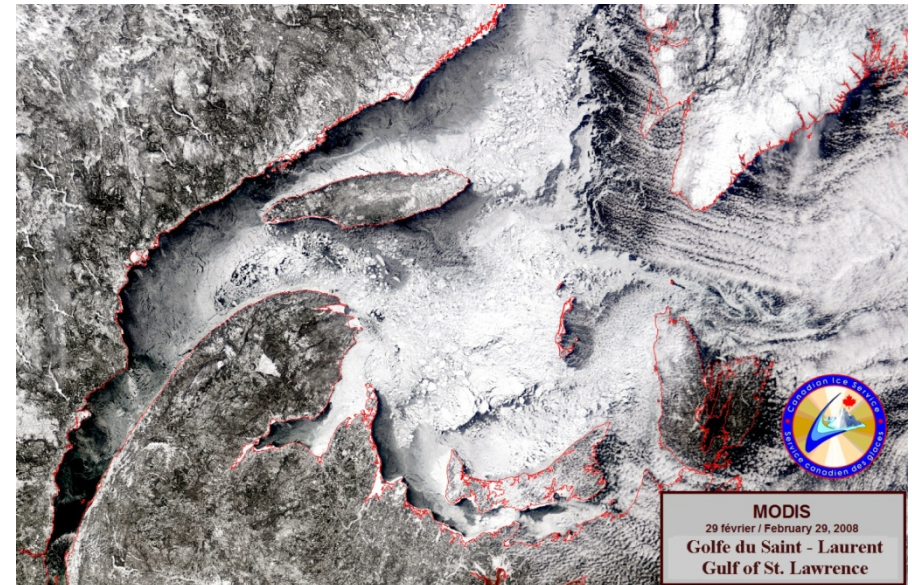# Environment Canada Operational Sea Ice Prediction: Status, Challenges and Opportunities

Hal Ritchie, Gregory Smith and the CONCEPTS Team
Meteorological Research Division and Canadian Ice Service, Environment Canada

NOAA Science Challenge Workshop, Boulder CO, May 13-15, 2014
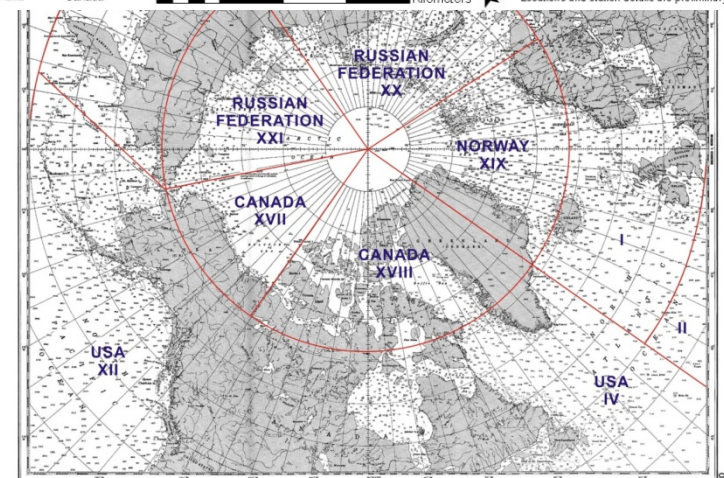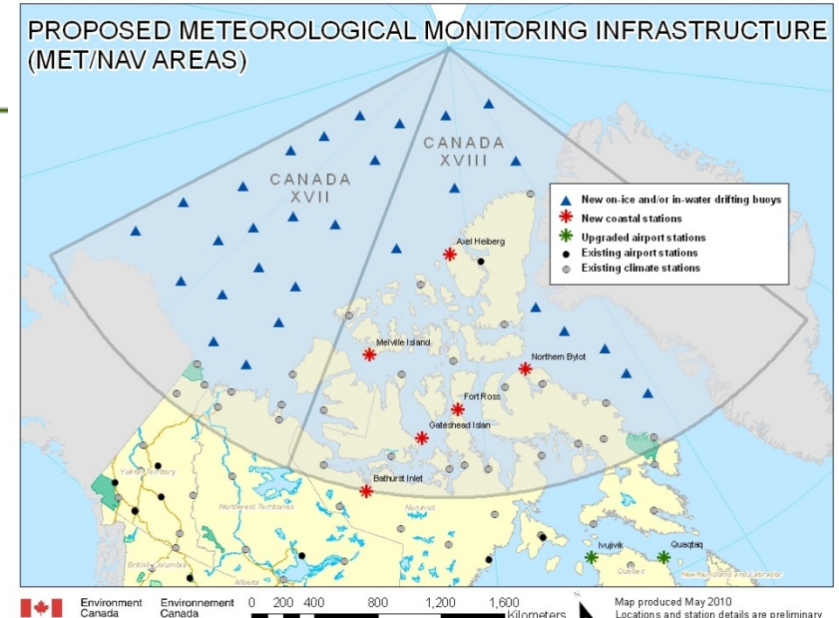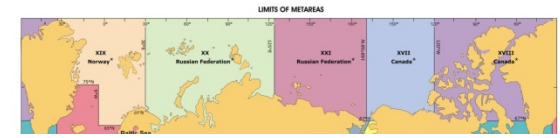
Environment Canada (EC) METAREAs Initiative: Backgrounder

- Decreasing Arctic ice cover has resulted in an increase in navigable Arctic waterways.

- In anticipation of increased marine traffic, the International Maritime Organization established 5 new METAREAs covering the Arctic.

- In 2007, EC & the Department of Fisheries & Oceans (DFO) expressed Canada's willingness to become an Issuing Service for METAREAs XVII & XVIII.

- In July 2010, EC commenced issuing meteorological Maritime Safety Information for these areas on a test basis.

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April 2007
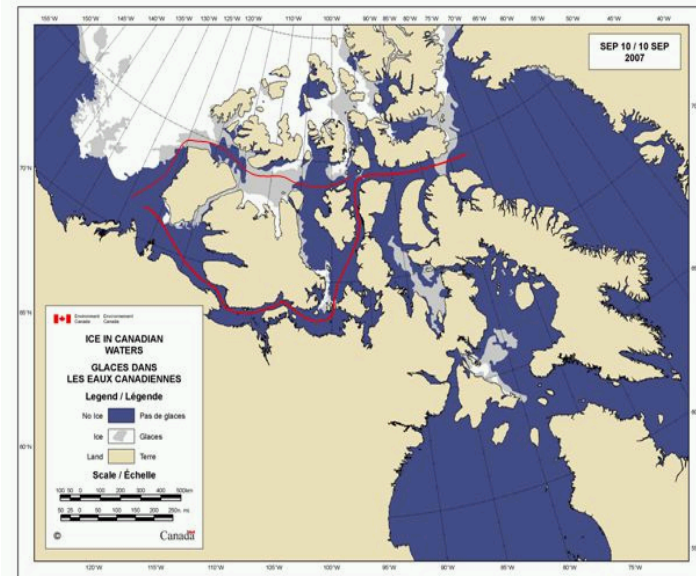
Our involvement in METAREA's


LIMITS OF METAREAS

- **Development of an integrated marine Arctic prediction system in support of METAREA monitoring and warnings.**

- **Development of short-term marine forecast system using a regional high resolution coupled multi-component modelling (atmosphere, land, snow, ice, ocean, wave) and data assimilation system**

- **To predict:**
  - Near Surface atmospheric conditions,
  - Sea ice (concentration, pressure, drift, ice edge)
  - Freezing spray,
  - Waves, and
  - Ocean conditions (temperature and currents)

