SYMPOSIUM OP'24

ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

Using a High-Resolution Regional Model to Develop a Mechanistic Explanation of Intrusion Events in Halifax Harbour, a Mid-latitude Fjord in Eastern Canada

Theme #7

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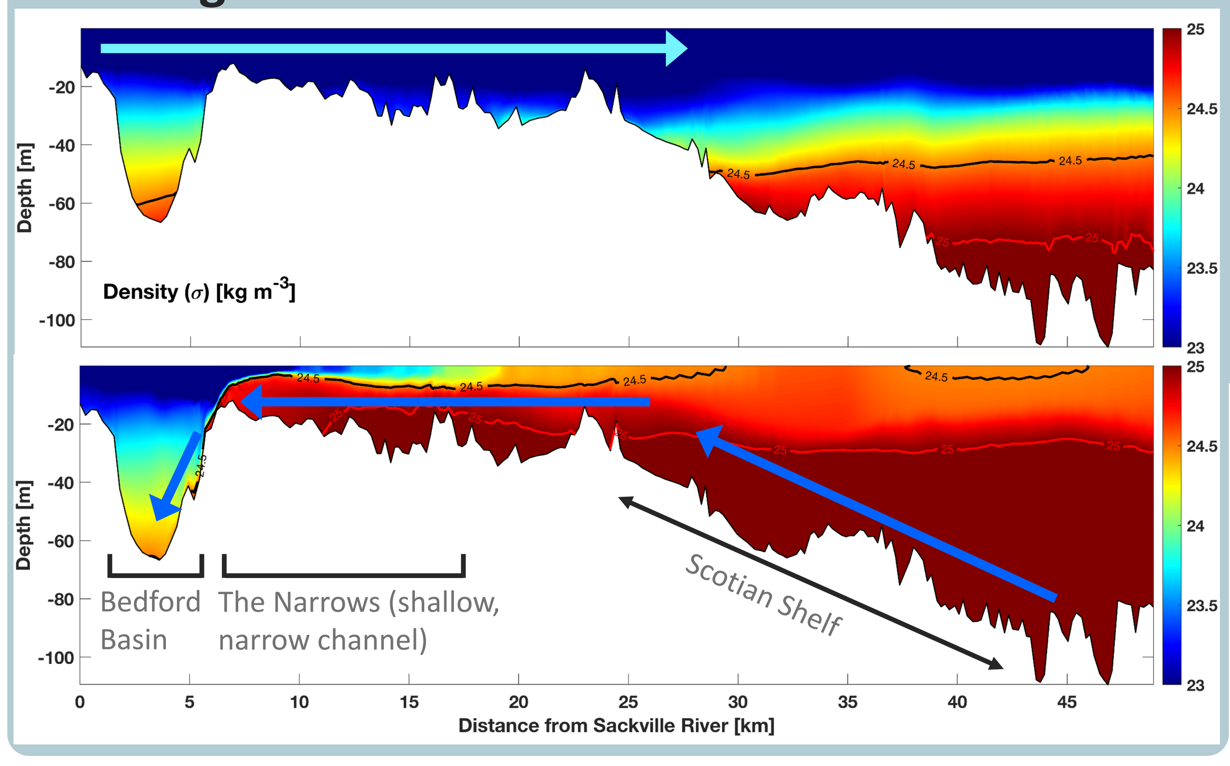
1. Background



