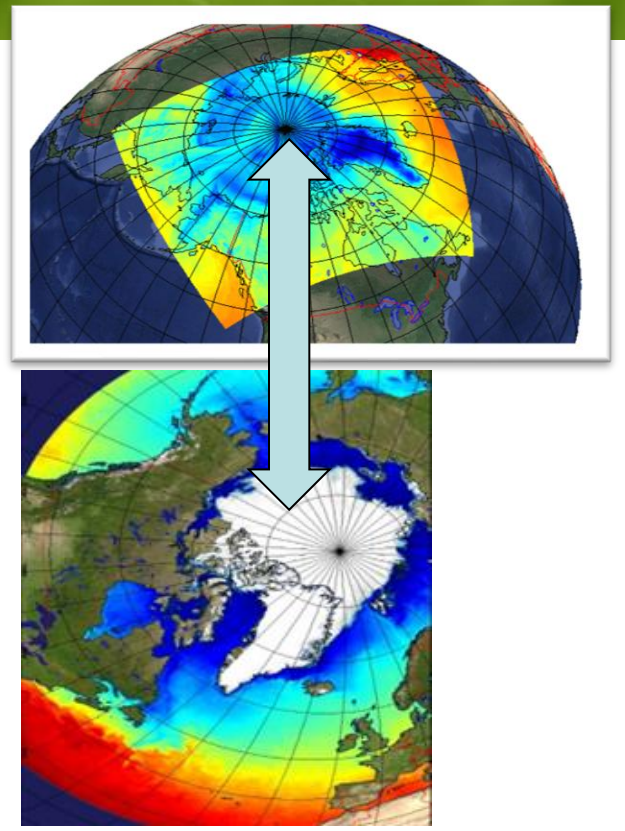
Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Coupled Canadian Arctic Prediction System version 2 – A multidisciplinary approach for coupled forecasting in the Arctic

F. Dupont, J.-P. Paquin, S. MacDermid, G. C. Smith, F. Roy, M. Plante, B. Casati, D. Paquin-Ricard, M. Faucher, J.-F. Lemieux, M. Gheta, G. Sutherland, F. Lemay, F. Davidson

Environment and Climate Change Canada, Dorval, Québec, Canada



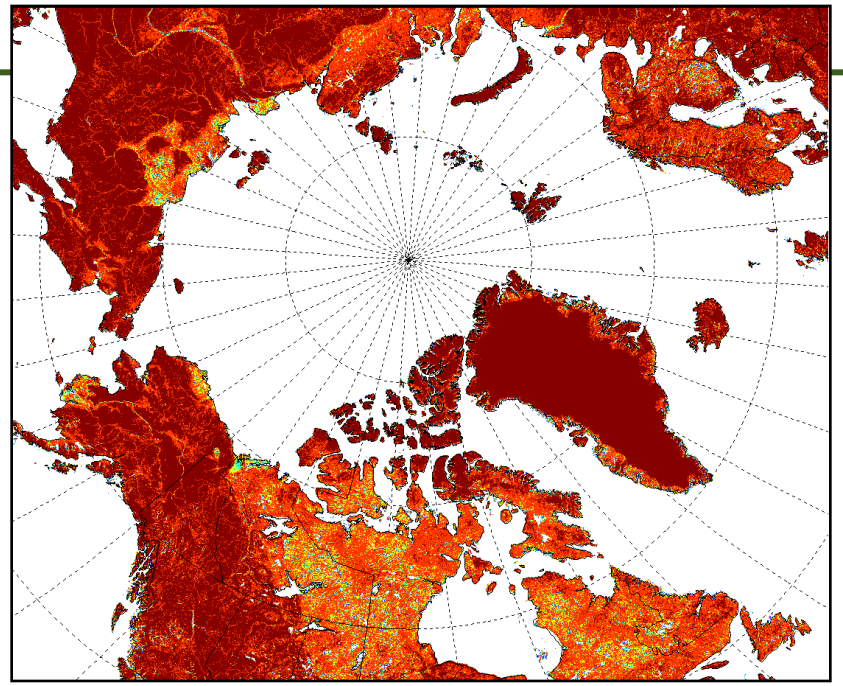
YOPP YEAR OF POLAR PREDICTION

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

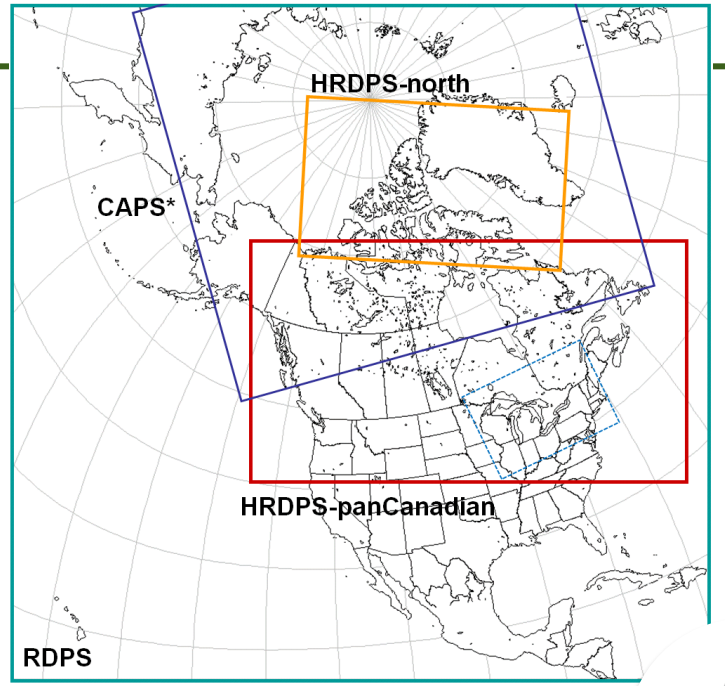
CONCEPTS

MERCATOR OCEAN INTERNATIONAL

Canadian Arctic Prediction System (CAPS)



Land-Sea Mask (MG), full CAPS domain



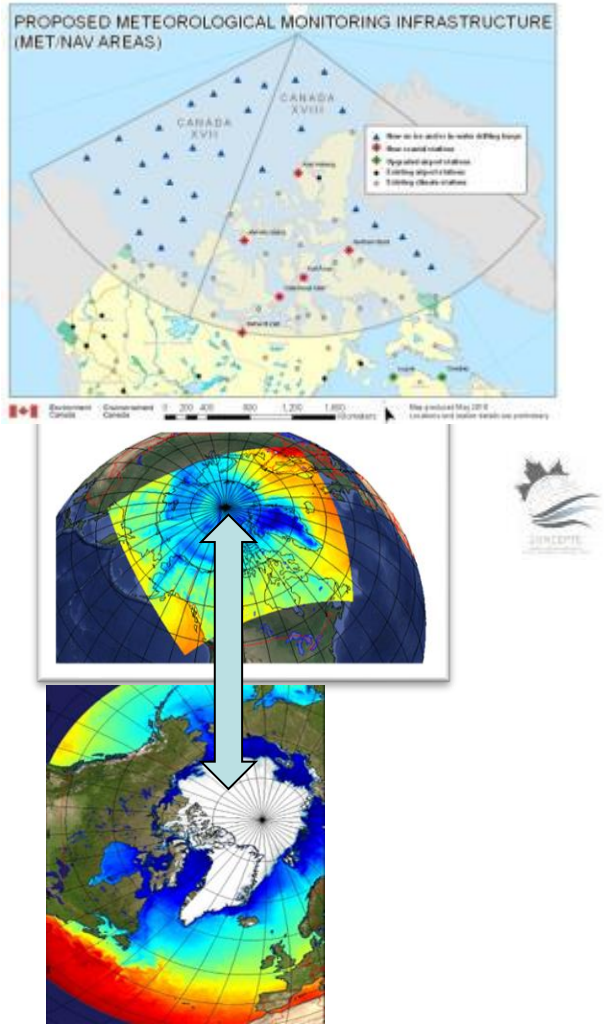
MAIN PURPOSE AND FEEDBACKS of CAPS v1:

1. Initially CAPS supported ECCC's modeling contributions to YOPP
2. Positive feedbacks during YOPP: Korea, Europe, CAPS surface winds impressed observation experts, navies (Canadian incl.)

