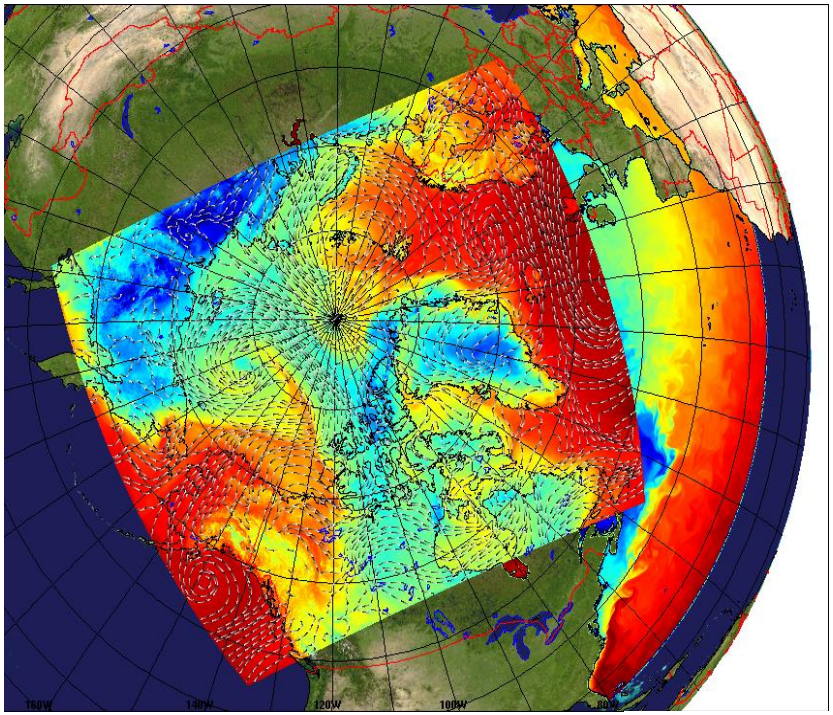
Canada

Impact of small-scale coupled atmosphere-ice-ocean interactions: Results from the Canadian high-resolution forecasting system for YOPP

YOPP YEAR OF POLAR PREDICTION

Gregory C. Smith, Jason Milbrandt, Jean-François Lemieux, Barbara Casati, François Roy, Frederic Dupont, Manon Faucher, Sarah MacDermid, Shunli Zhang, Ji Lei

Environment and Climate Change Canada, Dorval, Québec, Canada

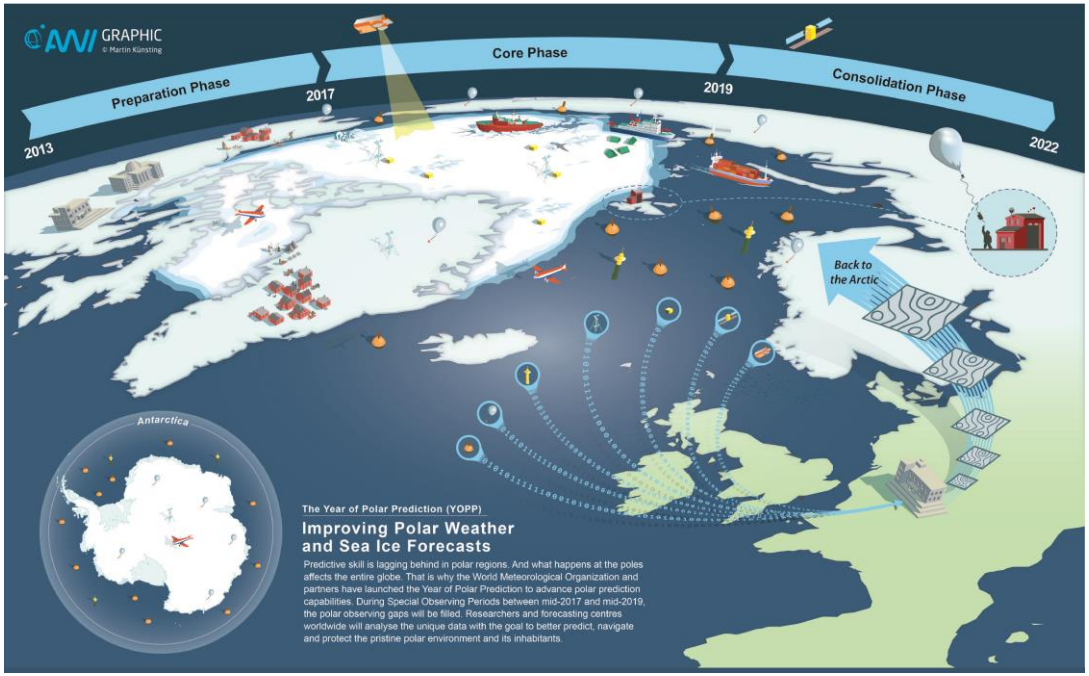


ceanPredict '19
GODAE OceanView Symposium 2019

6-10 May 2019, Halifax, Canada

Environment Canada | Fisheries and Oceans Canada | National Defence Défense nationale | MERCATOR OCEAN INTERNATIONAL | CONCEPTS

YEAR OF POLAR PREDICTION



Coordinated by the World Meteorological Organization (WMO)

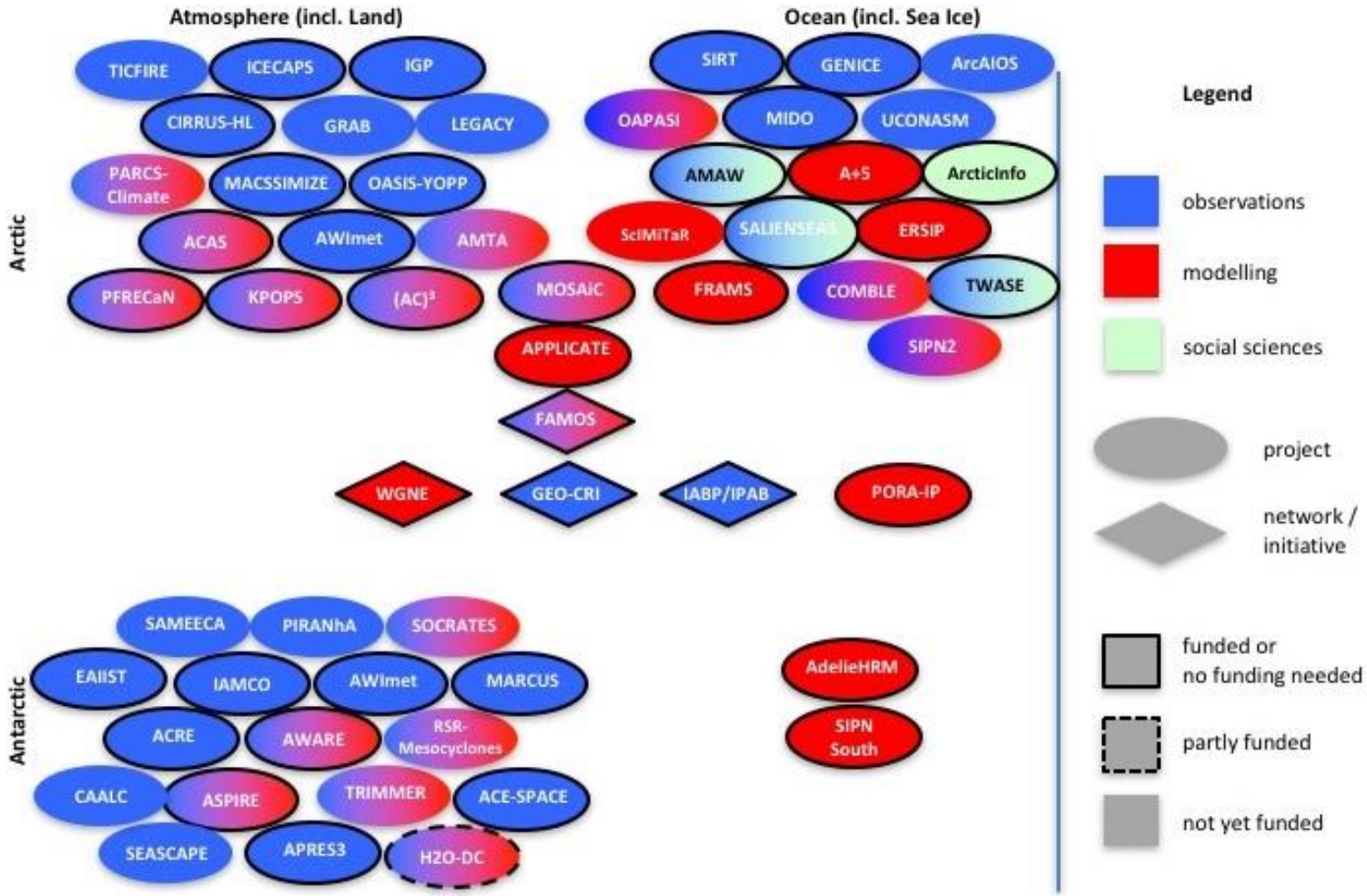
Period:
mid 2017– mid 2019
(Launch: 15th May 2017)

- **Goal: Improving predictions of weather and environmental conditions in polar regions and beyond**
- International collaboration between academia, operational forecasting centres, and stakeholders
- Improving the polar observing system, as well as weather and climate prediction models in polar regions

WMO OMM

www.polarprediction.net
@polarprediction

YOPP Endorsement

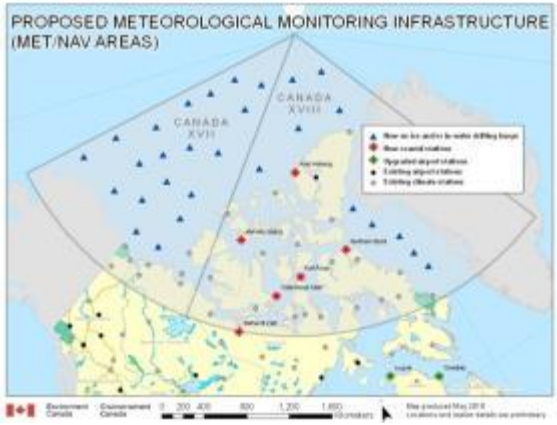


59 endorsed projects (28 August 2017)

Canadian Arctic Prediction System (CAPS)

