Numerical Study of Circulation and Hydrography over the Scotian Shelf using a Multi-Nested Ocean Circulation Model

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Outline

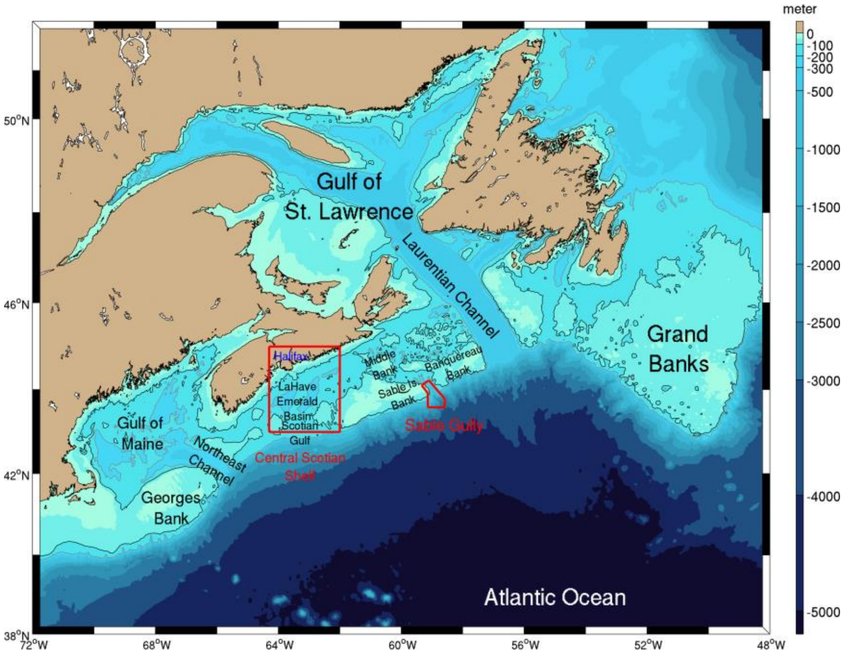
1. Introduction
2. Nested-grid ocean circulation model for the central Scotian Shelf (DalCoast-CSS)
3. Model validation
4. Process studies:
    (a) tidal mixing and wind-driven coastal upwelling in the formation of cold surface waters
    (b) the role of irregular coastline and topography in coastal upwelling
5. Summary

1. Introduction

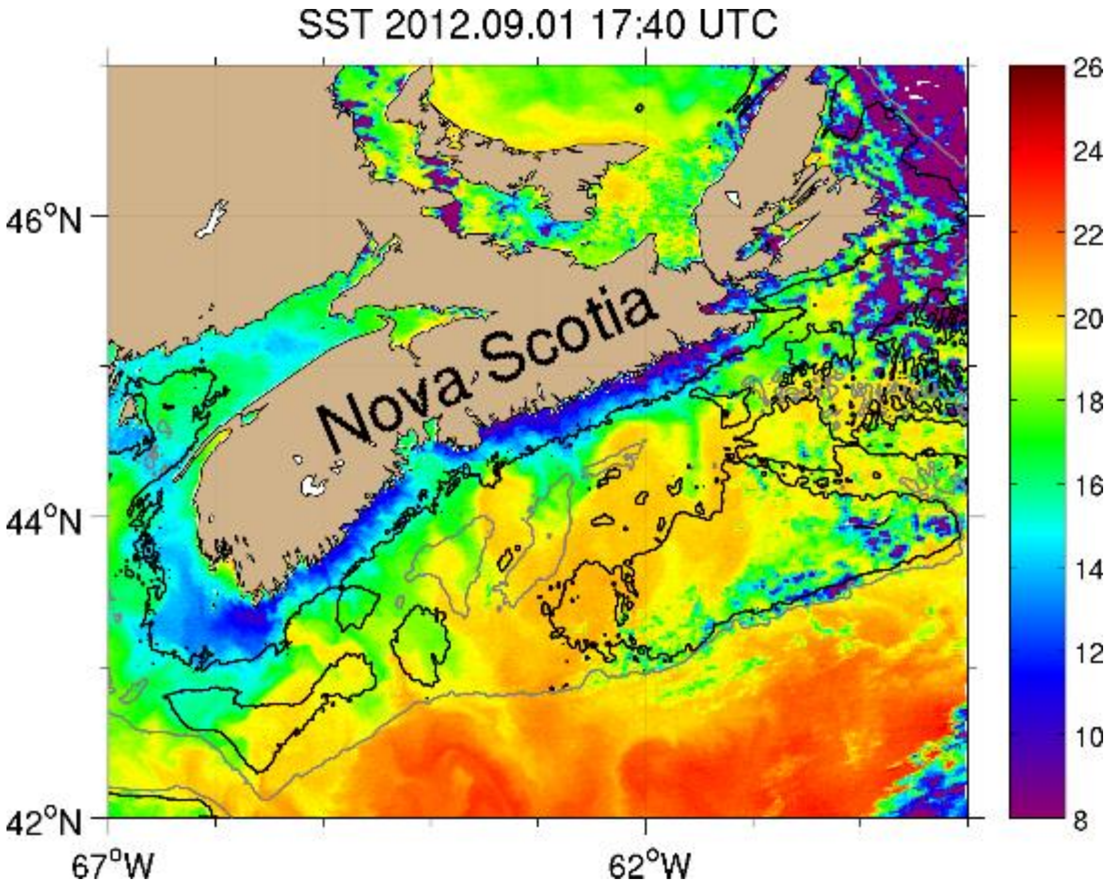
- **Circulation and hydrography on the Scotian Shelf have significant temporal and spatial variability**

- **Influenced by many forcing functions such as tides, surface fluxes of heat, freshwater and momentum, estuarine outflow from the Gulf of St. Lawrence**

- **Influenced by advection of the Labrador Current and the Slope Water intrusion.**



Cold surface coastal waters around Nova Scotia



The satellite remote sensing data of sea surface temperature reveal that the Atlantic side of Nova Scotia is occasionally surrounded by cold surface waters in summer.

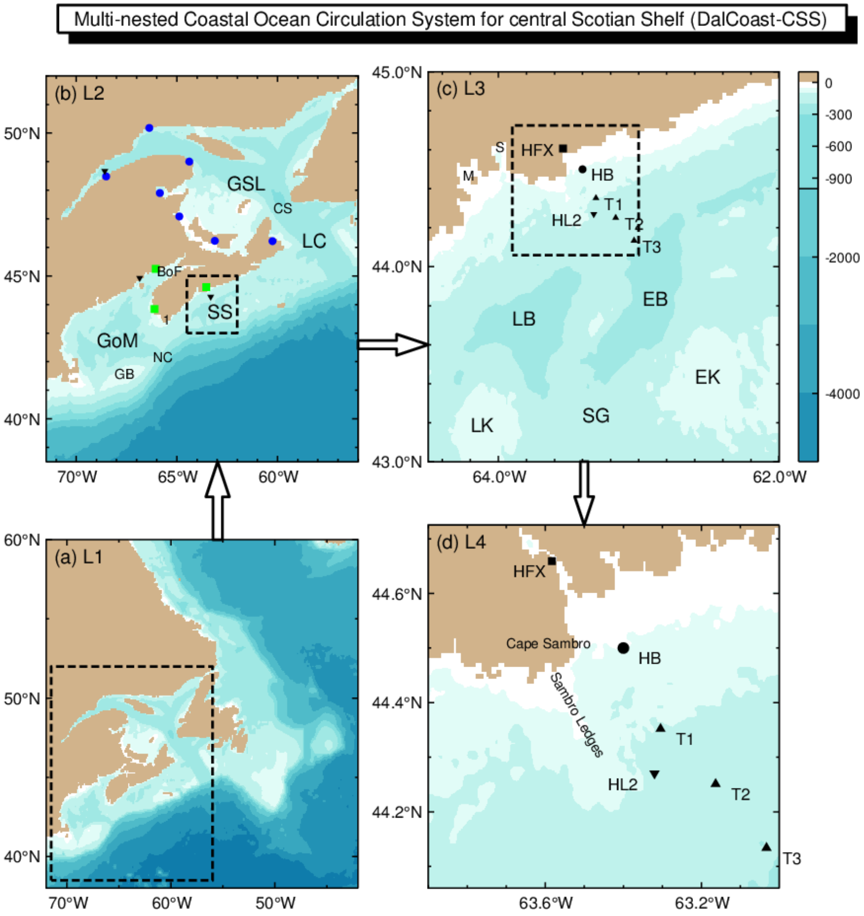
Main objectives:

- Assess the performance of the multi-nested ocean circulation model
- Examine the effect of winds, tides, and local topography in the formation of coastal upwelling and cold surface waters along the coast of Nova Scotia

Research approach:

- A multi-nested ocean circulation model with four sub-models (DalCoast-CSS)

A multi-nested circulation model (DalCoast-CSS)

