Modulation of Near-Inertial Oscillations by Low Frequency Current Variations on the Inner Scotian Shelf

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Outline

- Introduction
- A nested-grid operational shelf circulation model
- Model validations based on ADCP and high-frequency radar (HF-Radar) observations
- Examination of modulations of near-inertial oscillations by low frequency current variations
- Summary

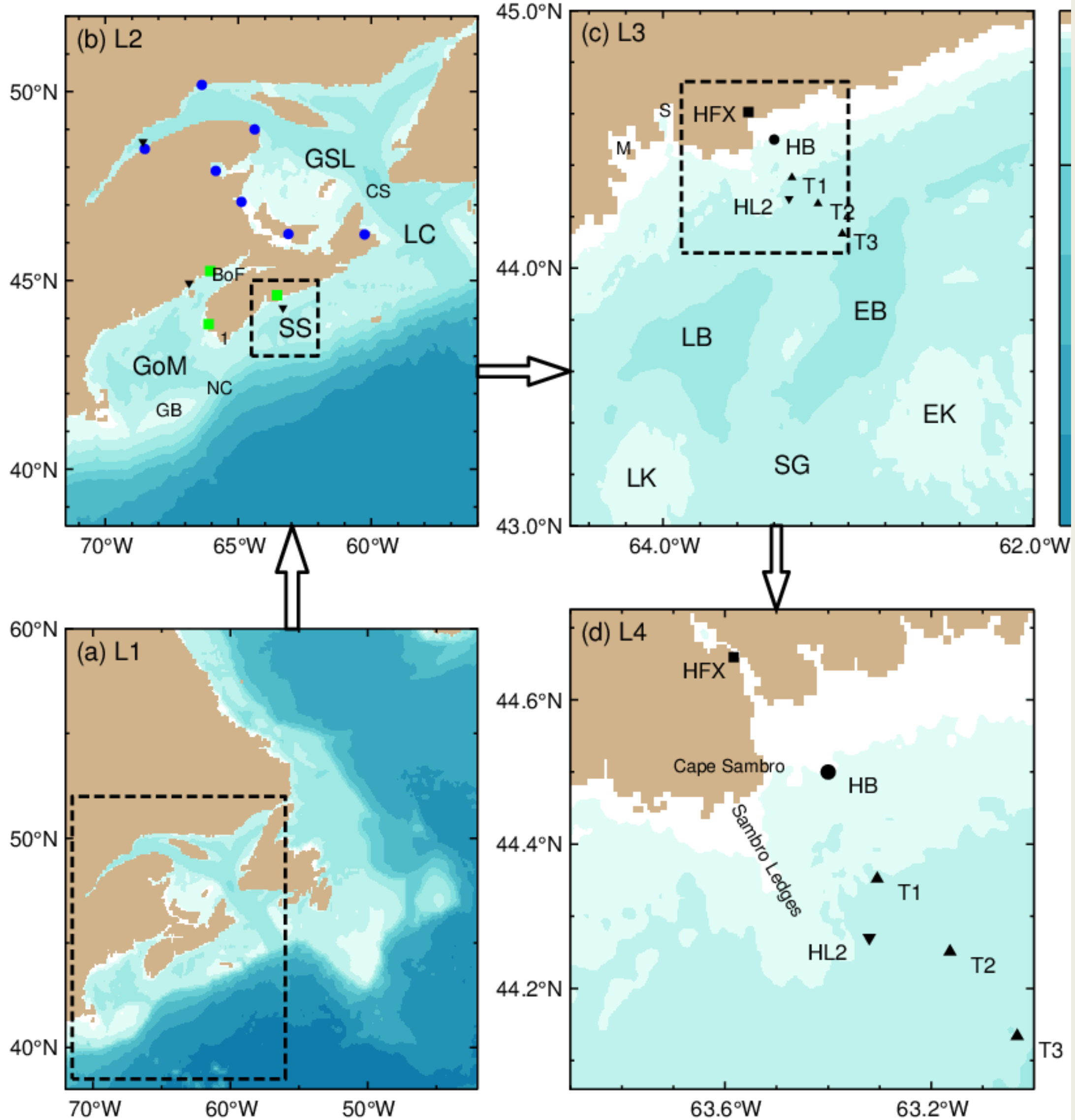
Introduction

- Circulation and hydrography on the Scotian Shelf have significant temporal and spatial variability, influenced by many forcing functions such as tides, surface heat and freshwater fluxes, estuarine outflow from the Gulf of St. Lawrence, resulting in a coastal current known as **the Nova Scotia Current**.
- Near-inertial oscillations (NIOs) are often generated over the region, which lead to strong vertical shear and contribute to upper-ocean mixing (e.g., Jochum et al. 2013).
- The NIOs can also influence the low-frequency flow in the ocean through the near-inertial Reynolds stresses (Taylor and Straub 2016).
- Low-frequency flows can influence the generation and propagation of NIOs (Alford et al. 2016).

- The effective inertial frequency of NIOs $(f_e = f + \frac{\zeta}{2}$, $\zeta = \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$) can be modified by a low-frequency flow through relative vorticity (ζ) (Kunze, 1985).
- Nonlinear interactions between NIOs and the mean flow in the open ocean were studied in the regions of the Gulf Stream (Zhai e al. 2004, Whitt and Thomas 2015) and Kuroshio Current (Jing et al., 2017). Studies were also made for some coastal and shelf waters.