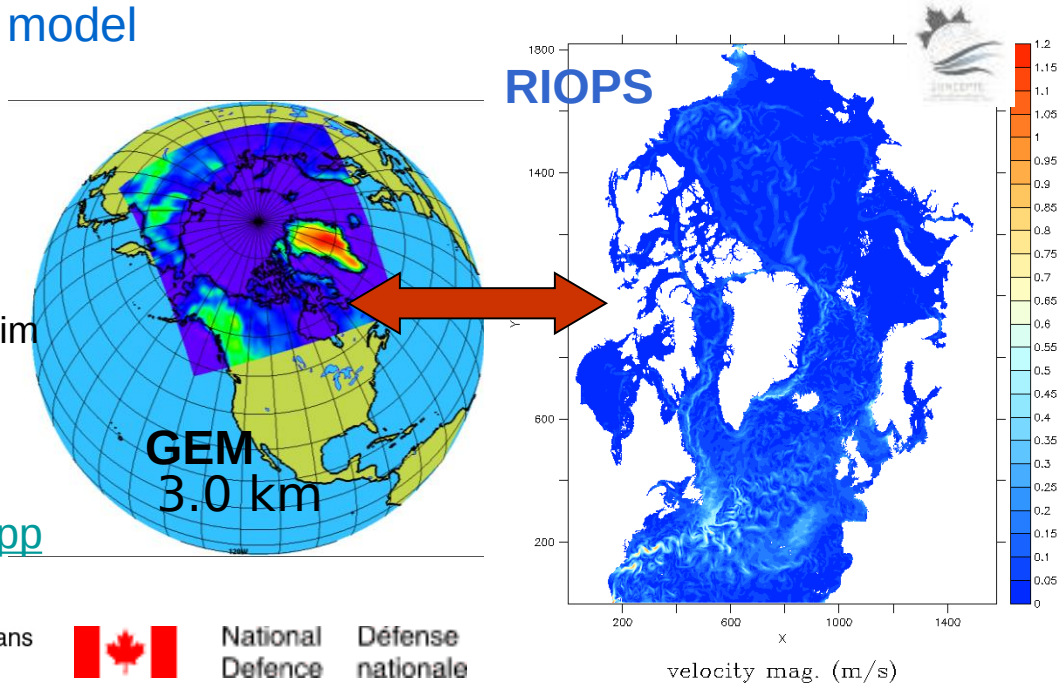
An ECCC contribution for YOPP

High-resolution coupled atmosphere-ice-ocean prediction system



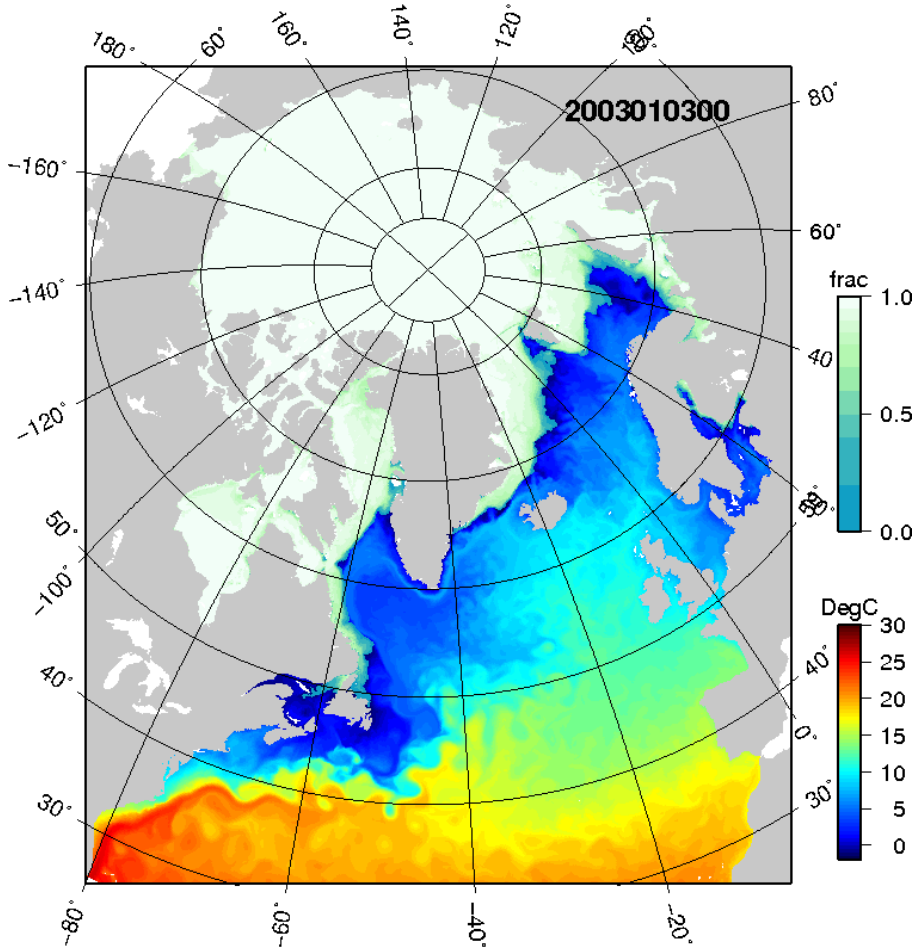
- In support of :
  - Weather prediction for northern Canada
  - EC METAREAs Services
  - Marine emergency response
- Coupled atmosphere-ice-ocean model
  - GEM (3.0 km)
    - Improved microphysics
  - NEMO-CICE (3-8 km)
    - Tides, landfast ice
    - Improved ice-ocean assim
  - 48 h forecasts (2/day)
  - Available at:

http://dd.alpha.weather.gc.ca/yopp



Environment Canada | Fisheries and Oceans Canada | National Defence Défense nationale

The Regional Ice-Ocean Prediction System (RIOPS)

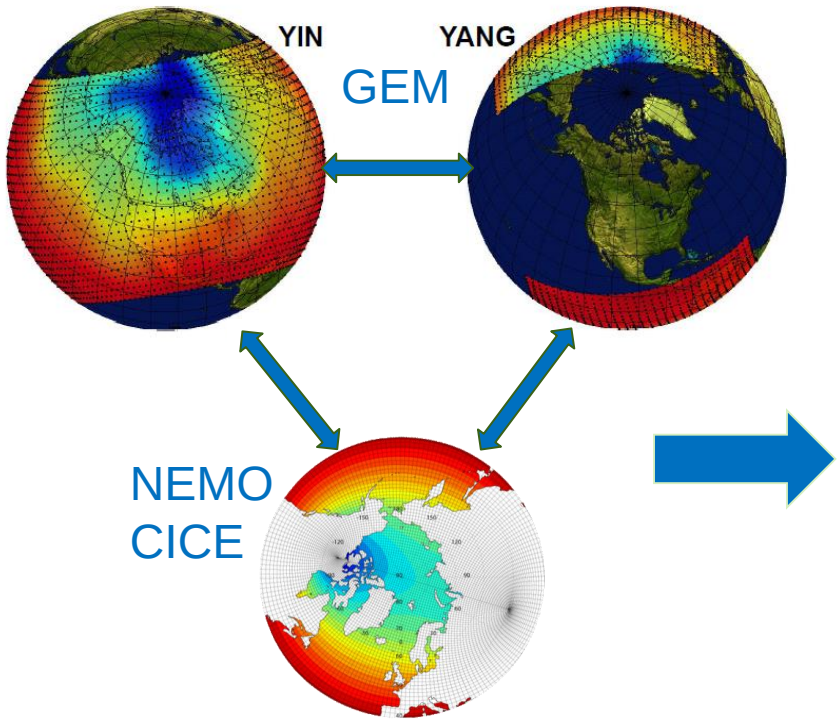


Lemieux et al., QJRMS, 2015
Dupont et al., GMD, 2015

- Purpose:
  - METAREAs 17&18
  - CIS support
  - Iceberg drift
  - Fisheries and aquaculture management
- 3-5km resolution in the Arctic
- 4x48hr ice-ocean forecasts
- 3DVar ice analysis
  - SSMI, SSMI/S
  - AVHRR, ASCAT, AMSR2
  - CIS charts, Radarsat analyses
- Improved ice model physics
  - Landfast ice, tensile strength
- Spectral nudging to GIOPS ocean analyses
- Real-time production since April 2016

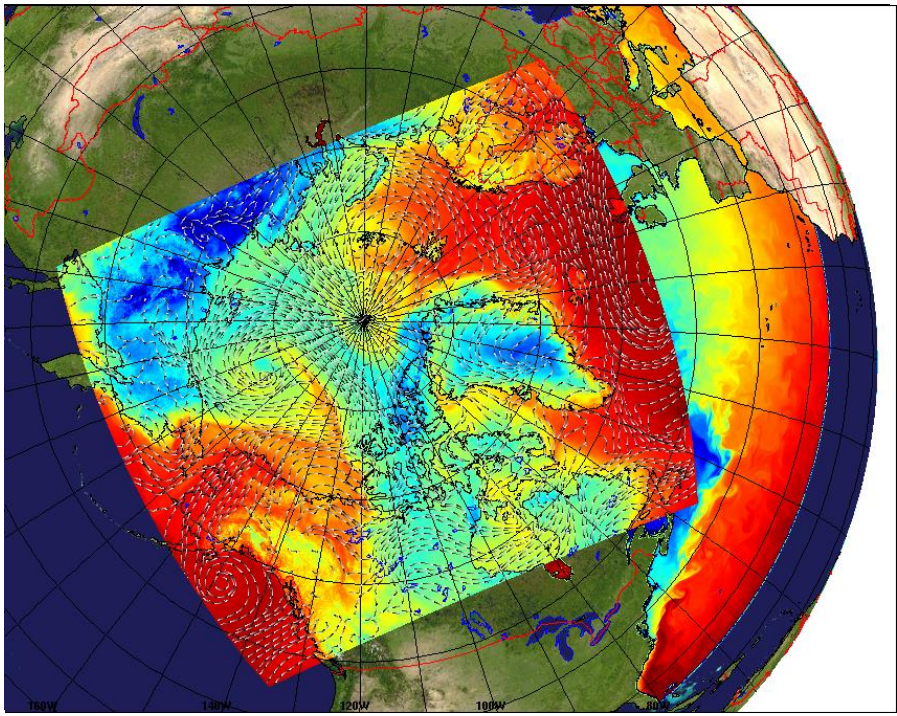
CAPS Configuration

Coupled GDPS-GIOPS
(Global Deterministic Prediction System –
Global Ice-Ocean Prediction System)



(10 day forecasts (2/day))

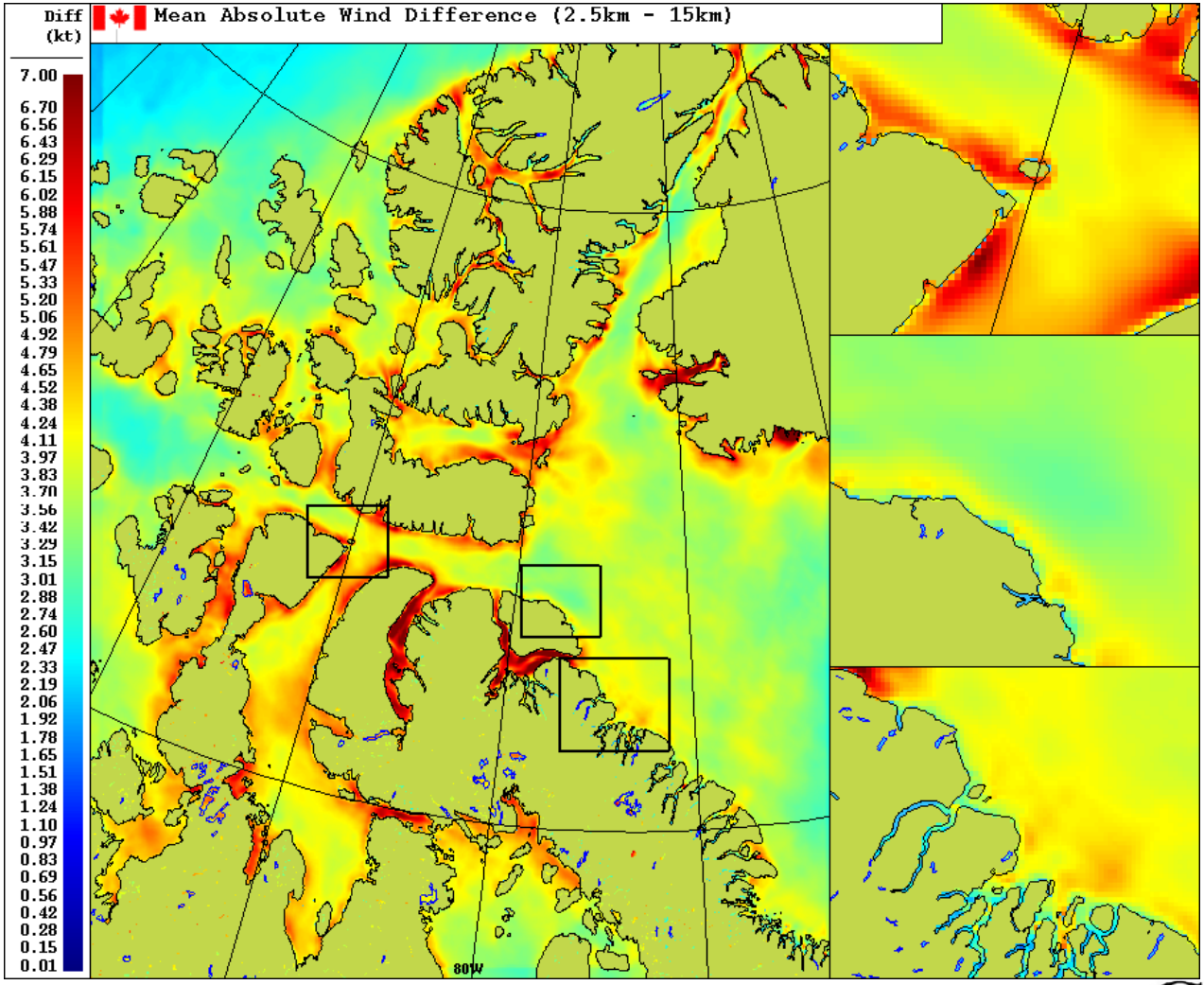
Coupled CAPS-RIOPS



(48 h forecasts (2/day))

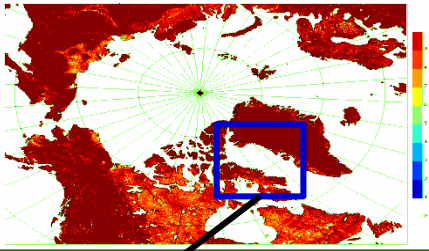
Impact of atmospheric resolution on winds

