MyWave

OpenDA

Deltares
Enabling Delta Life

TU Delft

Ensemble based data-assimilation for the SWAN spectral wave model

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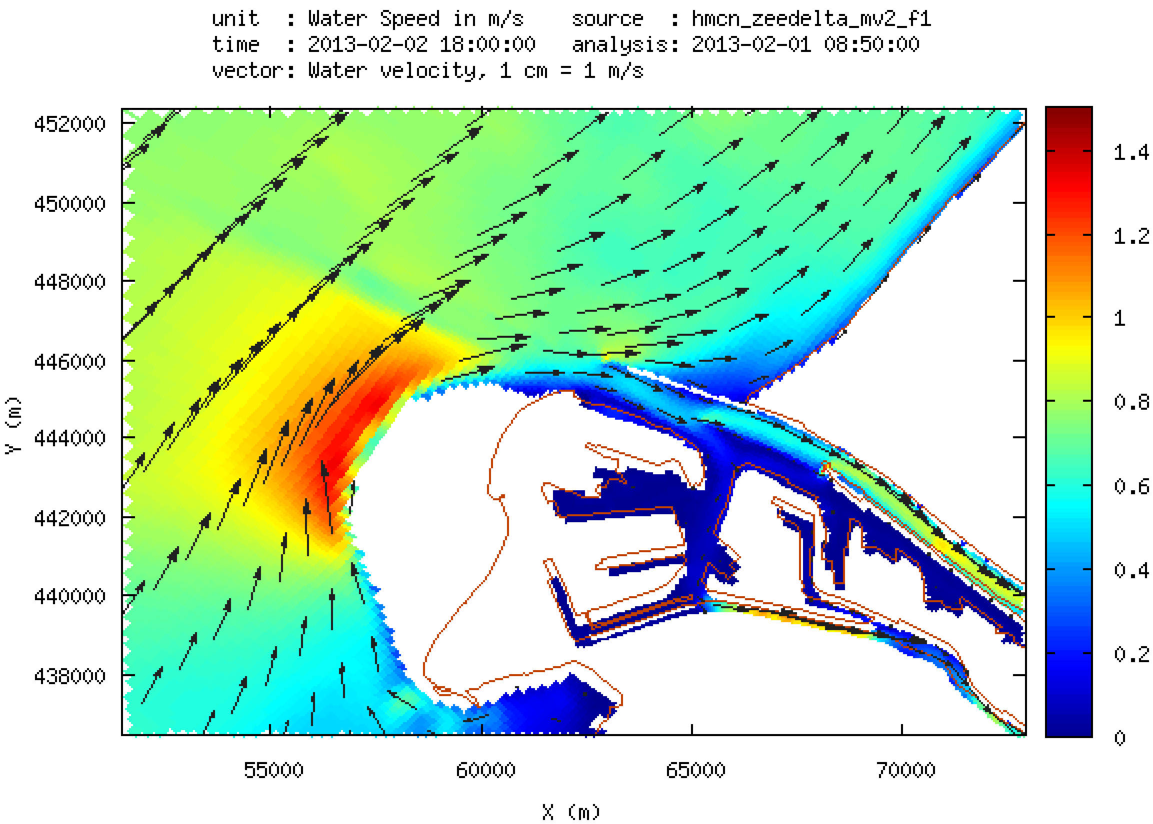
EnKF workshop
23-25 June 2014

Outline

- Wave forecasting
- Spectral wave model (SWAN)
- EnKF
  - OpenDA and implementation
- Twin expriments with 1D model
  - Model errors
- Twin experiments with 2D model
  - Parallel computing
- December 2011 with 2D model
  - Tuning parameters
- Future work

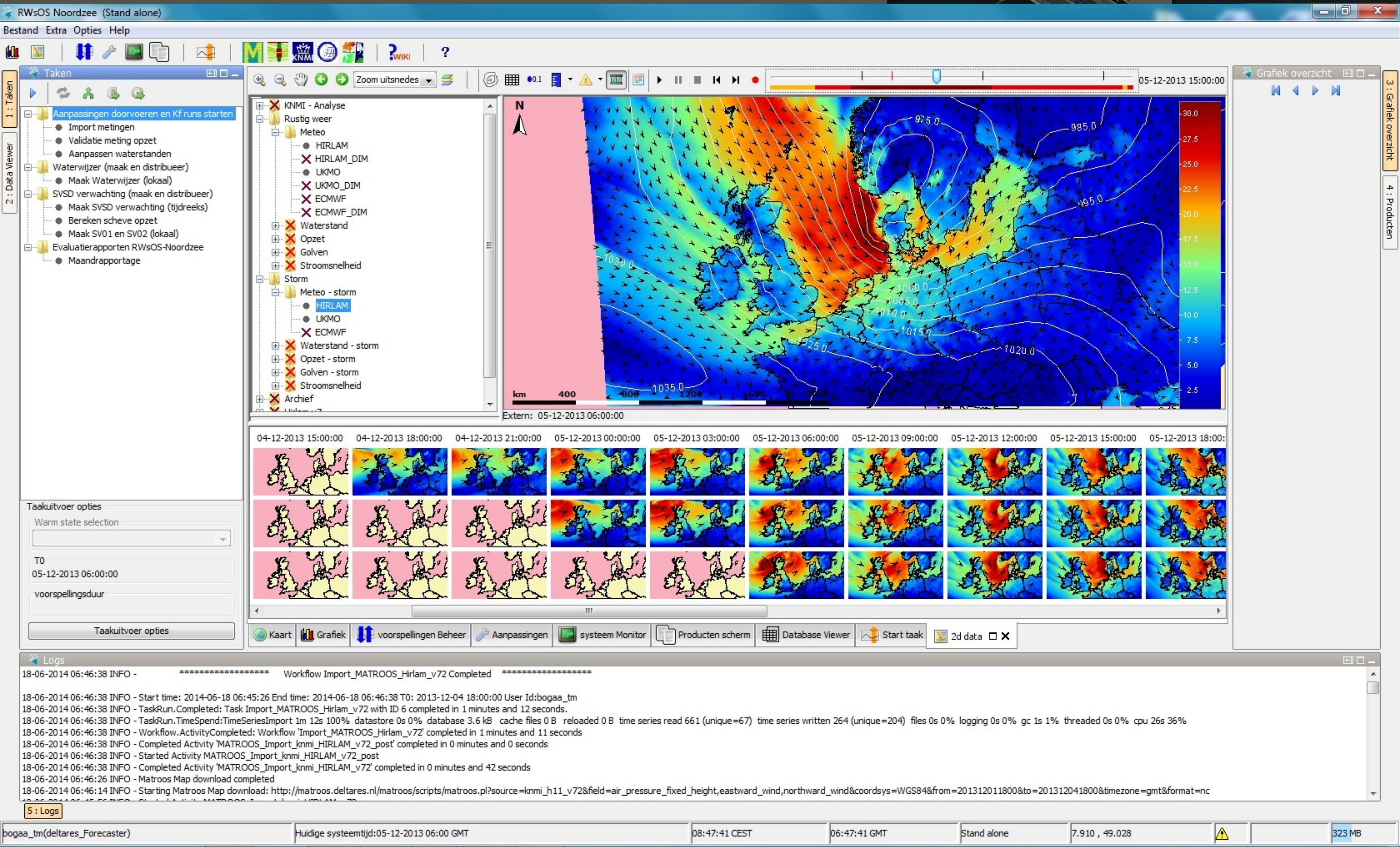
Maritime safety



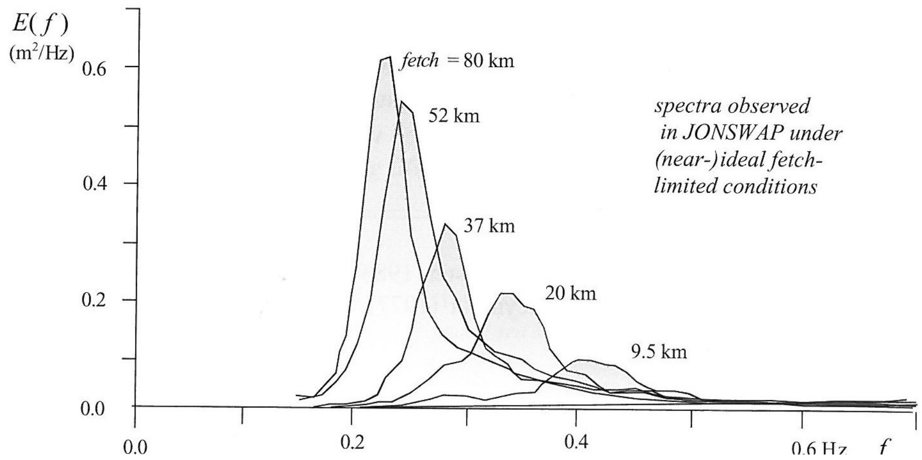
Shore protection

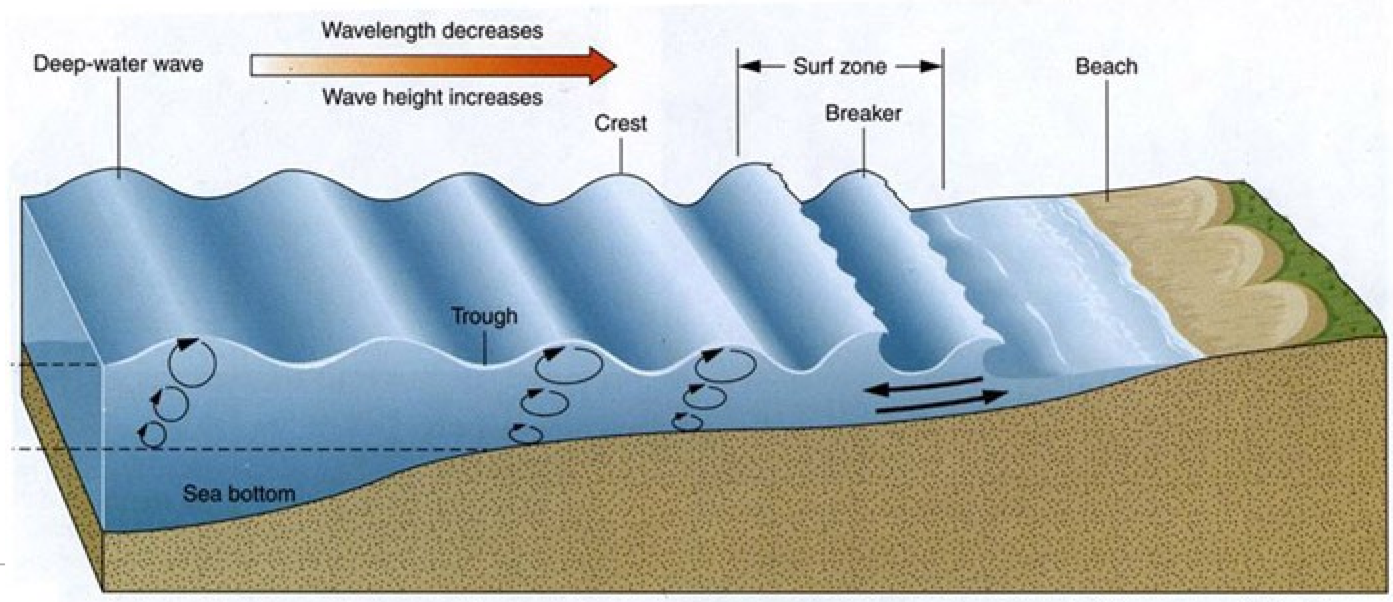
Floodmark

Forecasting system



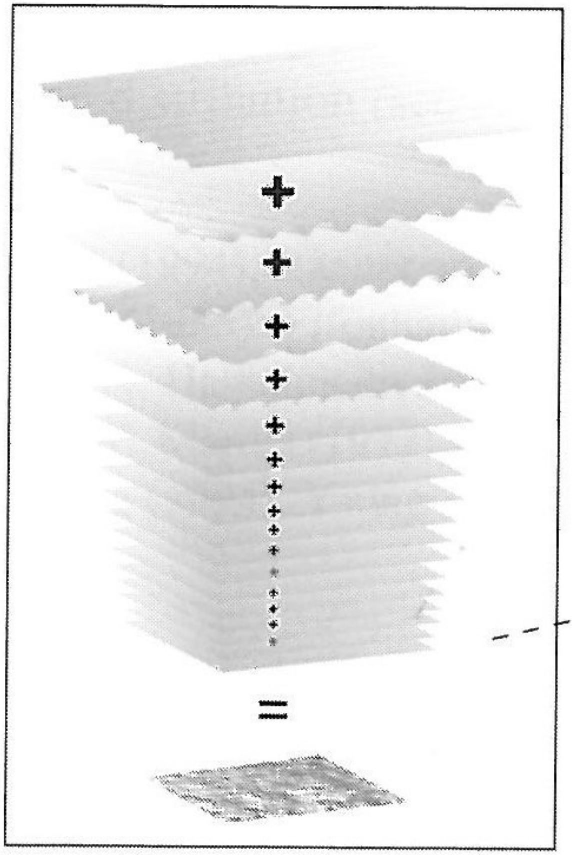
Simulating Waves Near-shore SWAN





(Plummer et al., 2001)

