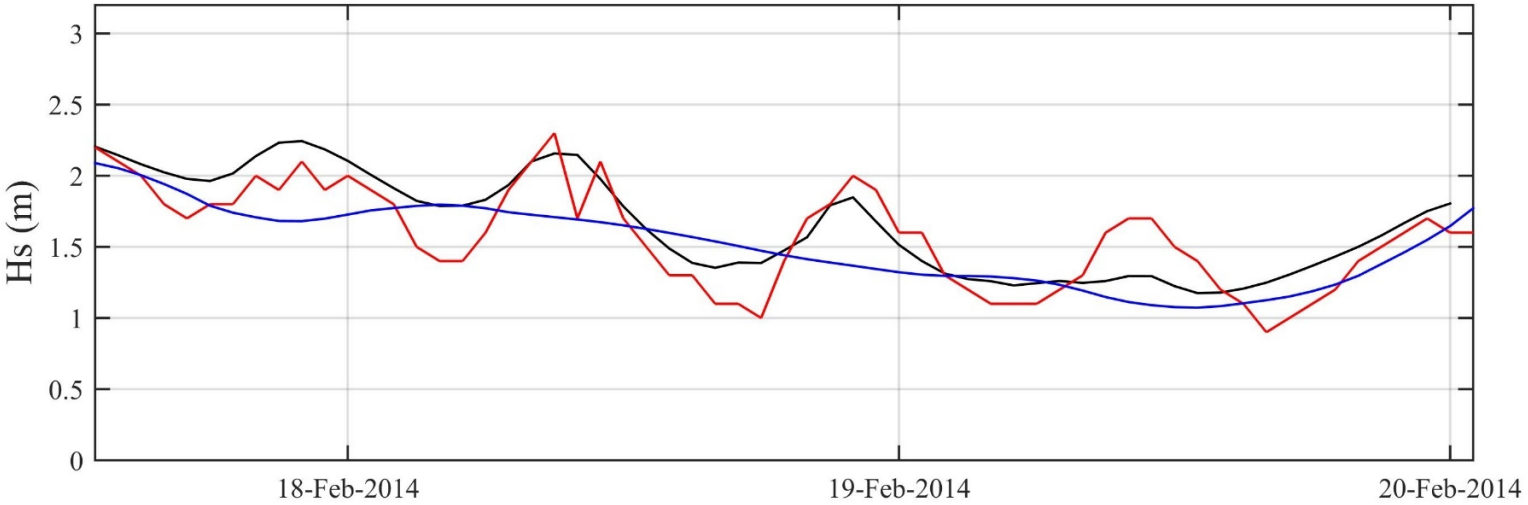
Observed and simulated wave-tide interaction in a region of high tidal flow



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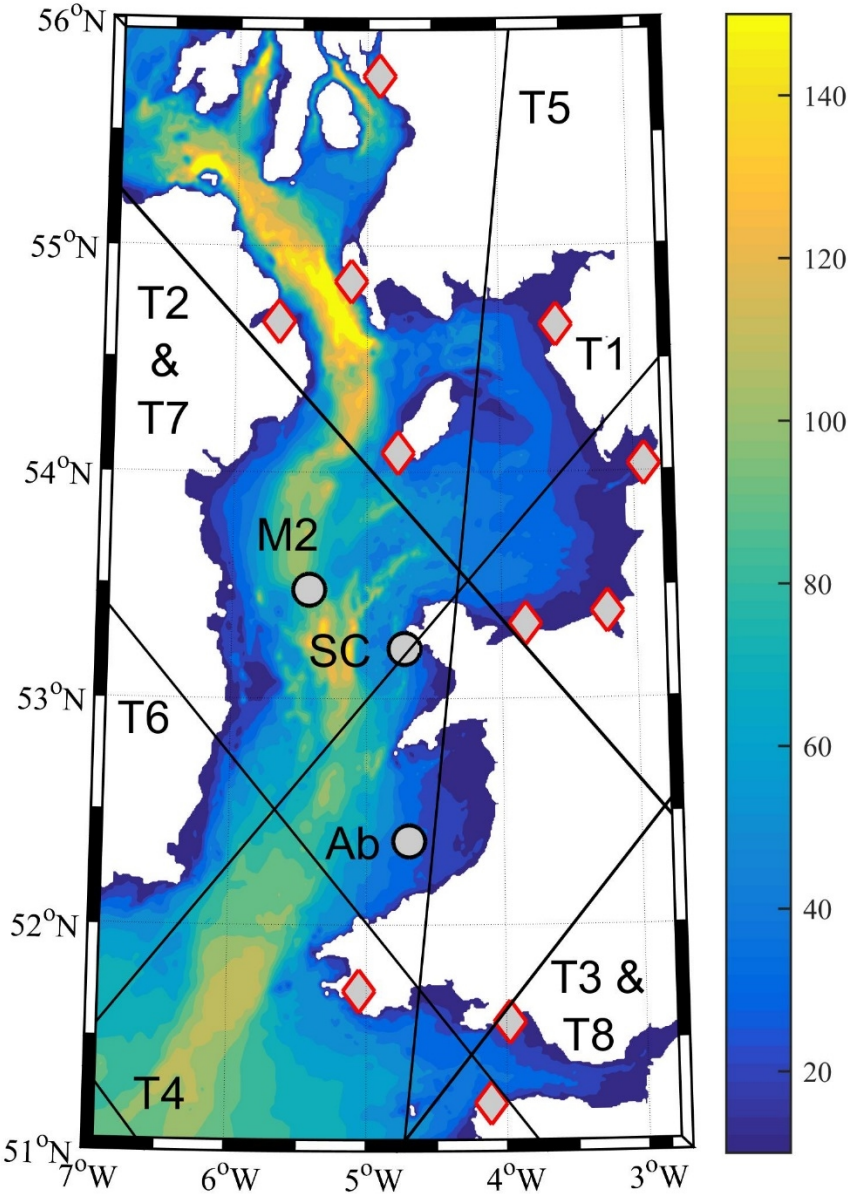
Summary

