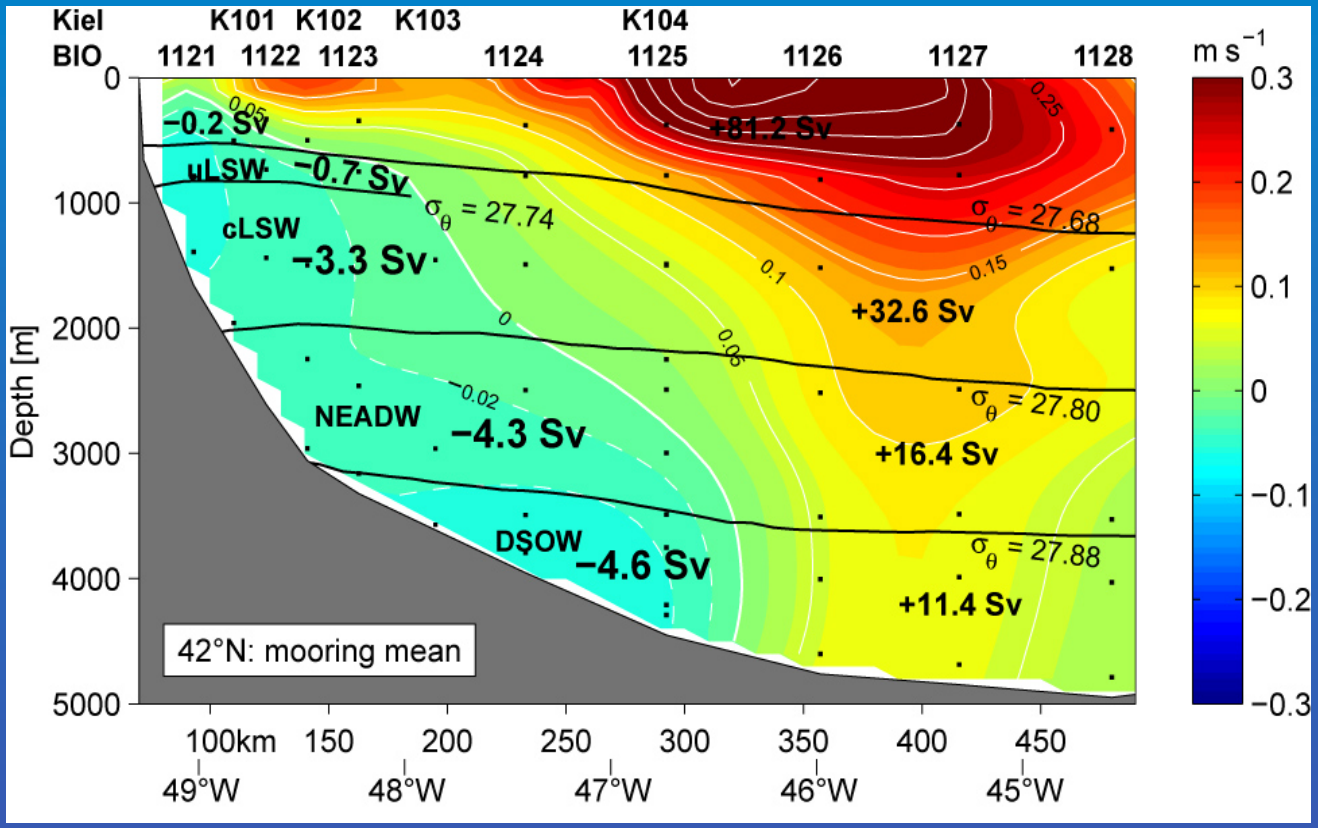
Mooring positions in the western boundary current:

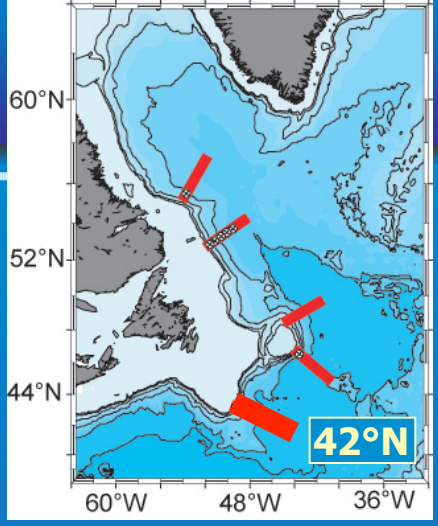
- 2 current meter and T-P recorder arrays in different configurations at 53°N (1997-2005) and east of Grand Banks (1999-2005)
- moored current meter array deployed east of the Grand Banks by the Bedford Institute of Oceanography between 1993-1995
- long-term current meter records from the western boundary current at 56°N (1996-2004)
- WHOI mooring array consisting of 6 moorings along Line W deployed since 2004

Average WBC transports east of the Grand Banks

western boundary current

North Atlantic Current (NAC)





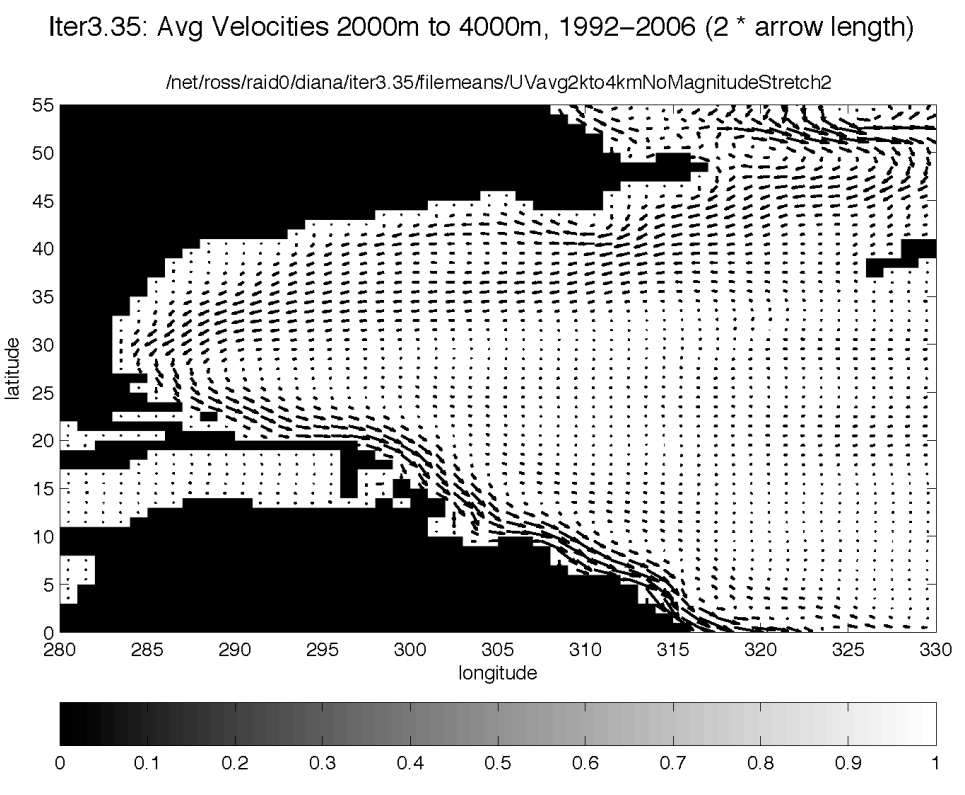
Average alongshore velocity determined from both mooring arrays

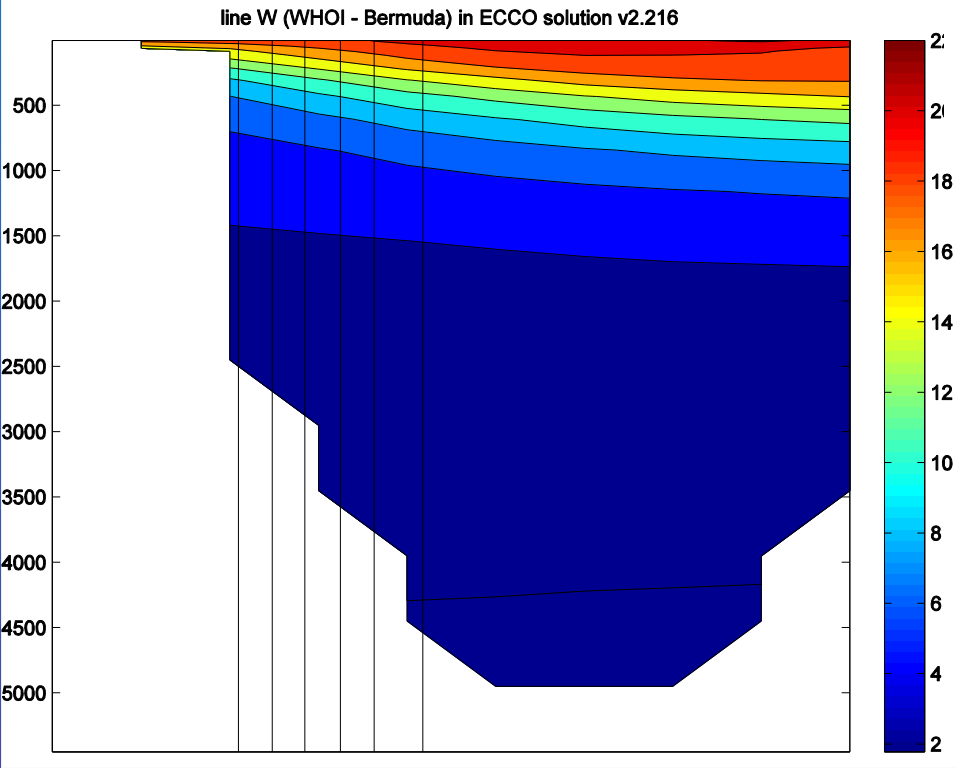
- **total DWBC transport (σ_θ>27.68) yields 12.9 Sv**
- NAC transport is 130-140 Sv *(Watts and Meinen, 2000; Meinen, 2001)*

