Proudman Oceanographic Laboratory
NATURAL ENVIRONMENT RESEARCH COUNCIL

Climate change effects on waves in UK waters

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Overview

- Definition of wave climate
- What can and can’t be learned from models
- What is storminess?
- Some results
- Effect of climate change via SLR and storminess on coastal wave climate and impacts (over to you Terry!)
- Conclusions

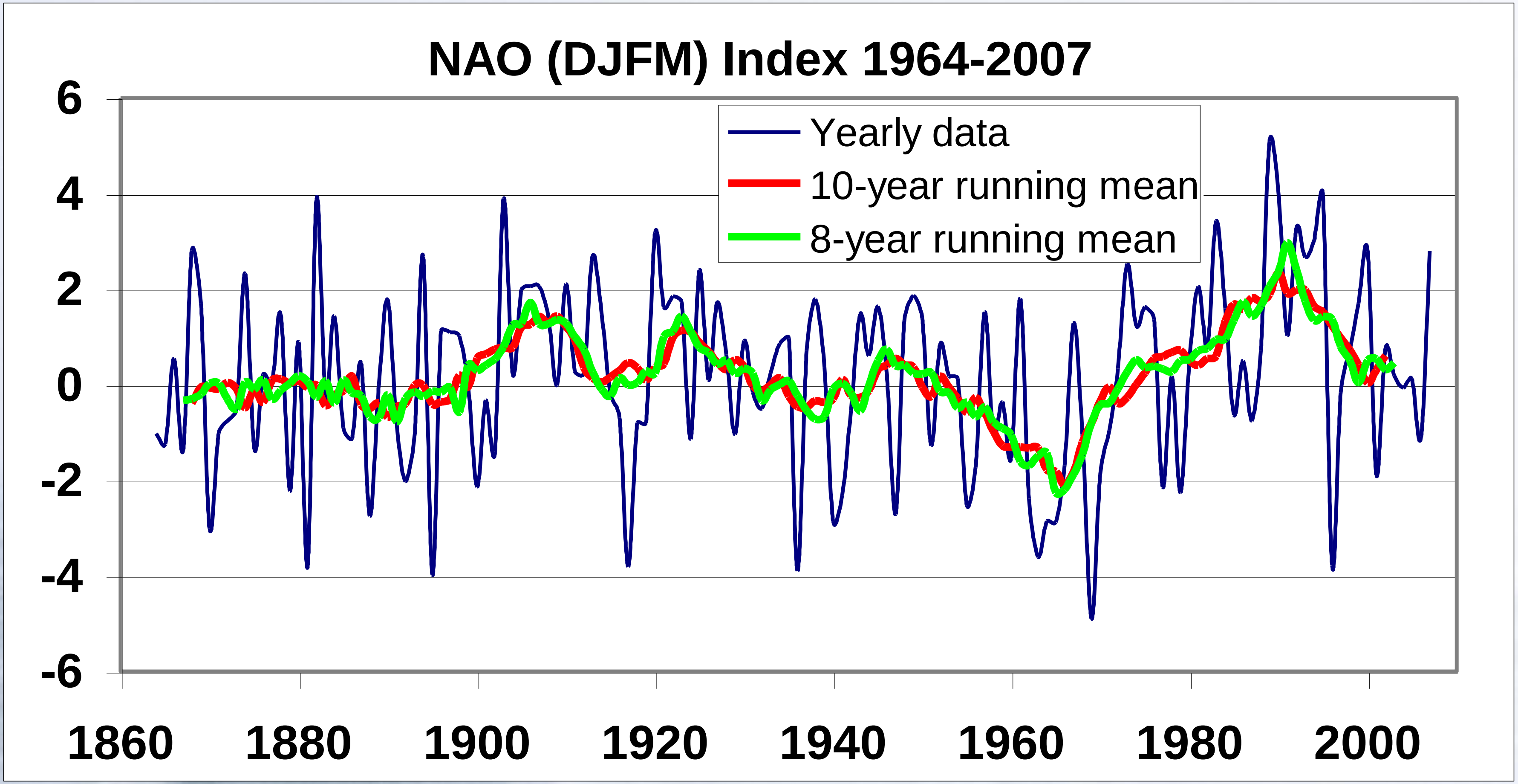
What is wave climate?

- Wave climate is usually described by the probability of occurrence of a range of wave parameters especially height, period and direction, but also others e.g. frequency bandwidth
- The wave climate can be considered as consisting of three parts: the long term mean climate, the annual or seasonal cycle and non-seasonal variability on both intra-annual and inter-annual time-scales.
- In UK waters, wave climate is strongly seasonal with mean wave heights peaking around January, but with a high risk of both high monthly mean wave heights and extreme wave heights throughout autumn and winter (October to March). There is also high inter-annual variability in monthly mean wave heights.

