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Long-Range Deterministic and Ensemble Storm Surge Prediction for Atlantic Canada

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Motivation

photo courtesy of Doug.Mercer@ec.gc.ca

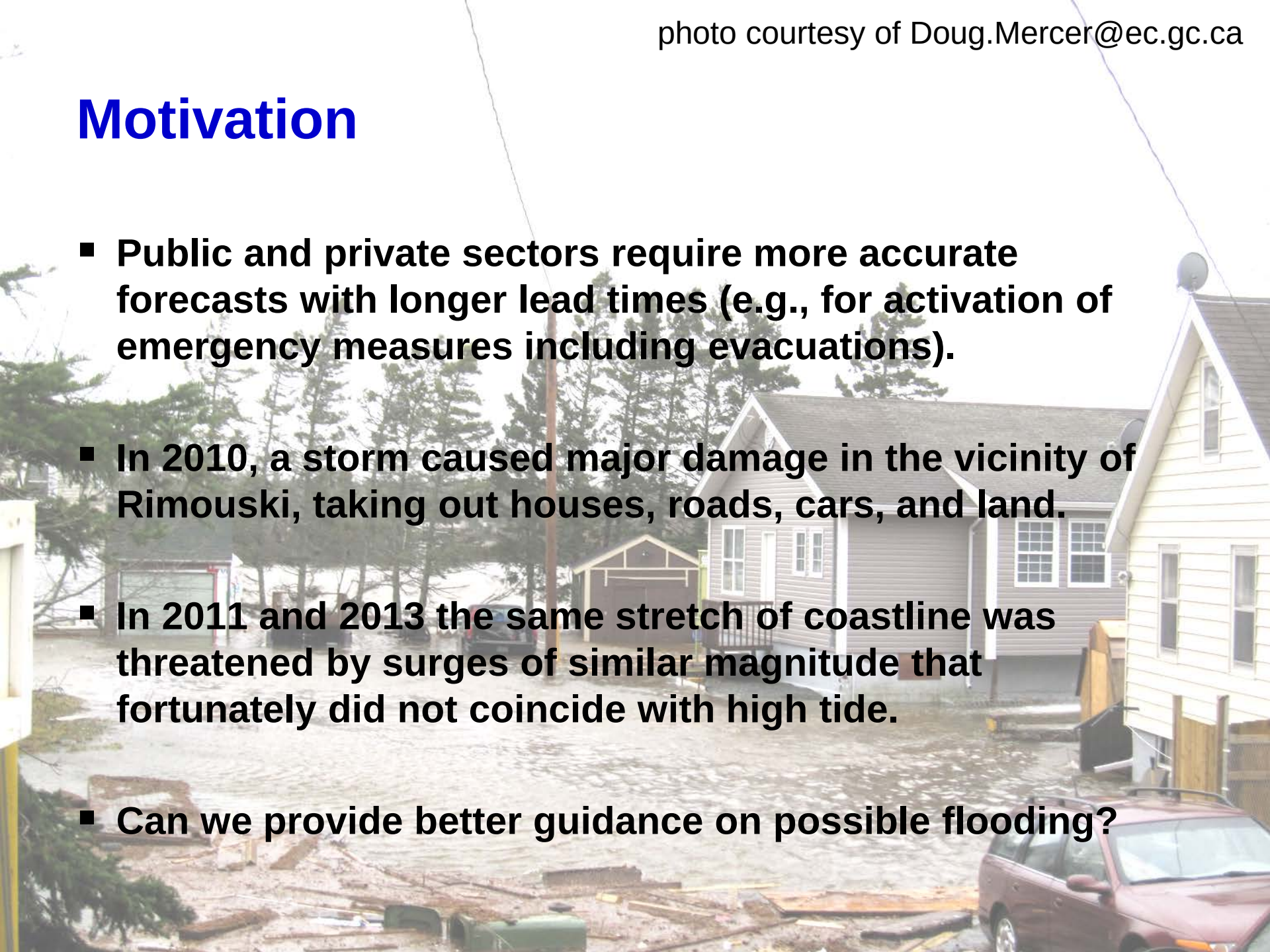


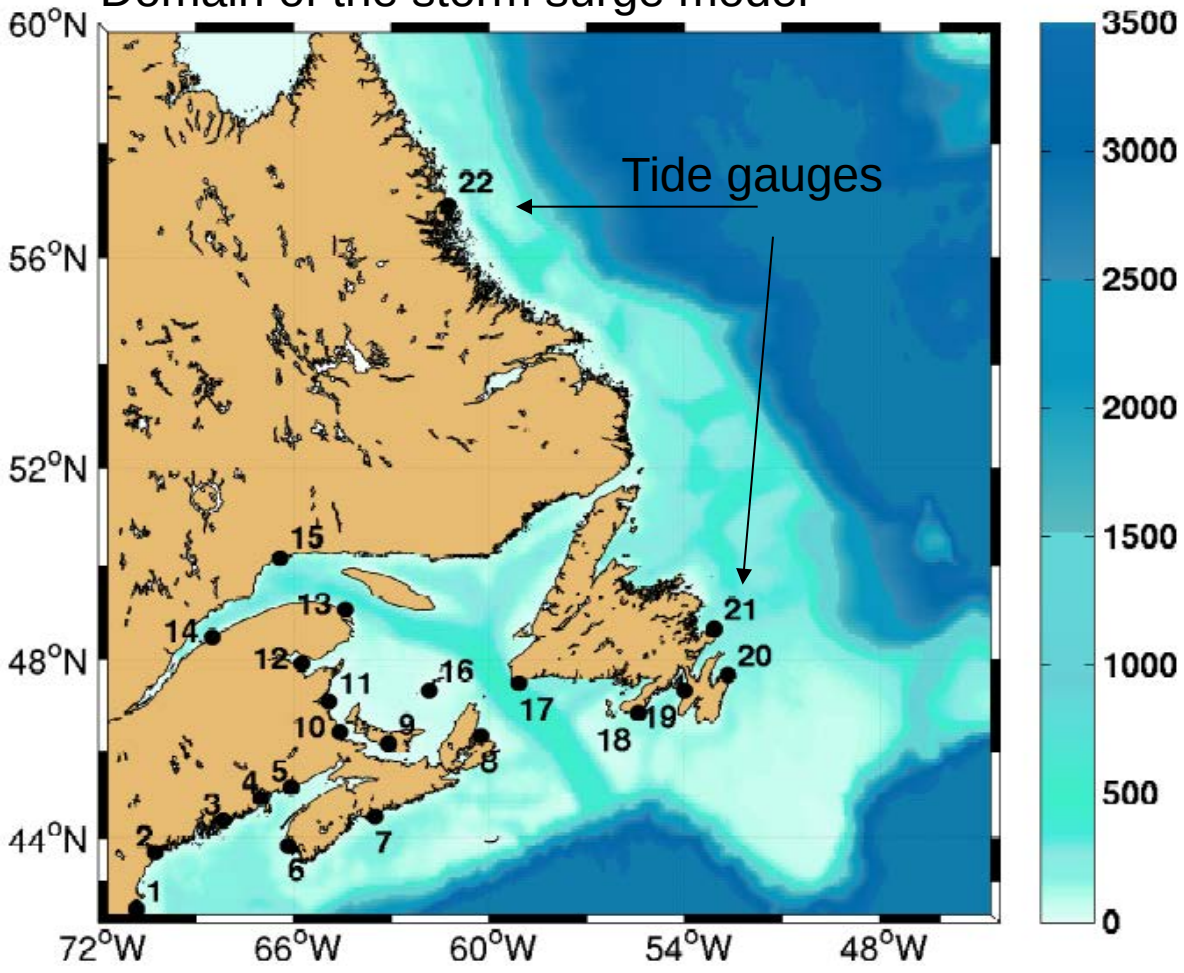
photo courtesy of Doug.Mercer@ec.gc.ca

Motivation

- **Public and private sectors require more accurate forecasts with longer lead times (e.g., for activation of emergency measures including evacuations).**
- **In 2010, a storm caused major damage in the vicinity of Rimouski, taking out houses, roads, cars, and land.**
- **In 2011 and 2013 the same stretch of coastline was threatened by surges of similar magnitude that fortunately did not coincide with high tide.**
- **Can we provide better guidance on possible flooding?**

Methodology

Domain of the storm surge model