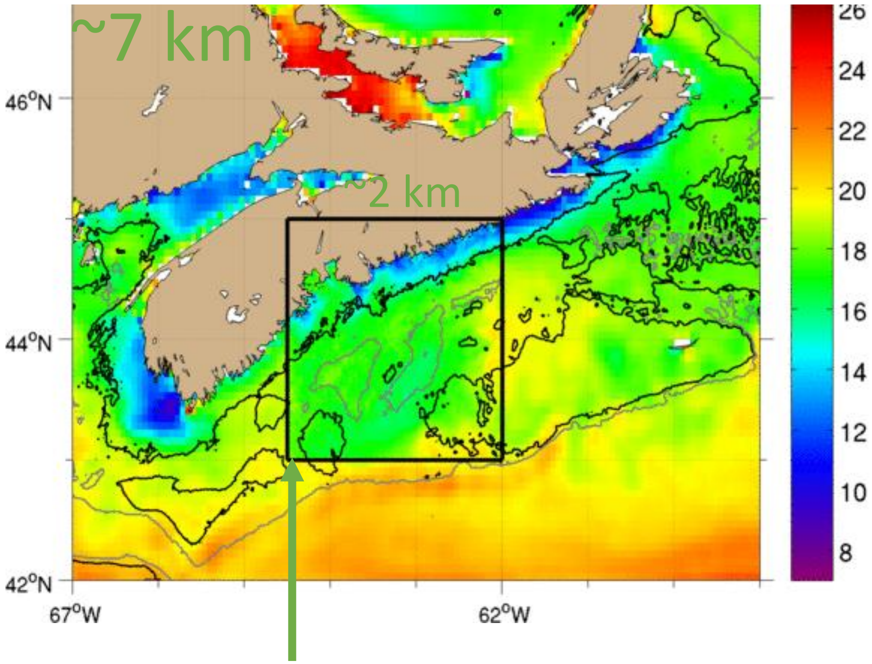

Multi-nested Coastal Ocean Circulation System for central Scotian Shelf (DalCoast-CSS)

Recent update of the system:

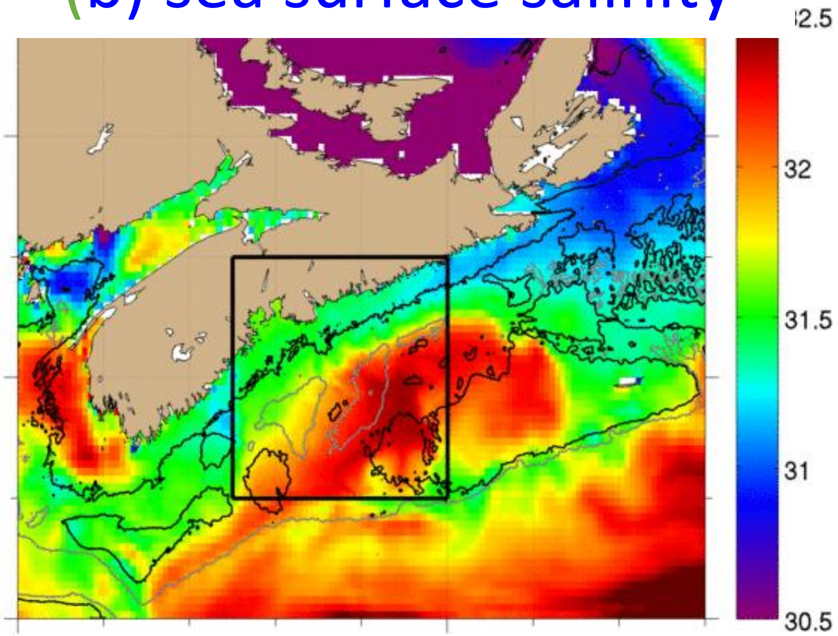
- GEBCO Bathymetry (1 min)
- Horizontal resolutions: 1/12°, 1/16°, 2 km, and 500 m.
- Vertical resolution: 40 sigma-levels for L2, 47 z-levels for L3 and L4.
- Tidal boundary conditions (8 TPXO tidal constituents)
- North American Regional Reanalysis (NARR) atmospheric forcing (~32 km)
- Discharge from rivers
- Spectral nudging in sub-models 2 and 3 (depth>40 m)

Model Results (Aug 31-Sep 15, 2012)

(a) sea surface temperature



(b) sea surface salinity



- Results over the region marked by the black box are produced by the fine-resolution (2 km) sub-model.
- Outside this region, the model results are produced by the coarse-resolution (7 km) sub-model.

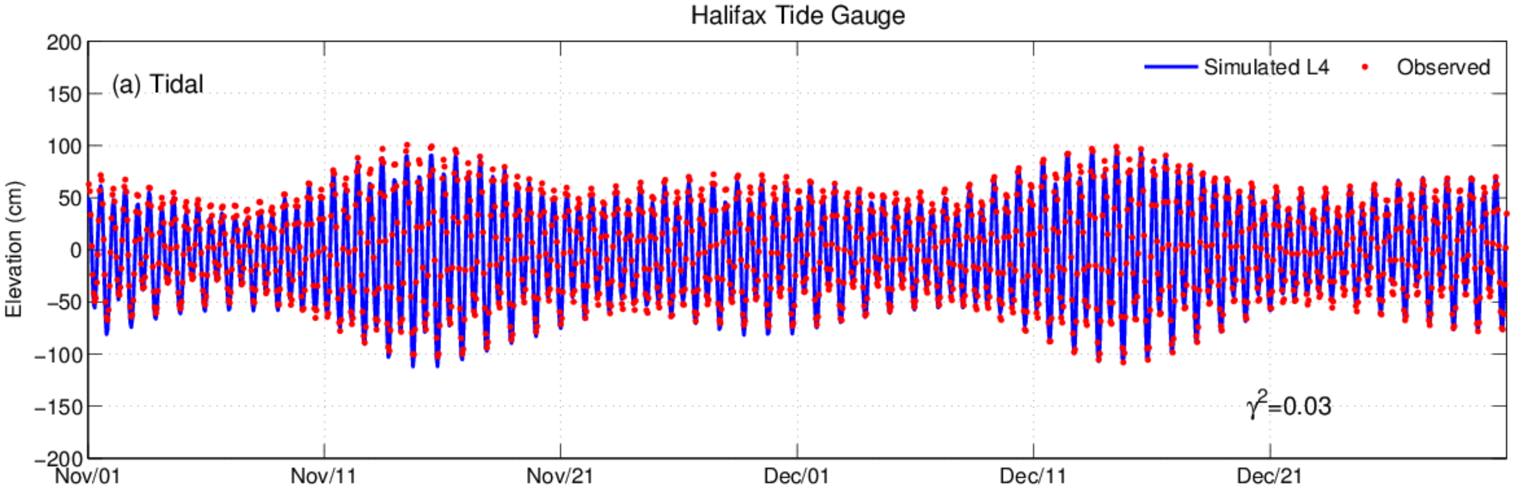
Model Validation

The performance of the multi-nested ocean circulation model is assessed by using satellite remote sensing data and *in-situ* observations:

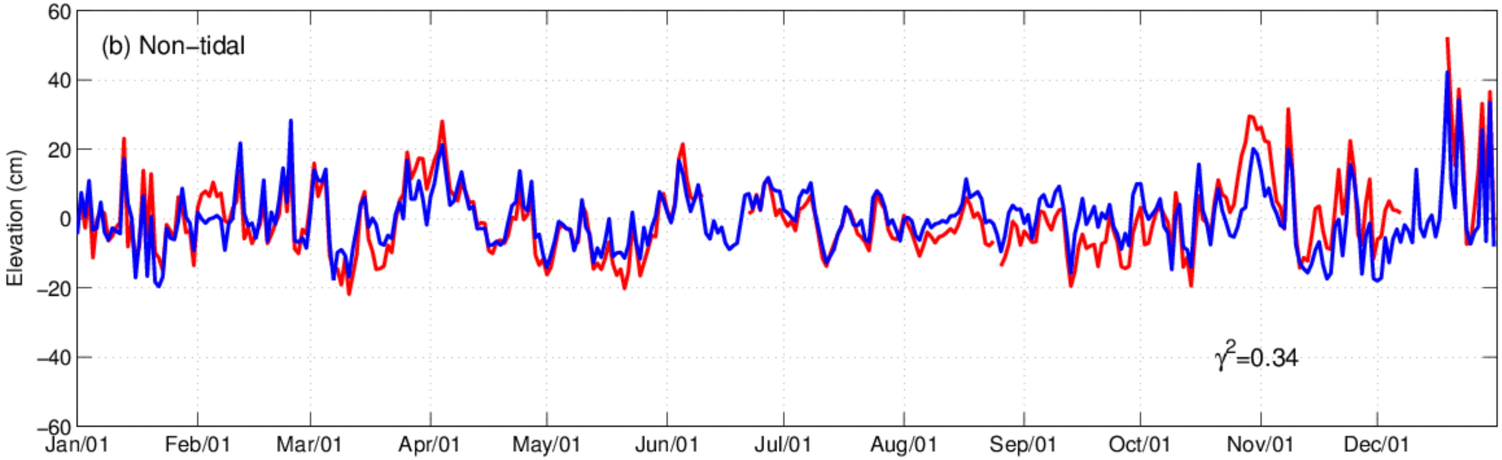
- SST from GHRSST products
- SSS from Aquarius products
- Sea level measured by tide gauges
- Hydrographic observations measured by CTDs
- Time series of SST measured by a marine buoy
- Current measured by ADCPs

