"GREY SWAN" EXTRA-TROPICAL STORM SURGES POSE A GREATER IMMEDIATE RISK FOR EUROPEAN FLOODING THAN CLIMATE CHANGE

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15 NOVEMBER 2019

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(NERC AWARD NE/P009158/1)

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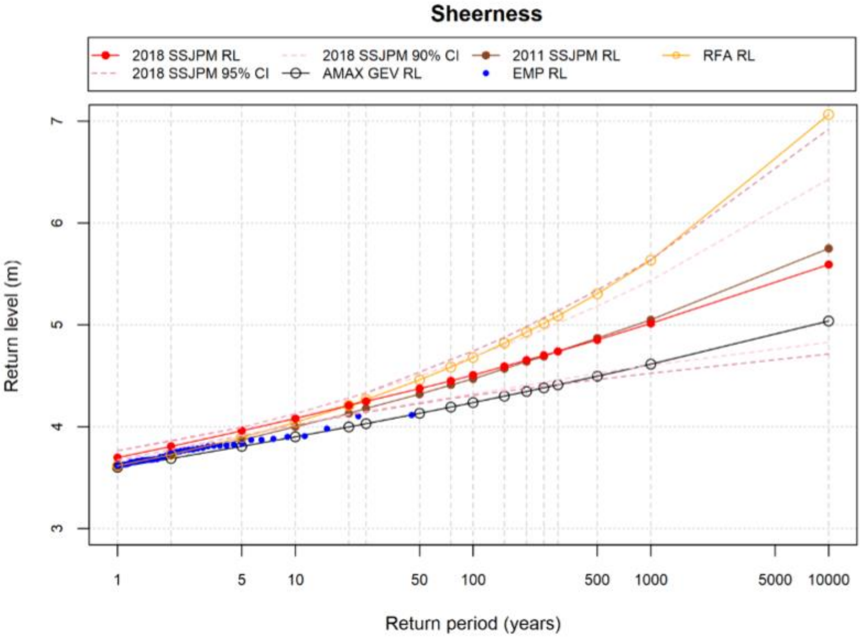
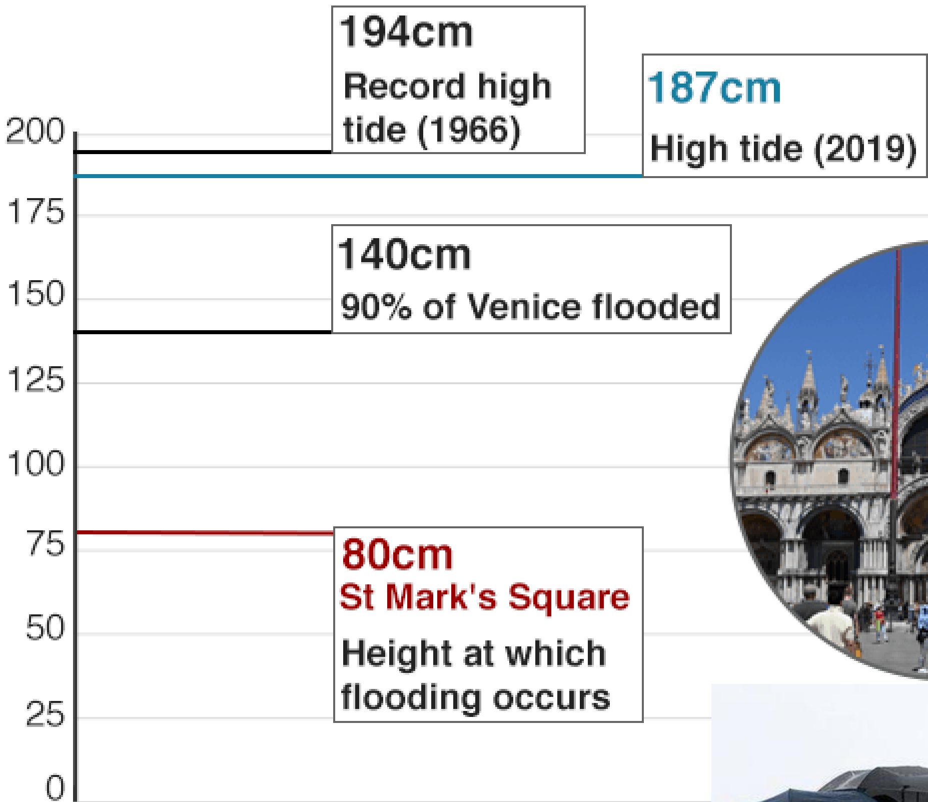
Our findings highlight that the natural variability of weather could be as important as mean sea level change in driving coastal extreme sea levels over the next century. We use “grey swan” as a metaphor for a high-consequence event that we might expect on the grounds of natural variability, is physically credible, but is not in our data record.

Lin, N, and K. Emanuel (2015) Grey swan tropical cyclones. Nature Climate Change, doi 10.1038



Whilst our current record of sea level from tide gauges is fairly long, it is arguably not long enough to derive robust statistics of the most extreme storm surges (statistics of extreme sea levels contain a high level of uncertainty)

Venice floods as tides approach record levels



Source: Venice city council/ Image: Getty

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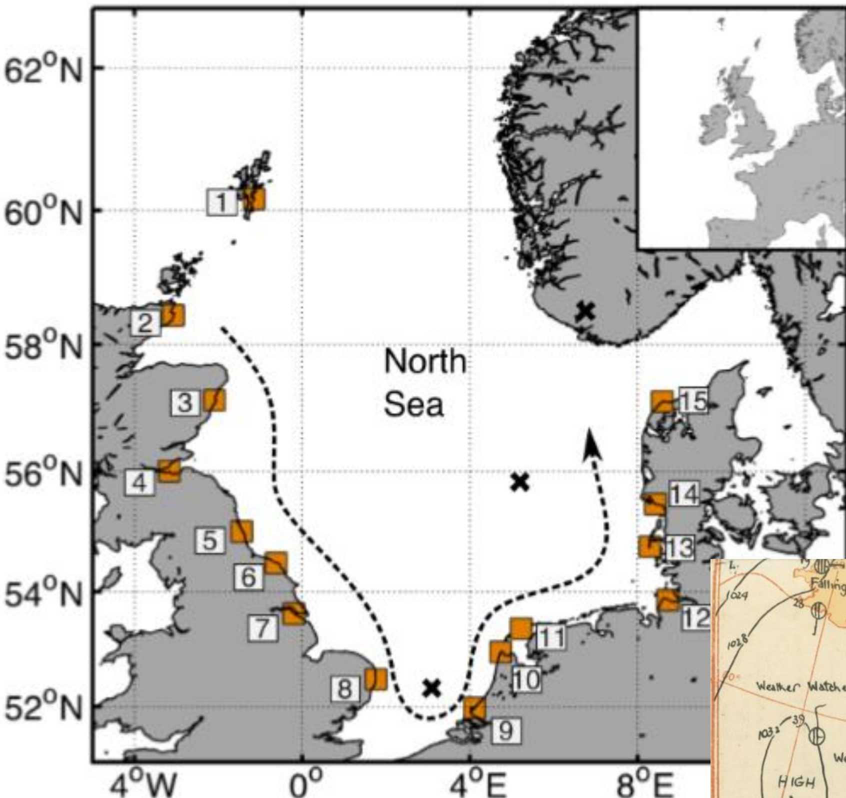
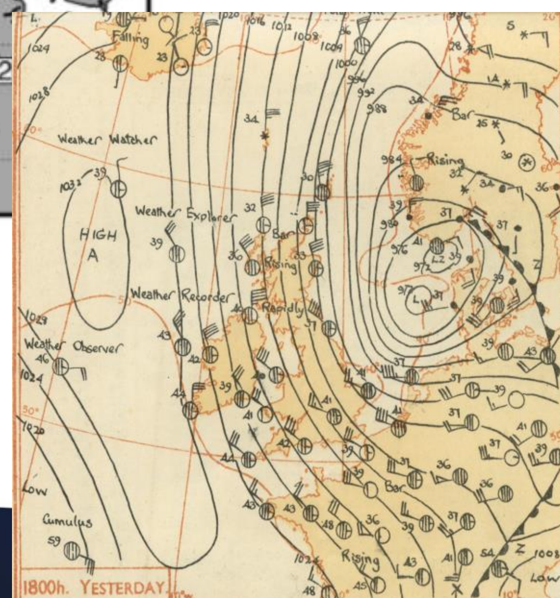
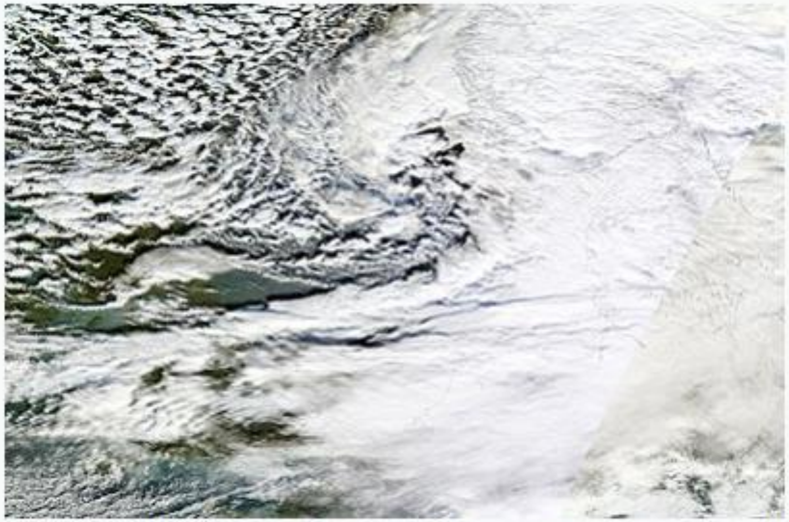
For the East Coast of the UK, there are two noteworthy storm surges where serious consequences and damage occurred: 31 Jan-1 Feb 1953 and 5-6 December 2013 due to Storm Xaver.





