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

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Ifremer

LOPS

1. Introduction

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1. Introduction

- **Context**

Accuracy of modeled storm surges is essential, as it impacts directly the accuracy of SLA products

- **Motivations**

  - Underestimation of storm surges in ocean models (Muller et al., 2014), as well large wave heights in wave models (up to 15% Rascle & Ardhuin, 2013)

  - Could be partly due to:

    (1) underestimation of strong winds in atmospheric models

    (2) inappropriate representation of wind stress in numerical models

- **Objective**

  - Investigate the impact of the waves on the wind stress, looking at the ocean response (the surges)

- **Method**

  - Atmosphere/wave/ocean modelling of extratropical storms

  - Test of two wind stress parameterizations, taking into account (or not) the waves

  - Model evaluation against tide gauges/altimeter

2. Case studies: storms in the North Sea

Analysis of sea level data to select storms with the highest surges

- Altimetry: 2008-2015 JASON-2 1Hz X-track coastal product, CTOH/LEGOS (Birol et al., 2016)

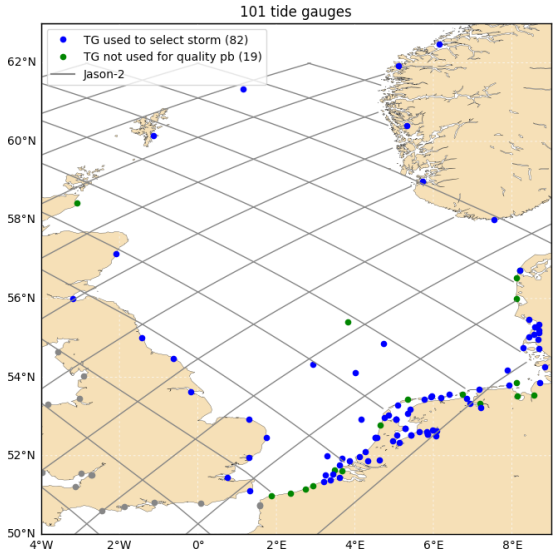
Surge = SLA + DAC

- Tide gauges : 2012-2017, 101 TGs from CMEMS

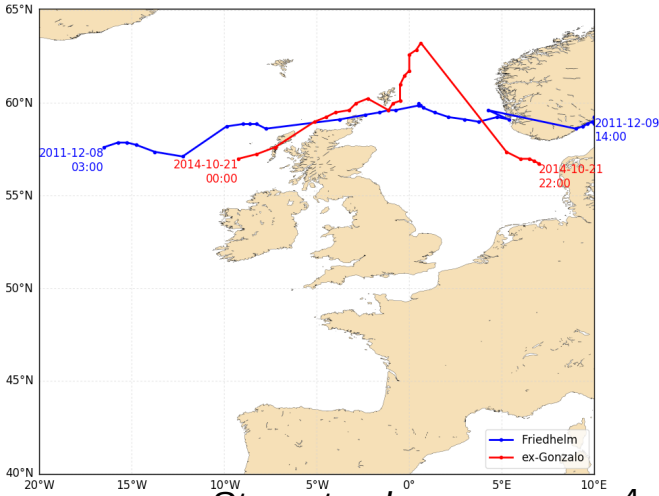
Surge = Observation - Prediction

- Two case studies

Name	Date	Max. Wind	Sea State
exGonzalo	2014-10-21	22.9 m/s	Young Sea
Friedhelm	2011-12-10	29.9 m/s	Old Sea

