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	2013
Project Title:	Wind stress in coupled wave-atmosphere models: storms and swells
Computer Project Account:	tpfa
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)	NA	NA	5600000	27079
Data storage capacity	(Gbytes)	NA	NA	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)

After a late start in April, F. Ardhuin visited ECMWF (7 to 10 May) to learn how to use IFS, PrepIFS, MARS … and submit jobs. Some difficulty that we are still dealing with is the re-development of analysis tools. For example, we are still waiting to see if we can compute forecast scores with 'verify'.

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. **Understanding the performance of forecasting systems with respect to winds and waves.**

a. Starting point of the project

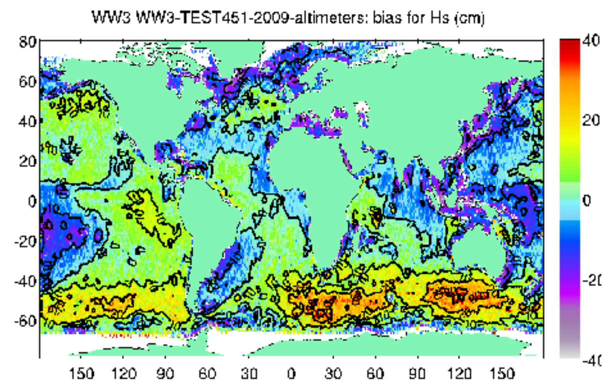
Prior knowledge on wave and atmosphere model behaviour was based on the monthly reports compiled for JCOMM by J.R. Bidlot. Because the forecasting systems use many different components, it is very difficult to determine the beneficial effect of any of these components on the final results. For example, although ECMWF, Meteo-France (MF) and SHOM-Ifremer (Previmer) all use the ECMWF analysed and forecast winds for their wave forecasts, but they use different resolutions, different assimilation procedures and physical parameterizations:

- ECMWF uses Janssen (1994) with later adjustements by Bidlot et al. (2005) and Bidlot (2012).
- MF uses Ardhuin et al. (2010) as modified by Rascle and Ardhuin (in press)
- Previmer uses the same parametrization as MF but in a different numerical setting (use of the WAVEWATCH III (WW3) code with different spatial propagation schemes and time integration schemes) and no data assimilation.

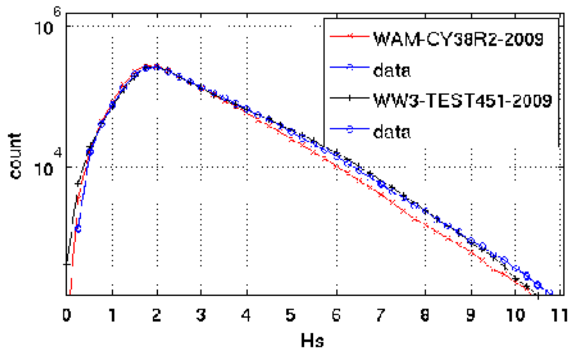
Also the JCOMM validation is only performed with buoy data.

b. Work performed and connection to MyWAVE and U.S. NOPP projects.

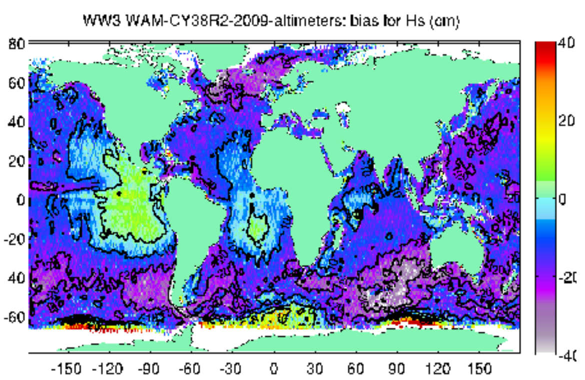
As part of the MyWAVE project, the version of WAM (MFWAM) used my MF has now been merged in the IFS, allowing a more direct comparison of the models. Our first simulations have thus consisted of free runs (without assimilation) in order to understand better the parameterizations behaviour and the IFS results compared to Previmer.



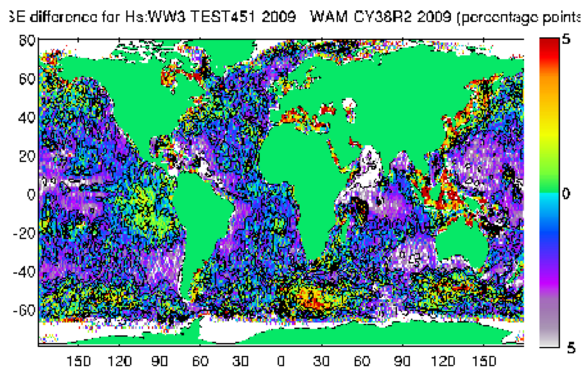
Bias map against altimeter data for the year 2009: parameterization by Ardhuin et al. (2010).



Distribution of wave heights for the two different parameterizations, ran in two different numerical codes, compared to satellite altimeter observations (Globwave database).



Bias map against altimeter data for the year 2009: parameterization by Bidlot (2011): free run of ECWAM.



