The role of high resolution ocean models in short-range predictions

Hal Ritchie and Greg Smith
Environment and Climate Change Canada and the CONCEPTS Team
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
Coupling Method

CICE (Ice Model)
NEMO (Ocean Model)

CICE is integrated into NEMO, its information transits via NEMO
U\text{oce}, SST, SSH, D_{ice}, H_{ice}, S_d, C_{ice}, U_{ice}, T_{ice}

耦合方式

耦合每一步时间
计算在小尺度网格上的传输，并做总和

Jean-Marc Belanger, Francois Roy, Natacha Bernier
Ice-ocean modelling with

Applications and domains

- Global 1/4° resolution (GIOPS)
  - Medium-monthly forecasting
- Global 1° resolution (CanSIPS)
  - Seasonal forecasting
- N. Atlantic and Arctic 1/12° (RIOPS)
  - Short-to-medium range forecasting
- East and West Coastal 1/36° (CIOPS)
- Great Lakes 2km (RMPS-GL)
- Gulf of St. Lawrence 5km (RMPS-GSL)
  - Short-term forecasting
Gulf of St. Lawrence (GSL) Coupled Atmosphere-Ice-Ocean Forecasting System

- Operational since June 2011
  - 48h forecast 4 times/day
- Coupled system:
  - Atmosphere
    - GEM (10 km)
  - Ice-ocean
    - NEMO-CICE (5km)
- Under development:
  - Atmosphere
    - GEM (2.5km),
  - Ice-ocean
    - NEMO-CICE (1km)
  - Include Great Lakes
  - PAN AM games
The Gulf of St. Lawrence (GSL) Coupled Atmosphere-Ice-Ocean Forecasting System

- A dynamic representation of sea surface conditions improves the meteorological forecast locally
- Time-evolving ice cover in coupled model allows vast stretches of ice-free water to open up, buffering atmospheric temperatures
- Use of coupled model results in significantly improved forecasts all around the GSL
- Demonstrates importance of air-sea-ice coupling even for short-range weather forecasts
Real-time evaluation of Coupled GSL Forecasting System

Mark Pilon, Sarah Dyck, Francois Roy

24 Stations - Observed Temperature and MAE

Uncoupled RDPS
Coupled GEM-NEMO

Surface air temperature

48 hr Gulf Mean Screen Temperature (Deg. C)

19 Dec - 30 Apr 2014

TT_48, regl_NC, regl_A

Environment Canada
Fisheries and Oceans Canada
National Defence
Défense nationale
Mercator Ocean
Ocean Forecaster
Impact of Coupled Forecasts over the Gulf of St. Lawrence

- Evaluation against all surface temperature observations
  - 48hr forecasts over Jan-Mar 2014
  - Colours show bias
  - Standard deviation shown by the size of each circle
- Smaller errors in coupled system over water
- GSL is an ideal laboratory for studying impacts of coupling!
Great Lakes and St. Lawrence Water Cycle Prediction System (Fortin, Dyck et al.)

WATROUTE routing model (1km)

GEM LAM (10 km) atmospheric model (ISBA land-surface scheme)

GEM RDPS (10 km) atmospheric model

Runoff

Streamflow

Turbulent fluxes

NEMO+CICE (2 km) ocean-ice model

• 2 forecasts/day (00Z and 12Z)
• 48-h forecasts
• Assimilation cycle: direct insertion of RADARSAT ice cover and WSC streamflow

GEM GDPS (25 km) atmospheric model
Impact of Atmosphere/Lake Coupling
20 cases -- JFM 2011
Better weather forecasts

Summer 2015
RDPS
GL-WCPS

Year 2015
RDPS
GL-WCPS

MEAN ERROR (P-O) OF DEW POINT TEMPERATURE (°C) 2015-07-01 @ 2015-09-30
comm obs ade_metar

1. rdpscgl 0z [91]
2. rdpscp 0z [91]

EQUITABLE THREAT SCORE OF 24-HOUR ACC. PRECIPITATION (mm) 2015-01-01 @ 2015-12-31
accum 12h @ 36h comm obs capa

1. rdpscgl 0z [361]
2. rdpscp 0z [361]
Better streamflow forecasts

Winter 2015-16 (2015-11-04 - 2016-01-31)

RDPS

GL-WCPS

![Graph comparing RDPS and GL-WCPS for streamflow forecasts](image-url)
Better streamflow forecasts

Difference between STDE of RDPS and GL-WCPS
Global Ice-Ocean Prediction System

Dorina Surcel Colan, Matt Reszka, Francois Roy, Daniel Deacu, Yimin Liu, …

- 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
- 3DVar Ice analysis:
  - SSM/I, SSM/IS, CIS charts, Radarsat image analyses
- Experimental implementation (March 2014)
- Operational since August 20, 2015
- Dissemination
  - External cluster (pegasus)
  - Available on MSC Datamart (Netcdf4)
    - WMS using GeoMet or RPNWMS
      - E.g., [www.meteocentre.com/plus](http://www.meteocentre.com/plus)

