High frequency hydrodynamics around Saint-Pierre and Miquelon archipelago

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Winter observations

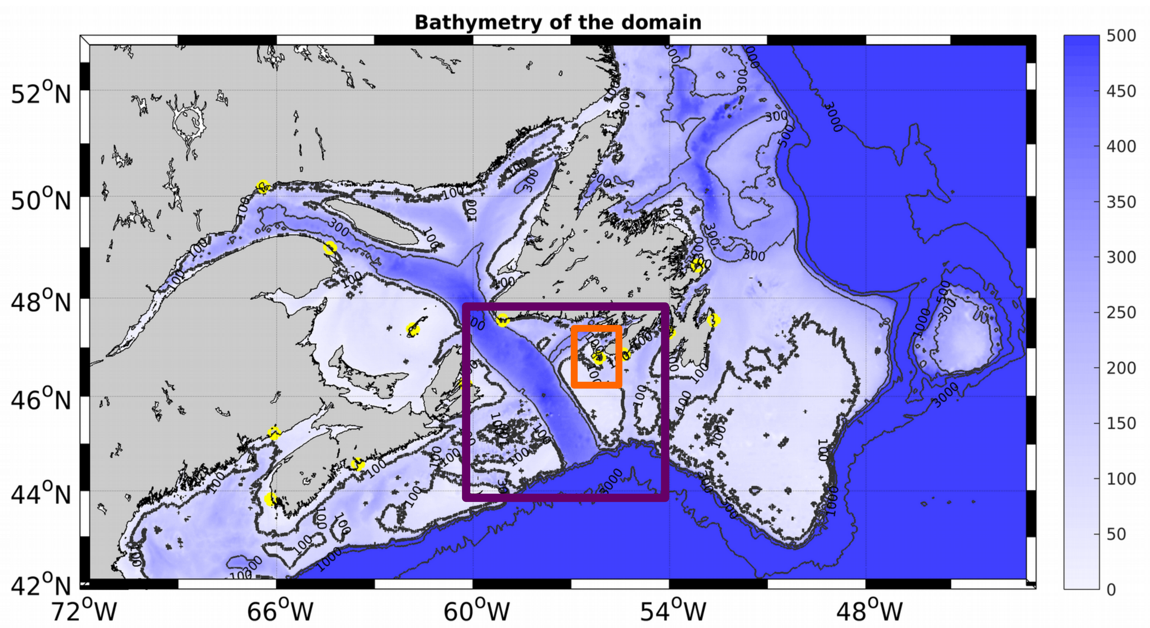


Fig. 1 : Bathymetry of the model domain. In orange: location of Saint Pierre and Miquelon. Yellow points: location of Canadian tide gauges.

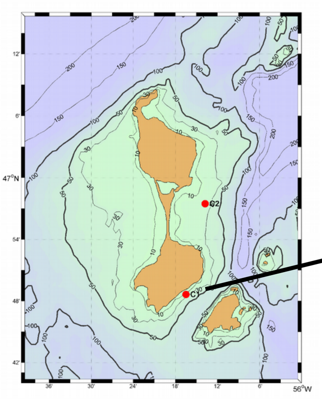


Fig. 2. Bathymetry at SPM and location of the 2 ADCPs in 2014.

