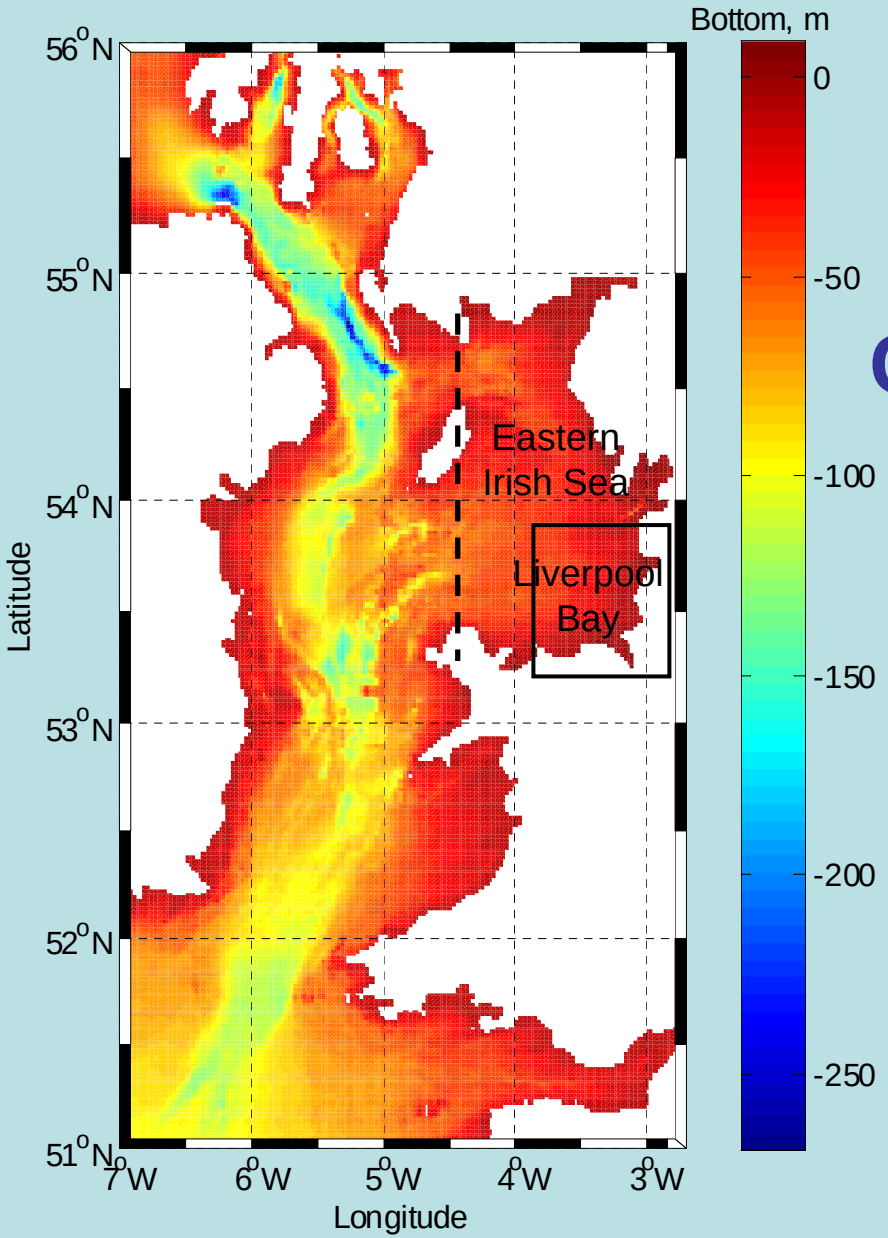


micore

Coupled tide-surge-wave modelling in extreme storm conditions

By Jenny Brown, Alex Souza & Judith Wolf

Proudman Oceanographic Laboratory
NATURAL ENVIRONMENT RESEARCH COUNCIL

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Presentation Outline

- Introduce the project and study area
- Modelling methods
- Show a past storm event used to validate the model setup
- Present the results from an 11year hindcast
- Discuss the detailed coupled Liverpool Bay modelling
- Suggested future climate
- Conclusions

The Project

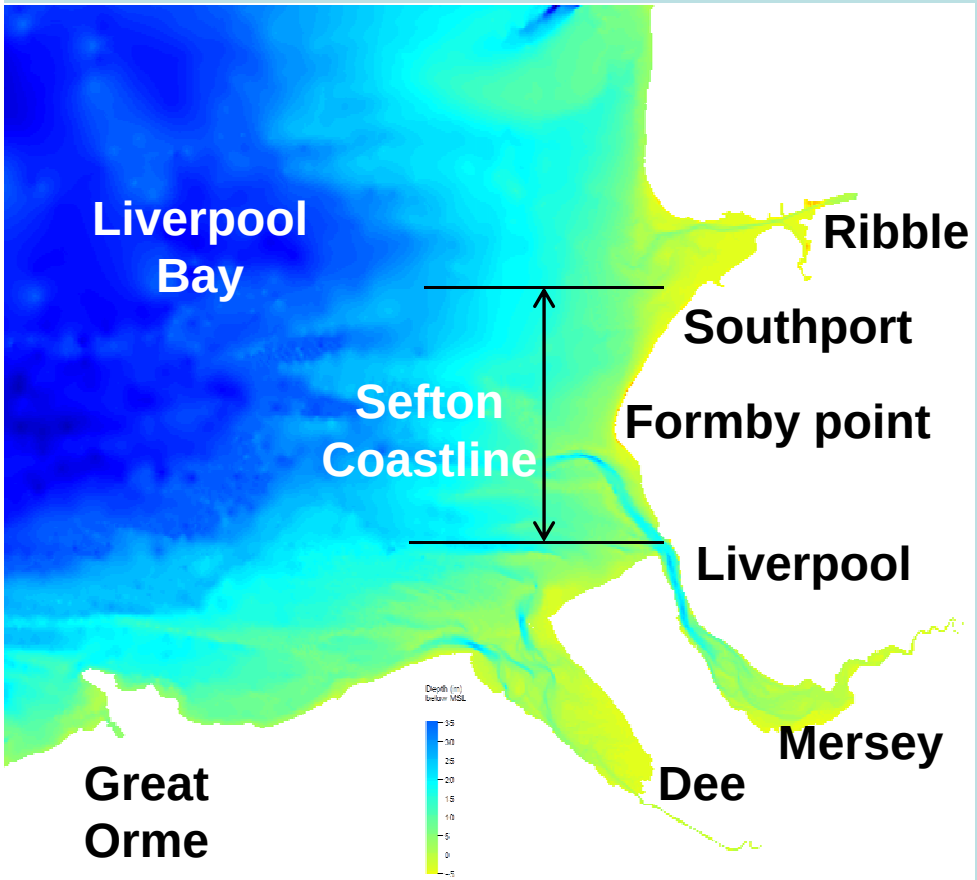
Investigate past, present and future flood risk and morphological change in response to extreme events

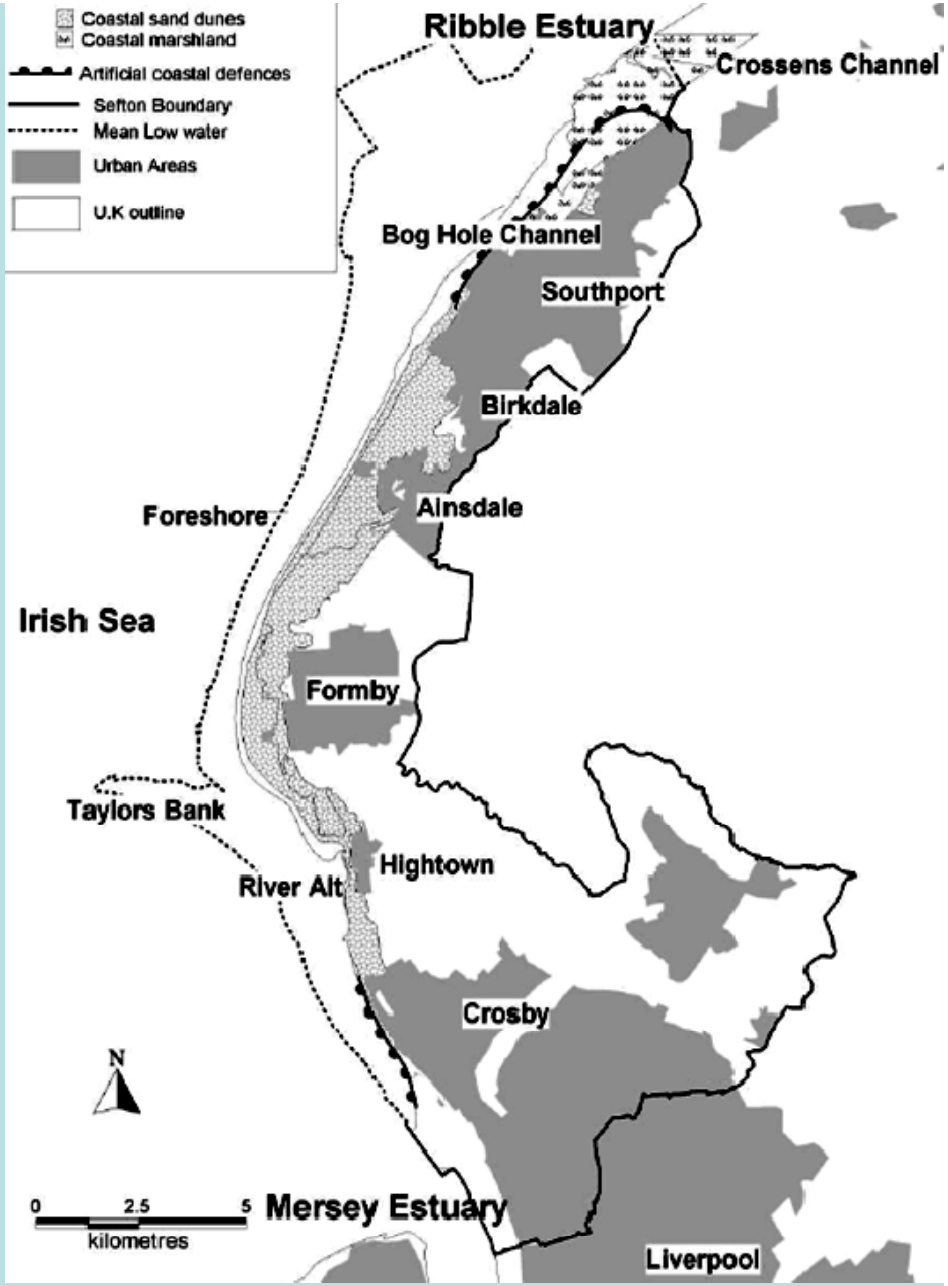
National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

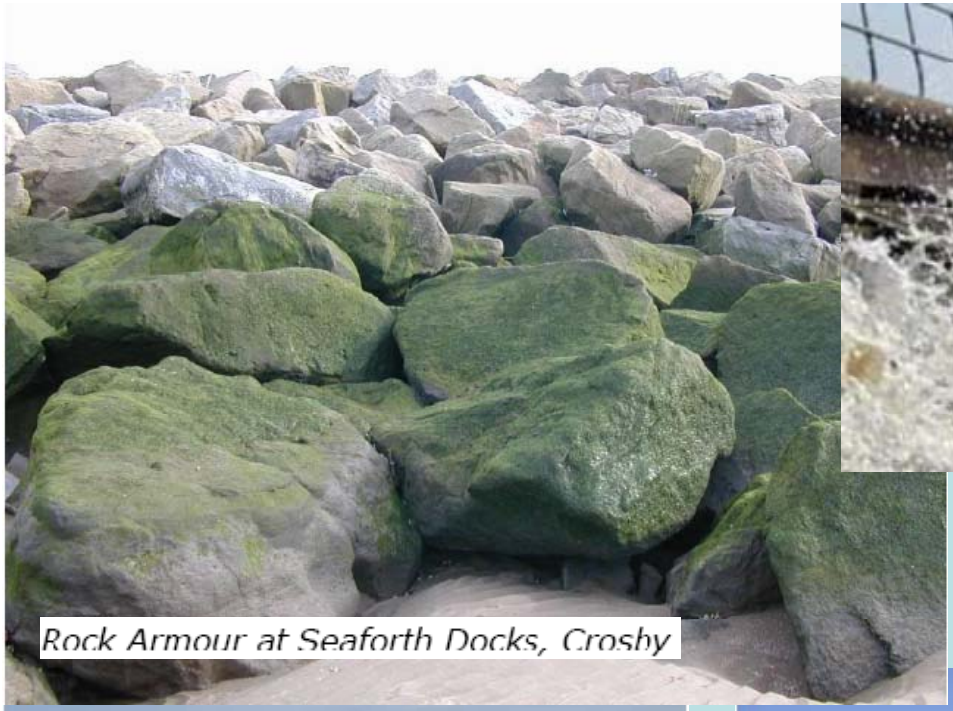
Modelling tide-surge-wave interaction during storms, provide accurate model data to predict coastal flooding and drive coastal evolution models

The Study Area:

Sefton Coast – representative of many different UK coastlines







Rock Armour at Seaforth Docks, Crosby

Sea Wall Southport

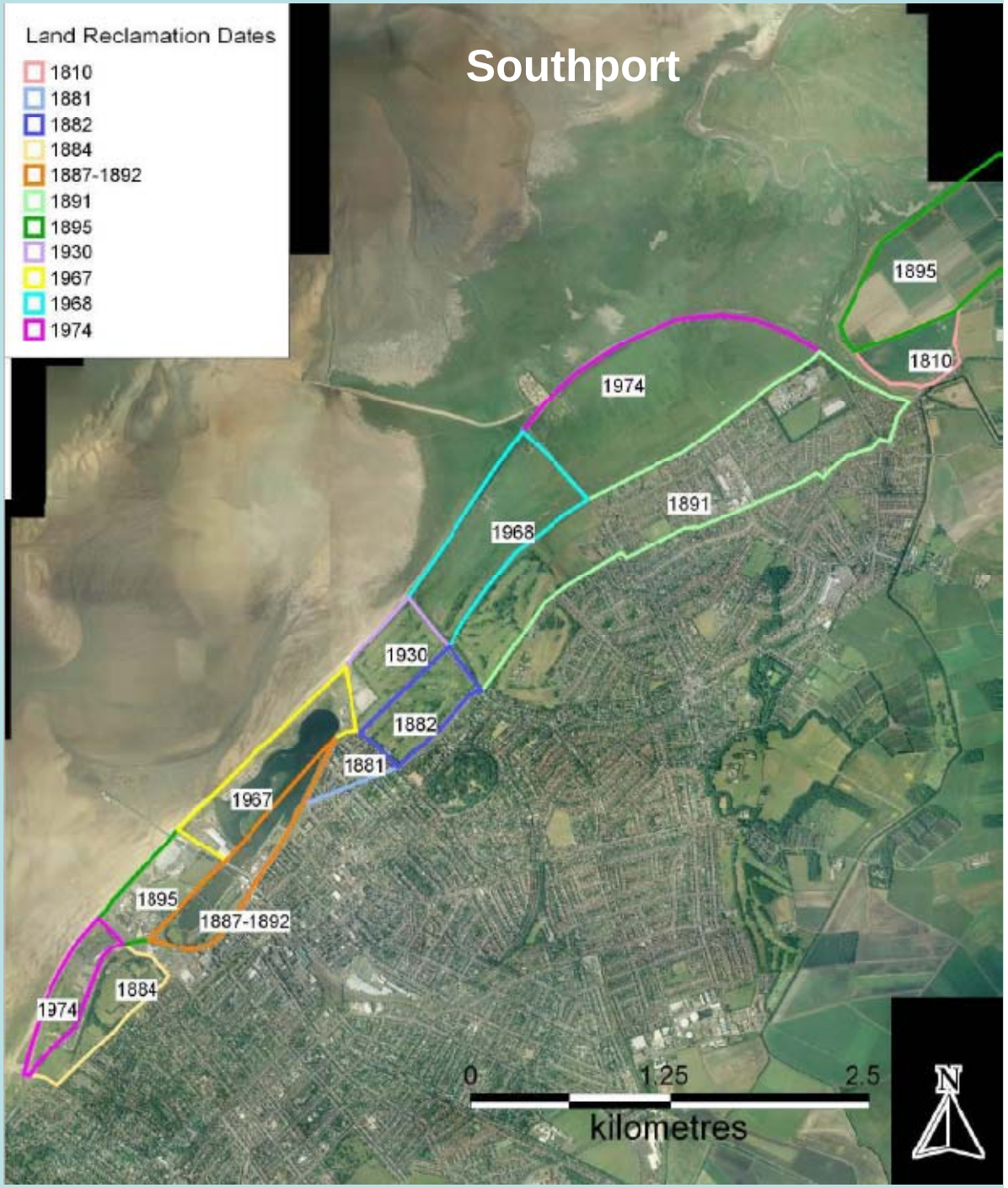
Rubble beach North of Crosby

The River Alt Training Wall

Roads susceptible to flooding

Sea wall completed 2002

Hard defences need to withstand present & future conditions



Saltmarsh at Fairways

Formby point

Largest dune system UK

Crosby

Formby storm 31st March – 1st April 2010

Natural defence – risk of erosion

Formby extreme high tide Feb 2010

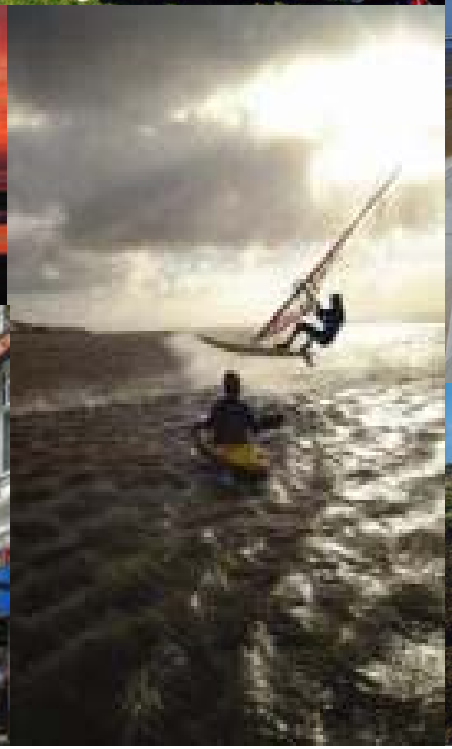
Provide Important Habitats



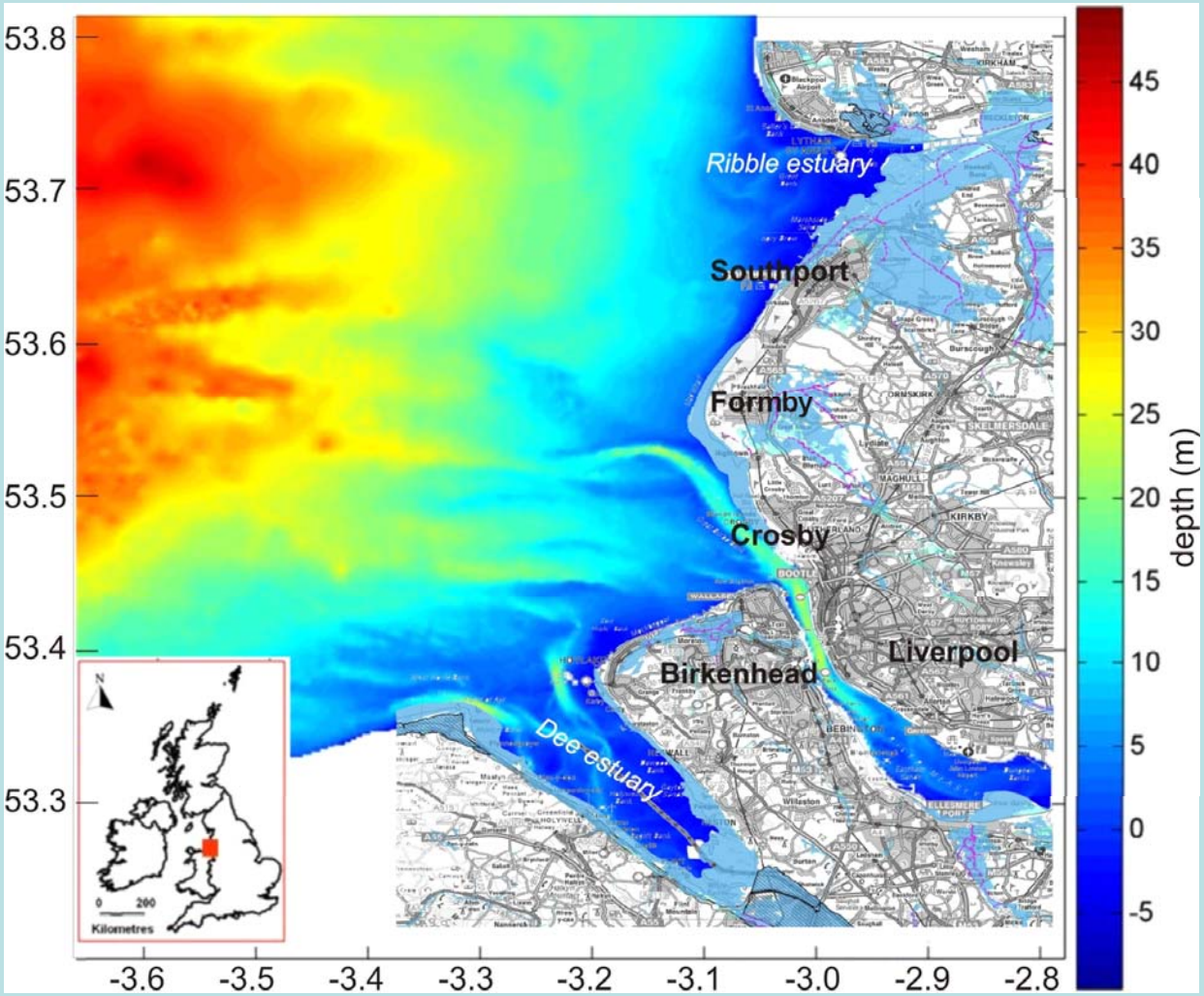





Economic Value



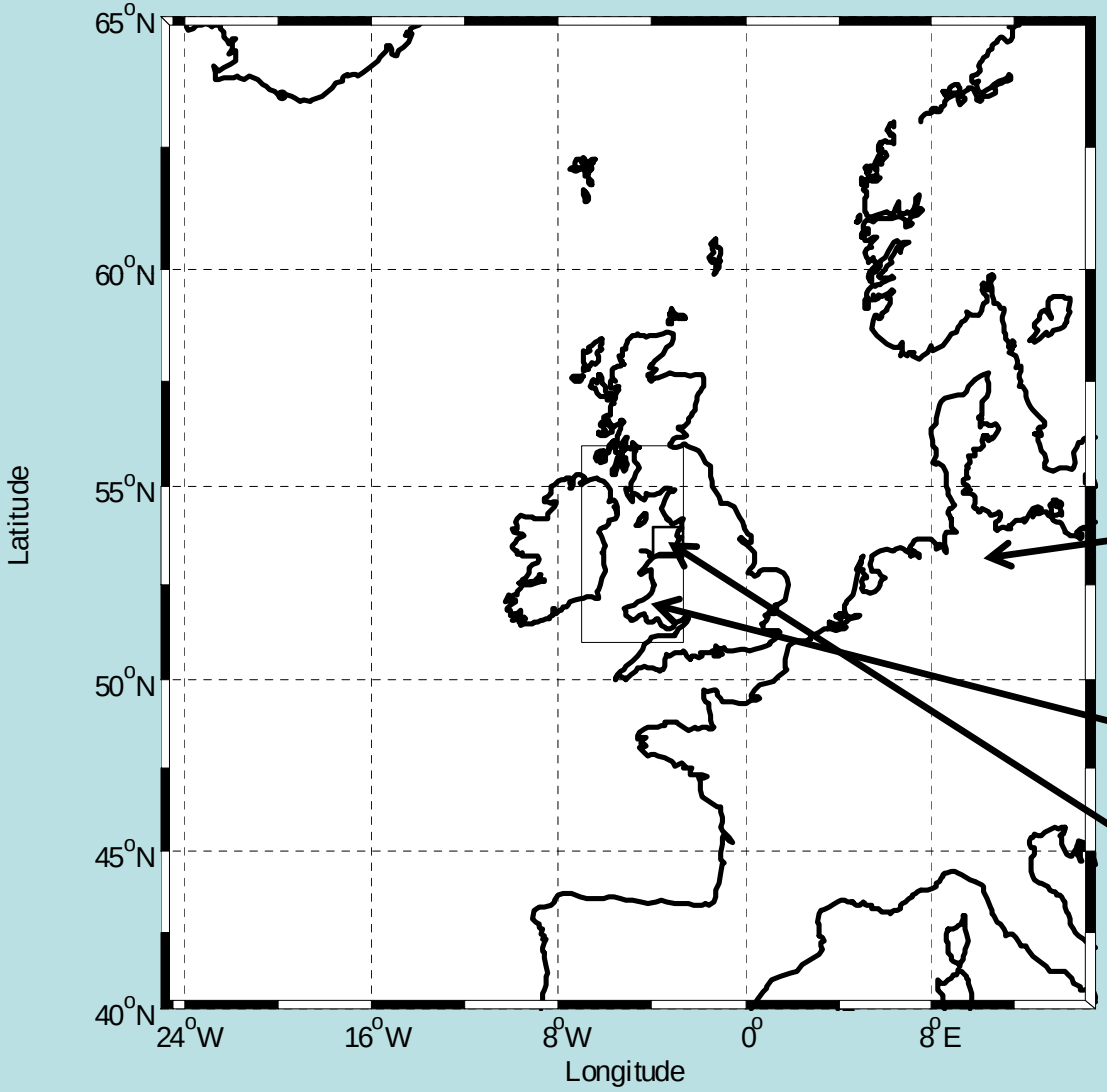
Coastal Management requires the best knowledge of storm conditions



Develop state-of-the-art wave-tide-surge Liverpool Bay modelling system

Wave Modelling: WAveModel

State of the art 3rd generation spectral wave model – extended for shallow water



One way nested model

To provide the external wave condition Liverpool Bay

North East Atlantic Model:

1° resolution

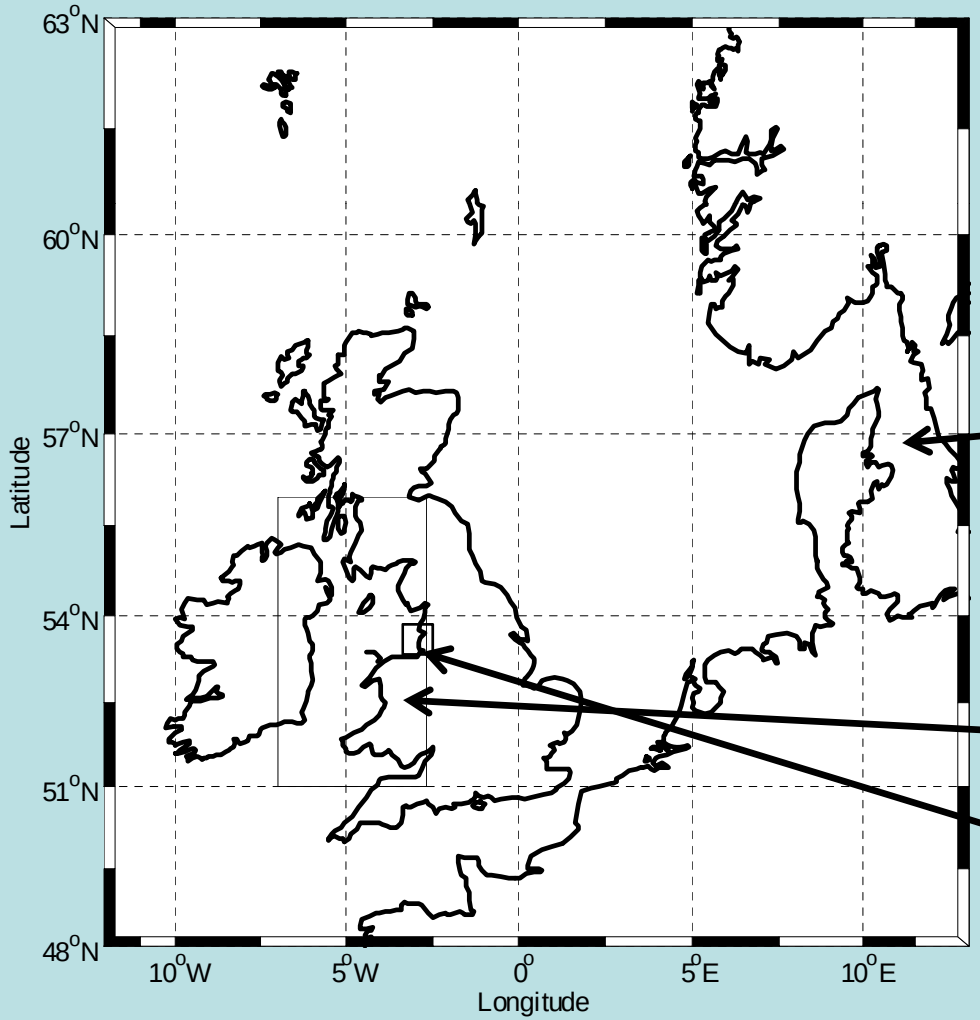
Irish Sea Model:
1.8km resolution

Liverpool Bay Model:
180m resolution

Tide – Surge Modelling:

Proudman **O**ceanographic **L**aboratory **C**oastal **O**cean **M**odelling **S**ystem

3D circulation model – tidal, riverine and meteorological forcing



One way nested model

To provide the external surge conditions to Liverpool Bay

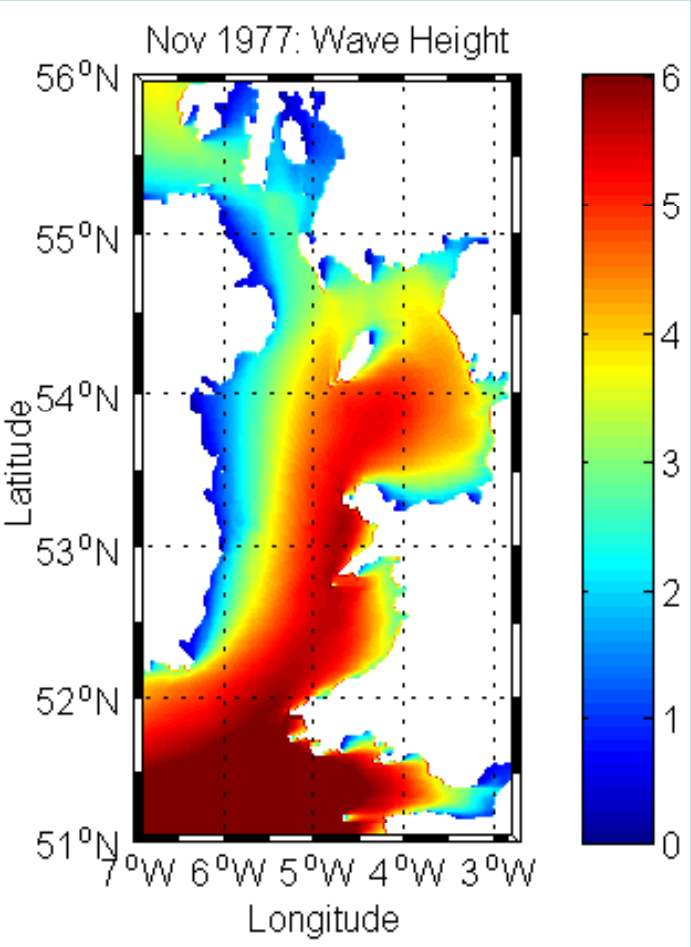
Operational Continental Shelf Surge Model:
Run at NOC for the UK Met. Office
12km resolution

