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Overview of Ice Modelling Projects

Tom Carrieres

Canadian Ice Service

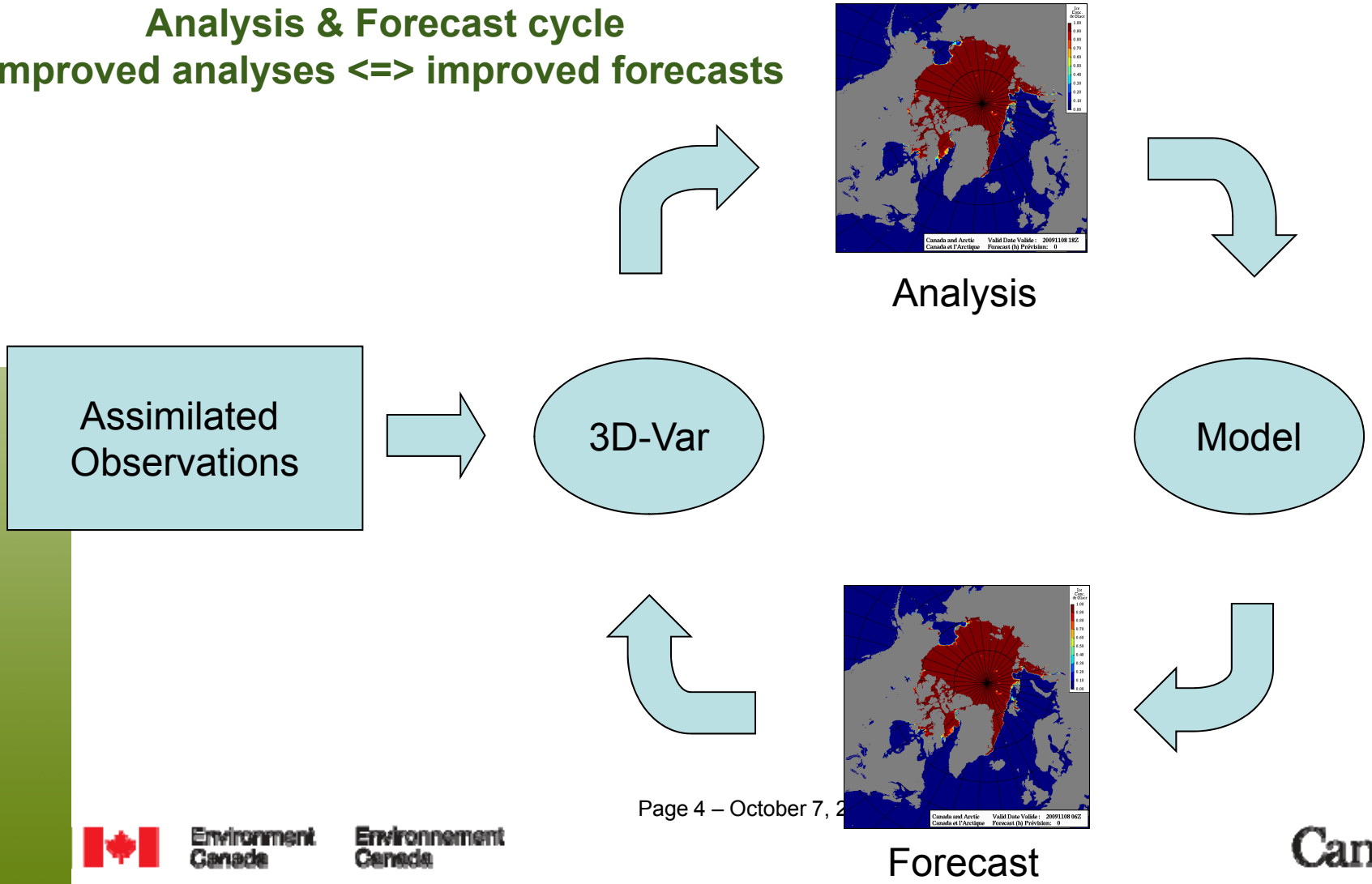
Outline

- Data Assimilation
- Sea Ice Models
- Iceberg Models
- Long Range Ice Forecast Models

Data Assimilation

IICWG-3 Direction: NWP-like ice service operations

Analysis & Forecast cycle
Improved analyses <=> improved forecasts



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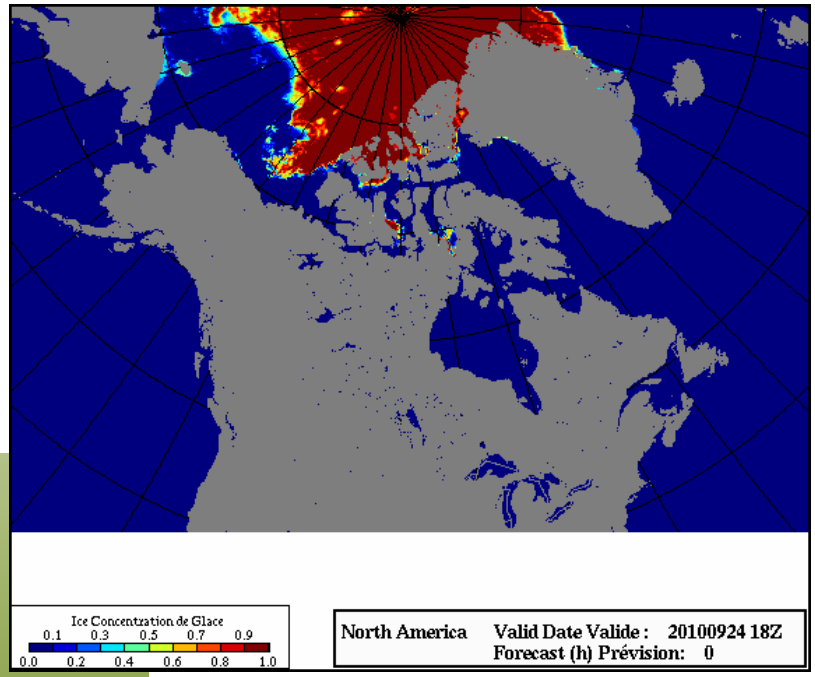
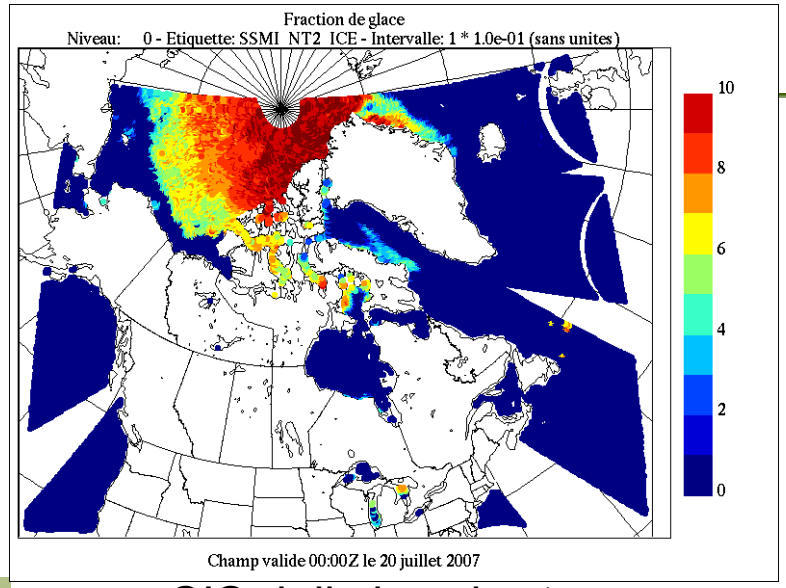
Regional Ice Prediction System (RIPS)



