



Environment
Canada

Environnement
Canada

Canada



Wave Ensemble Verification

Benoit Pouliot, Natacha Bernier, Syd Peel, Patrick Timko

8th NCEP Ensemble User Workshop
August 29, 2019

Outline

- CMC wave ensemble
- Data availability
- Verification at buoys
- Satellite verification
- Next steps



CMC GEWPS – Global Ensemble Wave Prediction System

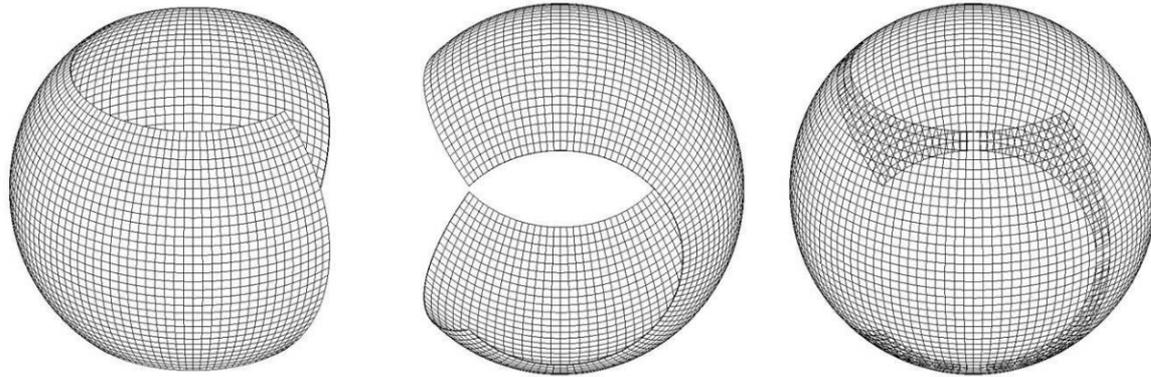
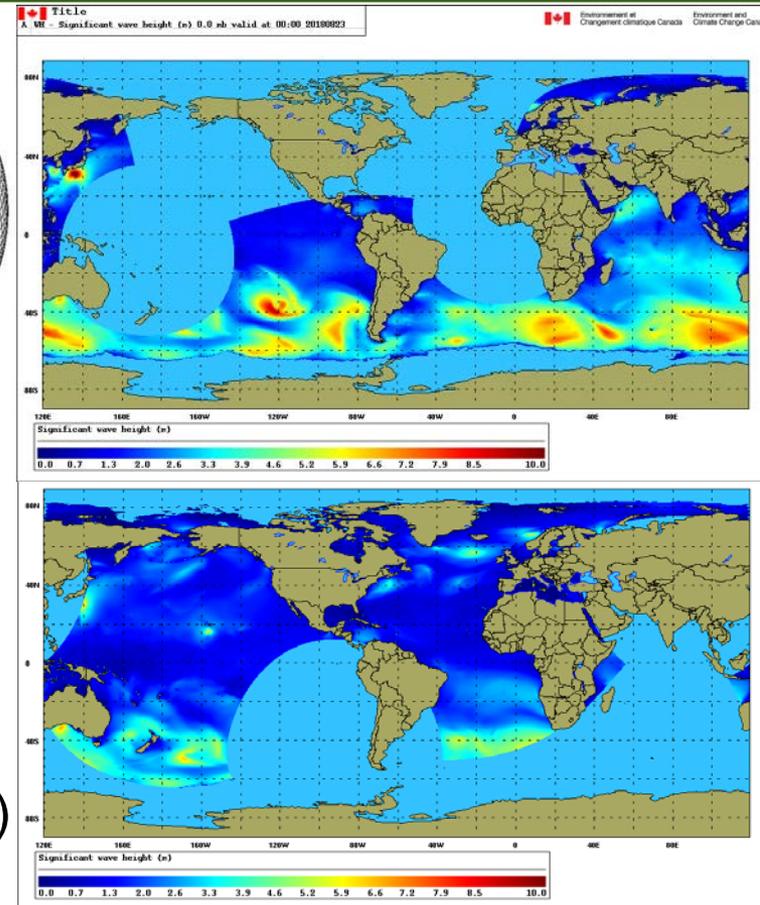


Figure 2: Yin subgrid (left) Yang subgrid (middle) Yin-Yang grid (right).

- One control plus 20 members
- Model: WaveWatch III
- Two 799 x 267 grids: Yin-Yang 39 km
- Minimum resolution: ~26.5 km
- Time step: 900s (vs 100s for lat-lon 86N)
- No perturbation, spread from forcings
- No DA. Member by member cycling allows persistence of spread
- Winds from CMC GEPS (Global Ensemble Prediction System)
- Ice forecast from coupled GDPS (coupled GEPS from July 3)



NAEFS Wave Data Availability for Verification (as of August 2019)

Center	Resolution (degree)	Frequency	Number of members
NCEP	0.5	3-hourly	20+1 control
FNMOOC	1.0	6-hourly	20
CMC*	0.35	Hourly	20+1 control