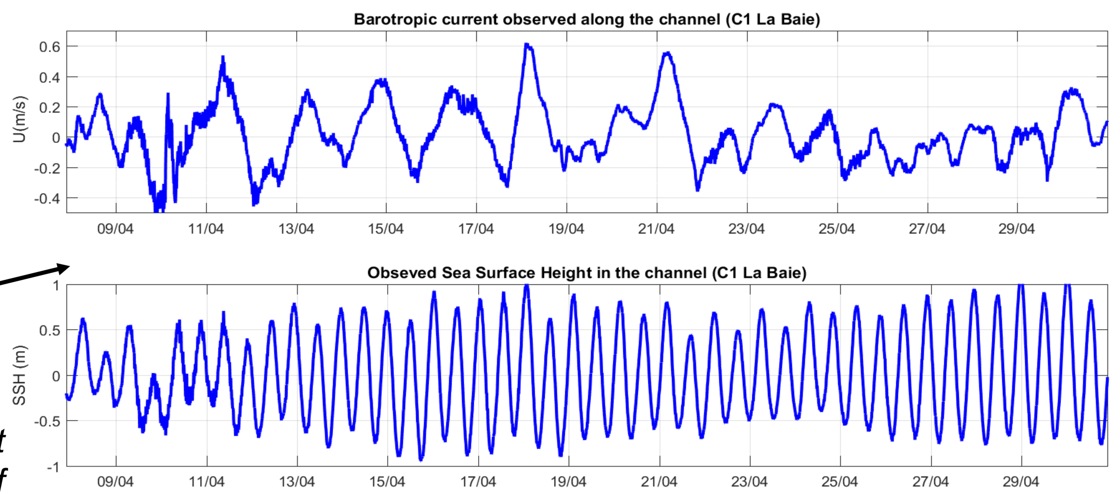


Fig. 3. Observed along channel current (top) and sea surface height (bottom) at the location of the ADCP in the channel.

Observations:

- Barotropic currents and no stratification in winter.

-Tidal currents are mainly diurnal and can reach 0.15 m.s^{-1} (ex: end of April).

-New: Strong currents can reach more than 0.5 m.s^{-1} with a surprizing periodicity ~2-days (ex. 10-22 April 2014).

What are the physical processes behind these ~2-days oscillations ?

Strategy : - Realistic barotropic model simulations and academic simulations to investigate the physical processes at stake.

Barotropic MARS Model (Lazure et Dumas 2008) encompassing: Newfoundland, Saint Laurent Gulf and Nova Scotia shelf (Fig.1) with a resolution of 2km

Boundary conditions : - Tidal boundary conditions : FES (Finite Element Solution) 2004, 8 tidal constituents, 1/8° grid (Lyard et al 2006).

- Wind forcing and pressure field : ECMWF reanalysis, spatial resolution is 30km and time resolution is 3h.

Validation: - The main tidal components are in good accordance with observations (not shown).

- Comparison of observations and model results on realistic simulation (Fig 4 lower panel).

Realistic simulations

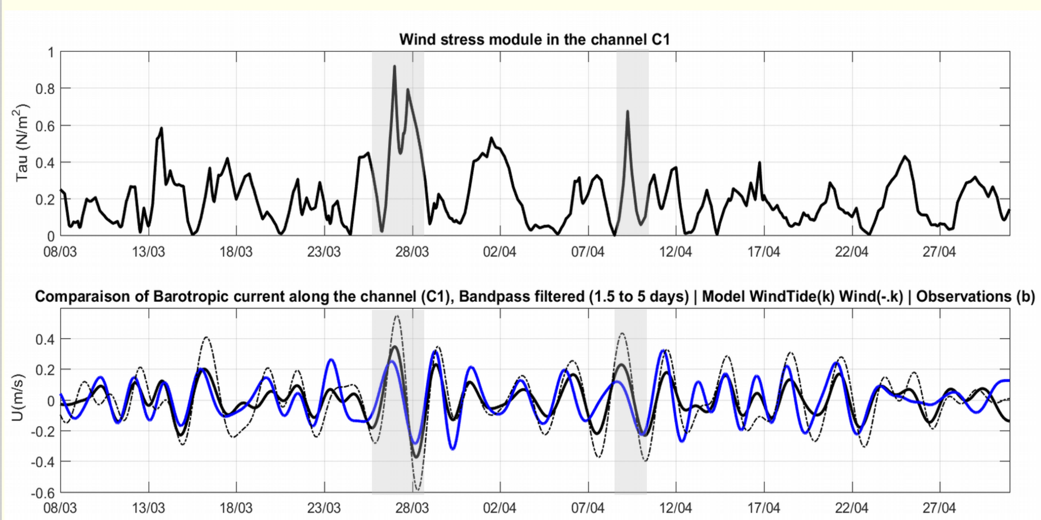


Fig. 4. Upper panel : Wind stress at the location of the ADCP (location fig.2). Lower panel : Along shore current, modelled (with wind and tide forcings in black line, with only wind forcing in dash line) and observed (in blue), filtered using a bandpass filter from periods of 1.5 to 5 days.