Sea level: Sub-model results vs data at Halifax tide gauge

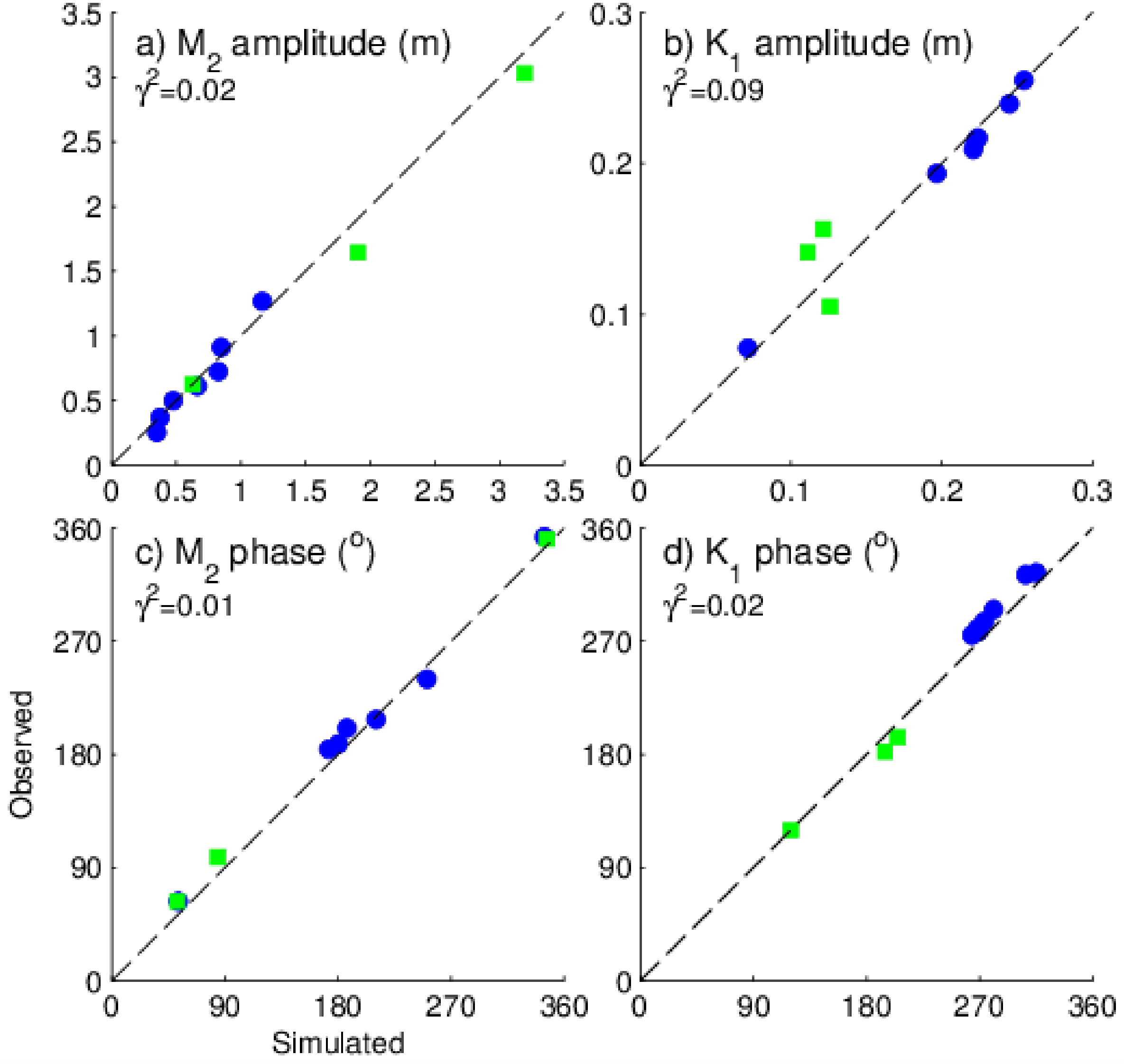
Tidal

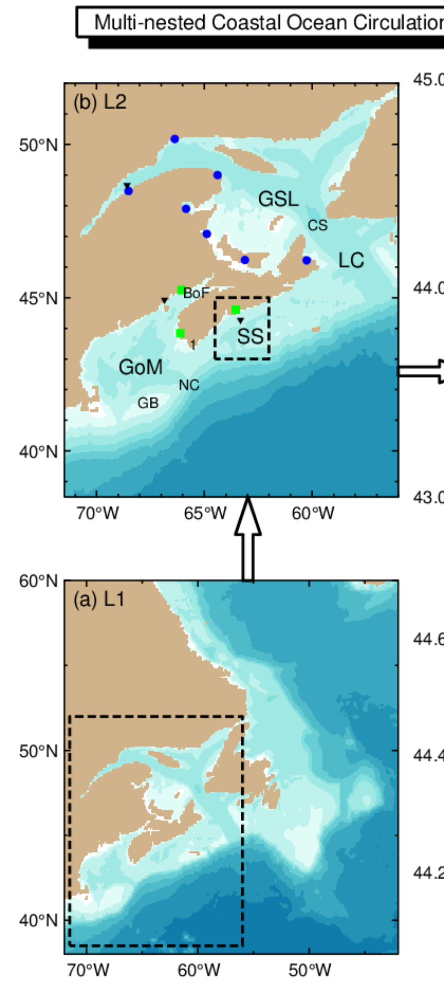


Non-tidal

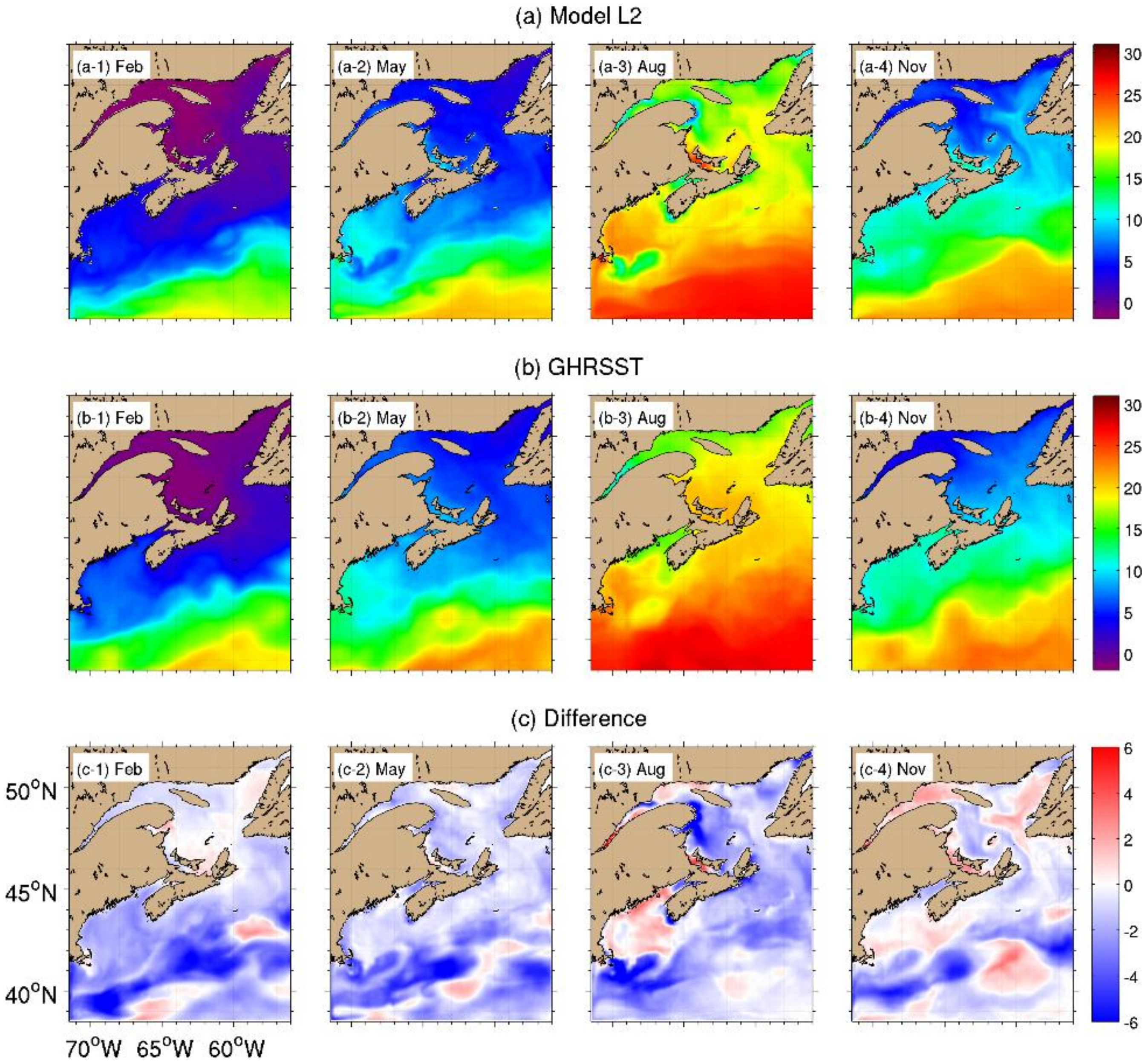


Observed and simulated M_2 and K_1





Monthly mean SST: Model L2 vs GHRSST



Model

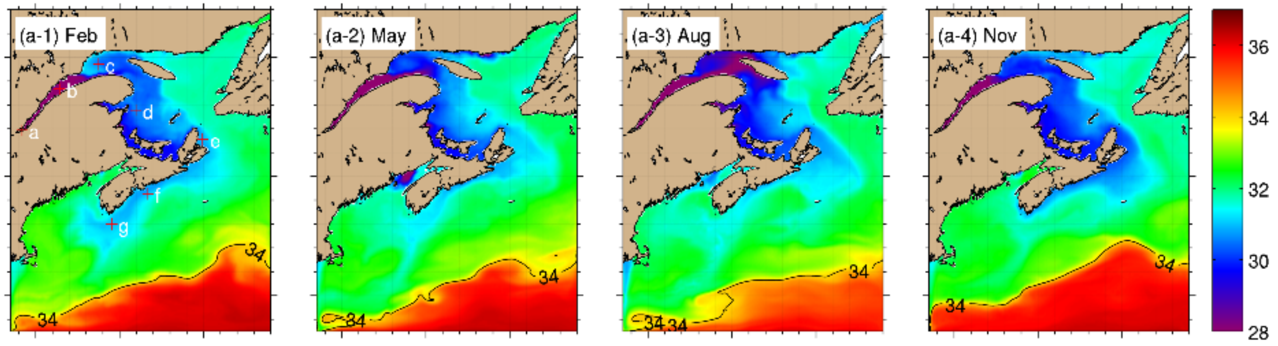
GHRSST

Differences

Monthly mean SSS: Model L2 vs Aquarius

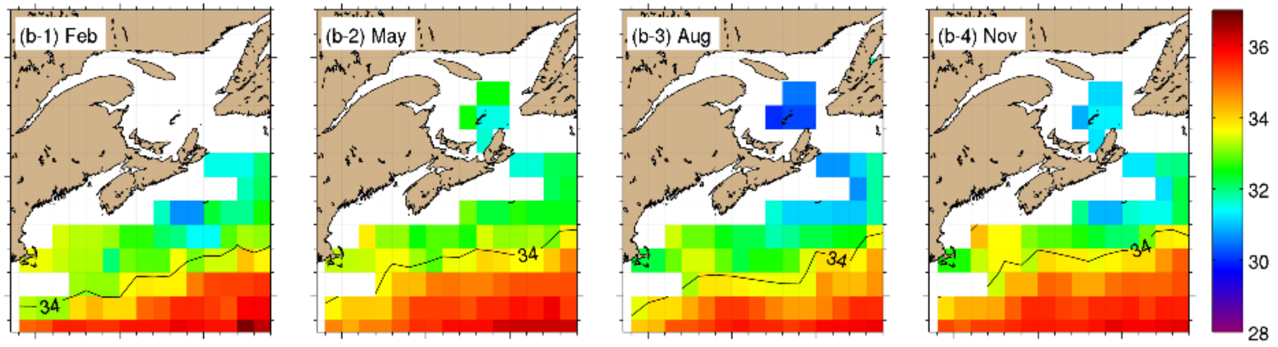
Model

(a) Model L2



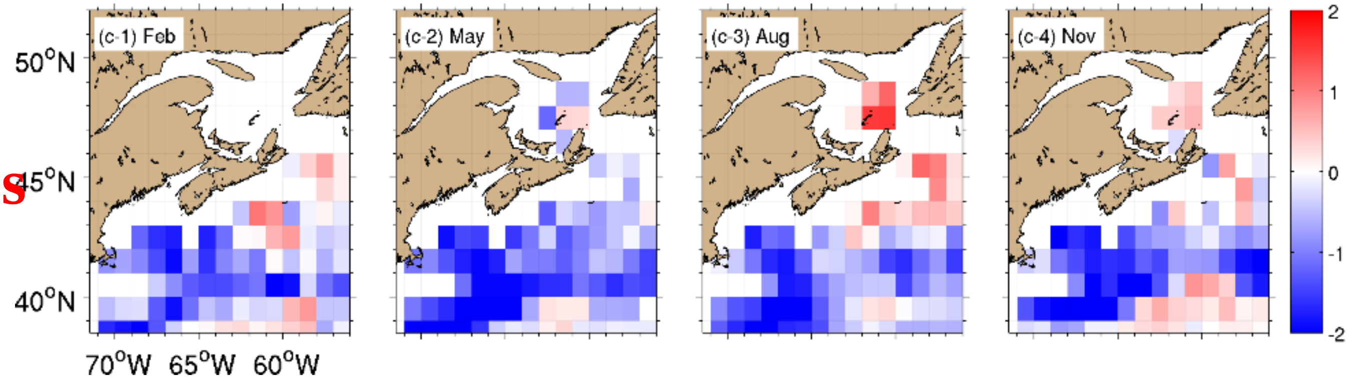
