COASTAL PREDICTION AT ECCC – OVERVIEW OF MODELING SYSTEMS & APPLICATIONS

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& many collaborators!

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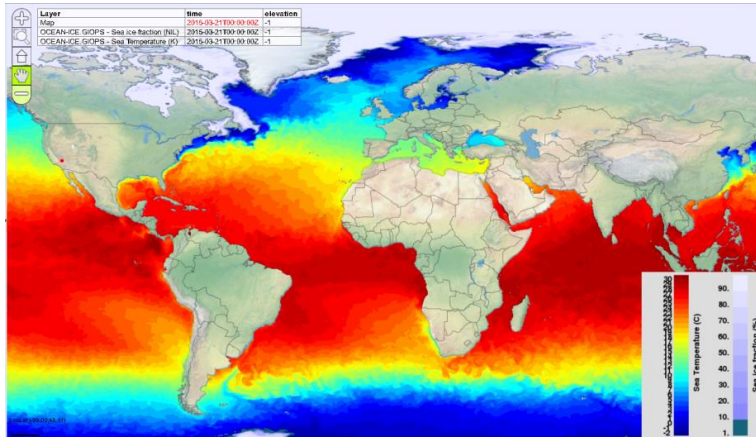[3] Bedford Institute of Oceanography, DFO, Canada

[4] Canadian Hydrographic Service, DFO, Canada
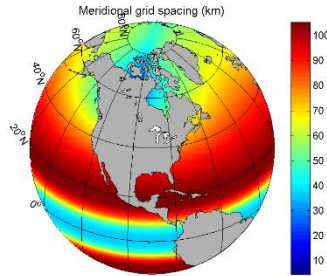
[5] Institute of Ocean Sciences, DFO, Canada

Coastal Ocean Shelf Seas Task Team Workshop, May 2-4 2023

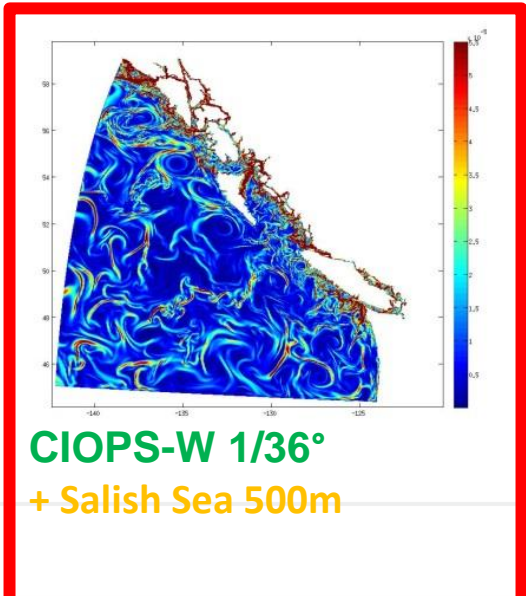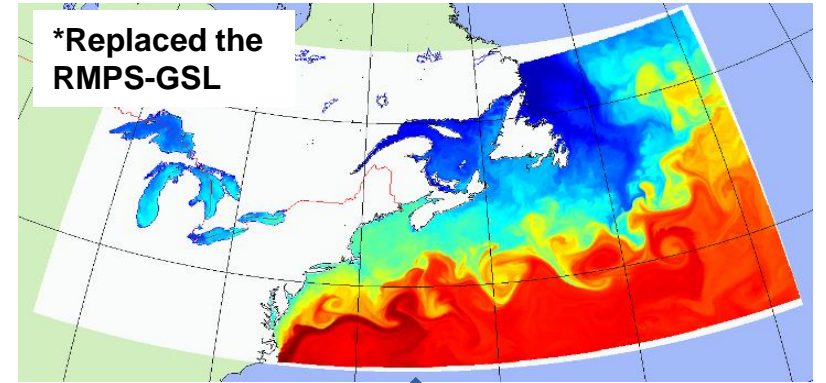# ECCC ICE-OCEAN FORECASTING WITH NEMO + CICE

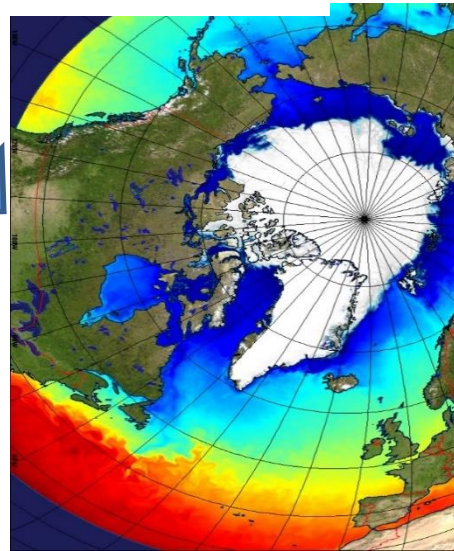GIOPS: 1/4° (assimilation)
Coupled with NWP