Cyclone Xaver



Xaver making landfall over Norway and Denmark on 5 December 2013.

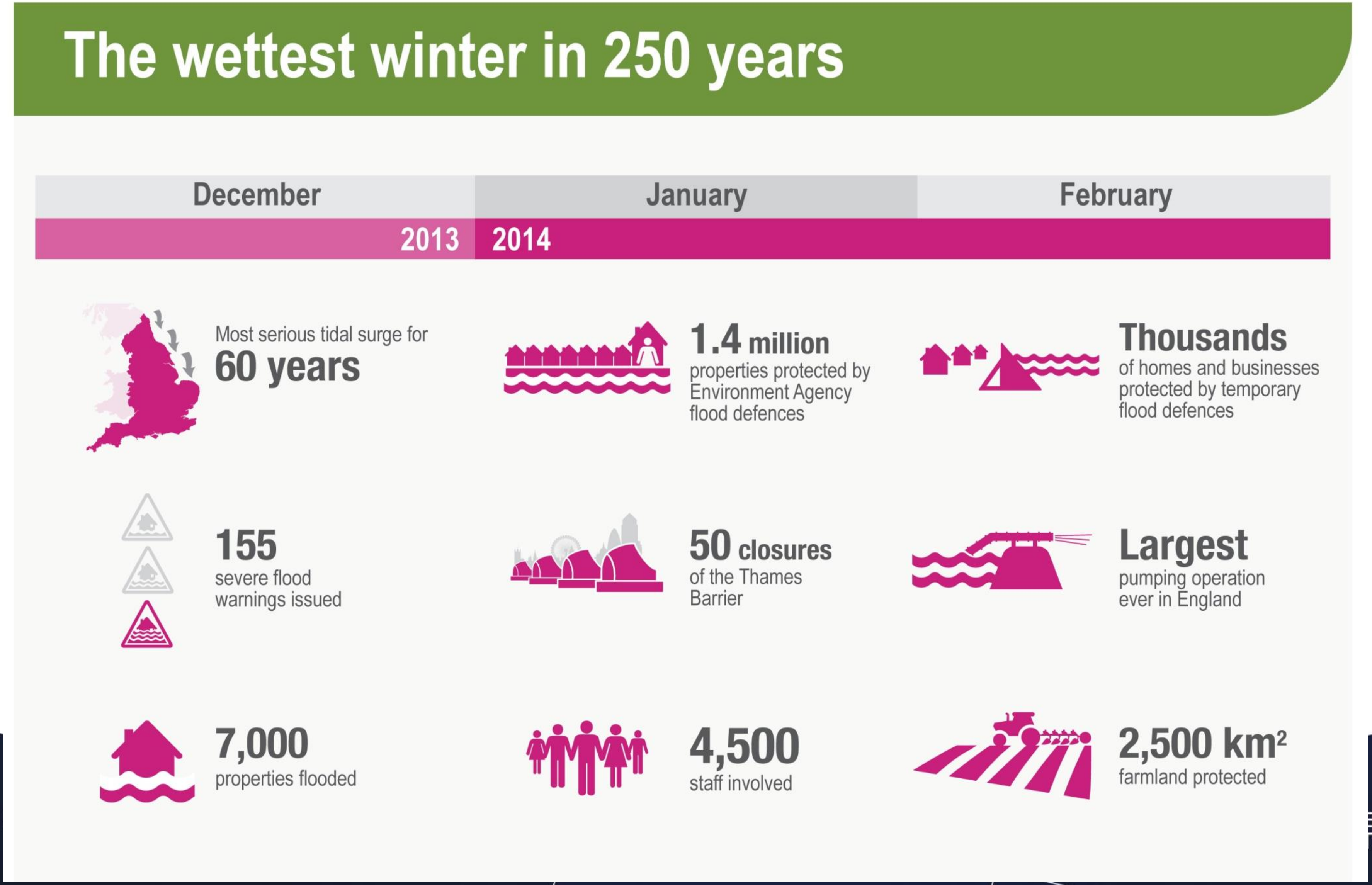
Type	European windstorm, extratropical cyclone, winter storm
Formed	4 December 2013
Dissipated	10 December 2013
Lowest pressure	962 mb (28.41 inHg)
Highest winds	81 mph (130 km/h), Nissum Fjord, Denmark
Highest gust	142 mph (229 km/h), Aonach Mòr, Scotland, U.K. [1]
Casualties	15

Cyclone Xavier

Aqua Modis satellite view of Xavier crossing Germany and Poland on 5 October 2017.

Type	European windstorm
Formed	4 October 2017
Dissipated	6 October 2017
Lowest pressure	985[1] mb (29.09 inHg)
Highest gust	202 km/h (126 mph), (Mountain value) Sněžka, Czech Republic[2]
Beaufort scale	10–12
Casualties	9 (7 Germany, 2 Poland)[3]
Areas affected	Germany Poland

Coastal flooding over the winter of 2013/2014 cost the UK £2.5 billion.



Since the storm surge during the 5-6 December 2013 event gave rise to extreme sea levels in several parts of the UK that were the highest ever recorded, it begs the question could small perturbations to that weather system create a more severe storm capable of generating an even larger storm surge.

We used the December 2013 storm (Xaver) as our baseline and then applied a number of small modifications to the weather system using a forecasting tool (NWP grid editing tool) developed at the UK Met Office. This allowed us to change the speed of movement of the storm, its central pressure (and hence associated wind fields), and its direction of travel – whilst maintaining the key physical properties of the storm system.

