Changes in extreme wave conditions of North West Europe, in response to high-end climate scenarios

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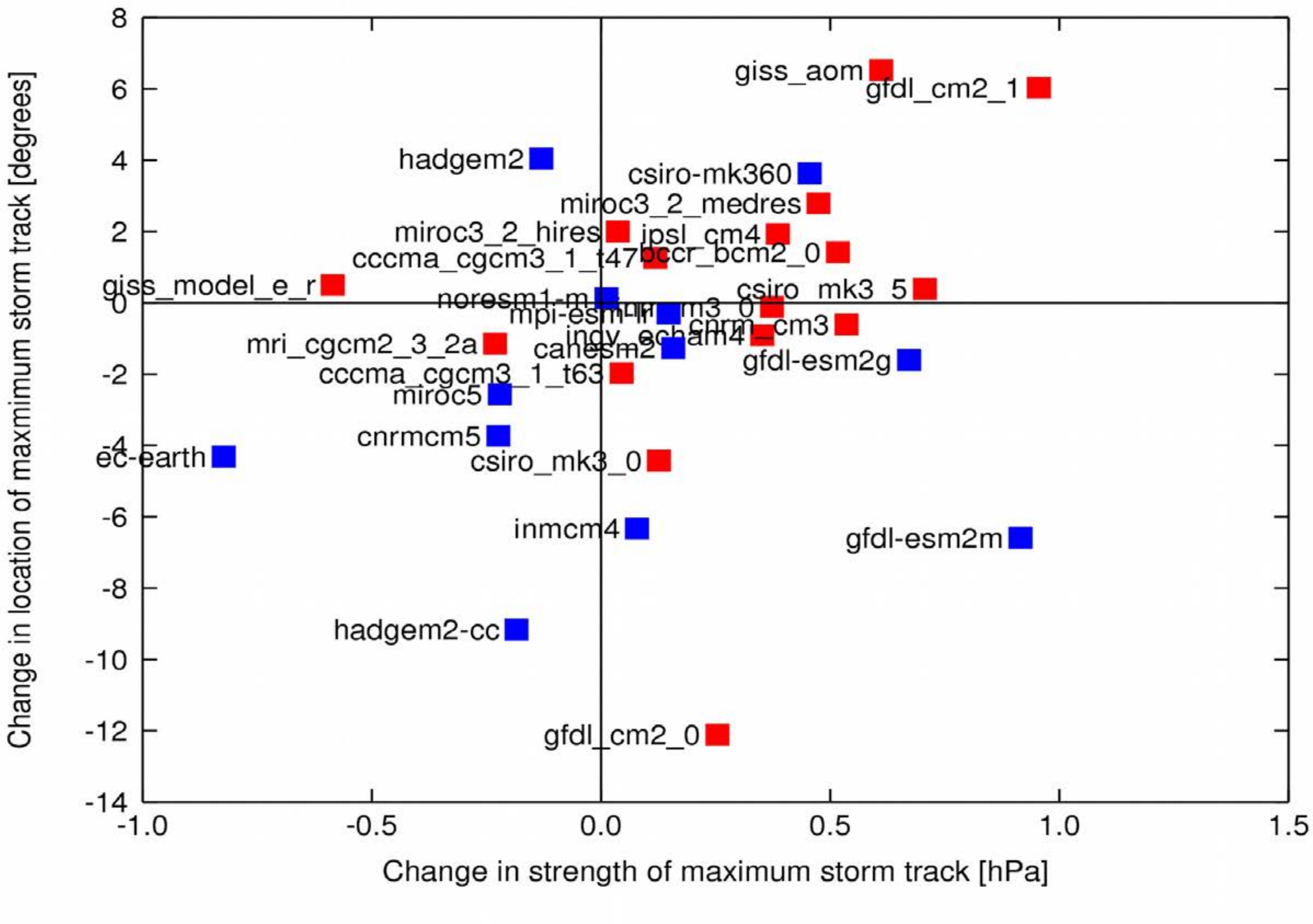
Outline

- Global wave models
  - Context of eight model: meta-analysis &
  - Future global change
- High resolution European modelling
  - Changes in mean and extreme waves
  - Coastal Impacts around Europe
- Conclusion

Projected changes in storms: CMIP3 vs CMIP5



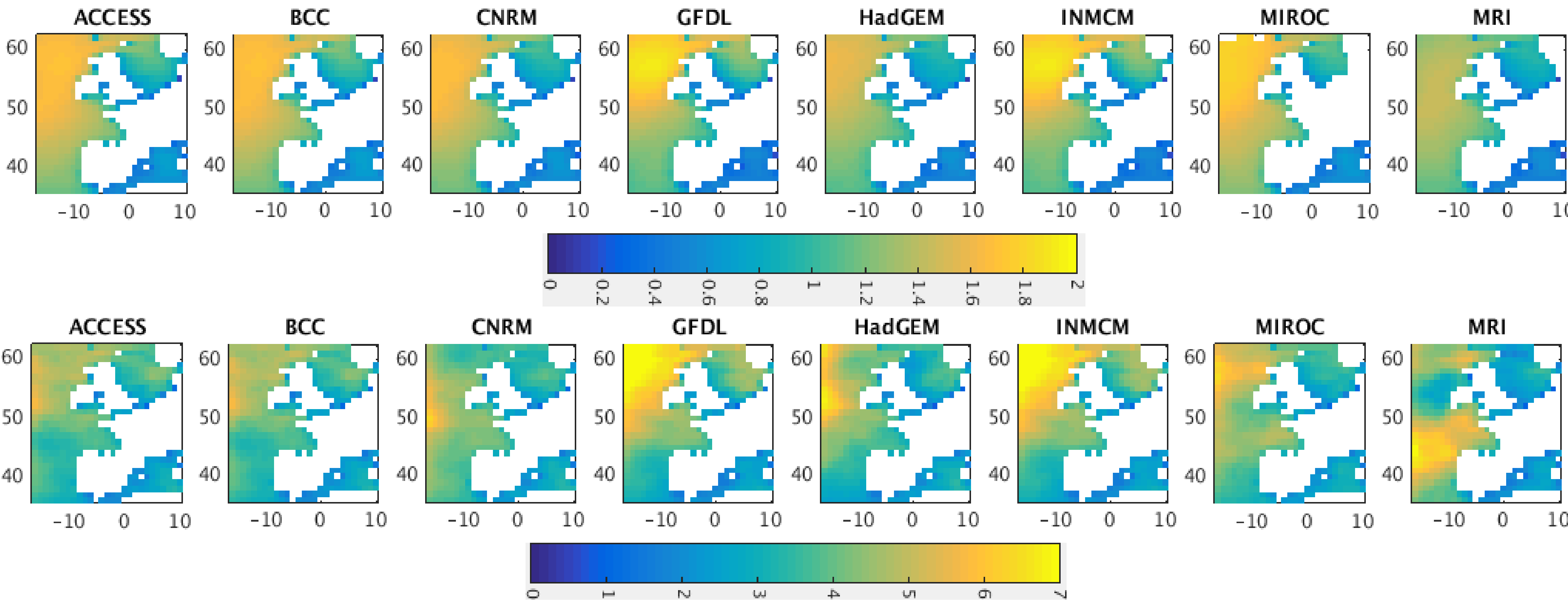
Credit: Ben Harvey, NCAS. Section at longitude=zero.

Blue: CMIP5 (RCP8.5) Red: CMIP3 (SRESA1B)

