



Ensemble based data-assimilation for the SWAN spectral wave model

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& Sofia Caires (Deltares)

EnKF workshop
23-25 June 2014



Outline

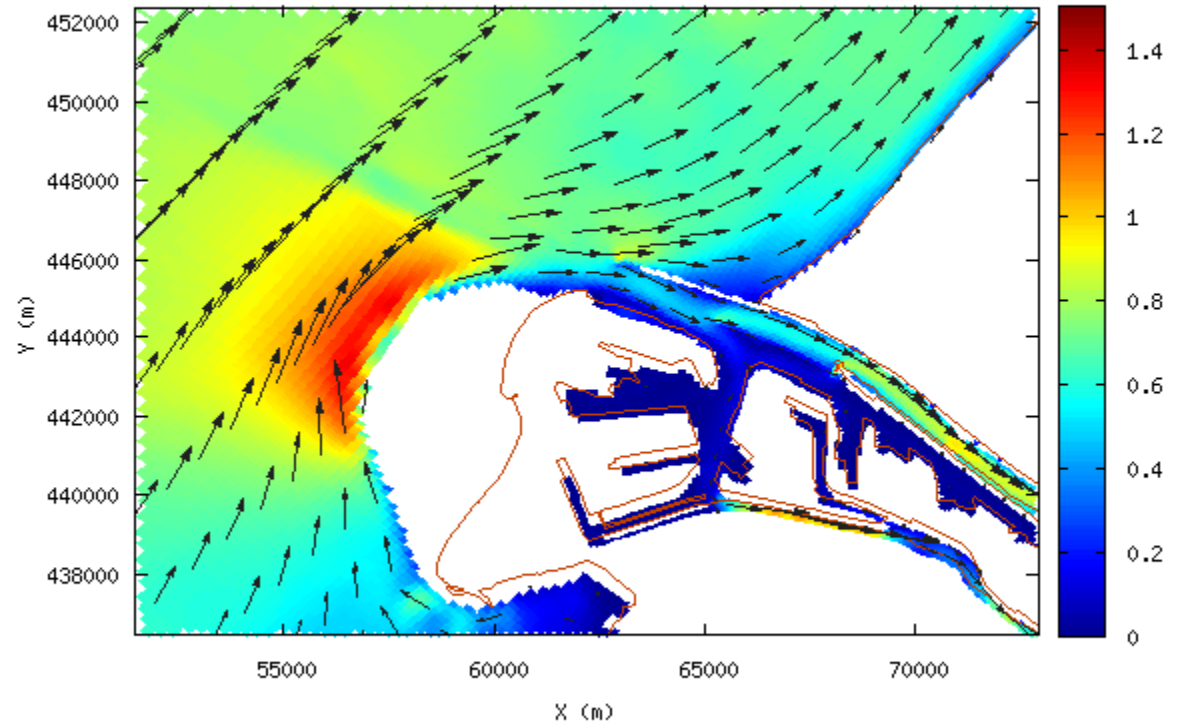


- Wave forecasting
- Spectral wave model (SWAN)
- EnKF
 - OpenDA and implementation
- Twin experiments with 1D model
 - Model errors
- Twin experiments with 2D model
 - Parallel computing
- December 2011 with 2D model
 - Tuning parameters
- Future work

Maritime safety



unit : Water Speed in m/s source : hmcn_zeedelta_mv2_f1
time : 2013-02-02 18:00:00 analysis: 2013-02-01 08:50:00
vector: Water velocity, 1 cm = 1 m/s



Shore protection



Floodmark



Forecasting system



RW:OS Noordzee (Stand alone)

Bestand Extra Opties Help

Taken

- 1. Taken
 - Aanpassingen doorvoeren en Kf runs starten
 - Import metingen
 - Validatie meting opzet
 - Aanpassen waterstanden
 - Waterwijzer (maak en distribueer)
 - Maak Waterwijzer (lokaal)
 - SVSD verwachting (maak en distribueer)
 - Maak SVSD verwachting (tijdsreeks)
 - Bereken scheve opzet
 - Maak SV01 en SV02 (lokaal)
 - Evaluatie rapporten RW:OS-Noordzee
 - Maandrapport lage
- 2. Data Viewer

2: Data Viewer

3: Grafiek overzicht

4: Producten

5: Logs

Warm state selection

T0
05-12-2013 06:00:00

voorspellingsduur

Taakuitvoer opties

Extern: 05-12-2013 06:00:00

04-12-2013 15:00:00 04-12-2013 18:00:00 04-12-2013 21:00:00 05-12-2013 00:00:00 05-12-2013 03:00:00 05-12-2013 06:00:00 05-12-2013 09:00:00 05-12-2013 12:00:00 05-12-2013 15:00:00 05-12-2013 18:00:00

Kaart Grafiek voorspellingen Beheer Aanpassingen systeem Monitor Producten scherm Database Viewer Start taak 2d data X

Workflow Import_MATROOS_Hirlam_v72 Completed

18-06-2014 06:46:38 INFO - Start time: 2014-06-18 06:45:26 End time: 2014-06-18 06:46:38 T0: 2013-12-04 18:00:00 User Id:bogaa_tm

18-06-2014 06:46:38 INFO - TaskRun.Completed: Task Import_MATROOS_Hirlam_v72 with ID 6 completed in 1 minutes and 12 seconds.

18-06-2014 06:46:38 INFO - TaskRun.TimeSpend:TimeSeriesImport 1m 12s 100% datastore 0s 0% database 3.6 kB cache files 0 B reloaded 0 B time series read 661 (unique=67) time series written 264 (unique=204) files 0s 0% logging 0s 0% gc 1s 1% threaded 0s 0% cpu 26s 36%

18-06-2014 06:46:38 INFO - Workflow.ActivityCompleted: Workflow 'Import_MATROOS_Hirlam_v72' completed in 1 minutes and 11 seconds

18-06-2014 06:46:38 INFO - Completed Activity 'MATROOS_import_knmi_HIRLAM_v72_post' completed in 0 minutes and 0 seconds

18-06-2014 06:46:38 INFO - Started Activity 'MATROOS_import_knmi_HIRLAM_v72_post'

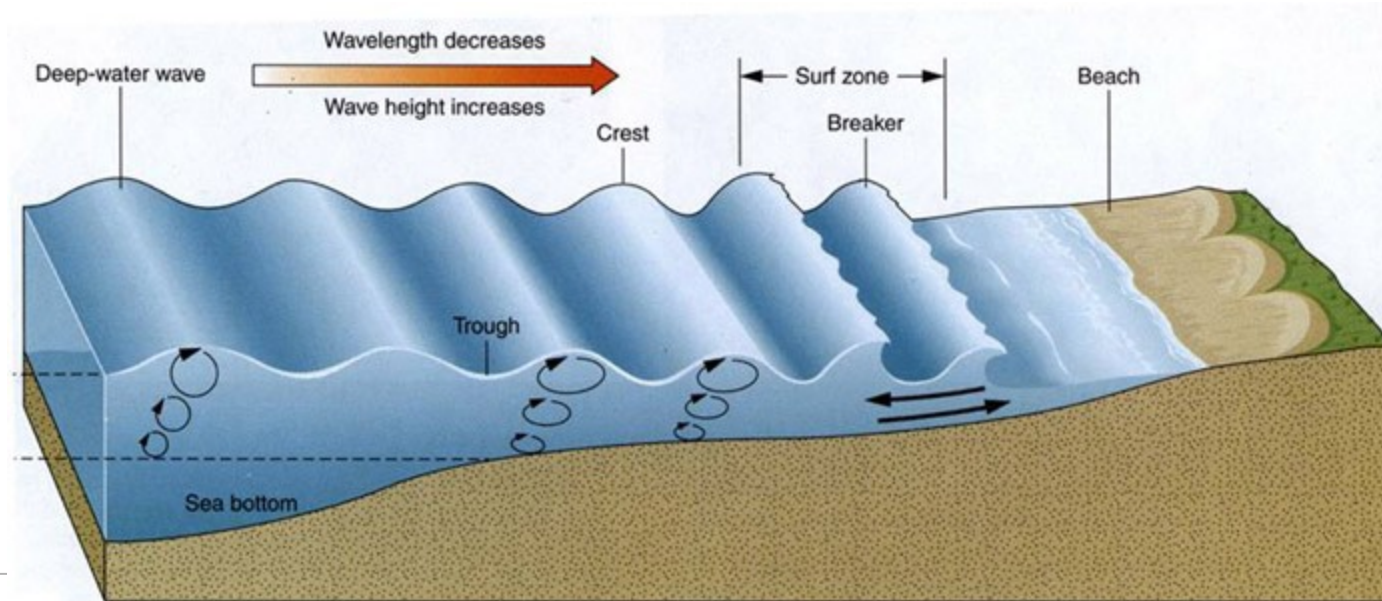
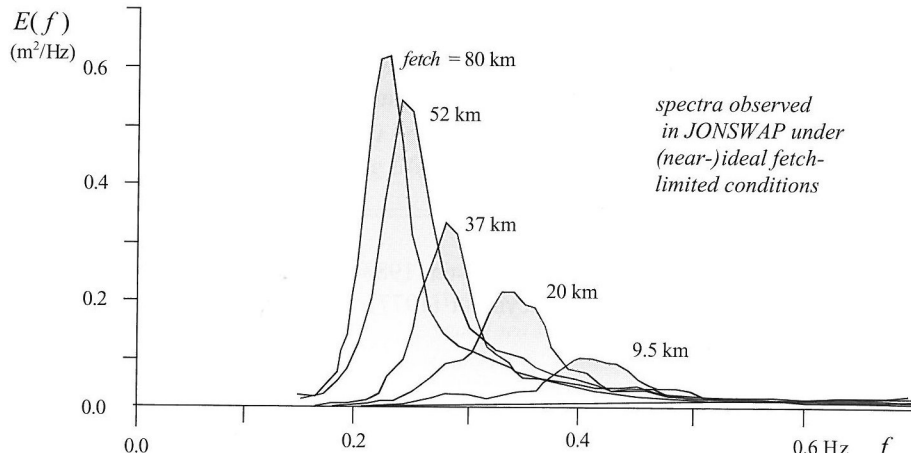
18-06-2014 06:46:38 INFO - Completed Activity 'MATROOS_import_knmi_HIRLAM_v72' completed in 0 minutes and 42 seconds

18-06-2014 06:46:26 INFO - Matroos Map download completed

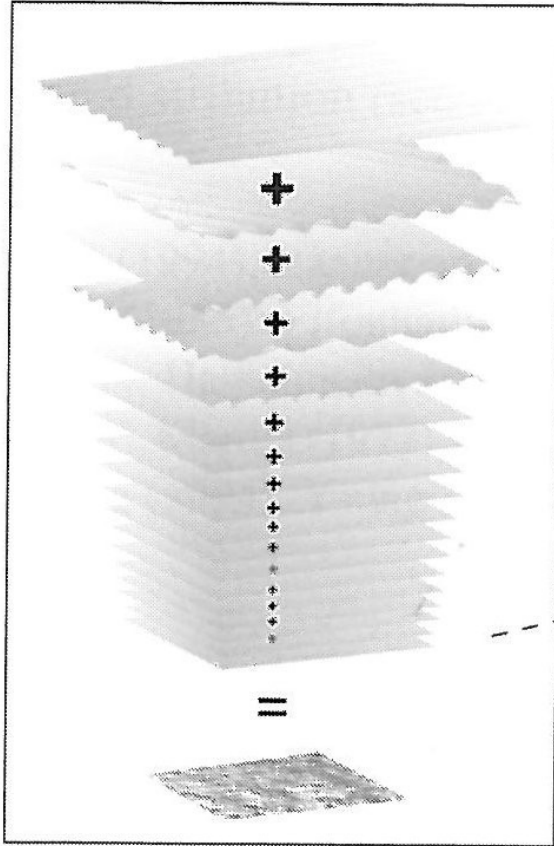
18-06-2014 06:46:14 INFO - Starting Matroos Map download: http://matroos.deltares.nl/matroos/scripts/matroos.pl?source=knmi_h11_v72&field=air_pressure_fixed_height,eastward_wind,northward_wind&coordsys=WGS84&from=201312011800&to=201312041800&timezone=gmt&format=nc

bogaa_tm(deltares_Forecaster) Huidige systeemtijd:05-12-2013 06:00 GMT 08:47:41 CEST 06:47:41 GMT Stand alone 7.910 , 49.028 323 MB

