Dynamically coupled wave-tide modelling at shelf sea scale

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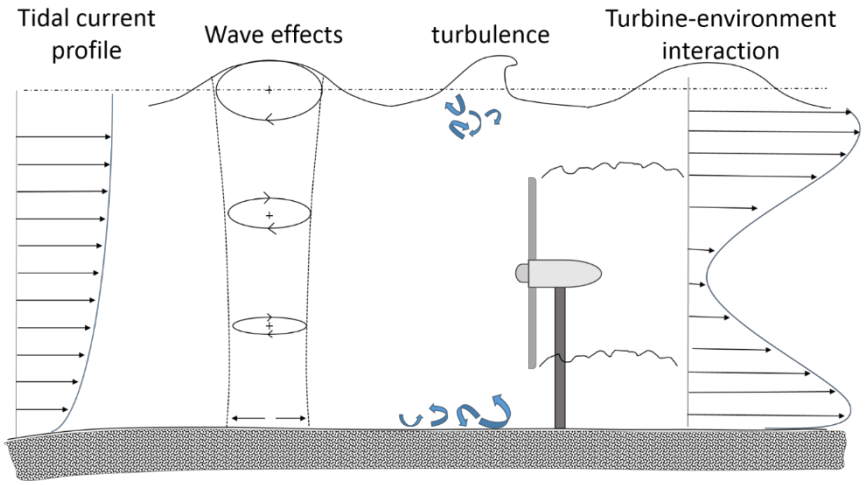
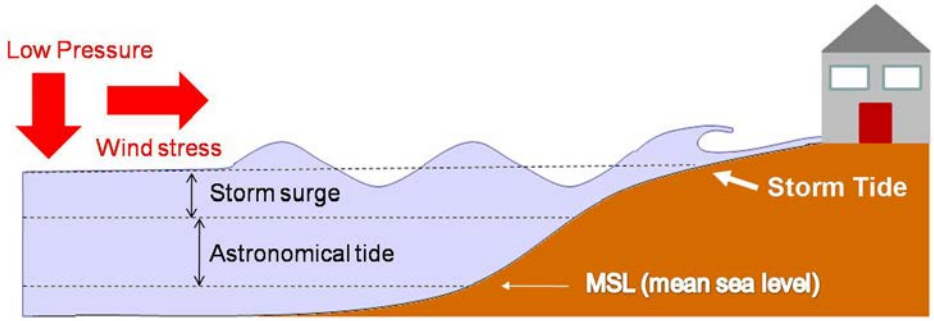
Aim

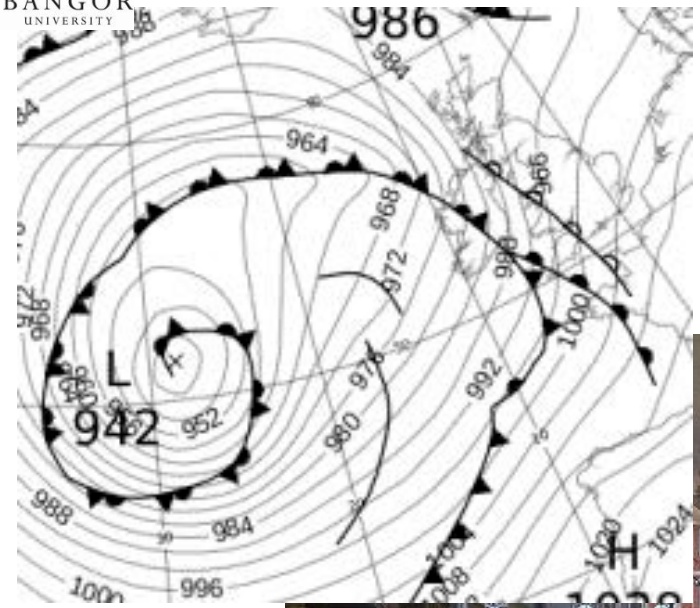
Simulate wave-tide interaction implications for engineering in coming century



Talk outline

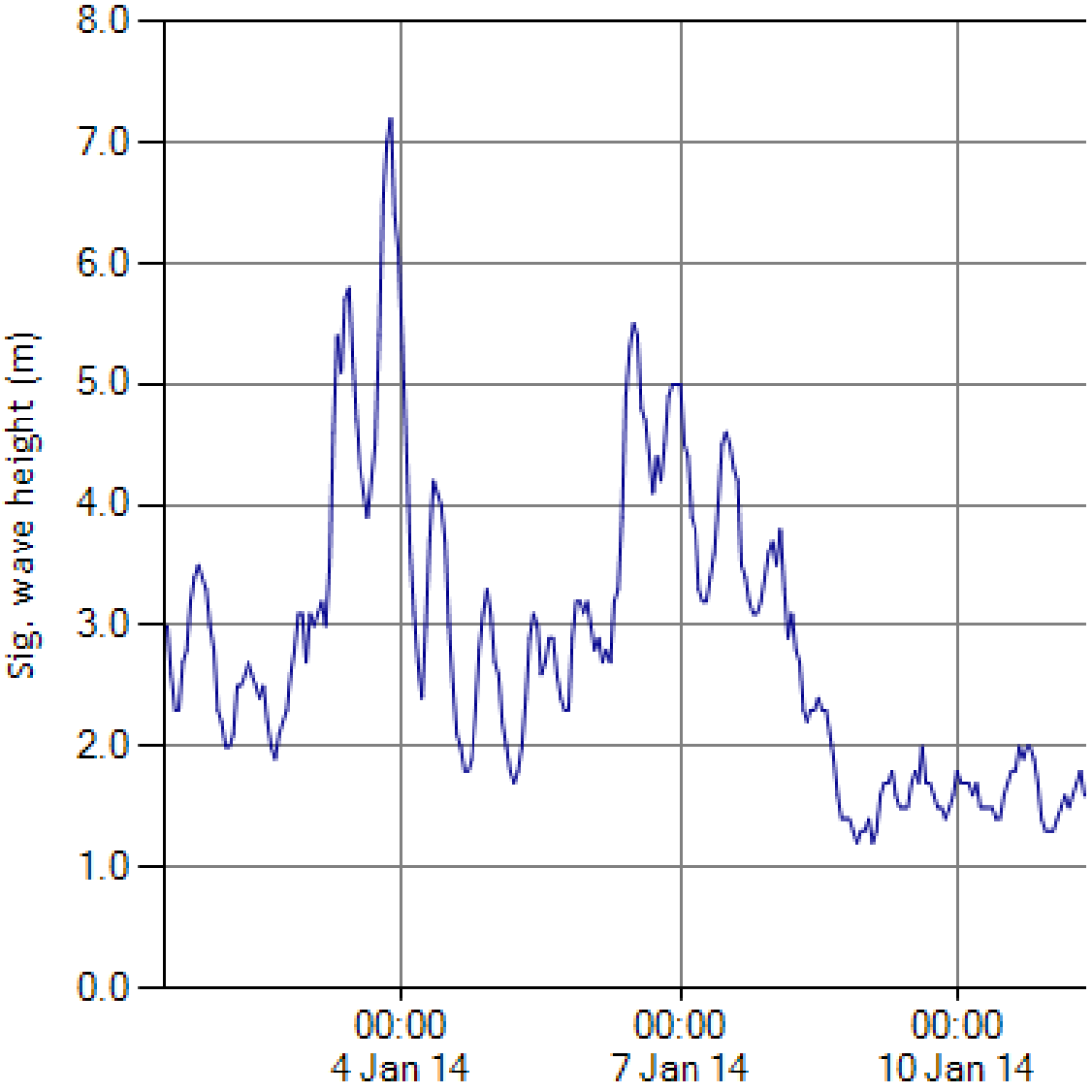
- Motivation
- Wave-tide interaction and model set up
- Coupled wave-tide model results
  - Flood risk – Hs 20% larger at HW in some regions of Irish Sea
- Sensitivity to model resolution
  - Resolution of tidal currents important in wave model