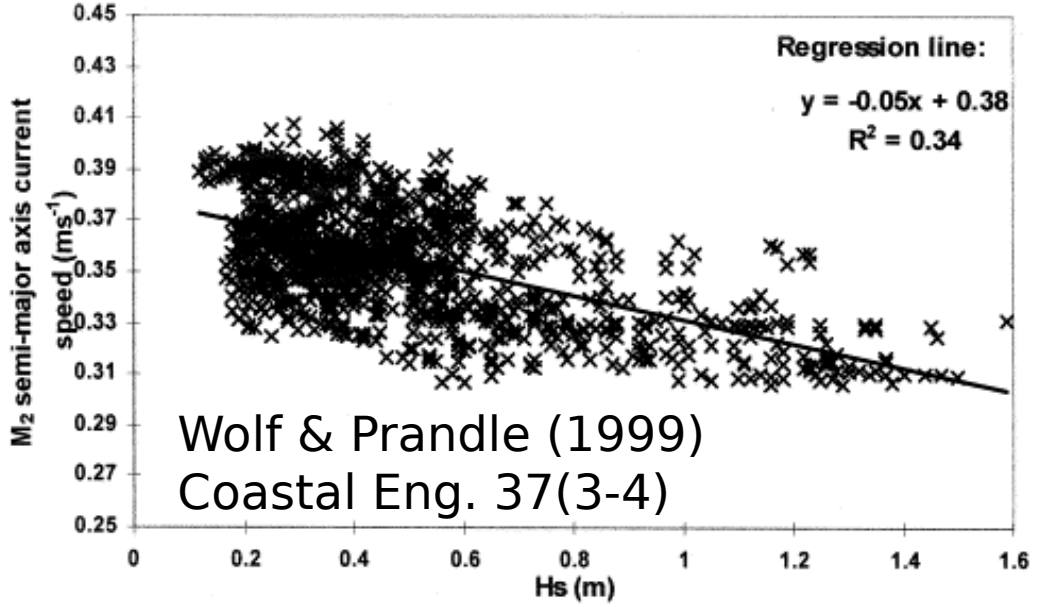


- Dynamically coupled wave-tide model (COAWST) simulated a 2 month period (Jan – Mar 2014)
  - Validated and idealised simulations used
- Effect of tide on wave *Hs* found in some regions
- On average, *Hs* could be up to 20% larger at HW in areas
- Wave-tide interaction observed with 5 beam ADCP and Wave buoy

Wave-tide interaction

(1) Waves on tides

- Enhanced bottom friction / stress (apparent Z_0)
- Additional mass and momentum to the flow (e.g. vortex forces and stokes drift)



Wolf & Prandle (1999)
Coastal Eng. 37(3-4)

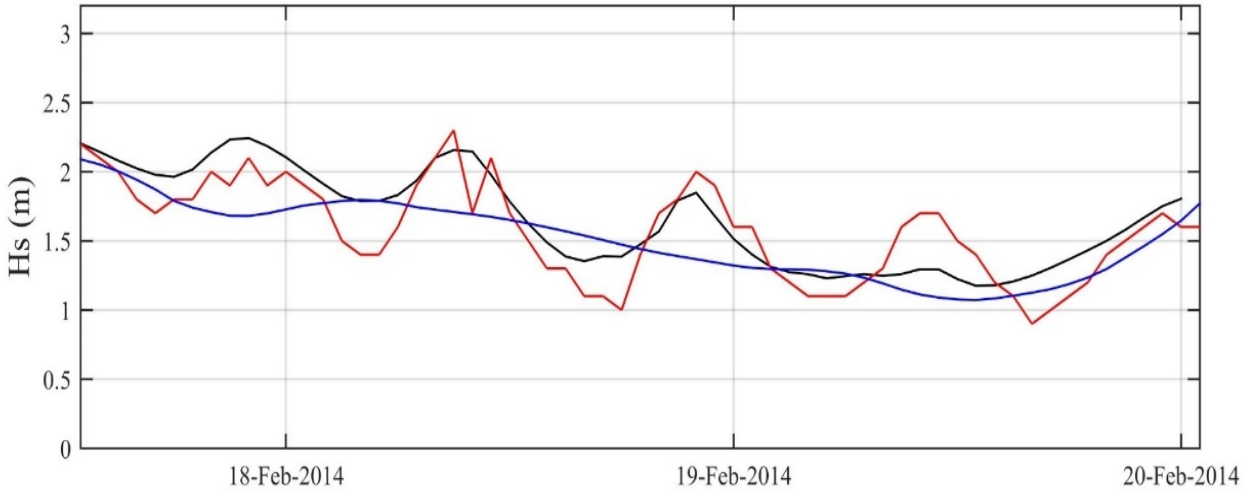
(2) Tides on waves

- **Currents**

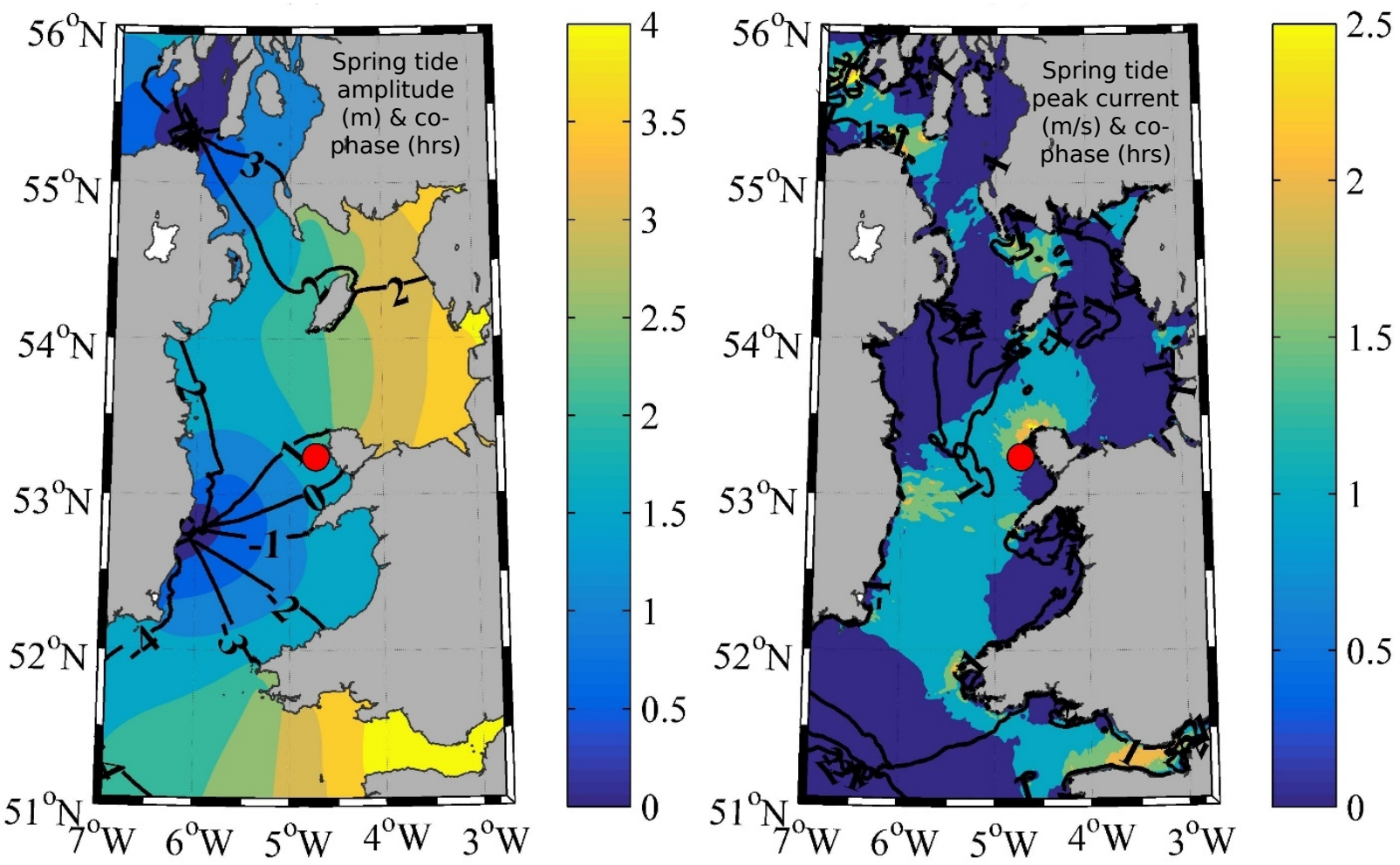
Wave generation (apparent wind speed), Doppler shift, refraction

