Environment and Climate Change Canada
Environnement et Changement climatique Canada

Tide-Surge Interaction in Ensemble Total Water Level Forecasts

Natacha B. Bernier,

O. Huziy, P. Wang,

K.R. Thompson, B. Pouliot, Y. Liu

Canada

MOTIVATION

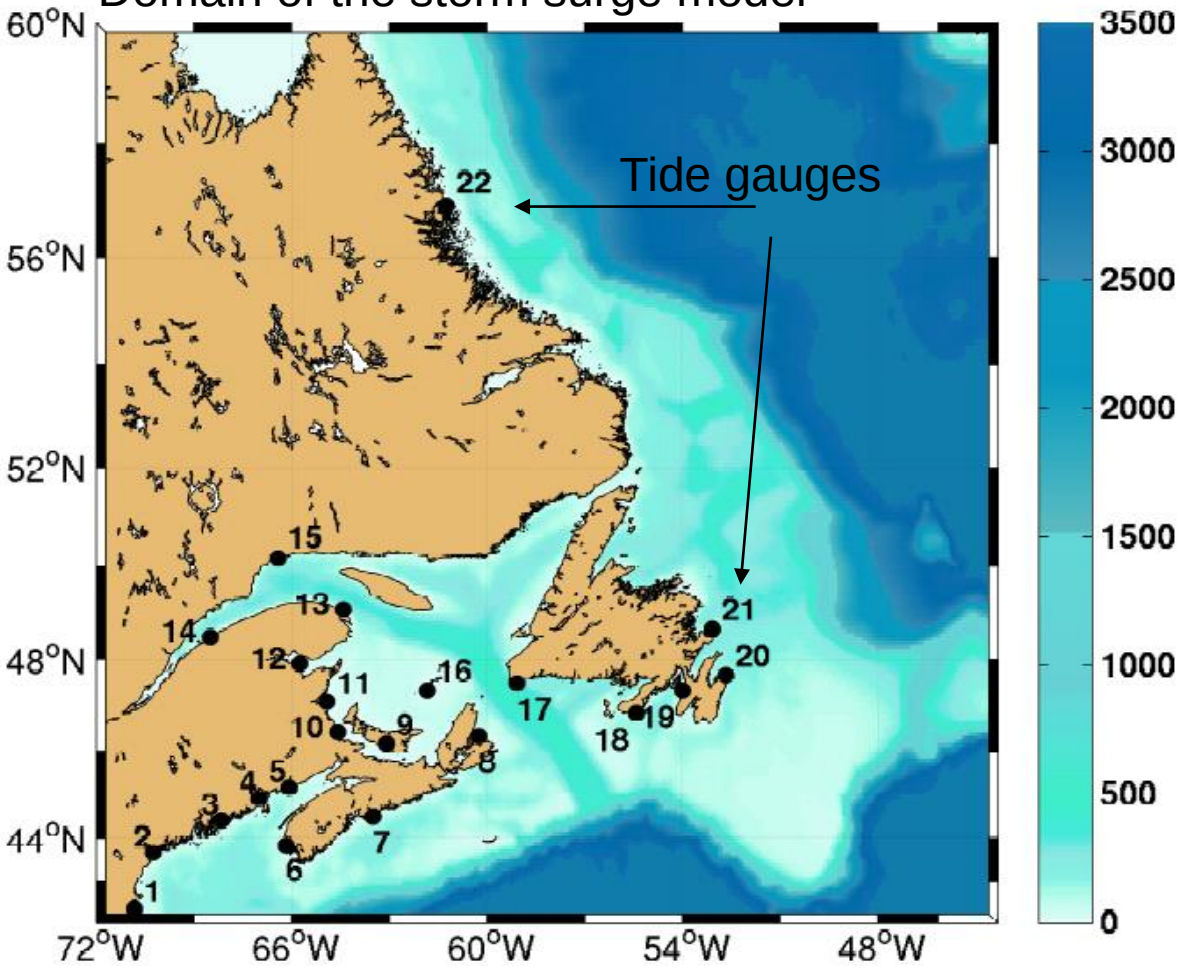
- Public and private sectors require more accurate forecasts with longer lead times (e.g., for activation of emergency measures including evacuations).

- Strong storms are an ongoing threat to Canadian coastlines (e.g., hours roads, cars, and land) including most recently Hurricane Dorian in 2019.

- Can we provide better guidance, including realistic estimates of uncertainty?