Difference between daily 3km and 15km 48hr forecasts for August 2012

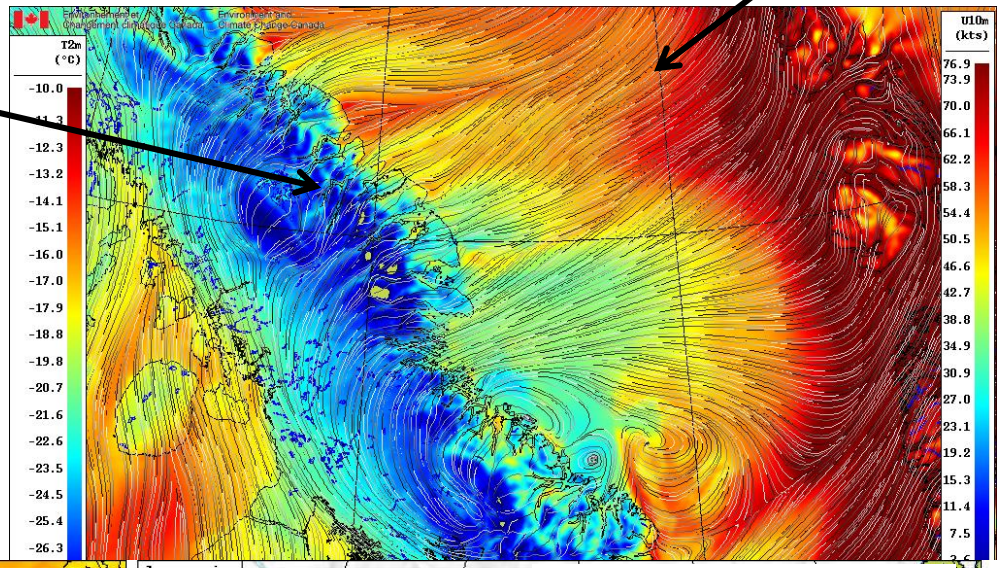


Impact of small-scale coupled atmosphere-ice-ocean interactions in CAPS

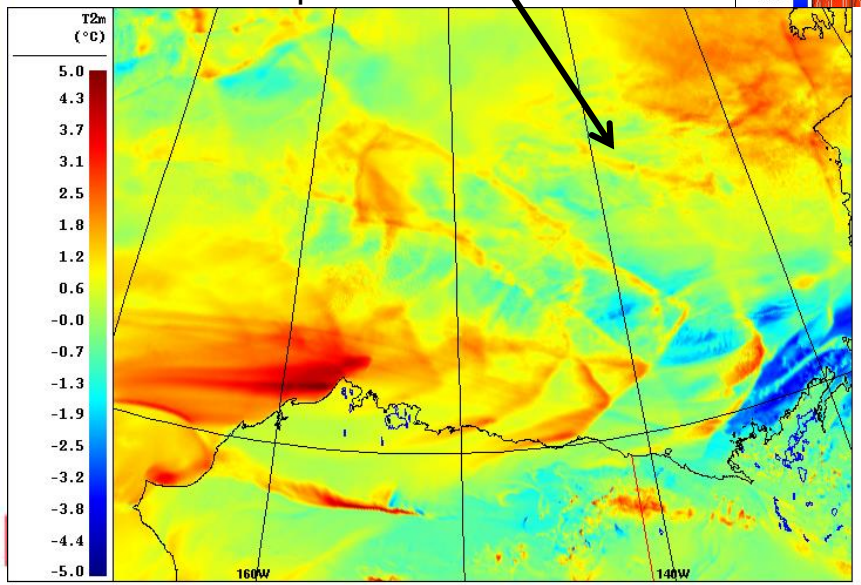
Forecast for 2017-01-01

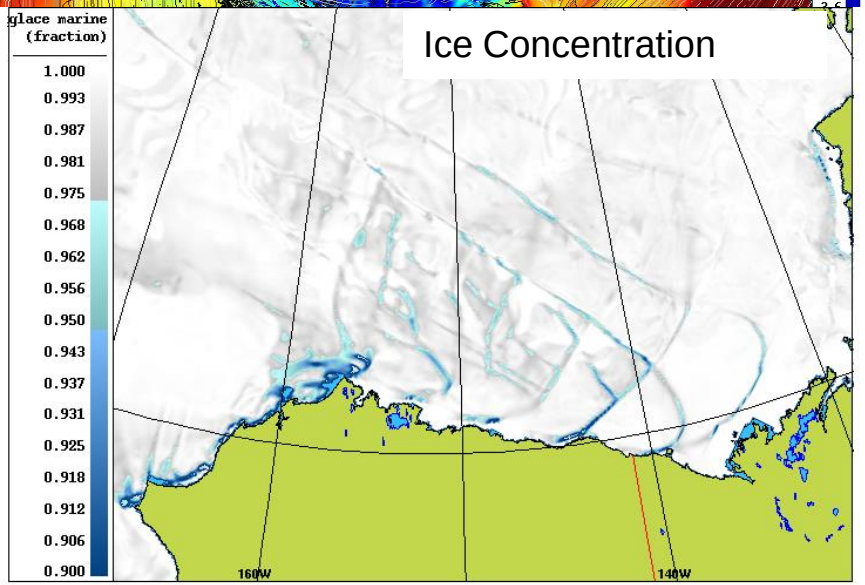


- Orographic features better represented
  - Flow through fjords
  - Potential impact on local ice drift
- Imprint of small-scale features on surface fluxes
  - Boundary layer interactions in marginal ice zone
  - Coastal polynyas and leads in sea ice



Surface Air Temperature

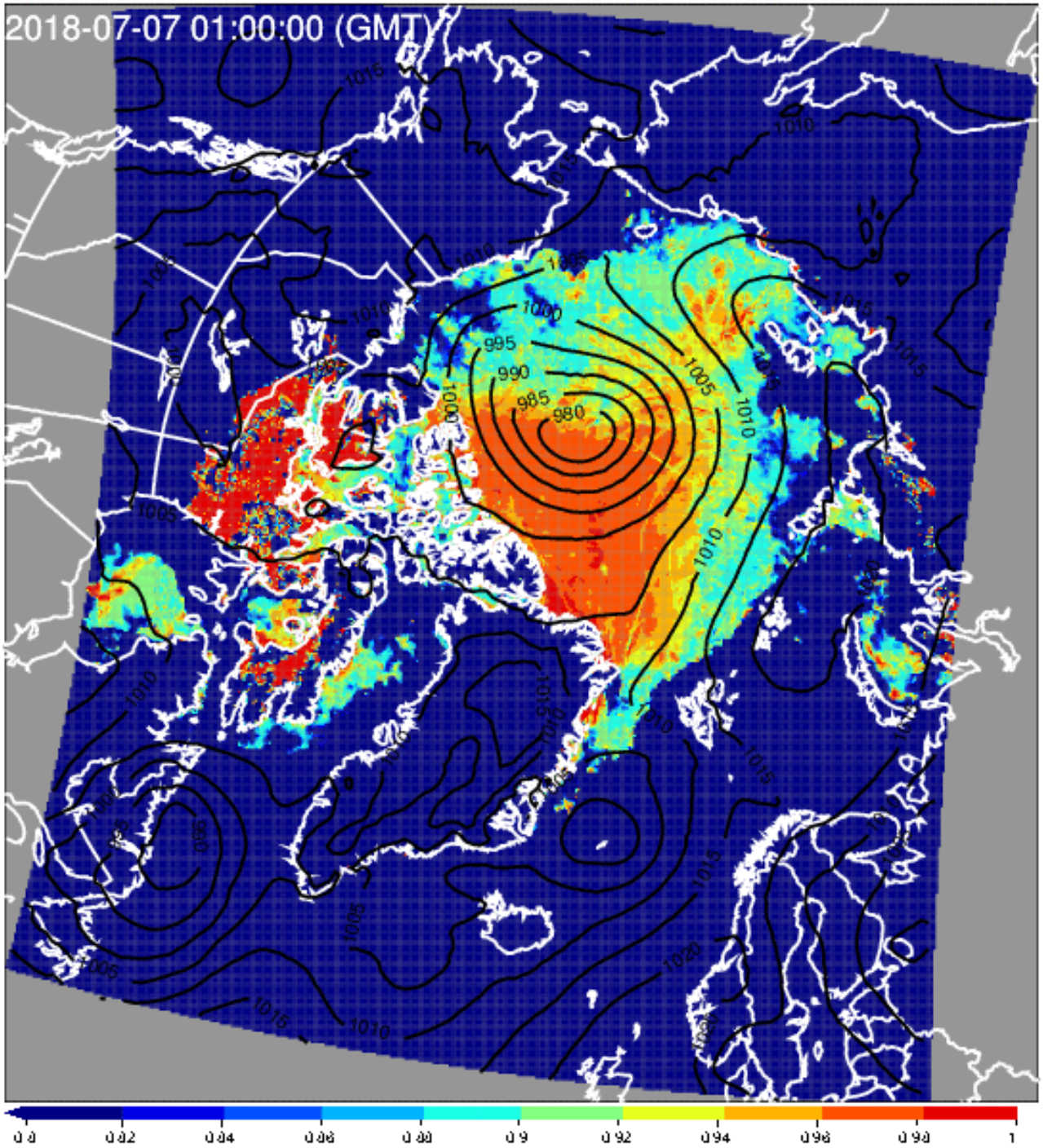




Ice Concentration

Case study from Arctic SOP2

48h forecast July 7

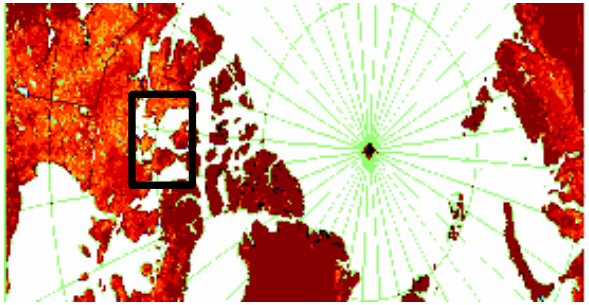


Sea level pressure

0.8 !!

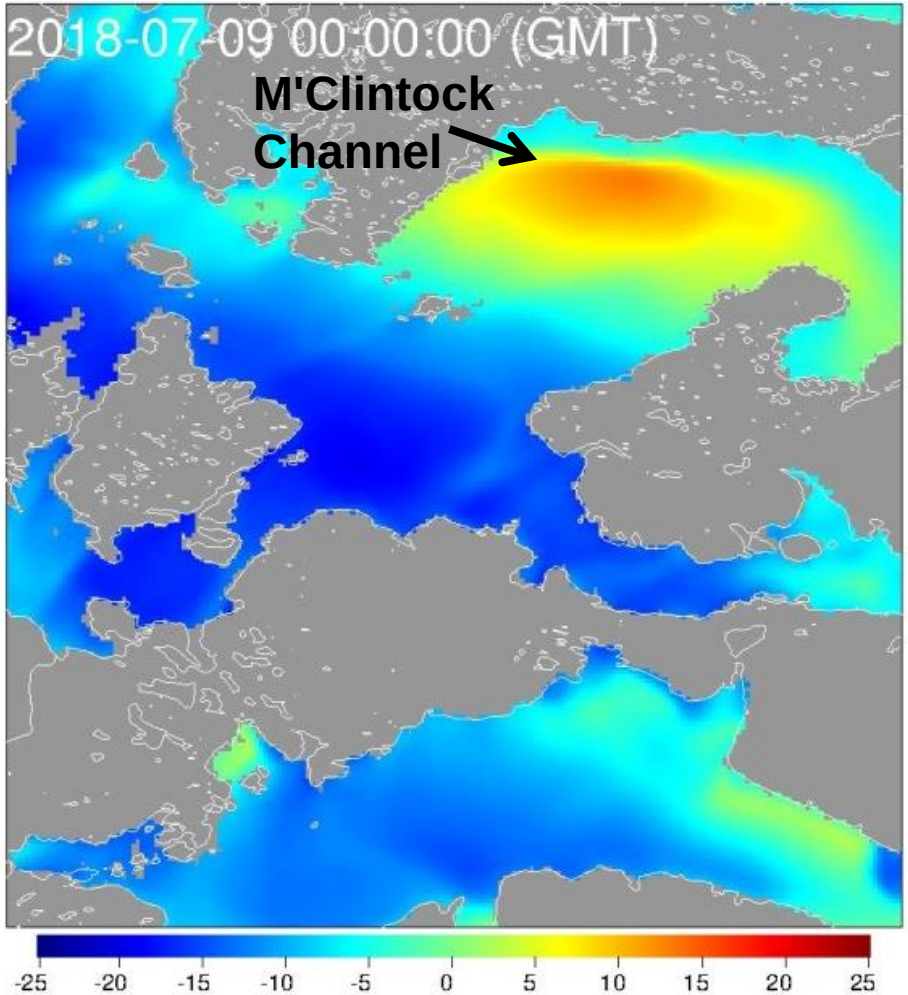
Ice fraction

Sensitivity experiment:
Lower resolution of atmospheric fields

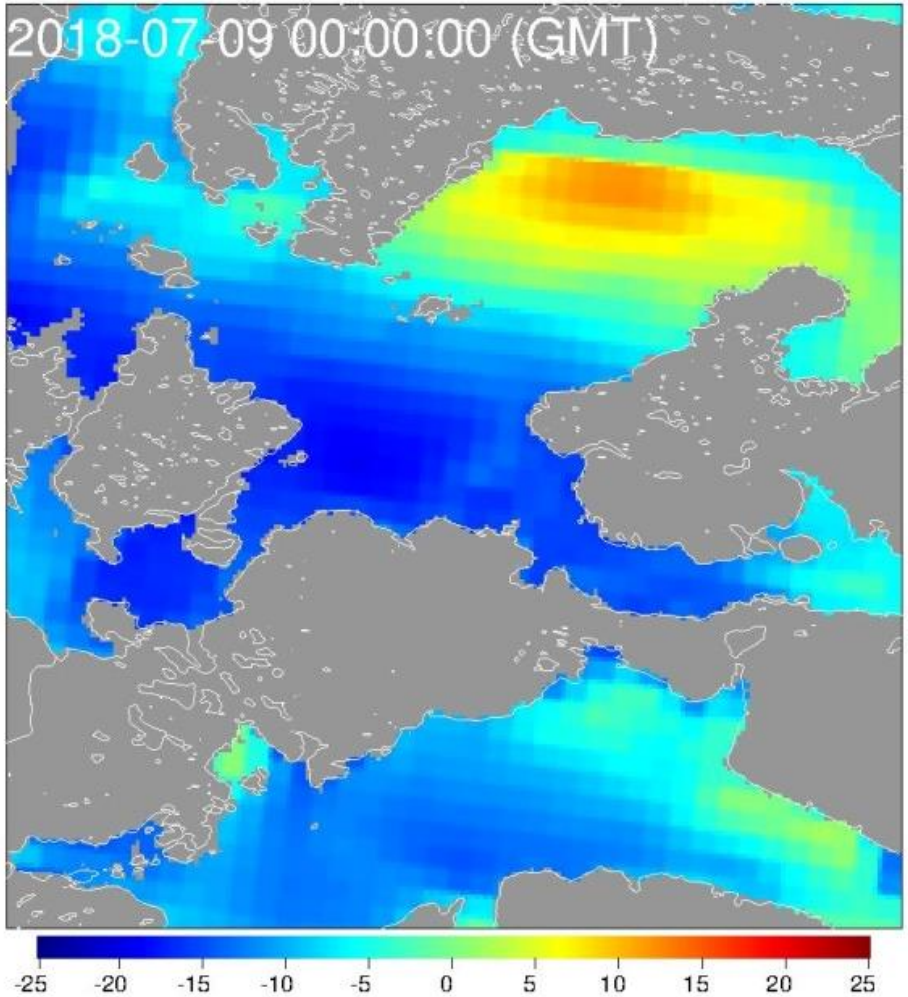


Potential impact for internal ice pressure, surface currents

U component of wind (3km)