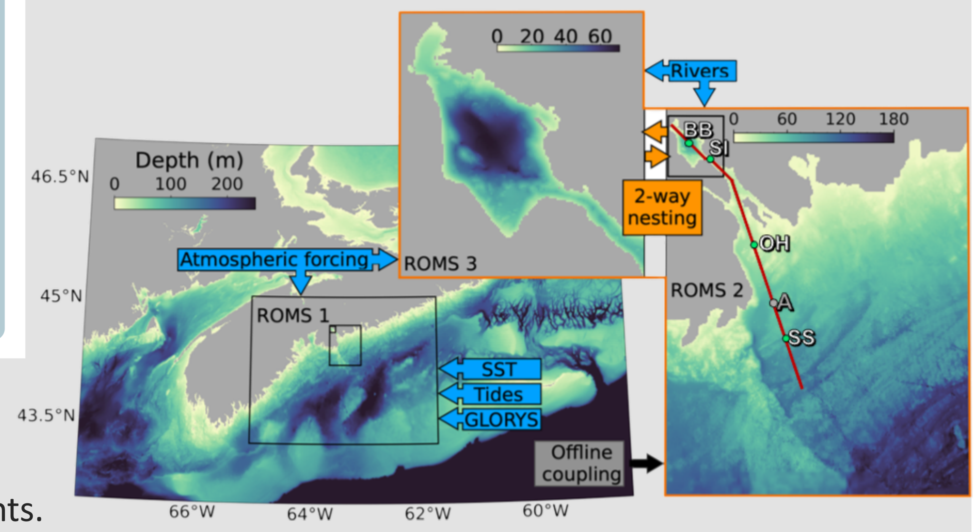
Research on Ocean Alkalinity Enhancement (OAE) is ongoing in Halifax Harbour, a small, mid-latitude fjord in Atlantic Canada.

The system is dominated by two-layer estuarine flow **(see left).**

Sporadic intrusion events replace the bottom water of Bedford Basin, the 70-m deep basin at the head of the Harbour, with waters from the adjacent Scotian Shelf.

Physical and biogeochemical properties relevant to OAE work are strongly influenced by these intrusion events.

2. The Model



Right The three nested domains of the Scotian Shelf and Halifax Harbour model set up with the Regional Ocean Modelling System (ROMS).

A hindcast from 2002-2022 was used to investigate simulated intrusion events.

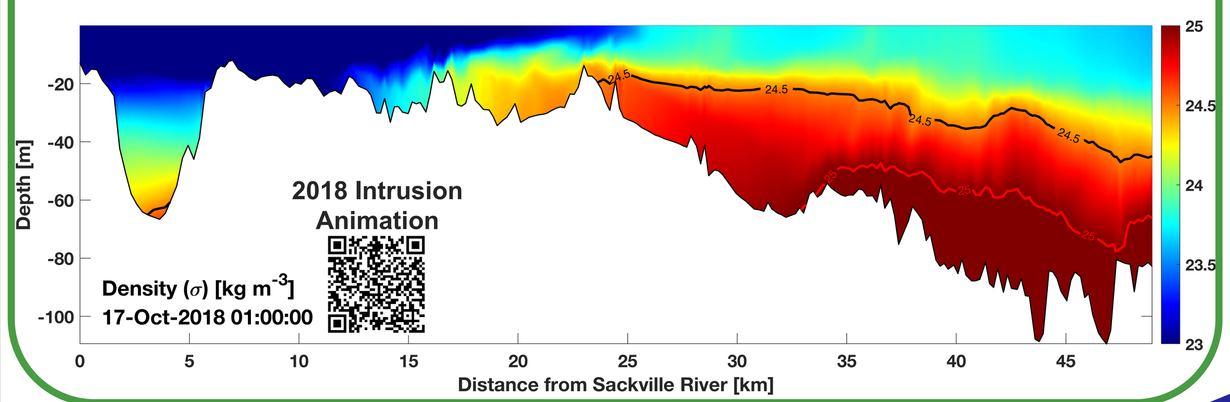
All oceanographic data used for this project were extracted from the transect **(in red)** and **stations BB (Bedford Basin), SI (Sill of The Narrows), OH (Outer Harbour), and SS (Scotian Shelf)** indicated in the ROMS 2 domain **above**.

European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 data is used for atmospheric forcing and was extracted at **station A**.