Adjustments were guided by a detailed analysis of all North Atlantic weather systems since 1950, that led to large storm surges in the North Sea. The storm surge and wave models used were those run operationally by the Met Office in the UK

NWP grid editing tool

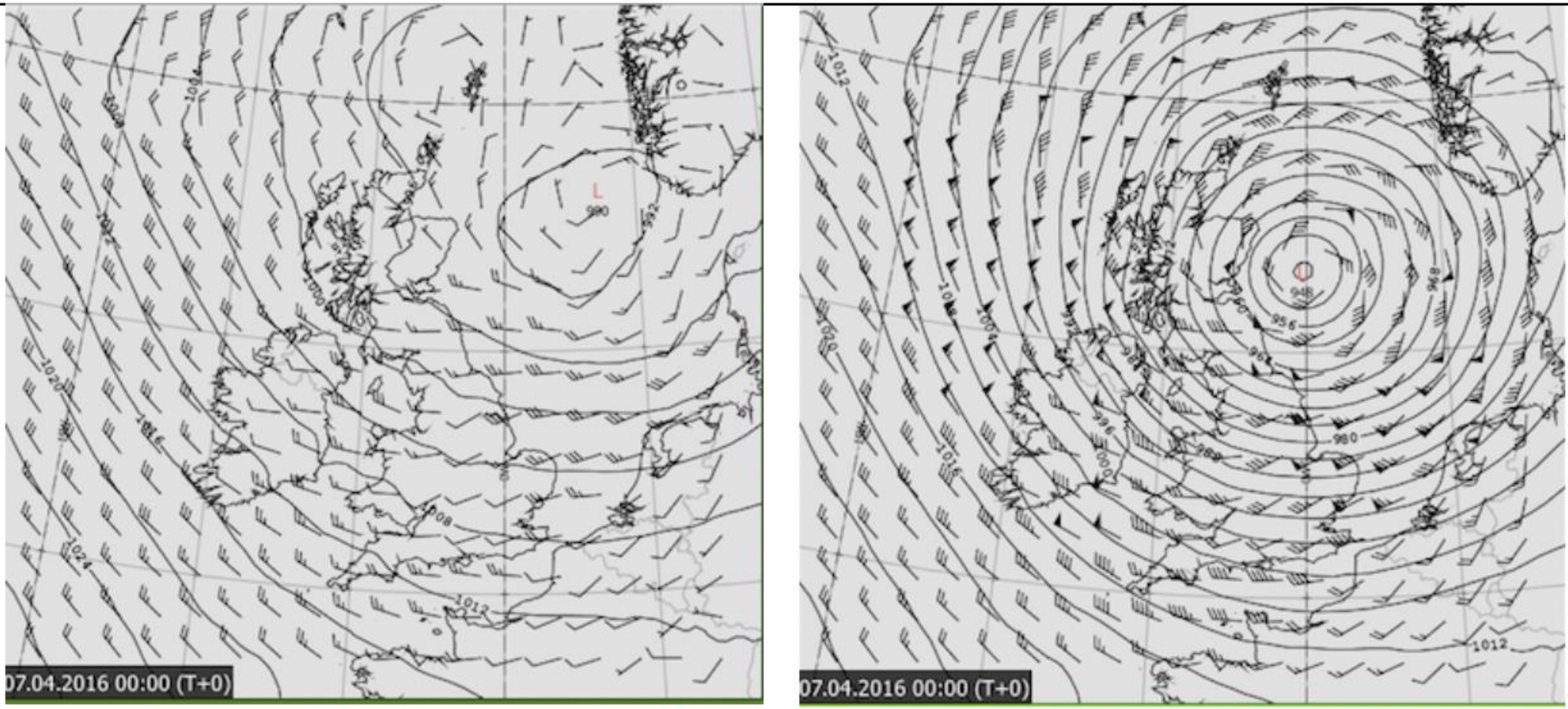
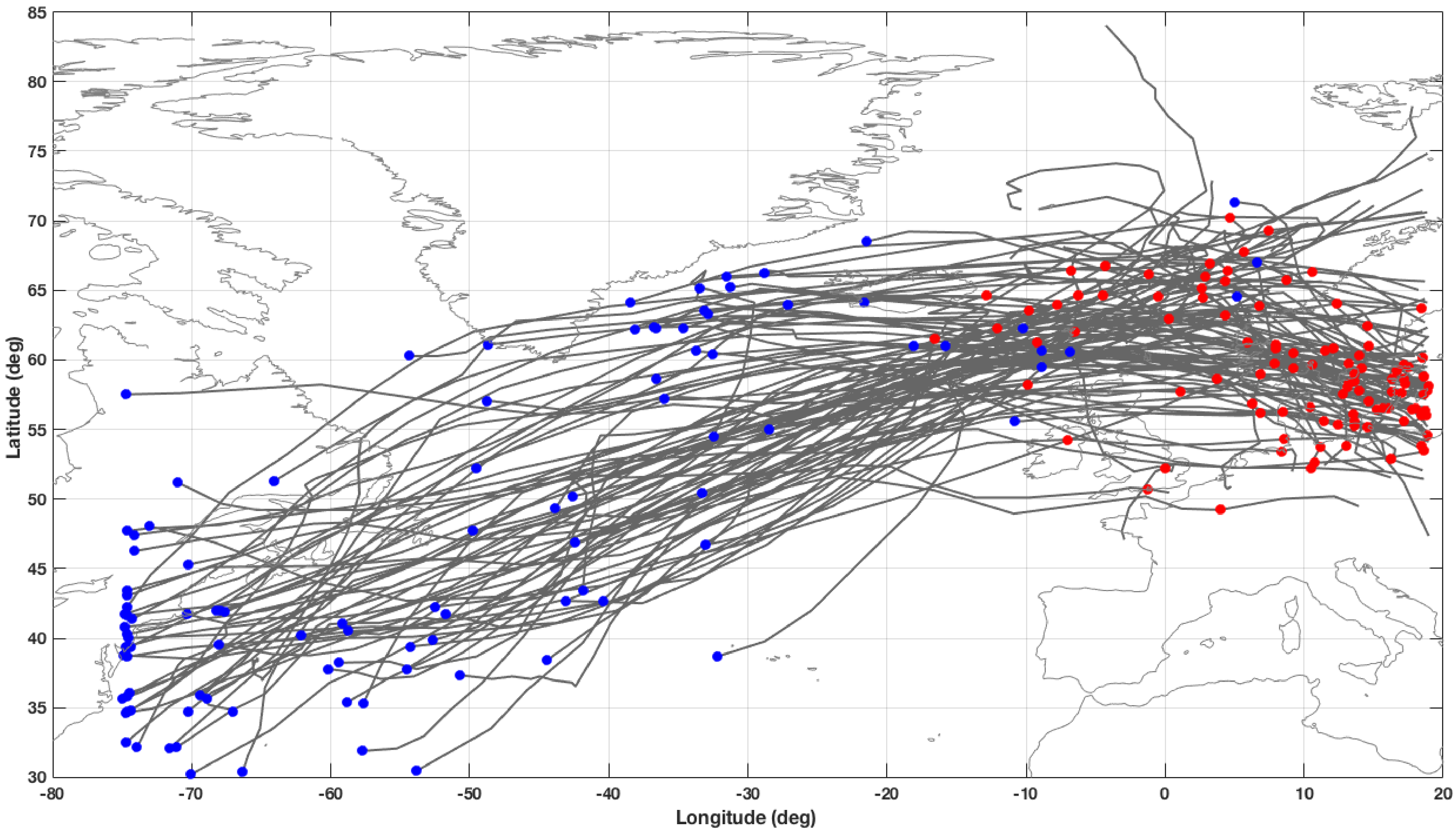