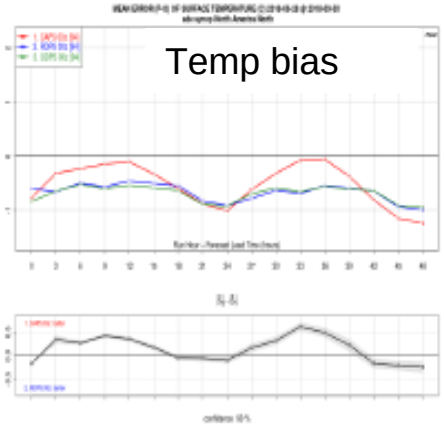


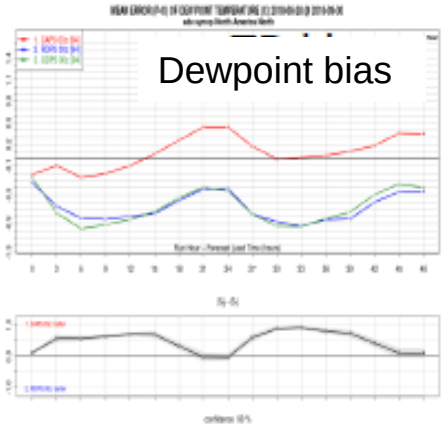
U component of wind (15km)

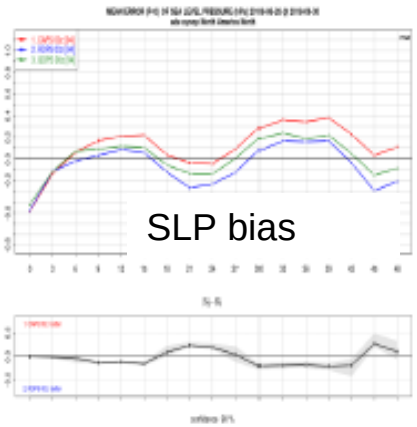


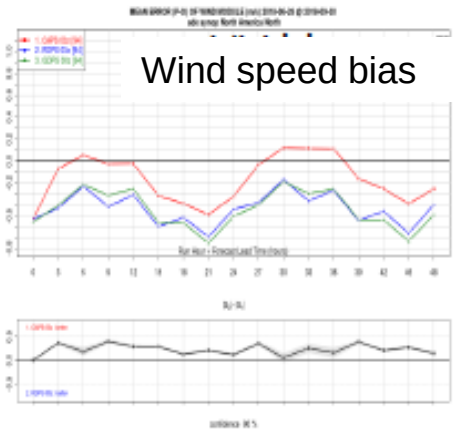
CAPS vs RDPS vs GDPS, North America

Bias : exhibits diurnal cycle; RDPS and GDPS underforecast TT,TD,UV;
CAPS best performance for wind and temperatures, worst for mslp;
Models cluster for wind and temperatures (RDPS+GDPS vs CAPS).

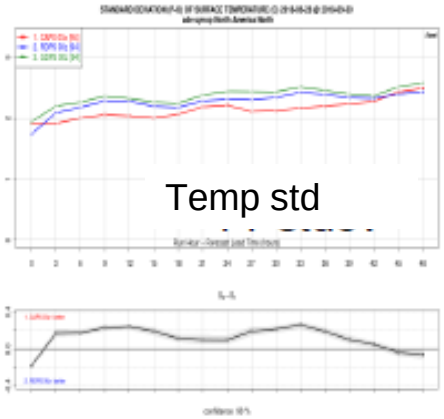


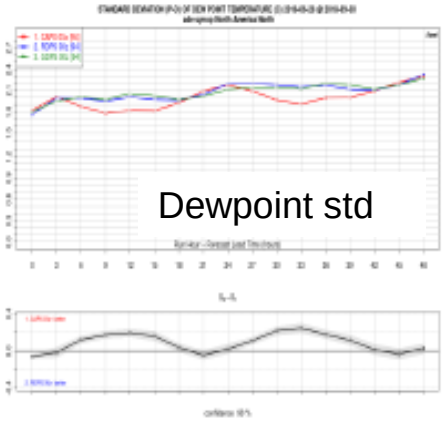


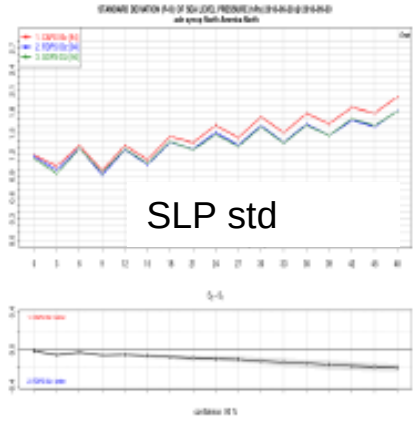


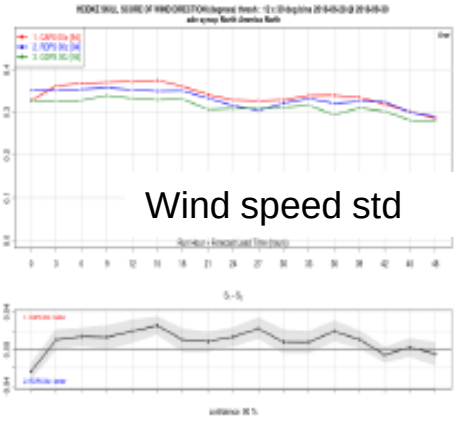


Verification against Surface Stations – Jul/Aug/Sep 2018





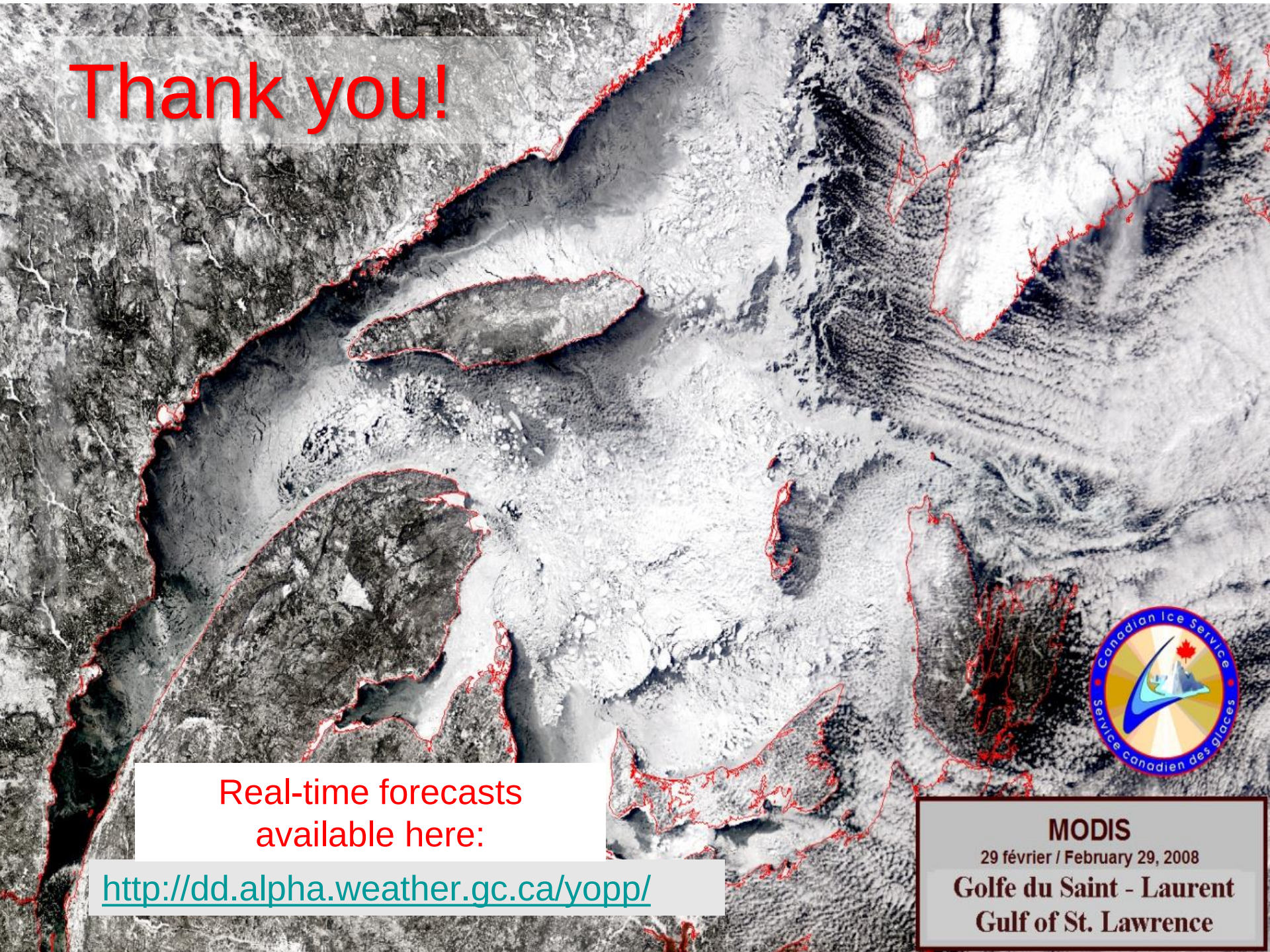




Ongoing CAPS evaluations during YOPP

- “Virtual Desk” subjective evaluation (P. Pestieau)
- Real-time NWP verification (G. Gascon)
- Real-time sea ice verification (J. Lei)
- YOPPSiteMIP intercomparison for supersites (B. Casati)
- SIDFex sea ice drift intercomparison (Helge Göβling)
- High-resolution forecast intercomparison with Met.no, Meteo-France and ECMWF (Morten Køltzow)
- Evaluation of impact of coupling for A-I-O forecasts (G. Smith)
  - Collocated observations needed…
- Various efforts associated with MOSAiC
- Join in! http://dd.alpha.weather.gc.ca/yopp

Thank you!