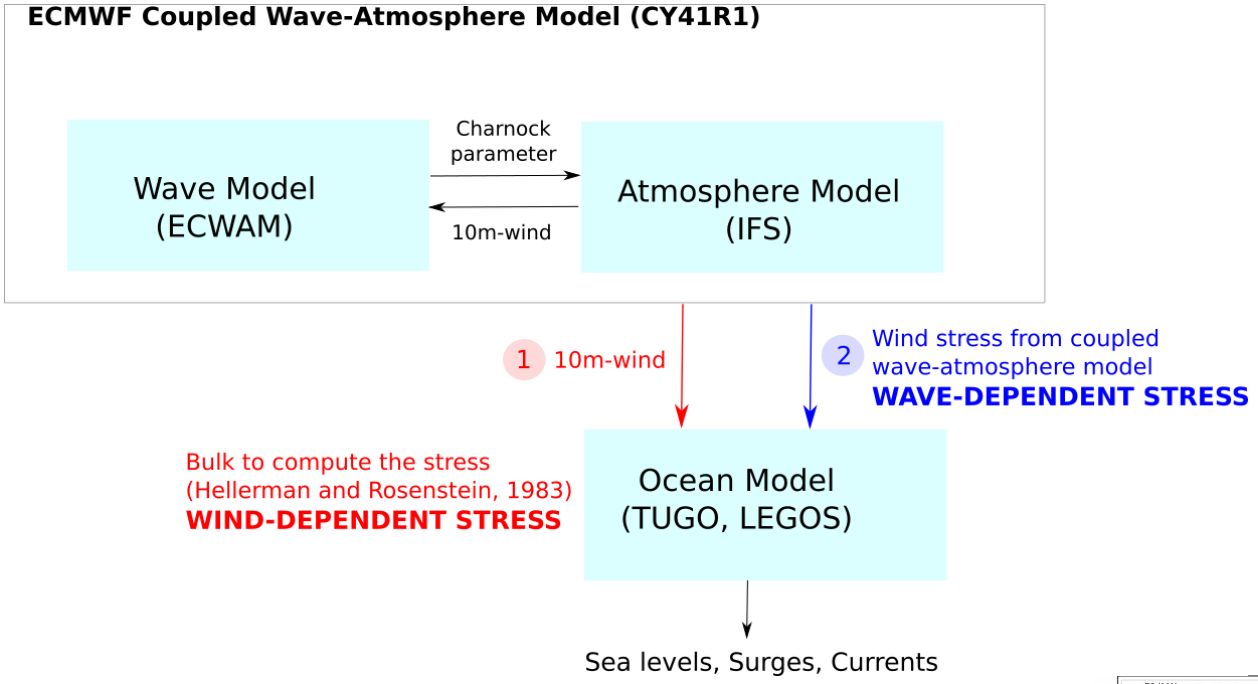


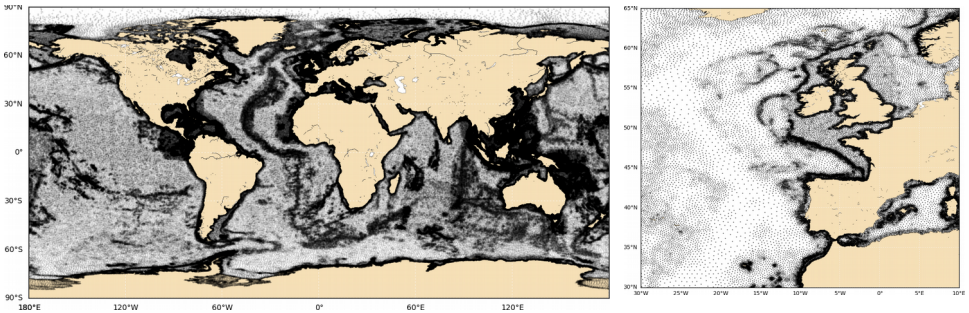
Sea level data in the North Sea



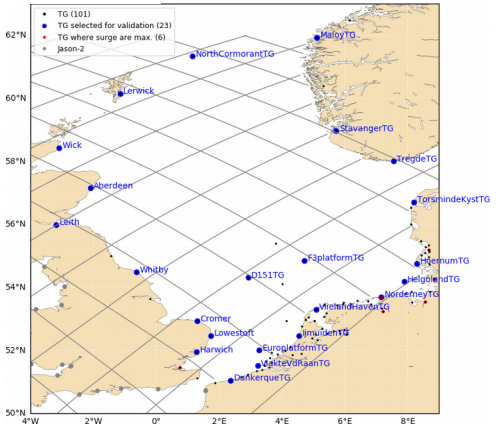
Storm tracks
(Min. of MSLP in ECMWF simulations)