Smith et al., QJRMS, 2015
Ocean data assimilation

• Système d’Assimilation Mercator (SAM) v2
  ➢ Multivariate SEEK filter

• SAM2 assimilates:
  ➢ Subsurface temperature and salinity (from Argo, CTD, XBT, moorings, marine mammals)
  ➢ Sea surface temperature (from both satellite and in situ observations)
  ➢ Sea level anomalies from satellite altimeters (AVISO)

Altimeters:
• Jason 2
• Cryosat2
• Altika

Lellouche et al., 2012
Smith et al., 2015
GODAE Oceanview Intercomparison

International near real-time evaluation of global ocean forecasting systems

- UK Metoffice (FOAM)
- Env. Canada (GIOPS)
- Mercator (PSY3, PSY4)
- US Navy (RTOFS)
- Australian BofM (OMAPS)

High quality SST critical for coupled forecasting

Jinshan Xu and Fraser Davidson
An operational regional ice-ocean prediction system (RIOPS) at 4-5km resolution in the Arctic

Domain presentation:
1580x1817x50
512 procs

Domain is as in RIPS2.0 (32 procs).
Extracted from ORCA12 (Mercator) with the north fold stitched back. Regional CONCEPTS domain (CREG).

Resolution is maximum near the artificial pole over northern Canada at 1.8 km and minimum along the Atlantic northern boundary (8.2 km)

Covers part of North Atlantic (27N), the whole Arctic Ocean.
First Rossby radius of deformation

Radius (km)

Red: good resolution for eddies

Blue-yellow: eddies under-resolved

Radius/DX (log2)

Red: good resolution for eddies

Blue-yellow: eddies under-resolved
RIOPS Prediction System

3 Components: RIPS 3DVar ice analysis, Pseudo-Analysis and 48hr Forecasts

A 24h run from previous restart is nudged to the GIOPS analysis using spectral nudging (Thompson et al., 2006)
Comparison of velocity on 2015-07-08

GIOPS

GIOPS interpolated on CREG12

RIOPS

Use of spectral nudging (Thompson et al. 2006, in space) towards GIOPS with timescale of 1 day
Other approaches that are implemented in RIOPS:

- Grounded landfast ice represented by a basal stress parametrization (Lemieux et al. 2015)

- Increase in shear and tension resistance (Lemieux et al., in preparation) improves the representation of land-locked ice (another form of landfast ice).
Landfast ice detection from mean ice speed over 7 days from 3-hourly averaged output. RIOPS is the more realistic of the two.

RIOPS
TIME: 15–APR–2015 01:30 to 22–APR–2015 01:30

RIPS
TIME: 15–APR–2015 01:30 to 22–APR–2015 01:30
Coastal Ice-Ocean Prediction System (CIOPS-E)

✓ Has a more energetic eddy field than RIOPS, but…
  • Can data assimilation adequately constrain small scales?
  • Does SLA filtering affect verification scores?
  • What is the effective resolution?
Coastal Ice-Ocean Prediction System (CIOPS-W)

Gradient of Sea Surface Temperature

CIOPS Configurations can serve as testbeds for development of high-resolution prediction techniques
• Intensive observational and modelling period to advance polar prediction capabilities.

• This will be augmented by research into forecast-stakeholder interaction, verification and a strong educational component.

• YOPP Summit held in Geneva (July 13-15, 2015)
ECCC YOPP Contribution
Modelling

High-resolution coupled atmosphere-ice-ocean prediction system

• In support of:
  – EC METAREAs Services
  – Marine emergency response

• Coupled atmosphere-ice-ocean model
  – GEM (2.5km)
  – NEMO-CICE (3-8km) and WW3
    – Tides, landfast ice,
    – wave-ice coupling
  – 48-72hr forecasts
Impact of atmospheric resolution on winds

Difference between daily 2.5km and 15km 48hr forecasts for August 2012
Impact of a dynamic ice cover on coupled forecasts over the Beaufort Sea

Difference in ice fraction (CPL-UNCPL)  Difference in 2m temperature

Forecast from global coupled model (GEM-NEMO-CICE; 33km-15km resolution) from the Canadian Meteorological Centre  
R. Muncaster, F. Roy, J.-M. Belanger
Impact of a dynamic ice cover on coupled forecasts over the Beaufort Sea

- Coastal polynya formation sensitive to:
  - Atmosphere-ice and ice-ocean stresses, ice thicknesses, parameterization of ice strength (all things we know poorly!)

Difference in ice fraction (CPL-UNCPL)  Difference in 2m temperature

Forecast from global coupled model (GEM-NEMO-CICE; 33km-15km resolution)
Summary

• CONCEPTS is currently developing a suite of global and regional coupled environmental prediction systems
  – Benefit for weather prediction as well as providing a marine core service
• Builds on the original Gulf of St. Lawrence system
• High resolution coupled ocean-ice modelling systems are demonstrating benefits compared to both uncoupled systems and lower resolution coupled systems as demonstrated by:
  – The Gulf of St. Lawrence system
  – The regional ice-ocean prediction system
  – The Great Lakes Prediction System

Benefits include more accurate predictions of conventional fields and variables, as well as new fields and variables for a variety of users.
Thank you!