Study of the Circulation and Variability in Gulf of St. Lawrence and the Scotian Shelf

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GOAPP Global Ocean-Atmosphere Prediction and Predictability

Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

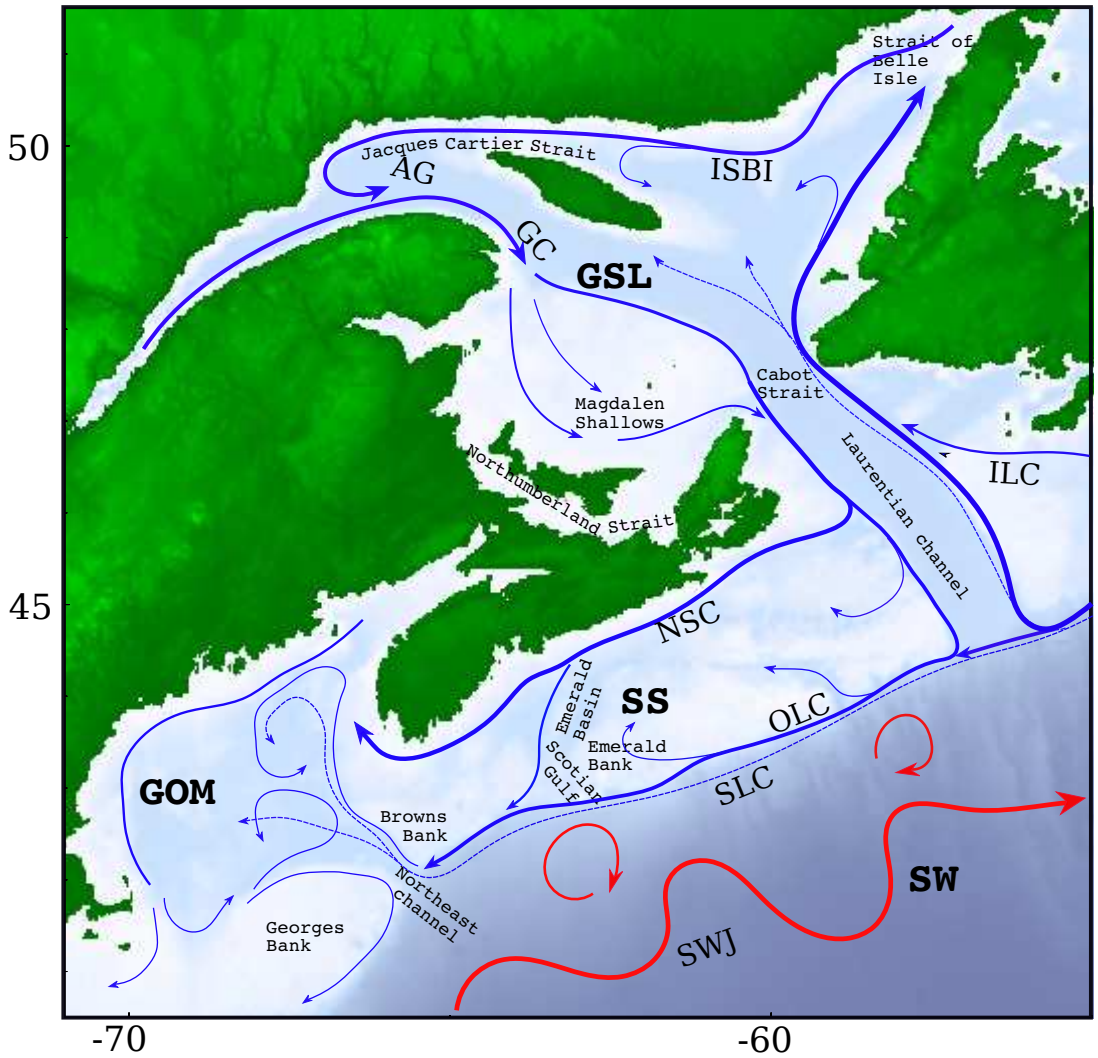
OCEAN TRACKING NETWORK

Outline

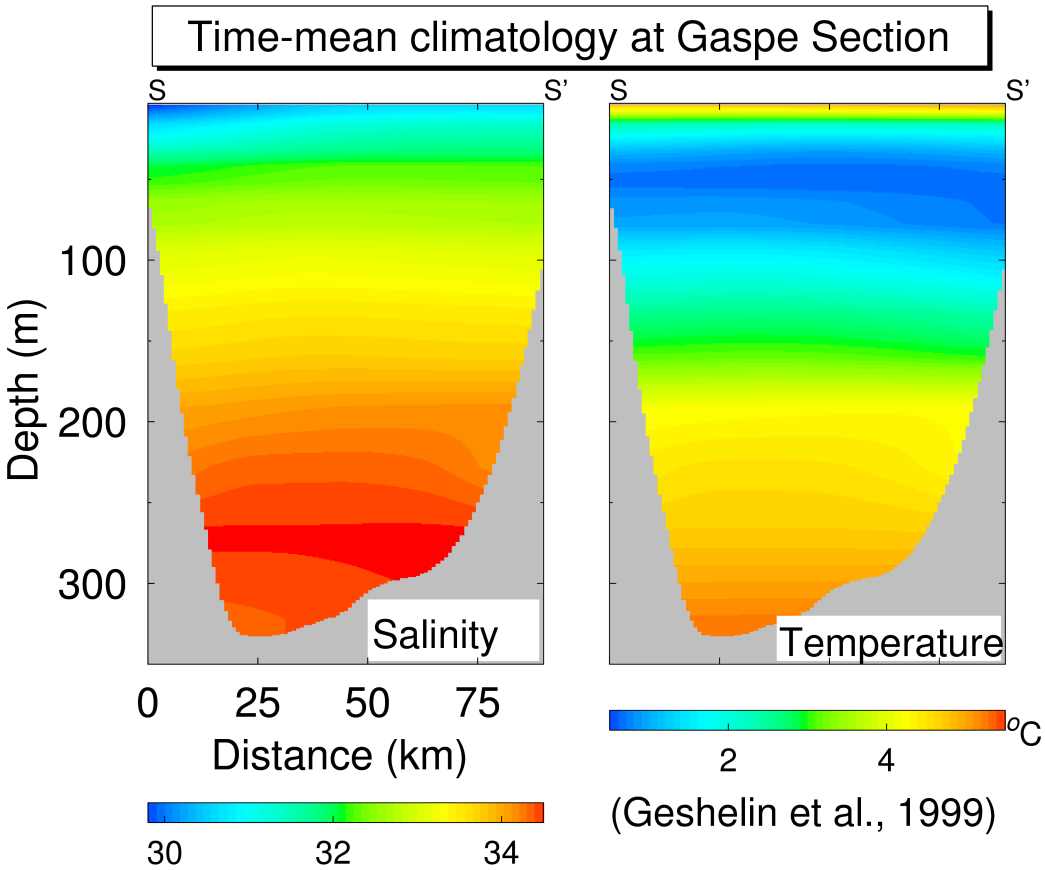
- Introduction
- Circulation over the Gulf of St. Lawrence - Scotian Shelf system (GSL-SS)
- Nested-grid circulation model based on NEMO, and model validation
- Study of circulation and variability over GSL-SS system
- Summary and conclusions

Introduction

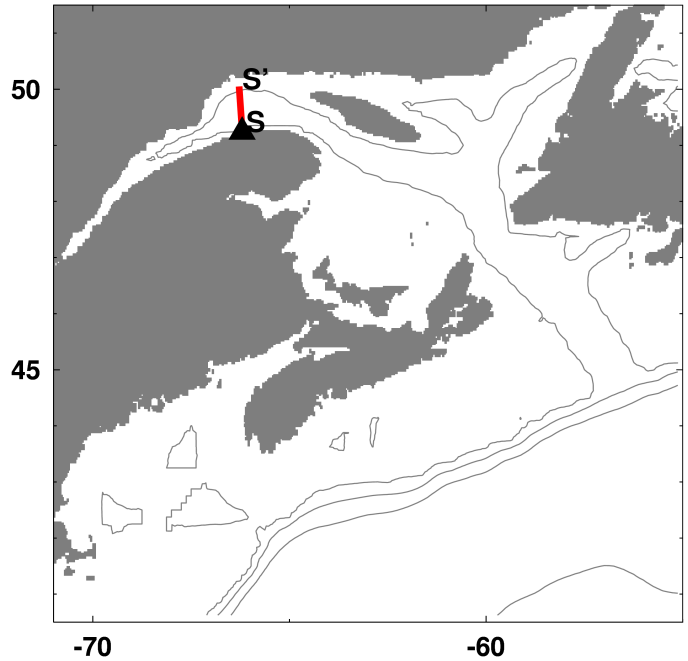
Schematic of the general circulation over the GSL-SS