3. The Stages of an Intrusion Event

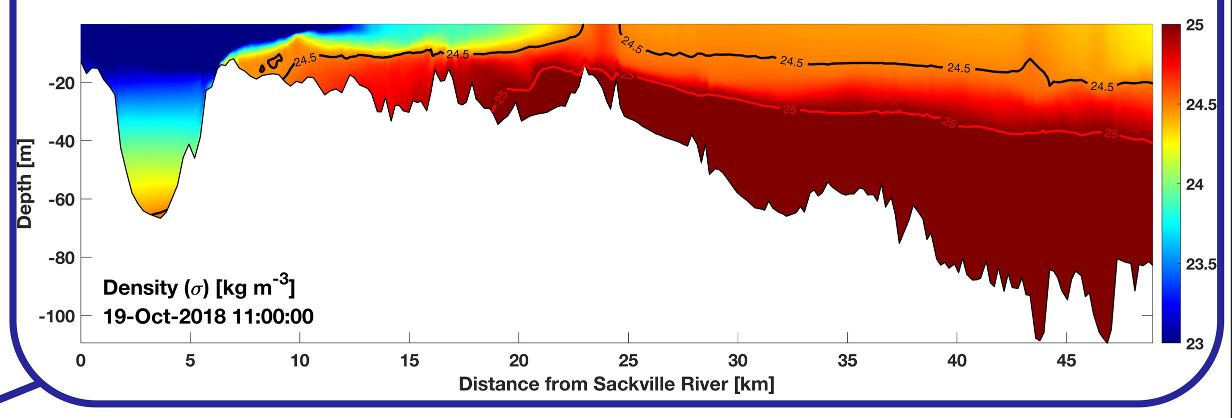
1. Shelf Setup

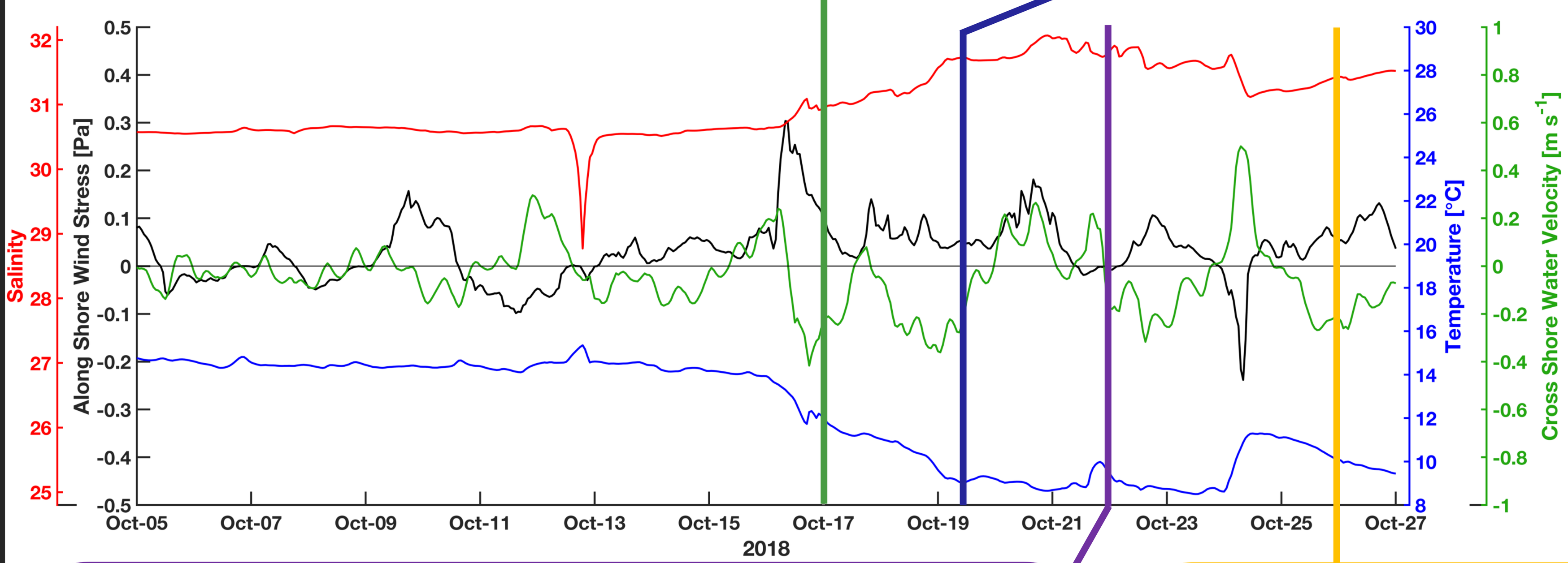
Dense shelf water is pushed up along the Scotian Shelf.