(Schott et al., 2004)

⇨ 27.8 Sv of NEADW and DSOW transported northward in the NAC need to return southward to the east of the section but to the west of the MAR

Mean velocity and temperature field at Line W from 1°- resolution ECCO





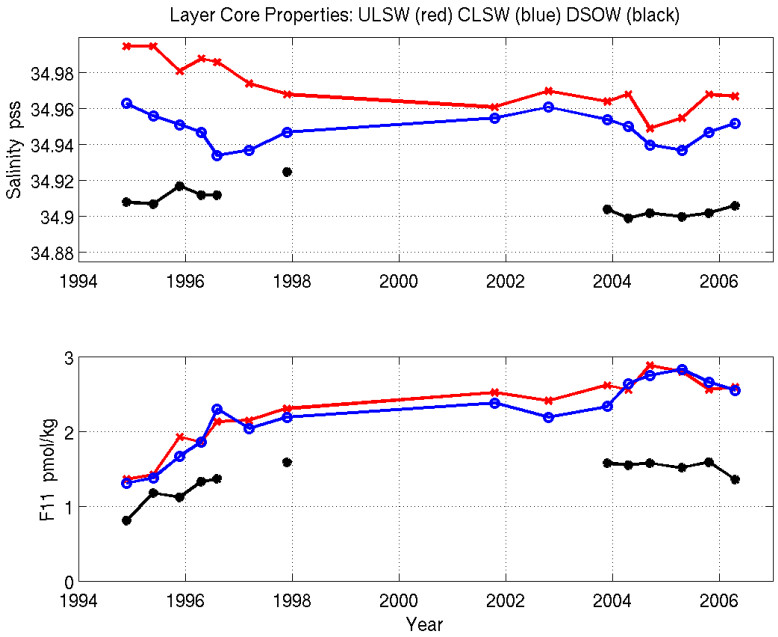
From Johanna Baehr

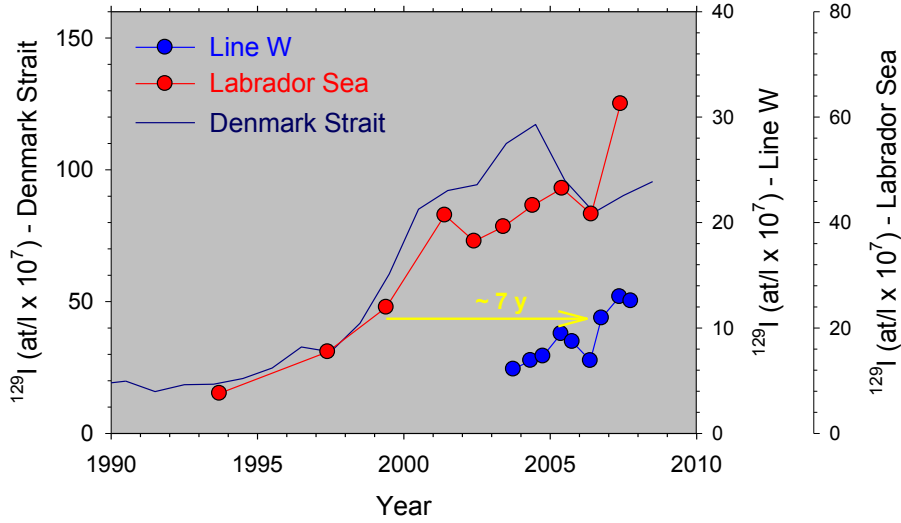
Variability at Line W

Tracer observations

Bill Smethie (LDEO): Time series of core water mass salinity and F_{11} at Line W

John Smith (BIO): Time series of ^{129}I concentrations in Denmark Strait, Labrador Sea and at Line W





Inferred Labrador Sea to Line W transit times are 5-7 years

Lag-correlation between the Gulf Stream path and SST anomalies

Maximum correlation →

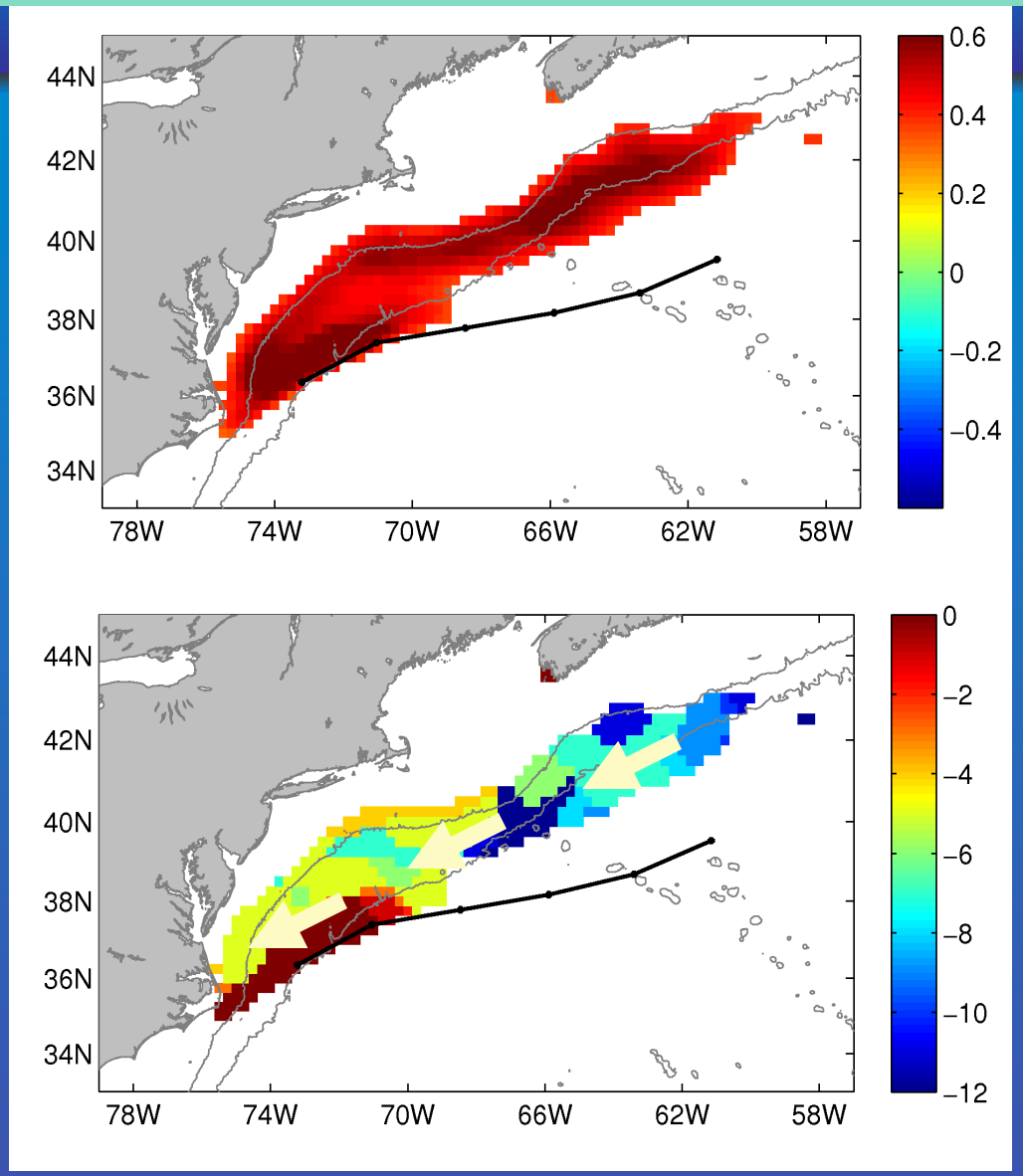
(90% significance level)

positive values meaning northerly paths are correlated with warmer water

Lag (months) →

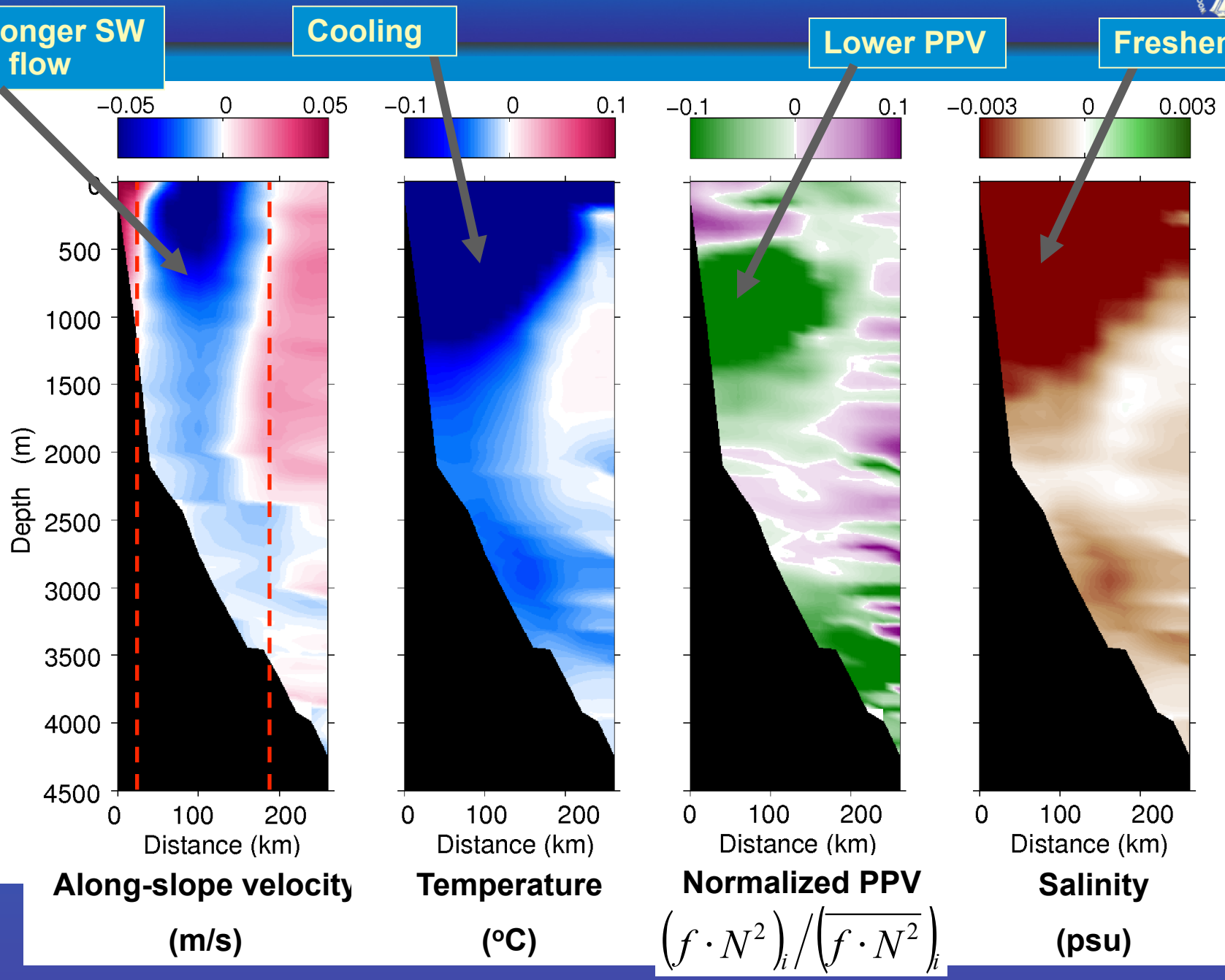
negative values imply SST is leading Gulf Stream path changes