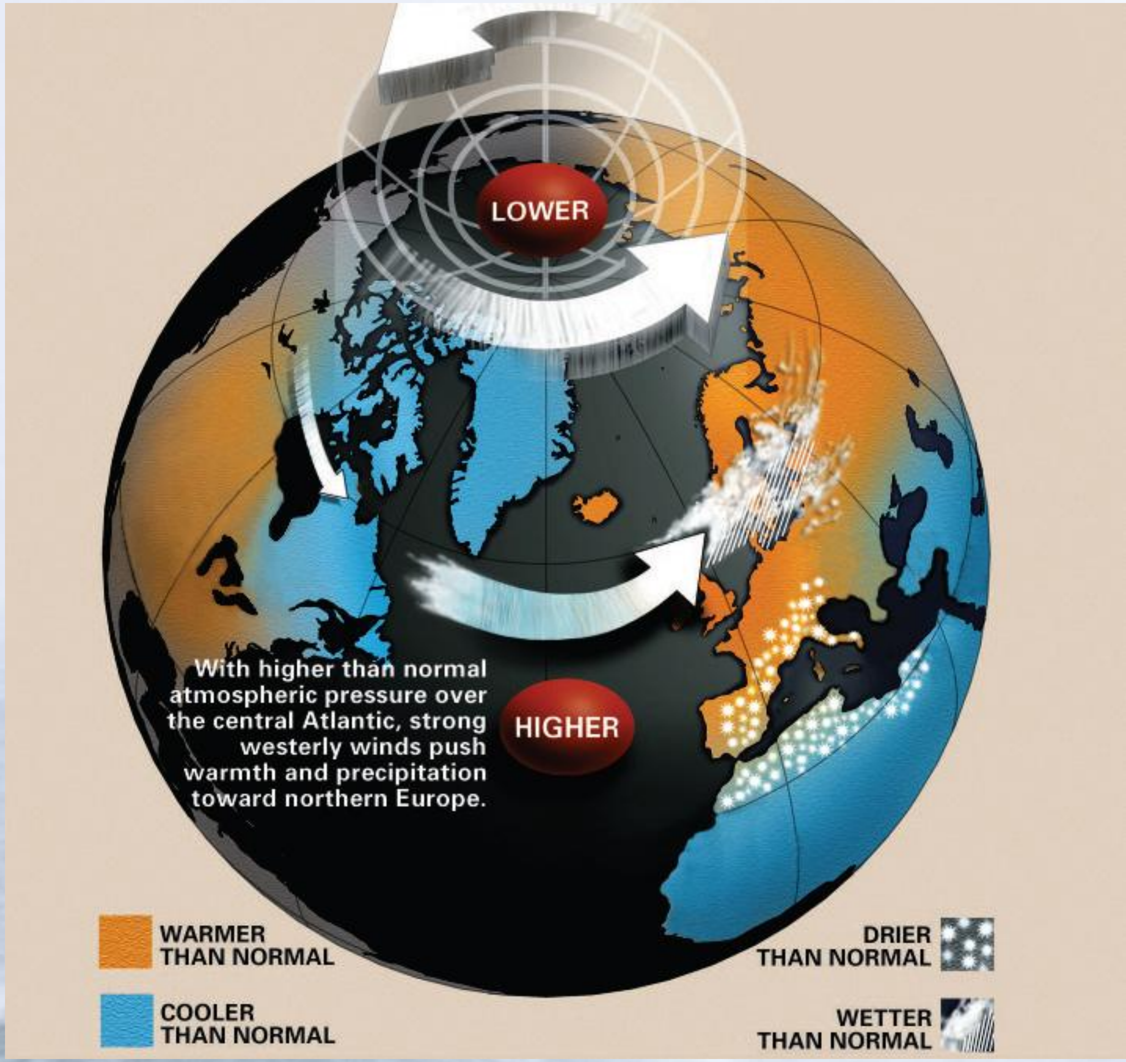
Summary of changes and trends in wave height in UK waters (IACMST 2004)

- Wave data from ships and buoys indicate that the mean winter wave height in the northeast Atlantic increased significantly between the 1960s and 1980s. Satellite data confirm that this increase continued into the early 1990s.
- In the northern North Sea, there was an upward trend of about 5-10% (0.2-0.3m) in mean significant wave height (Hs) for January–March for the period 1973-1995, but a decrease thereafter.
- In the central North Sea, the trend for January–March was upwards until 1993/94, with a decrease thereafter. The October–December Hs peaked around 1982/83 and 1983/84, with a similar high value in 1999/2000.
- In the southern North Sea, there is no discernible trend in Hs for January–March and only a slight indication of a downward trend in Hs for October–December from 1980/81.
- At Sevenstones LV, off Land's End, the acceptable value is an increase of 0.02 m/yr in mean wave height over a period of about 25 years. This trend seems to have persisted into the early 1990s at least, although recent winters have suggested a levelling off.

Decadal variability and the NAO



POSITIVE PHASE OF NAO AND NAM (from IPCC AR4)



NAO = North Atlantic Oscillation

NAM = Northern Annular Mode

Both modes are associated with strengthening of westerly winds

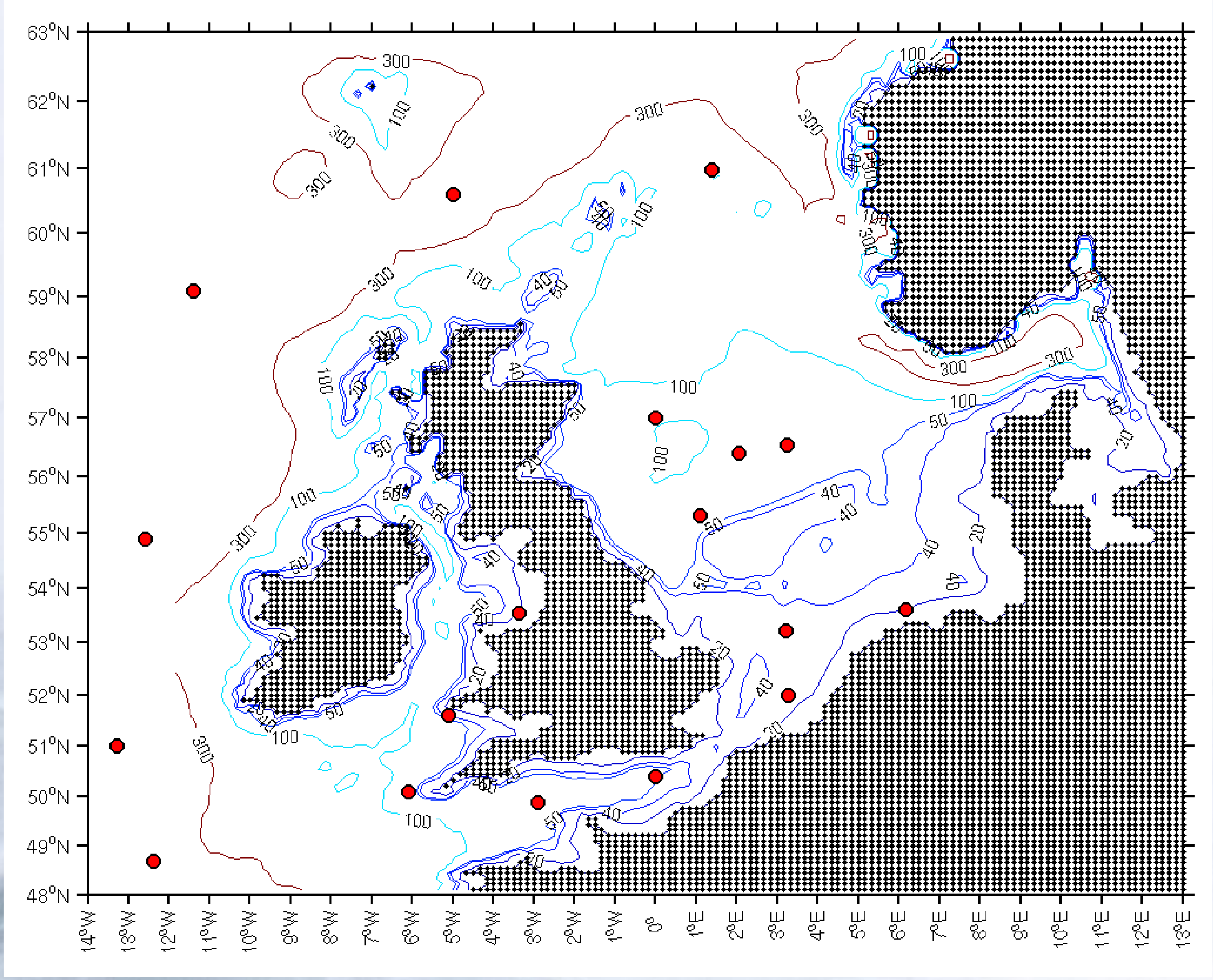
What can we learn from models (and what can't we)?