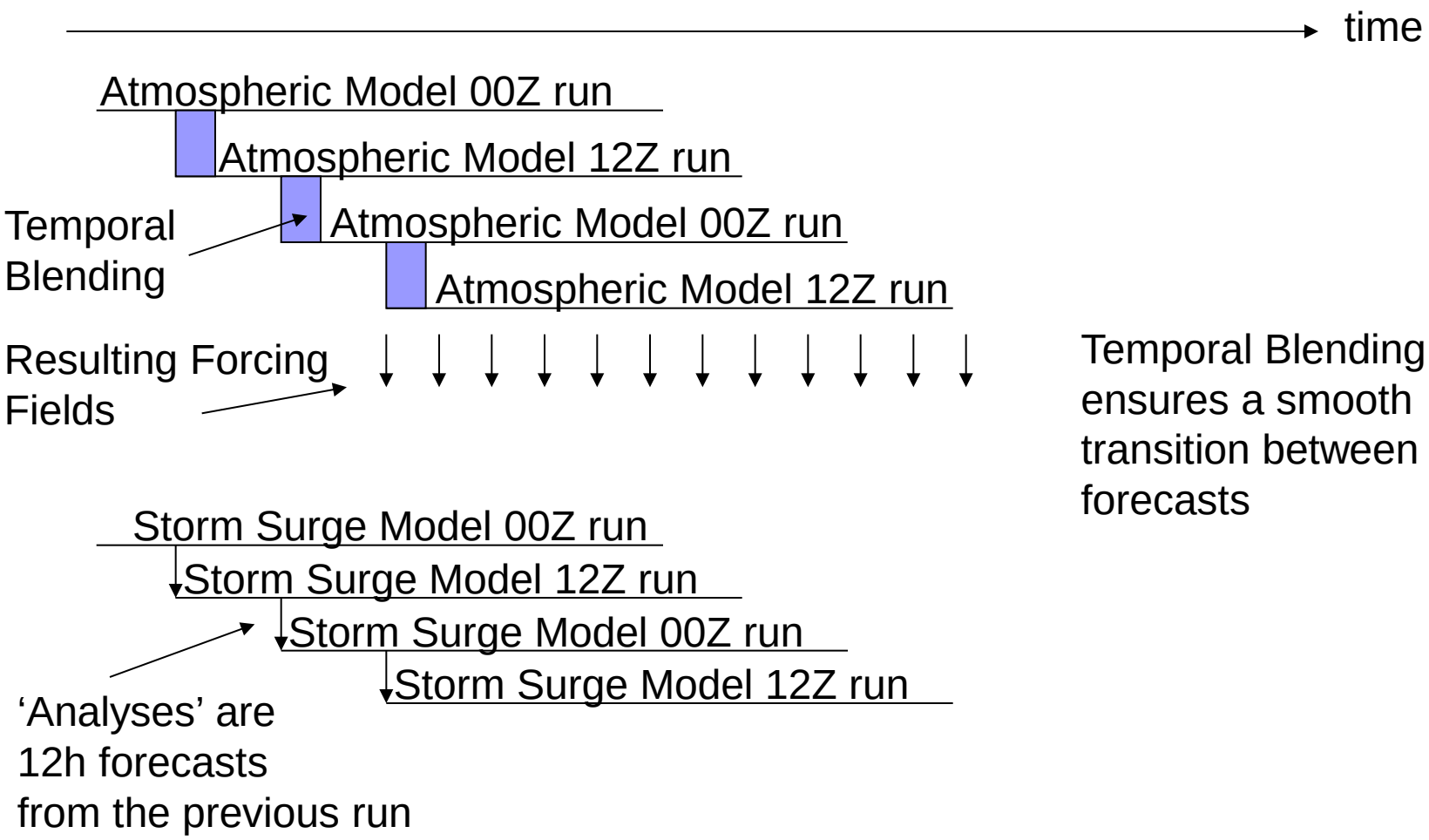
Twice daily (00Z and 12Z) deterministic runs at surge grid of 1/30° driven with the 10m winds and surface air pressure from the GDPS (~25km grid spacing)

Twice daily (00Z and 12Z) ensemble runs (20+1 members) at surge grid of 1/12° driven with the 10m winds and surface air pressure from the GEPS (~66km grid spacing)

Comments and Future Work

- Need for more accurate, and longer lead time, forecasts
- Initial runs with high resolution deterministic system show predictability out to 6 days
- Initial ensemble runs can identify events missed by the deterministic system
- Important to include physics beyond surges (e.g. tidal remnants, slow baroclinic changes). Statistical post-processing of ensemble is potentially useful
- Under MEOPAR, now working on a global system based on NEMO (and looking for a good student or postdoc!)
- → for more info:natacha.bernier@ec.gc.ca

