Ocean Predict

SYMPOSIUM OP'24

In partnership with unesco Intergovernmental Oceanographic Commission

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

10 years of ocean data assimilation and prediction at ECCC

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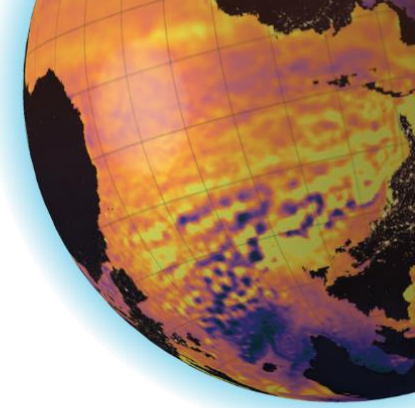
Outline

- Introduction – the need for ocean data assimilation and forecasting in Canada
- Timeline of ocean prediction at ECCC
- Where are we and what's next?

Introduction



- Development of the operational ocean forecasting systems in Canada have been driven by CONCEPTS (Canadian Operational Network of Coupled Environmental Prediction Systems – ECCC, DFO and DND)

  https://science.gc.ca/site/science/en/concepts

- In the last 10 years many ocean, ice and coupled systems have been implemented and are running operationally providing high quality forecasts responding to the increased demand in reliable ice and marine environmental prediction

CONCEPTS
CANADIAN OPERATIONAL NETWORK OF COUPLED ENVIRONMENTAL PREDICTION SYSTEMS

2015

2016

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2019

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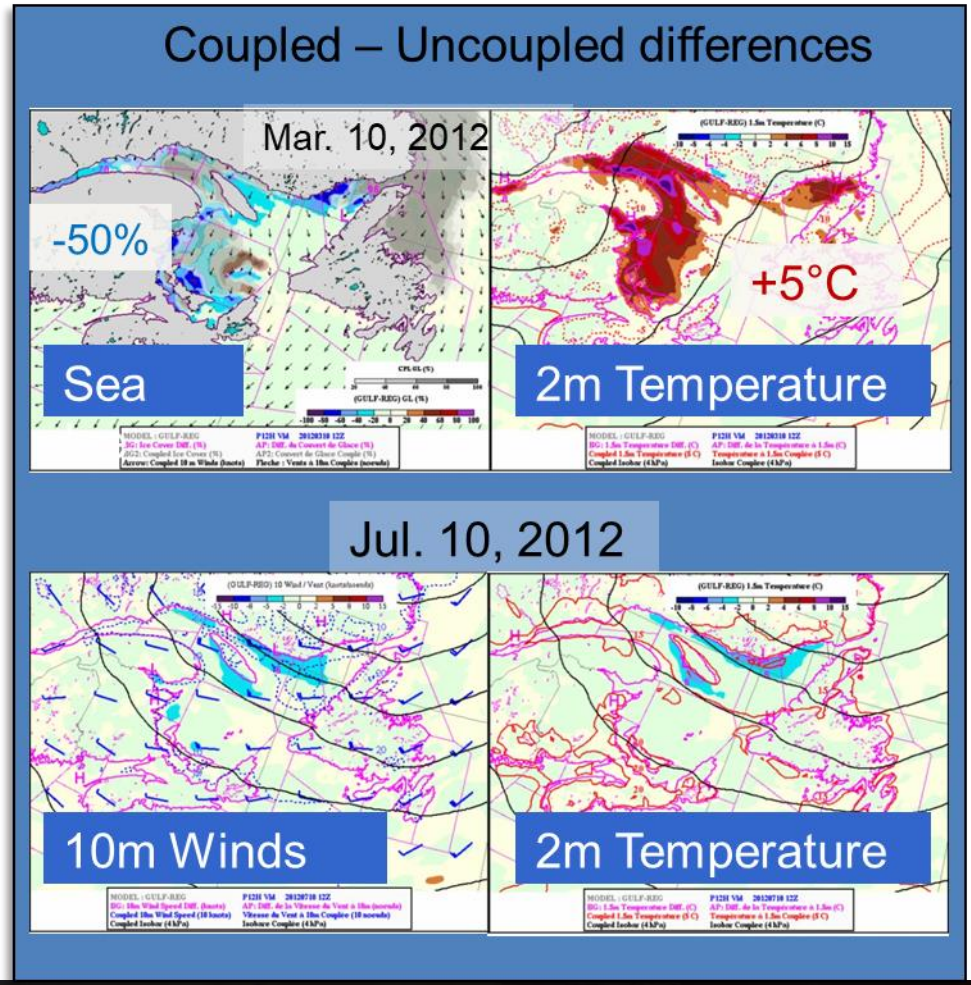
2024

Timeline

Before 2014

- Gulf of St. Lawrence Coupled Model
  - Collaboration with DFO to improve regional weather forecasts
  - Found to be useful by Canadian Ice Service
  - Implemented in operations in 2011