- When models can be validated against observed data we can use them to help understand the relative importance of different processes
- Model reanalyses e.g. ERA40, going back over decades, are very useful to give a consistent long-term reconstruction
- Climate models reproduce some aspects of decadal variability quite well but the recent positive phase of the NAO was larger than the variability of the model system (Tim Osborn)

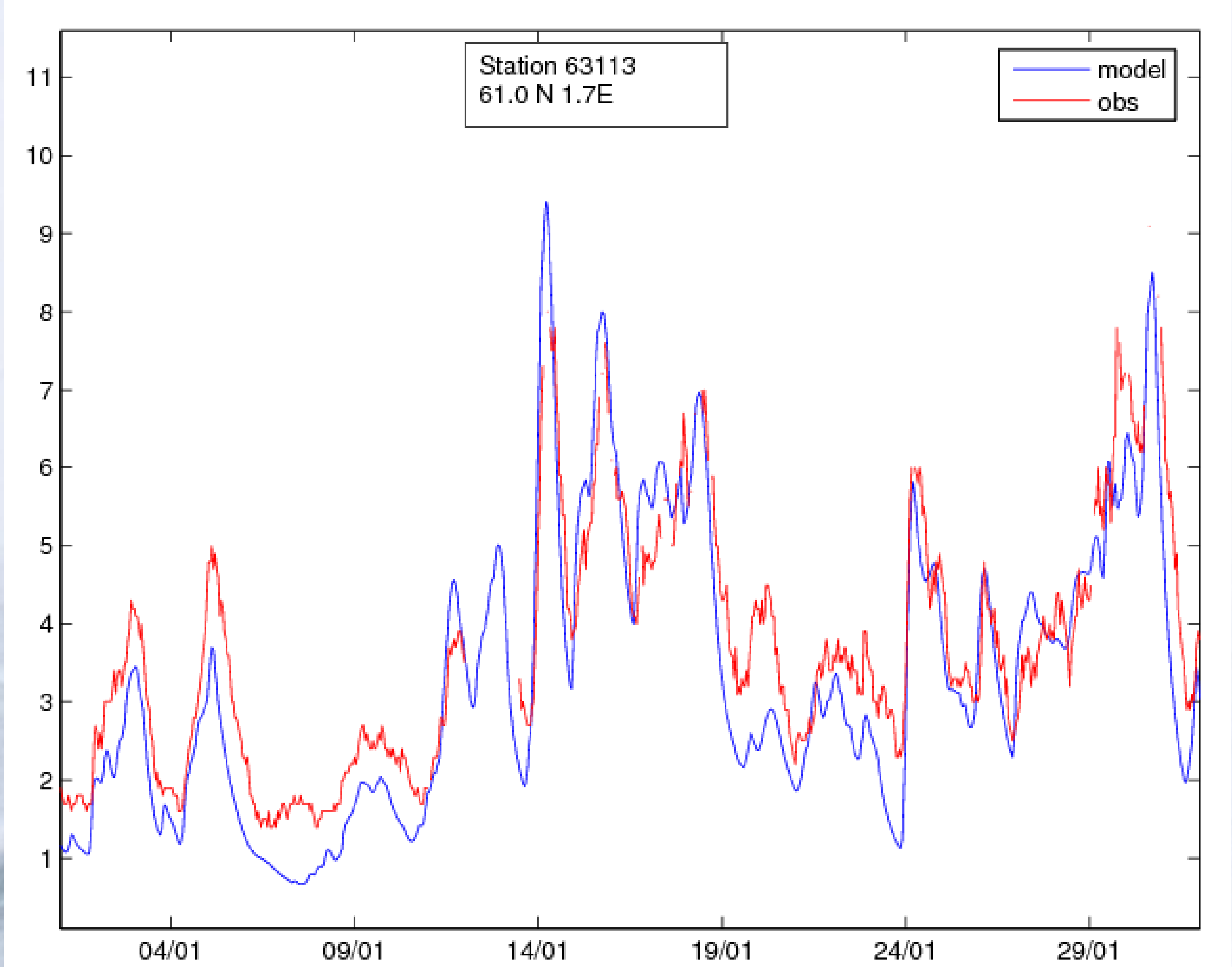
BUT

- Model resolution is limited e.g. global models cannot resolve storms properly
- Models omit processes we don't know about
- Remember GIGO
- We may learn more when models don't work!