- **Improved Arctic monitoring**

PROPOSED METEOROLOGICAL MONITORING INFRASTRUCTURE (MET/NAV AREAS)

Environment Canada   Fisheries and Oceans Canada   Mercator Ocean — Ocean Forecasters   Canada
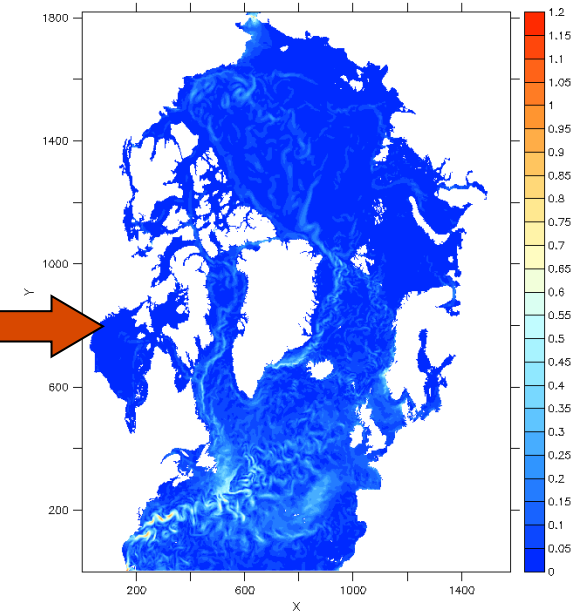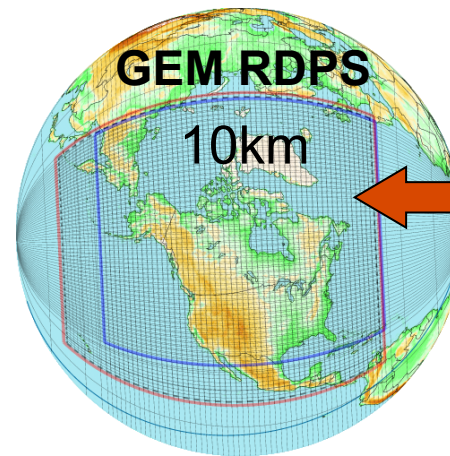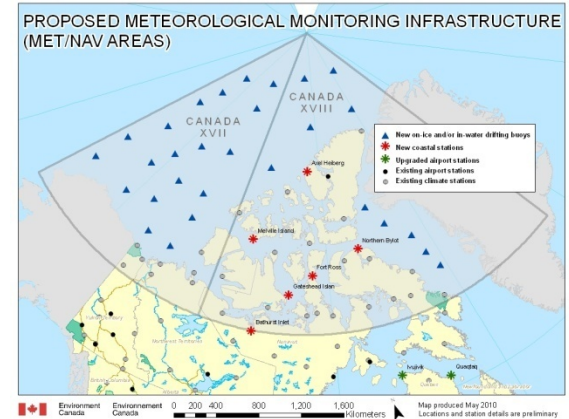
CONCEPTS connection

- **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 (Global Environmental Multi-scale) atmospheric model to NEMO (Nucleus for European Modelling of the Ocean)
- **Collaboration with Mercator**
  - French operational oceanographic group

CONCEPTS
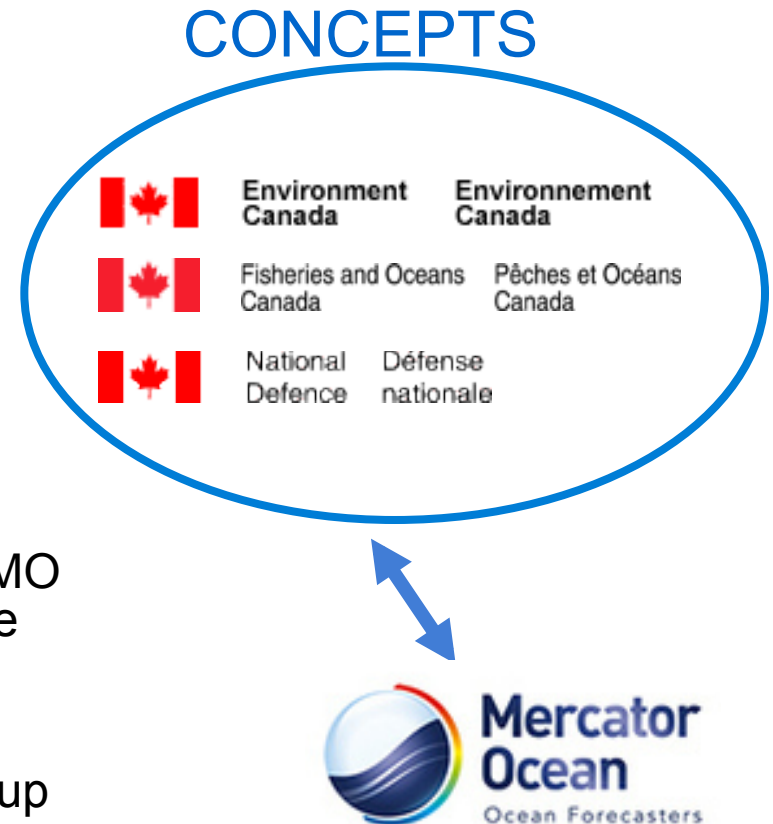
METAREA Integrated Marine Prediction System

- Coupled atmosphere-ice-ocean-wave-snow model
  - GEM (10km), NEMO-CICE(3-8km), WW3
  - 2-3 day forecasts
- Expected implementation:
  - March 2015

PROPOSED METEOROLOGICAL MONITORING INFRASTRUCTURE (MET/NAV AREAS)

GEM RDPS
10km

CREG12 velocity mag. (m/s)

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Builds on Gulf of St. Lawrence Coupled Atmosphere Ice-Ocean Forecasting System

- **Operational since June 2011**
  - 48 forecast daily at 00Z
  - Atm: GEM (10km)
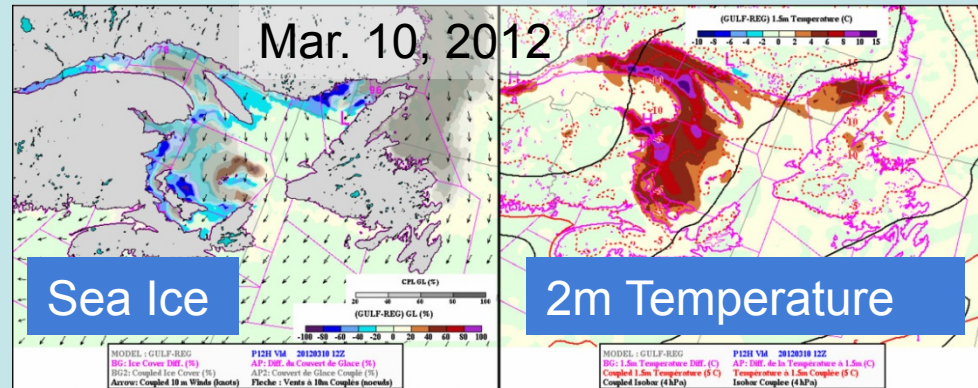 - Ice: CICEv1 (5km)
  - Ocean: MoGSL (5km)
- **Currently evaluating:**
  - Atm: GEM (10km)
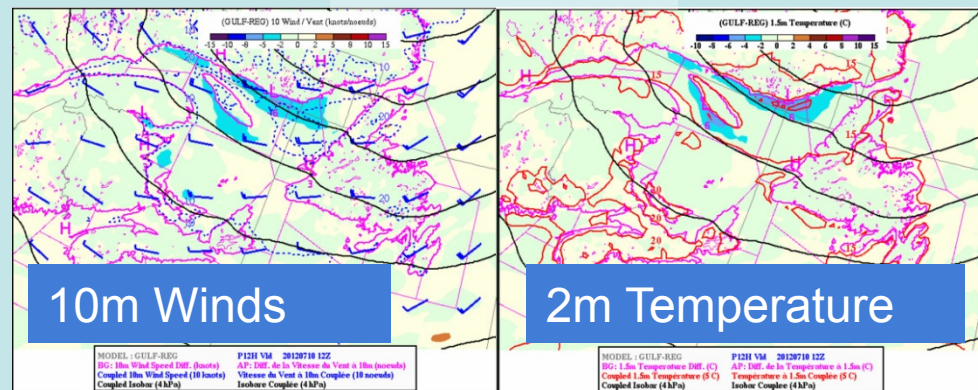 - Ice: CICEv4 (5km)
  - Ocean: NEMO (5km)
  - Flux coupling
- **Future system (in development):**
  - GEM (2.5km)
  - NEMO-CICE-WW3 (1km)
 - Including Great Lakes