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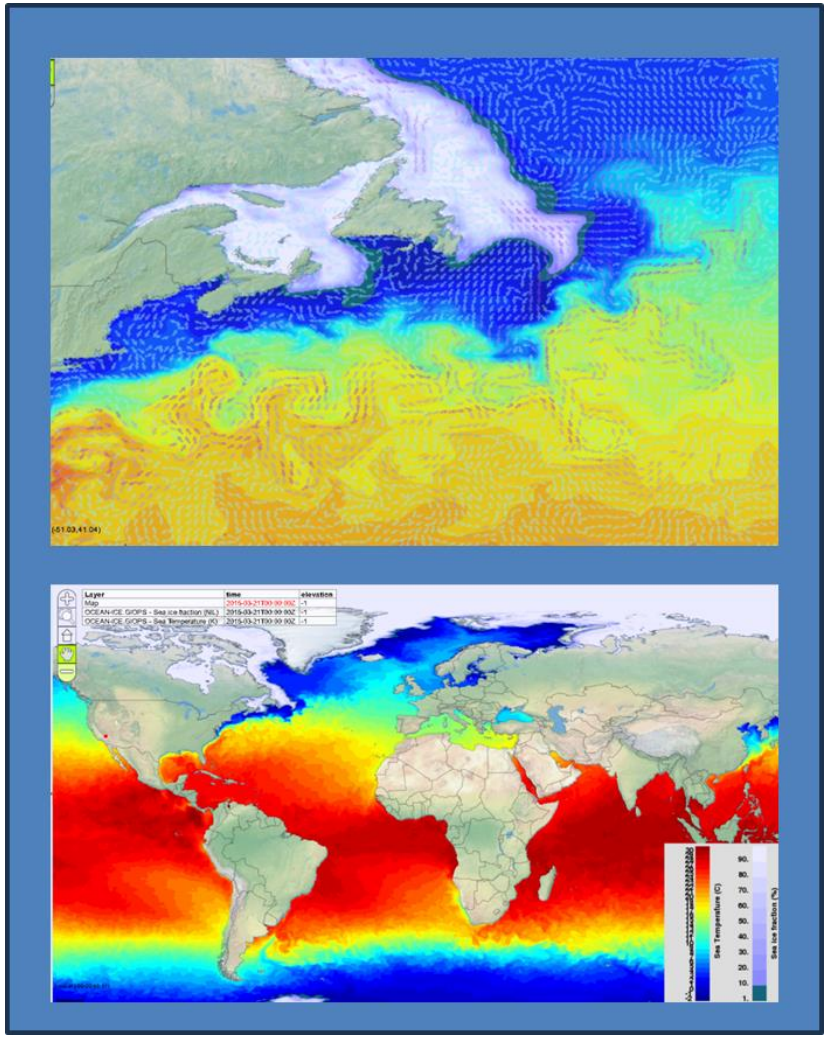
Timeline

- Global Ice Ocean Prediction System (GIOPS)- developed in collaboration with MOi
- First ocean data assimilation system at ECCC, run as experimental system in October 2013 (v1.0.0) and was upgraded to v1.0.1 in March 2014 and to v1.1.1 in June 2014; the system was declared operational in **August 2015**
- Models: NEMO(3.1) and CICE(4.0)
- Data assimilation: SAM2 (Systeme d'Assimilation Mercator version 2)
  - Based on SEEK, background error covariances modelled by an ensemble of multivariate three-dimensional anomalies derived from a multi-year hindcast simulation
  - Assimilates observations of SLA, SST and in situ T/S profiles
  - Ice insertion using RTF method for adjusting total ice concentration to thickness categories



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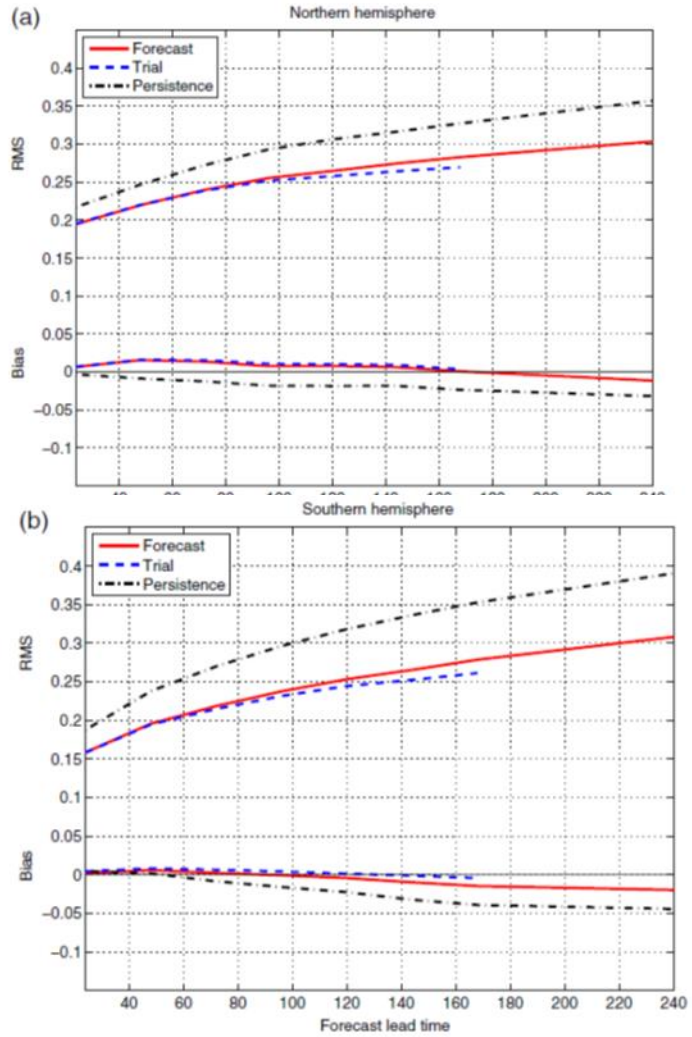
Timeline