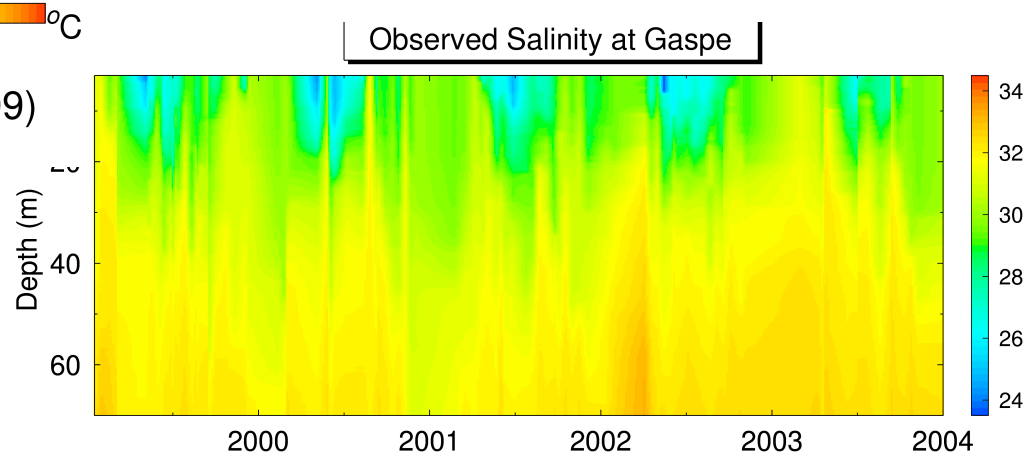


Circulation over the GOS-SS system



(Geshelin et al., 1999)





(ACZMP, DFO)

Objectives

- Develop a nested-grid regional circulation model for the Gulf of St. Lawrence and the Scotian Shelf using the NEMO coupled ocean-ice model system.

- Examine main physical processes affecting the subtidal variability over the GSL-SS based on model results produced by the nested-grid regional circulation model.

A nested-grid circulation model of the Gulf of St. Lawrence and Scotian Shelf

- Based on NEMO system with NEMO-OPA9 as ocean component and NEMO-LIM2 as the sea ice component
- 46 z-levels with partial cells in the vertical
- 2-way interaction between parent and child models

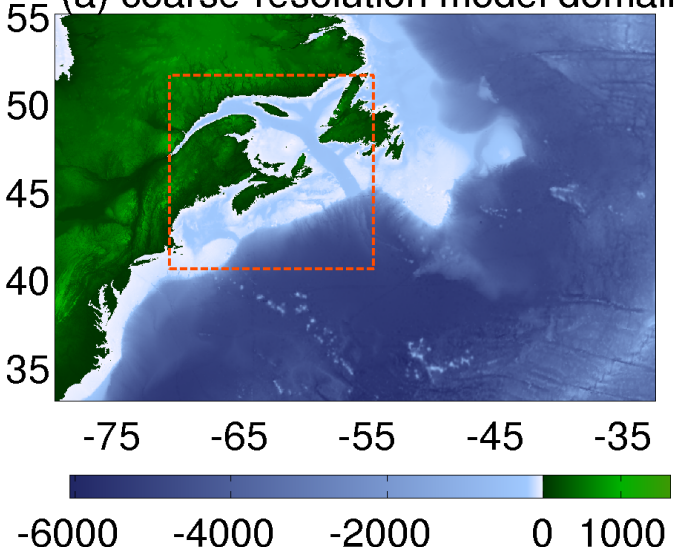
Parent model

- $\Delta x, \Delta y \sim 25$ km and $\Delta t = 40$ min.

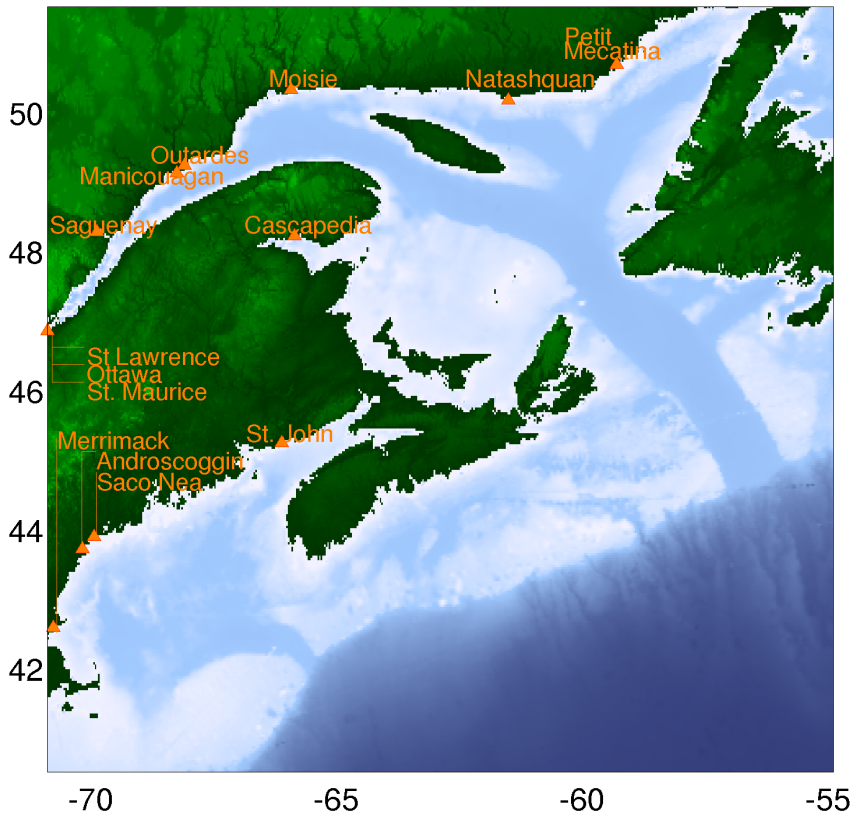
Child model

- $\Delta x, \Delta y \sim$ 7-8 km and $\Delta t = 10$ min.