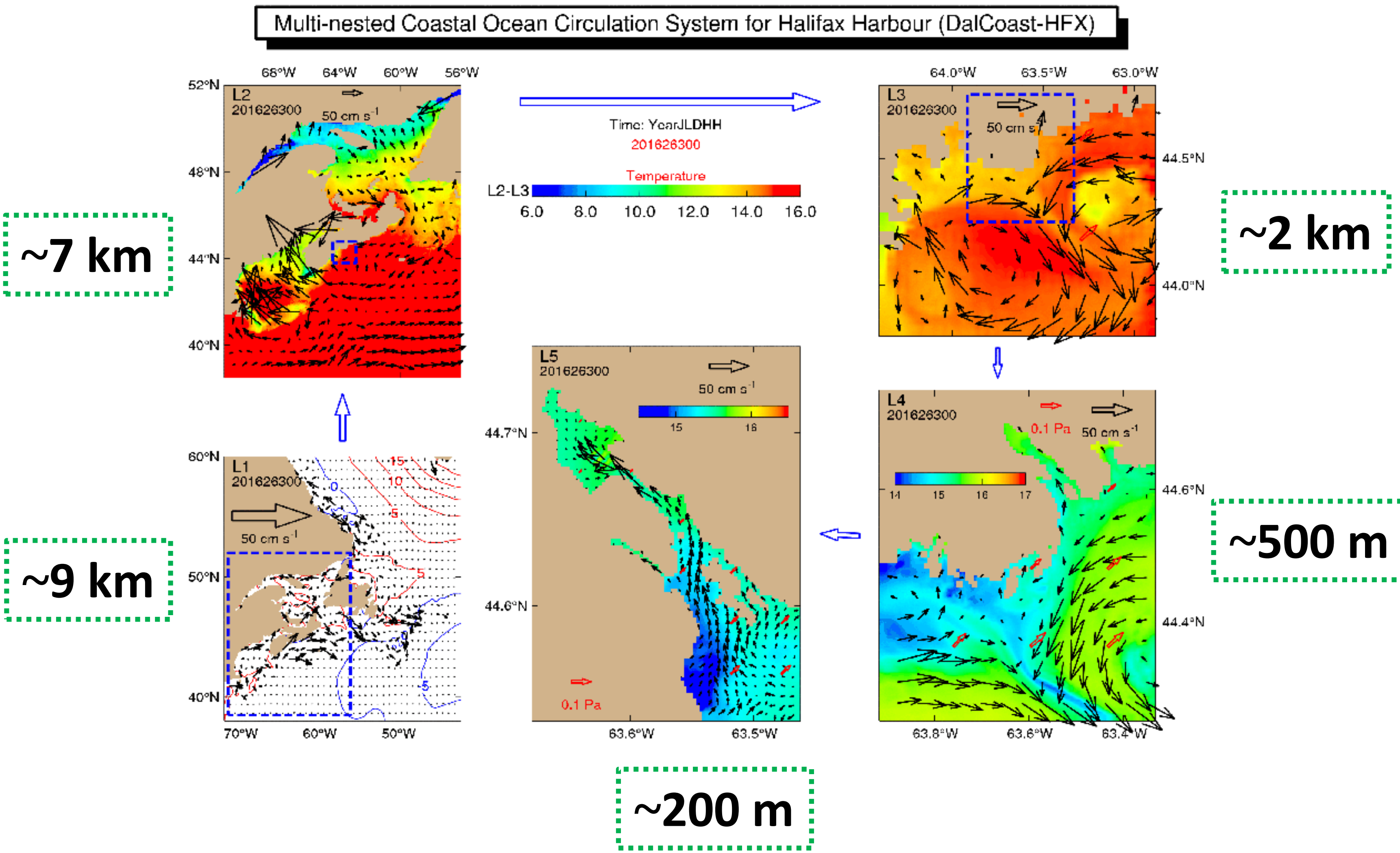
The main objective of this study is to examine how NIOs are modulated by the Nova Scotia Current over the inner Scotian Shelf using results produced by an operational shelf circulation model

An Operatinal Shelf Circulation model (DalCoast)



- **GEBCO Bathymetry (1 min)**
- **Horizontal resolutions: 1/12º, 1/16º, 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 submodels L2 and L3 (depth>40 m)**

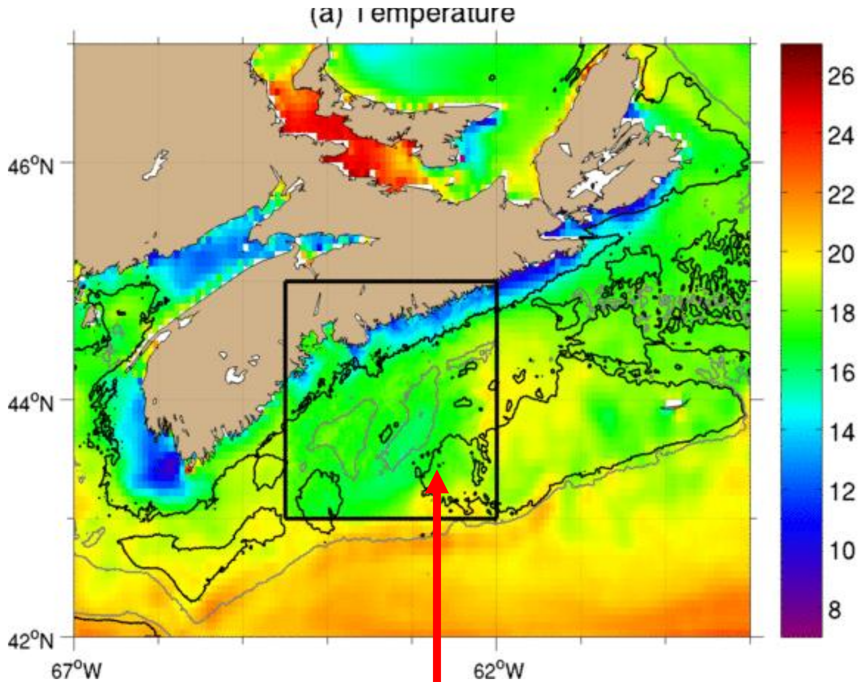
Real-time shelf circulation forecast system for Halifax Harbour (Sheng, Ohashi, Shan)



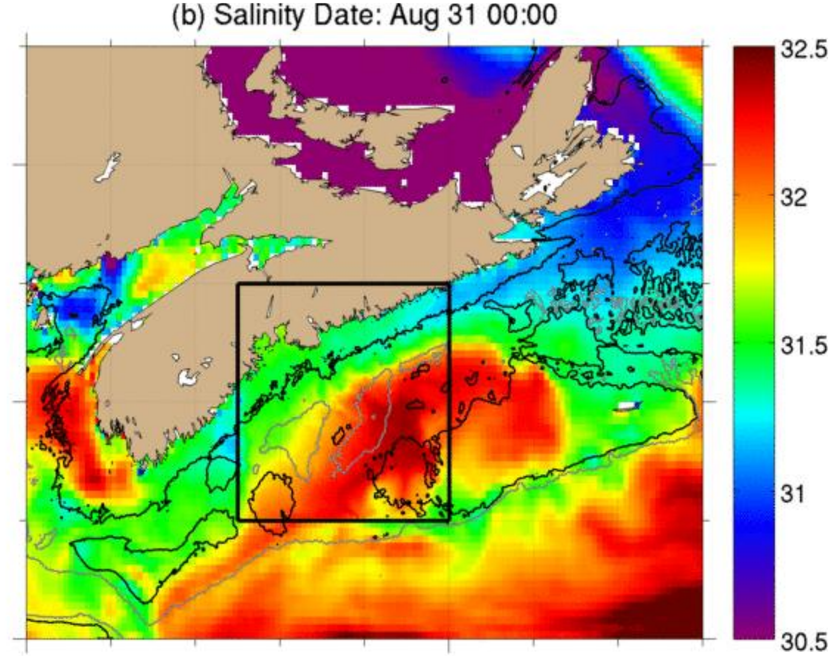
http://extrememarine.ocean.dal.ca/dalcoast/

