Extreme Weather, Sea Level Change, Tides & Waves in the Bristol Channel

Dr Judith Wolf
National Oceanography Centre, Liverpool

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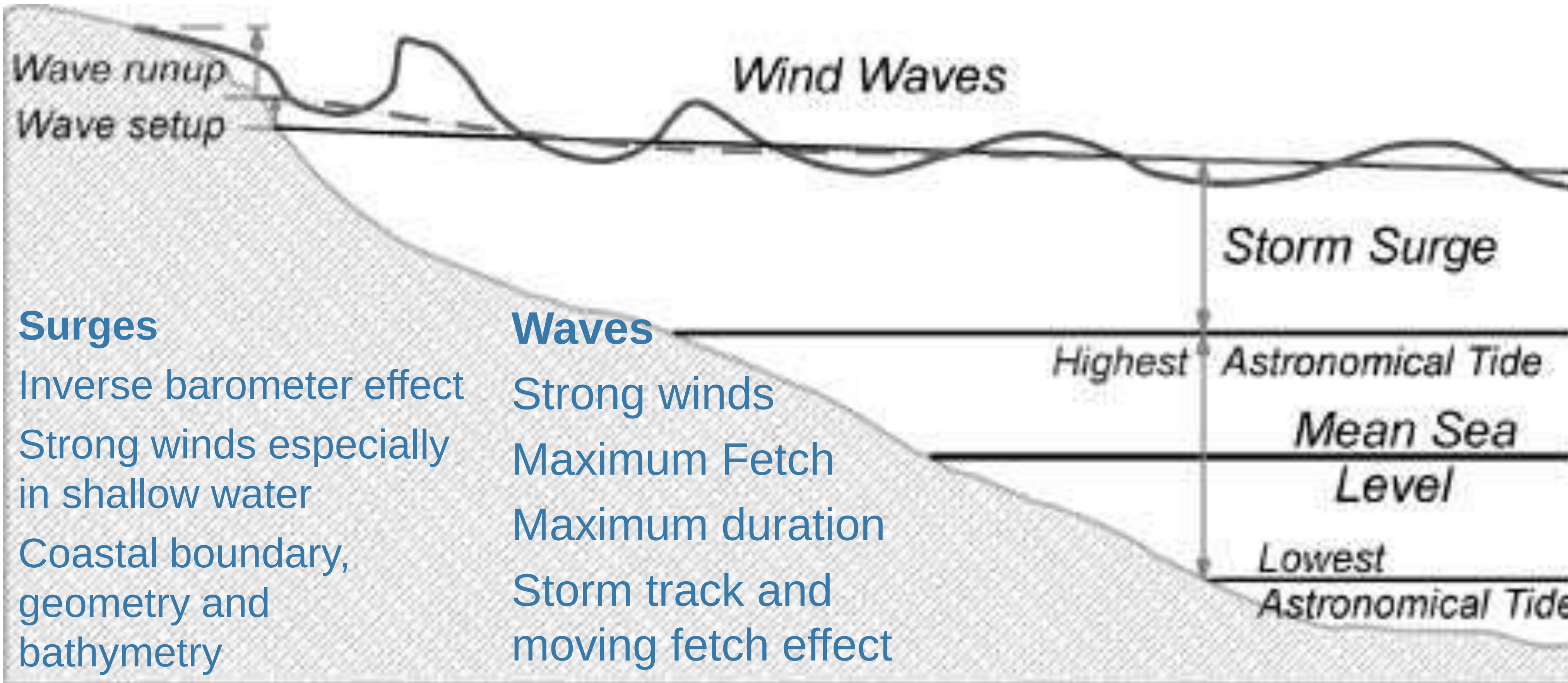
Outline of presentation

- Coastal flooding and surge-tide operational forecasting in the UK
- Surges in the Bristol Channel/Severn Estuary
- Tides in the Bristol Channel/Severn Estuary
- Waves in the Bristol Channel
- Sea level rise and climate change
- What exactly happened on **30th January 1607?**

Coastal flooding: factors causing large coastal impacts for UK



Surges

Inverse barometer effect

Strong winds especially in shallow water

Coastal boundary, geometry and bathymetry

Waves

Strong winds

Maximum Fetch

Maximum duration

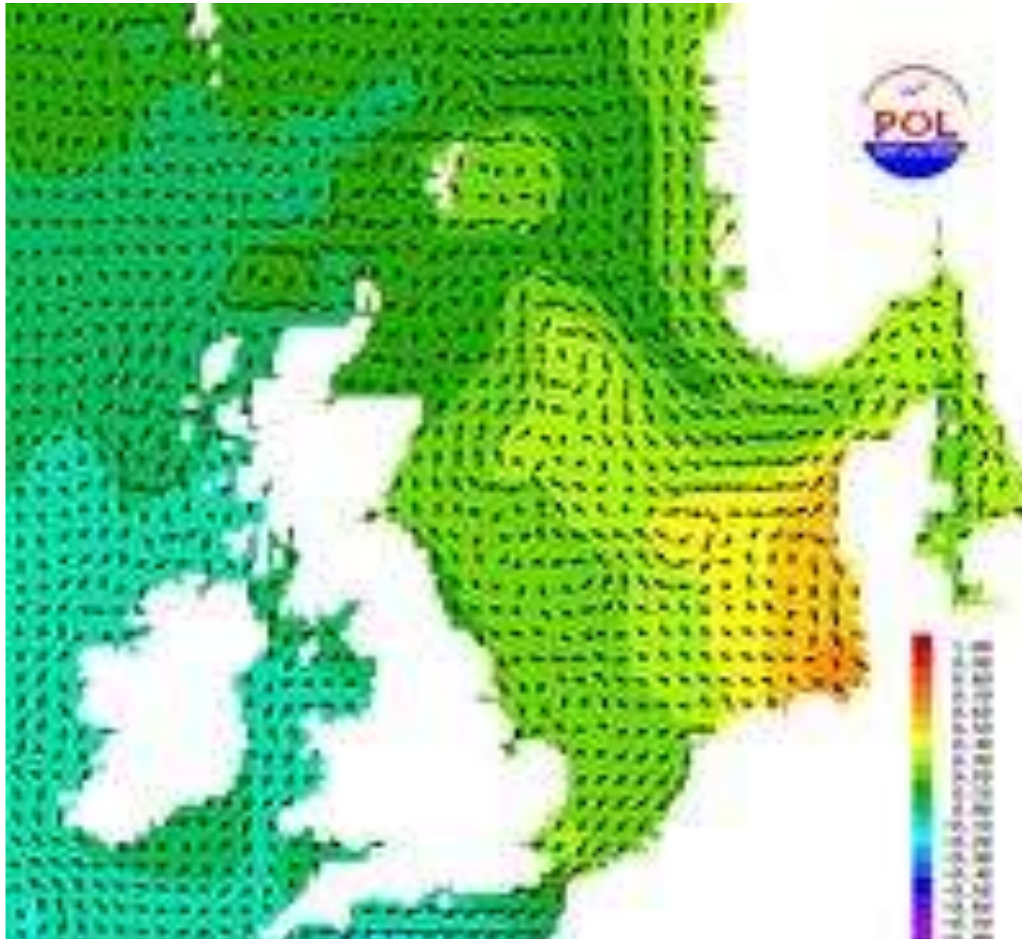
Storm track and moving fetch effect

1. Tides 2. Storms 3. Long-term changes in sea level

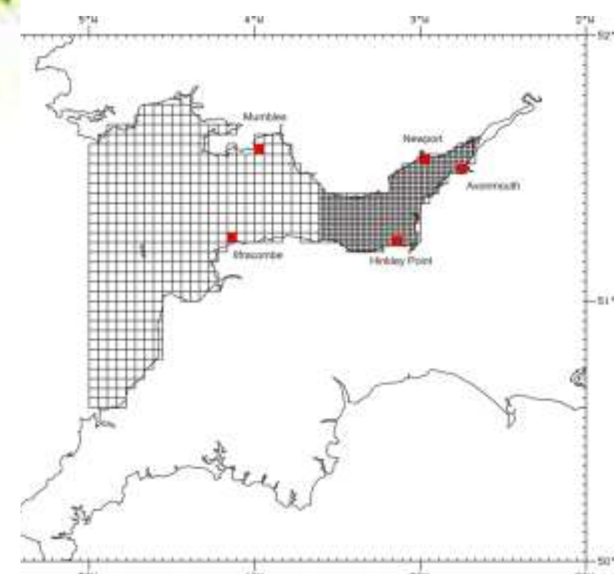
UK Tide-surge model at Met Office

UK Coastal Monitoring and Forecasting (UKCMF, Environment Agency)

Total water levels are forecast by calculating surge residuals (tide+surge – tide alone) then adding tidal predictions from the extended harmonic method (EHM).