STUDY AND SURGE MODEL REGION

Domain of the storm surge model



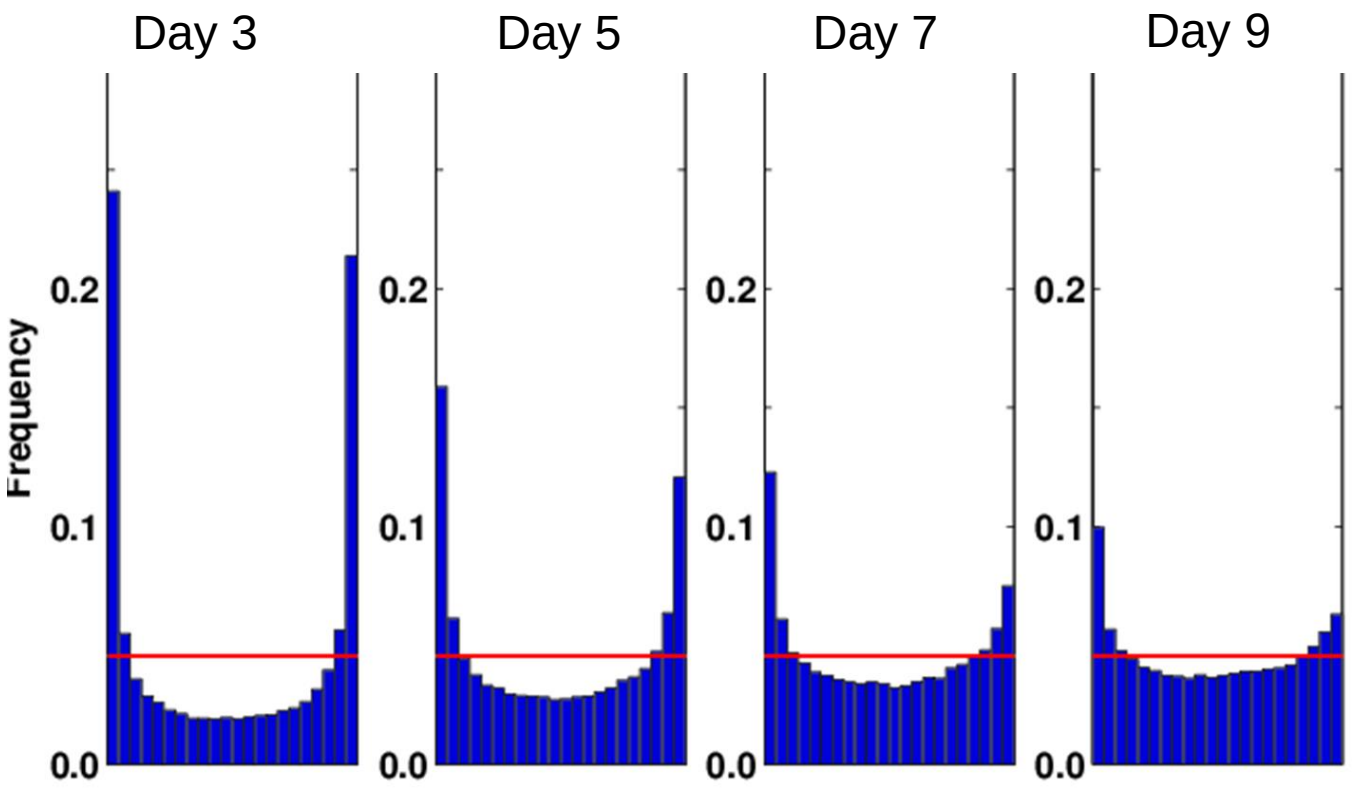
Twice daily (00Z and 12Z) ensemble runs (20+1 members) on surge grid of 1/12° driven with the 10m winds and surface air pressure from the GEPS (~39km grid spacing)

5 Flather type open radiation boundary conditions (N, E and S edge of the model plus GSL and BoF

Canada

WHAT WE KNOW

- Ensemble surge forecasts are typically the result of forced simulations using perturbed winds and air pressure
- Resulting surge predictions spread follows that of the atmospheric system.



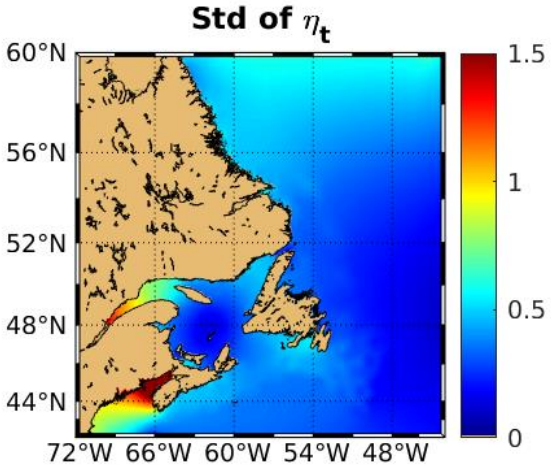
For each obs, ensemble members are sorted from lowest to highest.

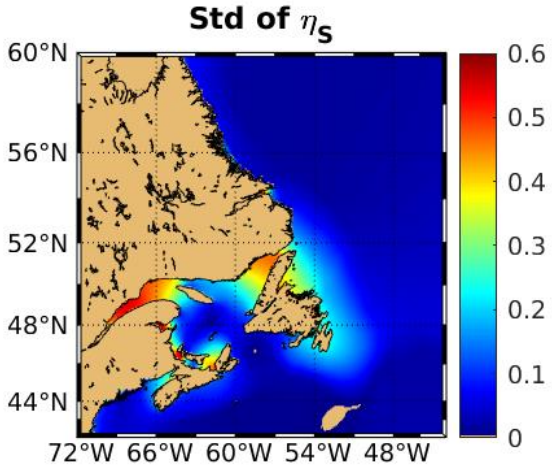
The “bin” for each obs is noted, and tallied into frequency of hits per bin.

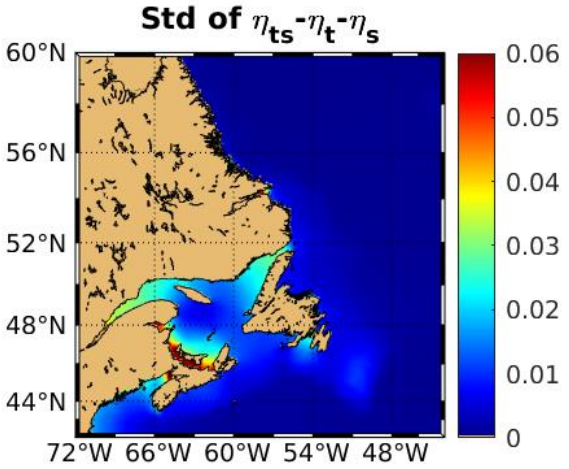
Desired outcome: Flat histogram.
The U-shape implies that the spread is too small

WHAT WE KNOW

- Tide-surge interaction (TSI) can “focus” surges on particular phase of the tides.
- TSI is present in the study region

