Progress Towards Operationalization of Six Port Scale Models on the East and West Coast of Canada

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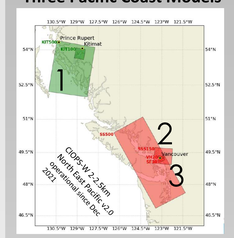
Fisheries and Oceans Canada | Pêches et Océans Canada

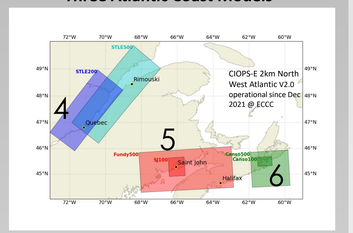
ABSTRACT

The oceanography sub-initiative of Canada's Ocean Protection Plan (OPP), aims to develop high-resolution operational port-scale hydrodynamic models, to enhance safe navigation and response to events such as oil spills. Six priority ports have been selected for this purpose and are being developed and validated, towards fully operational status which would provide clients with 48-hour forecasts every six hours. The port models are forced by the Coastal Ice-Ocean Prediction System (CIOPS) and the High-Resolution Deterministic Prediction System (HRDPS). Both are operational products available from Environment and Climate Change Canada (ECCC). An overview of the six port models will be provided with a summary of the preliminary validation. The modelling for this study was based on the Nucleus of European Modelling of the Ocean (NEMO v3.6; Madec et al., 2017*)

Three Pacific Coast Models

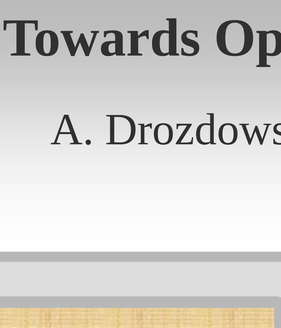


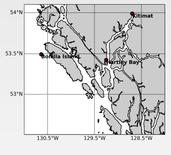
Three Atlantic Coast Models



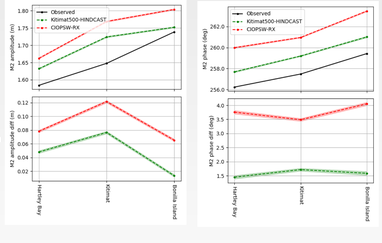
1. Kitimat

- Outer domain (KIT500): 500 m, 50 z-levels
- Inner domain (KIT100): 100m, 33 z-levels
- Hecate Strait OBC from CIOPS-W
- One-way offline forcing
- Tides: WebTide (8 constituents)
- Surface forcing HRDPS 2.5km
- Runoff:
  - Gauges @ Kitimat, and Kemano Rivers and Morrison climatology
  - Runoff applied as line source along shoreline
  - Freshwater temperature from Kitimat River applied everywhere except Skeena; Skeena temperature climatology from point measurements
- 6 year hindcast conducted
  - Jan 1, 2016 – Feb 1, 2022



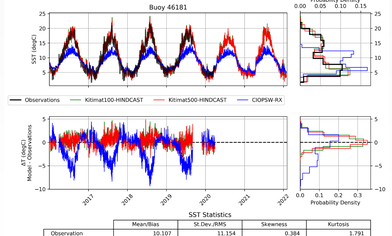


M2 Elevation @ 3 gauges



- Port model errors under 8 cm for amplitude and under 2° for phase
- Clear improvement over CIOPS-W

Sea Surface Temperature @buoy



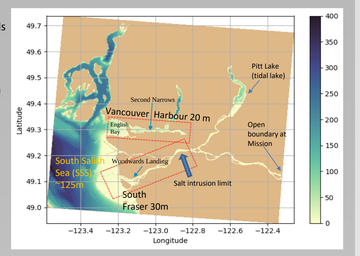
- Seasonal cycle well modelled
- Errors generally within a few degrees
- Clear improvement over CIOPS-W

SST Statistics

	Mean/Bias	St.Dev./RMS	Skewness	Kurtosis
Observation	10.107	11.154	0.384	1.791
Kitimat100-HINDCAST	10.243	11.348	0.383	1.862
$\Delta T_{Kitimat100-HINDCAST}$	0.371	1.148	0.352	3.032
Kitimat500-HINDCAST	10.083	11.187	0.401	1.888
$\Delta T_{Kitimat500-HINDCAST}$	0.214	1.092	0.251	3.079
CIOPSW-RX	8.677	9.013	0.07	1.753
$\Delta T_{CIOPSW-RX}$	-1.361	2.855	-0.537	2.274