- June 2016 – a major upgrade of GIOPS to version 2.1.1 included a much more up to date version of the SAM code from Mercator Ocean.
- In particular, the new system employs the incremental analysis update (IAU) approach, an improved mean dynamic topography (MDT) and bogus observations
- Refinements in the analysis kernel, and in the use of operational CMC SST and sea ice analyses
- Verification of ice forecast: RMS and bias errors represented as a function of forecast lead time – significant improvements over the persistence of initial conditions, especially in the marginal ice zone



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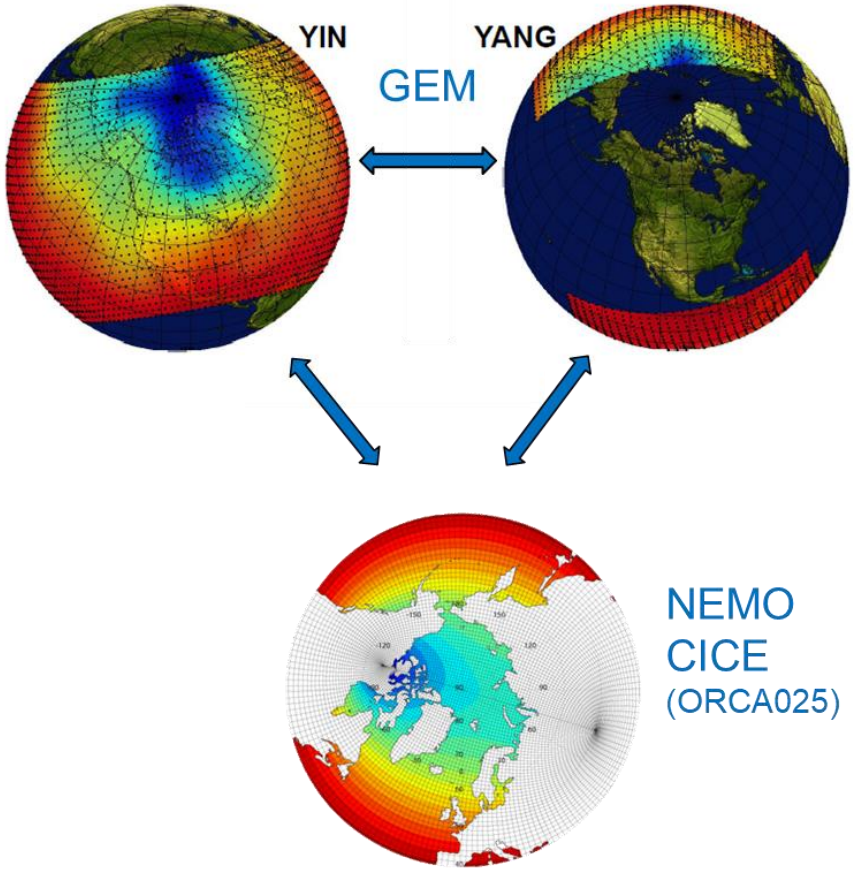
Timeline

- The coupled NWP was declared operational on November 1st, 2017
- Ocean and ice models are coupled with the atmospheric model GEM (version 5)
- The coupler allows the exchange of information between the atmosphere and the ocean, which simulates interactive and consistent transfer of momentum, heat and moisture.
- The initialization is done by four different analyses systems : atmosphere (Envar), SST (OI), ice(2D-Var) and ocean (GIOPS)