Schematic of the Prototype Storm Surge Prediction System



Temporal Blending ensures a smooth transition between forecasts

Sea Levels in Tidally Dominated Waters

In general, observed total water levels can be decomposed as follows

$$\eta_{obs} = \eta_S + \eta_T + \eta_E$$

In reality, tides are not purely deterministic and can vary with environmental conditions. This leads us to write

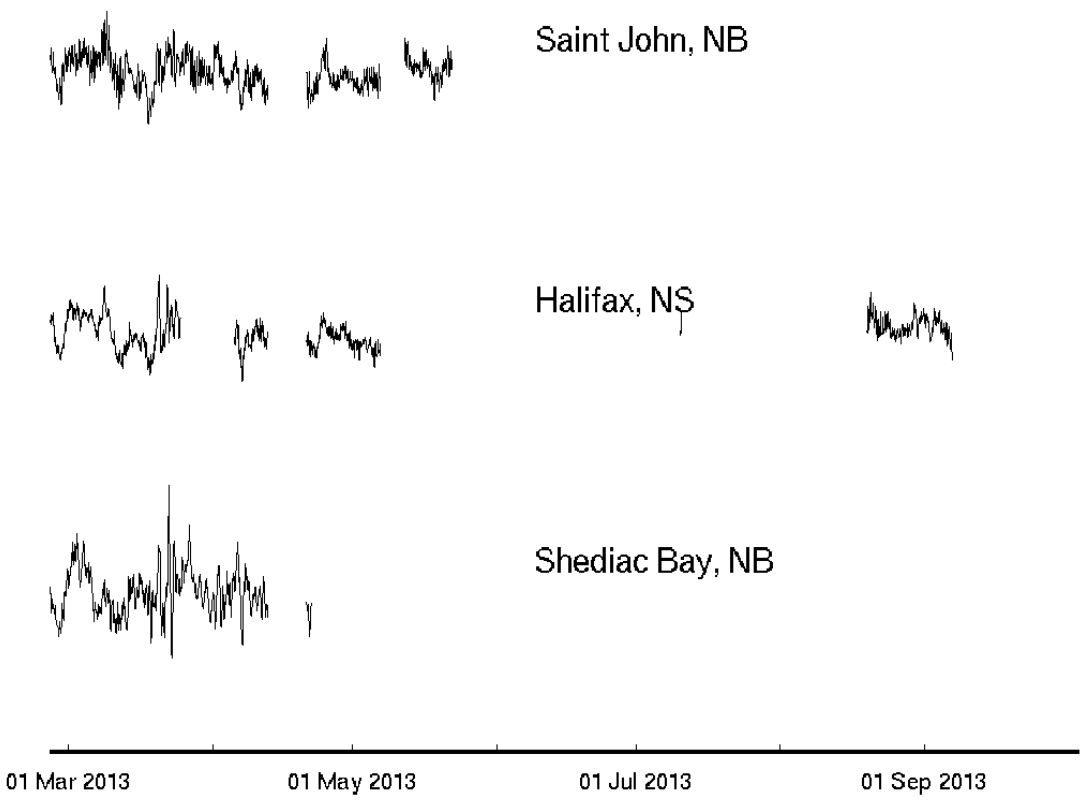
$$\eta_{obs} = \eta_{TD} + \eta_{TR} + \eta_S + \eta_E$$

For storm surge validation we use

$$\eta_{obs} - \eta_{TD} = \eta_S + \eta_{TR} + \eta_E$$

The surge forecast is an estimate of η_S. Comparing the forecast to $\eta_{obs} - \eta_{TD}$ ignores η_E and the tidal remnants, which are known to be large at times.

$\eta_{obs} - \eta_{TD}$ for Selected Gauges, 2013



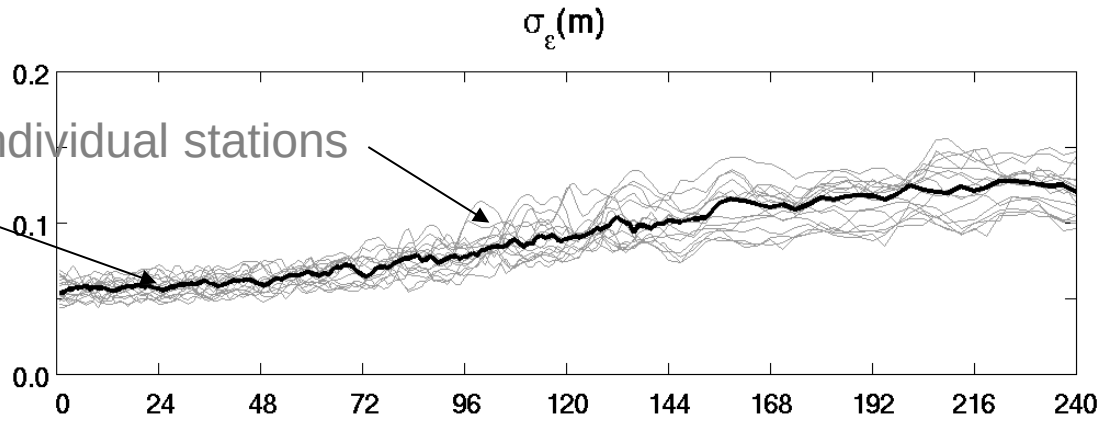
Several other records are no better. Choosing another year is not possible since both the GDPS and the GEPS underwent major changes in Feb 2013.

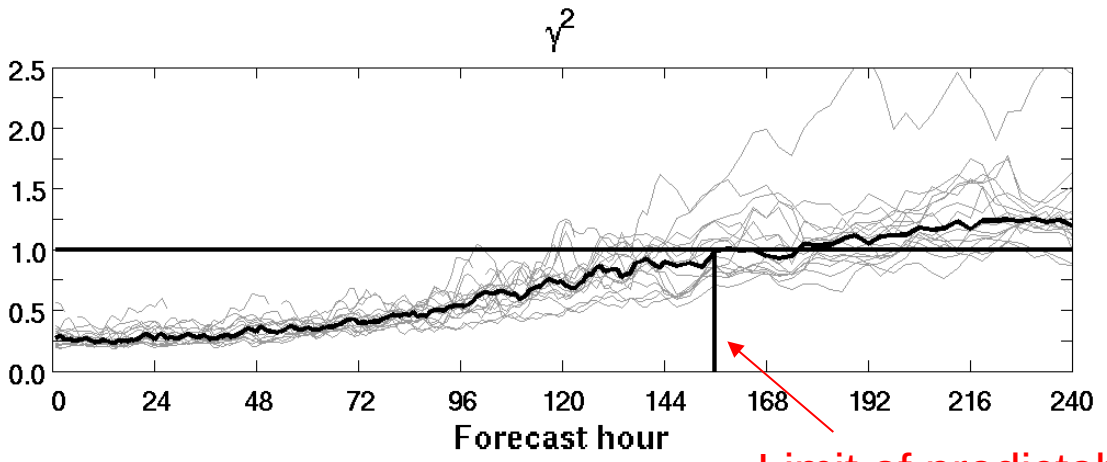
Removing the tidal signals in gappy records can be tricky – despite using all tricks short of brute band pass filtering, energy remains in some tidal bands.