Global Wave models

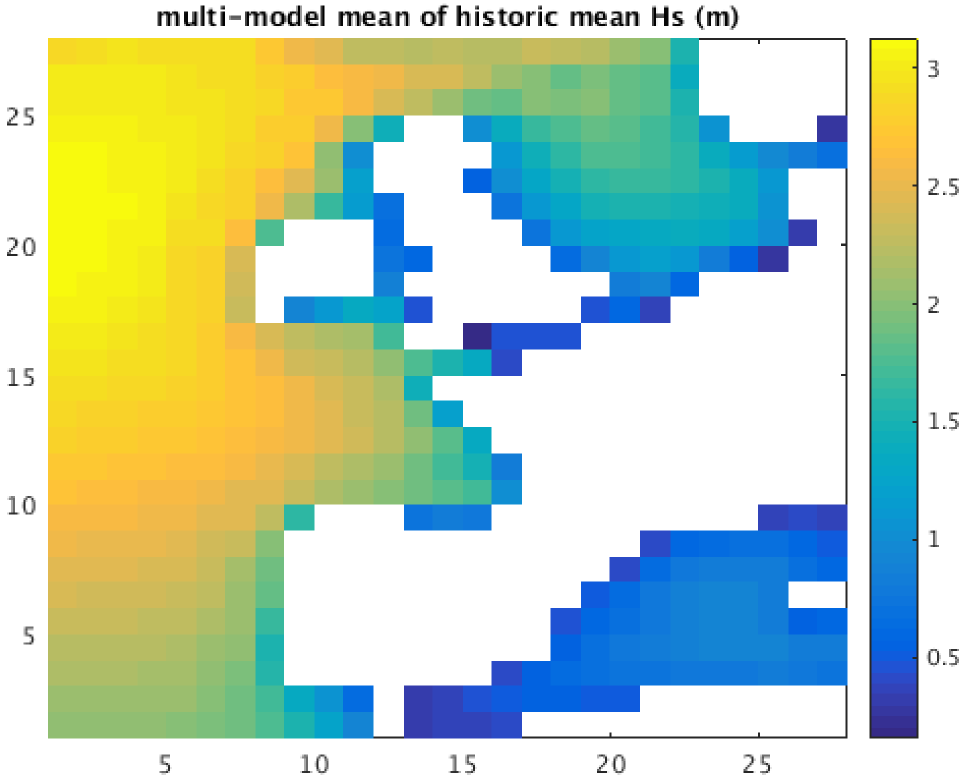
- We focus on significant wave height (Hs) from the CMIP5 modelled data for historic and two future scenarios: RCP4.5 and RCP8.5
- Modelled times
  - ERA Interim (1979 – 2015)
  - Historic climatology (1980 – 2005)
  - Mid-Century (2026 – 2045)
  - End-Century (2080 – 2099)
- The eight CMIP5 models compared are: ACCESS1.0, BCC-CSM1.1, CNRM-CM3, GFDL-CM3, HadGEM2, INMCM4, MIROC5, and MRI-CGCM3.

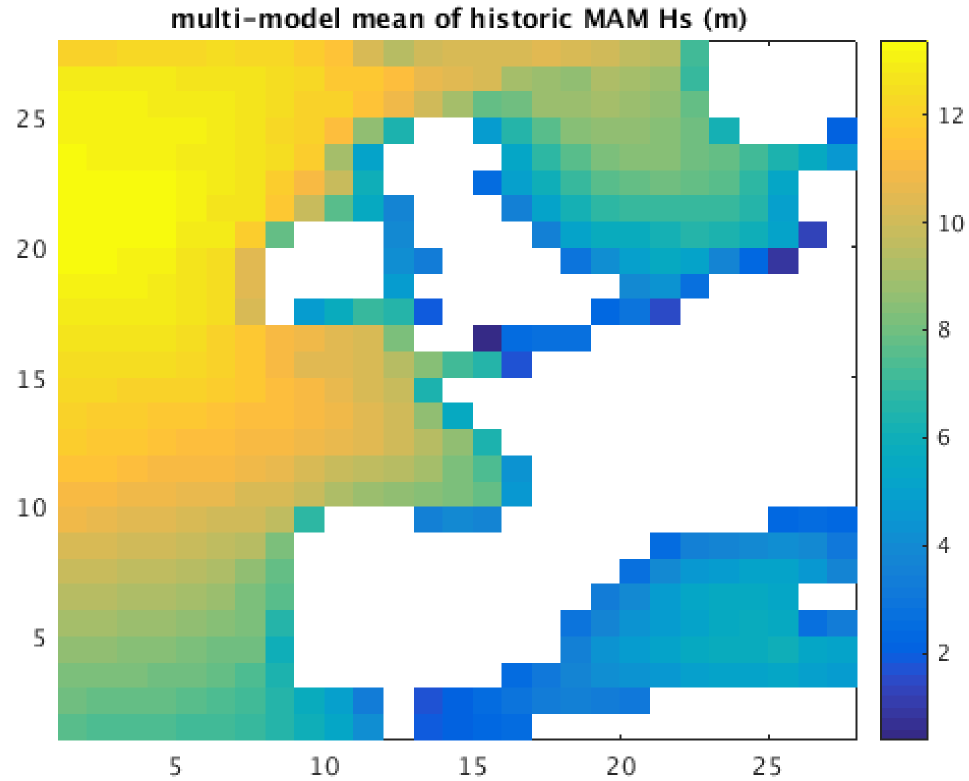
Global Wave models
8 different futures from 8 different methods



- Annual mean wave height (top) ranges from 0 to 4 m. The mean annual maxima (a measure of extreme waves, below) can be larger than 14 m.

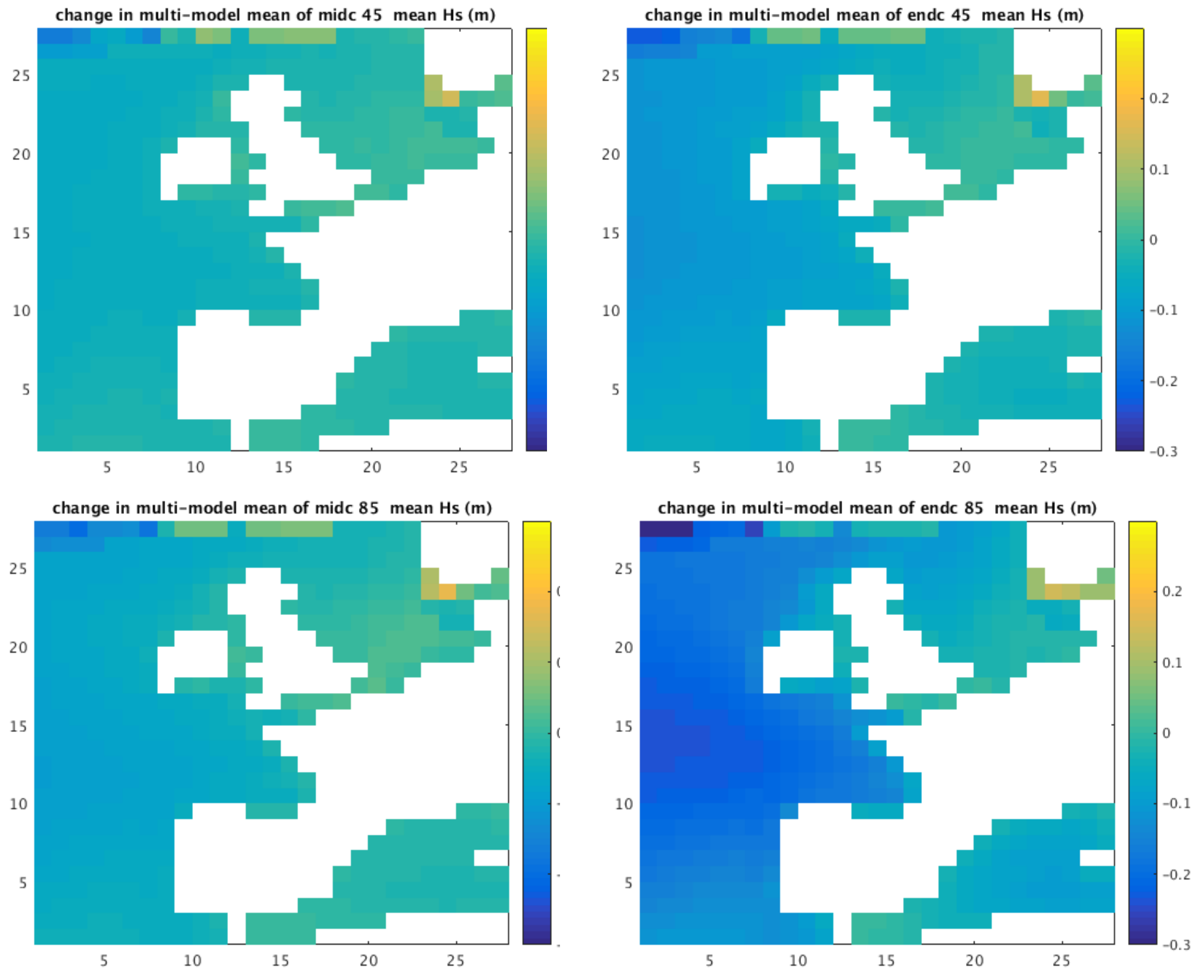
Summarise using multi-model ensemble





20 year average mean wave height from all 8 models (left)
20 year average mean annual maximum wave height from all 8 models (right)
Bias-correction made against the historic period (compared with ERA-Interim)