** Only available internally at CMC at this time*

- **FNMOOC**

- In the process of being made publicly available at 0.5 degree, 3-hourly

- **CMC**

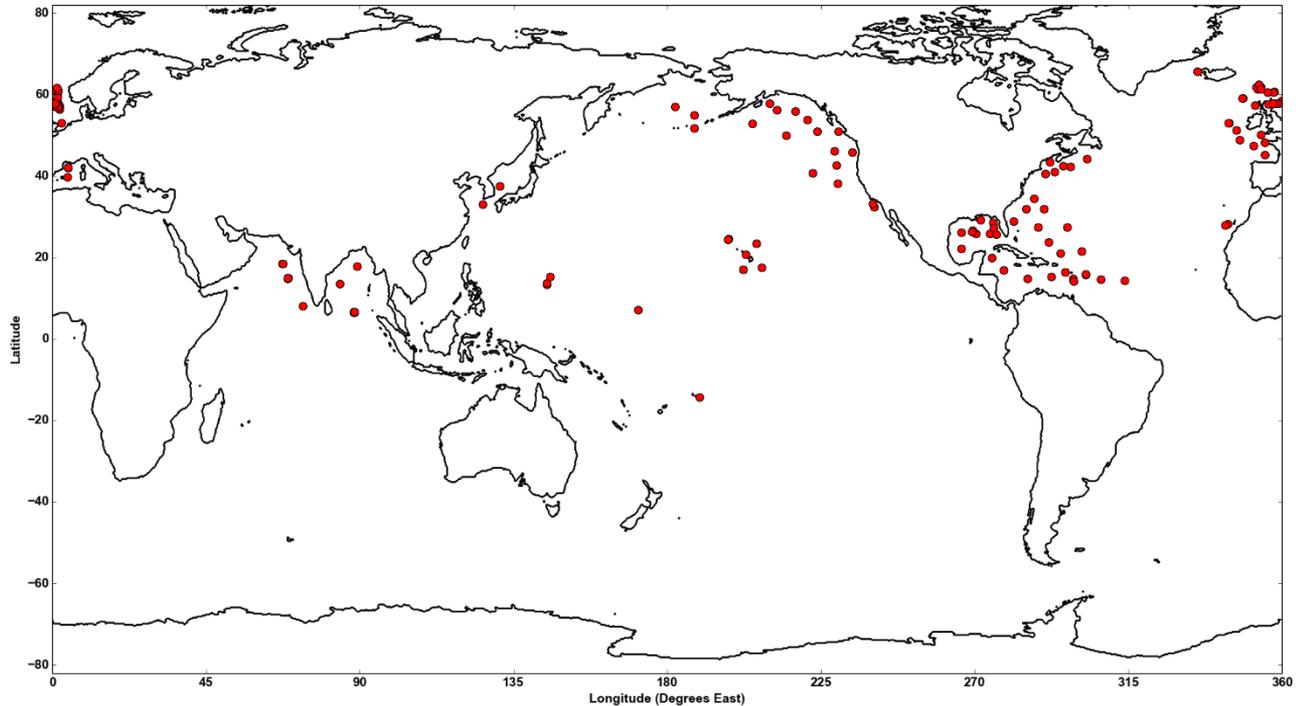
- Not operational yet
- Public availability target is summer 2020
- Likely will be made available at 0.5 degree, 3-hourly

Wave Verification at buoys

- Using JCOMM quality controlled observations
- No time interpolation: using 6-hourly forecast and corresponding observation
- Linear spatial interpolation
- Excluding buoys within 1 grid point of coast of any model
- Period of evaluation: February 2 to June 30, 2019