CanSIPS 1° coupled
Seasonal Prediction
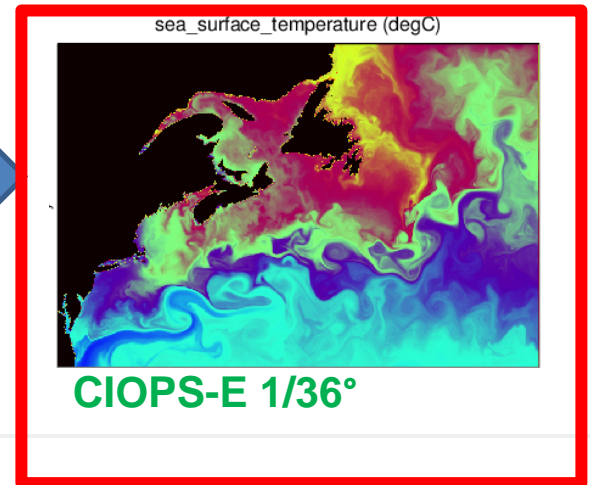
Water Cycle Prediction System (WCPS)
Great Lakes (1km) & CIOPS-E (1/36°)
Coupled Atm (10km) + hydrology + rivers *

*Replaced the RMPS-GSL

Status
Operational
Experimental

CIOPS-W 1/36°
+ Salish Sea 500m

RIOPS 1/12° (assimilation)
Coupled during YOPP
(3km atm.)

CIOPS-E 1/36°

CONCEPTS
CANADIAN OPERATIONAL NETWORK OF COUPLED ENVIRONMENTAL PREDICTION SYSTEMS

CIOPS – TECHNICAL SUMMARY

	CIOPS-E (NWA36)	CIOPS-W (NEP36)	Salish Sea* (Sal500)
Model	NEMO v3.6+ – CICE v4		
System Components	Pseudo-analysis: daily 24h runs Forecasts : 48h forecasts x 4 times per day (00, 06, 12,18Z)		
Horizontal Res.	1/36º ORCA grid (~1.7 – 2.5 km)		500 m
Vertical Levels	100 (Δz=1m from 1 -30m)	75 (Δz=1m from1 - 20m)	40 (1m – sfc; 27m bot.)
Atmospheric forcing	Hourly: Ta, qa, Ua: 1st prognostic level (~40m) PNM, LW$\downarrow$, SW$\downarrow$, Precip		
Atmospheric Blending	HRDPS-RDPS	HRDPS-GDPS	HRDPS
Ocean OBCs	Daily averages: T, S, U, V, SSH from RIOPS		≡ from CIOPS-W (NEP36)
Large-scale constraints	Spectral Nudging 3D T&S offshore toward RIOPS in pseudo-analysis		None
Tidal OBCs	OSU (13 const.)	WebTide (8 const)	Adjusted & obs.
River runoffs	Climatology (130) + 1D St-Laurent	Climatology (Morrisson + Dai & Trenberth)	Climatology + Fraser River

* : tech. transfert from SalishSeaCast via DFO (S. Allen et al.; UBC; https://salishsea.eos.ubc.ca/)