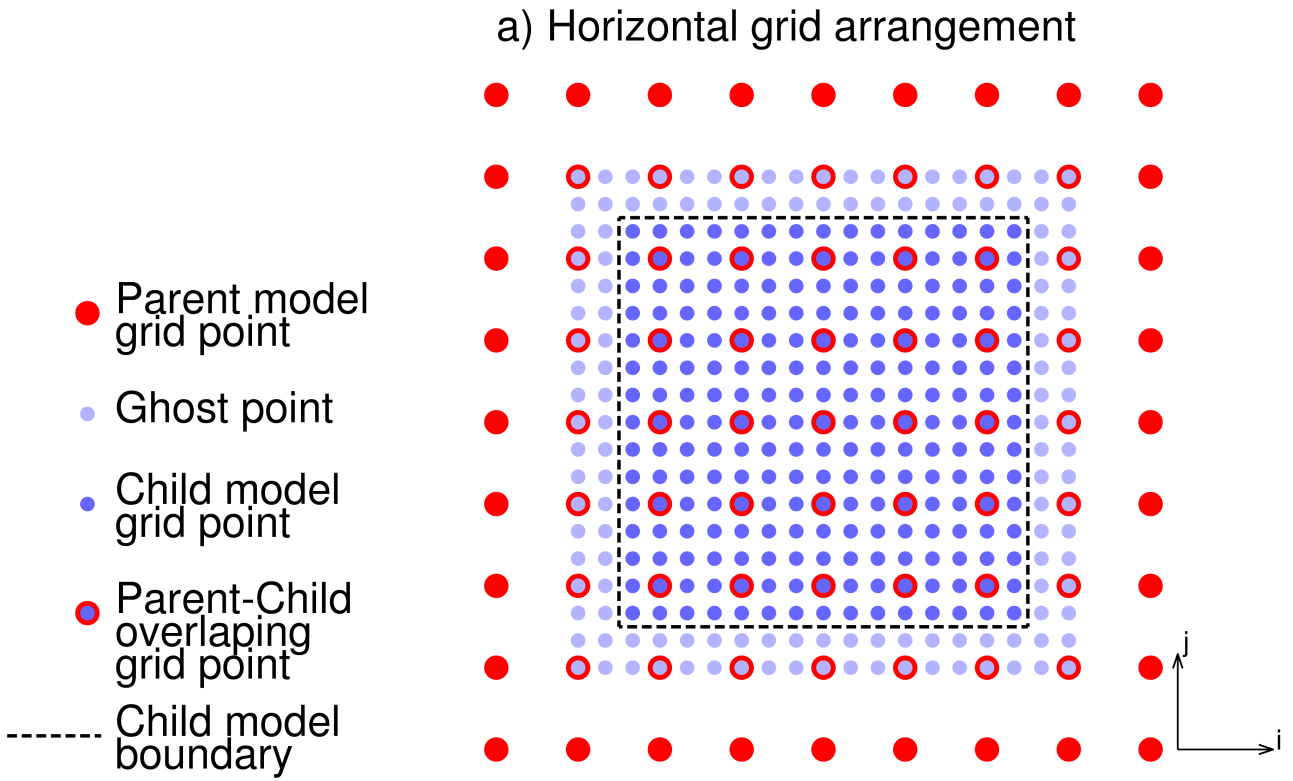
(a) coarse-resolution model domain



(b) fine-resolution model domain



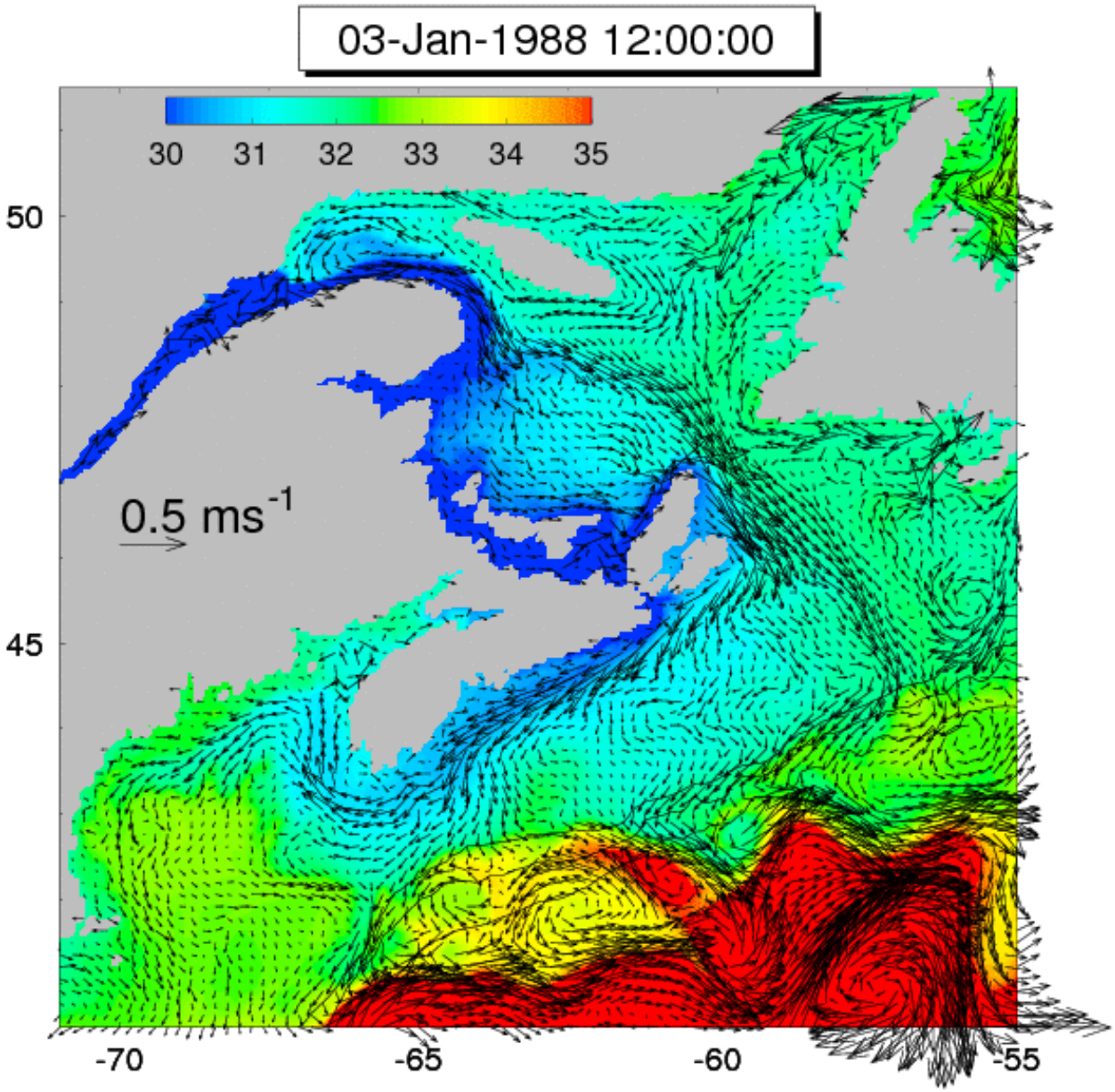
2-way interaction between Parent and Child models



Model Setup and forcing

- Use of the spectral nudging method (Thompson et al., 2006) and smoothed semiprognostic method (Sheng et al., 2001) with weaker than usual nudging strength coefficients to reduce seasonal bias and error.
- Forced by atmospheric reanalysis data (Large and Yeager, 2004): 6-hourly wind speed, air temperature and specific humidity 10 m above the sea surface, 12-hourly short and long wave radiation and monthly precipitation.
- Open boundary forcing for the parent model taken from 5-day mean global reanalysis data (Smith et al., 2010).
- The model is integrated for 18 years from 1987-2004.
- Monthly river runoff (Dai et al., 2009) is applied to the child model for the simulation period.

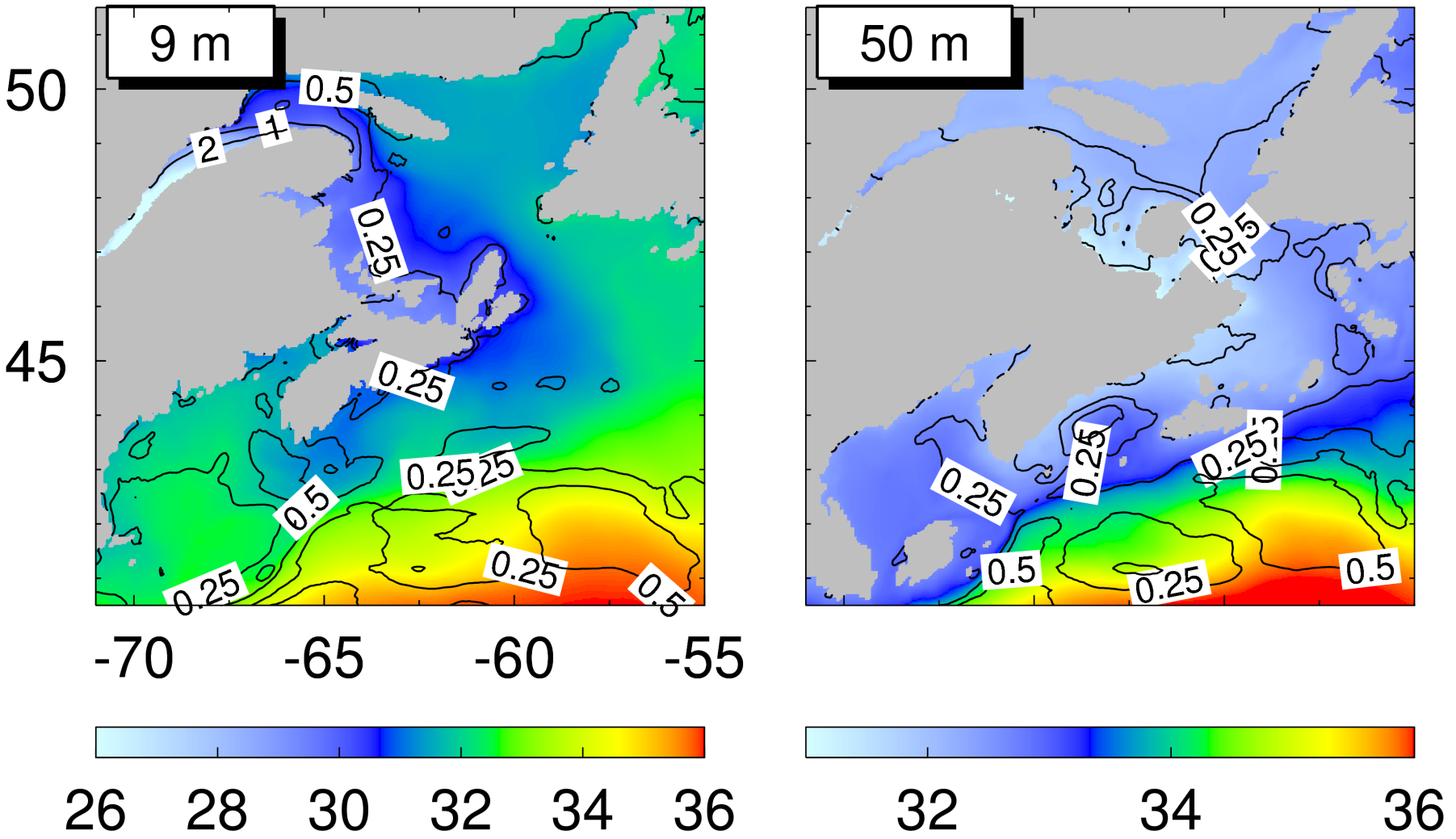
5-day mean near-surface simulated currents and salinity