Model Results (Aug 31-Sep 15, 2012)

(a) sea surface temperature



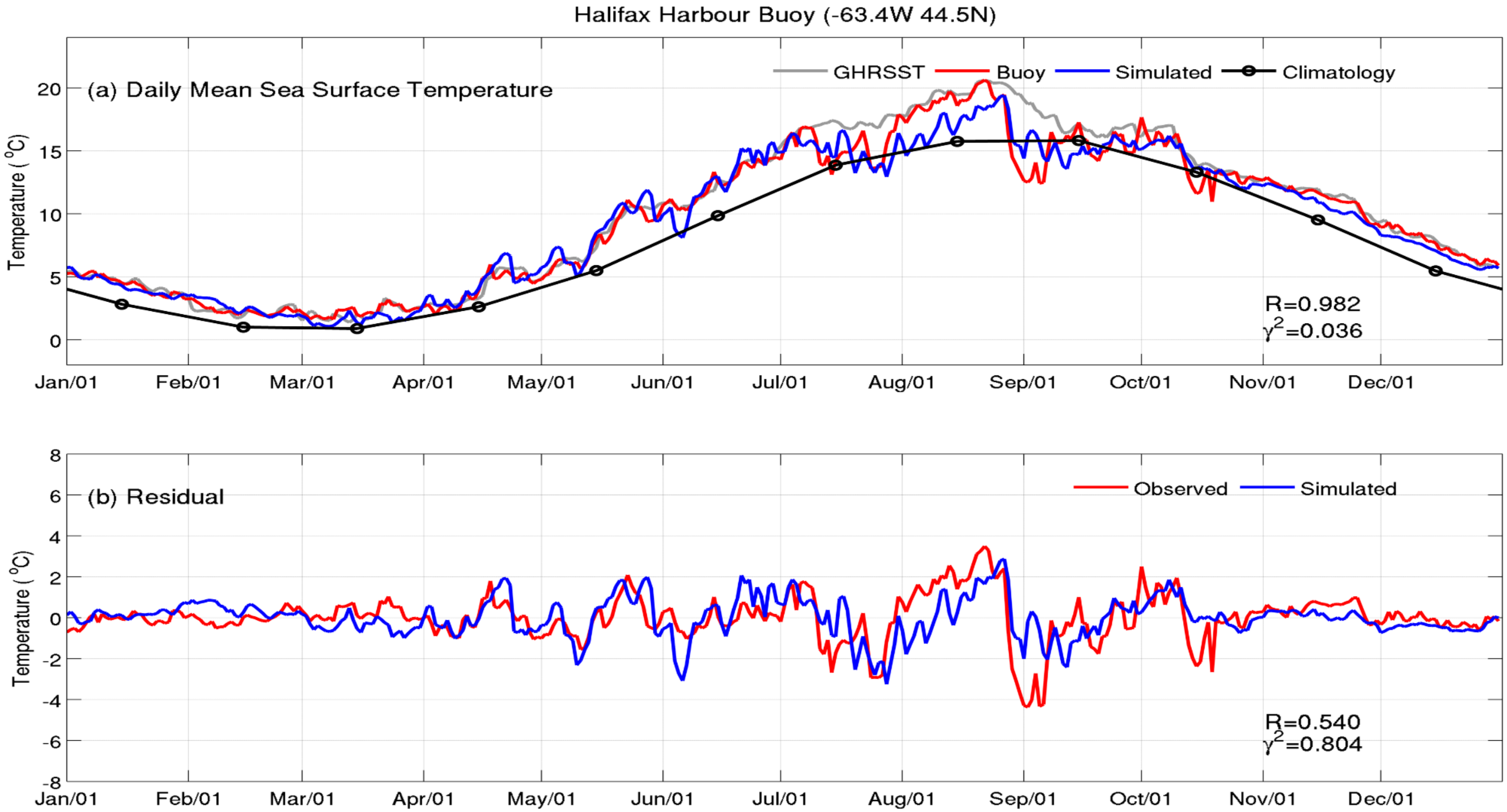
(b) sea surface salinity

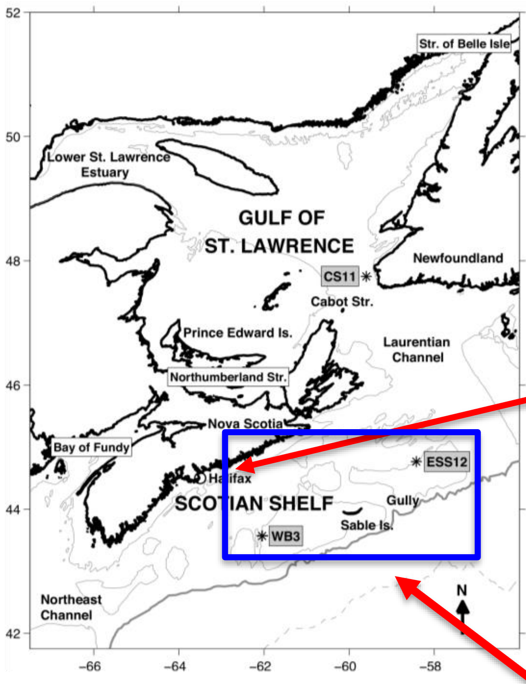


- **Results over the region marked by the black box are produced by the fine-resolution (2 km) sub-model.**
- **Outside this region, the model results are produced by the coarse-resolution (7 km) sub-model.**