HRDPS   : High Resolution Deterministic Prediction System
RDPS   : Regional Deterministic Prediction System
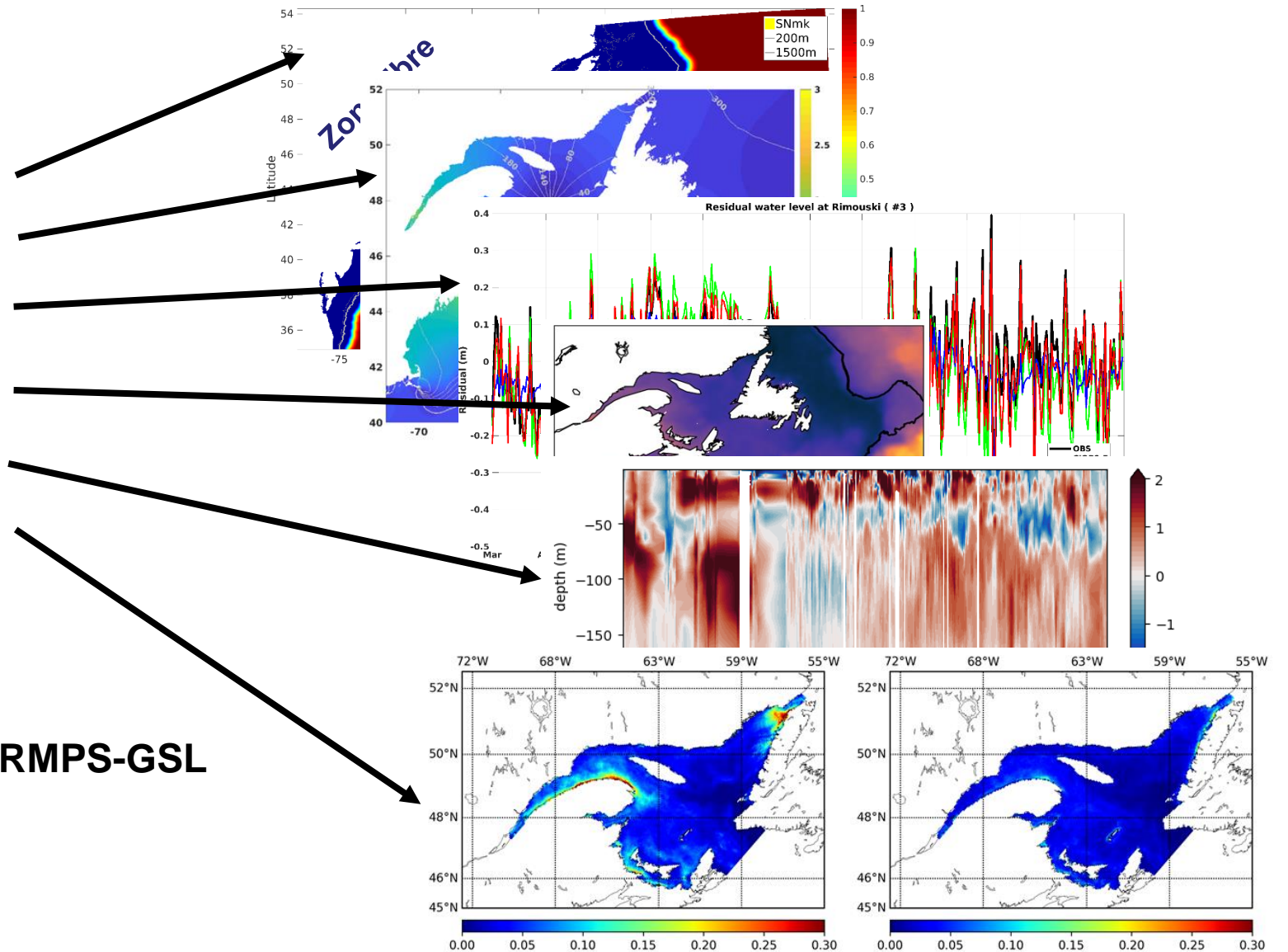GDPS   : Global Deterministic Prediction System
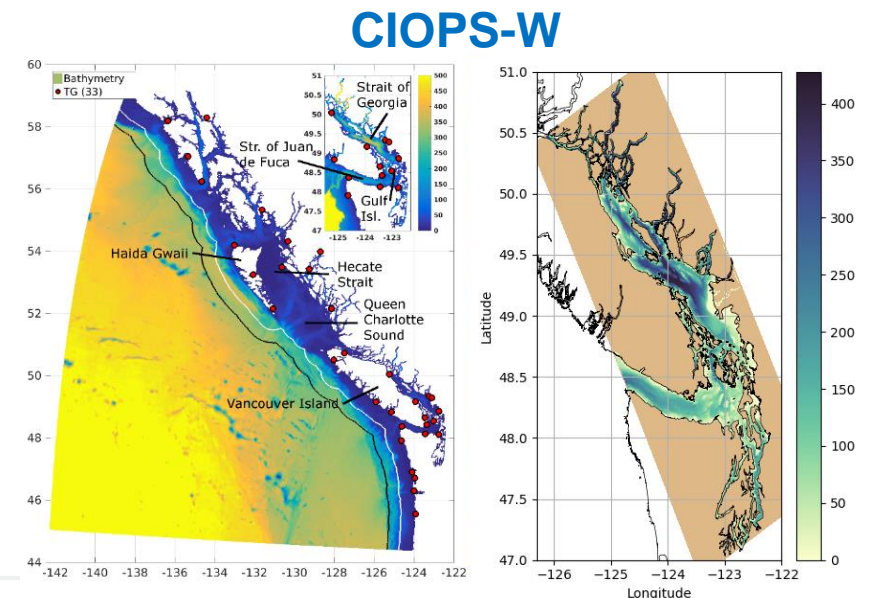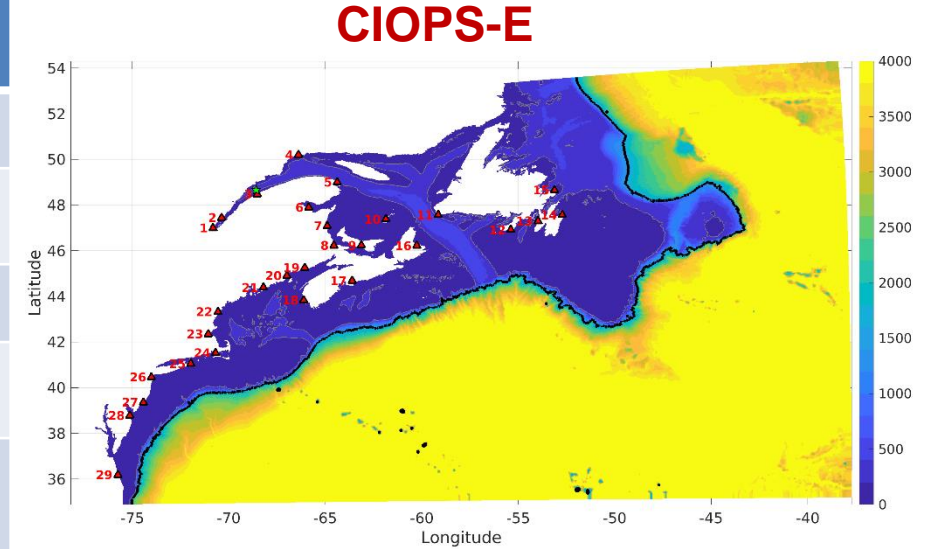
CIOPS-E