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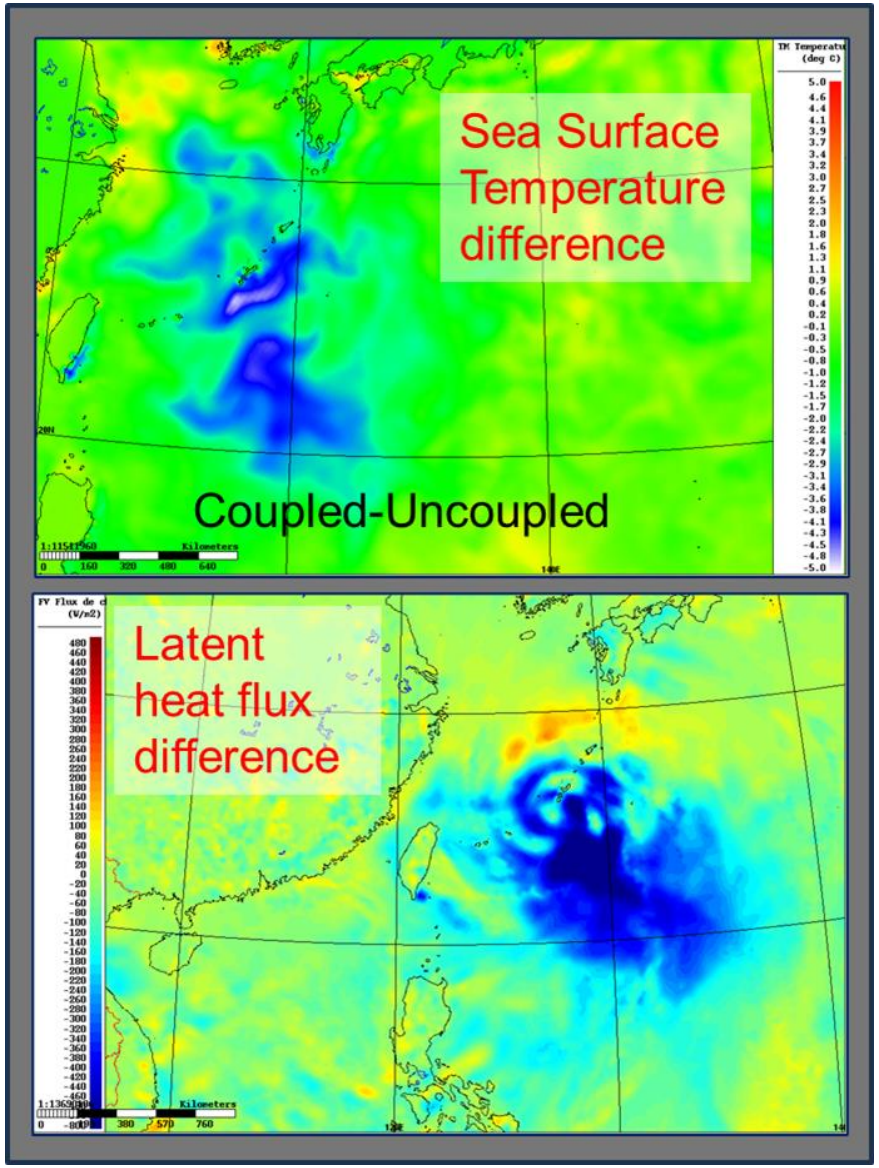
- The initialization is done by four different analyses systems : atmosphere (Envar), SST (OI), ice(2D-Var) and ocean (GIOPS)
- Impact of coupling: improved cyclone prediction, reduced forecast errors over a 5 to 7-day period specially in the northern extra tropics during summer and in tropical regions during winter



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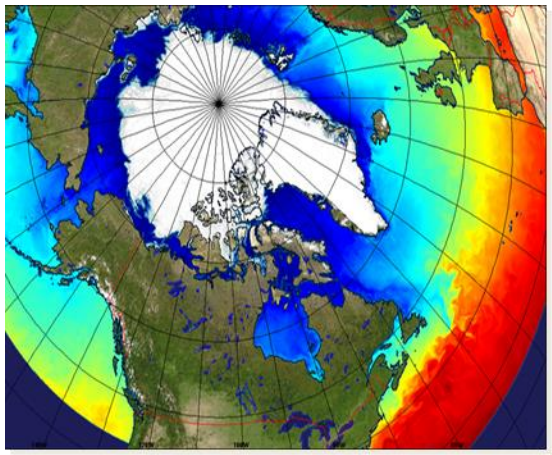
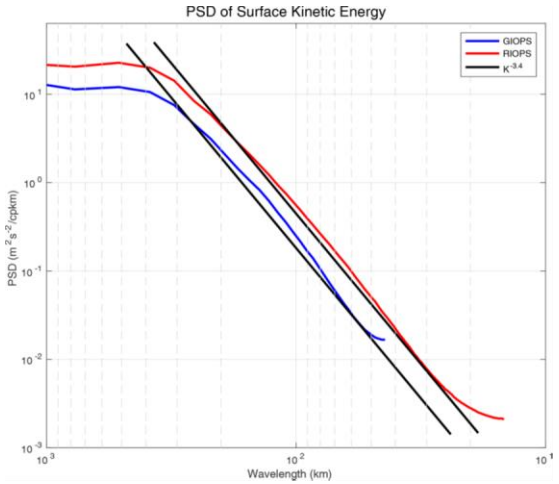
Timeline