2-3. Vancouver Harbour and Fraser River

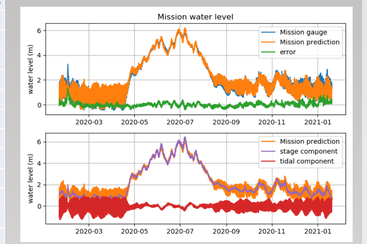
- 2: Vancouver Harbour (VH20): 20 m, 28 z-levels
- 3: South Fraser River (SF30): 30 m, 24 levels
- Outer domain SSS125: 125 m, 50 z-level with S,W boundaries from SSS500 + tuned tides
- SS500: Tech-transferred to DFO/ECCC from S. Allen at UBC. Experimental operations Dec 2021
- Fraser river east OBC from Mission water level & NS_TIDE model
- Freshwater input: gauge data from North Vancouver rivers climatological at Howe Sound, Indian Arm, Pitt Lake
- Fraser River discharge implicit via ssh boundary condition
- Surface forcing: HRDPS 2.5km
- 5 year hindcast (2017-2021)



Tidal error at Vancouver

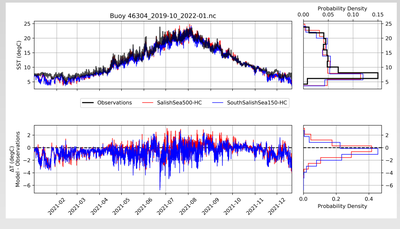
Constituent	Tidal error, Vancouver, 2019
2N2	0.005
J1	0.001
K1	0.008
K2	0.001
L2	0.003
M2	0.008
N2	0.002
NU2	0.000
O1	0.010
P1	0.008
Q1	0.003
S2	0.002

Non-stationary model @Mission



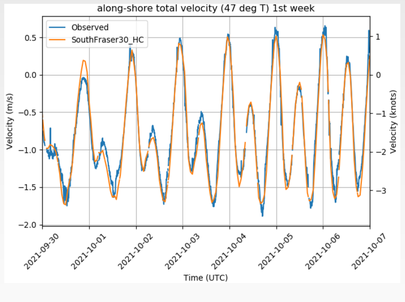
SST at English Bay buoy (2021)

- Capturing seasonal cycle
- Errors generally within a few degrees



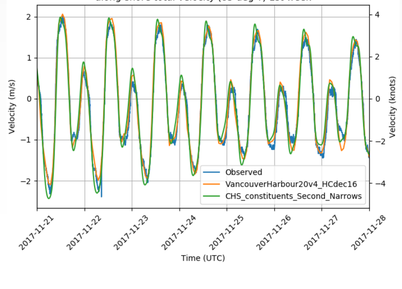
Woodwards Landing HADCP

- Positive upstream, negative downstream
- Capturing outgoing mean flow (~ 1 kt)
- Capturing range (4 kt)



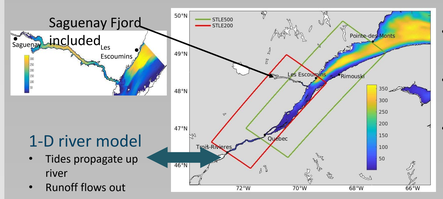
Vancouver Harbour Second Narrows HADCP

- Capturing range
- Mean flow small
- Sometimes better than constituents



4. Saint Lawrence Estuary

St. Lawrence modelling system

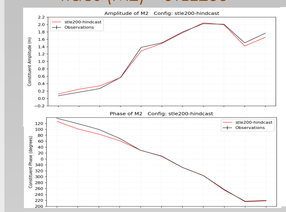


- Outer domain (STLE500): 500 m, 75 z-levels
- Inner domain (STLE200): 100m, 36 z-levels
- The only port with ice. -Uses NEMO's ice-if condition for thermodynamics only

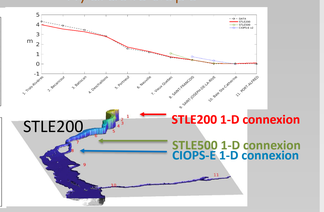
1-D river model

- Tides propagate up river
- Runoff flows out

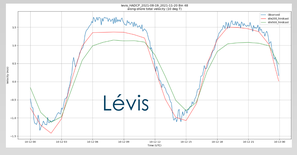
Tides (M2) – STLE200

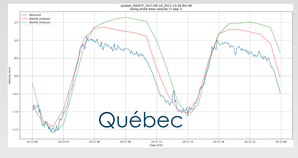


Hydraulic slope



Currents from HADCP



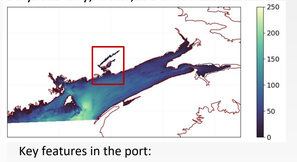


Compared to observations, model surface currents are too weak in Lévis and too strong in Québec, and this difference is larger in the 500m model. Why?

- Not enough resolution to resolve this spatial variability?
- Increase lateral friction locally?