- The filtered along channel currents from both the model and the observations are consistent and in phase. The ~2-days oscillations are well reproduced by the model.

- The ~2-days oscillations appear during storm event (ex 13-14 March or 27-28 March or 7 April 2014).

- In the realistic simulation with no tide we reproduce the ~2-days oscillations with larger amplitudes.

- The ~2-days oscillations are trigged by wind events.

- It suggests that the wind is able to give rise to a Continental Shelf Wave near SPM.

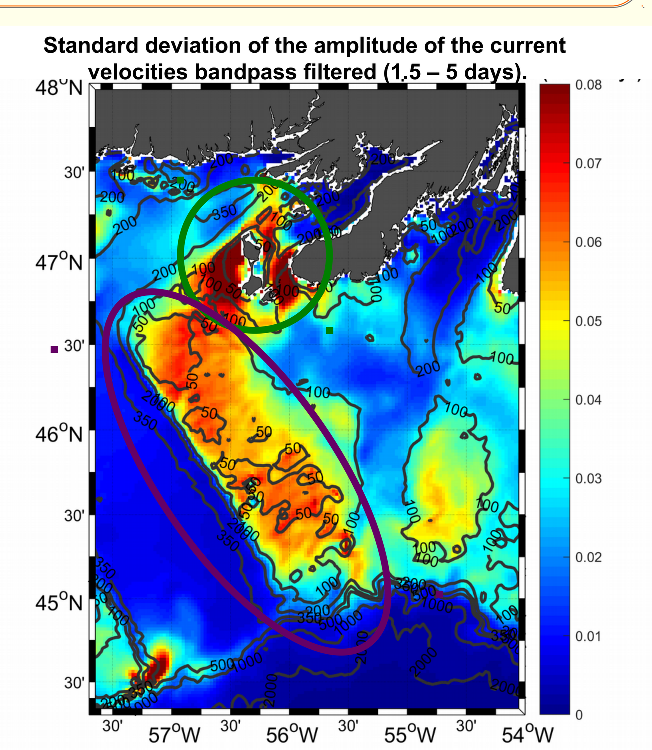


Fig. 5. Mean velocity of the filtered current components using a band pass filter which keeps periods from 1.5 to 5 days.

➜ **Areas where these ~2-days oscillations are maximum:**

- **around the archipelago of SPM.**
- **and Saint Pierre Bank.**

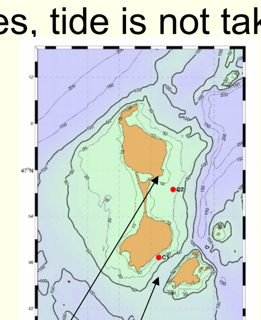
➜ Saint Pierre Bank is a major topographic feature with depth as shallow as 50m. It rises the question of the role of the bathymetry and the propagation of the Continental Shelf Waves around a topographic feature (Huthnance 1974).

Academic simulations

A periodic SW-NE wind, with a speed equal to 10 m/s is used in the academic cases, tide is not taken into account.

$$\tau_{xy} = \tau_0 \sin\left(\frac{2\pi}{T}t\right)$$

7 simulations with the period T ranging from a 1-day to a 5-days period.