3. Model & observations





TUGO ocean model grid

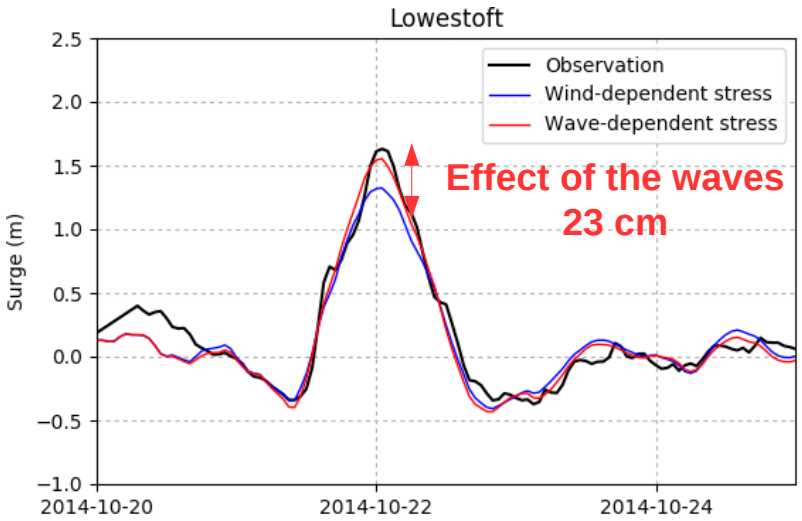


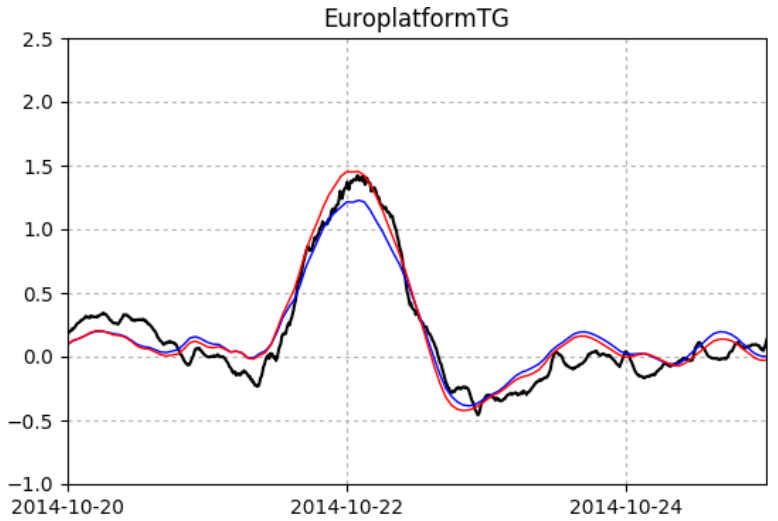
23 tide gauges selected for validation

4. Impact of the waves on the surges

- Case study : ex-Gonzalo (young sea state)
- Good agreement model/observation. In average RMSE 0.13 m

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

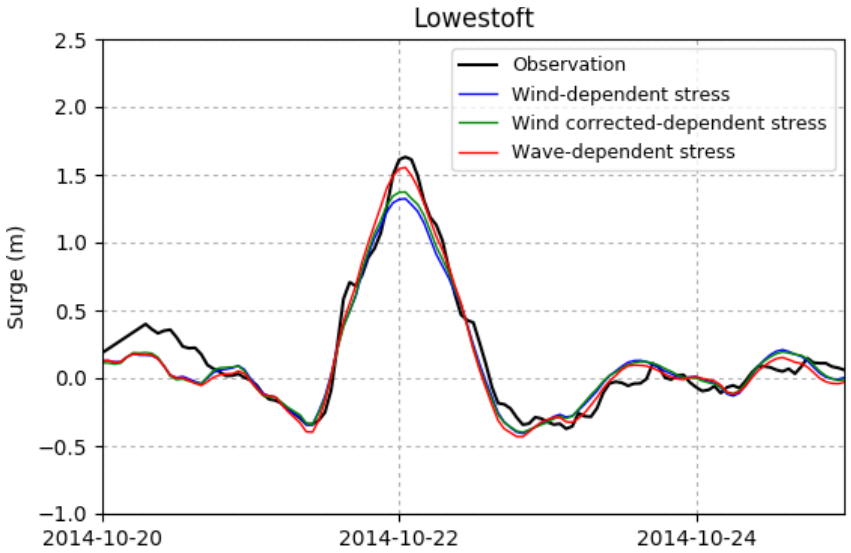


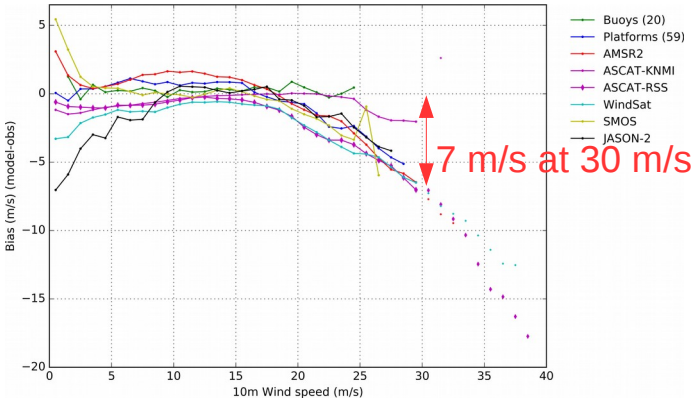


- Surges are greater with the wave-dependent stress
- **Wave-dependent parameterization reduces significantly the Peak Error**