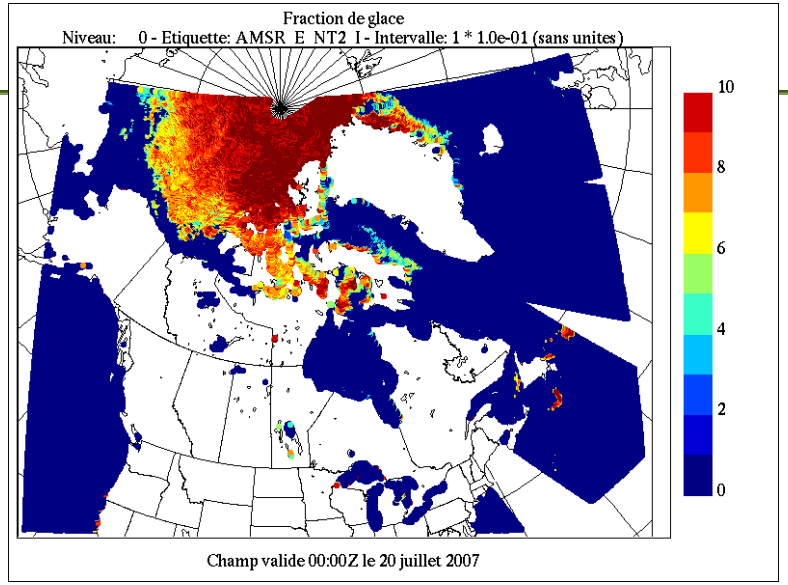
- Main use: provide input for generation of CIS operational products (both manual and automated)
- Four analyses per day of ice concentration at 5 km resolution on rotated lat-lon grid
- Domain chosen to include new METAREAs and meet the needs of North American Ice Service (USA/Canada)
- Includes the Great Lakes and many other lakes (those for which CIS already produces analyses)
- Also serves as the test-bed for evaluating upgrades for all implementations (global and regional)