Difference map of normalized RMS errors between two runs with the different parameterization: green to red correspont to regions where Bidlot et al. (2011) gives a lower RMS error against altimeters.

The free IFS (WAM) results confirm that random errors and biases against altimeter are indeed larger than those obtained with WW3 (see above). We note, however, that the recent modifications by Bidlot (2012) in CY38R1 strongly reduced the high wave height bias in the central Pacific swell pool to under 10 cm, compared to previous parametrizations which gave up to 40 cm (Bidlot et al. 2005, Rascle et al. 2008). This is typically the result of the reduction in the "ZALP" parameter which enhances the wave age and thus the growth of wind waves in storms. This reduction also comes with a reduction of very high waves in intense storms but that is likely compensated in part by an intensification of the winds in these systems coming from the higher horizontal resolution of the atmospheric model. However, there is still a low bias of -40 to -20 cm at mid-latitudes (35° to 70°). This bias is reversed to positive around Antarctica, probably as a result of the presence of icebergs (Ardhuin et al. 2011), not represented in the ECMWF WAM model.

Runs have just been performed with the MFWAM implementation of Ardhuin et al. (2011) and are expected to give the same results as the WW3 runs. They will be analyzed shortly. Such errors on the significant wave height are much reduced in the operational IFS system, probably in part thanks to the assimilation of satellite altimeter data. We will perform a few complete forecast cycles with assimilation to verify how large can the improvements be in an operational context, for wave heights, when using the alternative parametrization.

3. Impact of wave model parameterization of atmospheric evolution: high winds

This part of the work has only started: a few forecast cycles (one every 5 days) have been done, starting from the operational analyses and going out to 240 h, with a T511 horizontal resolution and 91 vertical levels. These differ in the wave & wind stress parameterization.
Run 1 is the operational configuration. (this is experiment tpfa_b0fw)
Run 2, is the same as run 1 but without the wave feedback: this corresponds to a constant Charnock parameter. (this is experiment tpfa_b0fz)
Run 3 is the same as run 1 but with the MFWAM implementation of Ardhuin et al. (2011) for which there is a very weak variation of the Charnock coefficient.

We are in the process of analyzing these first runs to define our methodology for analyzing the impact of the change in ocean roughness and analyzing the adjustment to the surface friction (e.g. Adamson et al. 2006). Once this is done we shall further define alternative wave model parameterizations with different degrees of variability of the Charnock coefficient. Starting from the Ardhuin et al. (2011) parameterization we may either reduce the sheltering term, which reduces the stress felt by short waves, as suggested by Lotfi Aouf, or include an enhancement of the stress that will be a function of wave breaking, as proposed by Banner and Morison (2010) and many others.

Finally, we will run complete cycles, generating a fresh analysis with these different parameterizations and not starting from the operational analysis.

4. Impact of wave model parameterization of atmospheric evolution: swells

We may decompose this effect in two parts.

4.a Wind sea modification by swells

In the first part the swell modifies the average roughness due to a nonlinear modulation effect, typically involving wave breaking. For this we will explicitly model wave spectra over oscillating water levels and currents corresponding to waves. This will be performed with WAVEWATCH III, and the result will be compared to measured modulation transfer function (Hara et al. 2003) and radar modulation transfer functions. From this, we will estimate an increase in the short wave dissipation, averaged over the phase of the long waves, and parameterized from the slope of the long waves. This will be also confronted to the gulf of Tehuantepec data. In the model it will result in a change in Charnock coefficient, which does not require any change in the atmospheric model.

4.b Swell impact on the atmospheric boundary layer

Recent 1D models that include swell effects on the planetary boundary layer include the works by Kudryavtsev and Makin (2004). The linearization of the shear stress with the wave amplitude yields a momentum flux that is linear in the swell amplitude, which is not consistent with the non-linear dissipation estimated from large-scale swell propagation (Ardhuin et al. 2009). Following Semedo et al. (2009), we shall thus use the boundary layer model of Kudryavtsev and Makin (2004), replacing the surface upward momentum flux by a given value. Here this value shall be provided by the wave model and based on these large scale estimates of swell dissipation (Ardhuin et al. 2010).

Using an vertical exponential decay for the upward momentum flux, we will thus introduce a vertical variation in the momentum flux within the PBL. Simulations will be performed first with the 1D column model and compared to the results of Semedo et al. (2009). This swell-affected layer being not necessarily resolved in operational simulations we will probably further parameterize the swell effect by either further modifying the Charnock parameter or setting a non-zero wind at the surface level, in a way similar to the parametrization of the streaming velocity induced by waves at the bottom of a shallow ocean.

5. References

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List of publications/reports from the project with complete references

No publication/report has yet been completed.

Summary of plans for the continuation of the project

(10 lines max)

The next steps to be taken are :

- 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 investigation of other wave parameters, in particular the mean square slope, which is related to altimeter cross section (which are routinely measured) and the high frequency tail of the wave spectrum.
- The evaluation of alternative wave model parameterizations (e.g. Ardhuin et al. 2010)
- The implementation of a surface upward momentum flux in the PBL and 1D simulations

A visit by F. Ardhuin (and MN Bouin) to ECMWF will probably take place in October 2013 to finalize some modifications on the wave model code and begin to discuss the PBL tests.