How Well Can The Deterministic Model Predict Observed Surges?

Scores at individual stations

Median





Validation period:
25 Feb -25 Sep 2013

$\eta_R = \eta_{obs} - \eta_{TD}$

σ_ε = std ($\eta_R - \eta_S$)

$\gamma^2 = var(\eta_R - \eta_S)/var(\eta_R)$

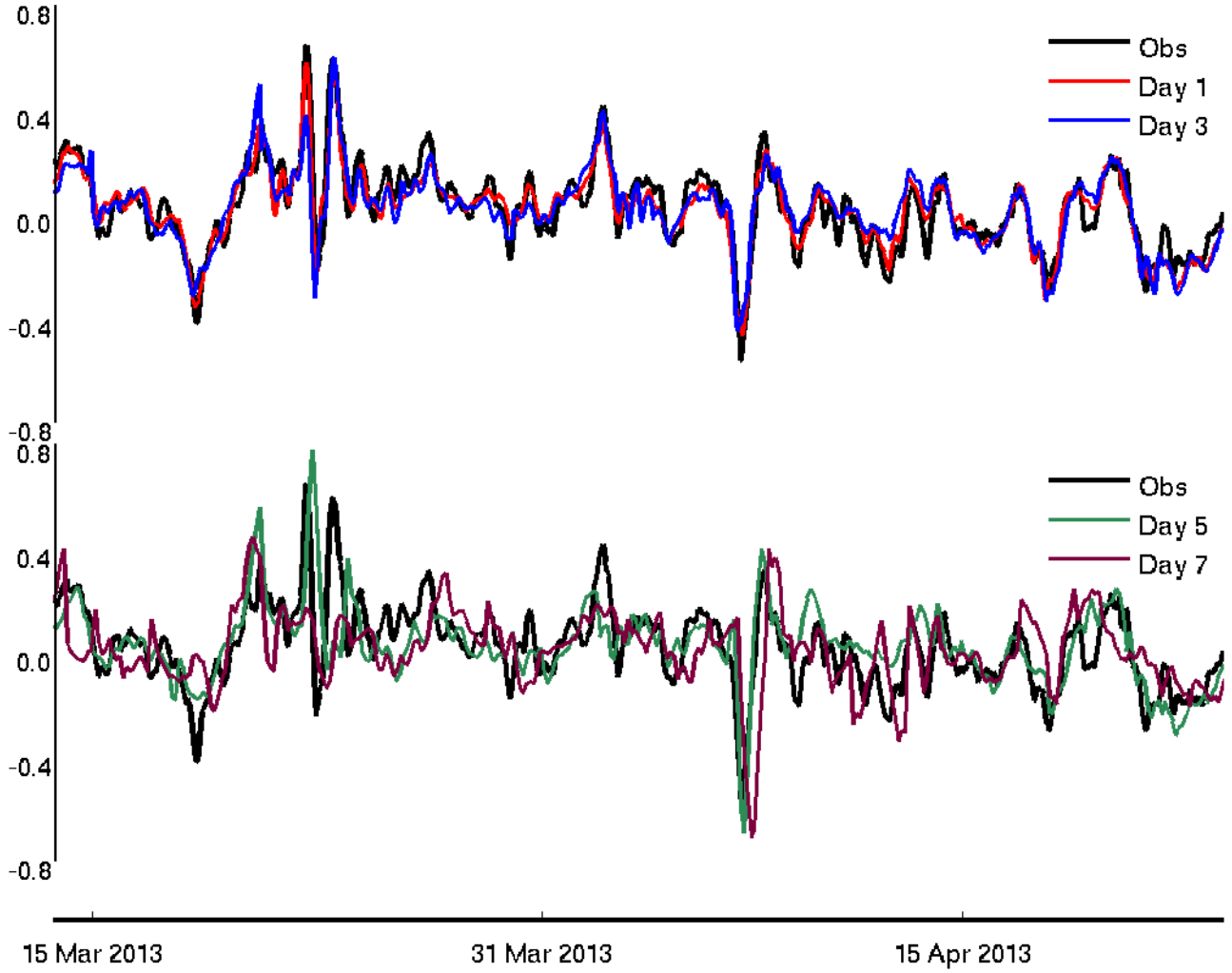
σ_ε and γ^2 are 'unforgiving' statistics, strongly influenced by small timing errors.

Is there useful information beyond 6d?

Limit of predictability of about 6 days

Deterministic Long Range Forecast Rimouski March 2013

With increasing lead time, timing of the occurrence of large surges is often off by a few hours resulting in large forecast error.