Future changes: multi-model ensemble - Mean Hs



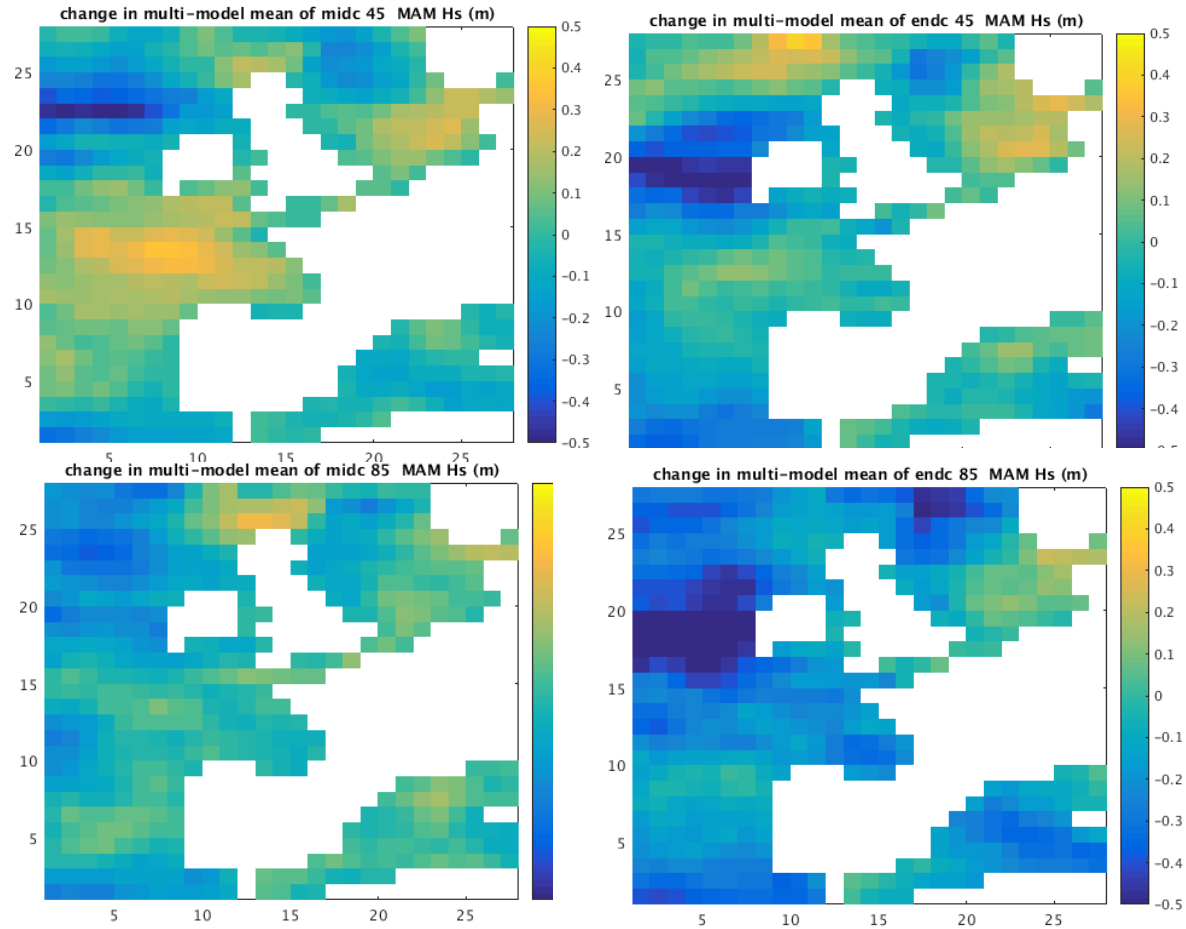
Difference in 20 year average mean wave height from all 8 models

RCP 4.5 (top row) RCP 8.5 (bottom row)

Mid century 2030-2050 (left) End century 2070-2090 (right)

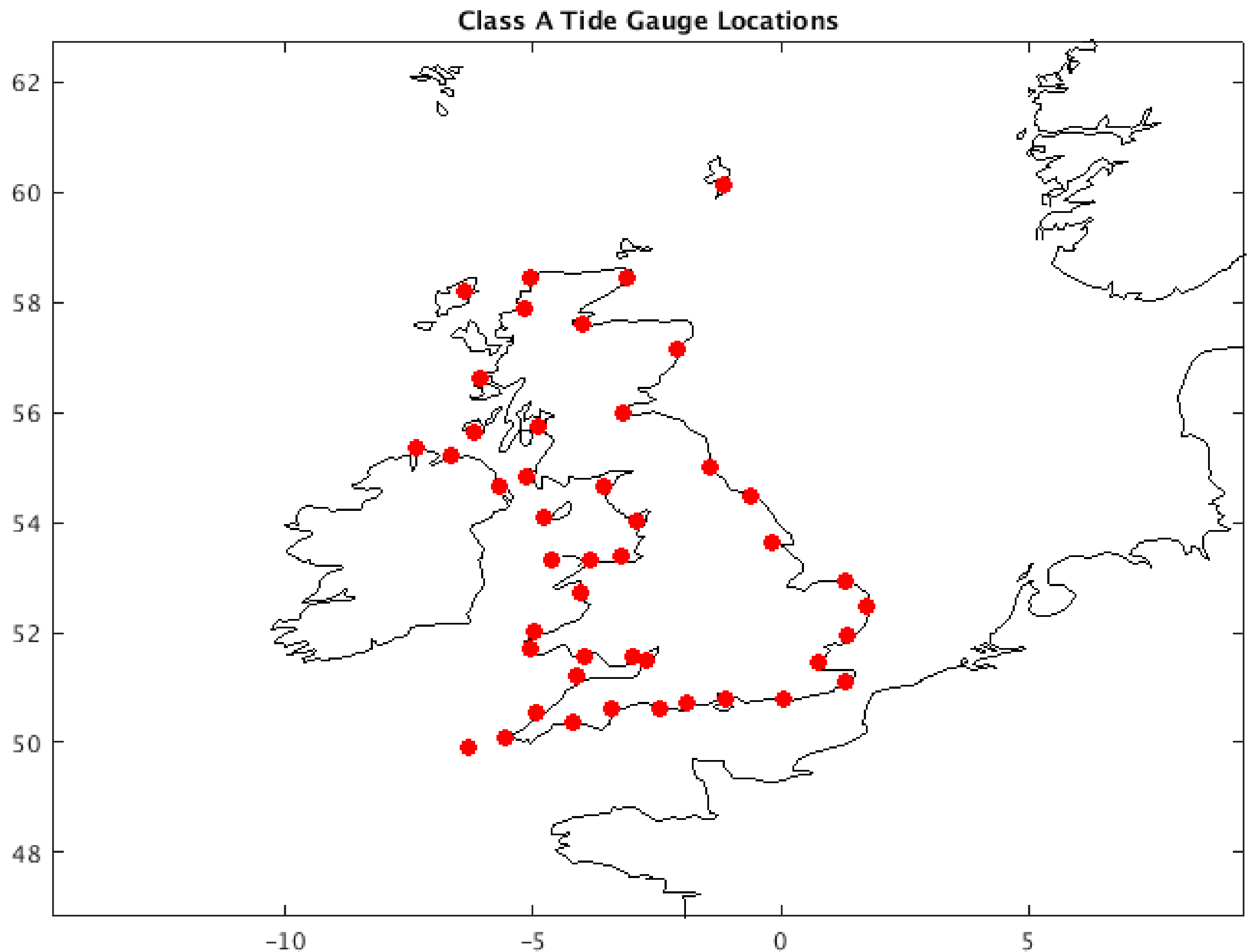
Average wave heights projected to drop by around 20 cm.

Future changes: multi-model ensemble - MAM Hs



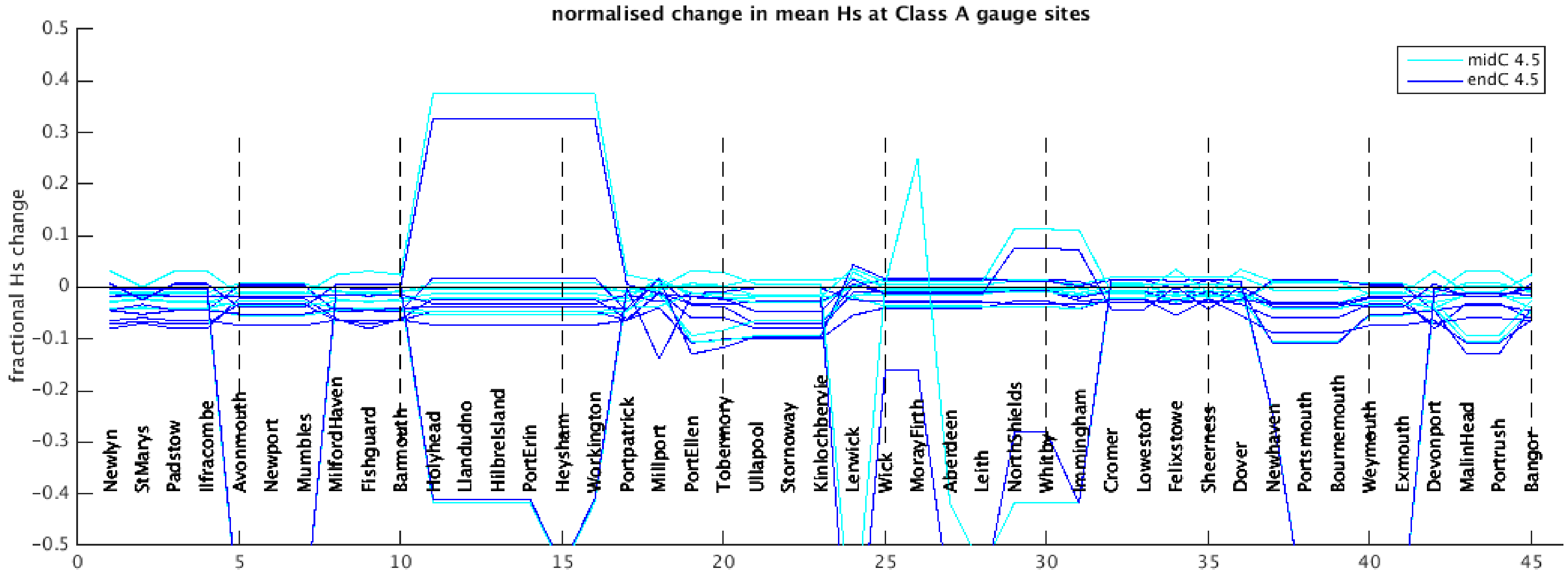
Difference in 20 year average extreme wave height from all 8 models
RCP 4.5 (top row) RCP 8.5 (bottom row)
Mid century 2030-2050 (left) End century 2070-2090 (right)
Extreme wave heights are more complex. Can increase / decrease by up to 50cm