5. Saint John Harbour

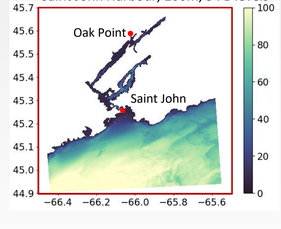
Bay of Fundy, 500m, 40 z-levels



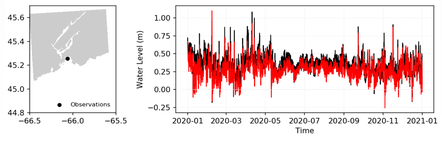
Key features in the port:

- 8m tidal range
- River up to ~5000 m^3/s
- Sea walls and dredged channels in the harbour

Saint John Harbour, 100m, 34 z-levels



Water Levels comparison to tide gauge



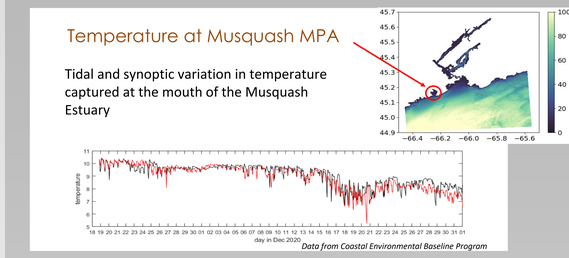
M2 Tide

Amplitude modelled to within a few centimetres and phases under a degree

Source	Amplitude 2018/2020	Phase 2018/2020
Tide gauge	3.08 / 3.04 m	97.79° / 98.44°
Fundy500	3.08 / 3.07 m	97.90° / 97.64°
SJ100	3.09 / 3.08 m	97.98° / 97.9°
WebTide	3.00 m	97.96°

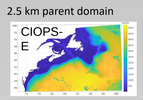
Temperature at Musquash MPA

Tidal and synoptic variation in temperature captured at the mouth of the Musquash Estuary



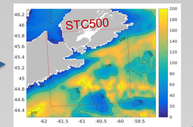
6. Strait of Canso

2.5 km parent domain



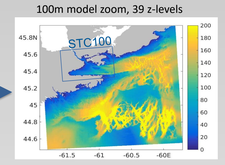
One way nesting CIOPS-E v2 forcing 2016 – 2022 -> OBC + INIT.

500m model zoom, 47 z-levels



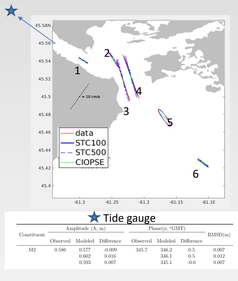
- Surface forcing -> HRDPS 2.5km
- River Runoff -> climatology from CIOPS-E

100m model zoom, 39 z-levels



- Tidal forcing coming directly from parent model's currents and elevation

M2 tidal elevation and currents



Tide gauge

Constituent	Amplitude (A, m)			Phase(G, °GMT)			RMSD(m)
	Observed	Modeled	Difference	Observed	Modeled	Difference	
M2	0.586	0.577	-0.009	345.7	346.2	0.5	0.007
		0.602	0.016		346.1	0.5	0.017
		0.593	0.007		345.1	-0.6	0.007

Several months of ADCP data at 6 stations

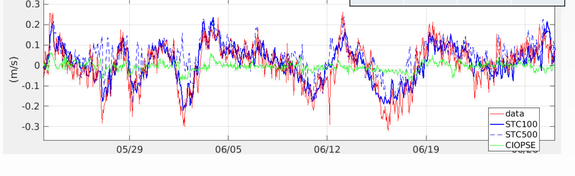
Station #	RMSD in cm s^{-1} (Phase Error °GMT)		
	100m	500m	CIOPSE
1	0.4 (2.7)	0. 2(-1.7)	1.8 (-27.5)
2	0.6 (-2.2)	0.6 (6.6)	2.8 (-14.9)
3	1.0 (0.4)	2.1 (1.7)	7.1 (-7.5)
4	0.9 (0.3)	1.2 (5.2)	6.5 (-3.2)
5	0.6 (3.9)	0.5 (1.0)	2.6 (-4.3)
6	0. 4 (1.3)	0.5 (0.6)	0.5 (6.4)

- Narrow ellipses constrained by topography
- Weak currents (<6 cm s^{-1}) except entrance (15 cm s^{-1})
- Port model RMS errors under 1.2 cm s^{-1} and phases within a few degrees for port models.
- CIOPS-E struggling at stations 1-5 due to low resolution
- M2 elevation modelled to within a centimetre

Residual surface currents

- Showing STN 3 North velocity residual near-surface (@7m)
- This is the most energetic stations residual currents exceed 30 cm s^{-1}
- Improving skill with increased resolution

Station #	RMSE in cm s^{-1} (Corr. Coef.)		
	100m	500m	CIOPSE
3	8.5 (0.75)	10.1(0.66)	11.3 (0.25)



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+ Contributions from Chengzhu Xu, Jonathan Coyne, William Xu & colleagues at ECCC

* Madec, G., Bourdalle-Badie, R., Bouttier, P.-A., Bricaud, C., Bruciaferri, D., Calvert, D., Chanut, J., Clementi, E., Coward, A., Delrosso, D., et al., 2017. Nemo ocean engine.