Deterministic Long Range Forecast Rimouski March 2013

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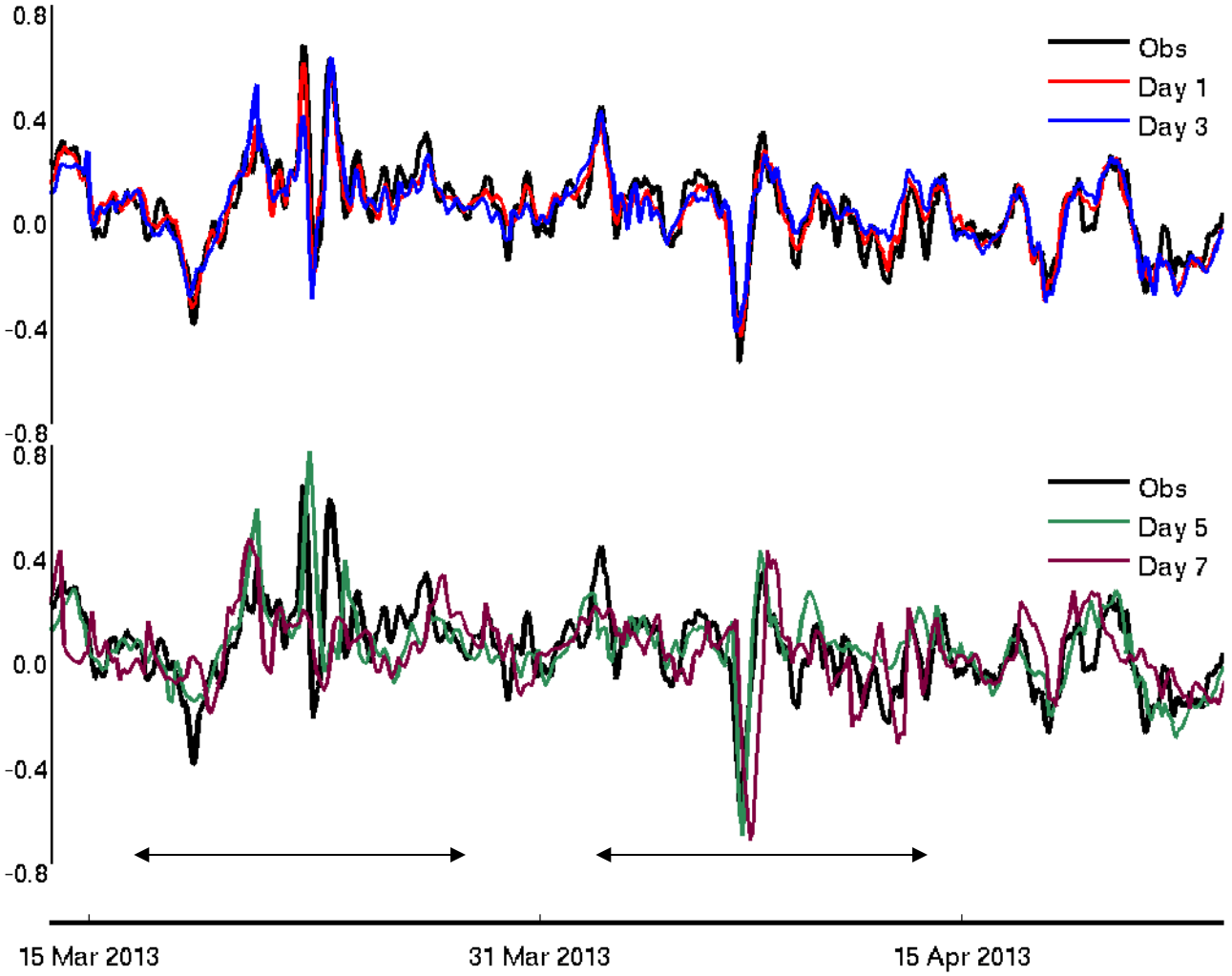
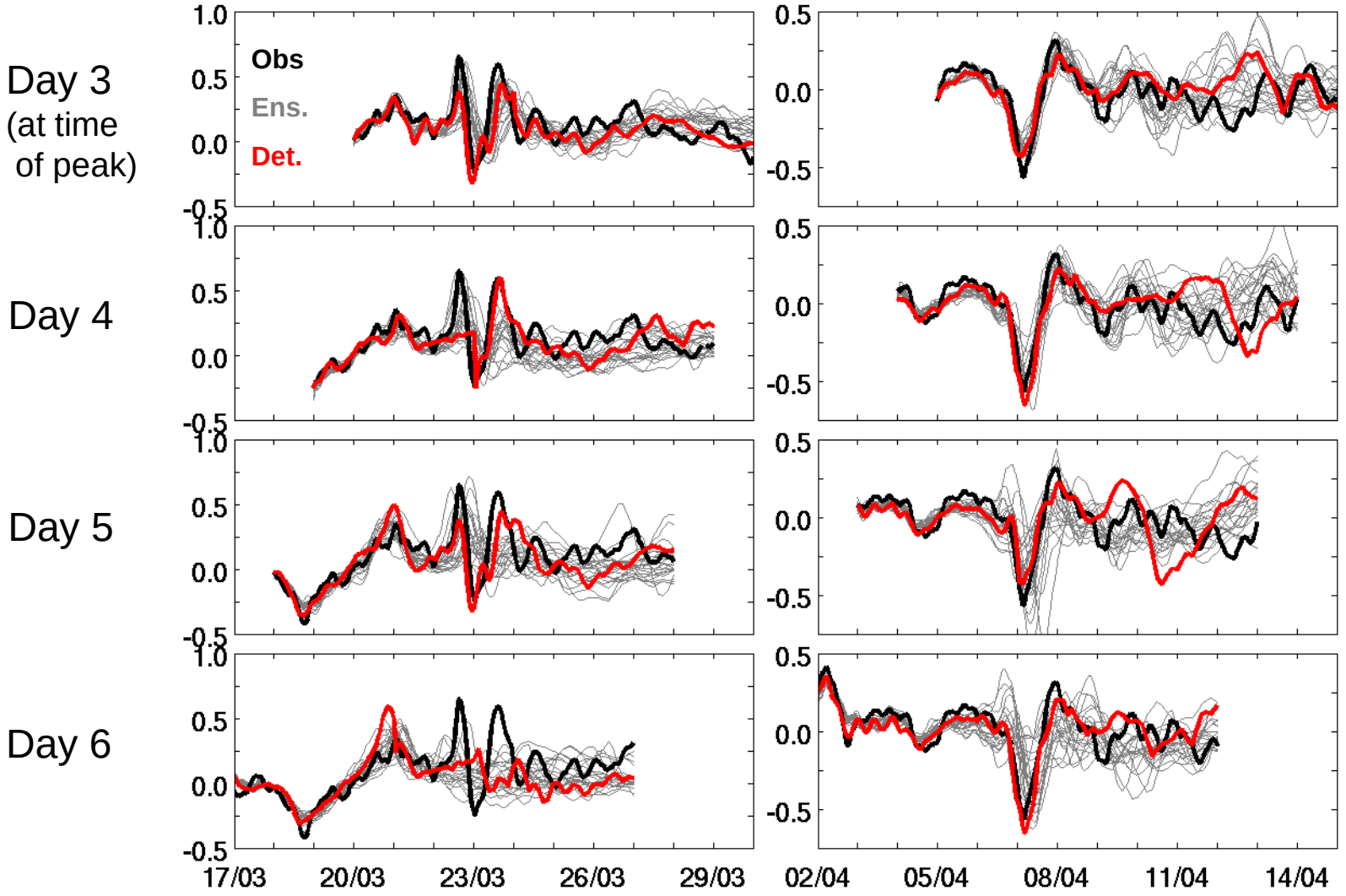
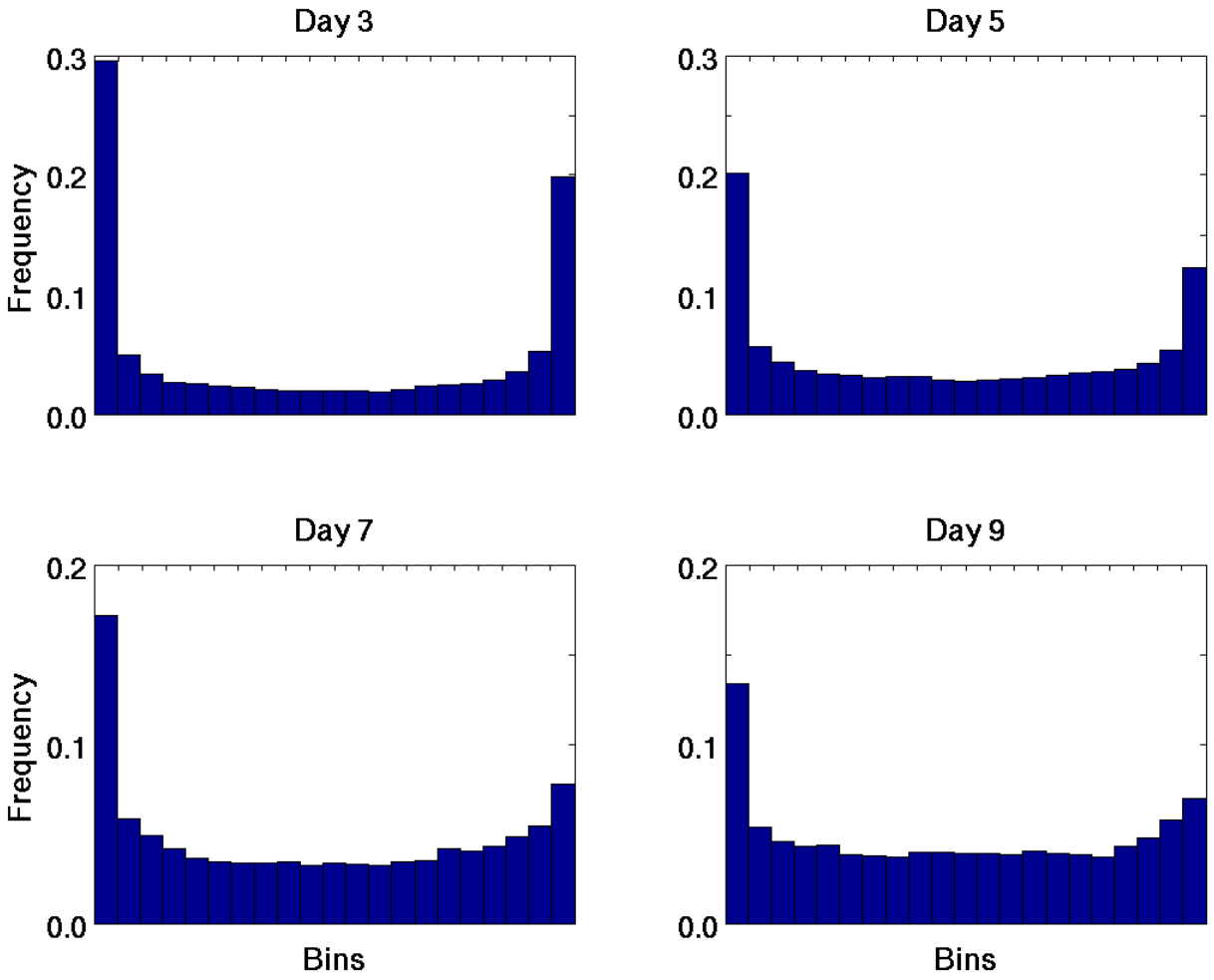
Can ensemble prediction increase the usefulness of forecasts for longer lead times?