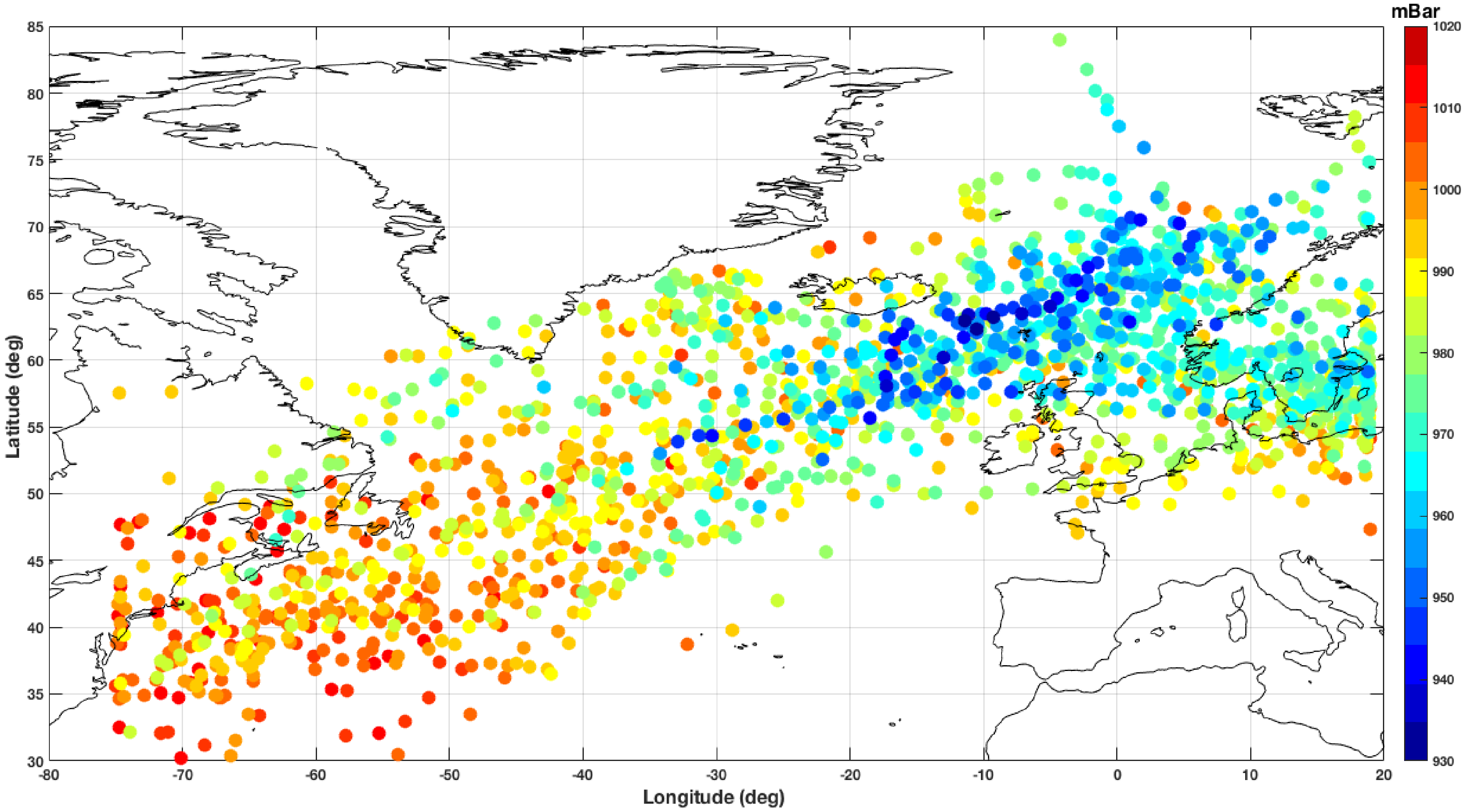
Figure 2. Unmodified (left) and modified (right) synoptic charts using the NWP Grid Editing tool

Carroll, E.B., and T.D. Hewson (2005) NWP grid editing at the Met Office, Weather and Forecasting, 20, 1021-1033

Tracks of the 113 storm events (NCEP/NCAR)