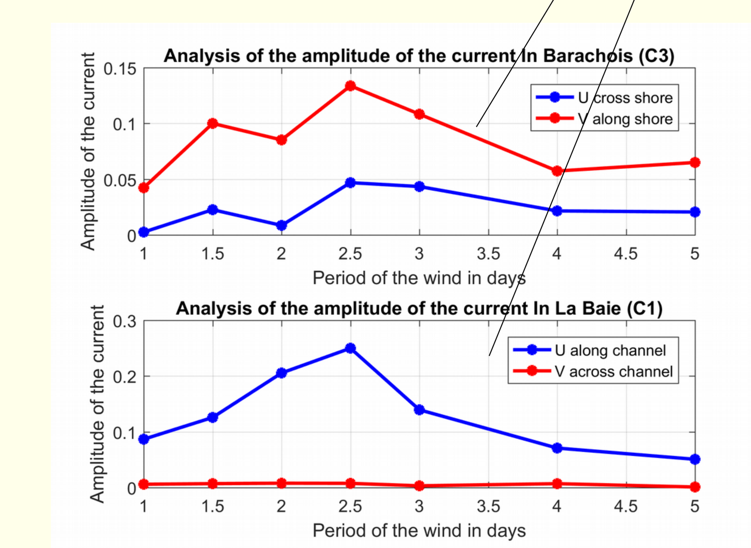
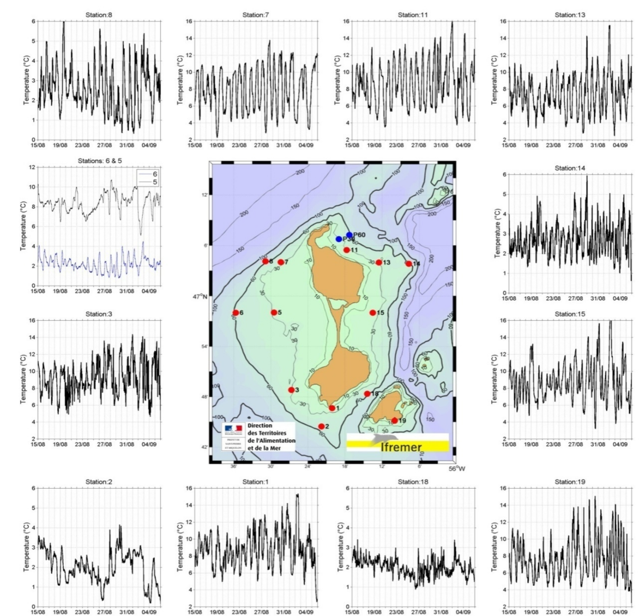


Fig. 6. Maximum amplitudes of the current velocities at the 2 ADCPs locations.

➜ **The wind with a 2.5 day period produces the strongest current. The periodic wind with that frequency can induce a resonance around the archipelago due to topography.**

Summer Circulation

The data set consist in two years of observations: In 2015 : 13 bottom temperature records at 30 m and 60 m depth. In 2017 : 5 cross shore transects of thermistor moorings (every 10 m from surface to bottom) by depth of 20-30-40-60-80 m.



-temperature oscillations everywhere around the archipelago witch can reach 10°C.

- dominant period of these oscillations is 25.81h = to the tidal component O1 period.

- M2 component in the bottom temperature signal on the Eastern coast of SPM (spectral analysis).

Fig. 8. Bottom temperature 30m and 60m depth summer 2015 (Lazure et al 2017 submitted).