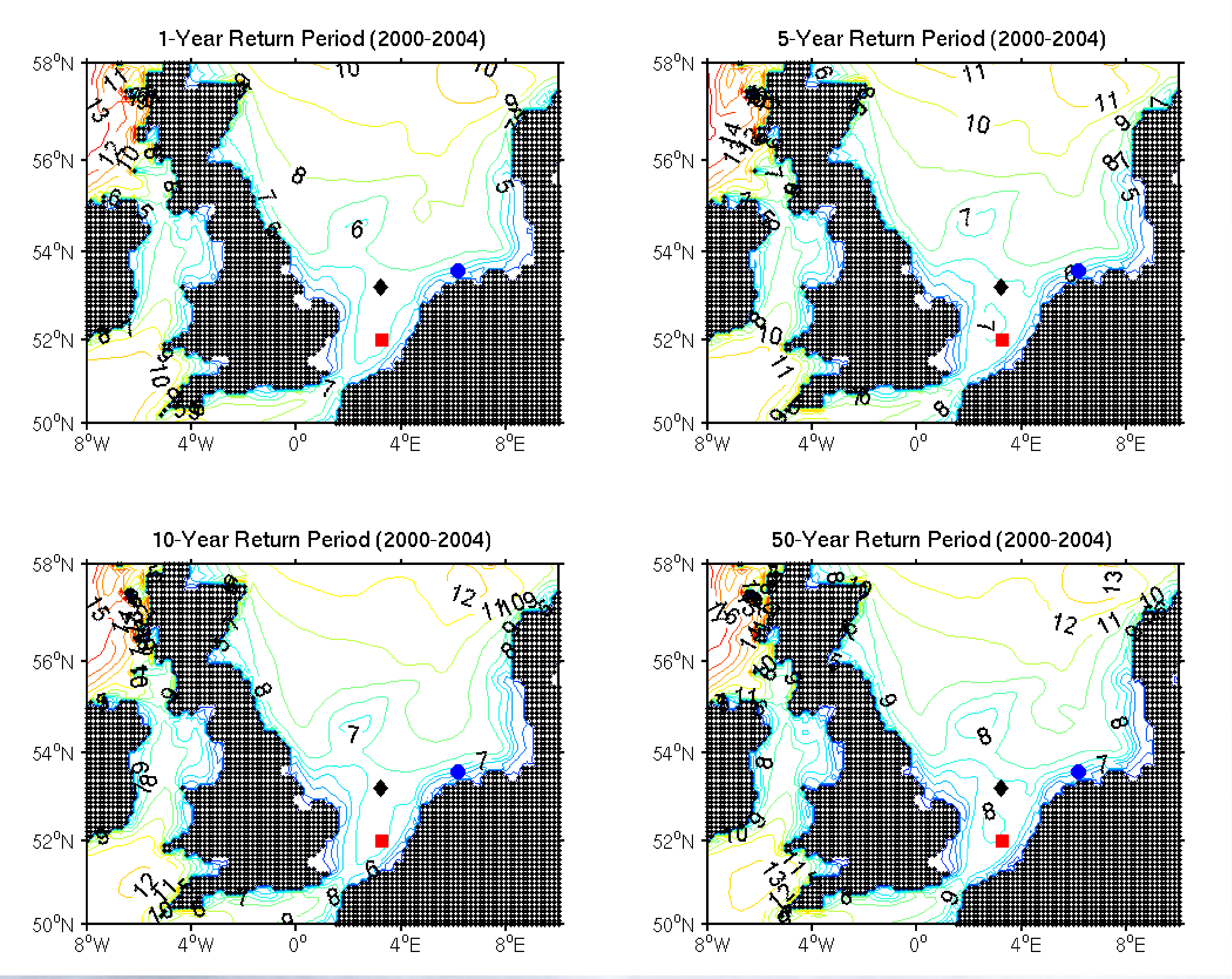
CS3 (12km) model wave climate 2000-2004 – Met Office mesoscale model forcing



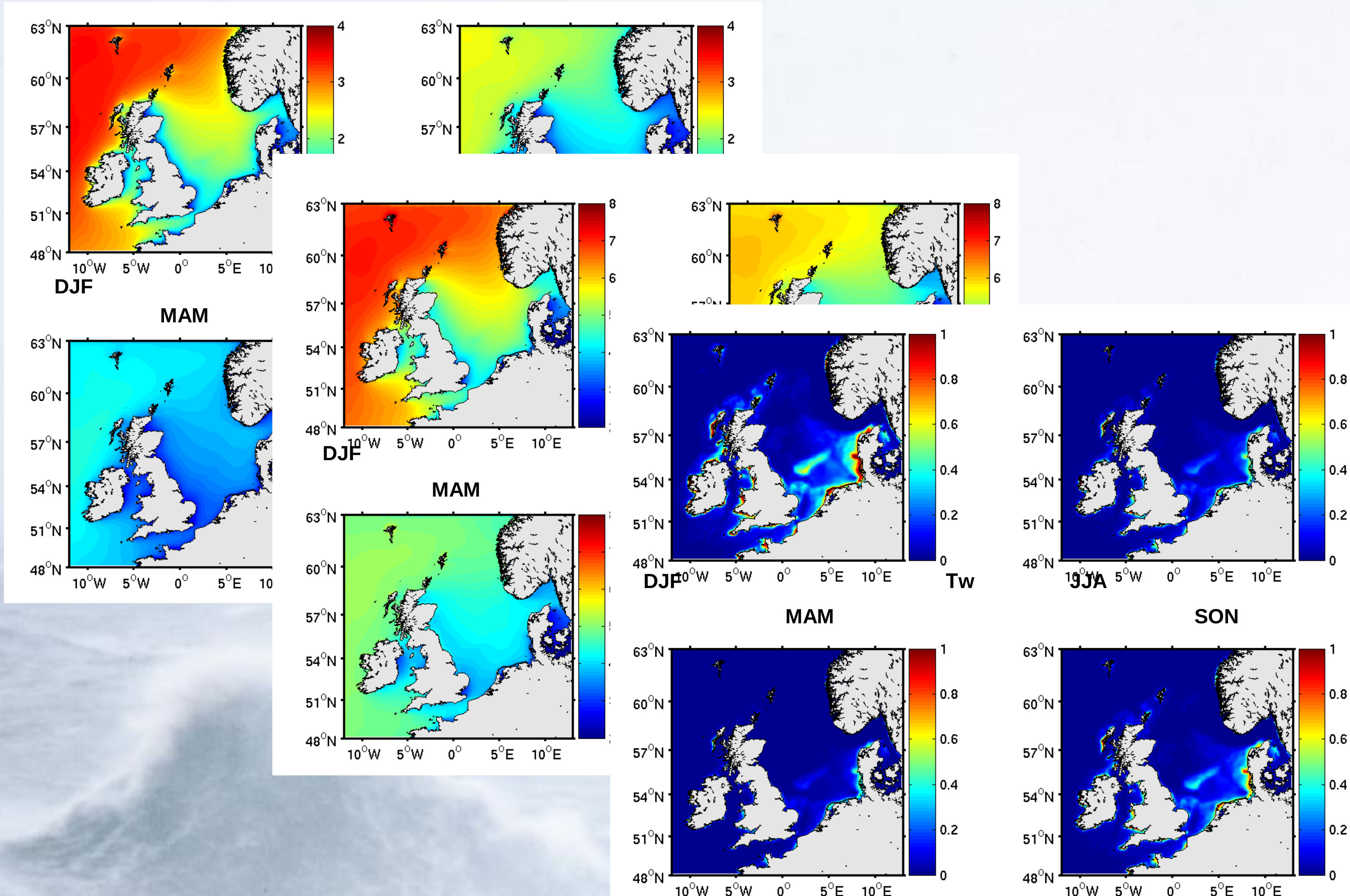
Validation – northern North Sea, Jan 2003



