SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2015
Project Title:	Wind stress in coupled wave-atmosphere models: storms and swells
Computer Project Account:	spfrardh
Principal Investigator(s):	Fabrice Ardhuin and Jean-Luc Redelsperger
Affiliation:	Ifremer, France and CNRS, France
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Jean-Raymond Bidlot and Peter Janssen
Start date of the project:	April 1st 2013
Expected end date:	December 2015

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	2800000	27079	6000000	16105
Data storage capacity	(Gbytes)	8000	101.784 Gbytes		

Summary of project objectives

(10 lines max)

The better performance of Meteo-France's operational wave model (MFWAM) in many regions of the world ocean (e.g. around Hawaii) shows that ECMWF wave forecasts can probably be improved by using different parametrizations for wind-wave generation and dissipation. However, MFWAM results are not consistent with expect wind stress variability. Our objective is thus to develop wave and boundary layer parametrizations to arrive at a consistent treatment of the both wave evolution and wind stress, leading to improved forecast capabilities in the context of the coupled atmosphere-waves IFS system. Wet considers both high wind conditions in extra-tropical storms of the North Atlantic, for which the stress at a given wind speed is expected to decrease with wave age, and low wind conditions on the global scale for which swells are known to modify the air-sea momentum flux. The first effect that is already taken into account in the IFS, but its magnitude is still debated. The swell effect will probably require a modification of the boundary layer parametrization.

Summary of problems encountered (if any)

(20 lines max)

The project has been delayed as the main PI, F. Ardhuin has been requested in September 2014 to take the chairmanship of a 80 people lab and merging with another 30 people. This has led to the opportunity to combine the special project with an internal Ph.D. thesis work for one of the lab engineers, L. Pineau-Guillou, who has an extensive experience in storm surge and water level modelling. She has taken up the modelling and analysis tasks after two visits at ECMWF in June 2015, and will be working on this project 80% of her time for the coming year. We thank ECMWF for the warm welcome she received and J.R. Bidlot for helping along after a formal one week training.

Summary of results of the current year (from July of previous year to June of current year)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

1. Visits at ECMWF

Lucia Pineau-Guillou has spent two weeks at ECMWF in June 2015.

From 1st to 5th of June, she went to ECMWF training "Numerical Weather Prediction - Avanced Numerical Methods for Earth-System modelling", which focus on recent advances and future challenges in high-resolution numerical modelling of the atmosphere and ocean (governing equations, horizontal and vertical discretisations, time-integration schemes, elliptic solvers, numerical techniques for massively parallel computer architectures expected in the future, coupled processes within Earth System models). The lecture concerning ocean/wave/atmosphere coupling (Peter Janssen) was particularly interesting in the framework of this Special Project.

From 15th to 17th of June, she visited ECMWF to work with Jean Bidlot, and to learn how to manage with IFS system. She learned how to use prepIFS (to prepare an experiment), MARS (to collect results), and perforce (to manage code versions). Environment and informatics problems have been rapidly solved, thanks to help of ECMWF team.

2. Objectives

The objective is to analyse the drag variability caused by the sea state and to estimate its impact on winds. The parameterization used is ECMWF default parameterization (Janssen 1991), comparison will be made in next steps with MFWAM parameterization (Ardhuin et al.; 2010).

3. Experiments

Experiments correspond to mid-latitude storms. Two storms have been simulated: Xynthia storm, which crossed North East Atlantic the 28th of February 2010, and Andrea storm, which occurred the 5th of January 2012.

Configuration for sensitivity tests is Integrated Forecasting System (cycle CY41r1) at resolution T511 (~40 km) coupled to the 55 km resolution WAM using 24 directions and 30 frequencies. Experiments have been carried out, starting from operational analyses and going up to 120 h (5 days). Xynthia storm initial date (which corresponds to operational analysis) is 2010-02-25, and Andrea initial date is 2012-01-02. Output data are every 3 hours (instead of 12h by default). Two experiments have been carried on:

- Experiment 1 is the operational configuration, coupling WAM/IFS (experiment *b0gz*)
- Experiment 2 is the same one, but without coupling WAM/IFS (experiment *b0h0*); this induces a constant Charnock parameter of 0.0018.

