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Effect of wind forcing on the oceanographic conditions in Fortune Bay a large mid-latitude fjord

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INTRODUCTION

Fortune Bay is a long (~130 km), wide (~20 km) and deep (~600 m at its deepest point and ~430 m within its main basin) fjord located on the southern shore of Newfoundland, a large island off the East coast of Canada and off the French archipelago of St Pierre and Miquelon (**Figure 1**).

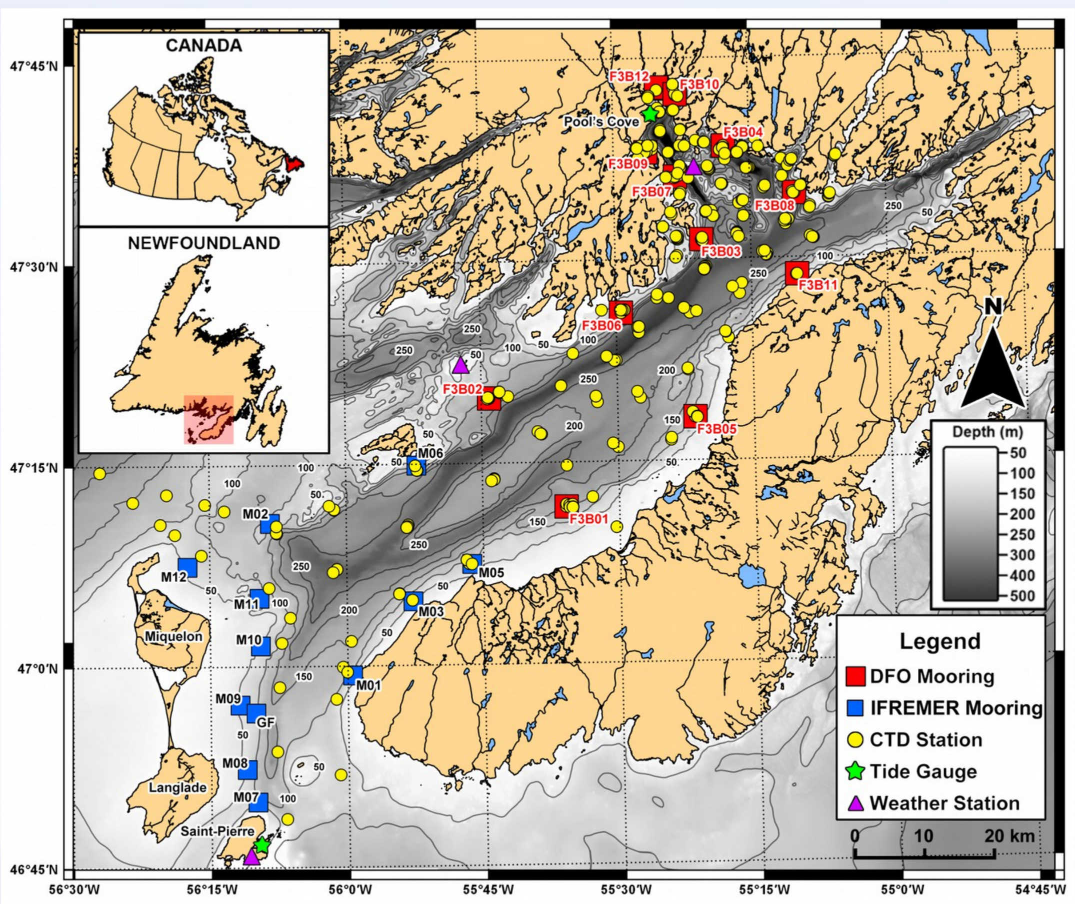

Figure 1. Study area (Fortune Bay) and summary of the observational program executed from May 2015 to May 2017.

Due to its shear size, volume and to the general lack of tidal amplification around Newfoundland, tidal ranges are small (~2m) and tidal currents are weak (<10% of the total variance of observed currents in most of Belle Bay, main head of the fjord; DFO, 2016).