Real-time forecasts available here:

http://dd.alpha.weather.gc.ca/yopp/

CAPS Schematic

- GDPS: Global Deterministic Prediction System
- GIOPS: Global Ice Ocean Prediction System
- RIOPS: Regional Ice Ocean Prediction System
- CAPS: Canadian Arctic Prediction System

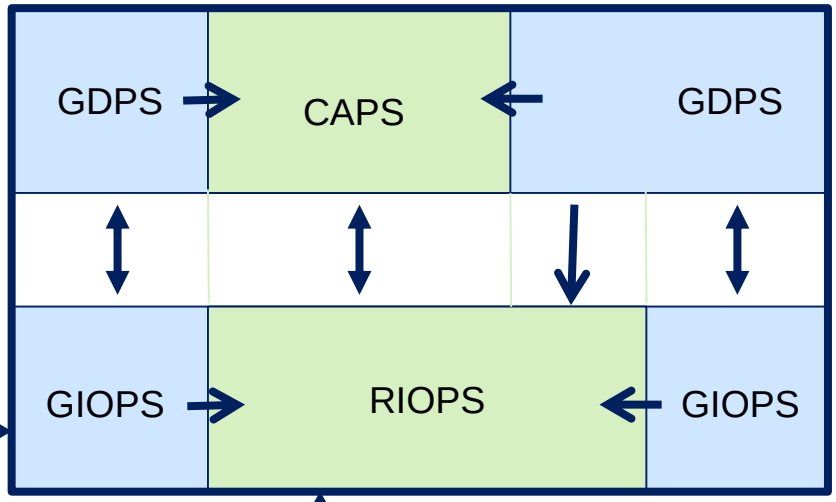
Analysis Components

GDPS
GEM-4.8LTS13
25km Yin-Yang
EnVar Atmospheric analysis

GIOPS
NEMO-CICE
1/4° global, 50 levels
SEEK Ocean Analysis
Assimilates SLA, SST, T&S profiles
3DVar Ice Analysis
Assimilates SSMI, SSMI/S, CIS charts

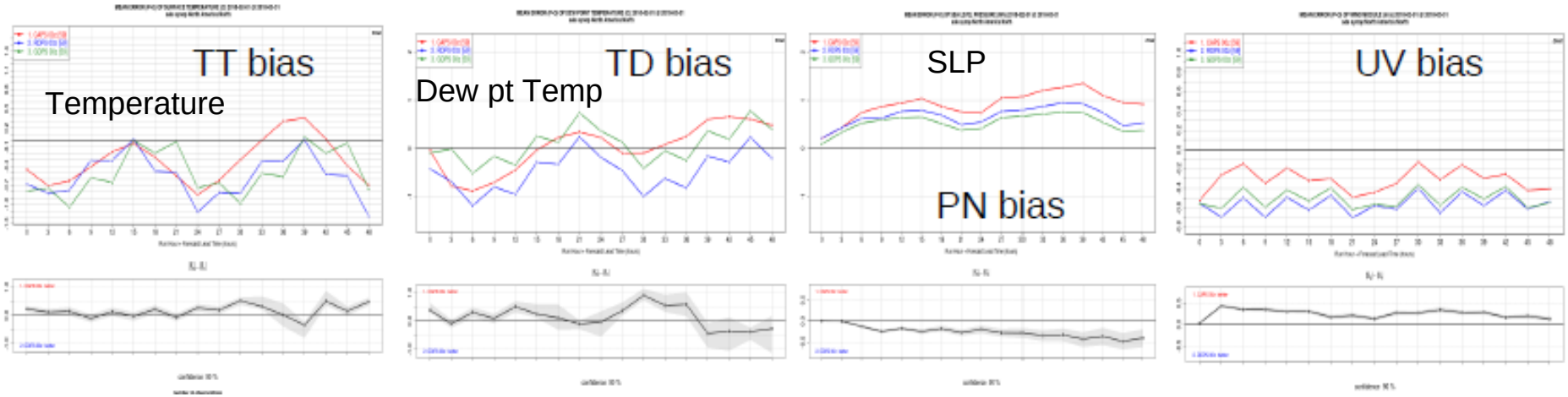
RIOPS
NEMO-CICE
1/12° Arctic/N. Atl, 75 levels
Spectral Nudging to GIOPS
SEEK Ocean Analysis this fall

Forecast Components

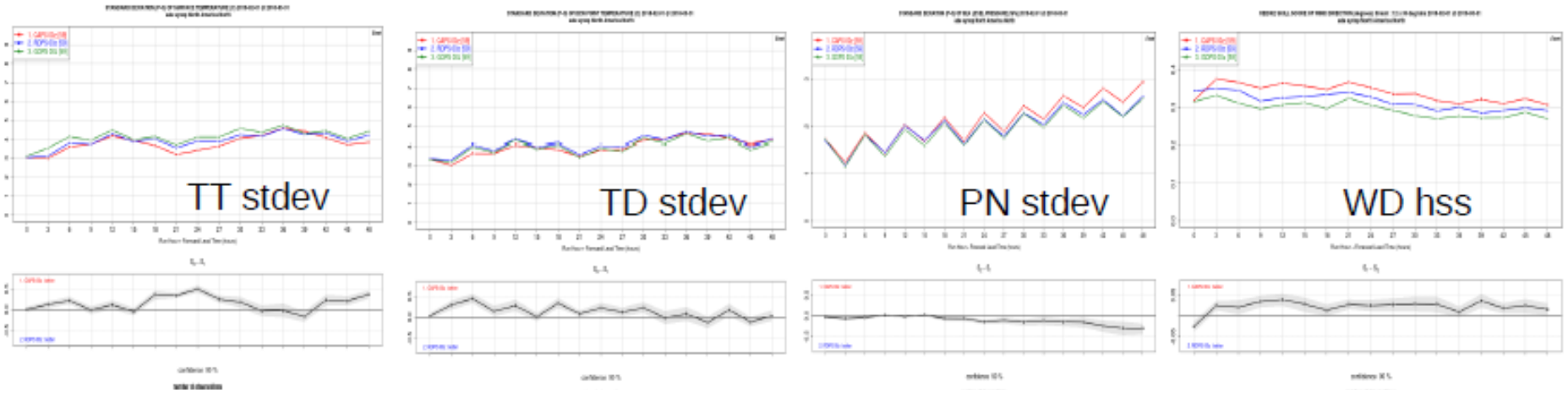


CAPS vs RDPS vs GDPS, North America, 00 run

TT,TD,PN bias: diurnal cycle (increasing trend for CAPS); PN: overforecast mean sea level pressure; UV: underforecast wind speed; CAPS best performance for wind (and temperatures), worst performance for mslp. 00~12 run



Verification against Surface Stations – Feb/Mar 2018



What is the Year of Polar Prediction?

A major international WMO project – Core phase of the 10-year WWRP - Polar Prediction Project (2013-2022)

"*to enable a significant improvement in the capacity to forecast weather, climate and the environment for polar regions and beyond*"

Photo from Llodys report

Photo: Resolute Bay Airport blog.esa.int

Ronwassink. blogspot.com

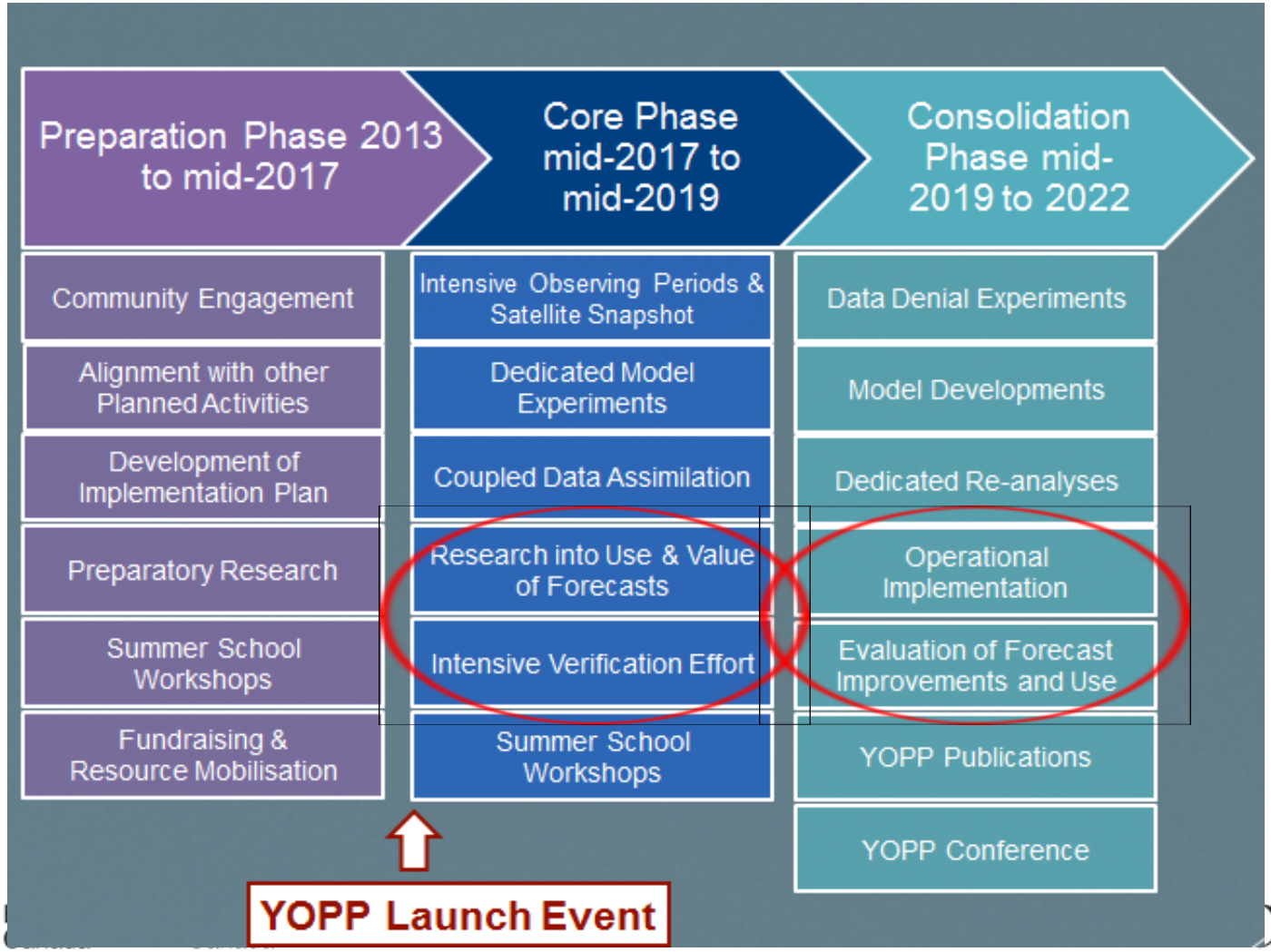
Photo by Chilean Navy/Reuters

Photo: A. Peacock / www.footloosefotography.com

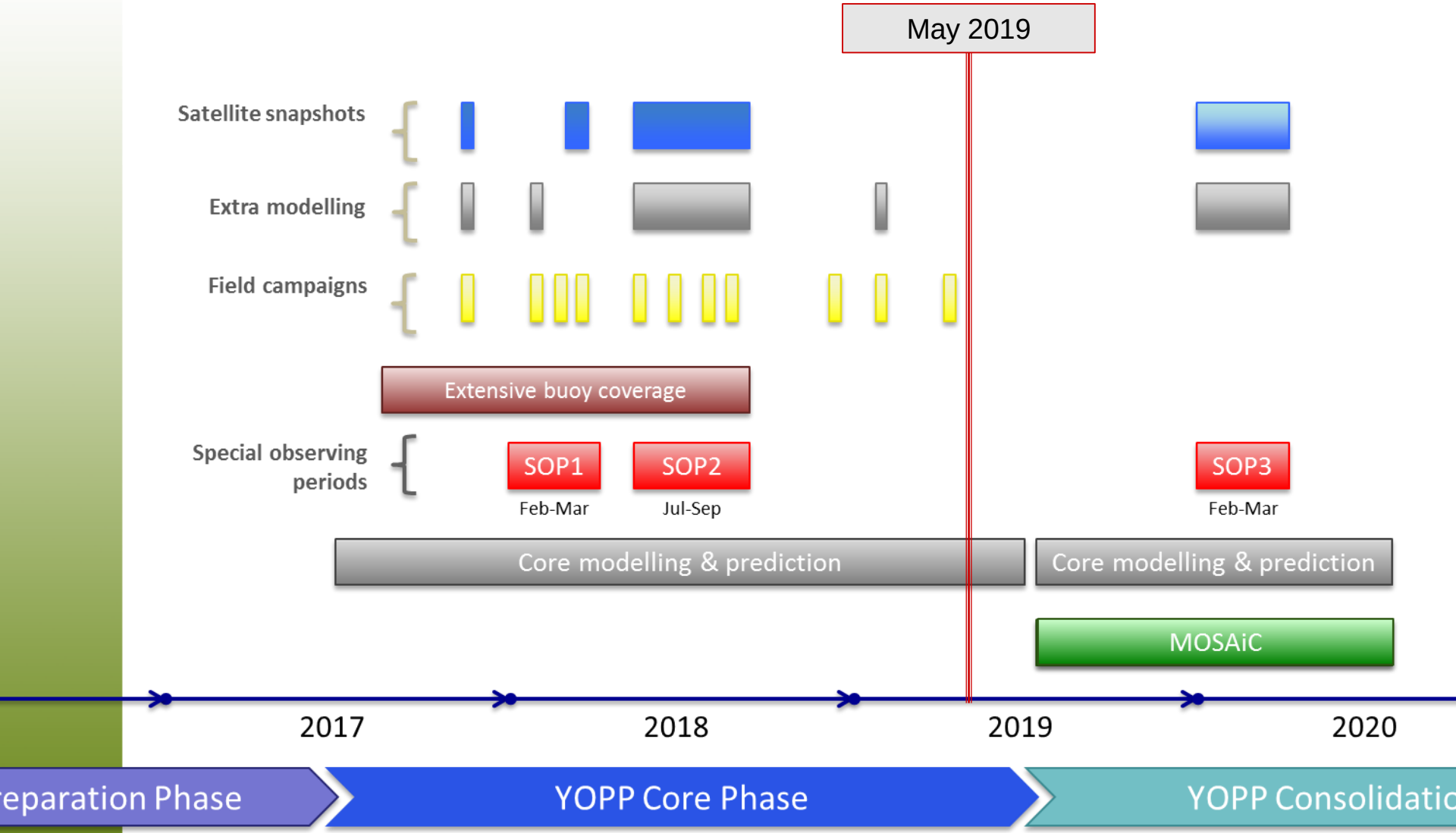
- Through coordination of intensive periods of <u>observing</u>, <u>modelling</u>, <u>verification</u>, <u>user-engagement</u> and <u>educational</u> activities at both poles from 2017 to 2019 – Official Kick-Off May 15th 2017 at WMO in Geneva
- Through mobilisation, via the World Meteorological Organisation (WMO), of all Arctic countries, and those close to Antarctica, and major weather centres (21 countries) **including significant ECCC in-kind contributions (~$2M)**
- Endorsed by the White House Arctic Science Ministerial (2016) and the European Commission (€30M in Horizon 2020 funding).

