Impact of waves on storm surges in the North Sea: model evaluation against observations

Lucia Pineau-Guillou (Ifremer/LOPS), Marie-Noëlle Bouin, Fabrice Ardhuin, Florent Lyard (LEGOS), Jean Bidlot (ECMWF), Bertrand Chapron

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1. Introduction

Motivations

Underestimation of simulated storm surges Due to inapropriate wind stress parameterization ?



Storm surge forecasting (https://marc.ifremer.fr)

Objective

Investigate the impact of **coupling waves and wind stress** on storm surge modelling

Method

- Use of a storm surge model, forced with a wave-atmosphere coupled model
- Numerical simulation of storms, with various sea states (young and old)

2. Case studies: storms in the North Sea

- Event selection: analysis of 101 tide gauges and JASON-2 altimeter data_
- Selection of storms with maximum surges and various sea states



Name	Sea state	Max wind
Friedhelm	Old sea	27 m/s
ex-Gonzalo	Young sea	23 m/s



3. Model & observations



30°

TUGO ocean model grid

3. Model & observations

1. Wind-dependent drag coefficient

 $C_d = f(U_{10})$ Hellerman & Rosenstein, 1983

2. Wave-dependent drag coefficient



Young sea state \rightarrow rougher sea with young and steep waves

- \rightarrow higher Charnock parameter
- \rightarrow higher drag coefficient







- Good agreement model/tide gauges (RMSE ~ 0.12 m)
- Surges are higher with the wave-dependent drag
- Wave-dependent parameterization reduces significantly the Peak Error

Parameterization	Bias	RMSE	Peak Error
Wind-dep. drag	0.01 m	0.13 m	- 0.21 m
Wave-dep. drag	0.00 m	0.12 m	- 0.09 m

Case study ex-Gonzalo with young sea state



- Very good agreement model/altimeter (RMSE ~ 0.10 m) Consistency with the Tide Gauge along the track
- Capacity of altimeter to measure surge with a good precision
- Wave-dependent parameterization closer to observations (RMSE 8 cm instead of 0.13 cm)

Case study Friedhelm with old sea state



- Good agreement model/altimeter
- No wave effect as the sea state is older

Conclusion : significant impact of the waves only in case of young sea state



Young sea state: wave-dependent drag higher that wind-dependent one → higher wind stress
→ higher surges

• Old sea state: wave-dependent drag close to wind-dependent one \rightarrow similar surges



Ex-Gonzalo storm 2014 October 21 23:00

5. Conclusions

• Consistency between model/altimeter/tide gauges confirms the capability of altimeters to accurately measure surges

- Wave-dependent parameterization gives higher surges, closer to observations Consistent with previous studies (Mastenbroek et al. 1993, Bertin et al. 2015) Effect of waves can reach 20 cm
- Recommendation : force the ocean model with the wind stress from a coupled waveatmosphere model (e.g. ECMWF)
 - \rightarrow more consistency between the drags from ocean and atmosphere model
 - \rightarrow improvement of storm surges taking into account the wave effect
- However, number of case studies should be increased to confirm these conclusions

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