(From Peña-Molino and Joyce, 2008)



Westward moving warm (cold) anomalies in the Slope precede northward (southward) changes in the Gulf Stream axis.

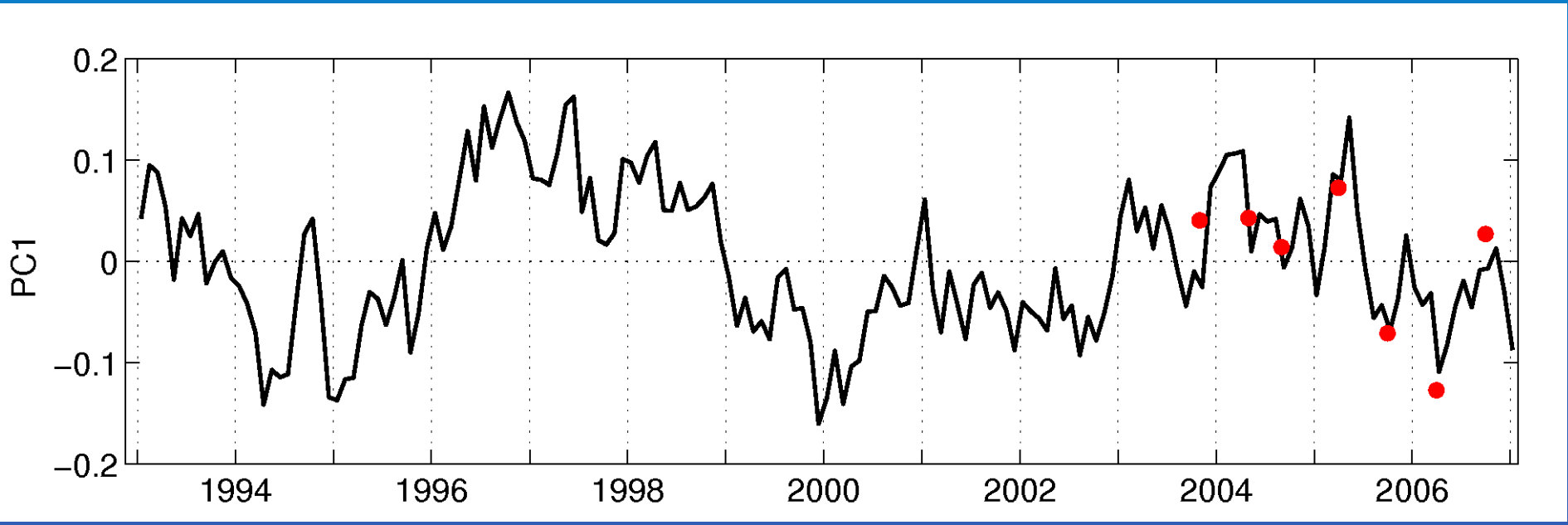
Peña-Molino: Joint EOF of Line W sections (LADCP velocity, T, PV and S)



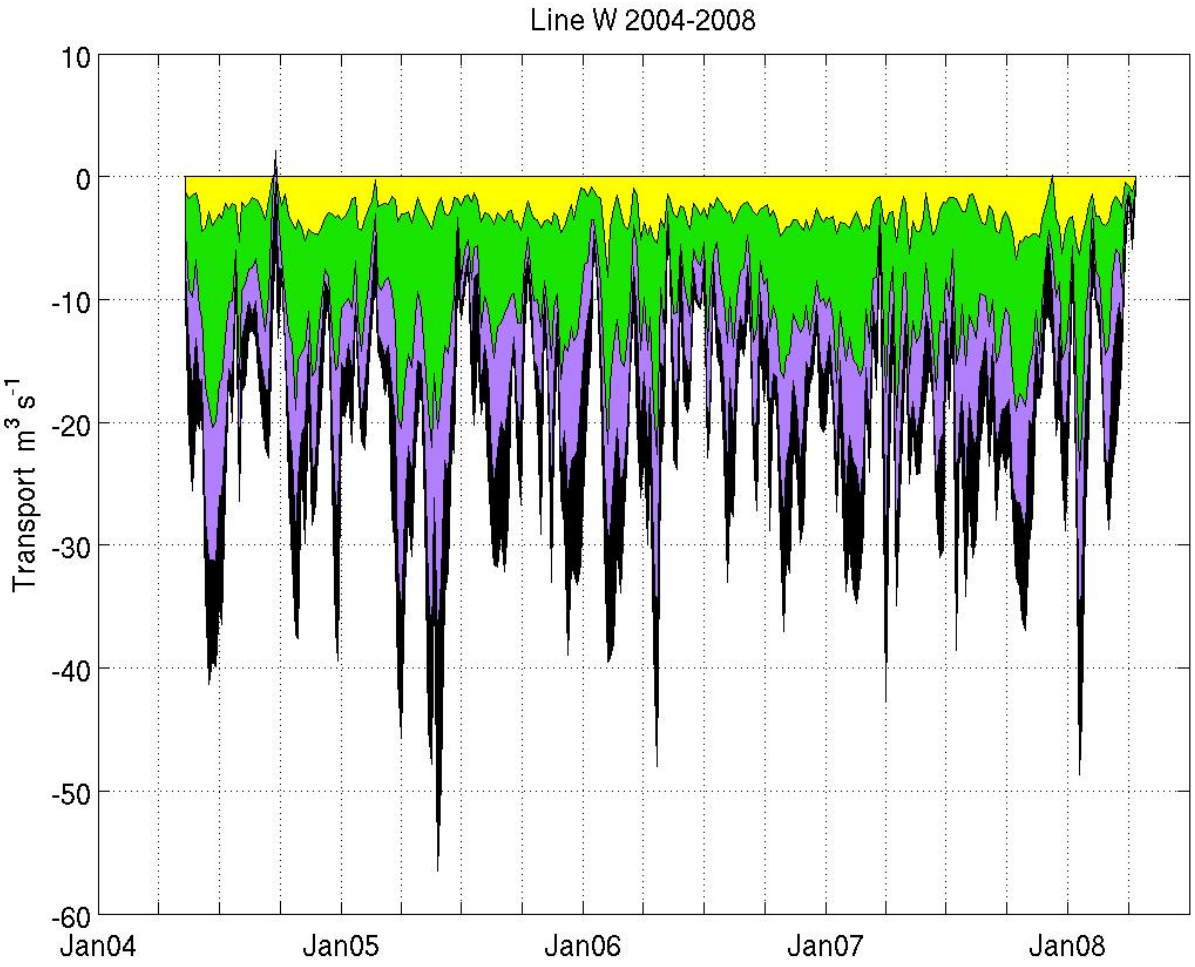
Principal components of the cruise and satellite EOF

Black line→ satellite PC1

Red dots→ cruise PC1



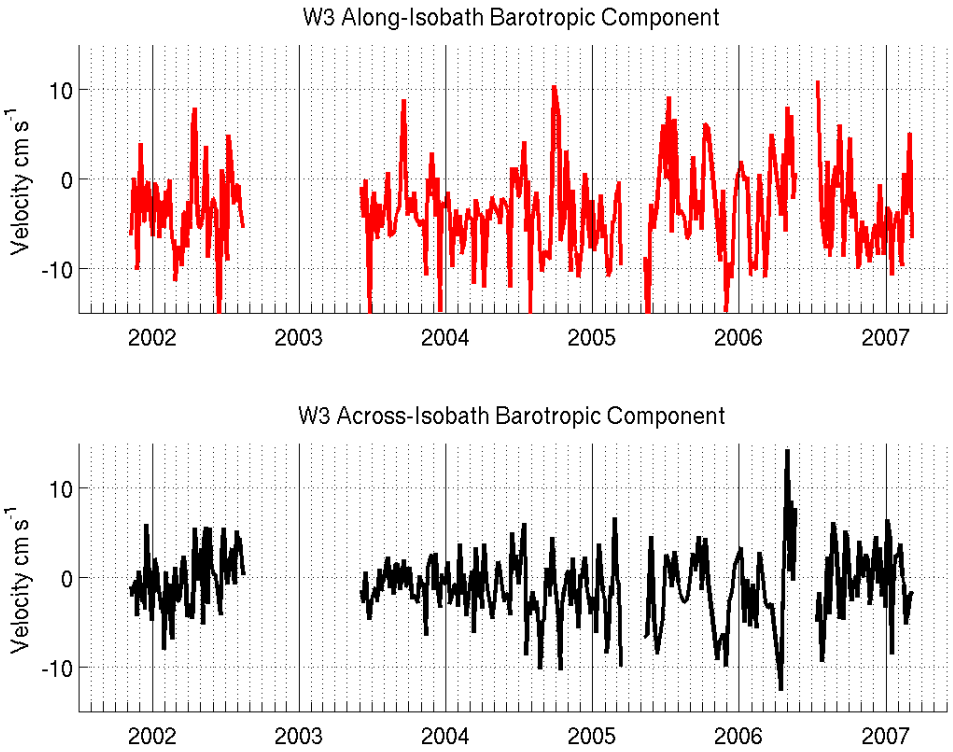
Equatorward transport across Line W partitioned by water mass: ULSW (yellow), CLSW (green), ISOW (purple), DSOW (black)



total mean : -22.5 Sv;
95% conf bounds =
+/- 2.3 Sv
(based on 10-d
decorrelation time)