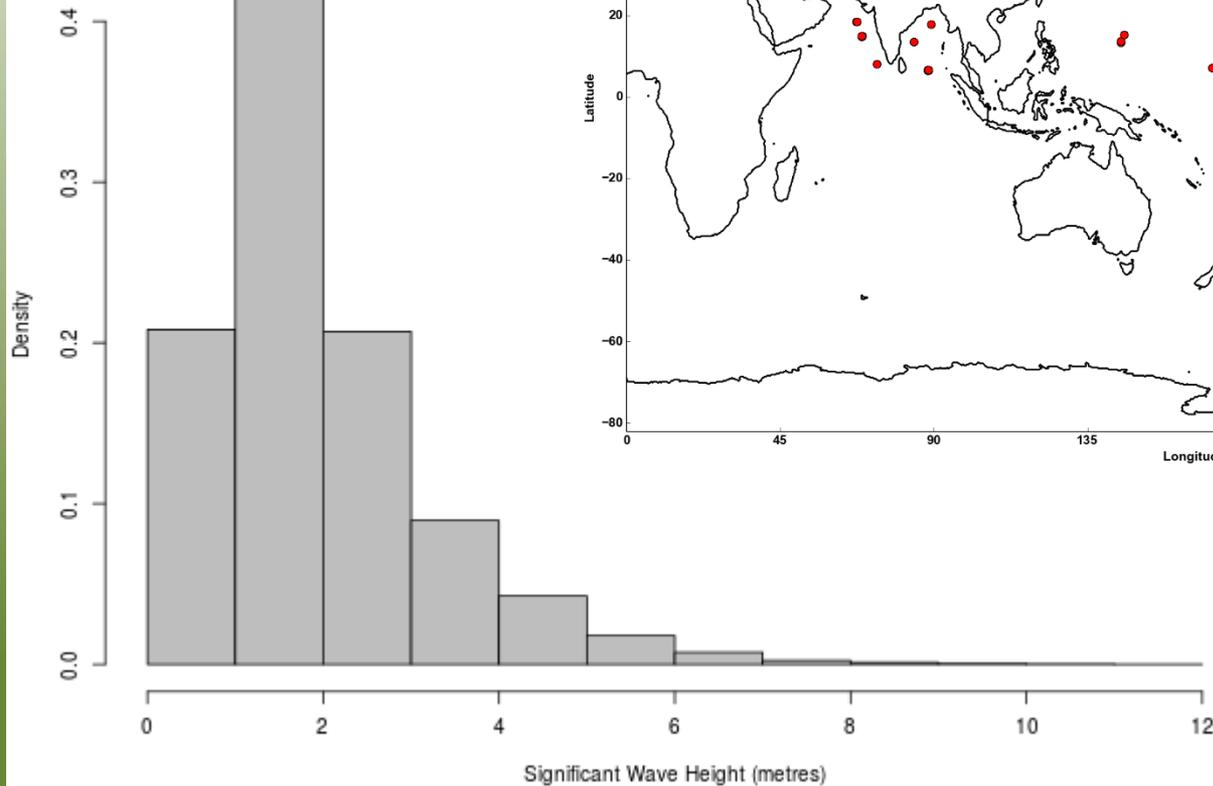
Verification at buoys

Buoys used for verification

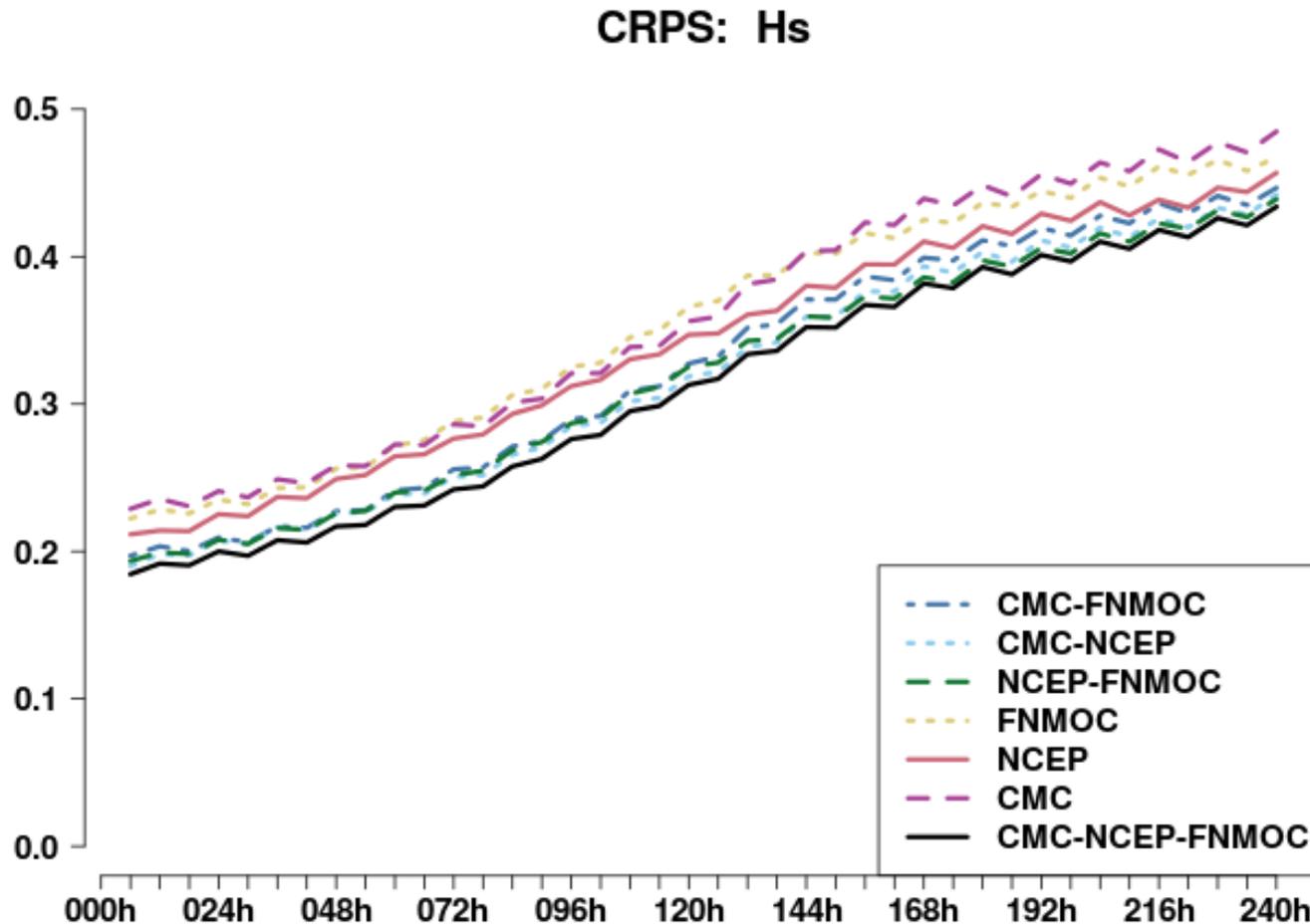


● All but one in North Hemisphere

Distribution of observed significant wave height