Coupled CAPS v2

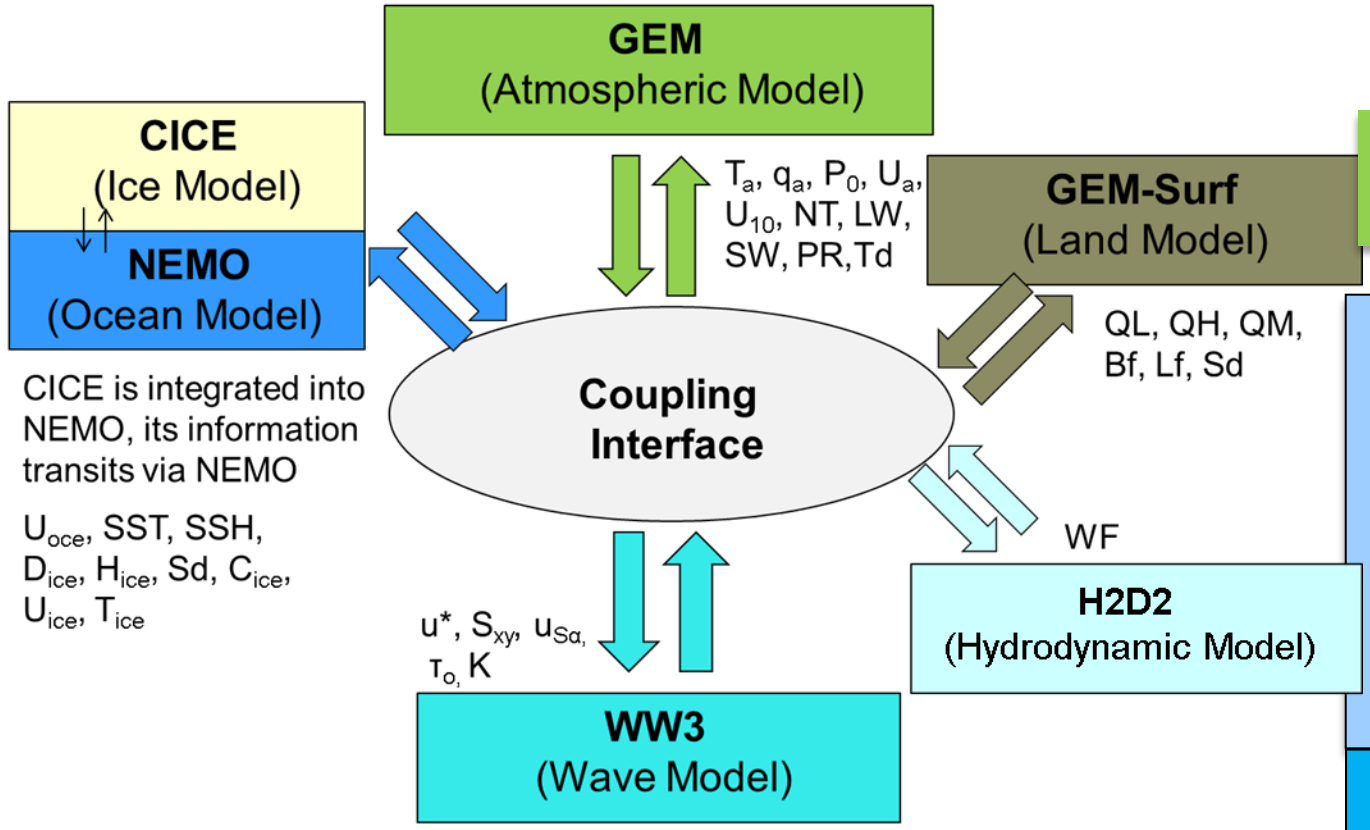
High-resolution coupled atmosphere-ice-ocean prediction system

- In support of Operations in Canadian Arctic
  - Airplane visibility, marine emergency response, marine acoustics, environmental prediction, transportation (DND, CCG, EC, local communities)
  - WMO metareas 17 &18
- Coupled atmosphere-ice-ocean model
  - GEM (3.0 km)
    - Predicted particle properties microphysics
  - NEMO-CICE (2-8 km)
    - Tides, landfast ice
    - Wave-ice interactions
    - Atmospheric pressure effect (Storm Surge)
  - 48 h forecasts (twice a day)

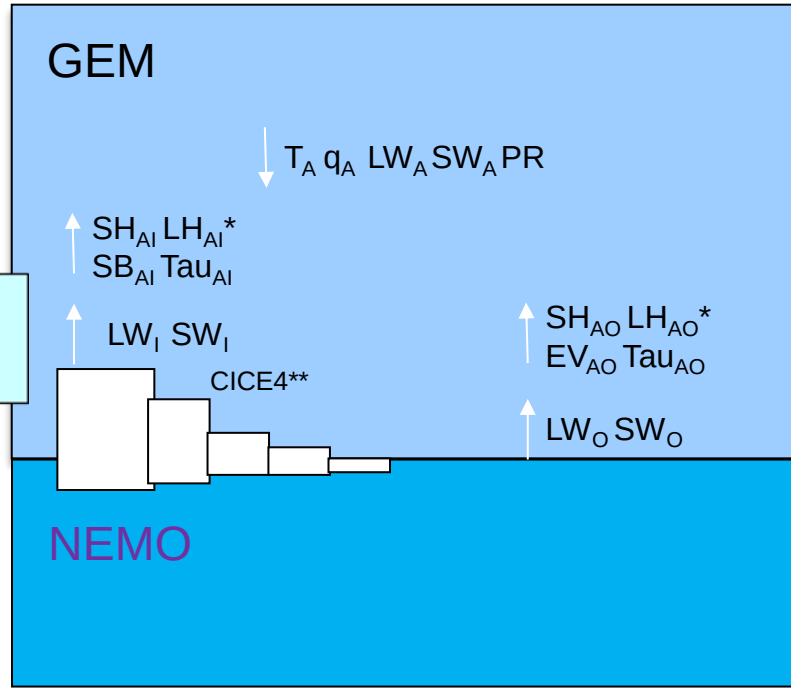


Coupling Method

New IRIS Coupler in construction



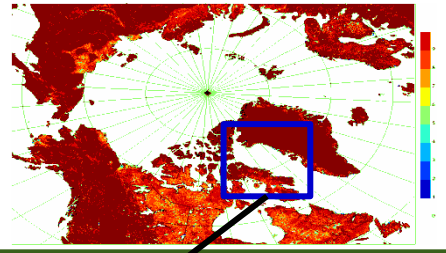
Flux Coupling via GOSSIP socket server



- Coupling every time step
- Calculate fluxes on ocean grid and aggregate

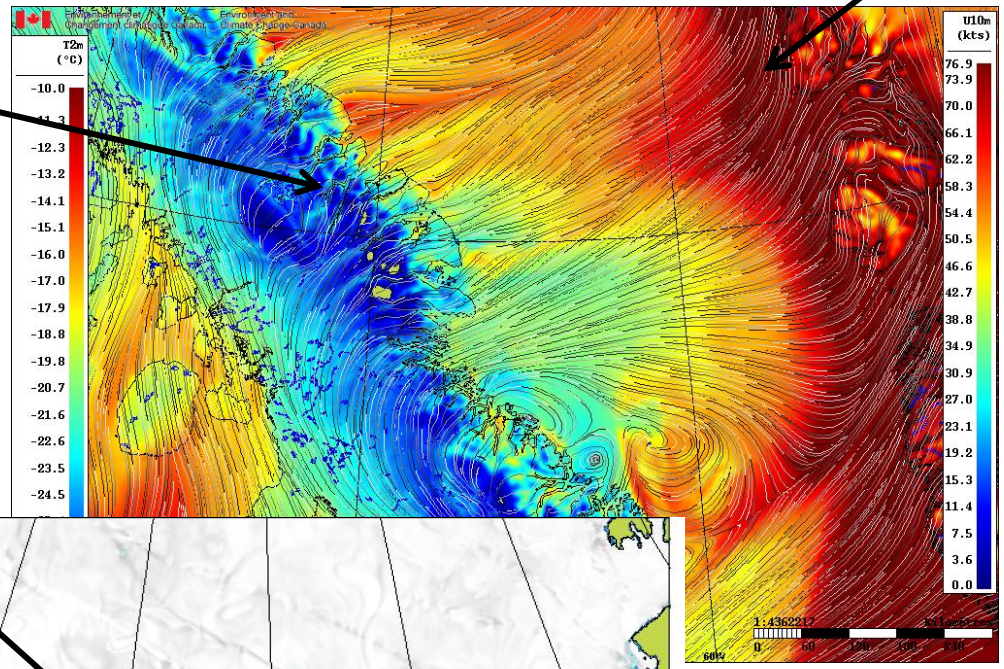
May, 2016

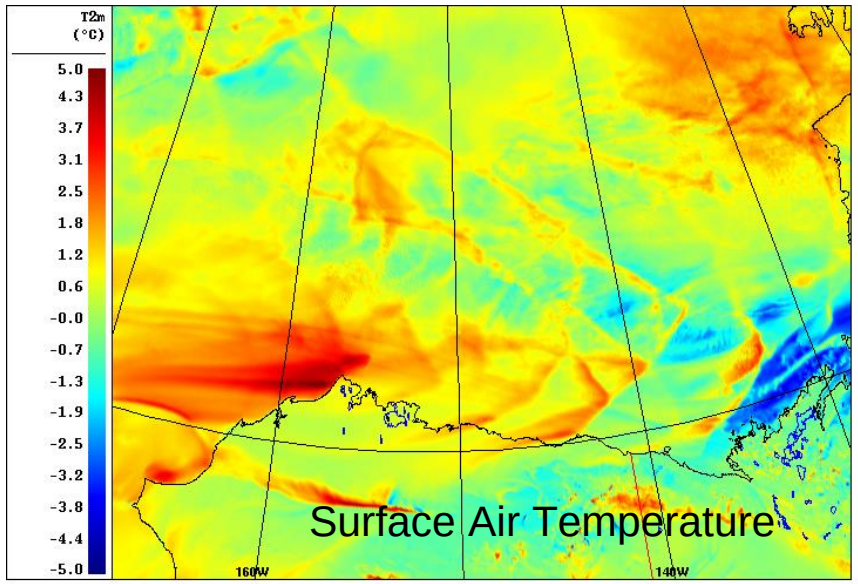
Impact of small-scale coupled atmosphere-ice-ocean interactions in the Canadian Arctic Prediction System (CAPS)