Minimum atmospheric pressure



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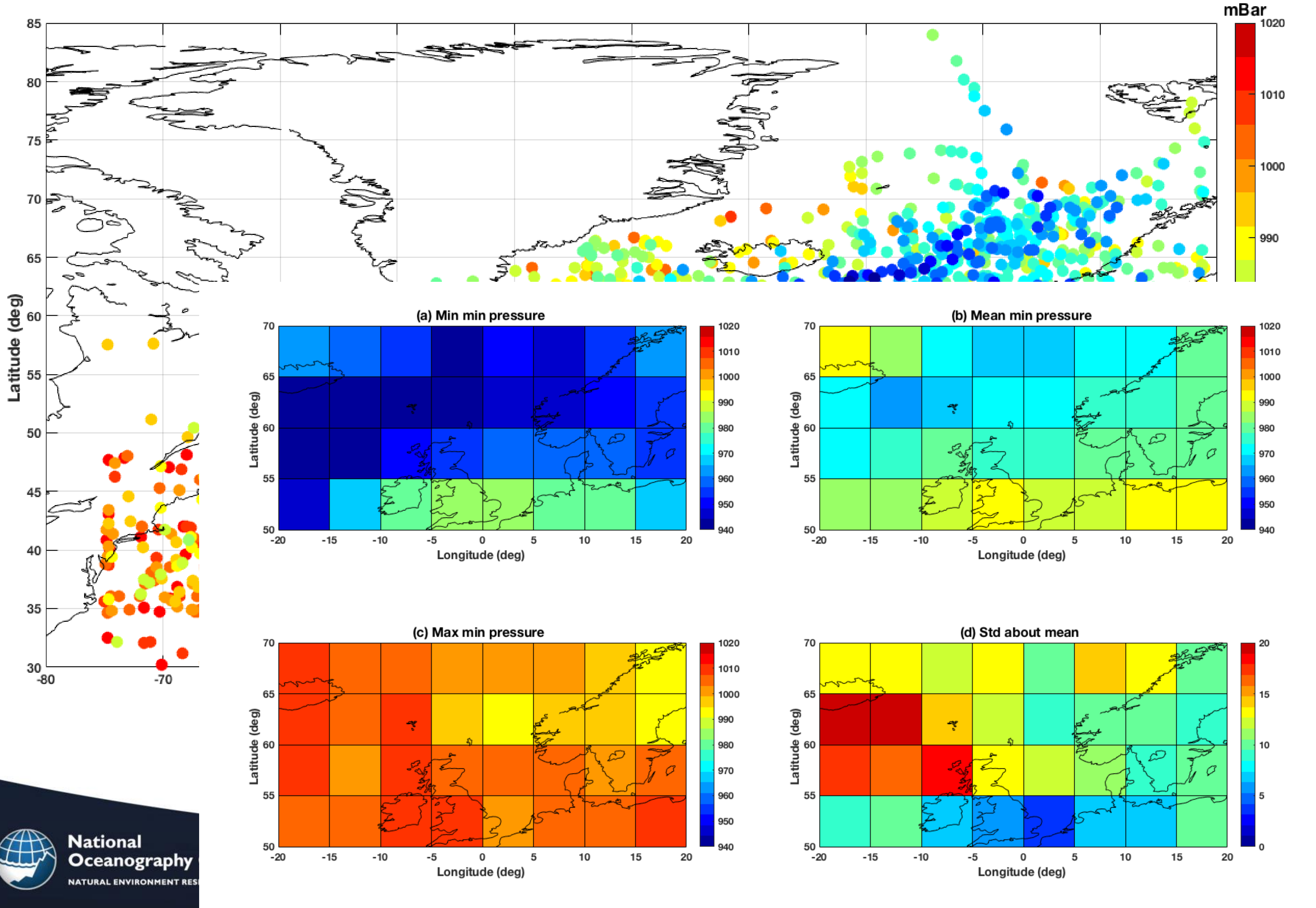
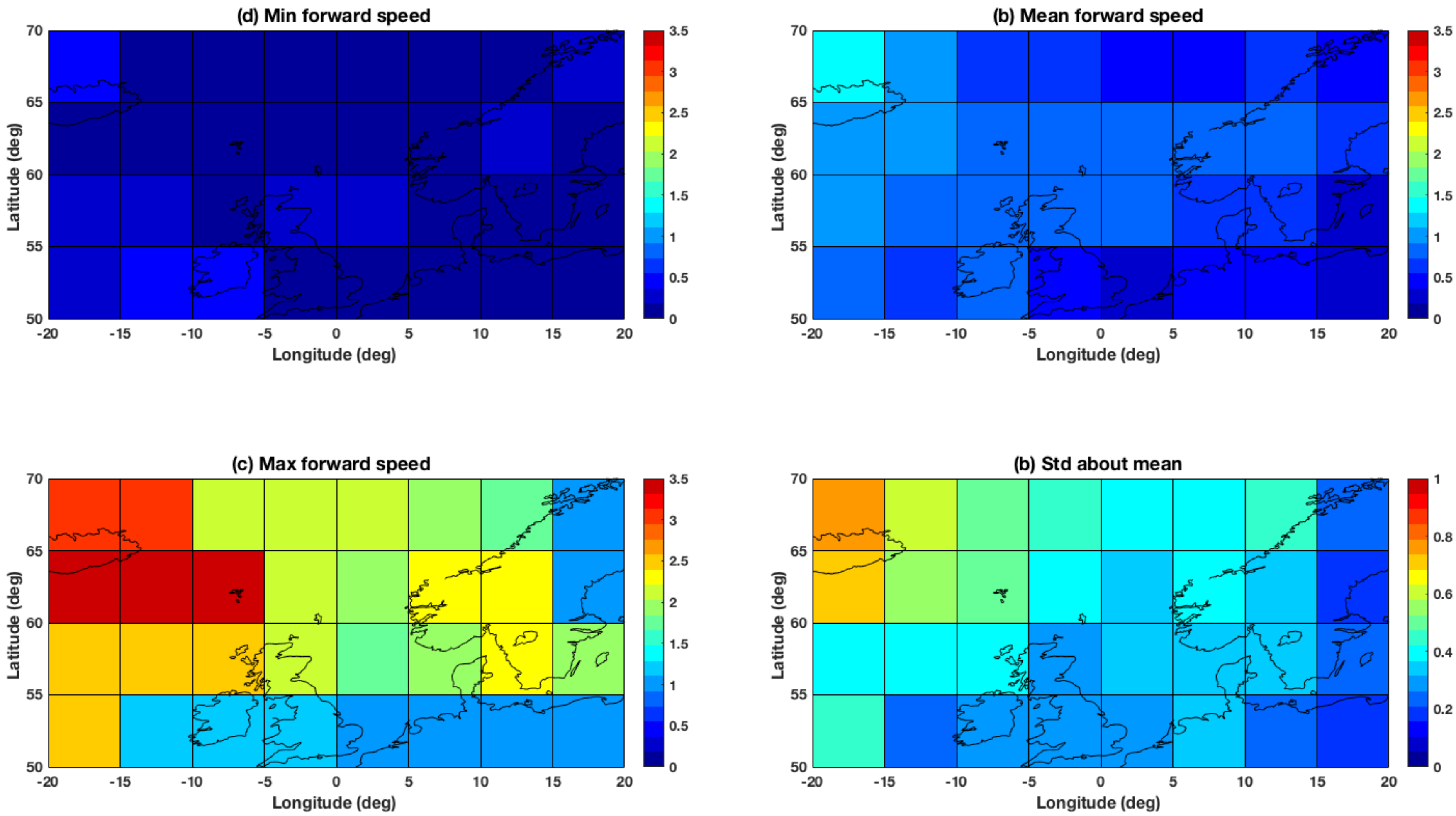