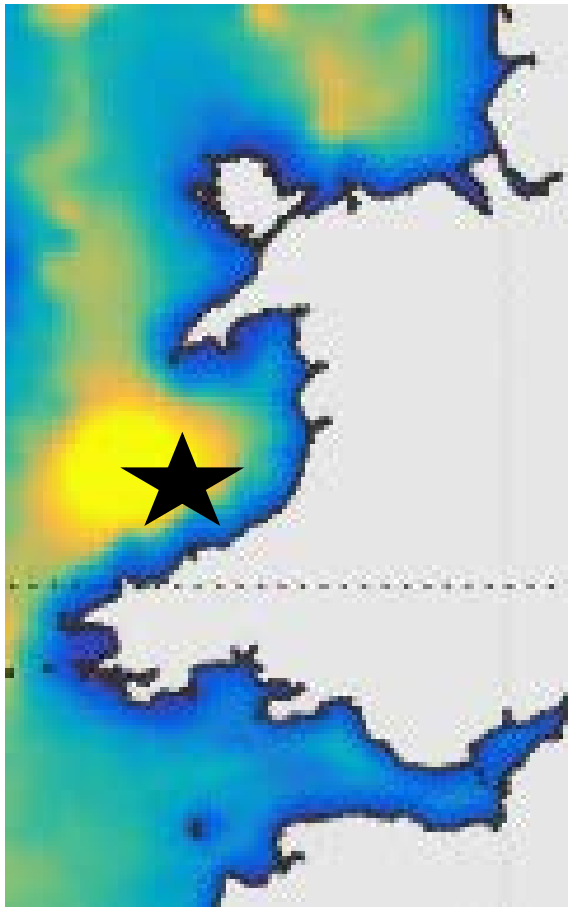




Jan 2014 Aberystwyth flooding caused £1.5M damage

"the waves will, obviously, drop off towards low tide" @westcoastsurf 3-jan-2014

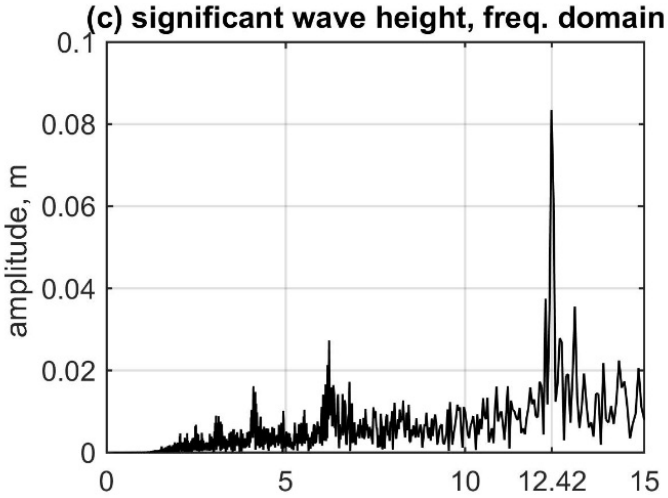

Sig. wave height (m)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
00:00
4 Jan 14
00:00
7 Jan 14
00:00
10 Jan 14



Tides effect wave generation and propagation

U and η modulate Hs, Tz (Doppler effect), θ, wave generation (white capping, effective wind stress)

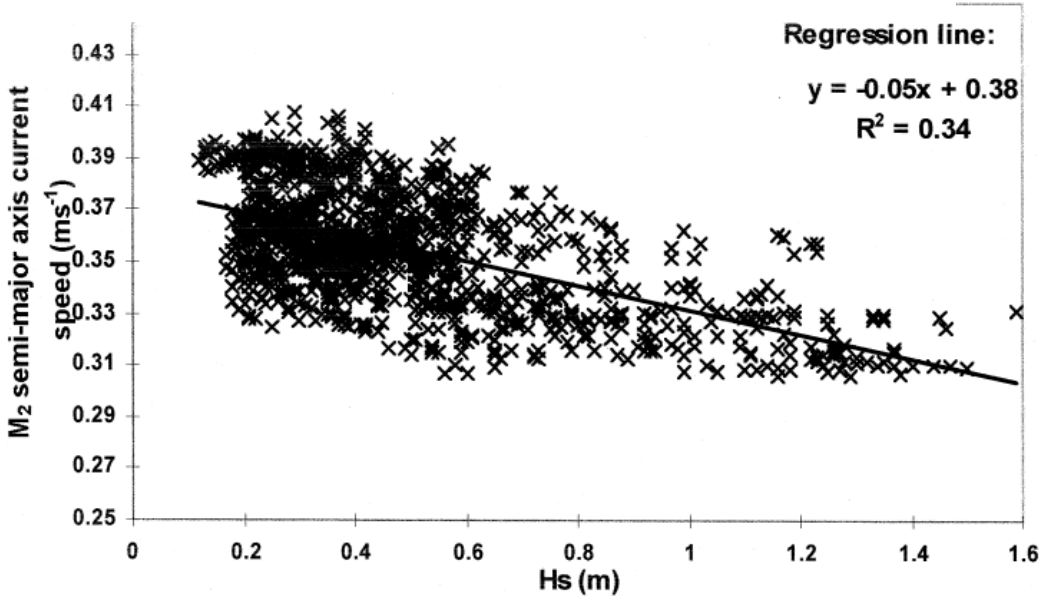
from Hashemi and Lewis (2017)