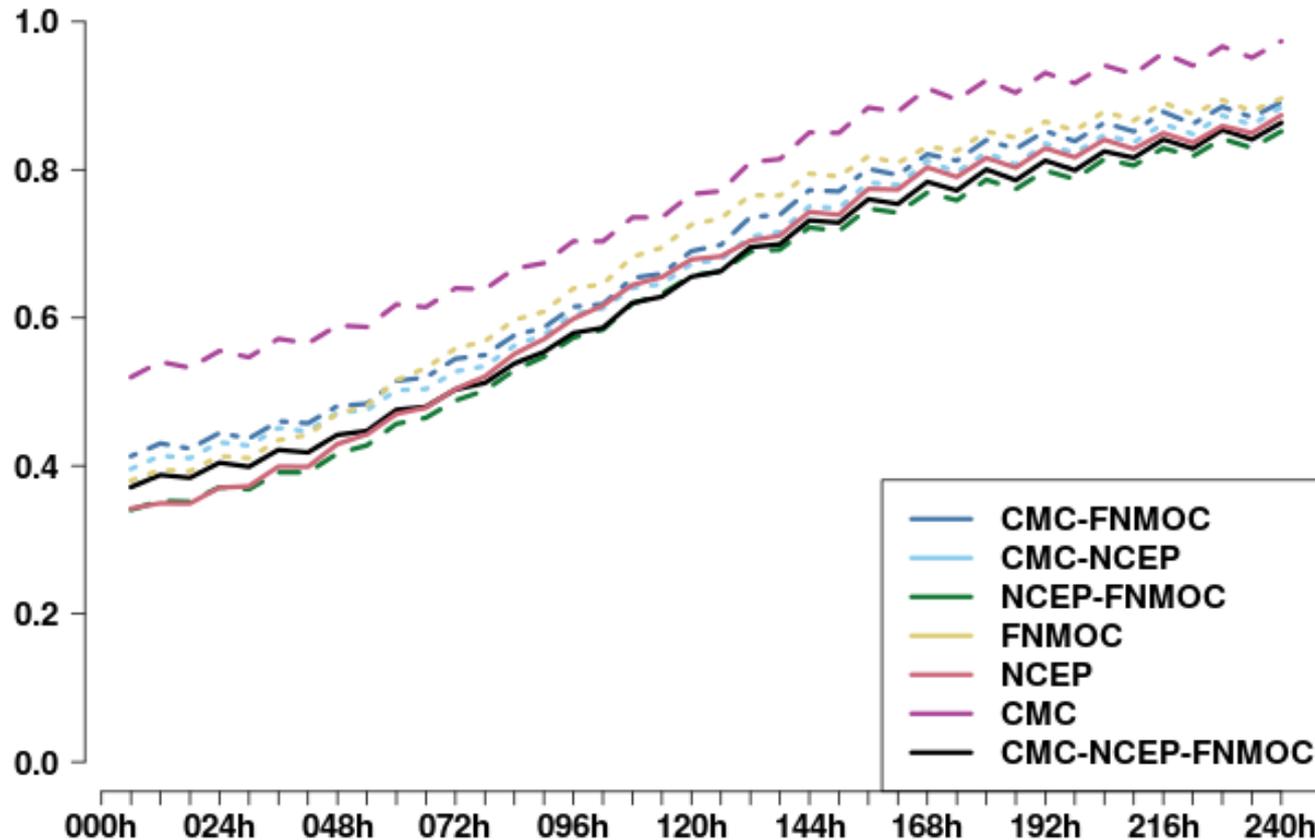


Continuous Rank Probability Score (CRPS) of Hs at buoys



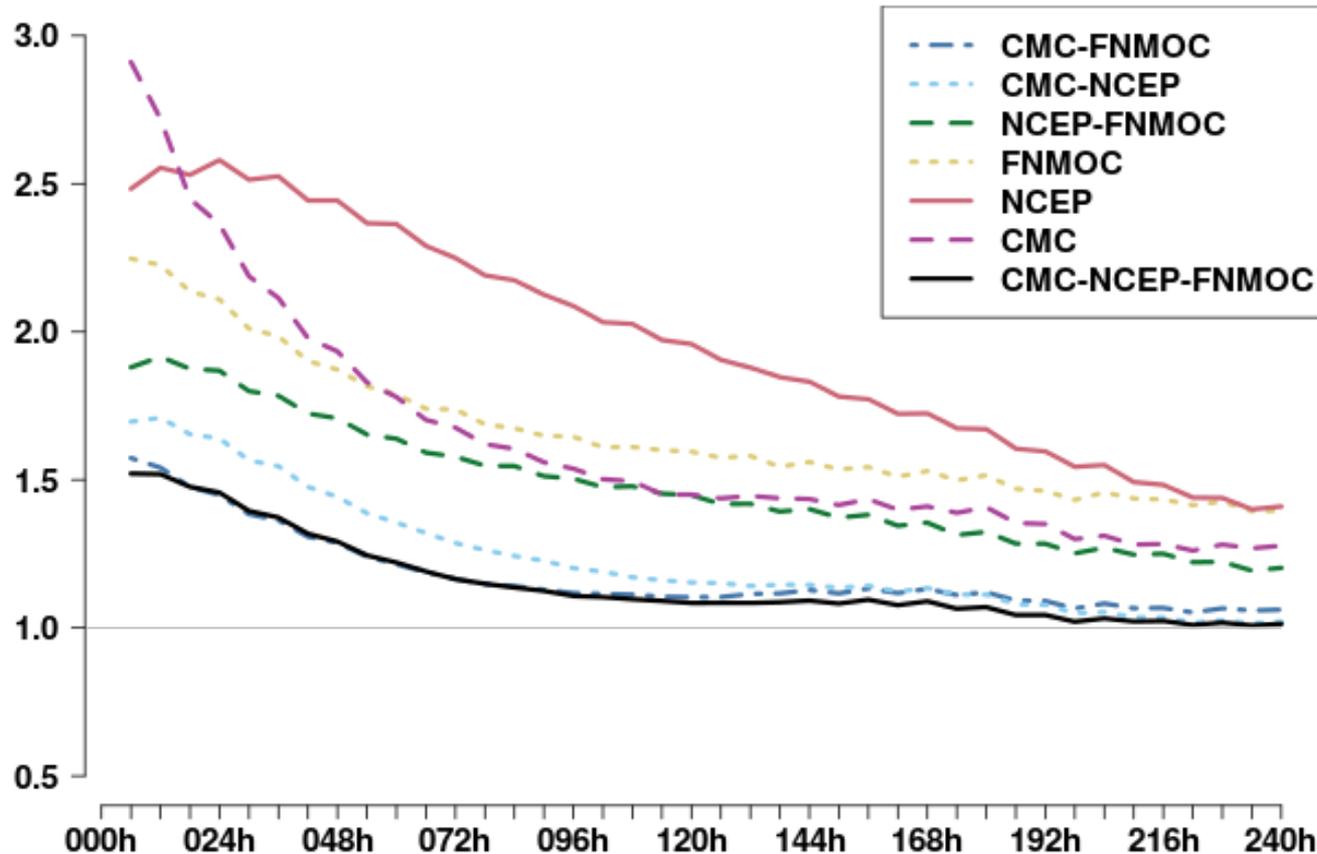
Root Mean Square Error (RMSE) of Hs Ensemble Mean at buoys