Simulating Waves Near-shore SWAN



Simulating Waves Near-shore SWAN

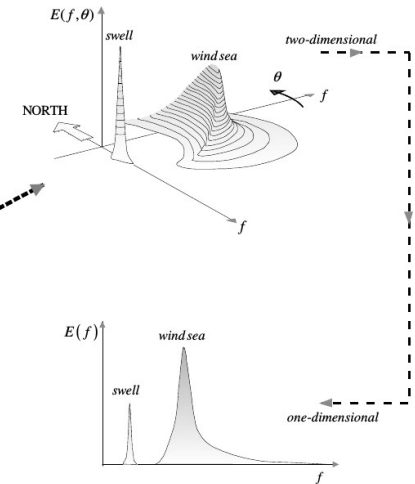


random-phase/amplitude model

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

Sources:

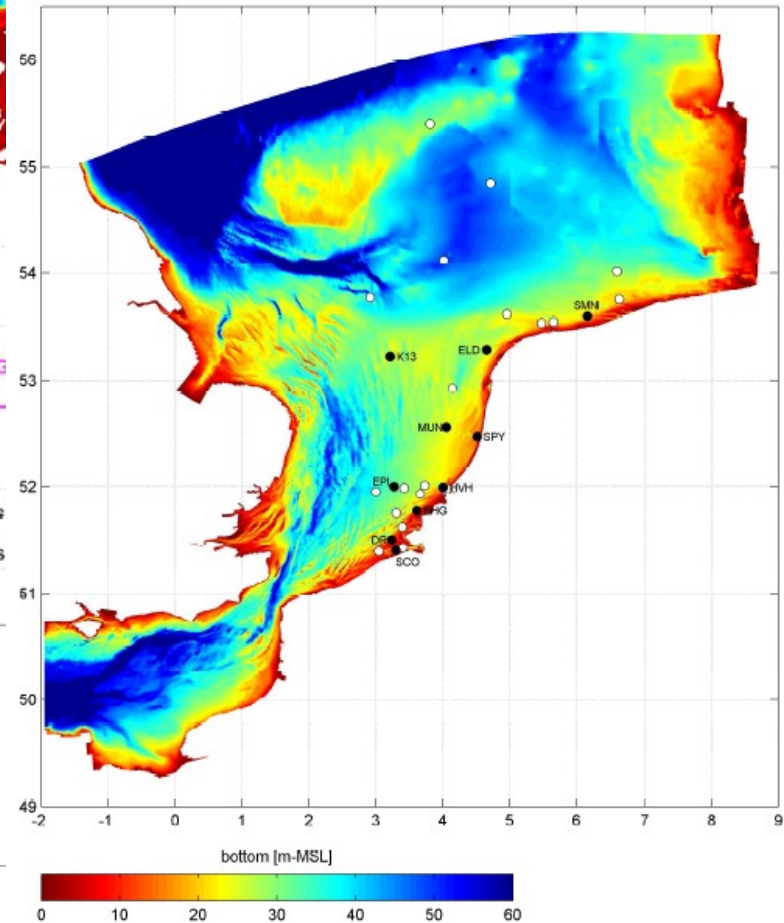
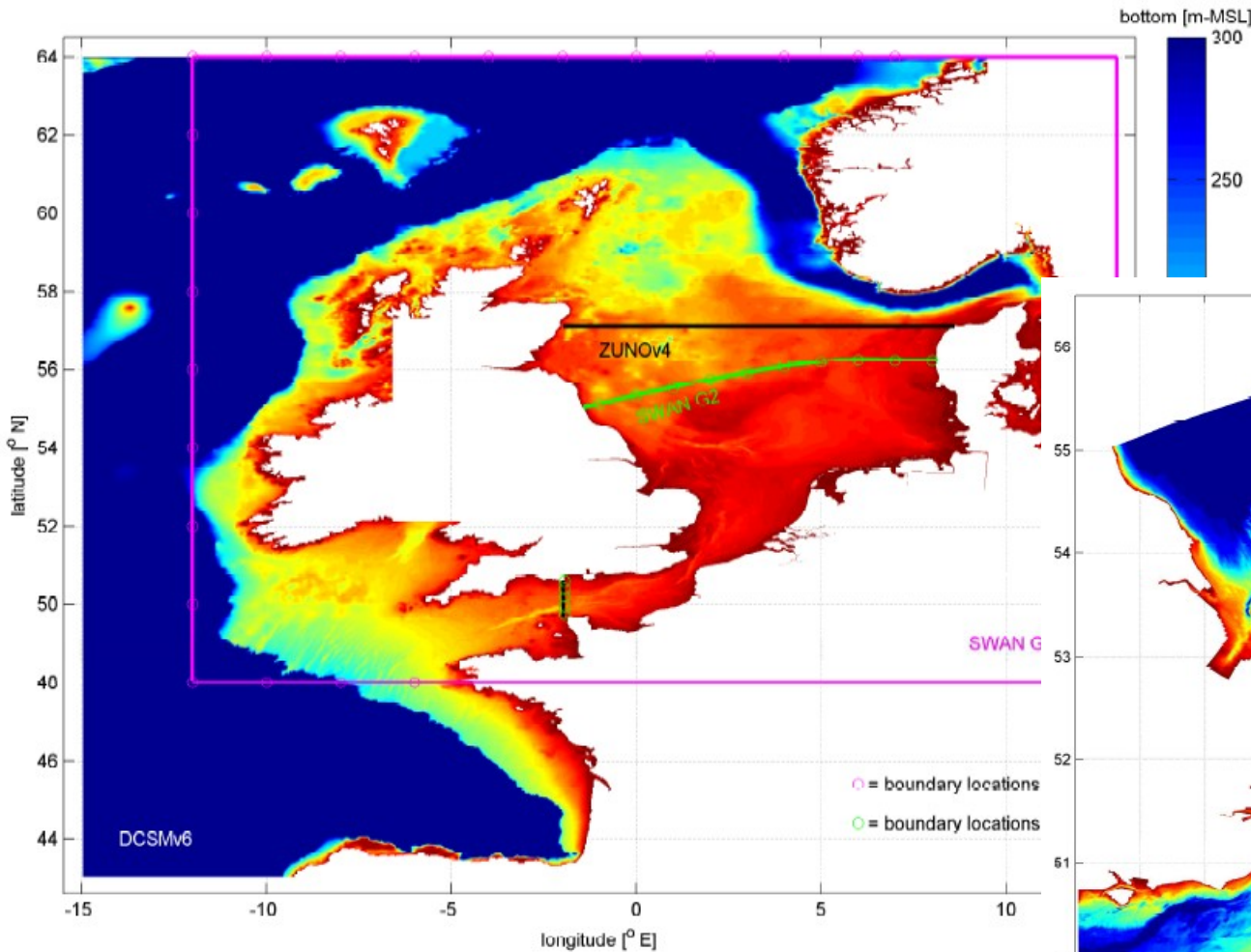
- Wind generation
- Non-linear interaction
- White-capping
- Friction
- ...



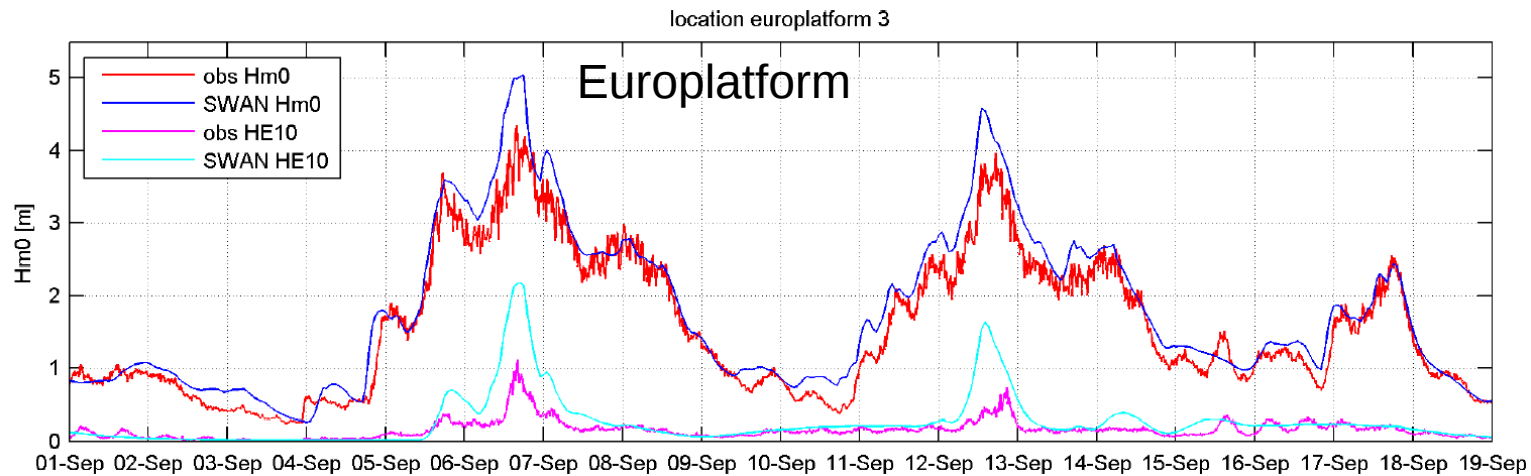
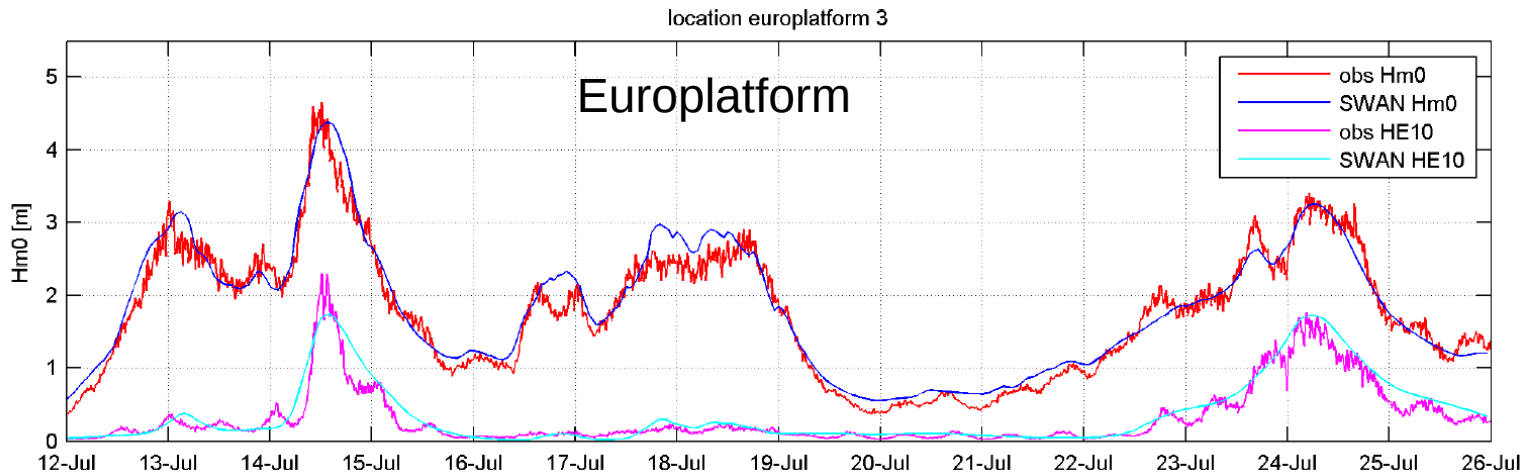
Significant waveheight $H_s(x, y) = 4 \sqrt{\iint N(x, y, \sigma, \theta) \sigma d\sigma d\theta}$

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

SANGOMA

<http://www.openda.org>



A screenshot of a Mozilla Firefox browser window displaying the OpenDA website. The browser's address bar shows the URL "http://www.openda.org/joomla/index.php". The website's header features the "OpenDA" logo in large white letters on a blue background, with a search bar to the right. The main content area is titled "Integrating models and observations" and contains two paragraphs of text. On the left, there is a "MAIN MENU" with links to "About OpenDA", "Downloads", "Documentation", "Forum", "Support", "Getting involved", and "Partners & Services". On the right, there is an "Announcements" section with two entries: "Full release now available" and "OpenDA 1.0 released". The browser's status bar at the bottom shows "Done" and the "S3Fox" logo.