- **Water depth**

Changes bottom friction, shoaling/refracting the wave



The Irish Sea



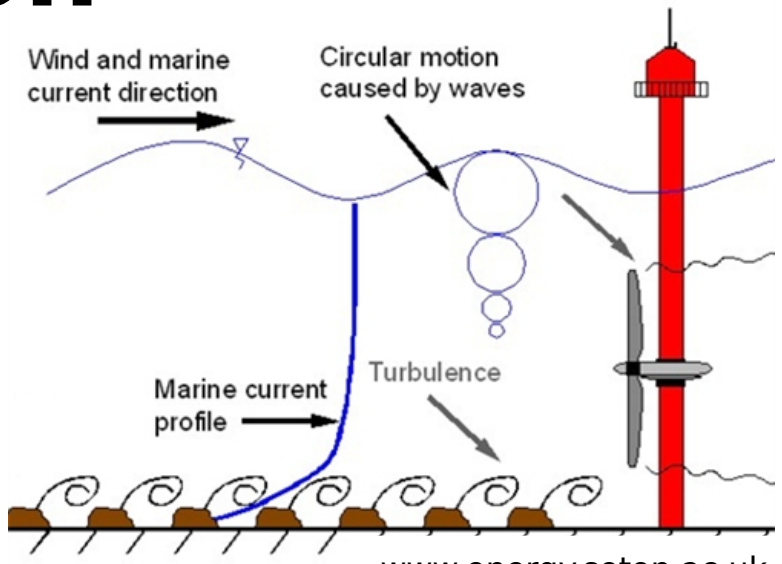
Previous Irish Sea wave-current interaction research

- Effect of tides on waves not uniform;
- 10% effect on *Hs* in coastal areas and regions of strong tides.
- Effect of waves on currents also evident ~10% (Wolf, 2009; Brown et al. 2010; 2011)

Motivation

Renewable marine energy

- Influence of waves on the tidal-stream energy resource and turbine design

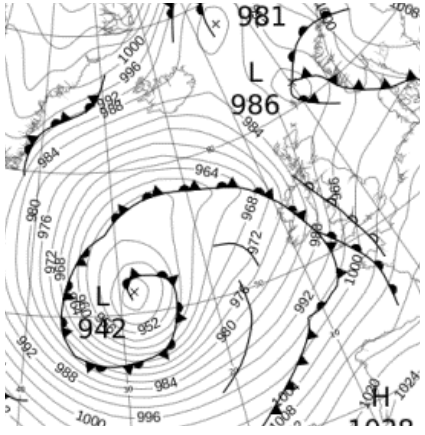


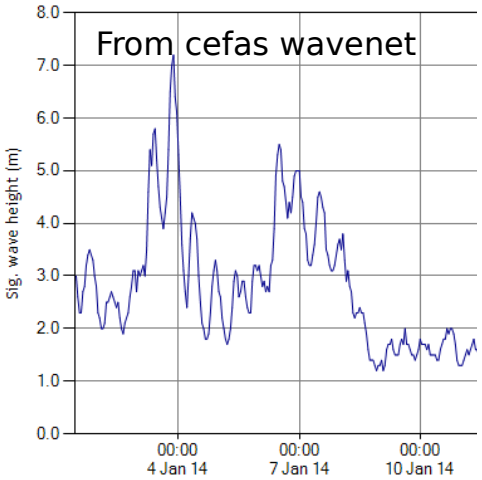
www.energy.soton.ac.uk

Coastal flood risk

- Wave run-up, erosion, dune failure
- **Do larger waves occur at high tide?**

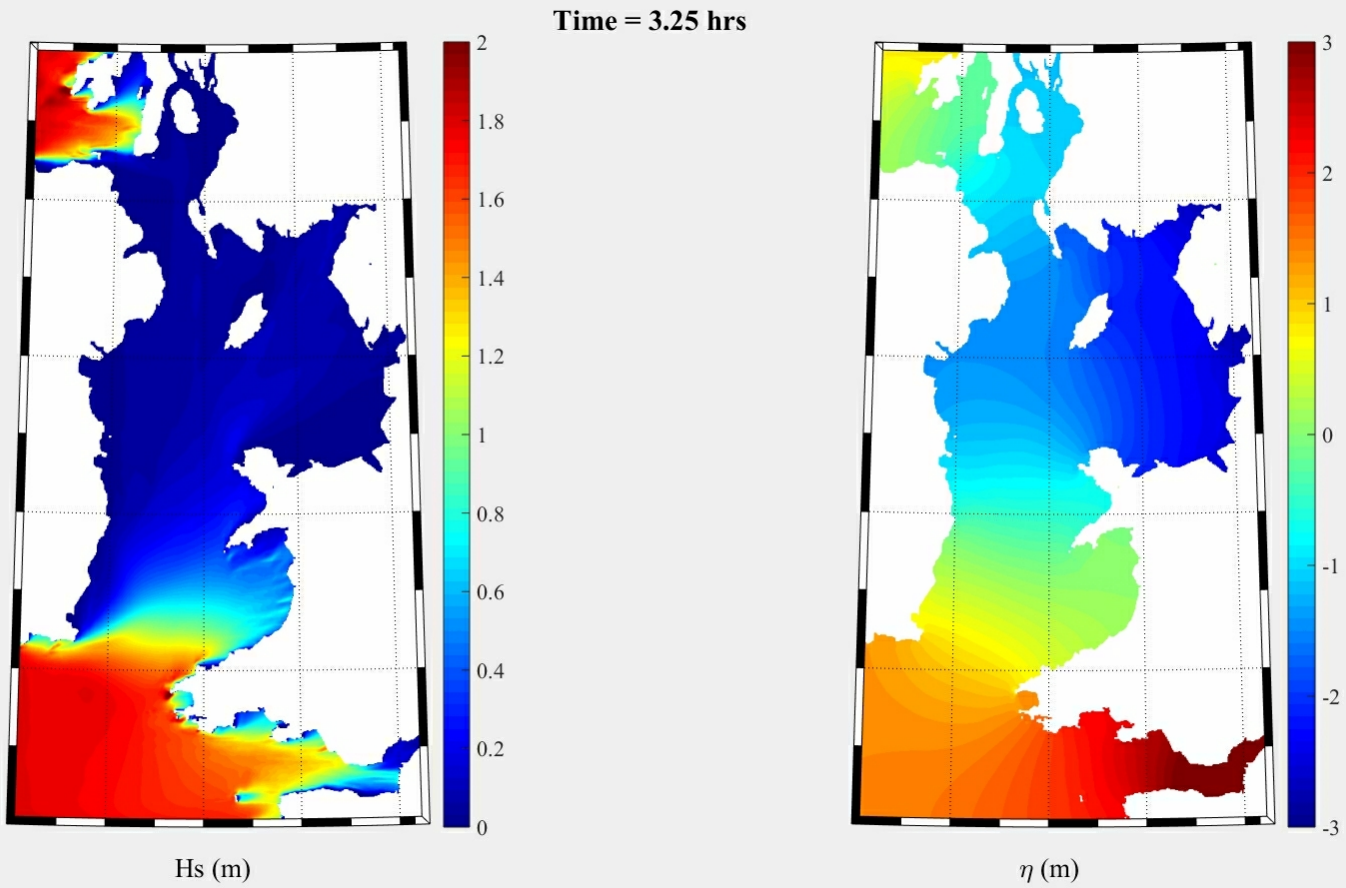
"the waves will, obviously, drop off towards low tide" @westcoastsurf report





Did wave-tide interaction have a role in the Jan-14 Aberystwyth flood that caused £1.5M?