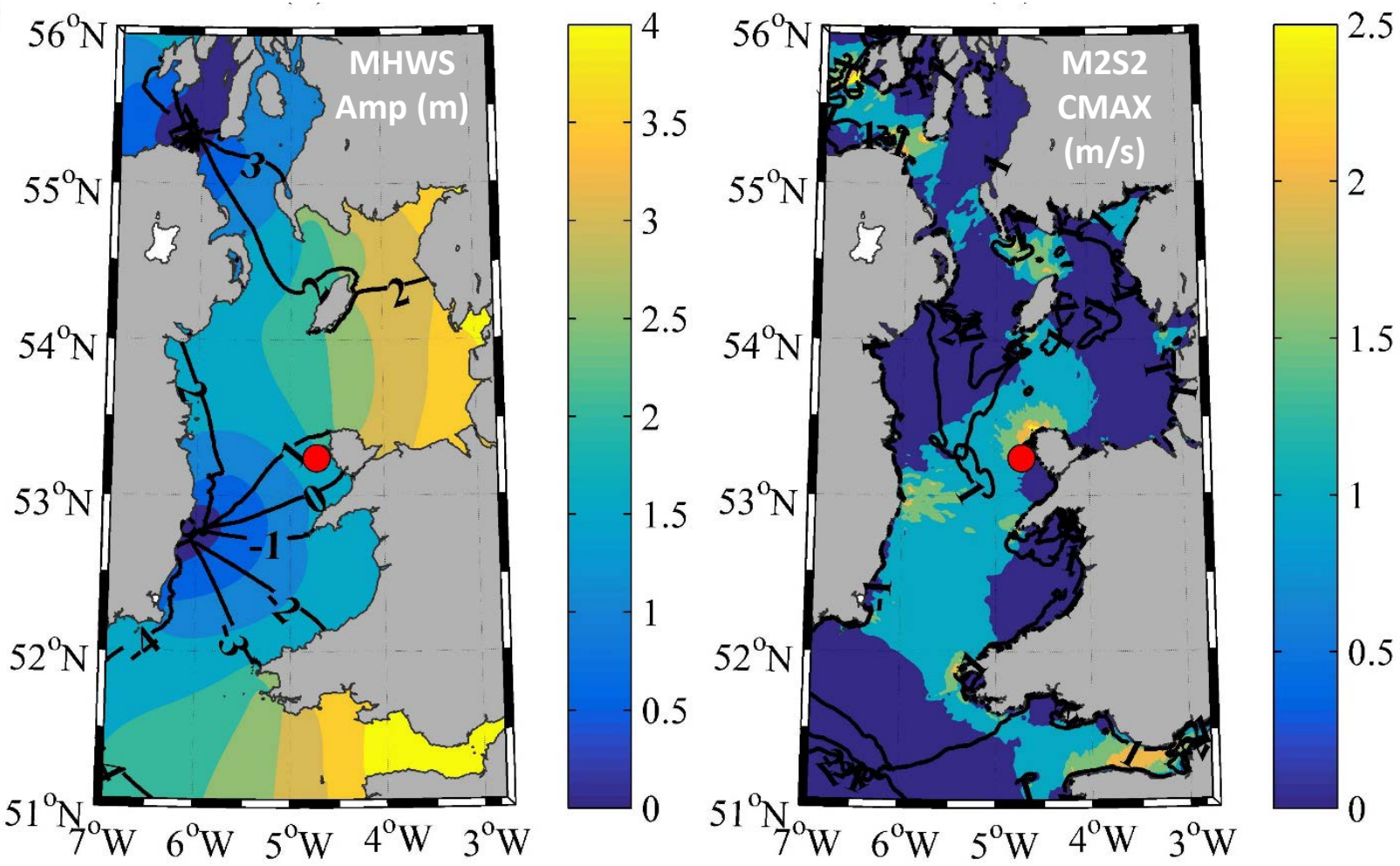


Waves effect tidal currents and elevation

Enhanced bottom friction reduces current speed and effects sediment transport. Stokes drift and wave radiation stress alter velocity profile

from Prandle and Wolf (1999)