Coupled – Uncoupled differences

Mar. 10, 2012 — Sea Ice / 2m Temperature

Jul. 10, 2012 — 10m Winds / 2m Temperature

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Evaluation of surface temperature against station data

24 Stations - Observed Temperature and MAE for OC , NC and A

Regl_NC: New coupled model
Regl_OC: Operational coupled model
Regl_A: Atmosphere only
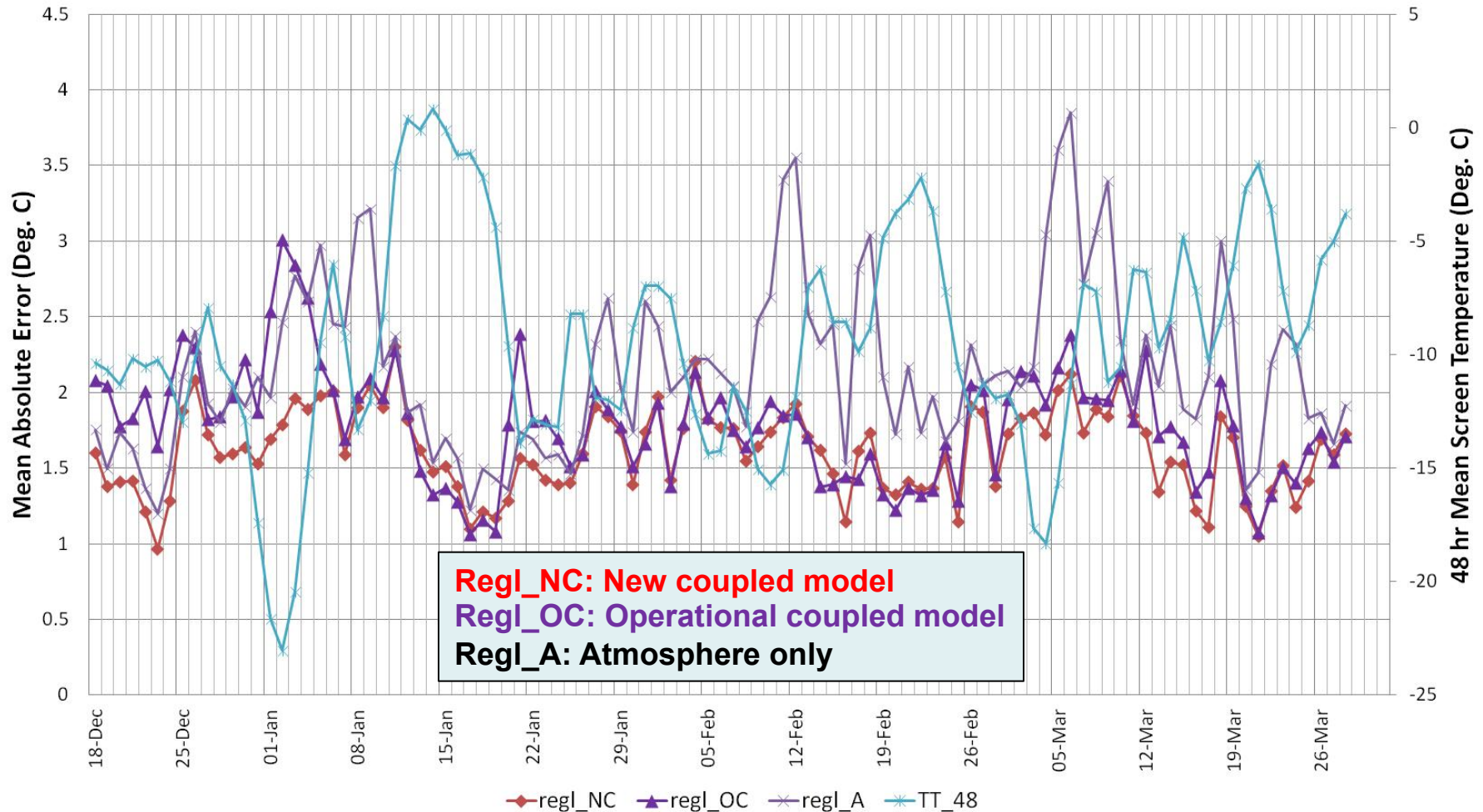
Regional Ice Prediction System: Analysis (RIPS-A)

M. Buehner, T. Carrieres, L. Pogson, A. Caya, …

SSM/I

CIS Chart

RadarSAT

Environment Canada

Environnement Canada
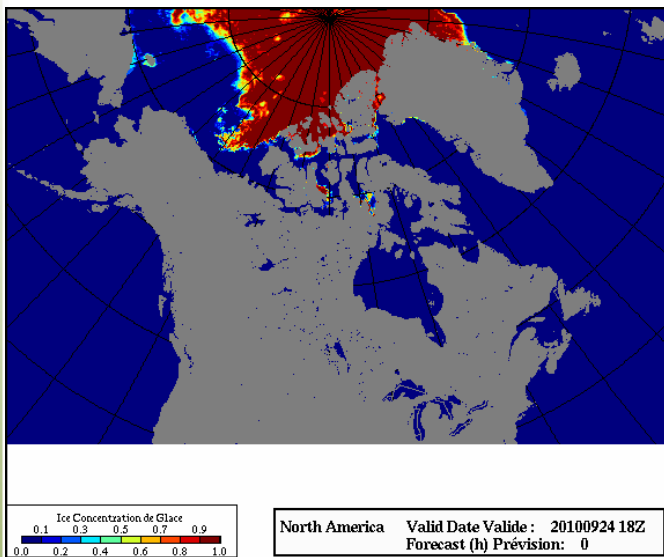
- North American Analysis:
  - Four 3Dvar FGAT analyses per day of ice concentration at 5 km resolution
  - Operational since March 2011
- Global Analysis:
  - Four analyses per day on 10km grid
- Assimilates:
  - SSM/I, CIS daily charts, Radarsat image analyses
  - SSMIS, scatterometer added 2013
- Work in progress:
  - Expanded domain (mid-2014)
  - Cycling with CICE model (end-2014)
  - AMSR2 (mid-2014)
  - Visible-infrared (end-2014)
  - SAR and ice thickness observations (~2015)
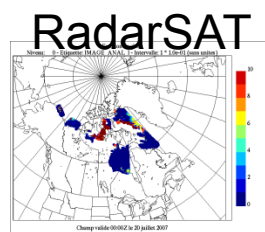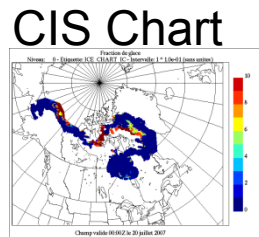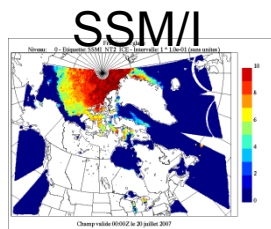
Canada