2. Harbour Intrusion

Dense shelf water makes it into the Outer Harbour.





Four distinct stages of an intrusion event, illustrated by hourly transect snapshots **(see QR code for the full animation)**, can be identified.

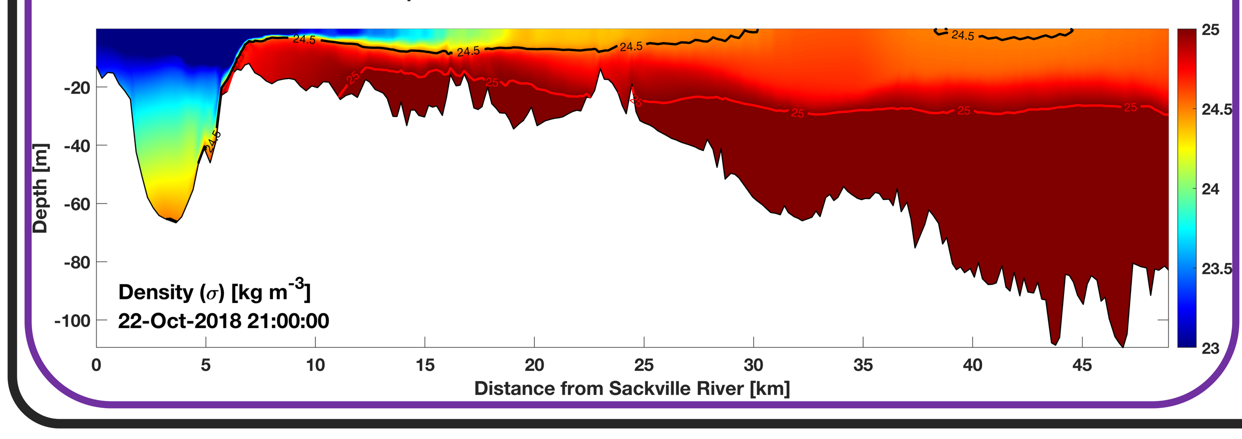
Left Timeseries of surface temperature, salinity, cross-shore velocity and along-shore wind stress at station A.

Positive along-shore wind stress: SW winds
Positive cross-shore velocity: towards shore

Not all events make it to each stage.

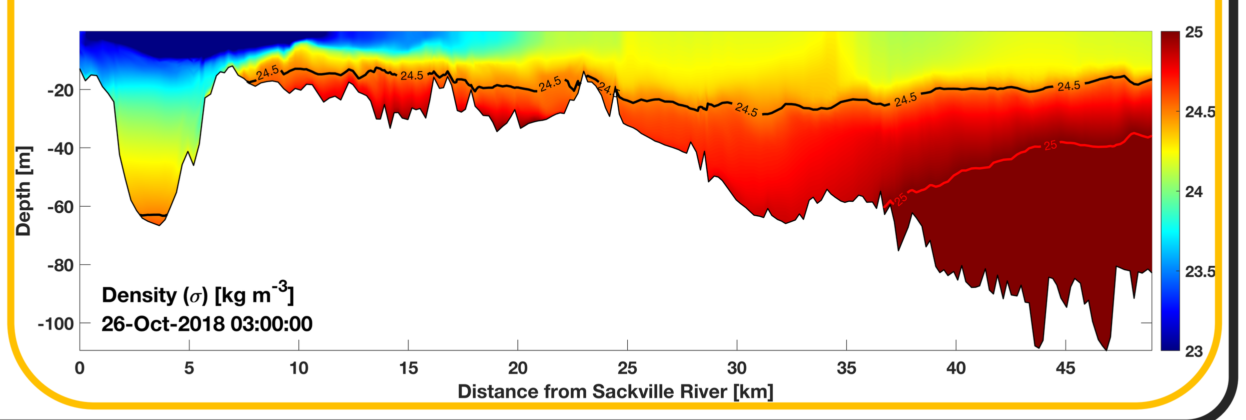
3. Bedford Basin Intrusion

Dense shelf water is pushed over the sill into Bedford Basin.