COAWST model to simulate wave-tide interaction



- ~0.6km resolution with 10 sigma layers
- ECMWF 3 hourly wind fields and outer N.Atlantic nested SWAN model, with 10 FES2012 tide constituents.
- CD= 0.003 with wave-τ parameterised as artificial roughness (SW-BBL D_{50} 3mm).

Velocity and depth (u, v, h, h)

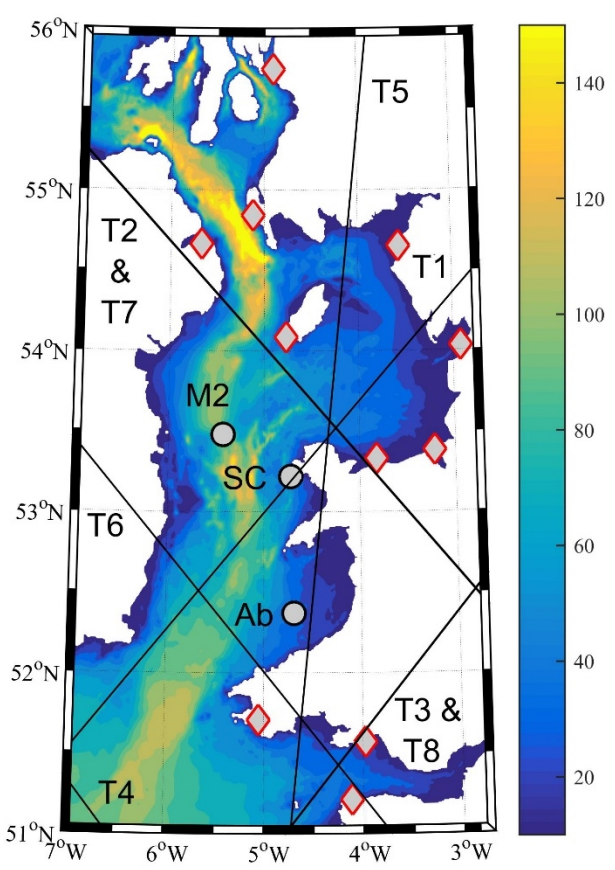
ROMS Regional Ocean Modeling System Research Community

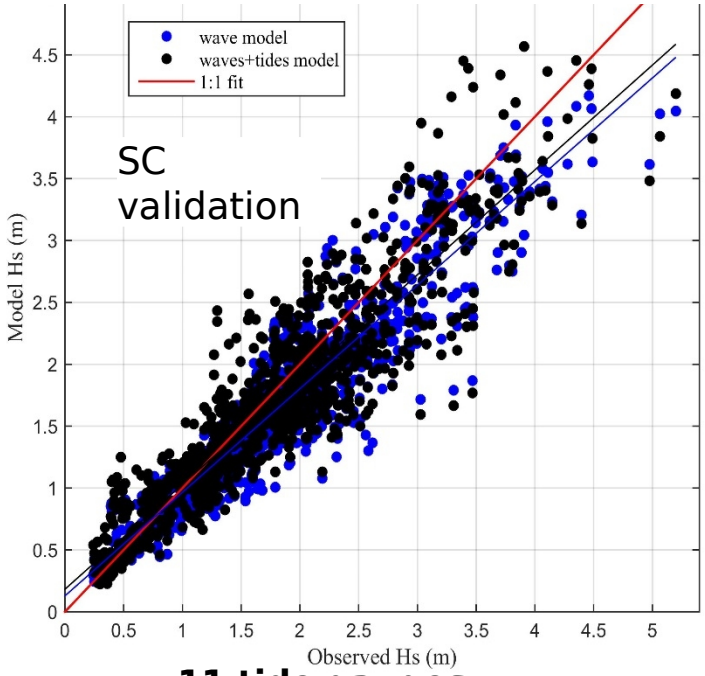
mct

SWAN Simulating WAves Nearshore

Wave forces and momentum (Dwave, Hwave, Lwave, Pwave_top, Pwave_bot, Ub_swan, Wave_dissip)

COAWST model 2 month validation

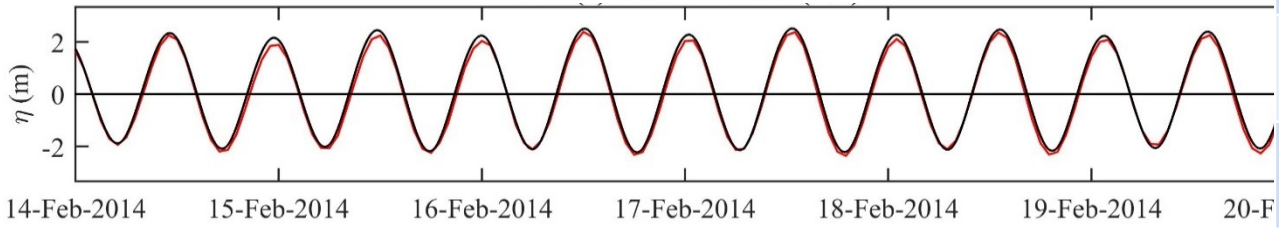




COAWST validates well & using COAWST does improve model skill (e.g. R^2 by 2-5%) compared to SWAN, but we find using COAWST does not improve accuracy for our case (RMSE similar ~2cm difference)

11 tide gauges:

- M2 RMSE = 0.11m & 8° (~6% error)
- S2 RMSE = 0.05m & 11° (~5% error)