Assimilated data: Typical data coverage

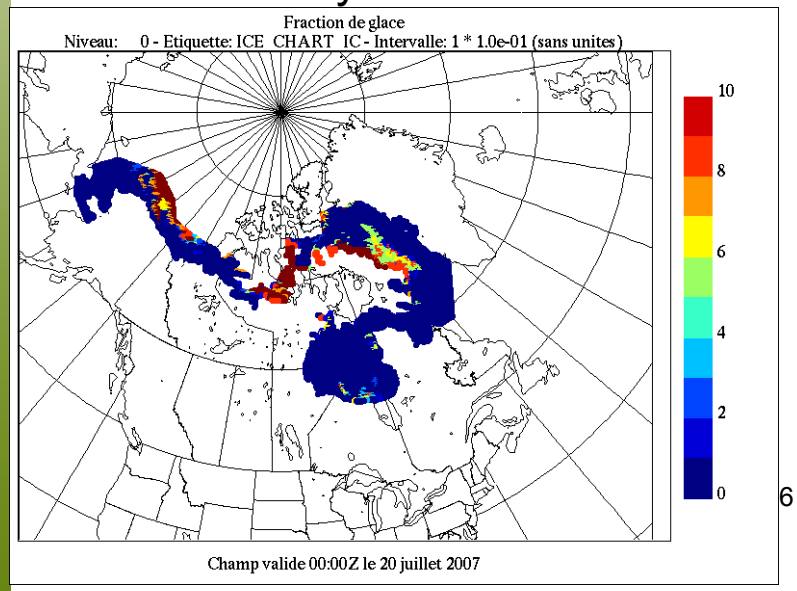
SSM/I ice concentration



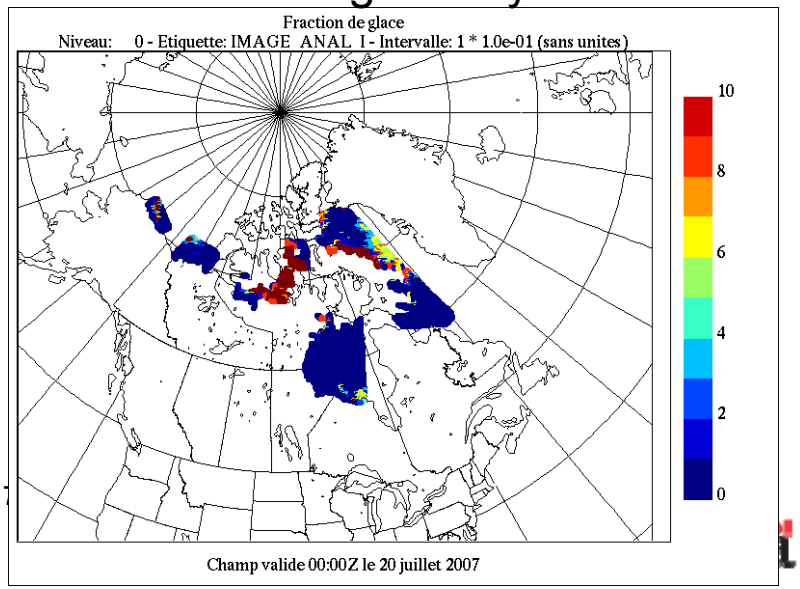
AMSR-E ice concentration



CIS daily ice charts



CIS image analyses



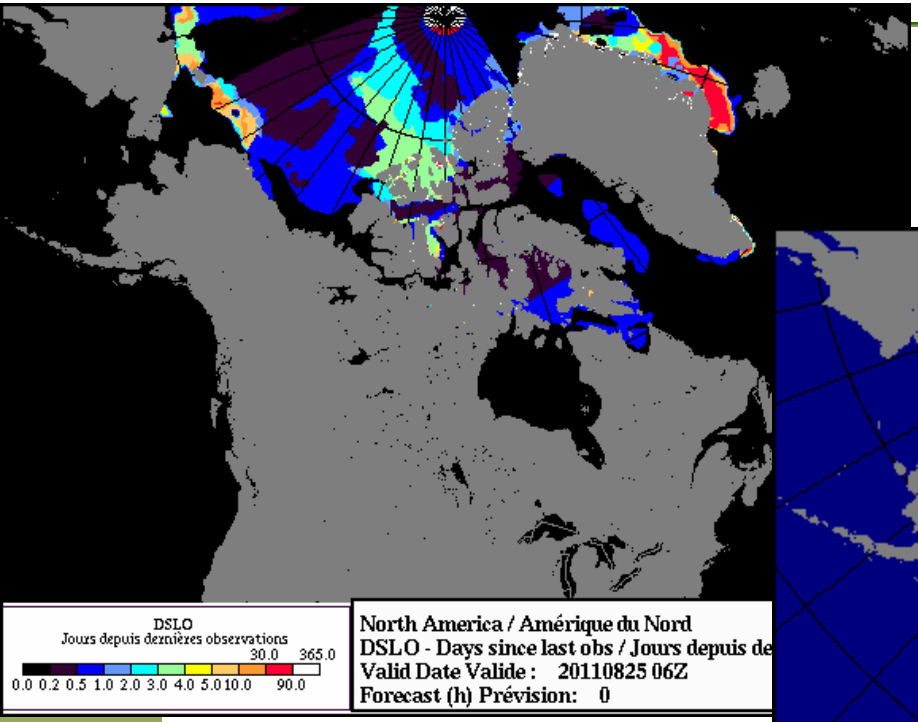
Variational data assimilation approach

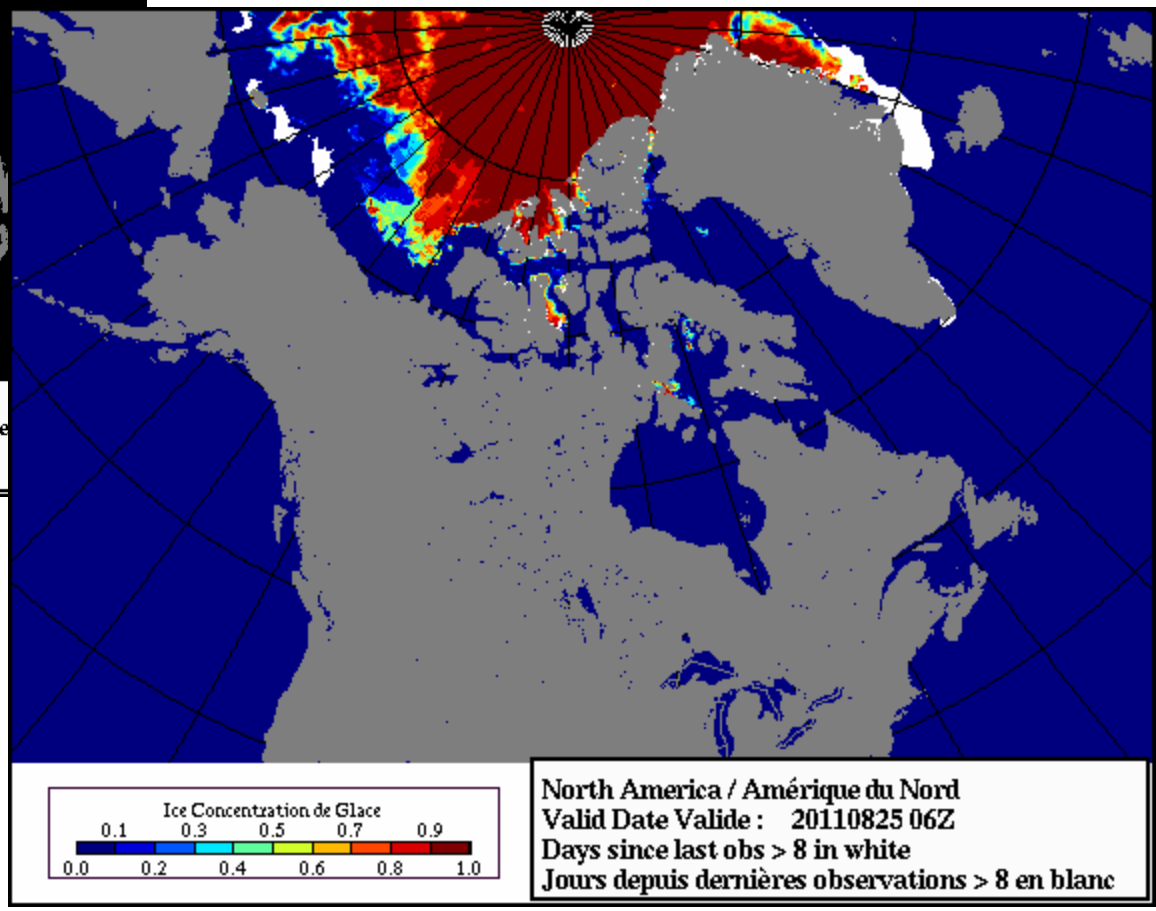
- Based on 3D variational data assimilation approach:
  - the code is independent from the NWP variational data assimilation code
  - but follows the same basic structure of NWP code and uses the same Quasi-Newton minimization algorithm (N1QN3)
- Assumes Normally distributed errors, but ice concentration in range [0,1] (reset unphysical values after analysis)
- Like NWP system, uses the preconditioned form of cost function:

$$J(\xi) = \frac{1}{2}\xi^T\xi + \frac{1}{2}(H[\mathbf{x}_b] + \mathbf{HB}^{1/2}\xi - \mathbf{y})^T \mathbf{R}^{-1}(H[\mathbf{x}_b] + \mathbf{HB}^{1/2}\xi - \mathbf{y})$$

- where:
  - $\mathbf{x_b}$ is the short-term forecast used as the background state
  - **B** is the background-error covariance matrix
  - **y** is the vector of observations
  - **R** is the observation-error covariance matrix
  - H observation operator: maps model variables into observation space

RIPS Sample Output





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Planned future developments of sea-ice analysis systems