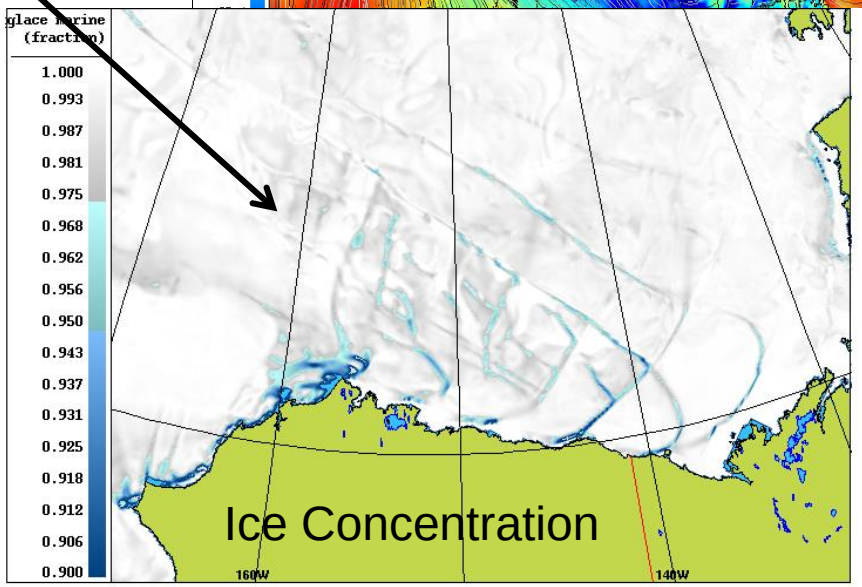
Forecast for 2017-01-01

- 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



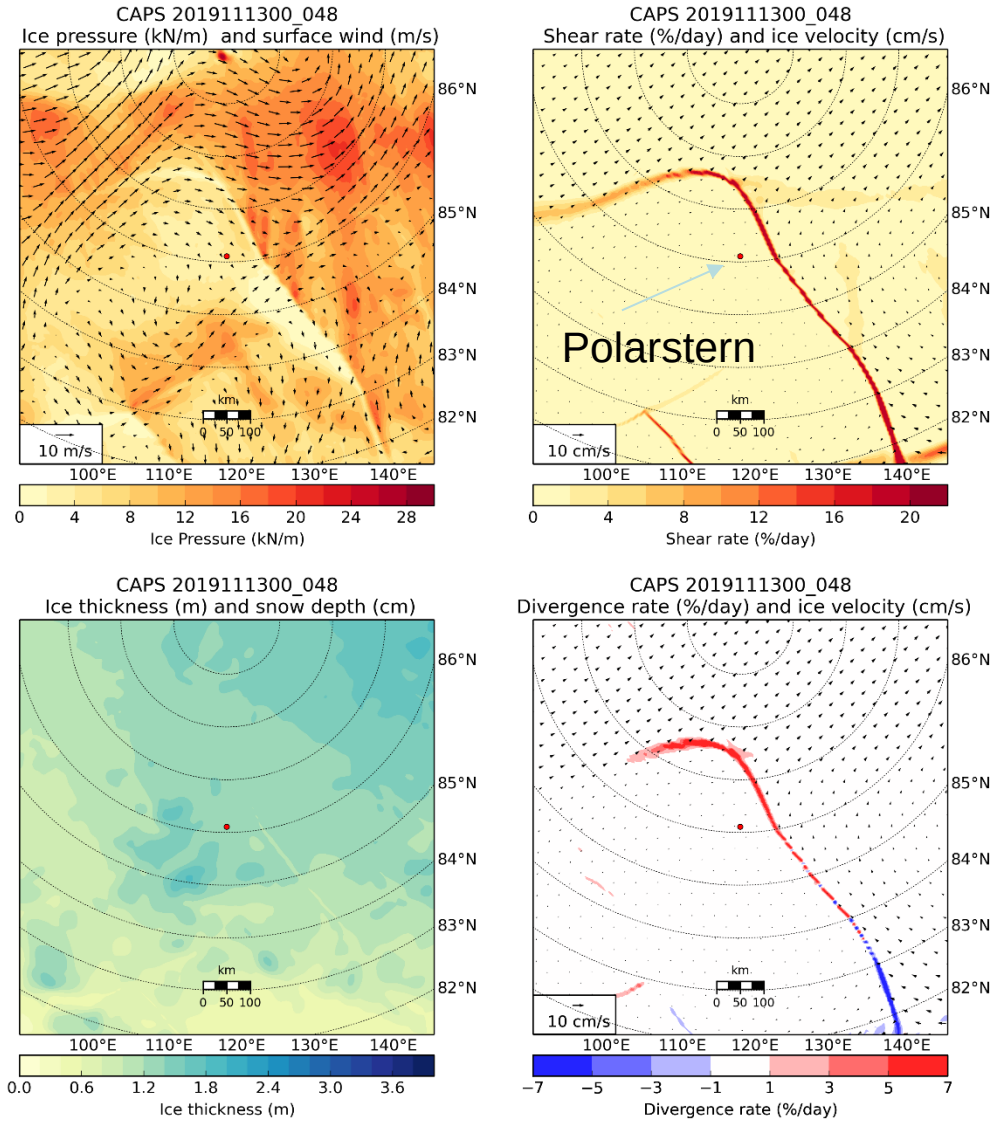
Ice Concentration

Canada

CAPS product for MOSAiC

- Daily image production:
  - Internal ice pressure
  - Tendency of internal pressure
  - Shear rate
- Images produced in real-time and sent to ftp server for use on Polarstern for MOSAIC
- Investigate usefulness for scientific planning
- Study interesting cases
  - Forecasted significant divergence around Polarstern for storm on Nov. 17, 2019
  - Lead opened up between Polarstern and on-ice camps

Zoom



Forecast valid: Nov. 15, 201

CAPS product for MOSAiC

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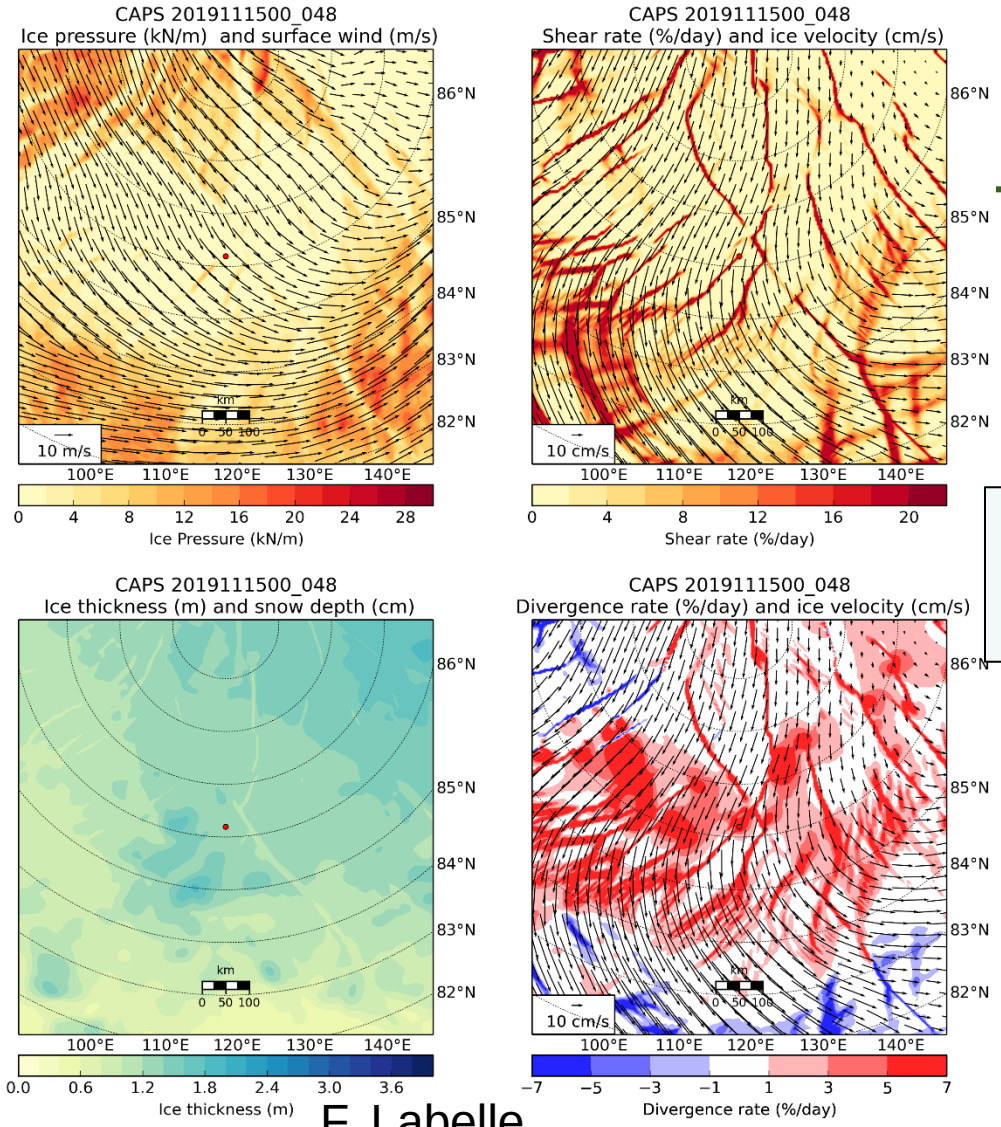