While being exposed from cold Arctic water (i.e., Labrador Current) Fortune Bay is located in mid-latitude (47°N), thus receiving a significant amount of solar radiation in summer which strongly stratifies its water column (**Figure 3**).

Wind, as opposed to the tide, appears to be a major force affecting the oceanographic conditions observed. Oceanographic response from this forcing is mainly expressed as spatial and temporal variations of the thermocline, i.e., as upwelling and downwelling events (**Figure 5**) associated with surface and sub-surface currents (Salcedo-Castro and Ratsimandresy, 2013).

RESEARCH OBJECTIVES

1) To identify the dominant processes generated by the wind, e.g., possible coastally trapped waves type internal Kelvin wave and/or seiche, by means of observations.
2) To reproduce those processes using a numerical model.

This poster presents a summary of the observation component with a focus on summer & fall.

DATA

The core of the observation program consisted of the deployment of oceanographic moorings made of ADCPs (Acoustic Doppler Current Profilers), CTDs (Conductivity, Temperature and Depth sensors) and thermistors which allowed continuous measurement of water column stratification (temperature and salinity) and current structure at the same time and along the same line (**Figure 1 & Figure 2**).

These long-term measurements were completed by other long-term but land-based observations of wind (speed and direction) from weather stations and water levels from tide gauges as well as short-term snapshots of the water structure (CTD surveys) at seasonal time scale (spring, summer and fall) as presented in **Figure 1**.

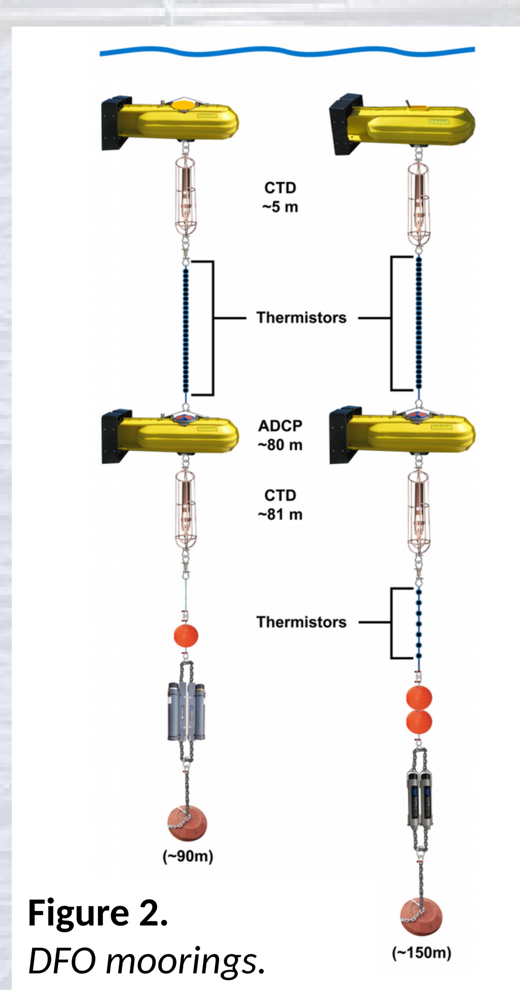

Figure 2.
DFO moorings.