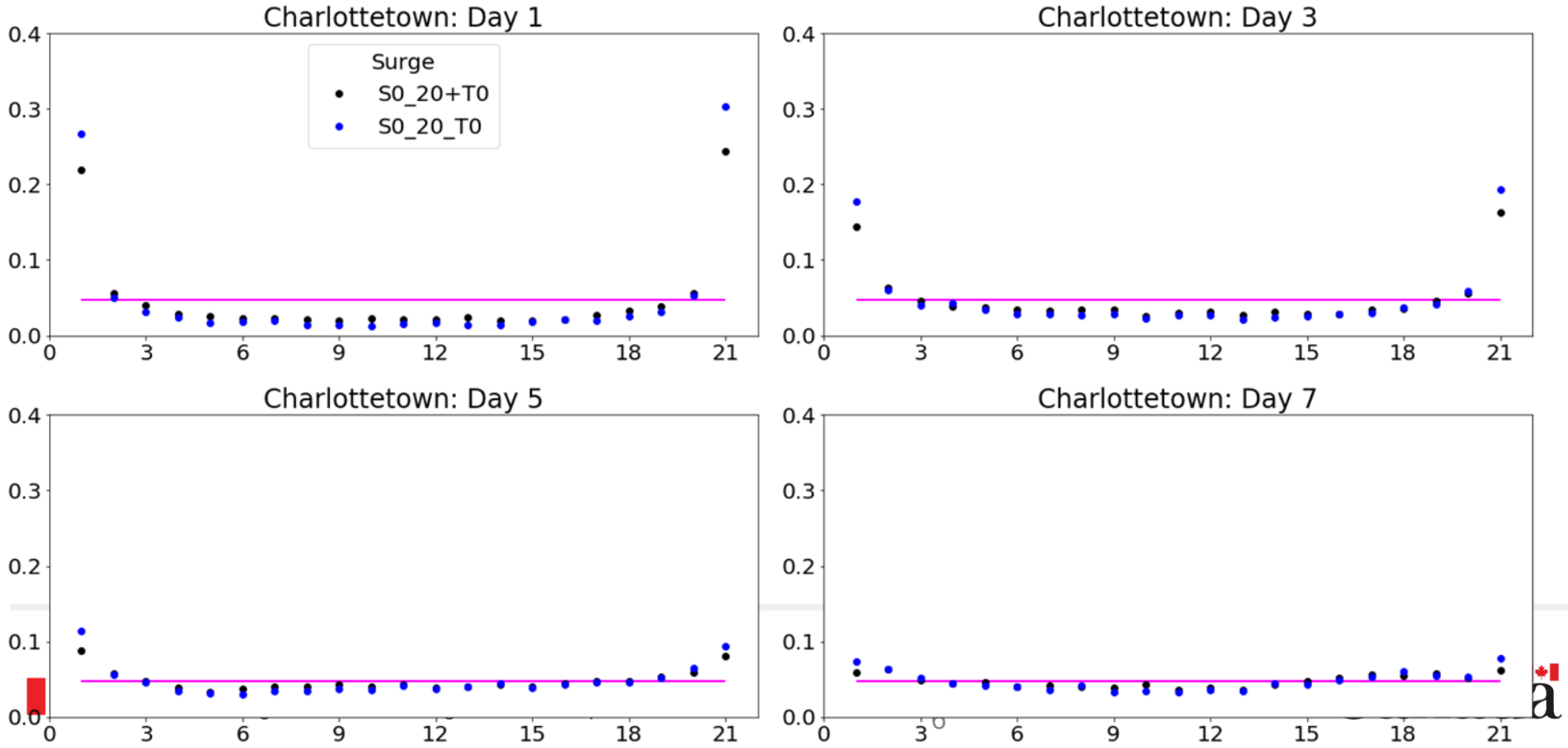






WHAT HAPPENS IF WE ALLOW TSI IN TWL ENSEMBLE FORECAST SYSTEM

- Spread in surges is reduced particularly in regions with strong tsi



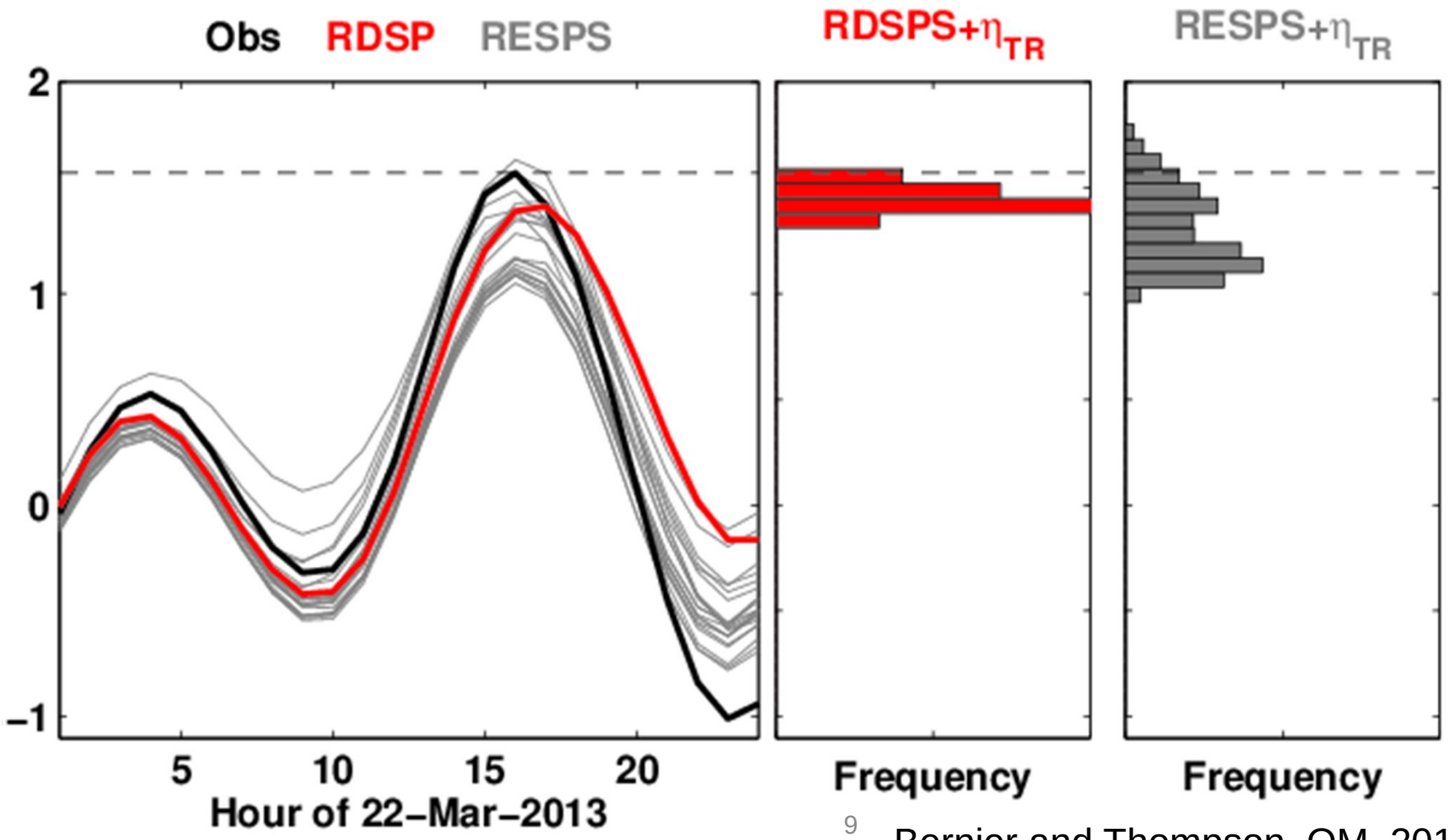
SAMPLING THE UNCERTAINTY

- Given the governing equations, perturbations of the drag coefficient, bathymetry, etc, further modify the spread already resulting from the perturbed atmospheric winds and air pressures.
- How else can we sample uncertainty? We know tides are affected by density structures hence they have a stochastic component. Can we usefully perturb the tides?

WHAT WE KNOW FROM SEA LEVEL OBSERVATION RECORDS

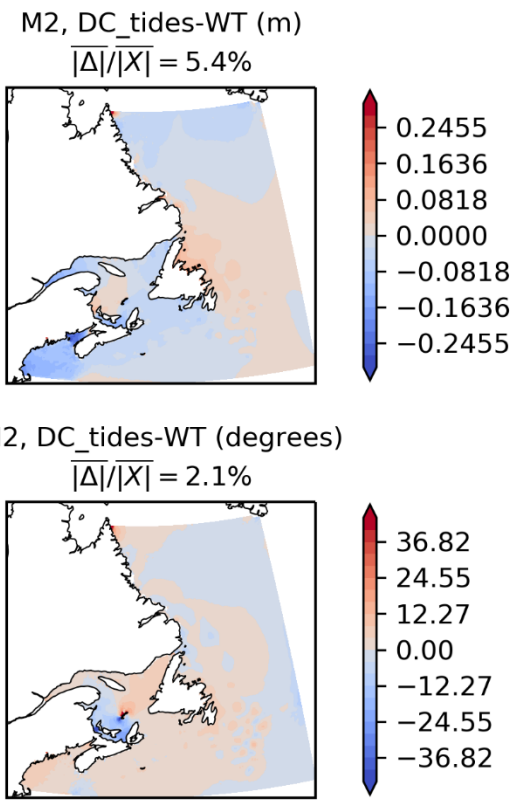