MAIN MENU

• About OpenDA

- [Questions and answers](#)
- [OpenDA applications](#)
- [The OpenDA association](#)

• Downloads

• Documentation

• Forum

• Support

• Getting involved

• Partners & Services

LOGIN FORM

Logging in is only necessary if you want to participate in the discussions on the forum. For all other uses of this site or

Done

Integrating models and observations

OpenDA is an open interface standard for (and free implementation of) a set of tools to quickly implement data-assimilation and calibration for arbitrary numerical models. OpenDA wants to stimulate the use of data-assimilation and calibration by lowering the implementation costs and enhancing the exchange of software among researchers and end-users.

A model that conforms to the OpenDA standard can use all the tools that are available in OpenDA. This allows experimentation with data-assimilation/calibration methods without the need for extensive programming. Reversely, developers of data-assimilation/calibration software that make their implementations compatible with the OpenDA interface will make their new methods usable for all OpenDA users (either for free or on a commercial basis).

OpenDA has been designed for high performance. Hence, even large-scale models can use it. Also, OpenDA allows users to optimize the interaction between their model and the data-assimilation/calibration methods. Hence, data-assimilation with OpenDA can be as efficient as with custom-made

Announcements

[Full release now available](#)

The full sources for OpenDA version 1.0 are now available on this OpenDA website. Click [here](#) to download the source, binaries for windows and linux, examples and more.

[OpenDA 1.0 released](#)

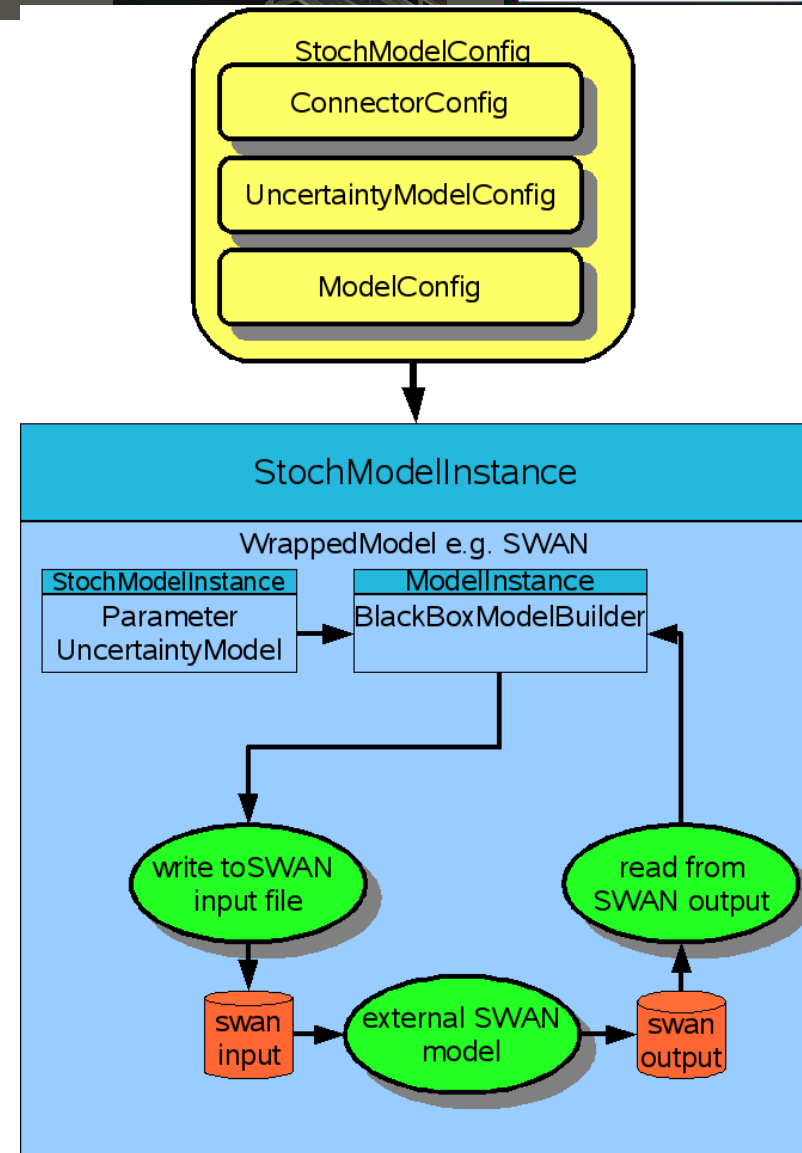
OpenDA version 1.0 has been officially released at May 10., 2010 during the JonsMod workshop at Deltares in the Netherlands.

Information relating to the release can be found [here](#)

Deltares

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

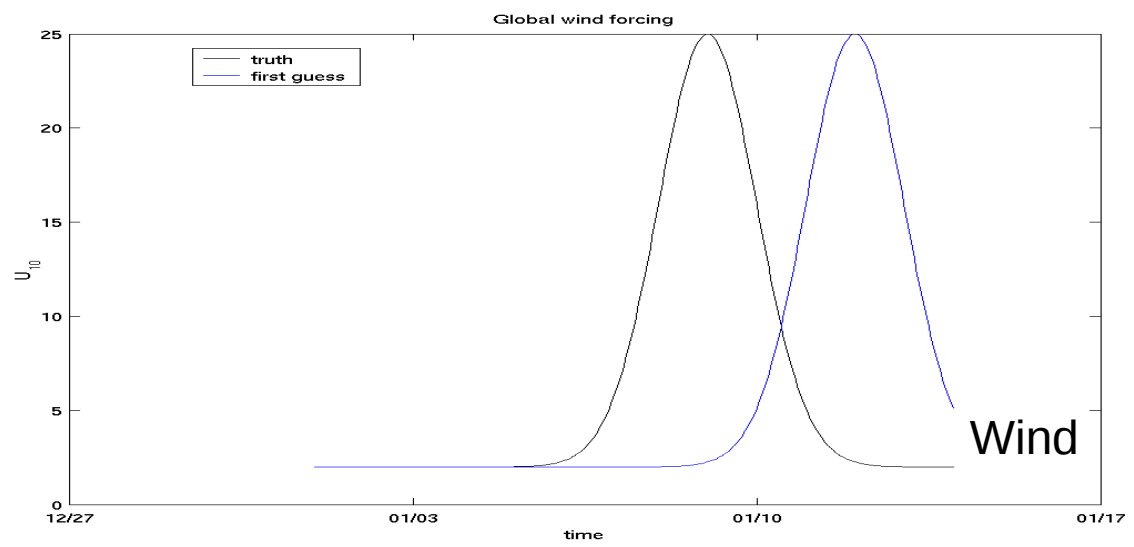
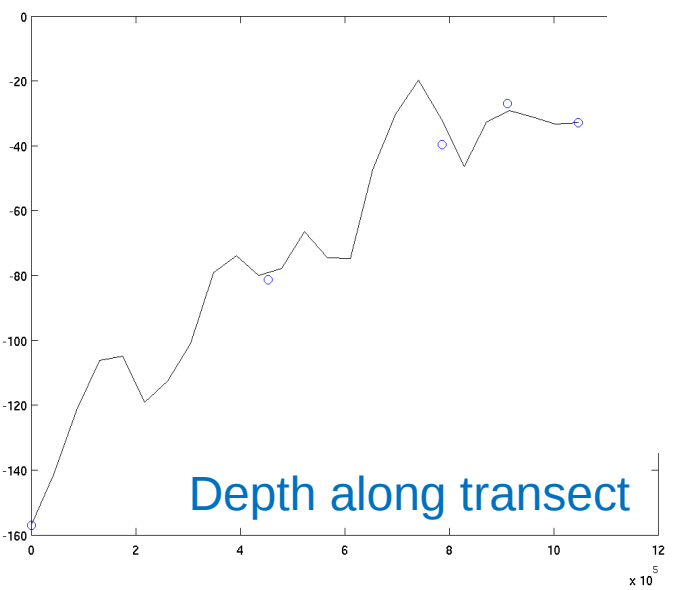
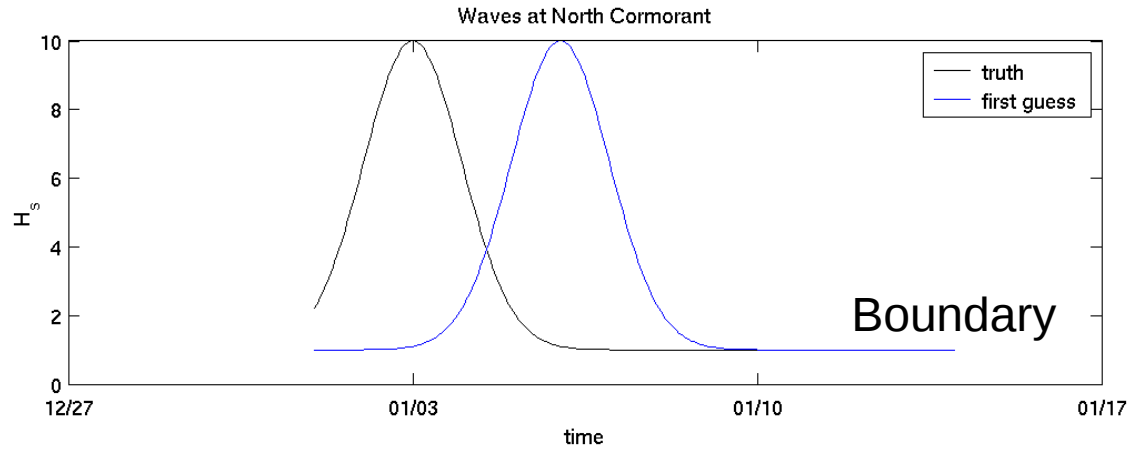
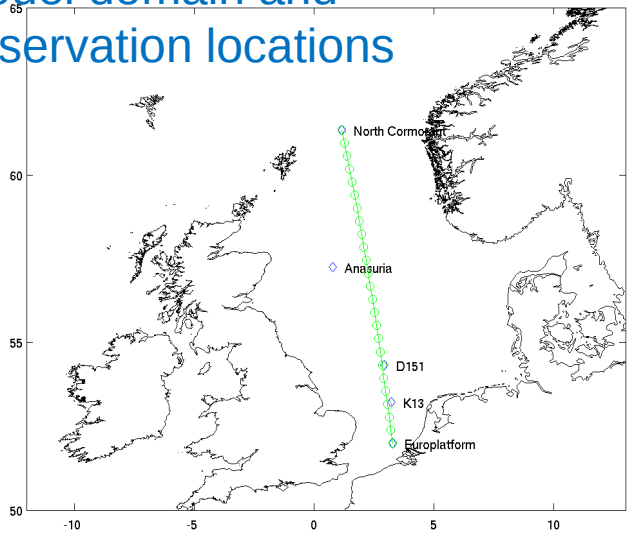


- EnKF algorithm
 - 128 ensemble members
 - Synchronous or asynchronous assimilation
 - No localization
 - No inflation
 - Truncation of negative energy densities
- Model uncertainty:
 - Exponential time-correlation for additive error to H_s at the boundary
 - Exponential spatial and temporally correlated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