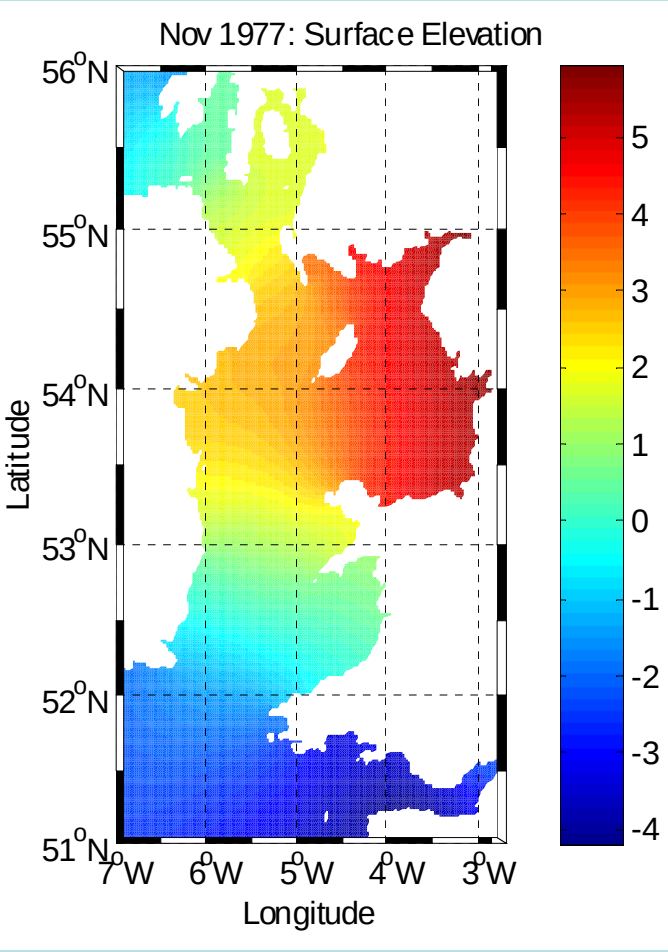
Irish Sea Model:
1.8km resolution

Liverpool Bay Model:
180m resolution

Irish Sea: Wave-tide-surge interaction

Exchange information between surge model and wave model



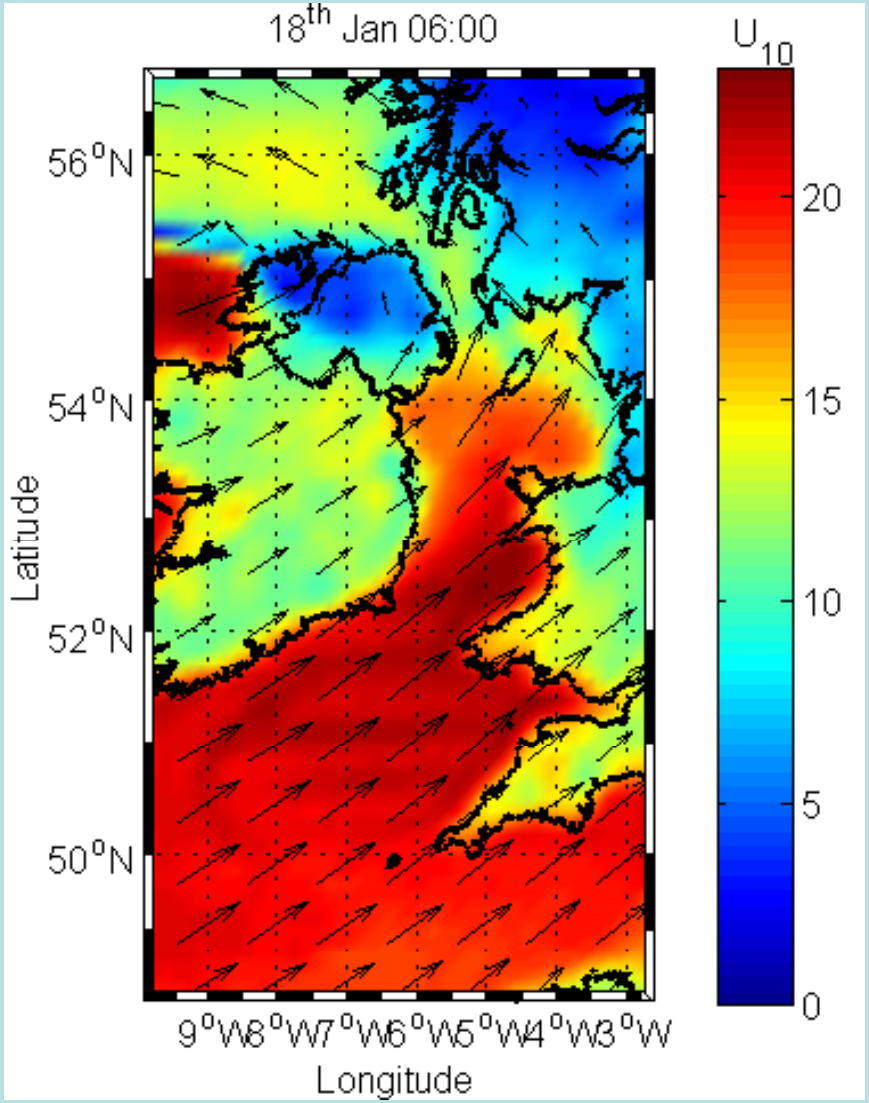


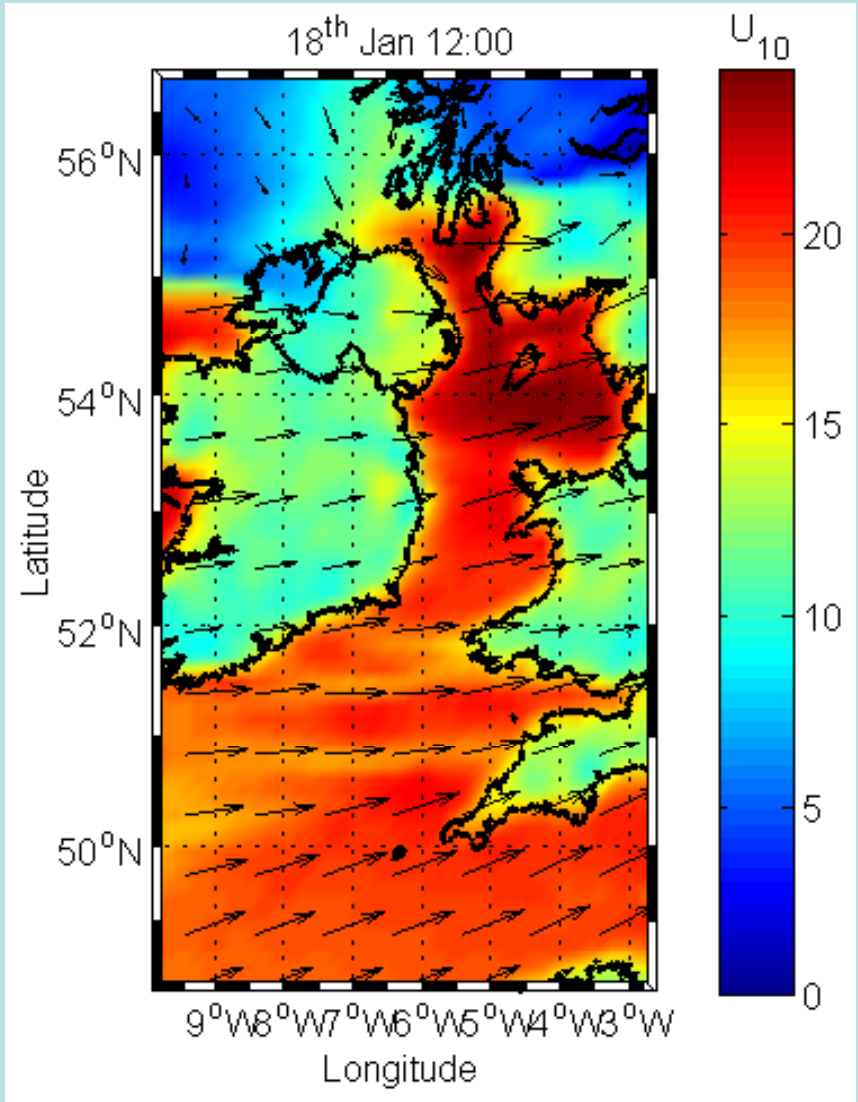
Coupling involves:

(I) time varying depth and velocity fields, which refract the waves
(II) wave-current bottom boundary layer
(III) wave dependent surface roughness to generate the surge

18th January 2007

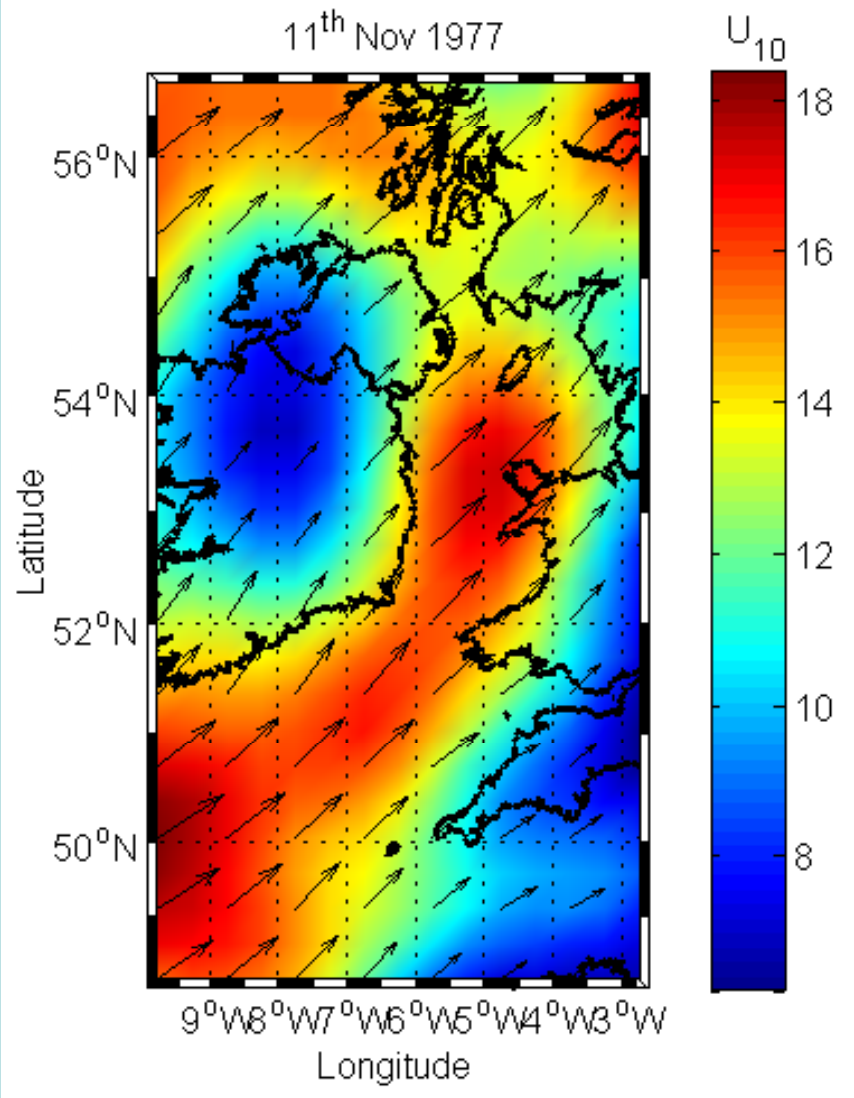
Depression travelled east to the north of Ireland and across Scotland.

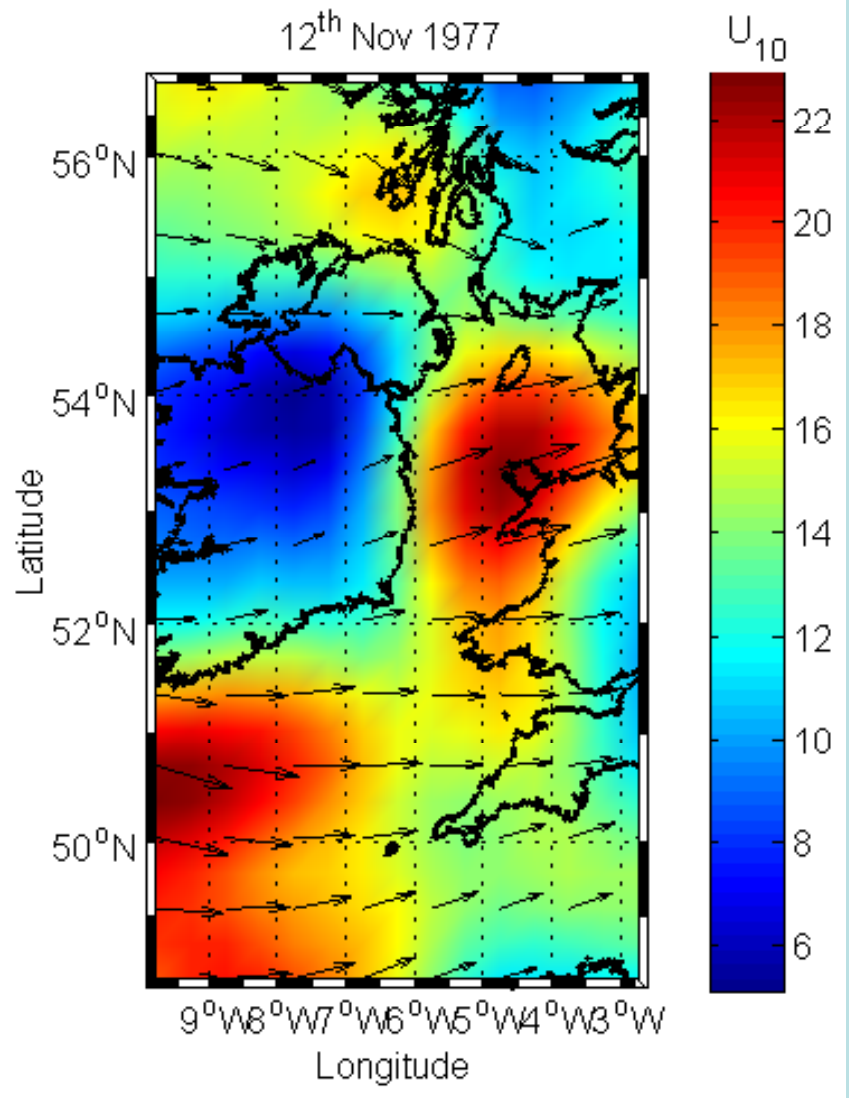




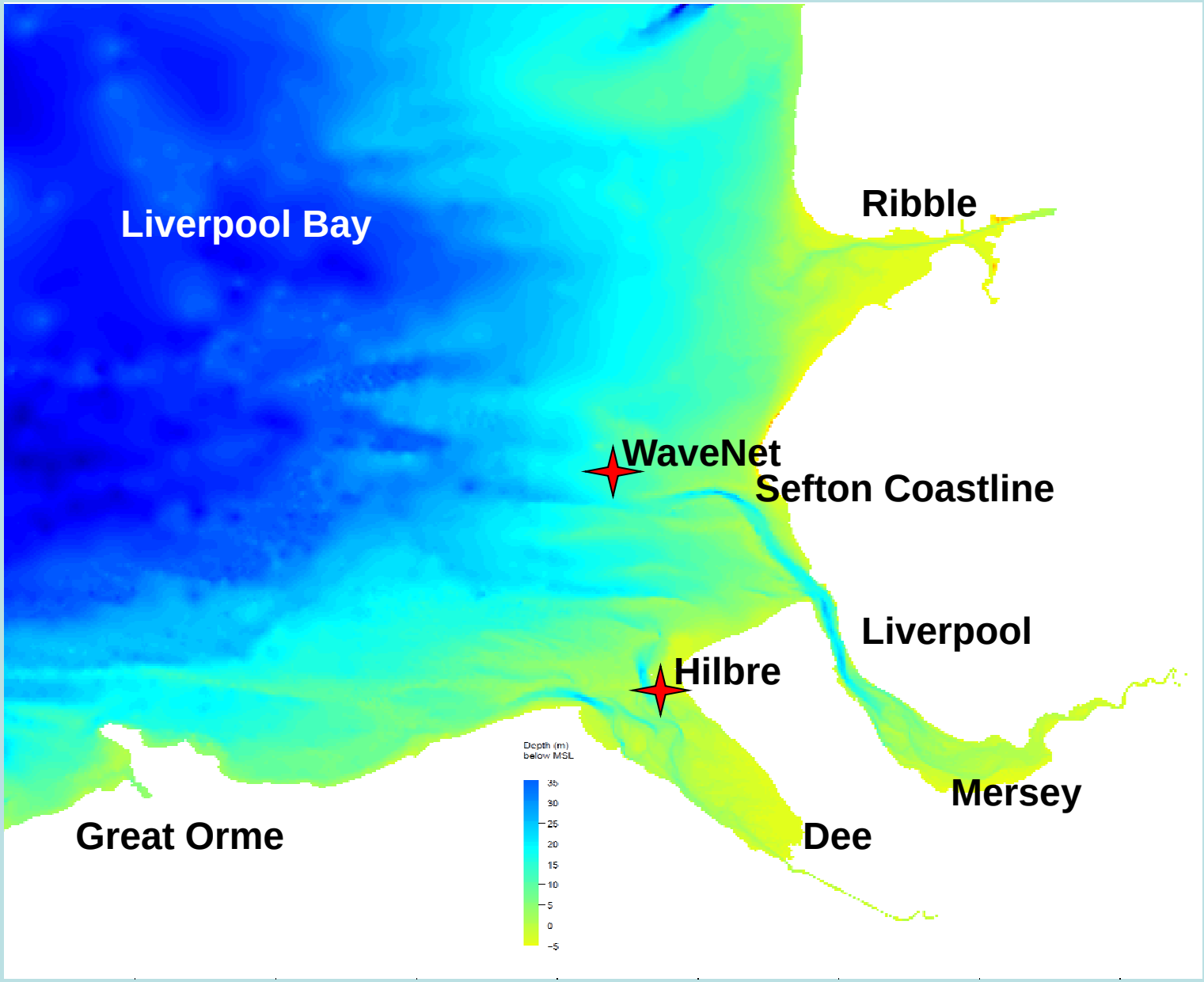
11-12th November 1977

Low pressure system moved from the west, easterly over the north of Scotland.