4. First results

4.1 Drag coefficient and Charnock parameter from WAM

Analysis of drag coefficient from WAM is underway, for Xynthia and Andrea storms. Figures 1 and 2 show that values are probably overestimated for high winds. Modelled drag coefficient reaches 0.0045, whereas observed drag coefficient for high wind speeds in tropical cyclones are lower than 0.003 (Powell et al.; 2013, see Figure 3). This could be due to an excess of energy level in the high wavenumber tail of the wave spectrum (Bidlot et al.; 2015). Ardhuin et al. (2010) have proposed a parameterization that generally gives a better variability of the high wavenumber tail, compared to Janssen (1991). This parameterization will be tested in next steps.

Analysis of Charnock parameters is also underway, for Xynthia and Andrea (Figure 4 and Figure 5). Graphs show a very strong variability of Charnock parameter, that will have to be analysed more precisely.

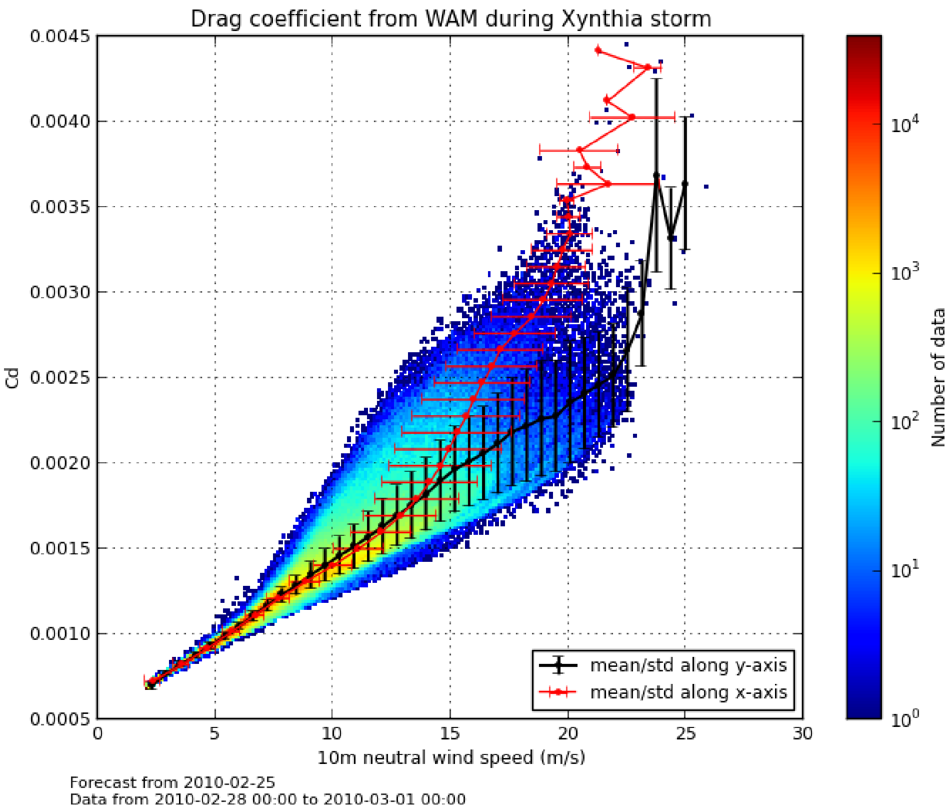

Figure 1: Drag coefficient during Xynthia storm (2010-02-28)