RMSE of Ensemble Mean: Hs



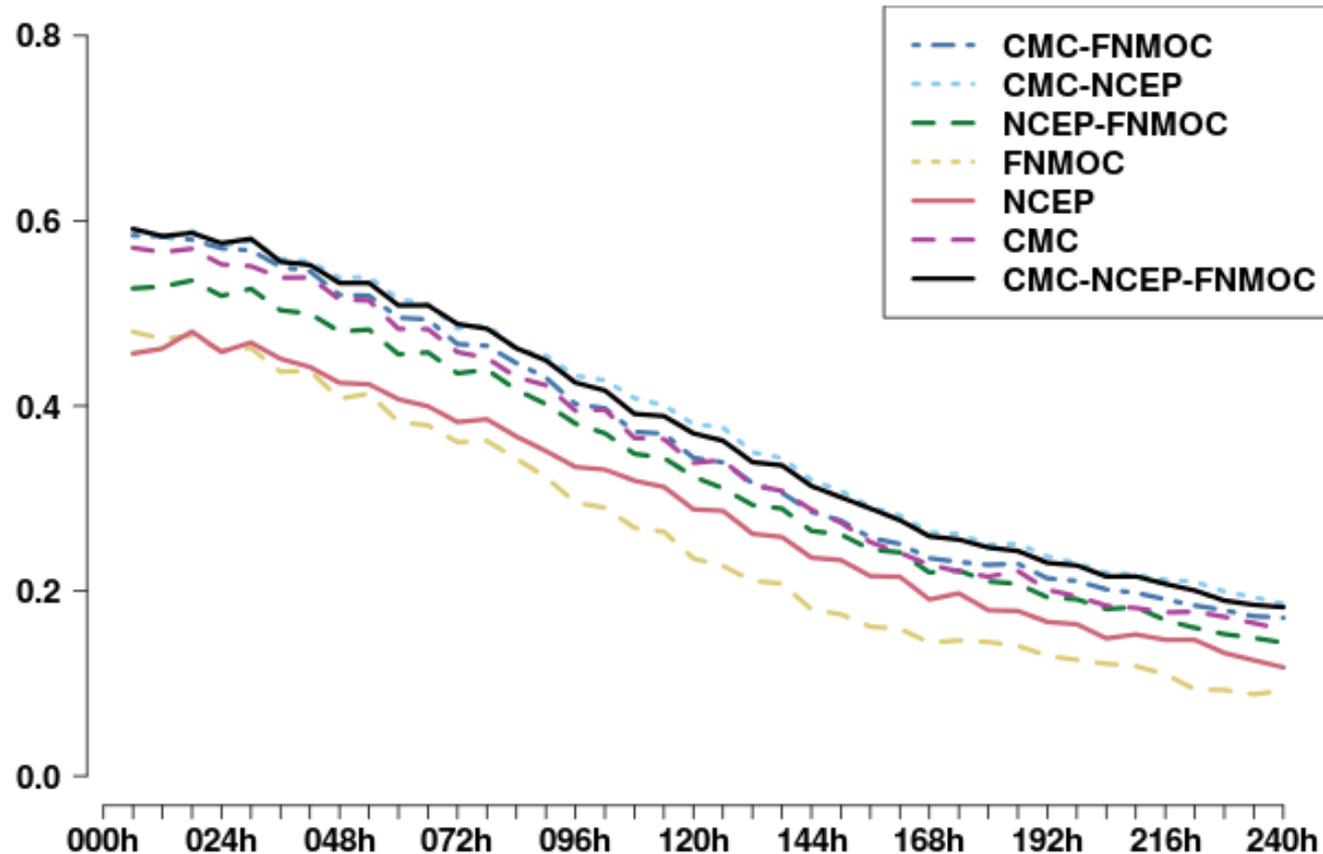
Reduced Centered Random Variable (RCRV) – Dispersion of Hs at buoys

RCRV - Dispersion: Hs



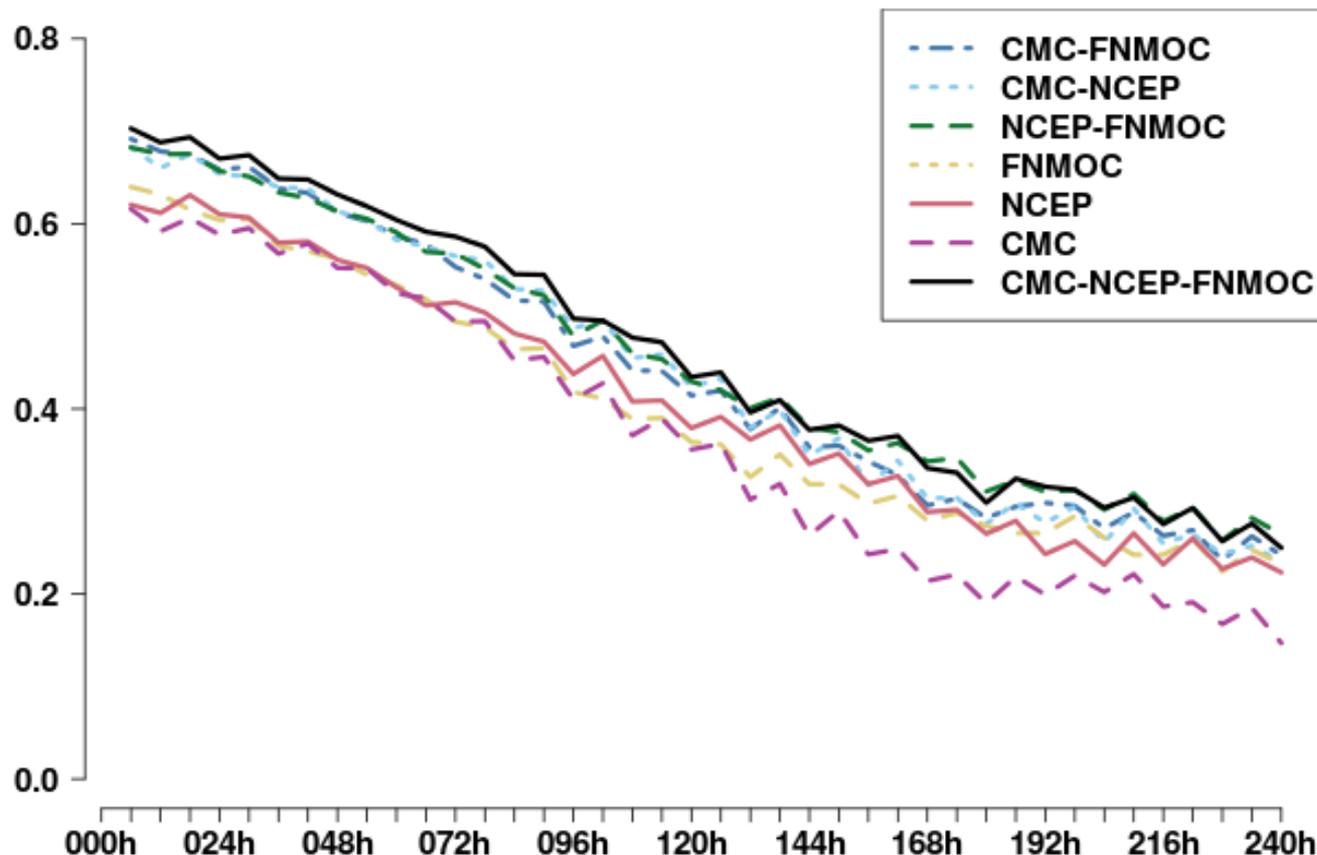
Brier Skill Score of Hs within 1-2 m at buoys