Aquarius

(b) Aquarius SSS

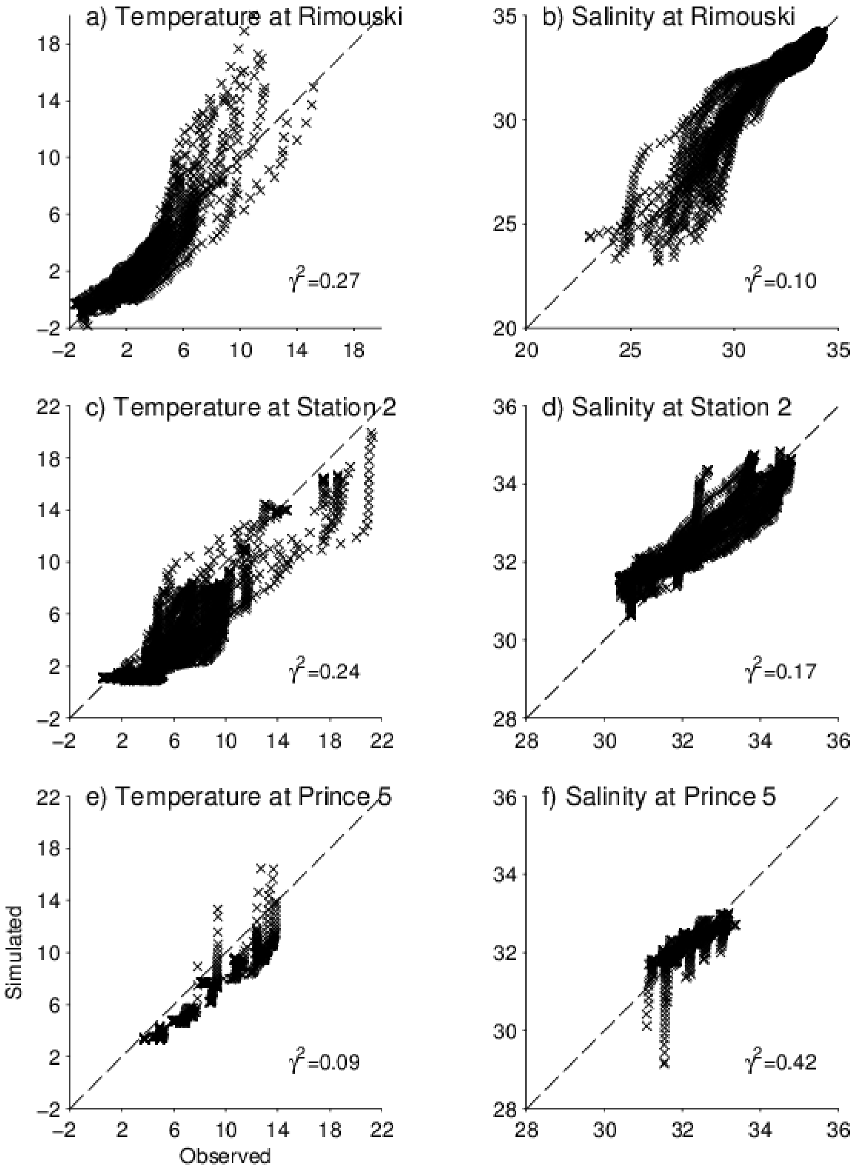


Differences

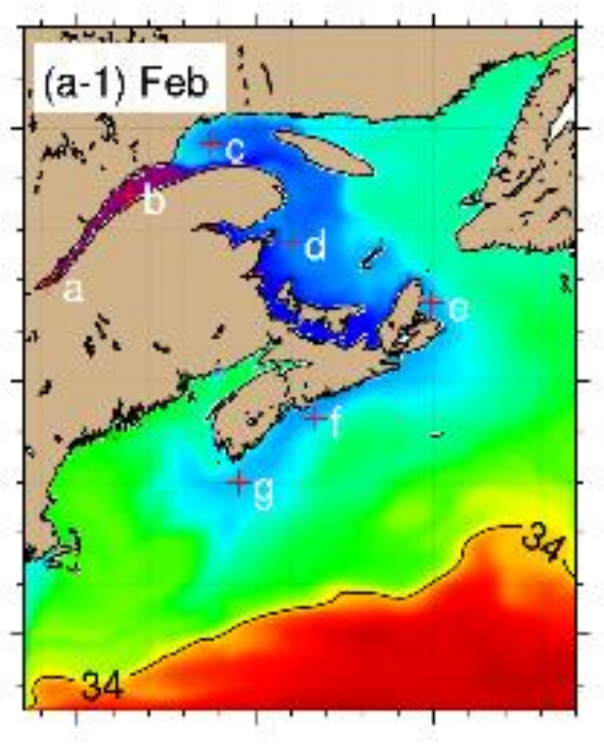
(c) Difference

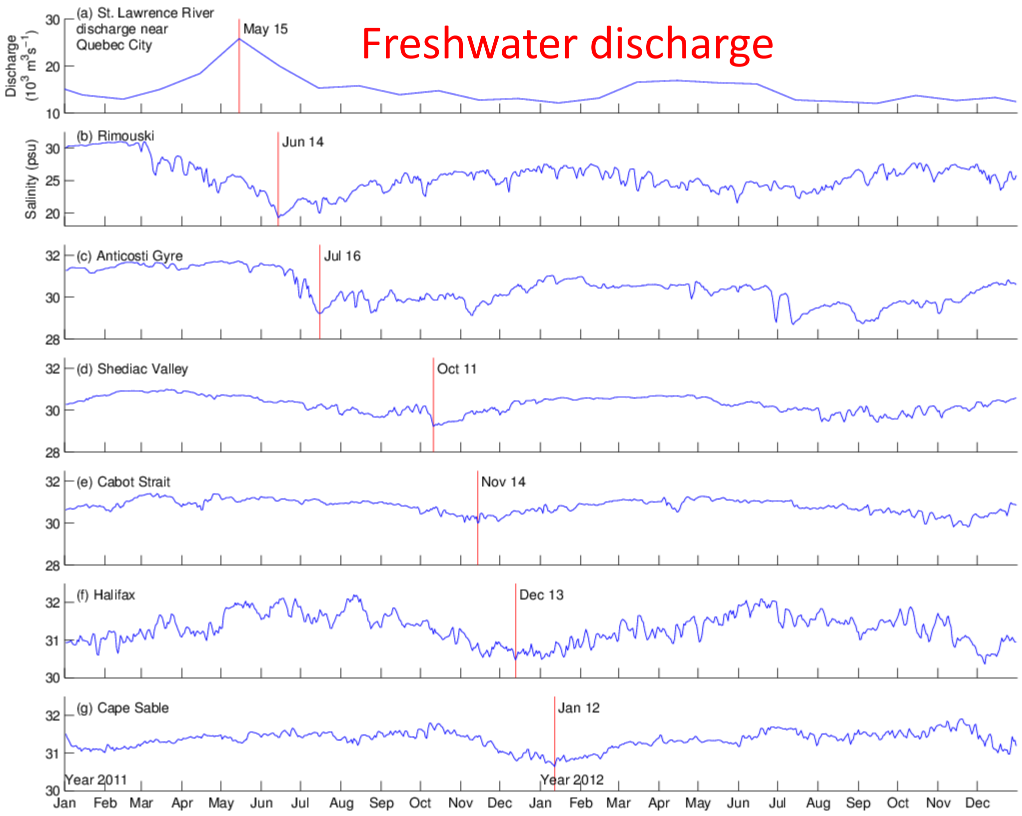


Comparison of simulated TS (sub-model L2) with CTDs



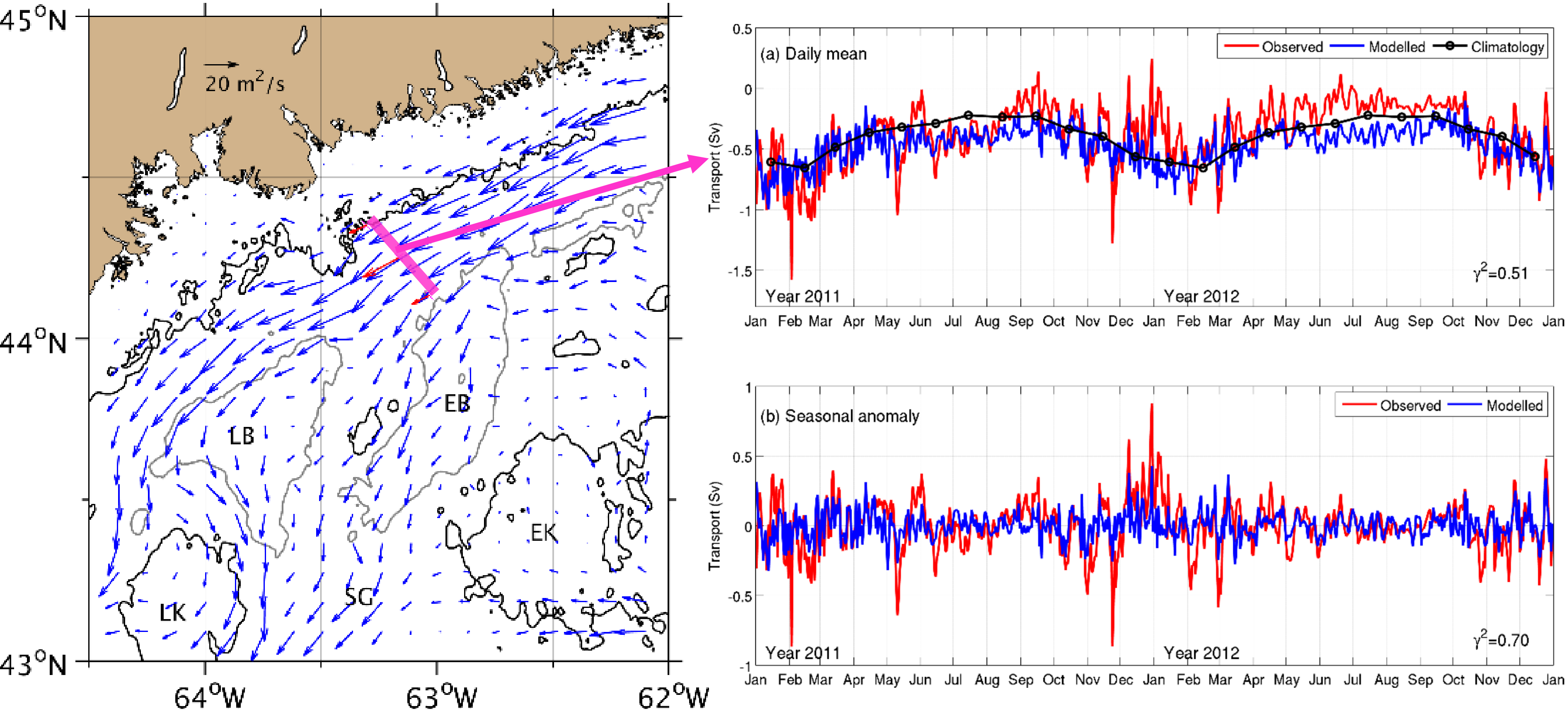
Advection of St. Lawrence River freshwater pulse




Freshwater discharge

A discharge peak is followed by the downstream reduction of the amplitude and phase propagation of a low-salinity signal. The travel time of the freshwater pulse from Quebec City is about 7 months and about 8 months to reach Halifax and Cape Sable, respectively. These estimated travel time is consistent with the values discussed in previous studies (Sutcliffe et al., 1976; Smith, 1989).

Nova Scotia Current: Model L3 vs ADCP



The model is able to capture the seasonal anomaly of the Nova Scotia Current transport. However, the model overestimates the transport in summer 2012.