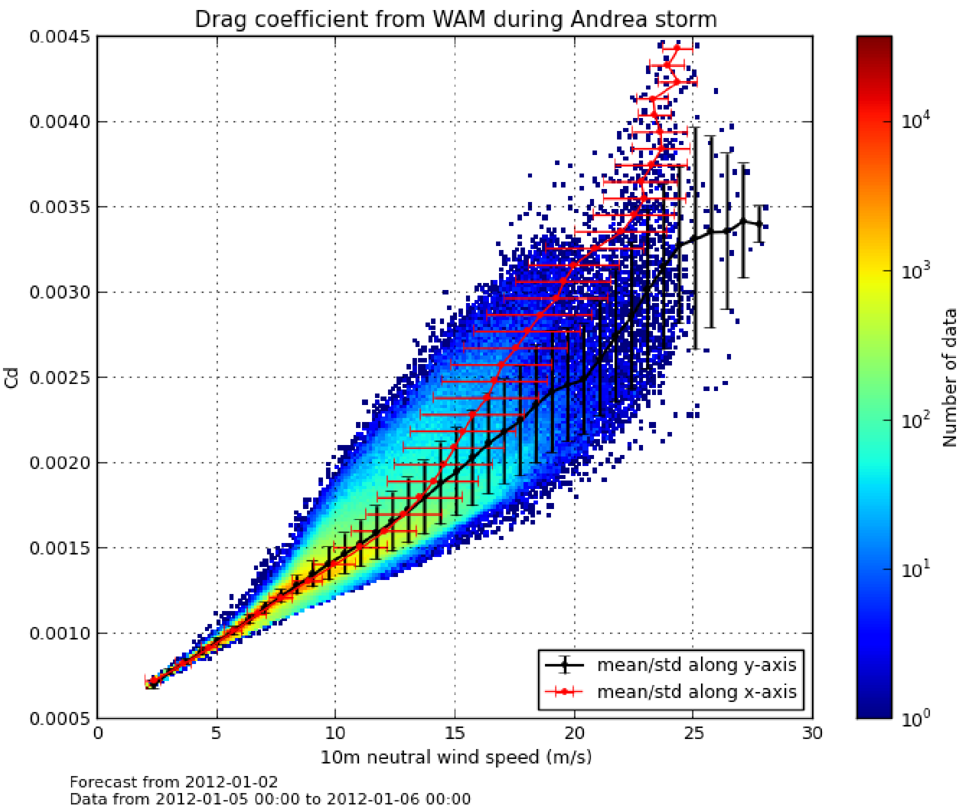

Figure 2: Drag coefficient during Andrea storm (2010-02-28)

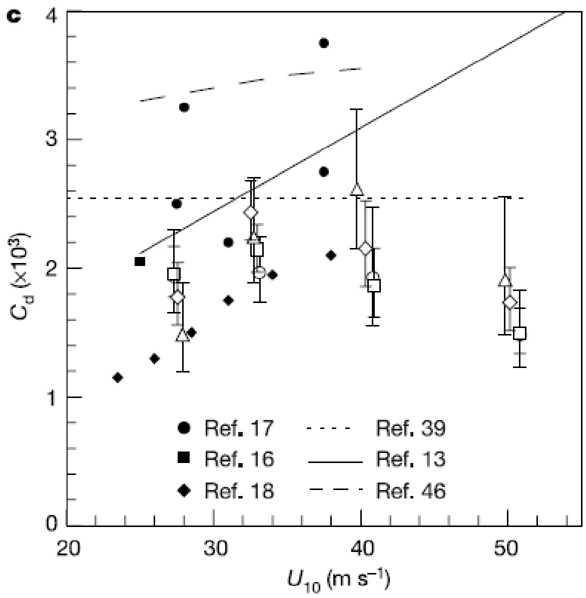

Figure 3: Drag coefficient measured for very high wind in tropical cyclones (Powell et. al 2003)