4. Impact of the waves on the surges

- Strong winds may be underestimated in atmospheric models (ECMWF)
- Impact of increasing the wind ?





Wind bias between model and obs. (Pineau-Guillou et al. 2018)

Parameterization	Peak Error (at Lowestoft)
Wind-dep. stress	-0.31 cm
Wind-corrected dep. stress	-0.26 cm
Wave-dep. stress	-0.08 cm

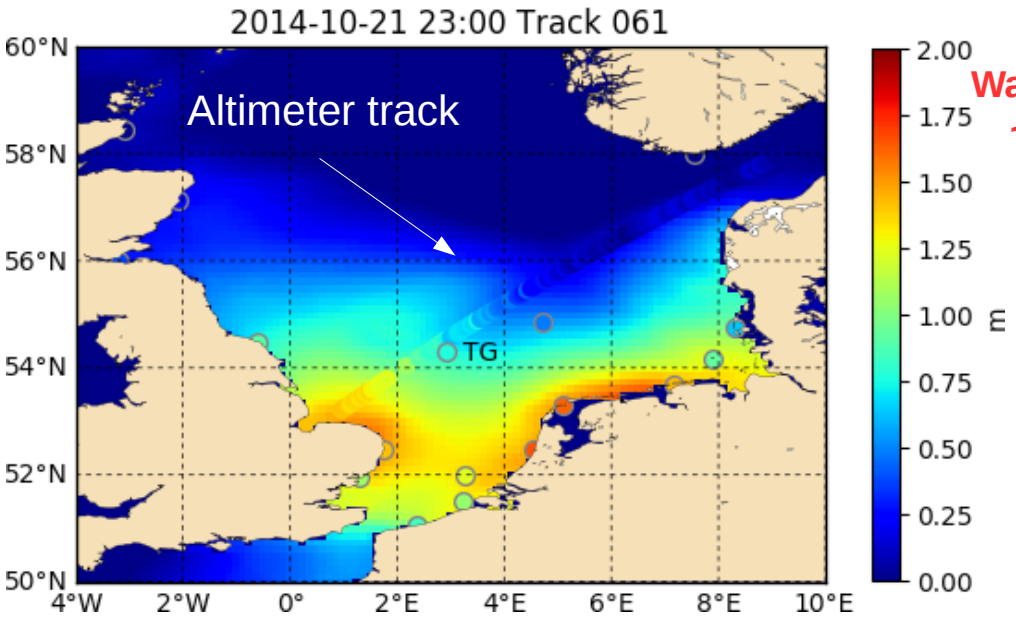
Impact of increasing the wind < taking into account the waves

Surge increase: + 5 cm

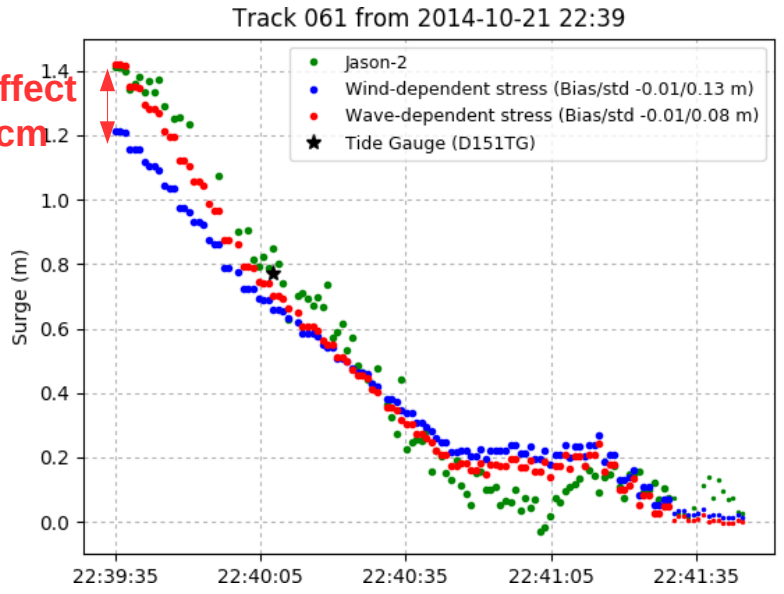
Surge increase: + 23 cm

4. Impact of the waves on the surges

ExGonzalo storm (young sea state)