# Regional Ice Prediction System: Analysis

- <u>RIPS 2.0</u> (in **experimental mode since 26 June, 2013**):
  - Additional assimilated observations:
    - SSM/IS (DMSP16-17-18)
    - ASCAT (1 satellite,… soon 2)
      - measure of anisotropy of 3 look angles related to ice concentration through linear forward model
      - no data rejected based on air temp, instead rejected when wind speed is low
  - A new analysis-error standard deviation field for ice concentration and correction procedure for grid points with high error
  - **Significant improvements, especially during summer and refreeze**

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Impact of RIPS2 vs RIPS1 Analysis

- Verification using the NOAA IMS (Interactive Multisensor Snow and Ice Mapping System)

- IMS is a manual determination of ice/no-ice, resolution ~4 km

- Significant improvements to ice concentration analyses over first version, especially during summer and start of winter

- Not shown: verification against other ice concentration estimates, results consistent with what is shown

North of 65°N

Proportion Correct Total

Bias

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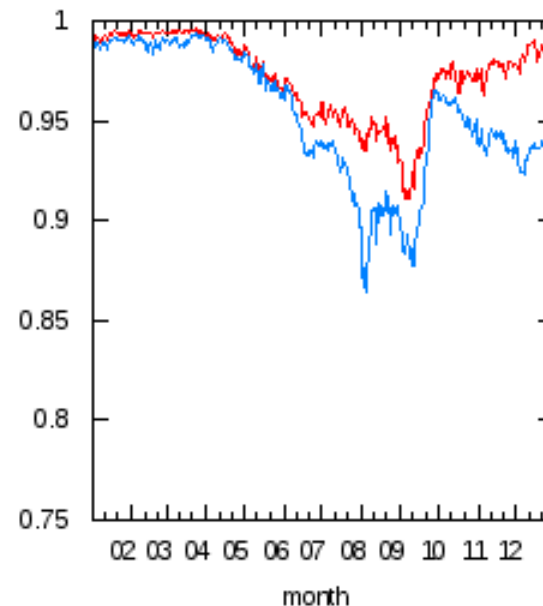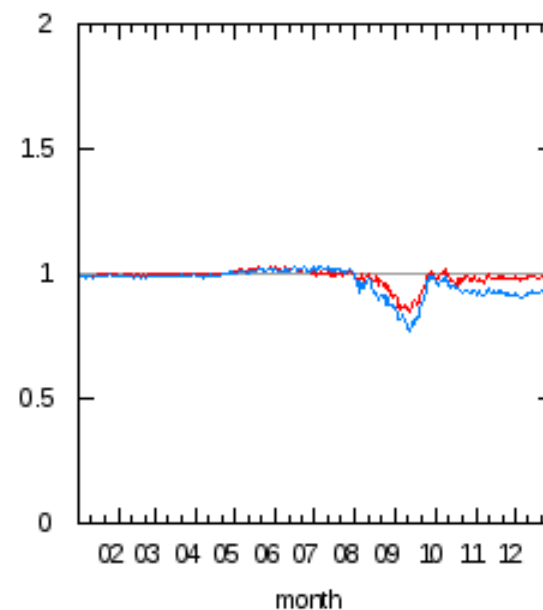
# Impact of Assimilating Visible/Infrared Data (AVHRR)

Expected by end 2014

Ice concentration verification against CIS Regional Analysis Charts:
Reduced error stddev during summer

Ice extent verification against the NOAA IMS manual analysis:
Improvements near coast and in narrow passages