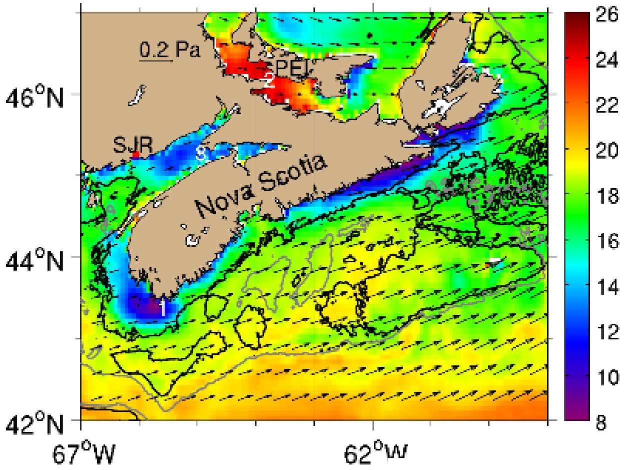
Process Studies

Six numerical experiments were conducted using DalCoast-CSS were conducted for examining:

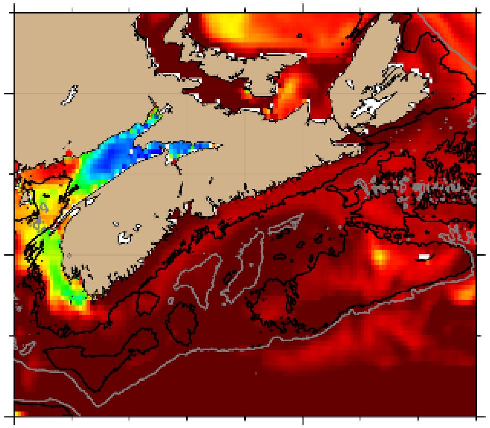
(a) the effect of tidal mixing and wind-driven coastal upwelling in the formation of cold surface waters along the coast of Nova Scotia

(b) The role of irregular coastline and topography in coastal upwelling.

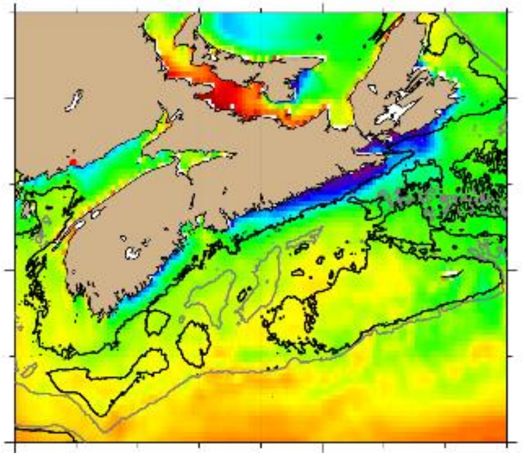
Experiment	**Description**
Control Run	driven by a suite of forcing functions
NoWind Run	no wind forcing
NoTide Run	no tidal forcing
SteadyWind Run	constant upwelling-favorable wind and realistic coastline run
StraightCoastline Run	straight coastline run
SmoothTopo Run	smoothed topography run



(a-1) Control Run: Temperature



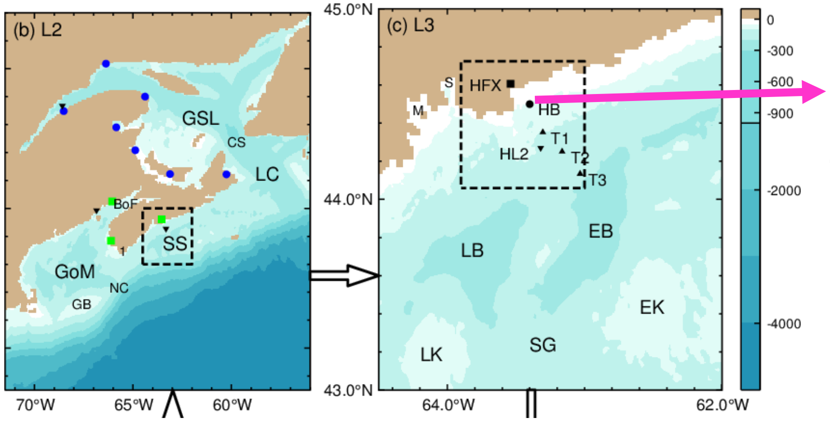
(b-1) No Wind: Temperature

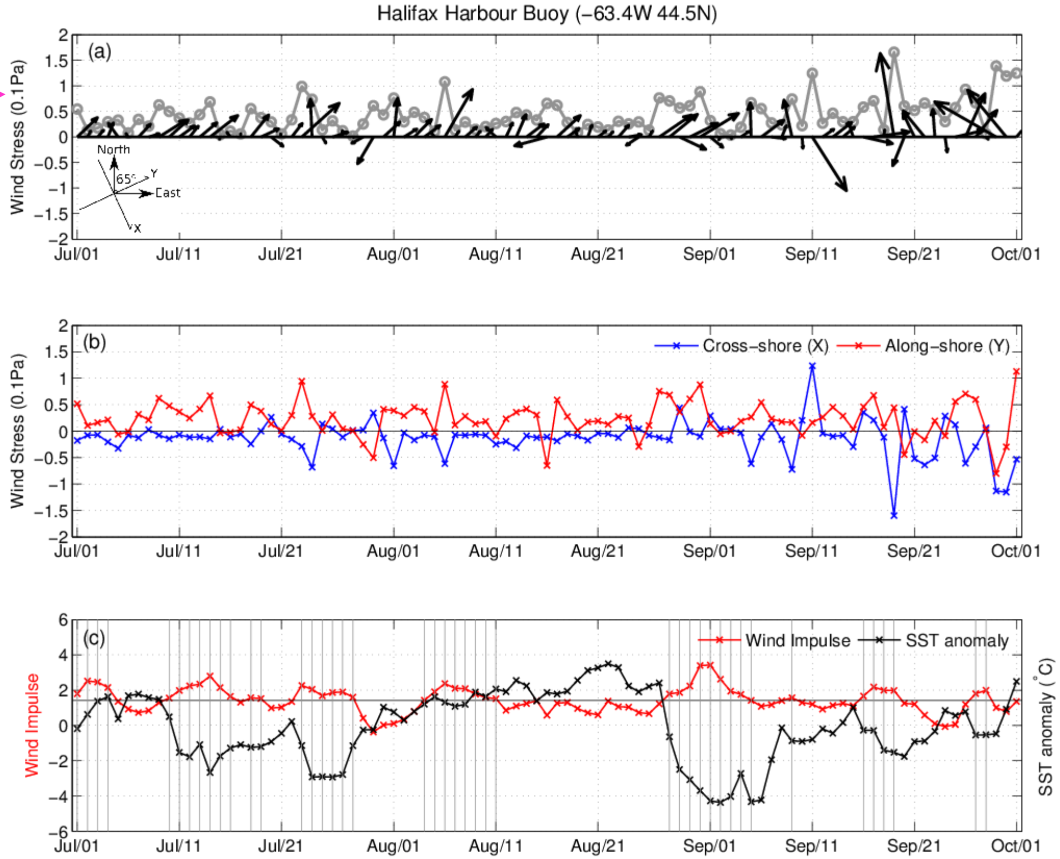


(c-1) No Tide: Temperature

- The formation of cold water in the Bay of Fundy and off Cape Sable is due mainly to tidal mixing and topographical upwelling.
- The cold water along the south shore of Nova Scotia is a result of wind-driven coastal upwelling.

