The origin of along-shelf pressure gradient (ASPG) in the Middle Atlantic Bight (MAB)

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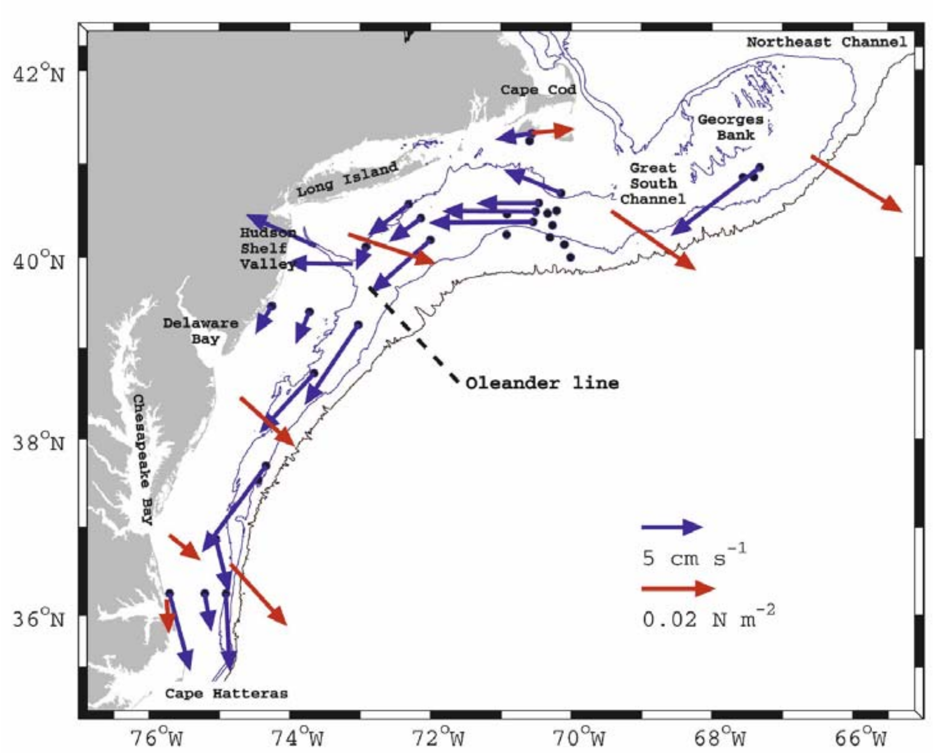
Why is the ASPG important?



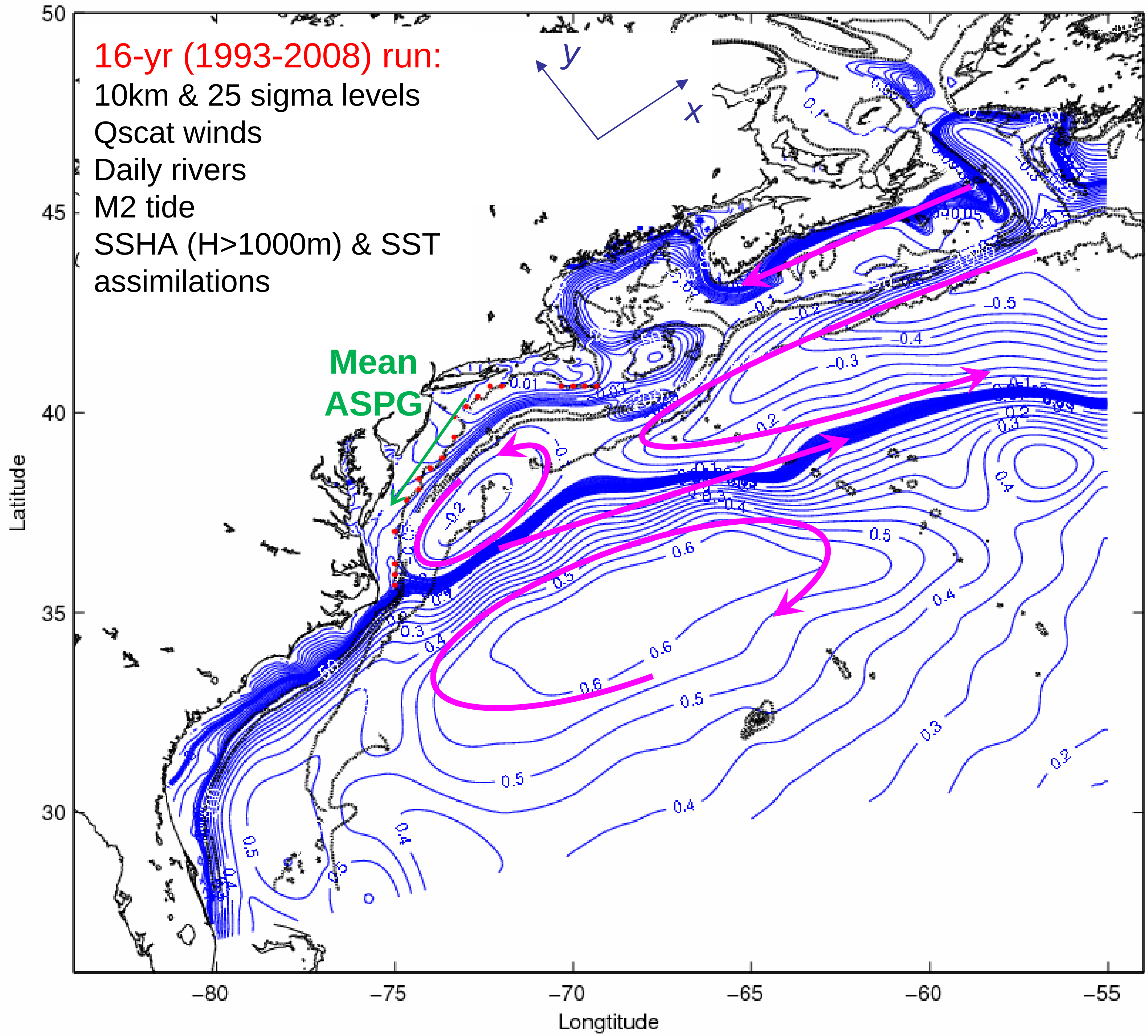
(Lentz, JPO, 2008)

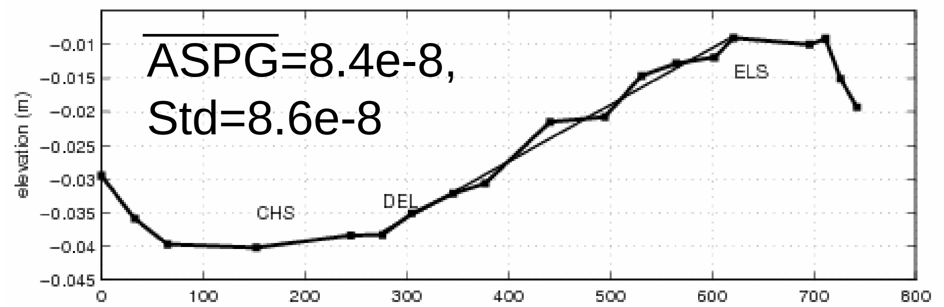
The ASPG exists to account for the mean along-shelf circulation.

Momentum Balance:

$$gh\frac{\partial \eta}{\partial x} = \frac{\tau^x_{wind}}{\rho_o} - \tau^x_b \approx -ru$$

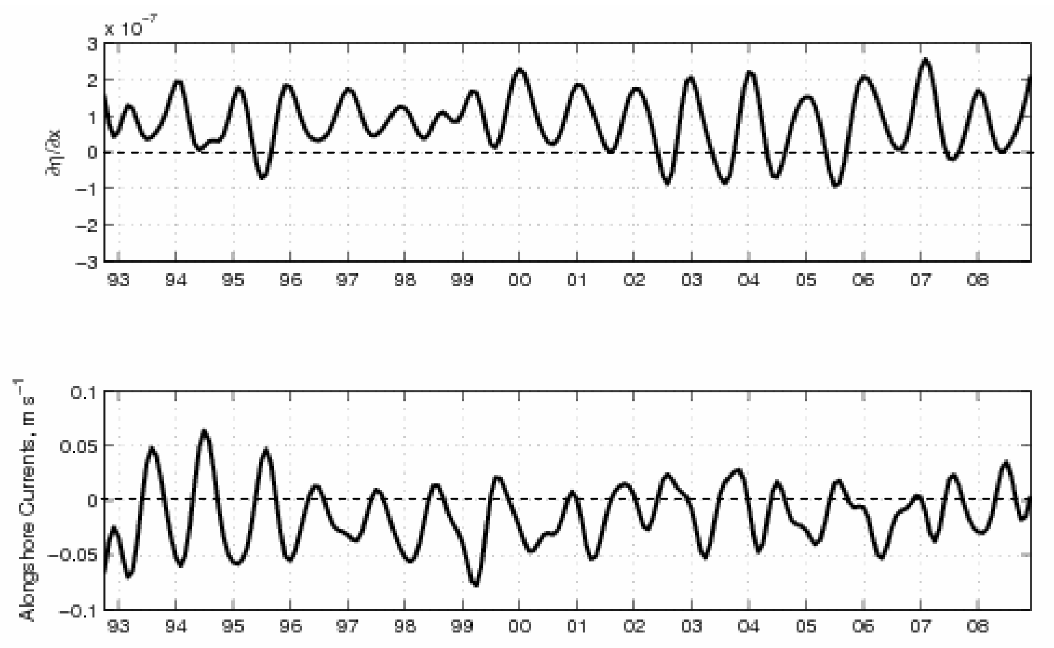
ASPG 10^{-8}~10^{-7} drives mean along-shelf flow towards the southwest (Stommel and Leetmaa,1972; Csanady, 1976; Lentz, 2008);


16-yr (1993-2008) run:
10km & 25 sigma levels
Qscat winds
Daily rivers
M2 tide
SSHA (H>1000m) & SST assimilations
Mean ASPG
y
x
Latitude
Longtitude
50
45
40
35
30
−80
−75
−70
−65
−60
−55