Brier Skill Score: Probability Hs within 1.00-2.00 m



Brier Skill Score of Hs within 3-5 m at buoys

Brier Skill Score: Probability Hs within 3.00-5.00 m



Wave Verification with Satellite Altimeter

- Time interpolation: nearest neighbour if within 30 minutes of observation
- CMC and NCEP: 3-hourly; FNMOC 6-hourly
- Spatial interpolation: linear
- Aggregation of data over 24 hours in 2x2 degree bins

- Satellites included: SARAL, Jason-2*, Jason-3
- Satellites to come: Cryosat-2, Sentinel-3A/3B

- Period of evaluation: February 2 to June 30, 2019

* Jason-2 unavailable February 17 to May 21

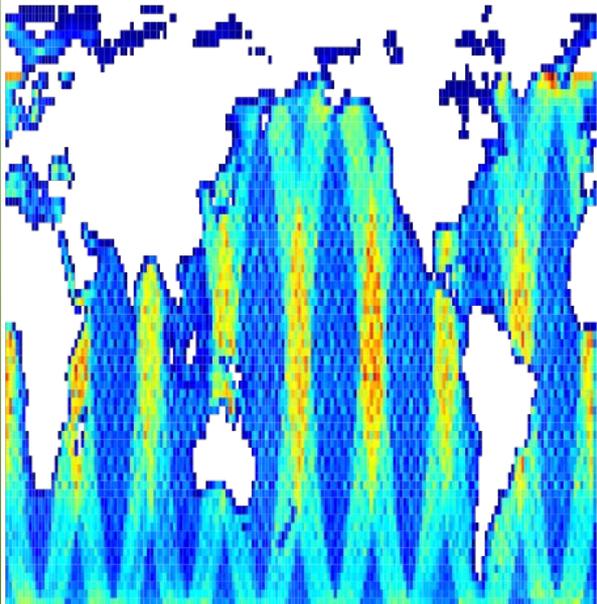


Satellite Altimetry Population

- FNMOC lower population due to 6-hourly data & data processing approach

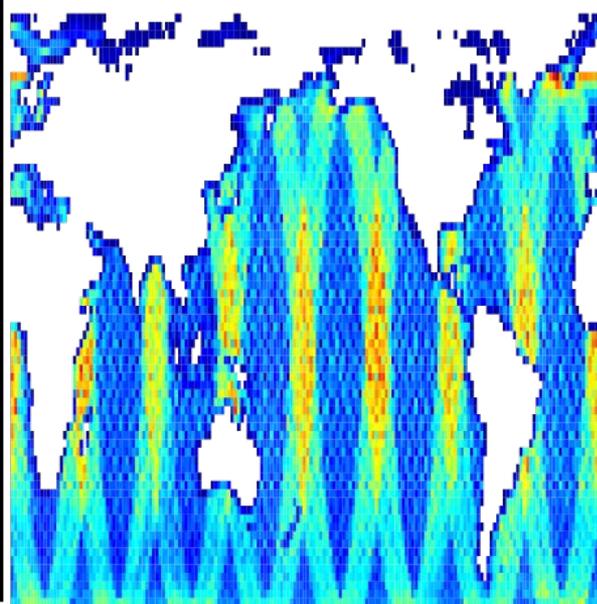
CMC

tile population
day 01



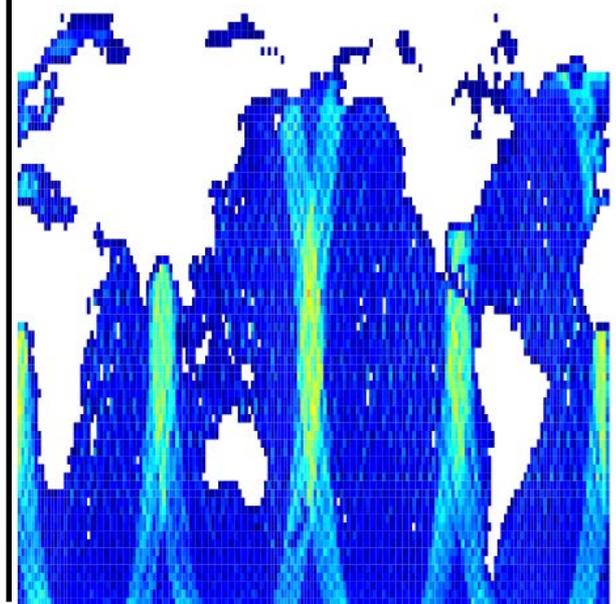
NCEP

tile population
day 01



FNMOC

pop
day 01



SARAL_Jason-2_Jason-3 : GEWPS



Environnement et
Changement climatique Canada

SARAL_Jason-2_Jason-3 : NCEP

Environment and
Climate Change Canada

SARAL_Jason-2_Jason-3 : FNMOC