CIOPS-W

CIOPS EVALUATION

Model evaluation

- Spectral nudging

- Tides : amplitude / phase

- Residual water levels

- SST

- T&S profiles

- Sea ice extent

- *Drifters*

CIOPS improvements over RIOPS & RMPS-GSL

- Tides

- Storm surge

- Water masses in Gulf of St Lawrence

CIOPS-E: Paquin et al. 2023 (*in review*)
CIOPS-W : ECCC technical reports

CIOPS-E MULTI-DECADAL SIMULATION (HINDCAST)

**Evaluate system's behavior & statistics**

- Interannual variability
- Identify potential drifts
- Extreme events characterisation

Methodology
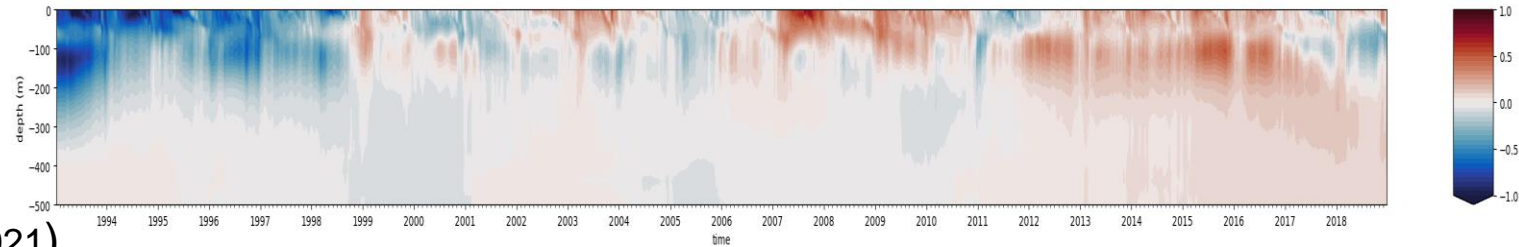
- CIOPS-E operational configuration
  - Pseudo-Analysis & Spectral Nudging
- 1993-2018
- OBCs & SN: GLORYS12 (MOi)
- Forcing: ECCC's RDRS (v2.1 ; Gasset et al. 2021)
  - GEM 10km resolution
  - 1979-2018
  - + LW/SW corrections

