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Towards an integrated marine Arctic METAREA prediction system:
Science Support and Technology Transfer

Hal Ritchie

On behalf of METAREA component 2 Team

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R&D Activity Leads

- Component lead: Pierre Pellerin
- Senior Scientist: Hal Ritchie
- Atmospheric model: Paul Vaillancourt & Martin Charron
- Atmospheric Data Assimilation: Luc Fillion
- Ocean-Ice / Sea Ice and coupling model: Greg Smith
- Sea-Ice Data Assimilation: Mark Buehner
- Iceberg / Ice Hazard Models: Tom Carrieres
- Satellite Products (Atmosphere): Ed Becker
- Wave model: Serge Desjardins

Technology Transfer Activity Leads

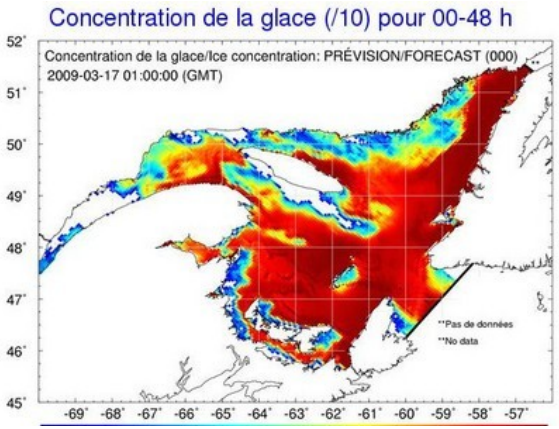
- Atmospheric model: Bertrand Denis A/ Amin Erfani
- Atmospheric Data Assimilation: Gilles Verner
- Ocean-Sea-Ice model: Bertrand Denis A/ Amin Erfani
- Sea-Ice Data Assimilation: Tom Carrieres
- Iceberg / Ice Hazard Models: Tom Carrieres
- Satellite Products (Atmosphere): Ed Becker
- Wave model: Serge Desjardins

Our involvement in METAREA's

- Development of an integrated marine Arctic prediction system and satellite products in support of METAREA monitoring and warnings.
- The integrated marine Arctic prediction system will feed into a highly automated information dissemination system.
- Development, validation and implementation of marine forecasts with lead times to 1-3 days 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)

Building on Coupled Atmosphere-Ice-Ocean Forecast System for the Gulf of St. Lawrence

- Initiated 14 years ago by the Maurice Lamontagne Institute (DFO) and Recherche en Prévision Numérique (EC)
- EC and DFO have successfully developed a fully-interactive coupled atmosphere-ice-ocean forecasting system for the Gulf of St. Lawrence (GSL)
- This system will become fully operational at the Canadian Meteorological Centre (CMC) imminently
- Results during the past years have demonstrated that the coupled system produces improved weather forecasts in and around the GSL during all seasons
  - Shows that atmosphere-ice-ocean interactions are indeed important even for short-term Canadian weather forecasts
  - Great potential for improved ice-ocean components and global systems
- This has important implications for coupled modelling and data assimilation partnerships.



Will accelerate 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

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Sea Ice Data Assimilation
Ice Hazards
Status of Development Activities

Tom Carrieres, Lynn Pogson, Matt Arkett
Marine and Ice Services Division

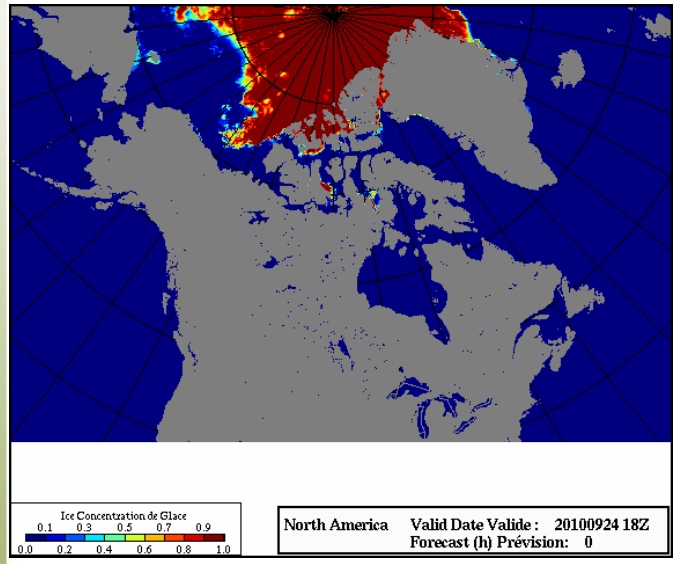
Mark Buehner and Alain Caya
Meteorological Research Division