Ensemble Forecasts (20+1 Members) Rimouski March 2013



Preliminary Evaluation of the Surge Ensemble Forecasts (25 Feb – 25 May 2013)



Talagrand diagram:

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.

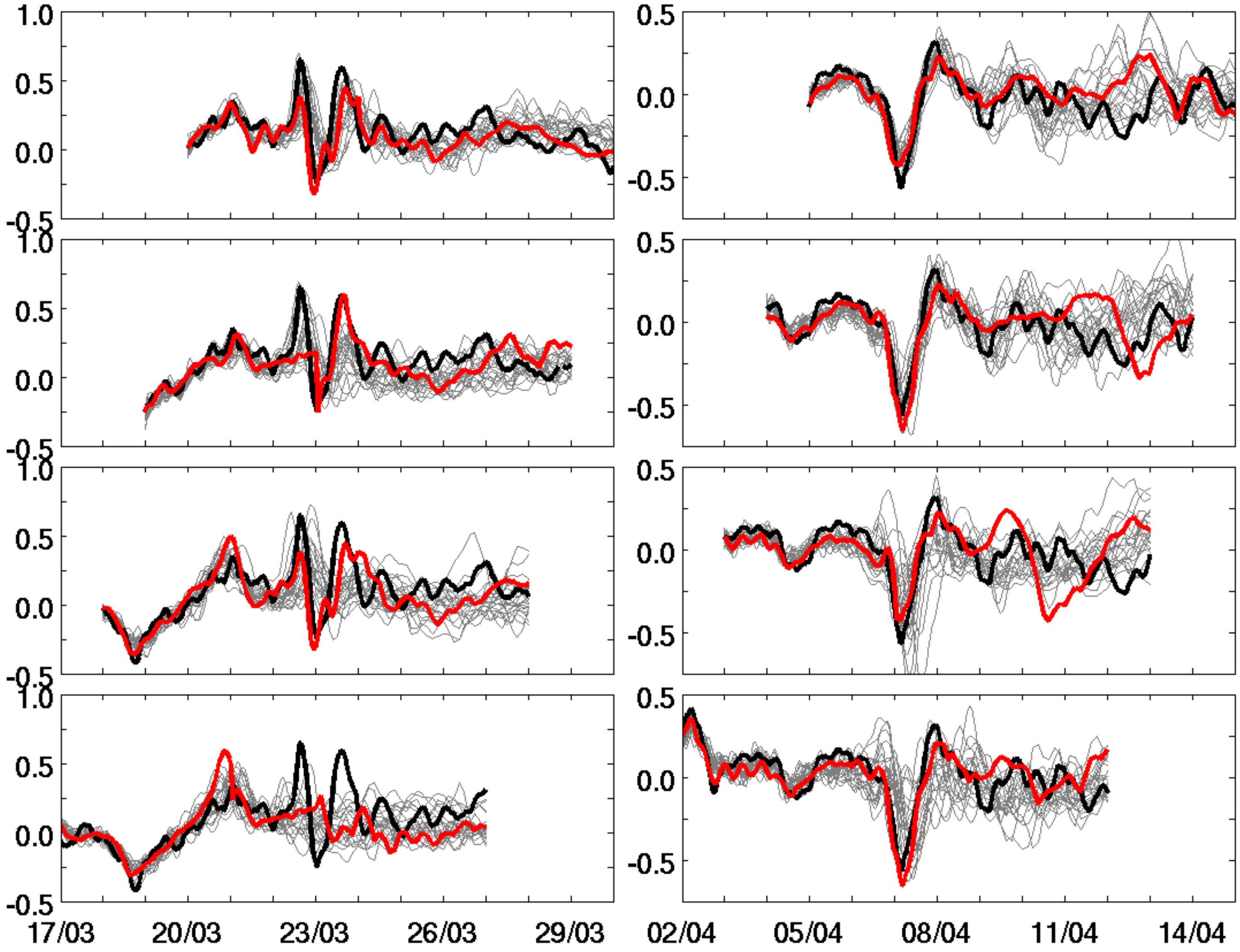
Desired outcome: Flat histogram.