Gulf St. Lawrence average anomalies
w.r.t. model climatology (1995-2008)
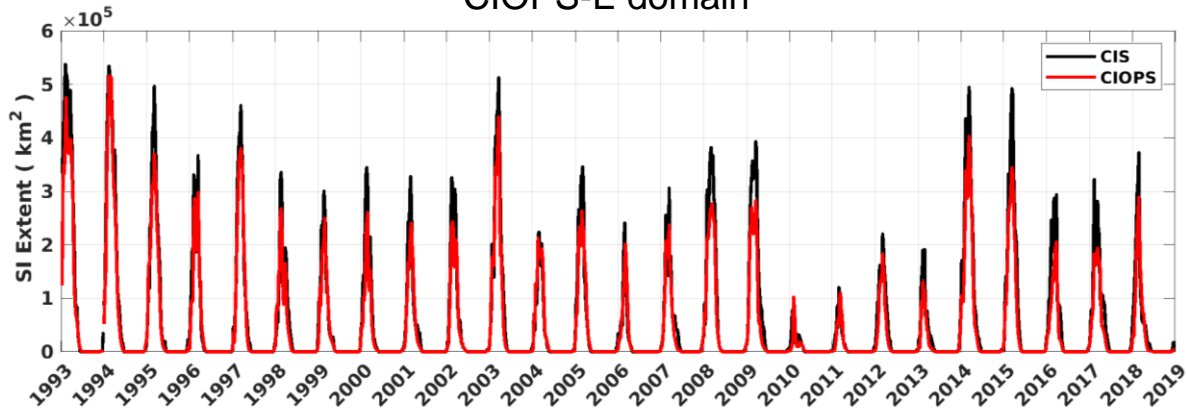
Temperature (0-500m)
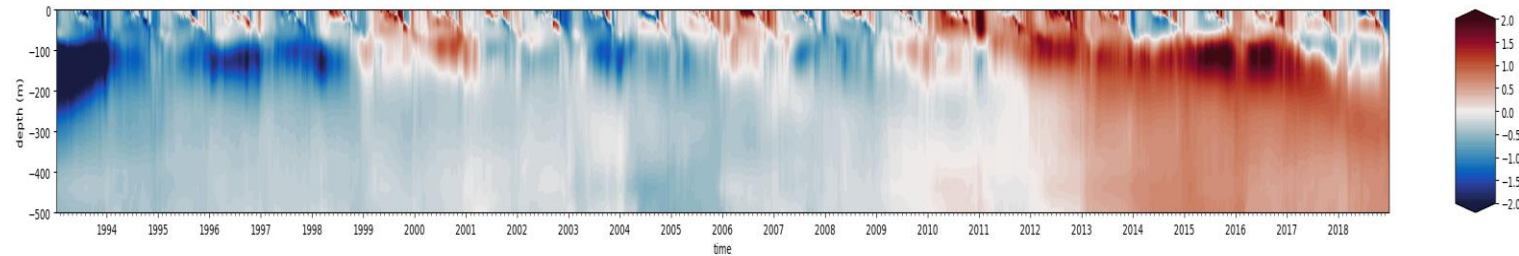
Salinity (0-500m)
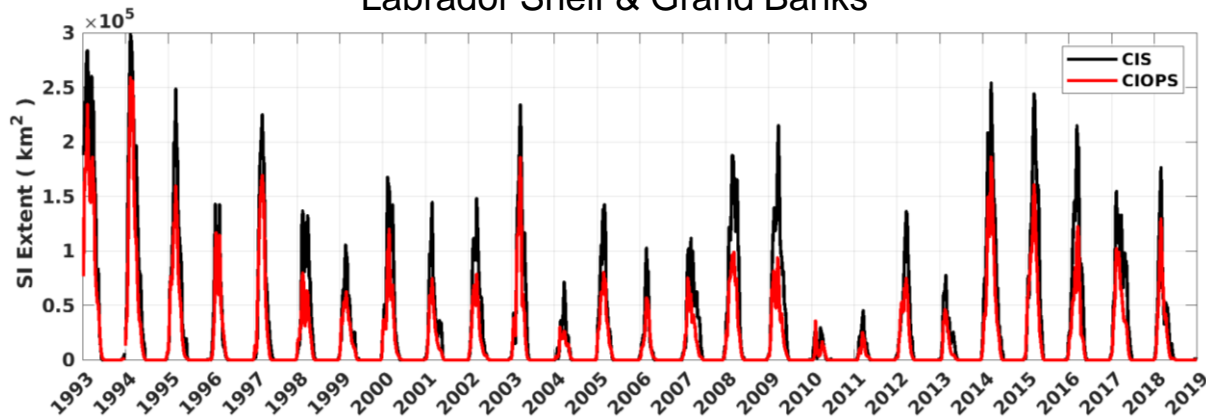
CIOPS-E MULTI-DECADAL SIMULATION

Sea ice Extent
(CIOPS-E; CIS)

CIOPS-E domain

Labrador Shelf & Grand Banks

Seasonal Ice Cover
- thin, mobile & easy to deform

Measurements
- SI extent : Satellite image analysis
- SI thickness measurements very rare

Canadian Ice Service (CIS) Ice analysis
- Interpretation of satellite images
- SIT estimated using "stage of development"
- Conservative approach for navigation uses

CIOPS-E
- Good representation of interannual variabiliy
- Decreasing SI Extent
- Larger errors over Labrador Shelf & Grand Banks (vs GSL)
   - Underestimation of SI extent & SI Volume

CIOPS-E MULTI-DECADAL SIMULATION

Seasonal Maximum sea ice Extent
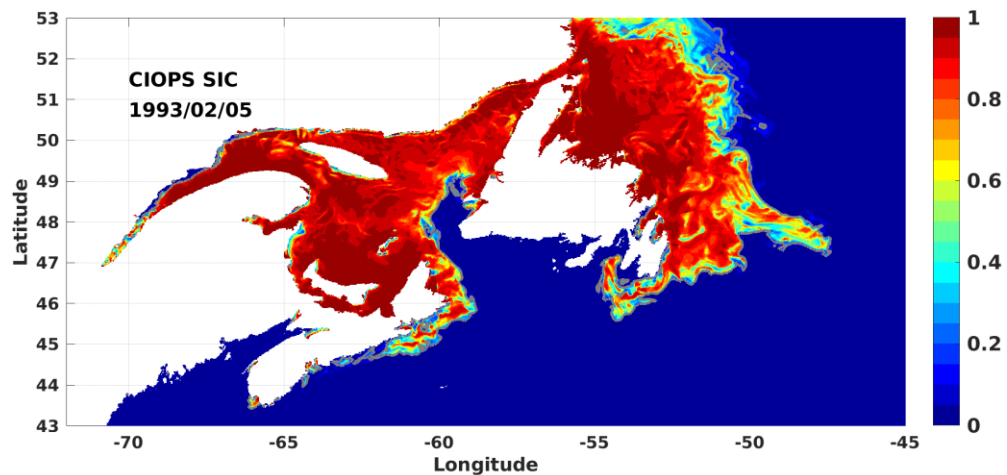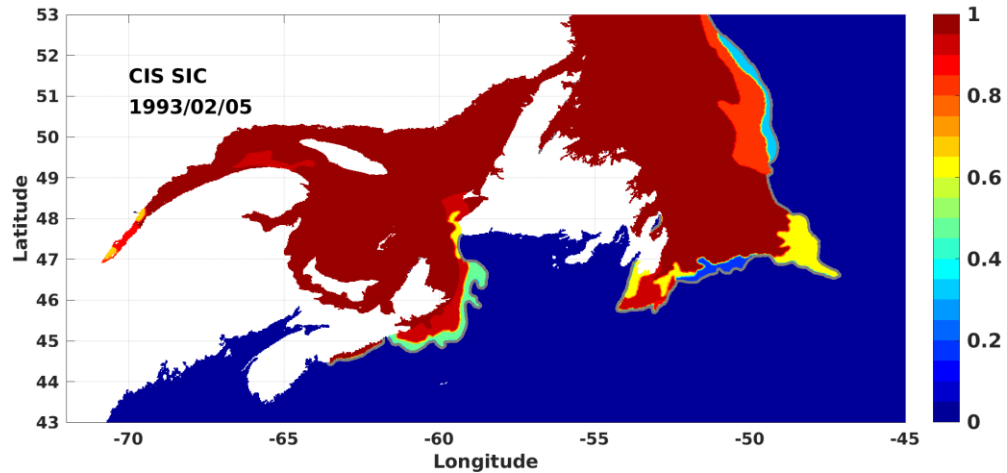
Maximum SI Extent for each year (CIS)
CIS: Polygon-based SI image analysis
CIOPS: Modeled SIC (outputs)