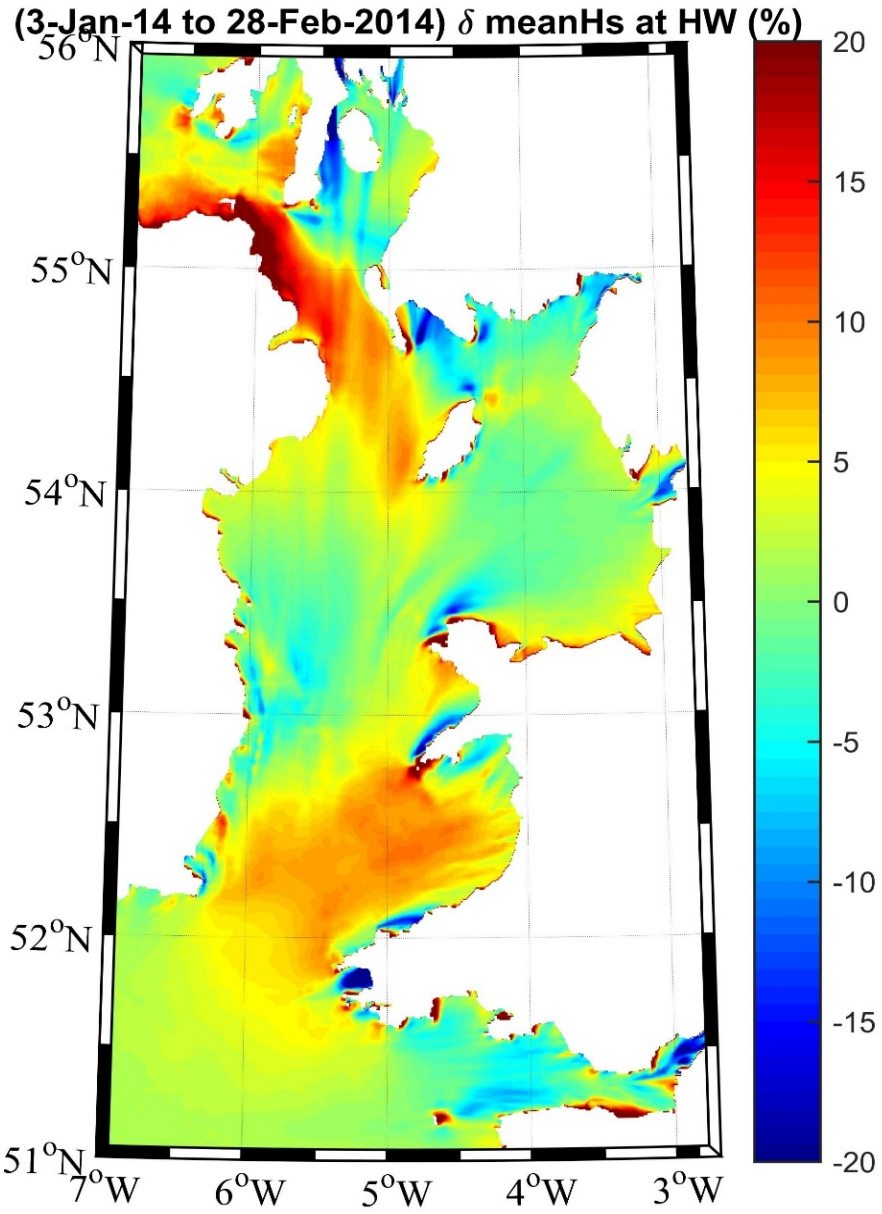


COAWST *Hs* validation:

Hs	RMSE	R^2	Bias
Ab	**0.64m (9%)**	**90%**	**-0.29**
SC	0.37m (7%)	84%	0.18
M2	**0.70m (17%)**	**92%**	**0.02**
esurge	0.58m	**56%**	**0.60**

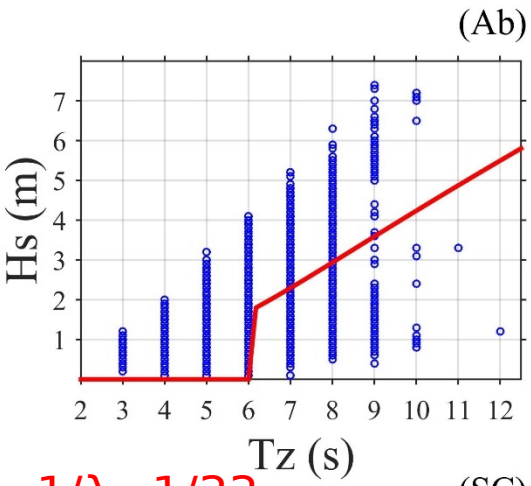
Validation data from: ntslf.org, Storm-surge.info, & Seacams

COAWST results: Hs larger at HW

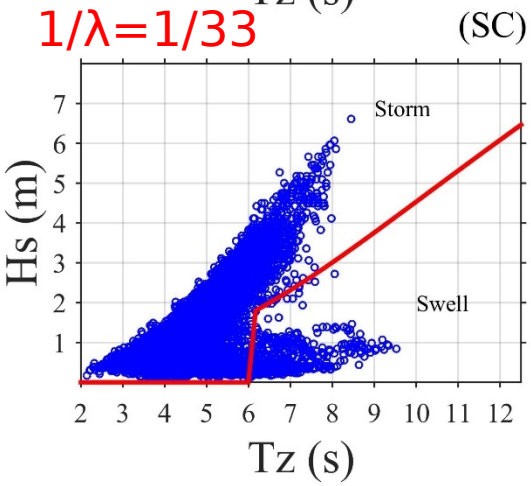


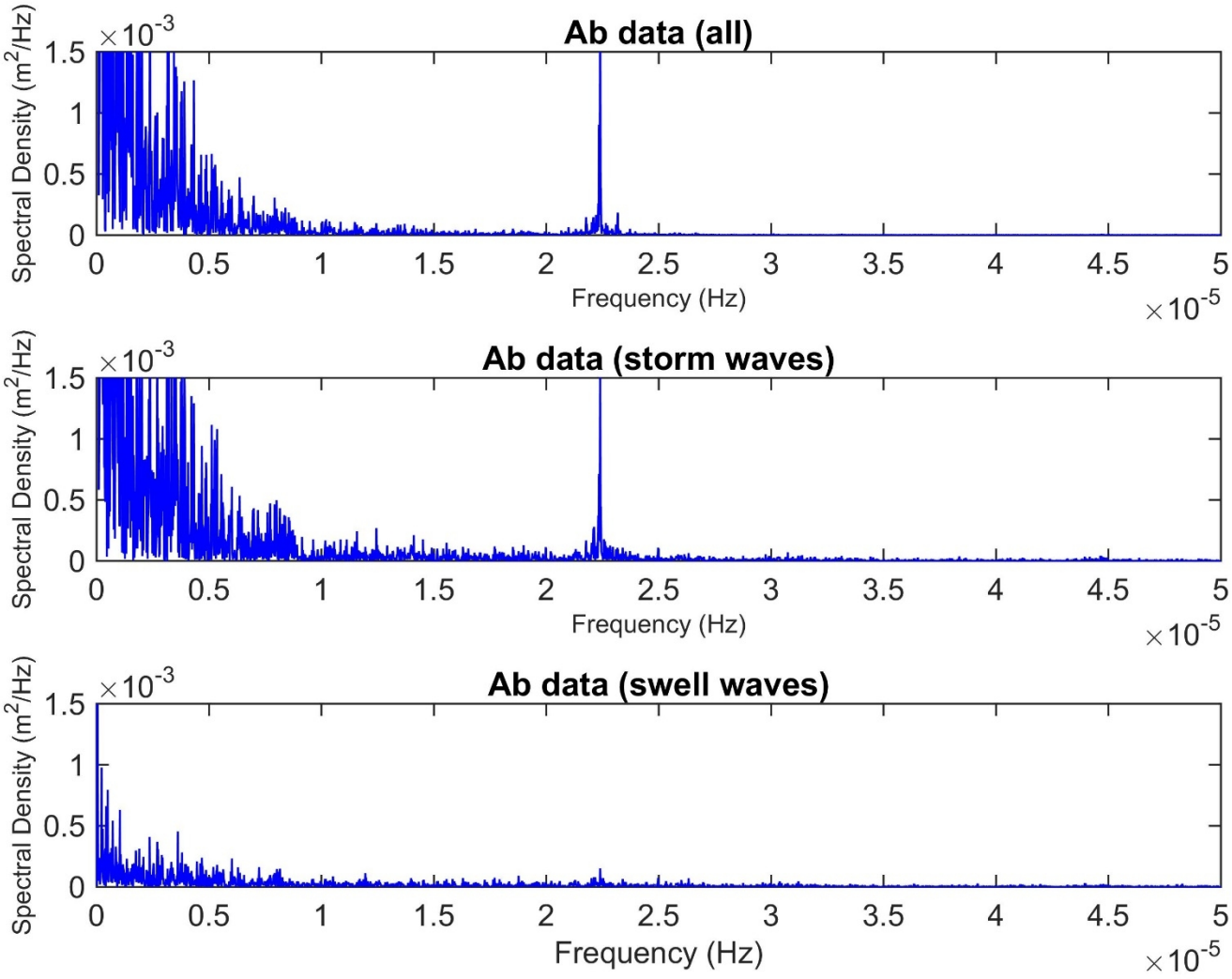
- Difference between Hs at HW between COAWST and SWAN calculated
- On average (for all η), COAWST Hs slightly larger (3%) than SWAN, especially so at strong tidal-flow regions (δHs ~ 0.3 – 0.5m)
- **Spatial variability, but on average Hs at HW is larger when including the tide for parts of the coastline**