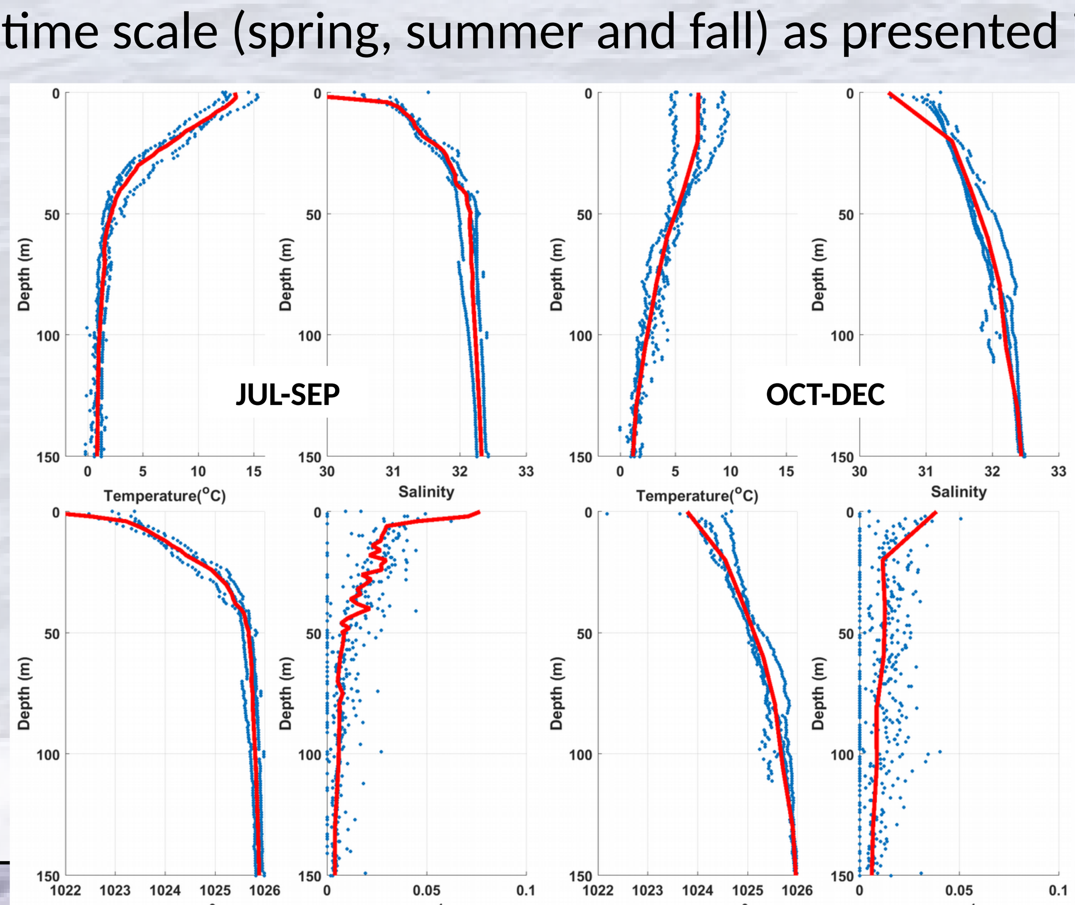

Figure 3. Temperature and Salinity profiles climatology based on 1349 casts collected from 1925 to 2017. Blue dots represent monthly averages while the red line is a vertical bin average of the later.

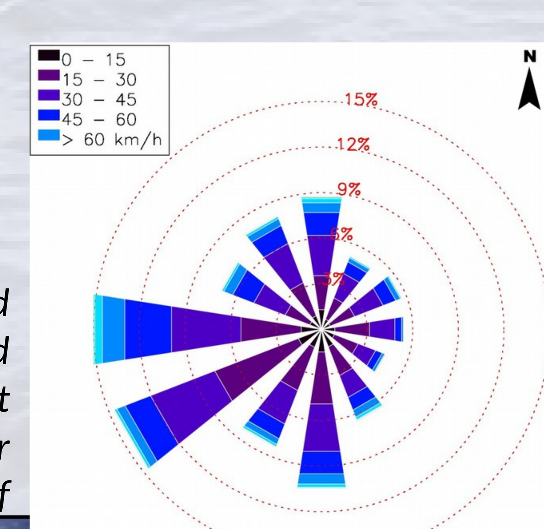

Figure 4. Wind rose climate based on hourly data collected from 1994 to 2013 at Sagona Island, a weather station located west of F3B02 on Figure 1.