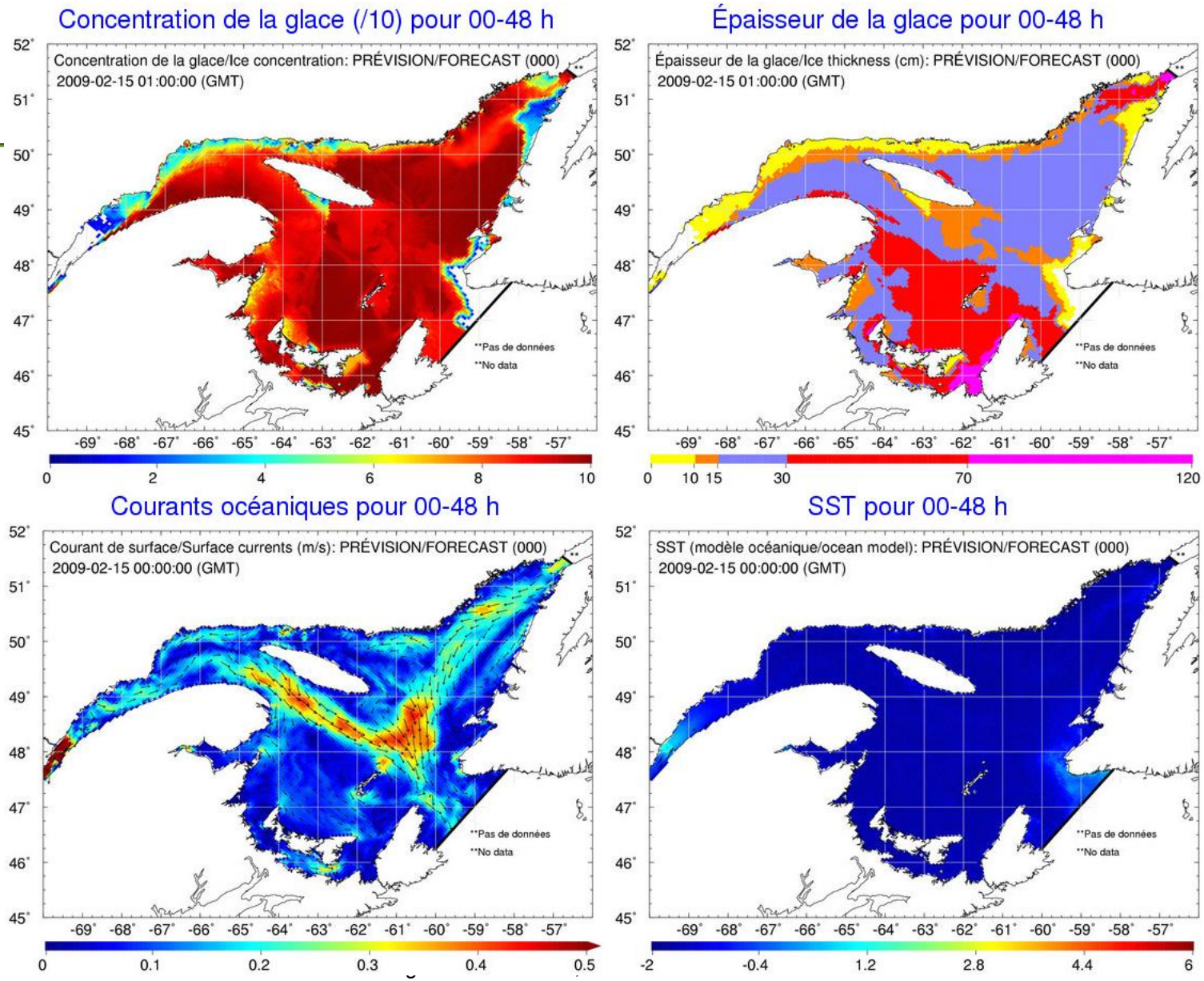
- Implementation at CMC of 3D-Var analysis system to provide initial conditions for coupled Gulf of St Lawrence system
- Development of a global sea-ice analysis system to replace currently operational CMC system for all NWP applications
- Coupling of regional sea-ice analysis system with a sea-ice forecast model to produce 1-2 day forecasts of ice concentration and pressure
- Assimilation of SSMIS, scatterometer, visible-infrared, SAR and ice thickness satellite-based observations
- Coupling to regional and global ice-ocean-atmosphere models

Sea Ice Models

MoGSL

- Description
  - An updated version of the IML ice-ocean model (5 km) with 2-way coupling to GEM-LAM
  - Ice conditions are initialized using CIS image analysis chart dex files
  - Will be available this winter on vizaweb and Polaris
- CIS Operations Involvement
  - Subjective operational evaluation including its utility and accuracy
- Planned developments
  - More sophisticated DA techniques have been tested
  - Will be replaced by C-NOOFS in a few years

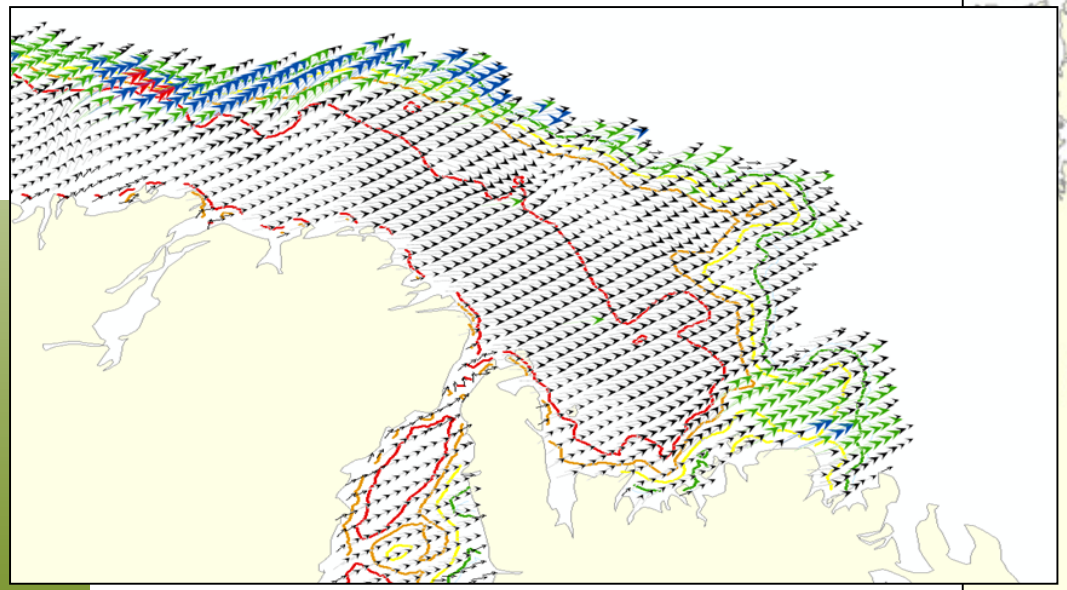
MoGSL Sample

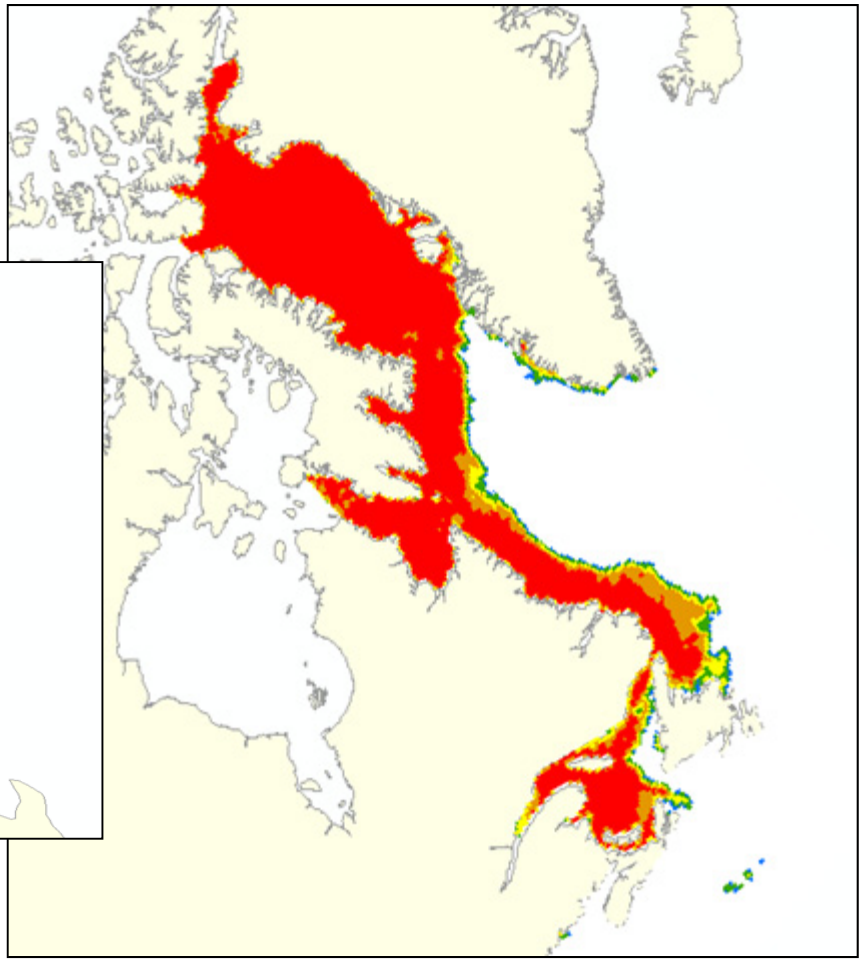


CECOM

- Description
  - A coupled ice-ocean model covering east coast up to Nares Strait
  - A completely updated version of BIO's CIOM with uniform 10 km resolution and more ocean levels
  - provides a standard for comparing new CMC based models
- CIS Operations Involvement
  - Subjective operational evaluation including its utility and accuracy
- Planned developments
  - Possibly add more sophisticated sea ice DA
  - Will be replaced by C-NOOFS in a few years