Simulating Waves Near-shore SWAN



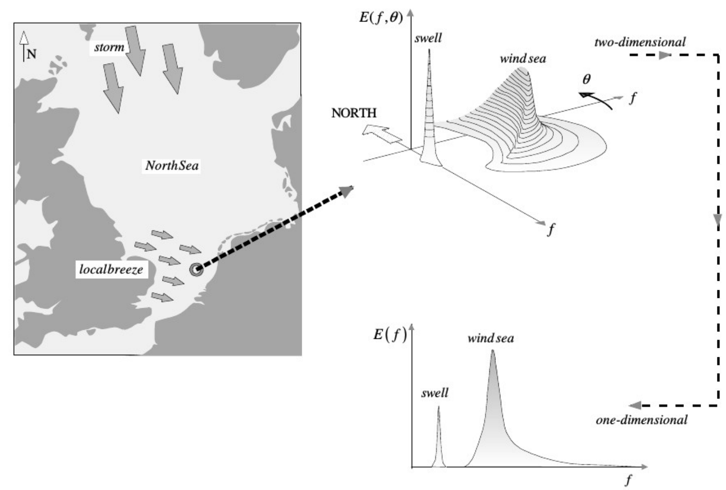
random-phase/amplitude model

$$\frac{\partial N(x,y,\sigma,\theta)}{\partial t}+\frac{c_x \partial N(x,y,\sigma,\theta)}{\partial x}+\frac{c_y \partial N(x,y,\sigma,\theta)}{\partial y}$$

$$+\frac{c_\sigma \partial N(x,y,\sigma,\theta)}{\partial \sigma}+\frac{c_\theta \partial N(x,y,\sigma,\theta)}{\partial \theta}=\frac{S(x,y,\sigma,\theta)}{\sigma}$$

Sources:

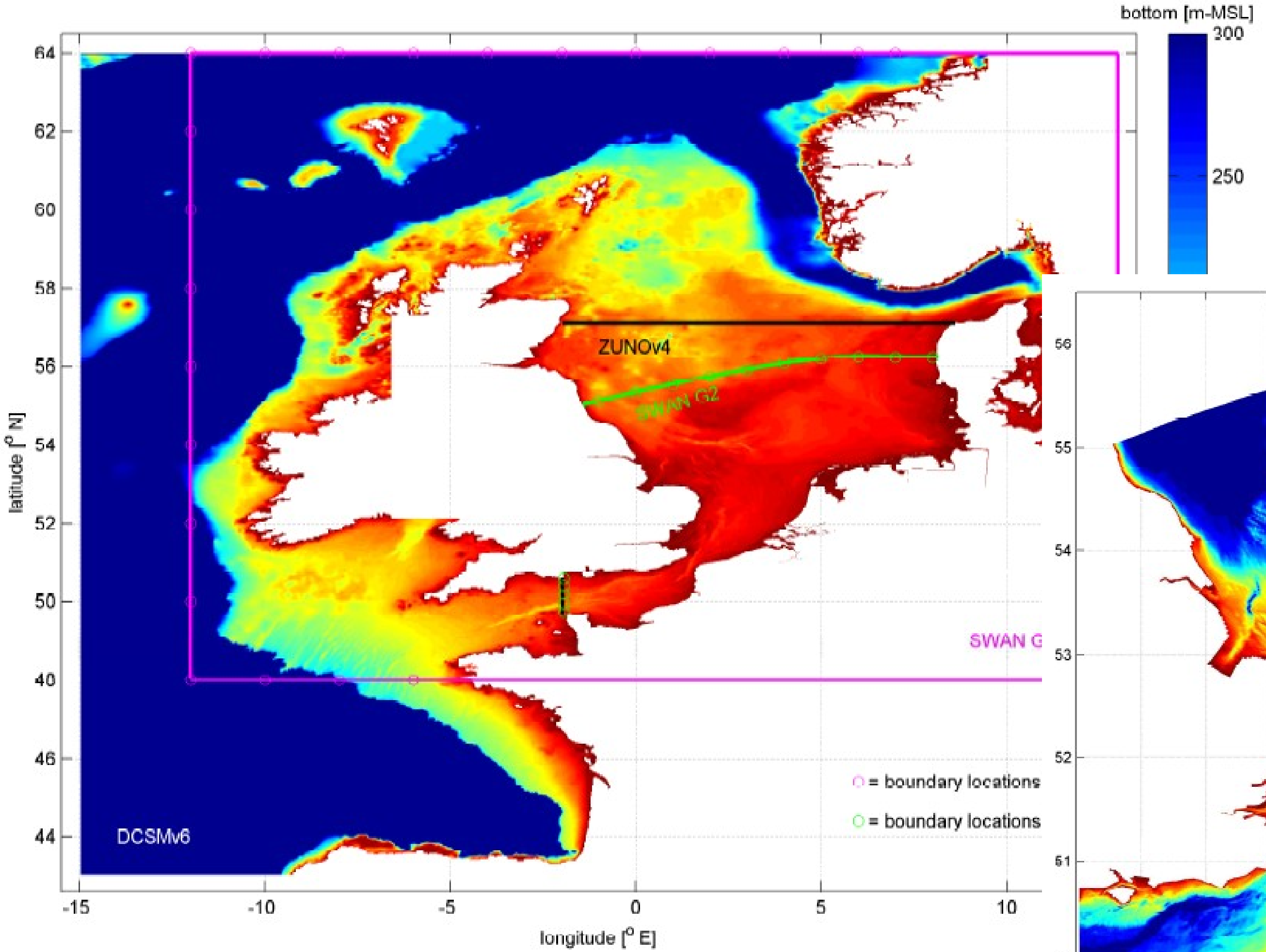
- Wind generation
- Non-linear interactio
- White-capping
- Friction
- ...

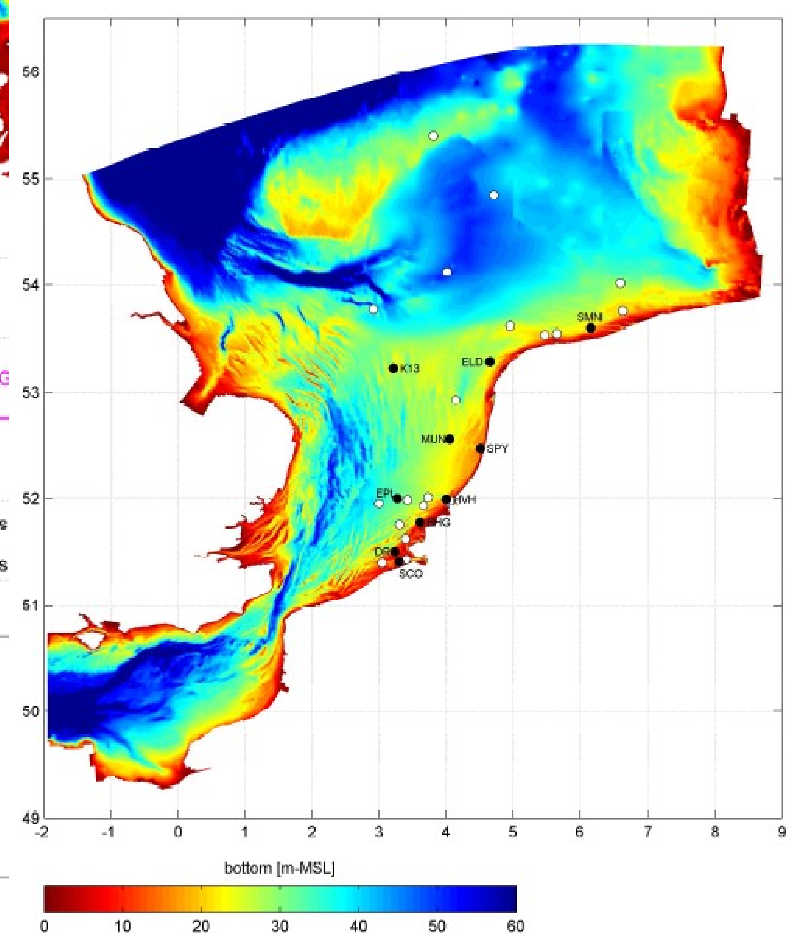


Significant waveheight $H_s(x,y)=4\sqrt{\iint N(x,y,\sigma,\theta)\,\sigma\, d\sigma\, d\theta}$

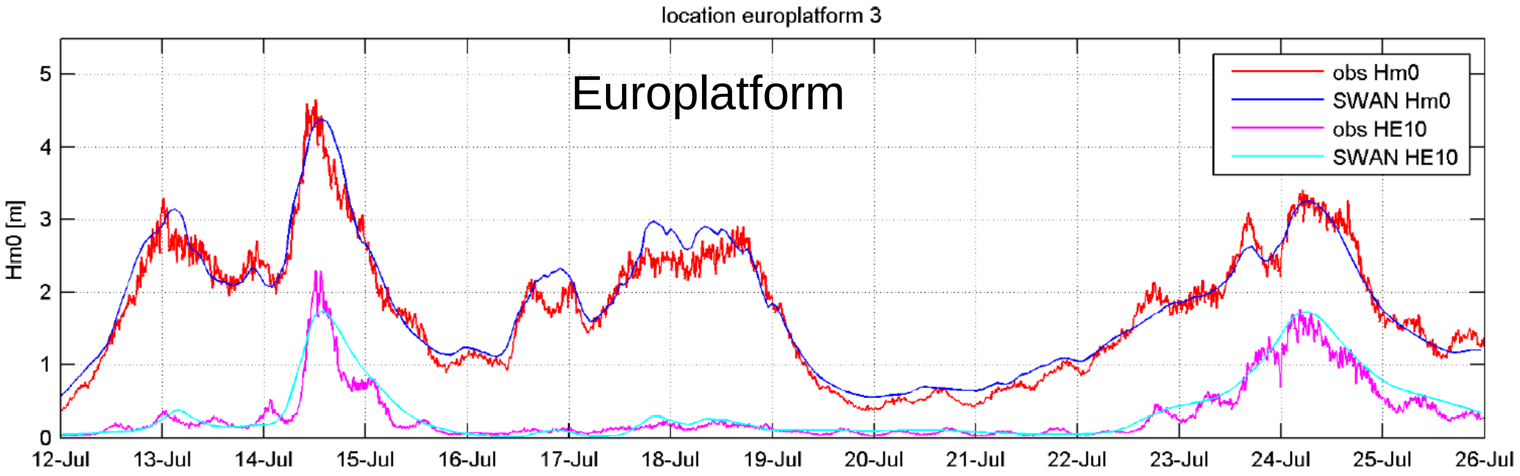
dispersion $c_g=\frac{\partial \sigma}{\partial k}$ $\sigma^2=g\,k\tanh k\,d$