Forecast valid: Nov. 17, 2018

F. Labelle

CAPS v2 status

Uncoupled version running since August 2023

Development of coupled CAPS (C-CAPS)

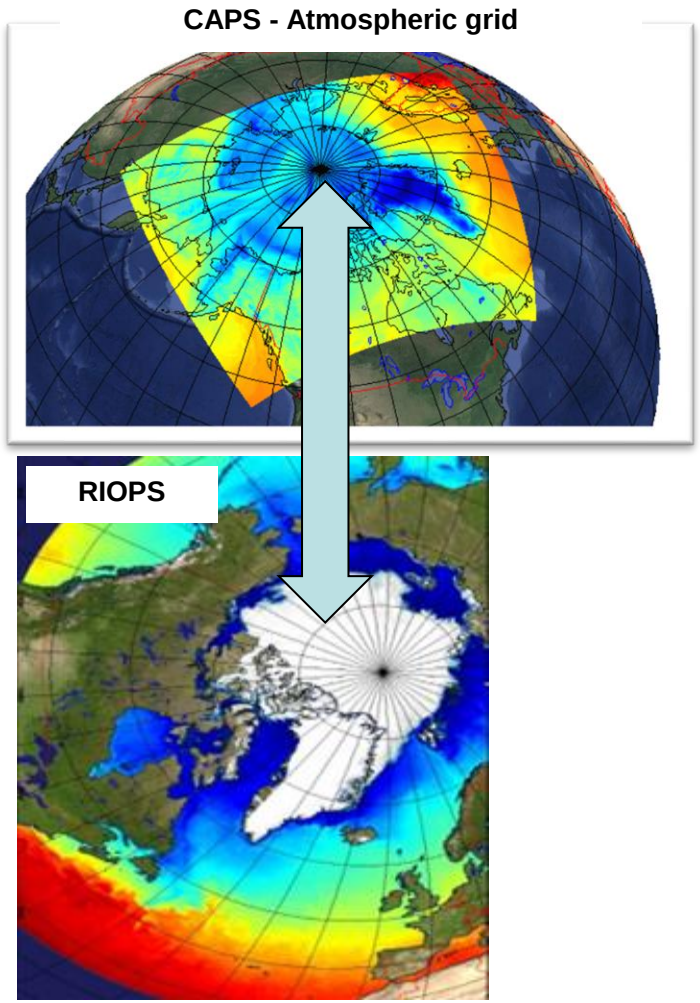
- Update of ocean suite & coupled configuration
  - Atmosphere : CAPS (HRDPS-North) IC-4 (latest) configuration
  - Ice-Ocean : Regional Ice-Ocean Prediction System (RIOPS: NEMO3.6+CICE6)

C-CAPS test phase (ongoing)

- Svalbard Marginal Ice Zone Project (focus-arctic.com/svalmiz2024.html)
  - ECCC participating in international Coupled model intercomparison project
- Final Cycles (internal requirement)

Creation of CAPS Working Group

- Multidisciplinary group with expertise in Research & Development from Atmosphere, Ocean & Sea ice
- Project management & coordinated experiments
- Model development
- Improvement of evaluation strategies
- User applications and products



C-CAPS objectives & Milestones

Technical - Propose C-CAPS for implementation in operations*

- Timeline: before end-of-fiscal year (& before freeze due to computer migration)
- Proposed: *experimental status

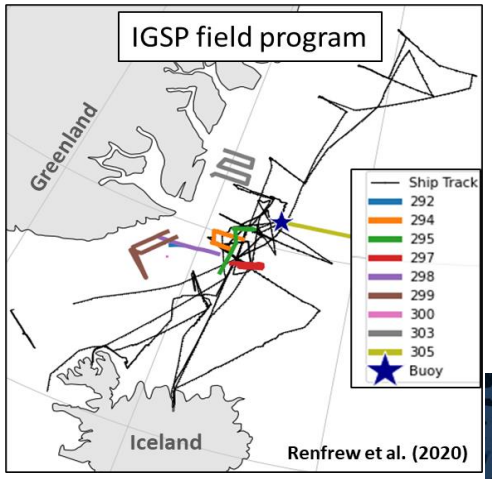
Scientific – improve evaluation at high-latitudes

- Timeline: **ongoing** – requires long-term commitments & efforts
- Key aspects
  - Standard NWP evaluation (focused on land & atm profiles)
  - Develop evaluation metrics suitable for Arctic environment
    - Clouds & visibility
    - Atmospheric boundary layer physics
    - Atmosphere-ocean turbulent flux
    - High-resolution sea ice motion, deformation & pressure
    - Impact of coupling on forecasts (i.e. conditional verification, specific meteorological events & conditions)

C-CAPS improved evaluation at high latitudes

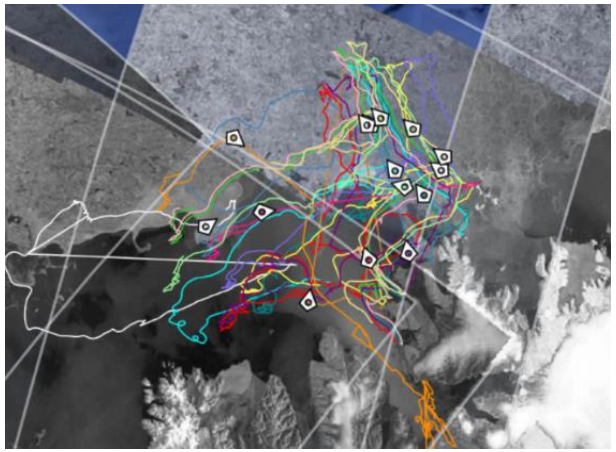
Special observation campaigns

- Iceland-Greenland Seas Project (Feb-March 2018)
  (Renfrew et al. 2019; https://doi.org/10.1175/BAMS-D-18-0217.1)
  - Winter 2018
  - Multiplatform observational campaign
    - Buoys, ship & aircraft measurements



- MOSAiC Expedition (mosaic-expedition.org)
  - Sep 2019 – Oct 2020
  - Polarstern drift in Central Arctic

- Svalbard Marginal Ice Zone Project
  - April-May 2024



CAPS - longer-term model improvements

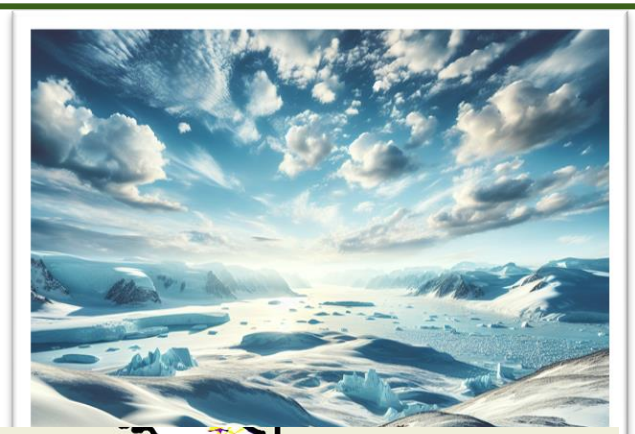
Improving Winter Cloud Prediction Accuracy