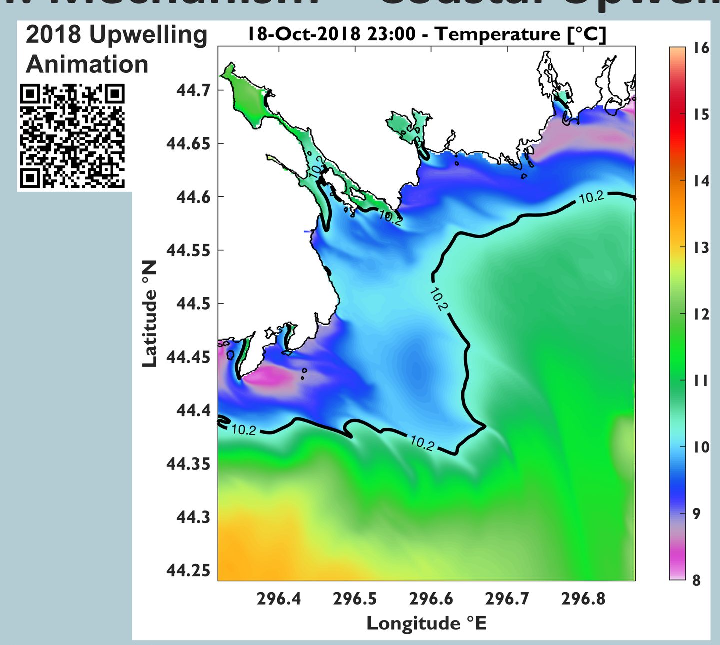


4. Receding

Dense water recedes back to the Scotian Shelf.



4. Mechanism – Coastal Upwelling



Above Surface temperature plot during the 2018 intrusion, see **QR code** for animation.

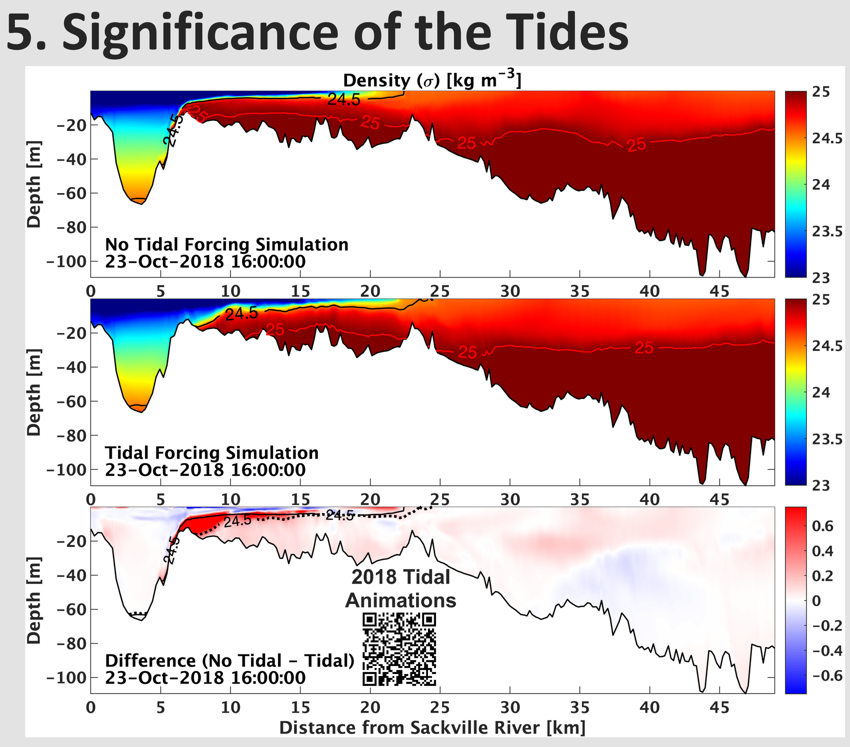
Coastal upwelling drives cold, dense bottom waters towards shore.

This upwelling leads to the "Shelf Setup" and "Harbour Intrusion" stages (1 and 2 **left**).

SW winds are known to drive coastal upwelling along the Nova Scotian coast. Note the large positive spike in the wind stress timeseries **(left)** on October 16, 2018.