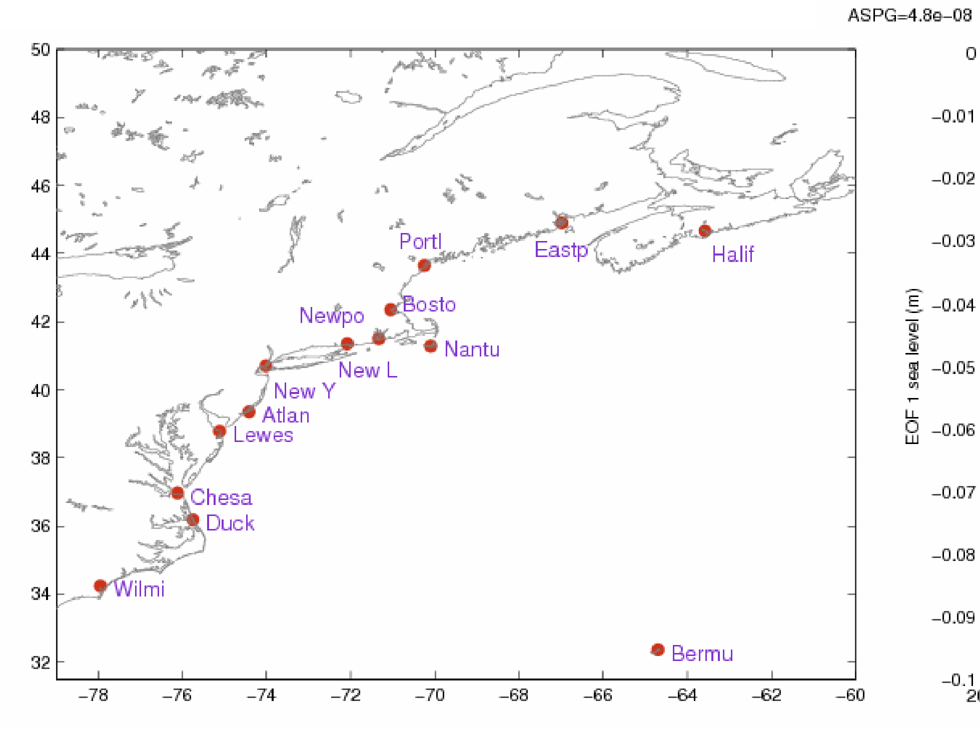
Distance from Cape Hatteras

R=-0.5

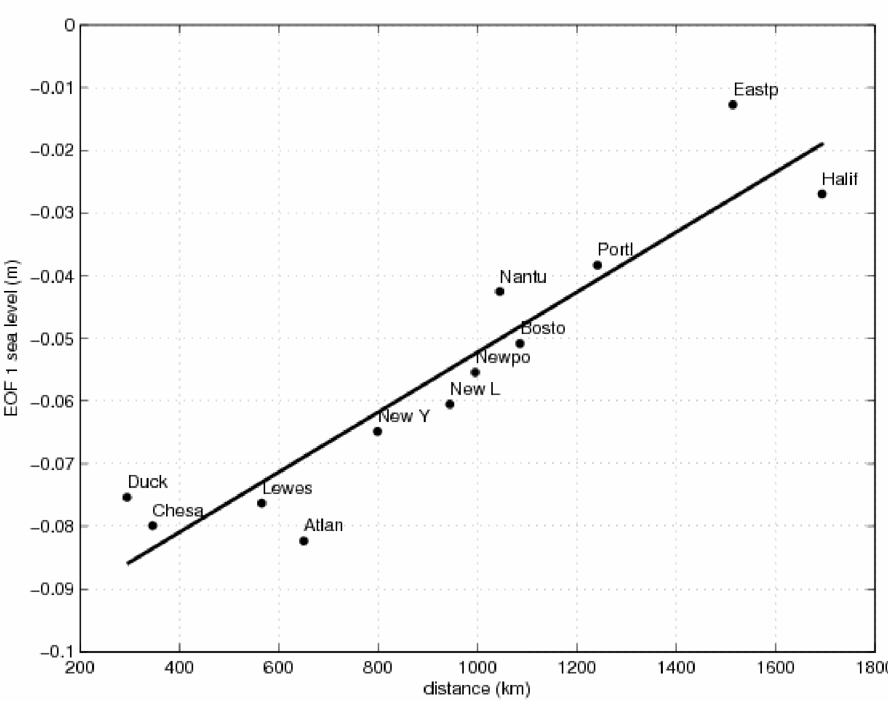


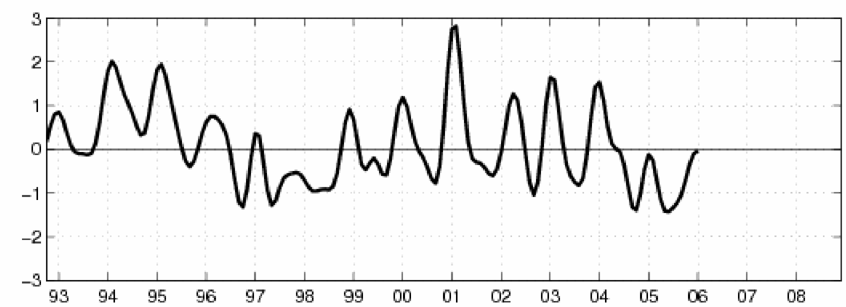
Years

Tide-gauge sea level data: demeaned



EOF mode 1: 67%





Previous Works:

- Due to offshore pressure field (Beardsley and Winant,1979)?

  But, pressure field not likely to penetrate onto the shelf (Wang, 1982; Chapman et al. 1986);

- Due to be rivers?

  This was questioned by Csanady (1979);

- Upstream transport? (Wang, 1982; Chapman et al. 1986).

The **origin** of (mean) ASPG remains unclear (Lentz, 2008)…

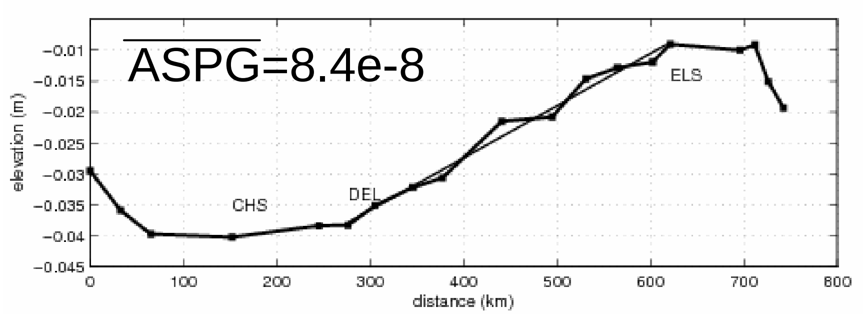
What is its origin?

What drive the seasonal and inter-annual variations?

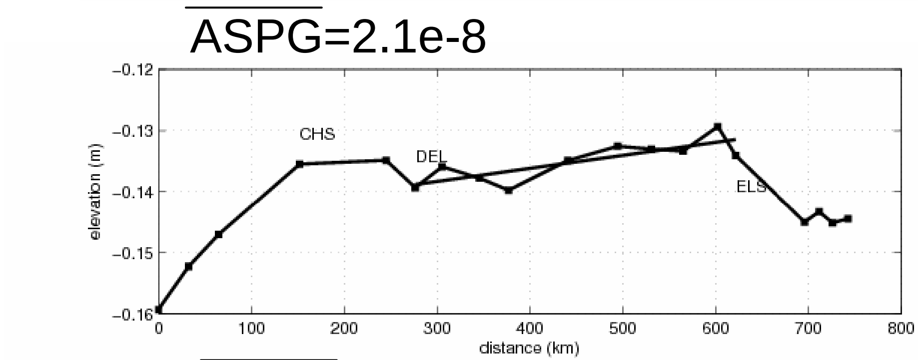
how and why?

Possible candidates:

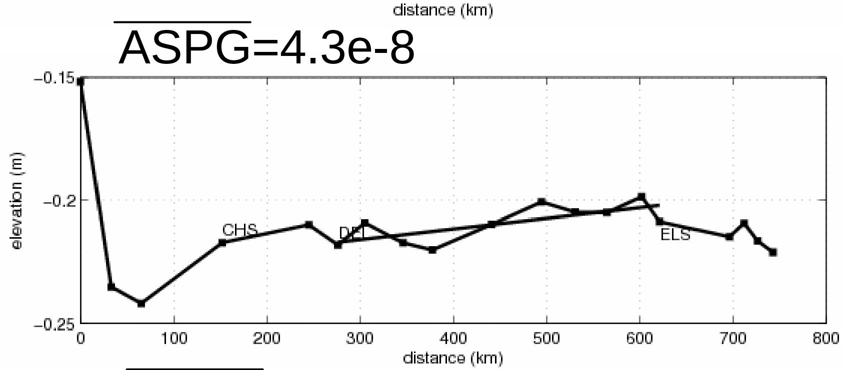
Winds	GS path	Rings
Rivers	Labrador transport	