Surge from model, altimeter, tide gauges



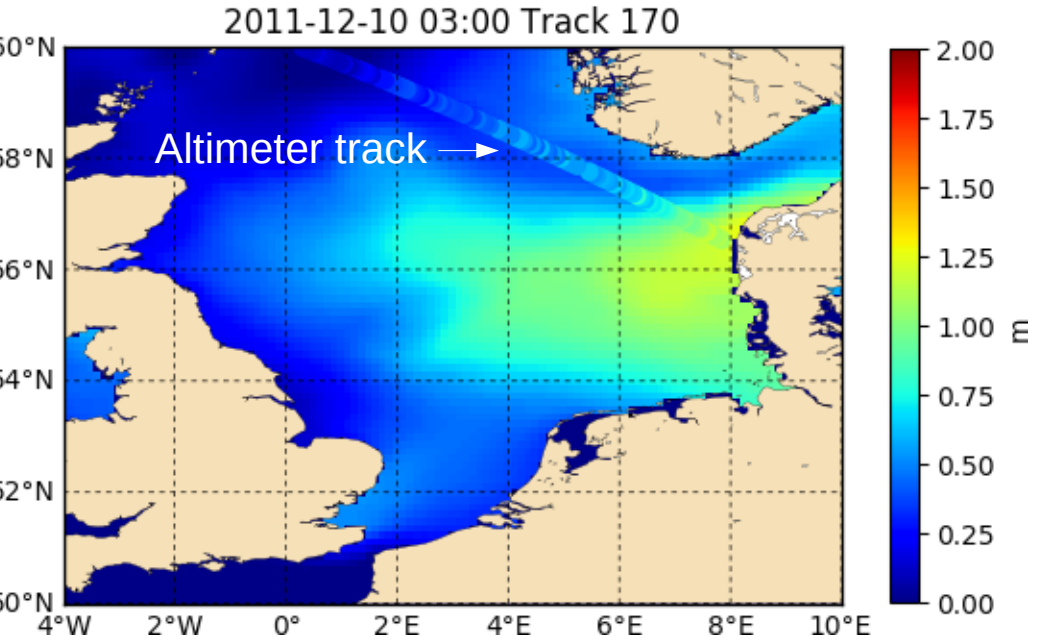
Wave effect ~ 20 cm

Surge along the track

- Very good agreement model/altimeter, RMSE ~ 10 cm
  Consistency with the TG 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)

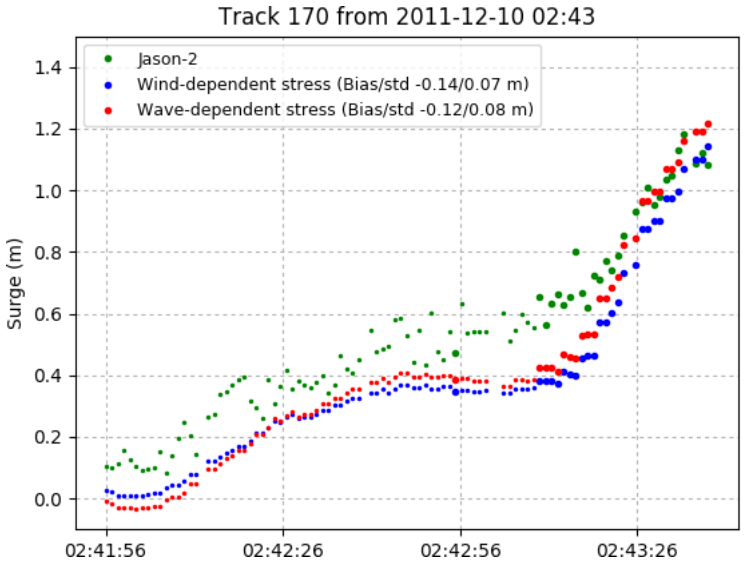
4. Impact of the waves on the surges

Friedhelm storm (old sea state)