SW winds persist during the "Shelf Setup" and "Harbour Intrusion" stages. We therefore suggest these to be the driving mechanism of these two stages.

5. Significance of the Tides



Above Density snapshots with and without tidal forcing **(middle and top** respectively), and the difference between the two simulations **(bottom)**.

Dense water continually enters Bedford Basin during intrusion without tidal forcing **(Top).**

The difference between tidal simulations is the greatest over The Narrows **(Bottom).**

6. Detecting Intrusion Stages and Mechanisms

Shown to the right is an hourly timeseries of bottom temperature, salinity and density at **stations BB, SI, OH, SS.**

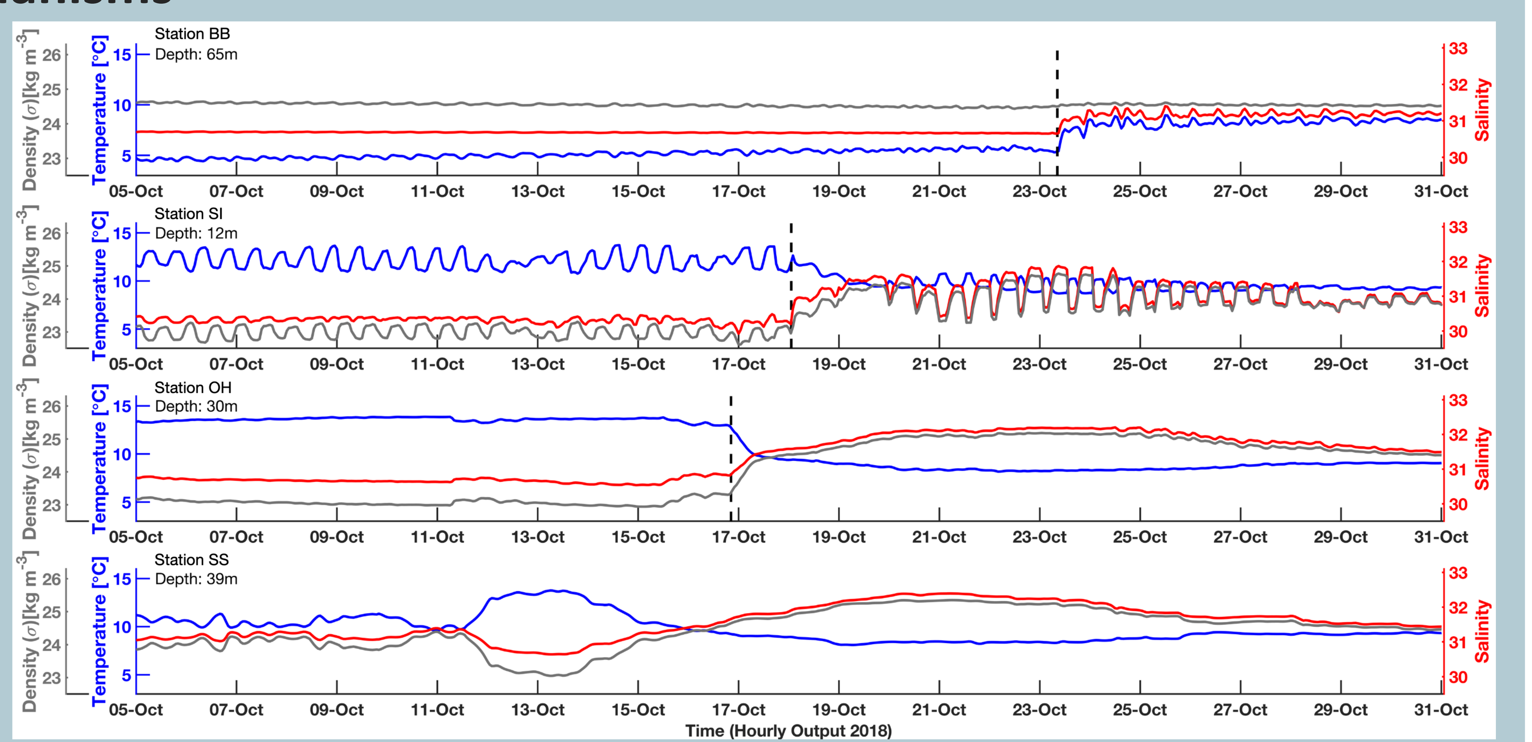
The **dashed line** indicates the intrusion interface at each station.