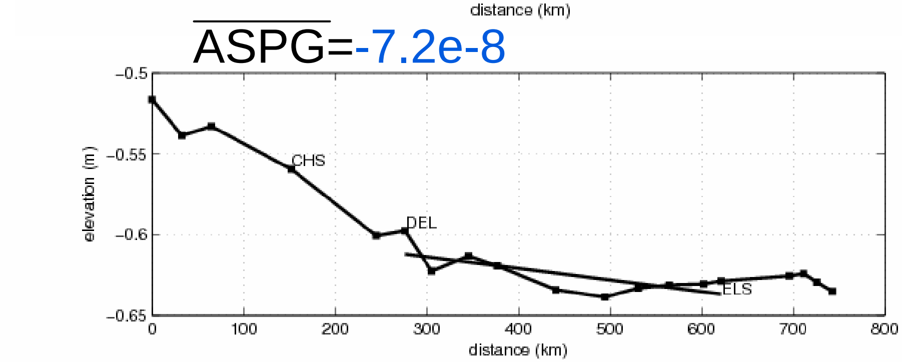
The base case



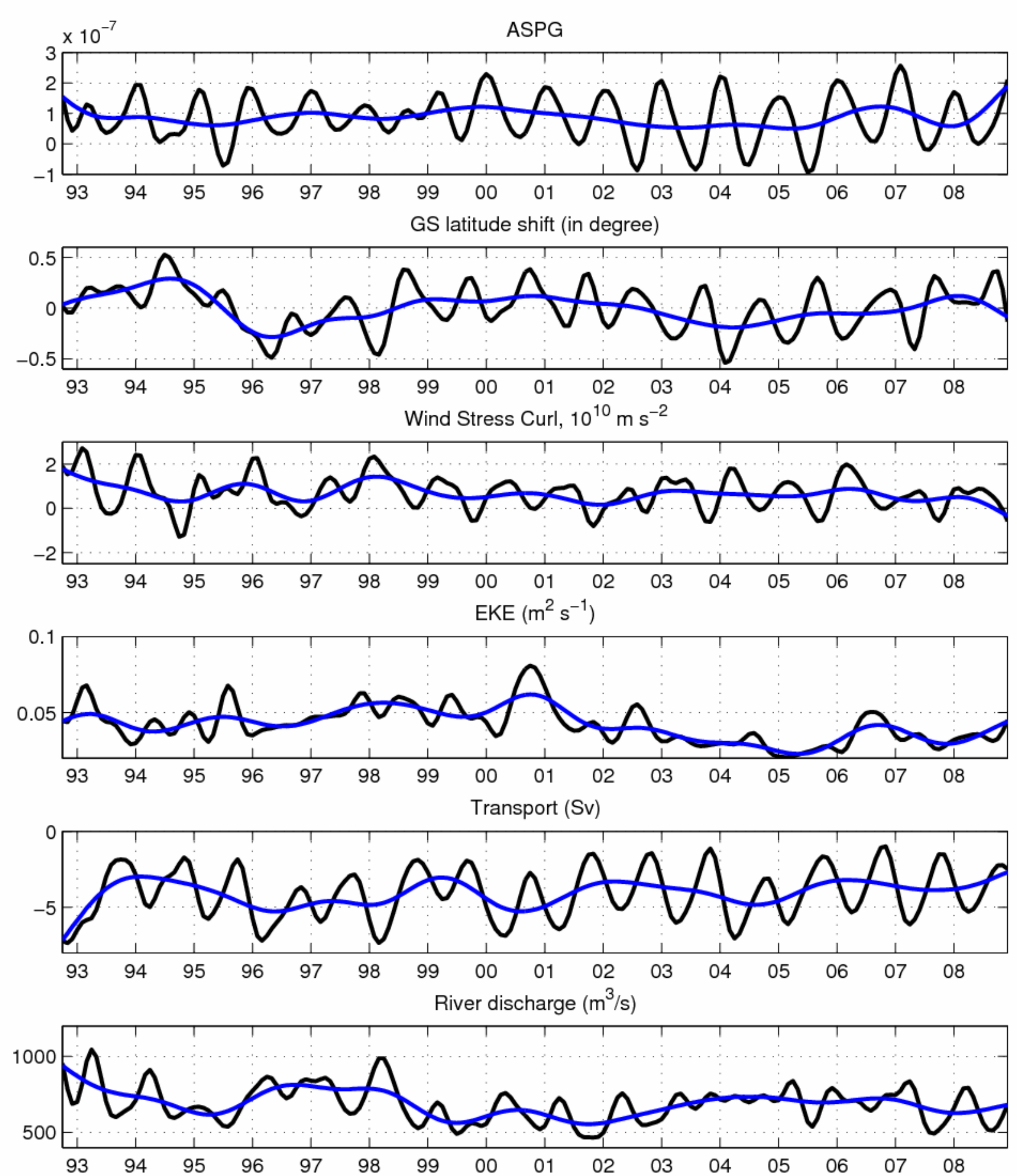
River only



River and transport



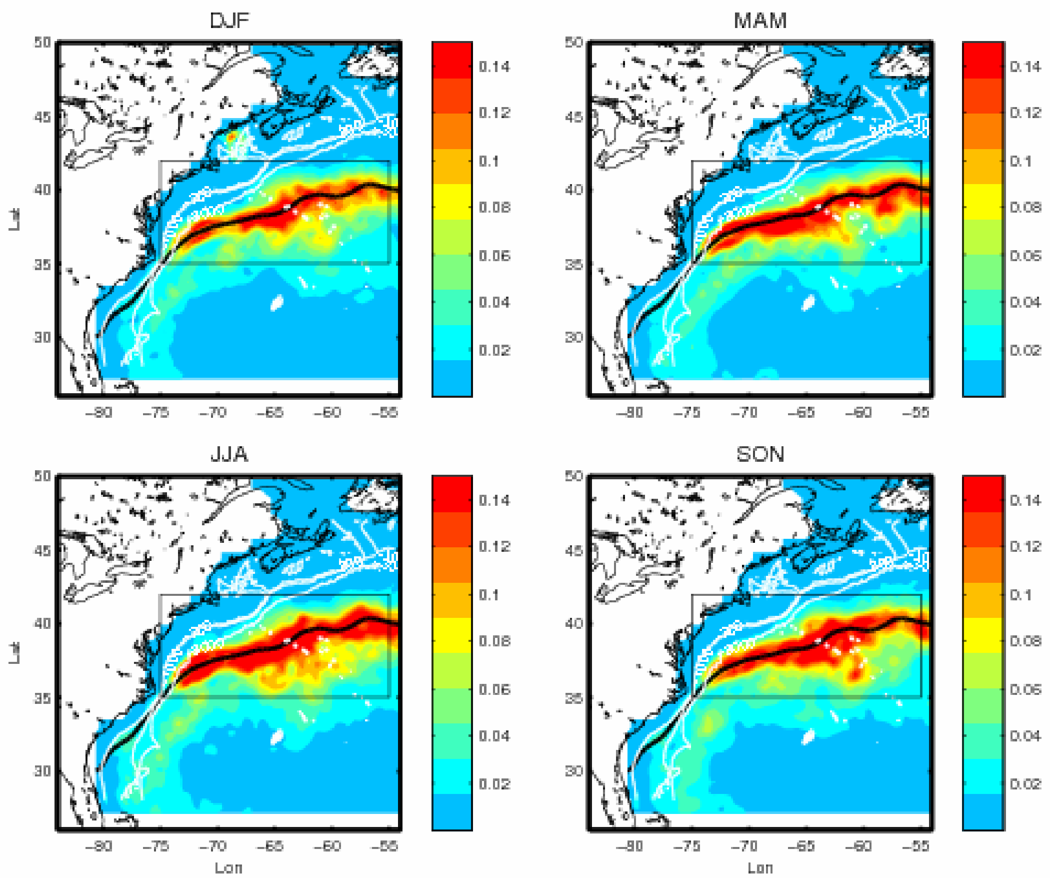
Wind only



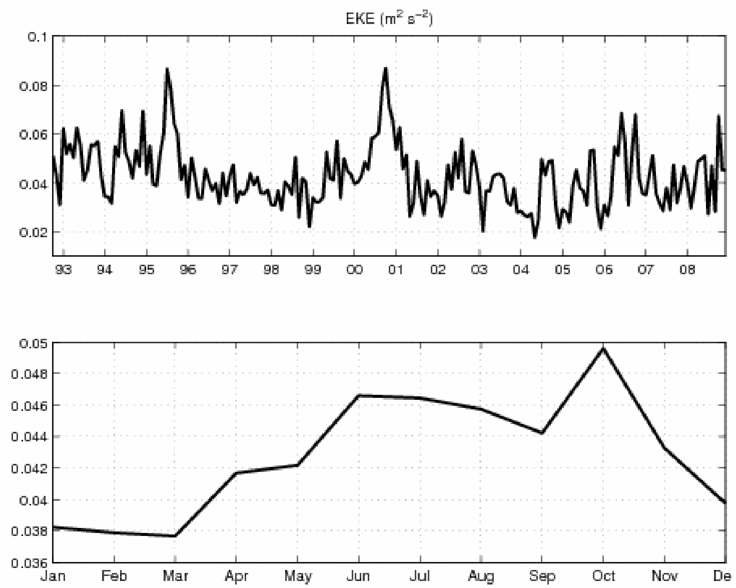
Correlation coefficient (R) and lags

R/Lag in month	ASPG	Wind curl	GS shifts
GS shifts	0.57 / 4	0.40 / -6	---
Wind curl	---	----	---
N - EKE	0.41 / 5	0.33 / -4	0.30 / 0
Transport	---	-0.65 / 0	---
River input	0.19 / 0	---	---
N - EKE	0.52	0.33	0.27

The EKE estimated from satellite geostrophic currents (Aviso)



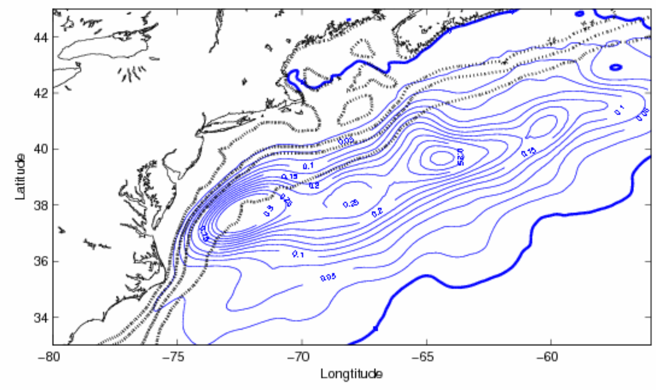
N-EKE

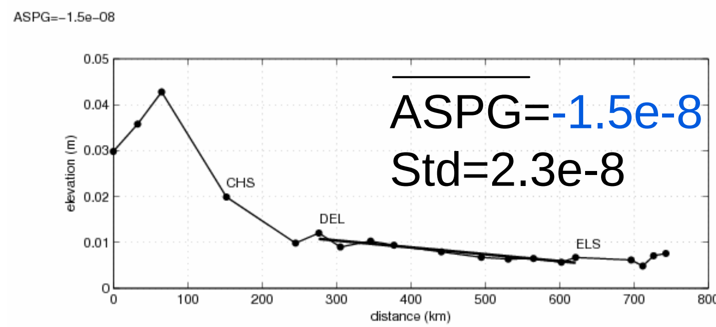


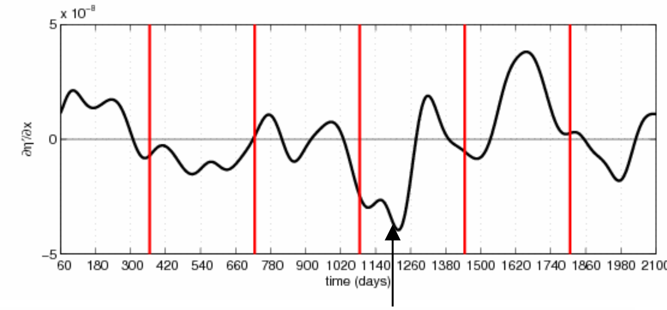
Black line: 16-year mean of GS path

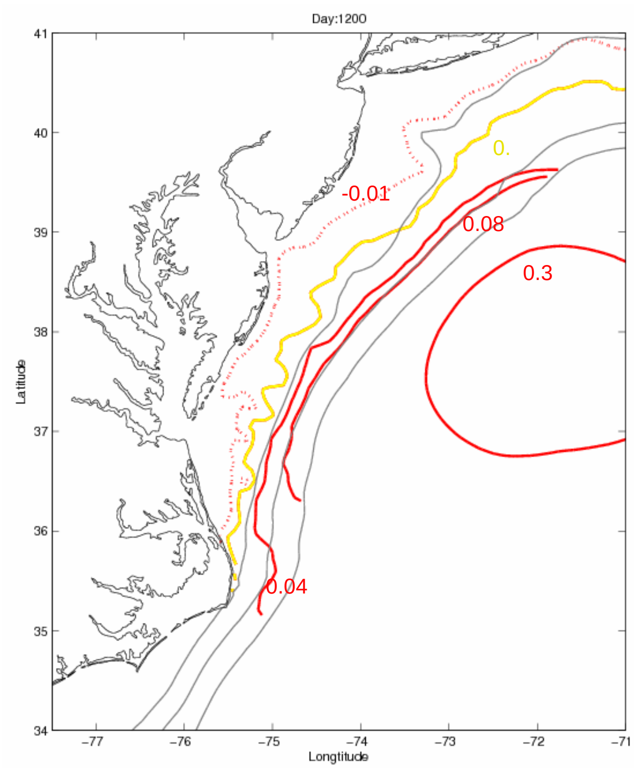
An Idealized simulation with warm-core rings injected every 360 days