- 22 tide gauges recording total sea level, η_{obs}
- To a first approximation
- $\eta_{obs} = \eta_S + \eta_T + \eta_E$ η_s : storm surge
- η_T : tides
- η_E : error
- Errors can result from observation errors, seiches, baroclinic changes driven by freshwater input and surface heating, etc
- Tides are not purely deterministic (e.g. can vary with environmental conditions such as baroclinicity) so we separate the deterministic and remnant component and rewrite
- $\eta_T = \eta_{TD} + \eta_{TR}$
- And it follows that
- $\eta_{obs} - \eta_{TD} = \eta_S + \eta_{TR} + \eta_E$

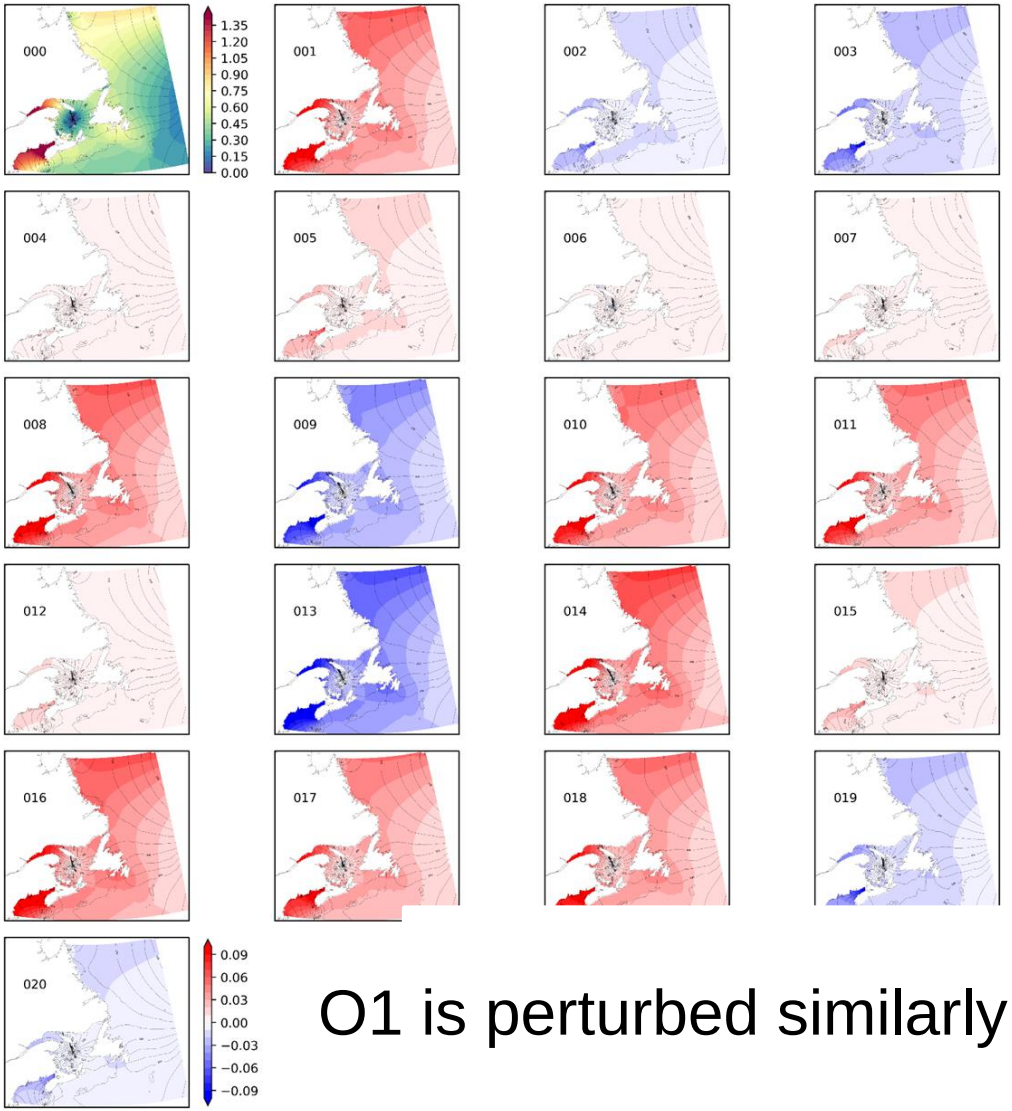
PERTURBING THE TIDES CAN BE IMPORTANT: A POST-PROCESSING EXAMPLE