Gridded Forward Speed

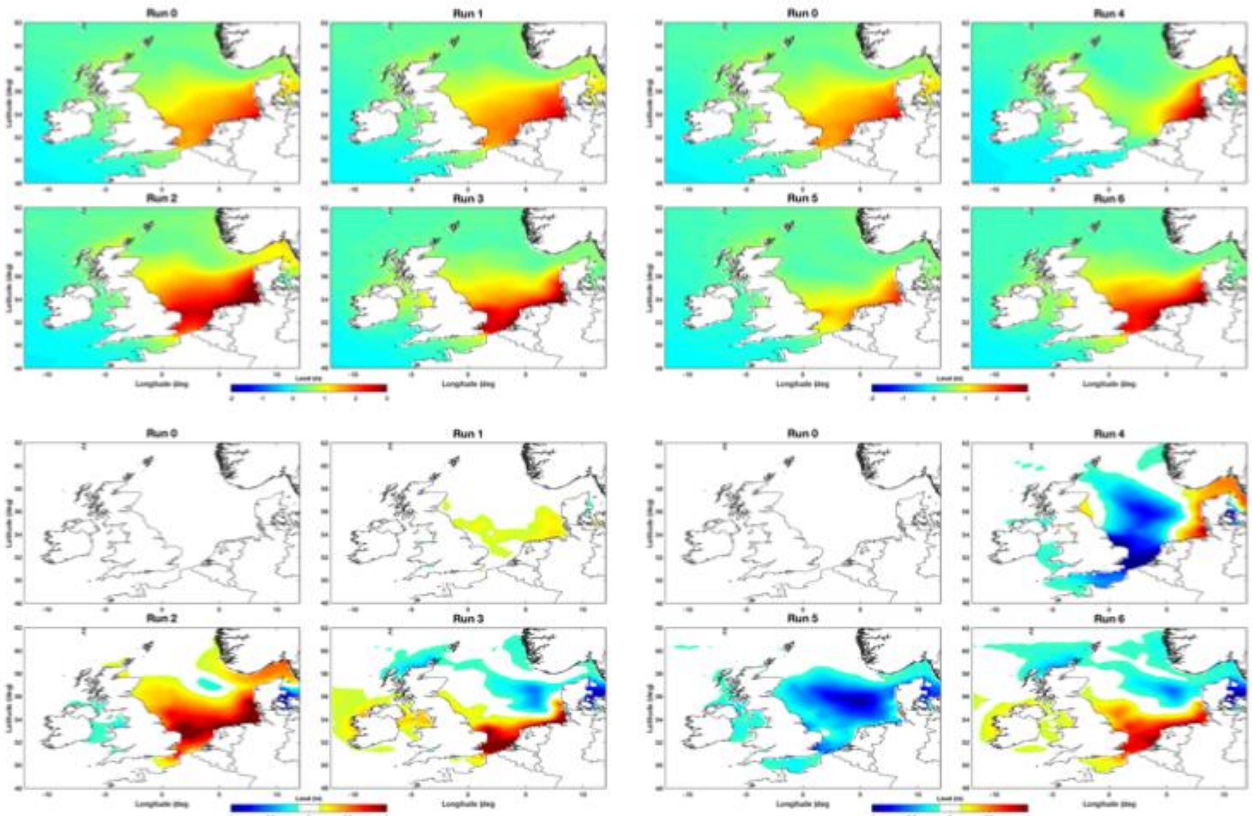


RESULTS - NORTH SEA STORM

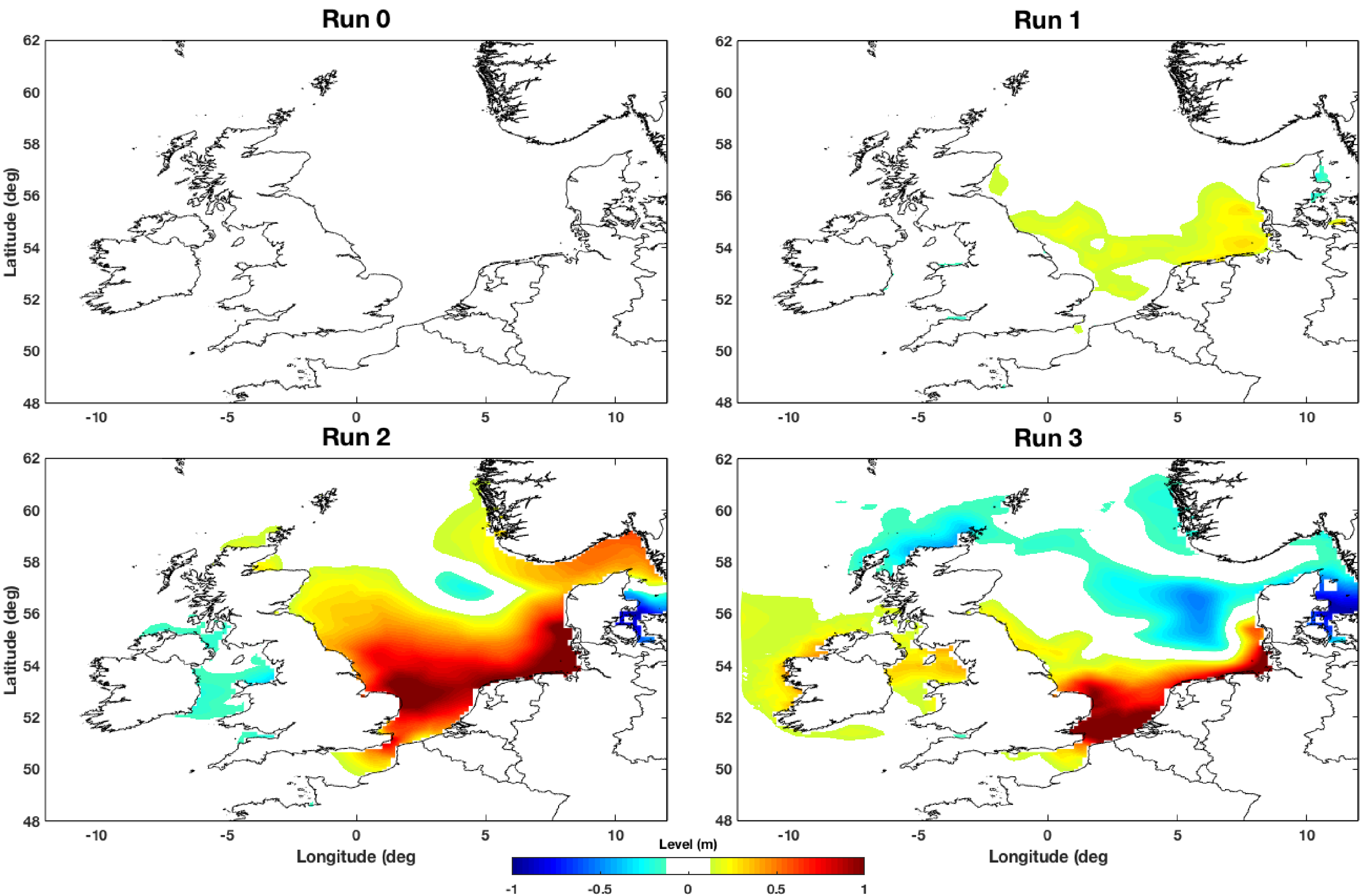
Changes in maximum surge level over simulation

4-6 December 2013 storm - modifications:

- **Run 1:** Same track, same forward speed, lower central pressure by 1 standard deviation.
- **Run 2:** Same track, same forward speed, make central pressure the minimum obtained for each location.
- **Run 3:** Same track, same pressures, slow movement of depression down by 1 SD.
- **Run 4:** Same track, same pressures, speed movement of depression up by 1 SD.
- **Run 5:** Same pressure, same speed, adjusted to the 1953 storm track.
- **Run 6:** Same pressure, same speed, adjust to the 1SD south storm track.



Maximum storm surge (Run – Xaver control)



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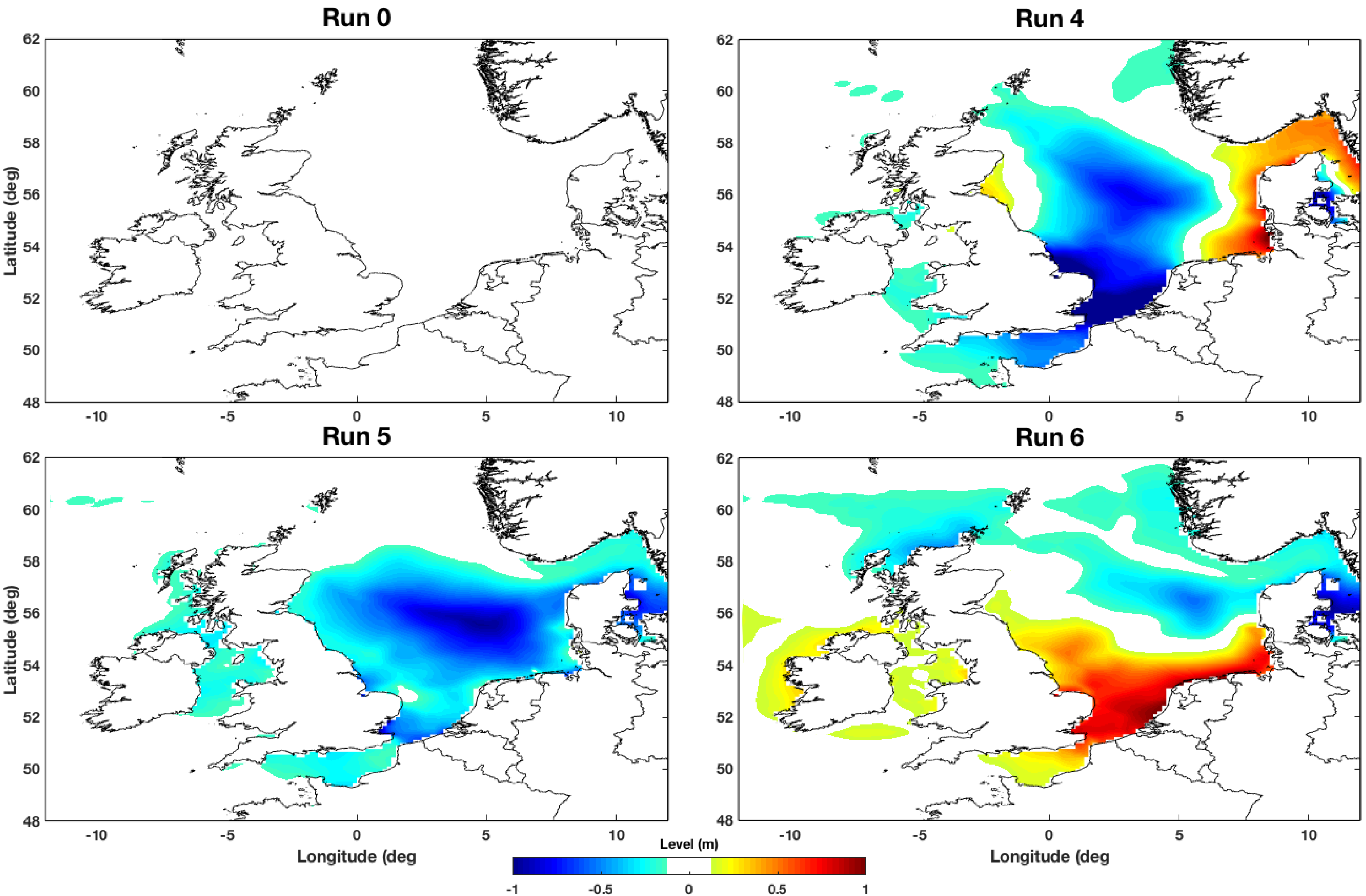


