Extreme waves and surges interaction with tide during storms in winter 2013-2014

Extreme coastal water levels can lead to floods. E.g. Winter 2013/2014 case study





Interactions between waves, surges and tides are the main drivers of high TWL. This can be studied with coupled numerical models. We use the UKC4 model. Where, when, and why did extreme waves, surges and tide occur in winter 2013/2014?



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FLOODS ARE INCREASING Sea level rise is increasing. Coastal urbanization is increasing. Storms are increasing. The increase is increasing.

FLOODS ARE A THREAT TO COASTAL COMUNITIES Top priority of UK National risk register.

£592.1 million in damages

from coastal floods alone in

FLOODS COST

(Information from: Chartteron et al., 2016, and UK national risk register 2017)

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1-What was the spatial distribution of waves surges and tide during winter 2013/14?

2- Did extreme occur more often over specific stages of the tidal cycle? Did they occur simultaneously?

> 3- Does this has implications in defining the severity of coastal hazard conditions?

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Interactions – summary part 1

$Ocean \leftrightarrow atmosphere:$

- Currents affect water temperature through upwelling and down-welling. This affects the atmosphere since it varies the rate of evaporation, heat transfer, and therefore high/low pressure zones.
- Atmospheric pressure can induce inverse barometer effect, inducing changes over the ocean.
 - Atmosphere affects the ocean back by affecting SST.

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Interactions – summary part 2

Ocean ↔ waves:

 Currents impact wave propagation
Wave modify currents through surface stress or bottom friction
Wave breaking (not implemented)
energy dissipation and radiation stress

Atmosphere \leftrightarrow waves:

 Wind affects surface waves
Waves affect sea surface roughness (SSR) which affects currents
SSR affects surface cooling.
Cooling affects evaporation, up-welling and down-welling.

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Interactions – summary part 3

Waves ↔ Surges:

 Strong wind induce surface shear pushing water and waves towards the coast.
Water piles up resulting in a wind surge.
Momentum flux resulting from waves results in radiation stress, which affects set up and set down of waves.

Tides ↔ Surges:

 tides and surges act as two shallow water waves, and mutually affect each other's phase (and speed) by altering the water depth when propagating.

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ocean-wave-atmosphere high resolution model (1.5 km) to simulate winter 2013/14. Hourly outputs.



2 -At each coastal

point find when the

Hs and surges are

above the 90th

percentile (i.e. when

are they are

extreme).

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Number of extreme (>90th percentile) Hs, surges and simultaneous Hs and surges for each hour of the tidal cycle (coastal average)





Coastal spatial distribution of simultaneous extreme Hs and surges during winter 2013/2014

 (a) Amount of extreme Hs and surge occurred simultaneously at high tide. Shown as a percentage of the total number of events at each coastal point.

E.g. 100% means all simultaneous extreme Hs and surges at that point occurred at high tide.

(b),(c),(d) Difference between the amount of event at high tide and at low tide, 3h before and 3h after high tide.

color legend: There are **more simultaneous extreme** Hs and surges **than at high tide**. There are **less simultaneous extreme** Hs and surges **than at high tide**.

Conclusions

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Coastal Hazard Proxy (HP)

calculated for all times in which the tide is higher than the lowest high water (overtopping more likely).

During winter 2013/2014 the hazard proxy more than double from the average value over more than ³/₄ of the UK and Irish coast.



Hazard Proxy (HP) = SSH+1/2Hs (Lyddon et al.2019)

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Waves occurred more often in the hours before high tide. This could be in part due to the tide-wave interactions:

The tide affects the waves amplitude through currents' variation, and changes to the bottom friction affecting wave's refraction. In return waves can affect water level and currents.



Surges occurred more often 3-4 hours before high tide. This could be in part due to the tide-surge interactions:





Work on the impact of storm duration and storm tracks.



(a) South West UK High tide 8 (f) West Scotland UK High tide of amount 10 (e) North East UK Hiah tide (h) West Ireland 9 High tide



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During winter 2013/14, most extreme Hs and surges occurred in average 2-3 hours before high tide.

It is possible for extreme waves, surges and tide to occur simultaneously. In winter 2013/14 extreme Hs and surges concurred at high tide in 7.7% of cases.

In this period the coastal HP more than double from the average over ¾ of the UK and Irish coasts

The spatial distribution of waves, surges and tides was not constant in space, each component was dominant in different regions. More work is needed to understand the dynamics specific to each regions as well as the impact of storm tracks and duration...

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