Bernier and Thompson, OM, 2015

PERTURBATIONS OF THE M2 OPEN BOUNDARY

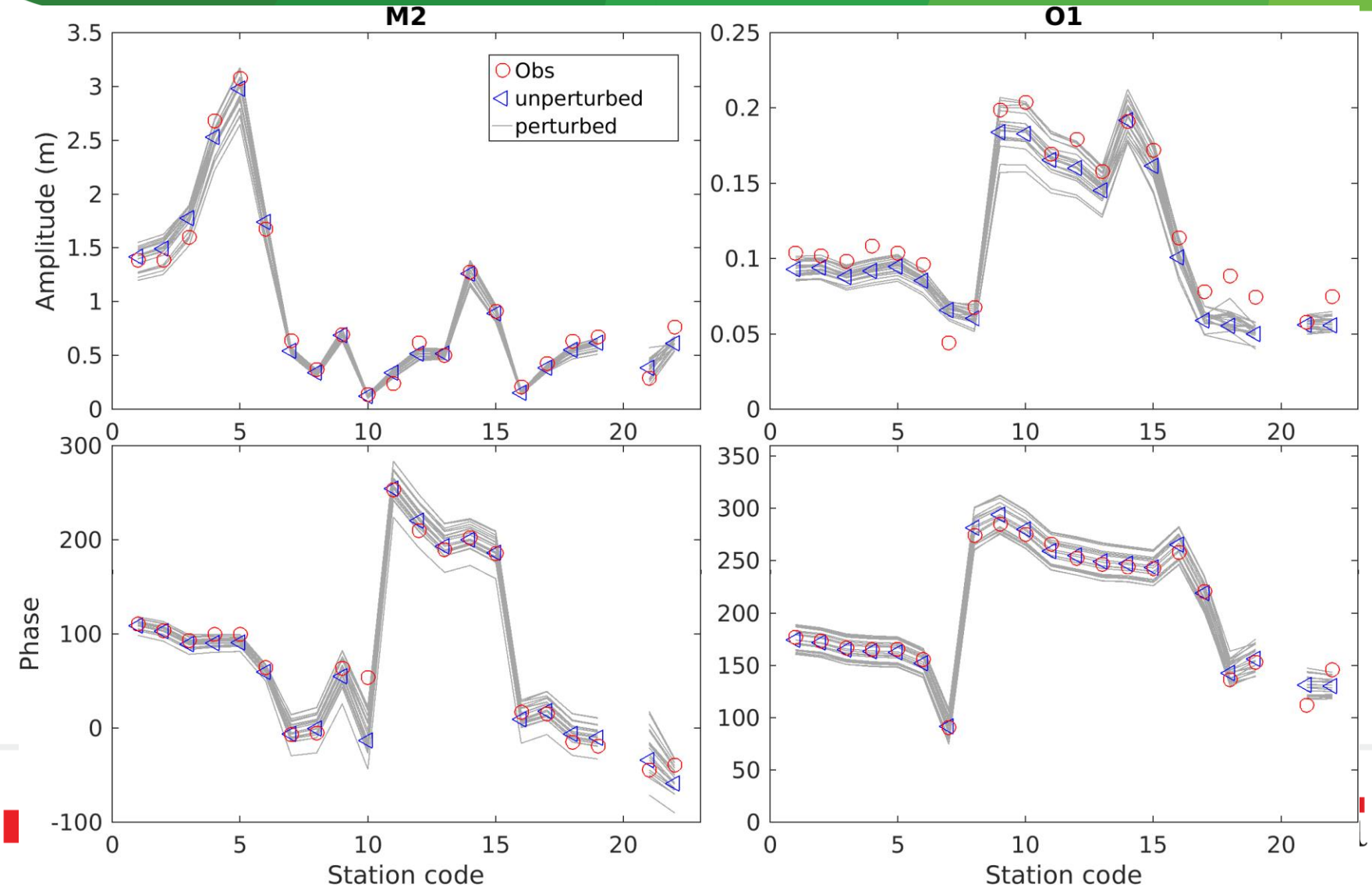




Environment and Climate Change Canada | Environnement et Changement climatique Canada