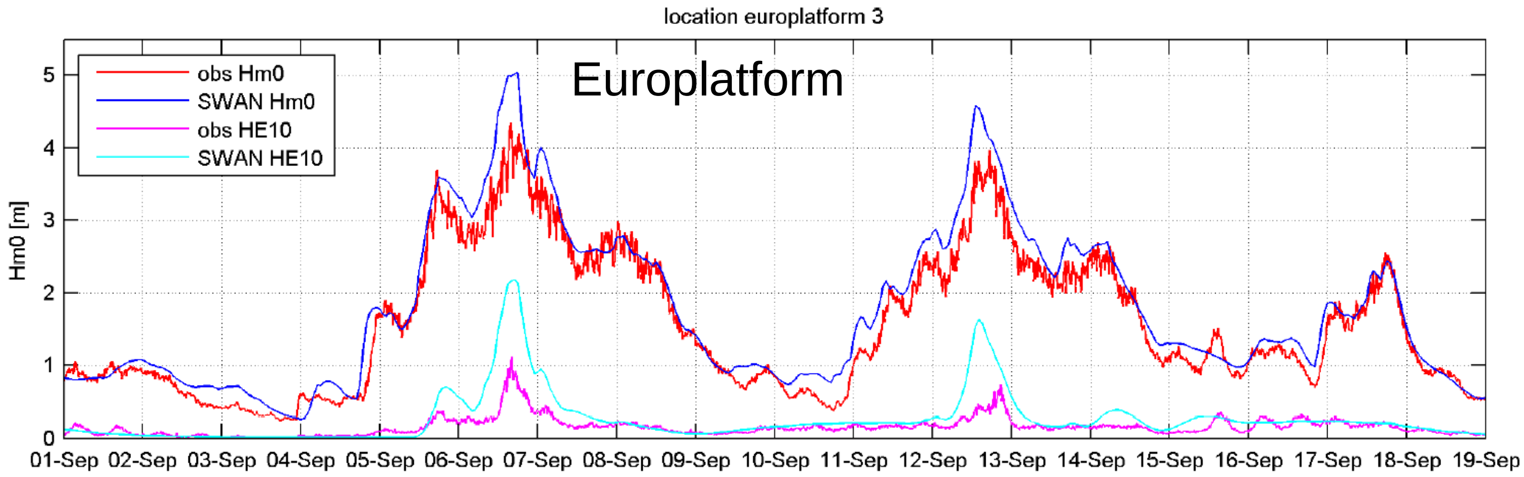
SWAN model for North Sea





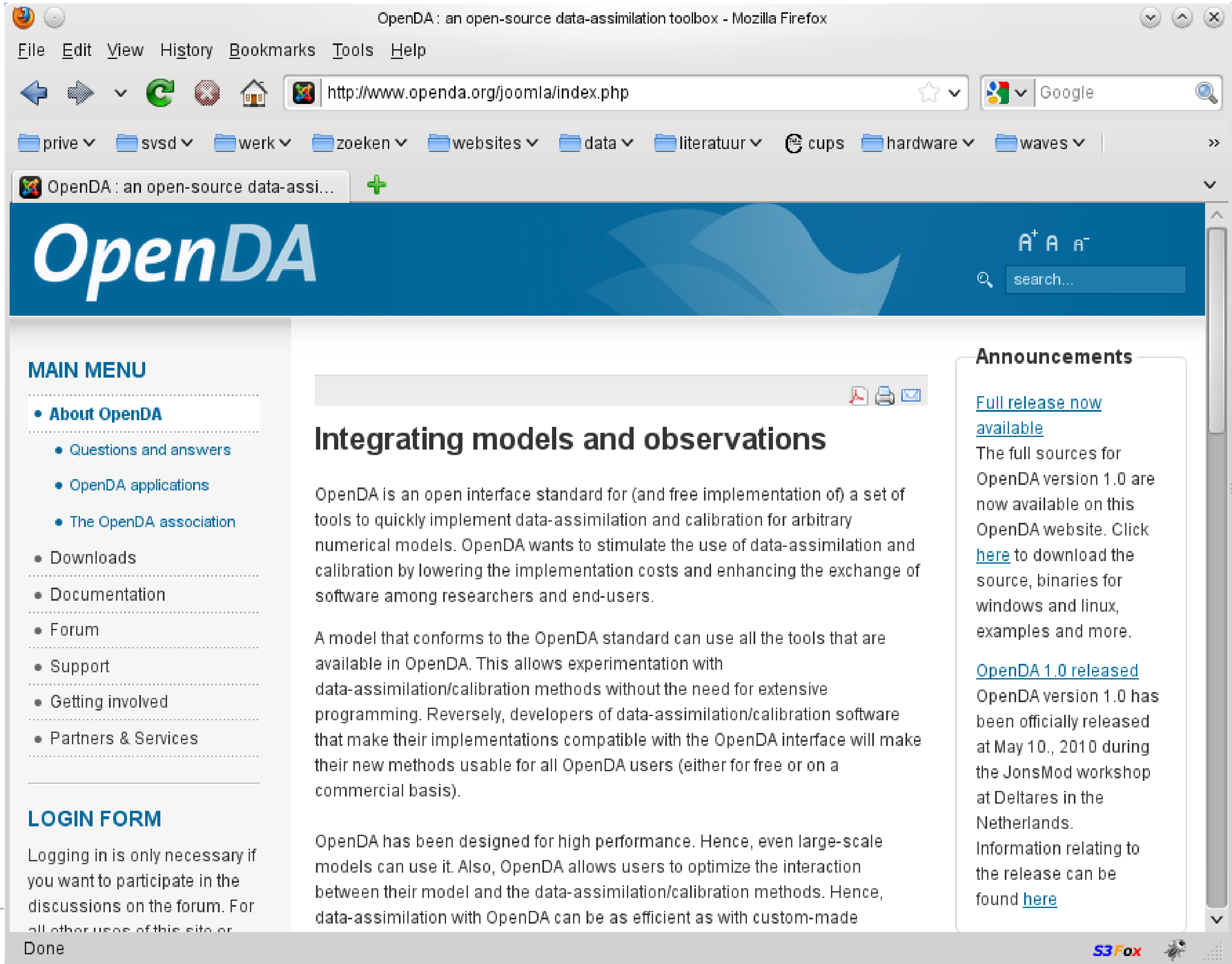
SWAN model for North Sea





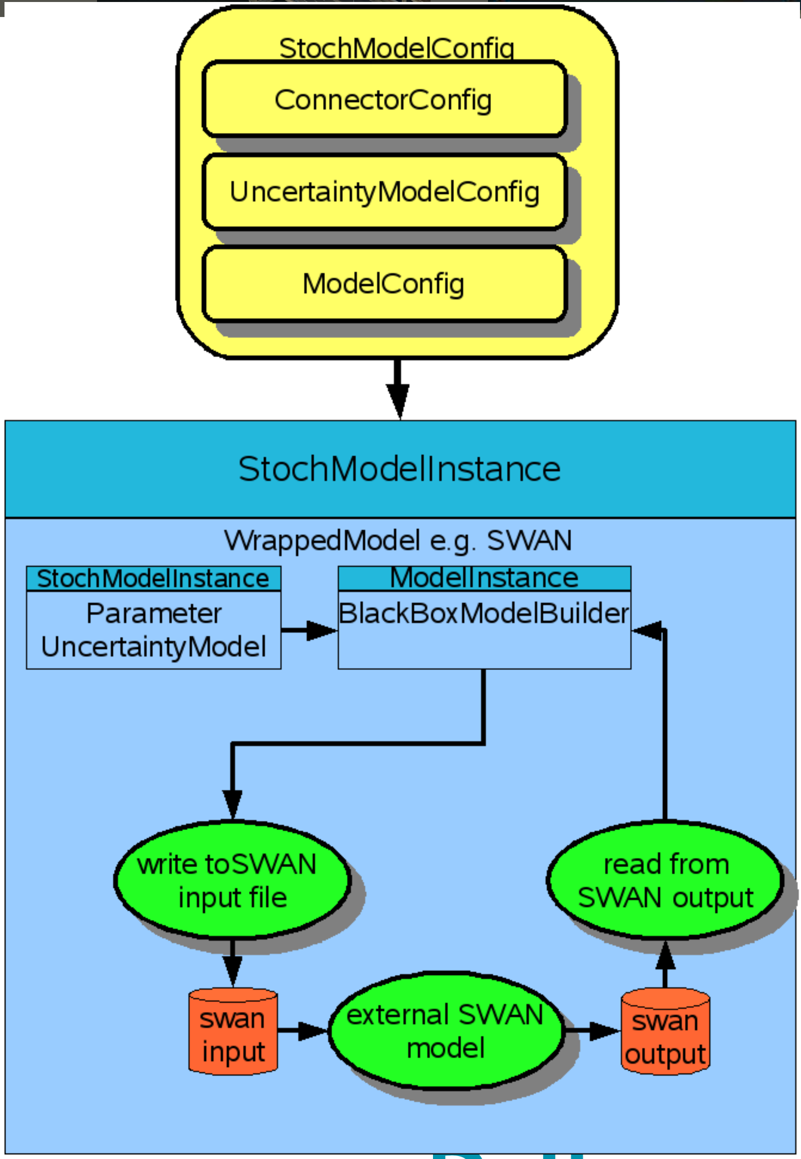
Open-source data-assimilation tools

http://www.openda.org



OpenDA black-box wrapper

- Uses input and output files of the model
- No source code of the model is needed
- Easy to implement
- May hinder performance



Data-assimilation settings

- EnKF algorithm
  - 128 ensemble members
  - Synchronous or asynchronous assimilation
  - No localization
  - No inflation
  - Truncation of negative energy densities
- Model uncertainty:
  - Exponential time-correlation for additive error to H_s at the boundary
  - Exponential spatial and temporally correlated wind errors
- Uncorrelated observation errors

Twin experiment 1D

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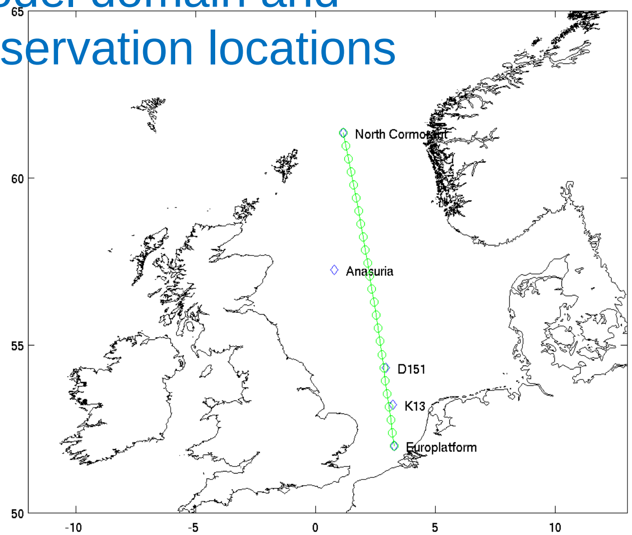
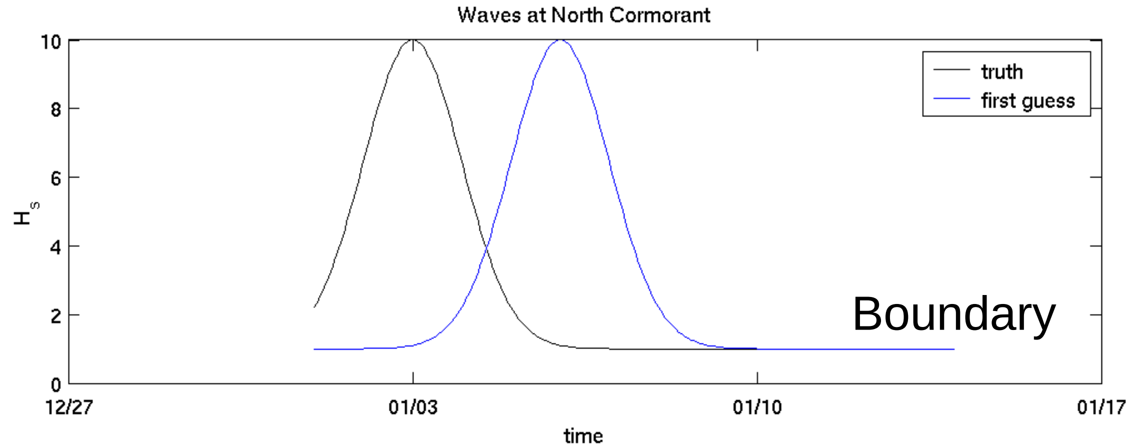
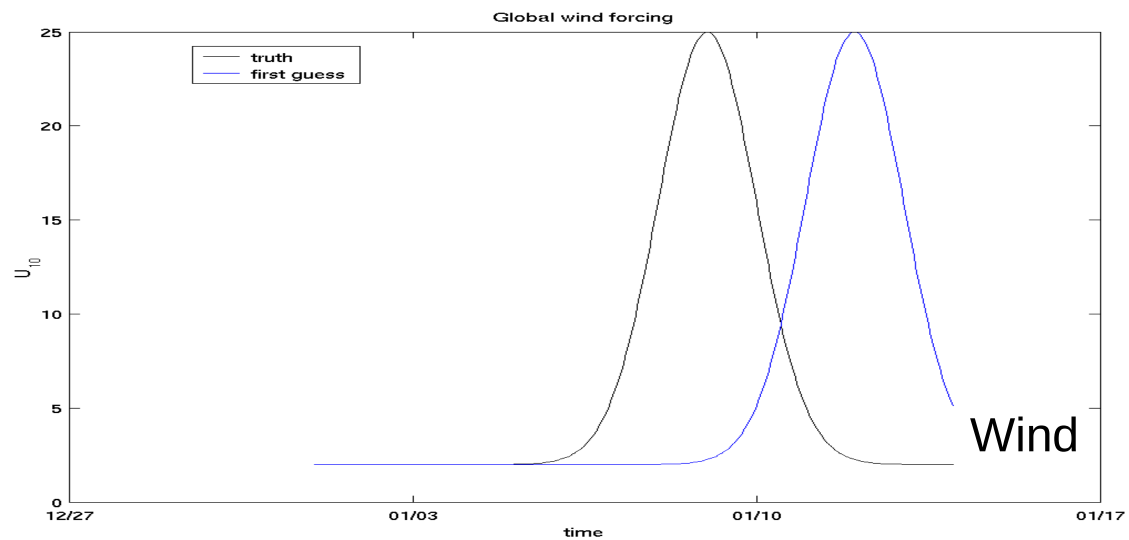
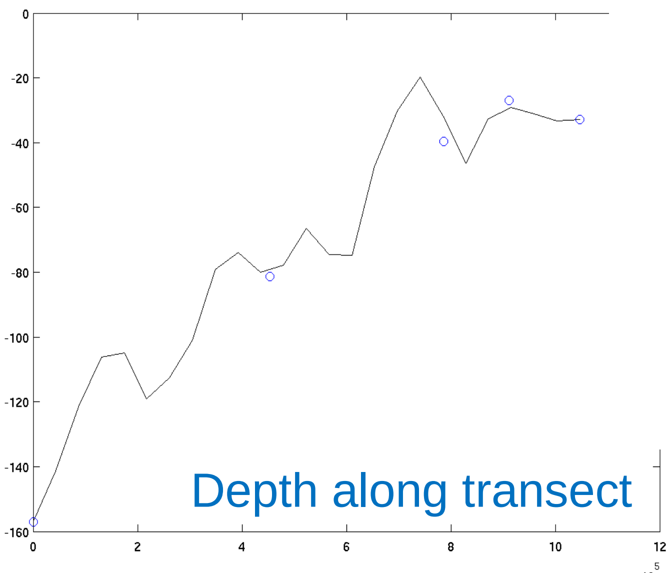
Model domain and observation locations