***Note:** wind is comparable at all stations presented in Figure 1.*

KEY RESULTS AND DISCUSSION

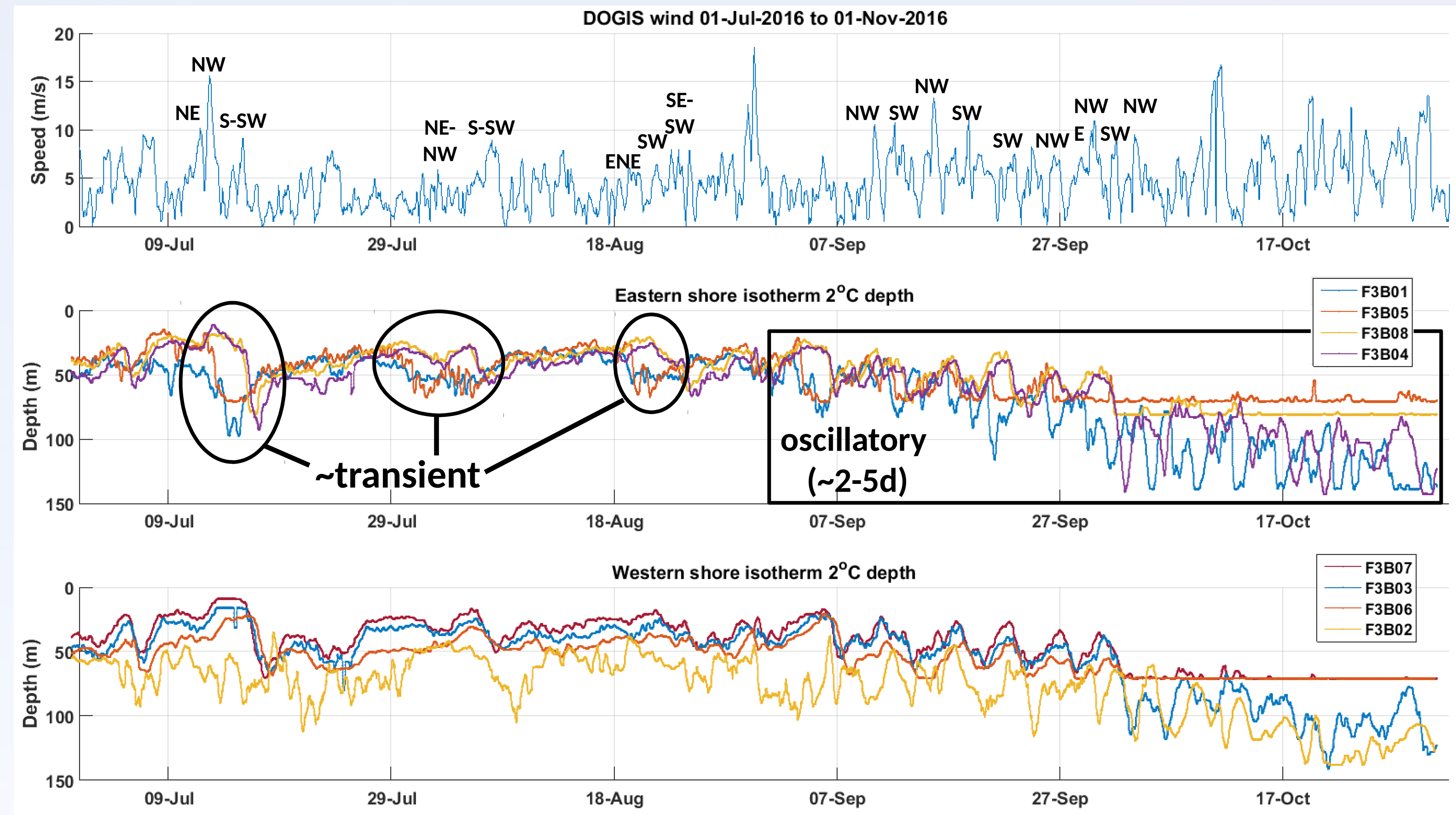

*Figure 5. timeseries of wind speed as measured at Dog Island (between F3B07 & F3B04) and 2°C isotherm depth measured at the moorings 01-08 (Figure 1). **Note:** in fall, the 2°C isotherms were located deeper than mooring's depth at F3B05, 08, 07 and 06.*