Funding from METAREAs with support from PERD/CSA-GRIP

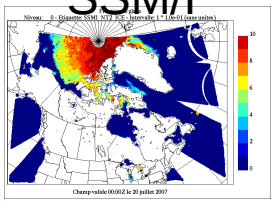
Planned Activities/Deliverables

- Year 1:
  - Implementation and validation of a prototype high-resolution sea ice concentration analysis for North America (4 analyses/day)
- Year 2:
  - Development and/or implementation of an experimental sea-ice forecasting system - initialized by the North American ice analysis system and forced by the regional atmospheric forecast model. (4 forecasts/day, 1-2 day lead time).
- Year 3:
  - Implementation and refinement of North American sea-ice analysis-forecast system, including incorporation of high-resolution visible-infrared satellite based observations.
  - Operational implementation of a sea-ice forecasting system
- Years 4-5:
  - Refinement of the North American sea-ice analysis-forecast system, including high-resolution satellite space-based ice thickness observations and coupling to the ice-ocean model.

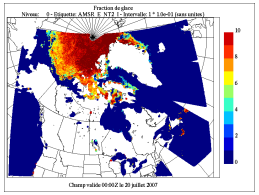
CMC/CIS Sea-ice Analysis System



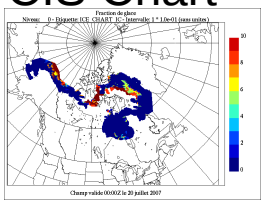
SSM/I



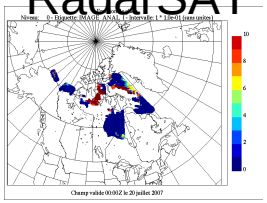
AMSR-E



CIS Chart

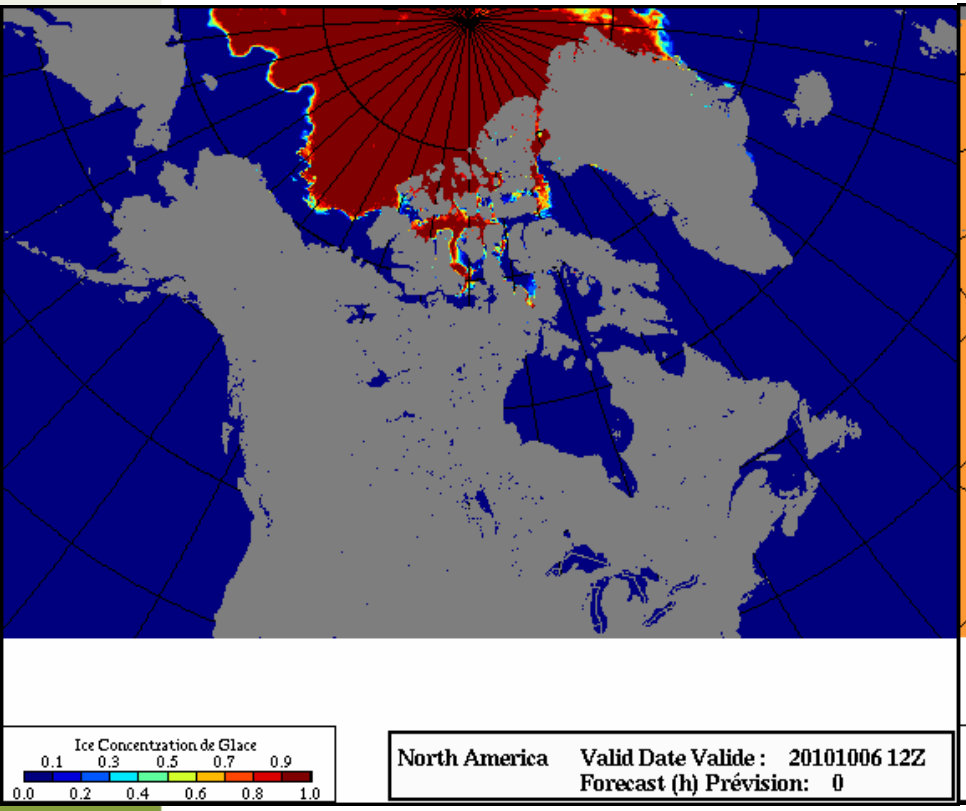


RadarSAT

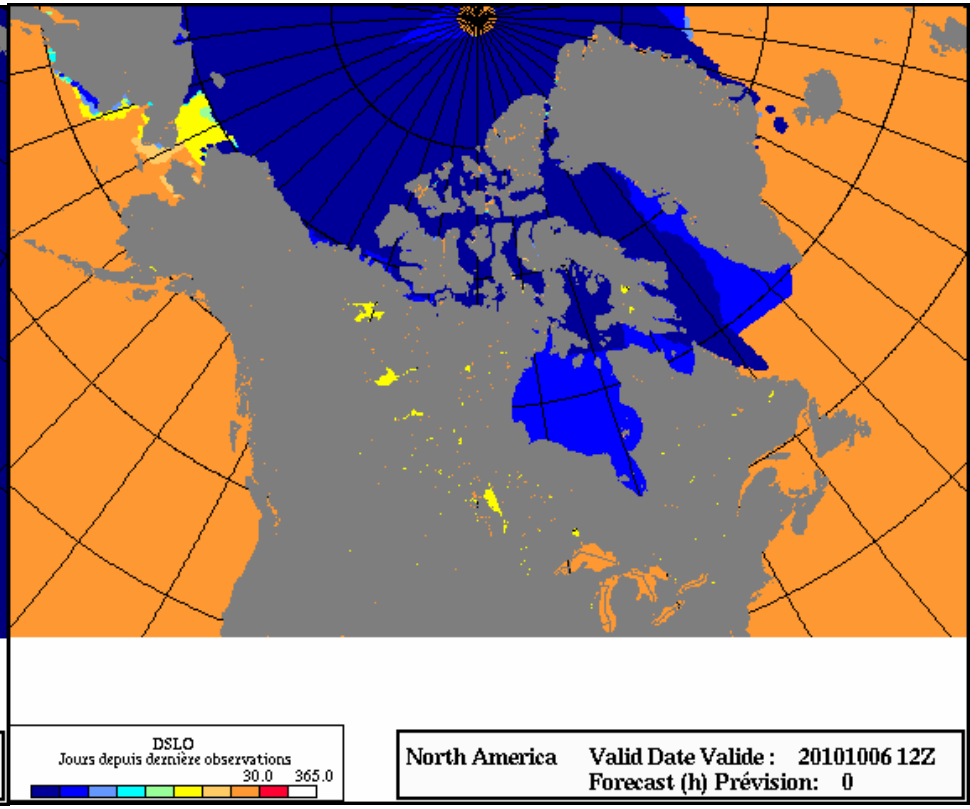


- North American Analysis:
  - Four analyses per day of ice concentration at 5 km resolution
- Global Analysis:
  - two analyses per day on 10km grid
- Currently assimilates:
  - SSM/I, AMSR-E, CIS daily charts, RadarSAT image analyses
- Work in progress to add:
  - SSMIS, scatterometer, visible-infrared, SAR and ice thickness satellite-based observations

System Outputs



Ice Concentration



Days Since Last Observation
(to indicate reliability of analysis)

Year 1: Status

- North American analysis system setup and tested at CMC
- Extensive verifications have demonstrated that system has skill for initial applications
- Implemented in “experimental” mode on March 17, 2011
- Users can access images on internal Vizaweb
- CIS Operations and Field Services staff will be expanding the products from this system for the coming summer shipping season into the Canadian Arctic

Ice Hazards

Planned Activities/Deliverables

- Year 1:
  - Development of techniques to reliably identify ice hazards (i.e. icebergs, ice islands and multiyear ice boundary) from SAR imagery.
- Year 2:
  - Extension of current operational iceberg model to an Arctic ice hazard tracking system, i.e. consideration of ice islands and icebergs surrounded by ice.
- Years 3-4:
  - Refinement of ice hazard tracking system and associated product/bulletin definition
- Year 5:
  - Implementation of operational ice hazard tracking system