Twin experiment 1D



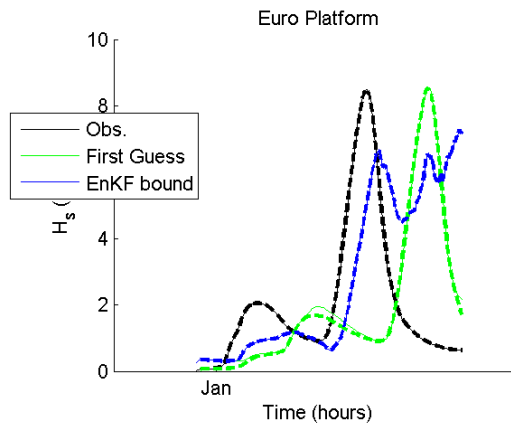
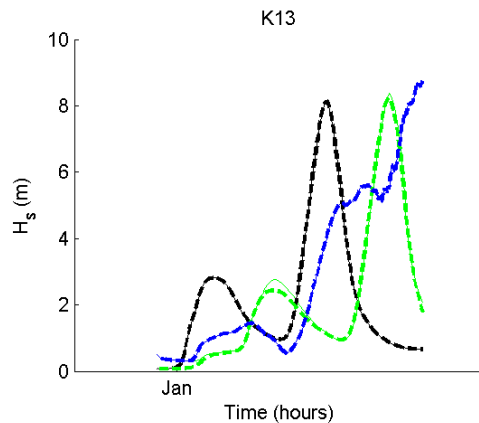
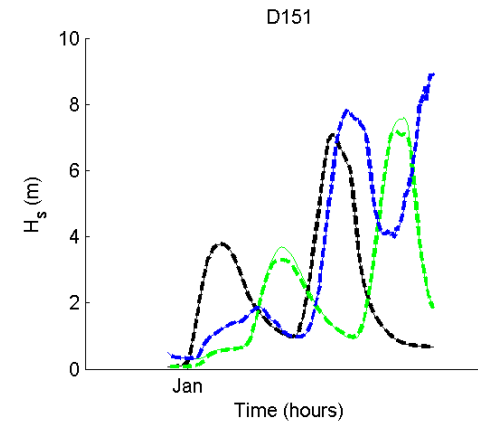
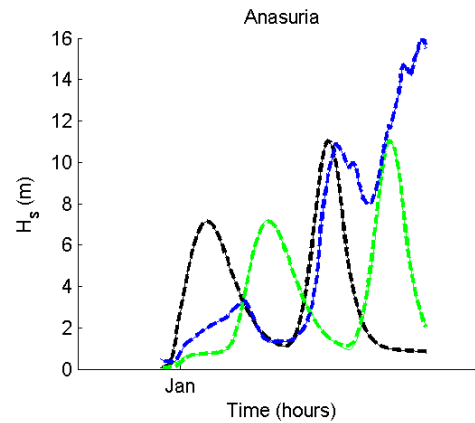
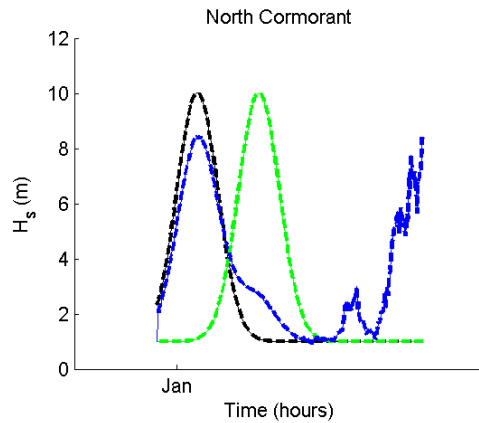
Model domain and observation locations



1st experiment for boundary



H_s



Assimilation of H_s at the 5 buoy locations

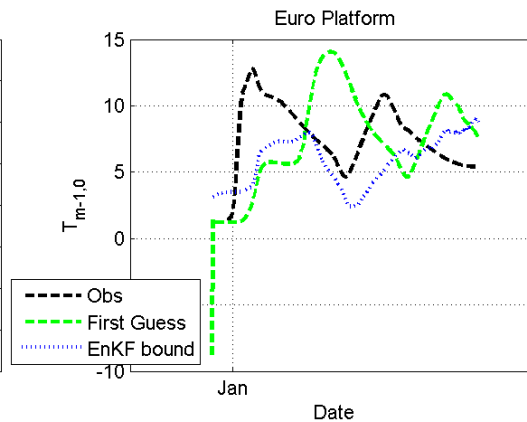
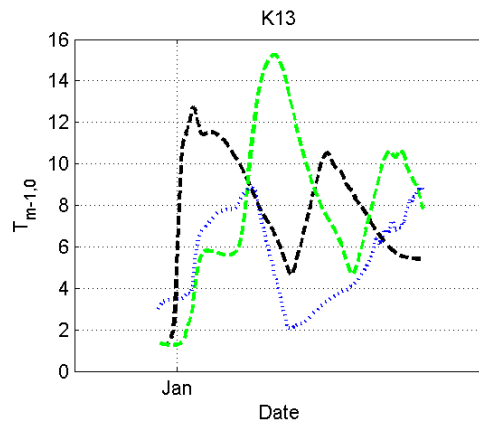
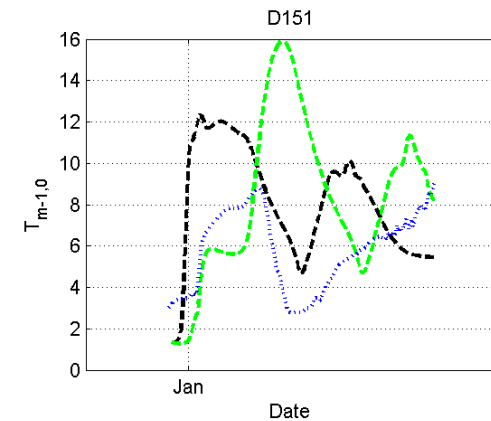
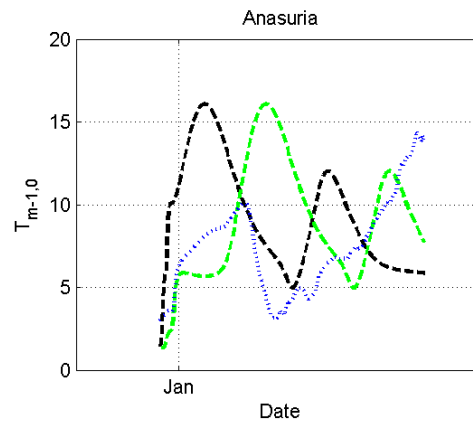
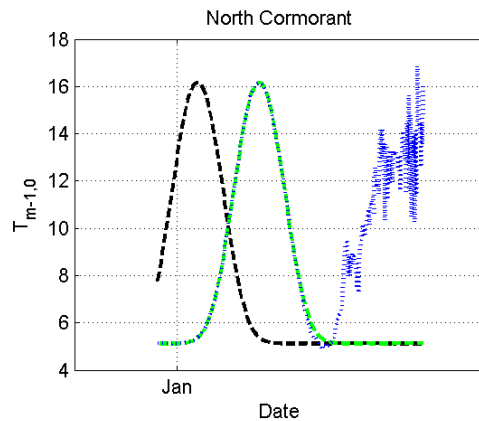
Adjustment of **boundary wave conditions** and of the 2D spectra at each computational grid location

→ Waves from boundary are dissipated

1st experiment for boundary



$T_{m-1,0}$



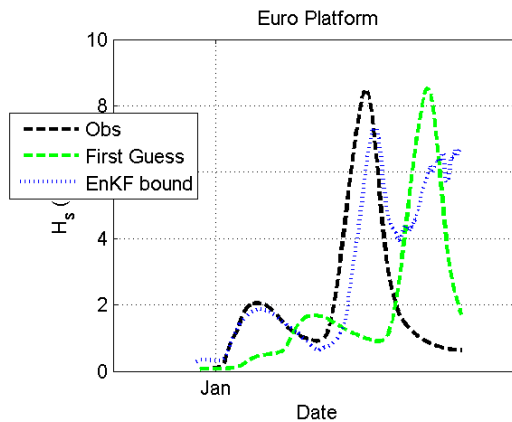
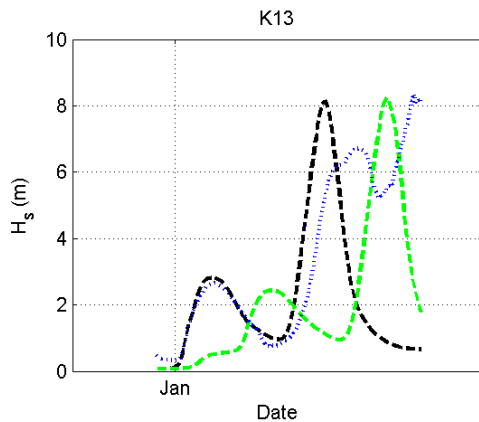
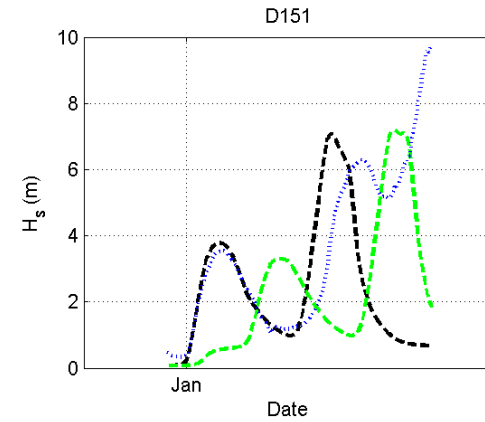
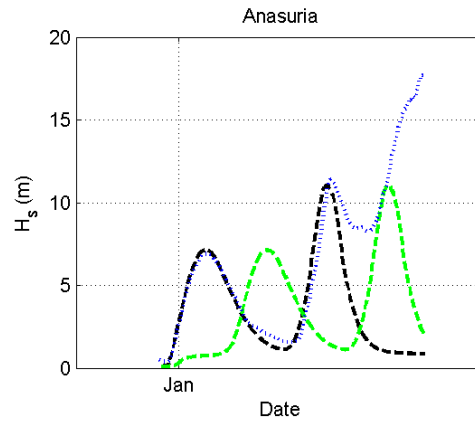
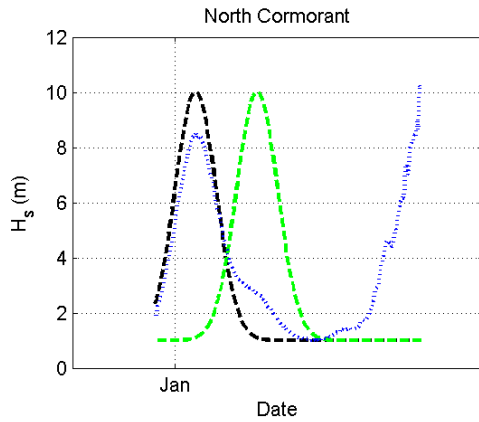
Wave period is not observed