Coastal Upwelling: Wind Conditions

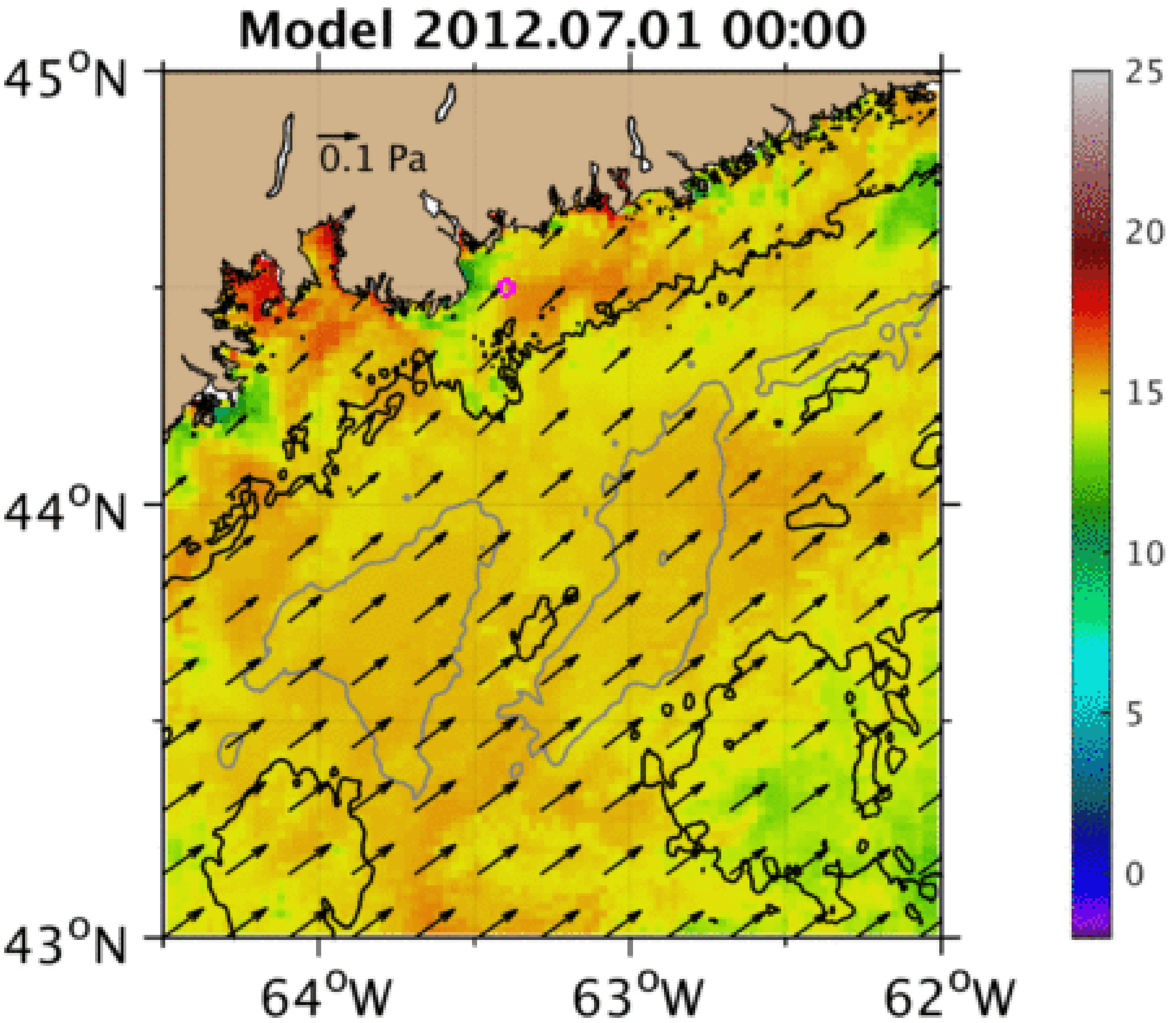




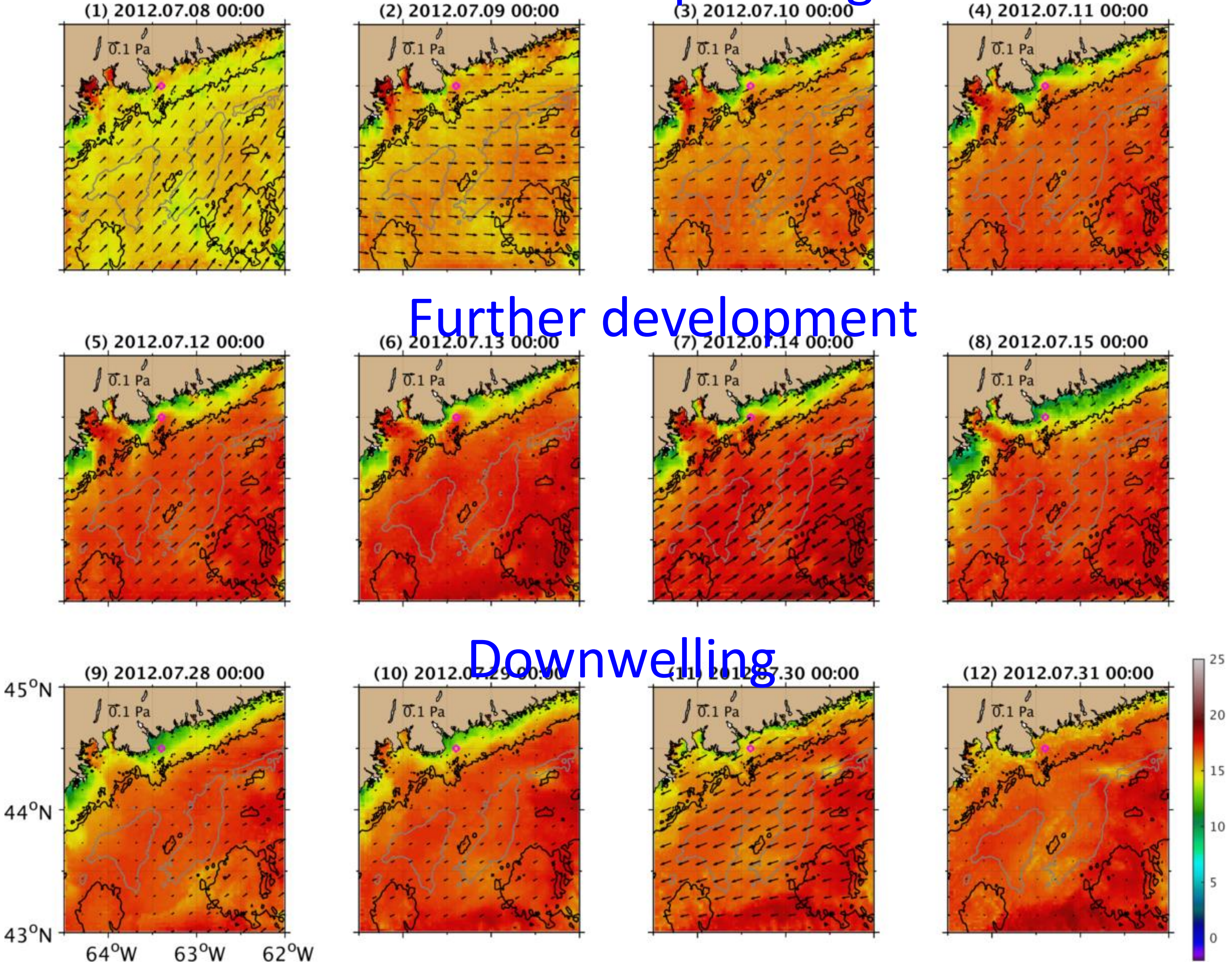
$$I = \int_0^T \tau_a \, dt$$

The negative SST anomalies coincide with positive wind impulse anomalies.

Simulated Coastal Upwelling (SST in July, 2012)



Simulated Coastal Upwelling (SST in July, 2012)