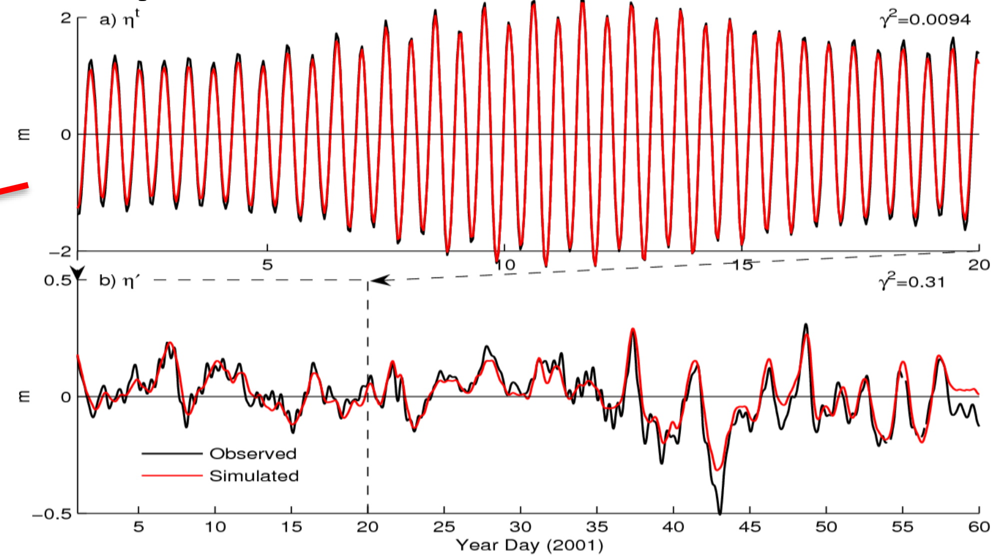
Model Validation

(a) Observed (red) and simulated (blue) SST in Halifax Harbour

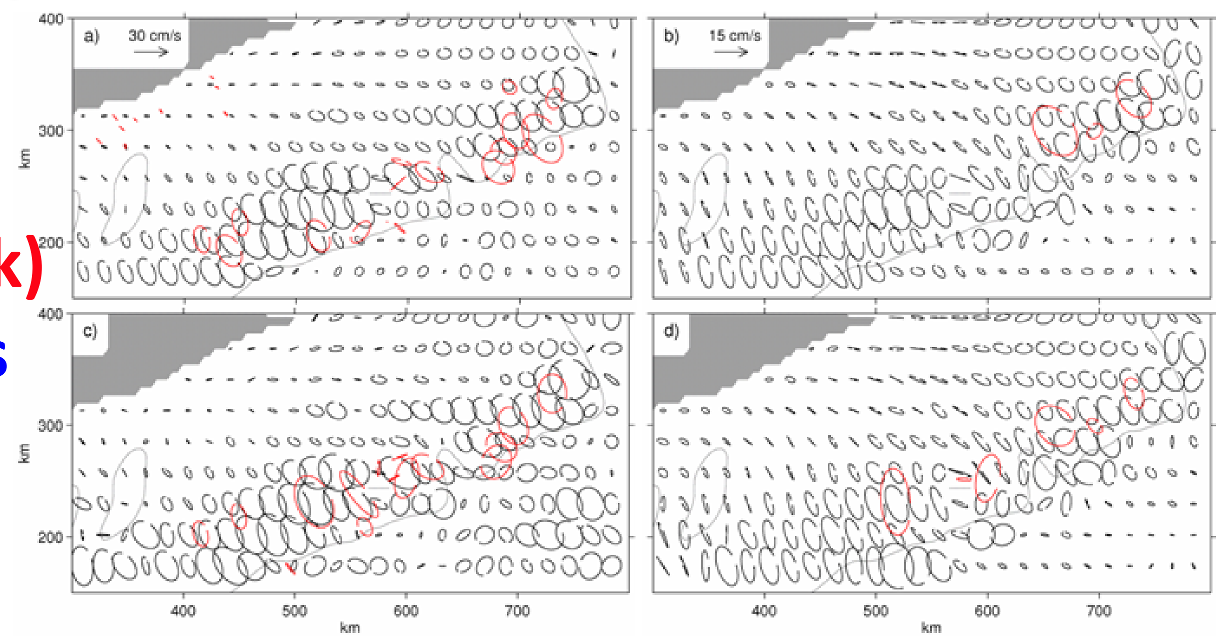




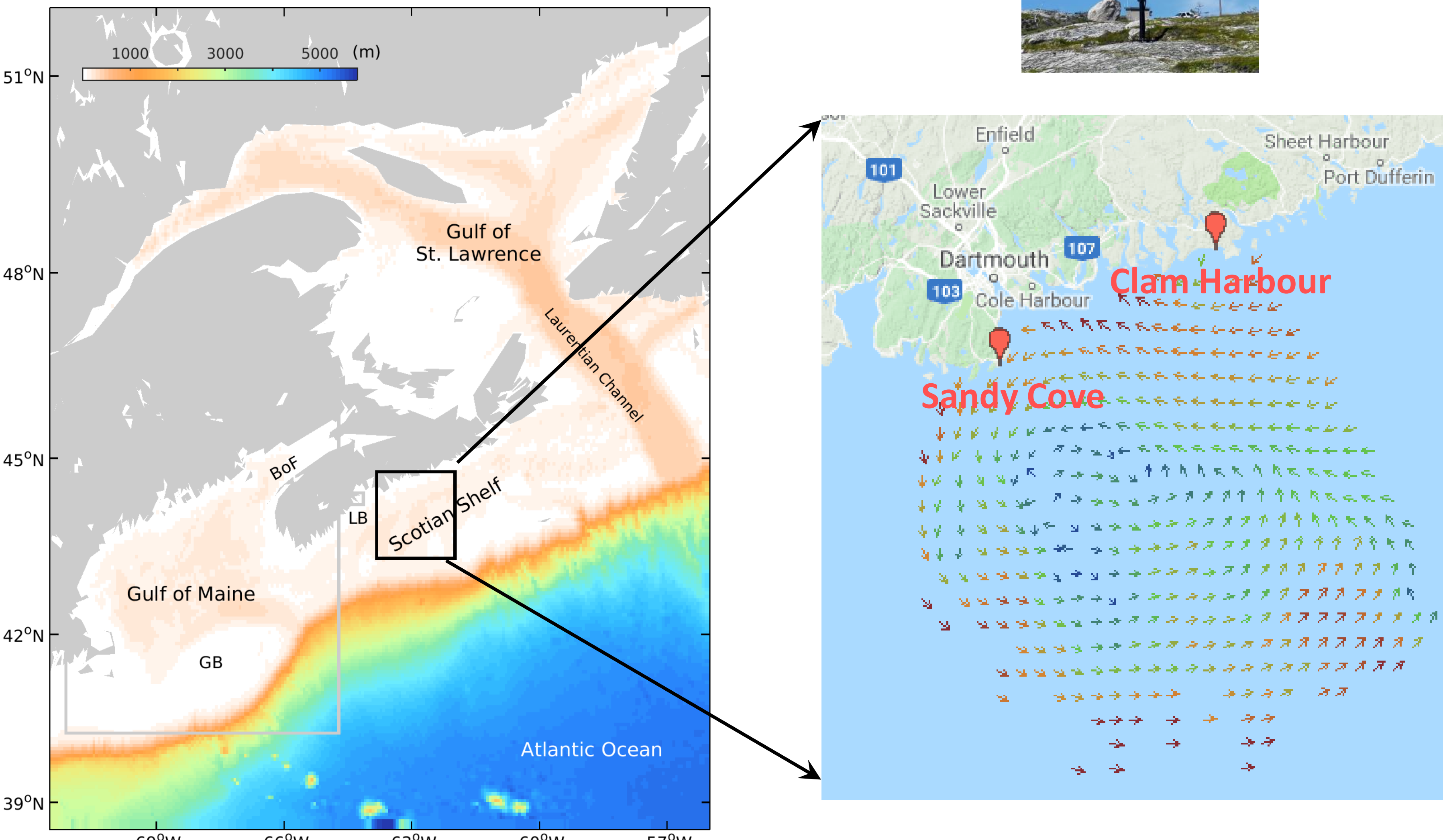
(b) Observed (red) and simulated (black) surface elevations