Year 1: Status

- C-CORE Report: An Assessment of Iceberg Detectability Using RADARSAT-2 SAR Data – draft
- CIS Report: Preliminary Research Plan for Glacial Ice Hazards - draft
- PDF Report: Detectability of Ice Islands – not yet received
- NAIS iceberg model – experimental implementation underway

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Ice-Ocean Modelling and Coupling

Gregory C. Smith

Planned Activities/Deliverables

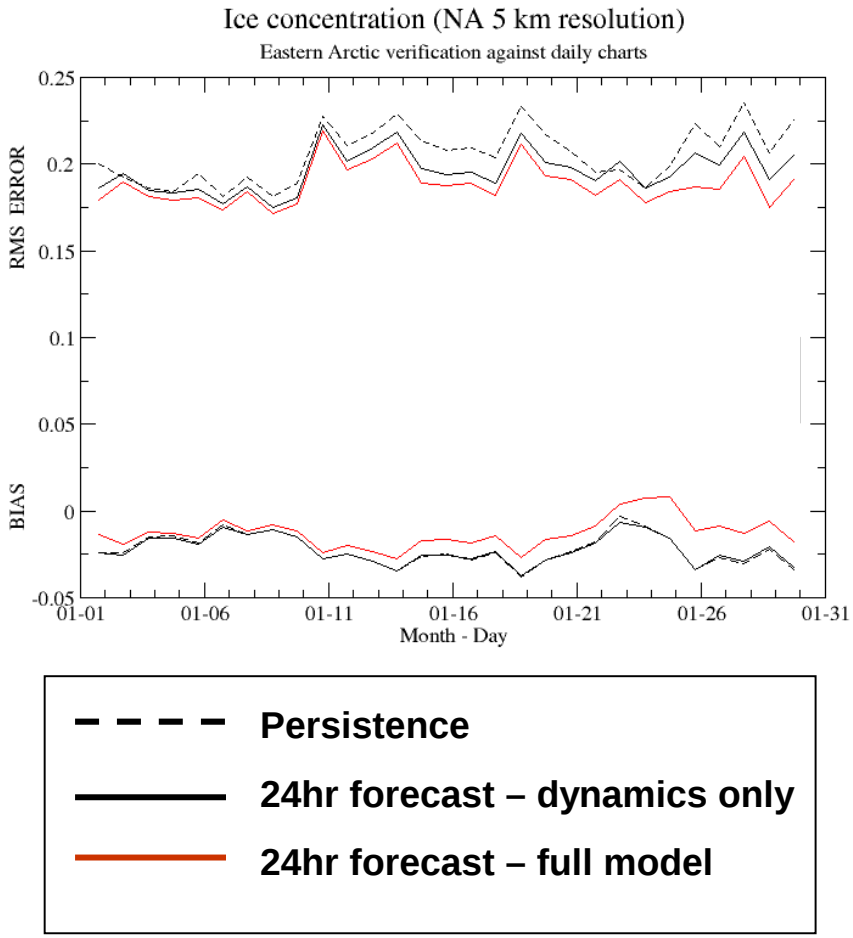
- Year 1:
  - Development of a sea-ice forecasting system over the Canadian Arctic Archipelago. Sea-ice model forced by the regional atmospheric forecasts (1-3 day lead time).
- Year 2:
  - Development of the high-resolution regional ocean-ice model in collaboration with DFO as part of CONCEPTS inter-ministerial initiative.
  - Development and/or implementation of an experimental sea-ice forecasting system (Y1). This system will be initialized by the North American ice analysis system (Y1) and forced by the regional atmospheric forecast model. (4 forecasts/day, 1-3 day lead time).
- Year 3:
  - Coupling of ice-ocean and atmospheric models (Y2).
  - Validation of ocean-ice-snow model and ice hazard tracking system in using the augmented Arctic observation network (e.g Canadian Arctic Buoy Array).
  - Operational implementation of a sea-ice forecasting system (Y2).
- Year 4:
  - Implementation of the high-resolution regional ocean-ice model (Y2) in the sea-ice forecasting system (Y2): 3-4 day lead time.
- Year 5:
  - Implementation of fully coupled atmosphere-ocean-ice-snow forecasting system (Y3). Improved atmosphere-ocean-ice forecasts.