PPP timeline of activities

(Unlike IPY) PPP-YOPP is heavily committed to Operational outcomes



YOPP Observations – Arctic

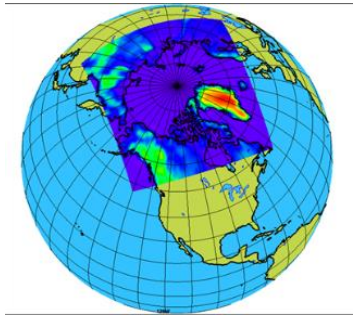


Canadian and International contributions

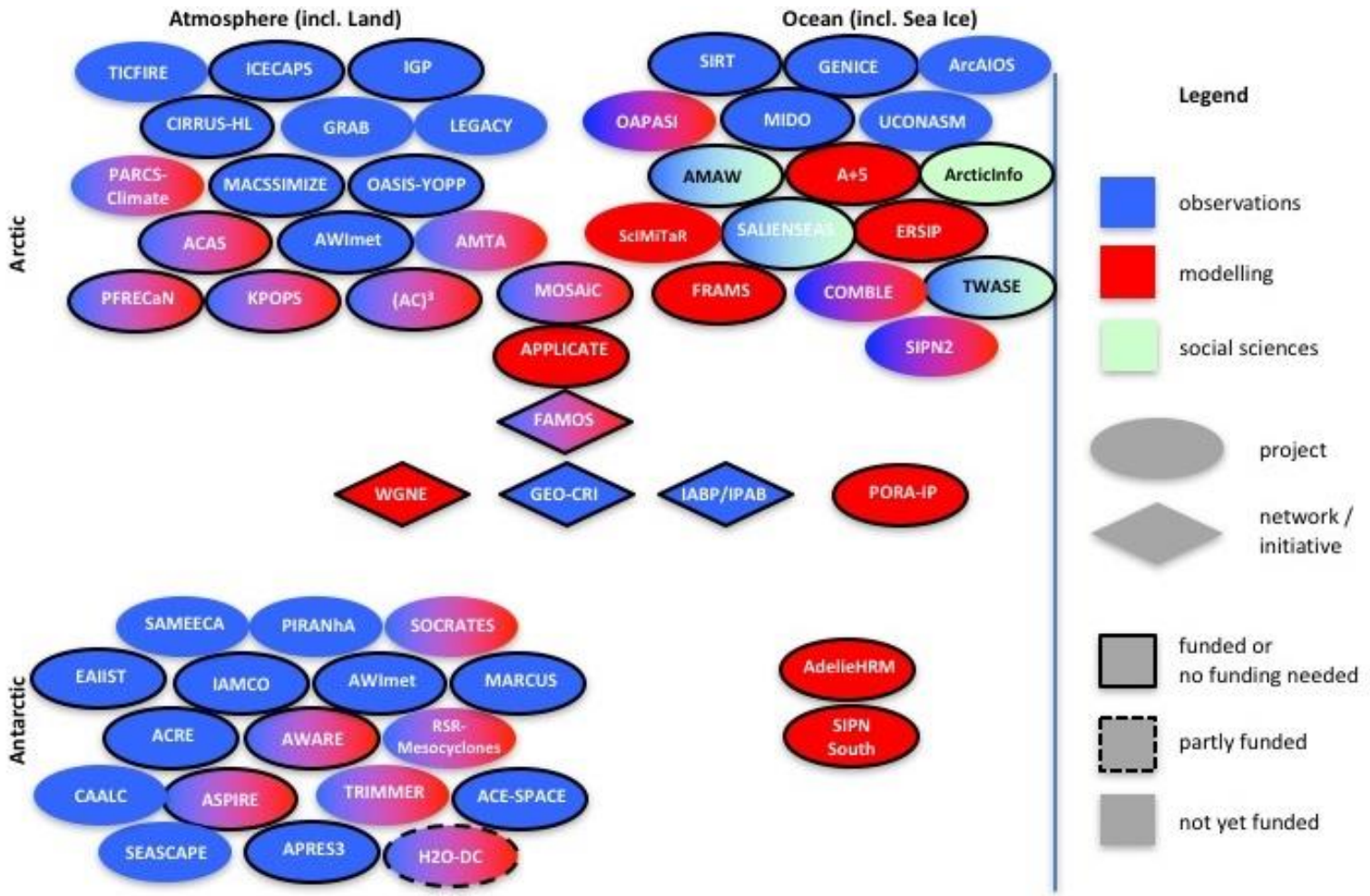
→ www.polarprediction.net for info on endorsed projects

- **Observations:**
  - Buoys – incremental deployments: **All Arctic countries, including Canada, Russia (?), and Germany + good coverage of Antarctica**
  - Radiosondes – increased frequency : **Denmark; Sweden; Germany; US; Canada (4/day at 6 sites)**
  - Ships: **China, South Korea, Japan, Norway, Sweden, Germany**
  - Aircrafts: **UK MetOffice, US Office of Naval Research**
  - UAV: **US** (proposed. i.e.: Global Hawk)
  - Possible extra satellite access (Radarsat, Sentinel, TerraSar-X)

- **Forecasting & Modelling**
  - **ECMWF & ECCC** to provide core datasets for SOPs
  - **UK MetOffice:** Ice modelling diagnostics
  - Frontier experiments (e.g. high resolution models – 2.5km or higher): **ECCC; Met-Norway; Meteo-France**
  - **Norway** to host forecast data exchange and archive portal



YOPP Endorsement

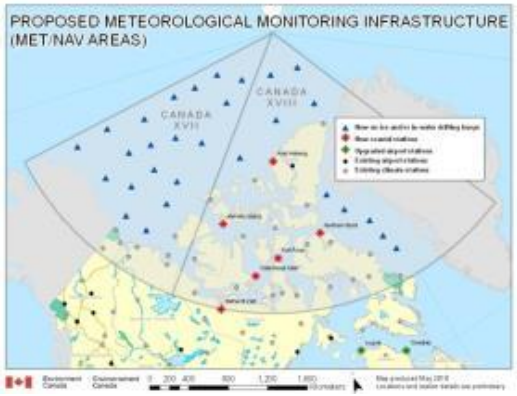


59 endorsed projects (28 August 2017)

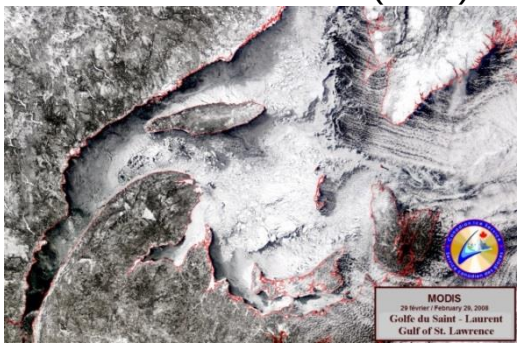
Canada's interest in YOPP

- Close to a third of Canada is North of the Arctic Circle
- PPP - YOPP objectives align with Canada's Arctic Policy Framework (science, sovereignty, safety)
- Builds on Canada's leadership and investments to respond to MetAreas XVII and XVIII responsibilities
- Builds on ECCC's leadership in Atmosphere-Ocean-Ice data assimilation and prediction
- MSC was the first centre with an atmosphere-ice-ocean coupled system (GSL) and is now first with a global coupled medium-range atmosphere-ice-ocean forecasting system (GDPS) in operations
- Co-benefits further plans Government of Canada has recently funded such as OPP and C-IOOS

MetAreas 17&18



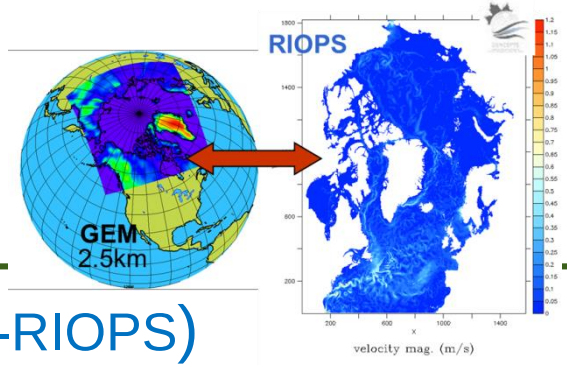
Gulf of St. Lawrence (GSL)



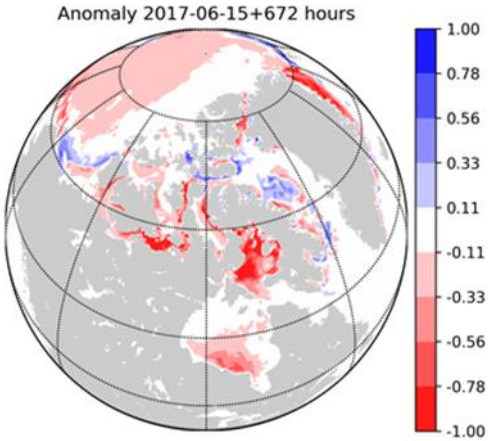
Environment Canada Environnement Canada

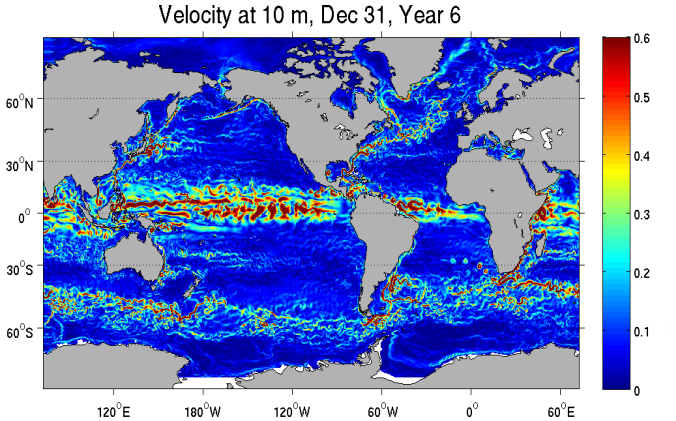
CONCEPTS
CANADIAN OPERATIONAL NETWORK OF COUPLED ENVIRONMENTAL PREDICTION SYSTEMS

ECCC Polar Forecasts



- Canadian Arctic Prediction System (CAPS-RIOPS)
  - For YOPP , fully-coupled A-I-O, 3km(A)-3-8km(IO), 2day
- Coupled Global Medium-range Deterministic System
  - GDPS-GIOPS (producing operational forecasts)
  - fully-coupled A-I-O, 15km(A)-1/4deg(IO), 10day
- Monthly Ice-Ocean Ensemble Forecasts
  - EnsGIOPS, Global, 1/4deg, 20 member, 32day
- Seasonal Predictions (CanSIPS)
  - CanCM3/4 with improved sea ice, and
  - Also including GEM-NEMO-CICE
    - Global, 1deg, 20 member





Outputs available on MSC Datamart

For sharing nationally and internationally

Summary and a few thoughts…

Summary

- Accuracy of sea ice verifying analyses plays an important role for sub-monthly timescales
- Ensemble sea ice forecasts may help to bridge the gap with users (probabilistic products)
- Evaluation of fine-scale coupled interactions underway…open for collaboration!