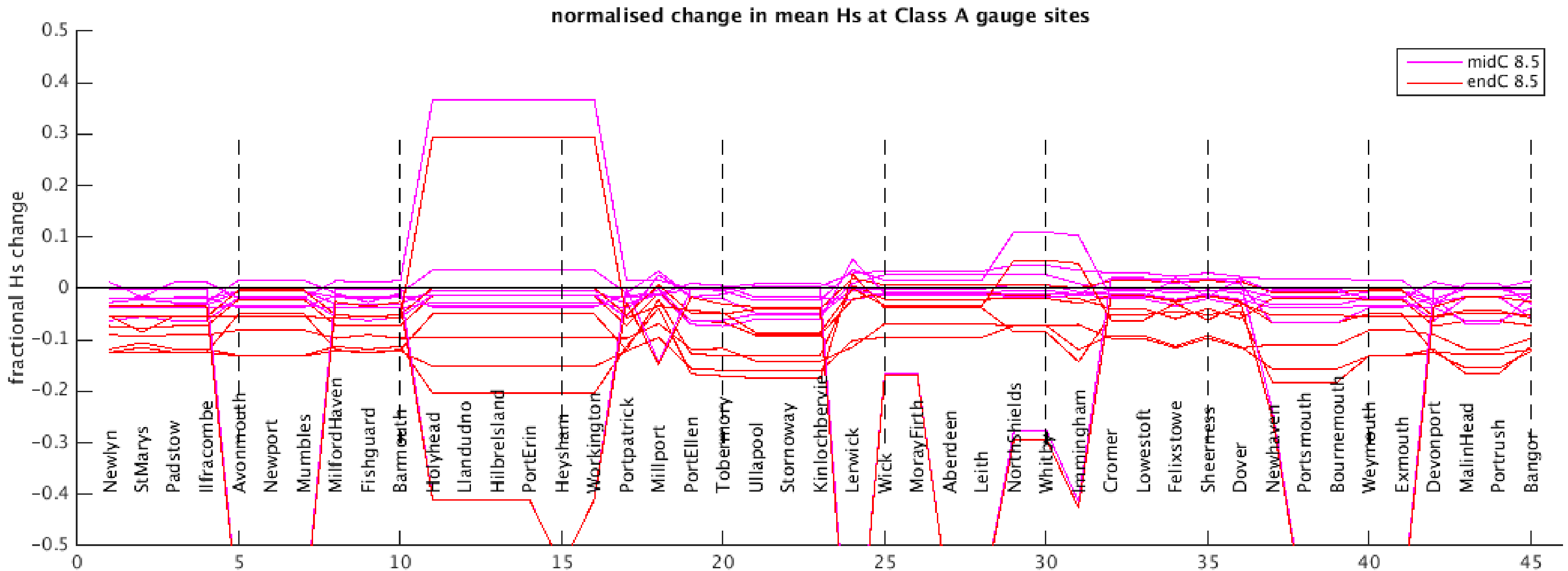
Coastal Specific Projections



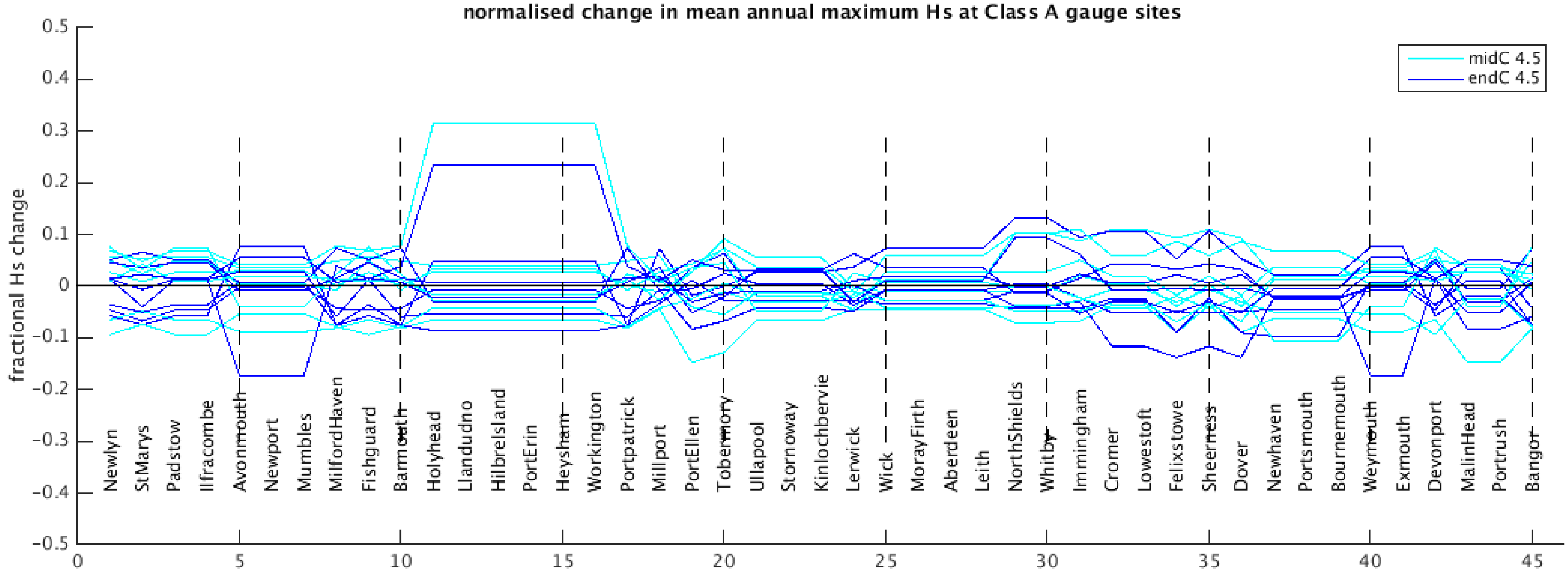
Concentrate only on points of interest – for example, extract data just close to known coastal tide gauges.