- The Regional Ice Ocean Prediction System version 2 (RIOPSv2) was implemented in operations in July 2019
- RIOPS - METAREAs Initiative(regions17 and 18; support CIS for Ice hazards and warnings for Global Marine Distress and Safety System (GMDSS)
- The domain extended to cover the North Pacific. Horizontal resolution 1/12 (8 km in the North Atlantic to 3 km in the Canadian Arctic Archipelago), vertical sampling 75 levels
- The models NEMO 3.6, CICE4 with updated parameters for atmosphere-ice and ice-ocean drag coefficients and ice strengths
- Include a multivariate data assimilation based on SAM2 with 7-day IAU, online harmonic analysis, new background error covariances, updated SSH and SST observation operators





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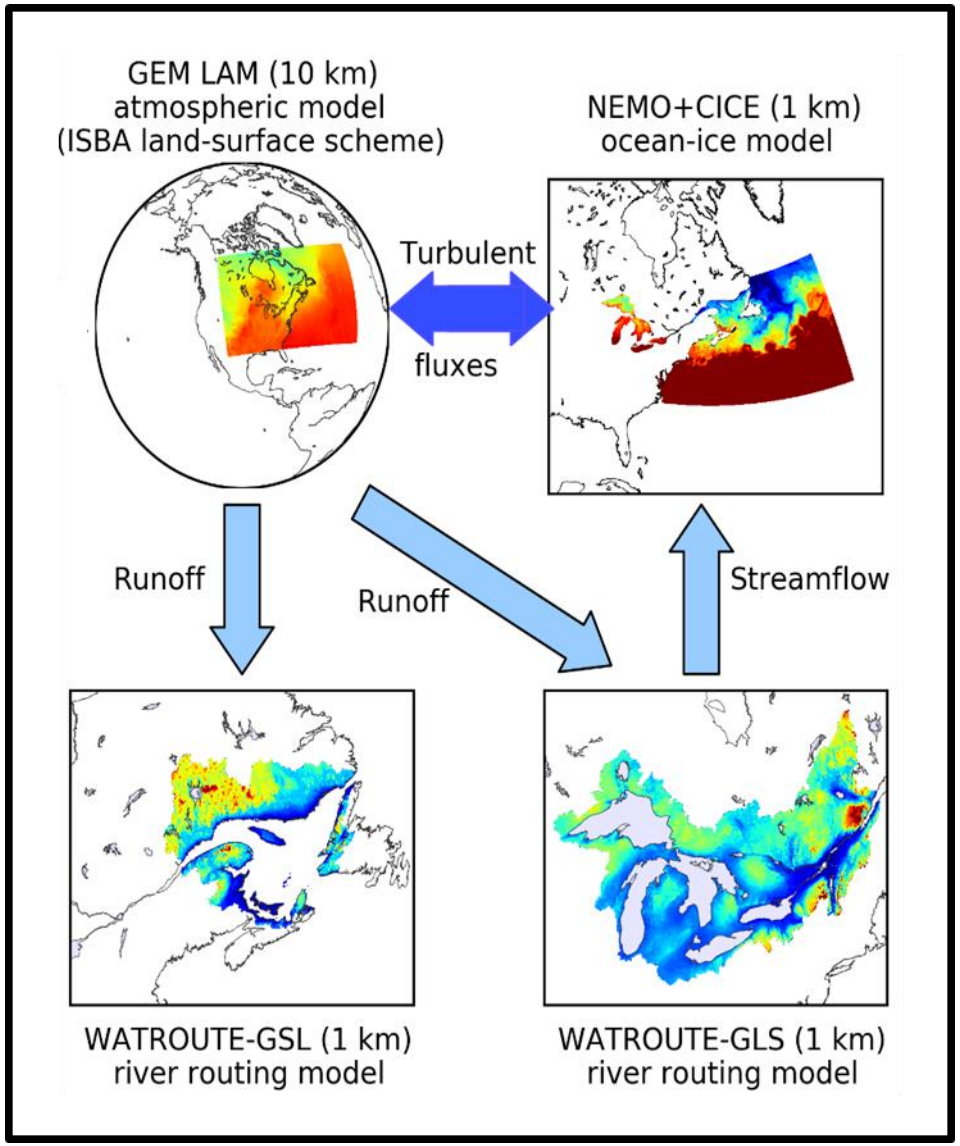
Timeline

- July 2019 – many updates for other ocean and ice predictions systems
- Water Cycle Prediction System (Great Lakes)
  - Water level support, as well as CIS, EER