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

Correction of peak-period at boundary



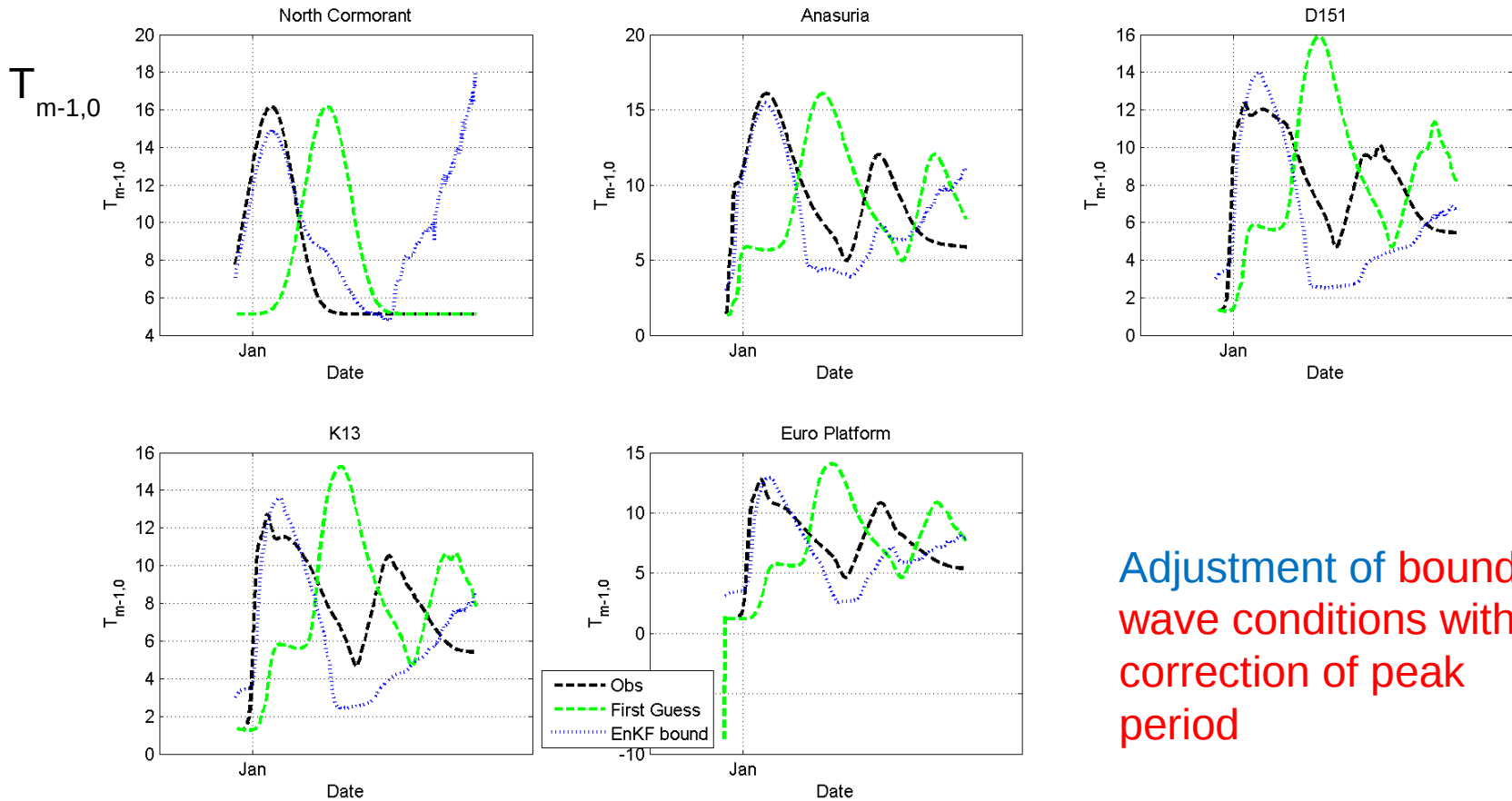
H_s



$$\hat{T}_p = T_p \sqrt{\left(\frac{\hat{H}_s}{H_s}\right)}$$

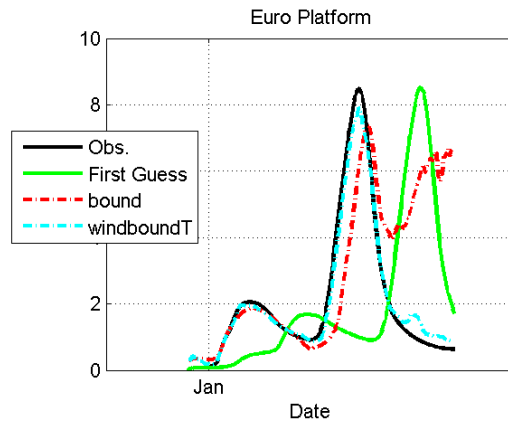
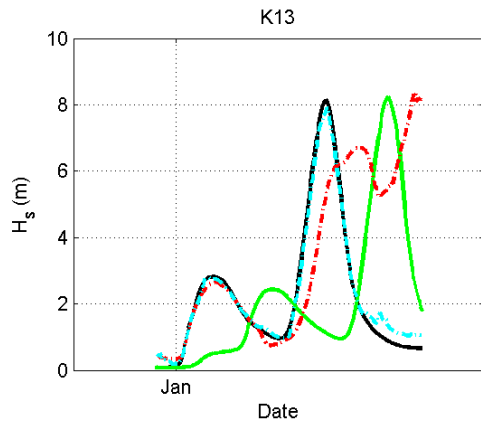
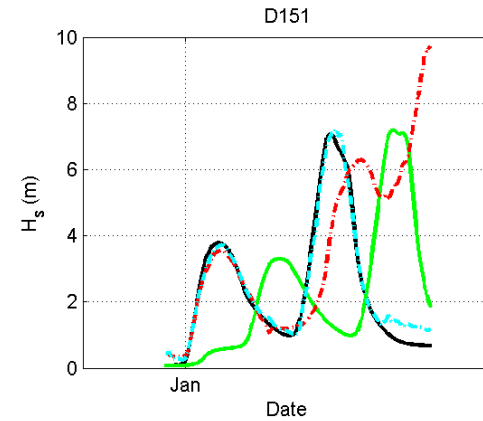
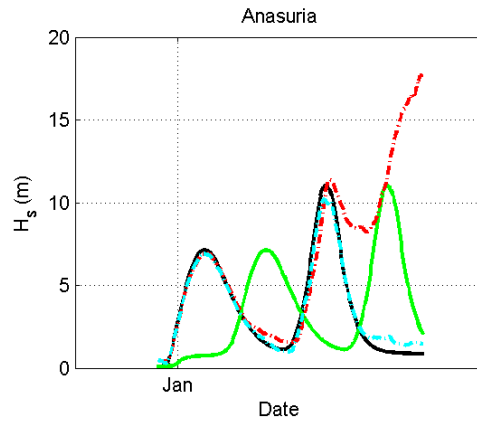
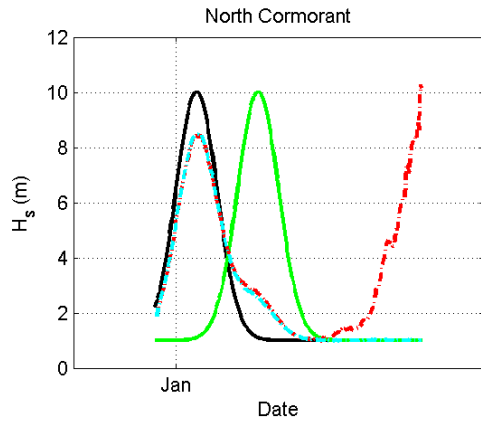
Adjustment of boundary wave conditions with correction of peak period

Correction of peak-period at boundary



Adjustment of boundary wave conditions with correction of peak period

1D experiment with wind uncertainty



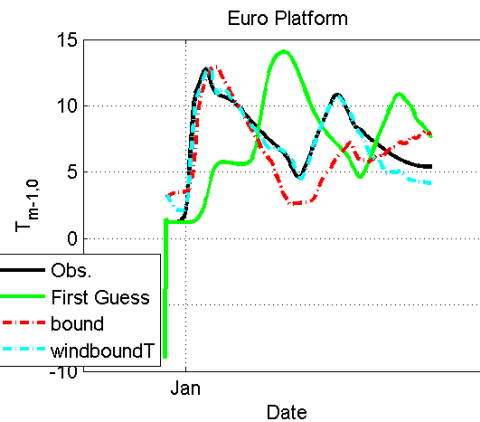
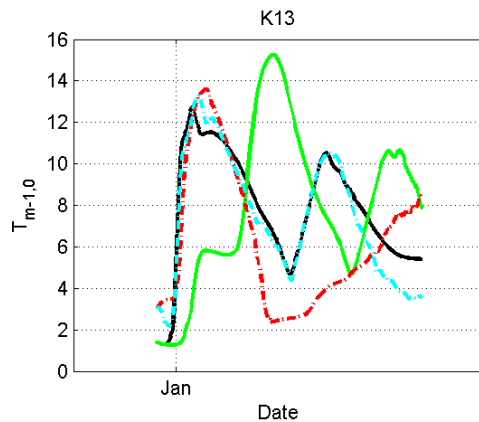
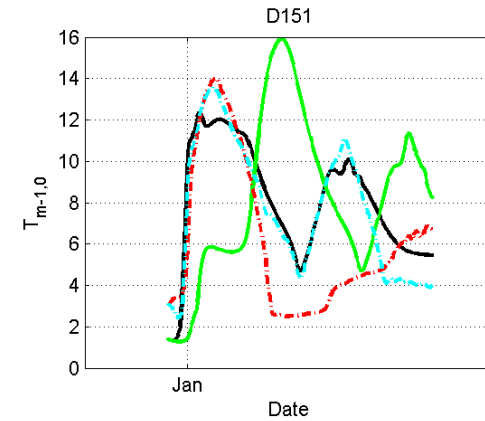
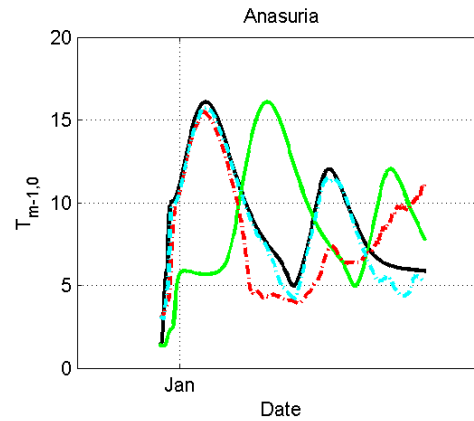
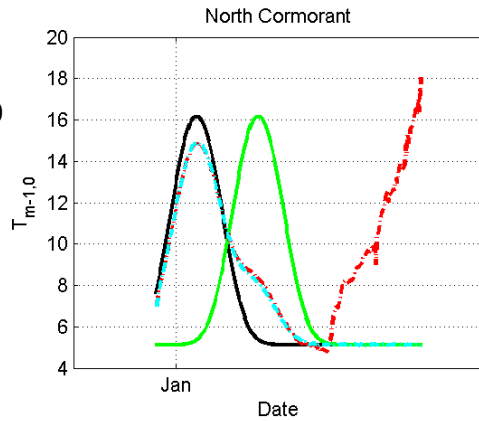
Assimilation of H_s at the 4 buoy locations

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

1D experiment with wind uncertainty



$T_{m-1,0}$



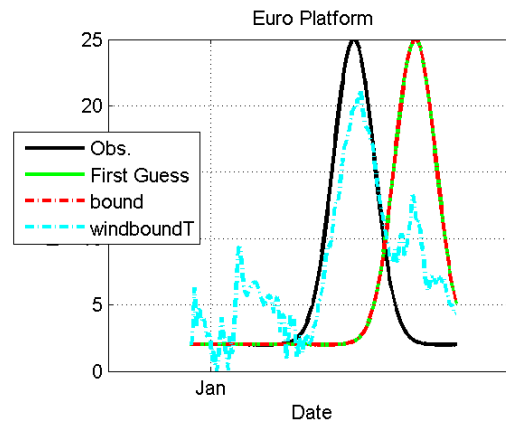
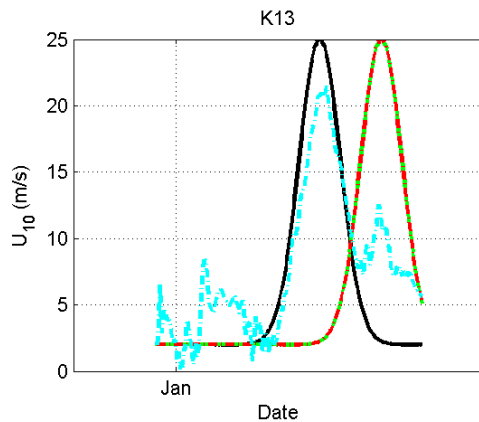
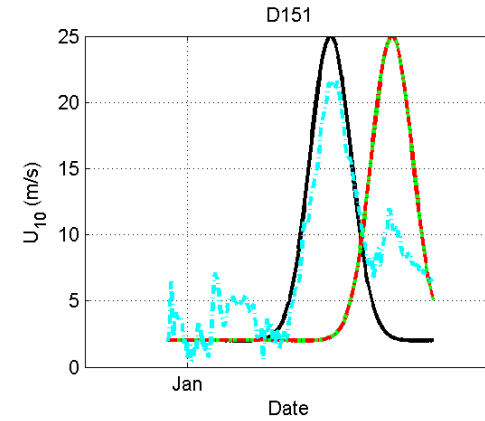
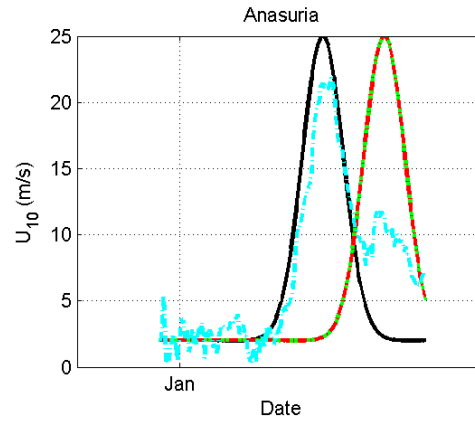
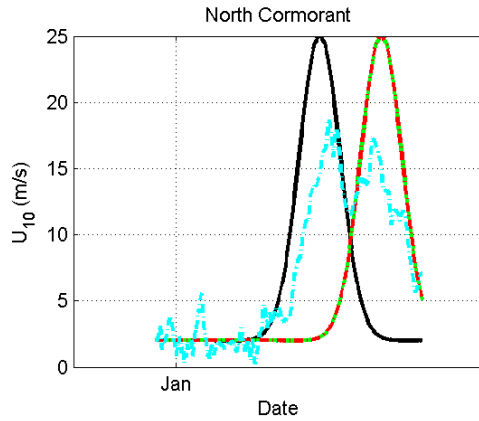
— Obs.
— First Guess
- - bound
- - windboundT

Wave period is adjusted by assimilation of H_s only.