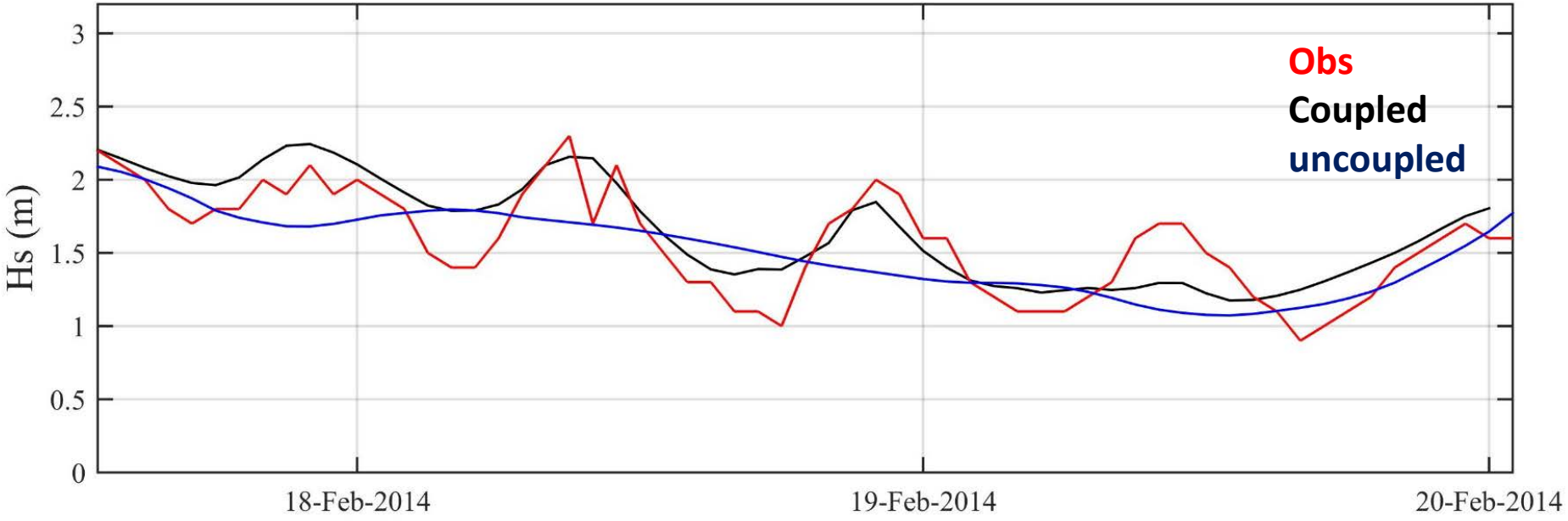


Shallow, mega-tide region

Exposure to Atlantic storm waves

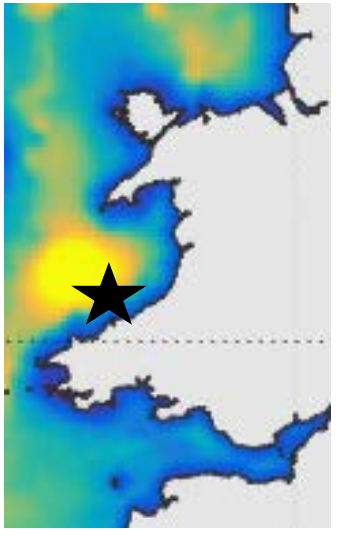
Tide has 10% effect on *Hs,* and 10% wave effect on current, in some areas (Wolf, 2009; Brown et al. 2010; 2011)

Wave-tide interaction simulated with dynamically coupled model

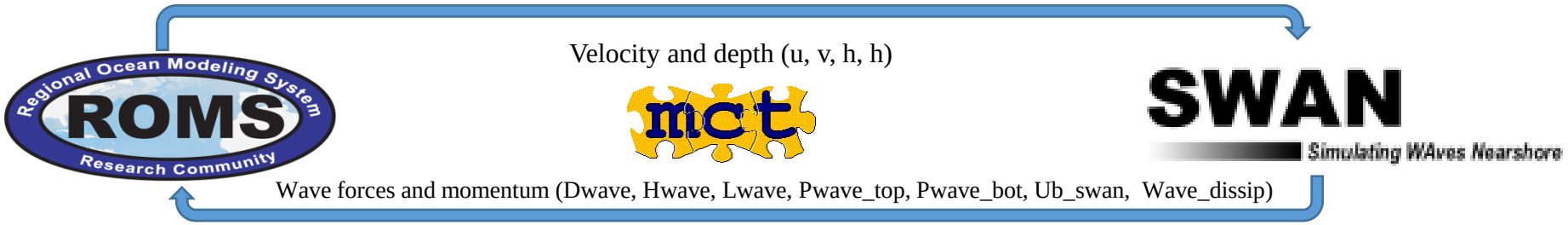


Wave action density *(not spectral density)* is conserved in presence of currents, so 3rd Gen. spectral wave models can simulate *u* and *η* effects to waves

Enhanced bottom stress, stokes drift, wave forces (vortex force) & stresses (radiation stress) parameterised into tidal models



COAWST



ROMS

- **WEC_VF** (3D **vortex force** from Uchiyama et al., 2010)
- **WDISS_WAVEMOD wave-dissipation** from a wave model
- **SW_BBL** wave-τ parameterised as **artificial roughness** (D_{50} 3mm).

SWAN

- **BSBT** used, with **water-levels and current grids** input into SWAN at each *dt (40s)*

MCT

- Exchange information every 600s (no difference if *dt* 200s or 800s for me)

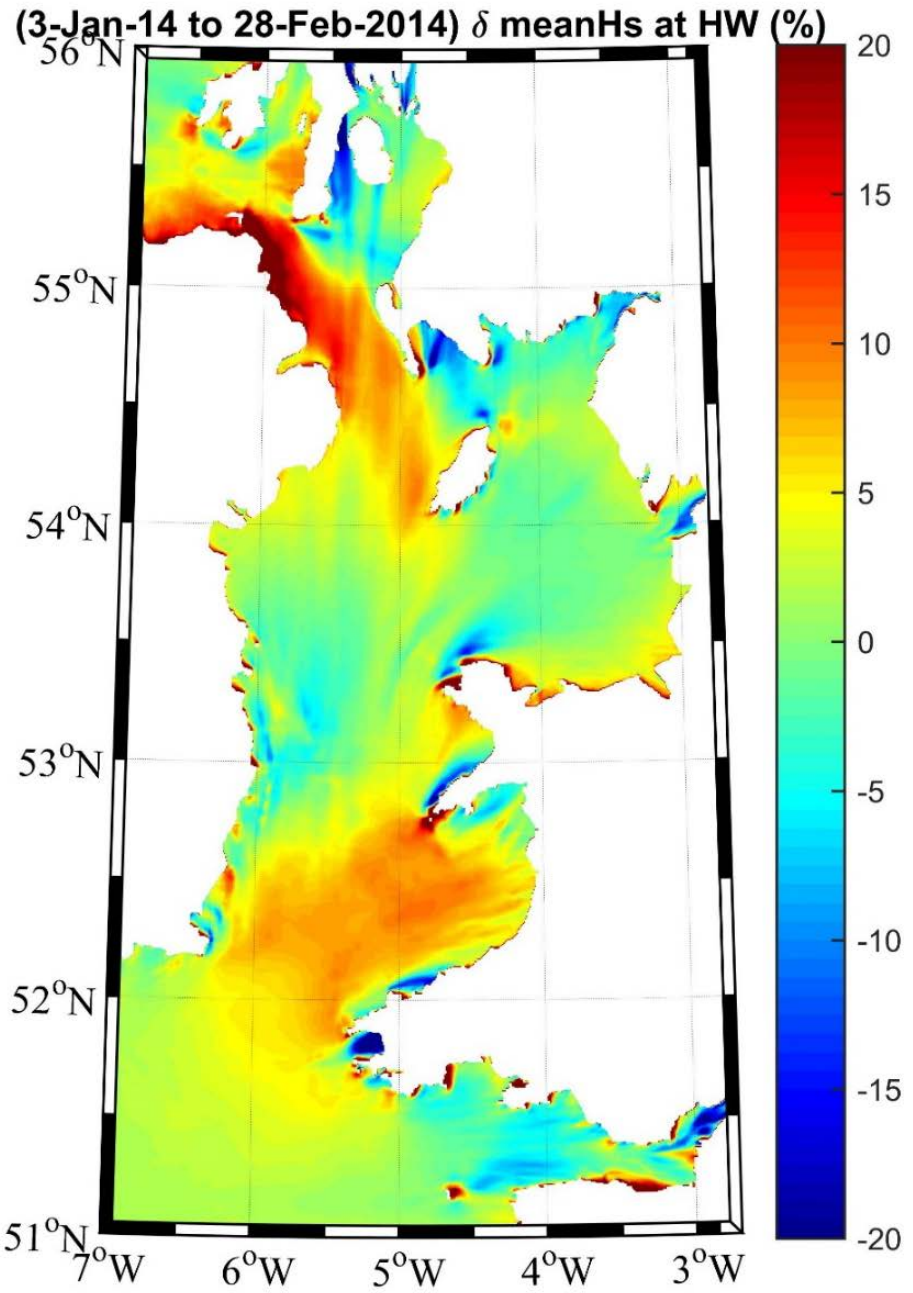
FORCINGS

- ECMWF 3 hourly wind fields and outer N.Atlantic nested SWAN model
- 10 FES2012 tide constituents and Digimap bathymetry
- 10σ layers, no wetting / drying.
- ~280m, **~550m**, ~1100m spatial resolution