For the Bristol Channel and Severn Estuary two additional high-resolution models were added (see below)



For the majority of UK tide gauge sites, the Mean Absolute Error (MAE) associated with EHM predictions is typically in the region of 5–6 cm, but in the Bristol Channel region, owing to a combination of shallow water effects and large tidal range of around 12 m, these errors more than double resulting, for example, in a MAE of 14.37 cm at Avonmouth and 15.83 cm at Newport for 2006–2009 inclusive (Hibbert et al., JOO, 2015) www.ntslf.org/storm-surges/latest-surge-forecast?port=Avonmouth&chrt=3

National Tidal and Sea Level Facility

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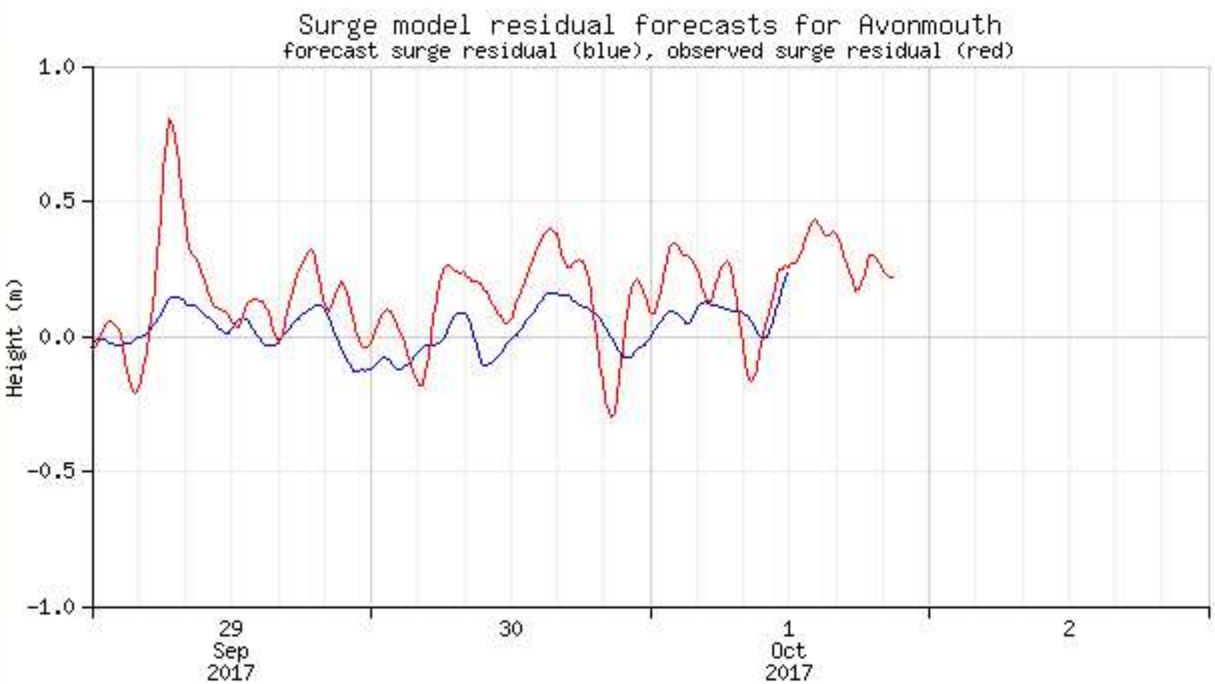
Latest surge forecast for Avonmouth

Storm surge model | Surge model forecast

Latest forecasts (residual) | Latest forecasts (total level) | Archived 0–6hr forecast | Archived forecast and observed residuals



Modelling Tides and Tidal Resonance

Gao and Adcock (2017), Serhadlıoğlu (2014), Webb (2013), Fong and Heaps (1978), explore resonances of the M2 tide in the Bristol Channel/Celtic Sea.

Fong and Heaps suggest there is a near ¼-wave resonance for the M2 tide between the head of the Bristol Channel/Severn Estuary and the Celtic Sea Shelf edge.

Webb states ‘the tides in the Bristol Channel are very sensitive to changes in the physical system’.

Gao and Adcock note the resonant period of the Bristol Channel is about 11.9 hours (shorter than M2 period of 12.4 hours)

Tidal energy flux from observations

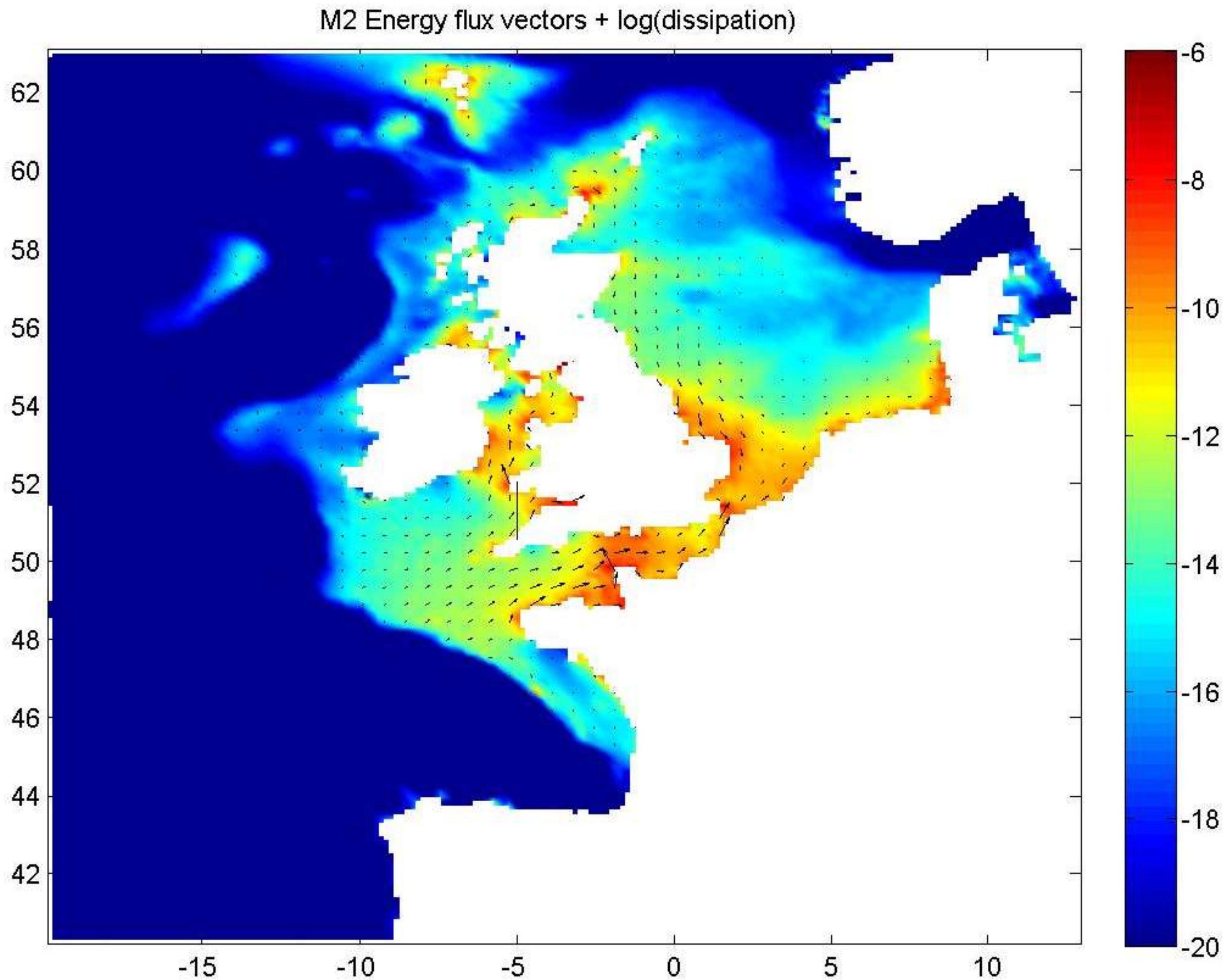
Figure G.4. Average tidal powers measured by Cartwright et al. (1980).