Challenges

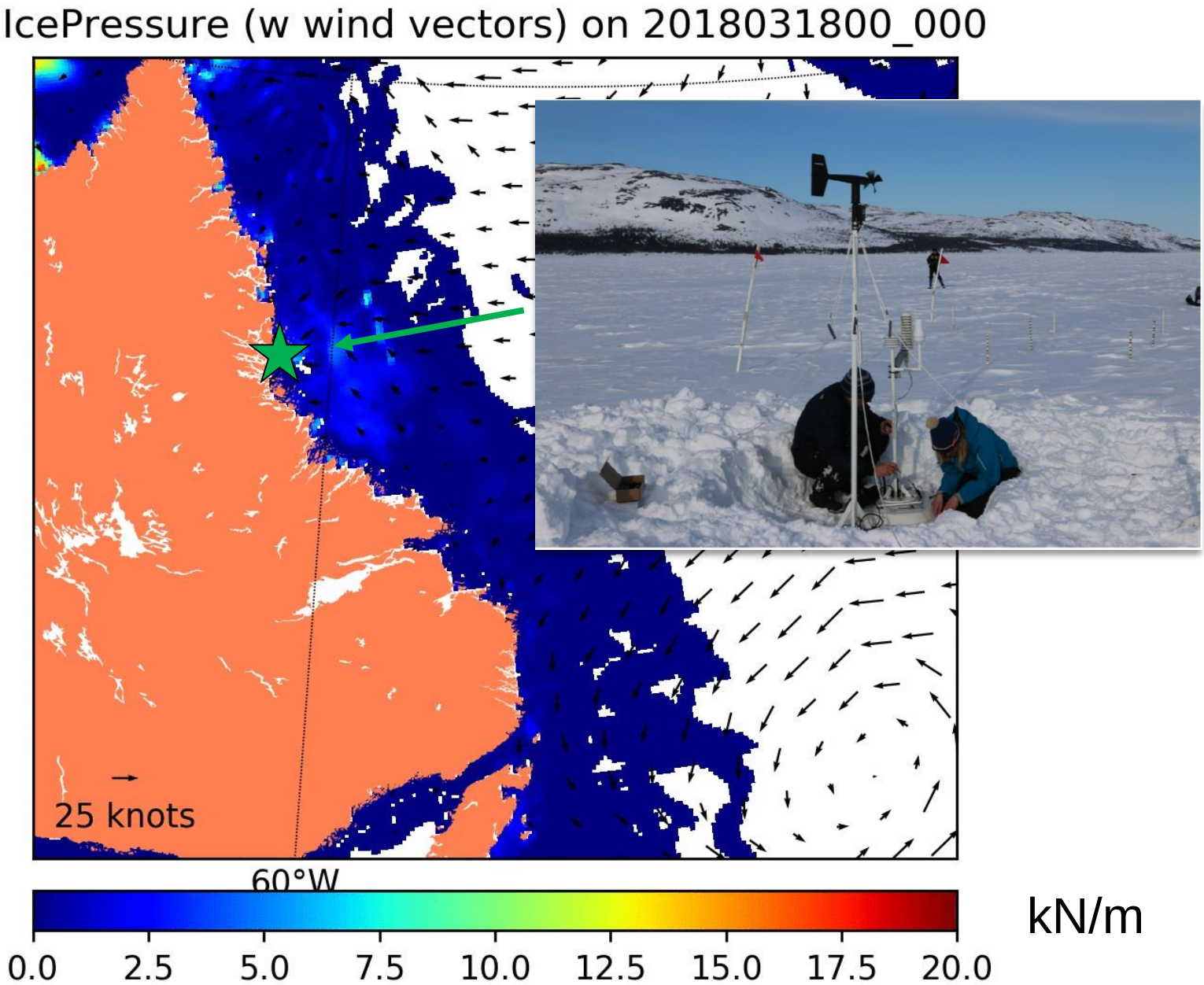
- How to generate perturbations in ice analyses and forecasts to adequately sample uncertainty (*stochastic physics vs differing parameterizations*)
- Assessment of sources of error (*model physics vs atmospheric uncertainty?*)
- Treatment of biases (*exaggerated melt*)

Adapting to user needs….

Forecasts/analyses available at:
dd.weather.gc.ca
dd.alpha.weather.gc.ca
navigator.oceansdata.ca
meteocentre.com/plus (geomet)

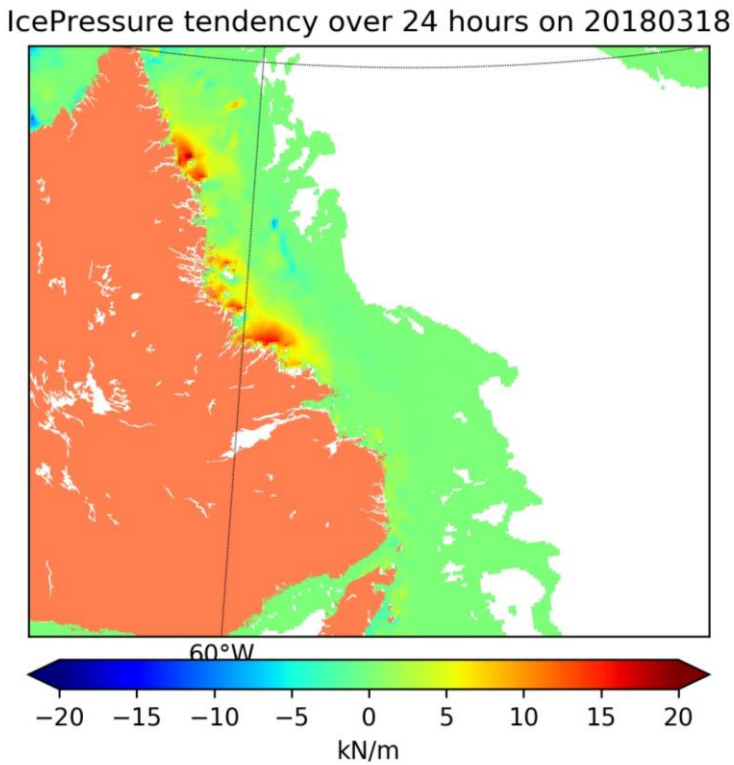
Courtesy Corinne Bourgault-Brunelle

Internal Ice Pressure

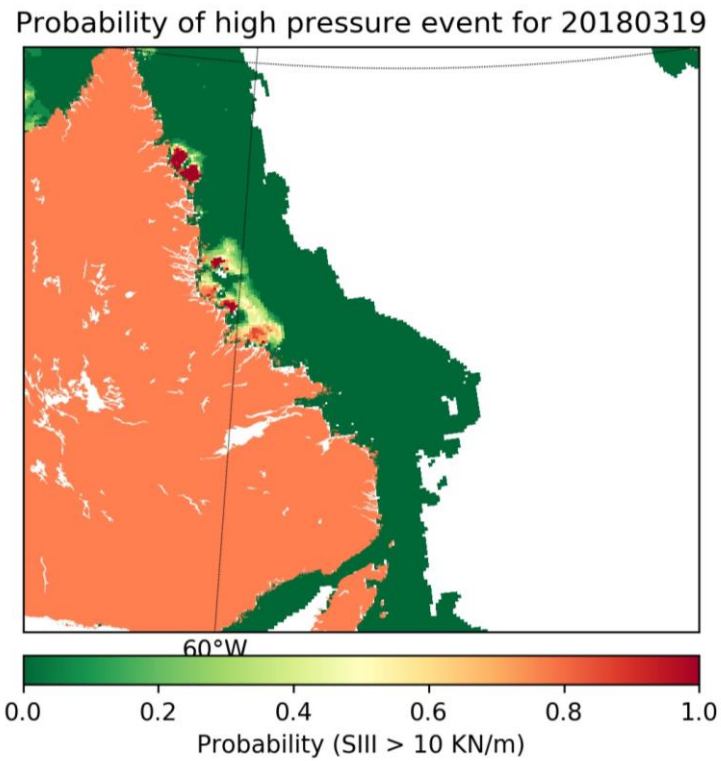


Other Potential Ice Pressure Products…

Ice Pressure Tendency

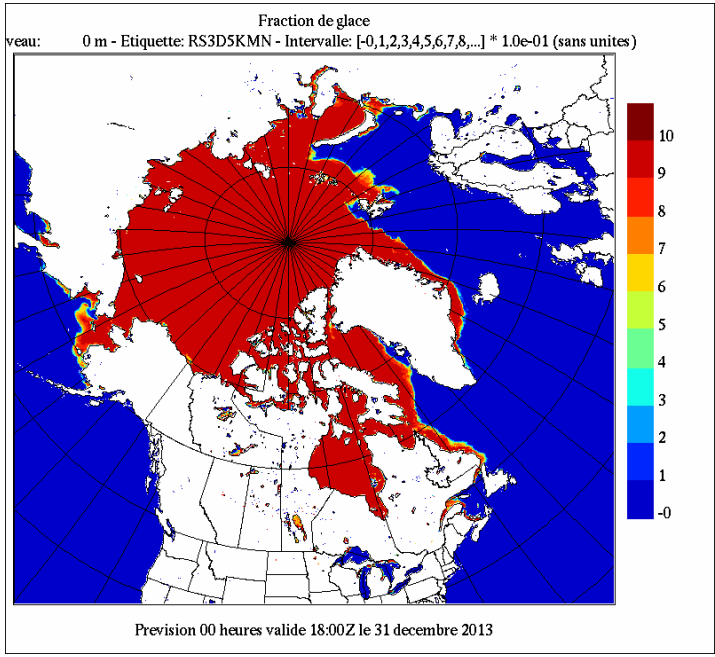


Probability of a high pressure event



Regional / global ice concentration analyses
(Buehner et al. 2016)

- Regional: ~ 5.0 km resolution; Global: ~10 km resolution
- 4 analyses per day
- background = analysis 6 hours earlier
- total ice concentration (3DVar) and analysis-error stddev estimate (KF)
- observations assimilated:
  - CIS image analyses and daily and regional ice charts, lake bulletins
  - SSM/I, SSM/IS, AMSR2
  - ASCAT
  - AVHRR (ice/water)
- ice is removed where SST > 4°C
- ice field is “corrected” where analysis-error stddev is high



1768 × 1618 grid points

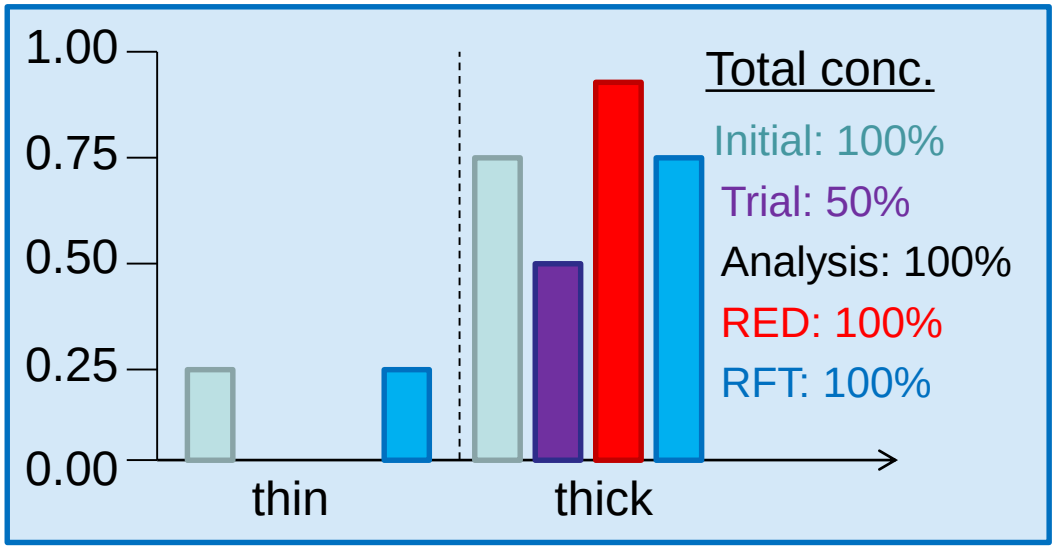
Blending with 3DVAR ice analyses

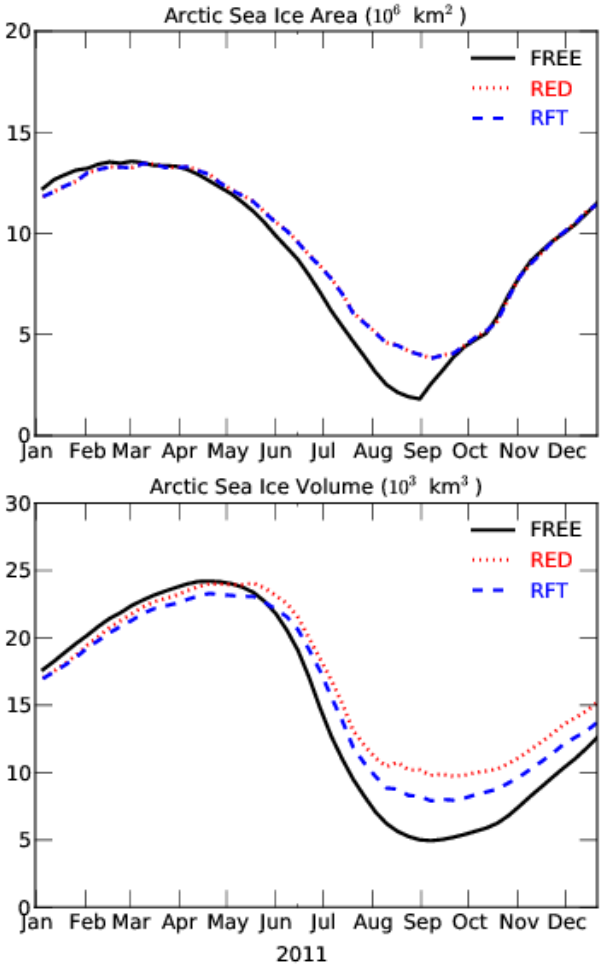
Impact on ice thicknesses

Smith et al., QJRMS, 2015

- Require multicategory blending for CICE
- Method 1: Rescale distribution (RED)
- Method 2: Rescale Fcst Tendency (RFT)
- Use of RFT results in a smaller impact on total ice volume

Thought experiment (excessive melt)