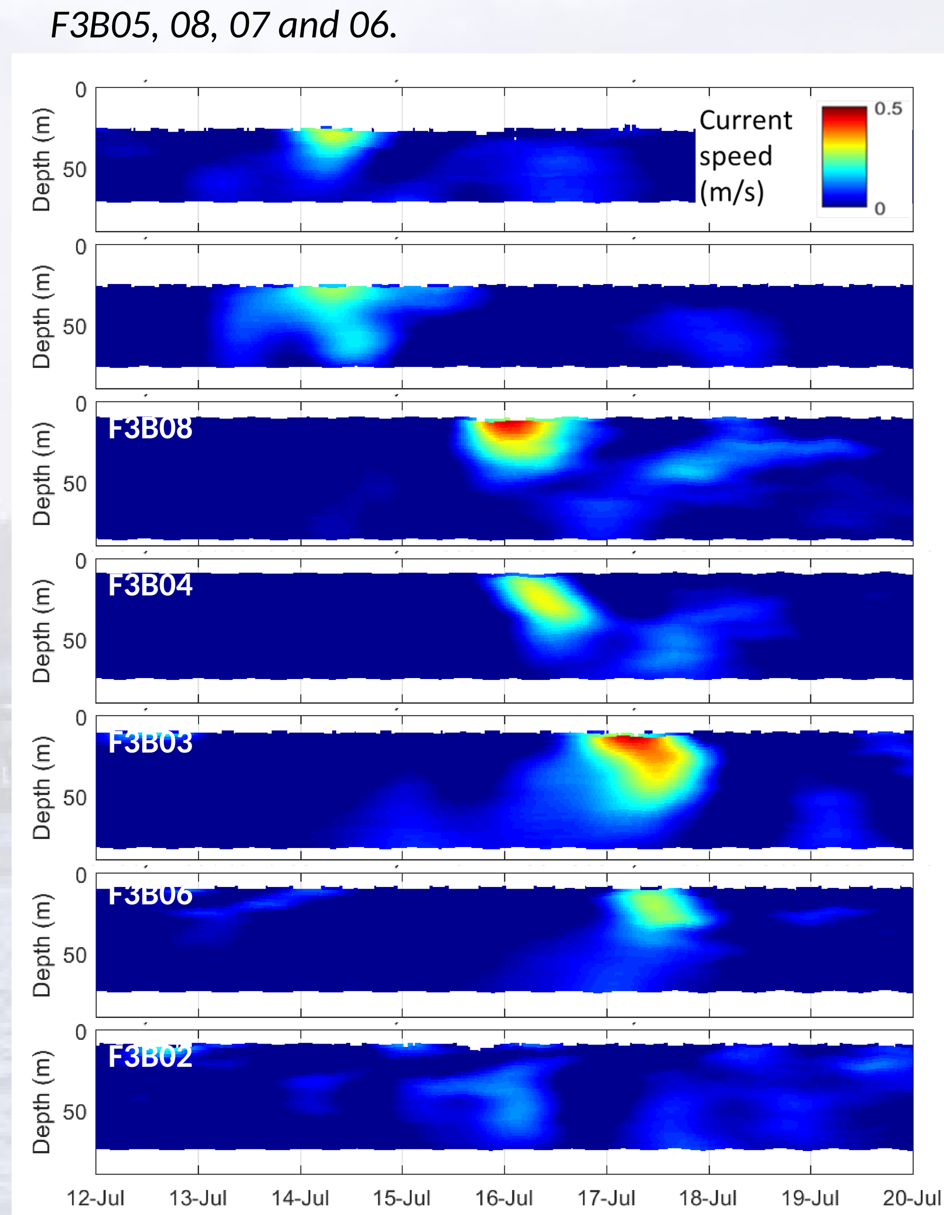

Figure 6. Transient event example showing current speed (25hr low pass) as measured from F3B01 to F3B08 (Figure 1).

- **Transient upwelling**
- NE-NW wind (Jul 12-13) generated upwelling from F3B01 to F3B04 and was followed by a relaxation (light winds) enhanced by SW winds (**Figure 5**).
- Similar events occurred an other couple of times during summer (**Figure 5**).