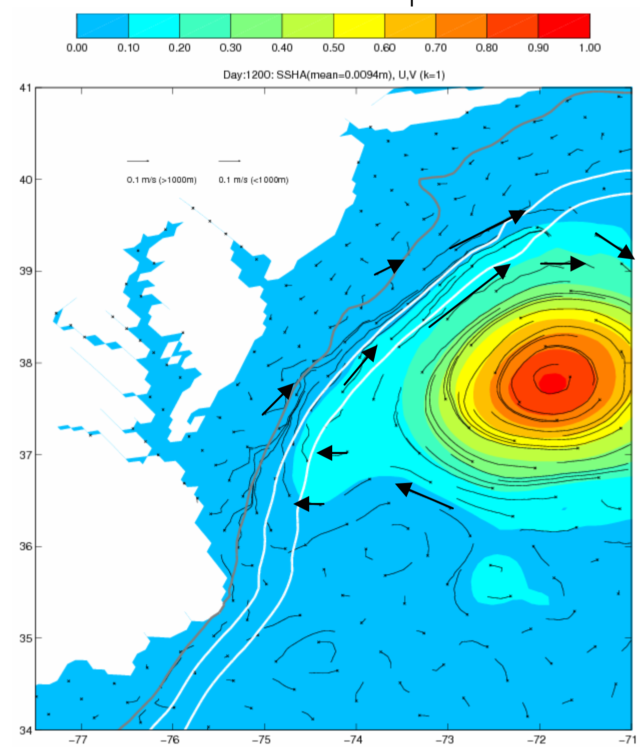
SSH



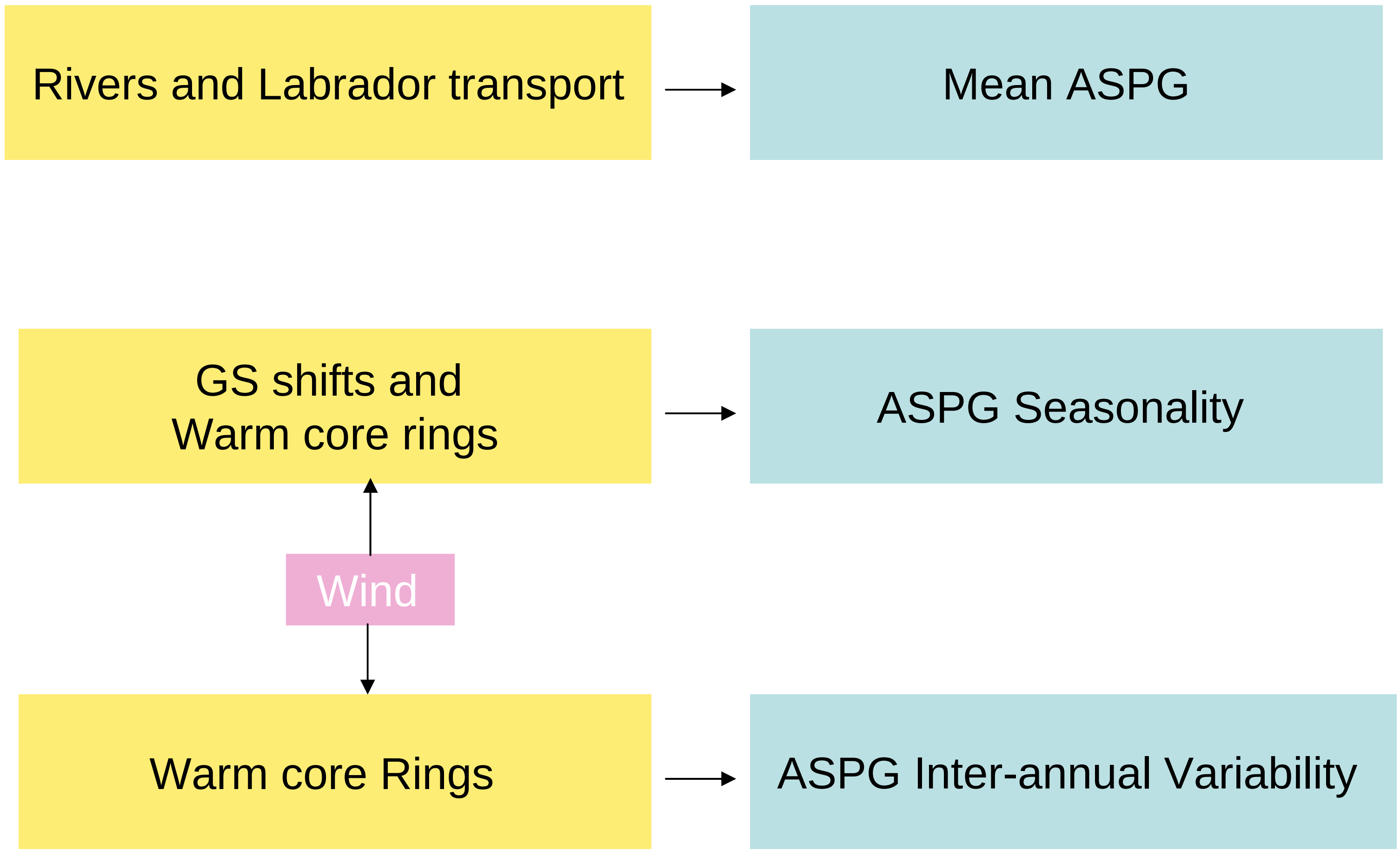








Summary



Rivers and Labrador transport
Mean ASPG
GS shifts and
Warm core rings
ASPG Seasonality
Wind
Warm core Rings
ASPG Inter-annual Variability

Thank you! Questions?

Along-shelf momentum balance

$$\rho_0 fv = -P_x + \tau_z^x$$

$$\int fvdz = -\frac{1}{\rho_0}\int P_x dz + \frac{1}{\rho_0}\int \tau_z^x dz$$

$$\frac{1}{\rho_0}\int P_x dz = gH\frac{\partial \eta}{\partial x}$$

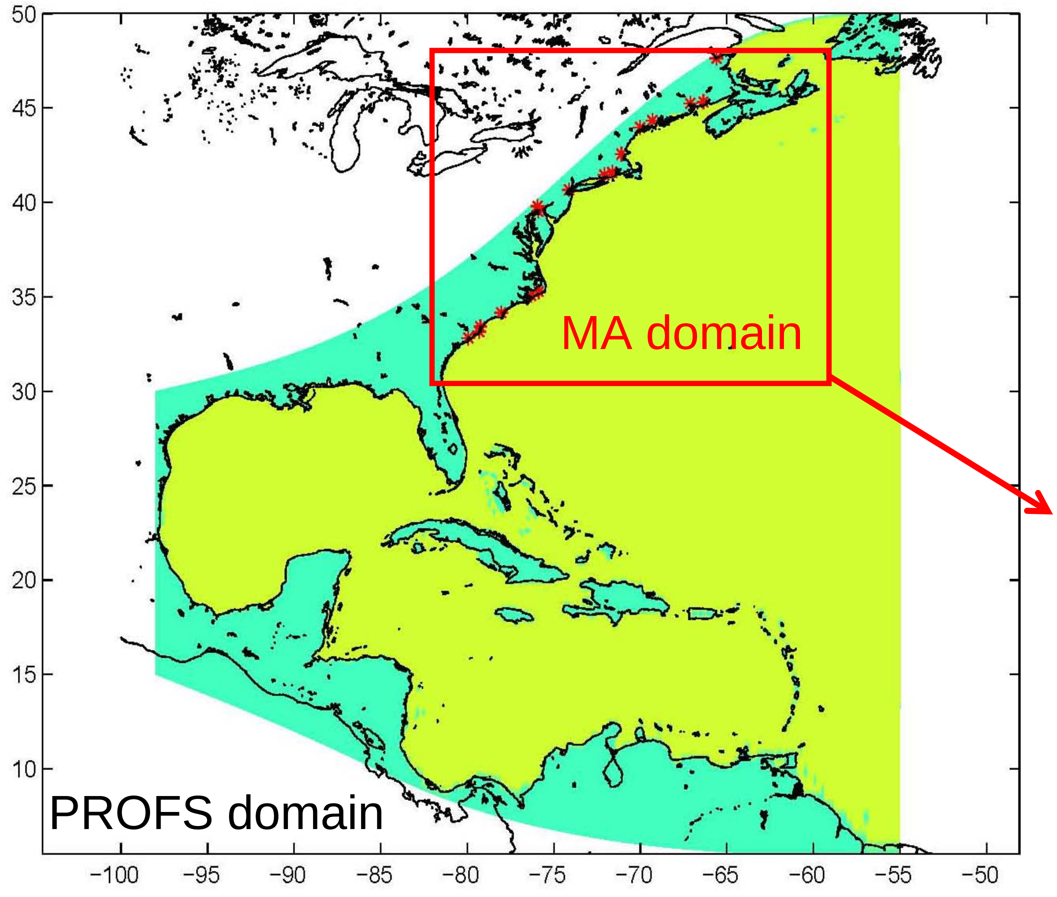
$$\frac{1}{\rho_0}\int \tau_z^x dz = \tau_{wind} - \tau_{bottom} \cong -ru$$

So, $$u \cong -\frac{gH}{r}\frac{\partial \eta}{\partial x}$$

Inter-annual Correlation coefficient

R/lags	ASPG	GS latitude shifts	Wind stress curl	Transport	River Input	Model EKE
ASPG	---	0.15/0.25	-0.07/0.12	-0.06/0.1	0.09/0.18	0.52/0.19
GS latitude shifts	0.15/0.25	----	-0.11/0.18	0.40/0.16	---	0.27/0.16
Wind stress curl	-0.07/0.12	-0.11/0.18	---	-0.48/0.14	---	0.33/0.15
Transport	-0.06/0.1	0.40/0.16	-0.48/0.14	---	---	---
River input	0.09/0.18	---	---	---	---	---
Model EKE	0.52/0.19	0.27/0.16	0.33/0.15	---	---	---

POM
Princeton Regional Ocean Forecast System (PROFS)

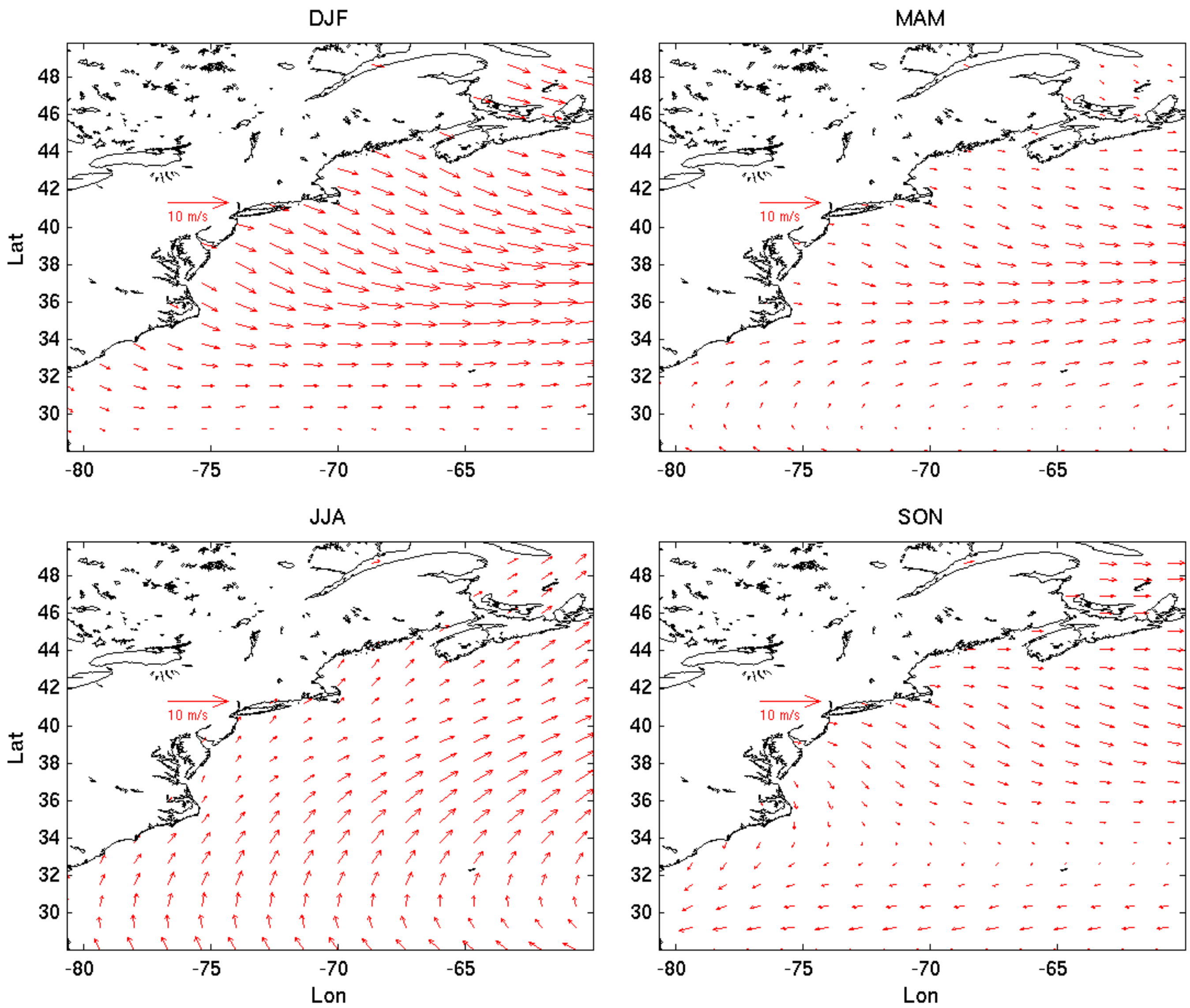


- Curvilinear grid
- Grid size:
  Horizontal: ~10km
  Vertical: 25 σ levels

Mid-Atlantic Model:

- Winds, rivers & tides
- Nesting from PROFS
- Finer grid size: ~5km
- DA for GS & Eddies

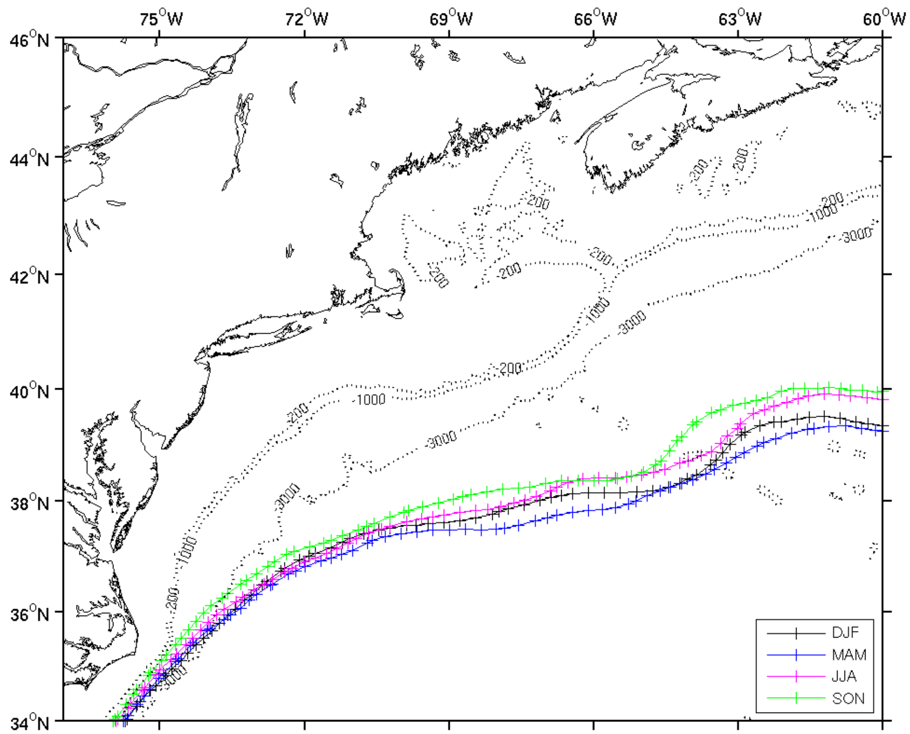
Seasonal mean CCMP winds



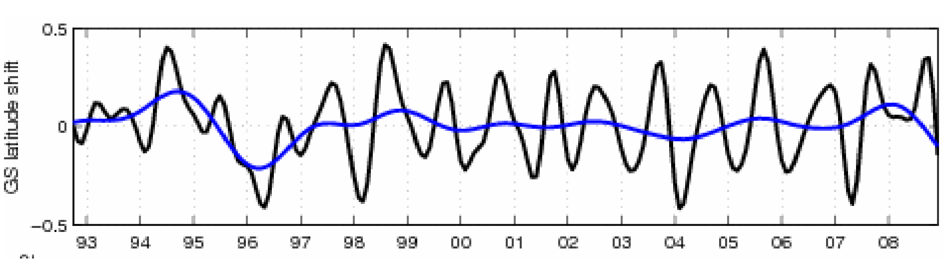
Summary

1. The NWAOM produced the mean along-shelf circulation southwestward. The model dynamics produce an ASPG, 8.4×10^{-8}, consistent with the value inferred by previous studies.
2. The total freshwater discharge and upstream transport mainly contribute to the mean ASPG setup.
3. The wind stress may not affect the ASPG directly, but the upstream transport and GS path shifts are deeply influenced by wind. So the wind is important to the ASPG.
4. The westward propagating Rossby waves and warm-core rings can influence ASPG in both seasonal and inter-annual time scale.

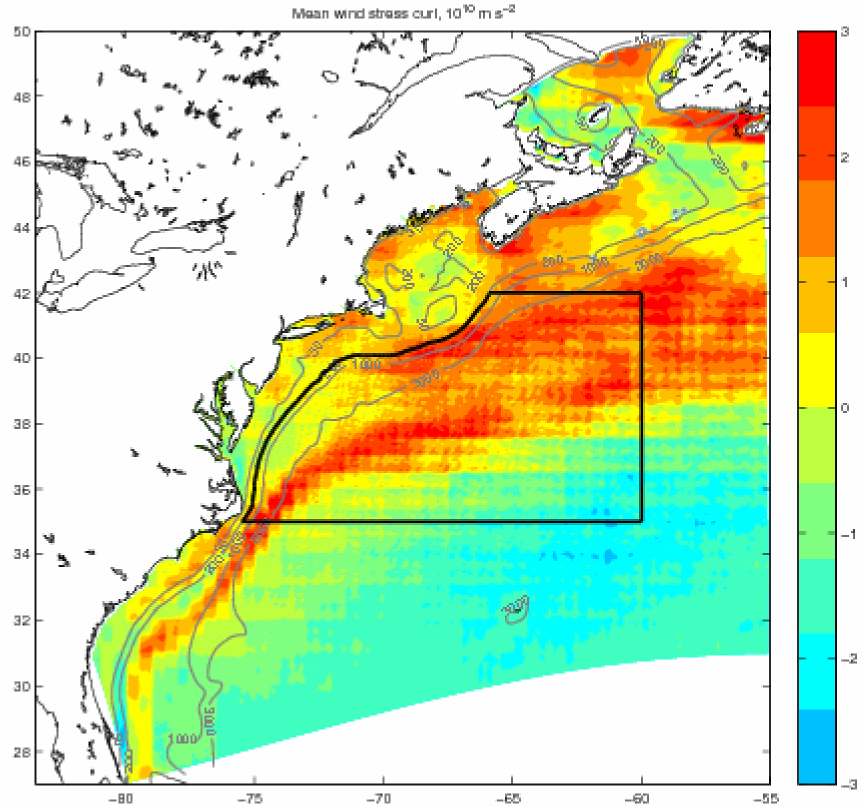
1. The variability of Gulf Steam path

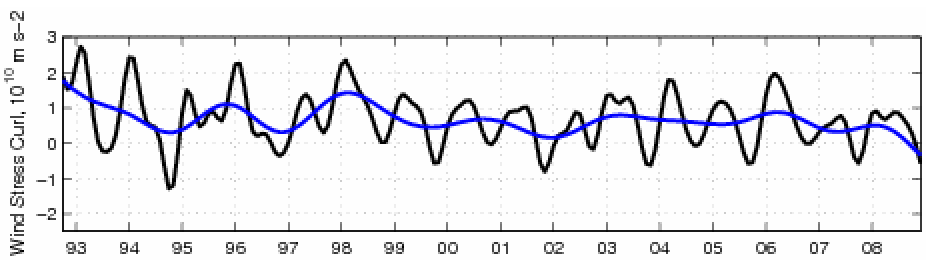


GS Front location-Bathymetry

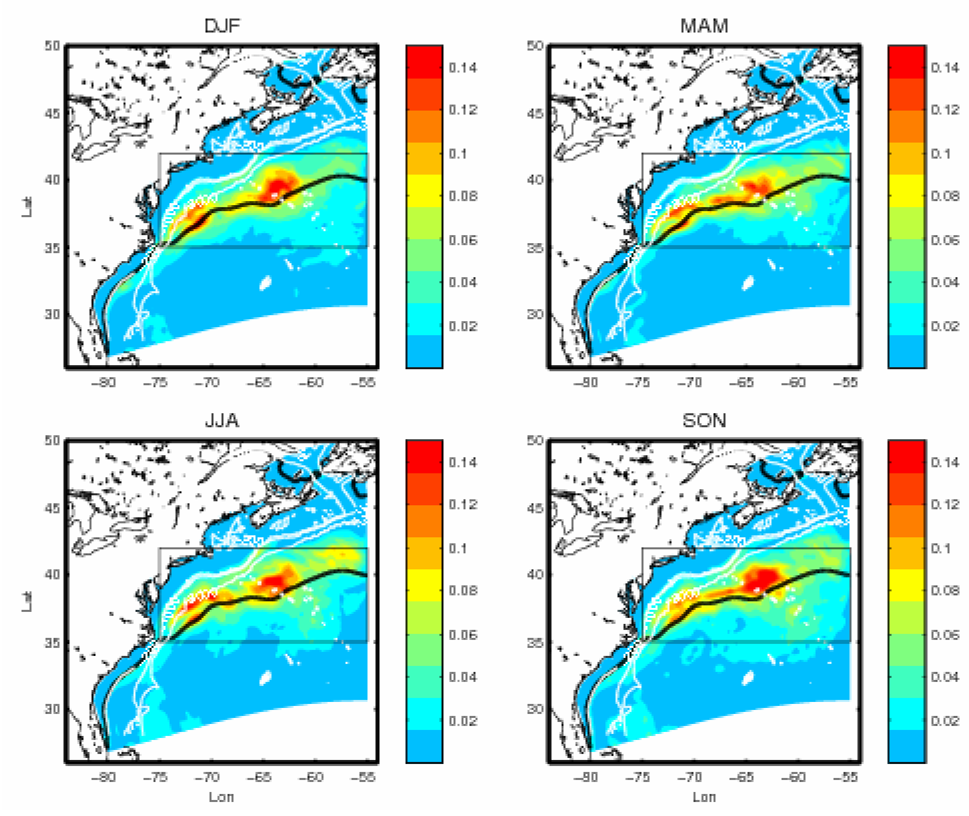


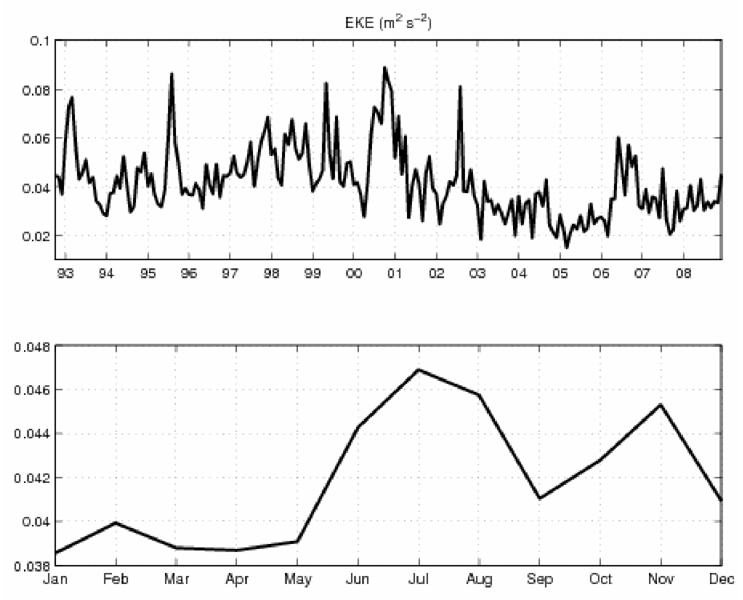
2. Wind stress curl: $(\partial\tau_y/\partial x - \partial\tau_x/\partial y)/\rho$