The U-shape implies that the spread is too small (obs often fall outside of the ensemble).

Impact of Tidal Remnants on Spread ?

Let's add a rough estimate of η_{TR} to assess the impact on the under-dispersion of the ensemble

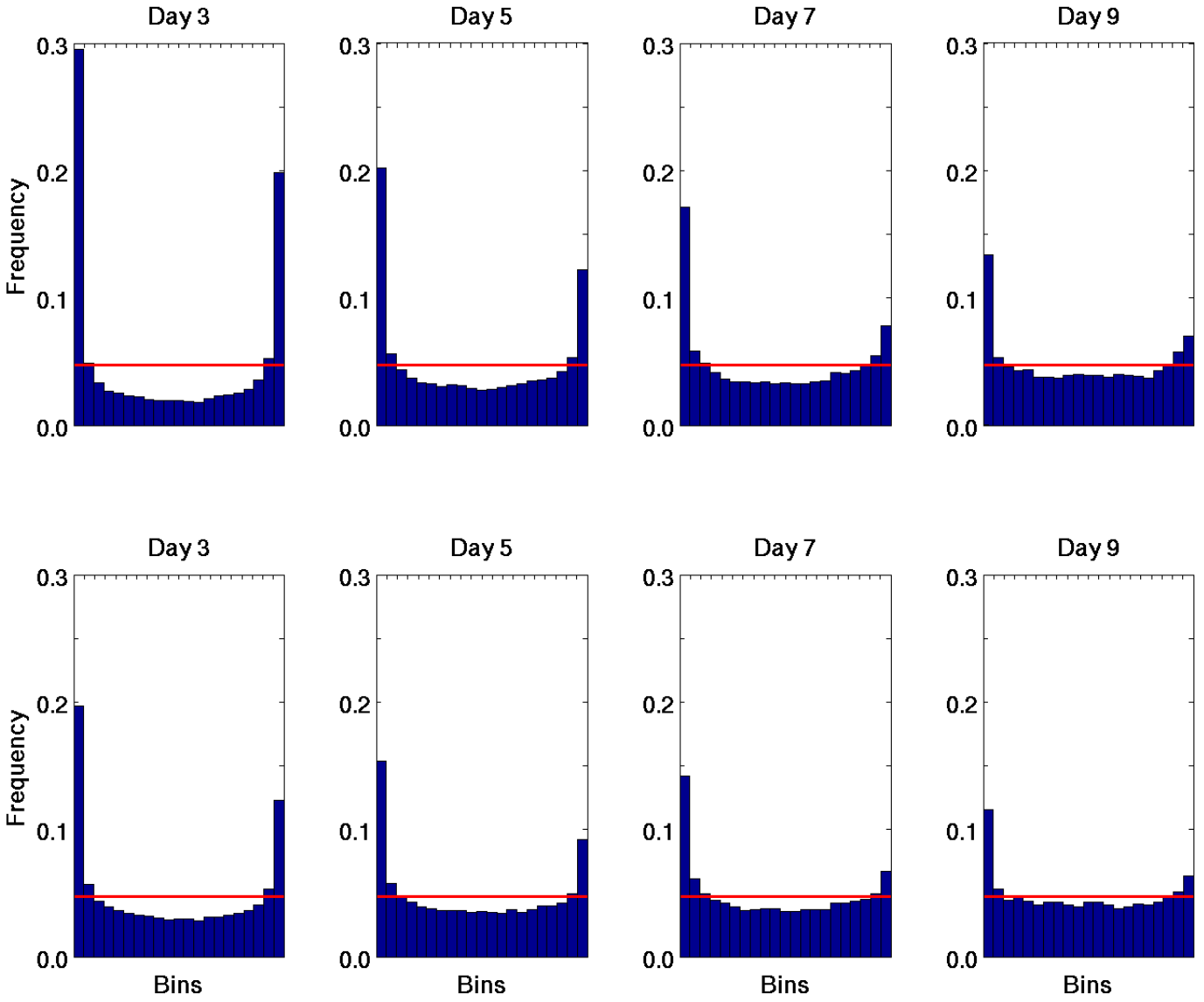
Not much difference in the overall forecasts but is the dispersion better?