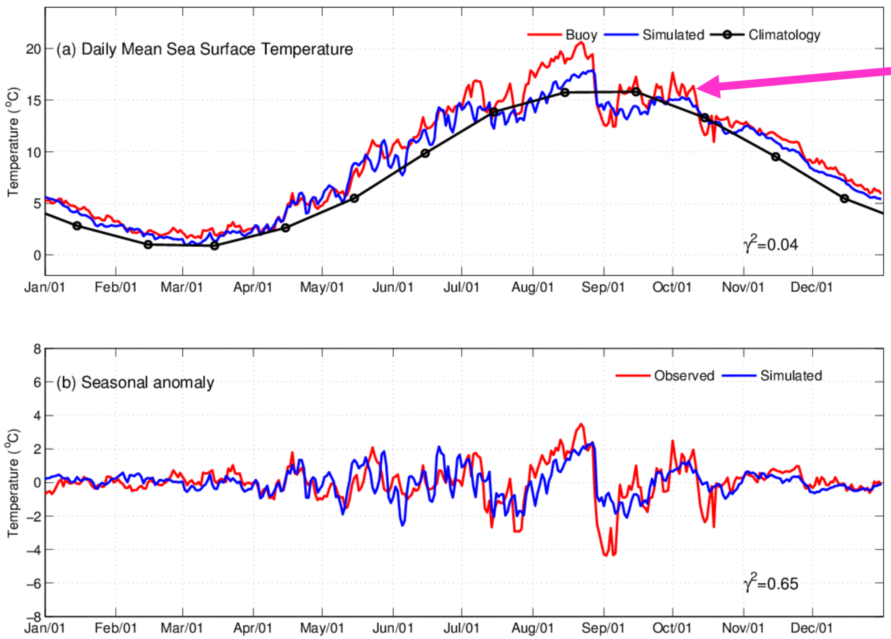


Onset of upwelling

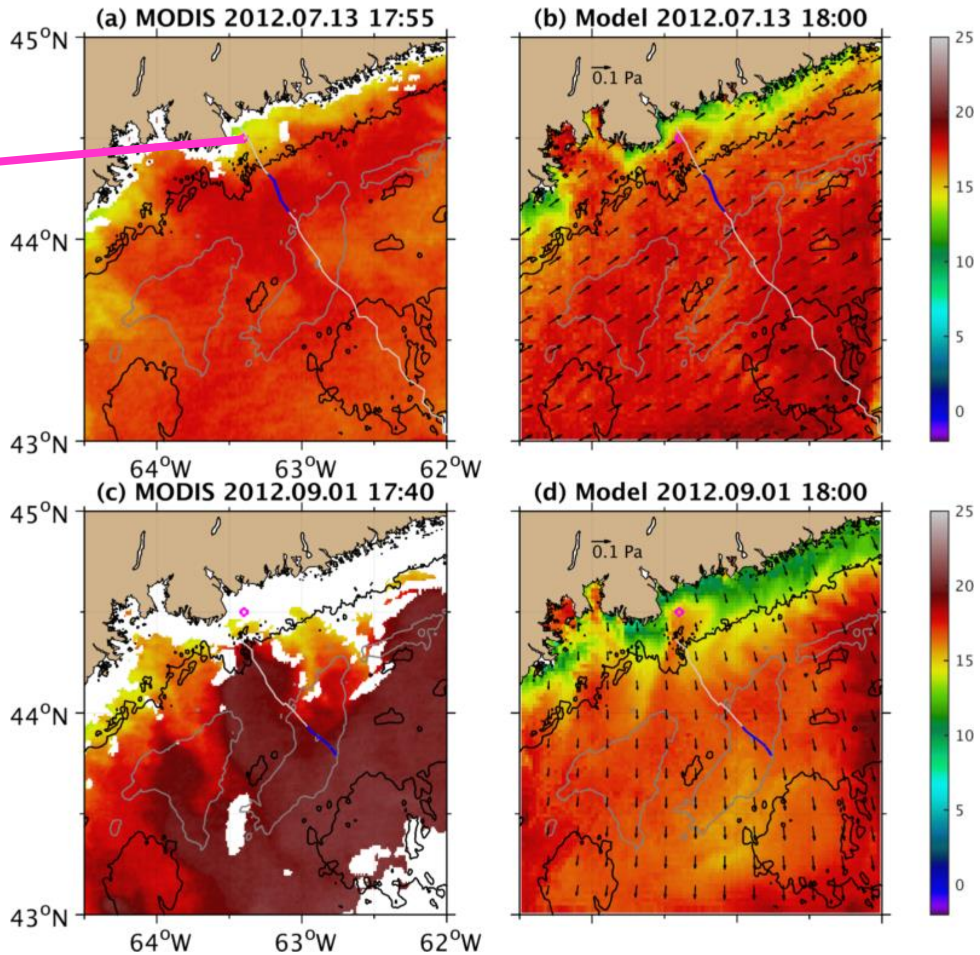
Further development

Downwelling

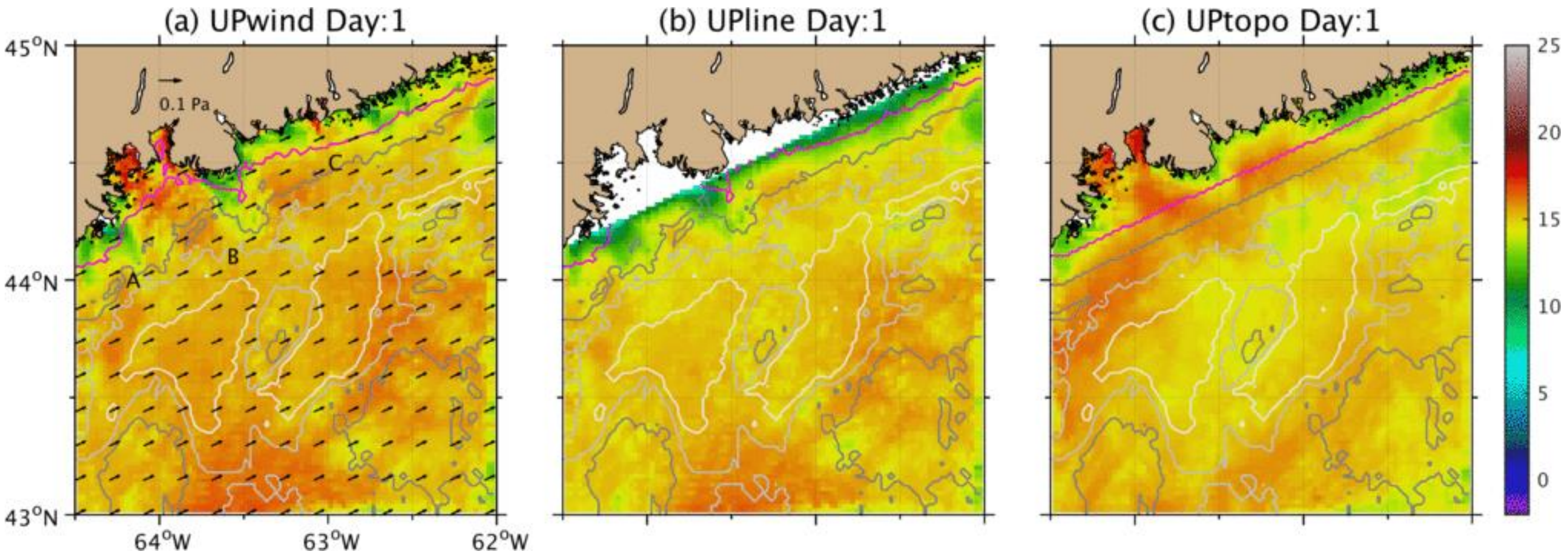
Simulated Coastal Upwelling vs Observations



The model is able to capture the SST anomaly during the upwelling events in July. The model also has skill in capturing the onset of the upwelling at the end of August. However, the model underestimates the sharp decrease in the SST anomaly of this upwelling event.



The model performs well in capturing the cold water band along the coast. However, the model performs less well in simulating the observed filaments.

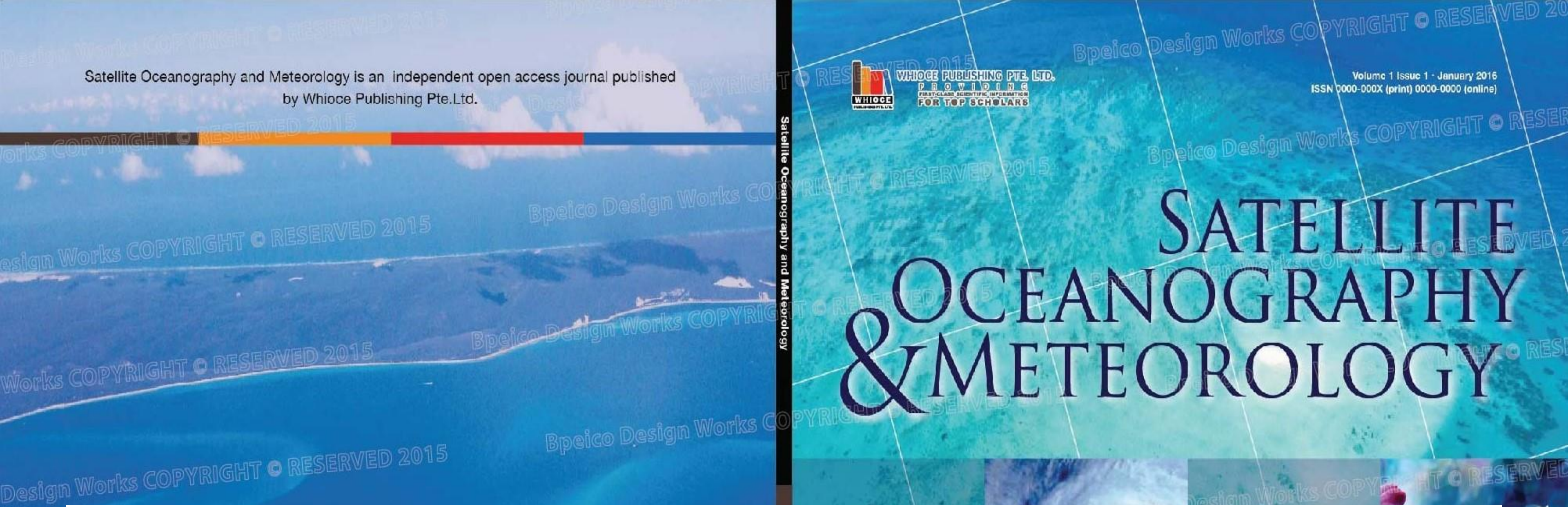


(a) Steady Wind **(b) Straight Coastline** **(c) Smoothed topography**

- Irregular coastline (e.g., cape) has a scattering effect to the along-shore wave propagation of filaments.
- Irregular topography (e.g., submerged bank) can influence the further offshore development of filaments.

Summary

- **A multi-nested ocean circulation model was developed (DalCoast-CSS).**
- **The model was validated using satellite remote sensing data and *in-situ* oceanographic measurements.**
- **Process studies were made in examining (a) the effect of tidal mixing and wind-driven coastal upwelling in the formation of cold surface waters along the coast of Nova Scotia, and (b) the role of irregular coastline and topography in coastal upwelling.**
- **Irregular coastline has the scattering effect to the along-shore wave propagation of filaments and irregular topography can influence the offshore development of filaments.**



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