Figure from MacKay (2009)

'Sustainable Energy- without the hot air'

The calculations of energy flux in Cartwright et al (1980) were from bottom pressure and current meter measurements

Energy flux from Flather 12km tidal model

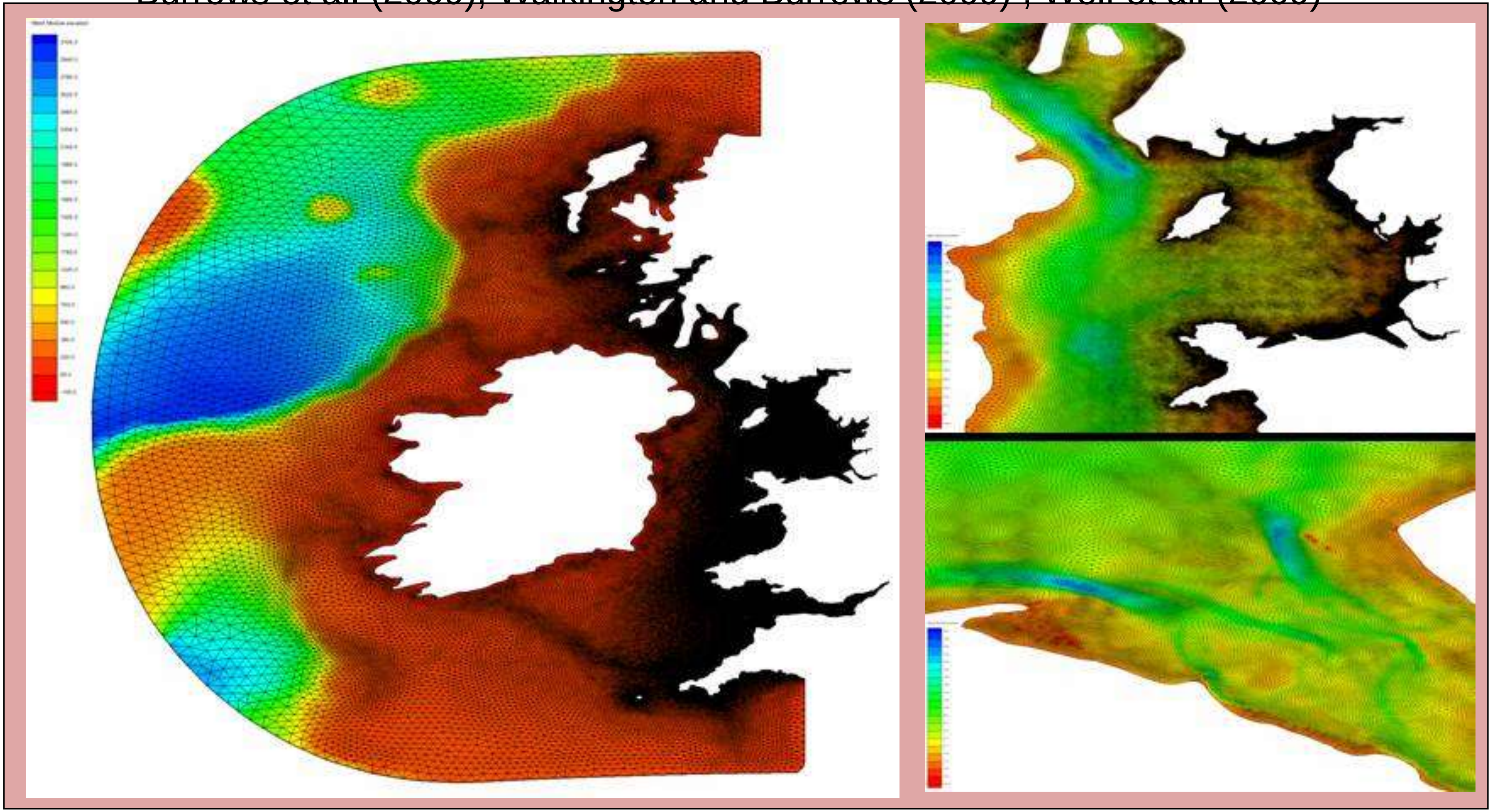


Energy flux across shelf edge ~balanced by Energy dissipation in Bristol Channel – but it's hard to get right in finite difference/regular/ structured grid.

There is some improvement with an unstructured grid model e.g. ADCIRC or FVCOM

2-D Tidal Energy Modelling using ADCIRC unstructured grid model

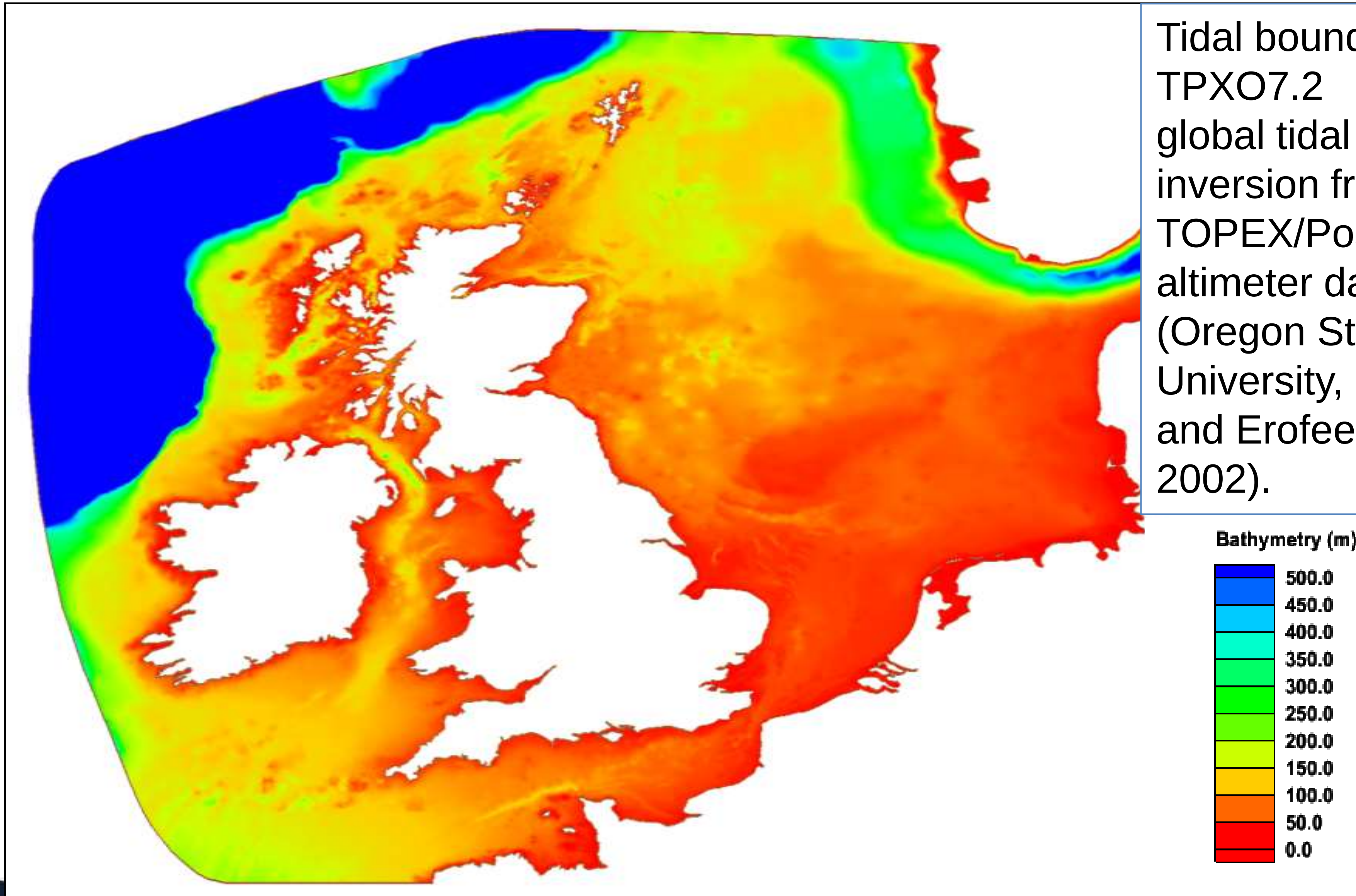
Burrows et al. (2009), Walkington and Burrows (2009) , Wolf et al. (2009)