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1^{st} experiment for boundary

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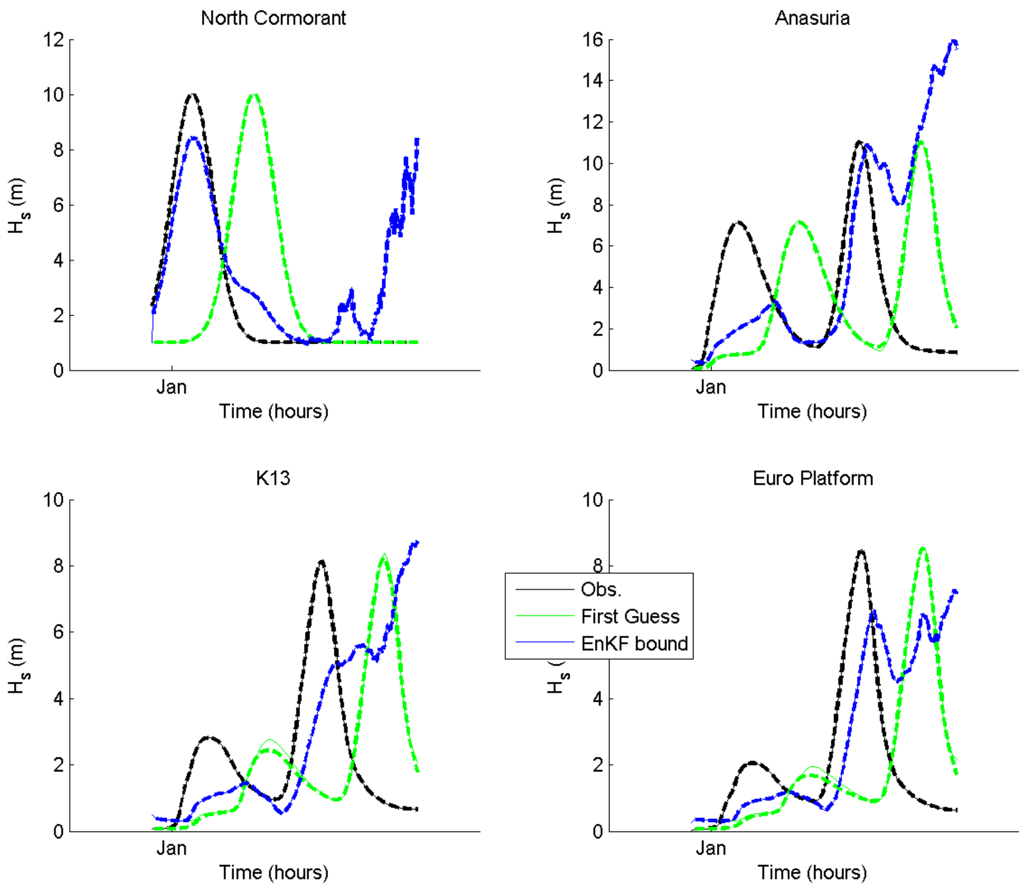
H_s



Assimilation of Hs at the 5 buoy locations

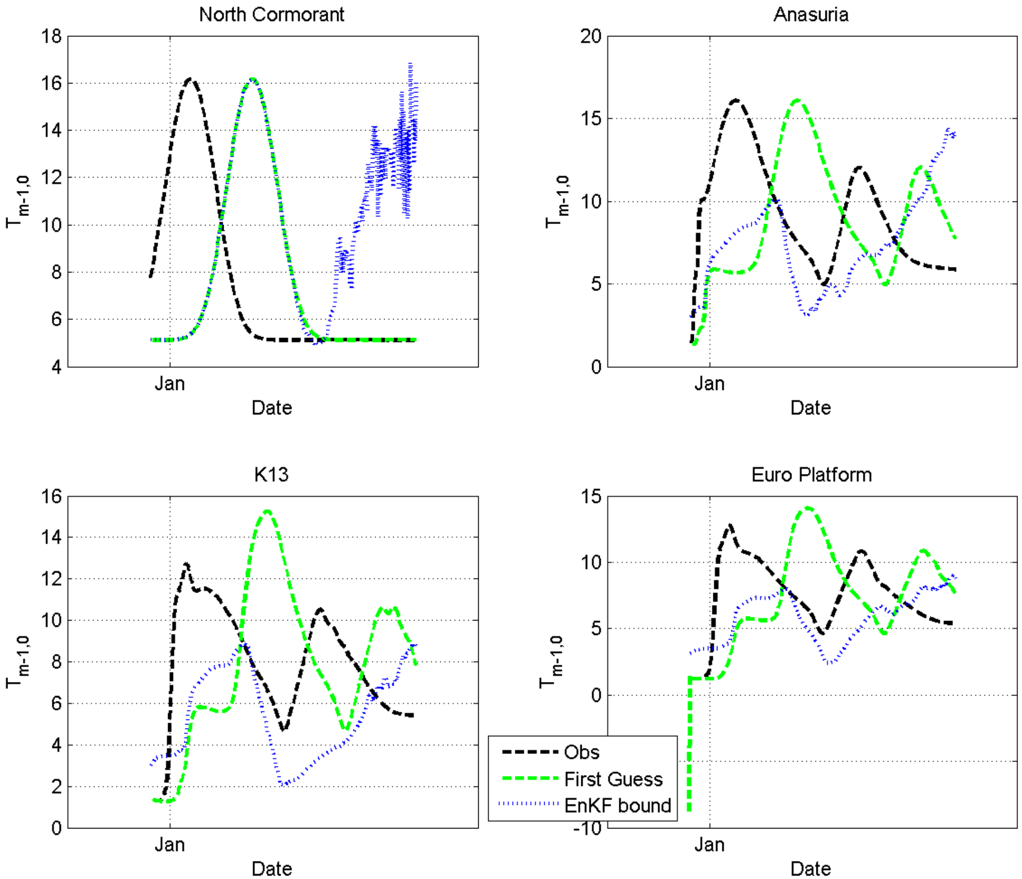
Adjustment of boundary wave conditions and of the 2D spectra at each computational grid location

→ Waves from boundary are dissipated

Deltares

1^{st} experiment for boundary

$T_{m-1,0}$

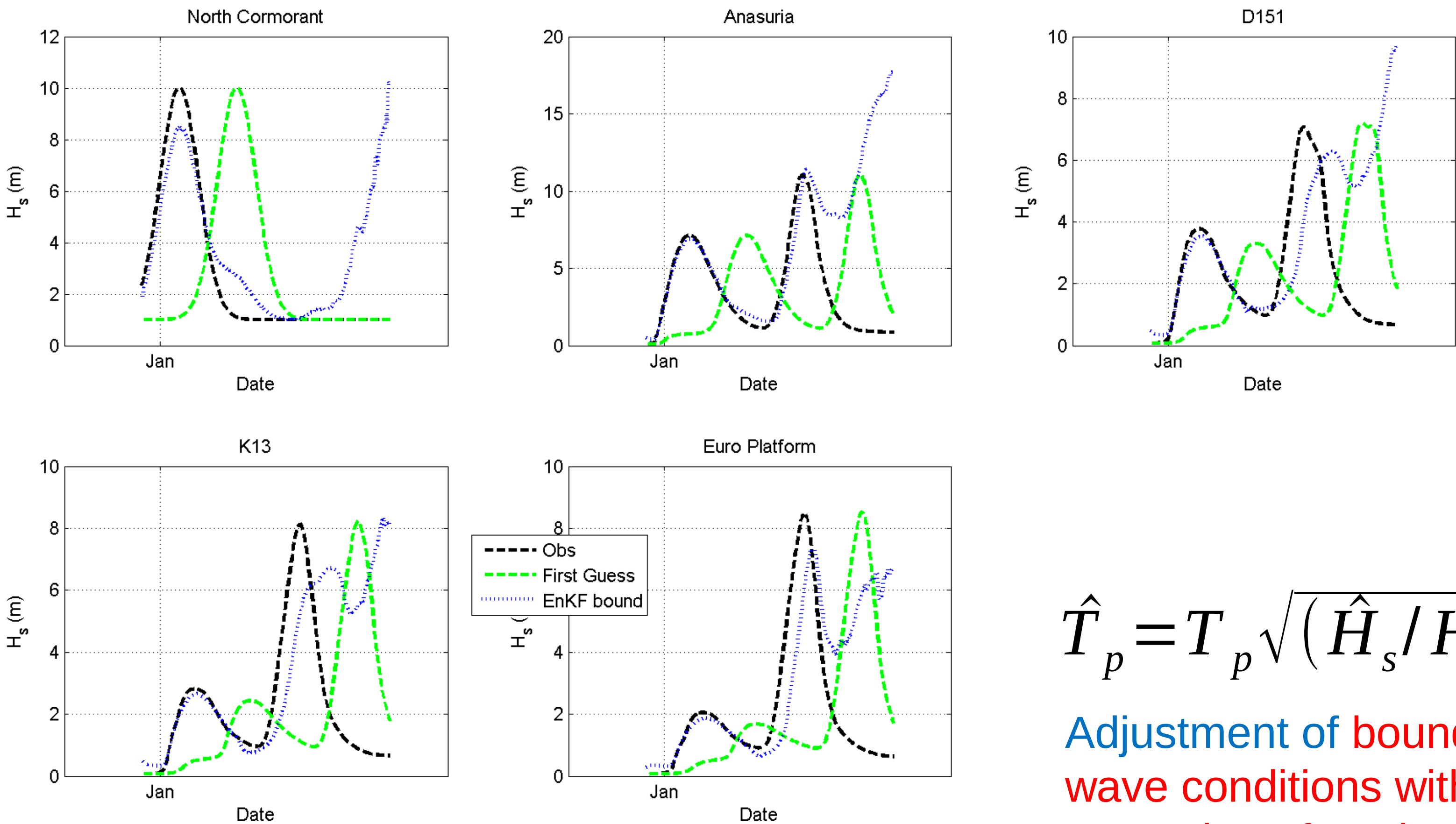


Wave period is not observed

→ waveperiod is not adjusted at the boundary creating too steep waves.