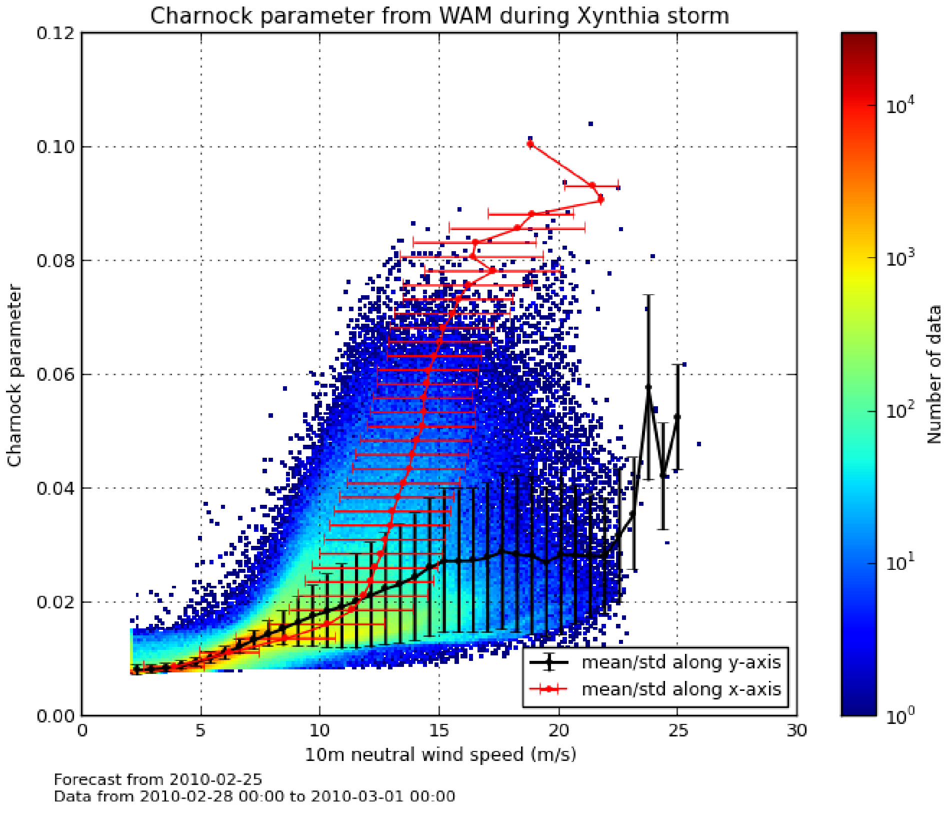

Figure 4: Charnock parameter during Xynthia storm (2010-02-28)

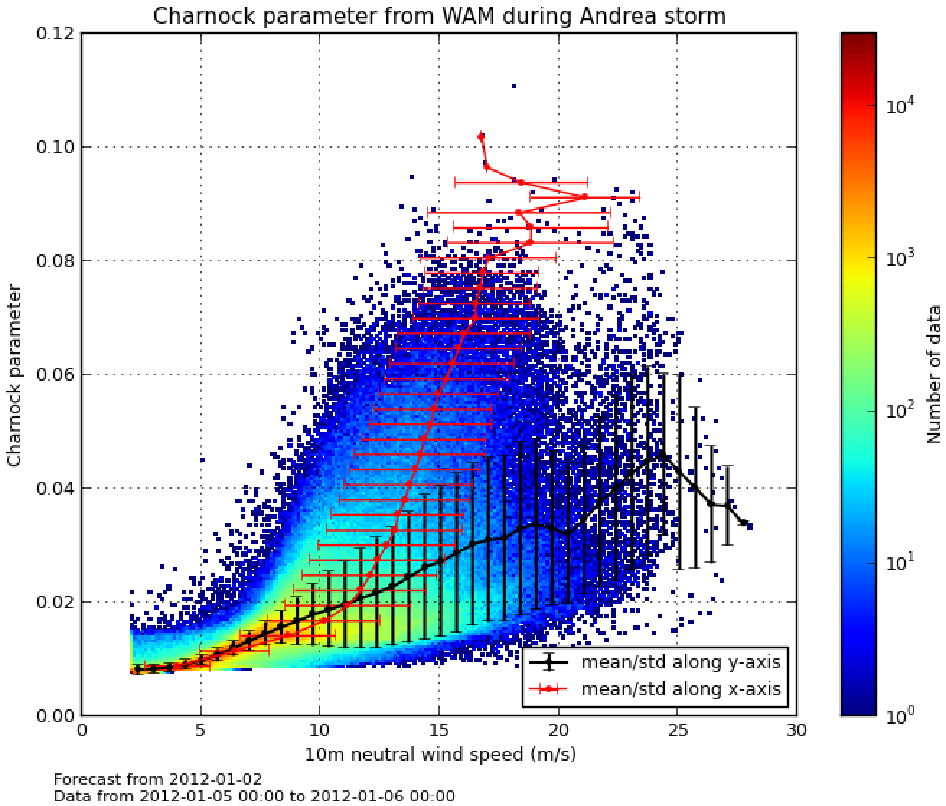

Figure 5: Charnock parameter during Andrea storm (2012-01-05)