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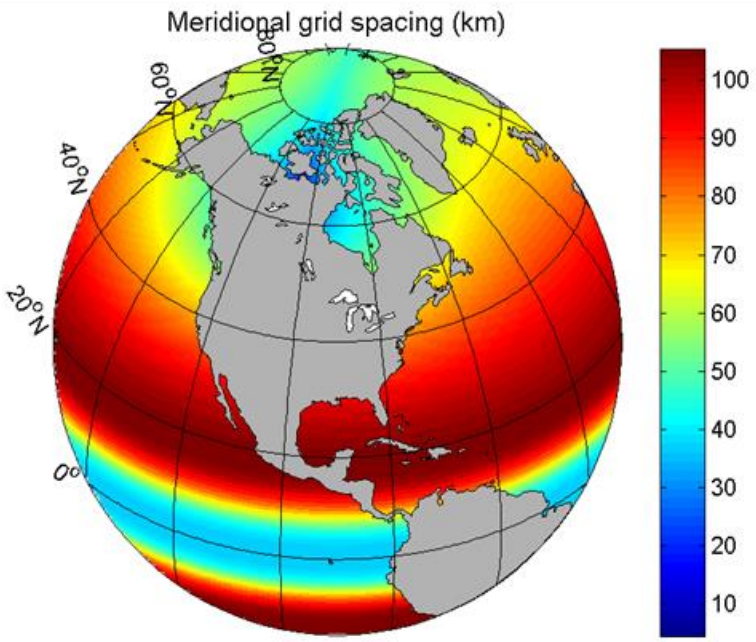
- Coupled seasonal predictions (CanSIPS)

1° Global



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Timeline

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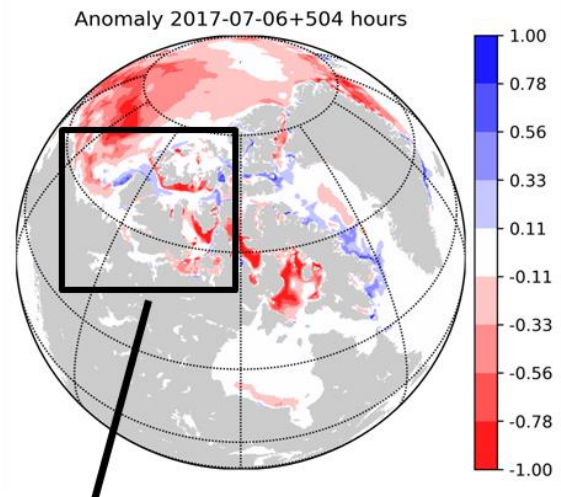
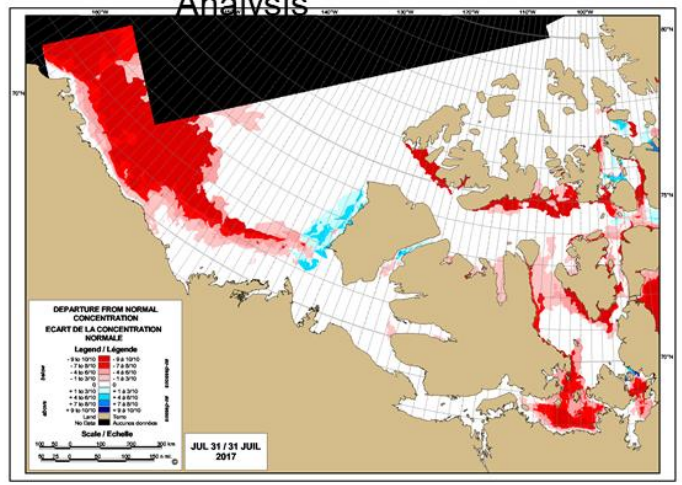
- Water Cycle Prediction System (Great Lakes)
  - Water level support, as well as CIS, EER
- Coupled seasonal predictions (CanSIPS)
- Coupled Ensemble Predictions (GEPS)
  - Support for long-range ice forecasts and improved NWP



Canadian Ice Service Regional Analysis



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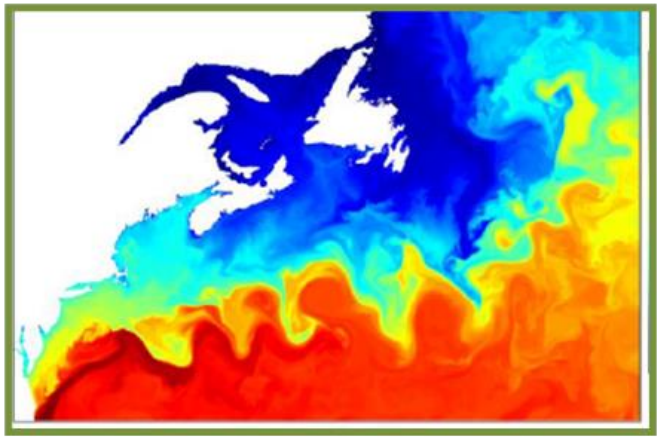
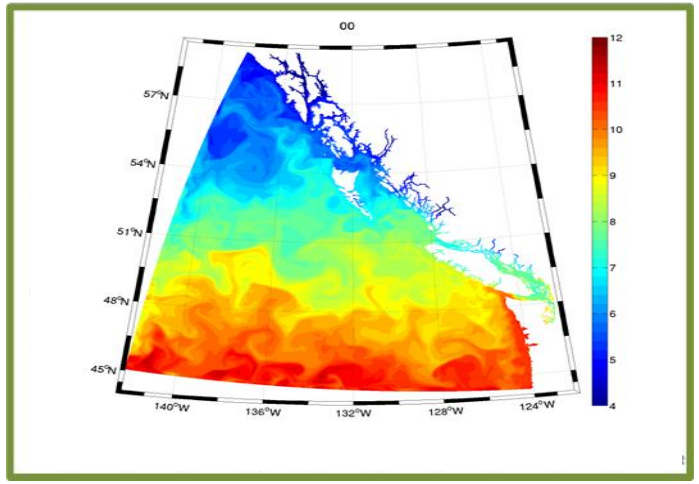
Timeline