AVONMOUTH (Lat=51.51 Lon=-2.71 M2 Obs. Amp.=4.27m,.phase=200.7deg, Mod amp=4.28m, phase=199.5 deg

Grid resolution varies from 15km at the ocean boundary to ~50m in estuaries of interest: Severn, Dee, Mersey, Ribble, Morecambe Bay and Solway Firth

Scottish Shelf Model (SSM) FVCOM model

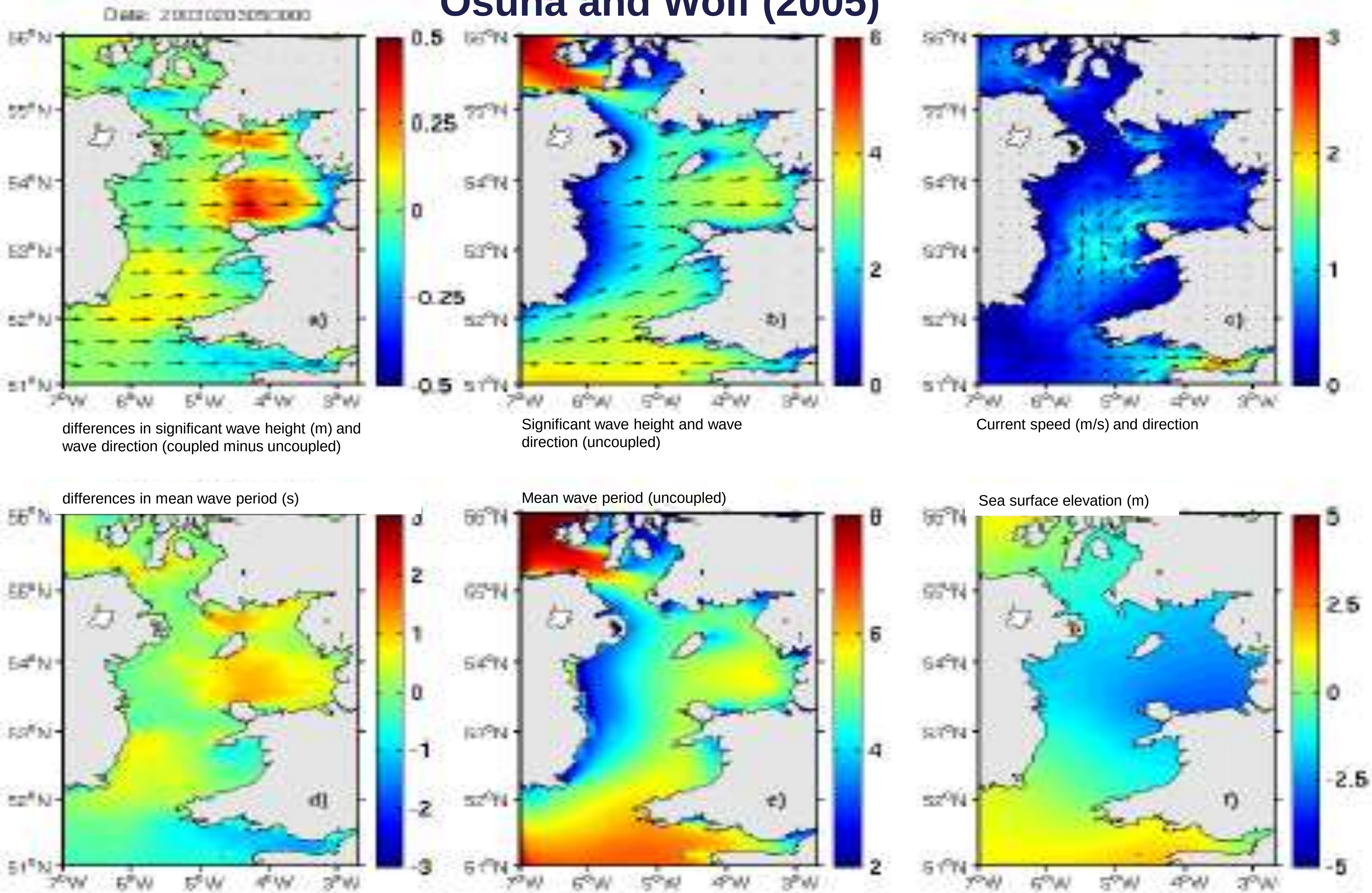


Tidal boundary TPXO7.2 global tidal inversion from TOPEX/Poseidon altimeter data (Oregon State University, Egbert and Erofeeva, 2002).

Effect of waves on water levels

- Recently interest has increased in the contribution of waves to coastal flooding events
- The evidence suggests wave models do a good job of turning winds into waves for mid-latitude storms, the largest errors still being the errors in the wind-field as is the case for surges
- UK coastlines can be partitioned into sea areas with a similar response to wind fields. We have selected a subset of storms in the recent past from a global and regional hindcast for NW Europe to increase the robustness of this analysis
- For each area a worst case storm will be designed and its probability identified with reference to the historical record
- These wind and wave fields are being used to explore storm events impacting the UK as part of the ongoing SUCCESS project

Coupled wave-current model: Irish Sea 1.8km resolution
Osuna and Wolf (2005)



a) differences in significant wave height (m) and wave direction (coupled minus uncoupled)

b) Significant wave height and wave direction (uncoupled)

