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 2018……………………………………………………

Project Title: Improvement of wind stress parameterization in coupled wave-atmospheric models ……………………………………………………….……

Computer Project Account: SPFRARDH ……………………………………………………….……

Principal Investigator(s): Fabrice Ardhuin ……………………………………………………….……

Affiliation: LOPS (Laboratoire d'Océanographie Physique et Spatiale), CNRS ……………………………………………………….……

Name of ECMWF scientist(s) collaborating to the project (if applicable) Jean Bidlot ……………………………………………………….……

Start date of the project: 2016……………………………………………………

Expected end date: 2018…………………………………………………….

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)	3,000,000	2,277,885	3,000,000	581,103
Data storage capacity	(Gbytes)	8		10	

Summary of project objectives

(10 lines max)

Wind stress is a key parameter for ocean-atmosphere mechanical exchanges. As such, its realistic parameterization in atmospheric models is of special interest. In particular, it may significantly influence evolution of storms, both hurricanes and extra-tropical storms (e. g. Emanuel 2003). This research work aims at better representing the wind stress in numerical models, leading to an improved parameterization of turbulent fluxes, namely momentum flux, sensible and latent heat fluxes. This study will be based on experiments using Integrated Forecasting System (IFS) coupled with Wave Model (WAM).

The objective is to define an optimal wind stress parameterization, based on a more physical approach, taking into account (1) the wave influence, especially dependence of the drag on the wave age, by moderate to strong winds, (2) the spray influence by very high winds.

Summary of problems encountered (if any)

(20 lines max)

We did not encountered any problem in 2016.

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.

We first tested the impact of different wind stress formulations on the atmosphere. The results are detailed in Pineau-Guillou et al. (2018).

We then tested the impact of these formulations on the ocean. In ocean models, wind stress is parameterized using bulk formulae, that express it as a function of the wind speed and of a drag coefficient. Various wind stress parameterizations can modify the resulting storm surges amplitude by up to 20% (Mastenbroek et al., 1993; Muller et al., 2014). Most formulations depend only on the wind speed - e.g. Hellerman and Rosenstein (1983) in TUGO ocean model (Lyard et al., 2006), whereas others take into account the wave effect on the drag coefficient through a larger roughness length for a given wind-speed - e.g. Janssen (1991) in ECMWF (European Centre for Medium-Range Weather Forecasts) coupled wave-atmosphere model.

Here, we used the global ocean model TUGO from LEGOS (Lyard et al., 2006). We focused on the North Sea (Figure 1), where the wind stress significantly impacts the storm surges, because of very shallow waters.

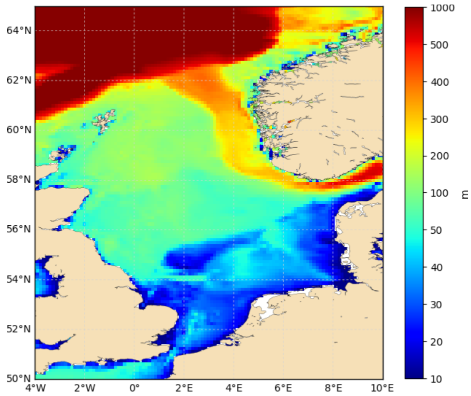

Figure 1: Bathymetry of the North Sea, from TUGO ocean model

To select the storms, we focused on the maximum surges in the North Sea. We analysed 101 tide gauges (Figure 2), obtained thanks to Copernicus Marine Environment Monitoring Service (CMEMS). Tide gauge data cover the period 2012-2017. We also analysed 8 years (2008-2015) of JASON-2 data along tracks in the North Sea (Figure 2), from the Center for Topographic studies of the Ocean and Hydrosphere (CTOH) 1Hz Sea Level Anomaly product in the North East Atlantic. To be consistent with the model and the tide gauges, we added to the Sea Level Anomaly the Dynamic Atmospheric Correction (DAC), to obtain the surge. The DAC corresponds to the ocean response to atmospheric forcing (atmospheric pressure and winds).

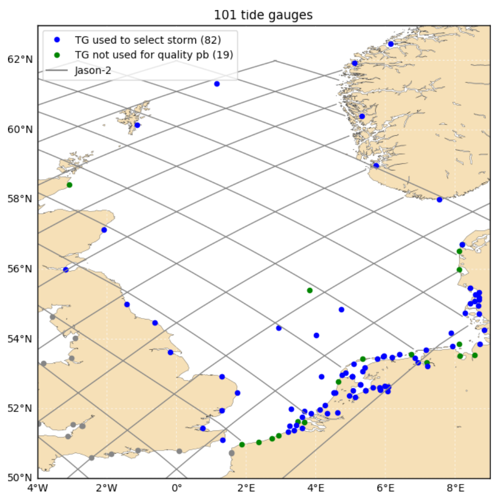

Figure 2: Tide gauges and JASON-2 tracks in the North Sea

The objective was to select storms with various sea state. Data analysis led to the selection of four storms: Friedhelm, ex-Gonzalo, Felix and Gunter (Table 1).