- In December 2021 two Coastal Ice Ocean Prediction Systems have been implemented in operations
  - Configuration 1/36° (2km) developed specifically for Ocean Protection Plan, support Environmental Emergency response, electronic Navigation, Search and Rescue
  - provide best estimates of surface currents
- GIOPS updates:
  - Inclusion of a diurnal cycle
  - Ice strength parameter updated
  - Ice roughness adjusted to fit GEM model value
  - Atmospheric forcing taken from the assimilation run instead of the forecast run
- RIOPS updates:
  - Introduction of a new schema for vertical blending
  - 3Dvar bias correction for temperature and salinity profiles
  - Reduction of turbulence due to breaking waves
  - Increase ice roughness
  - Inclusion of a diurnal cycle

CIOPS-East



CIOPS-West



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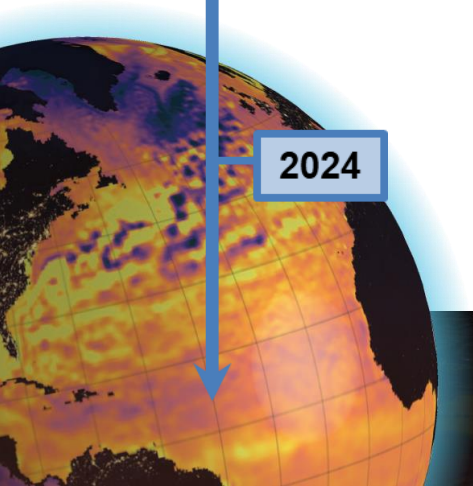
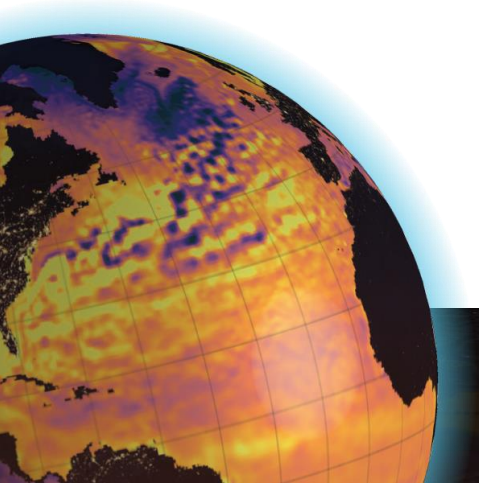
Timeline

- Major updates for all ice-ocean systems - ice model CICE6.2
- GIOPS and RIOPS updates included:
  - Delta-Eddington Radiation Scheme
  - Mean Dynamic Topography (MDT) Update
  - Activation of New Altimetry Datasets



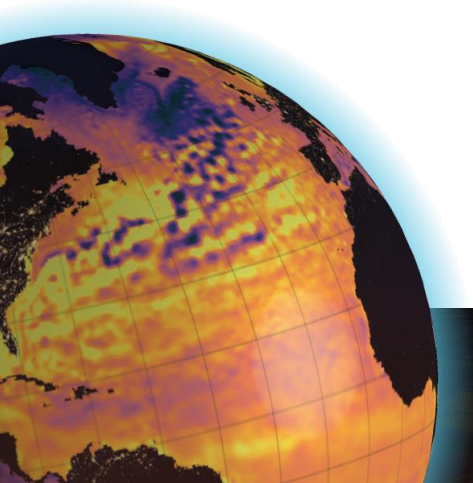
Where we are now

- 5 global ice-ocean data assimilation and prediction systems (3 coupled with the atmosphere)
- 4 regional ice-ocean data assimilation and prediction systems
- 4 systems for wave prediction and 2 systems for storm surge prediction
- Data available in real time on different platforms :
  - Open data : https://eccc-msc.github.io/open-data/msc-data/readme_en/
  - Ocean navigator: https://www.oceannavigator.ca/public/
  - MSC GeoMet: https://eccc-msc.github.io/open-data/msc-geomet/readme_en/