Evidence of wave-current interaction



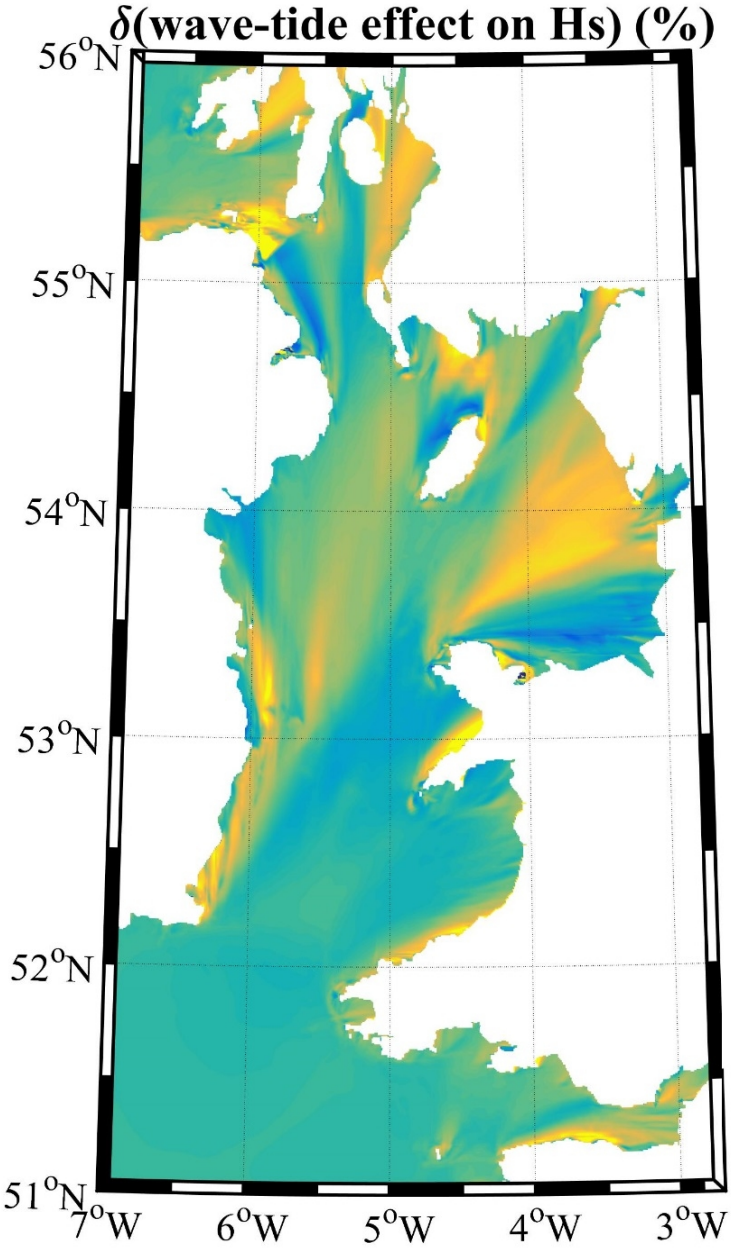
1/λ=1/33





"Shorter period storm waves more affected by the tides compared to swell waves" (e.g. Hashemi et al. 2014).

Are shorter period waves more affected? Idealised simulation



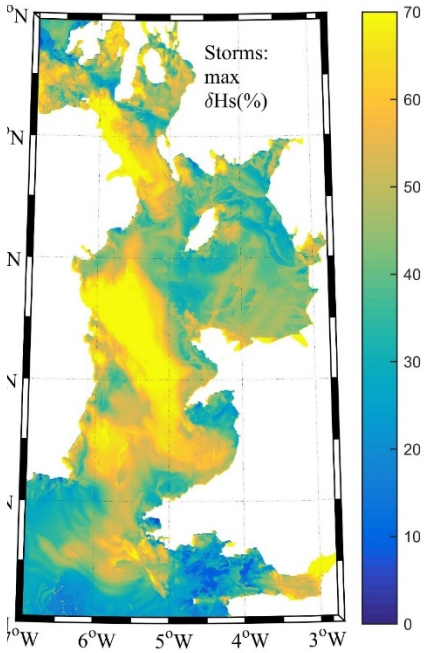
A = “SW swell”: 2m Hs & 10s Tz

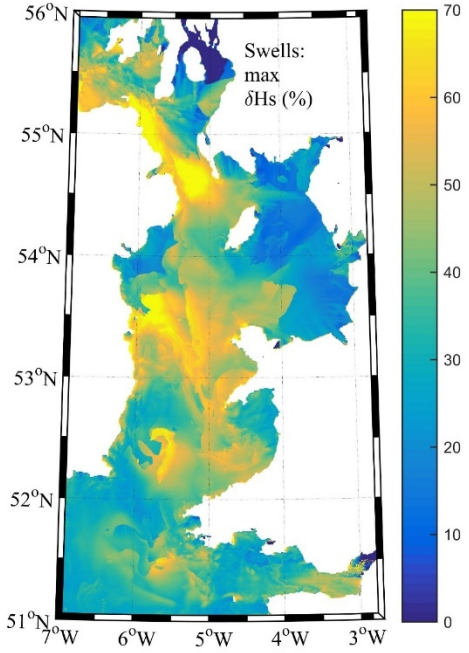
B = “SW storm”: 2m Hs & 5s Tz

Simulated δHs over a tidal cycle (%) calculated, and δHs of B - δHs of A (so: >0% = storm waves more effected by the tide)