4.2 Impact of coupling on winds

Comparisons are under way between coupled and uncoupled simulations (Figure 6), and further simulations will be performed with different Charnock parametrizations based on sea state variables. As previously described by Janssen et al. (2005) and other ECMWF reports, the coupling enhances the Charnock coefficient for high winds. This enhancement yields a higher wind stress, which is partly compensated by a reduced wind speed at 10 m as the atmospheric boundary layer adjusts. There is a strong debate in the scientific community on what should be the right level of the drag coefficient Cd and its dependence on wave age. Many studies suggest that the Cd should not exceed 0.003 (e.g. Powell et al. 2003, Jarosz et al. 2007). There is also a known strong difference between wind speeds from ECMWF and other wind estimates. In particular, ECMWF winds above 20 m/s are typically 10% lower than NCEP (e.g. Rascle and Ardhuin, Ocean Modelling 2013), which can have a big impact on extreme sea states (Hanafin et al. BAMS 2012). We will use independent buoy and satellite to verify if ECMWF is biased low or NCEP is biased high. Our working hypothesis is that the wave-atmosphere coupling used at ECMWF introduces some realistic variability of the wind stress, but that the level of the stress at high wind may be too high, which would be compatible with low bias in the wind speeds.

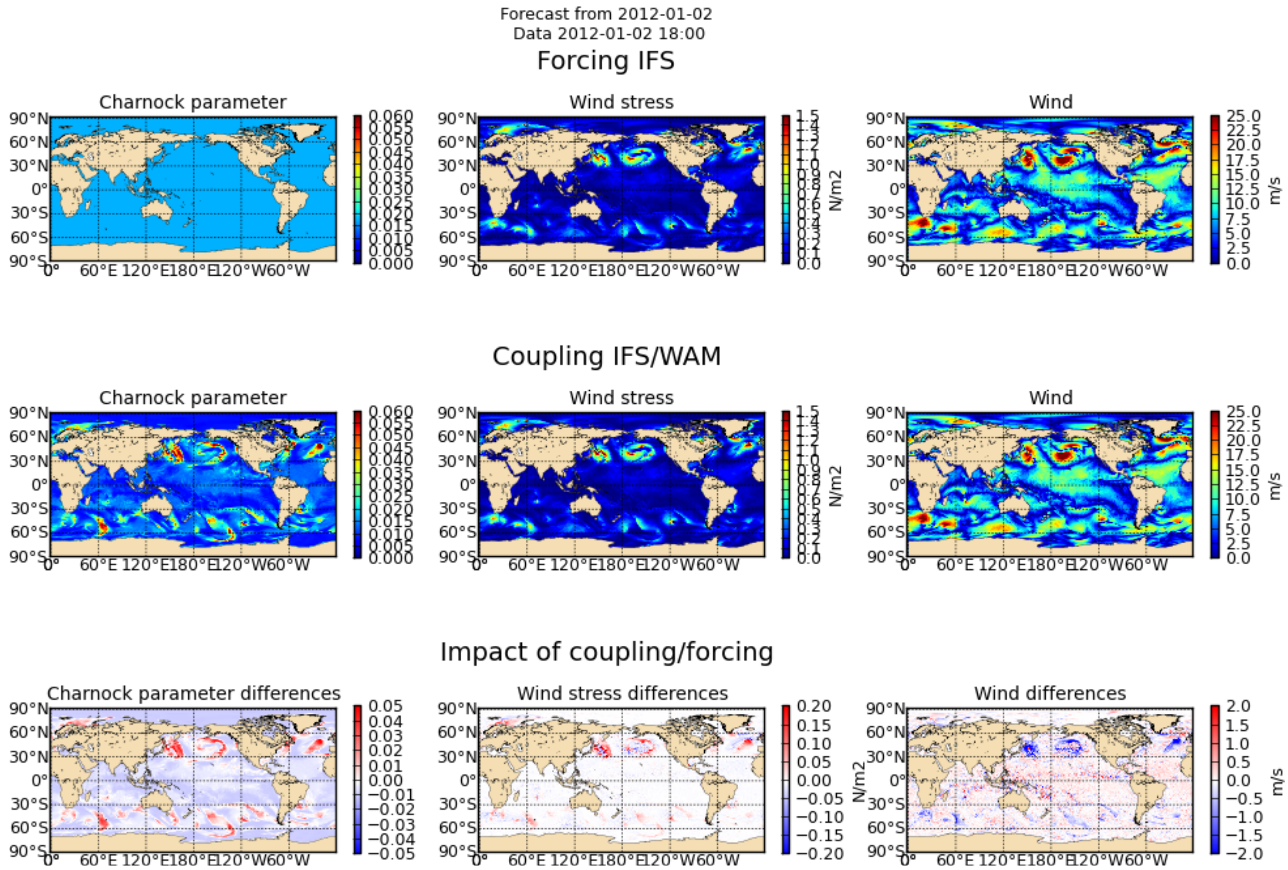

Figure 6: Comparison of Charnock parameter (left colum), wind stress (middle column) and wind (right colum) without coupling IFS (first line) and coupling IFS/WAM (second line), 2012 January 2nd 18h. The third line represents differences between coupling and forcing (differences between second and first line).

4.3 500mb geopotential height anomalies

A preliminary analysis of the Andrea storm is done here, starting from the operational analysis on 2012-01-02, with a 5 day forecast, verified against the analyses. Using the standard score of the 500 mb geopotentiel height anomalies, there is a clear difference between the coupled and uncoupled run which must be caused by the lower stress in the coupled run, with a different atmospheric adjustment. A comparison between analysis and forecast the 4th of January 2012 is presented Figure 7. Correlations between forecast and analysis, show that increasing the forecast range, correlation coefficient decreases (Figure 8). Evolution of correlation coefficient with forecast range from the 2nd to 6th of January 2012 coupling/uncoupling WAM/IFS is presented Figure 9. Results coupling/uncoupling WAM are very similar, but after a 3 days forecast, uncoupled results have a higher correlation with the analyses. Further case studies will help document if this is a persistent feature and if coupling but with a different parameterizations can provide an improved forecast score.