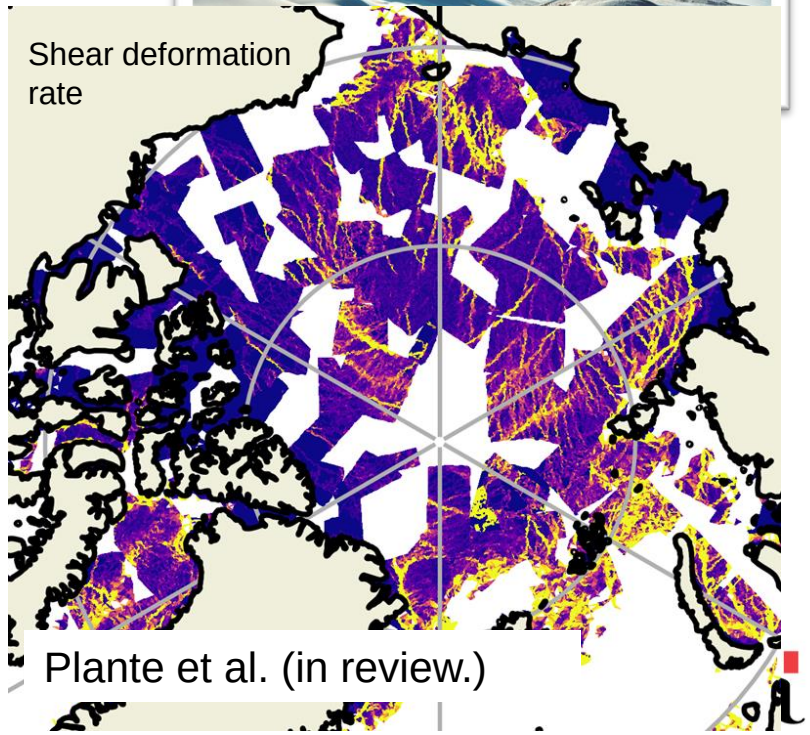
- **Known issues in winter forecasts related to cloud representation**
- **Possible Impacts being investigated :**

  Cloud fraction, Cloud ceiling
  Radiative balance
  Near-surface temperature and humidity
  Horizontal Visibility

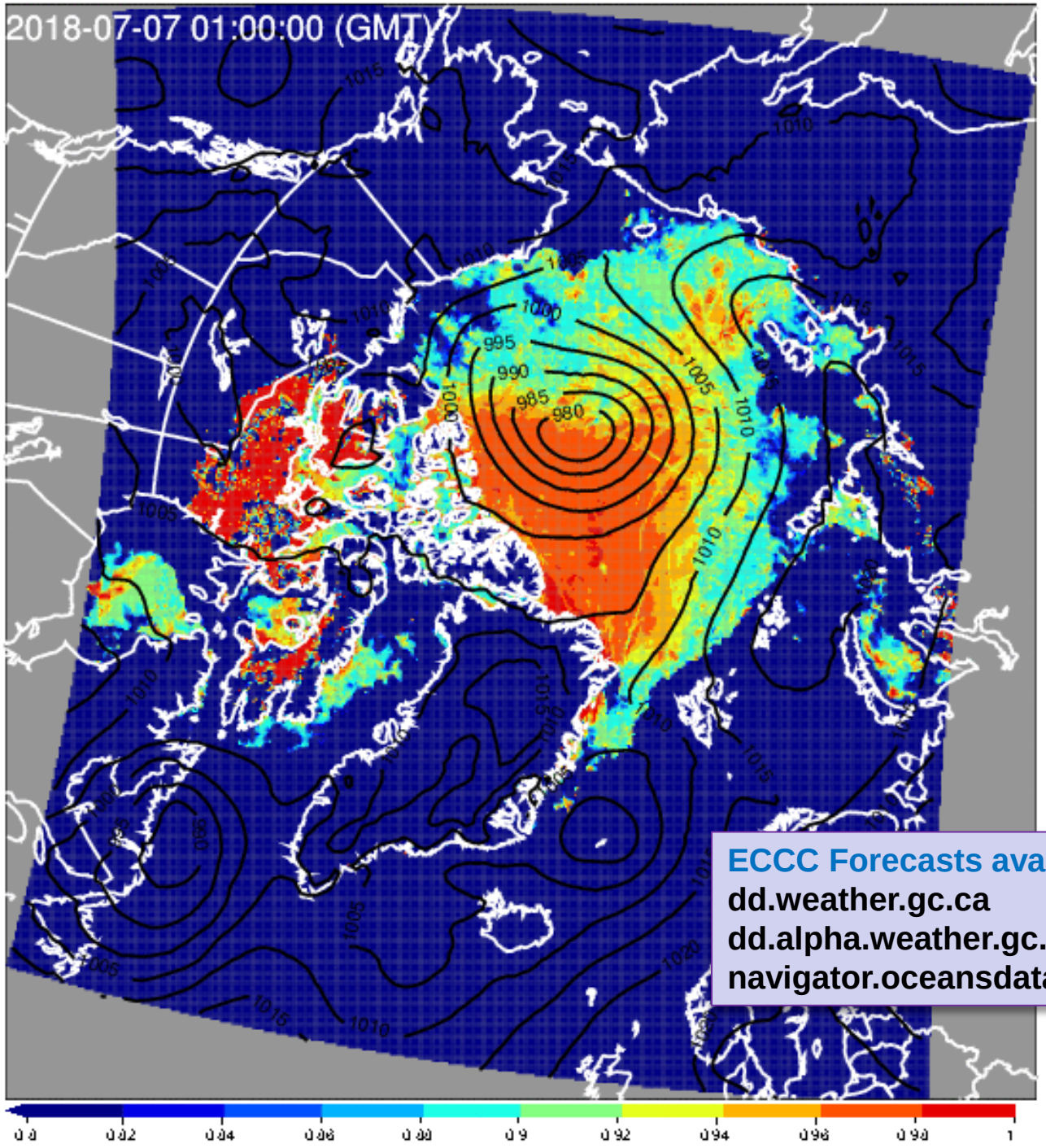
Marginal Ice Zone modelling:

- **Wave-ice interaction**
- **Form drag formulation, Ice drift**
- **Impact of coupling on representation of ice fractures / leads (LKFs)**





Thank you!!



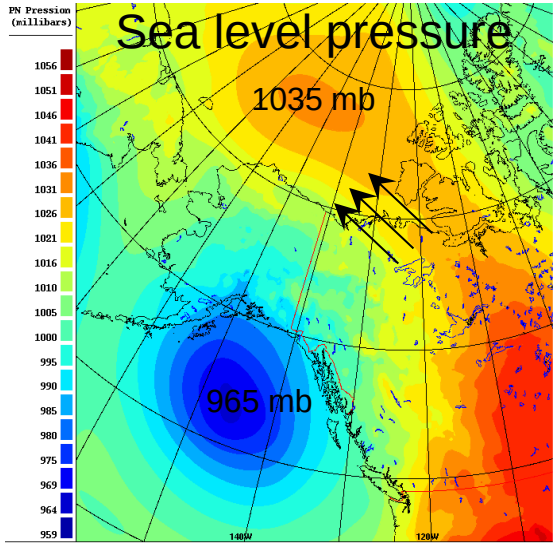
Sea level pressure

ECCC Forecasts available at:
dd.weather.gc.ca
dd.alpha.weather.gc.ca
navigator.oceansdata.ca