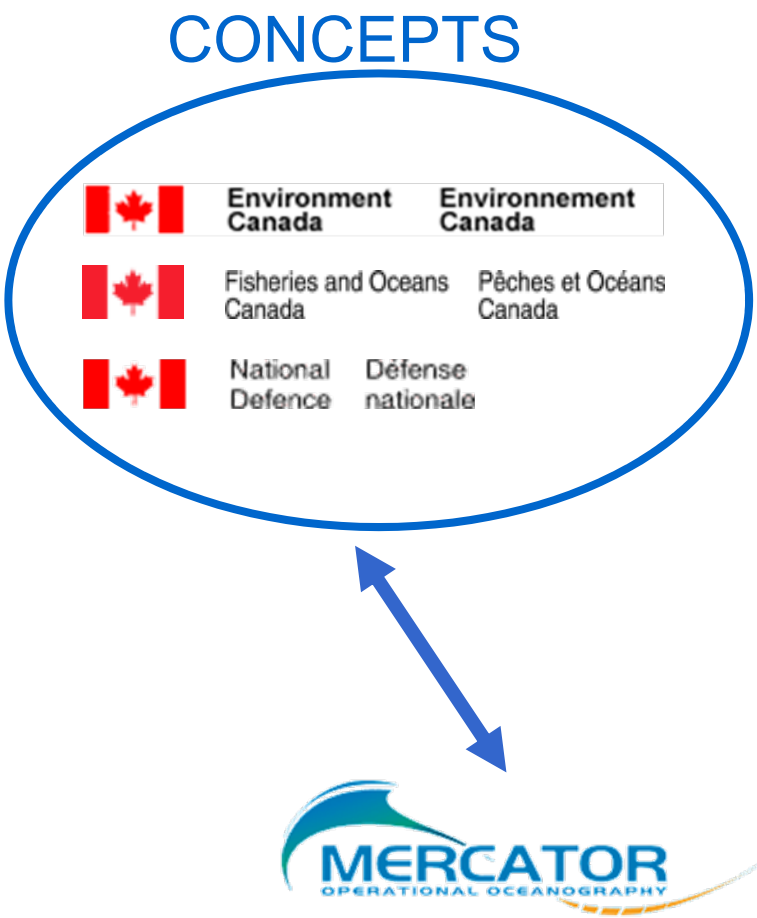
CECOM





CONCEPTS

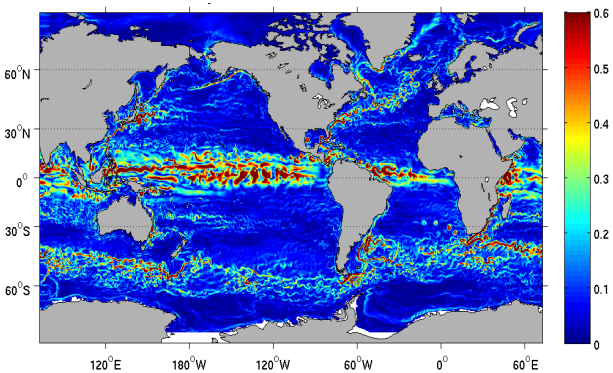
- Several new coupled systems under development as part of CONCEPTS
  - Canadian Operational Network of Coupled Environmental Prediction Systems
- Tri-departmental collaboration
  - To develop coupled atmosphere-ice-ocean forecasting systems
- Model development
  - Coupling GEM to NEMO (Nucleus for European Modelling of the Ocean)
- Collaboration with Mercator
  - French operational oceanographic group



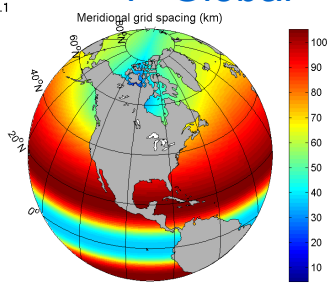
Ice-ocean modelling using NEMO

- Global 1/4° resolution
  - Medium range forecasting
- Global 1° resolution
  - Monthly-to-seasonal forecasting
- N. Atlantic and Arctic 1/12°
  - Short-to-medium regional forecasting
- Great lakes 2km
  - Short term forecasting