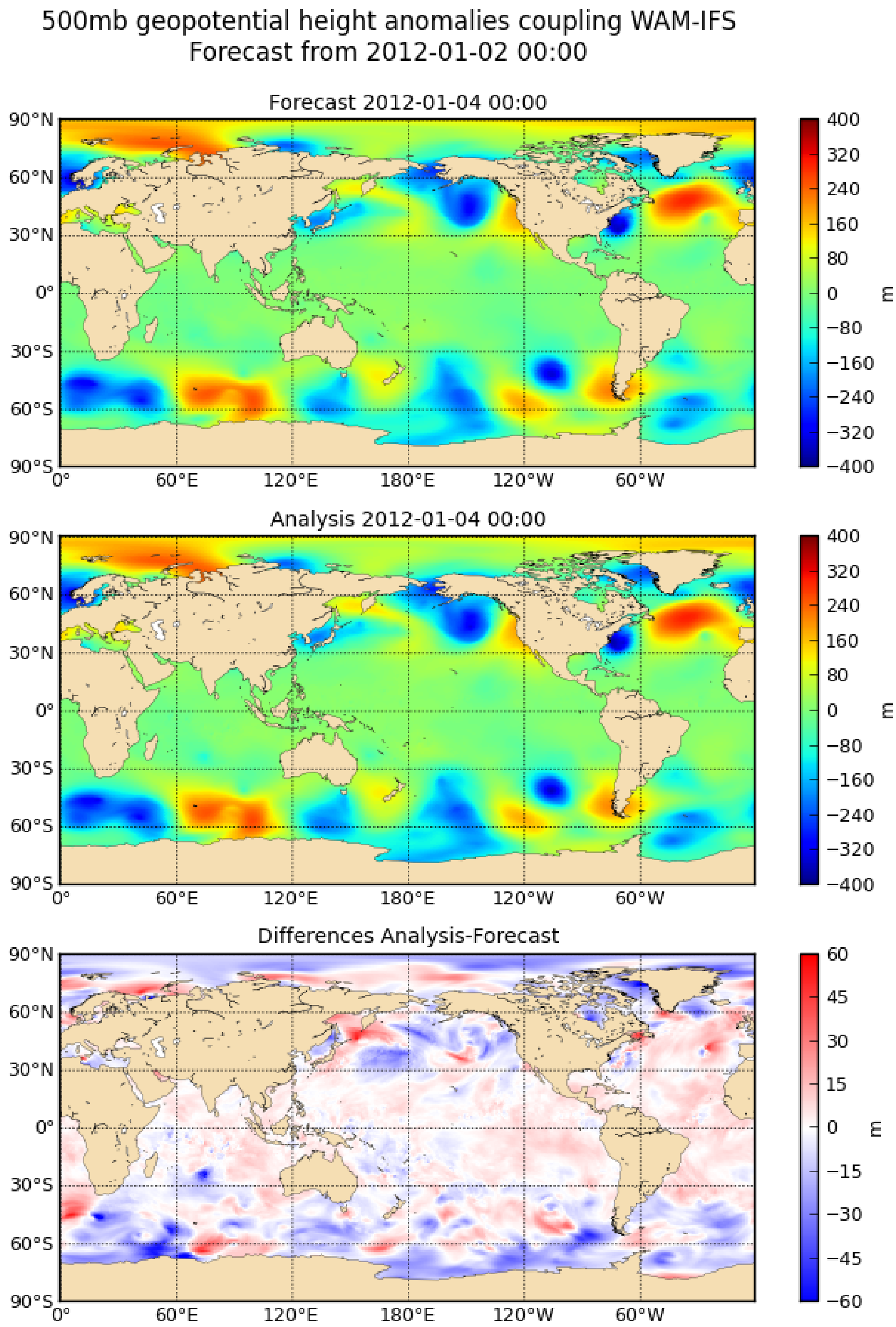

Figure 7: 500mb geopotential height anomalies from forecast (top), analysis (middle) and differences between analysis and forecast (down) the 4th of January 2012; forecast from the 2nd of January 2012 coupling WAM/IFS.