Extreme waves



Seasonal variation of wave height, period and bottom stress



Storminess

- Storminess may be defined as the number of wind events exceeding a certain threshold e.g. gale force
- Proxies need to be used to derive long time series e.g. pressure and sea level
- Models of future climate suggest there may be fewer but more intense storms, with storm tracks moving poleward – is this increased storminess?
- What is the role of decadal cycles – just a red herring?
- Recent positive phase of NAO happened to coincide with most intensive observations ever (including satellite data), also increasing concern about global warming
- We really need to better understand the natural variability of the ocean-atmosphere system

Future changes in the frequency of winter mid-latitude storms (from Macdonald)

Reference	Model	Experiments	NH Change	SH Change
Carnell and Senior 1998	HadCM2 N48	IS95a 3x30y	Fewer	
Geng and Sugi 2003	JMA T106	20y OBS 2050s	Fewer Poleward and eastward	Fewer
Fyfe 2003	CCCma	3xIS92a 500y Ctrl		Sub-Antarctic 30% fewer
La[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Watterson 2006	CSIRO Mk2 R21, Mk3 T63	30y A2	Fewer	Fewer
Lambert and Fyfe 2006	IPCC 4AR GCMs	20y	Fewer No shift	Fewer No shift
Bengtsson et al. 2006	ECHAM5 OM T63	3x30y A1B	No change Poleward shift	No change Poleward shift

Summary: There are fewer mid-latitude storms in winter in both hemispheres in the future simulations

Future changes in the frequency of intense Northern Hemisphere winter mid-latitude storms (from Macdonald)

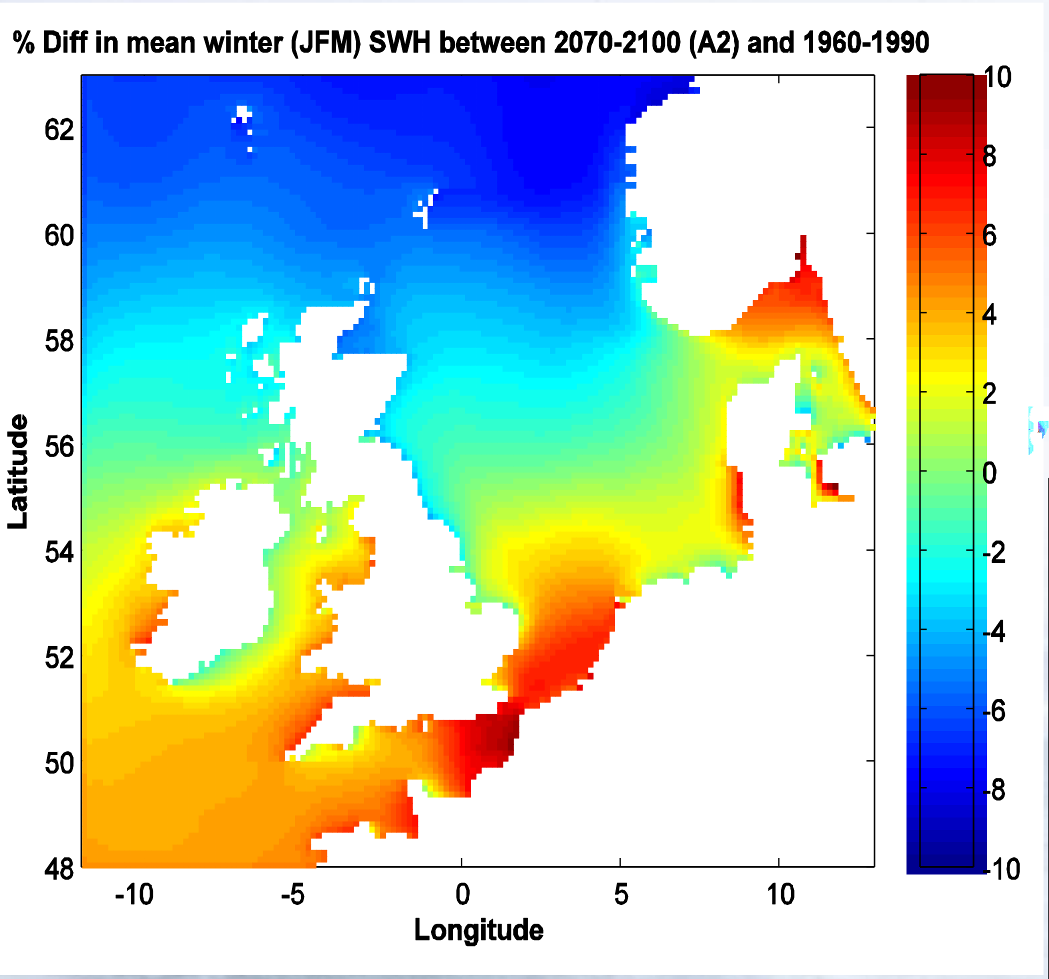
Reference	Model	Experiment	Intensity measure	Change in frequency of intense cyclones
Carnell and Senior 1998	HadCM2 N48	IS95a 3x30y	Central MSL pressure	More intense
Geng and Sugi 2003	JMA T106	20y OBS, 2050s	Central MSL pressure gradient	More intense
Lambert 2004	CGCM1	1%	Central MSL	More intense
2006	Mk2 R21, Mk3 T63	A2	measures & precipitation	dynamical intensity, more precipitation
Lambert and Fyfe 2006	IPCC 4AR GCMs	20y	Central MSL pressure	More intense
Bengtsson et al. 2006	ECHAM 5 OM T63	3x30y A1B	Central Relative vorticity	Fewer weak

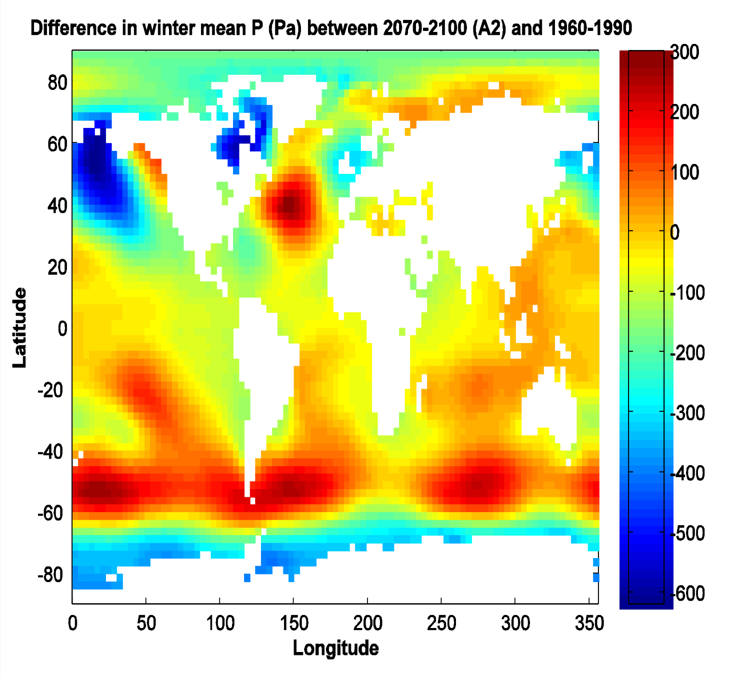
Summary: There is some evidence of an increase in the frequency of the deepest storms in the future simulations