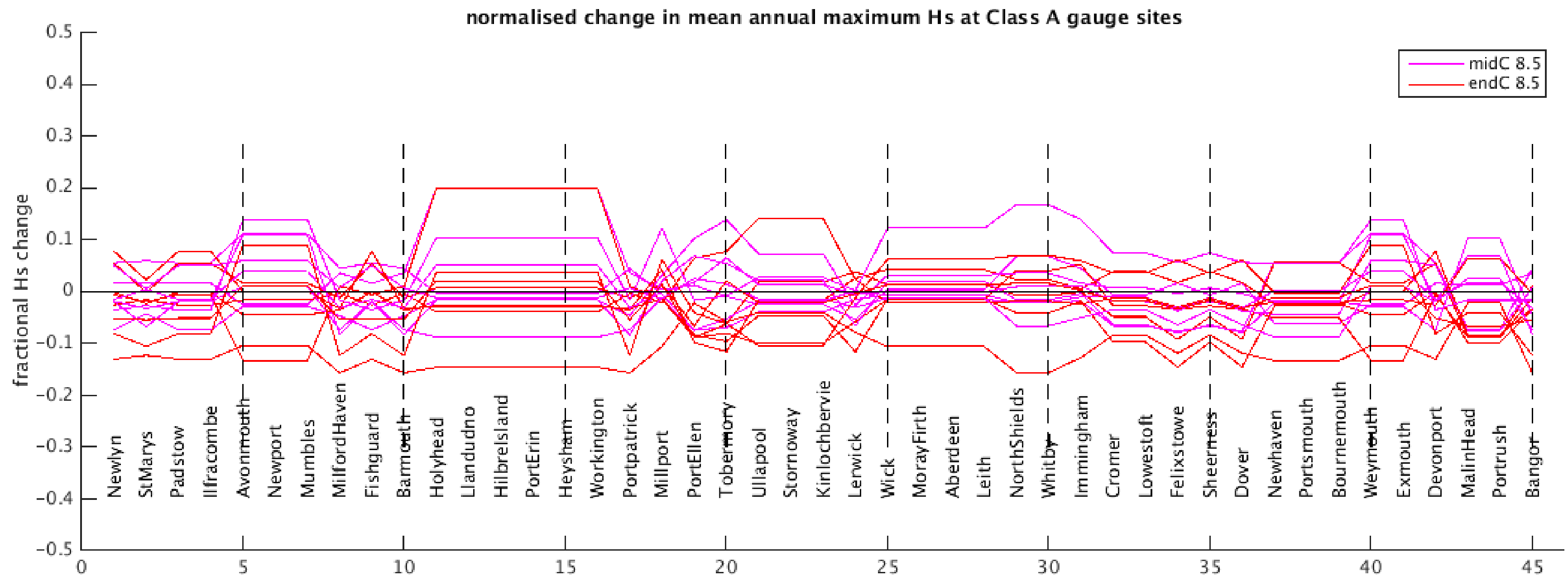
Future projections: Mean



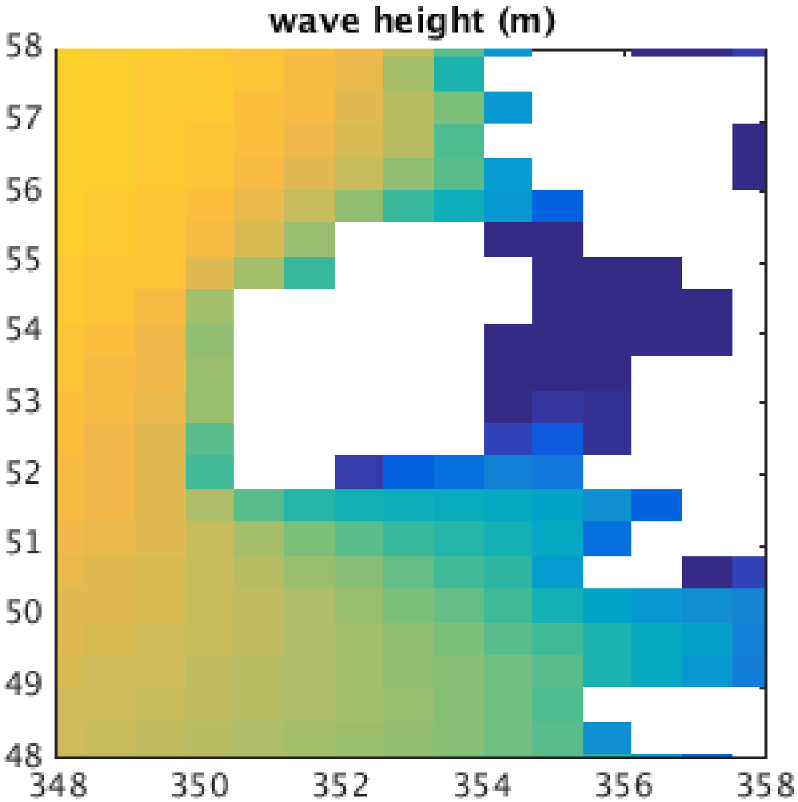


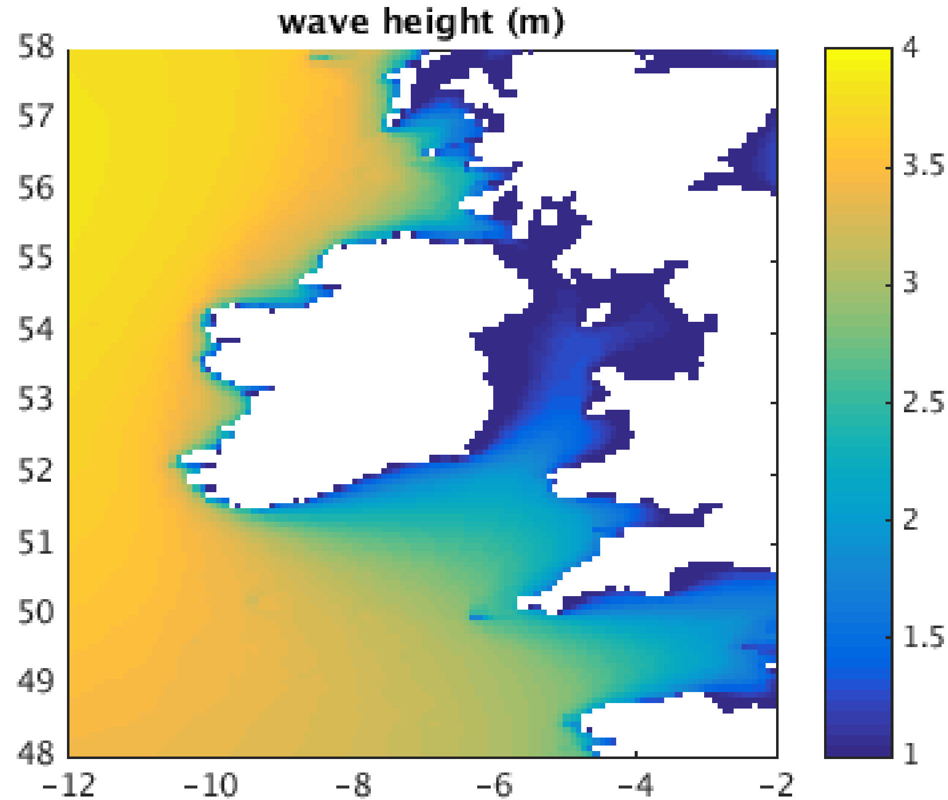
Future projections: Extremes





High resolution European modelling



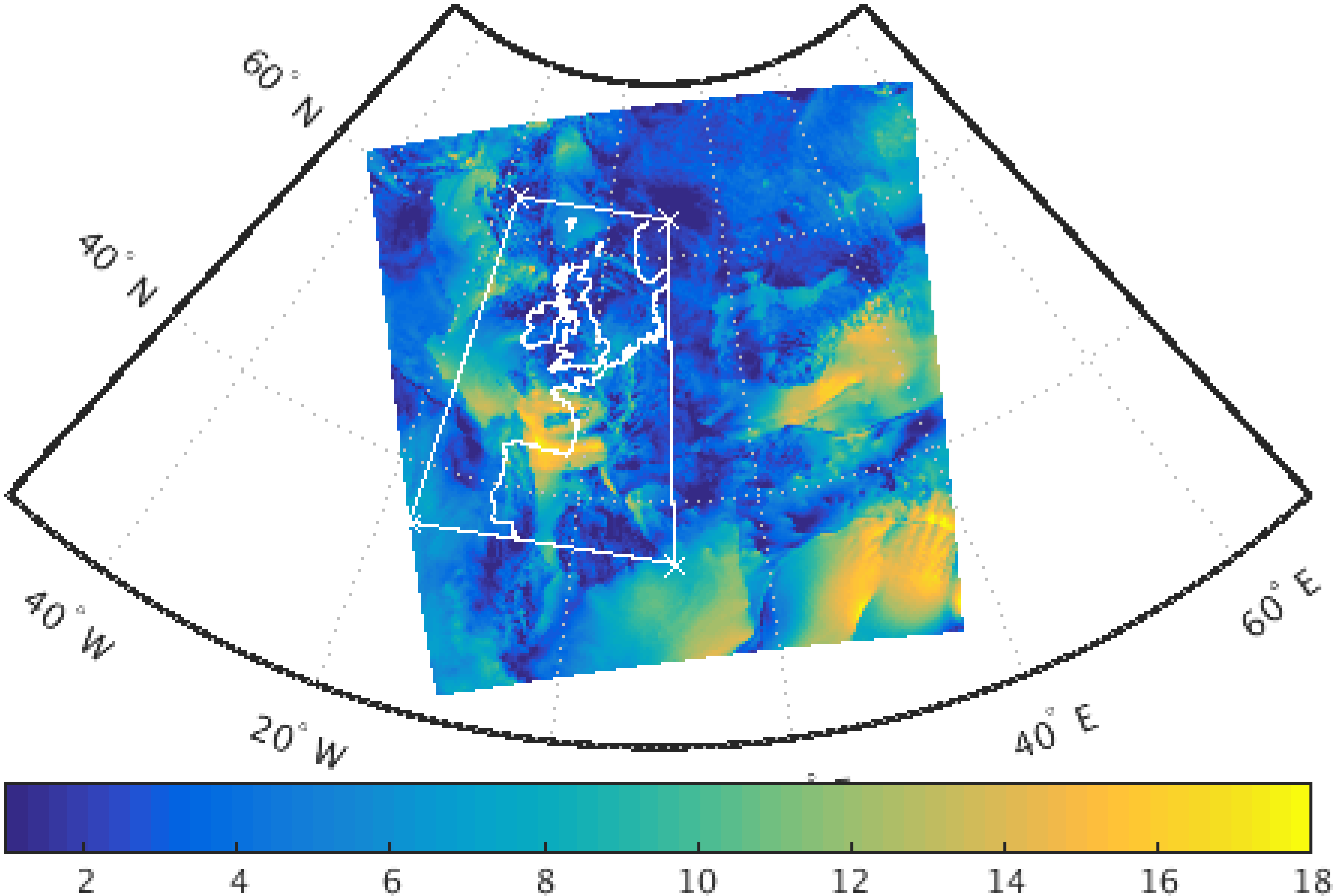


Global model (left) resolution ~ 0.83° High resolution (right) resolution ~ 12km. 30 year means for historic run 1970 – 1999