- **Propagation around the bay**
- Pulse of current generated (**Figure 6**) is strongest during downwelling.
- Current pulse (wave) is propagating counter-clockwise with the coast to the right (from F3B01 to F3B02) and is much dissipated at F3B02 (**Figure 6**), consistent with the hypothesis of an internal Kelvin wave.
- 'Return' flow appears weak compared to the 'inward' (wave propagation direction) flow (light blue area occurring 1-2 days after yellow-red peak; **Figure 6**).
- Phase propagation is ~0.25 m/s in summer and increases to ~0.4 m/s in fall; which is slower than theory would predict for a pure internal Kelvin (~0.5 to 0.7 m/s, respectively).

- **Oscillatory period**

Seems to be the result of direct wind forcing within 1-5 d frequency band (**Figure 8**). Zoom on the currents for this period (as in Figure 6 but not shown) indicates same counter-clockwise propagation pattern.

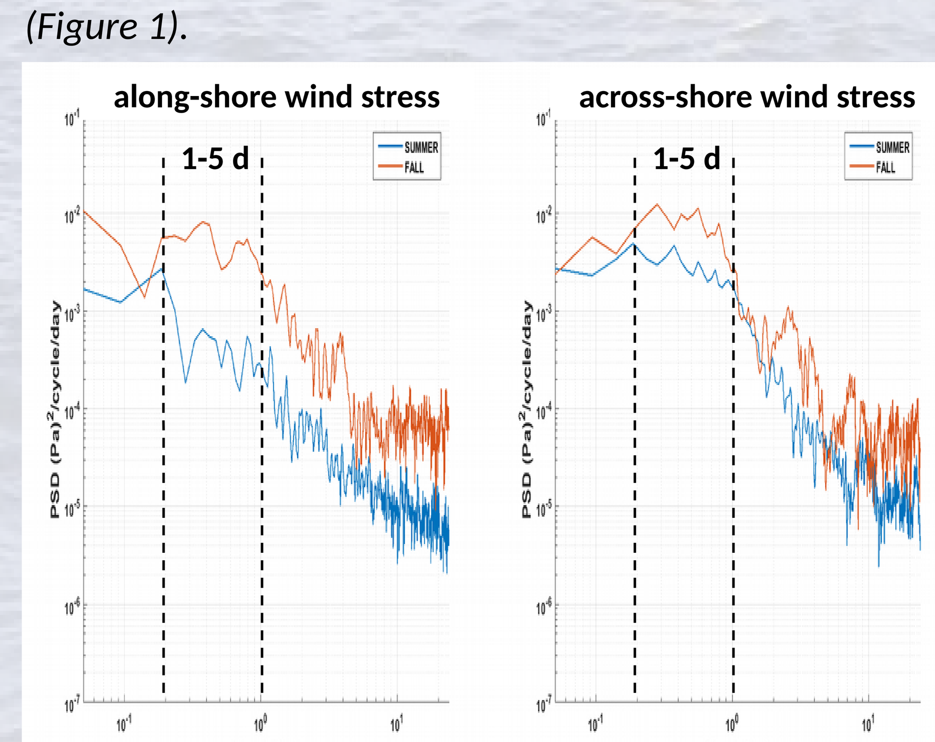

Figure 8. Power spectrum of along-shore (SW-NE) and across-shore (NW-SE) components of wind stress.

PERSPECTIVES

Reproduce those processes using a numerical model.

REFERENCES

- Fisheries and Oceans Canada, 2016. State of Knowledge of the Oceanography and Water Exchange on the South Coast of Newfoundland to Support the Development of Bay Management Areas for Finfish Aquaculture, Ottawa, ON: Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Science Advisory Report 2016/039.
- Salcedo-Castro, J., and Ratsimandresy, A.W. 2013. Oceanographic response to the passage of hurricanes in Belle Bay, Newfoundland. Estuarine, Coastal and Shelf Science. 133: 224-234