Year 1: Status

- Development of a sea-ice forecasting system over the Canadian Arctic Archipelago. Sea-ice model forced by the regional atmospheric forecasts (1-3 day lead time).
  - A prototype system is running daily and an evaluation is underway.
    - Based on CICEv1 (ice model used operationally in current Gulf of St. Lawrence coupled atmosphere-ice-ocean system)
    - Updating code to CICE v4 (nearly complete)

Experimental Sea Ice Forecasting System

- Produces 48hr forecasts twice daily on 5km grid
- Initialized from North American Ice Analyses
- Preliminary results show significant forecast skill in ice concentration (C. Beaudoin)
- Planned operational implementation for 2012



Ocean Waves

The Gulf of St-Lawrence : a Laboratory for the Arctic

- The development of the operational wave forecast system for the Arctic will be done using the operational coupled atmospheric-ice-ocean forecasting system for the Gulf of St-Lawrence (GSL) as a prototype.
- Work in progress through CONCEPTS to develop successor system
  - Currently the GSL system is composed of GEM-MoGSL
  - Coupled GEM-NEMO configuration under development
  - NEMO configuration for GSL and NW Atl underway by C-NOOFS
  - An Arctic extension of C-NOOFS will be used to produce ice-ocean forecasts. This system will be referred to as the Sea-ice Prediction System (SIPS).
  - GEM coupled to SIPS will be integrated into the Regional Deterministic Prediction System (RDPS).
- **SIPS-Wave(P1)** (1-3 Years) : The wave model utilizes output fields such as ice cover, thickness and surface currents fields generated by the SIPS and wind fields from GEM configuration used in the RDPS.
- **SIPS-Wave (P2)** (4-5 Years) : The wave model is integrated in the operational Arctic atmospheric-ice-ocean-wave Coupled System (RDPS).

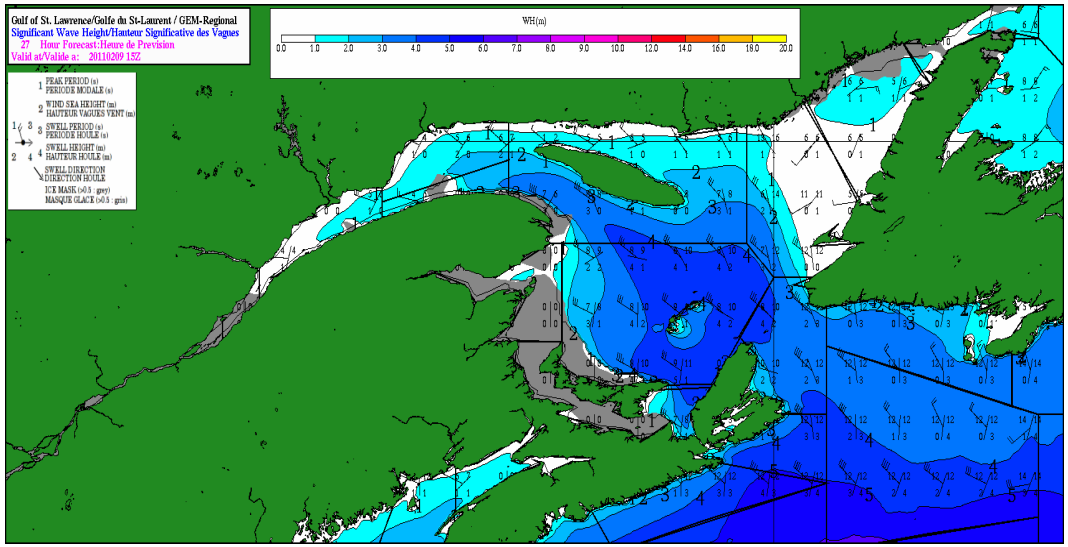
Planned Activities/Deliverables

- Year 1:
  - Development of Arctic domains and pre-operational setup based on the current atmospheric model outputs (Global) and the current operational WAM
  - WAM uses a dynamic ice field from GSL system.
- Year 2:
  - Development of the bathymetry for the Arctic Domains (based on CHS and ETOPO1 databases)
  - Development of WAM model Grids and runs based on the regional model outputs and when available, the higher resolution atmospheric model chosen for RDPS.
  - Importation of an experimental SIPS-wave (P1) over the Arctic based on work done with CDPS.
- Year 3:
  - Implementation of the ocean wave forecasting system (4 times / day) based on SIPS-wave(P1)
  - Probable replacement of WAM by WW3 as the Canadian operational wave model (Work done under other funds)
  - Exploration of integrating SWAN (shallow water model) into the Arctic wave model suite.
- Year 4:
  - Development of SIPS-Wave (P2)
- Year 5:
  - Operational Implementation of SIPS-Wave(2) in RDPS.