Total Ice Concentration

18Z RIPS 2.0
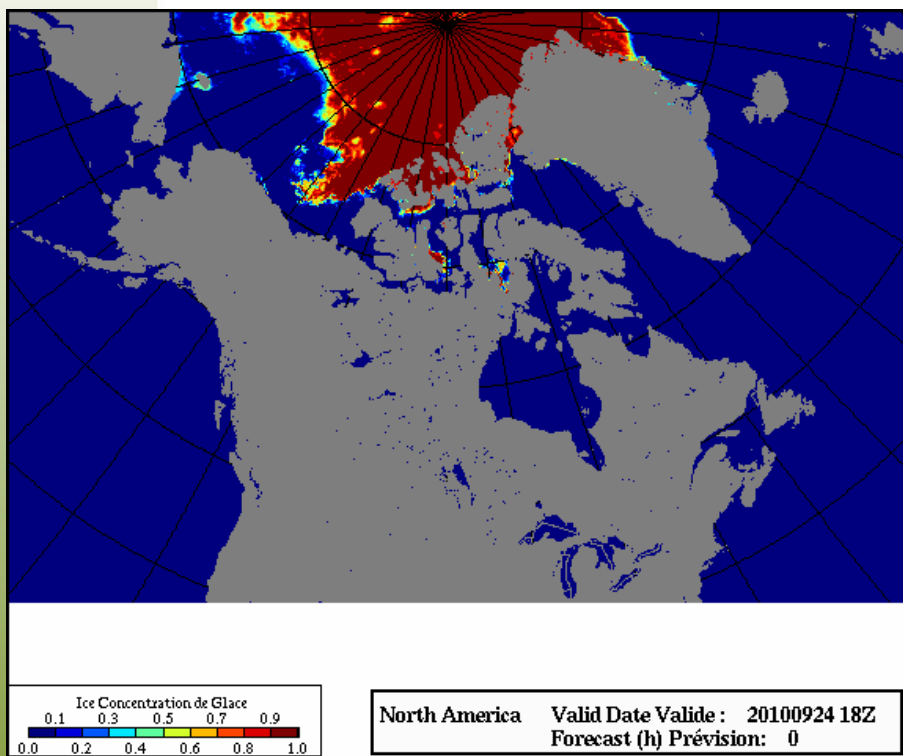18Z RIPS 2.0 + AVHRR

Std Dev

Week from March to September 2011
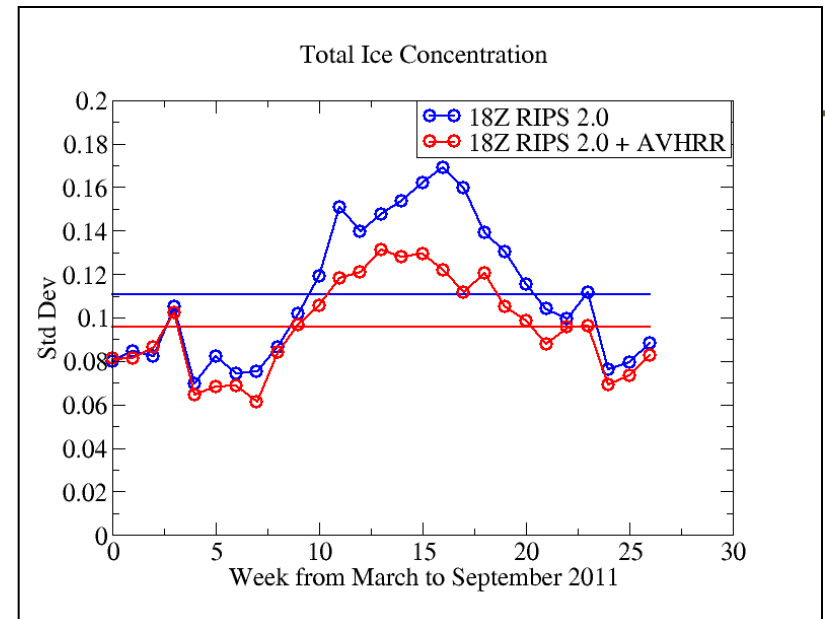
Improvement to total proportion correct
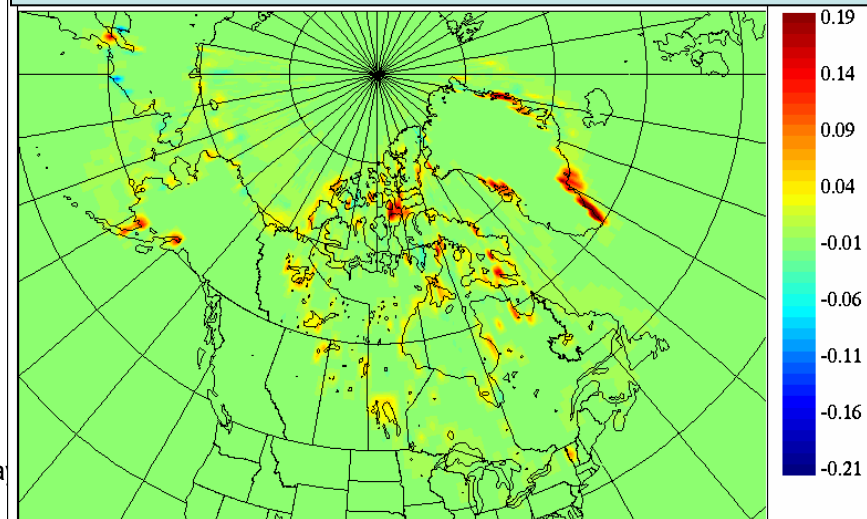
PCT*X*   0 mb 0* 0*V19101010.100000*[RIPS2+AVHRR-RIPS2]

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Regional Ice Prediction System: Forecasts (RIPS-F) – Running experimentally at CMC

Ice Concentration de Glace
0.1 0.3 0.5 0.7 0.9
0.0 0.2 0.4 0.6 0.8 1.0

North America   Valid Date Valide :   20100924 18Z
   Forecast (h) Prévision: 0

- 4 - 48hr forecasts per day:

  -CICEv4.1 forced by CMC RDPS

  -5km North American grid

- Initialized with 3DVar ice concentration Analysis (00Z, 06Z, 12Z and 18Z).

- Also initialized with

  -CMC operational SST analysis

  -Mercator Glorys1v1 thickness climatology

  -Glorys1v1 mixed layer depth climatology

  -Glorys1v1 ocean current climatology

Environment Canada   Environnement Canada
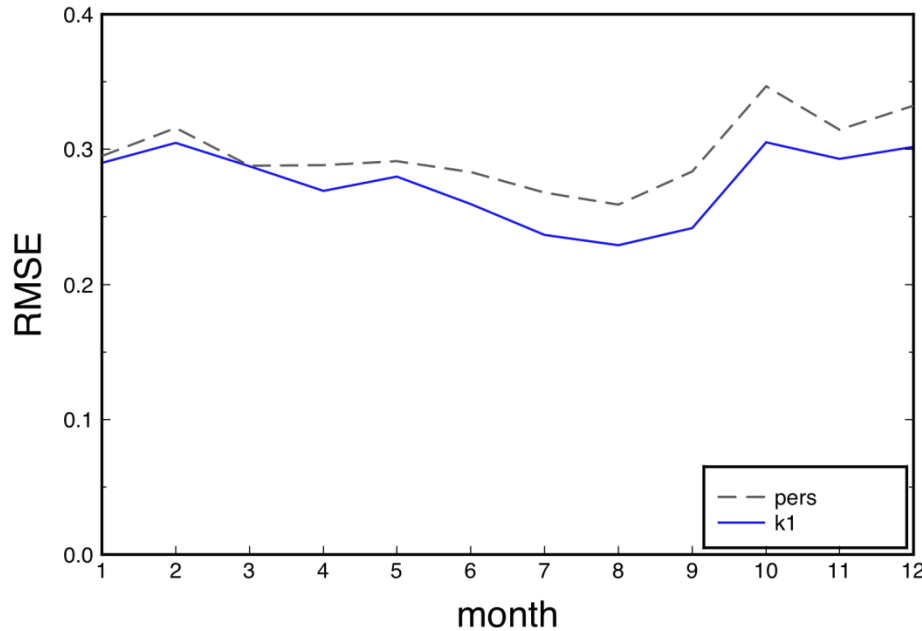
Canada

Better than persistence for all the months but not statistically significant in January and March.

Implemented in experimental mode at the Canadian Meteorological Centre (CMC) in July 2013.
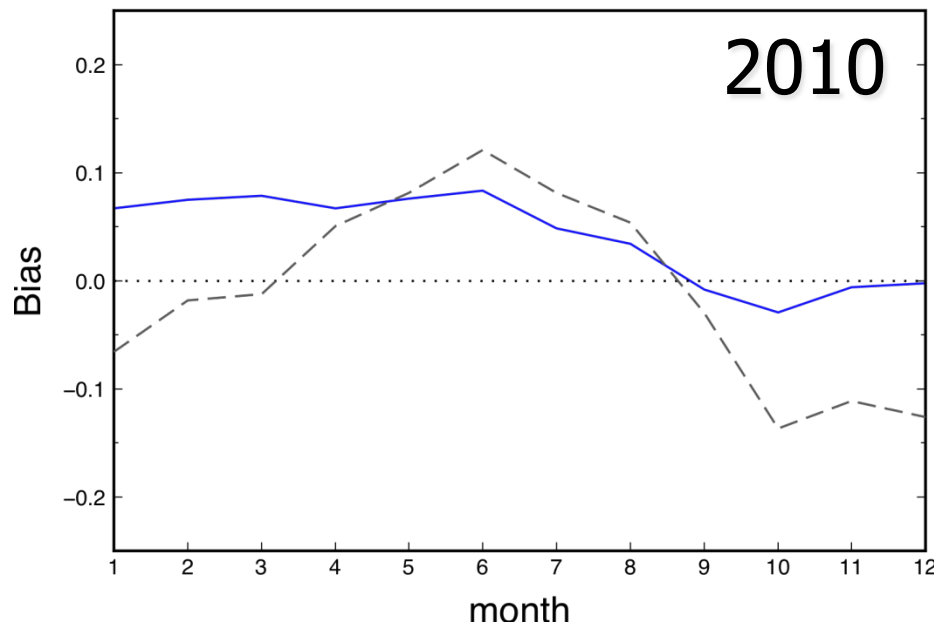
CONCEPTS Global Ice-Ocean Prediction System (GIOPS)

- Mercator Ocean Assimilation System (SAM2):
  - Sea surface temperature (CMC analysis)
  - Temperature and salinity profiles
  - Sea level anomaly from satellite altimeters
- 3DVar Ice analysis:
  - SSM/I, SSMIS, CIS charts, Radarsat image analyses
- Daily blended ice-ocean analysis and 10day forecasts
- Model configuration:
  - ORCA025 (~1/4°), 15km over Arctic
  - NEMOv3.1++, CICEv4.1
- Running experimentally since Sept. 2013
- Purpose:
  - Boundary conditions for regional system (ice, wave)
  - Initialize seasonal forecasts
  - Emergency response
  - Global coupled forecasting
- Article on GIOPS sea ice forecast verification:
  - Smith et al., submitted to QJRMS