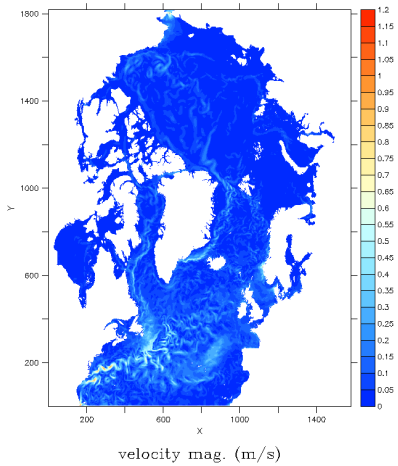
1/4° Global

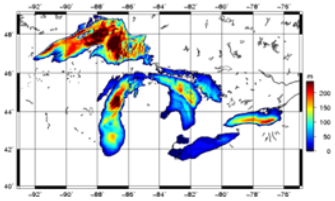


1° Global



1/12° N. Atlantic and Arctic





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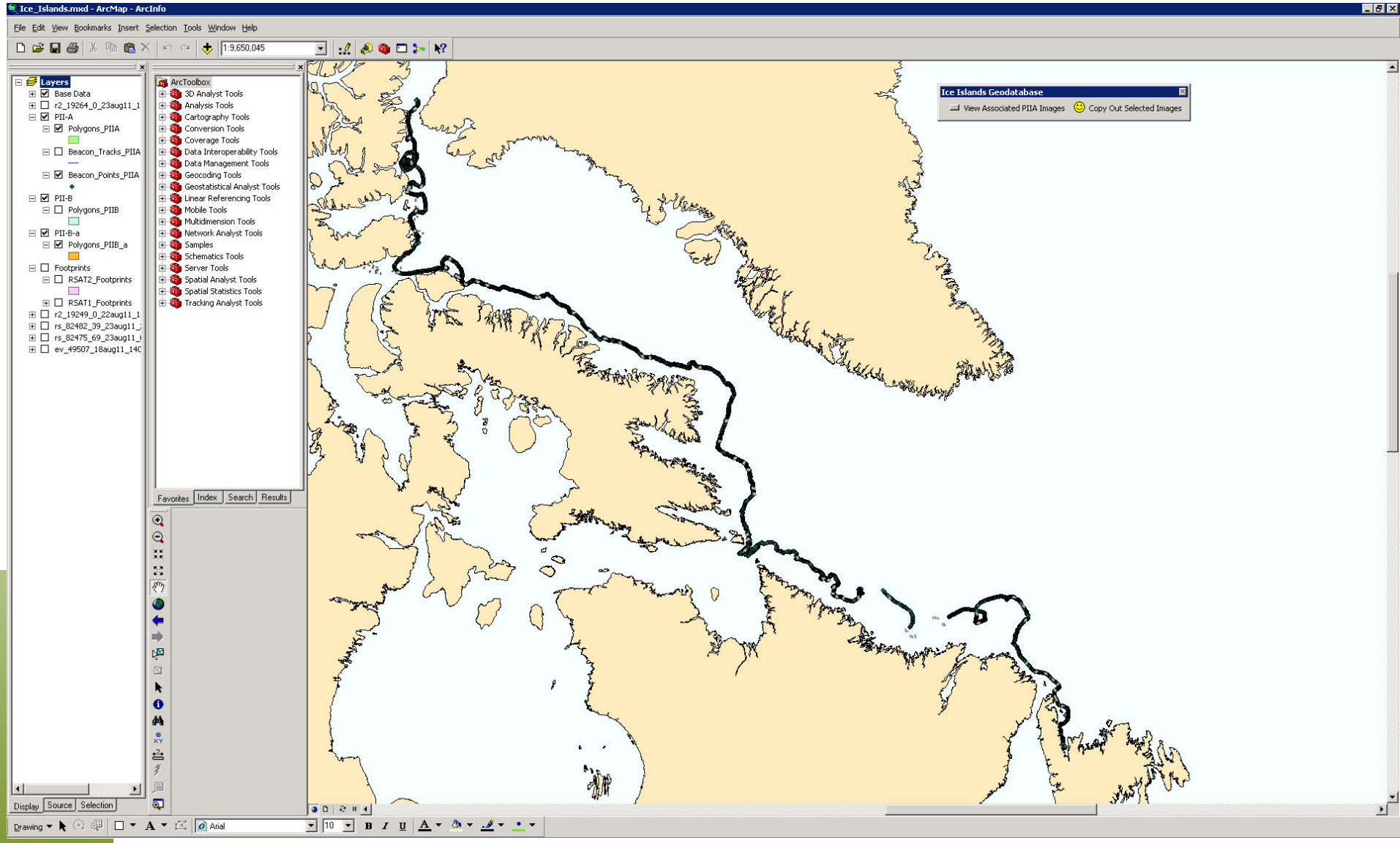
Ice Hazards

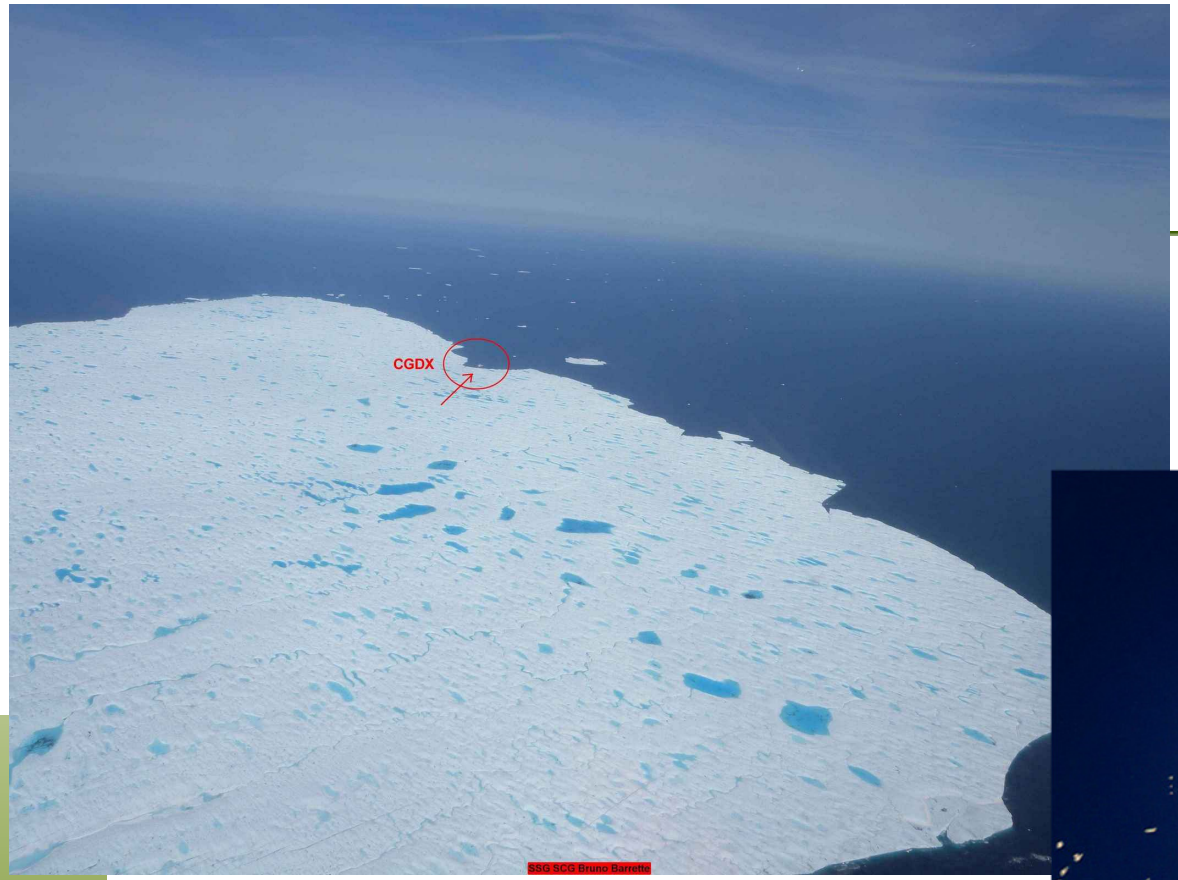
(icebergs, ice islands and MY ridges)

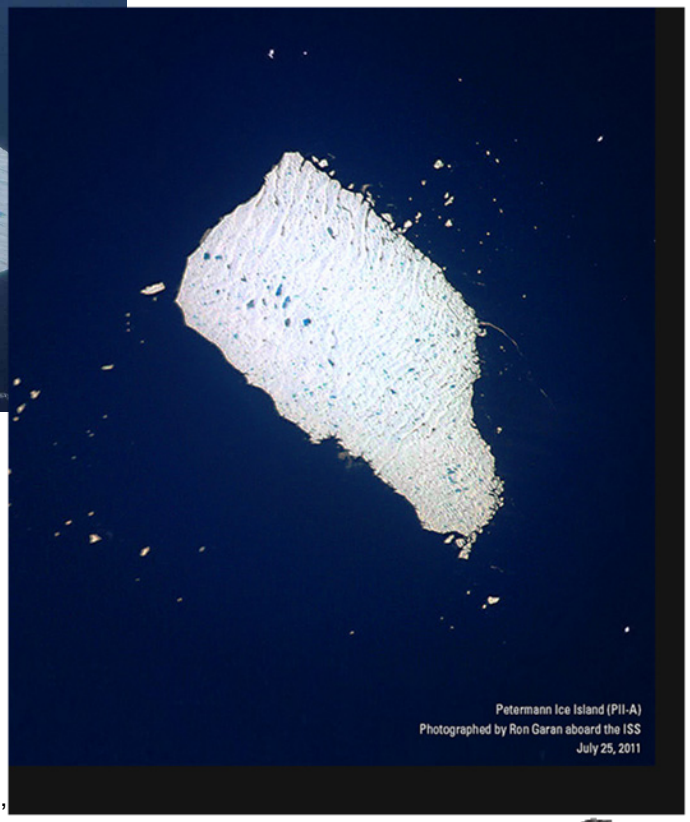
NAIS Iceberg Model

- Drift
  - Ocean currents (upper 200m)
  - Winds (near surface)
  - Wave radiation stress
  - Other (Coriolis, added mass, …)
- Deterioration
  - Calving
  - Wave erosion
  - Forced convection
  - Other (solar radiation, buoyant flux, …)