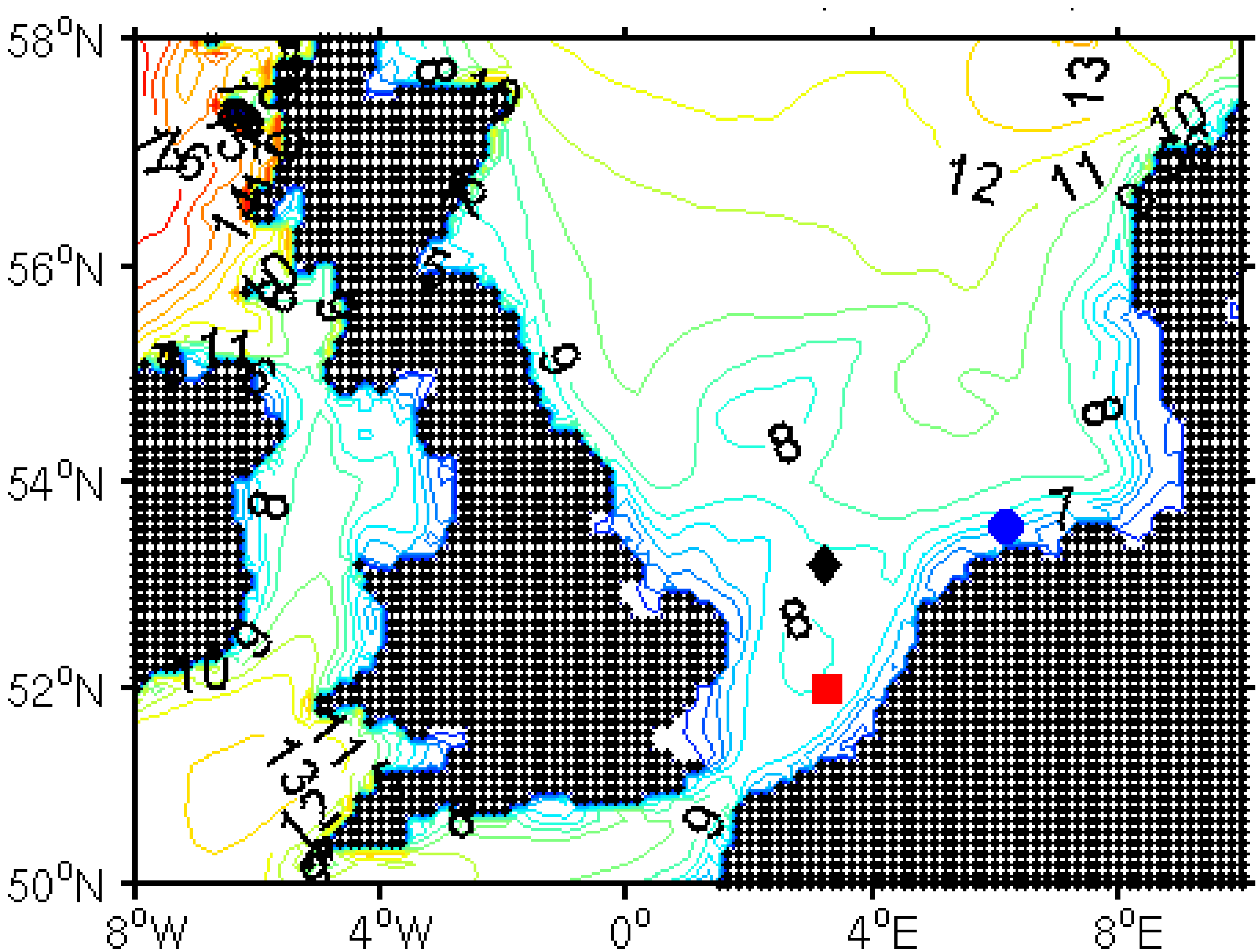
c) Current speed (m/s) and direction

d) differences in mean wave period (s)

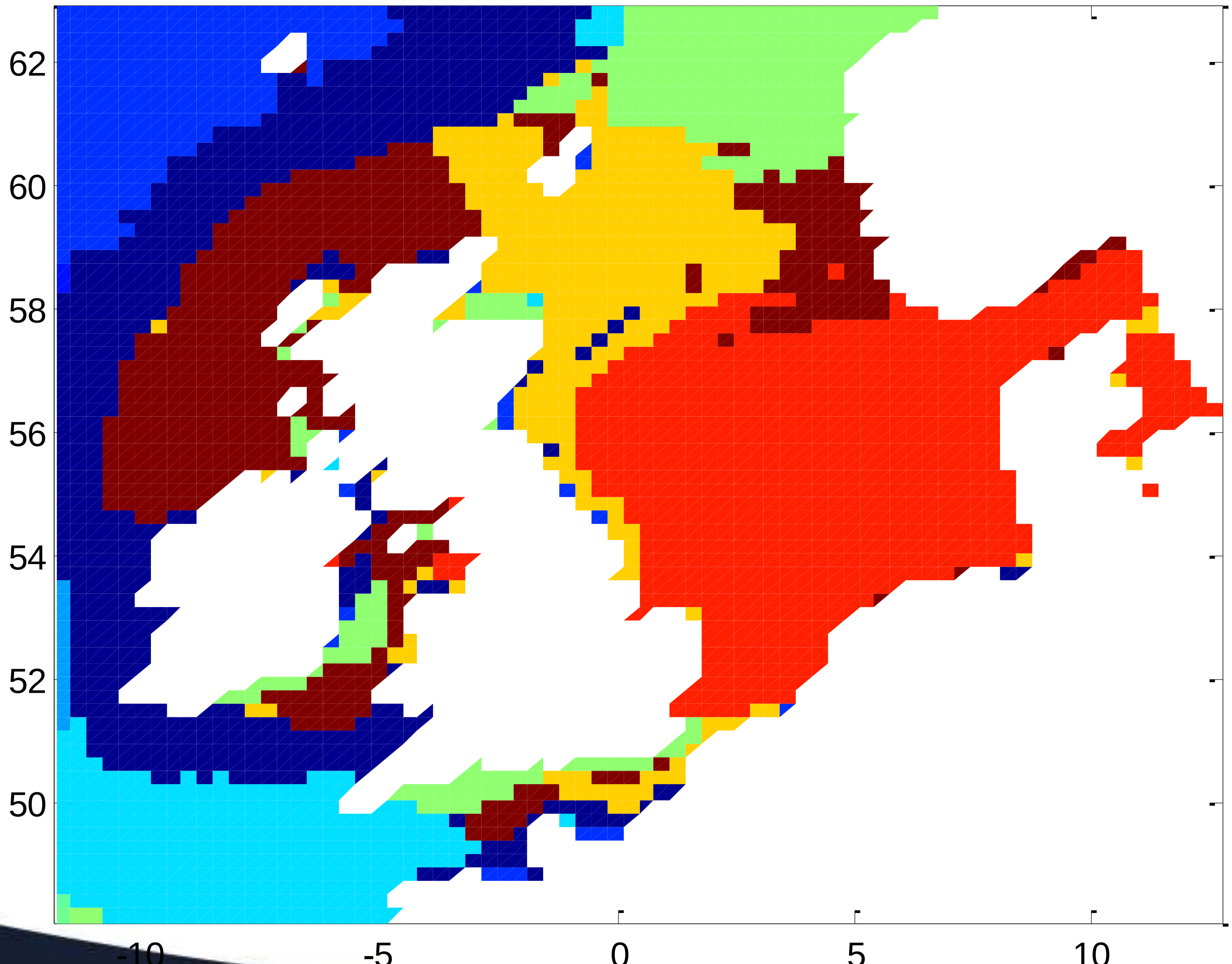
e) Mean wave period (uncoupled)

f) Sea surface elevation (m)

50-y return period waves from r-largest GEV



Storm Wave characteristics – cluster analysis



7 clusters from 4 correlation arrays:

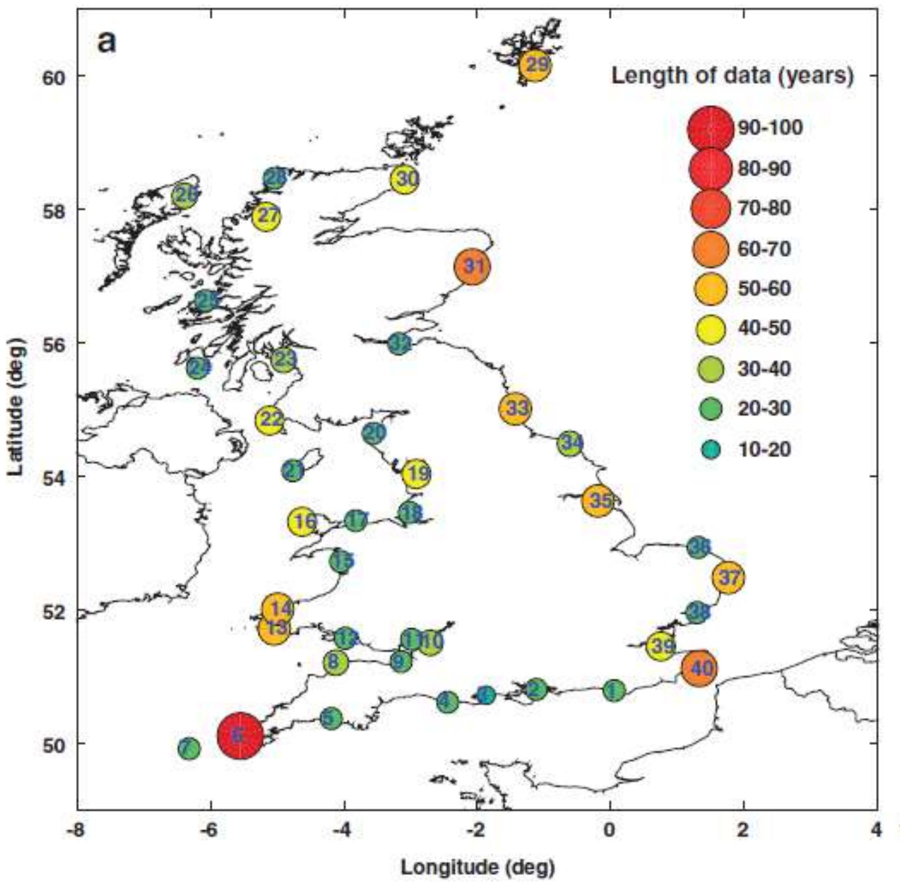
Wave height with wind speed,
Wave height with mean wave period,
Wave height with peak wave period
Wave height with mean wave direction