Correction of peak-period at boundary

H_s

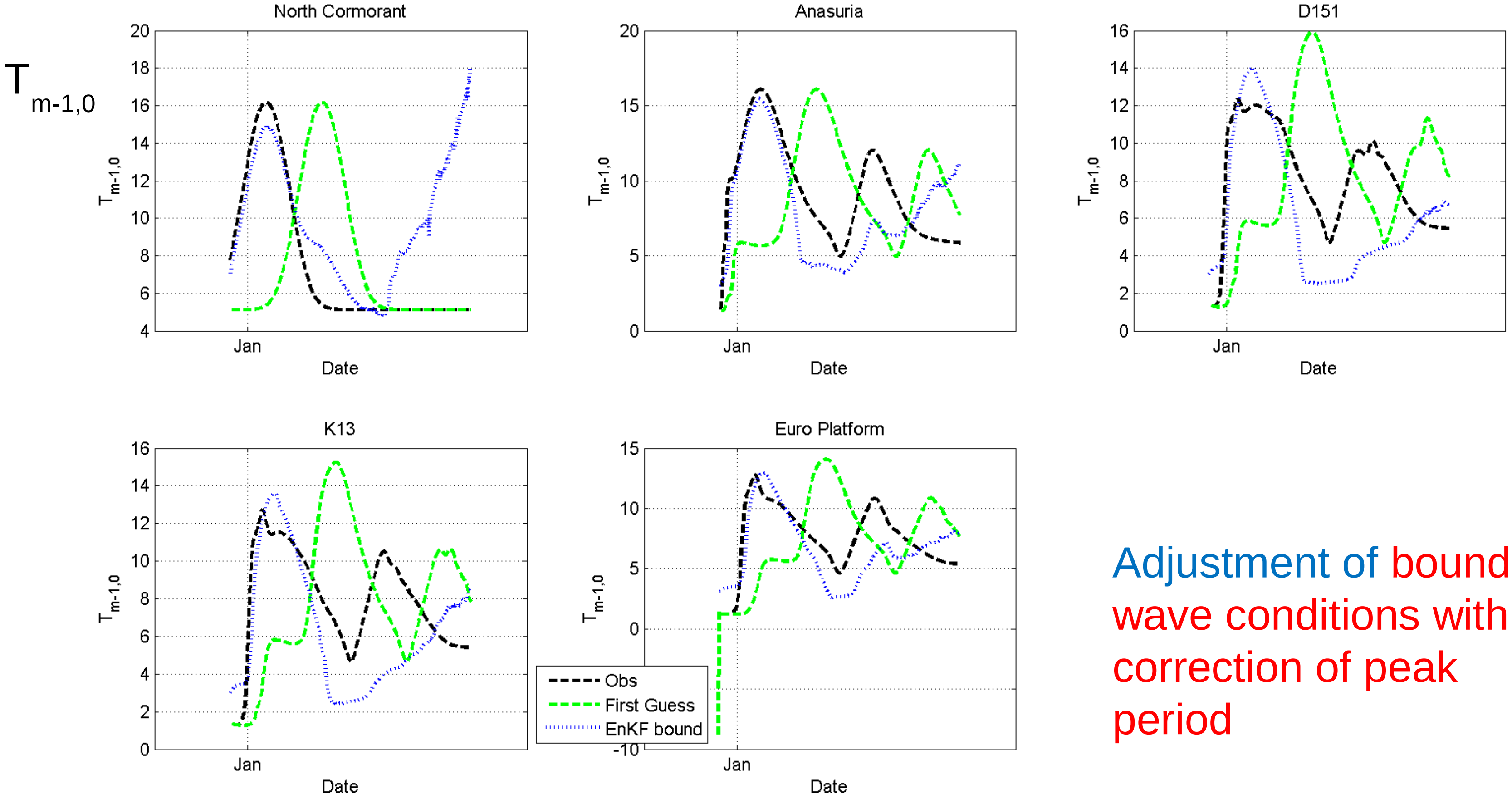


$$\hat{T}_p = T_p \sqrt{(\hat{H}_s / H_s)}$$

Adjustment of boundary wave conditions with correction of peak period

Deltares

Correction of peak-period at boundary



Adjustment of boundary wave conditions with correction of peak period

Deltares

1D experiment with wind uncertainty

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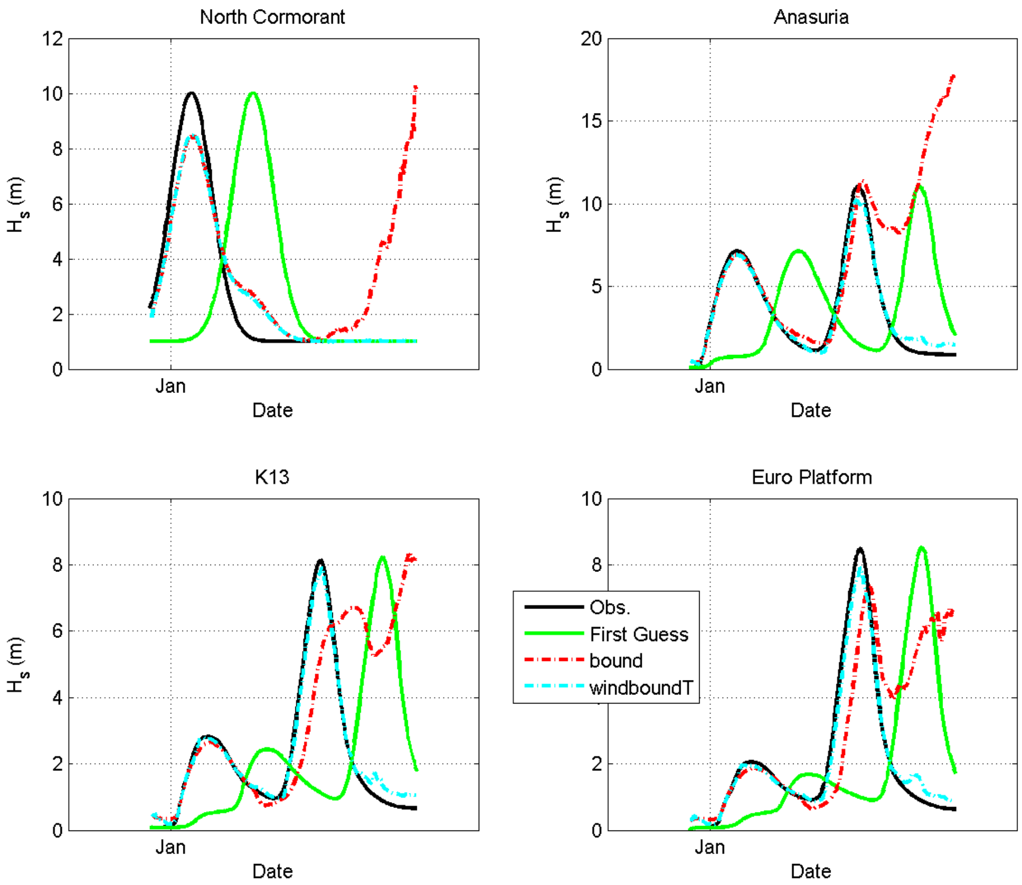


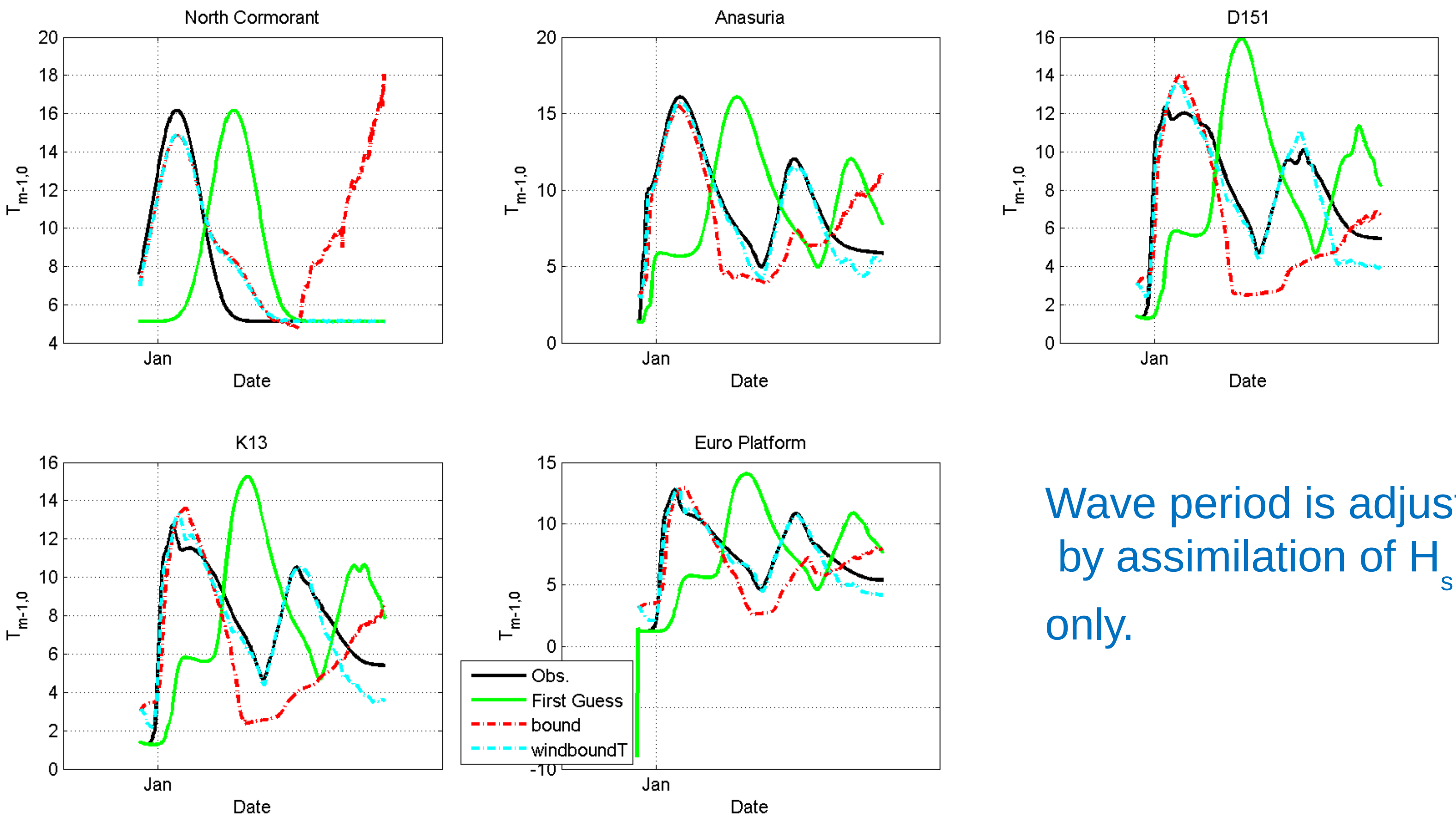
Assimilation of Hs at the 4 buoy locations

Adjustment of boundary wave conditions and wind input and of the 2D spectra at each computational grid location

Deltares

1D experiment with wind uncertainty

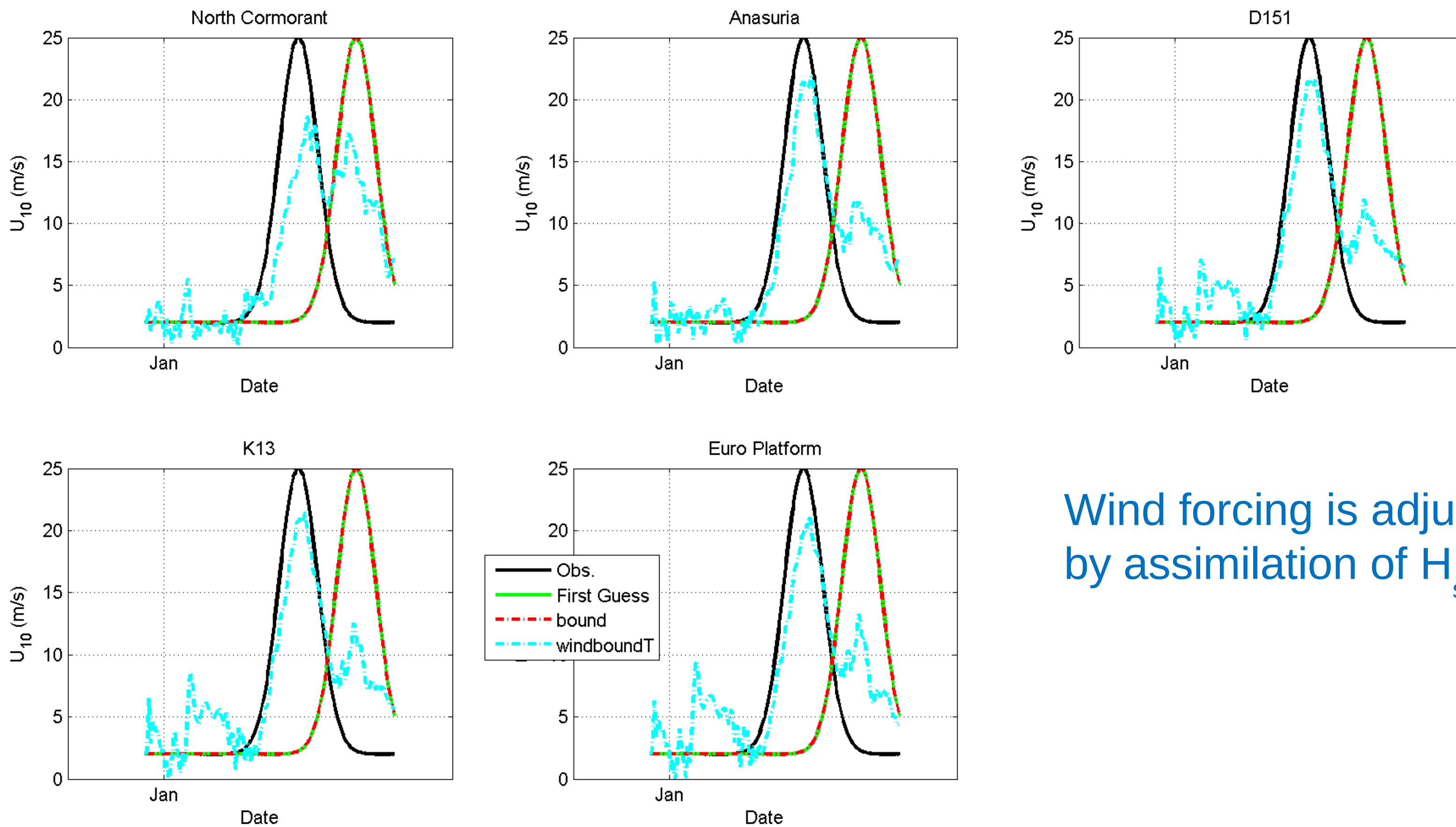
$T_{m-1,0}$



Wave period is adjusted by assimilation of H_s only.