- 1/120° resolution (~550m) COAWST model validated
  - NRMSE 5% tides 10% currents 9% HS

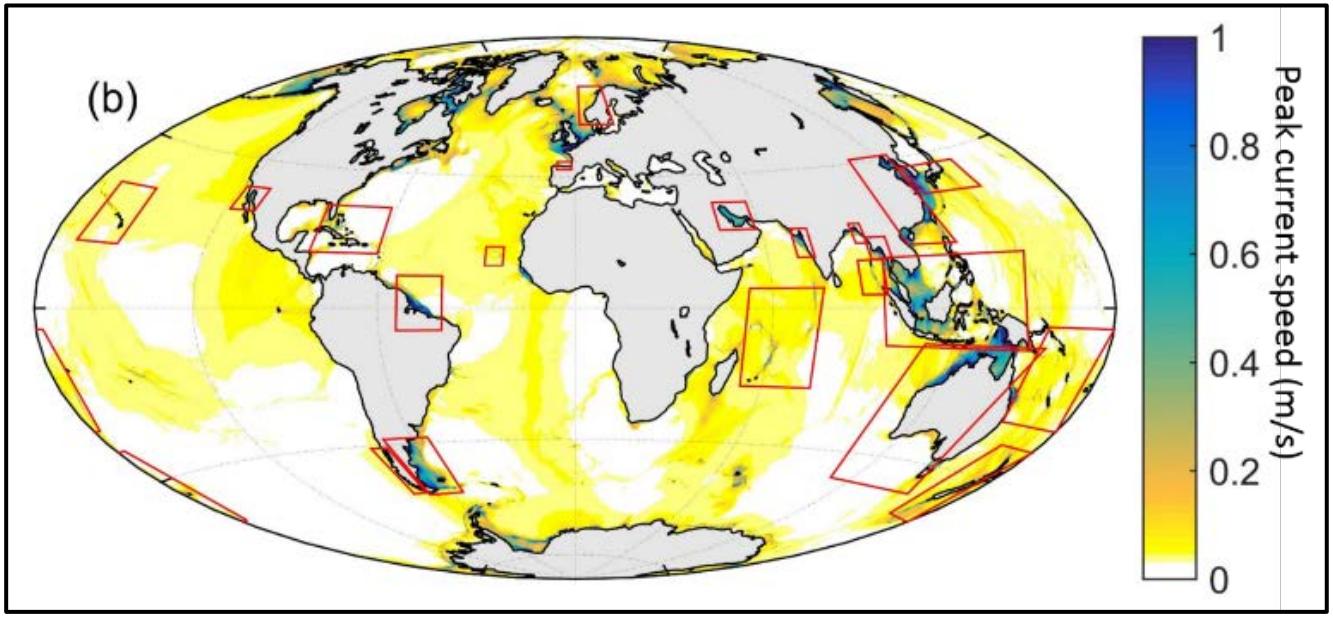
- On average, *Hs* could be up to 20% larger at HW
  - tides changing refraction
- Implications for JPM and EWLS
- Could this increase in the future with SLR?

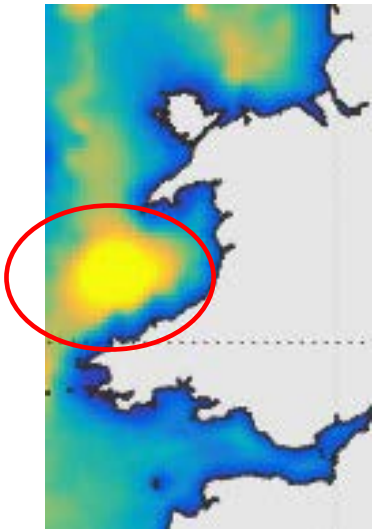
$$\frac{A}{A_0} = \frac{C_0}{\sqrt{c(c+2U)}}$$



Current work

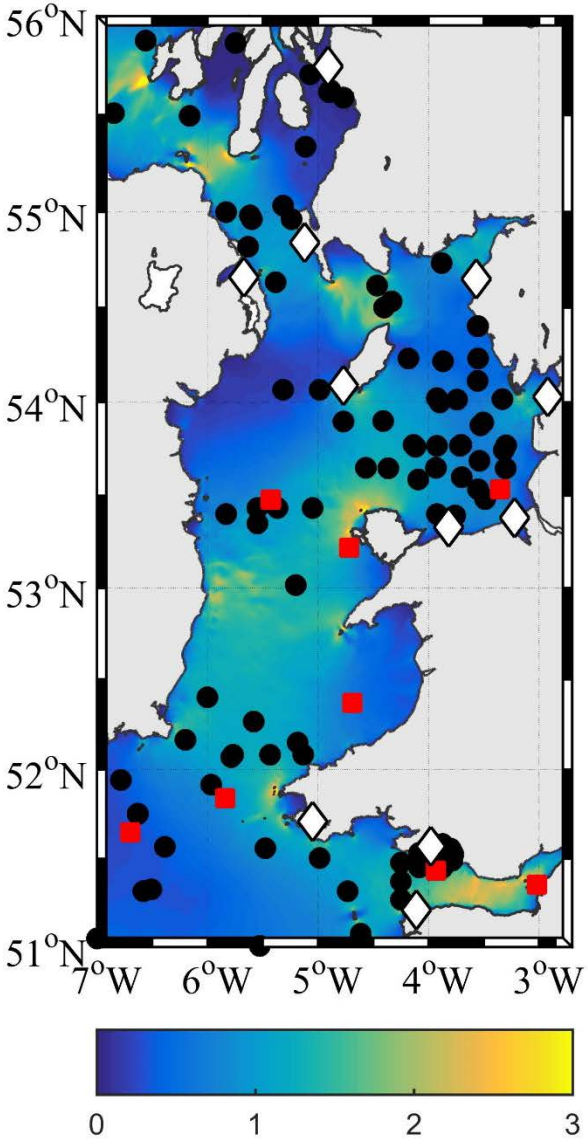
Are higher resolution coupled models needed?
At what resolution: 60km, 8km, 5km, 1.5km?
Are global datasets (e.g. GEBCO) suitable?