Change in density is masked at station **BB** (in Bedford Basin) by the coincident increasing salinity and temperature.

Hourly output is required to resolve the tidal oscillations seen at **station SI** (the sill of The Narrows).

Intrusion events are best identified by a rapid increase in salinity. Temperature can increase or decrease depending on the season.

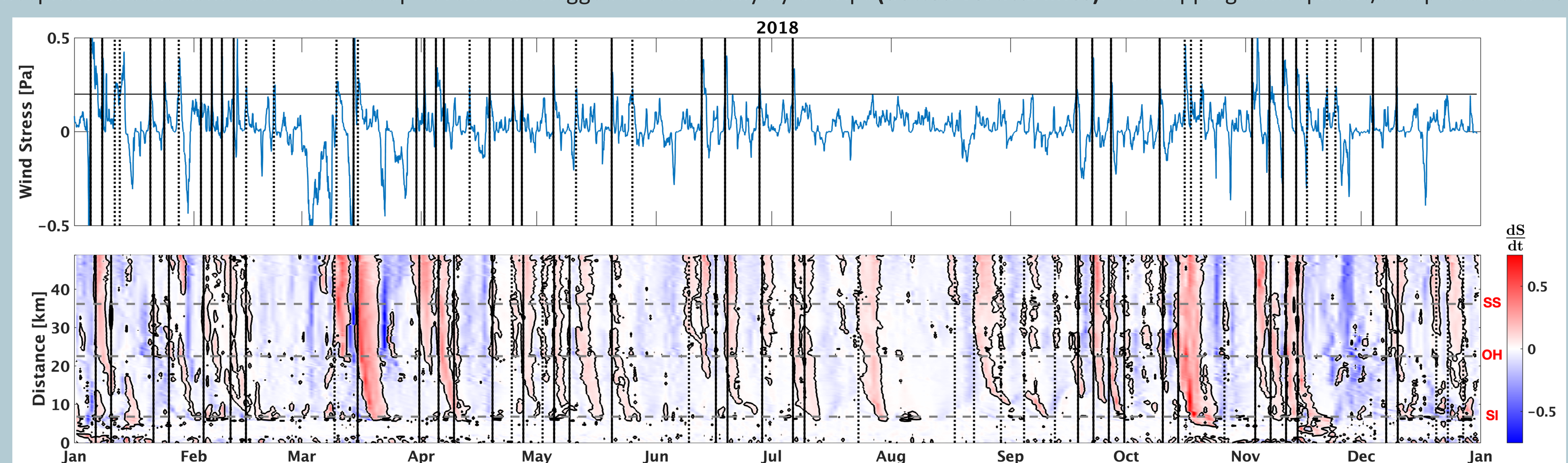
Therefore, the temporal gradient of salinity $\left(\frac{dS}{dt}\right)$ is ideal for identifying intrusion signals.



Below are timeseries of along-shore wind stress from model forcing **(top)** and bottom $\frac{dS}{dt}$ along the transect **(bottom),** from daily output of the 20-year hindcast.

Stage 1 intrusions can be identified by $\frac{dS}{dt}$ above 0.035 [S d⁻¹] **(black contour; bottom)** reaching station **station SS (upper dashed grey line; bottom)**.

Atmospheric mechanisms and "Shelf Setup" events are flagged automatically by a script **(dotted vertical lines)**. Overlapping atmospheric/setup events are **solid**.



Next Steps

We hypothesize that the mechanisms we have identified as driving the 2018 intrusion event apply more generally. This requires testing against the entire 20-year model hindcast and validation in the observational record. The intrusion stage and atmospheric forcing event detection method **(left)** will continue to be refined and applied to all intrusion stages. A quantitative relationship between SW wind stress and intrusion events would aid in predicting these events and is relevant for ongoing OAE field trials in the Bedford Basin.

Acknowledgements

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