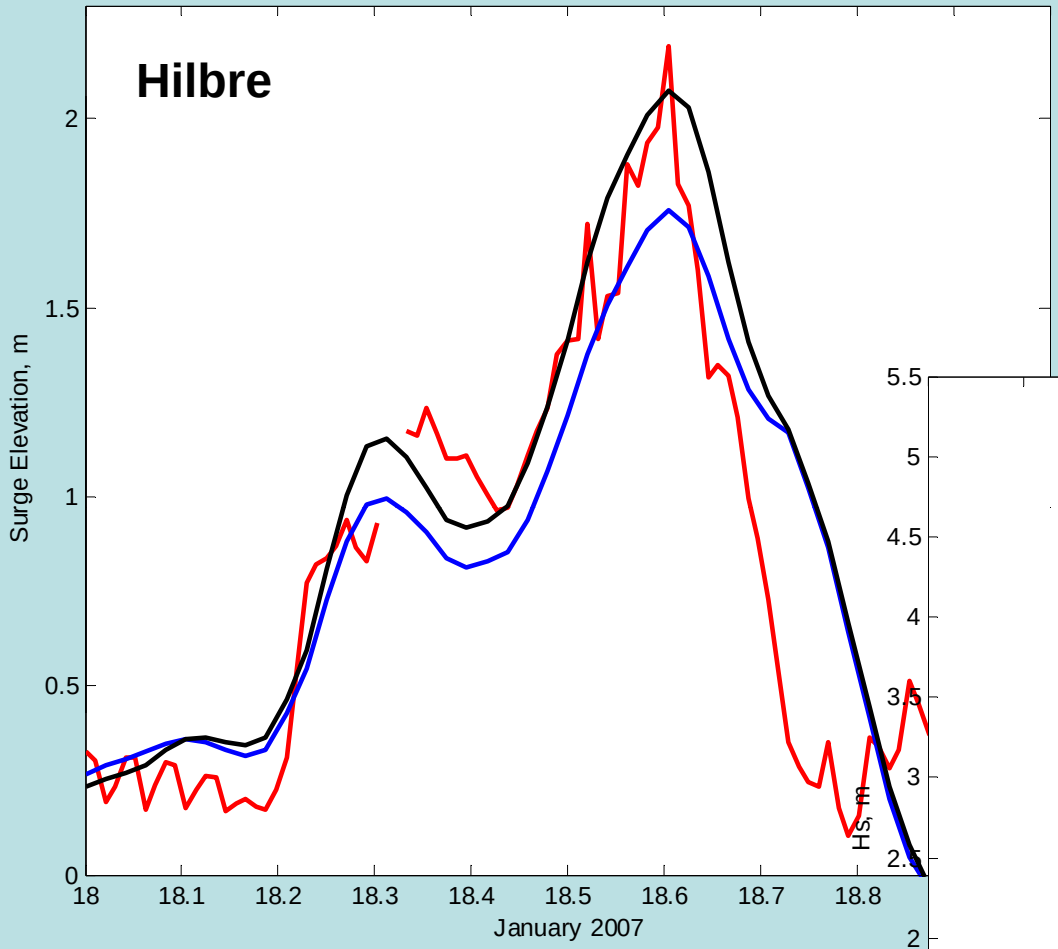


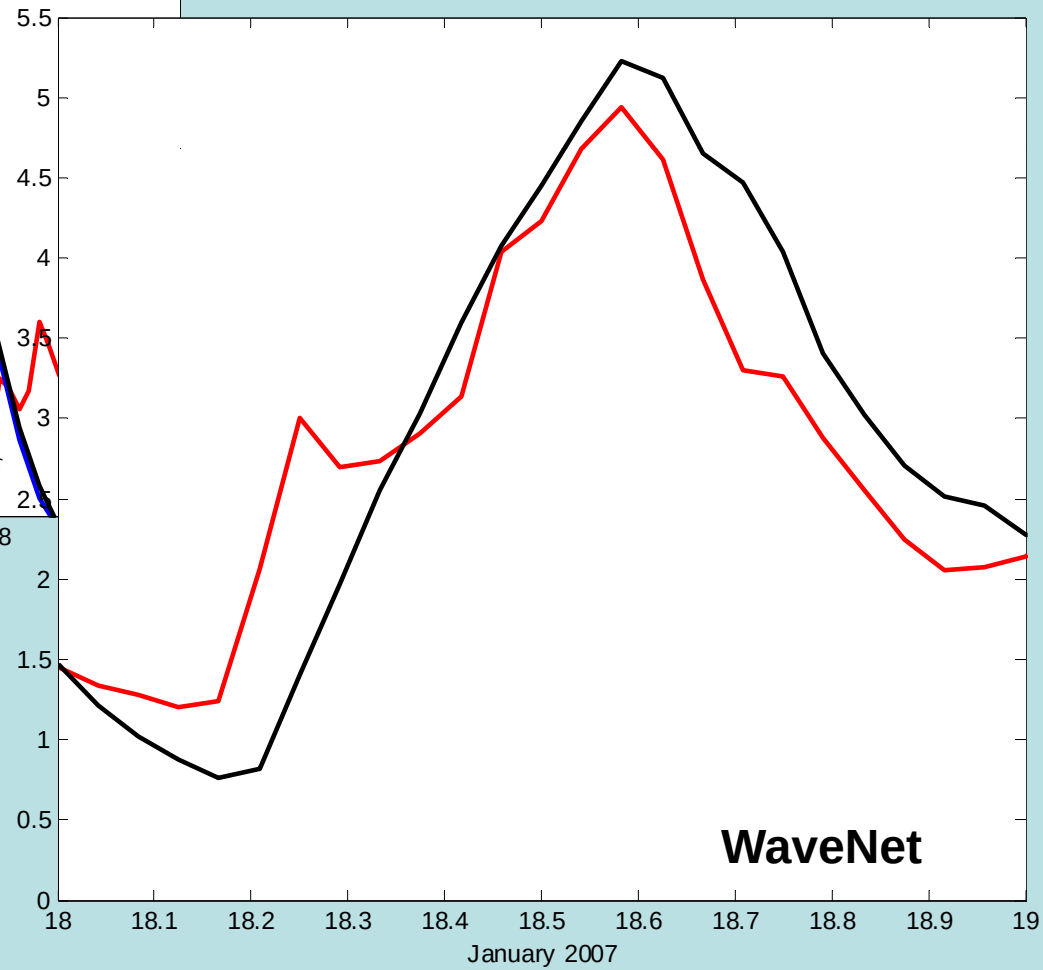


Location Map



Model Results 2007



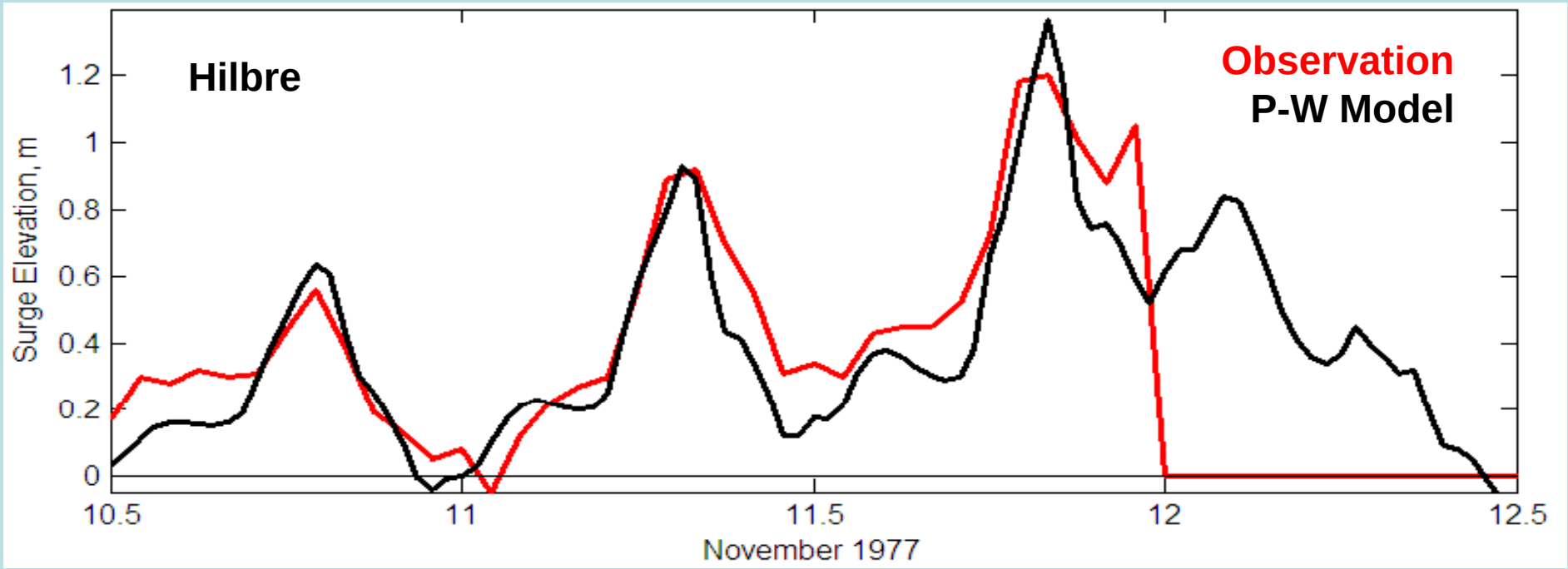


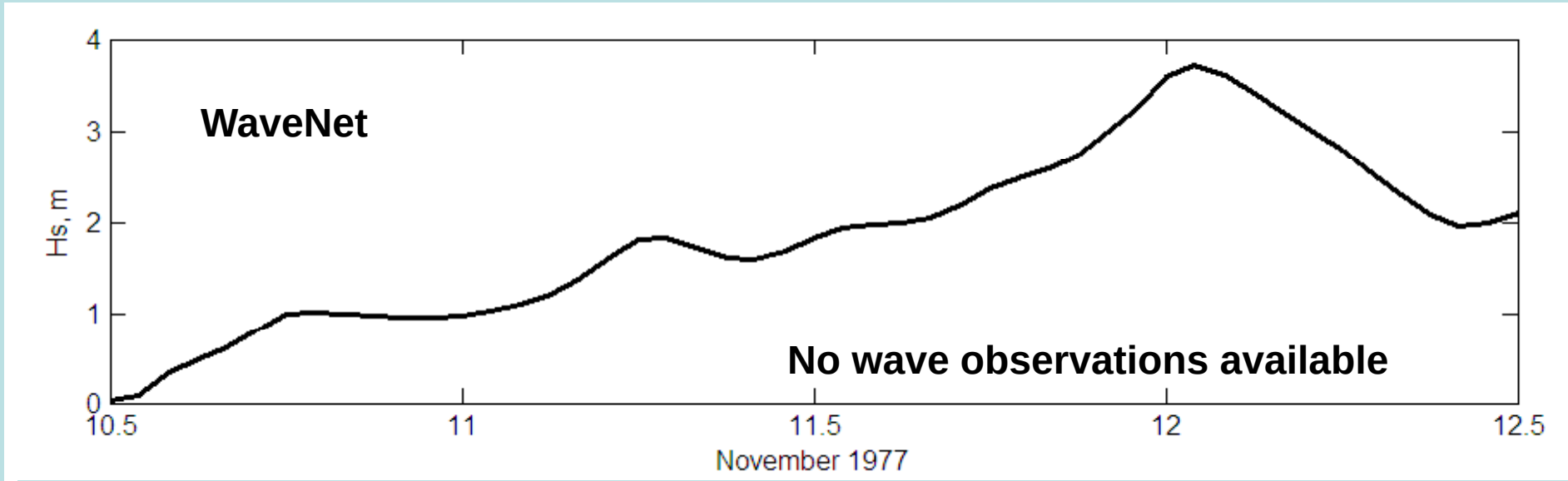
Observation

POLCOMS-WAM Model

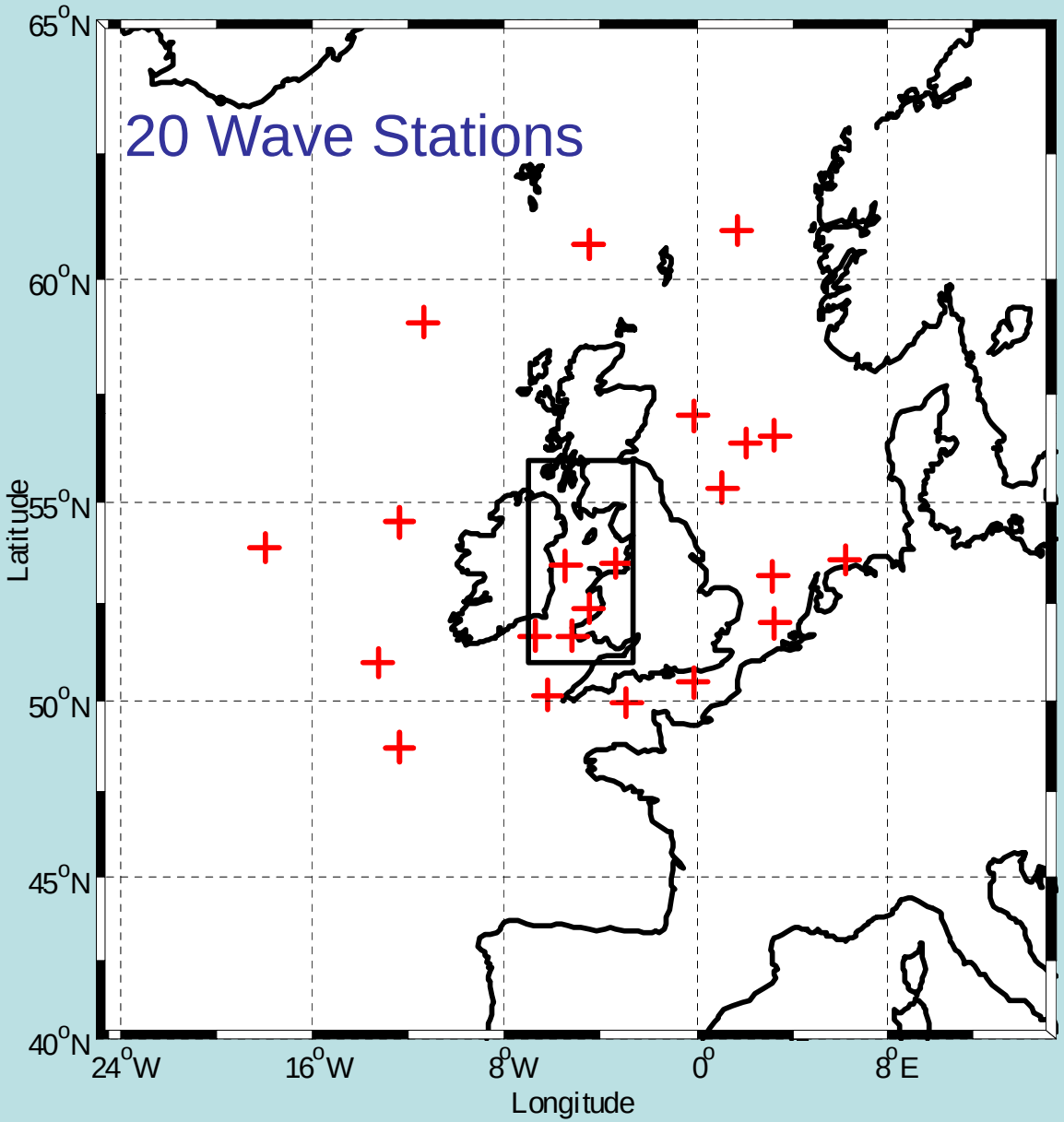
POLCOMS Model

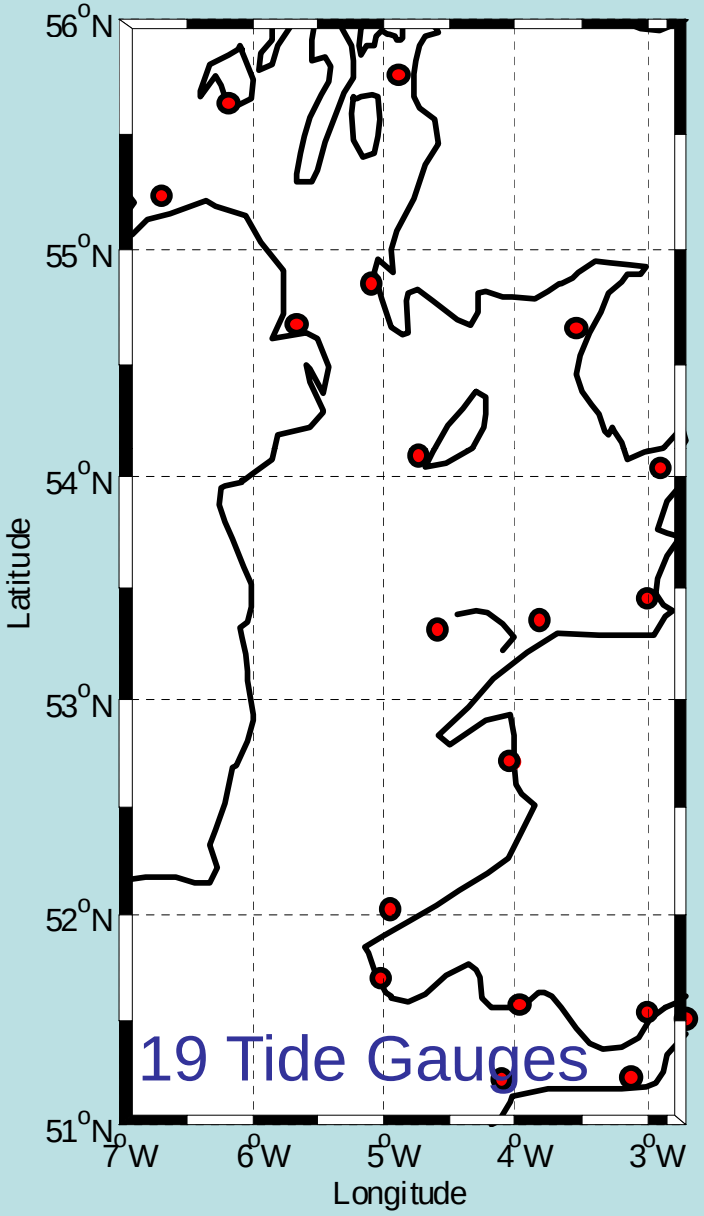
Model Surge Results 1977



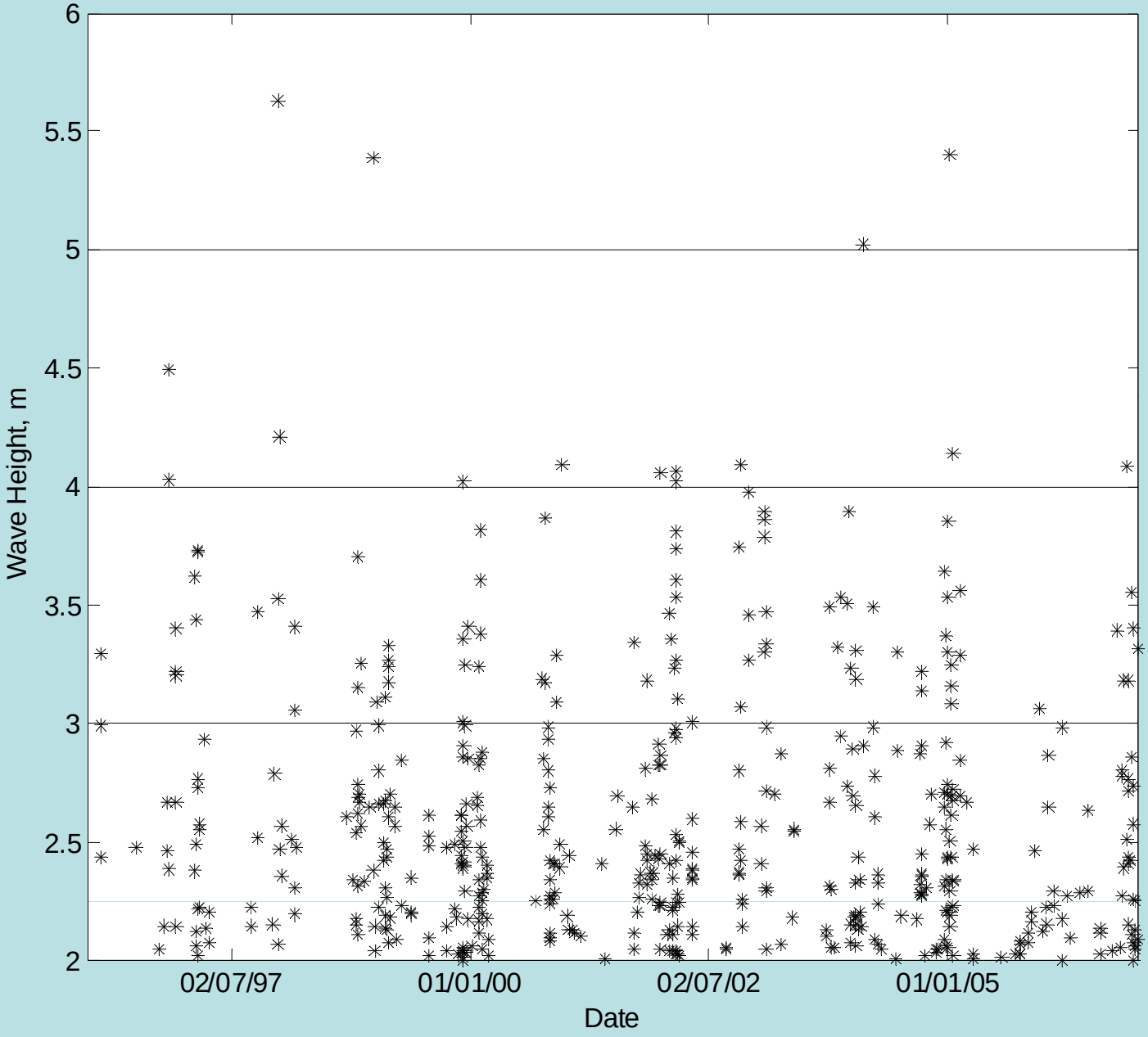