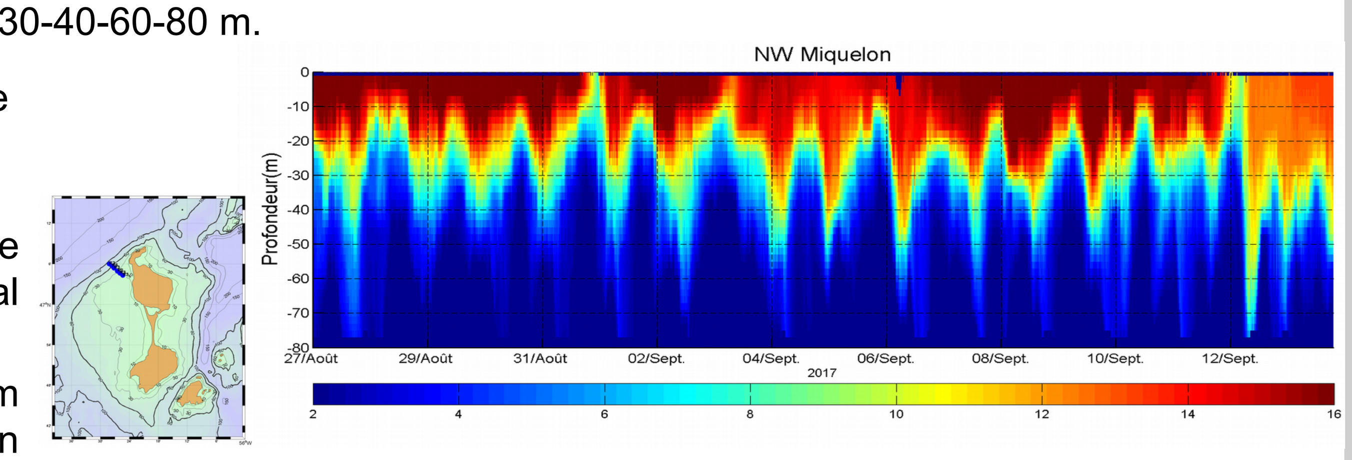


Fig. 9. Positions and Temperature record of 80 m depth mooring summer 2017

-Diurnal isotherm oscillations is observed in the water column.

- Ranging from 2 to 14°C with a vertical range of 10 to 40 m.

What are the physical processes behind these diurnal temperature oscillations ?

First simulation in 3D modelling, tidal considering a schematic summer stratification.

•3D MARS Model (Lazure et Dumas 2008) with a spatial resolution of 500 m, on a smaller domain (see purple square fig.1.).

•Tidal boundary conditions provided by the large scale 2D simulation.

•Summer stratification, spatially homogeneous in the all domain

•From 0 to 80 m mean profit from the measurement of summer 2017

•From 80 to 6600 m values from the climatology GDEM

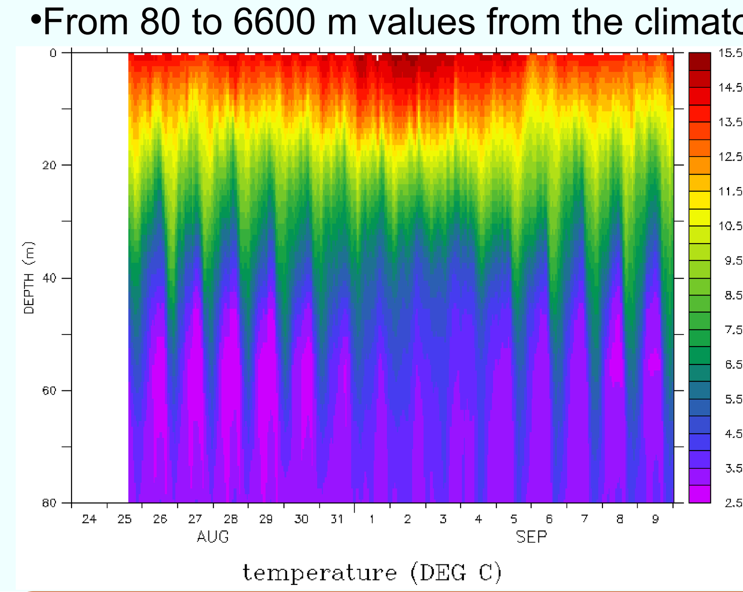


Fig. 10. Temperature modeled at 80m depth (same location than fig.9)

- Results of the first 3D model simulation.

•Range of the temperature is consistent with the data.

•Diurnal oscillation is accurately represented.