Surge from model, altimeter, tide gauges

No wave effect (old sea)



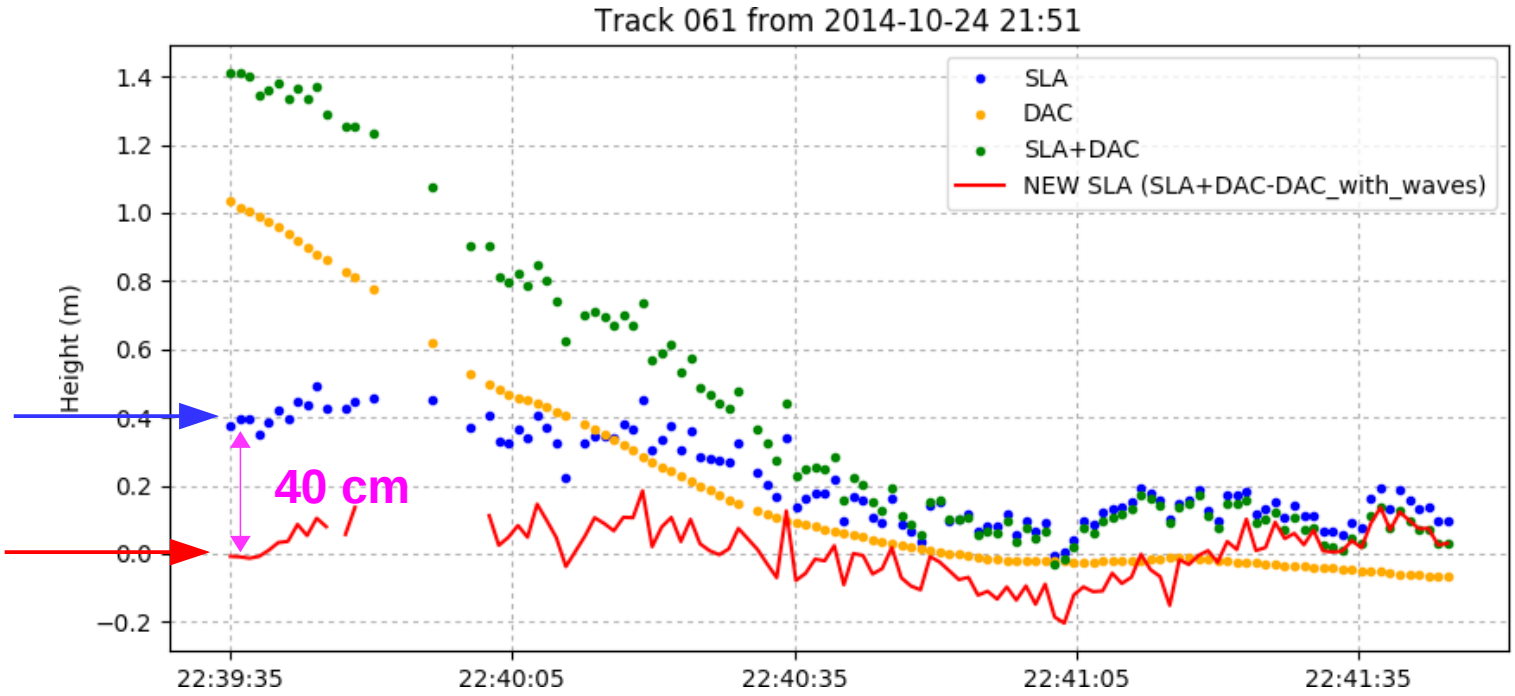
Surge along the track
(marker size is smaller when bathy > 100 m)

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

5. Impact on altimetric corrections

Default SLA

New SLA
DAC from the wave-dep. param.



Taking into account the waves improves the SLA, removing some surge residual due to atmospheric effect

6. Conclusions

- Wave-dependent stress gives higher surges, closer to observations
  Consistent with previous studies (Mastenbroek et al. 1993, Bertin et al. 2015)
- Increasing the wind is not appropriate, impact of the waves is more significant
- Recommendation: force the model with wind stress from an atmospheric model

- Capacity of altimeter to measure surge with a good precision
- Impact of taking into account the waves can be significant on altimetric corrections (20-40 cm)

However, need to increase the number of case studies, comparisons with data are not always as consistent.