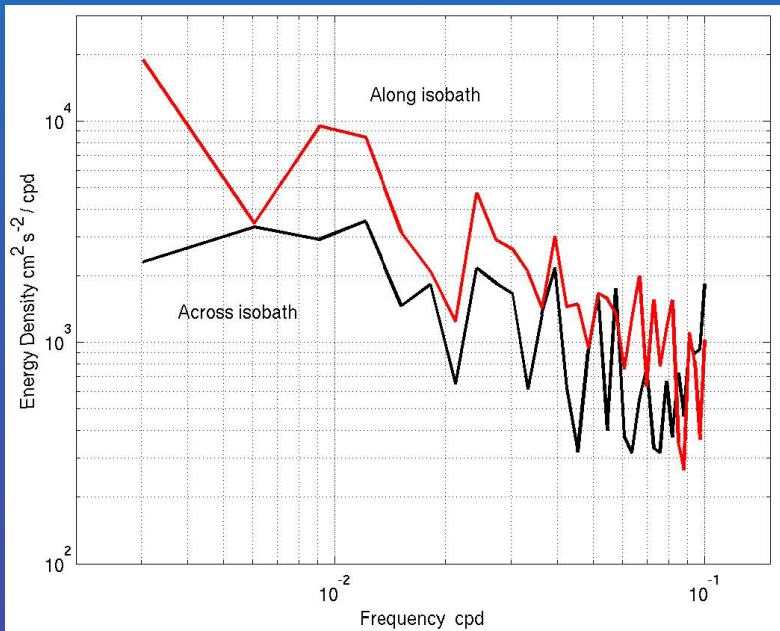
range = -0.9 to
-56.5 Sv;
std dev = 9.7 Sv

~60% of the sub-inertial variance accounted for by depth-independent motions



Along-isobath variance is ~twice the across-isobath

Due chiefly to motions at periods longer than a month



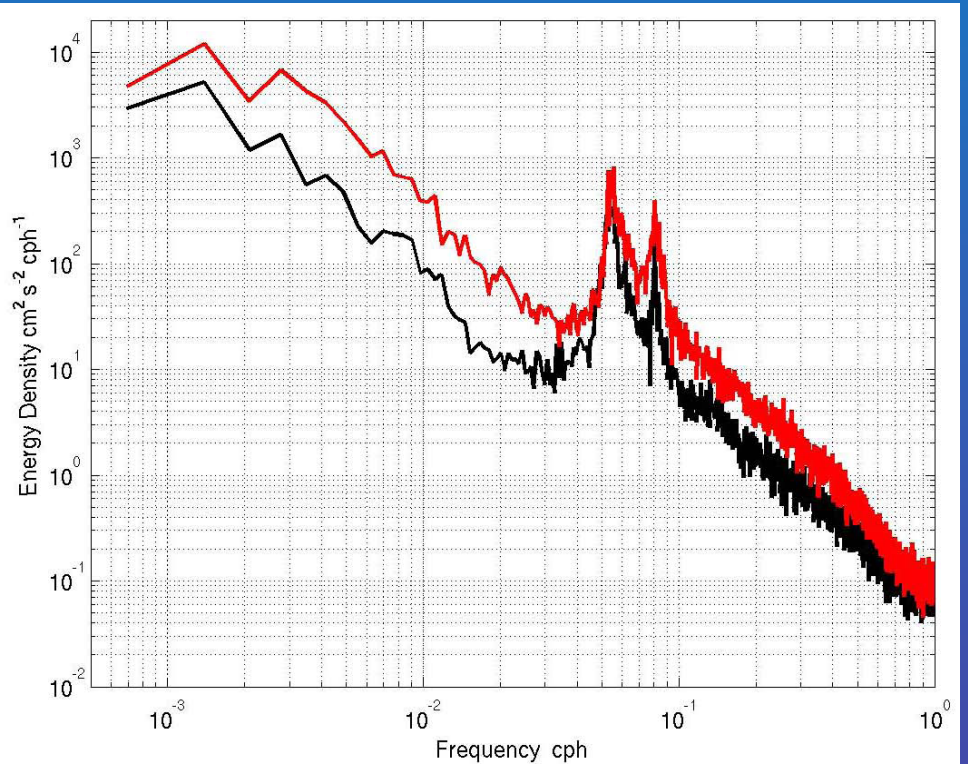
Kinetic Energy Frequency Spectra from W2