Result

Spatial variability, but storm waves are more affected by tides, with similar pattern and result found in 2-month simulation



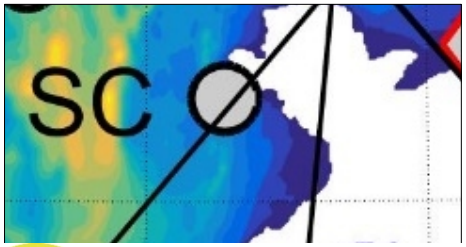


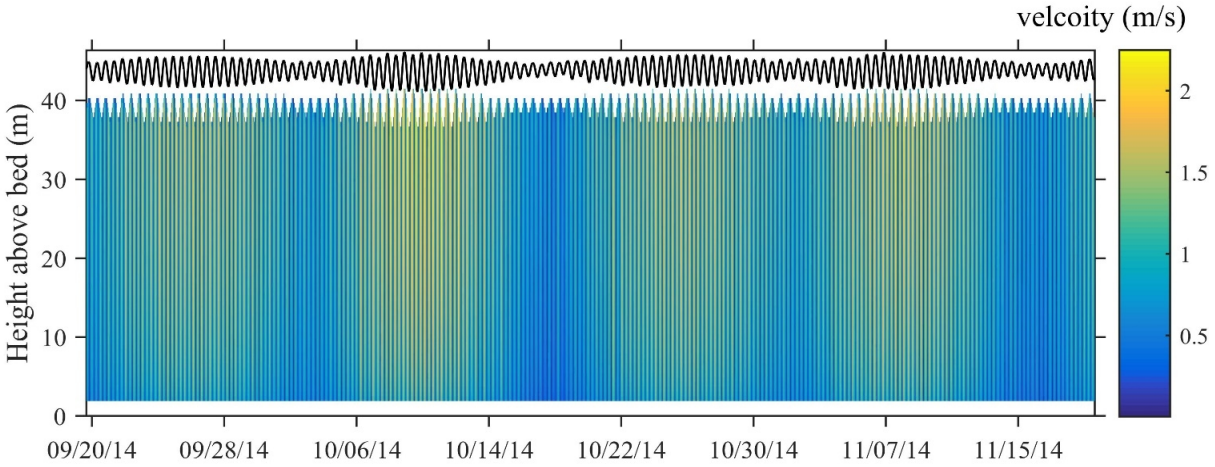
Observations from the tidal-stream energy demonstration zone

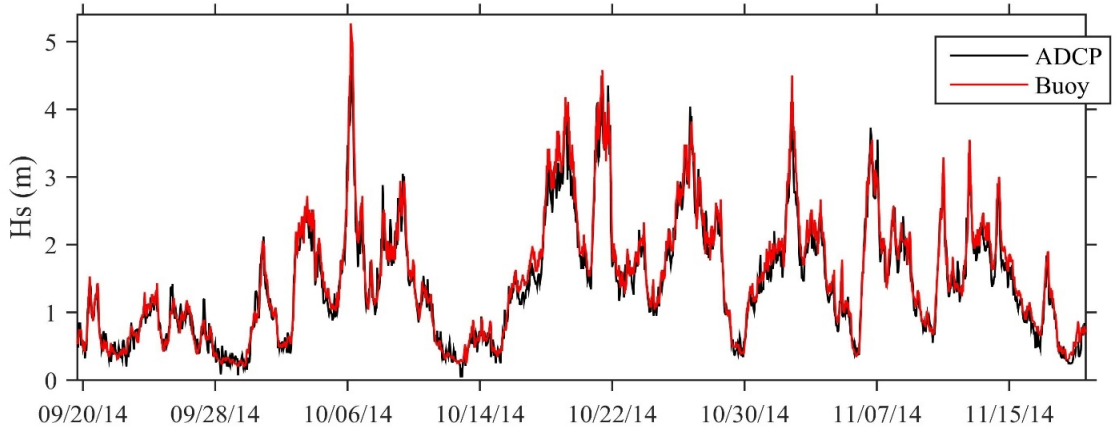
- 5-beam ADCP @ 600kHz with 0.5m bins, ensemble-averaged to 30mins.
- Datawell directional wave-rider buoy around 2km SW of ADCP with 30min outputs.

COAWST *Hs* validated well here (RMSE = 0.37m ~7% with R^2 of 84%)

But if I use Hs measured with ADCP, validation improves (RMSE = 0.34m) so COAWST now more accurate than SWAN at all sites







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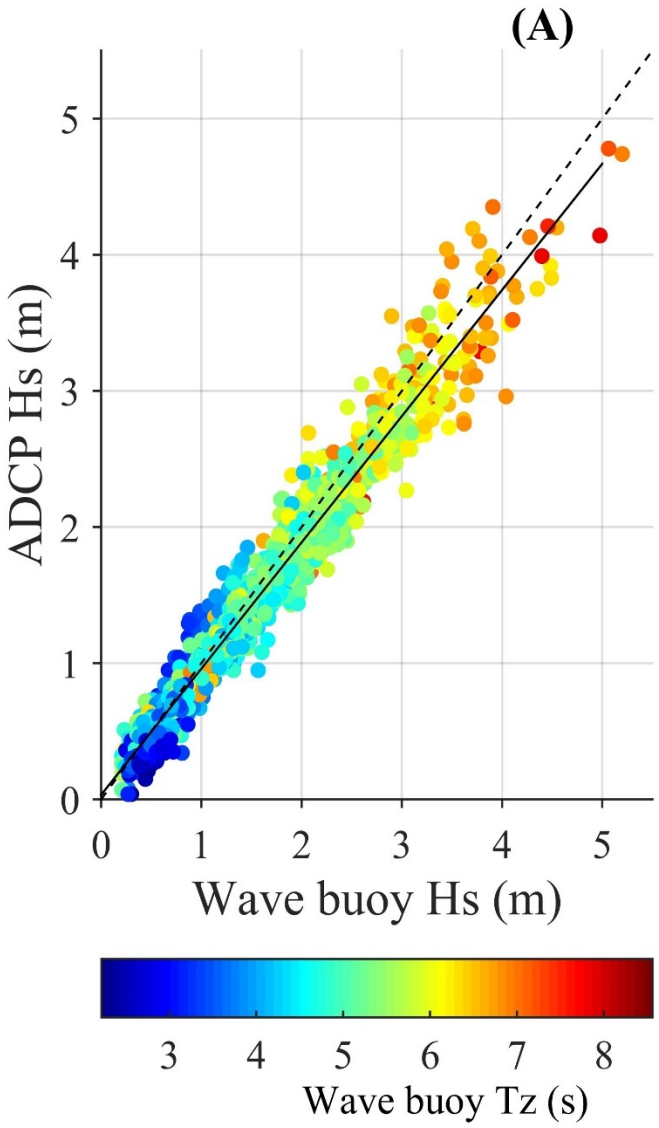
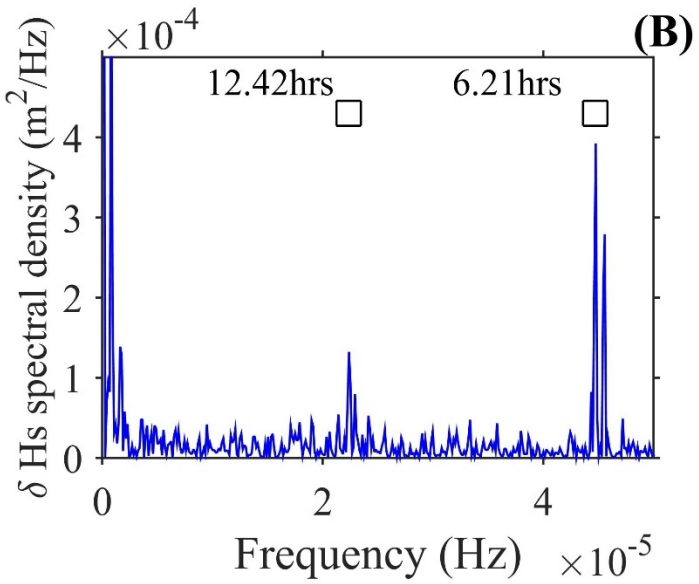
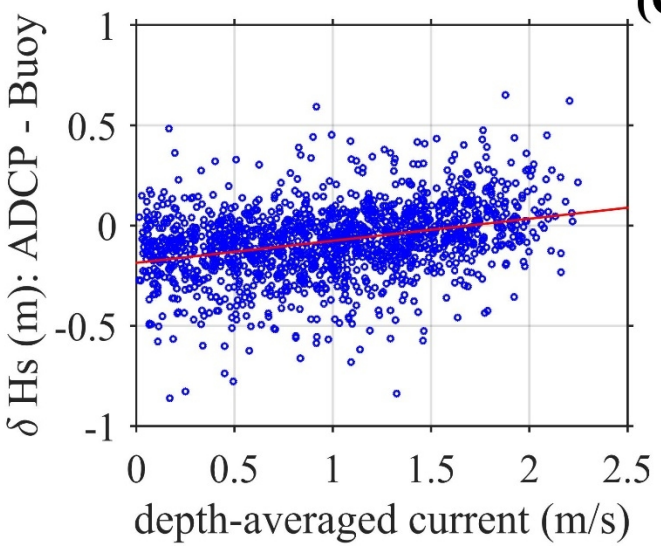
ADCP measurement of waves