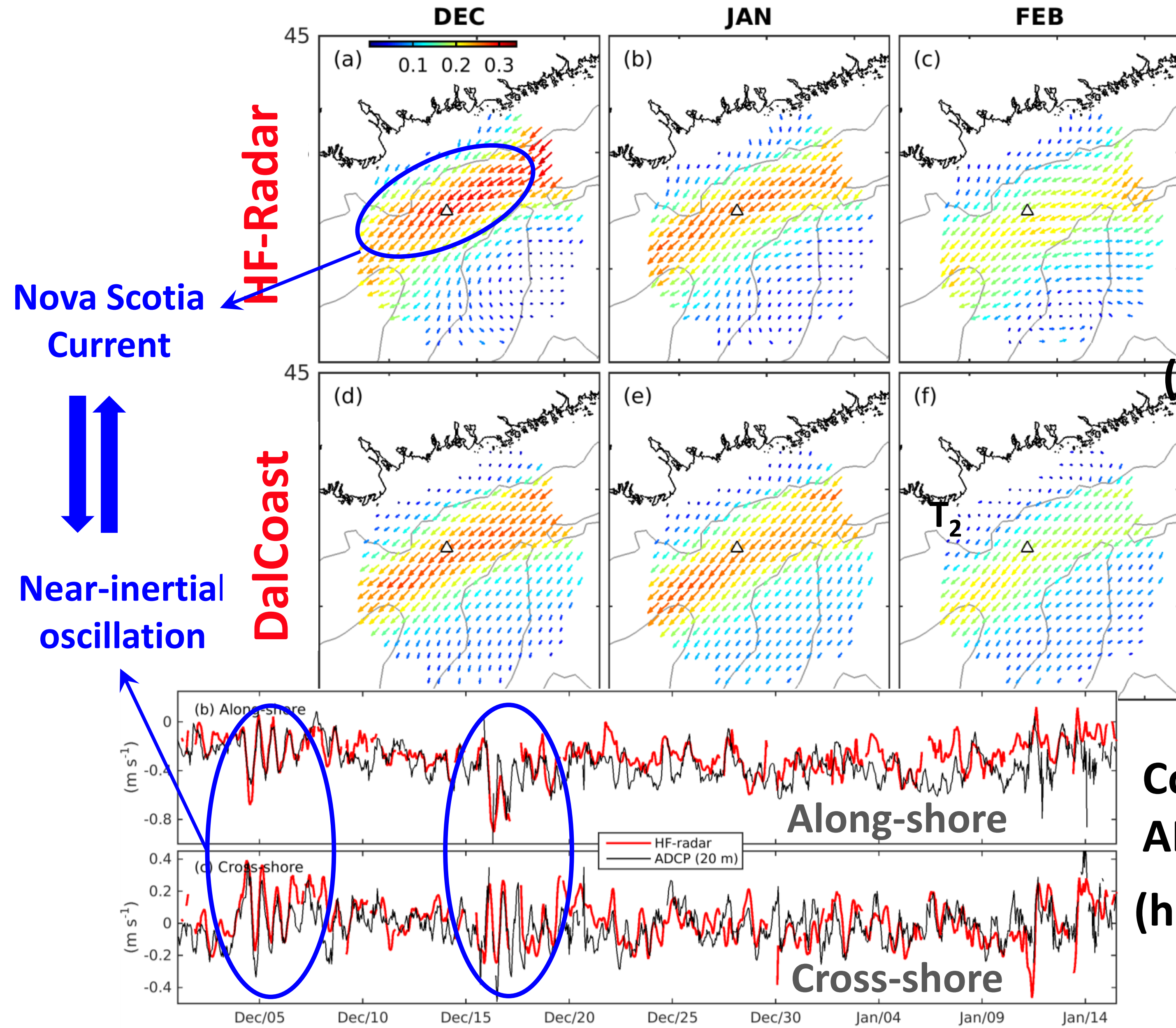
(c) Observed (red) and simulated (black) tidal current ellipses



A High-frequency (4.8 MHz) radar system for the Inner Scotian Shelf



(d) Observed (upper) and simulated (lower) monthly mean surface currents over the inner Scotian Shelf (Dec 2015-Feb 2016)