Impact on the Ensemble Spread

Before

After



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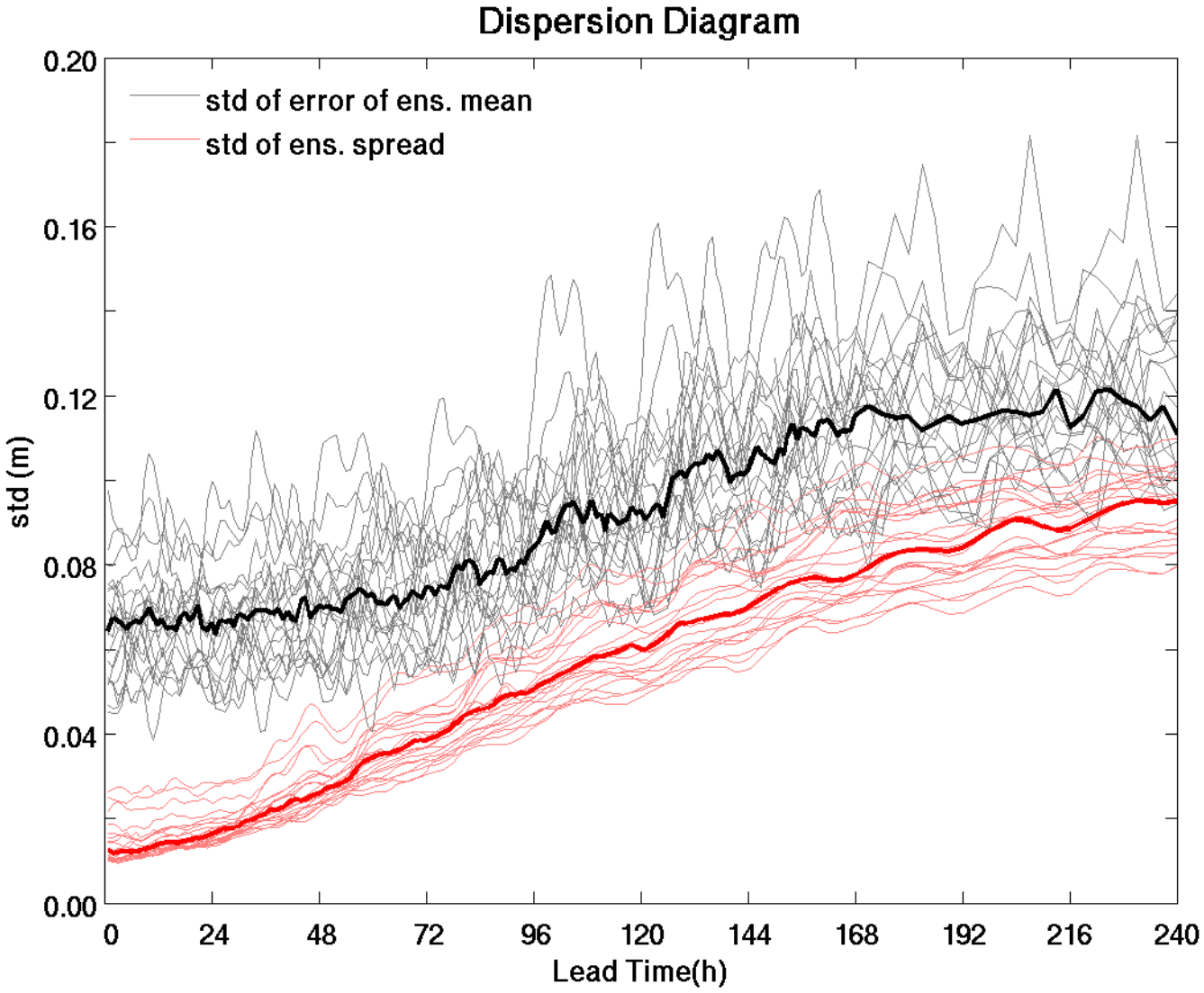
How Much Spread is Missing Before η_{RT} is Added?



In an ideal ensemble prediction system the std of the spread (red) should match the std of the error of the ensemble mean (gray).

In this system, spread (which can also be though of as a measure of uncertainty is under-forecast.

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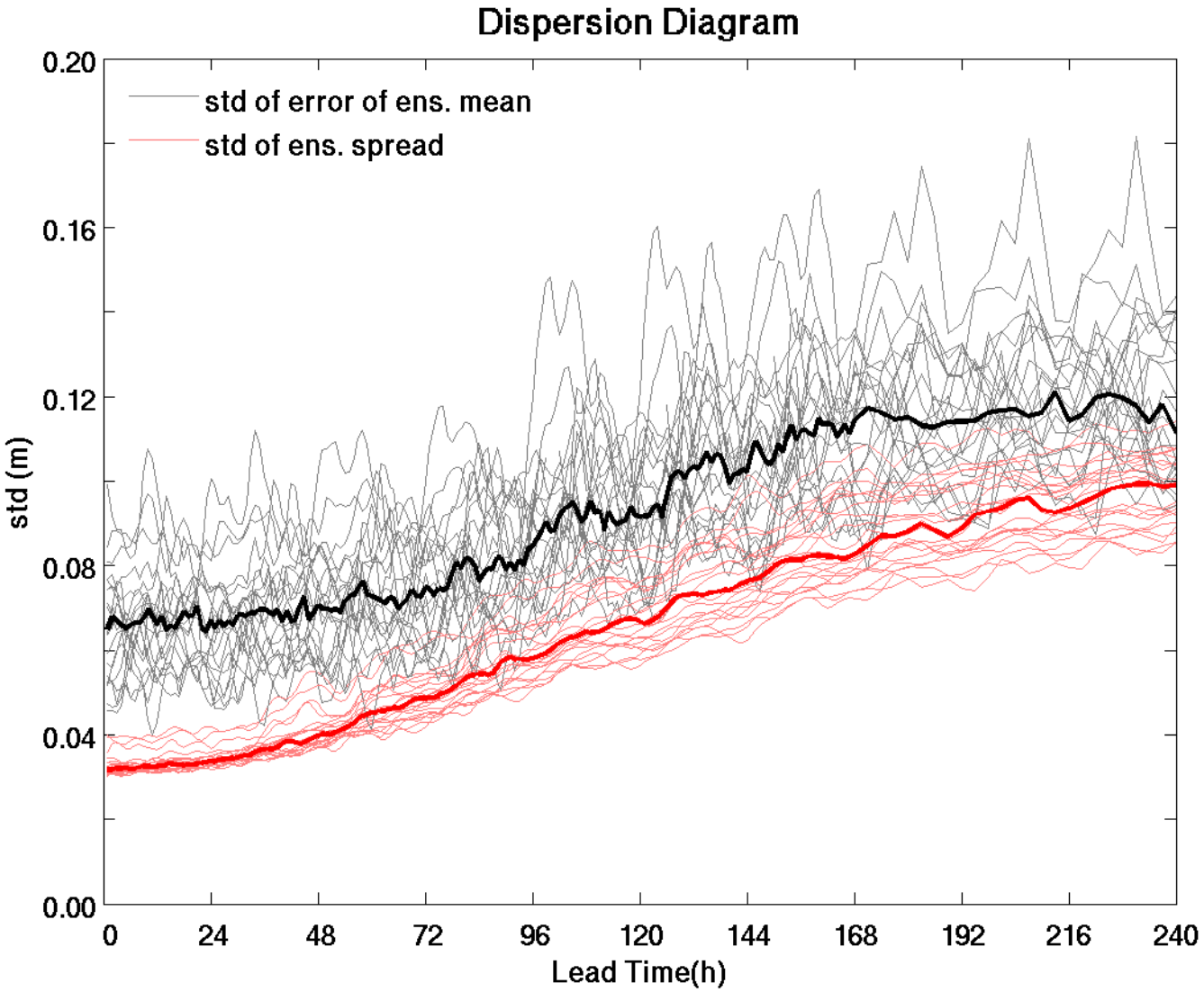

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