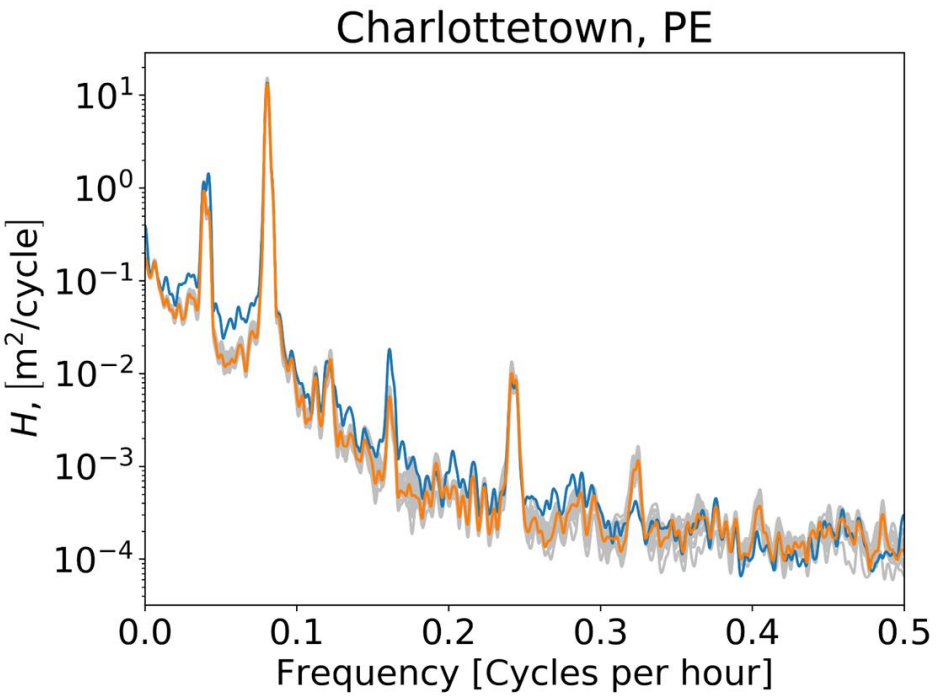
O1 is perturbed similarly

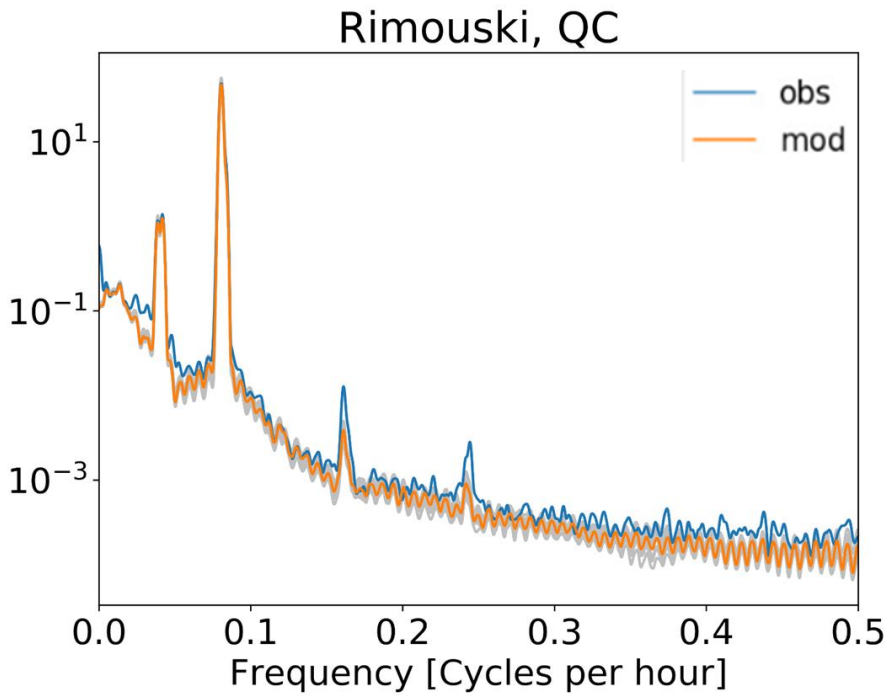
IMPACT OF PERTURBED OBC AT COASTAL TIDE GAUGES



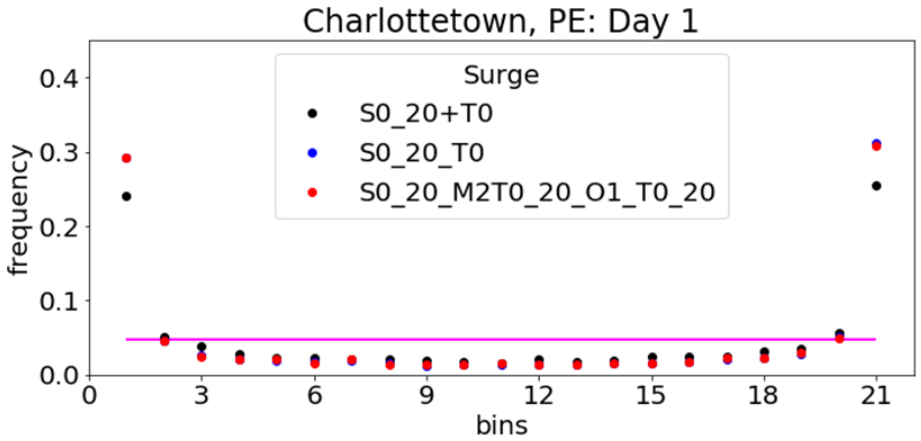
TWL SPECTRA FOR PERTURBED SURGE AND TIDES

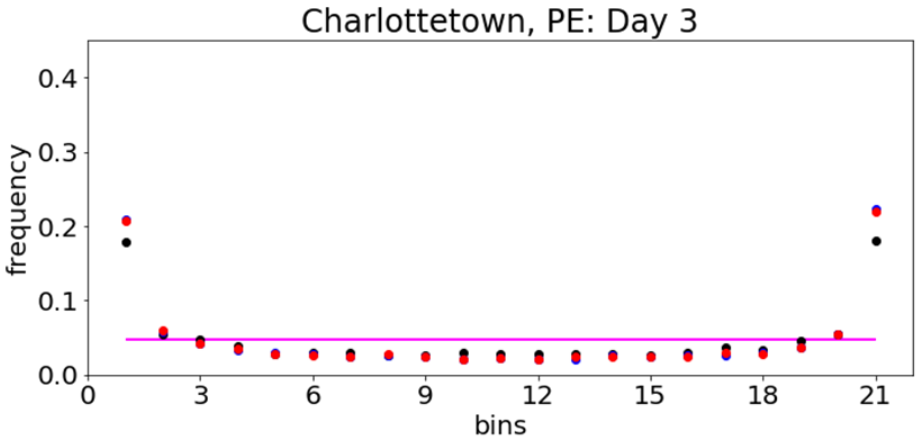
Grey lines show the power spectra of the perturbed members.