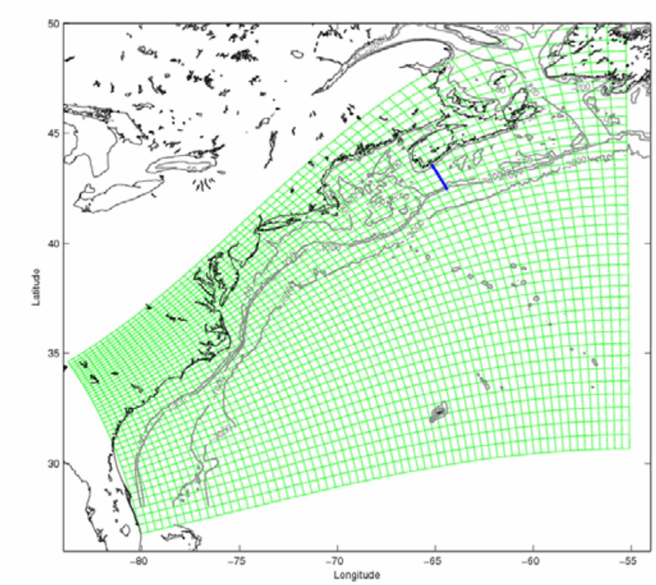


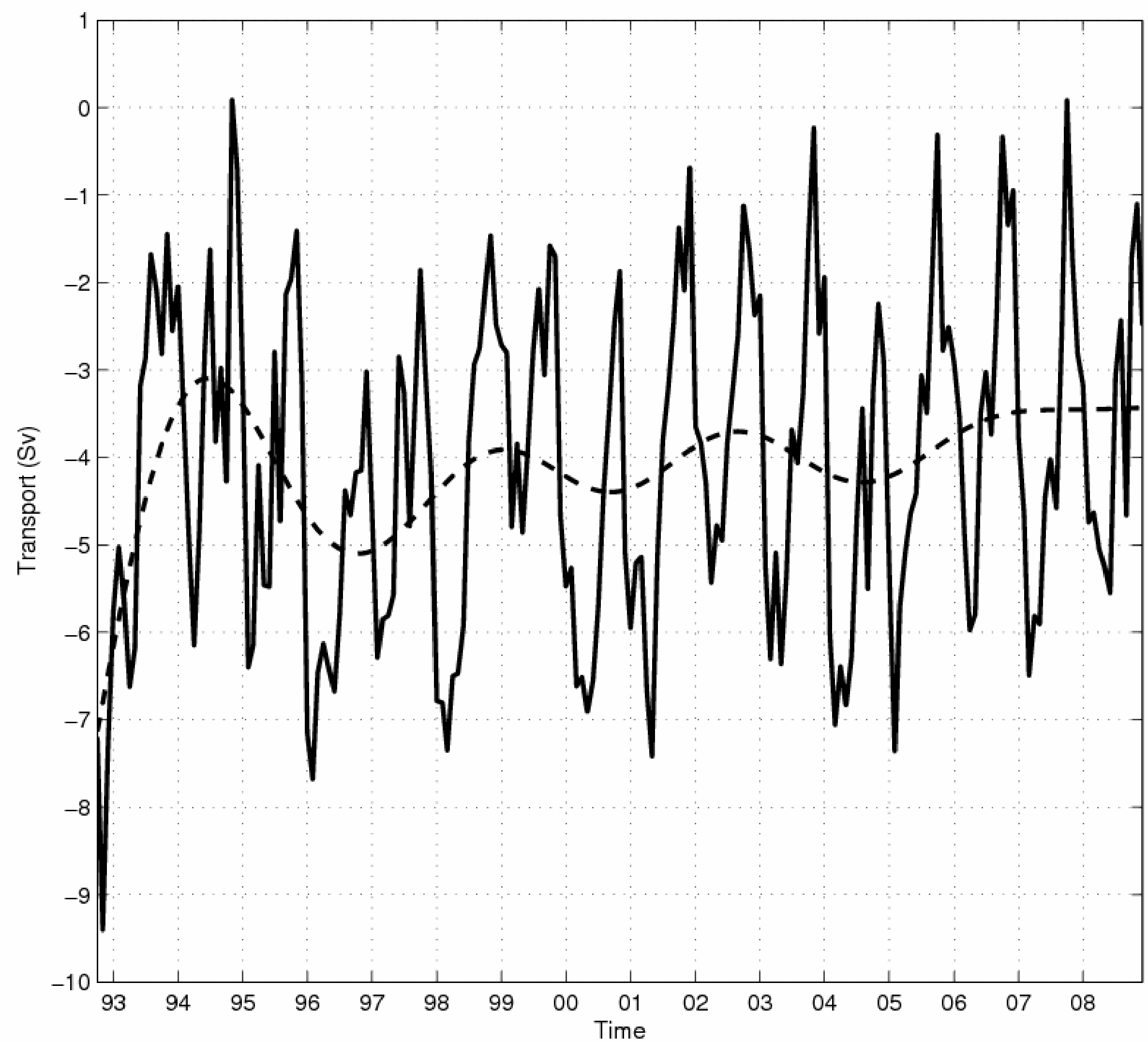
3. The Gulf Stream warm-core rings



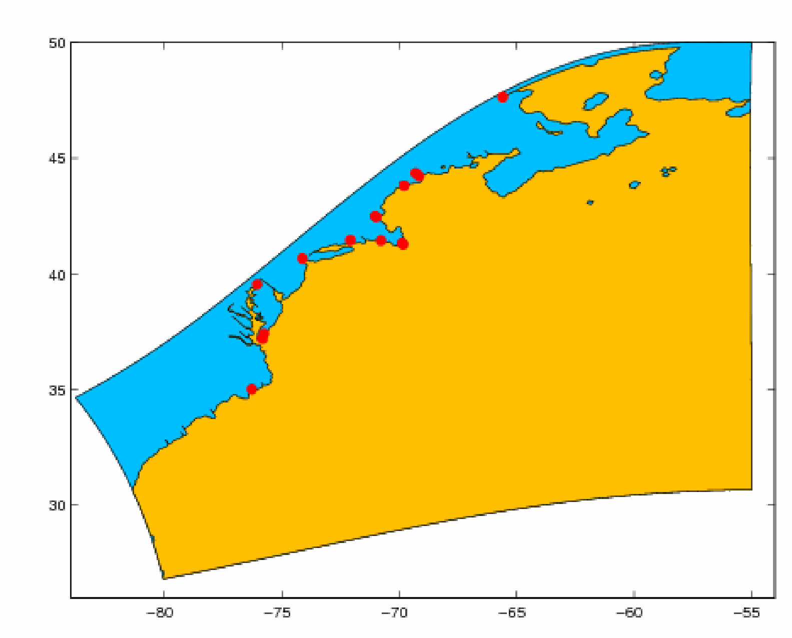


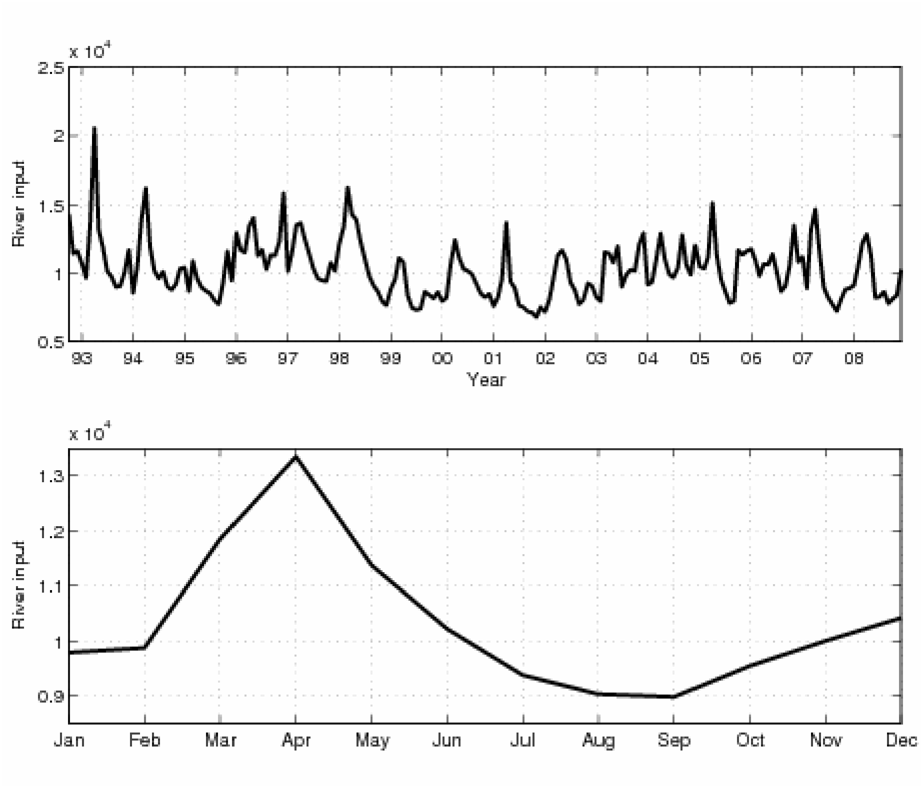
4. Upstream Transport: $\int \overline{U} H dy$