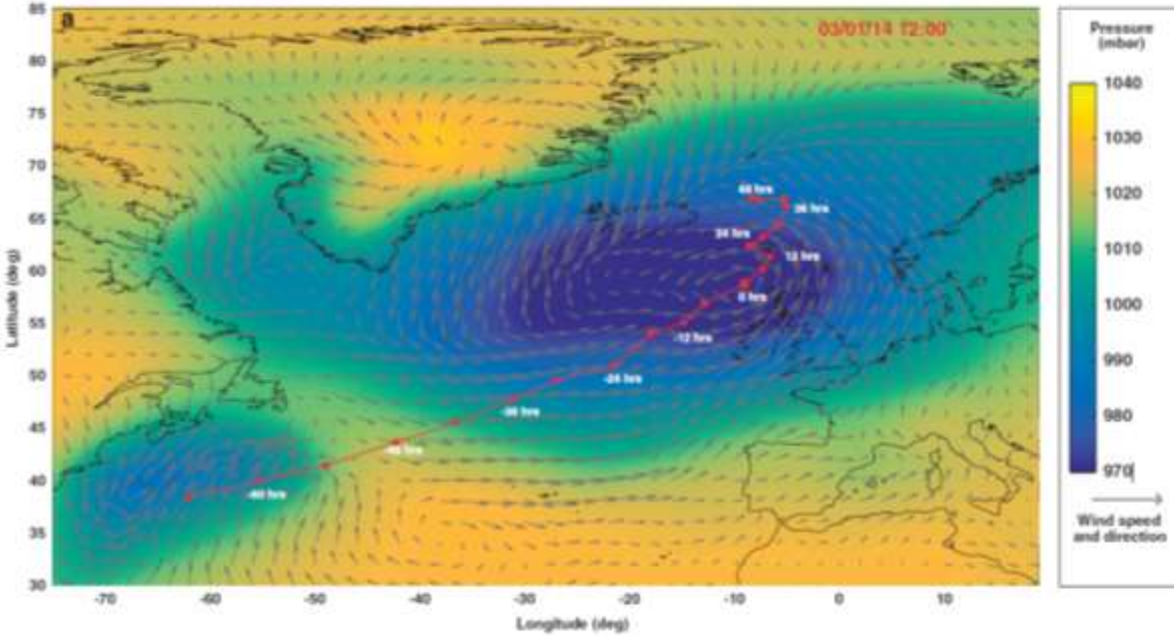
The Bristol Channel is exposed to large waves from the North Atlantic

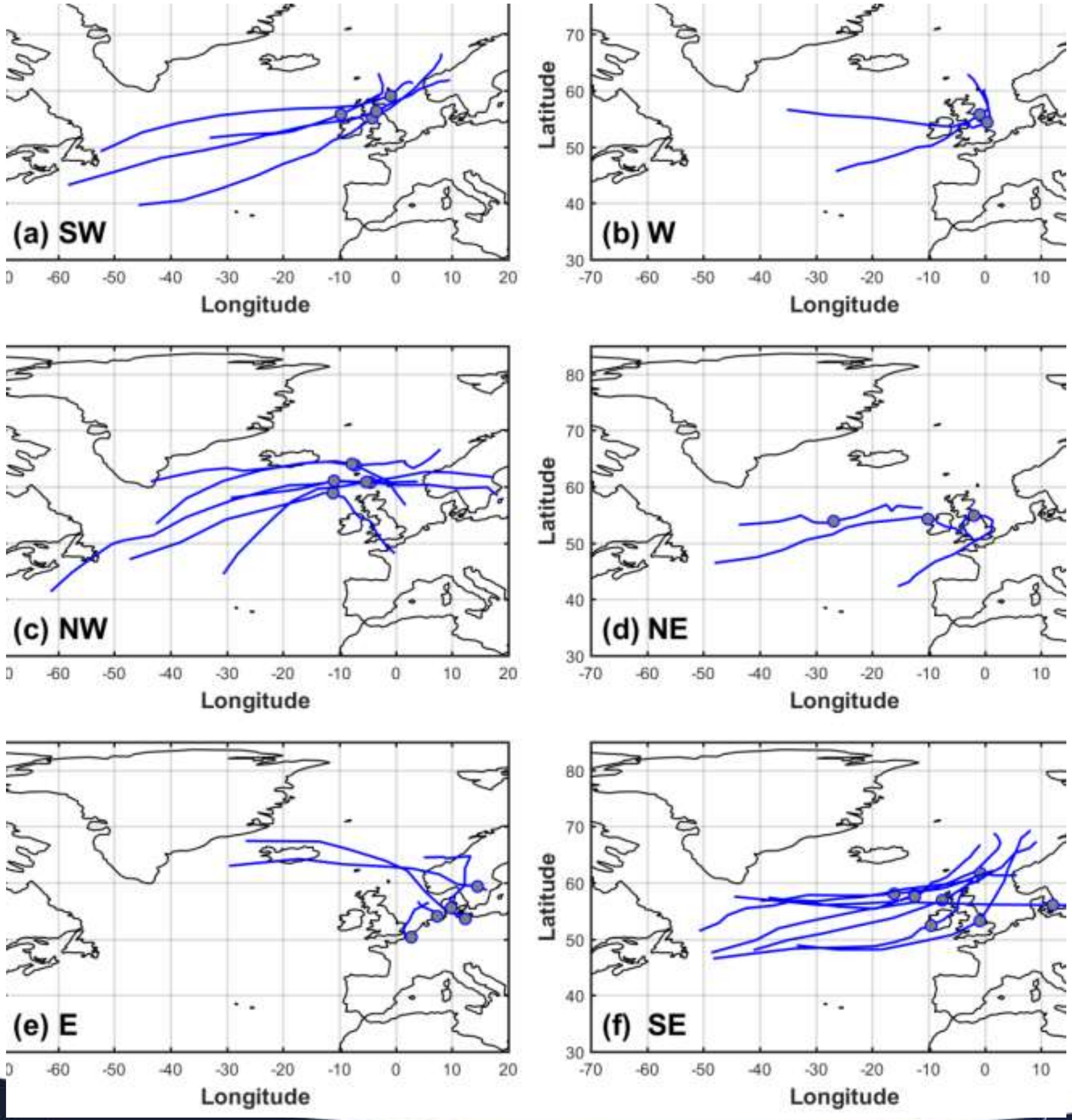
SurgeWatch database

Haigh et al. (2016)