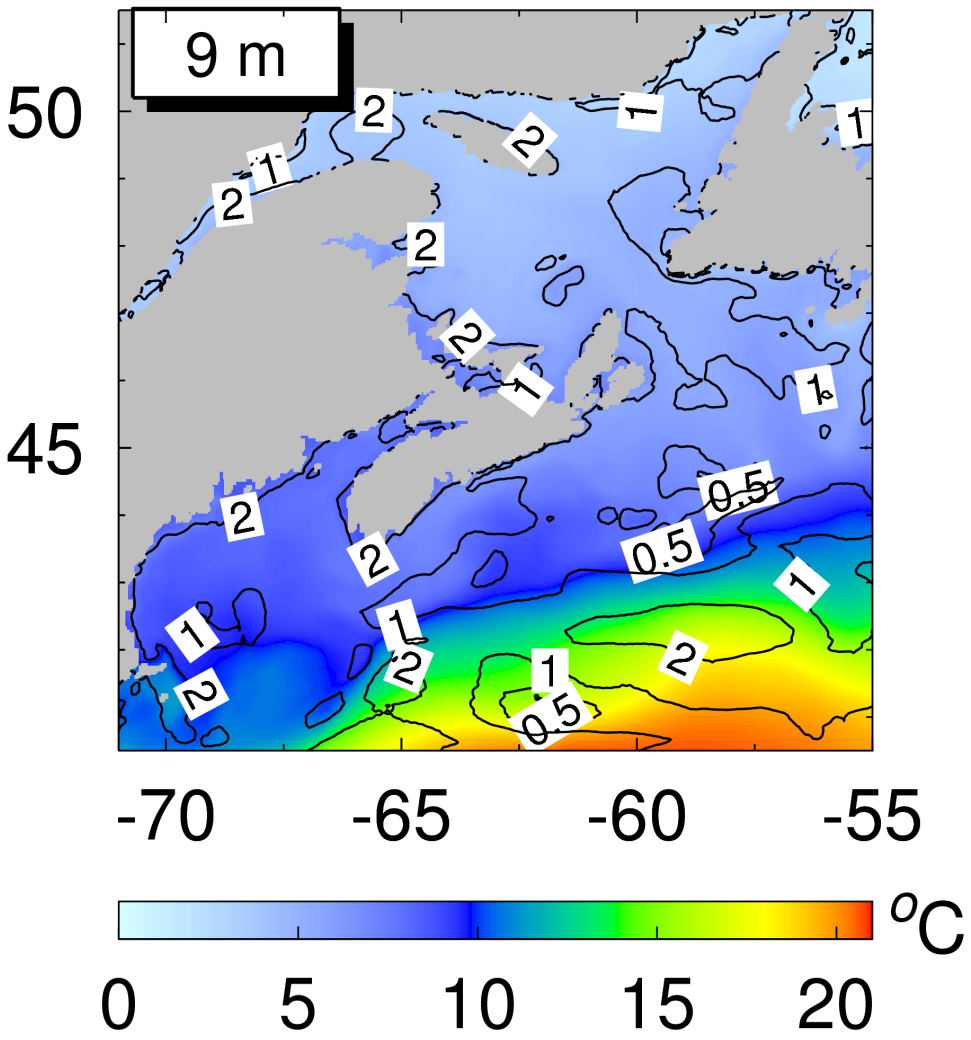
Time-mean simulated salinity and AAD

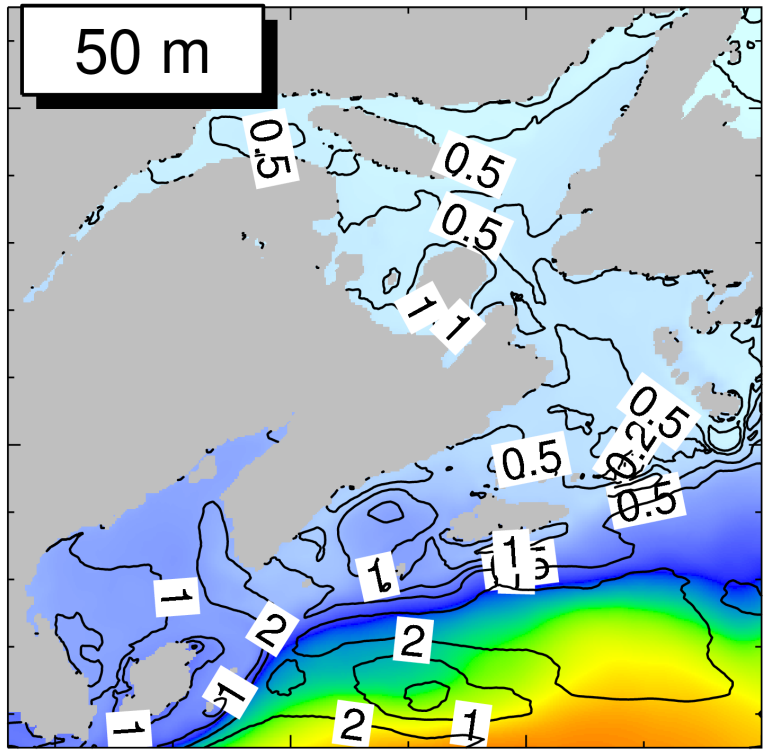
Average Absolute Difference (AAD) between monthly mean observed climatology (Geshelin et al, 1999) and model results:

$$AAD = \frac{1}{12}\sum_{i=1}^{12} |\hat{O}_i - \hat{M}_i|$$

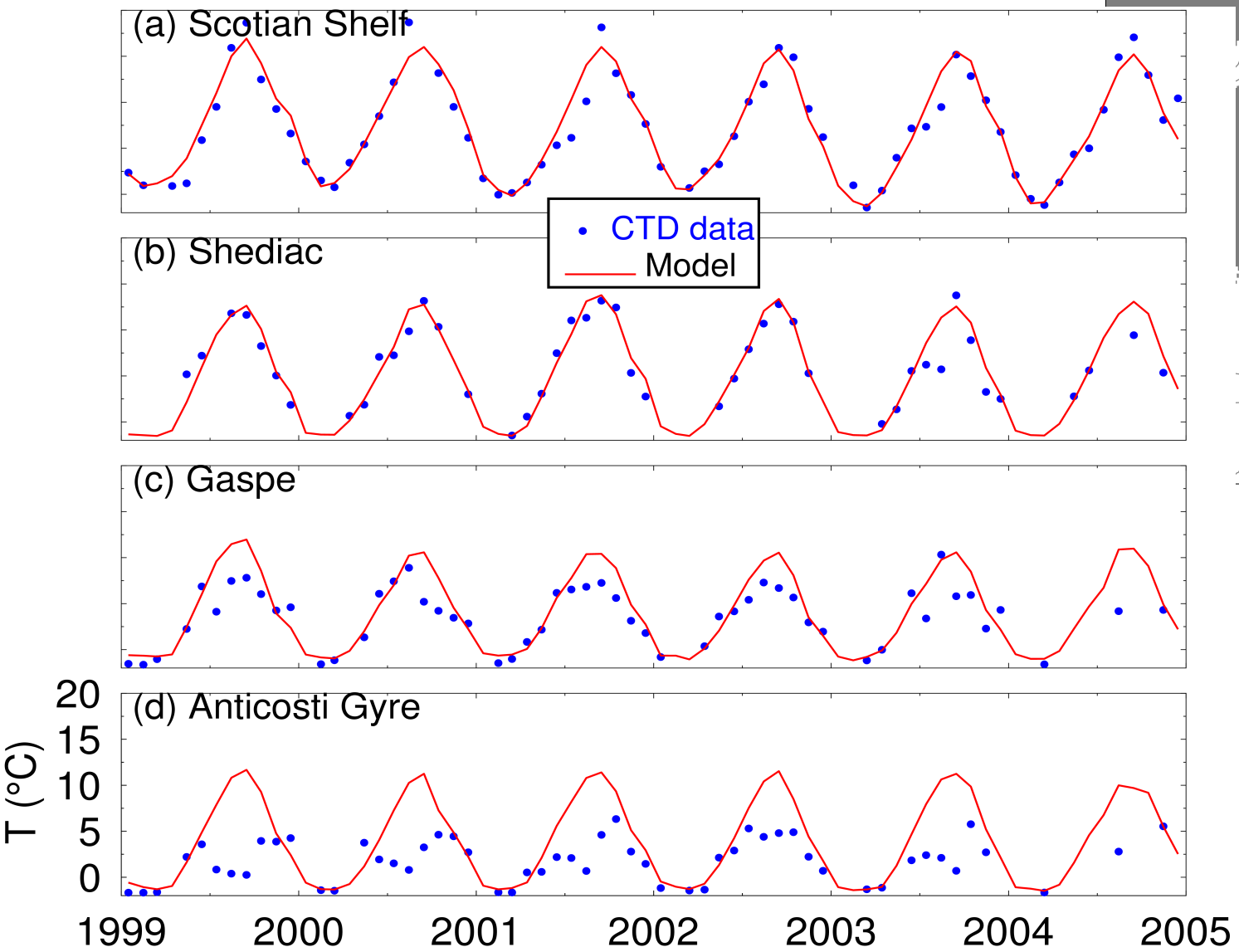


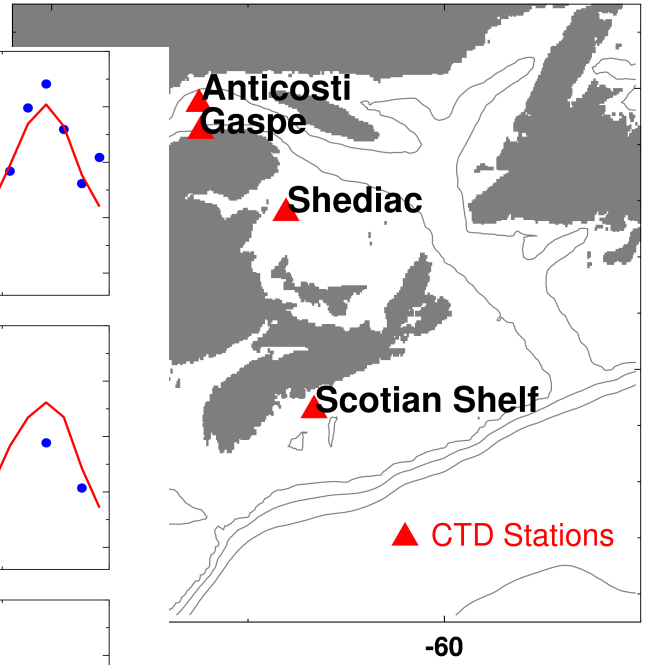
Time-mean simulated temperature and AAD



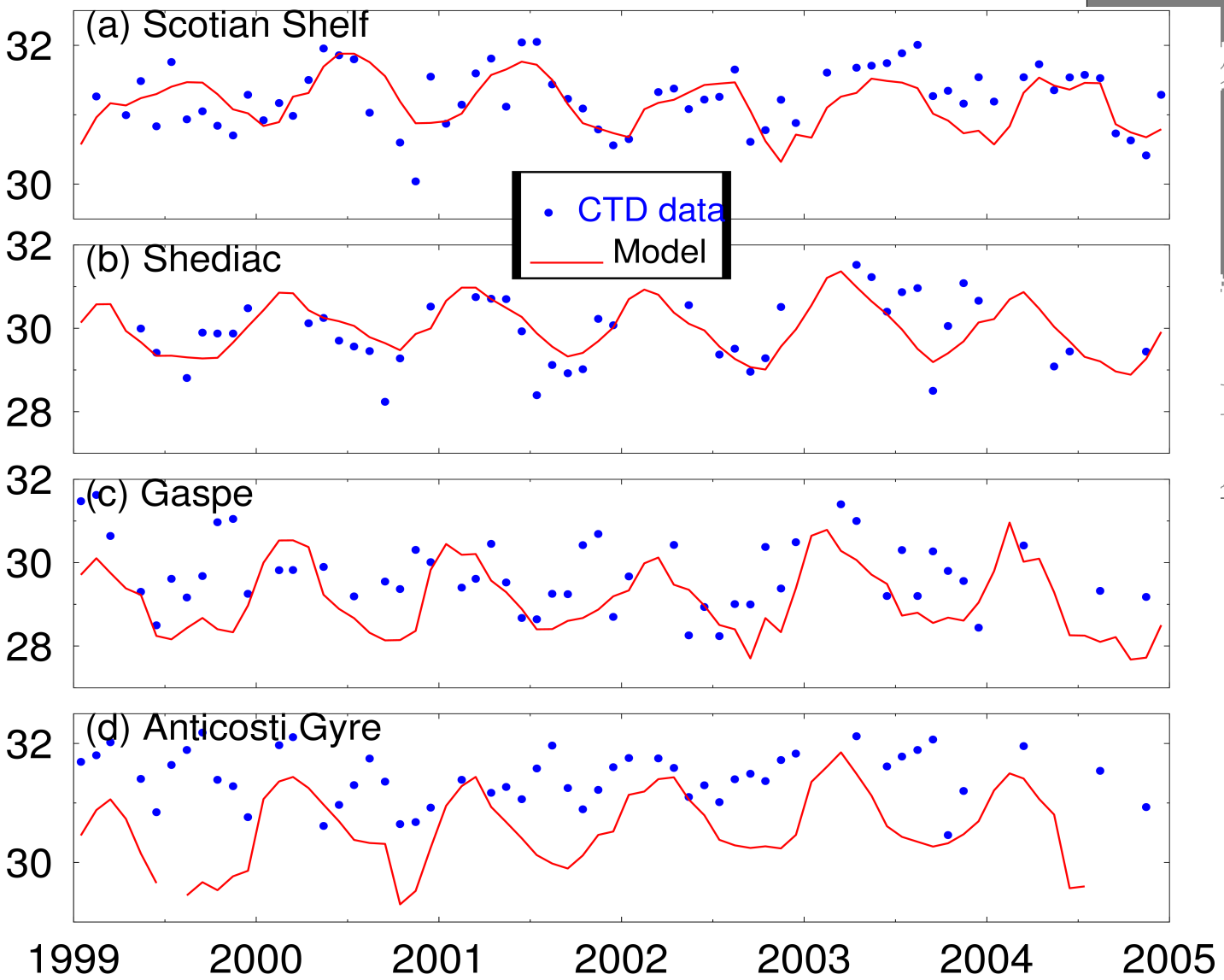


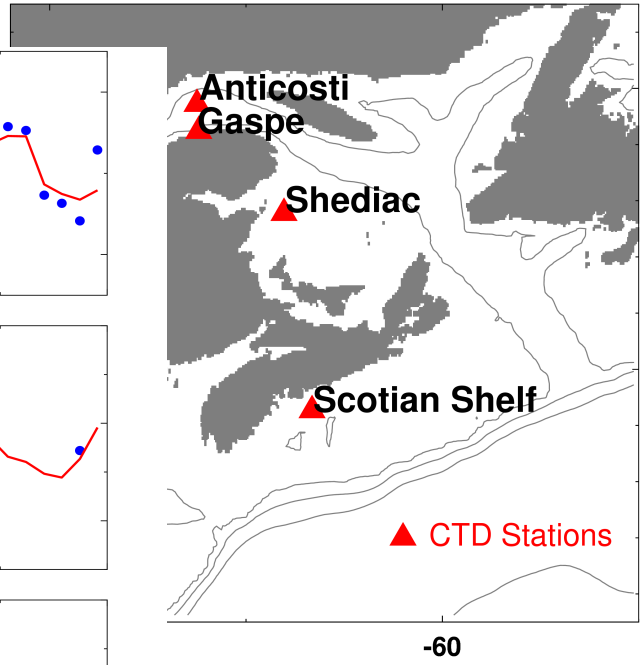
Observed vs Simulated monthly sub-surface temperature