Results – ongoing projects

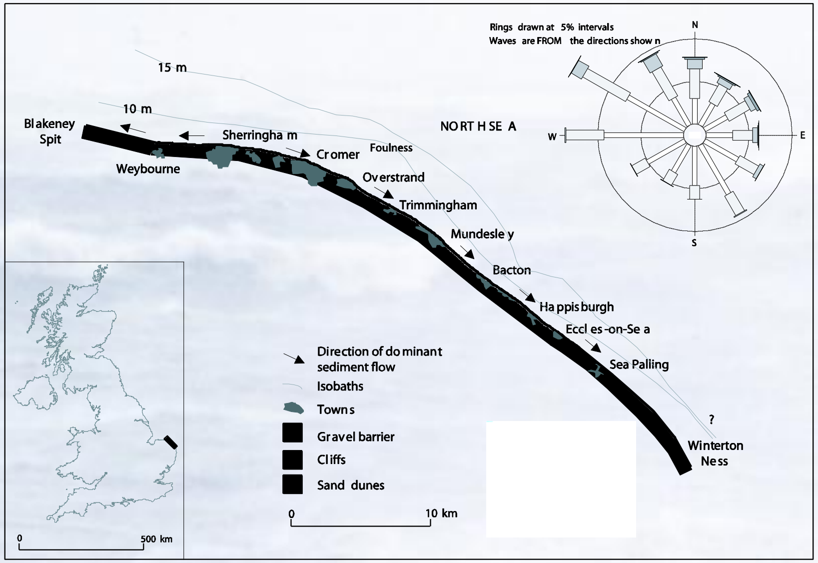
- Tyndall wave climate modelling for Coastal Simulator
  - 30y time slices, 1960-1990, 2070-2100
  - Nested wave models (Atlantic to CS3), downscaling from OGCM to RCM
  - 3 scenarios from UKCIP02 (A2 and B2) and UKCIP08 (ensemble extremes)
- COFEE (NERC FREE programme)
  - Surge and wave modelling of Liverpool Bay
  - Application to coastal evolution of the Sefton coast

Integrated Modelling For Coastal Impacts: The Tyndall Coastal Simulator





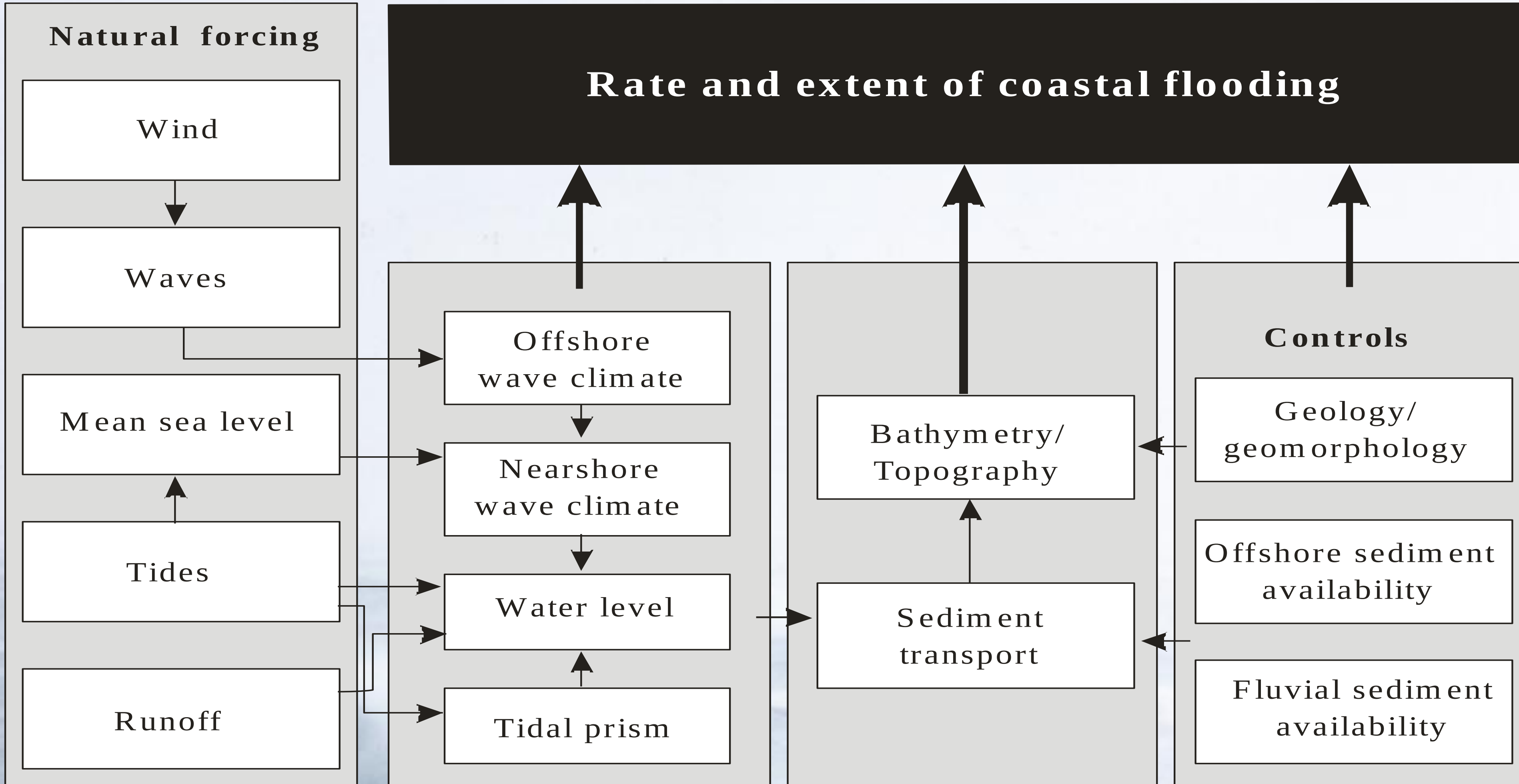
Morphological model area



CoFEE - Coastal Flooding by Extreme Events

- Aim – to assess present and future flood risk in a range of environments
- Study area – eastern Irish Sea/Liverpool Bay – cell 11a – Great Orme’s Head to Ribble Estuary, with particular focus on Sefton coast
- Extensive field data to calibrate, validate and verify predictions from numerical models (POLCOMS/WAM/SWAN)
- Personnel: PI Jon Williams (U Plym), Andy Plater (UoL), Alex Souza, Judith Wolf, Roger Proctor, Jenny Brown (POL), Graham Lymbery Sefton BC), Annie Worsley (Edge Hill)