96 storms identified 1915-2014 where surge level exceeded 1:5 y return period



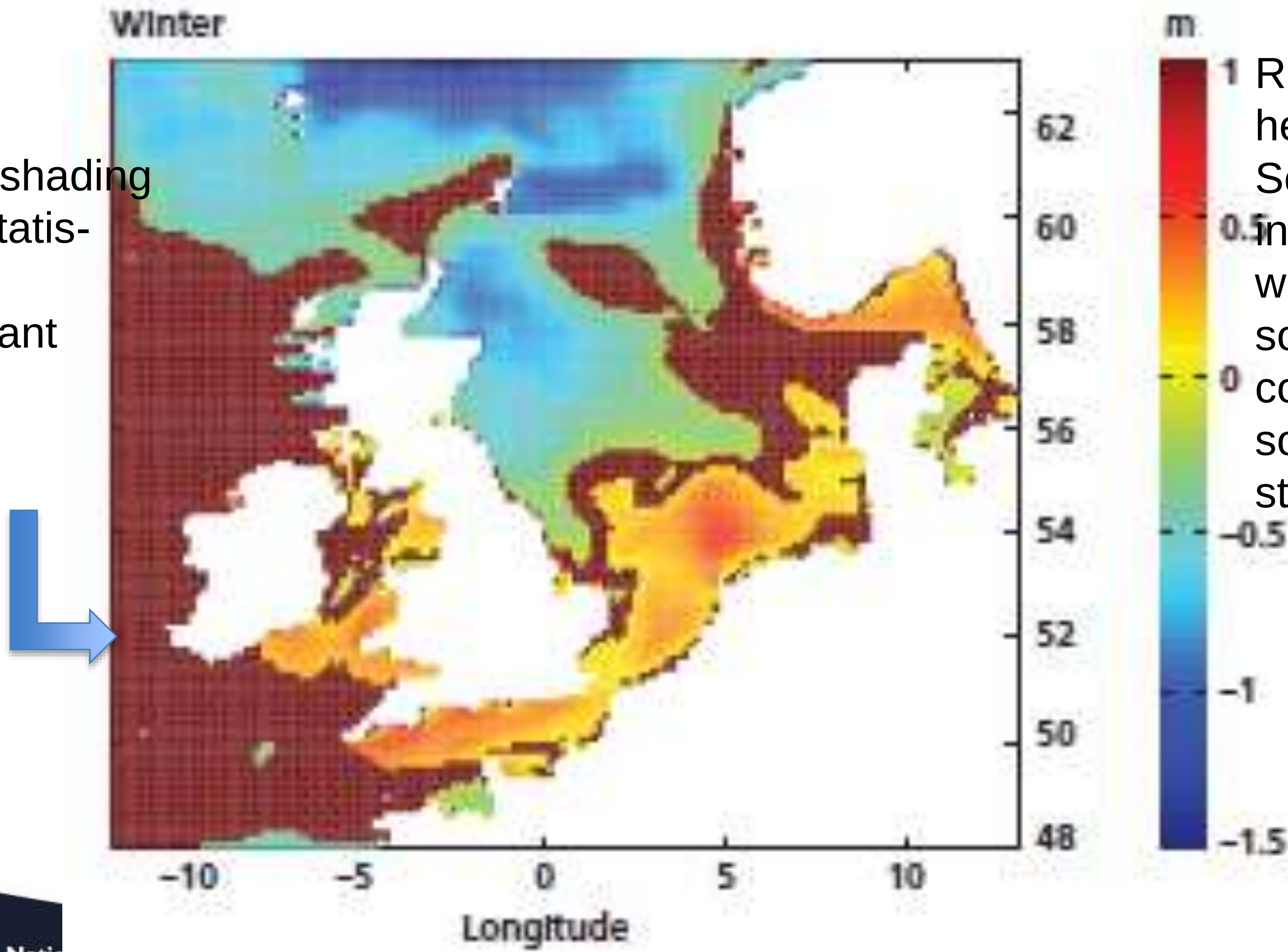




Santos et al. (2017) identified 6 sea areas for waves

Projected changes in mean winter wave height in UKCP09 (CMIP3), Wolf et al (2015)

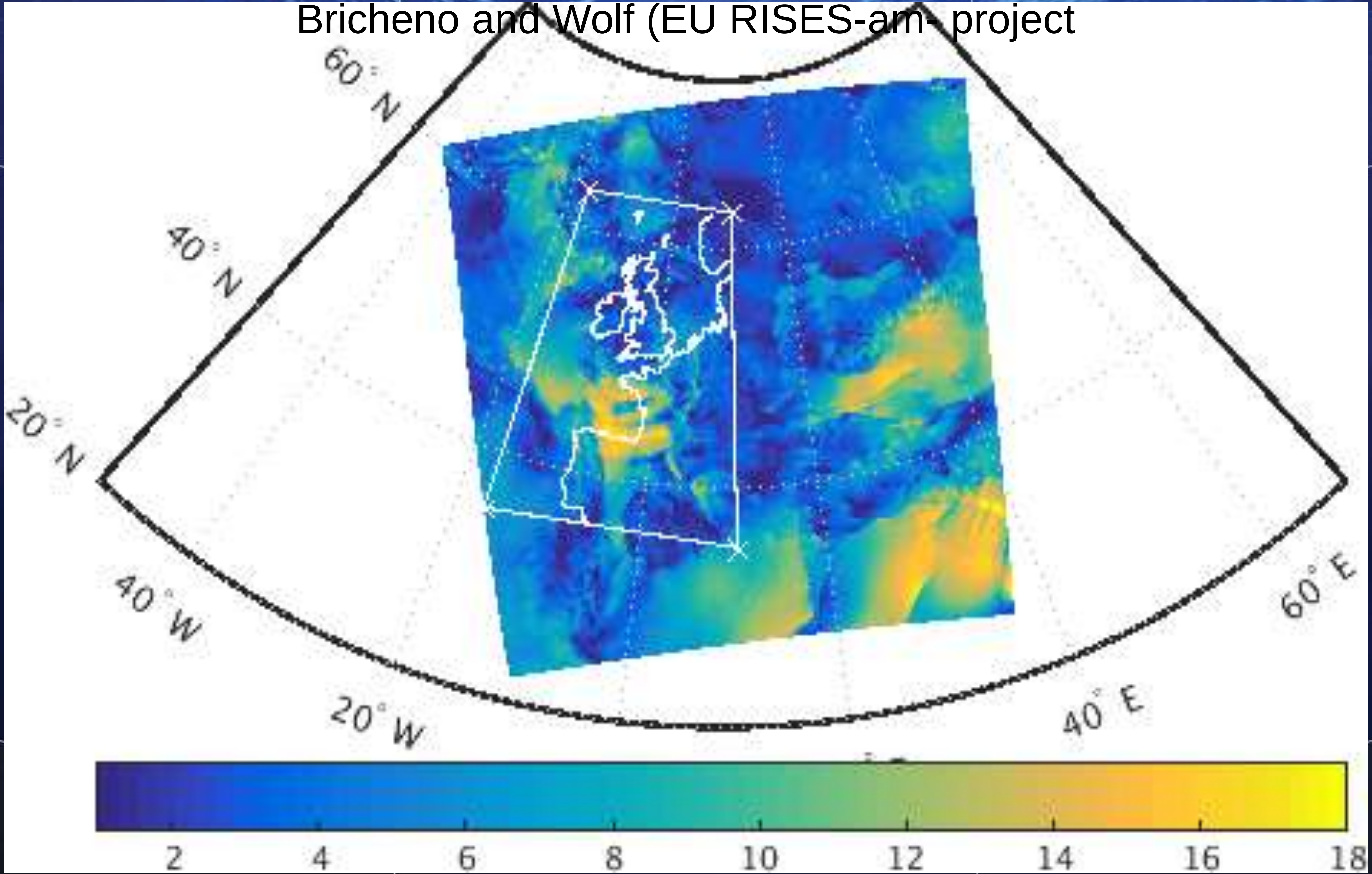
Brown shading = not statis-tically significant