Where we are now

- ECCC contributions to international groups and research activities related to ocean:
  - SWOT Science Team (*OSEs and OSSEs; Liu et al., 2024*)
  - Clean Arctic – *Smith et al., 2024*: *Impact of assimilation of absolute dynamic topography on Arctic Ocean circulation, Front. Mar. Sci. 11:1390781. doi: 10.3389/fmars.2024.1390781*
  - SynObs project – *K Andrew Peterson, Gregory C. Smith*: *Impact of Observations on ECCC's Global Ocean Analysis, GIOPS*
  - Year of Polar Prediction (YOPP) – *F. Dupont et al*: *Coupled Canadian Arctic Prediction System version 2 – A multidisciplinary approach for coupled forecasting in the Arctic*
  - Sea Ice Rheology Experiment *(SIREX; Bouchat et al., 2022)*

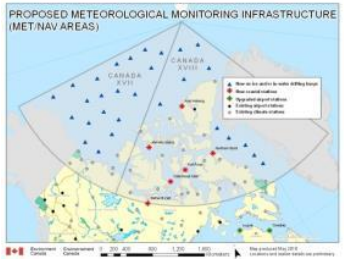


Ocean prediction users and applications

DFO Applications
- Fisheries and Aquaculture management
- Ocean climate monitoring

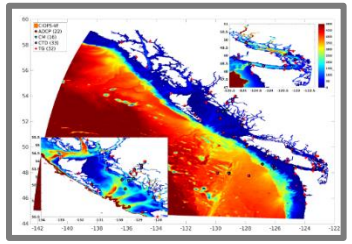
National Environmental Emergency response Centre (NEEC)
- Oil spill

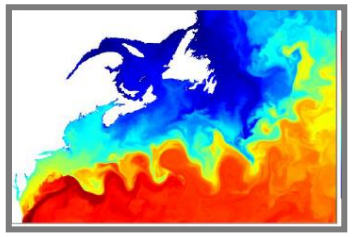
DND Applications
- Situational awareness
- Anti-submarine warfare
- Operational support



Canadian Ice Service
- High-pressure ridges
- Automated analyses
- Iceberg drift

Canadian Coast Guard
- Search and Rescue
- Environmental Emergency Response





Downstream systems
Ports, e-Nav, Waves, Storm surge
NWP (coupling)

Ocean Predict

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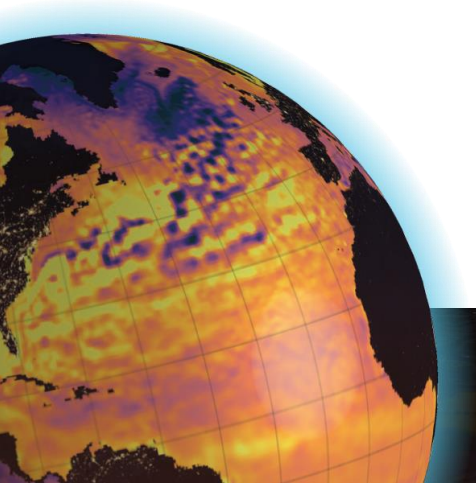
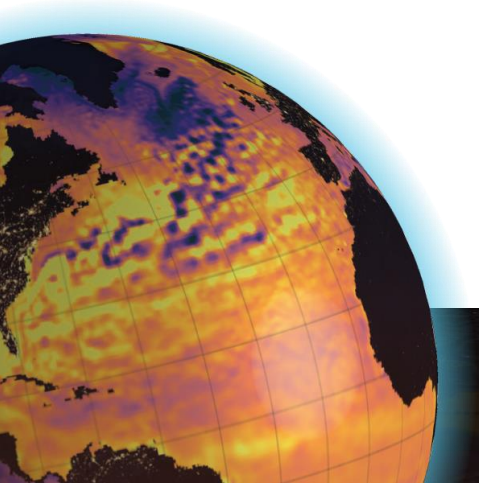
What is next

- **Ensembles**
  - Required to provide better estimates of model error for data assimilation
  - Provides ensemble of initial conditions to support probabilistic forecasting
  - Ensemble analyses and forecasts can be used to provide uncertainty estimates (frequently requested by users)
- **Fine-scale (~1km) coupled forecasting**
  - Improved atmosphere-ice-ocean exchanges (boundary-layer fluxes)
  - Development of new configuration to combine RIOPS, CIOPS and WCPS (CREG36)
  - Support needs for EER, S&R along all Canadian coastlines (i.e. including in the north!)
  - Make use of wide-swath altimeter (SWOT) to constrain smaller spatial scales



What is next

- **Historical reconstructions (“Reanalysis”)**
  - Production of 30yr long simulations
  - Needed for initialization of CanSIPS and GEPS
  - Provides better understanding of errors and contextualization for extreme events (e.g. return rates)
  - Opportunity to make case studies (e.g. response to extreme events)
  - Training datasets for AI-based forecasting

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ADVANCING OCEAN PREDICTION
SCIENCE FOR SOCIETAL BENEFITS
Thank you!
European Commission
Copernicus Marine Service
EU4oceanobs
INTERNATIONAL OCEAN GOVERNANCE
EU COMPONENT TO GLOBAL OCEAN OBSERVATIONS
esa
cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES
Met Office
NERSC
MERCATOR OCEAN INTERNATIONAL
Australian Government
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Canada