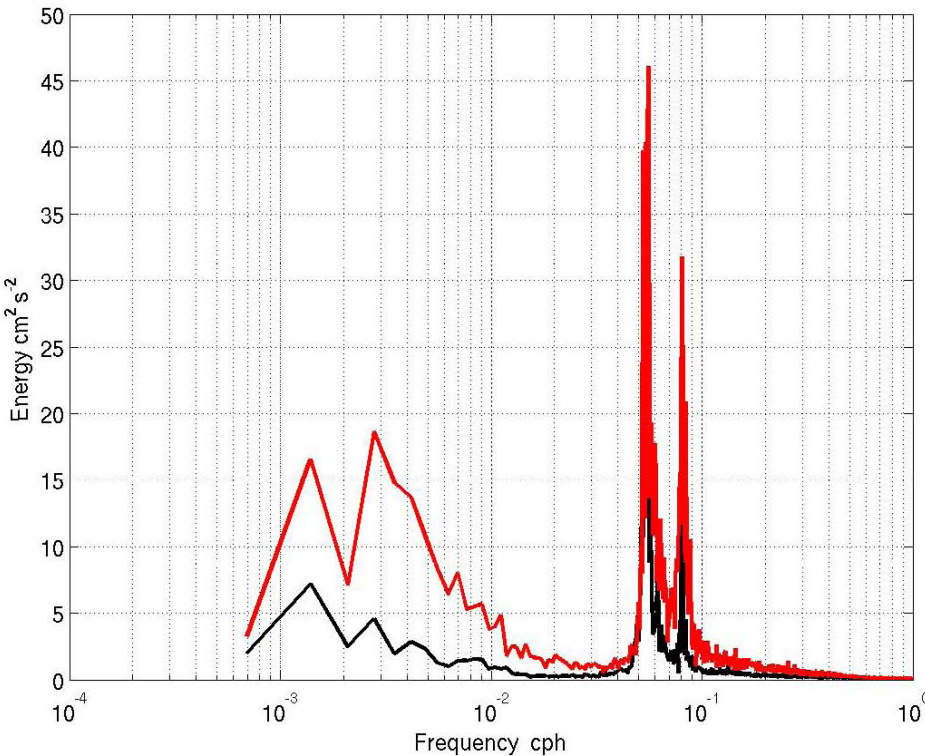
Black = 1000 m

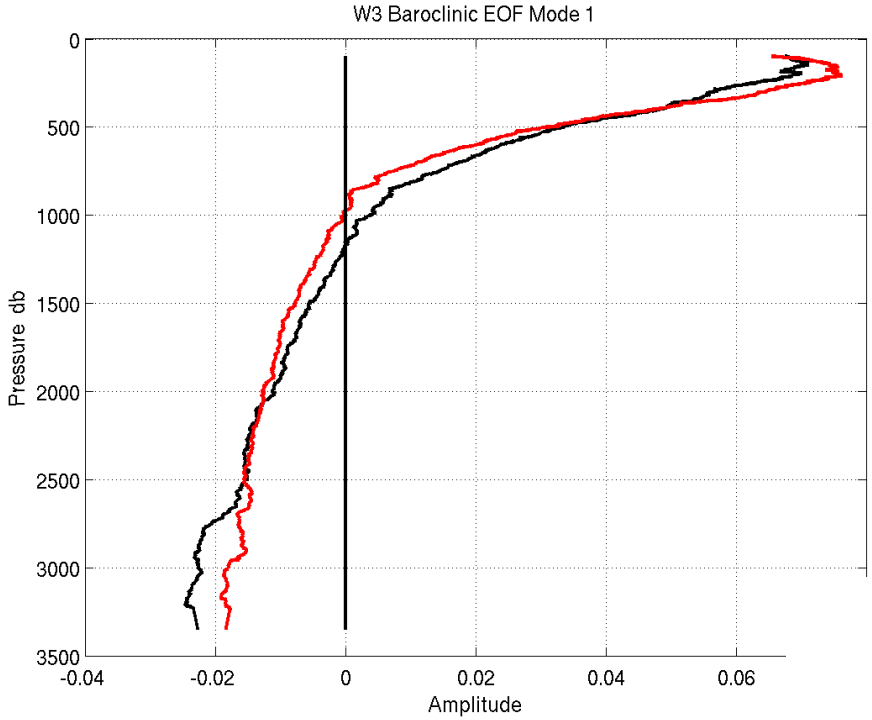
Red = 2700 m

(more) evidence of

Topographic Rossby Wave variability



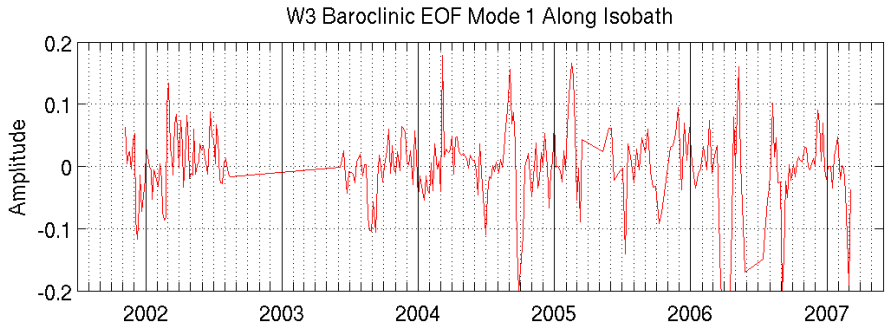


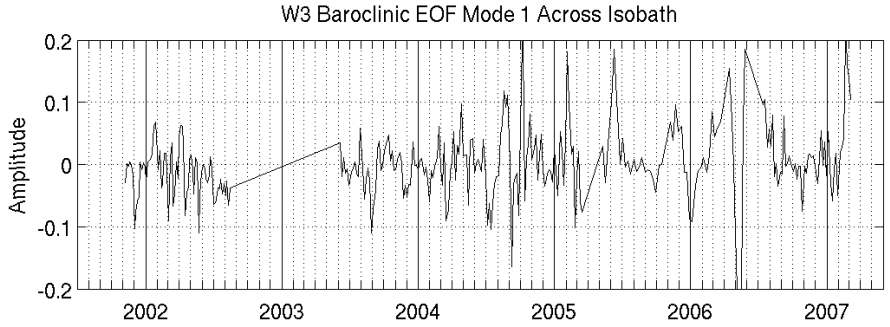


~60% of baroclinic variance accounted for by 1st EOF mode

Red = along-isobath component
Black = across-isobath

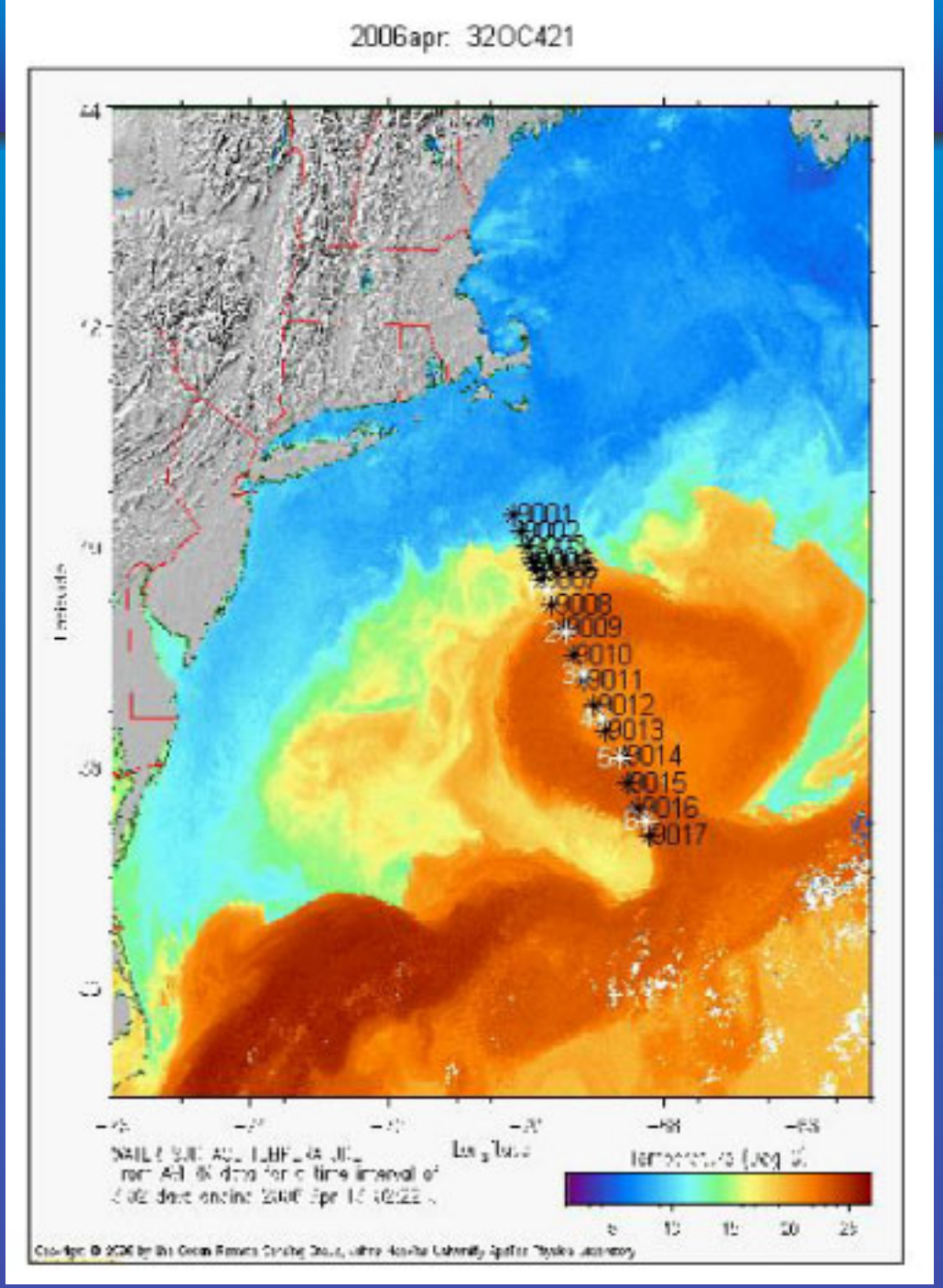
Similar to first baroclinic mode for flat-bottom ocean, but bottom isn't flat