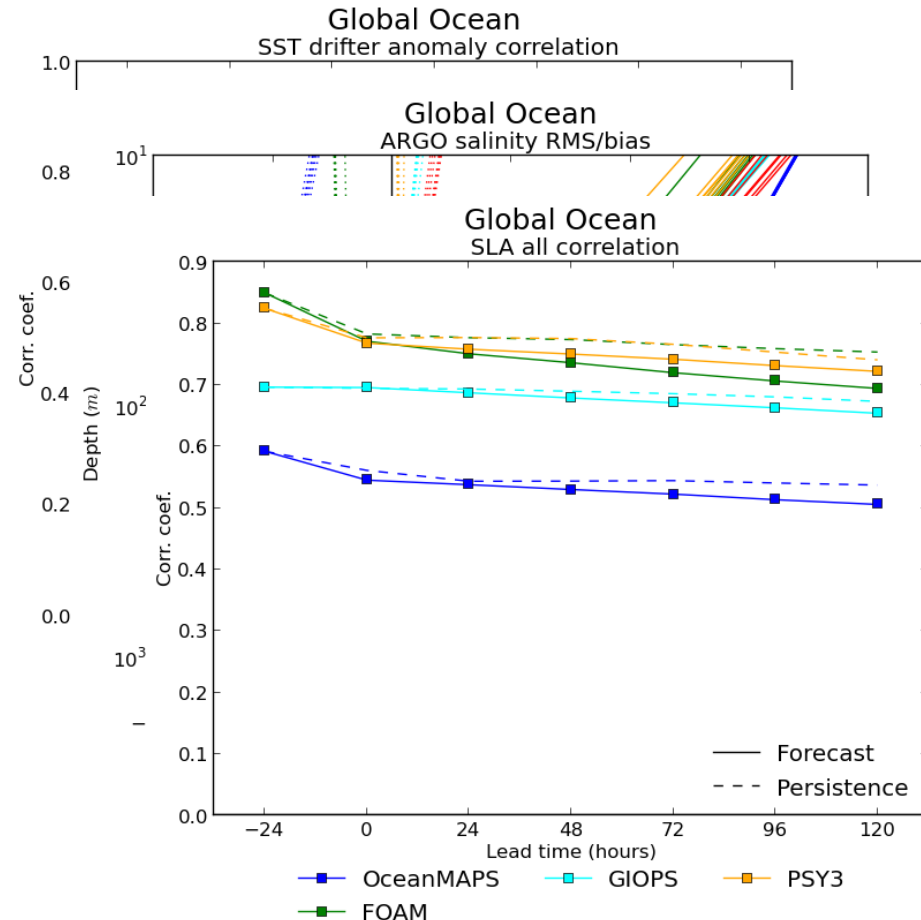Environment Canada   Environnement Canada

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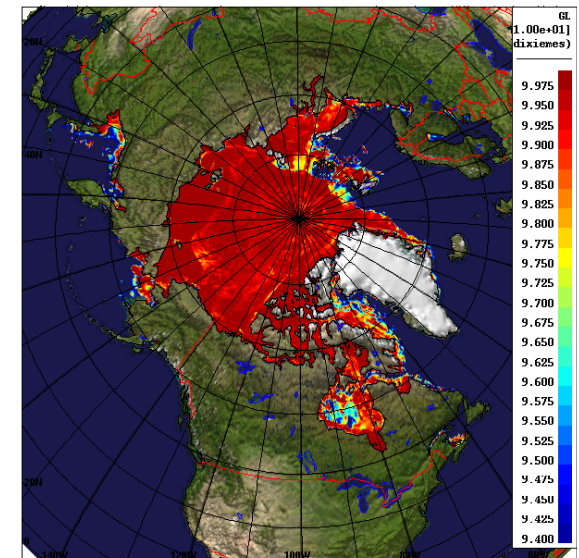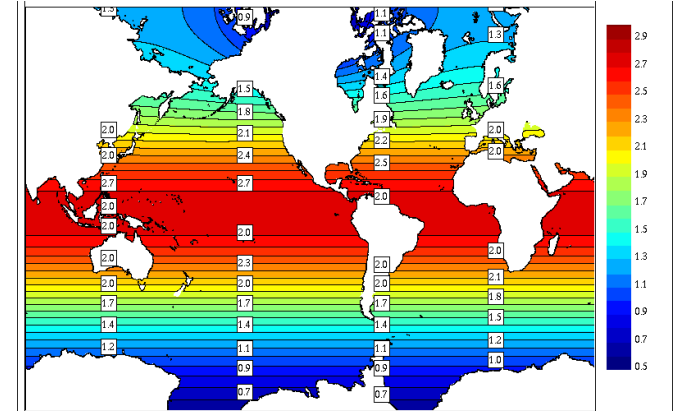
GODAE Oceanview Intercomparison

- Intercomparison of various global systems:
  - UK Metoffice (FOAM)
  - Mercator (PSY3)
  - CMC (GIOPS)
  - US Navy (RTOFS)
  - Aus BofM (OceanMAPS)
- Near real-time comparison against shared data sets:
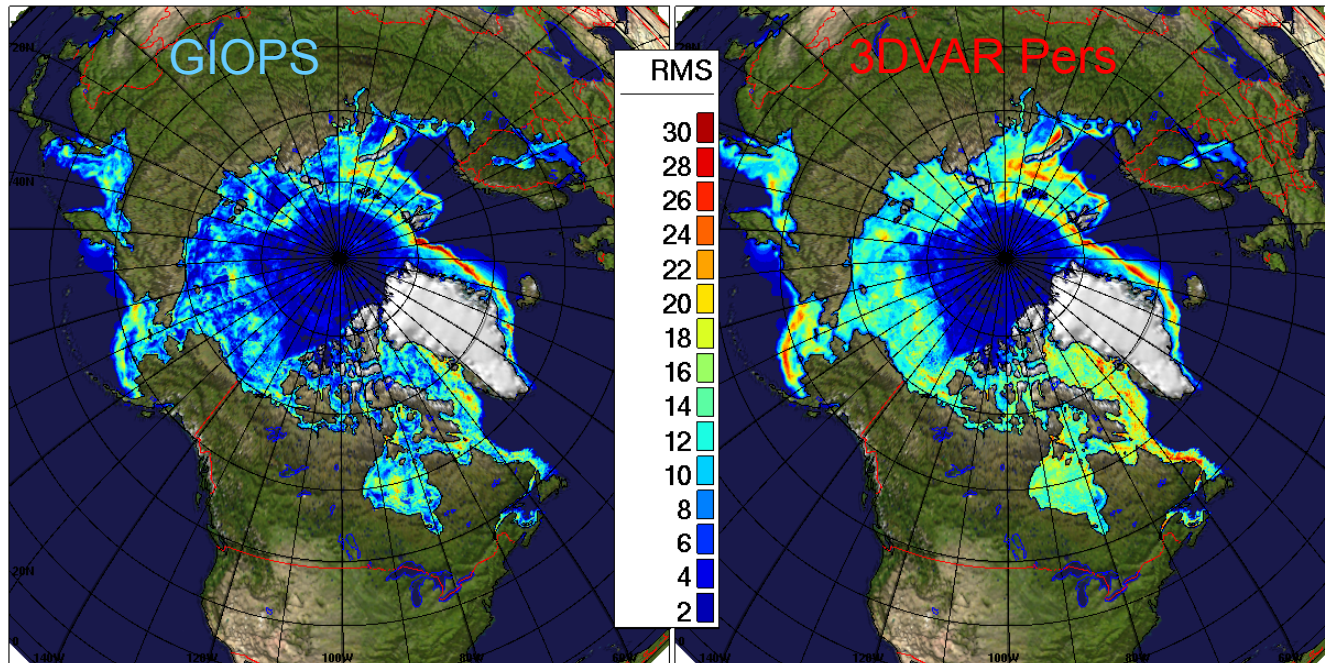 - Sea level anomaly
  - In situ obs (T&S)
  - Sea surface temperature

Ryan et al., Submitted to J. Op Ocean.