11-Year Simulation: Present Day (1996 – 2006)





Wave events (wave buoy) > 2m, 1996 – 2006



Max = 5.63m

Extreme > 4m

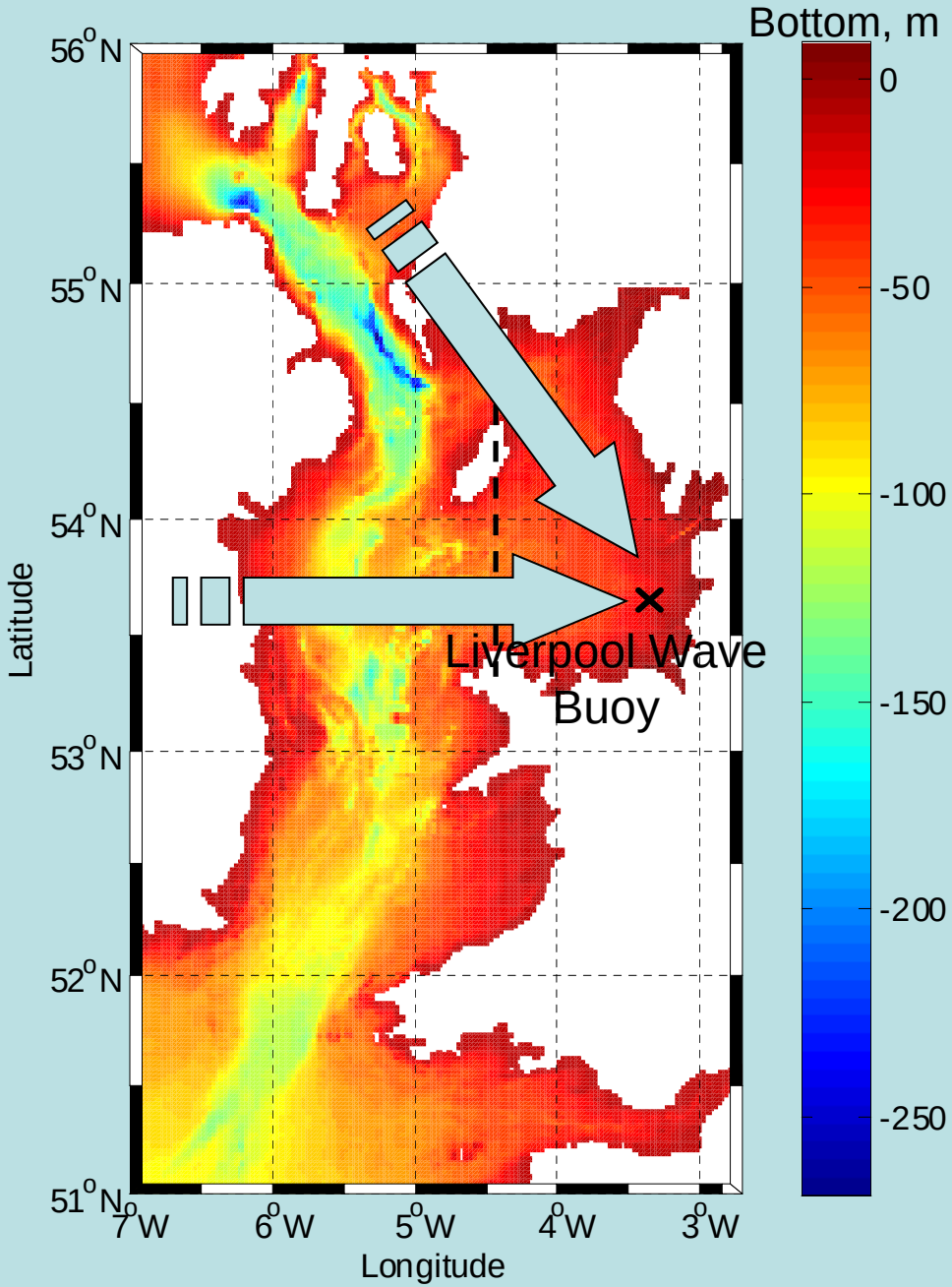
40 events > 3.5m

15 events > 4m

4 events > 5m

No trend linked to climate change~ 11years to short

Extreme Waves in Liverpool Bay



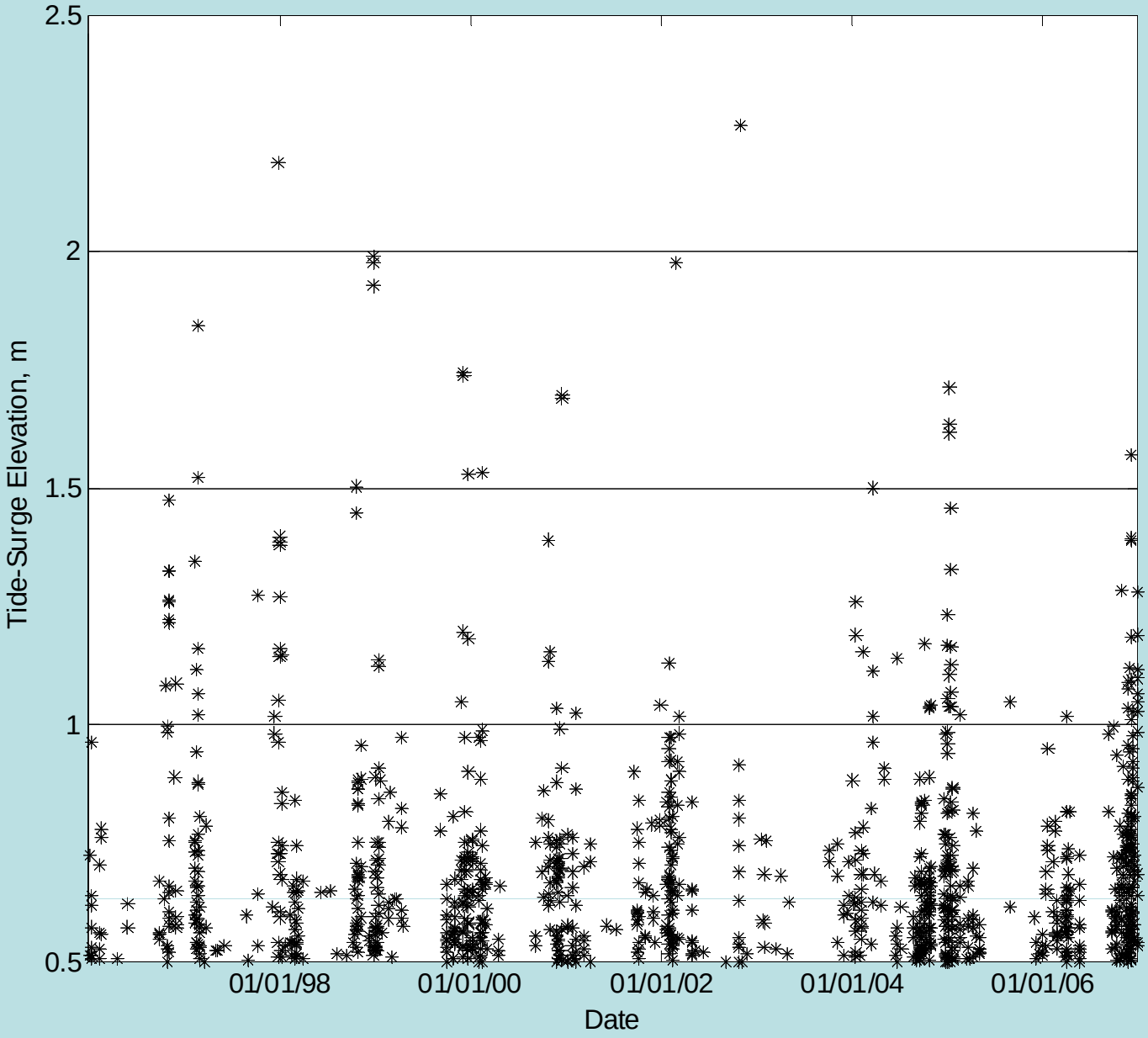
Observation + model hindcast at wave buoy location

Generated: NW – W winds (longest fetches)