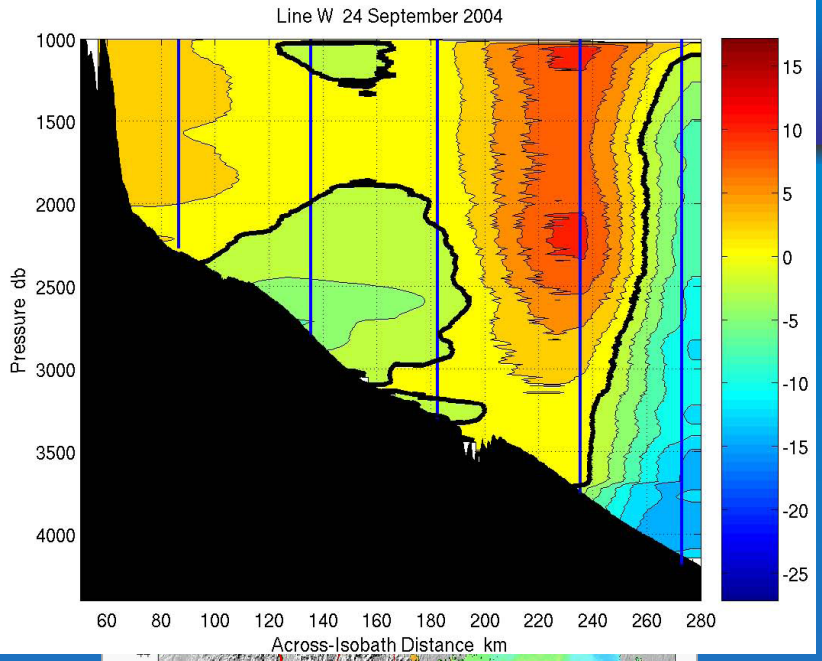


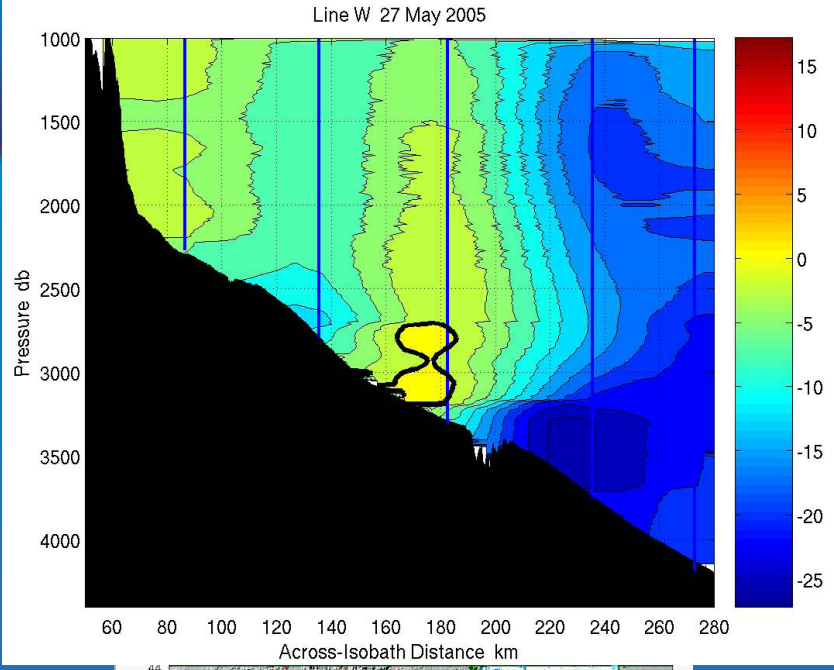


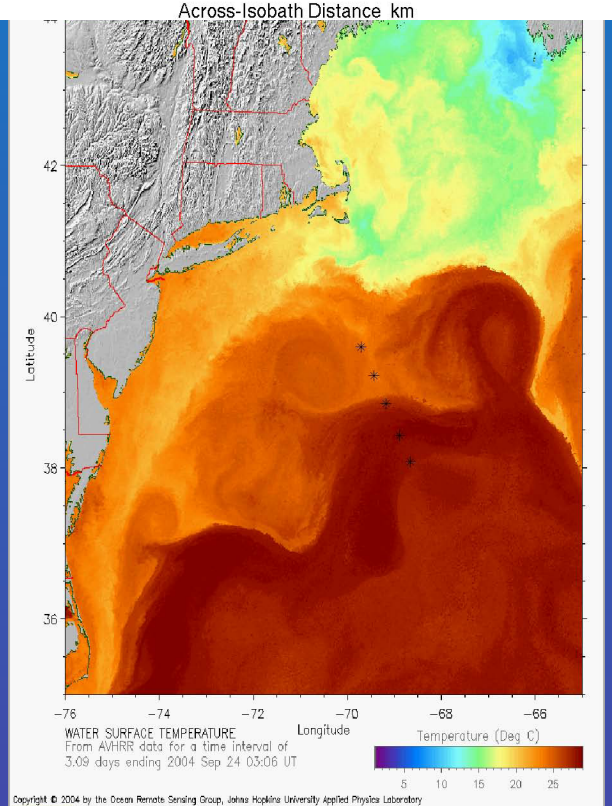
Gulf Stream Warm Core Rings

rings near Line W
~1/3rd of the time
2004-2006
based on Navy
surface analyses

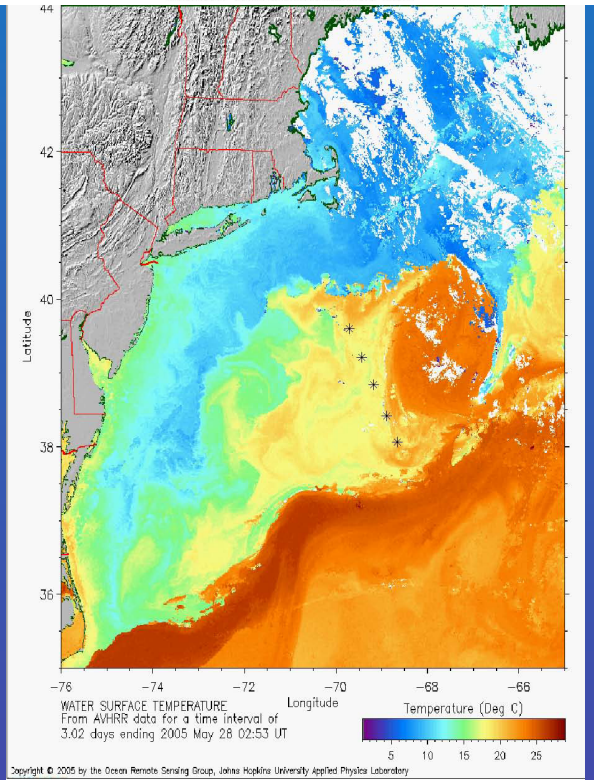








Times of Minimum ← and Maximum → DWBC Transport



Line W is ongoing

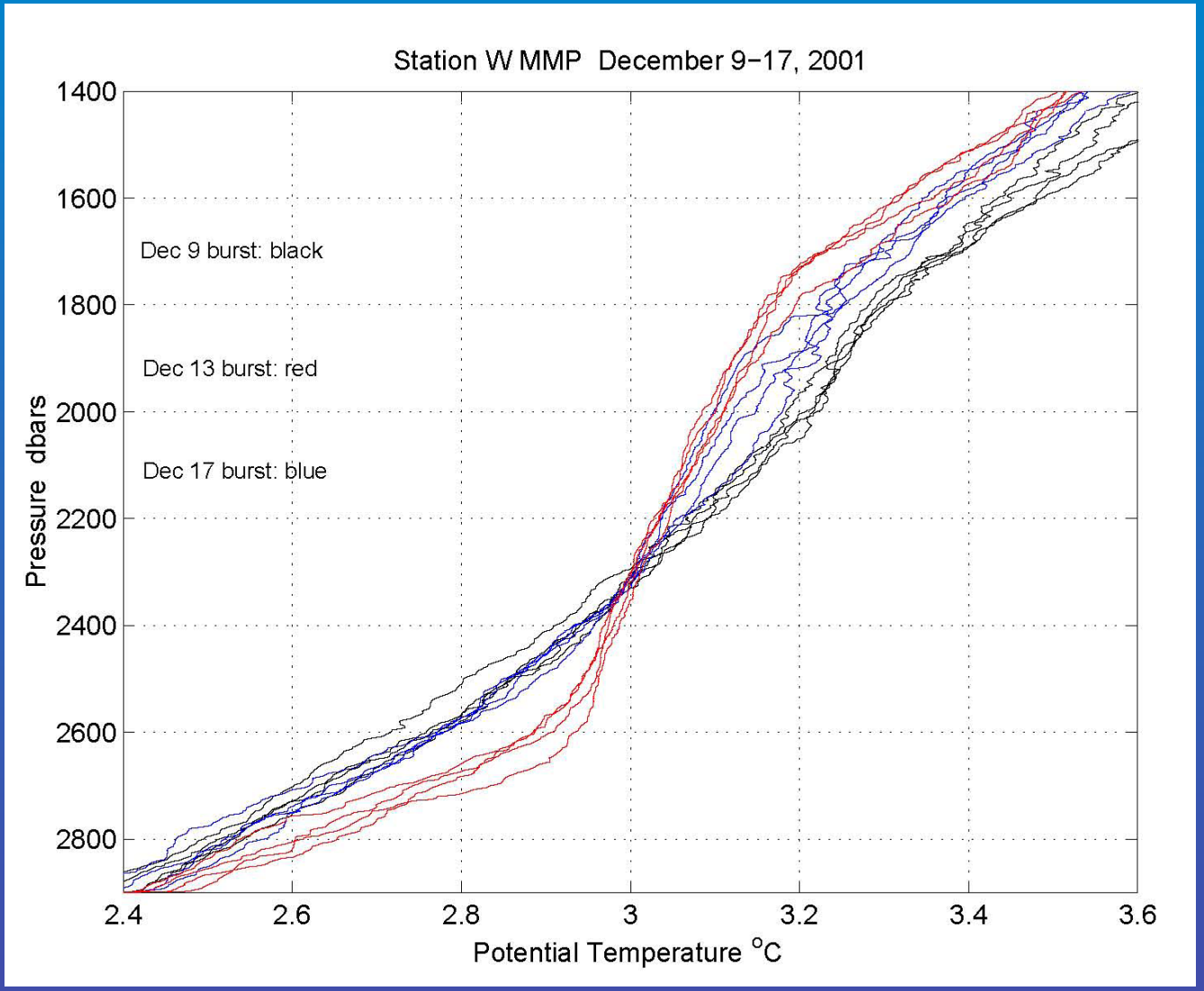
In June, the remaining 2 moorings of the array
will be deployed,
the hydrographic section will be occupied in September

the array and shipboard data
for the period 2004-2008
are now in hand and analysis is underway

Invite collaborations to use these data,
to investigate ways to extend to full-basin-width,
and ultimately
help us learn how the time-varying DWBC at 39°N 70°W
fits into the North Atlantic MOC

