Sea Ice Forecast Verification in the Canadian Global Ice Ocean Prediction System

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Background

CMC currently produces ice forecasts from 3 systems:
- Coupled Gulf of St. Lawrence Forecasting System (RDPS-CGSL)
- Regional Ice Prediction System (RIPS)
- Global Ice Ocean Prediction System
- Updates to all three accepted for CMC operations in May

Overview

- Update to Coupled GSL system
  - MoGSL -> NEMO
  - Impact on atmospheric and sea ice forecast skill
- RIPS
  - Increased resolution and improved downscaling
- GIOPS
  - Update to SST assimilation and impact on ice forecast skill
CONCEPTS Global Ice-Ocean Prediction System

- Produces daily ice-ocean analyses and 10-day forecasts
  - NEMO-CICE (~1/4°), < 15km in Arctic
- Mercator Ocean Assimilation System (SAM2):
  - Sea surface temperature
  - Temperature and salinity profiles
  - Sea level anomaly from satellite altimeters
- Global 3DVar Ice analysis:
  - SSM/I, SSM/IS, CIS charts, Radarsat image analyses
- Experimental implementation (March 2014)
- Purpose:
  - Boundary conditions for regional systems
  - Initialize seasonal forecasts
  - Emergency response
  - Global coupled forecasting
  - Sea ice forecasting

See presentation by D. Surcel-Colan, Thurs. 1:20pm
Ocean data assimilation

- Système d’Assimilation Mercator (SAM) v2
- SAM2 assimilates:
  - Sea surface temperature (from both satellite and in situ observations)
  - Subsurface temperature and salinity (from Argo, CTD, XBT, moorings, marine mammals)
  - Sea level anomalies from satellite altimeters (AVISO)

Altimeters:
- Jason 2
- Cryosat2
- Altika

Lellouche et al., Ocean Sci., 2013.
Smith et al., QJRMS, 2014, accepted
Blending with 3DVAR ice analyses

Smith et al., QJRMS, 2014, accepted

• Require multicategory blending for CICE
• Method 1: Rescale distribution (RED)
  • For each category i:
    • \( C_a(i) = C_f(i) \times A_a/A_f \)
    • \( C_a = \) analysis partial conc
    • \( C_f = \) trial partial conc
    • \( A_a = \) total conc from 3DVAR analysis
    • \( A_f = \) total conc from trial
• Method 2: Rescale Fcst Tendency (RFT)
  • \( C_a_t(i) = (C_f(i)-C_{a_t-1}(i)) \times A_a/A_f \)
  • Use of RFT results in a smaller impact on total ice volume
    • Due to a reduction in the impact of assimilation on thick ice categories
    • Some errors remain…
Update to GIOPS (v1.1.0)

**Motivation for update**
- SST errors near ice edge problematic for RIPS (degradation of forecast skill).
- Especially relevant when cycling CICE in RIPS (under development)

**Modification included in GIOPSv1.1.0**
- Under-ice sea surface temperature assimilation
  - GIOPSv1.0
    - rejects SST data when ice concentration in trial > 0.0
  - GIOPSv1.1
    - uses 3DVar ice concentration analysis as proxy for freezing temperature.
    - Sets SST=freezing when ice conc>0.2. Full SST field assimilated.
- Improved ice blending algorithm (RFT)
Comparison with CMC SST analysis
Mean differences for 2011-06-01 to 2011-08-31

- Previous experimental system:
  - GIOPSV1.0.1 (SAMv1.5.7)
- Updated system
  - GIOPSV1.1.0 (SAMv1.8.2)
- Improved under-ice SST assimilation substantially reduces differences with CMC SST analysis
Evaluation of sea ice forecasts using 3DVAR 10km global analyses

➢ Only evaluate points where the 3DVAR analysis changes by more than 10% (RIPS DGLA Verification)

✔ Pro: Only includes points where we have confidence in 3DVAR ice analysis
  • Focus on ice edge in particular

❖ Con: Excludes areas of incorrect model changes
  • E.g: coastal polynyas, false alarms along the ice edge
  • Examine RMS error and biases:
    • as a function of lead time
    • spatially
    • temporally
Verification of ice forecast skill

Compared to 3DVar analyses (where ΔGL>0.1)

- Reduction in RMS in both hemispheres
- Improvements most notable in Southern Hemisphere
Verification of ice forecast skill

Compared to 3DVar analyses (where $\Delta GL > 0.1$)

- Reduction in RMS in both hemispheres
- Improvements most notable in Southern Hemisphere
- Lower RMS error over Arctic in fall/winter
Verification of ice forecast skill

Compared to 3DVar analyses (where $\Delta GL > 0.1$)

• Reduction in RMS in both hemispheres
• Improvements most notable in Southern Hemisphere
• Lower RMS error over Antarctic in fall/winter

![Graph showing RMS and Bias over time in the Southern Hemisphere for different versions of the model and the persistence model.](image)
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
Verification of ice forecast skill

Compared to 3DVar analyses (where ΔGL>0.1)

- V1.8.0 forecasts show lower RMS errors than v1.5.7 over most regions
- Largest improvements: East of Greenland, Baffin Bay, Hudson Bay and Barents/Kara Sea
Evaluation of cycling using IMS analyses

• Comparison with IMS Analyses:
  – Interactive Multisensor Snow and Ice Mapping System (NOAA-NIC)
  – Daily Northern Hemisphere ice analyses on 4km grid (ice/water)
  – Assimilates: AVHRR, GOES, SSM/I

• Evaluation Methodology:
  – Interpolate model forecasts to IMS grid
  – Calculate contingency table values using 0.4 ice concentration cutoff
  – Bin results on 1° lat-lon grid

<table>
<thead>
<tr>
<th></th>
<th>IMS Ice</th>
<th>IMS No ice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forecast Ice</td>
<td>Hit ice</td>
<td>False Alarm</td>
</tr>
<tr>
<td>Forecast No ice</td>
<td>Miss</td>
<td>Hit water</td>
</tr>
</tbody>
</table>
Verification of ice forecast skill

Compared to IMS analyses

- Improved PCT in winter, summer and fall
- Due mostly to reduced false alarms by warming SST near ice edge

![Graphs showing proportion correct for total, ice, and water over months for v1.8.0f and v1.5.7f.](image)
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
  - With wave breaking parameterization
  - Without additional mixing
Small-scale ocean variability

- CMC Global Ice-Ocean Prediction System (GIOPS)
  - 7 day RMS forecast error evaluated against analyses for 2011 (50 weekly forecasts)
  - Restricted to points where analysis changed by more than 10%
- Ice forecast skill exhibits strong sensitivity to ocean mixing
  - With/without parameterization for surface wave breaking
  - Comparison with Argo shows better results with additional mixing
  - Highlights need for more polar observations!

Smith et al., ECMWF Proc., 2013
Summary and Outlook

• Three sea ice forecast suites are now running in operations at CMC
  – Coupled Gulf of St. Lawrence (5km; 48hr)
  – Regional Ice Prediction System (Arctic-N. Atl, 3-8km; 48hr)
  – Global Ice Ocean Prediction System (12-25km; 10days)

• All three systems have been verified with available observations and show significant forecast skill with respect to persistence

• Forecast skill sensitive to details of SST assimilation and vertical mixing parameterization

• Verification methods and observation error hinder our ability to improve these systems
Thank you!