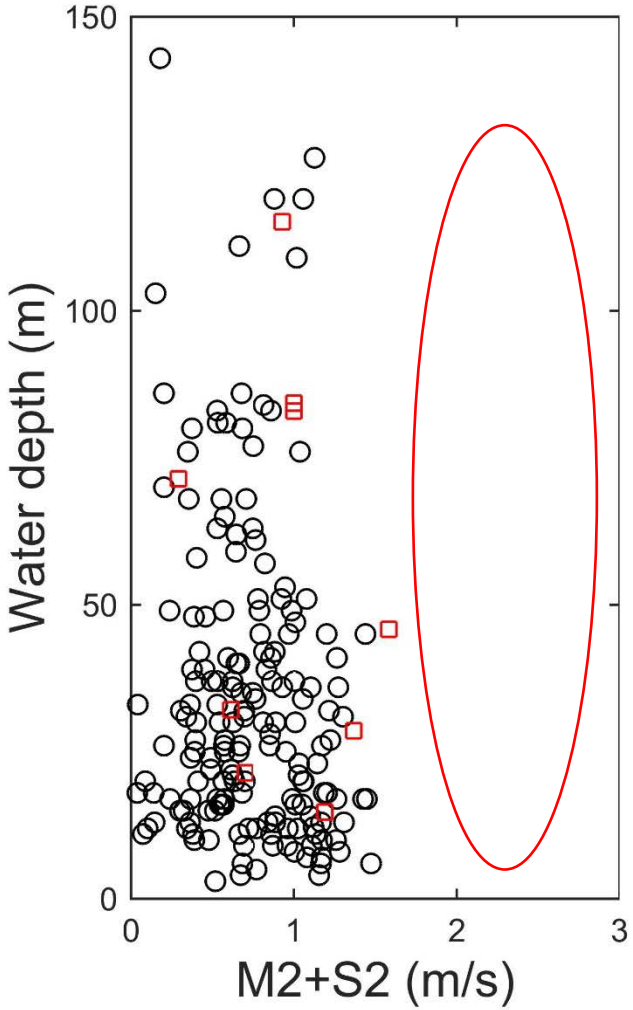




Aim: Use COAWST to investigate spatial resolution sensitivity of coupled wave-tide models (in Irish Sea)

<1km needed to resolve tidal energy sites and possible "bias" in validation data?