Other modes of mesoscale variability

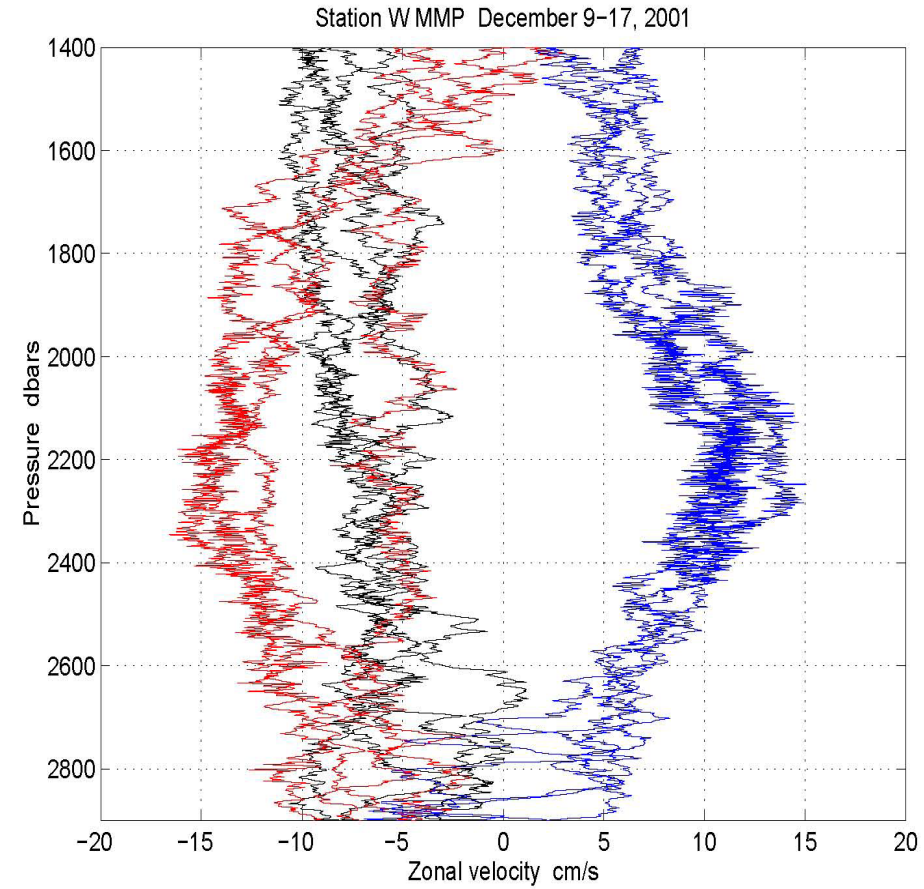
Low-PV lens passage

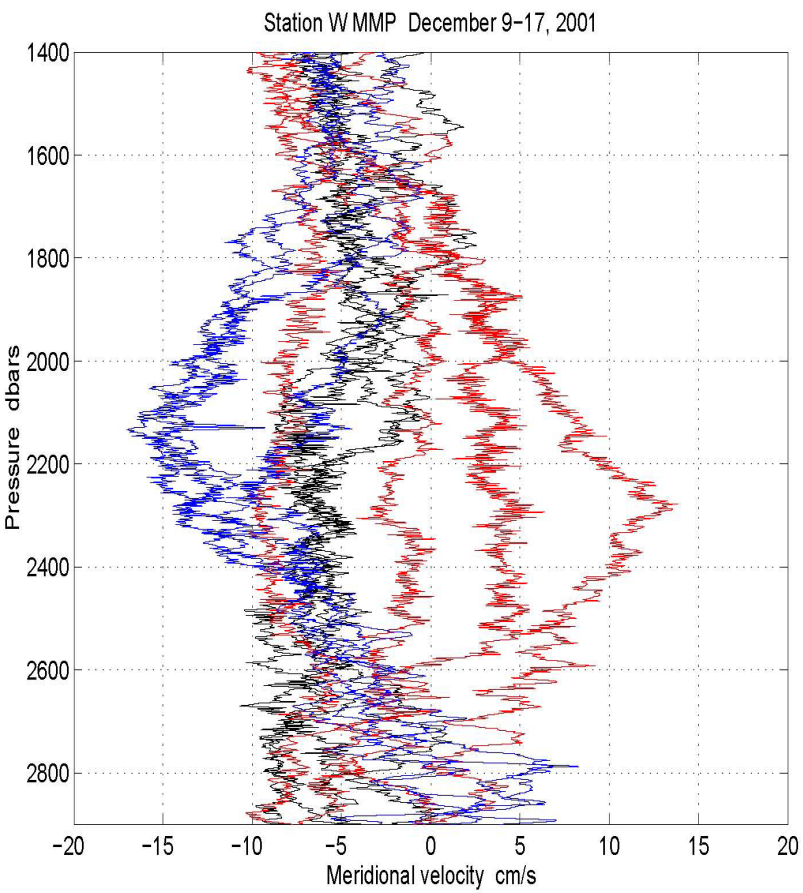


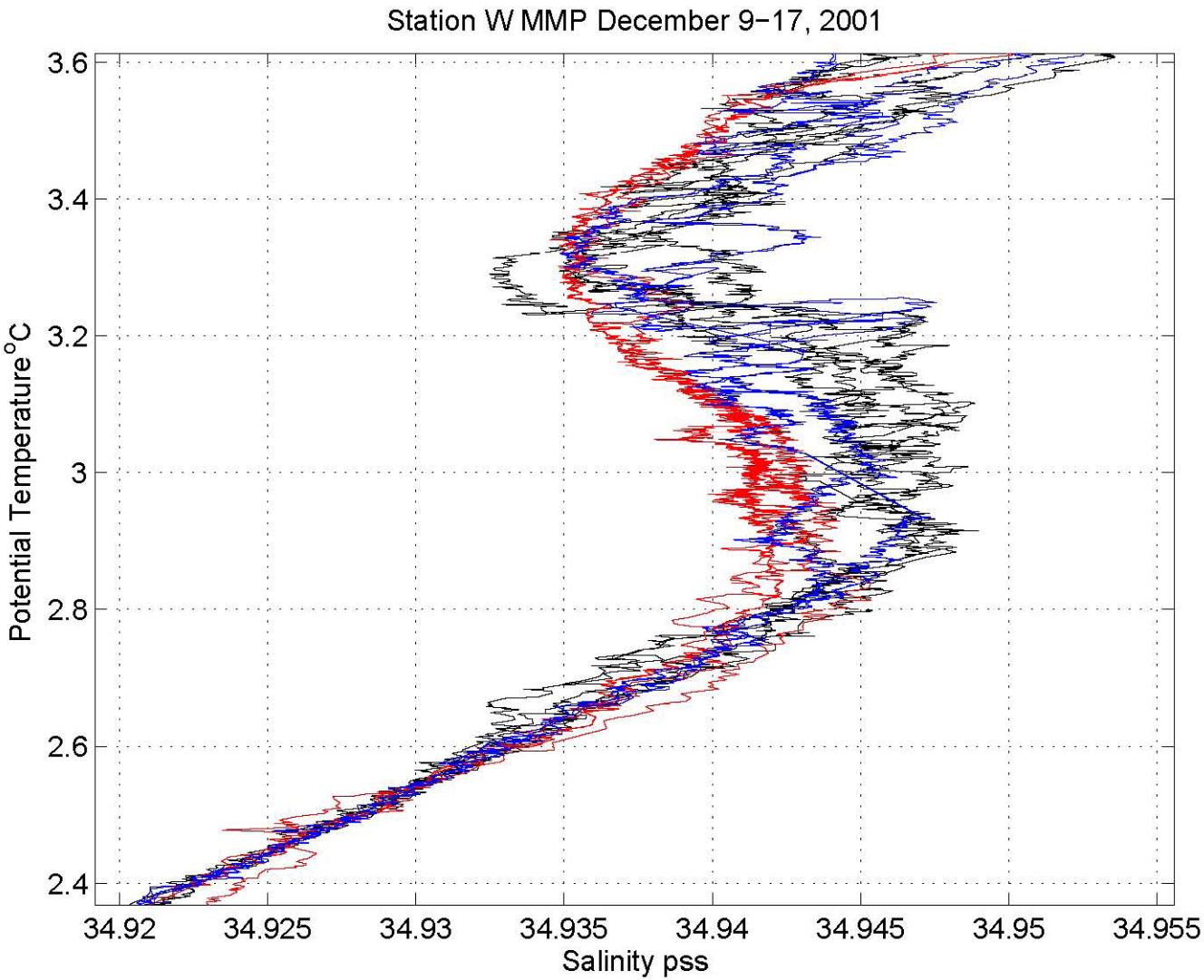
associated velocity profiles

Zonal

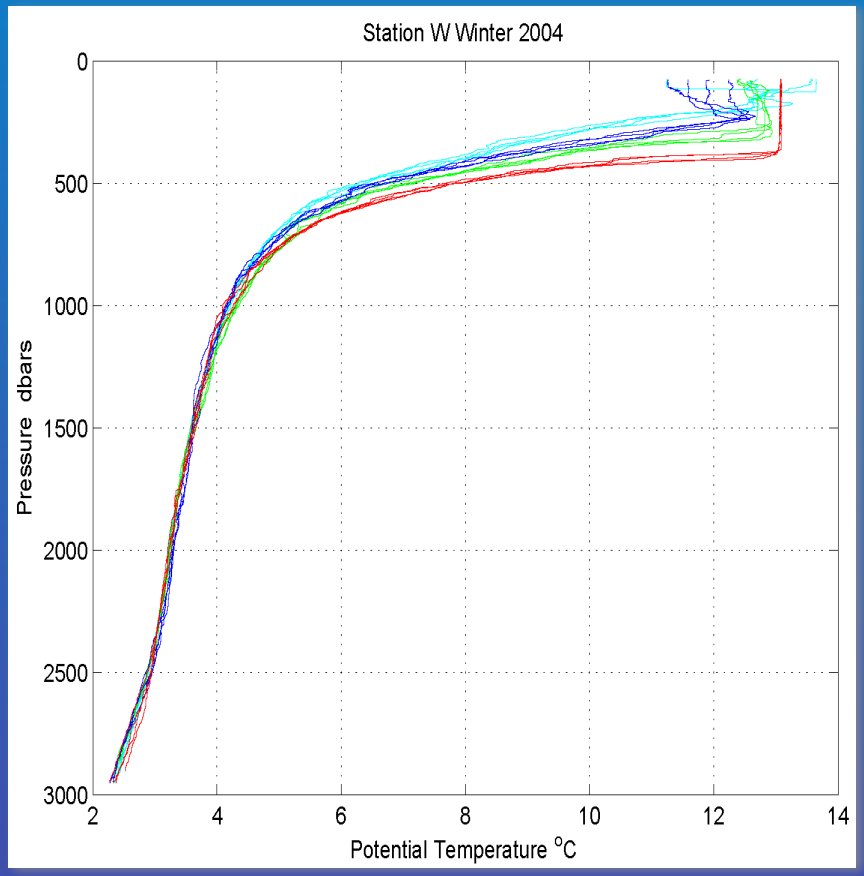
Meridional

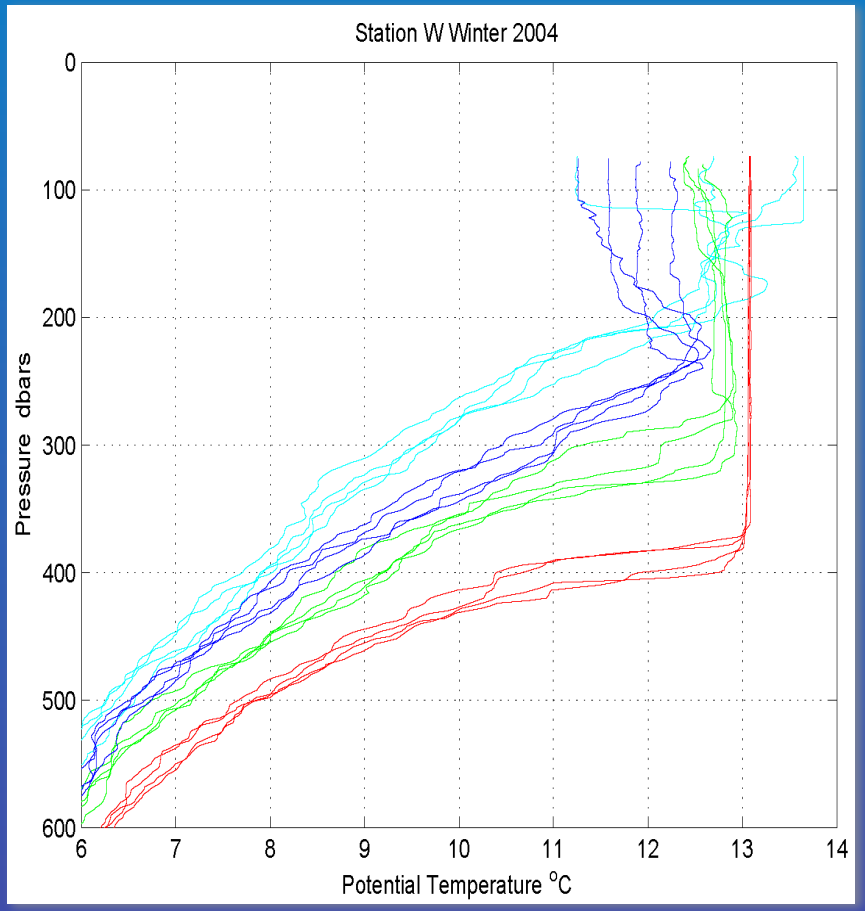





Station W MMP December 9−17, 2001
Potential Temperature °C
3.6
3.4
3.2
3
2.8
2.6
2.4
34.92
34.925
34.93
34.935
34.94
34.945
34.95
34.955
Salinity pss