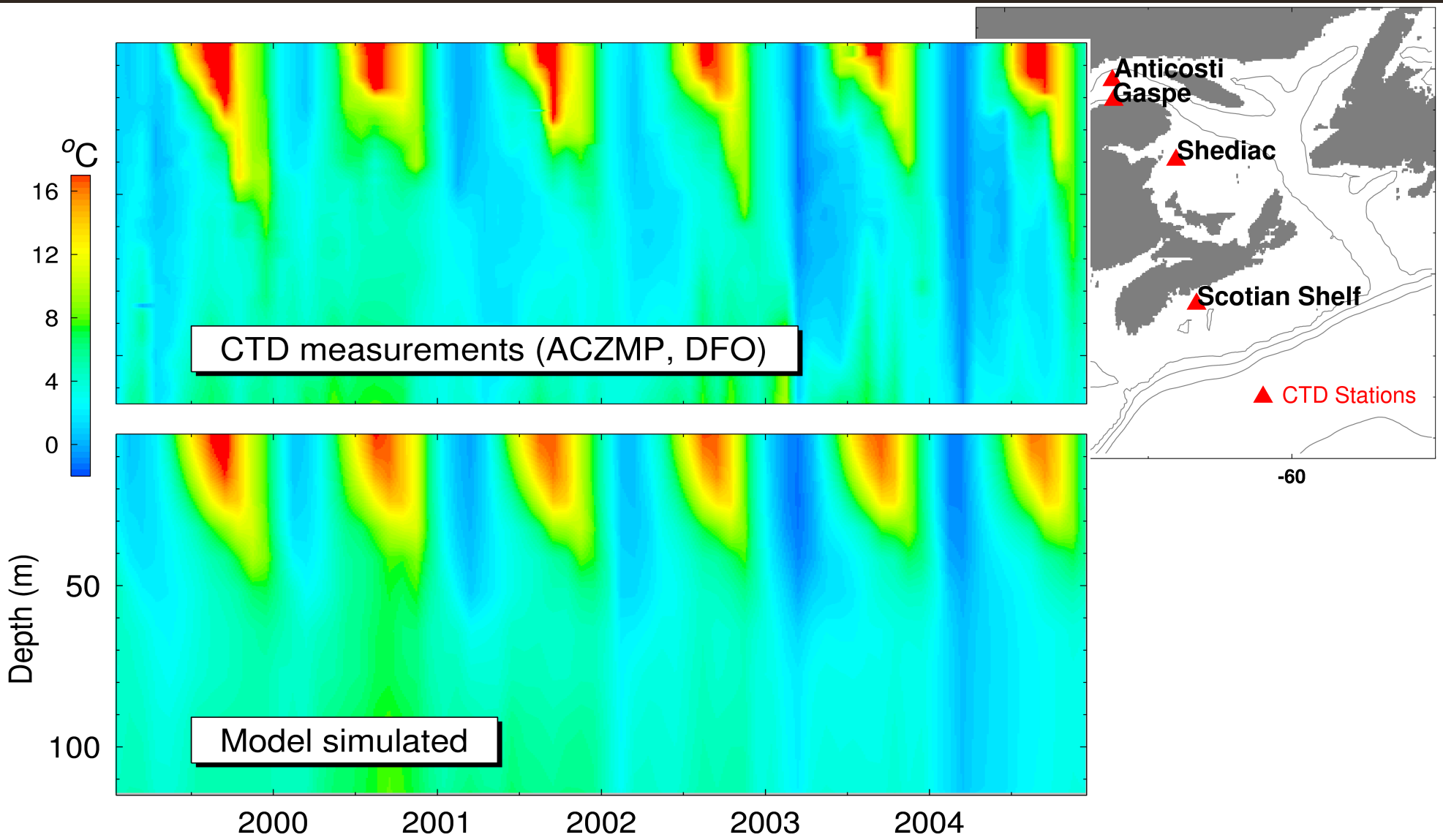


Observed vs Simulated monthly sub-surface salinity



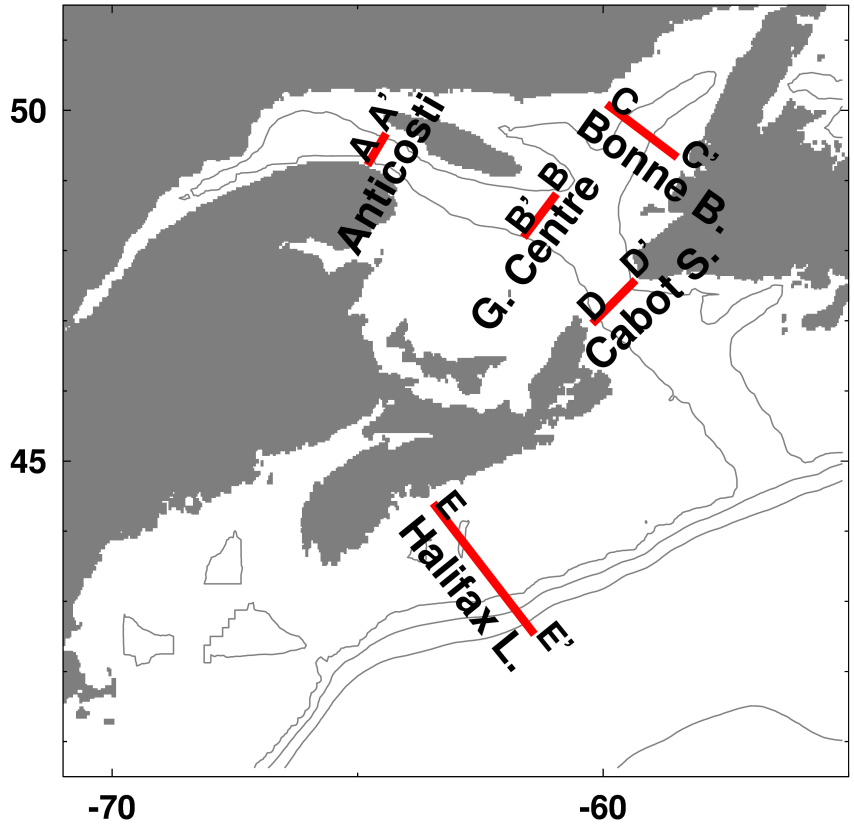


Observed vs Simulated monthly Temperature in the Scotian Shelf

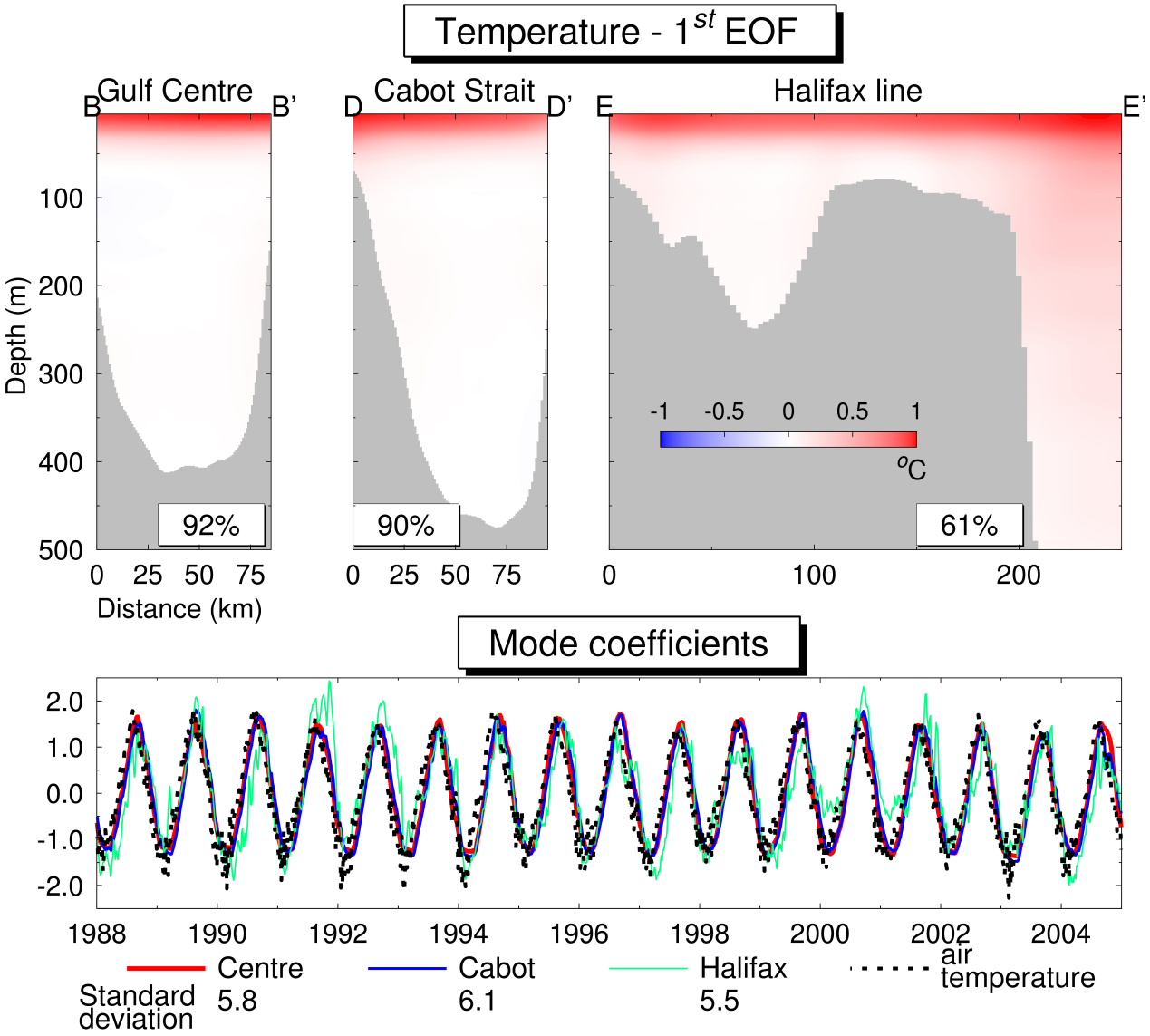


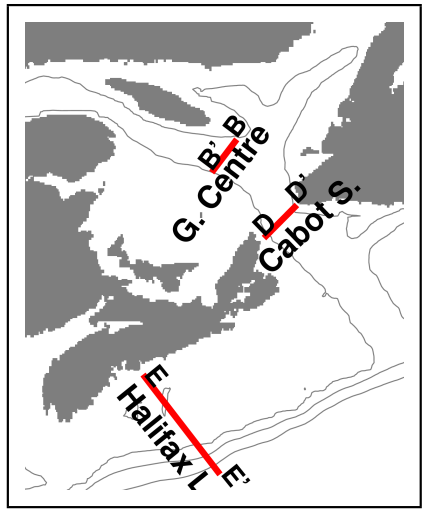
Standard EOF of hydrography in GSL

- Standard EOF analysis for T and S variability in the GSL-SS system.
- Five sections analized over the study region: Bonne Bay, Anticosti, Gulf Centre, Cabot Strait and Halifax Line.
- Correlation analisys to determine mechanisms driving variability in the region.