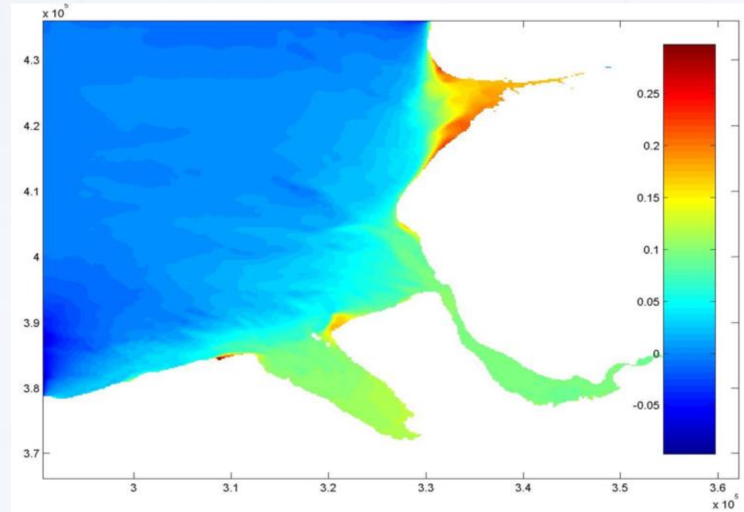
Overview of processes

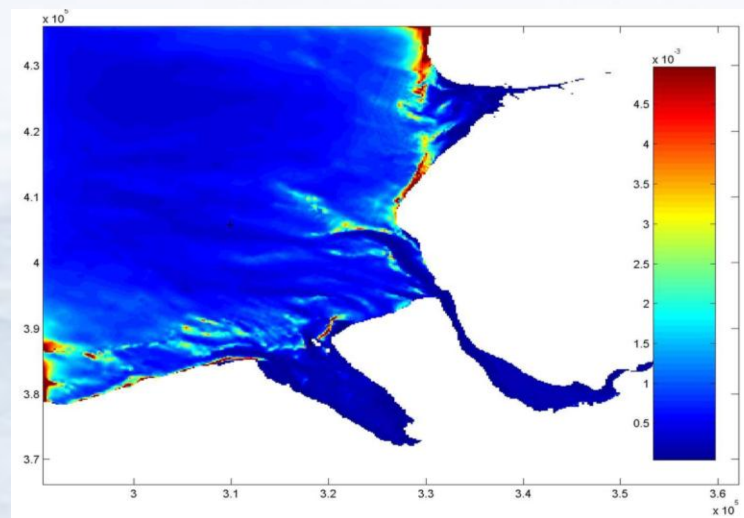


Flood risk and preliminary wave model results –20m/s NW wind

EA flood risk map

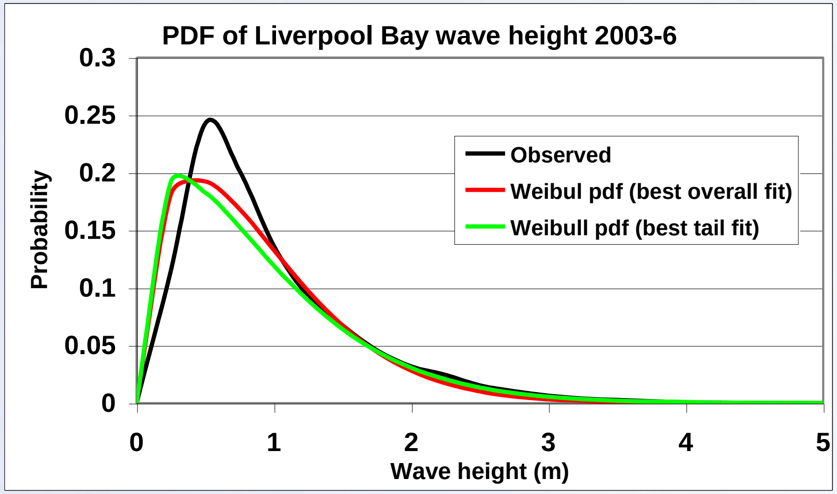
Wave setup

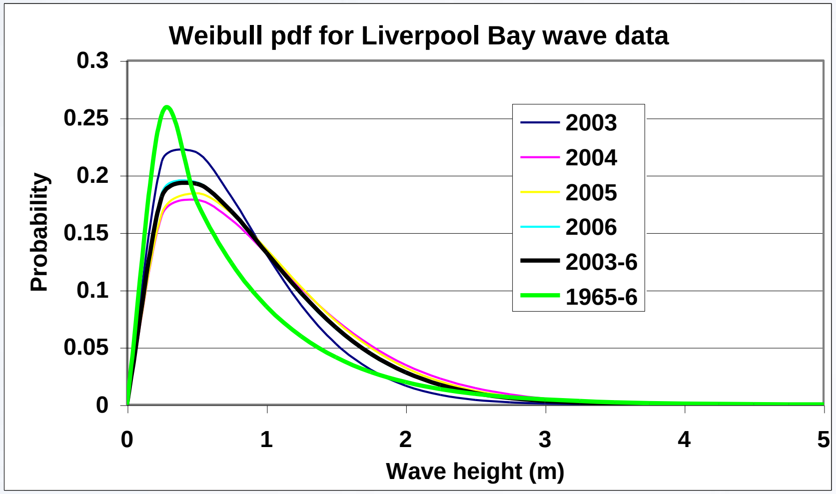


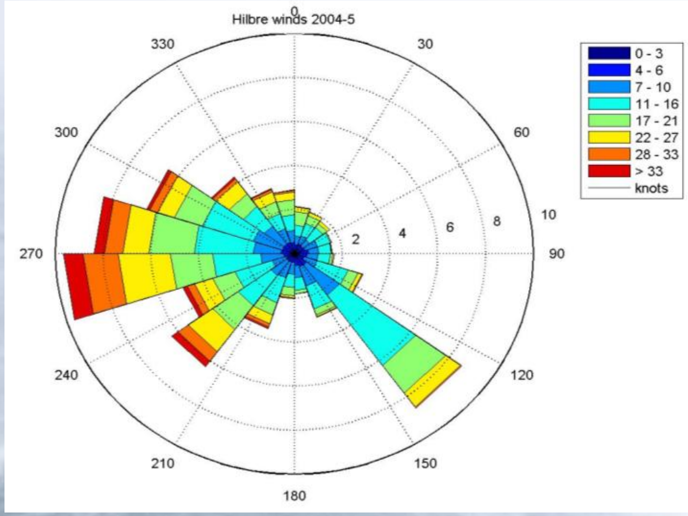


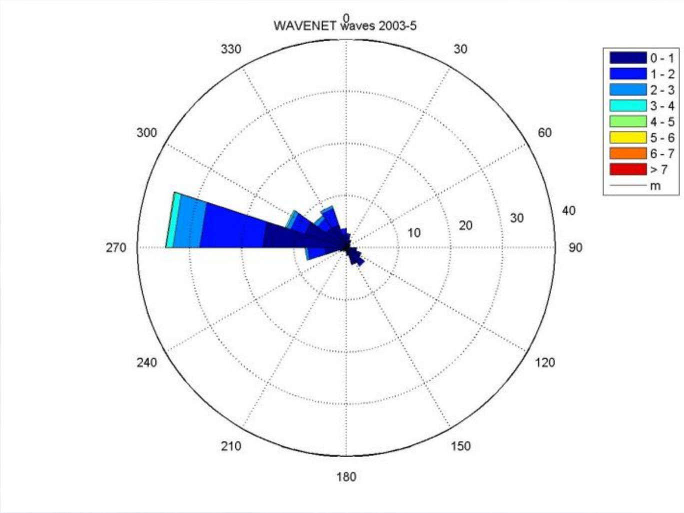
Bottom dissipation

Waves in Liverpool Bay





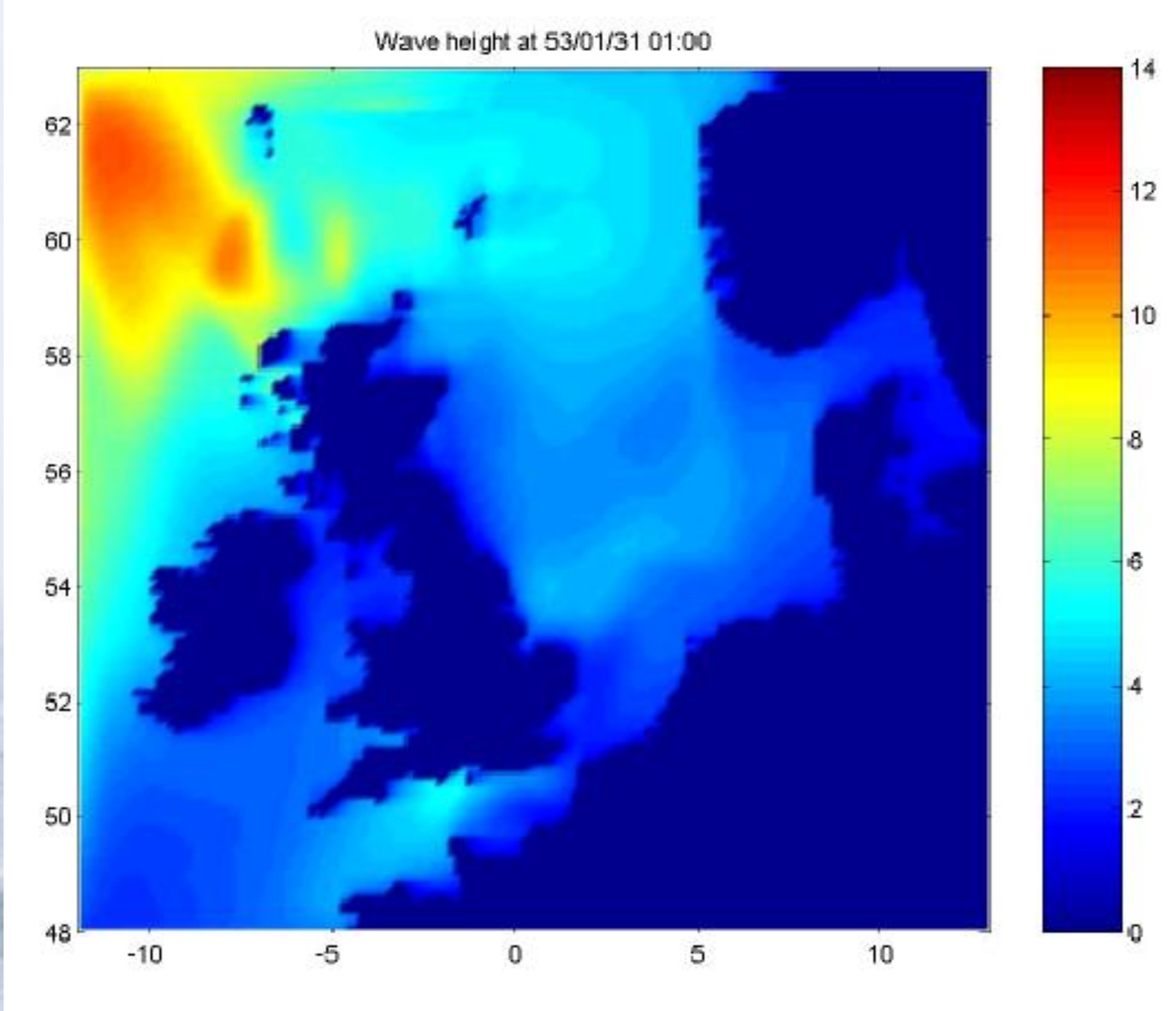




Conclusions

- Wave models are quite accurate in general, main limitation is accuracy of the wind forcing
- There is a lack of long-term wave observations, need to understand storm climate, interrannual variability
- Impacts of waves include coastal flooding and erosion – present-day ‘extreme’ events may become more commonplace, just due to sea level rise
- Future climate – still more questions than answers?

1953 storm waves



1953 storm surge – Sea Palling

Coastal erosion at Happisburgh