- Good spatial correlation
- Resolution differences between
  Observation estimates vs CIOPS
  - Unconstrained small-scale features
- Local effects (Anticosti, PEI)

FUTURE WORK 1 – HINDCAST

Hindcast

1. Water masses
   - Comparison with GLORYS (OBC impacts)
   - Comparison AZMP data & Gliders
   - Comparison with *in situ* profiles

2. Sea Ice (GSL, LS, GB)
   - Sea ice drift & landfast ice representation

3. Evaluation of residual water levels, return period & extreme events

4. High-frequency variability & circulation regimes in GSL

General

1. Wave-ocean interactions and sensibility

   -Actual parameterization / Outputs from wave models / coupling

2. Wave ice interactions

3. Uncertainty estimates for surface currents

   Emergency response & Coast Guards
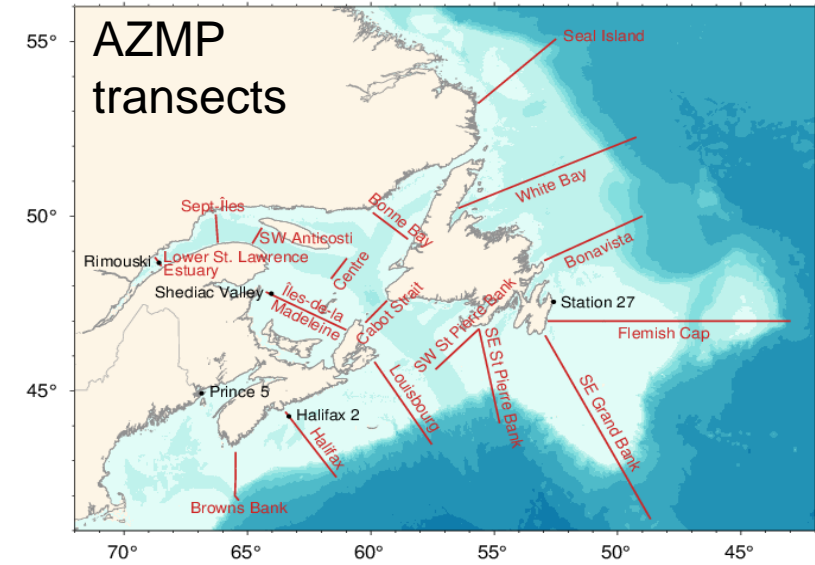
Other CONCEPTS research projects
- Water level: interannual variability & long-term trends
- Marine heat waves
- Coastal upwellings Nova Scotia

External collaborations & applications
- Contribution souhaitée aux groupes AZMP
- Toxic algea bloom (IML-DFO)
- Snow Crab & lobster (MPO)
- Rightwhale habitat studies (DFO)
- Many others (SWOT, HF Radars, etc.)

MERCI

Links & references

Paquin, J.-P., Roy, F., Smith, G. C., MacDermid, S., Lei, J., Dupont, F., Lu, Y., Taylor, S., St-Onge-Drouin, S., Blanken, H., Dunphy, M., and Soontiens, N.: A new high-resolution Coastal Ice-Ocean Prediction System for the East Coast of Canada, EGUsphere [**preprint**], https://doi.org/10.5194/egusphere-2023-42, 2023.

Gasset, N., Fortin, V., Dimitrijevic, M., Carrera, M., Bilodeau, B., Muncaster, R., Gaborit, É., Roy, G., Pentcheva, N., Bulat, M., Wang, X., Pavlovic, R., Lespinas, F., Khedhaouiria, D., and Mai, J.: A 10 km North American precipitation and land-surface reanalysis based on the GEM atmospheric model, Hydrol. Earth Syst. Sci., 25, 4917–4945, https://doi.org/10.5194/hess-25-4917-2021, 2021.