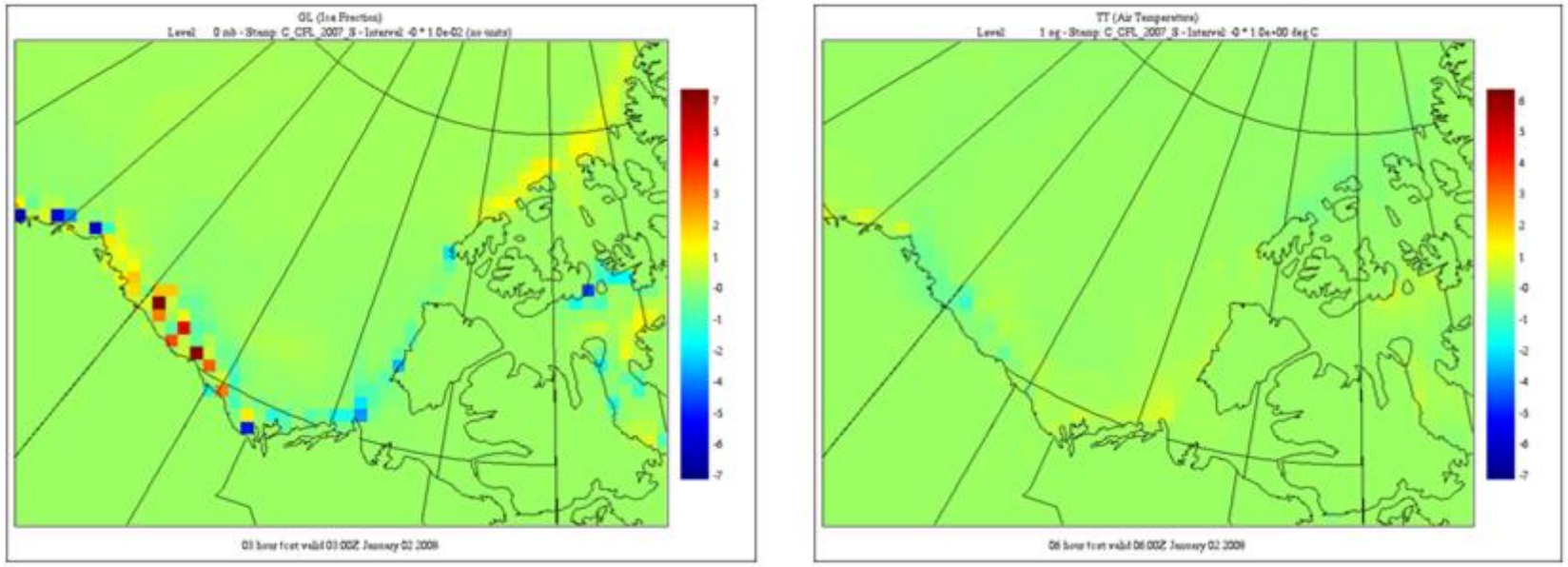
Ice fraction

Extra slides

Impact of a dynamic ice cover on coupled forecasts over the Beaufort Sea



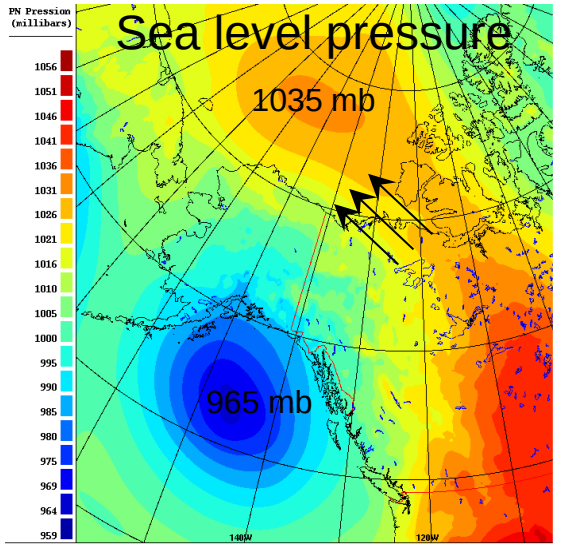
Difference in ice fraction (CPL-UNCPL) Difference in 2m temperature



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

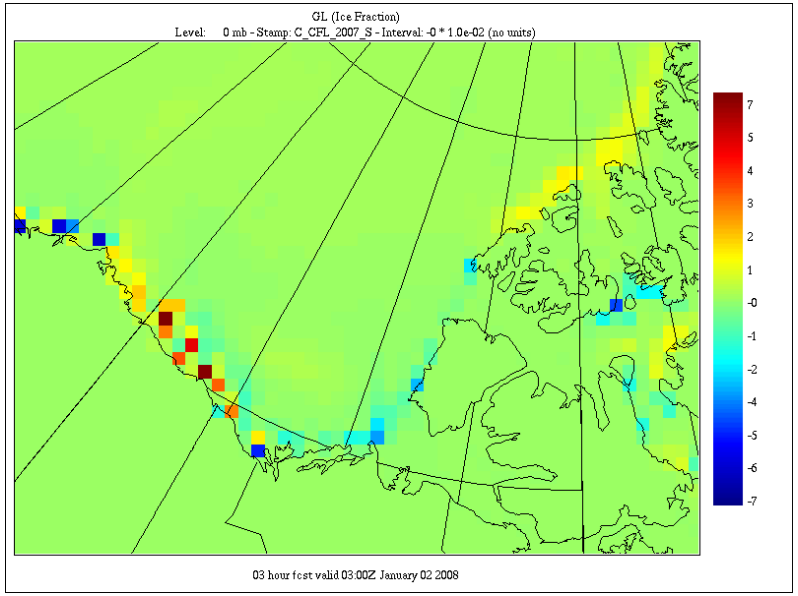
R. Muncaster, F. Roy, J.-M. Belanger

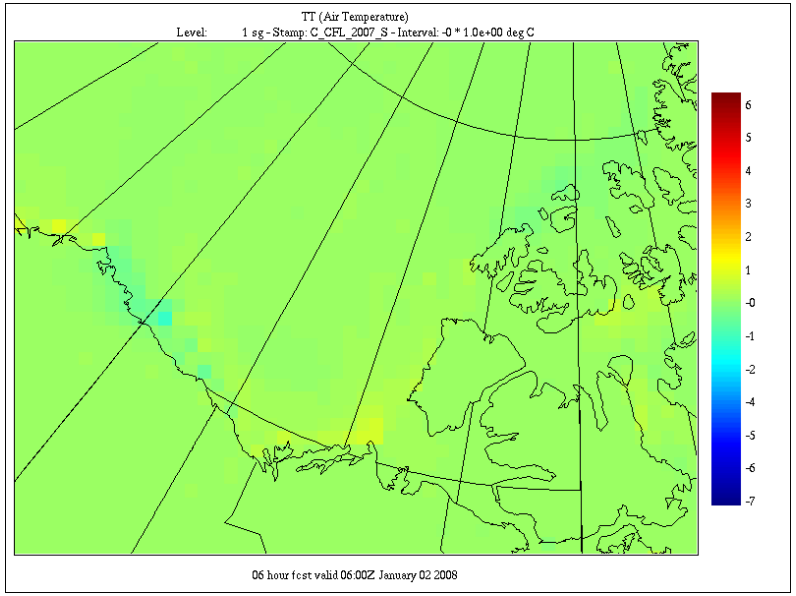
Impact of a dynamic ice cover on coupled forecasts over the Beaufort Sea



- Coastal polynya formation sensitive to:
  - ➢ Atmosphere-ice and ice-ocean stresses, ice thicknesses, landfast ice parameterization, uncertainty in atmospheric forecasts

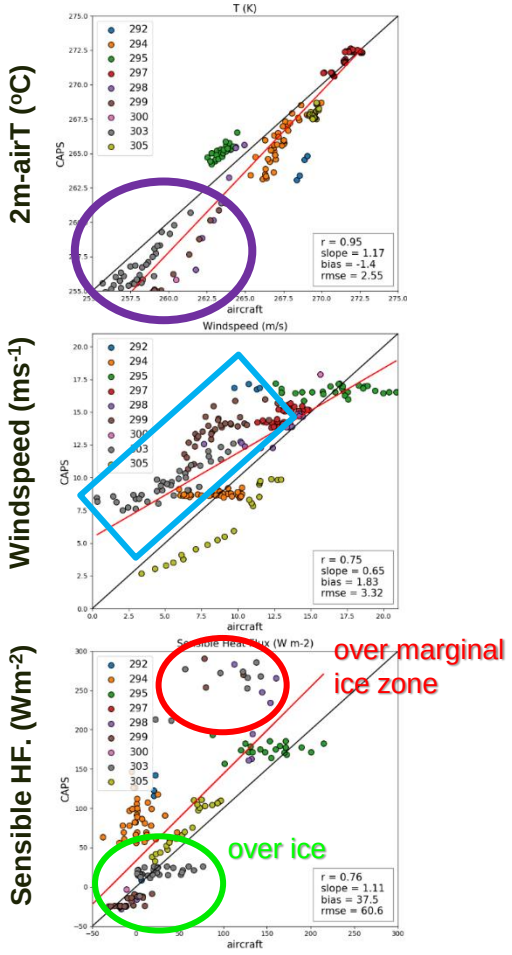
Difference in ice fraction (CPL-UNCPL) Difference in 2m temperature



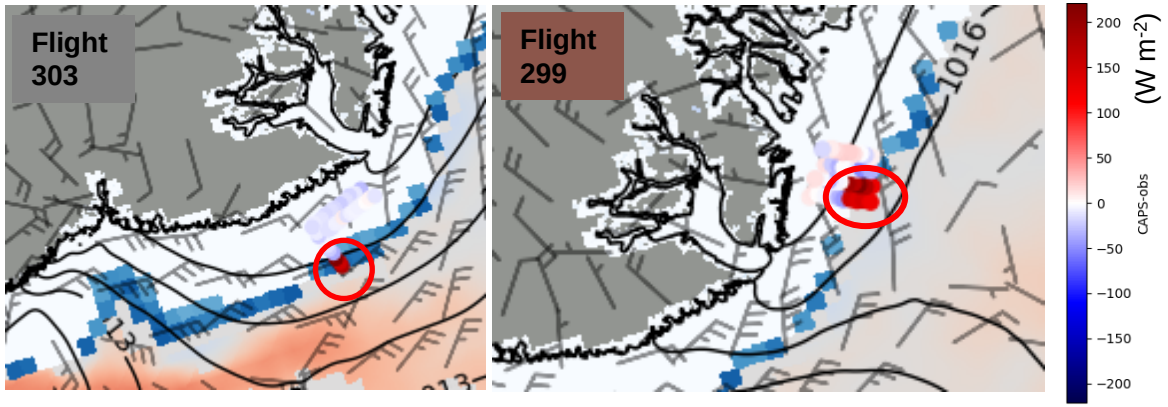


Forecast from global coupled model (GEM-NEMO-CICE; 33km-15km resolution)