Locally generated waves

Reach: 5.6m

Surge events (Liverpool) > 0.5m, 1996 – 2006



Max = 2.26m

Extreme > 1.5m

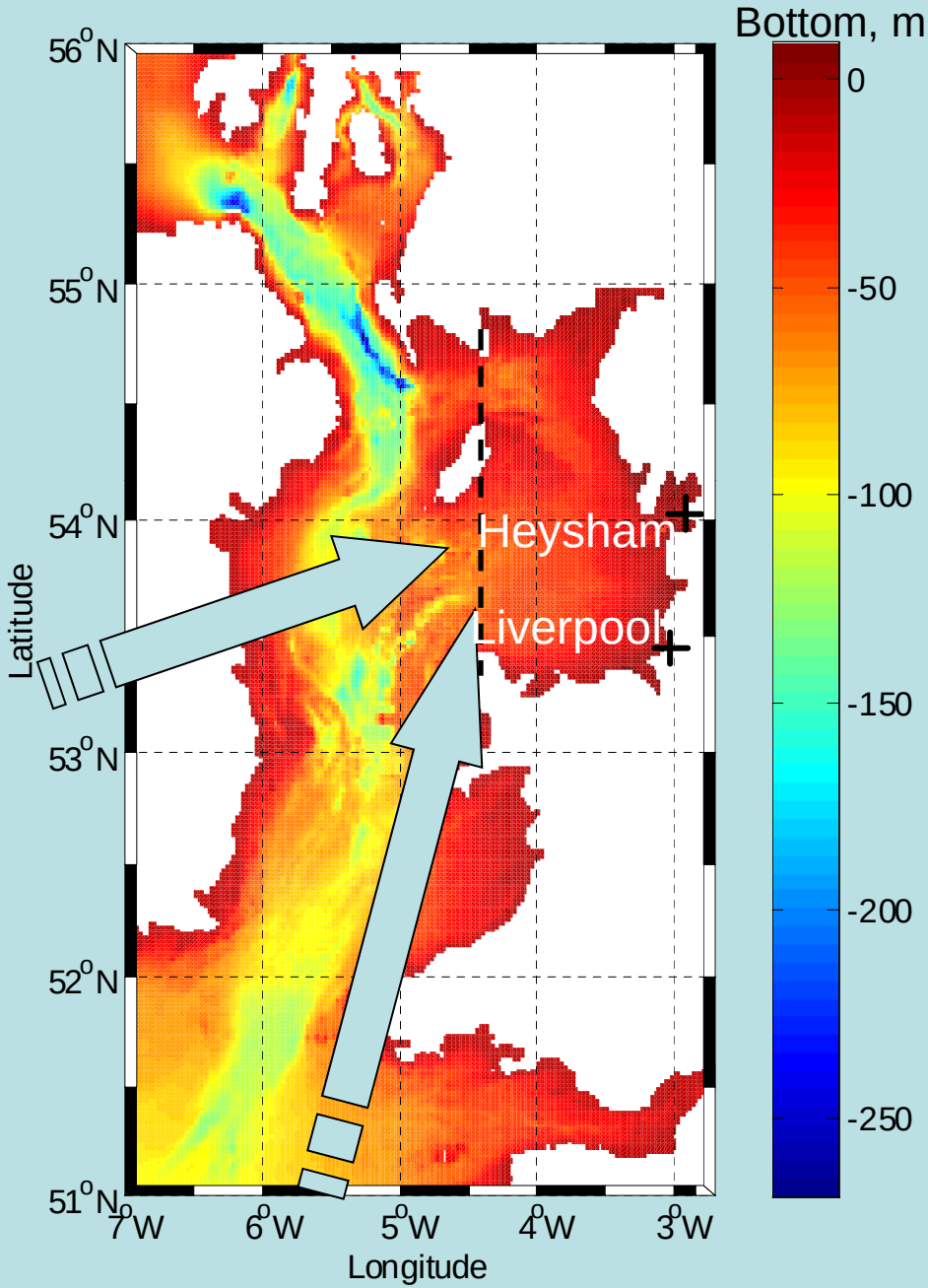
100 events > 1m

19 events > 1.5m

2 events > 2m

No trend linked to climate change~ 11years to short

Extreme Surges along the Sefton Coast



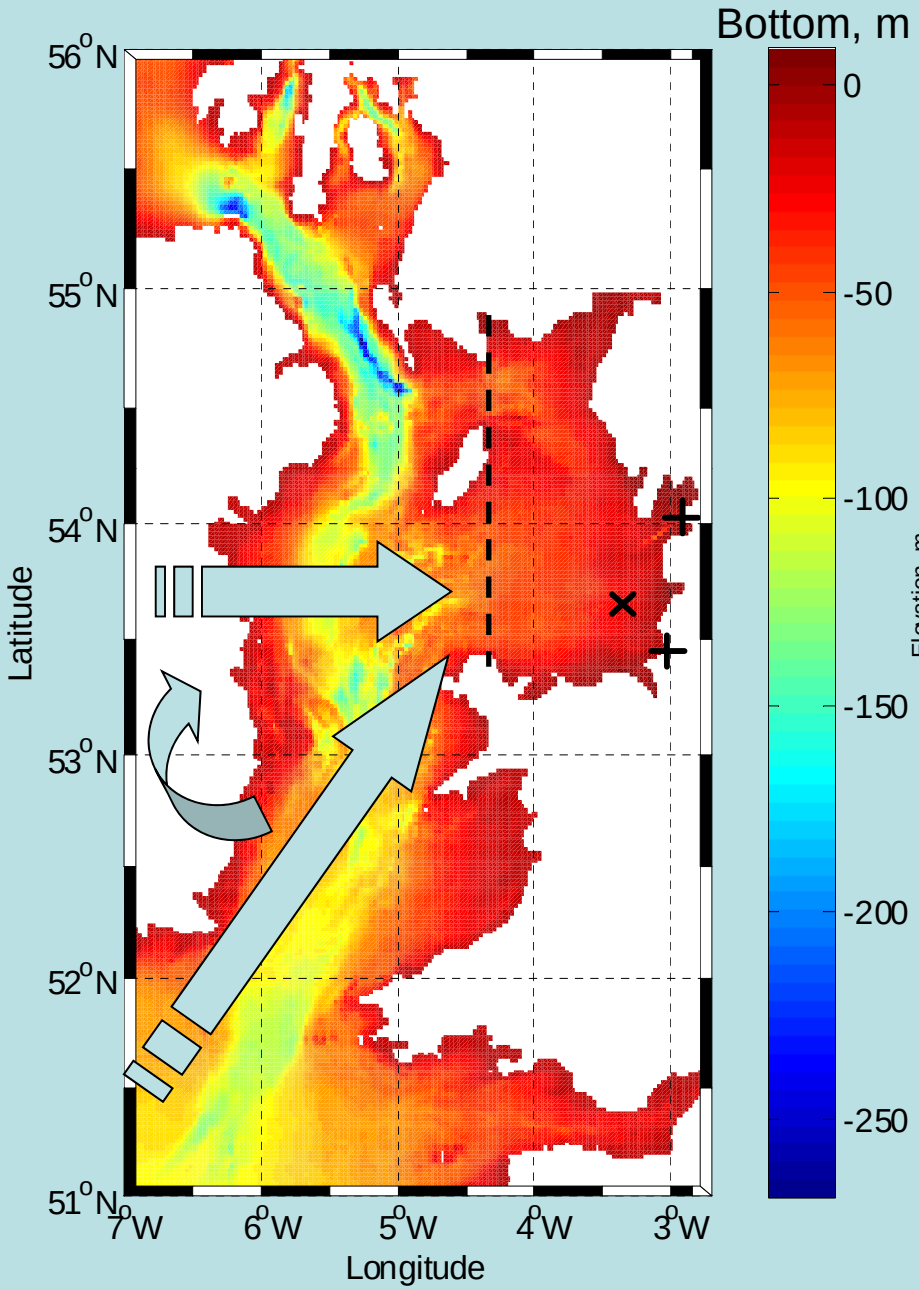
Observation + model hindcast at tide gauges either side of Sefton Coast

Generated: SSW – WSW winds (longest fetches)

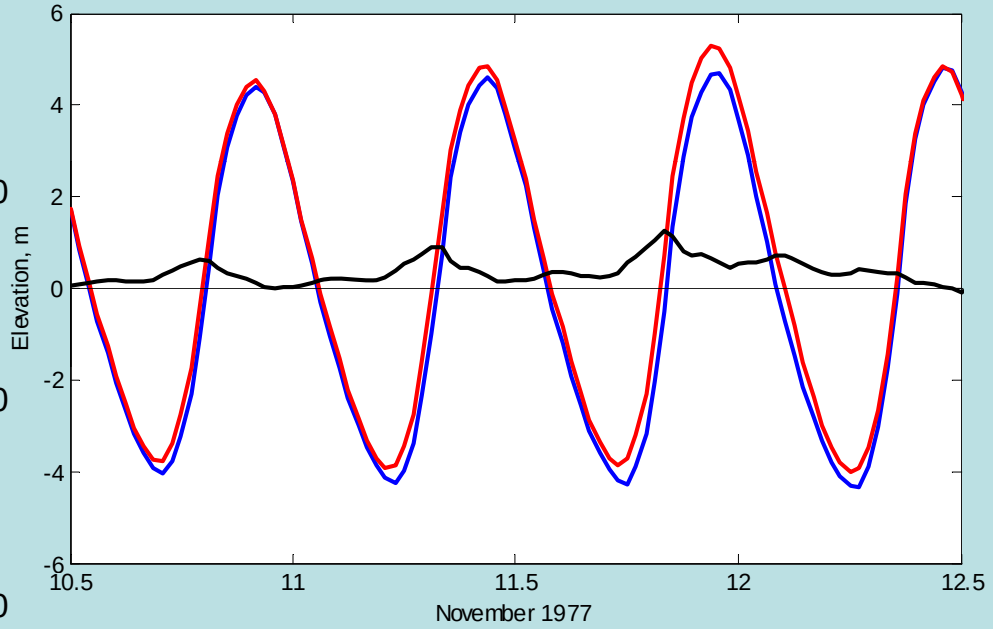
The external surge from the SW approaches/Celtic Sea dominates the surge generation.

Reach: 2.6m

Flood Risk in the study area



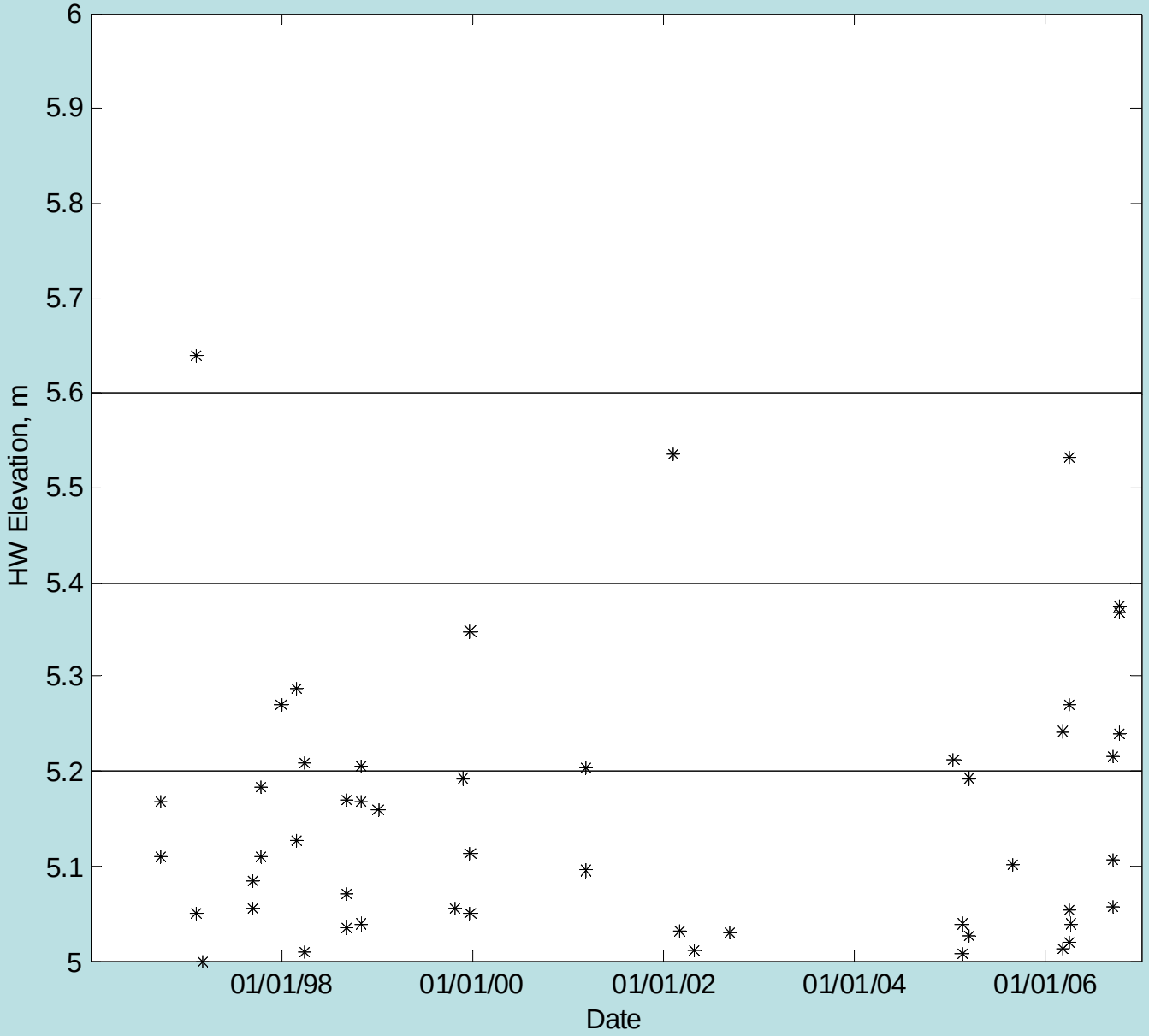
Large 10m tidal range Liverpool Bay causes tide-surge interaction, preventing the peak surge at HW.



Greatest risk SW wind veers W during spring tides.

Extreme wave generation occurs on top of extreme high tide levels, which are increased by extreme surge conditions.

HW events (Liverpool) > 5m, 1996 – 2006



Max = 5.64m

Extreme > 5m

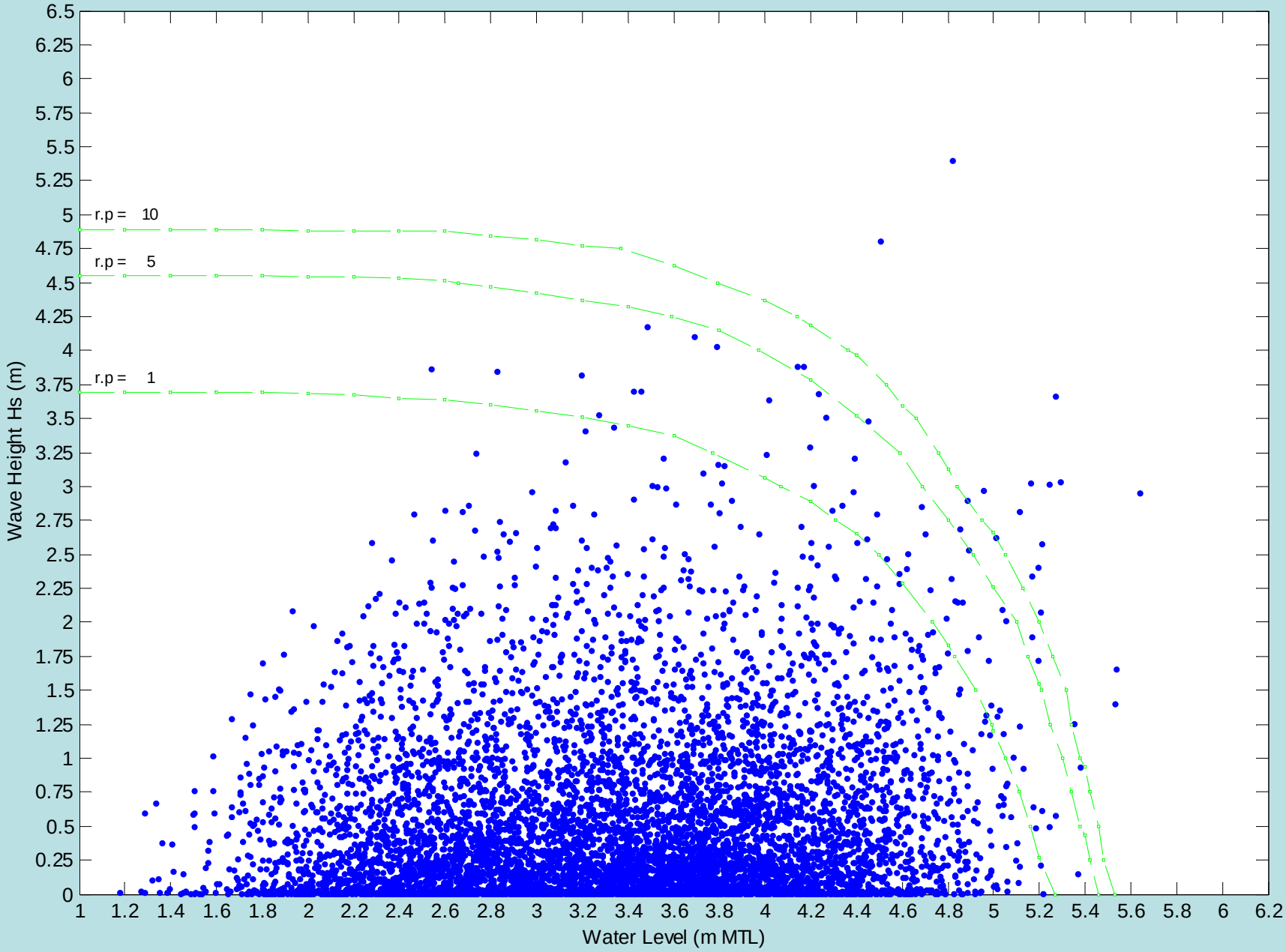
50 events > 5m

16 events > 5.2m

3 events > 5.4m

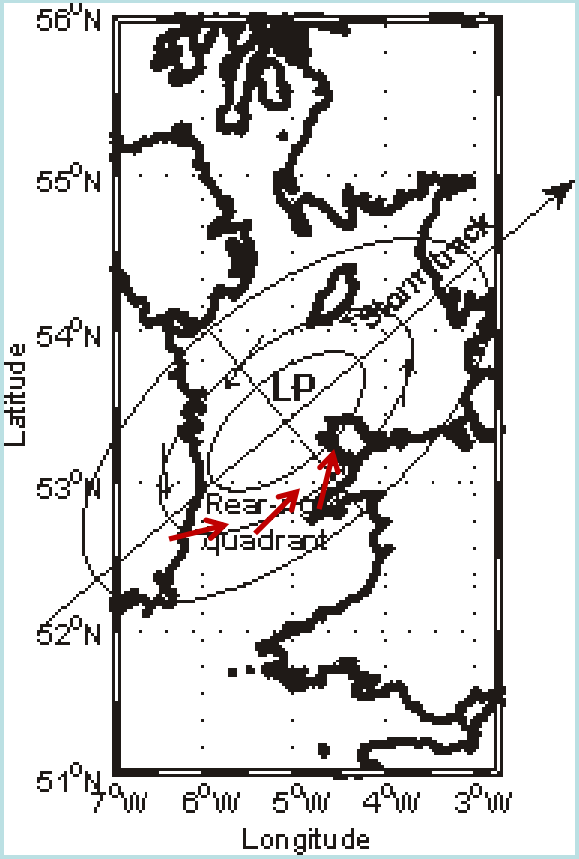
No trend linked to climate change~ 11years to short