Environment Canada

Fisheries and Oceans Canada

Mercator Ocean
Ocean Forecasters

CONCEPTS

National Defence

Evaluation against 3DVAR ice analyses

Weekly forecasts for 2011 (50 total), lead time of 168h


- Forecasts show lower RMS errors than persistence over most regions
- Largest forecast errors East of Greenland, Baffin Bay, Hudson Bay and Barents/Kara Sea

Evaluation against 3DVAR ice analyses

Global domain, lead time of 168h

- Overall, forecasts show lower RMS errors than persistence

- Despite strong seasonality and differing regional errors, overall forecast skill remarkably constant (about 0.28)

- Strong sensitivity to vertical mixing and quality of ocean analysis
  - Etau=1
  - Etau=0
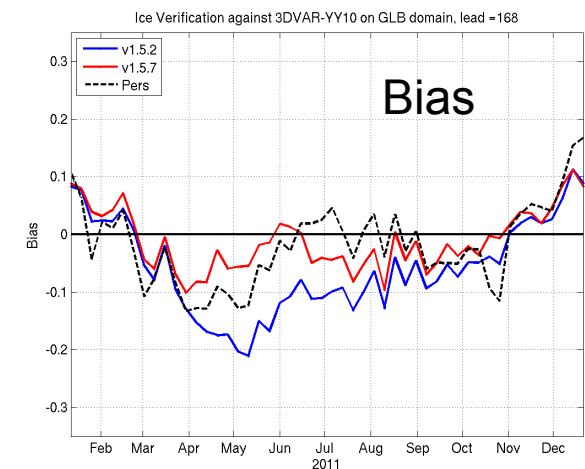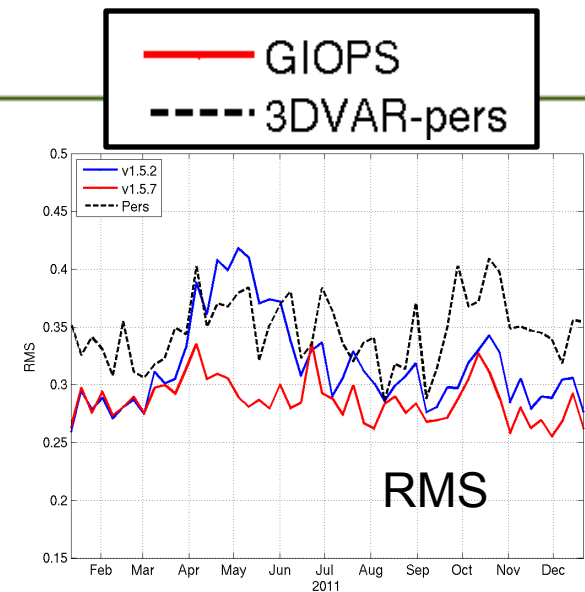
GIOPS Conclusions

- Ice forecast skill very sensitive to ocean properties near (and under!) ice edge.

- Compared to the 3Dvar ice analysis system, the Coupled Analysis System seems to improve the ice analysis in most areas.

- The accuracy of ice model forecasts has a large impact on ice analyses, and is very sensitive to lateral ice accretion and ice-ocean drag parameters (hiccrit and cw).

- Next steps:
  - Cycling using CICE
  - Additional sensitivity experiments with vertical mixing and CICE parameters
 - Full-year experiments

Environment Canada

Fisheries and Oceans Canada

Mercator Ocean
Ocean Forecasters

CONCEPTS

Canada

RIPS-F upgrade (2.1)

- **Running on CREG12 grid**
- **Initialized with GIOPS:**
  - Mixed layer depth
  - Sea surface temperature
  - Sea surface salinity
  - Sea ice thickness
- **Forced by GIOPS currents**
- **IMS verifications for 2011**
  - Forecast (red)
  - Persistence (blue)
  - 48h lead time

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Environnement
Canada

Canada
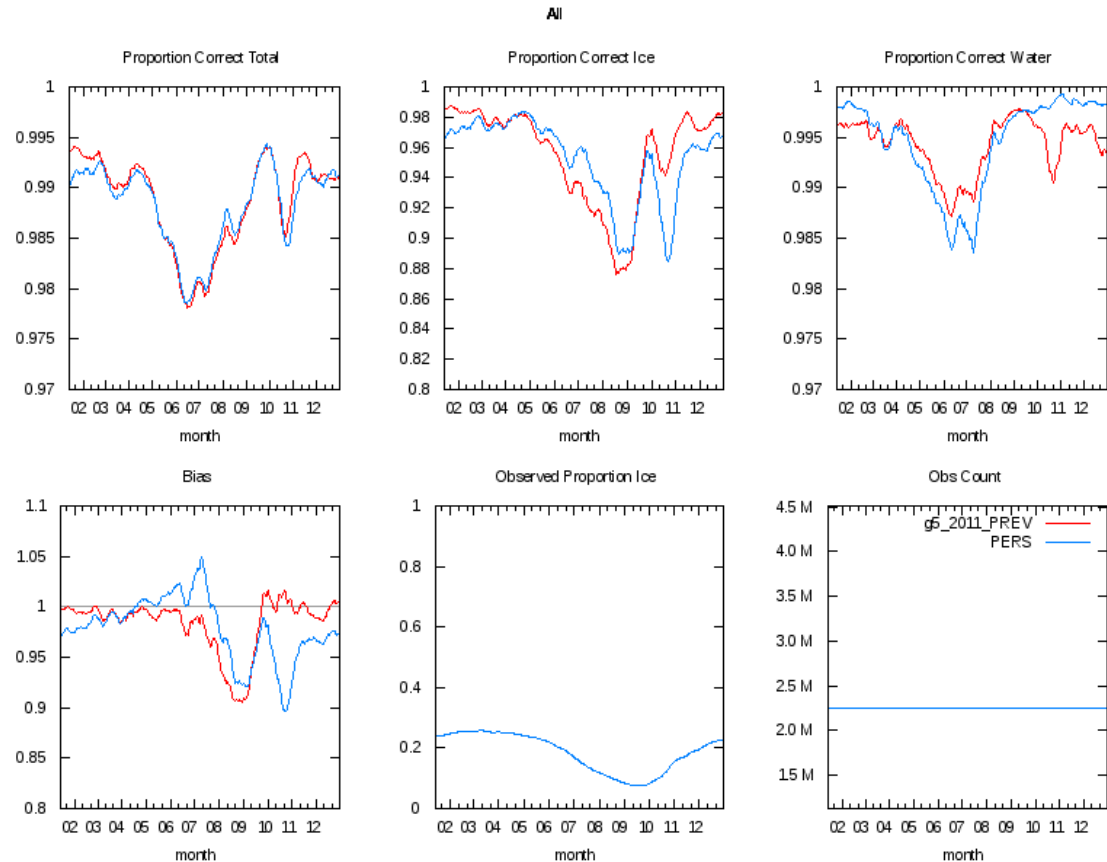
Regional Ice-Ocean Prediction System

- Couple RIPS to NEMO
  - 3-8km Arctic/N.Atl configuration (CREG12)
- SAM2 ocean assimilation (SEEK) with 3DVar ice assimilation
- Expected experimental implementation of forecast system for March 2015

Temperature (C)