1D experiment with wind uncertainty



$|U_{10}|$

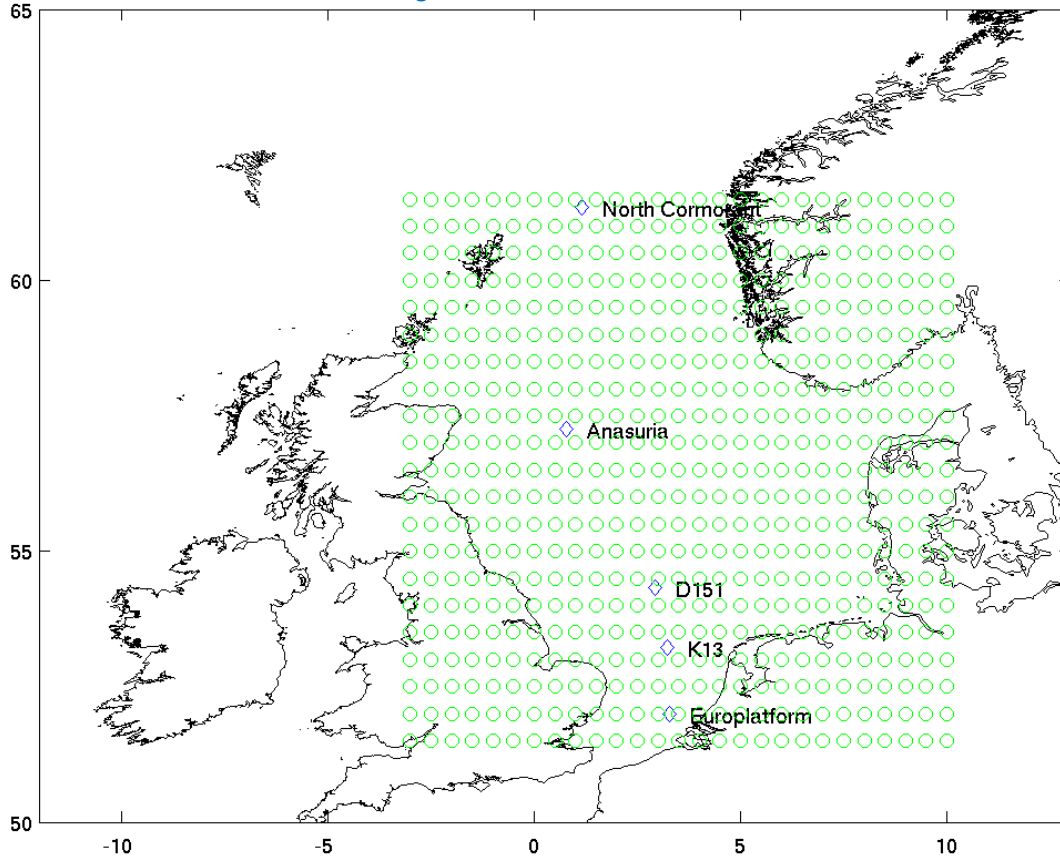


Wind forcing is adjusted by assimilation of H_s

2D experiment



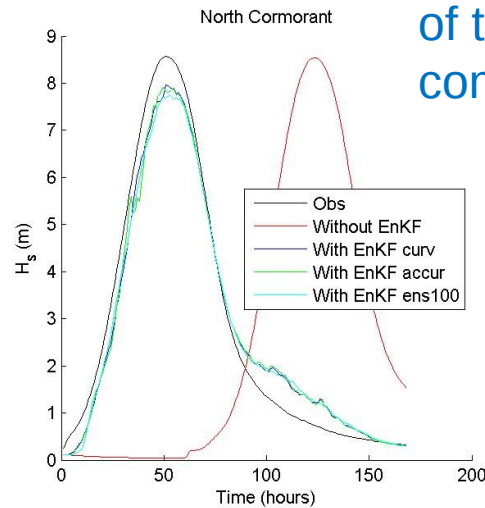
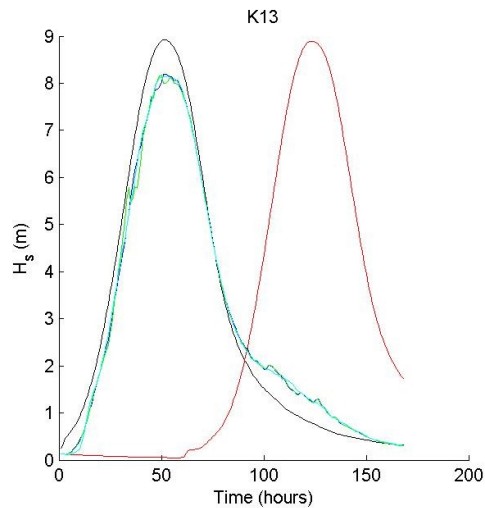
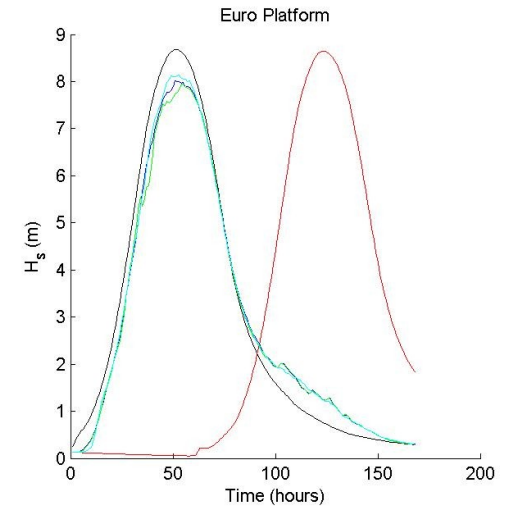
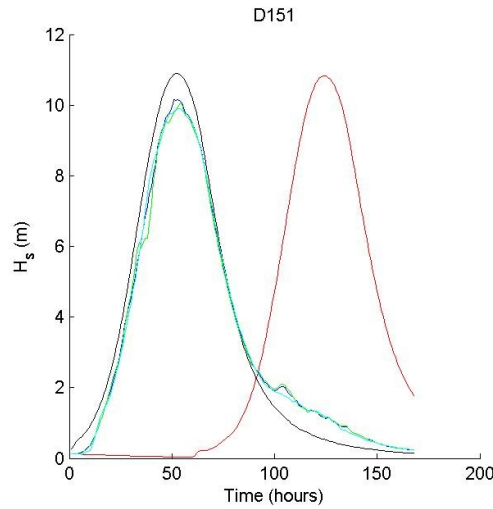
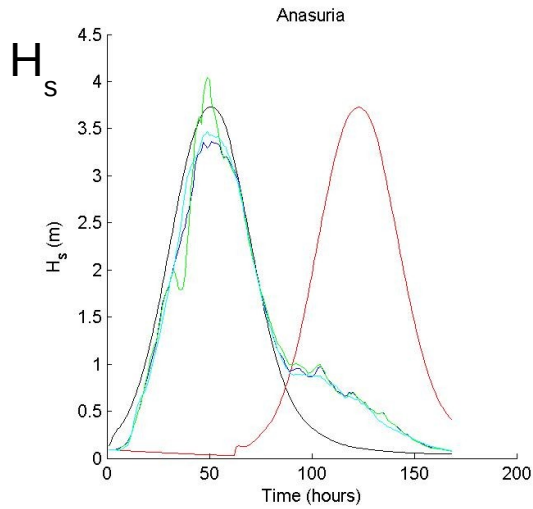
Assimilation of H_s at the 5 buoy locations



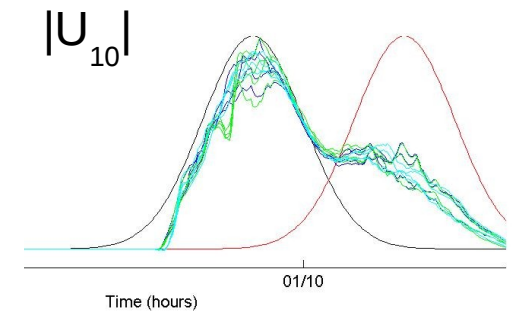
Adjustment of **input wind field** and
of the 2D spectra at each
computational grid location

Task 2.1: Data-assimilation

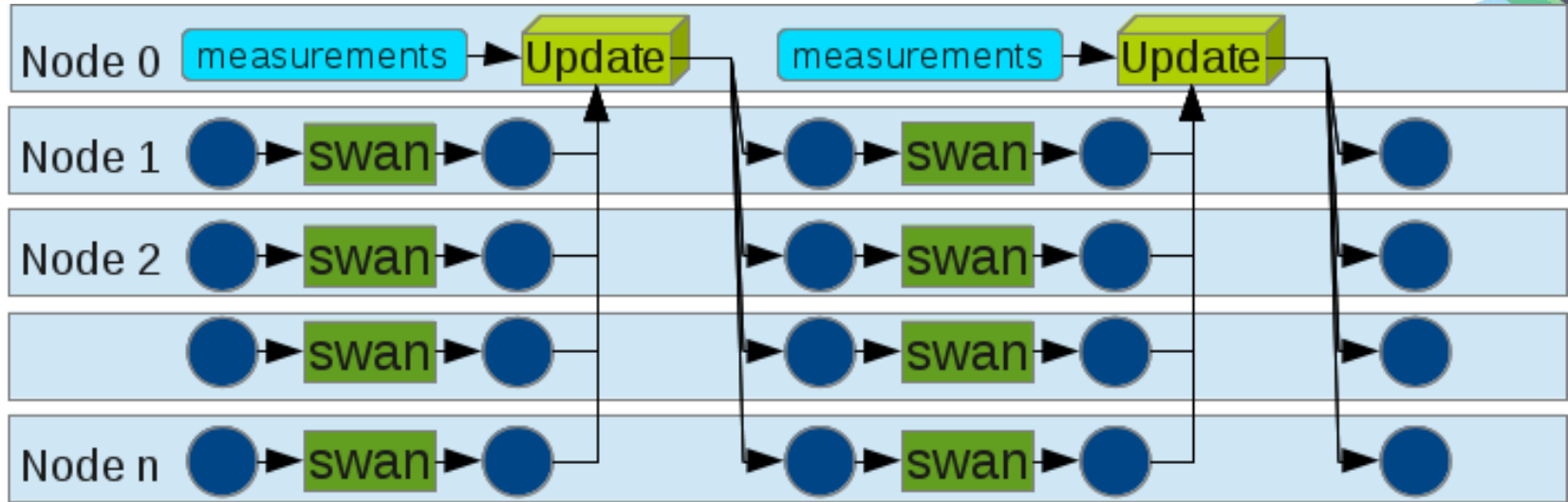
Twin experiment 2D



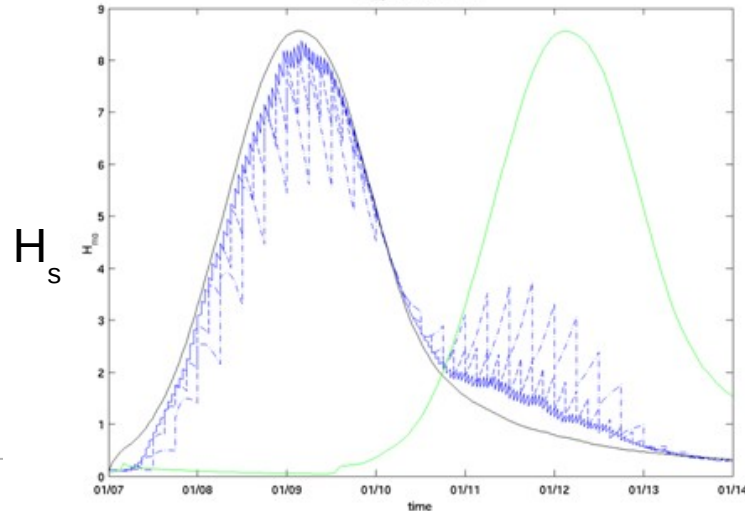
Adjustment of **input wind field** and of the 2D spectra at each computational grid location