CAPS non coupled vs IGSP YOPP Observations



Sensible Heat flux <u>differences</u> along flight paths



- **Cold biases** over the ice (no leads)
- **Overestimated wind speeds** over ice
- Sensible heat fluxes
  - Underestimated sensible heat flux over the ice (no leads)
  - Overestimated sensible heat fluxes at ice edge (abrupt transition vs. obs)
    - overestimated against ship data (>100 Wm^{-2} differences)
- Biases all highly dependent ice edge location & representation

M. Gheta – Summer 2023 internship

CAPS Schematic

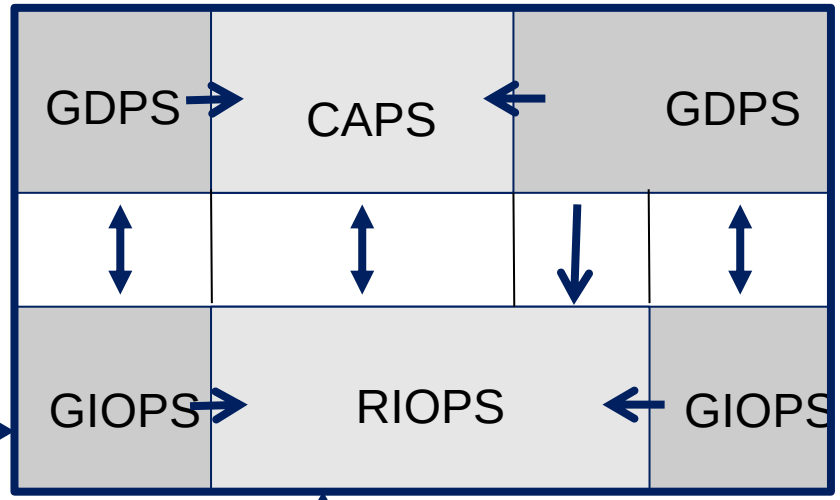
- GDPS: Global Deterministic Prediction System
- GIOPS: Global Ice Ocean Prediction System
- RIOPS: Regional Ice Ocean Prediction System
- CAPS: Canadian Arctic Prediction System

Analysis Components

GDPS
GEM-5
15km 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

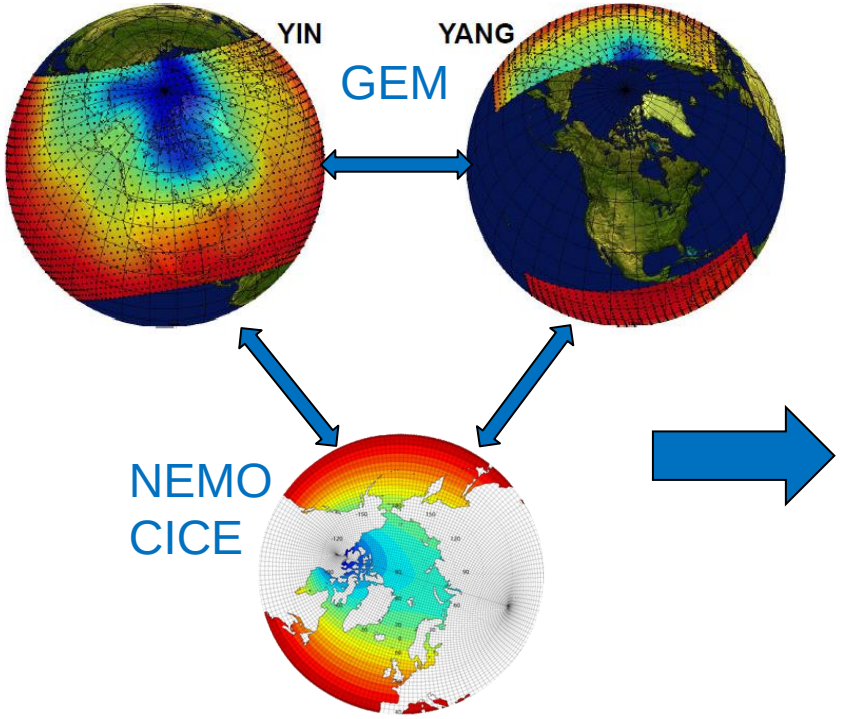
Forecast Components



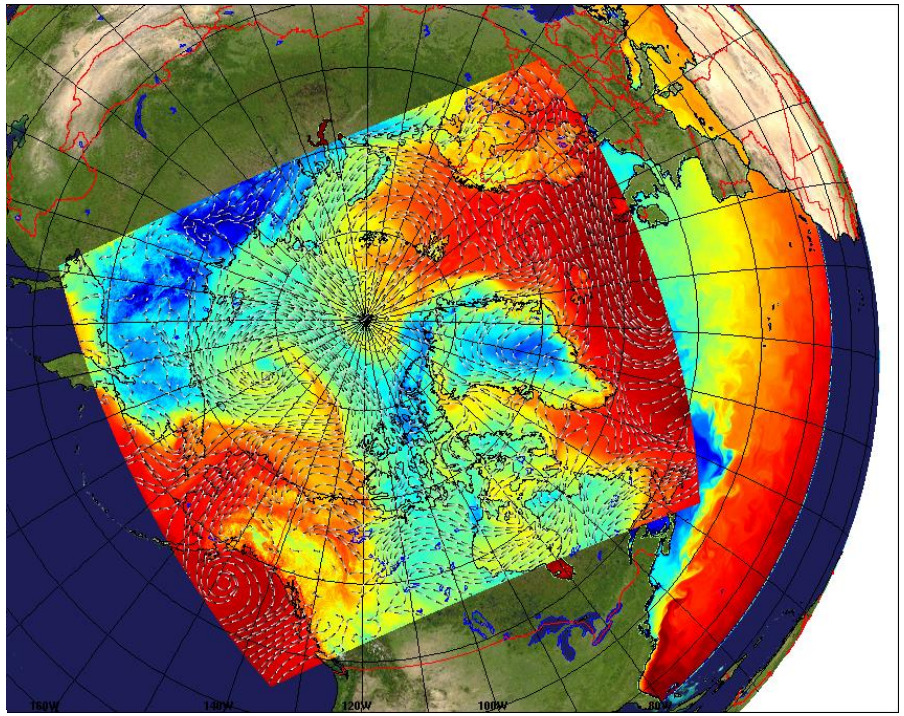
RIOPS
NEMO-CICE
1/12° Pac/Arctic/N. Atl, 75 levels
Spectral Nudging to GIOPS
SEEK Ocean Analysis this fall