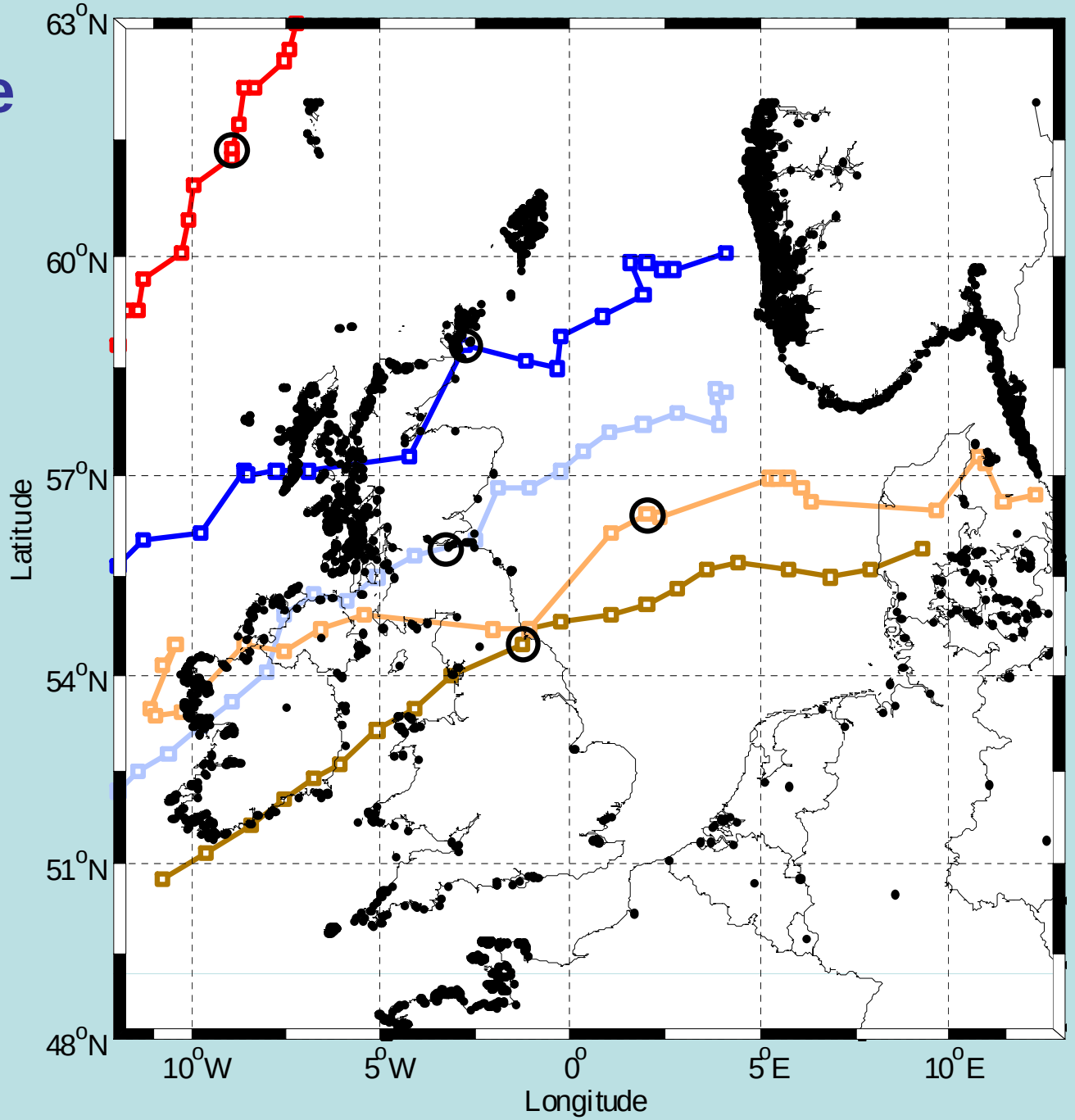
Joint Probability, 1996 – 2006



Extreme surge storm tracks

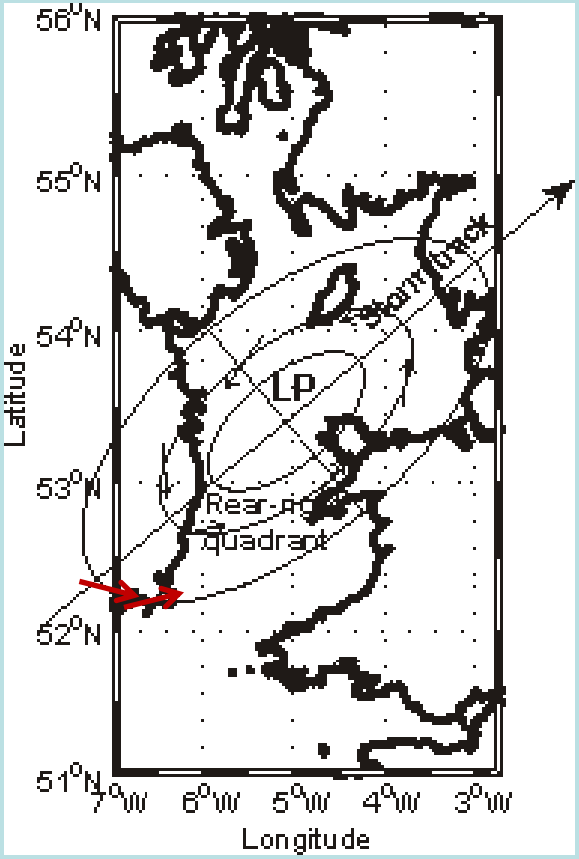
- SW-W winds

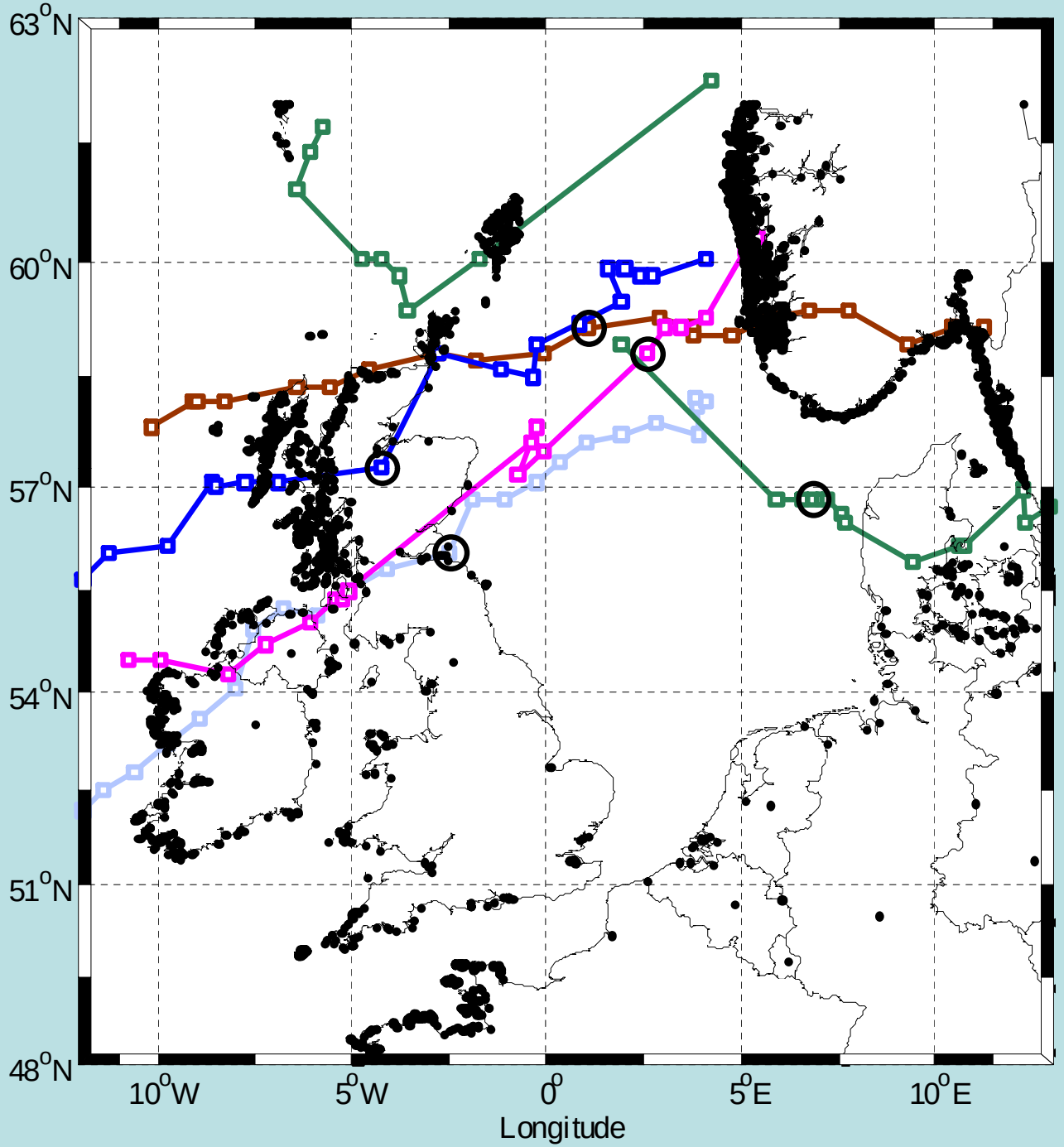




Extreme wave storm tracks

- W-NW winds





Wave-tide-surge Liverpool Bay model

Includes:

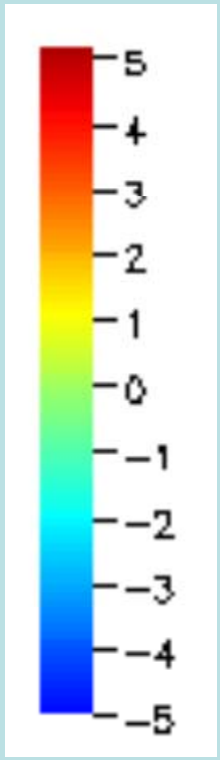
(i) radiation stress – wave setup & wave-induced currents