Parallel computing & asynchronous filter



Time →



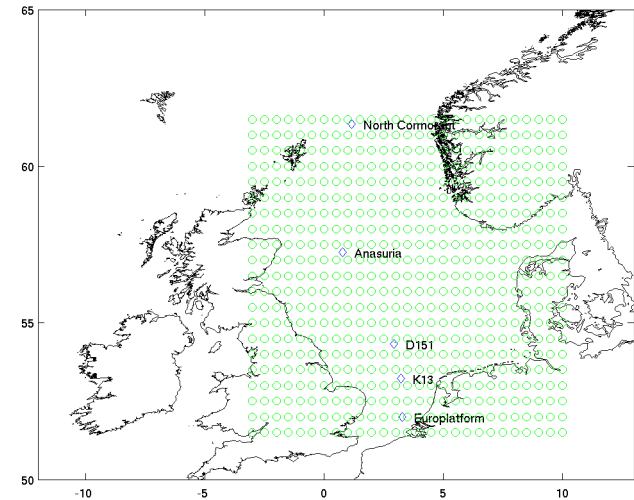
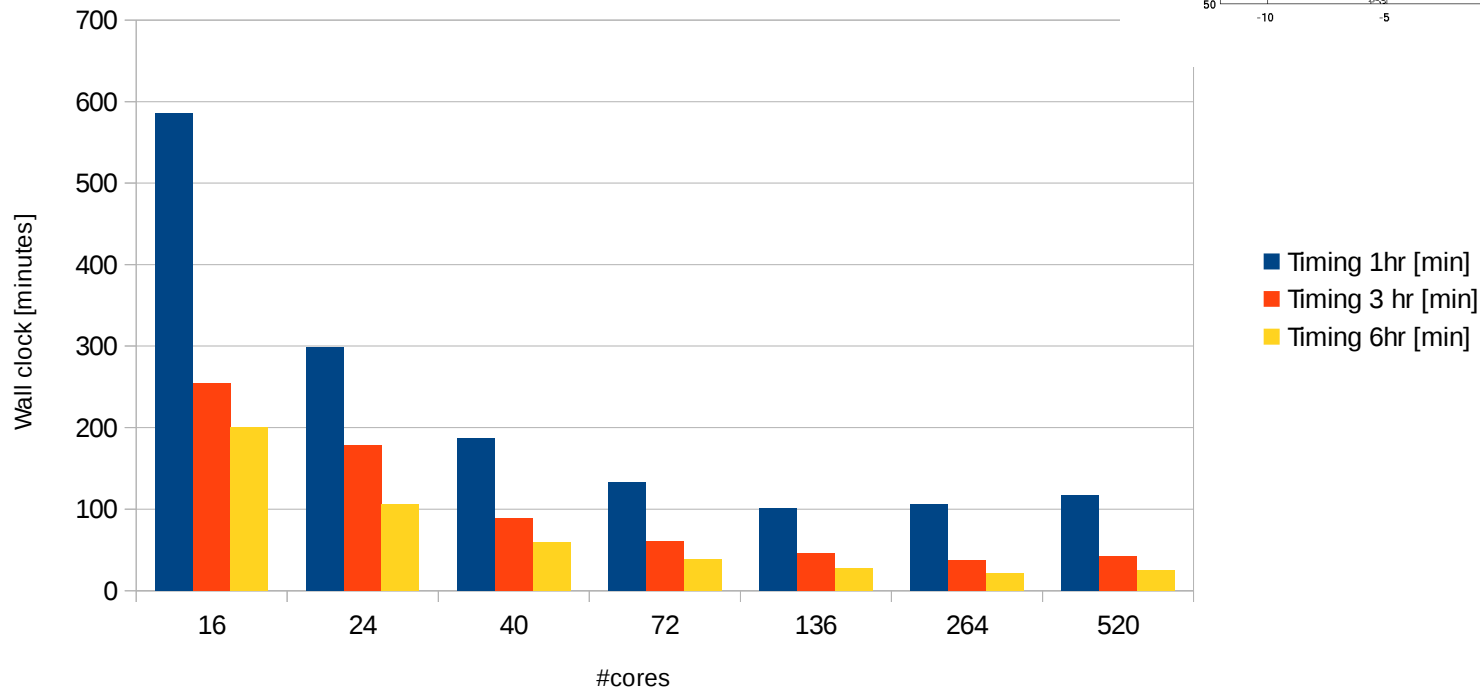
Analysis every 1, 3 and 6 hours

Parallel scaling results



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

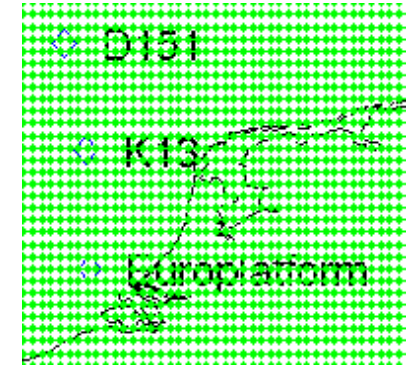
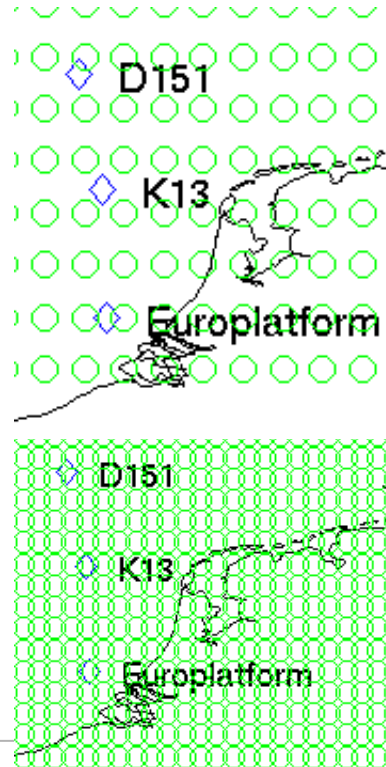
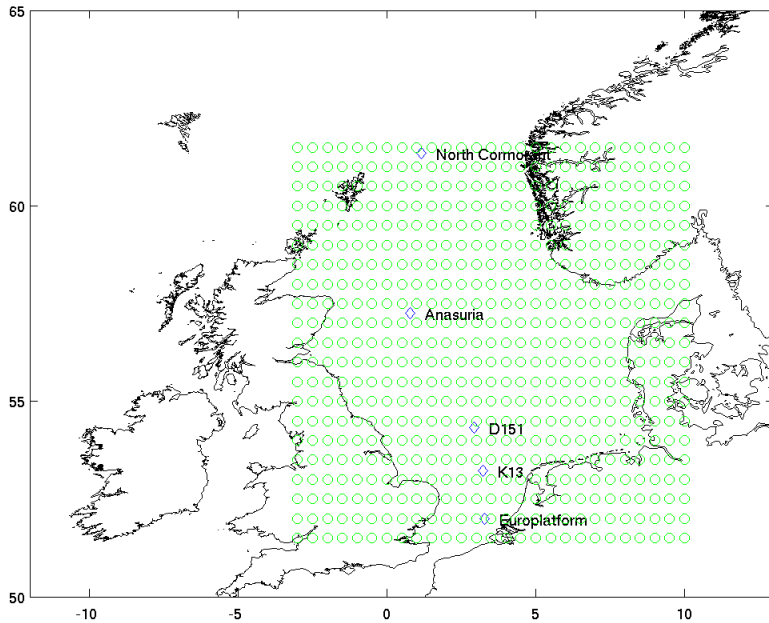
Wall clock for 7day simulation



Case 2: 2d-grid 0.5x0.5°



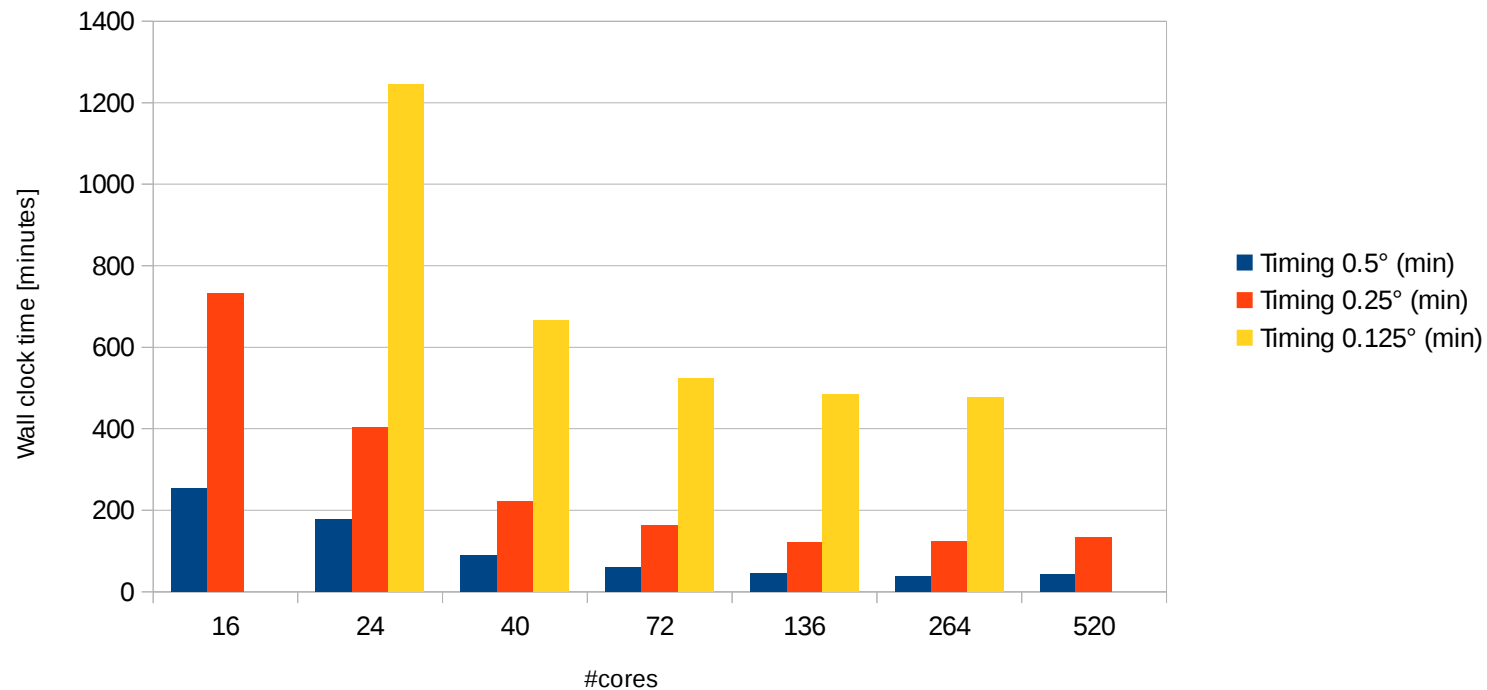
resolution	Number of grid cells	State dimension	Size of ensemble
0.5° x 0.5°	27x21x32x36	653,184	0.3Gb
0.25° x 0.25°	52x42x32x36	2,612,736	1.2Gb
0.125° x 0.125°	104x84x32x36	10,450,944	5.0Gb