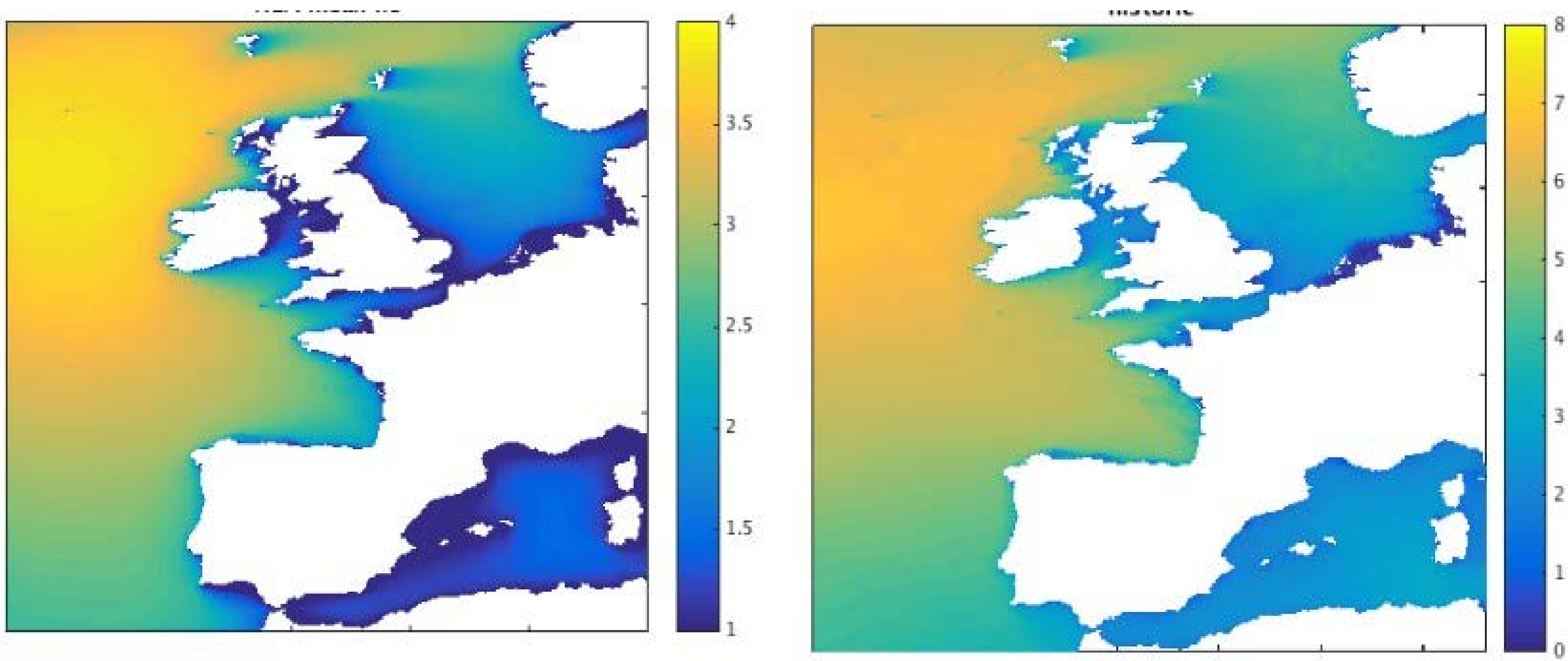
Part 1 - Conclusion

- Combination of ensemble analysis and high resolution downscaling – for context setting, and coastal projections
- A bias correction must be applied to climate-model forced waves, for a consistent historic climate, before changes are analysed
- The Global model ensemble projections suggest an overall decrease in mean Hs, and a large degree of uncertainty in mean annual max.

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

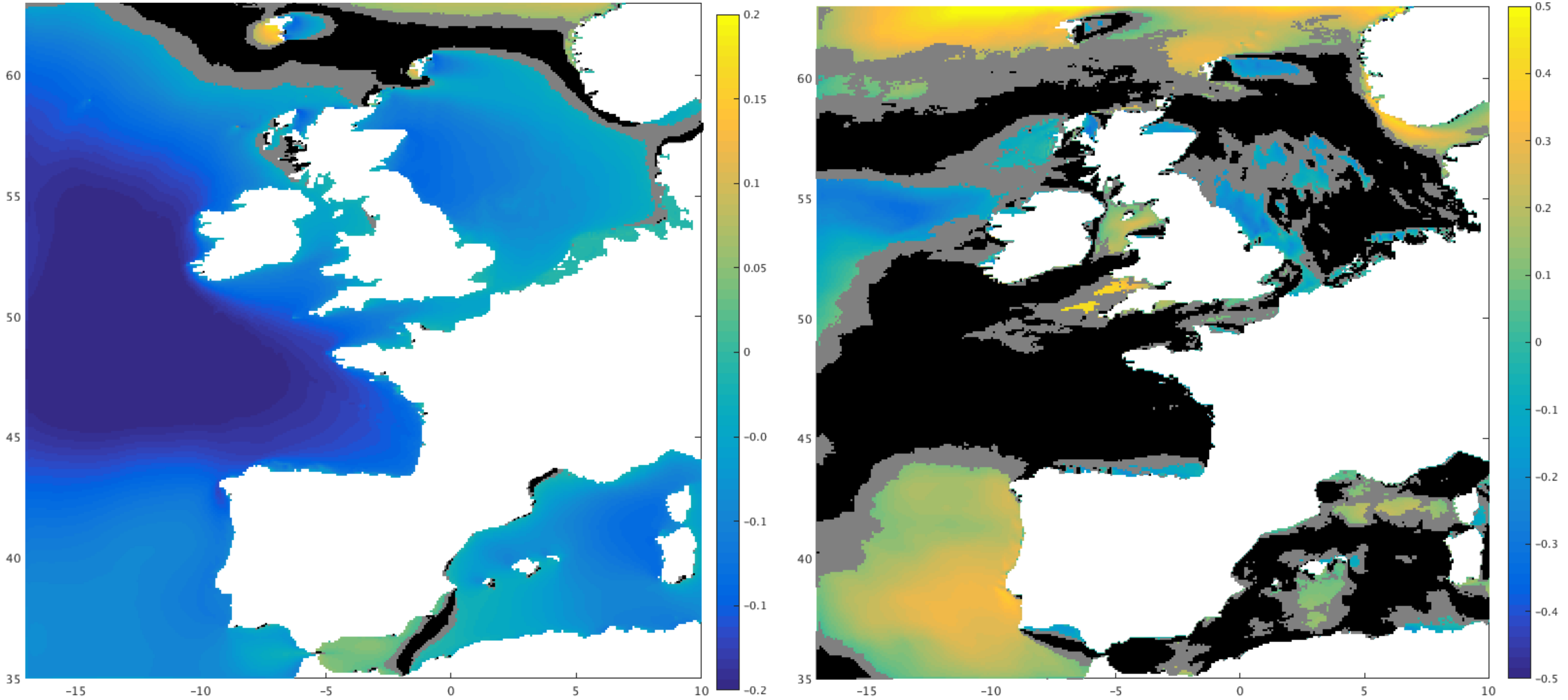


Mean and extreme wave climate



- Mean Hs (left) varies between 0-4 m.
- Mean annual maximum Hs (right) can be as large as 8 m.