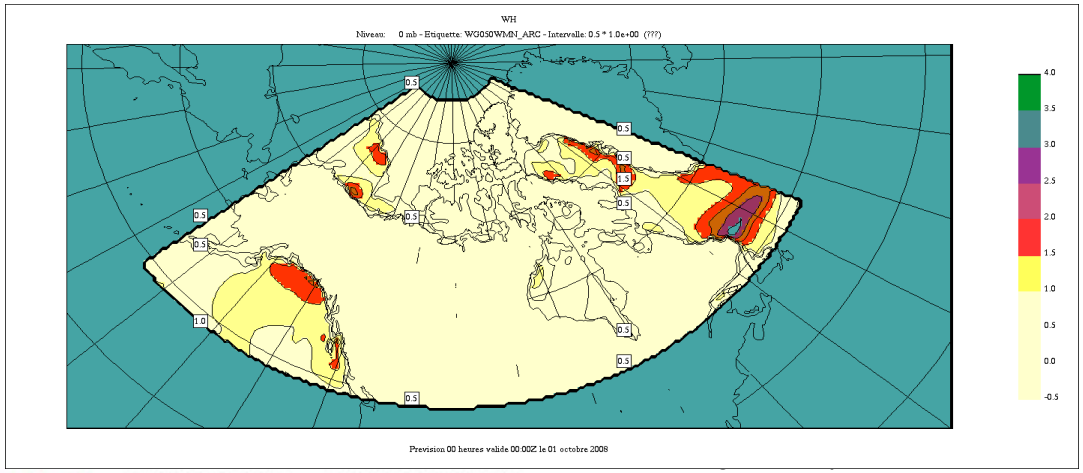
Year 1: Status

- *Development of Arctic domains and pre-operational setup based on the current atmospheric model outputs (Global) and the current operational WAM*
  - 2 runs/day already producing pre-operational outputs
- *The wave model uses a dynamic ice field from GSL system*.
  - 4 runs/day already producing pre-operational outputs

Results illustrating progress



- Forecast of Significant Wave Height (SWH) in metres resulting from REG-GEM & CDPS (for ocean fields). Ice mask in grey representing ice cover > 50%.



- Pre-operational setup of for Arctic WAM running with GLB-GEM winds.

Atmospheric Data Assimilation

High-Resolution Analysis for METAREA P.1

It is planned to locally enhance Canadian Operational Regional Analyses by designing a second-stage high spatio-temporal analysis in order to efficiently assimilate new and high density data.

Key features are:

- Analysis increments produced around 5 km and high vertical resolution (Regional analysis increment being 65km).
- Based on the Ensemble Kalman Filter (En_KF) analysis approach. This will allow situation dependent error covariance structures to better link atmospheric fields with e.g. surface pressure data thus maximizing the impact of observations.
- Based on a strategy where the a High resolution version of GEM Atmospheric Model is driven laterally and vertically over the METAREA by the Regional operational model.
- Due to the important data gap existing in the Arctic region, it is crucial to anchor the high resolution analysis on further observations known to be of first order importance in impacting forecasts. *Surface pressure and surface temperature* from buoys are excellent candidates.

High-Resolution Analysis for METAREA P.2

As a complement to surface data (ps,Ts), other additional data are envisaged.

Plans are to:

- Pursue the direct assimilation of SAR data into the high-resolution analysis to enhance near surface wind analysis.
- Improve surface emissivity to enable the assimilation of lower peaking satellite radiances in the Regional analysis, which will serve to initiate the second-stage analysis of finer scale structures over the METAREA.
- Use of additional data such as AMSR-E that are currently used operationally in Dorval for ice analysis. It is planned to include radiances from this instrument within the Regional analysis, as well as within the high-resolution analysis but under the form of surface wind retrieval (wind modulus data at high spatial resolution ~ 21 km).

Impacts of High-Res Analysis:

- Improve sea ice forecasting
- Improve weather forecasting through better initial conditions transferred to GEM model.

Organizational Structure
METAREA Environmental Prediction System