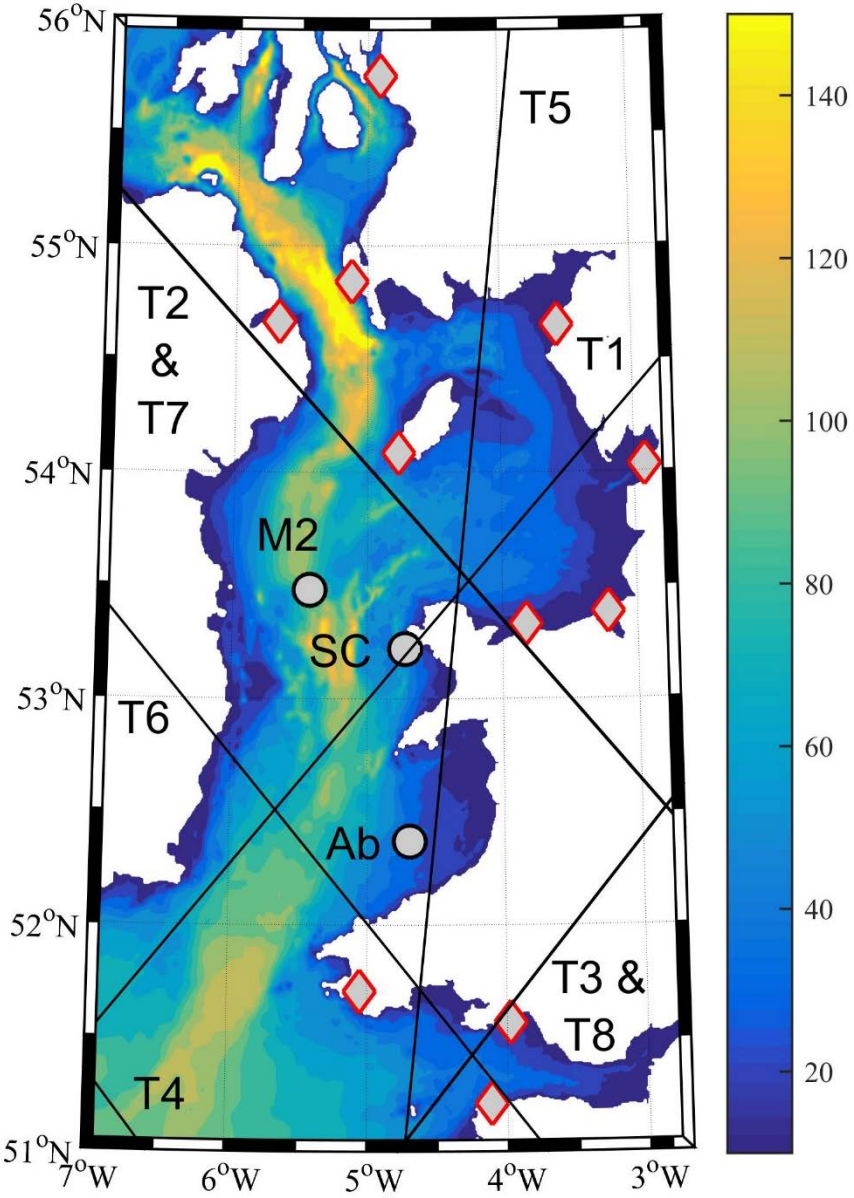


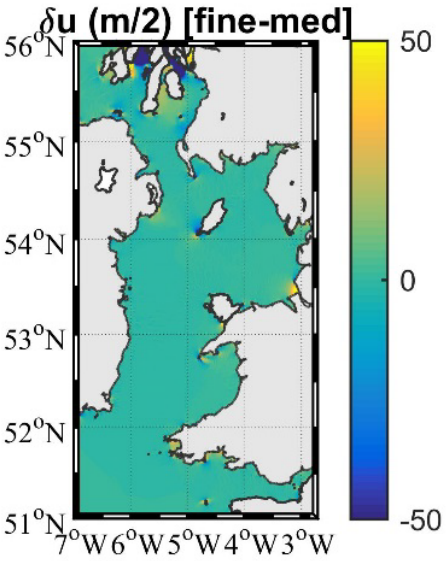


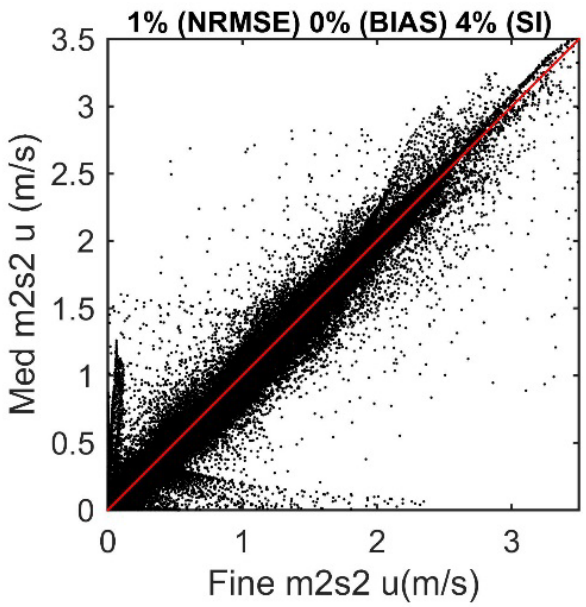
Irish sea model validation

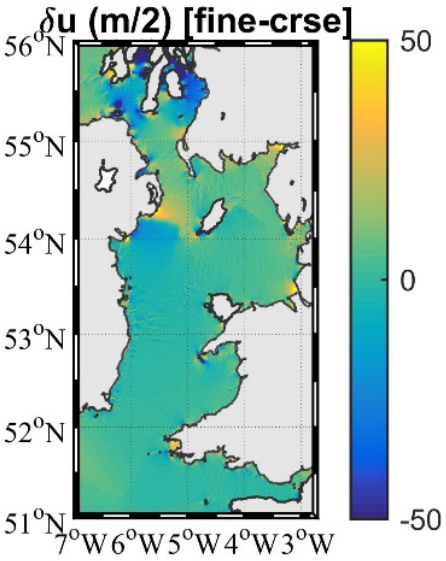
Resolution (fixed longitude)		η	U	Hs	Tm02
Very coarse	1/30° (~2200m)	?	?	?	?
coarse	1/60° (~1100m)	5%	10%	9%	?
Medium	1/120° (~550m)	5%	10%	9%	?
Fine	1/240° (~280m)	4%	9%	9%	?

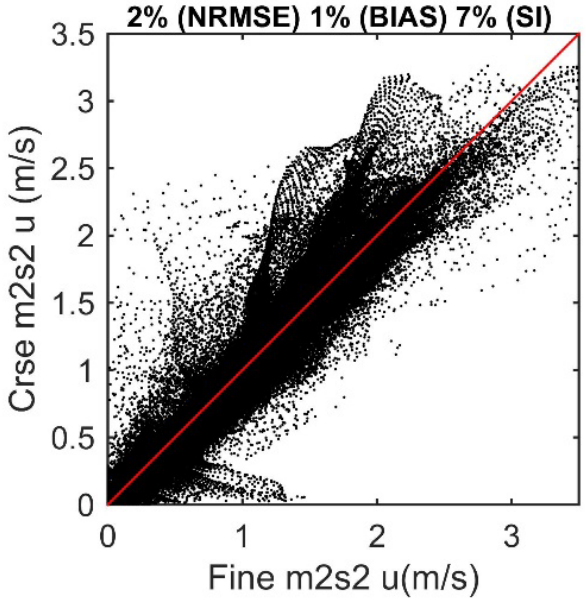
Similar validation for all resolutions and uncoupled models too (not shown)




δu (m/2) [fine-med]
56°N
55°N
54°N
53°N
52°N
51°N
7°W 6°W 5°W 4°W 3°W
50
0
-50


1% (NRMSE) 0% (BIAS) 4% (SI)
Med m2s2 u (m/s)
Fine m2s2 u(m/s)
0
0.5
1
1.5
2
2.5
3
3.5


δu (m/2) [fine-crse]
56°N
55°N
54°N
53°N
52°N
51°N
7°W 6°W 5°W 4°W 3°W
50
0
-50


2% (NRMSE) 1% (BIAS) 7% (SI)
Crse m2s2 u (m/s)
Fine m2s2 u(m/s)
0
0.5
1
1.5
2
2.5
3
3.5

Summary

- Wave-tide interaction important
- Hs up to 20% bigger at HW
  - Important for JPM & flood risk?
- Spatial resolution appears important
  - Bias in validation data ?
- Currents (thus tidal model resolution) is important in coupled models
- Case for higher resolution coupled models

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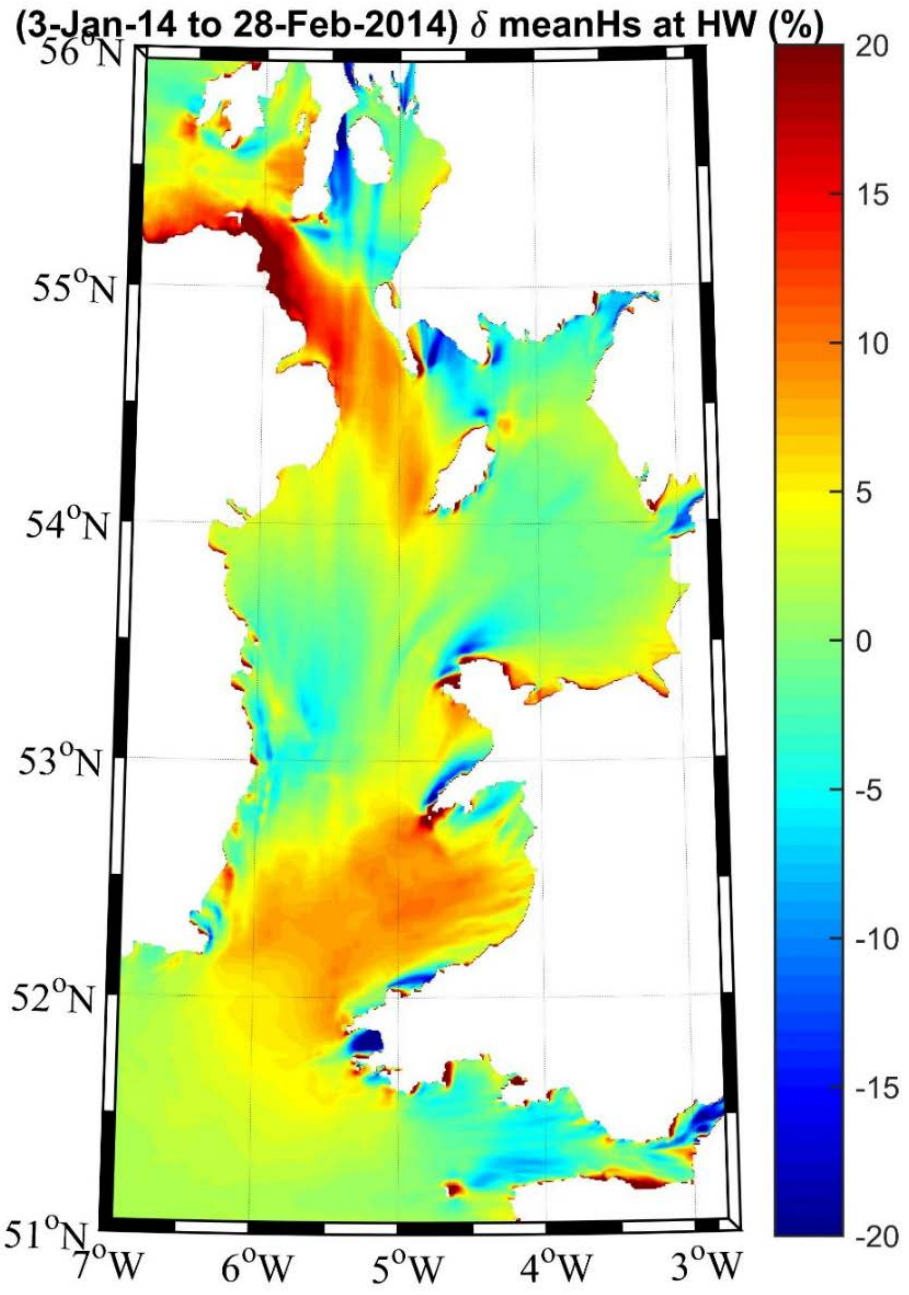