Date	Name	Track number	Type of sea state	Rank from JASON-2 analysis	Rank from Tide Gauge analysis
2011-12-10	**Friedhelm**	170	old sea	5	/
2014-10-21	**ex-Gonzalo**	061	young sea	2	1
2015-01-10	**Felix**	94	young sea	6	5
2015-01-13	**Gunter**	170	old sea	20	/

Table 1: Storms selected for the study

The minimum of Mean Sea Level (MSL) Pressure was computed from ECMWF simulations (Figure 3), over the North East Atlantic (30°W 10°E 30°N 65°N). The storm ex-Gonzalo corresponds to the remnants of Category 4 Atlantic Hurricane Gonzalo. It is the strongest storm in terms of surges, but not in term of winds. One of the characteristic of this storm is that the strong winds moves from west to east along a quite vertical front of around 1 000 km long. This explains the discontinuity in the MSL Pressure observed in ex-Gonzalo track in the North Sea (red curve on Figure 3), as the minimum moves along this front.

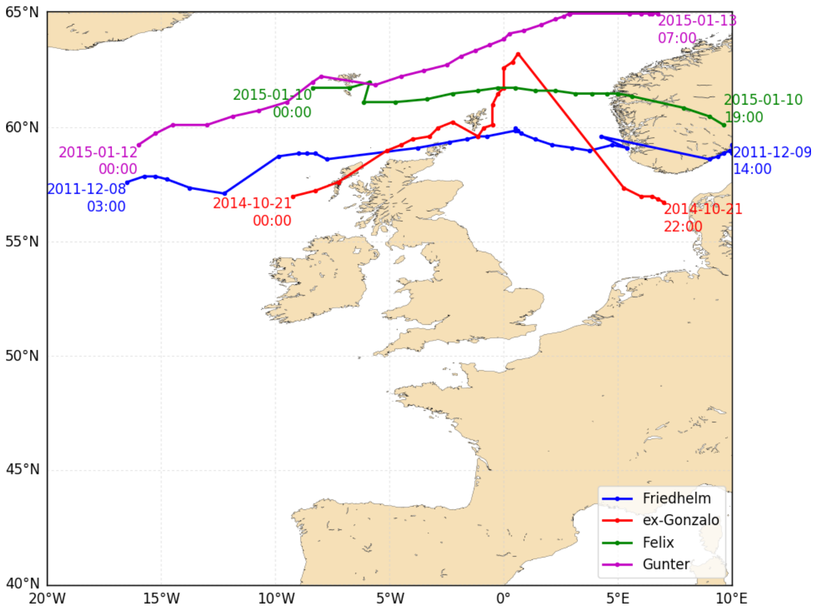

Figure 3: Minimum of Mean Sea Level Pressure on the North East Atlantic from ECMWF simulations

List of publications/reports from the project with complete references

Results have been presented to the following conference:

- Oral presentation, American Meteorological Society 21st Conference on Air-Sea Interaction, 11-15 June 2018, Oklahoma City, USA

Publication:

Pineau-Guillou, L., Ardhuin, F., Bouin, M.-N., Redelsperger, J.-L., Chapron, B., Bidlot, J.-R., and Quilfen, Y. (2018). **Strong winds in a coupled wave-atmosphere model during a north atlantic storm event: evaluation against observations. Quart. Journ. Roy. Meteorol. Soc.**, 144:317–332

Summary of plans for the continuation of the project

(10 lines max)

We plan to run the storm surge model for the four different case studies (Table 1), with different wind stress parameterizations. The objective is to investigate the possible effect of the waves on the wind stress. We will compare the results between the default ocean model parameterization (Hellerman and Rosenstein, 1983) which is only wind-dependant, and the default ECMWF parameterization (Janssen, 1991) which is wave-dependant. In this last case, the ocean model will be directly forced with the wind stress from ECMWF simulations. Simulated storm surges will be compared with in-situ (tide gauges) and remote sensing (JASON-2) data.

References

Emanuel, K. (2003), A similarity hypothesis for air-sea exchange at extreme wind speeds, J. Atmos. Sci., 60, 1420– 1428.

Hellerman, S. and Rosenstein, M. (1983). Normal monthly wind stress over the world ocean with error estimates. J. Phys. Oceanogr., 13(7):1093–1104.

Janssen, P. A. E. M. (1991). Quasi-linear theory of wind wave generation applied to wave forecasting. J. Phys. Oceanogr., 21:1631–1642.

Lyard, F., Lefevre, F., Letellier, T., and Francis, O. (2006). Modelling the global ocean tides: modern insights from FES2004. Ocean Dynamics, 56:394–415.

Muller, H., Pineau-Guillou, L., Idier, D. and Ardhuin, F. (2014). Atmospheric storm surge modeling methodology along the French (Atlantic and English Channel) coast. Ocean Dyn. 64: 1671–1692.

Mastenbroek, C., Burgers, G., and Janssen, P. A. E. M. (1993). The dynamical coupling of a wave model and a storm surge model through the atmospheric boundary layer. J. Phys. Oceanogr., 23:1856–1867.