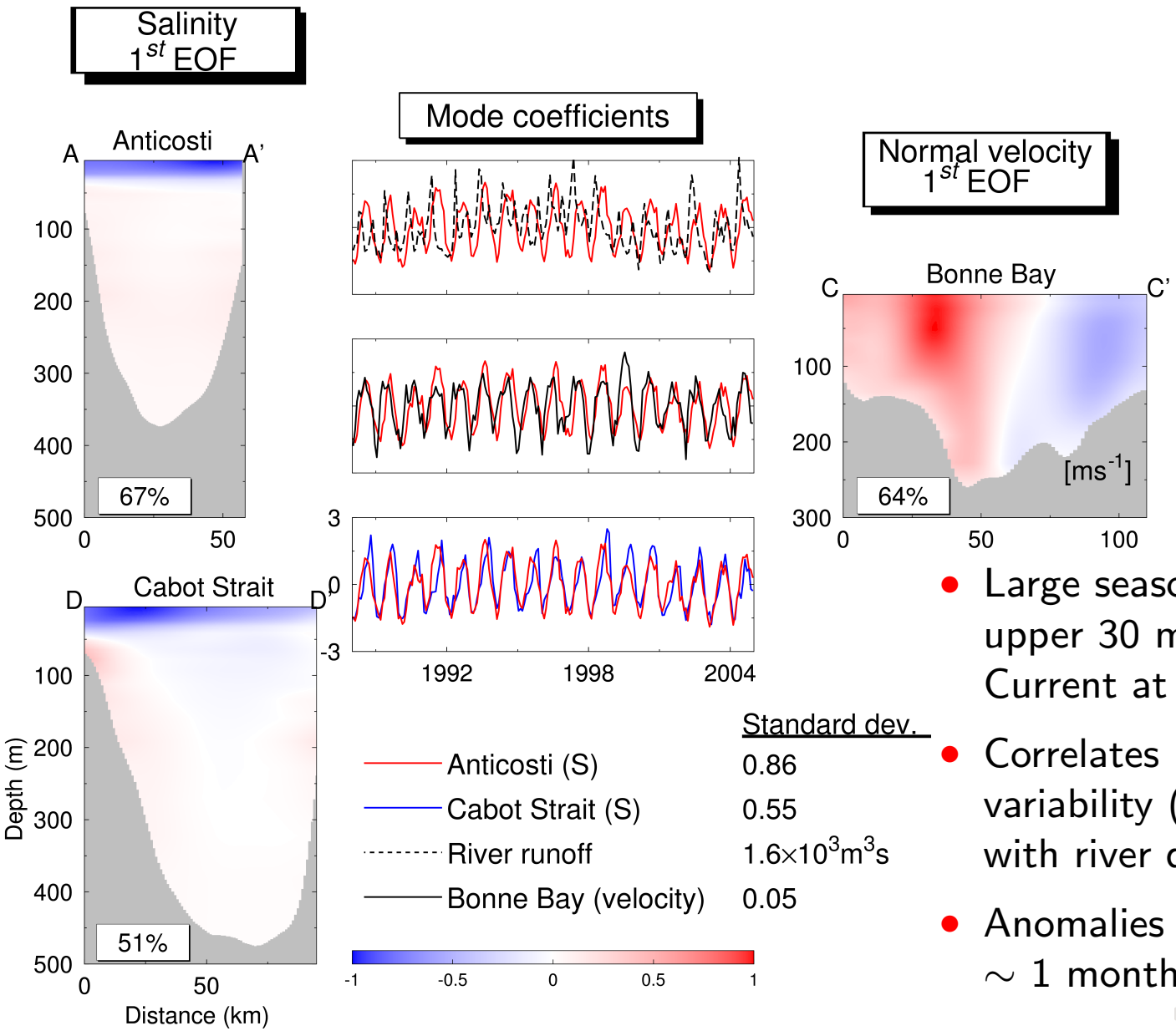
Seasonal variability of Temperature

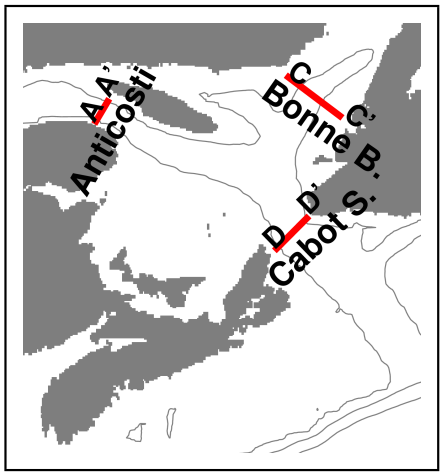




- Mainly in the upper 50 m.
- Correlation with 1^{st} mode of air temperature $\sim$0.96 in GSL and $\sim$0.85 in SS.
- Local effect in GSL and local + advection in SS (lags $\sim$ 1 month).
- High seasonal variability in deep waters over the Slope Water Region.

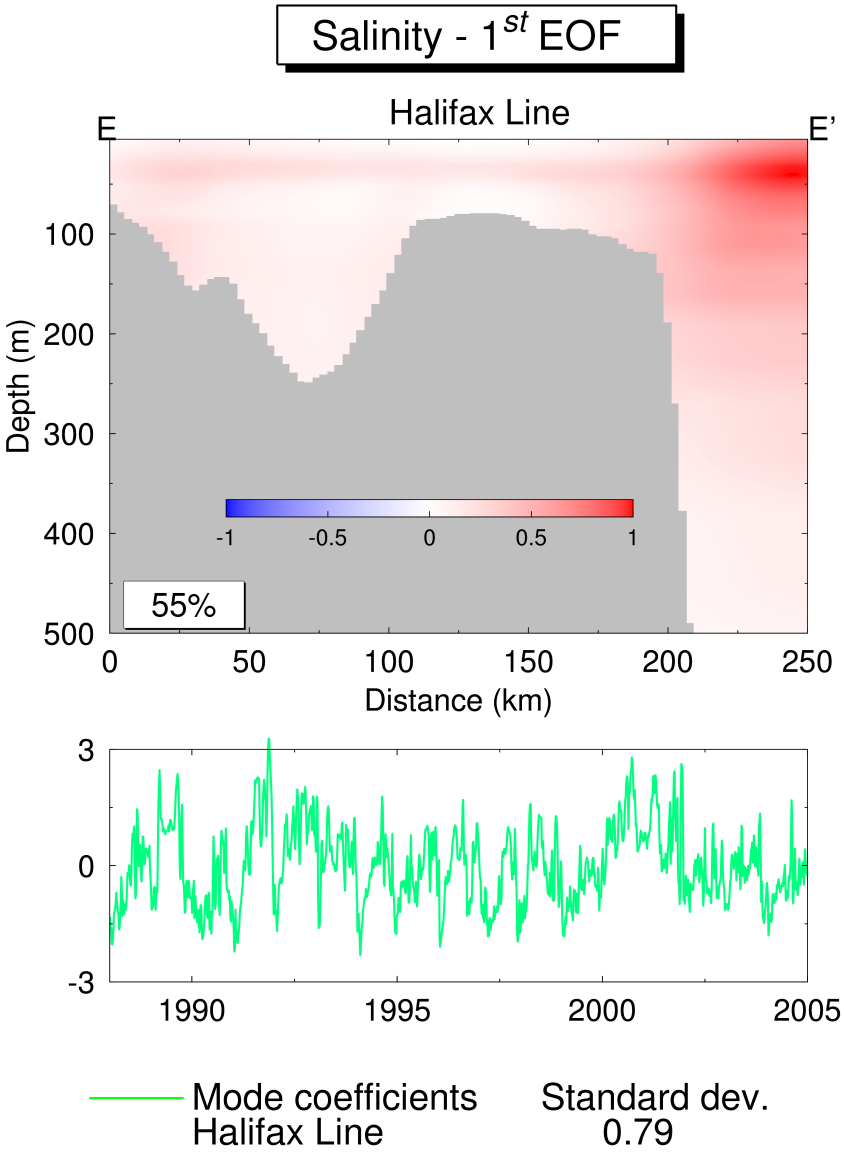
Seasonal variability of Salinity in the GSL

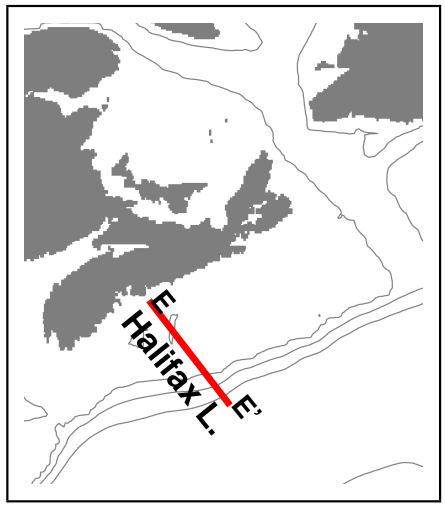




- Large seasonal variability in the upper 30 m, intensified in the Gaspe Current at the Cabot Strait.
- Correlates better with velocity variability (0.8) at Bonne Bay than with river discharge variability (0.5).
- Anomalies in Cabot Strait lag by $\sim$ 1 month those at Anticosti section.