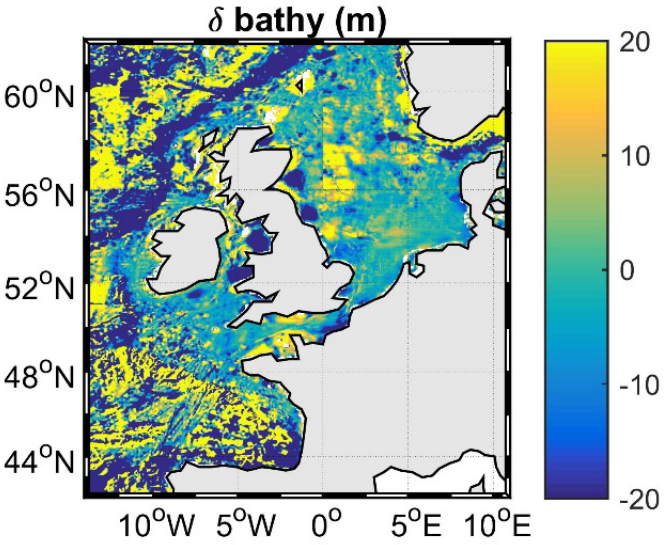

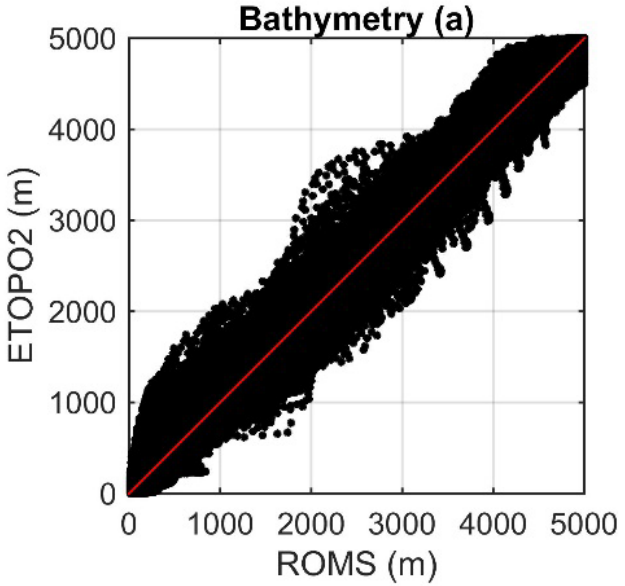

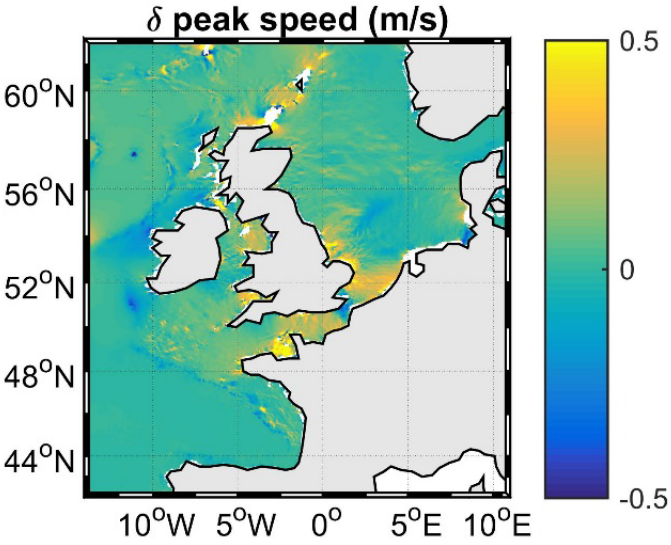

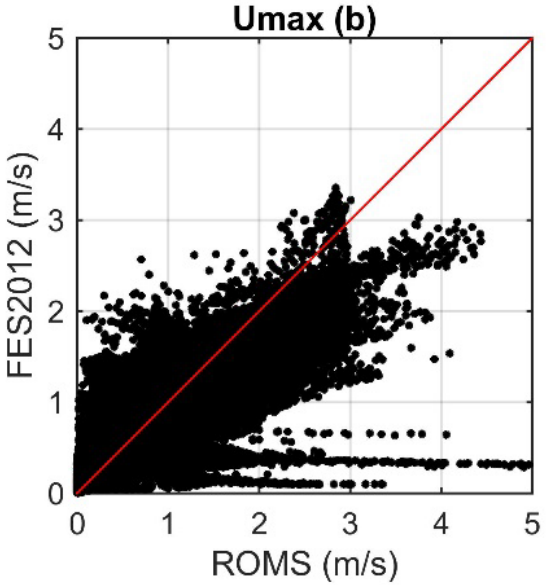

Implications of data accuracy in basin-scale and global modelling techniques