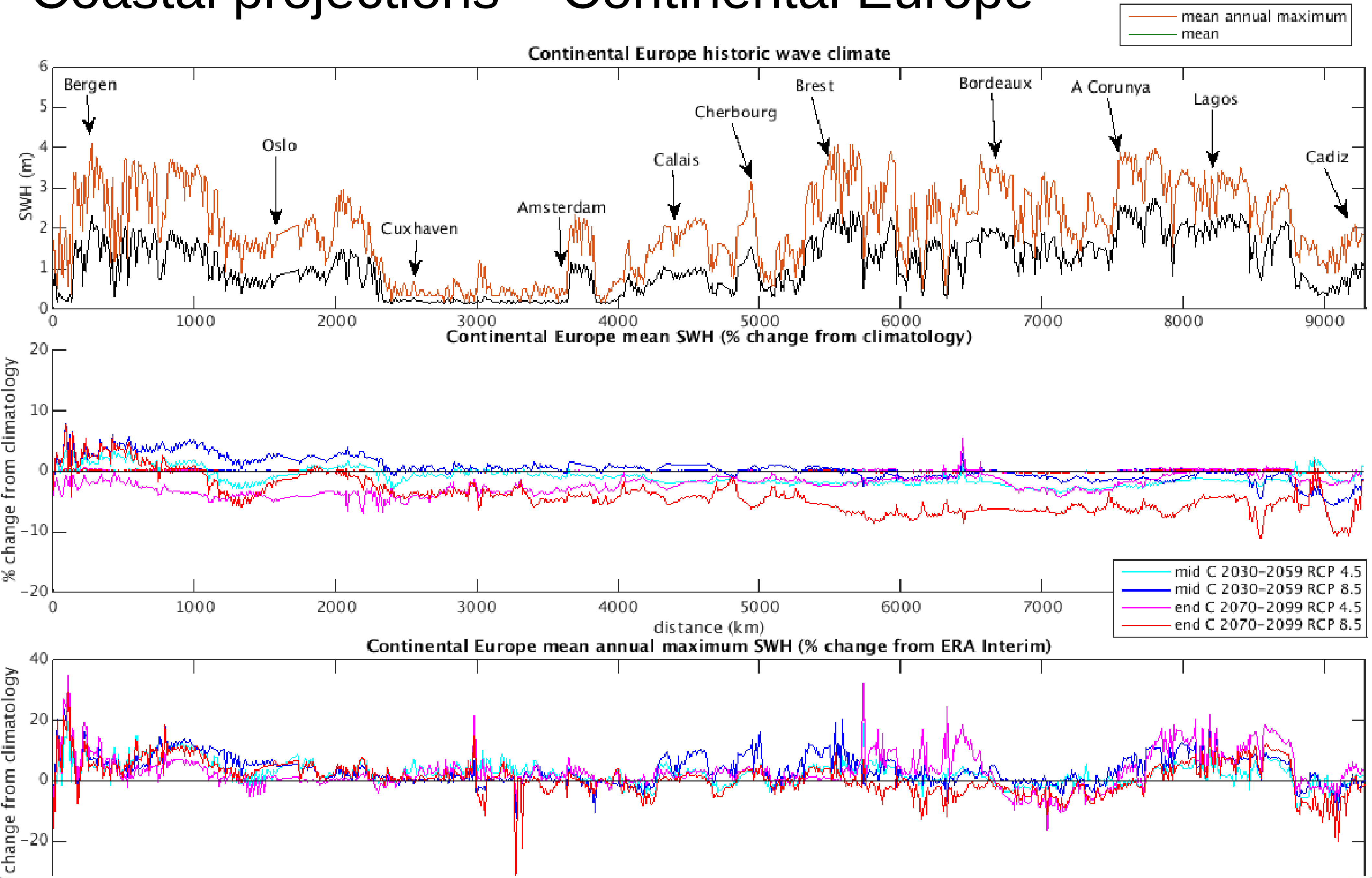
Future changes in mean and mean annual maximum Hs
End century, RCP 8.5



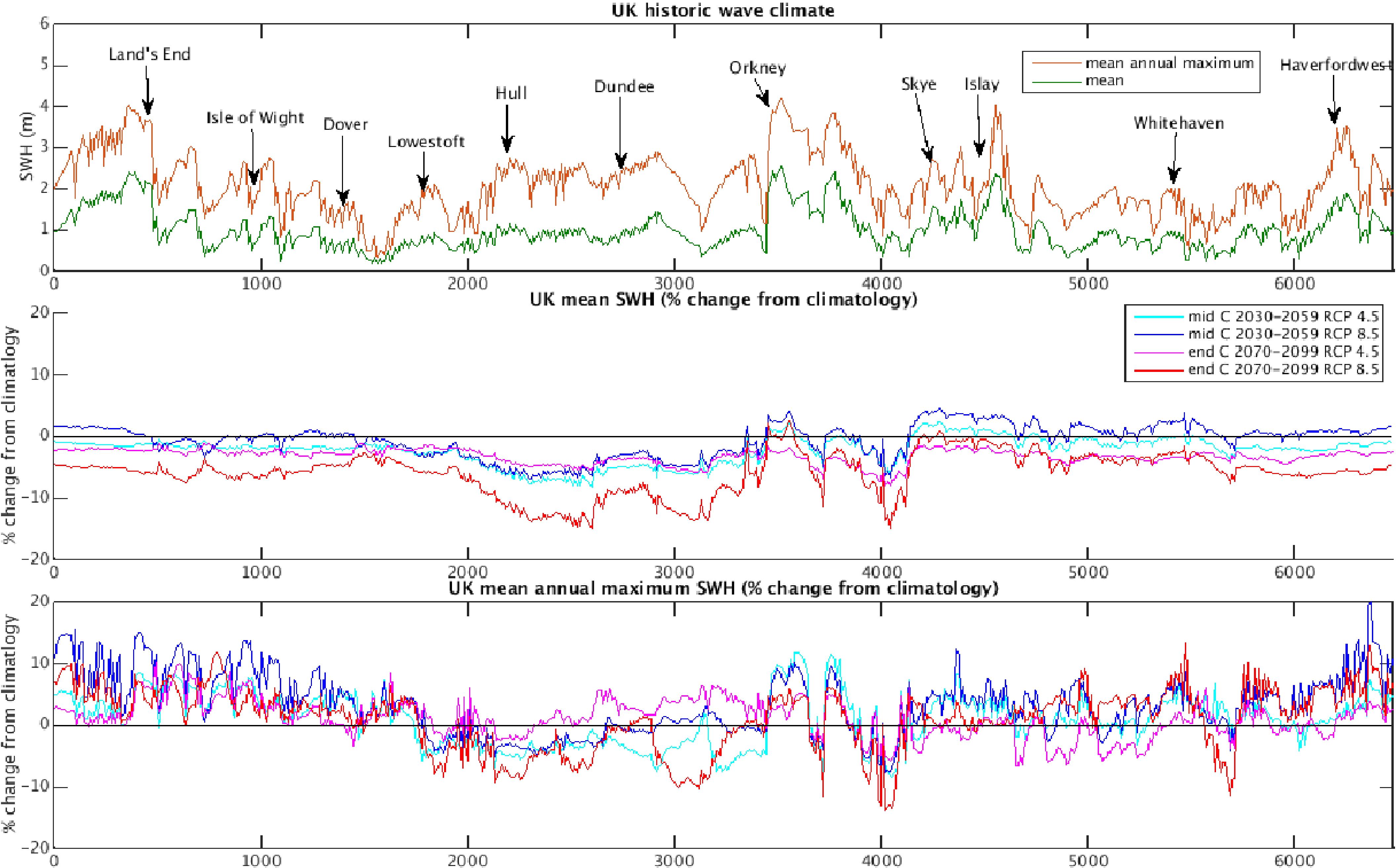
Left: future mean wave height projected to decrease (up to 20 cm in places).
Right: future mean annual maximum more complex, with increase /decrease~ 50 cm

Shading indicates areas of low confidence (<75% grey, <50% black)

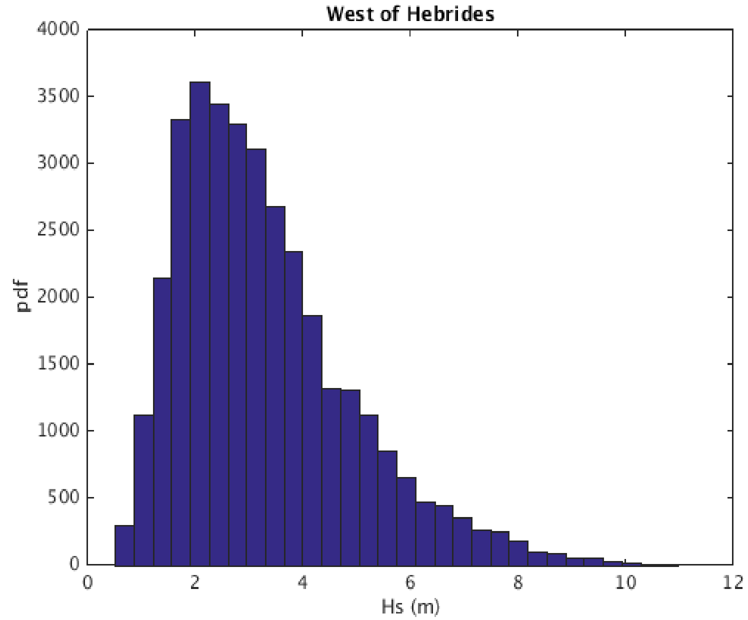
Coastal projections - Continental Europe