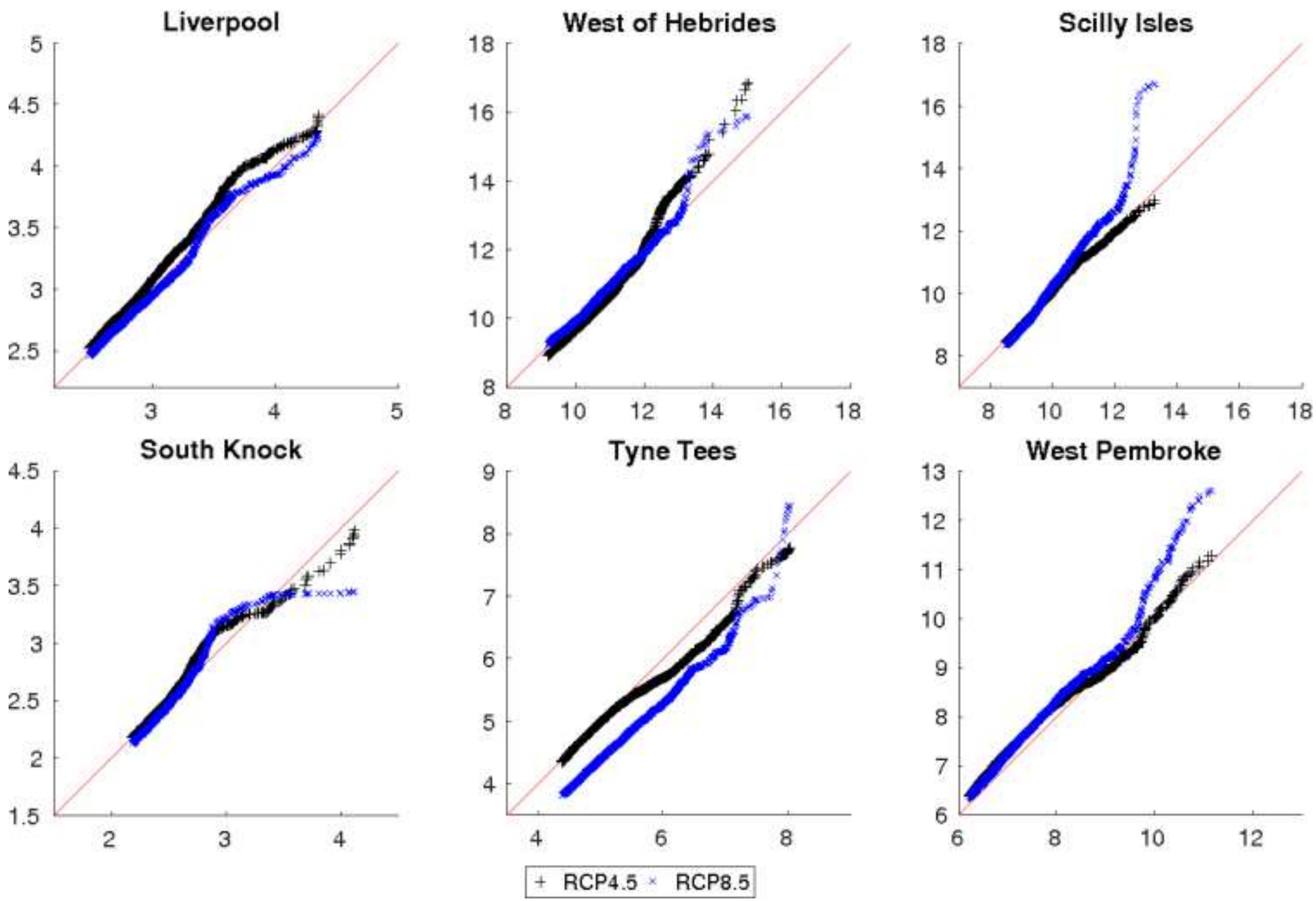
Reduced wave height north of Scotland, increase in wave height to south – consistent with southerly shift of storm tracks

High resolution climate model winds drive a local nested wave model to focus on NW Europe

Bricheno and Wolf (EU RISES-am- project

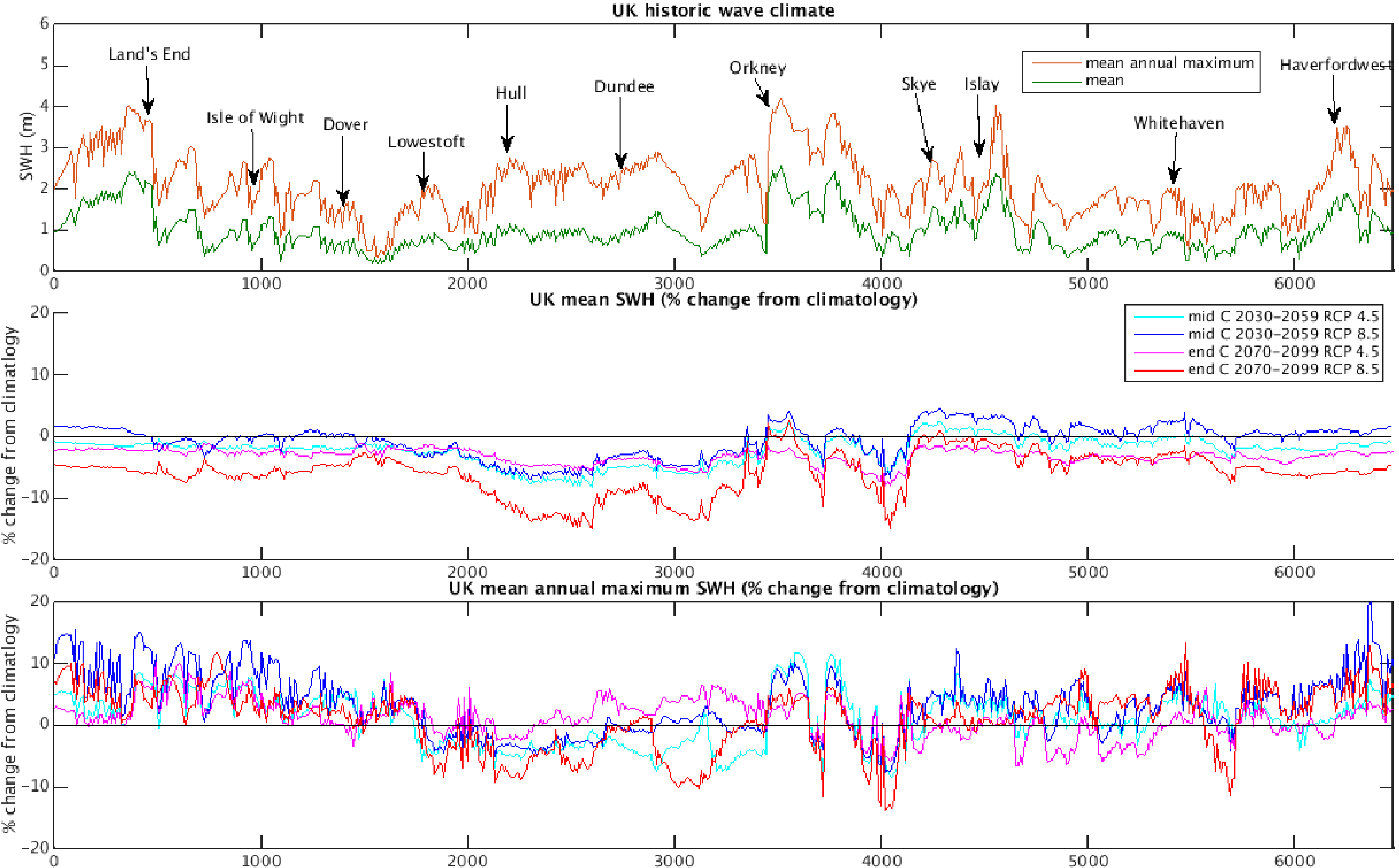


Changing extreme waves



Quantile-Quantile plots of the top 1% of significant wave height for six sites. By plotting the historic (x-axis) against 2 futures (y-axis) we can see divergence where the extreme wave climate changes in future.

Coastal projections - UK



30th January 1607

- At approximately 0900 on 30 January 1607, the lowlands surrounding the Bristol Channel suffered possibly the worst coastal flooding on record. The flood waters caused extensive damage to Bristol and many surrounding villages on the Somerset levels as well as Barnstaple in North Devon. Reports from parish registers and contemporary pamphlets also detail the devastation caused to the Gwent levels on the north side of the Bristol Channel.
- There has been some discussion about the possibility of a tsunami (Timewatch 2005; Disney 2005; Bryant and Haslett 2002). One contemporary report suggests the flooding came out of the blue during calm weather.
- However areas on the opposite side of the country flooded on the same day and several other sources suggest it was stormy, with John Stow (in 1631) noting that a westerly wind blew for 16 hours (he was also aware that it was a spring tide).
- This was most likely a storm surge on top of a spring tide as analysed by Horsburgh and Horritt (Weather, 2006)

Thanks for your attention