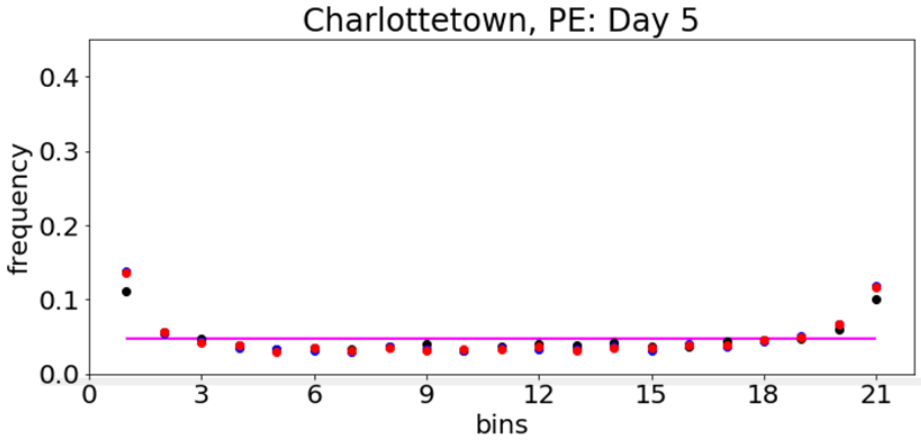


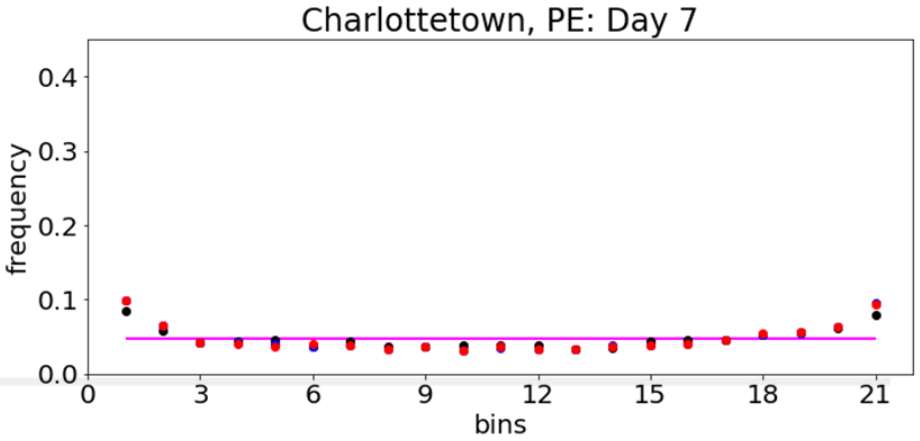


SURGE ONLY SPREAD: TSI ACTS TO FOCUS THE SURGES

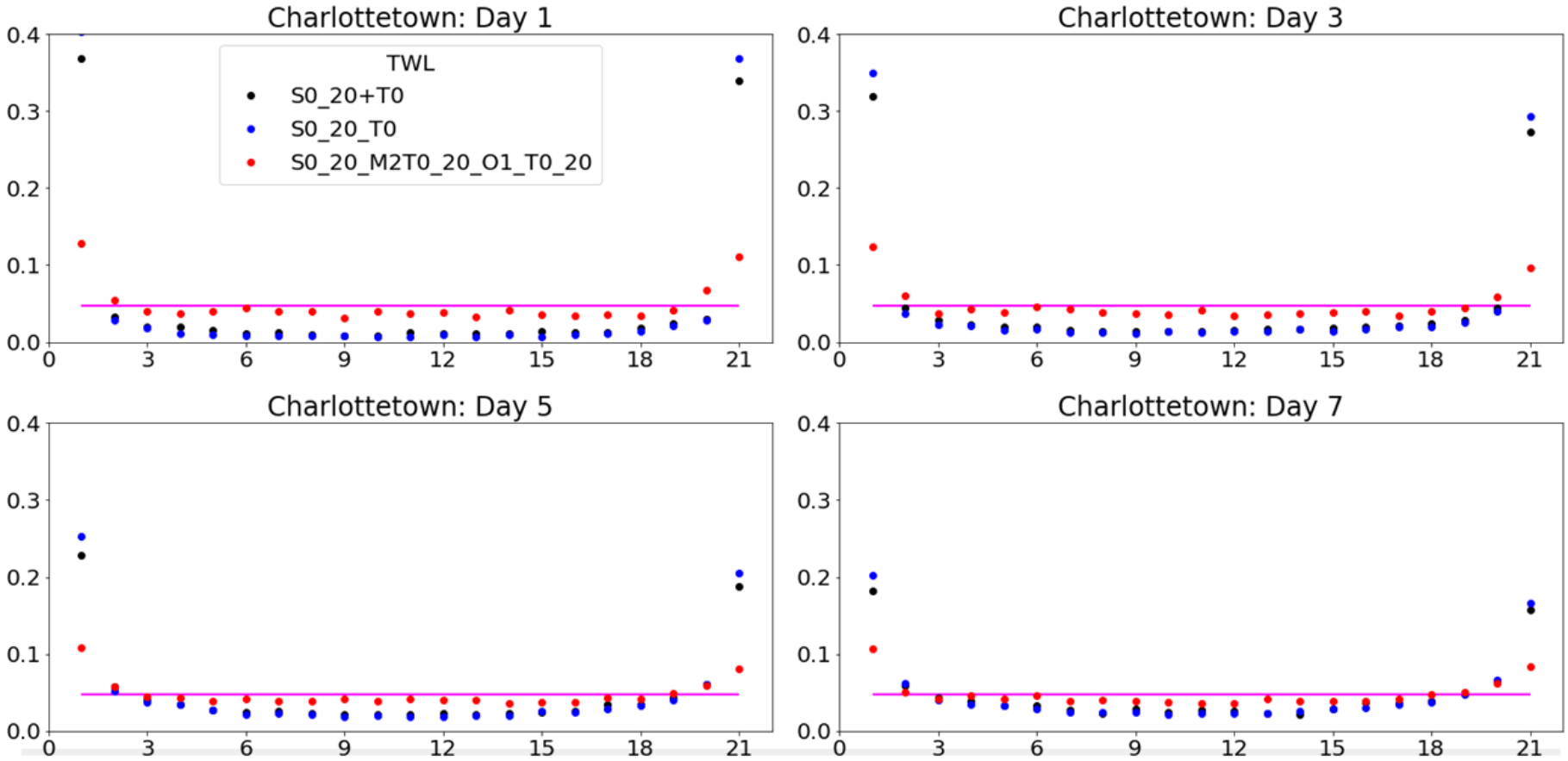




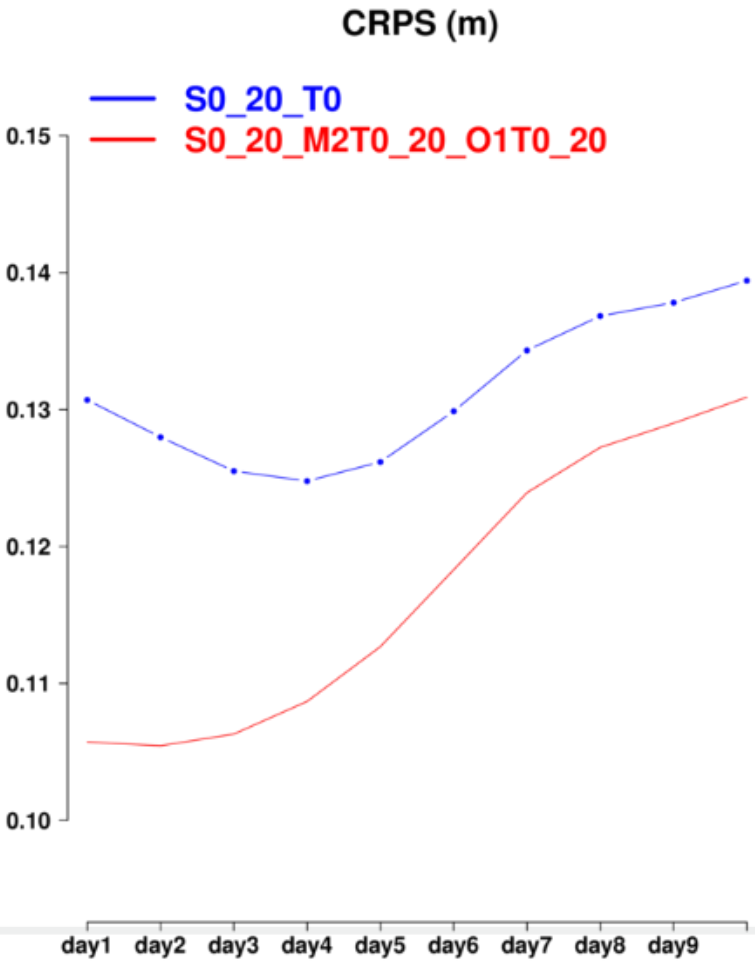


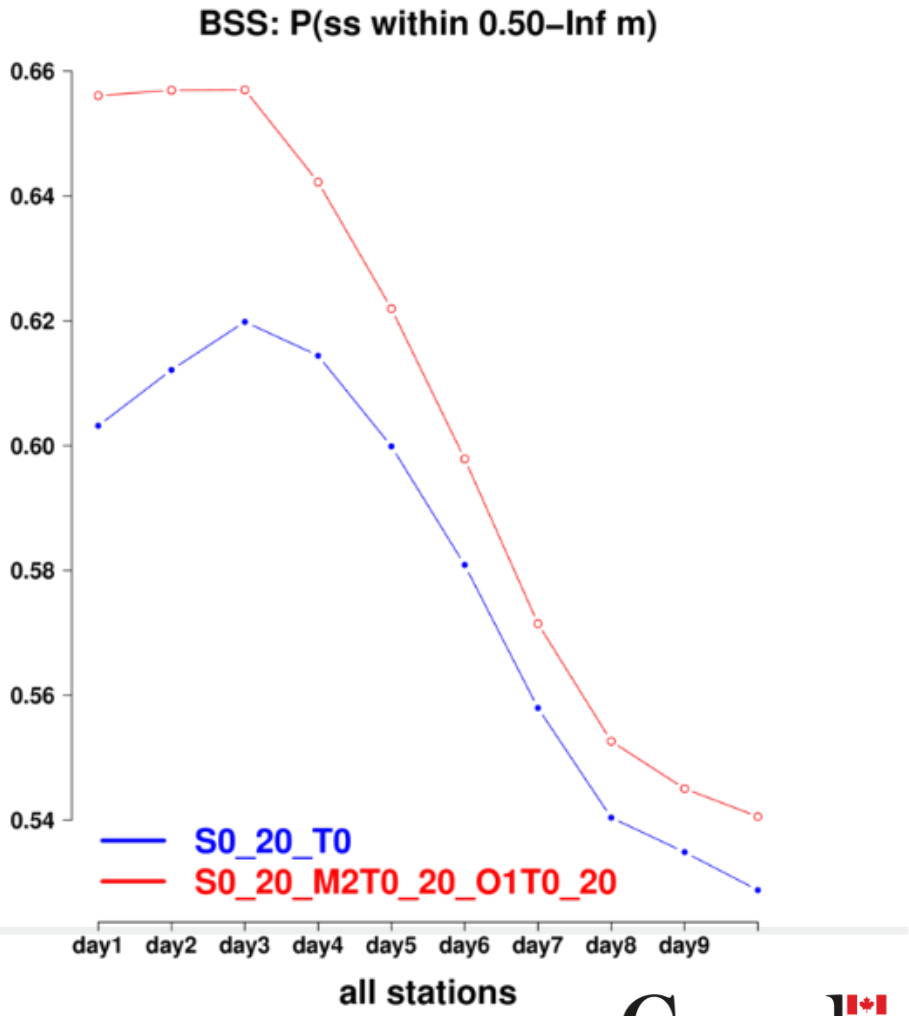


PRELIMINARY RESULTS: TIDAL PERTURBATIONS IMPROVE SPREAD OF TWL FORECASTS



OVERALL IMPROVEMENT IN OTHER SKILL SCORES WHEN TIDES ARE PERTURBED





Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

CONCLUSIONS

- Uncertainty is not a sign of bad models or science.
- Surge predictions are improving. Expect rapid progress over next 5 years at ECCC with (i) better atmospheric forcing, (ii) global, higher resolution models of TWL (iii) improved perturbation methodology (iv) coupling to wave models. But uncertainty will remain.
- An outstanding problem is the communication of risk of flooding to individuals and organizations.

FUTURE: GLOBAL TWL FORECASTS

M2 complex error in m(shading, left colorbar) and
RMSE of TWL at gauges in m (dots, right colorbar)