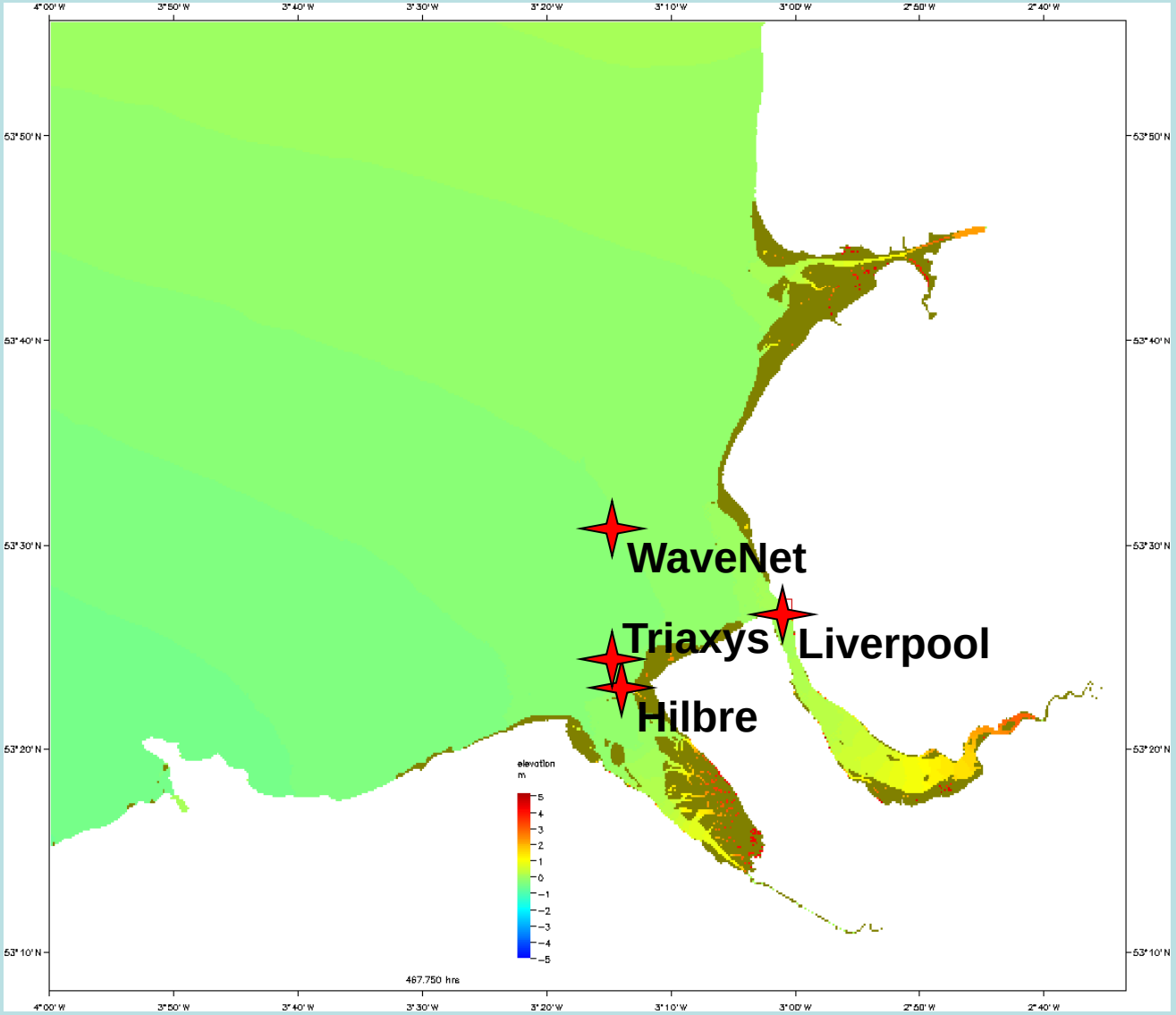
(ii) Stokes drift

(iii)Wave breaking

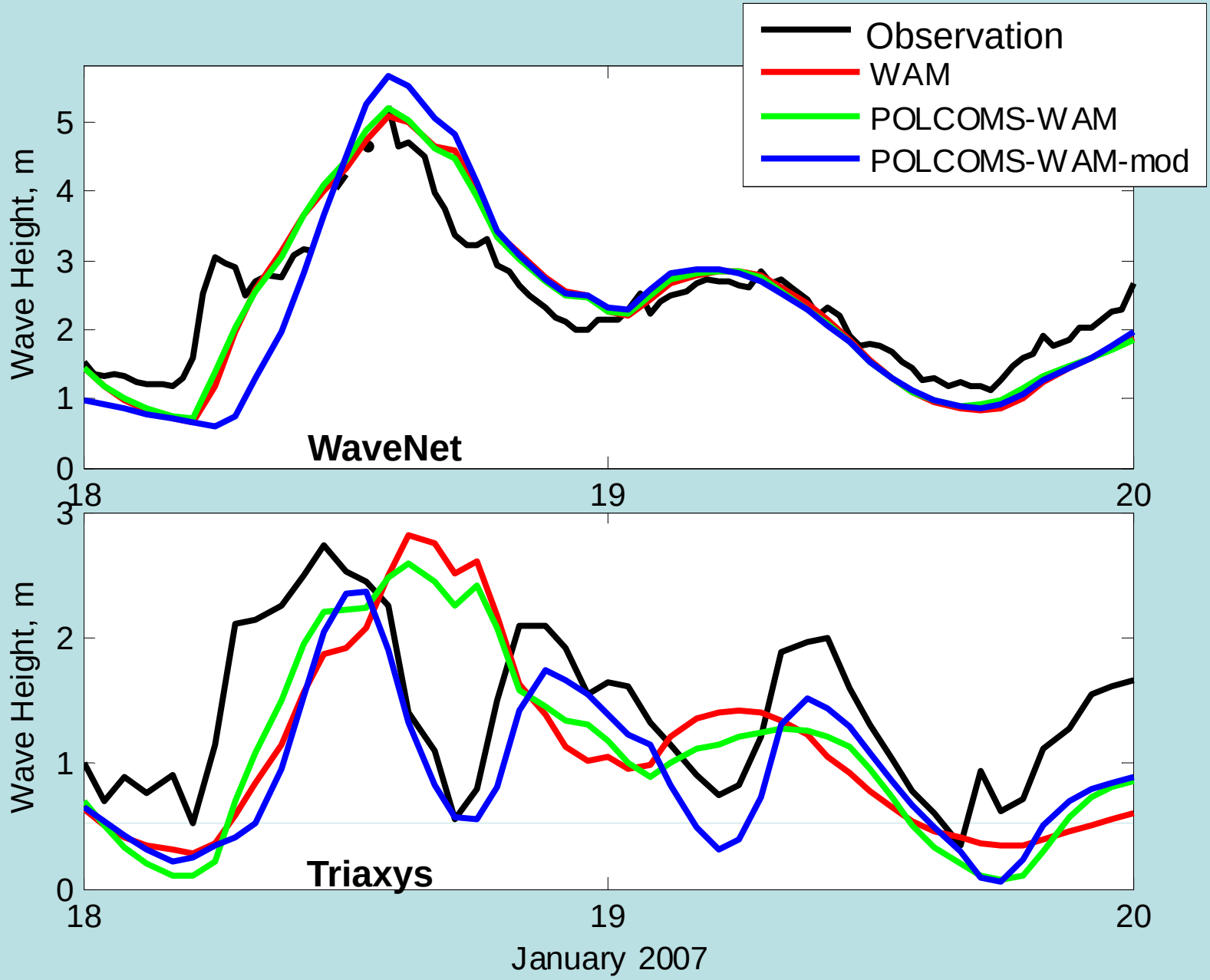
(iv)Wetting & drying

Elevation, m

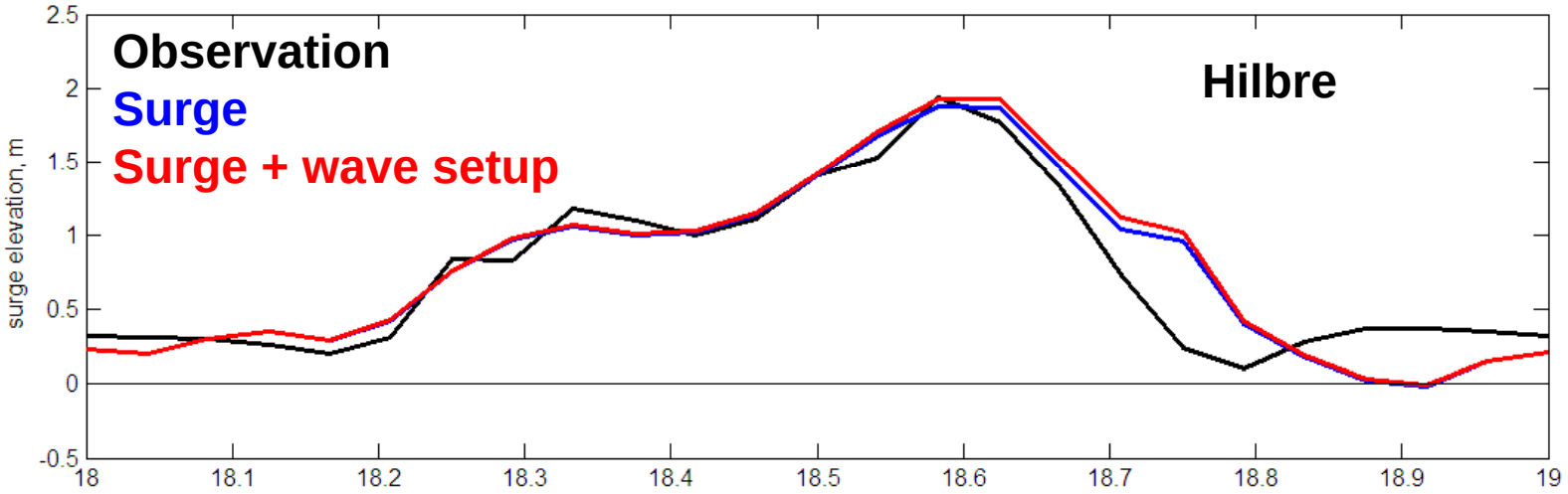




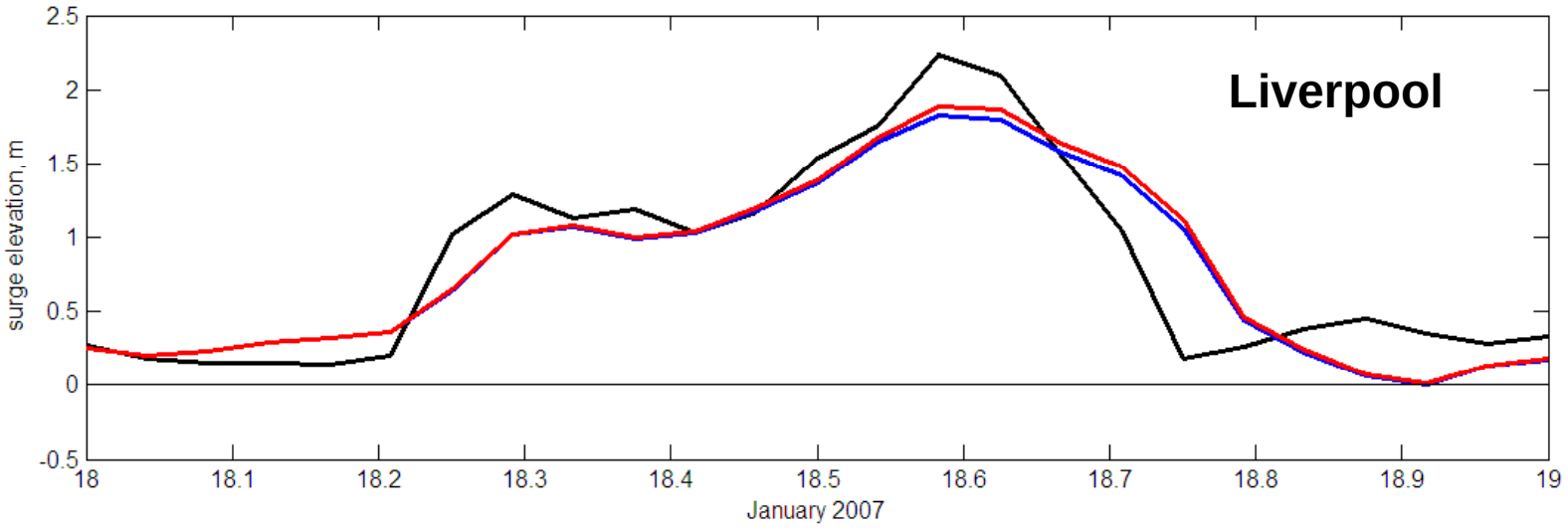
Improved wave simulation:



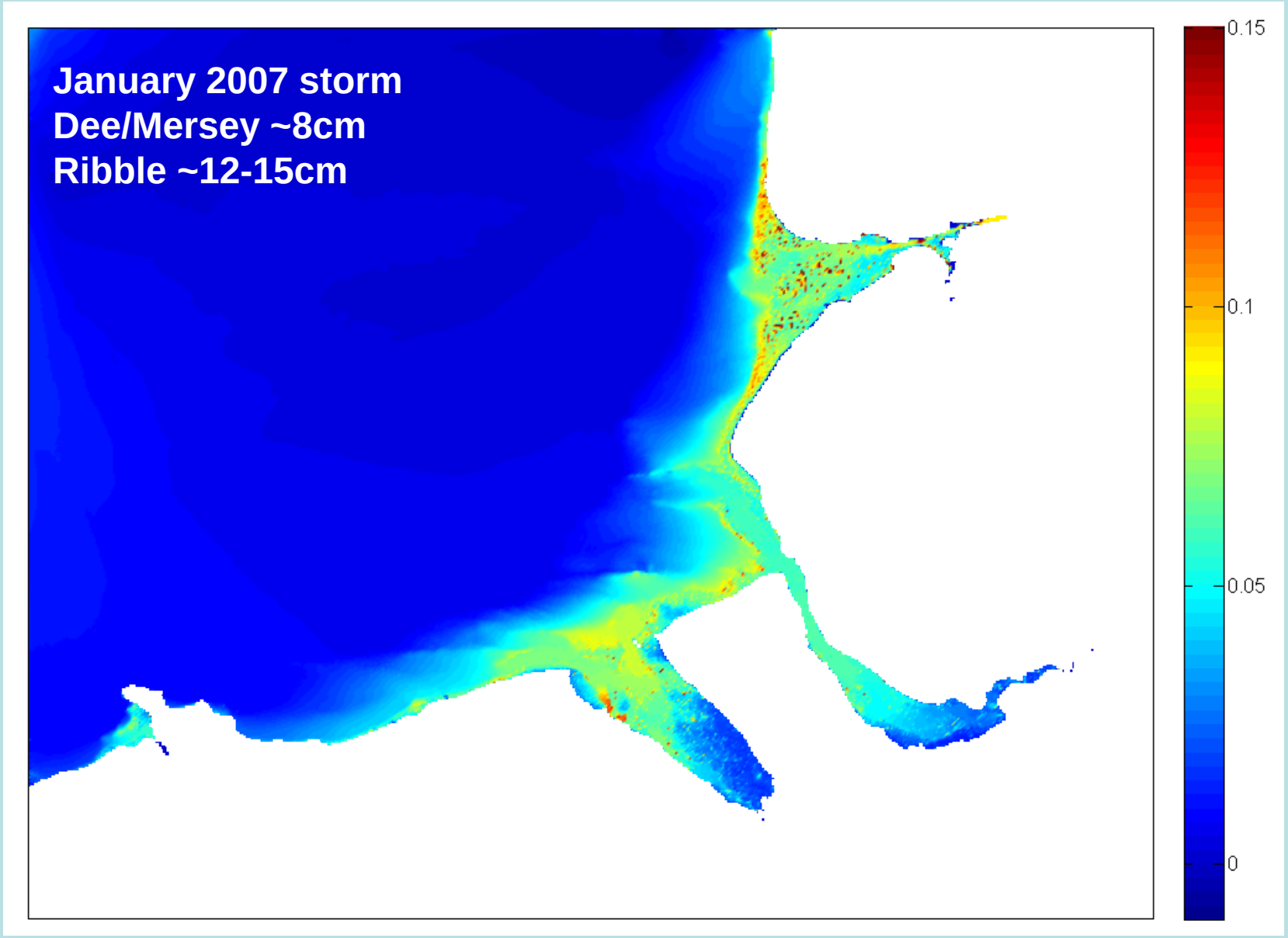
Wave setup in addition to the surge.



~6cm (12%) increase



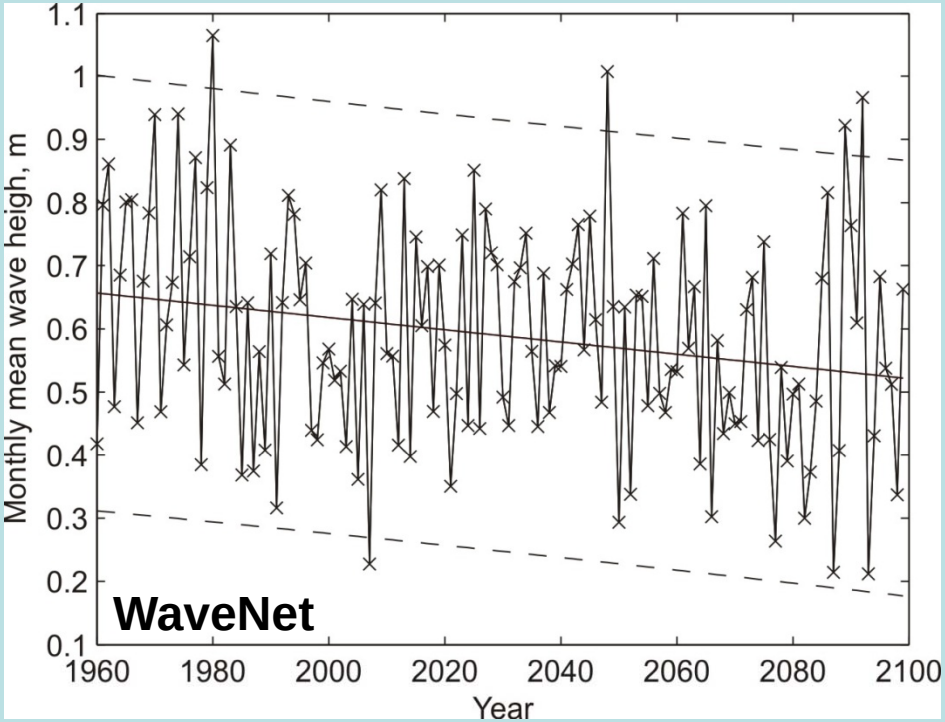
Maximum wave setup over Liverpool Bay.

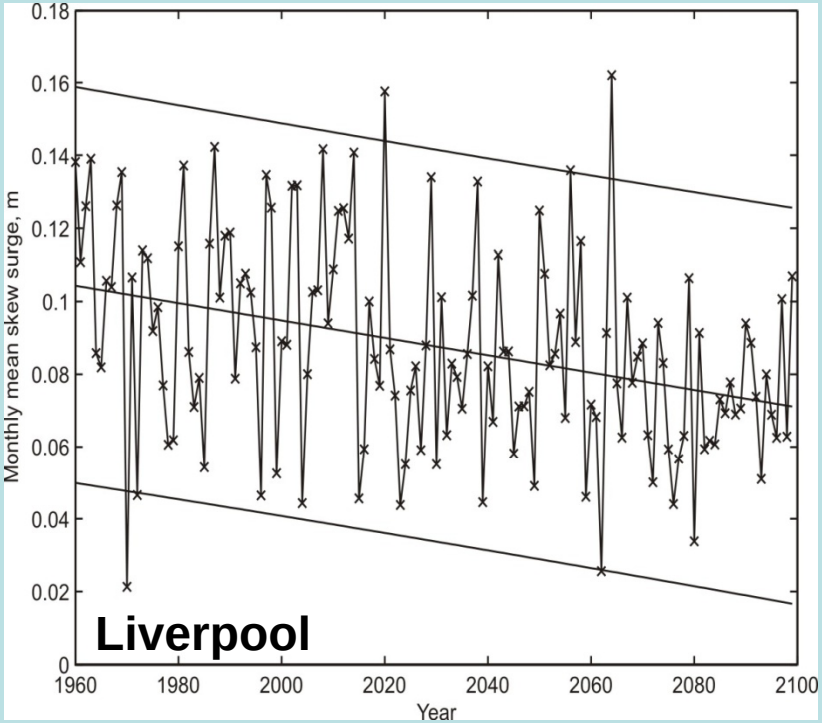


Future climate?

Related to storm track position

UK climate Projection 2009: Model projection 1960 - 2100





~2% increase in the running mean of the annual maximum Hs
~12% increase in the running mean of the annual maximum Skew Surge

Suggested more extreme, but less frequent??

Conclusions

•Extreme surge levels (2.6m) along the Sefton coast occur due to storms tracking NE generating SW winds & extreme external surge.

•Extreme wave heights (5.6m offshore / 2.5m nearshore) in Liverpool Bay occur in response to local NW – W winds generated by storms tracking E north of the eastern Irish Sea.

•Storm generating SW winds veering W lead to most severe conditions.

•Shallow water need a coupled model:

(i) Tidal modulation of the waves.
(ii) Wave setup increases the surge peak.

•POLCOMS-WAM is a valid wave-tide-surge model to apply to the Irish Sea and Liverpool Bay.

•Can now be used for future flood risk projection.

micore

micore

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Thank You

Southport Pier