- ADCP Hs<buoy Hs consistently
- ADCP under-predicts larger/swell waves*
- δHs oscillates with period of tidal currents
- δhs = 0.1*U ?

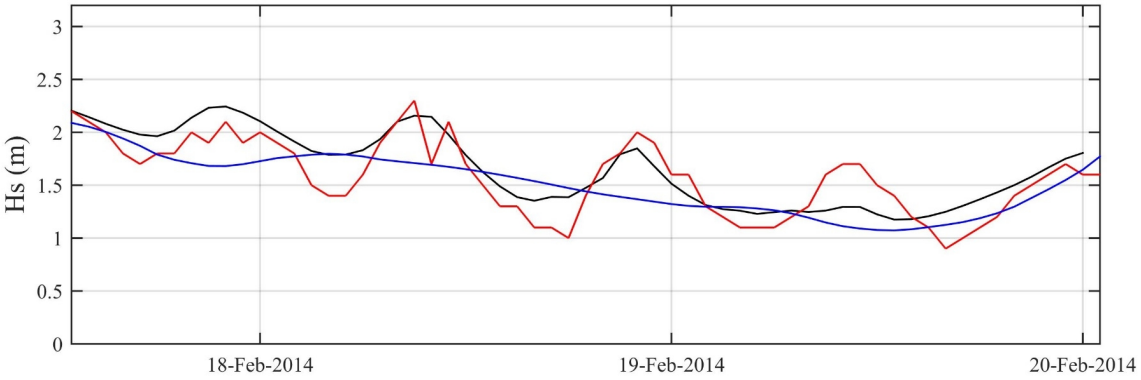
(Rho 32% & R^2 11%)

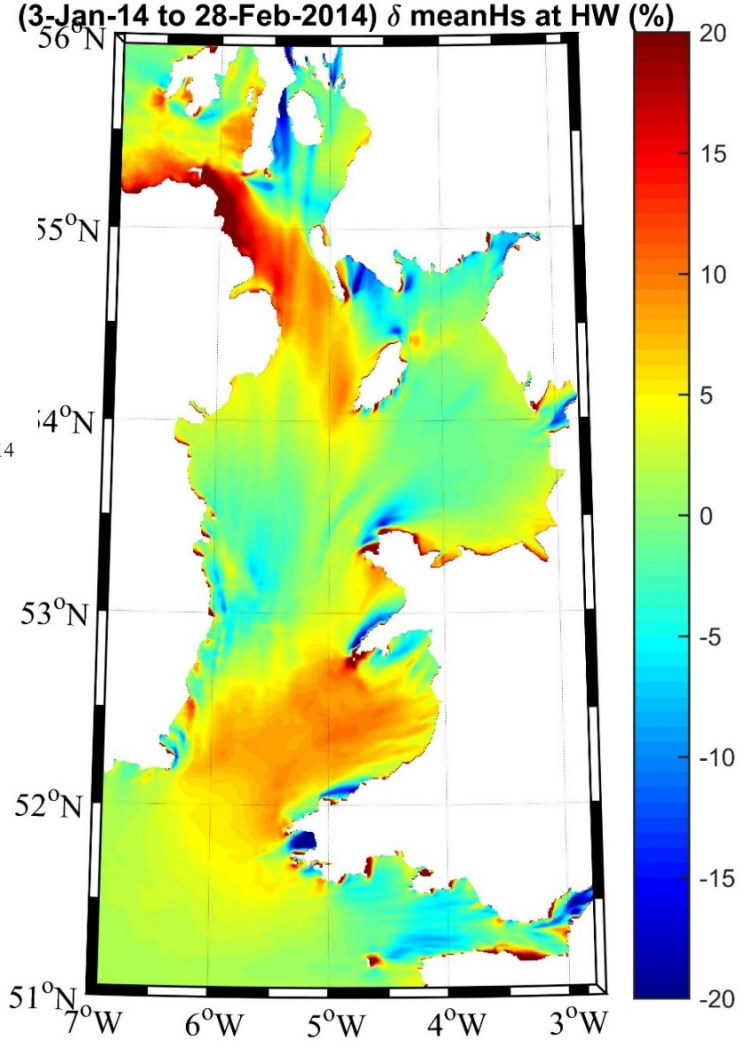
*converse to literature, but could this be the “bender” moment?

Is the current affecting buoy observations?

Conclusion

- Tides significantly affect *Hs*
- Storm wave *Hs* more affected by tides
- Simulated *Hs* is larger at HW for some regions
- Is the wave buoy affected by tidal currents?





Future work:

- Further analysis with observations (e.g. wave direction & Tz)
- Effect of waves on tides
  - Velocity profile?
  - MRE resource?
- Wave-tide interaction effects to flood risk
  - Asymmetry on sediment transport from wave-tide interaction?
  - Beach and dune effects?