5. Rivers

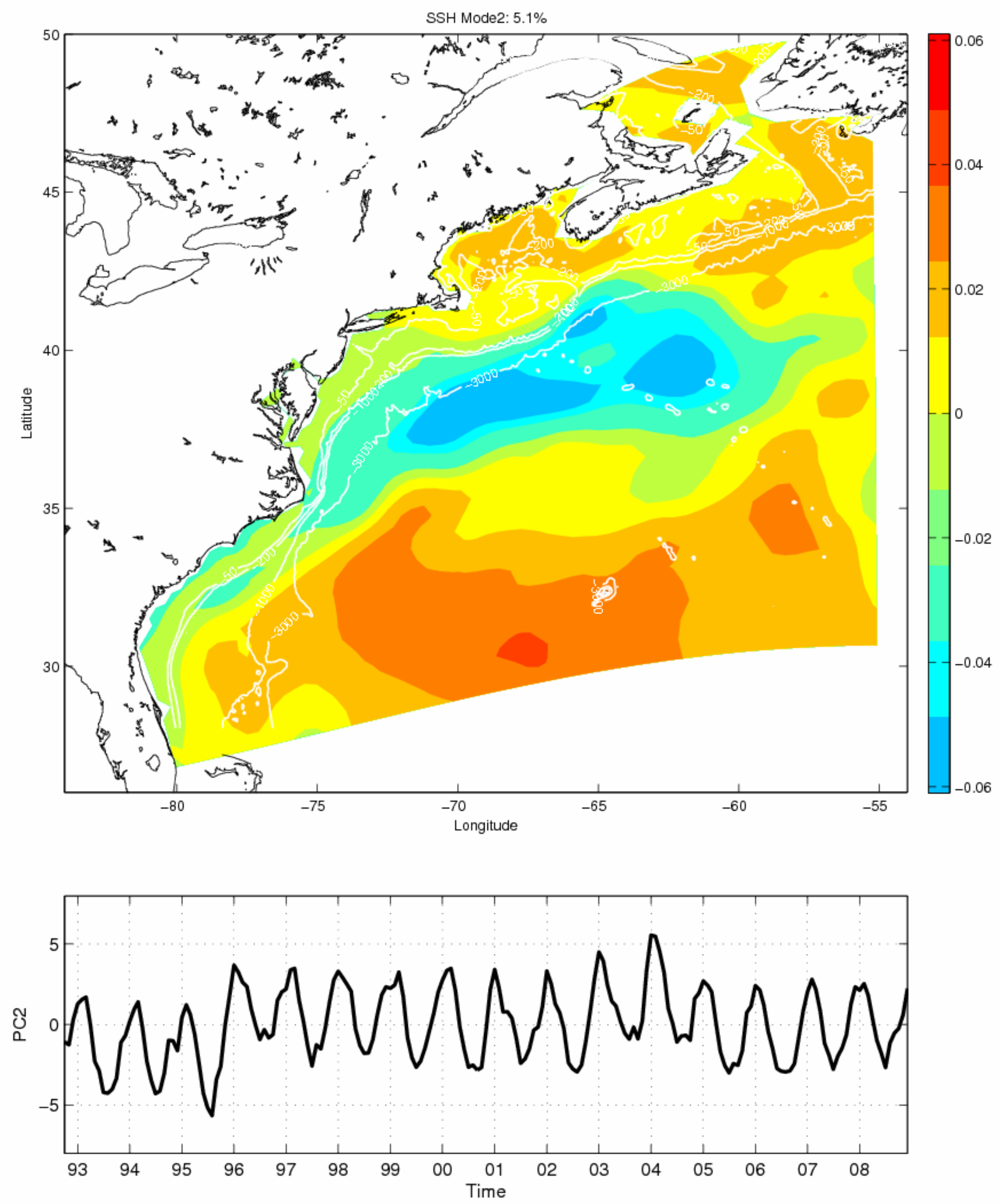

50
45
40
35
30
−80
−75
−70
−65
−60
−55

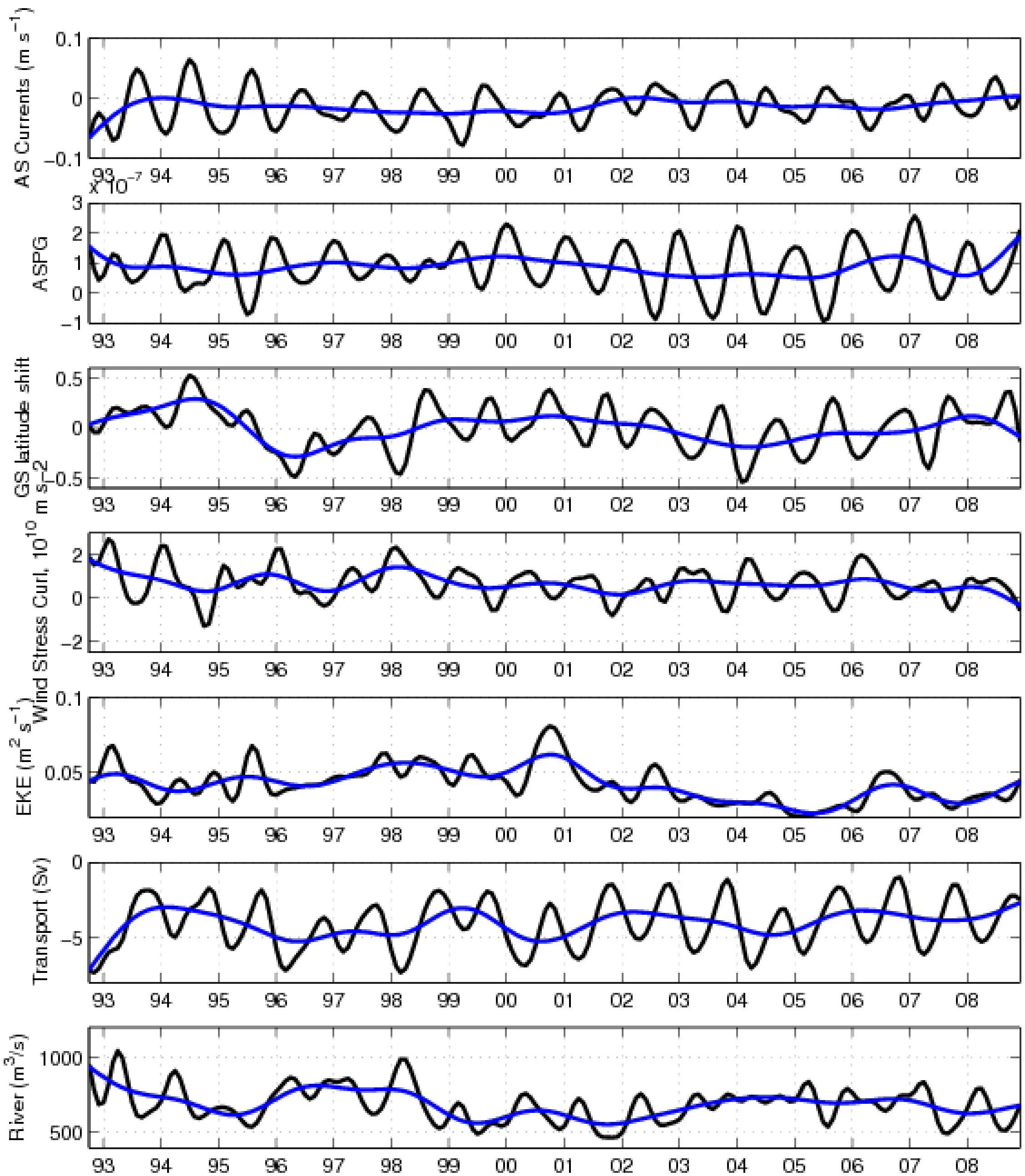

x 10^4
River input
Year
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08
x 10^4
River input
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Hypothesis

- The ASPG is affected by westward Rossby waves and Gulf Stream (GS) warm-core rings (WCR) .

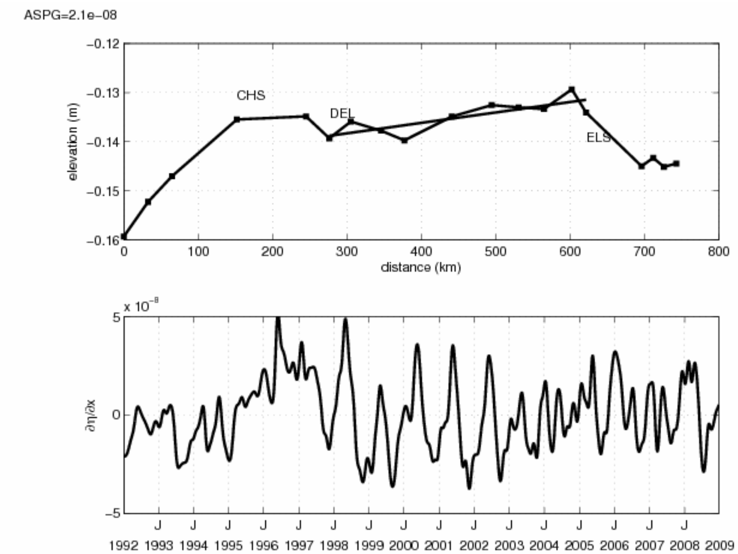
WCR->SSH near shelf break->ASPG



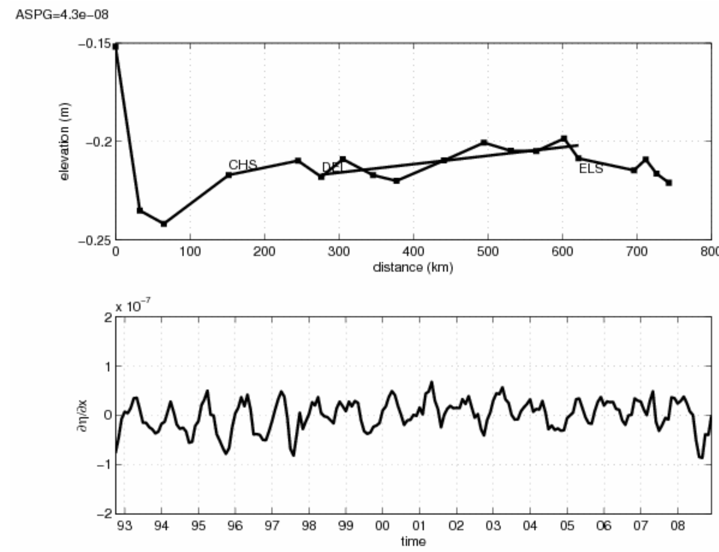


R	AS currents	ASPG
AS currents	---	-0.52
ASPG	-0.52	---
GS shifts	0.47	-0.31
Wind curl	-0.59	0.22
Model EKE	-0.05	-0.08
Transport	0.51	-0.10
River input	-0.44	0.19
Model EKE	-0.54	0.52