CAPS Configuration

Coupled GDPS-GIOPS

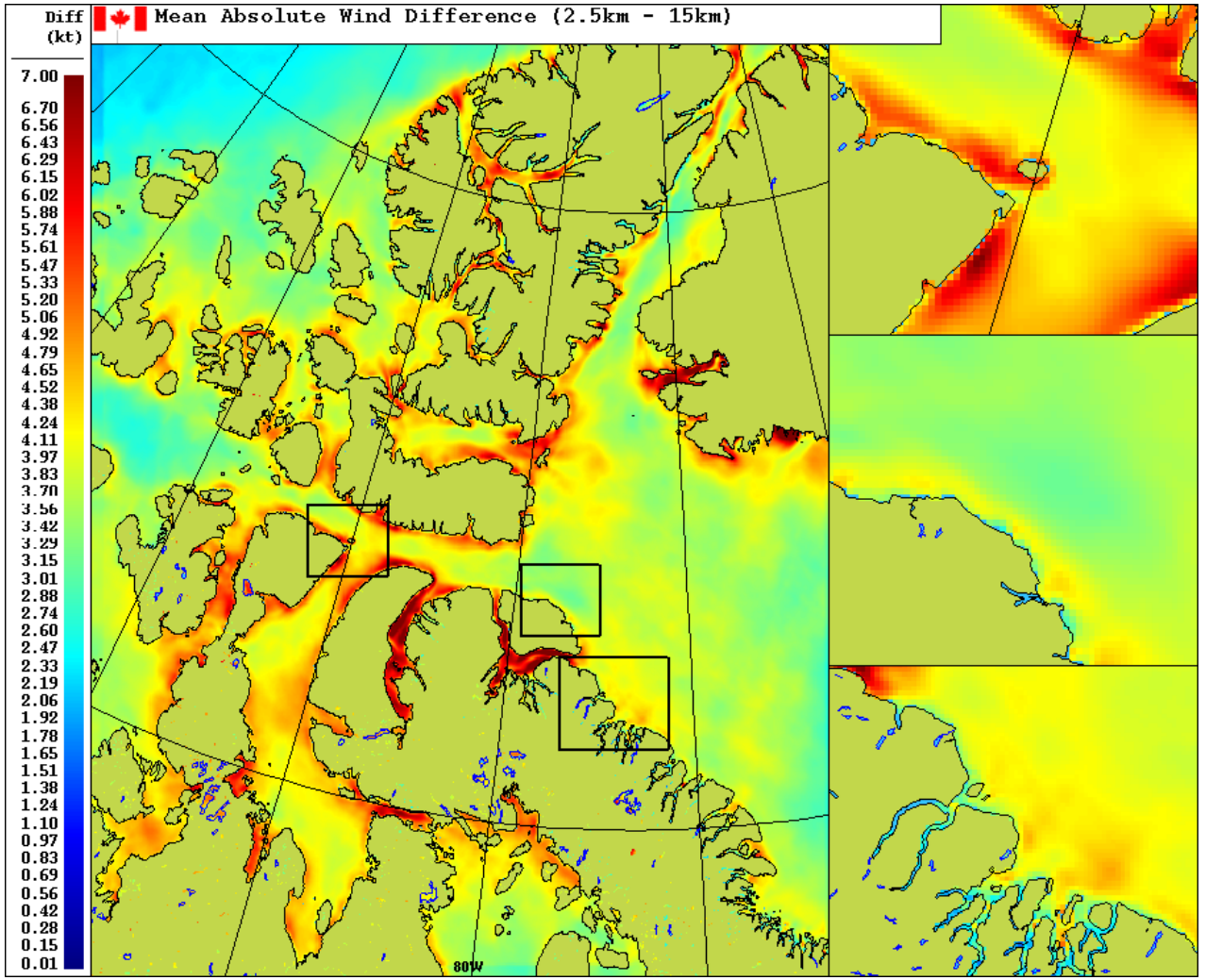


Coupled CAPS-RIOPS



Impact of atmospheric resolution on winds

Difference between daily 2.5km and 15km 48hr forecasts for August 2012



CAPS YOPP Evaluation

Performance of the Canadian Arctic Prediction System during the YOPP Special Observing Periods

Barbara Casati[1,*], Tom Robinson[2], François Lemay[2], Morten Køltzow[3], Thomas Haiden[4], Eva Mekis[5], Franck Lespinas[2], Vincent Fortin[1], Gabrielle Gascon[6], Jason Milbrandt[1], and Greg Smith[1]

- CAPS outperforms RDPS and GDPS in predicting near-surface temperature, dewpoint, temperature, wind and precipitation, in both seasons and domains
- YOPP verification exercise revealed some issues related to the verification of surface variables and has **led to better verification practices for the polar regions (and beyond)**

ATMOSPHERE-OCEAN 61 (4) 2023, 246–272
https://doi.org/10.1080/07055900.2023.2191831

CAPS 3-km resolution vs operational GDPS

- **Enhanced Physical Process Representation**: Atmospheric modeling at a 3-km resolution provides a more accurate depiction of physical processes.
- **Reduced Near-Surface Errors**: This resolution is likely to decrease errors in representing conditions near the surface.
- **Improved Microphysics Resolution**: Phenomena related to cloud formation and precipitation are better resolved.
- **Ocean-Ice Coupling**: Improved parameterizations of ice-ocean, atmosphere-ocean & atmosphere-ice exchanges.

Surface summary score cards

North America > 60°N

CAPS-RIOPS vs CAPS:

	winter		summer	
	00	12	00	12
TT bias	++	++	--	--
TT stdev	++	++	--	--
TD bias	++	++	--	--
TD stdev	++	++	--	--
PN bias	++	++	/	/
PN stdev	/	/	++	++
UV bias	++	++	/	/
UV stdev	/	/	/	/
WD hss	/	/	/	/
PR6h fbi	/	/	/	/
PR6h hss	/	/	/	/
TCC fbi	/	/	/	/
TCC hss	/	/	/	/

North Pole (> 60°N) thin2

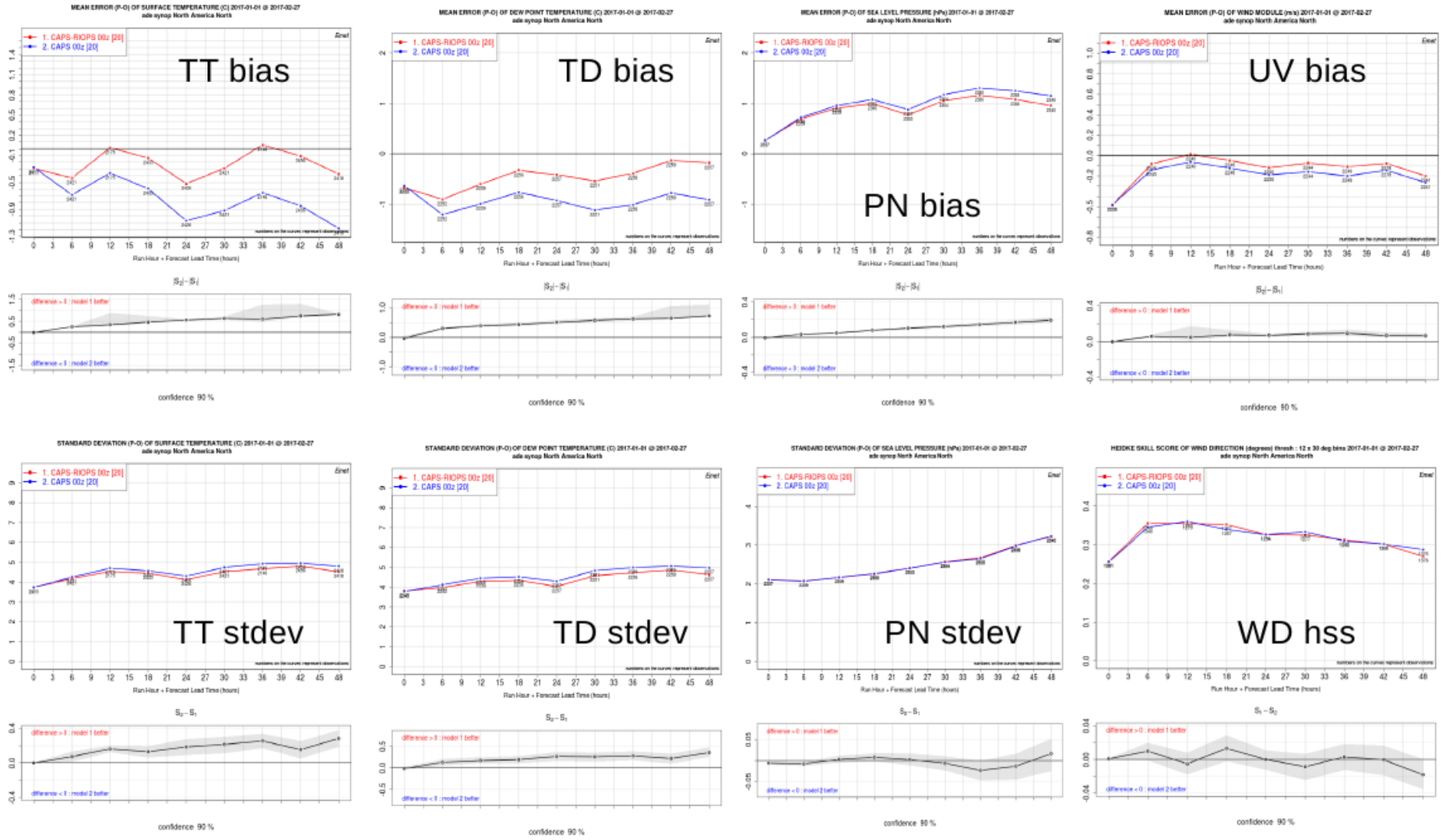
CAPS-RIOPS vs CAPS:

	winter		summer	
	00	12	00	12
TT bias	++	++	--	--
TT stdev	++	++	--	--
TD bias	++	++	--	--
TD stdev	++	++	--	--
PN bias	++	++	++	++
PN stdev	++	++	/	/
UV bias	--	--	/	/
UV stdev	/	/	/	/
WD hss	/	/	/	/
PR6h fbi	/	/	/	/
PR6h hss	/	/	/	/
TCC fbi	++	++	--	--
TCC hss	/	/	--	--

nadā

CAPS-RIOPS vs CAPS, North America North, winter 2017, 00 run

TT,TD : improved bias, stdev; PN improved bias, neutral stdev; UV improved bias, neutral stdev (not shown); WD neutral hss.



CAPS-RIOPS vs CAPS, North America North, summer 2016

TT,TD : worse (colder) bias, stdev; PN neuter bias, better stdev; UV neutral bias, stdev (not shown); WD neutral hss; 00~12 runs.