1D experiment with wind uncertainty

$|U_{10}|$

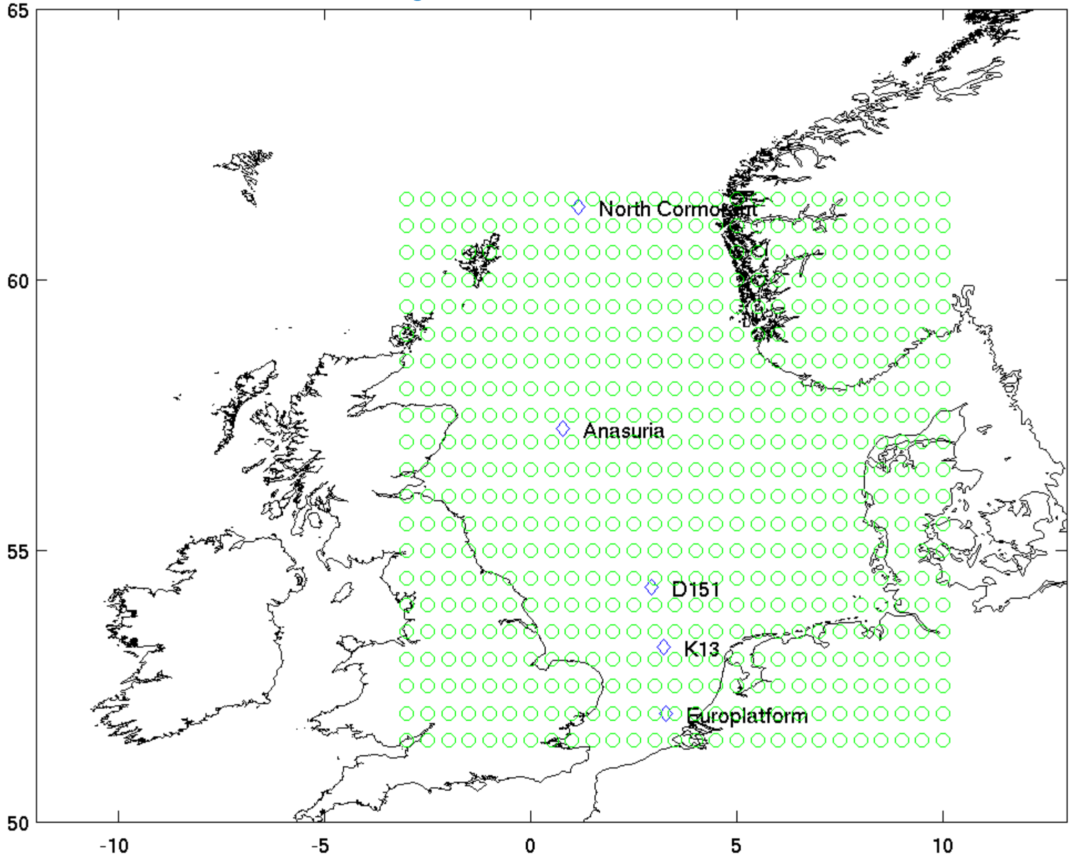


Wind forcing is adjusted by assimilation of H_s

Deltares

2D experiment

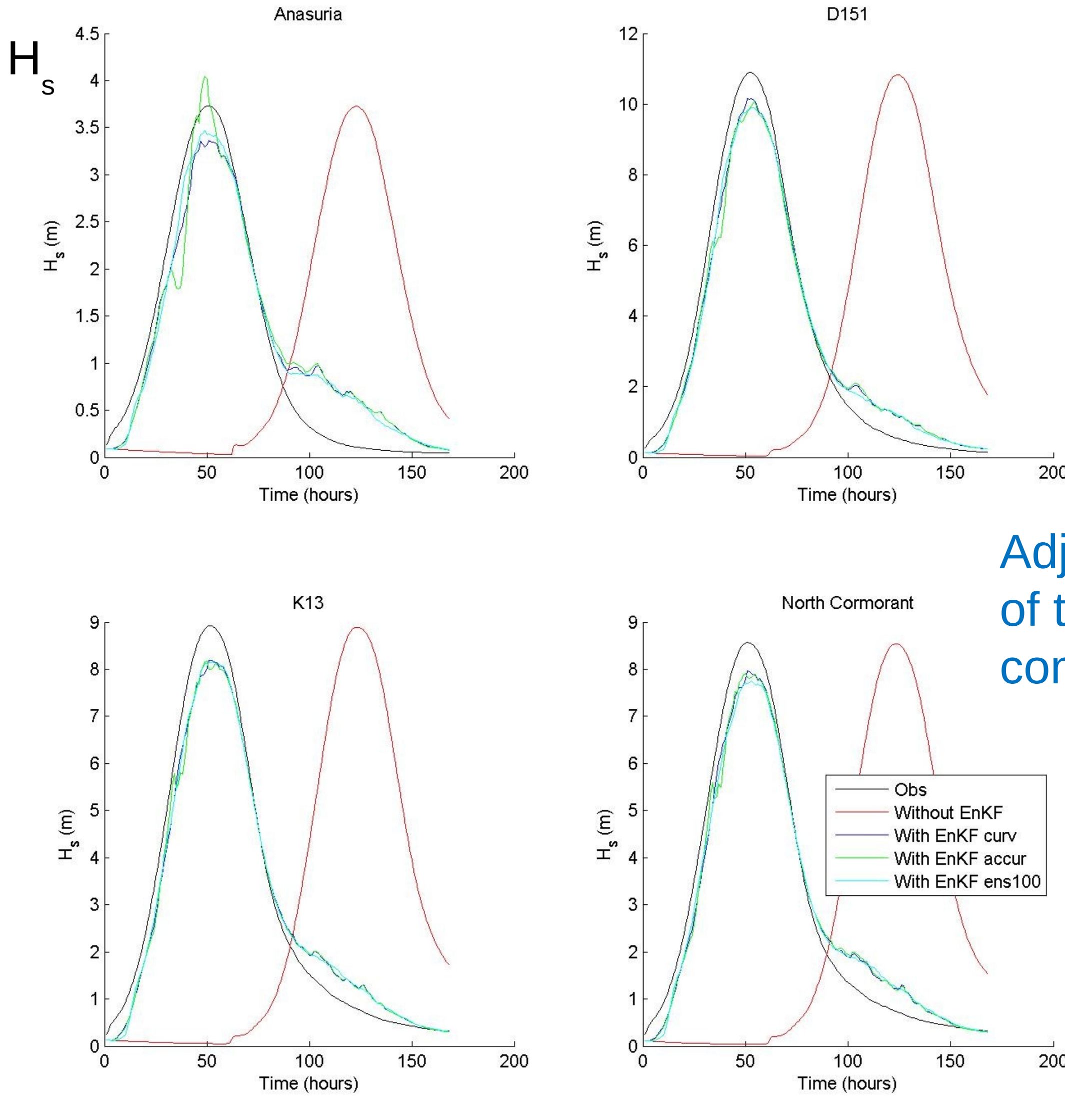
Assimilation of H_s at the 5 buoy locations



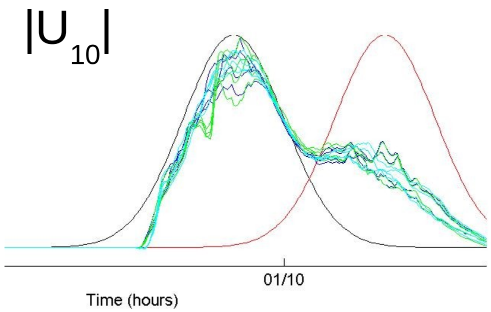
Adjustment of input wind field and of the 2D spectra at each computational grid location

Task 2.1: Data-assimilation

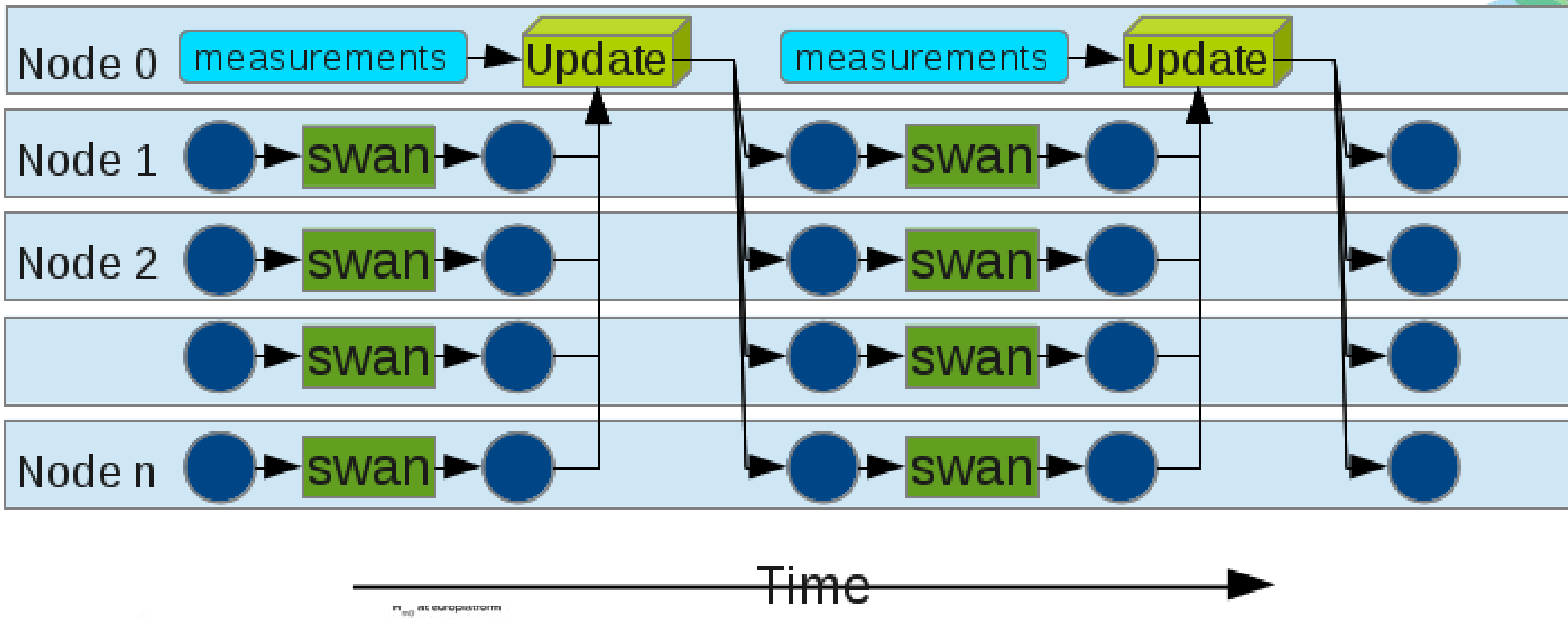
Twin experiment 2D

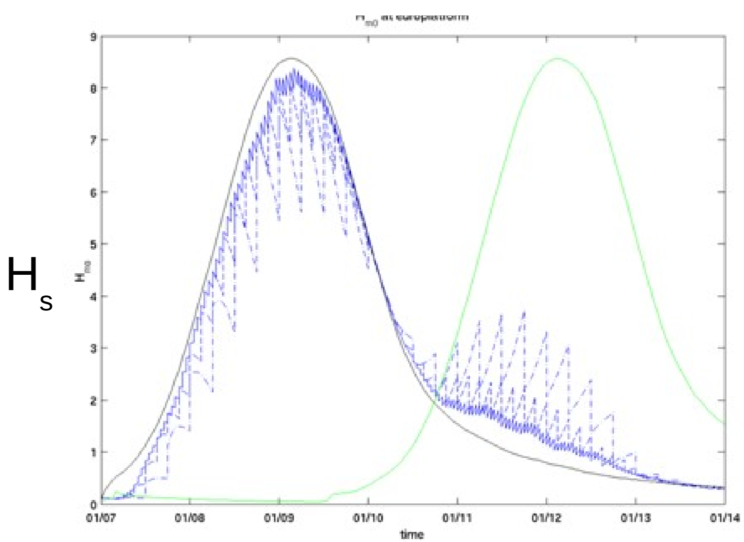


Adjustment of input wind field and of the 2D spectra at each computational grid location