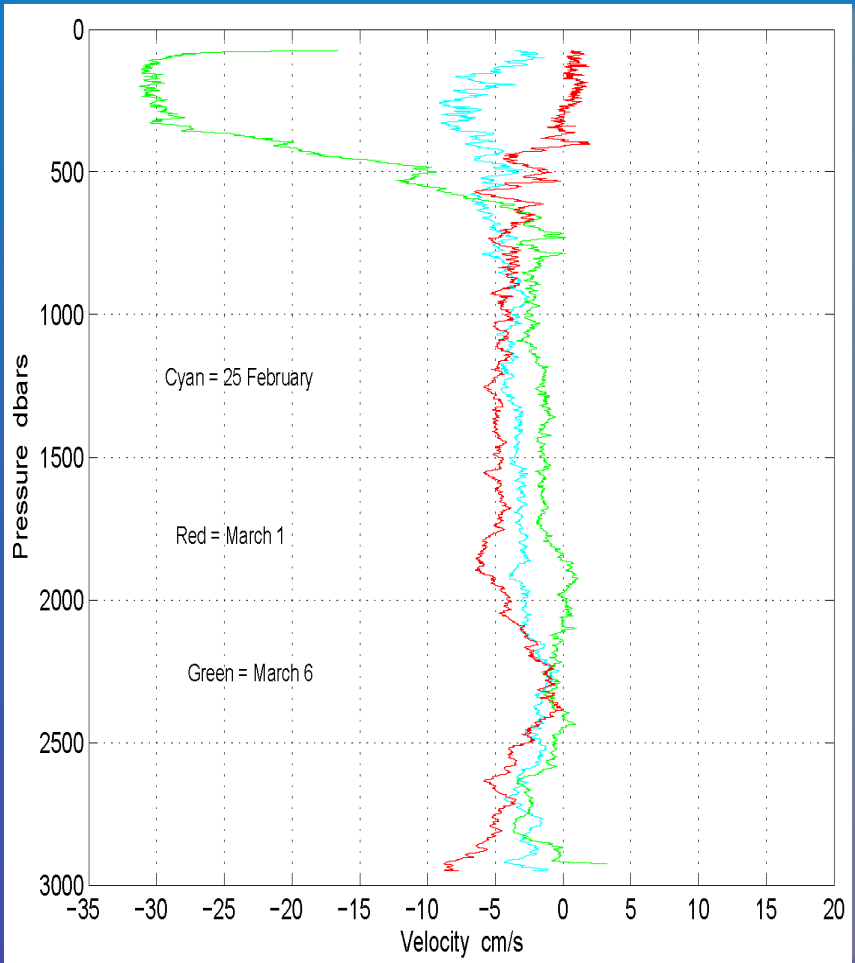
Winter 2004 Gulf Stream Ring



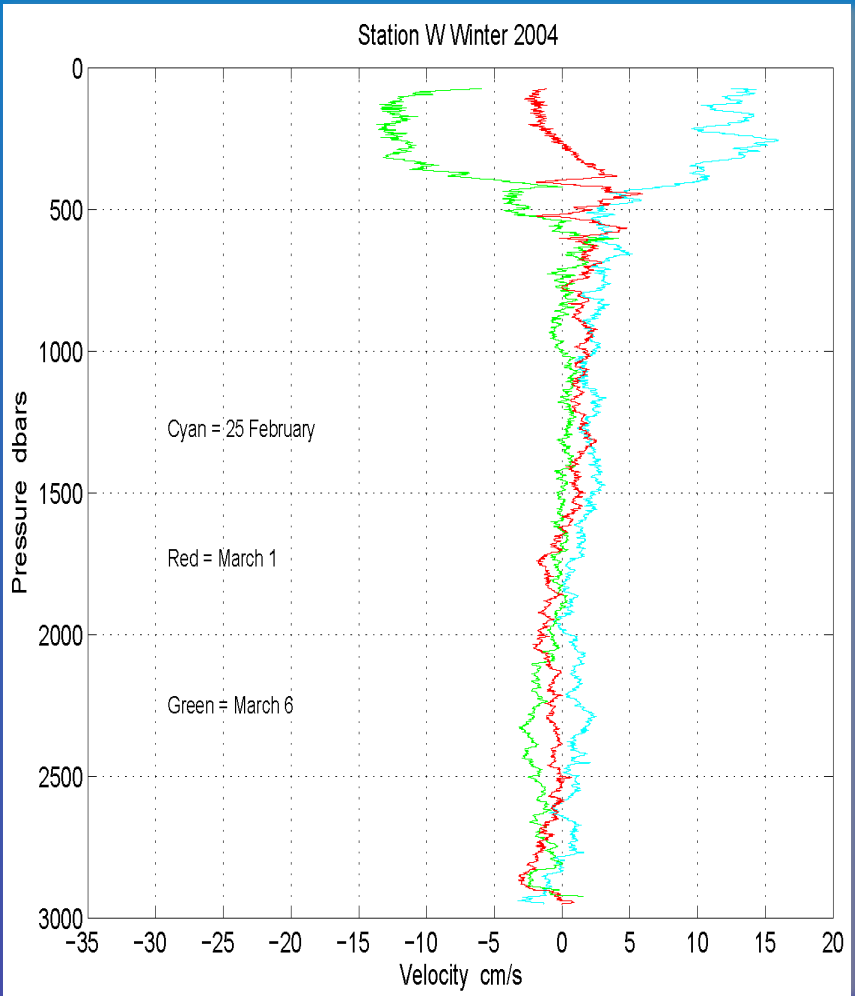


Burst-averaged velocity profiles

Zonal

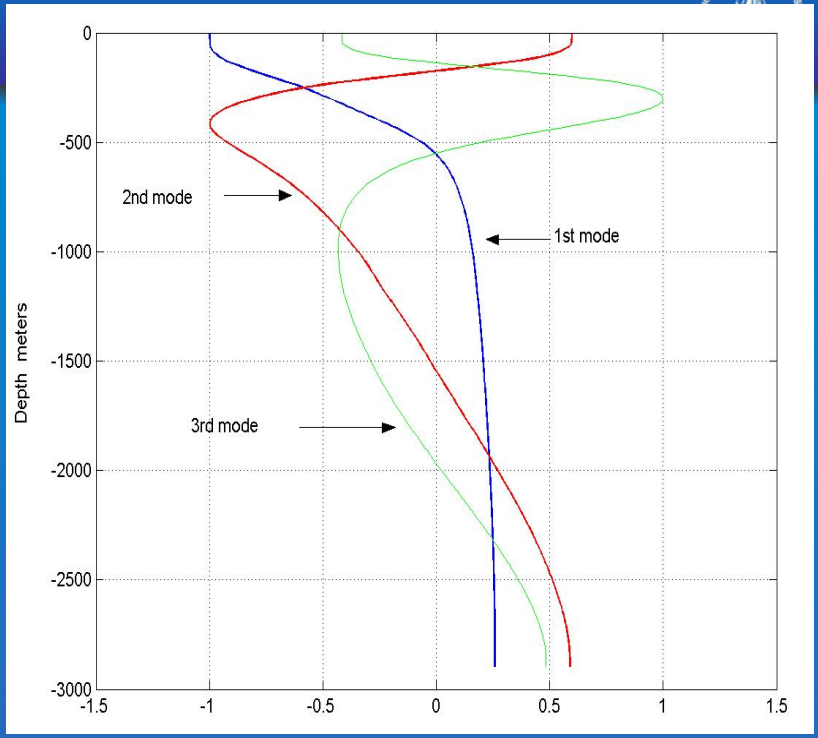


Meridional

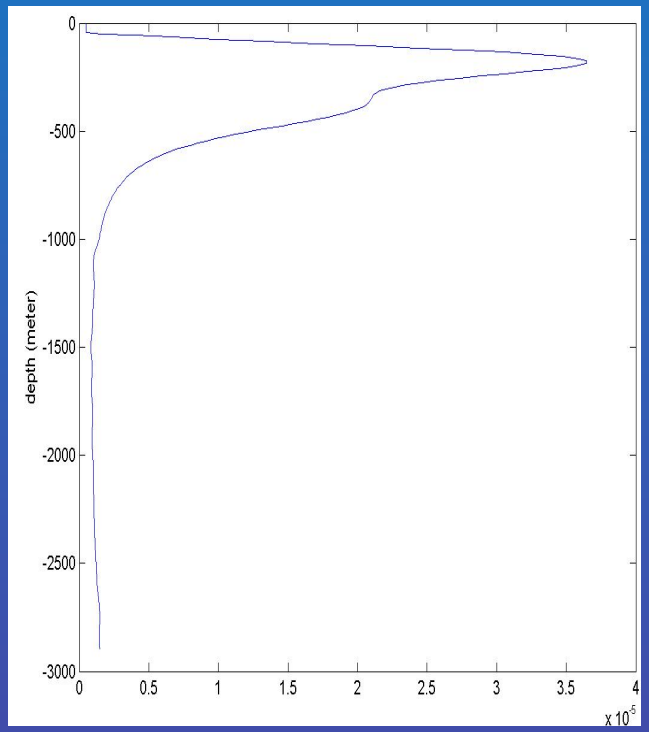


Dynamical baroclinic modes

flat bottom



N^2 profile



sloping bottom

TRW