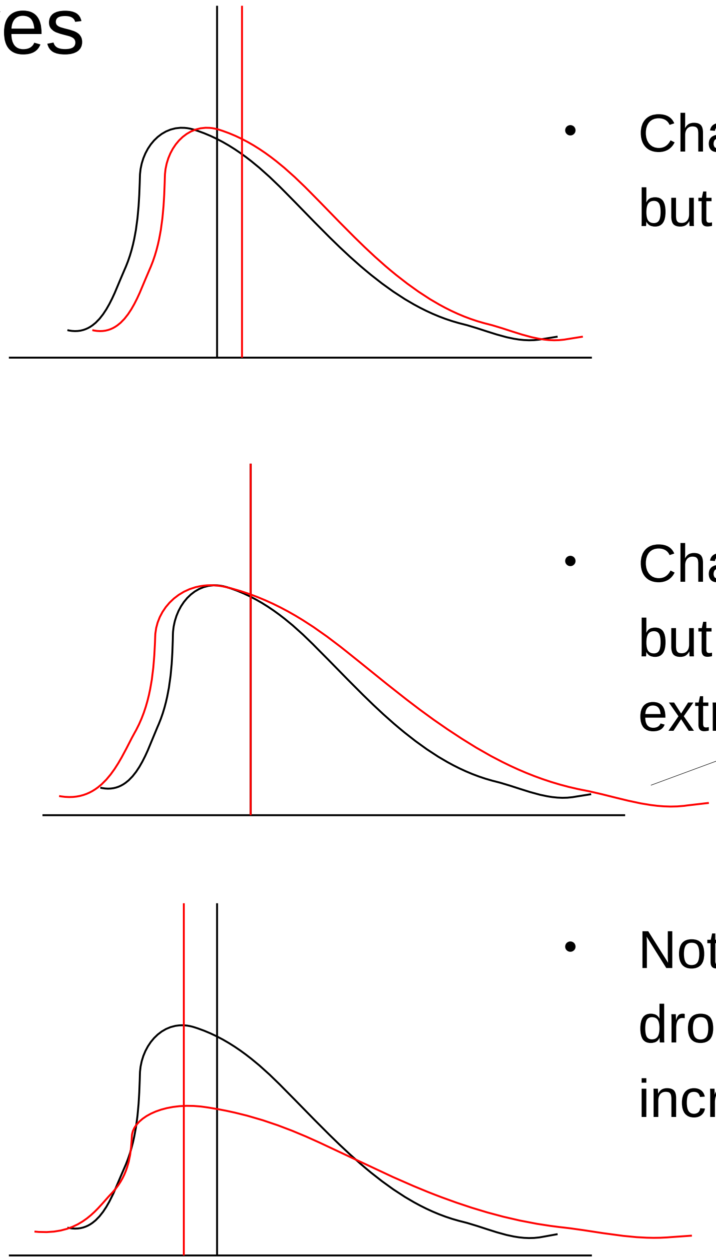
Coastal projections - UK



Changing extreme waves

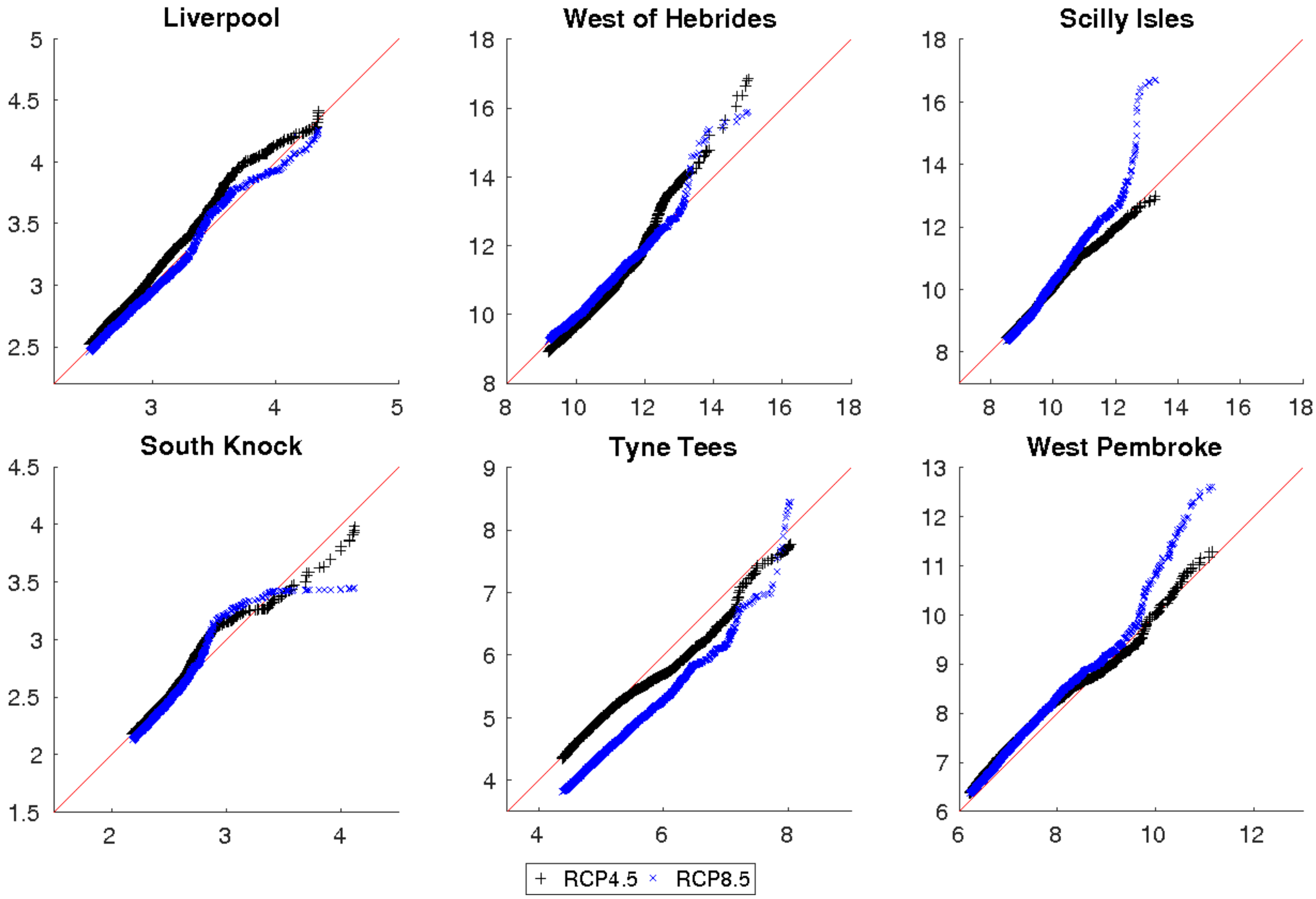


Example data set from the ERA Interim run



- Changing mean, but not shape
- Changing shape, but not mean. N.B. extremes
- Note mean can drop, but extremes increase

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.

Part 2 - Conclusion

- High resolution winds, bathymetry, and geometry give an improved results at the coast for the ERA-Interim forced validation period.
- Mean wave height seen to decrease across most of Europe (exception is in the North - suggesting decreased sea-ice cover)
- Mean annual maximum waves are heterogeneous and more uncertain. Statistically robust positive & negative changes are seen of up to 50cm.
- Projections in Atlantic facing coasts are more robust. In semi-enclosed seas there is more uncertainty.
- The shape of the distribution, especially the tails must be changed in order to captured future extreme waves

Acknowledgements

- This work was funded through a NERC Knowledge Exchange Fellowship RC Grant reference: NE/P01321X/1 and Grant Agreement No: FP7-ENV-2013-Two-Stage-603396- RISES-AM-.

- The work is in line with UKCP18, a follow-up of UKCP09 and earlier projects

- We acknowledge the World Climate Research Programme's Working Group on Regional Climate, and the Working Group on Coupled Modelling, former coordinating body of CORDEX and responsible panel for CMIP5.

- **The Coordinated Ocean Wave Climate Project (COWCLIP)** provides a set of wave climate projections. This community-based framework, inter-comparison project provides data for wave climate projections forced from CMIP5 datasets. The dataset is summarised in Hemer et al. (2015)

- We also thank **Grigory Nikulin of SMHI** for making available their model output. We also acknowledge the Earth System Grid Federation infrastructure, an international effort led by the U.S. Department of Energy's Program for Climate Model Diagnosis and Intercomparison, the European Network for Earth System Modelling and other partners in the Global Organisation for Earth System Science Portals (GO-ESSP).

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Thanks for your attention

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