Wave model results

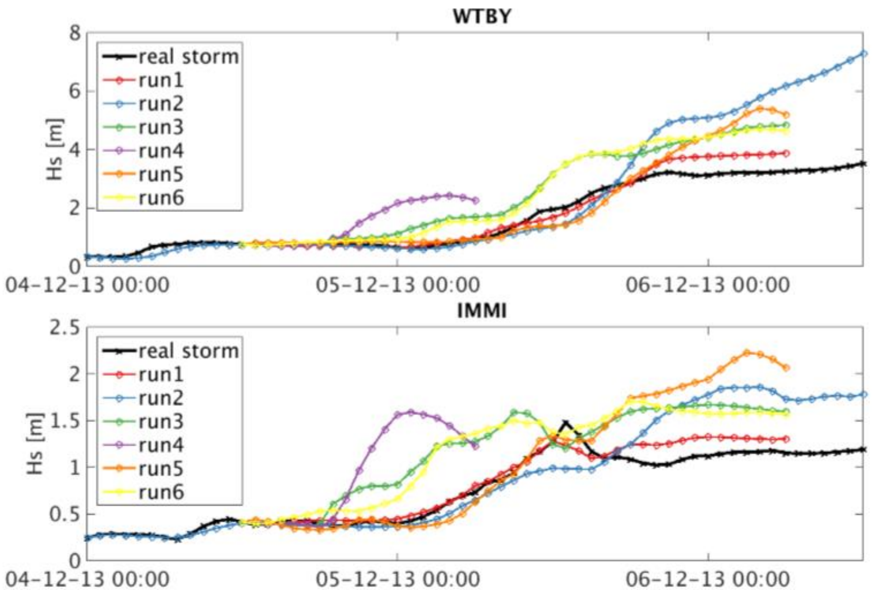
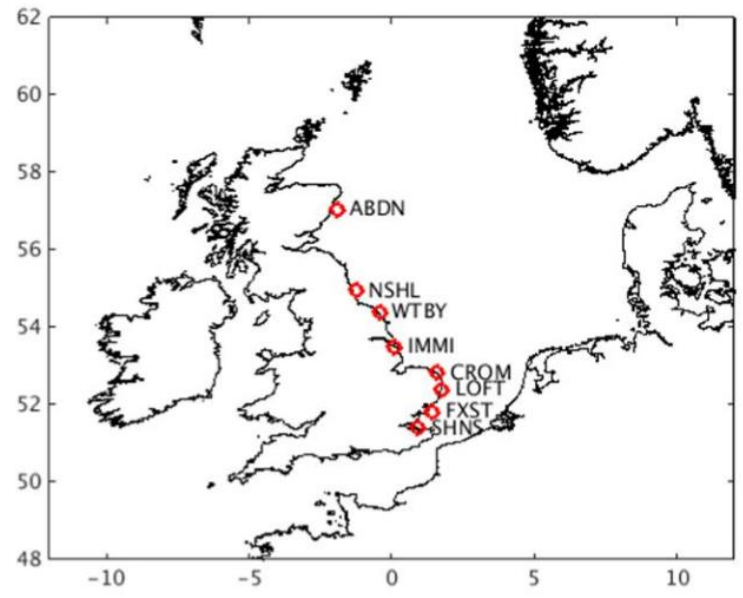
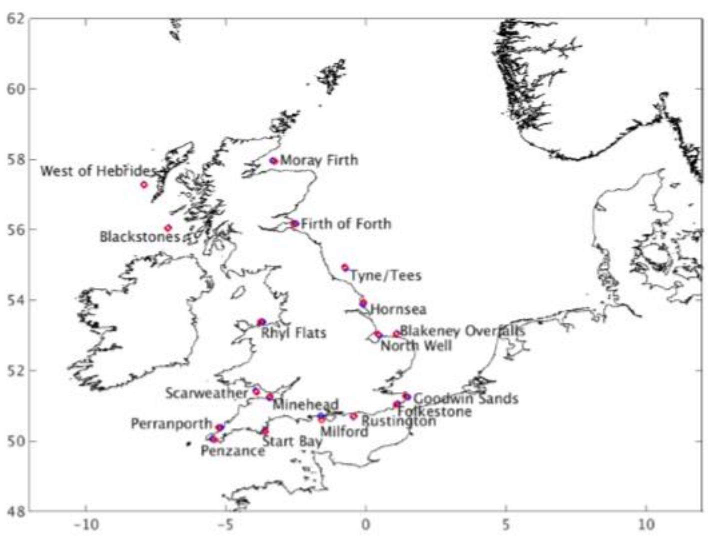
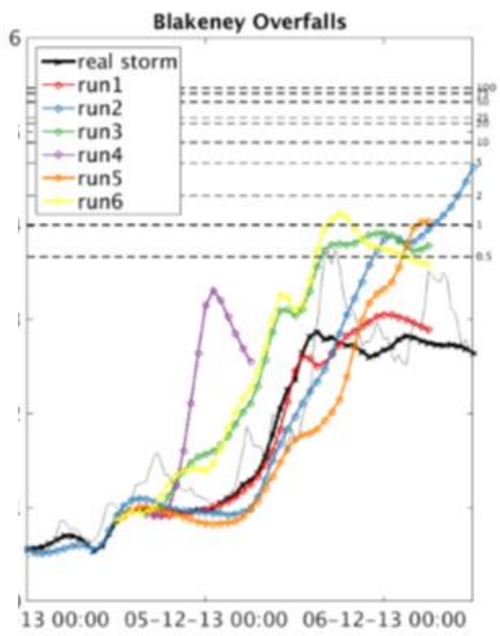


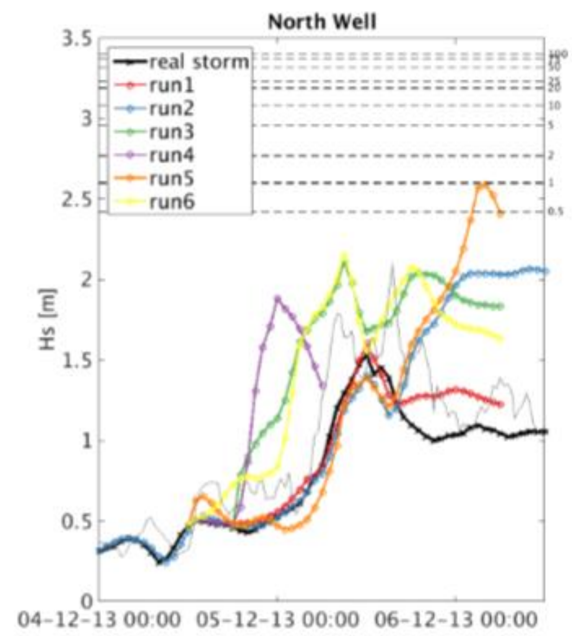
Figure 3. Hs evolution during the real and the modified storms (North East UK coastal locatic



Santos et al (2017)