- A geodatabase and ArcMap project was created to house the movement and ancillary information about the Petermann ice islands
  - Currently PII-A, PII-B, and PII-B-a have been tracked up to date
  - Size, shape, location (points and polygons) and associated SAR imagery are in the geodatabase
  - SAR backscatter statistics will be a future addition
- RADARSAT-2 imagery being ordered on a best effort basis at a frequency of once per week (Fine Quad, Wide Fine Quad)


CGDX
SSG SCG Bruno Barrette


Petermann Ice Island (PII-A)
Photographed by Ron Garan aboard the ISS
July 25, 2011

Planned Activities

- Support operational transition and evaluation
- Modifications for ice islands
- Sea ice effects on icebergs
- Automated ice hazard detection
- Ensemble/probabilistic iceberg models
- Optimal re-sighting and increased automation

Long Range Ice Forecast Models

CLIF Statistical Forecast Models

- **Regression Based Seasonal Forecast System -** Multiple linear regression (MLR) model to forecast (3 - 18 month lead) the spring opening date for the shipping route to Churchill, and East Coast Ice conditions, Arctic and Hudson Bay

- **Canonical correlation analysis** (CCA) model to forecast summer averaged ice conditions at a 3 – 9 month lead for Hudson Bay (East Coast and Beaufort Sea)

- **Optimal Filtering Based** Model to forecast ice conditions from past ice conditions (1-3 year leads) for the East Coast (and Great Lakes)

East Coast

Examples from winter season 2010/11

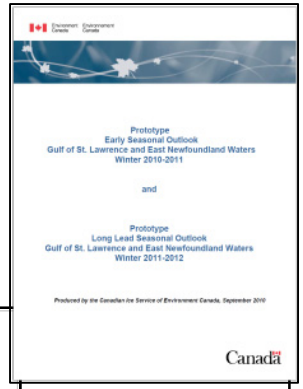
Prototype
Extended Range & Long Lead
Seasonal
Outlook

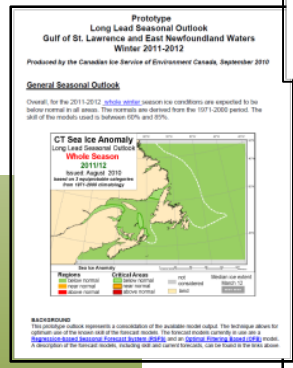
using **MLR** & **OFB**
statistical
techniques

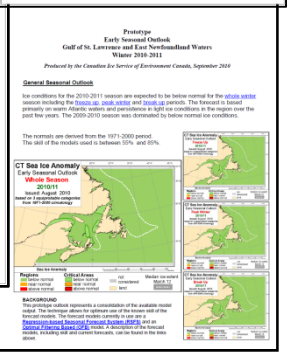
Seasonal Outlook Support

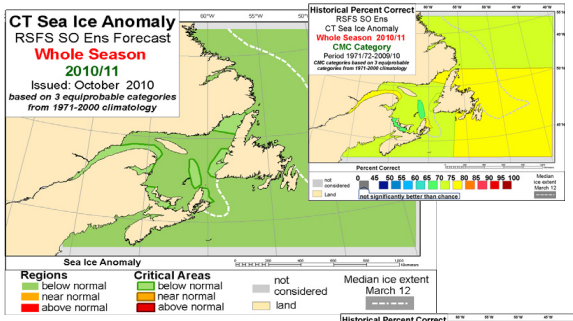
MLR Prediction System Forecast and Historical Percent Correct

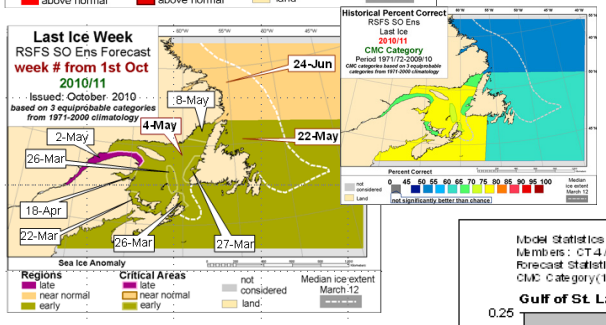
Verification East Coast 2010/11
Green= correct category forecast