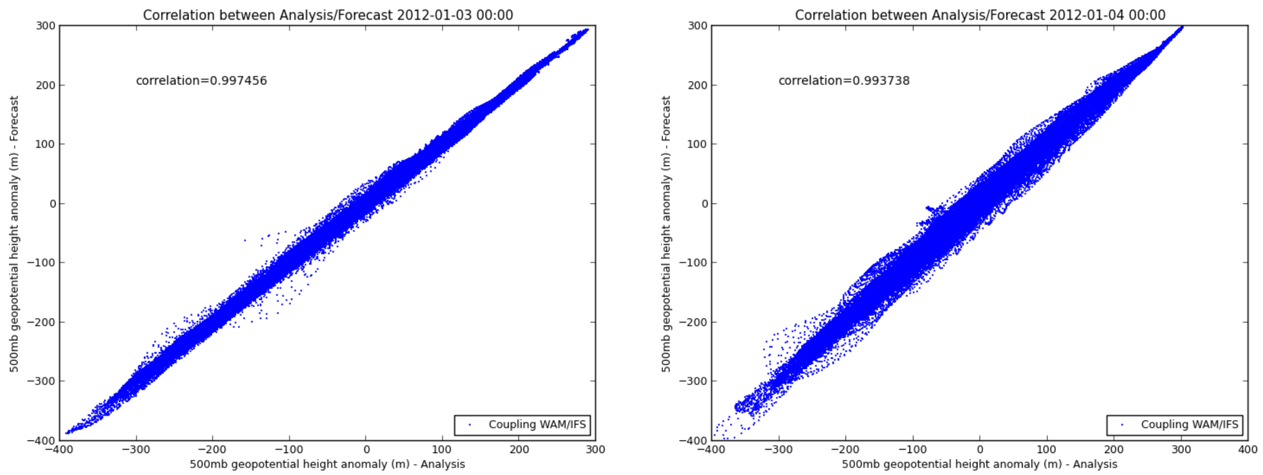

Figure 8: Correlation between analysis and forecast of 500 mb geopotential height anomalies the 3rd of January 2012 (left) and the 4th of January 2012 (right); forecast from the 2nd of January 2012 coupling WAM/IFS.

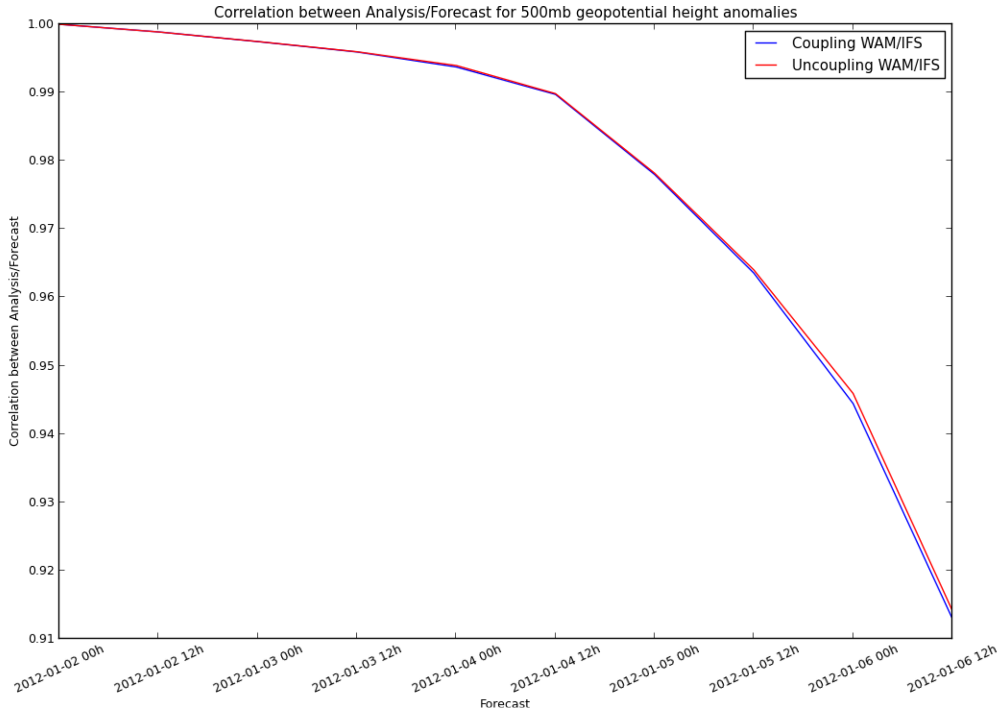

Figure 9: Correlation coefficient between analysis and forecast of 500 mb geopotential height anomalies; forecast from the 2nd of January 2012 coupling WAM/IFS (in blue) and uncoupling WAM/IFS (in red).

5. References

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List of publications/reports from the project with complete references

No publication/report has yet been completed. A final report is planned by the end of the year.

Summary of plans for the continuation of the project

(10 lines max)

The experiments have been made only on two storms. In order to have a more statistical approach, experiments will be led on about 10 cases, of main storms at mid-latitude in North East Atlantic during the last 10 years. The choices will be established from analysis of ECMWF production, pointed out maximal values.

The next steps to be taken are:

- the analysis of drag coefficient and Charnock parameter,
- the analysis of the forecasts with coupled and uncoupled waves, in order to identify interesting cases and understand better the adjustment to roughness (change in stress, wind speed, SLP …),
- the analysis of the impact on heat fluxes,
- the evaluation of Meteo France wave model parameterization (Ardhuin et al. 2010).