CIOPS – technical documentation & data access

https://eccc-msc.github.io/open-data/msc-data/nwp_ciops/readme_ciops_en/

https://collaboration.cmc.ec.gc.ca/cmc/CMOI/product_guide/docs/tech_notes/technote_ciops-east-200_e.pdf

https://collaboration.cmc.ec.gc.ca/cmc/CMOI/product_guide/docs/tech_notes/technote_ciops-east-100_e.pdf

https://collaboration.cmc.ec.gc.ca/cmc/CMOI/product_guide/docs/tech_notes/technote_ciops-west-100_e.pdf

https://collaboration.cmc.ec.gc.ca/cmc/CMOI/product_guide/docs/tech_notes/technote_ciops-west-200_e.pdf

AZMP: https://www.dfo-mpo.gc.ca/science/data-donnees/azmp-pmza/index-eng.html

Salish Sea Cast https://salishsea.eos.ubc.ca/

Soontiens et al. (2016) https://dx.doi.org/10.1080/07055900.2015.1108899

Soontiens & Allen (2017) https://dx.doi.org/10.1016/j.ocemod.2017.02.008

Coastal Ice Ocean Prediction System (CIOPS)

- Two 1/36° (2km) configurations have been developed specifically to provide best estimates of surface currents for Environmental Emergency Response

- Evaluation made in tight EC-DFO collaboration
  - Water level, currents, in situ profiles, drifters

- Spectral nudging to RIOPS analyses offshore
  - Able to constrain SSH mesoscale features and provide more accurate cross-shelf exchanges

- Developing methods to estimate uncertainty in surface currents
  - based on ensembles and unconstrained variability
  - drift error
  - A priori estimates by component (tides, geostrophic, Ekman, ..)

CIOPS-W SST

CIOPS-E SST

AVISO   RIOPS   CIOPS   CIOPS-FREE
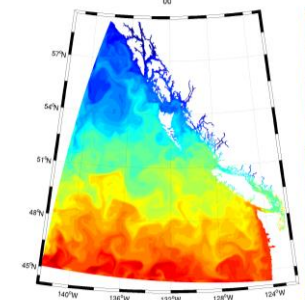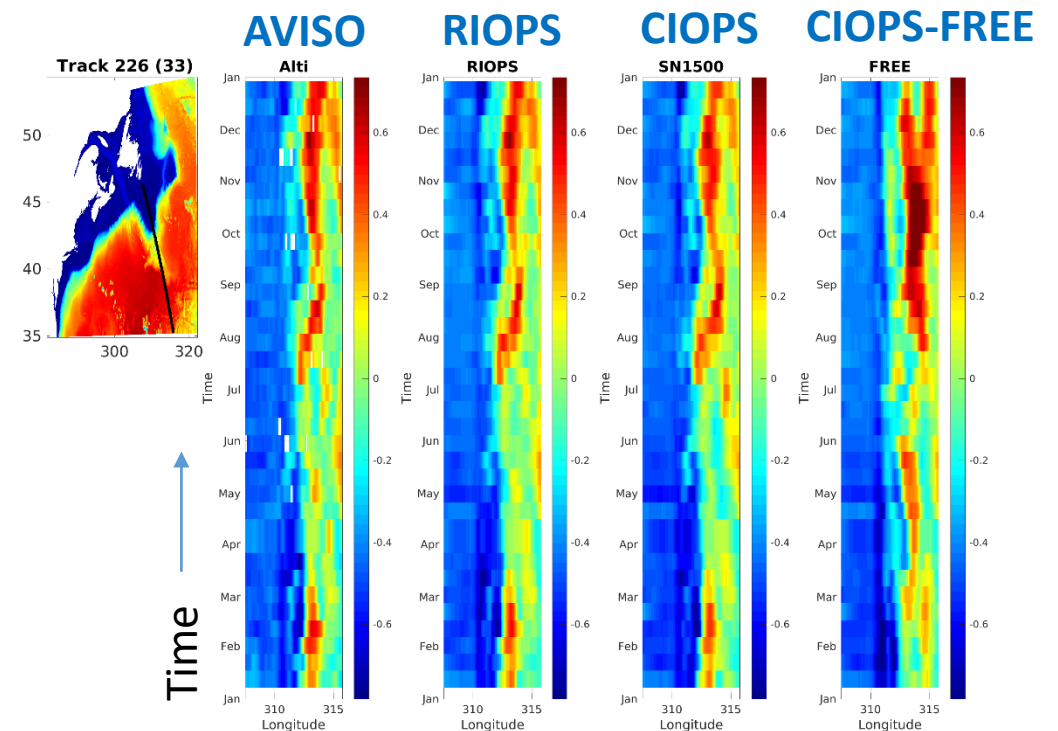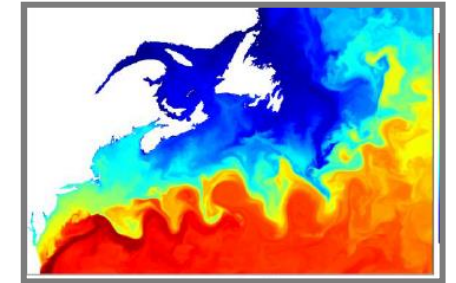
Paquin et al. (in prep)