Parallel computing & asynchronous filter





Analysis every 1, 3 and 6 hours

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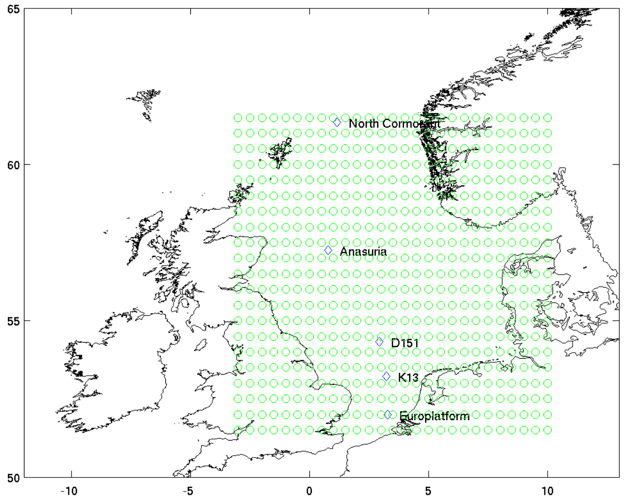
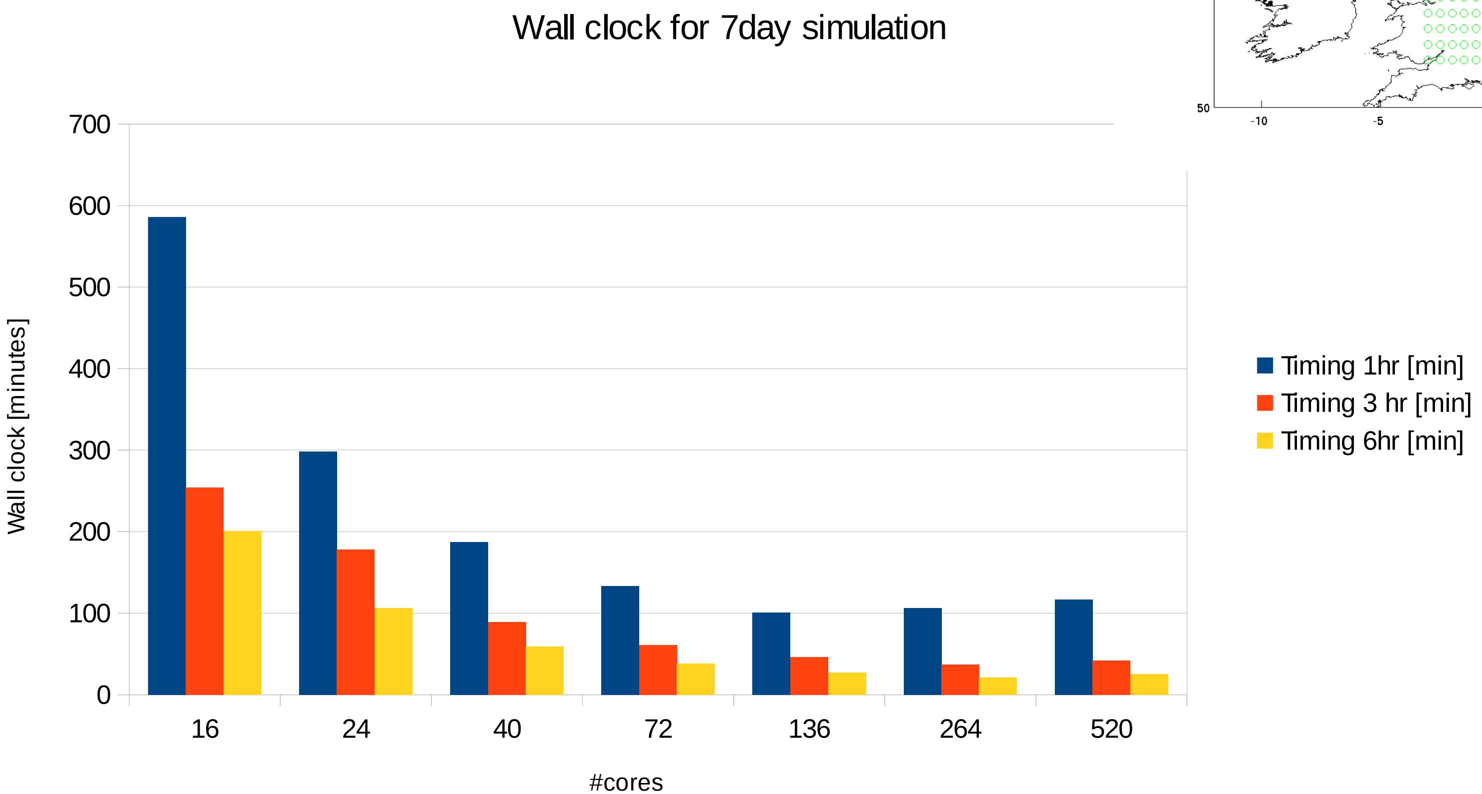
Parallel scaling results



Good scaling with standard OpenDA code for up-to 16 nodes (each 8 cores)



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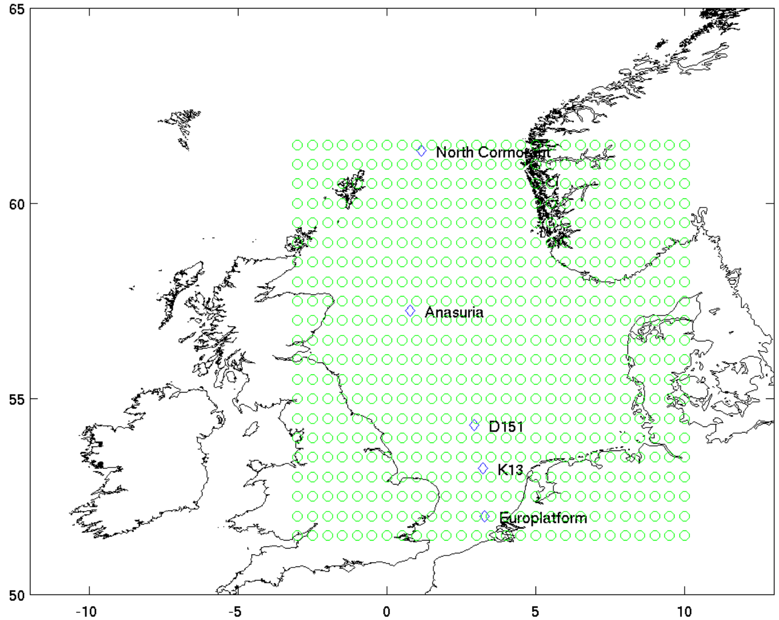
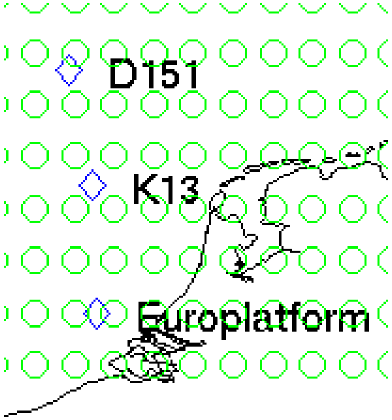
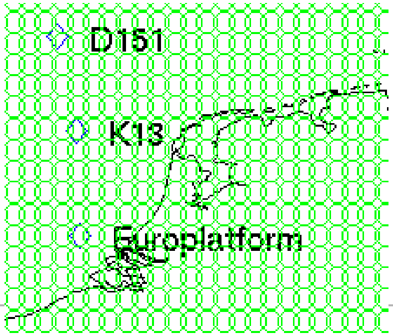
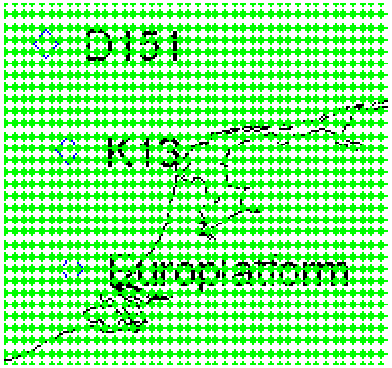
Case 2: 2d-grid 0.5x0.5°

resolution	Number of grid cells	State dimension	Size of ensemble
0.5° x 0.5°	27x21x32x36	653,184	0.3Gb
0.25° x 0.25°	52x42x32x36	2,612,736	1.2Gb
0.125° x 0.125°	104x84x32x36	10,450,944	5.0Gb









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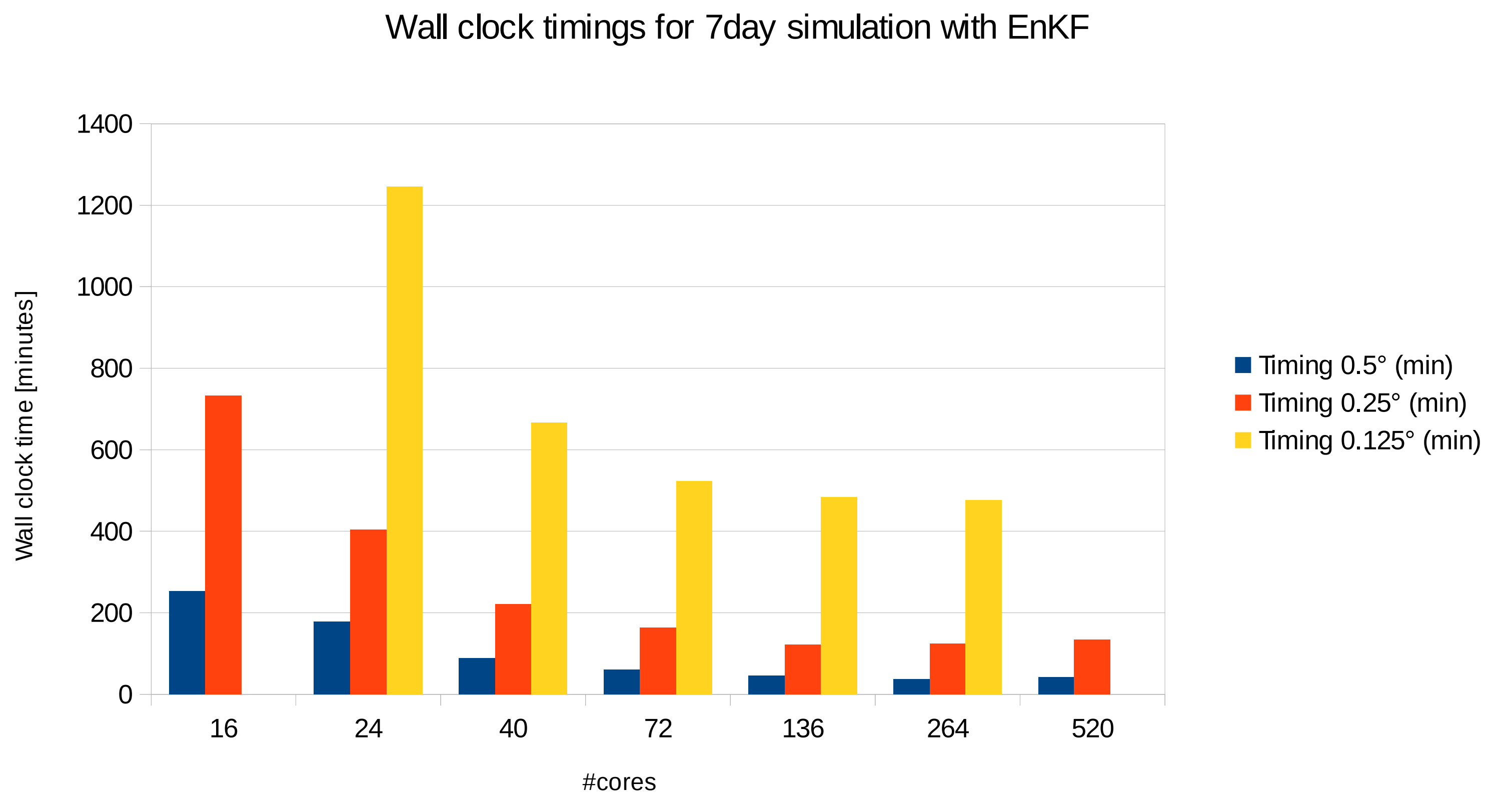
Performance and resolution