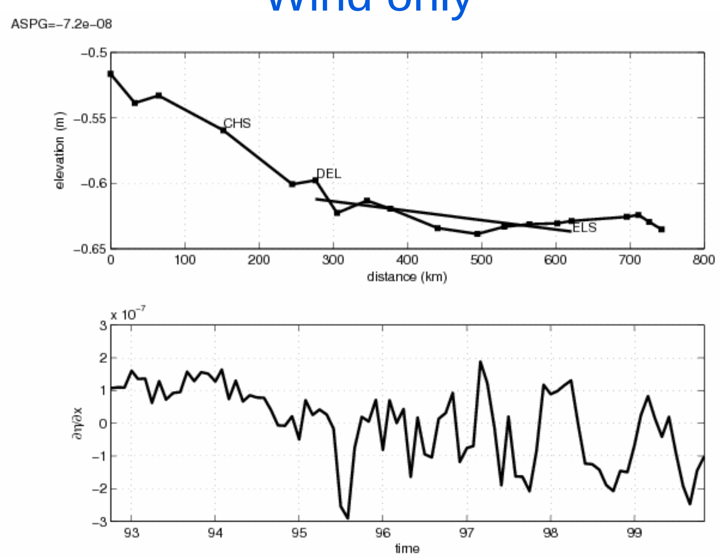
River only



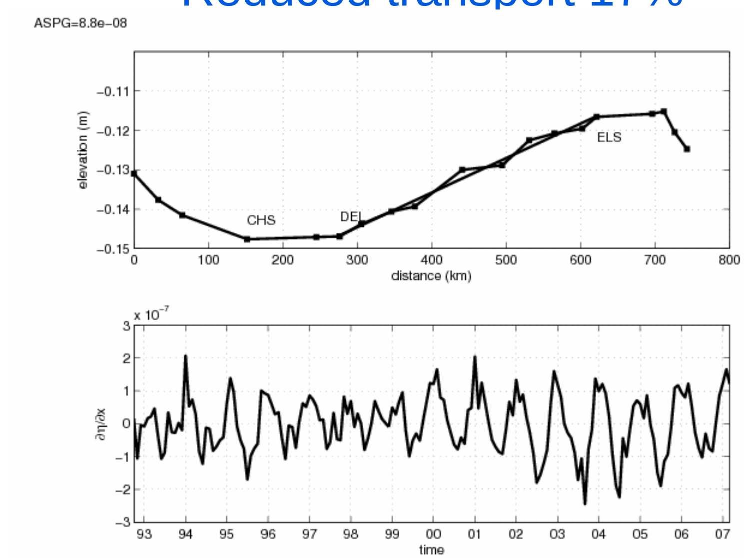
River with reduced transport 34%



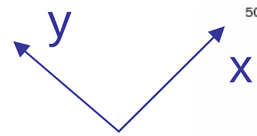
Wind only

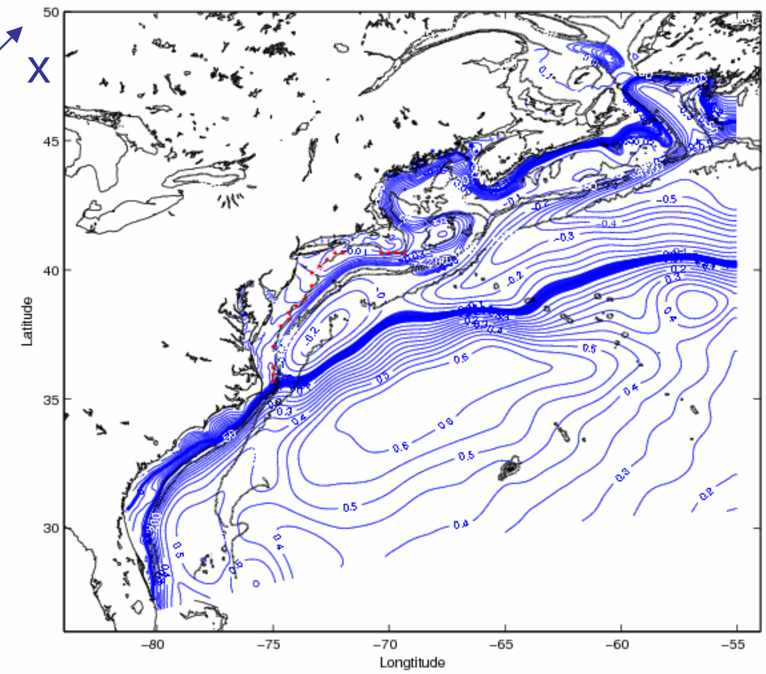


Reduced transport 17%

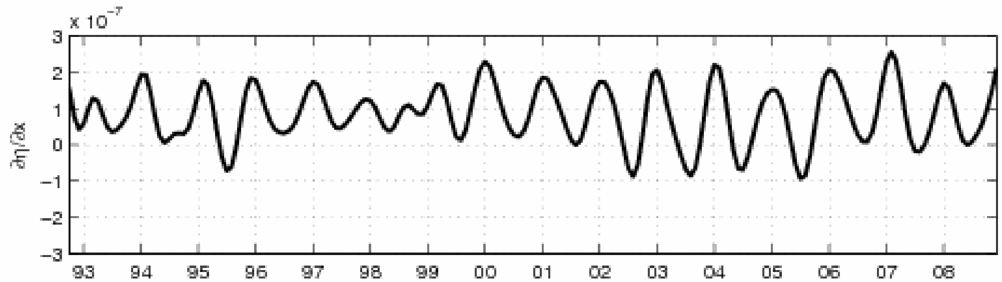


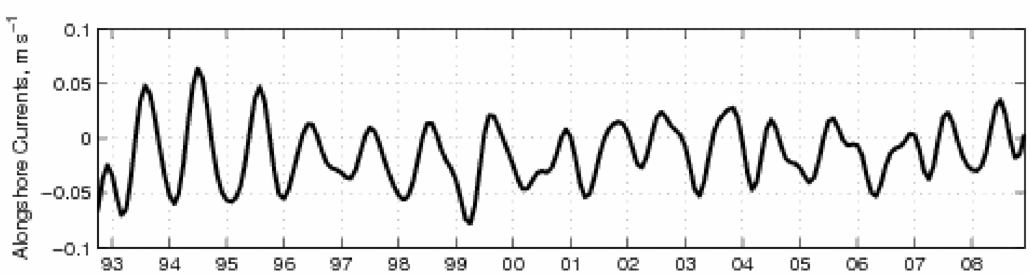
NWAOM : Along shelf currents and Along shelf pressure gradient (ASPG)

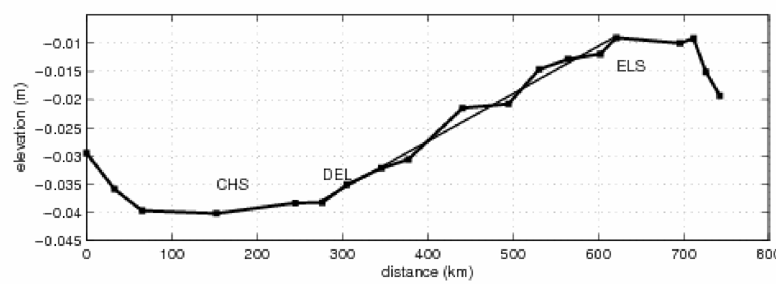


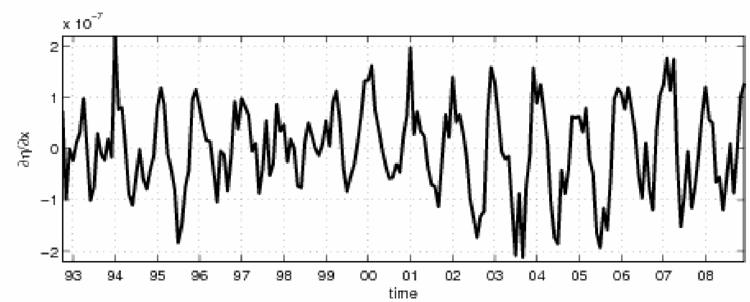


R=-0.52, S=0.33





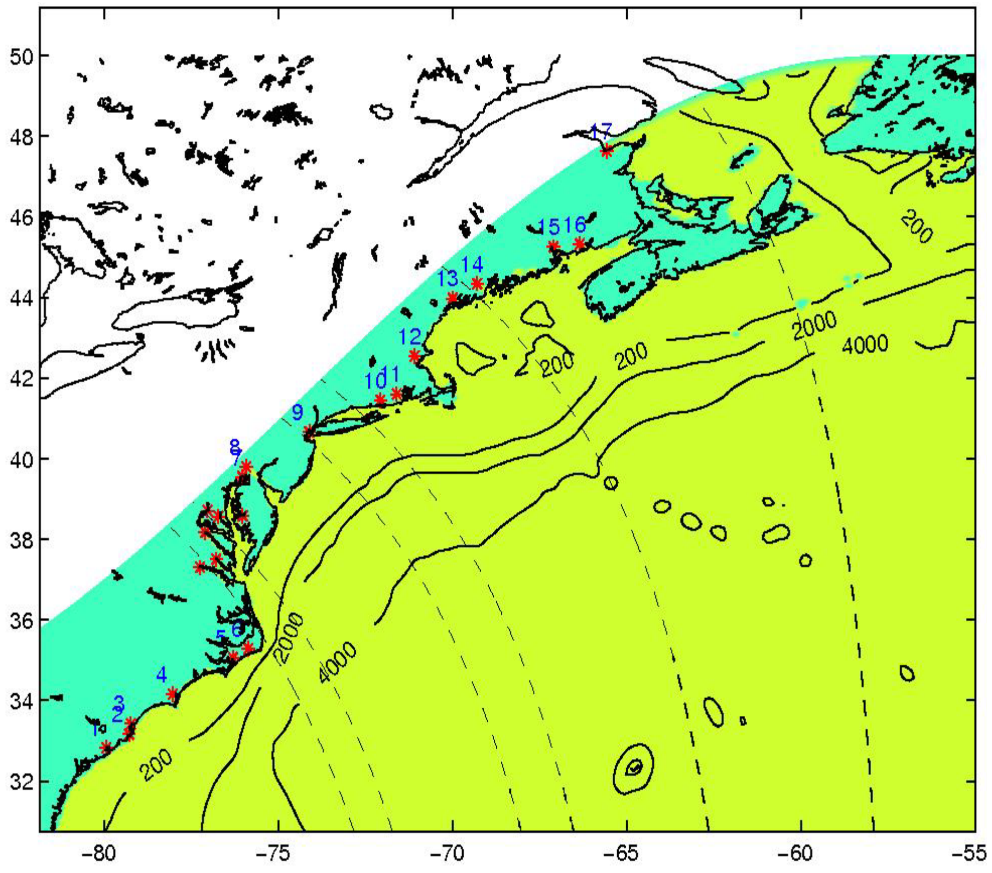


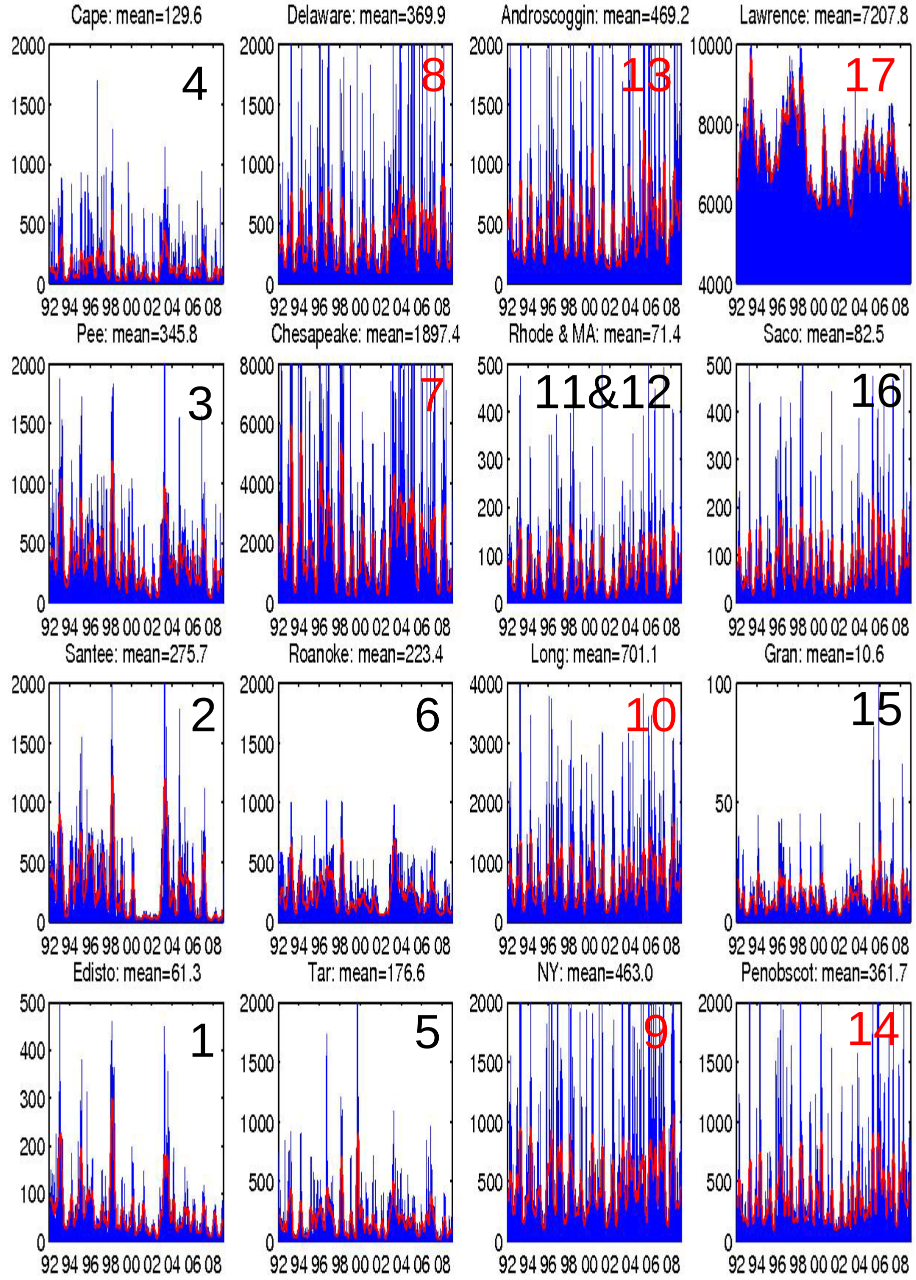


$\overline{\text{ASPG}}$=8.4e-8, Std=8.6e-8

$\overline{\text{U}}$=-0.015 m s^{-1} m/s Std=0.03 m/s

Rivers: 1992-2008





R for monthly data

R/lags	Alongshore currents	ASPG	GS latitude shifts	Wind stress curl	Transport	River Input	Model EKE
Alongshore currents	---						
ASPG	-0.44/0.20	---					
GS latitude shifts	0.32/0.12	-0.21/0.17	----				
Wind stress curl	-0.34/0.09	0.18/0.12	-0.24/0.07	---			
Transport	0.43/0.18	-0.09/0.27	0.41/0.15	-0.35/0.11	---		
River input	-0.41/0.10	0.16/0.13	-0.34/0.09	0.23/0.06	-0.46/0.12	---	
Model EKE	0.01/0.04	-0.10/0.04	0.21/0.05	0.04/0.03	0.003/0.05	-0.05/0.06	---