Canada

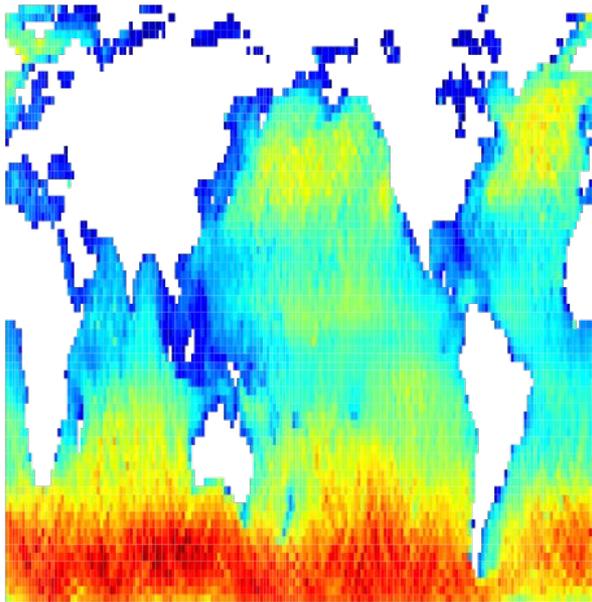
Satellite Altimetry

Mean Observed Hs

- FNMOOC mean observed Hs more jumpy due to smaller population

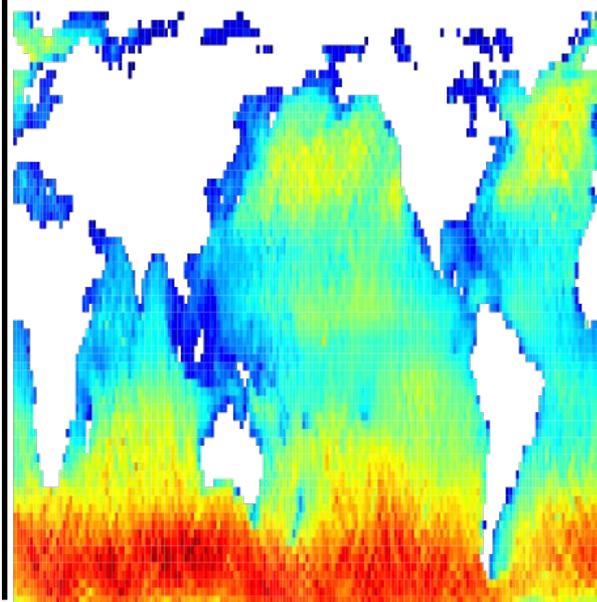
CMC

mean obs
day 01



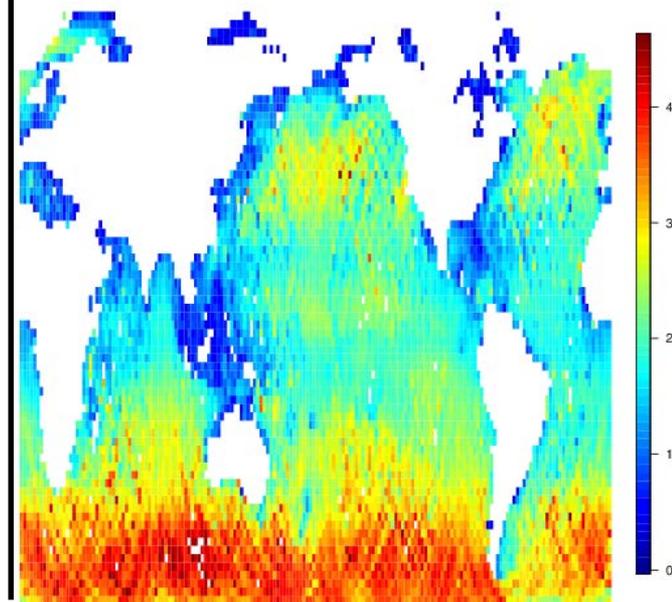
NCEP

mean obs
day 01



FNMOOC

mean obs
day 01



SARAL_Jason-2_Jason-3 : GEWPS



Environnement et
Changement climatique Canada

SARAL_Jason-2_Jason-3 : NCEP

Environment and
Climate Change Canada

SARAL_Jason-2_Jason-3 : FNMOOC

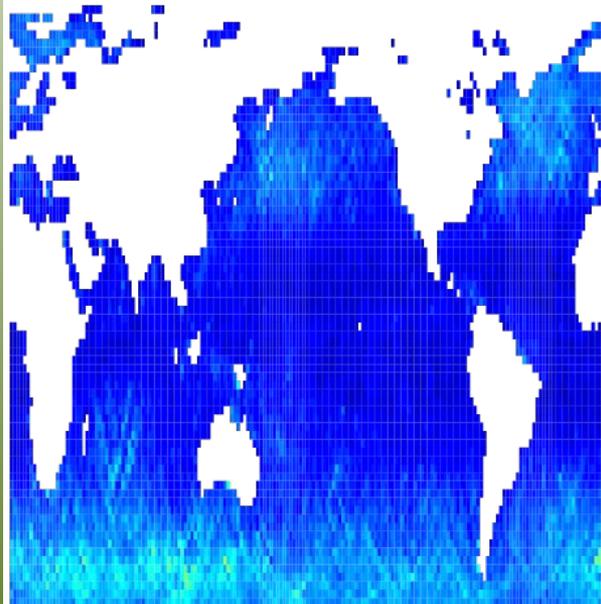
Canada

Satellite Altimetry: Continuous Rank Probability Score (CRPS) at Day 7

- NCEP better in North Atlantic
- CMC and FNMOC better in Southern Ocean

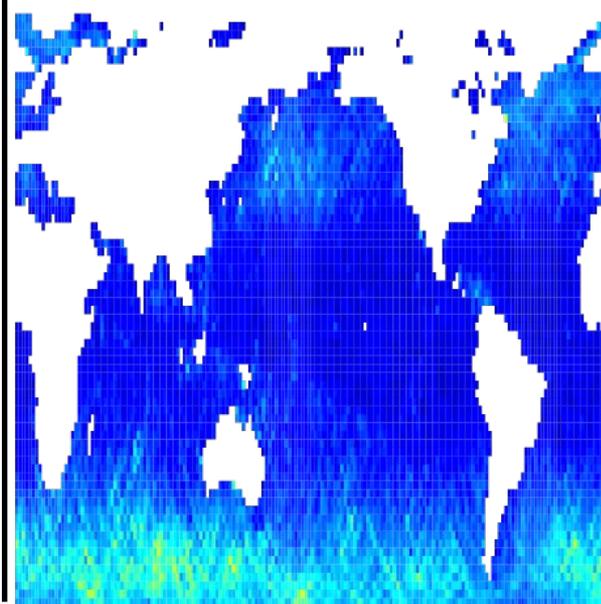
CMC

CRPS (m)
day 07



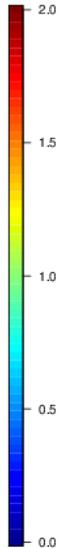
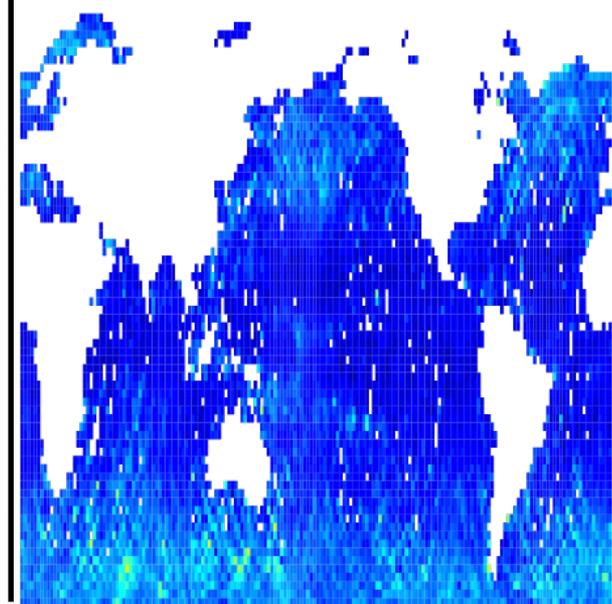
NCEP

CRPS (m)
day 07



FNMOC

CRPS (m)
day 07



SARAL_Jason-2_Jason-3 : GEWPS



Environnement et
Changement climatique Canada

SARAL_Jason-2_Jason-3 : NCEP

Environment and
Climate Change Canada

SARAL_Jason-2_Jason-3 : FNMOC

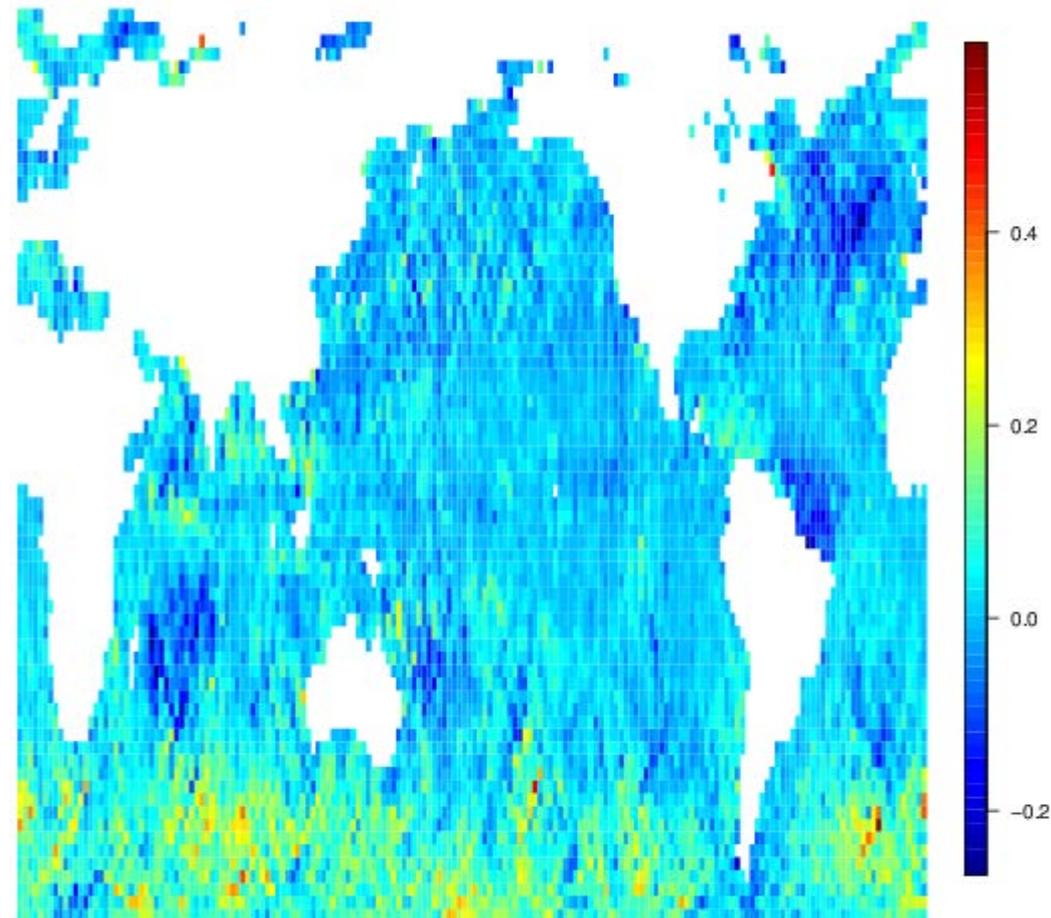
Canada

Satellite Altimetry

CRPS Difference Day 7

- NCEP better in North Atlantic, Amazon and Madagascar
- Generally neutral in North Pacific
- CMC significantly better in Southern Ocean

CRPS NCEP-CMC day 7



Discussion

- Ensembles from each centers have their strengths and weaknesses
 - NCEP generally better in North Hemisphere
 - CMC and FNMOC generally better in South Hemisphere
 - NCEP has good RMSE of ensemble mean but lacks spread
 - CMC has fair spread but seems to struggle with larger waves
 - FNMOC overall well balanced
- Two wave ensembles together generally perform better than any single ensemble
- The combined CMC-NCEP-FNMOC wave ensemble at buoys is best or near-best for all metrics studied here
- NAEFS type cooperation is valuable



Next steps

- Satellite verification of combined ensembles
- Further automation of verification process
- More satellites
- Availability of FNMOC wave data at 0.5 degree at 3-hourly interval
- Operational implementation of Canadian wave ensemble – target spring 2020

Thank you!

Contact: benoit.pouliot@canada.ca