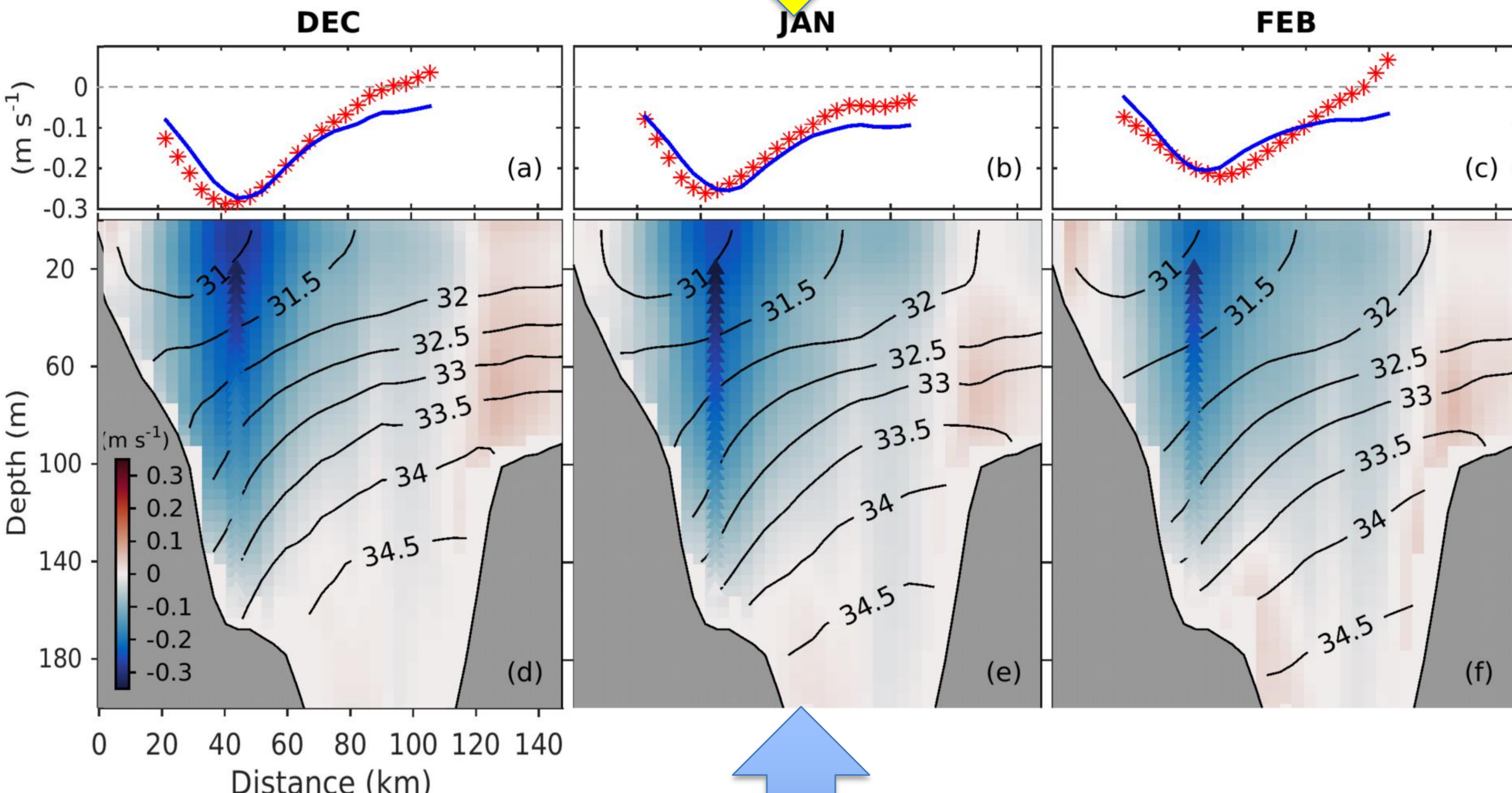
(Wang et al., *JPO, 2019)*

(monthly mean)

Comparison with ADCP data at site T_2

(hourly time series)

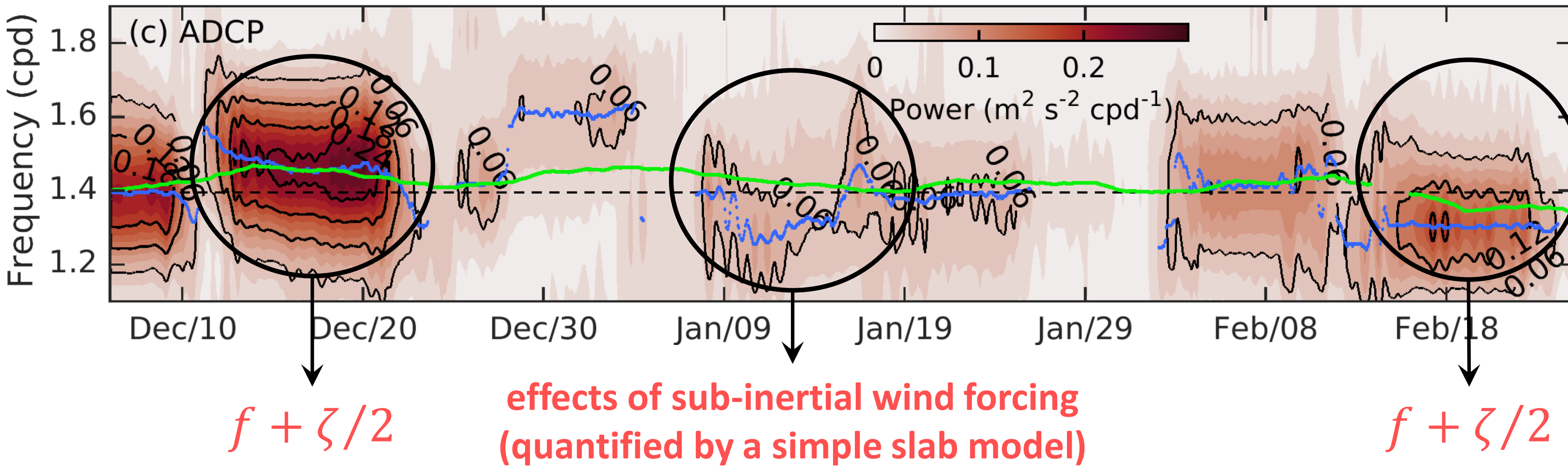
Observed (red) and simulated (blue) monthly mean alongshore surface currents at the Halifax Line as a function of offshore distance



Vertical profiles of monthly mean simulated currents and salinity at the Halifax Line. Colored triangles show the monthly mean currents observed by ADCP at location T2