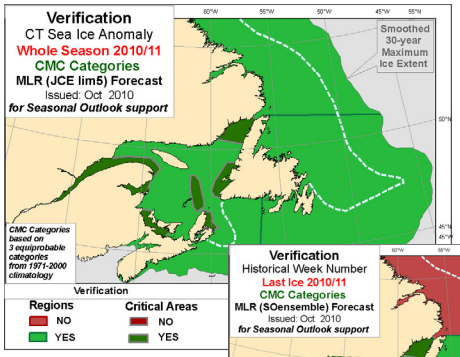


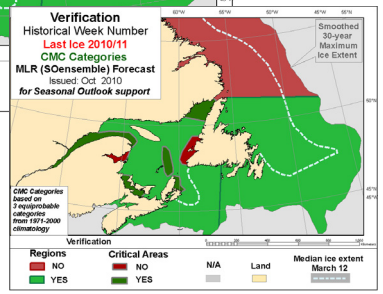


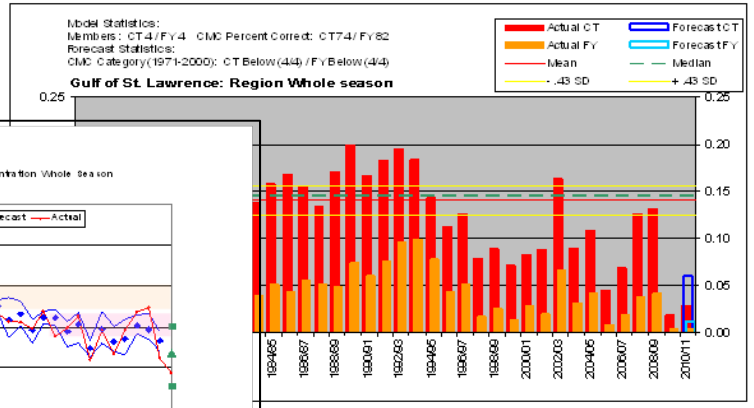


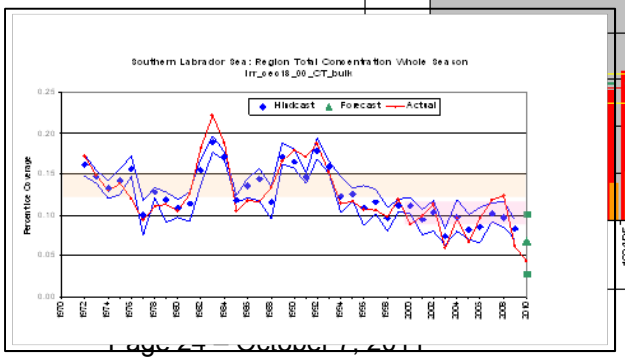


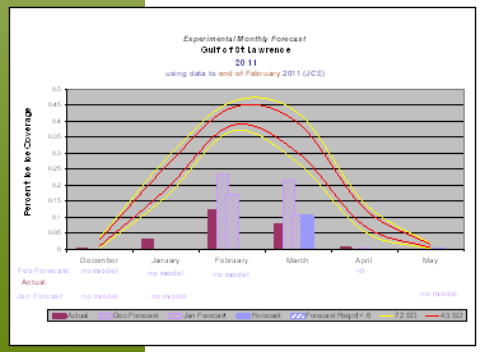












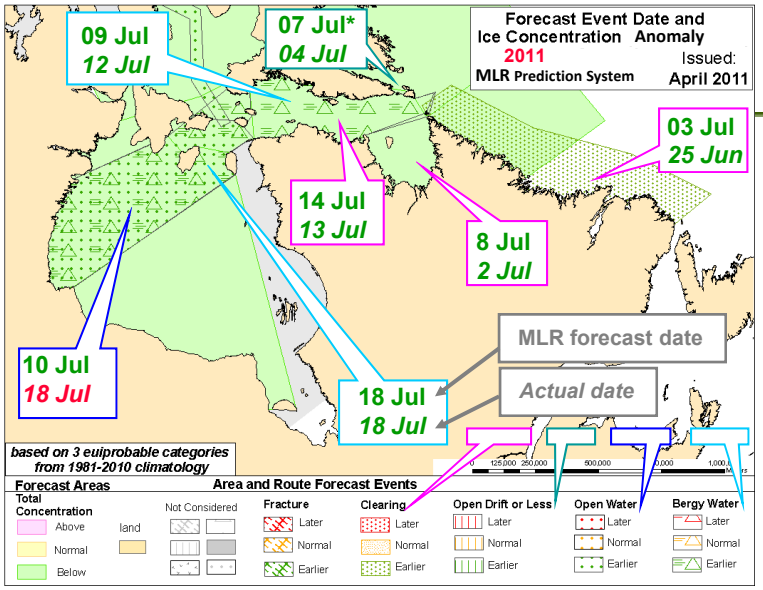
New
Monthly
ice anomaly
prototype
product

Range of ensemble members for training period and forecast with 2010/11 verification

Total and First Year Ice concentration for training period with forecast and verification

Seasonal Outlook Support: Northern Waters

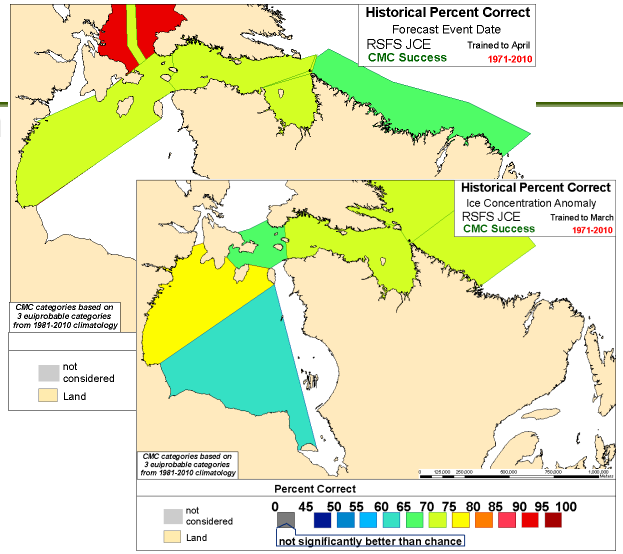
Example from Hudson Bay (also support Eastern and Western Arctic)



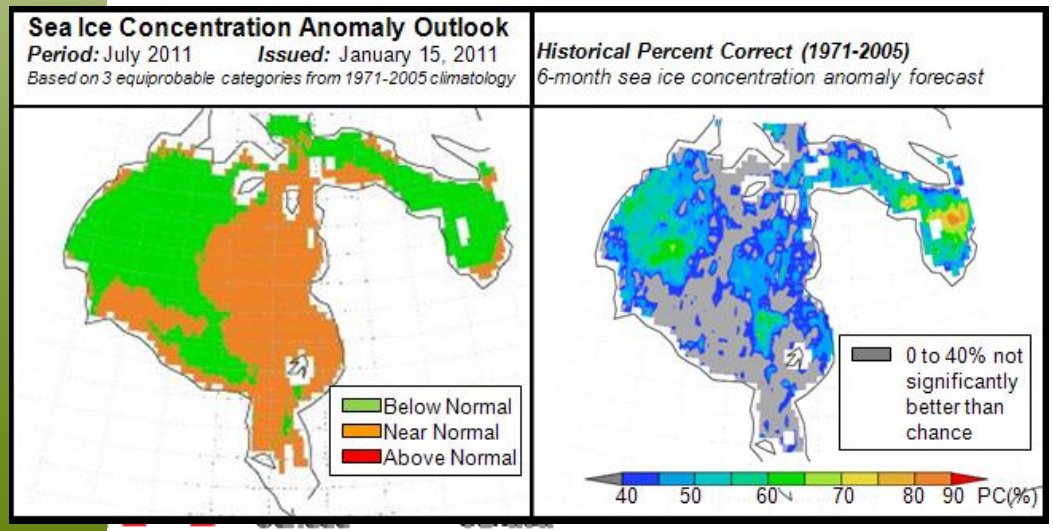
MLR
Prediction System
Forecast
with
Verification

and

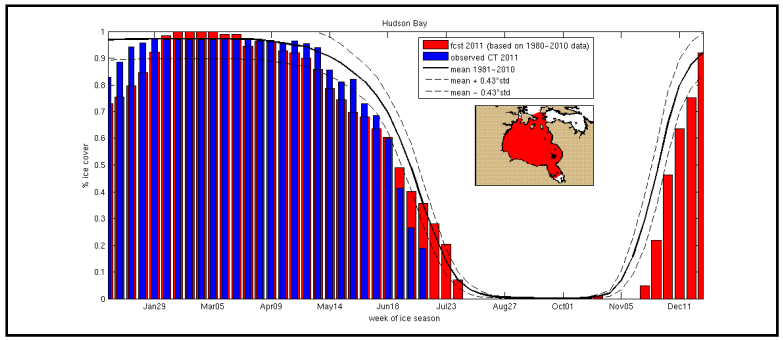
Historical Percent Correct



CCA Forecast and Historical Percent Correct



2011



OFBM experimental weekly
Forecast with **Verification**

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Thank You!

Any Questions?