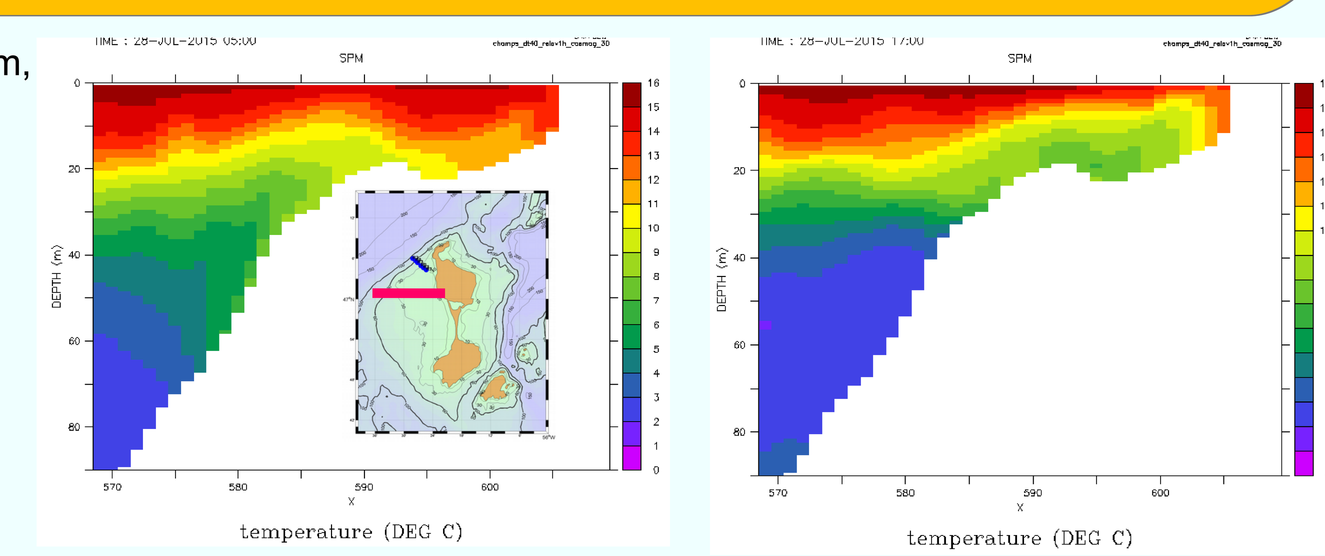


Fig. 11. Modeled Temperature evolution on the transect North West of Miquelon. Right panel : temperature on July 28th 2015 at 5h, Left panel : temperature on July 28th 2015 at 17h.

- The temperature is at the same range than the observation. The cold waters from the bottom are moving to surface along the slope of the topography, with a period of 26h.

Conclusions and Perspectives

Conclusions :

- As shown by the model strong wind events are the root cause of these ~2-days oscillations.

-This study is consistent with previous studies of the impact of different storms on the Newfoundland Shelf which highlights current and sea level oscillations from 22h to 4 days (Ma 2015, Thiebault and Vennell 2010). According to the academic experiments, the response of the current near Saint Pierre et Miquelon and Saint Pierre Bank is maximum for a 2.5 day period wind forcing.

- Diurnal (dominated by O1 period 26h) oscillations on bottom temperature has been observed in 2015 and summer and early fall in 2017 with the cross shore transect moorings deployed. Considering that at the latitude (~47°) those oscillations are sub-inertial, the internal tide can't propagate freely. It is trapped by bathymetry and forced to propagate clockwise as shown by the theory (Huthnance 1978, among others)

Perspectives :

- Improvement of the theoretical model and study the propagation of wind driven motions over continental shelf (Brink et Chapman 1987).

- Validation of the 3D model. Sensitivity studies on different parameters such as turbulence for the 3D model. Investigation of the effect of the stratification and coastal trapped waves dynamics.

- Analysis of the data from the field trip of September 2017.

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