Modulation of near-inertial frequencies by low-frequency current variations

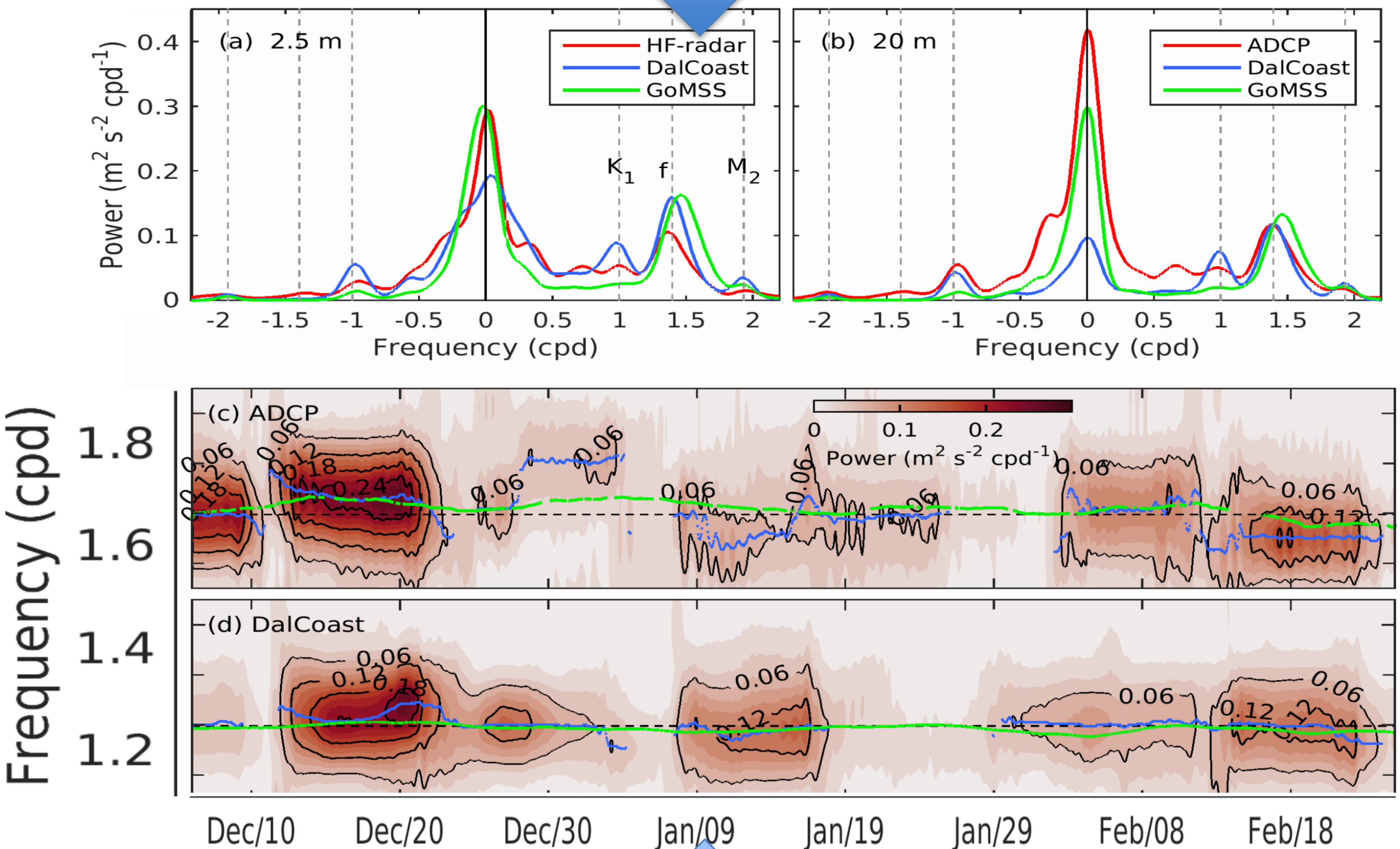
Relative vorticity correction: $f_e \approx f + \zeta/2$ (*Kunze*, 1985)



- - - - - - - - -	f	**Local Coriolis frequency**
(green line)	f_e	**Calculated from HF-radar data**
(blue line)	f_p	**Peak frequency of NIOs**

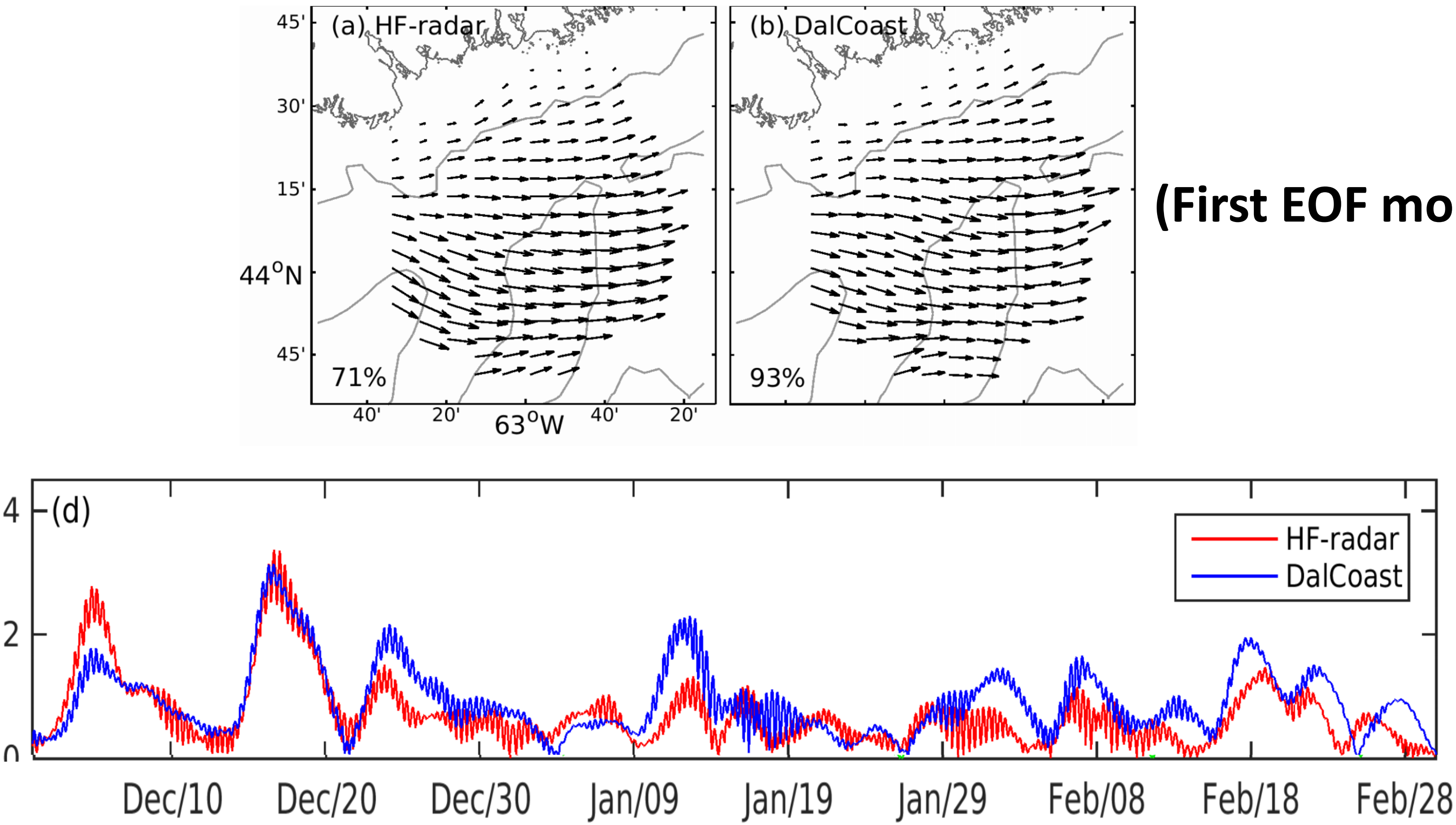
Time-evolution of ADCP observed rotary spectra at T2

Rotary spectra of observed and simulated currents at T2 at depths of (a) 2.5 m and (b) 20 m.