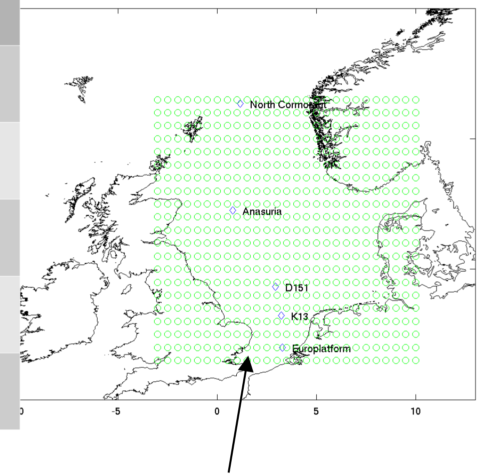


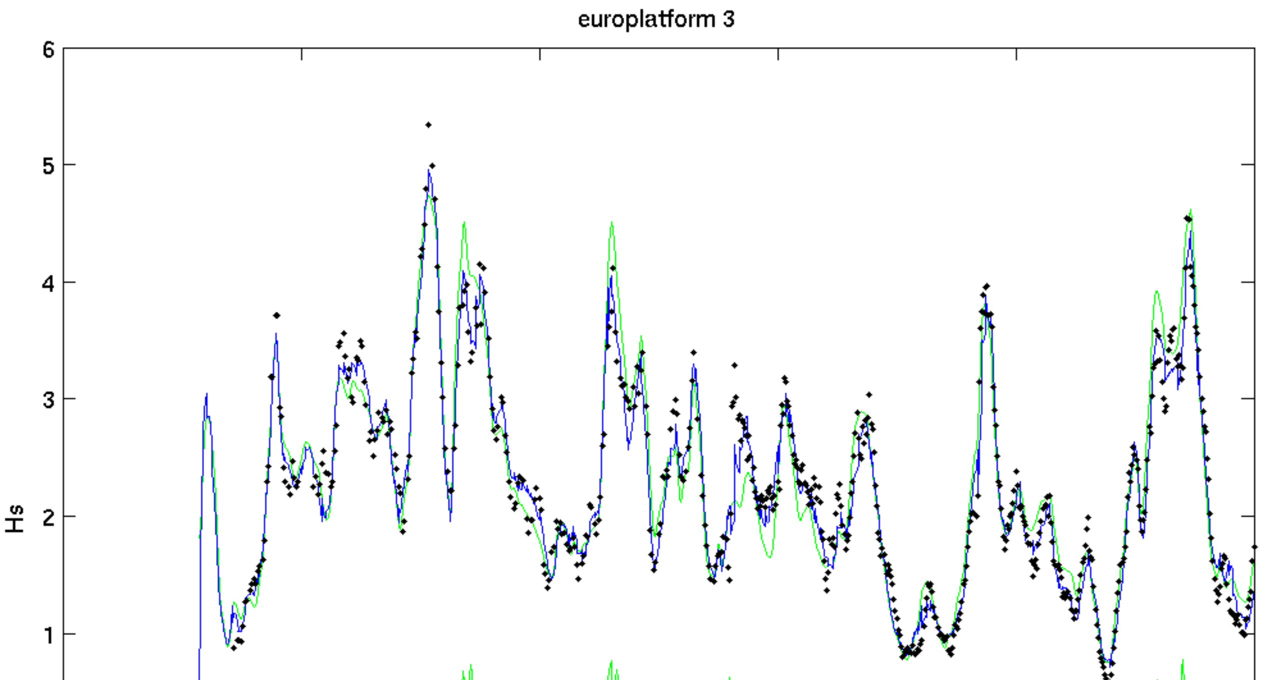
Timing asynchronous EnKF (3hour updates and 128 members)

→ Scaling becomes poor at around 16nodes independent of resolution

2D model with real observations

Location	RMS Hs simulation	RMS Hs EnKF
north cormorant 1	0.89	0.52
anasuria	0.43	0.34
d151	0.44	0.31
platform k13a	0.28	0.18
europlatform	0.26	0.21





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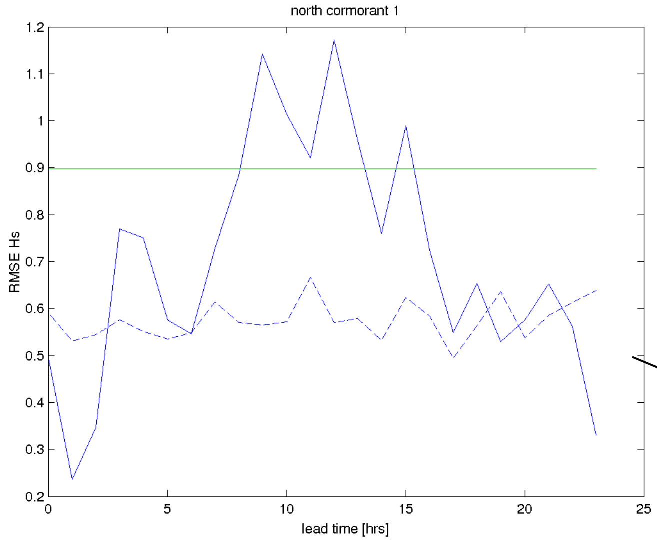
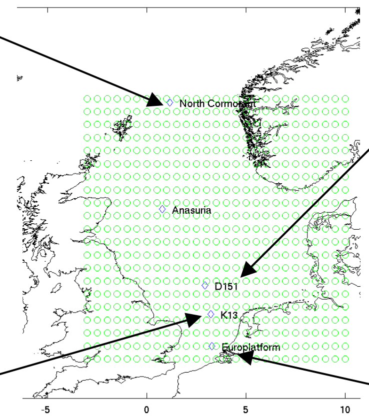
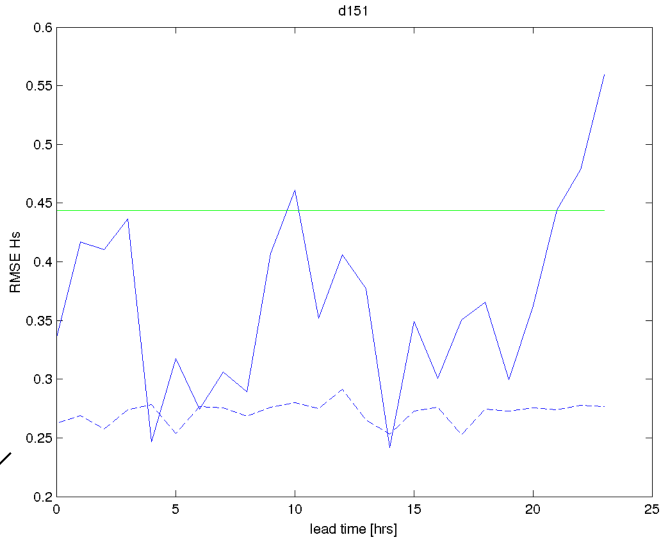
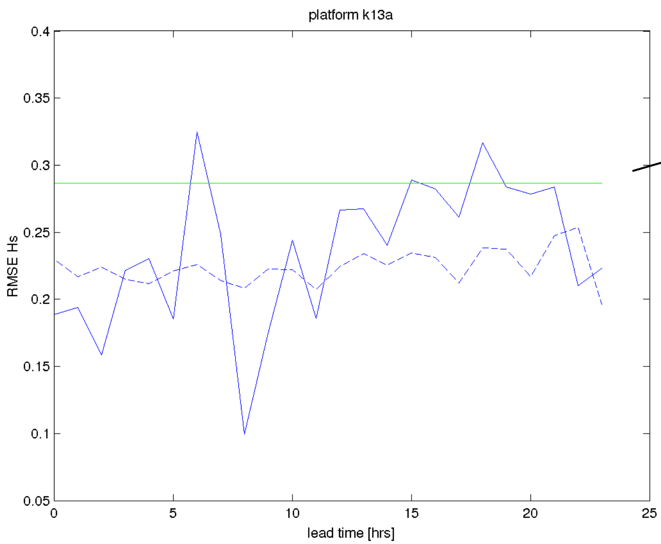
Forecast accuracy

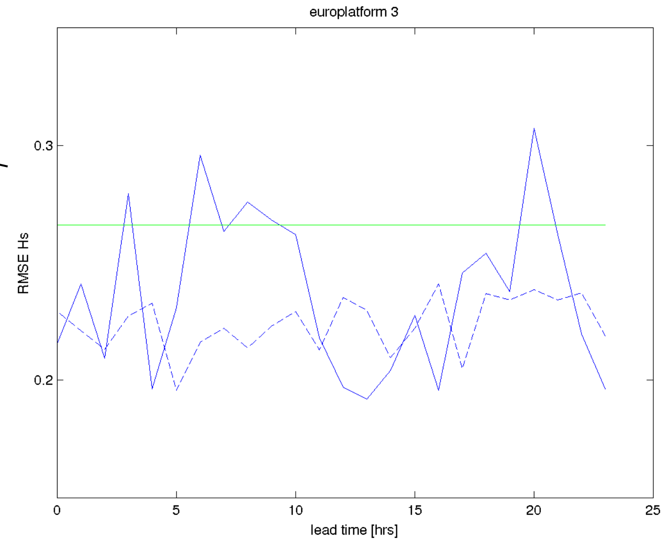
Preliminary results





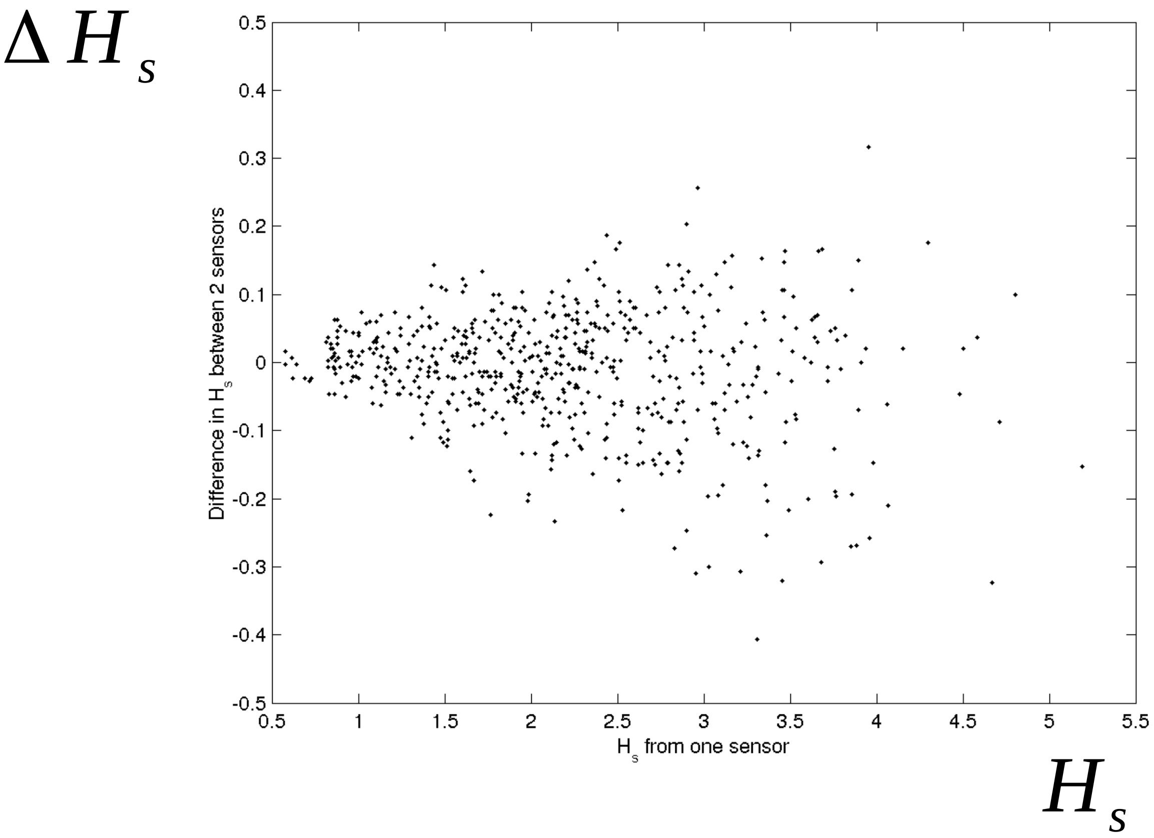






Accuracy of observations

Compare two sensors that are close



Next steps

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OpenDA

- Further testing with real observations
  - Complete tuning of noise parameters
  - Make observation errors depend on wave-height
  - Study specific cases
- Scale to realistic model size
  - Compare parallel computing strategies
  - Replace ASCII input/output files with NetCDF
- Assimilate other parameters and spectra
- Documentation & code publication