Performance and resolution



Wall clock timings for 7day simulation with EnKF



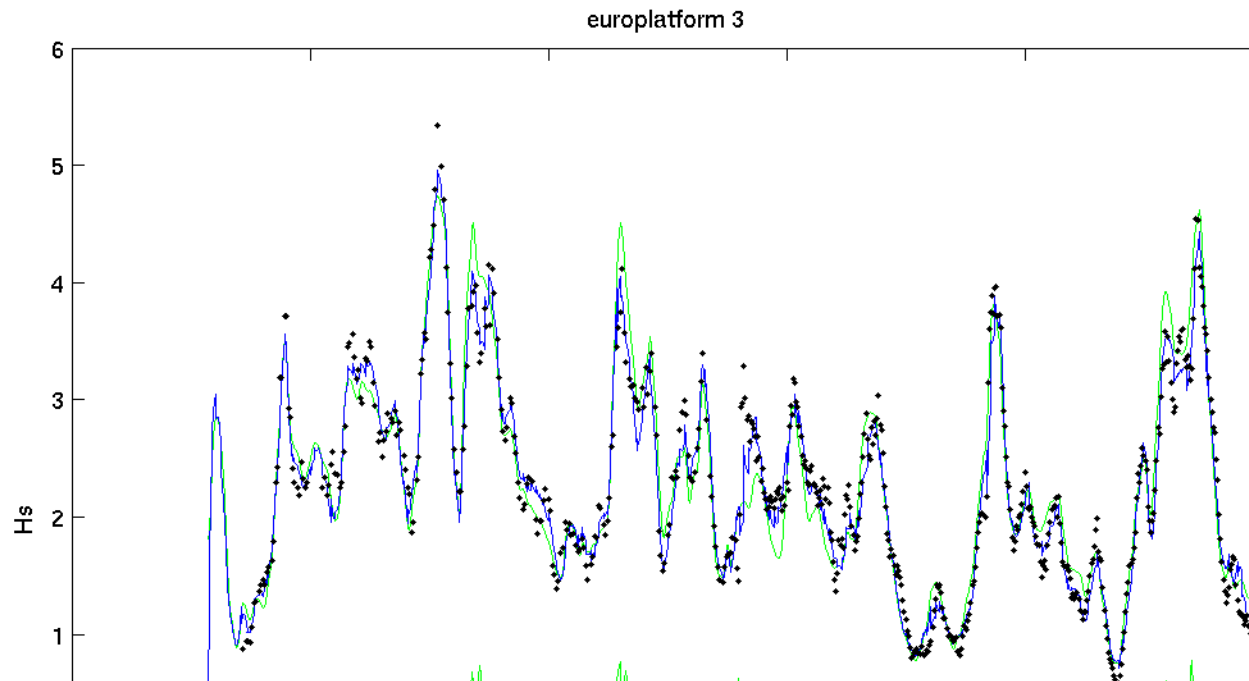
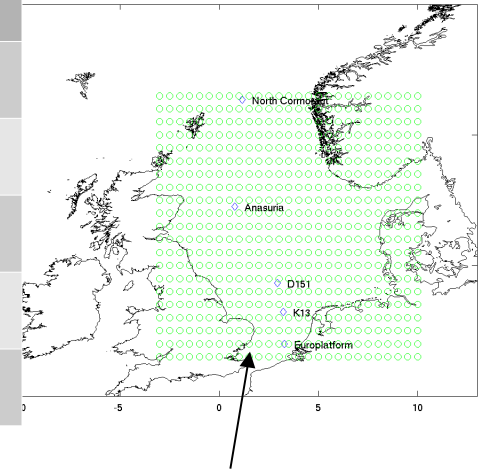
Timing asynchronous EnKF (3hour updates and 128 members)

→ Scaling becomes poor at around 16nodes independent of resolution

2D model with real observations



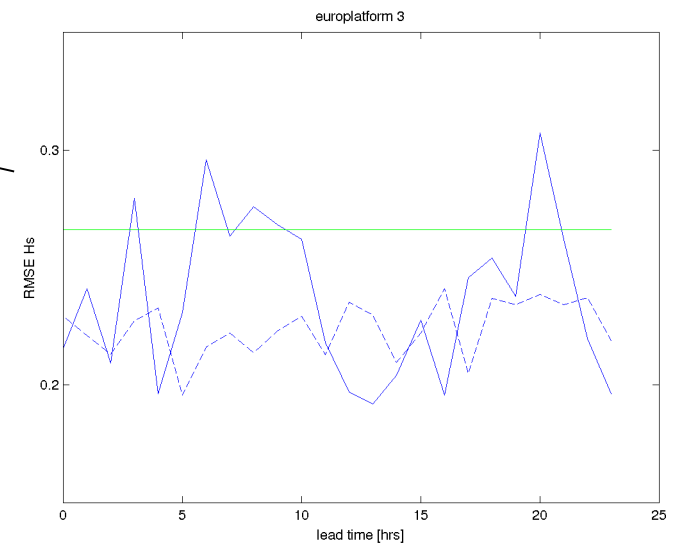
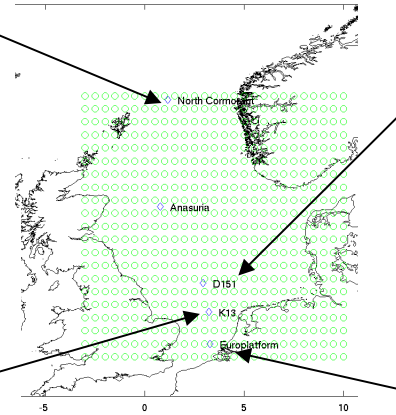
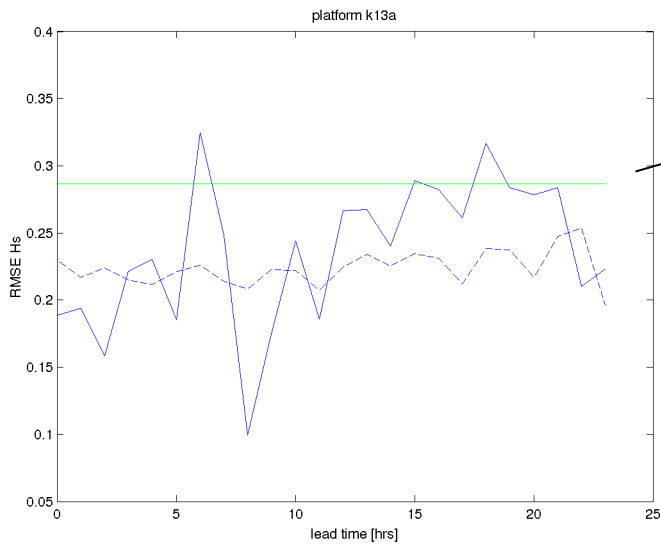
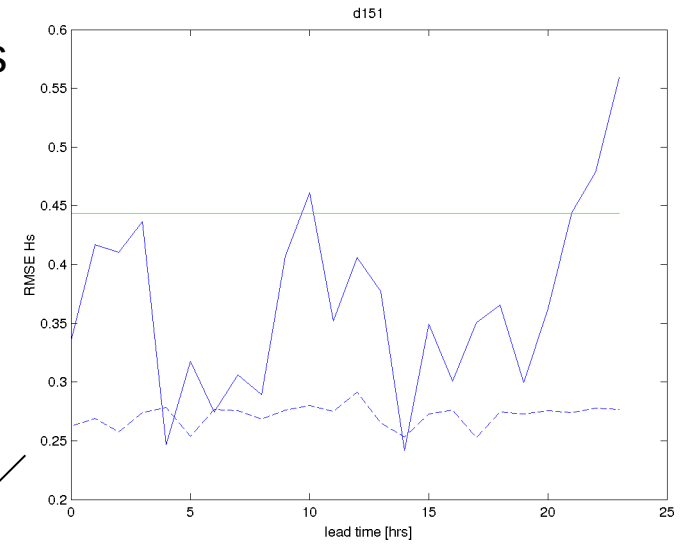
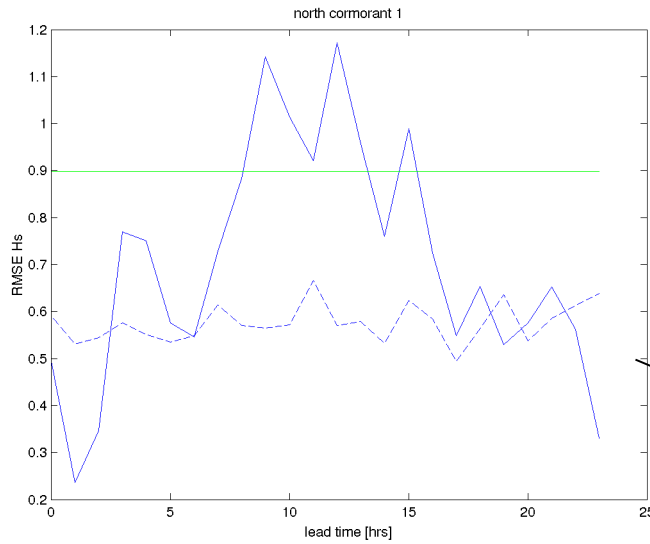
Location	RMS Hs simulation	RMS Hs EnKF
north cormorant 1	0.89	0.52
anasuria	0.43	0.34
d151	0.44	0.31
platform k13a	0.28	0.18
europatform	0.26	0.21



Forecast accuracy



Preliminary results

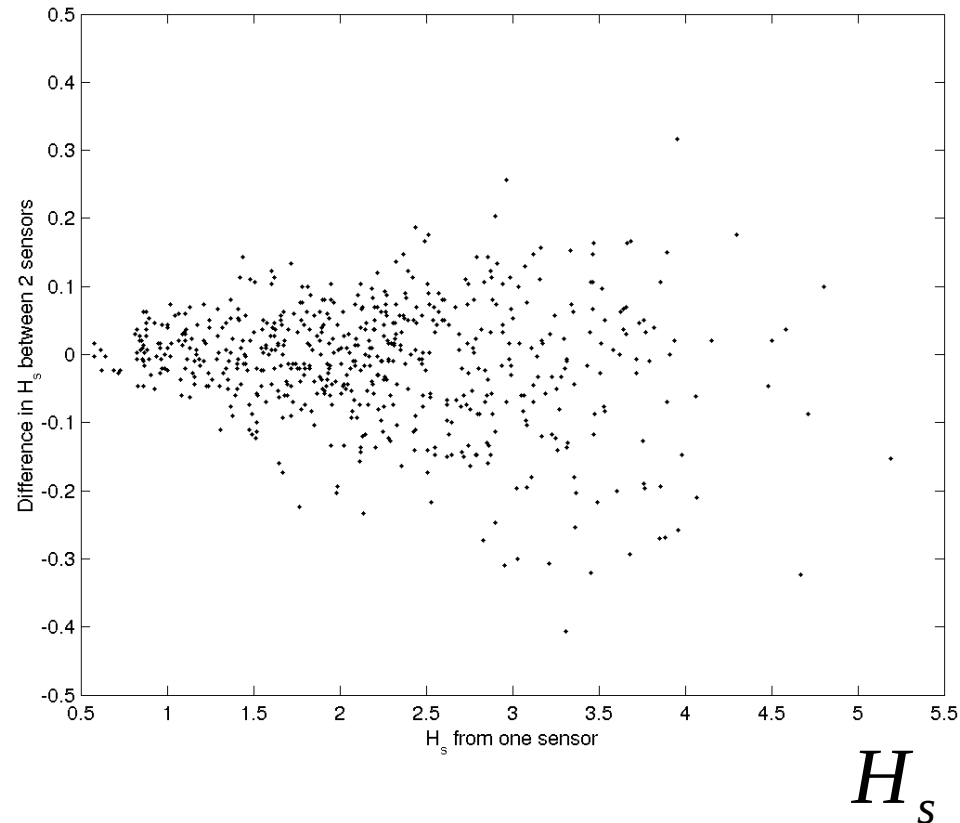


Accuracy of observations



Compare two sensors that are close

$$\Delta H_s$$



Next steps



- 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