WATER CYCLE PREDICTION SYSTEM

Evaporation from coupled model improves precipitation leading to lower streamflow errors

Dynamic ice cover affects fluxes throughout forecasts leading to improved weather forecasts
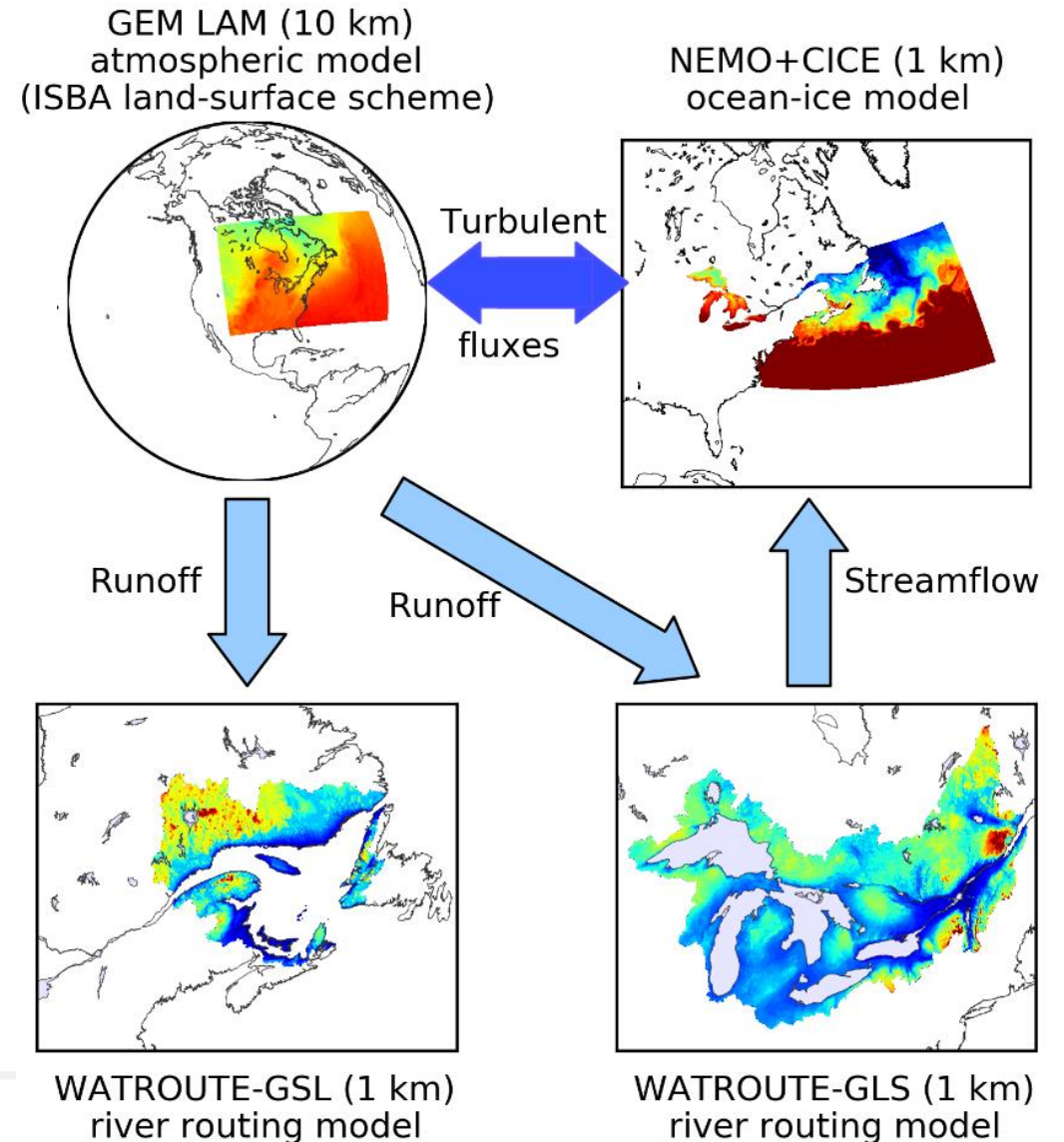- Coastal polynya formation
- Rapid ice formation

Coastal upwelling of cold winter waters can affect fog formation
- Upwelling not typically represented in SST analyses used in NWP

GEM LAM (10 km) atmospheric model (ISBA land-surface scheme)

NEMO+CICE (1 km) ocean-ice model

Turbulent fluxes

Runoff

Runoff

Streamflow

WATROUTE-GSL (1 km) river routing model

WATROUTE-GLS (1 km) river routing model

Durnford et al. (BAMS, 2018)

CIOPS-E MULTI-DECADAL SIMULATION (HINDCAST)

Seasonal Maximum sea ice Extent