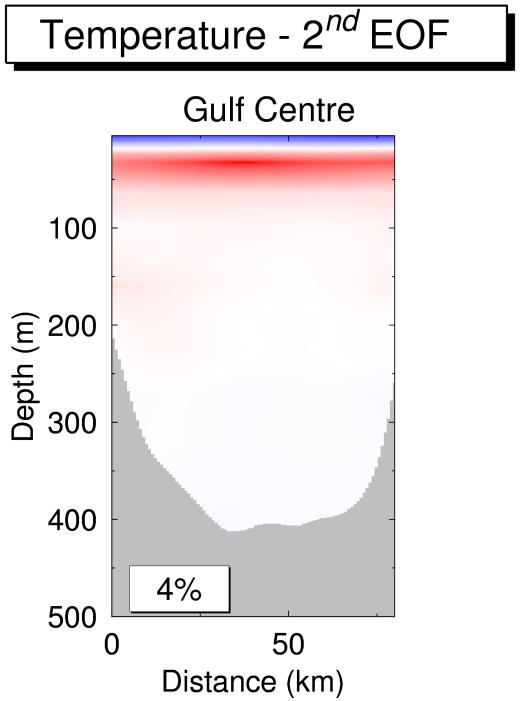
Variability of Salinity in the Scotian Shelf

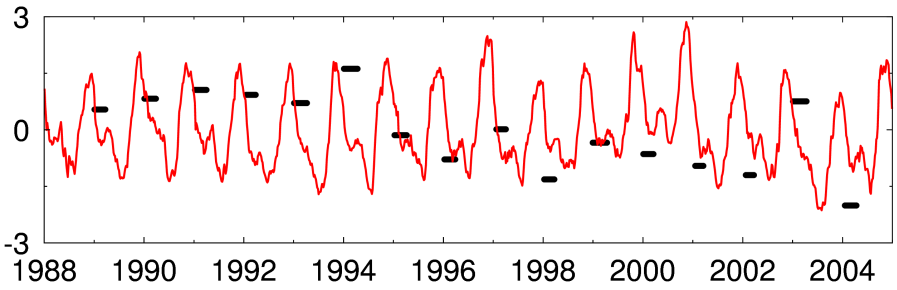




- 1^{st} mode (55% of variance) intense at the offshore Labrador Current (top 100 m) and significant through the water column.
- Significant in inner basins.
- 3^{rd} mode explains 8% of salinity variability and corresponds to the 1^{st} first mode in the GSL. concentrated in the Nova Scotia Current and the Offshore Labrador Current.

Sub-surface temperature variability

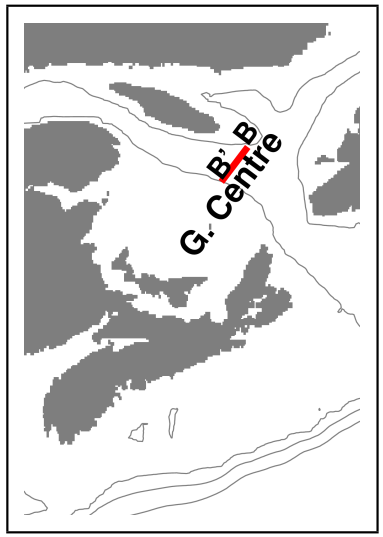




Mode coefficients Gulf Centre

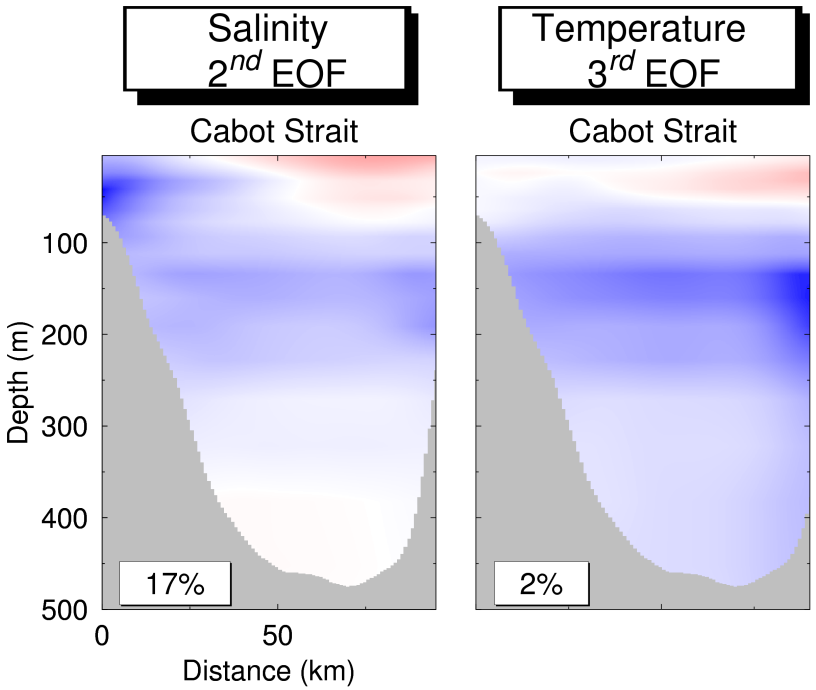
Section-averaged sea-ice concentration

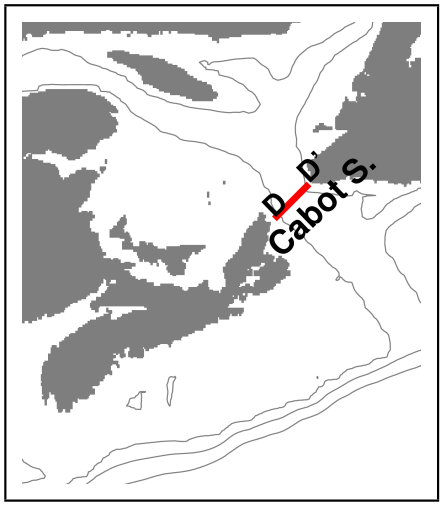
Standard dev.	1.03	0.33



- Uppermost layer out of phase with subsurface waters.
- Indicates variability in the cold intermeadiate layer.
- Indication of reduced heat loss as sea ice is formed at the surface.

Interannual variability of T and S in subsurface waters





- High modes explaining covariation of Temperature and Salinity. Cooler(warmer) and fresher (saltier) water masses.

Summary and Conclusions

- The NEMO coupled ocean-ice system was used to develop a nested-grid regional circulation model, and the model results used to study subtidal variability in the region.
- The model simulates reasonably well the circulation and has skill in simulating available observations and climatological fields of hydrography in the region.
- Seasonal air temperature variability controls most of the upper water column temperature variability in the GSL-SS system.

Summary and Conclusions

- Seasonal variability of the circulation in the northeast GSL is the main factor affecting the salinity variations in the upper layer of the GSL and has a weak connection with the salinity variability in the Scotian Shelf.
- The salinity variations in the Scotian Shelf are significantly affected by oceanic features such as the Offshore Labrador Current and the Gulf Stream.
- Indications of variability affecting the cold intermediate layer in the GSL need further study.

Thanks!!!

END

Spectral Nudging and Smoothed Semiprognostic methods

- Spectral Nudging (Thompson et al., 2006)

$$\frac{\partial T}{\partial t} = -\vec{u} \cdot \nabla T + \nabla \cdot A \nabla T + \left\langle \frac{T_c - T_m}{\tau} \right\rangle$$

- Smoothed Semiprognostic Method (Sheng et al., 2001; Eden et al., 2004)

$$\hat{\rho} = \rho_m + (1 - \alpha)(\overline{\rho_c - \rho_m})$$

$$\frac{\partial P}{\partial t} = -\hat{\rho} g$$

Connection of Variability of Salinity in the GSL and SS