Time evolution of rotary spectrum of (c) ADCP observations and (d) model simulations at a depth of 20 m.

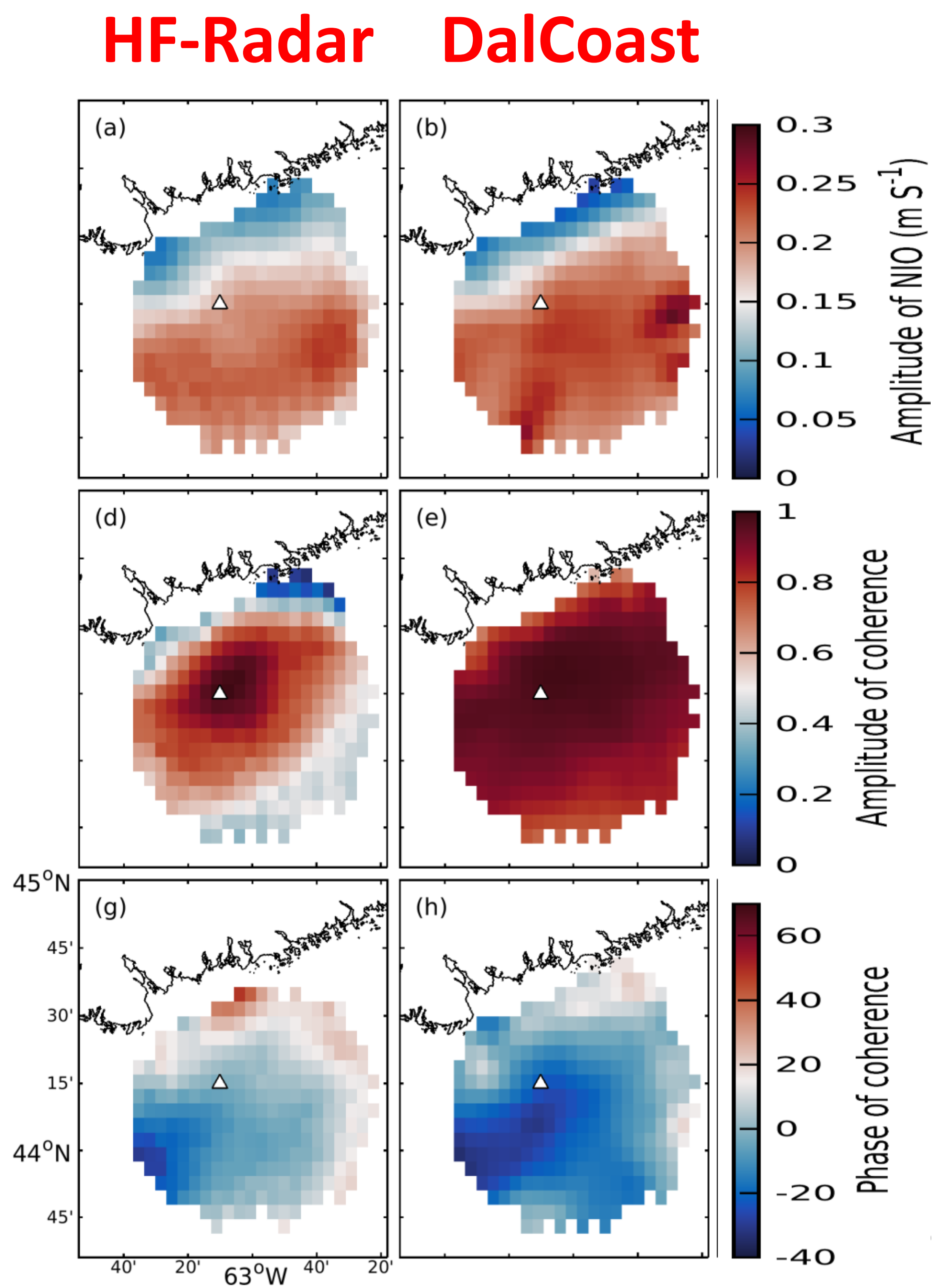
(a) HF-Radar (b) DalCoast



(First EOF mode)

EOF analysis of the HF-radar observations and model simulations after filtering to pass variations in the near-inertial band.

Distributions of observed and simulated amplitudes (upper), coherences (middle), and phases (lower) of NIOs over the inner Scotian Shelf.



Wang, He, Thompson and Sheng, 2019: Modulation of Near-Inertial Oscillations by Low-Frequency Current variations on the inner Scotian Shelf (Journal of Physical Oceanography)

Modulation of Near-Inertial Oscillations by Low-Frequency Current Variations on the Inner Scotian Shelf

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ABSTRACT

Near-inertial oscillations (NIOs) on the inner Scotian shelf are studied using observations, a simple slab model, and two operational shelf circulation models. High-frequency radar and ADCP observations from December 2015 to February 2016 show that individual NIO events forced by time-varying wind stress typically lasted for three to four inertial periods. NIOs with speeds exceeding 0.25 m s^{-1} were observed in the offshore part of the study region, but their amplitudes decreased shoreward within ~40 km of the coast. The NIOs had spatial scales of ~80 and ~40 km in the alongshore and cross-shore directions, respectively. The NIO phases varied moving from west to east, consistent with the typical movement of winter storms across the study region. Evolving rotary spectral analysis reveals that the peak frequency f_p of the NIOs varied with time by ~7% of the local inertial frequency. The variation in f_p can be explained in part by local wind forcing as demonstrated by the slab model. The remaining variation in f_p can be explained in part by variations in the background vorticity associated with changes in the strength and position of the Nova Scotia Current, an unstable baroclinic boundary current that runs along the coast to the southwest. Two operational shelf circulation models are used to examine the abovementioned features in the high-frequency radar and ADCP

Summary

- Near-inertial oscillations (NIOs) on the Scotian Shelf were examined using observations and model results.
- The observed peak frequency of NIOs varied with time by about 7% of the local inertial frequency, due to local wind forcing and variations in the background vorticity associated with the Nova Scotia Current.
- NIOs on the Scotian Shelf are driven primarily by time variations in wind stress associated with the passage of storms. Individual NIO events typically lasted for three or four inertial periods. NIOs with speeds exceeding 0.25 m/s were observed in the offshore part of the study region.
- The horizontal distribution of the phase of the NIOs suggests northeastward propagation, consistent with typical movement of winter storms.

Thank you!