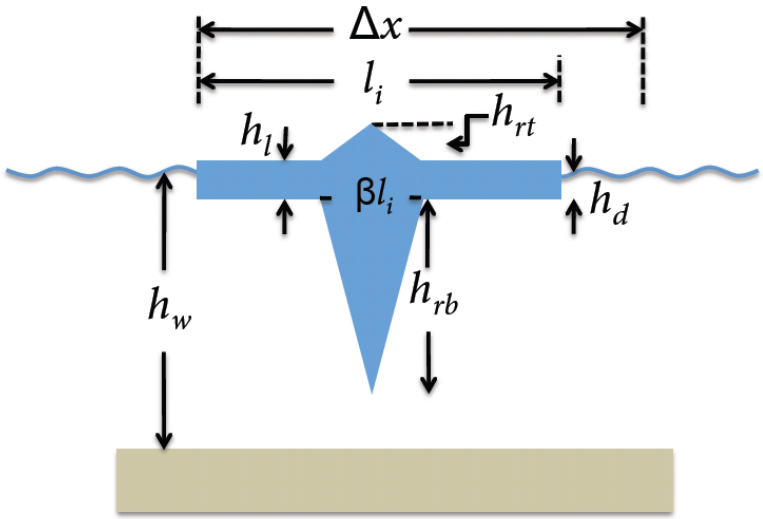




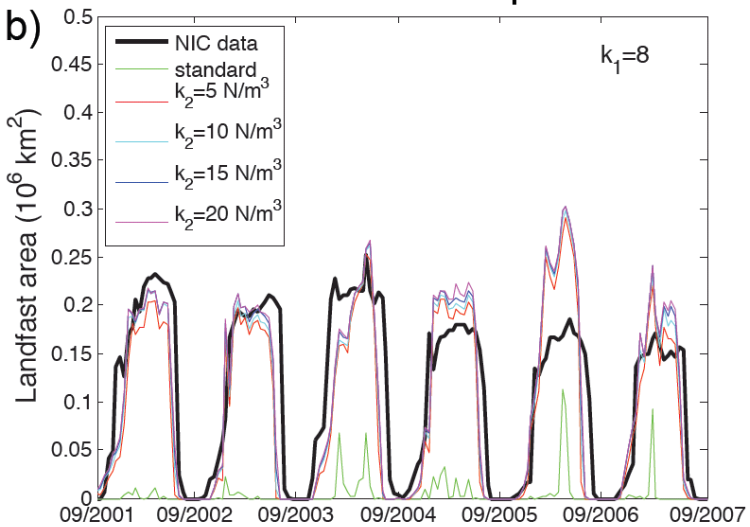
Parameterization of Landfast Ice

Lemieux, J. et al. (2015): A basal stress parameterization for modeling landfast ice. *J. Geophys. Res. Oceans*, doi: 10.1002/2014JC010678

- Landfast ice is parameterized by estimating the drag of ice keels on the ocean bottom
- Currently evaluating impact in operational systems



Landfast ice area in Laptev Sea

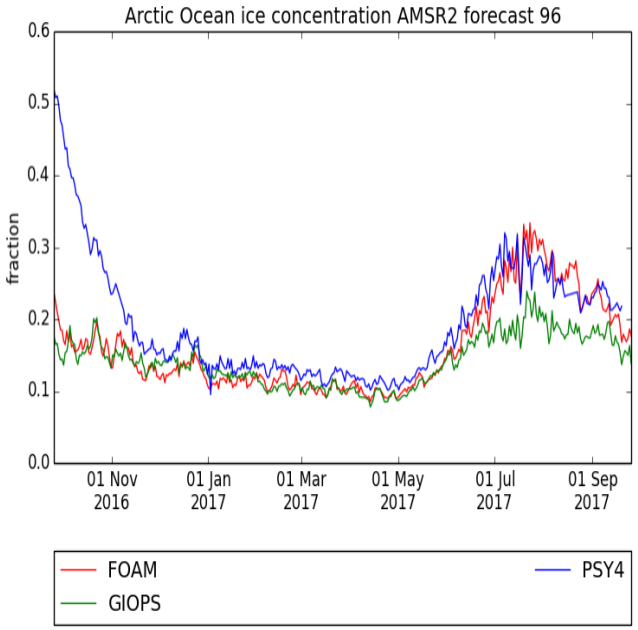


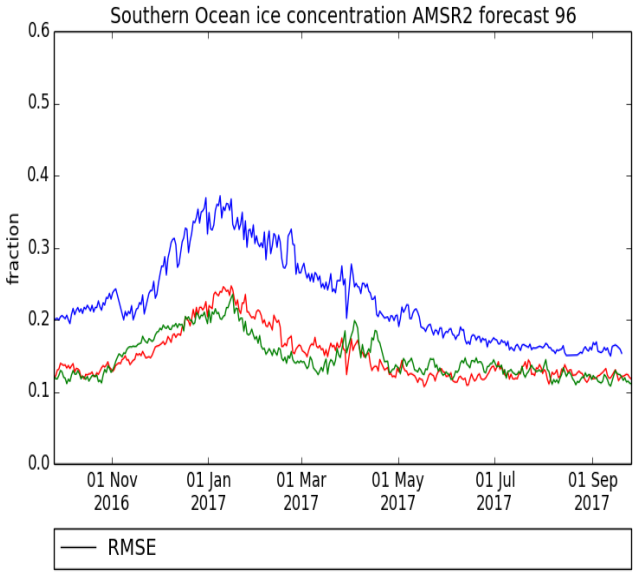
- Parameterization represents well the amplitude of landfast ice area
- Shows some interannual variability
- Addition of tensile strength (Lemieux et al., 2016)

GODAE Oceanview "Class4" real-time sea ice intercomparison

- Common set of obs shared in real-time
- Groups calculate model equivalents for al lead times
- Use AMSR2 with NasaTeam2 retrieval
- Quality control applied to observations to reject obs affected by surface melt
  - SST>4°C or Tair>0°C
- Participating Groups
  - **Mercator (PSY4)**
  - **UK Metoffice (FOAM)**
  - **Env Canada (GIOPS)**
  - **NERSC (new addition! Not shown)**

4 -day forecasts
RMS error





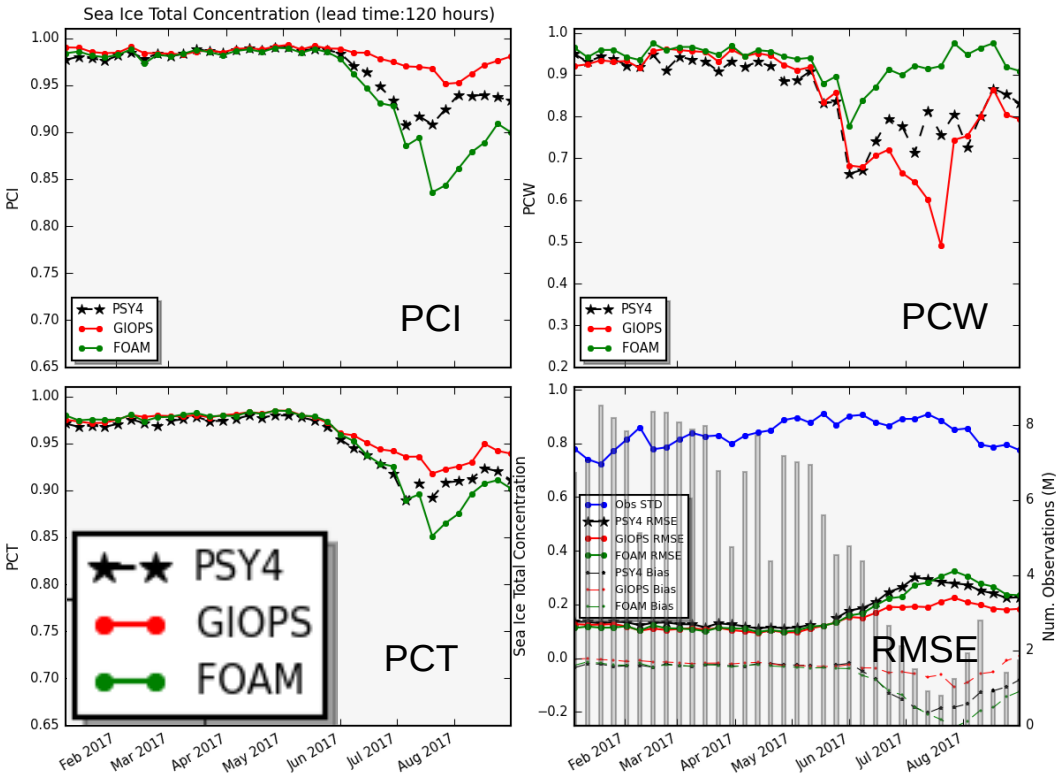
Courtesy Andy Ryan, UK Metoffice

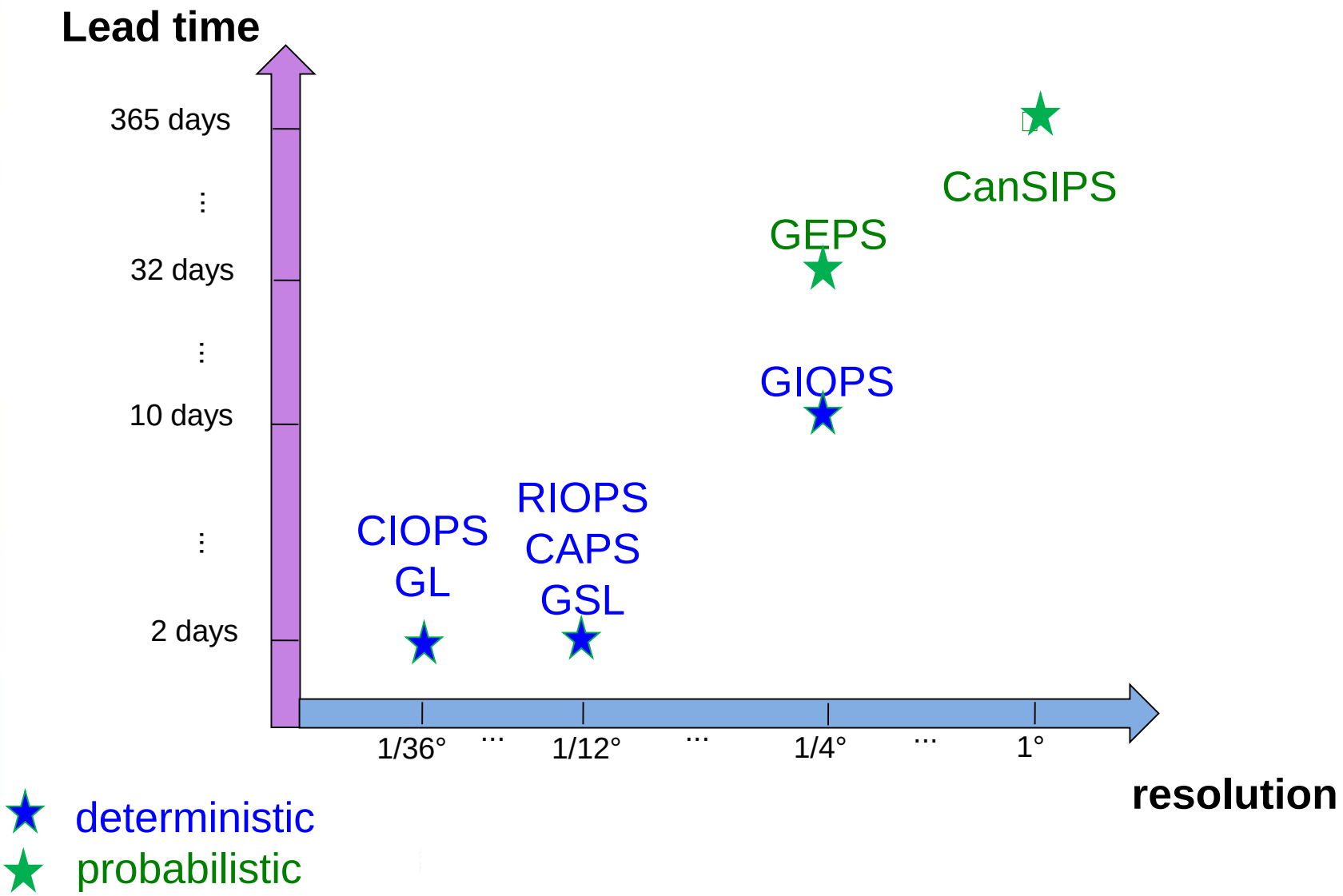
GODAE Oceanview Class 4 Sea ice concentration (AMSR-2) intercomparison 5 day lead

Conc > 0.25	AMSR2 Ice	AMSR2 Water
Forecast Ice	Hit ice (a)	False Alarm (b)
Forecast Water	Miss (c)	Hit water (d)

- Scores calculated using contingency table metrics:
  - **Proportion correct total**: PCT=(a+d)/n
  - **Proportion correct Ice:** PCI=a/(a+c)
  - **Proportion correct Water:** PCW=d/(b+d)
  - Range [0,1]; 1 is perfect score
- **Timeseries of sea ice intercomparison growing, available for external use as part of YOPP**
- **NERSC is now contributing**
- **Other groups have expressed interest in joining**
  - GOFS, DMI, …
- **Data to be distributed through YOPP Data Portal:**
  - **Yopp.met.no**

Northern Hemisphere 2017



Courtesy: Jinshan Xu, DFO

2019 ECCC ice-ocean prediction systems