Environment Canada   Environnement Canada
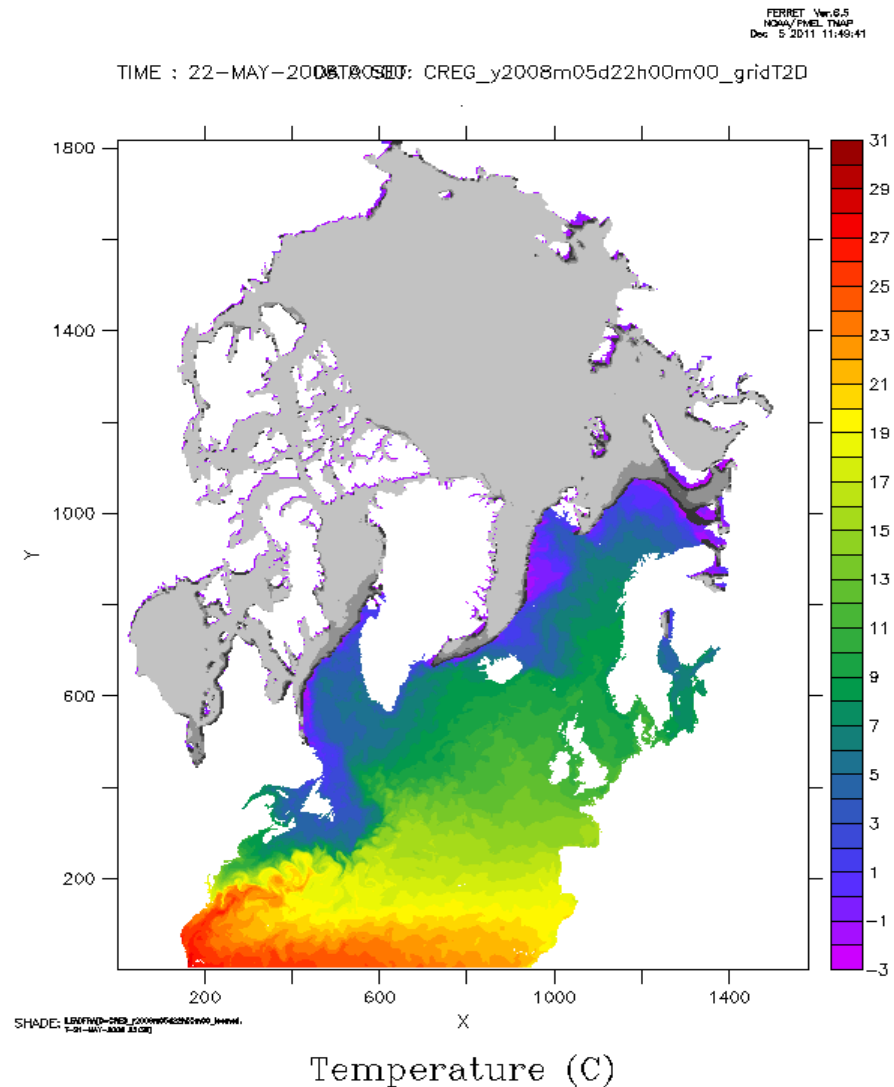
Multi-annual forced runs

- 5 Hindcasts over 2002-2011 now completed

- Detailed evaluation of:
  - water mass properties
  - freshwater storage
  - circulation
  - ice area, thickness and drift

- Beginning work on high-resolution analysis system for CREG12 in collaboration with Mercator

- Bottom panel: Histogram of ice thickness in Davis Strait (2005)

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Davis Strait, mooring C1, 2005, Hindcast05
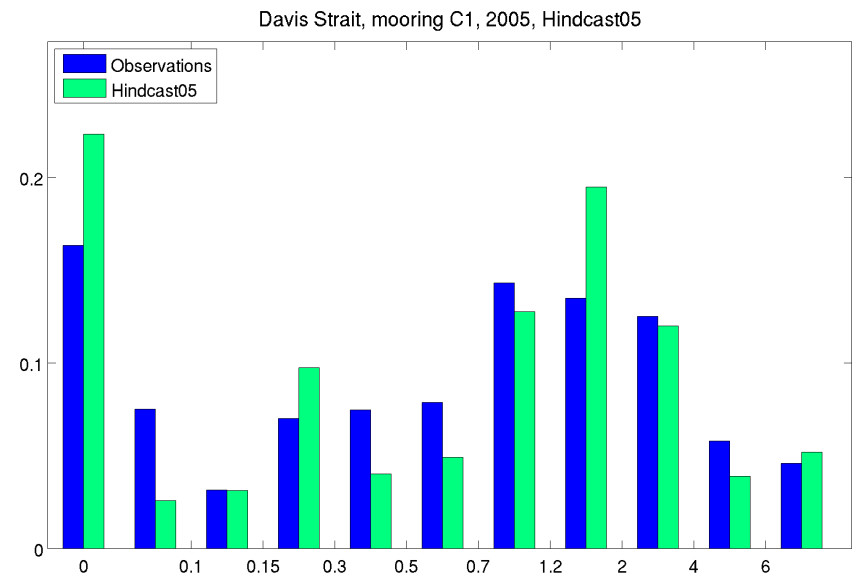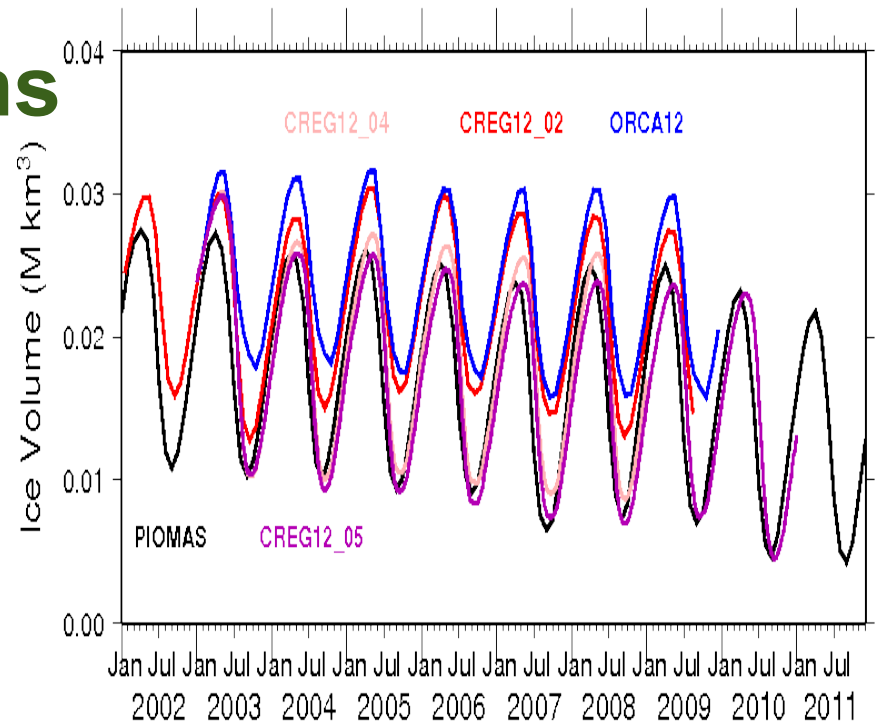
Sea Ice Summary and Challenges

Status

- Evolving sea ice cover affects regional weather forecasts on very short timescales
  - Details matter!
- Arctic leads have a large impact on global coupled forecast skill

Challenges

- Evaluating and improving the representation of leads
- Including wave-ice interactions
- Atmosphere-ice-ocean momentum transfer
- Constraining sea ice thickness
- Sea ice forecast verification

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