With these synthetic storms, we were able to produce storm surges at all tide gauges along the UK East Coast that were consistently higher than those experienced during the December 2013 event. **The most extreme storm surge simulated was nearly one metre higher in the Thames estuary than the levels recorded during the disastrous 1953 storm (see table).** This potential additional storm surge height is comparable to the expected mean sea level rise by the year 2100 under the most severe (RCP8.5) scenario

Quite coincidentally, this is the same level obtained if you add the highest astronomical tide to the largest skew surge actually observed (shown in the final column in the table). At Lowestoft we synthesised a level that exceeded this simple, plausible metric

Changes to significant wave heights were obtained but, since we are concerned with coastal waves, none of the significant wave heights were comparable with extreme values obtained from wave observations

Port	Observed total water level on 5 December 2013	RP (years) of 2013 event	Best estimate of 1953 water level[a]	Highest synthetic level obtained in SUCCESS	RP of synthetic storm surge	HATMOSS
Whitby	4.28	588	3.7	4.41	1000	4.55
Immingham	5.22	800	4.5	5.26	1000	5.75
Lowestoft	3.24	193	3.4	3.84	> 1000	3.46
Sheerness	4.10	15	4.7	5.65	> 1000	5.65

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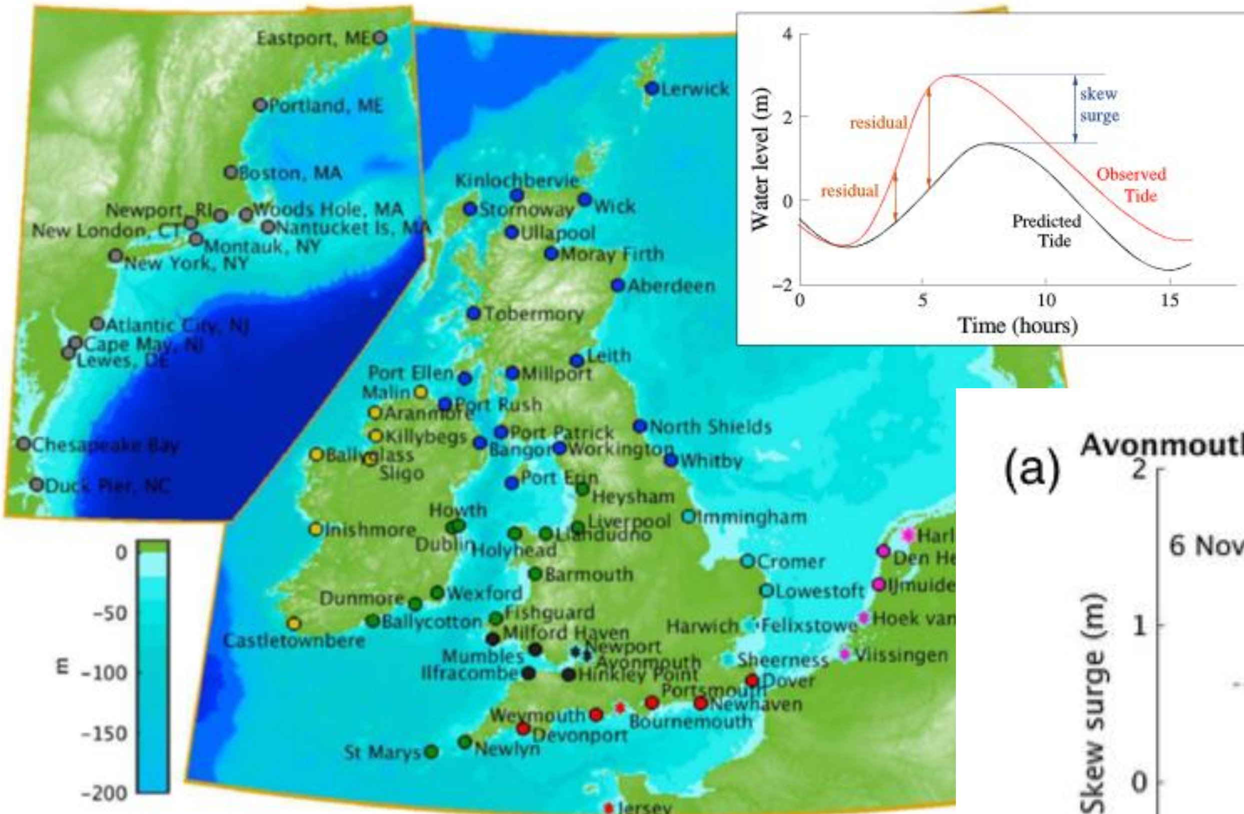
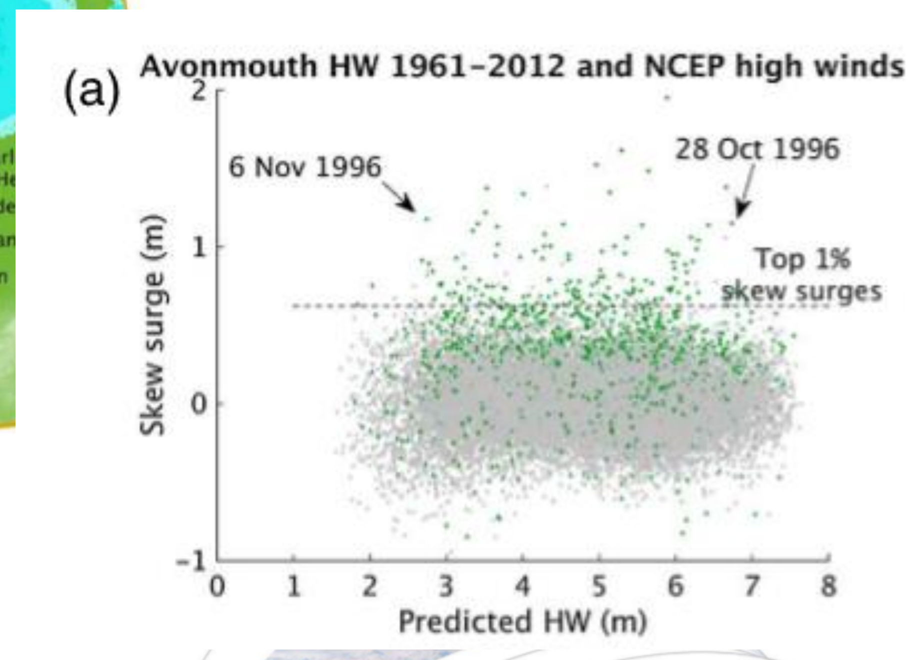
HAT+MOSS – a physically expected high value






Geophysical Research Letters

RESEARCH LETTER
10.1002/2016GL069522

Tide and skew surge independence: New insights for flood risk

Joanne Williams[1], Kevin J. Horsburgh[1], Jane A. Williams[1], and Robert N. F. Proctor[1,2]

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Key messages

Our results show that small, meteorologically plausible, changes to European storm systems can alter the height of storm surges significantly. Wave fields are affected but less significantly near the coast, in terms of extreme values

We found (as have others) that in semi-enclosed basins like the North Sea, the most severe storm surges are caused by very slow-moving depressions.

ELSEVIER

Ocean Modelling

Volume 143, November 2019, 101472

Impact of storm propagation speed on coastal flood hazard induced by offshore storms in the North Sea

Xiaoyan Wei [a], Jennifer M. Brown [a], Joanne Williams [a], Peter D. Thorne [a], Megan E. Williams [a, b], Laurent O. Amoudry [a]

As for waves, for storm surges in certain geometries duration can be important

$$V_r = A \sum_{i=1}^{N} (\eta_i^{full} - \eta_i^{tide}),$$

Byrne et al (2019)
In preparation

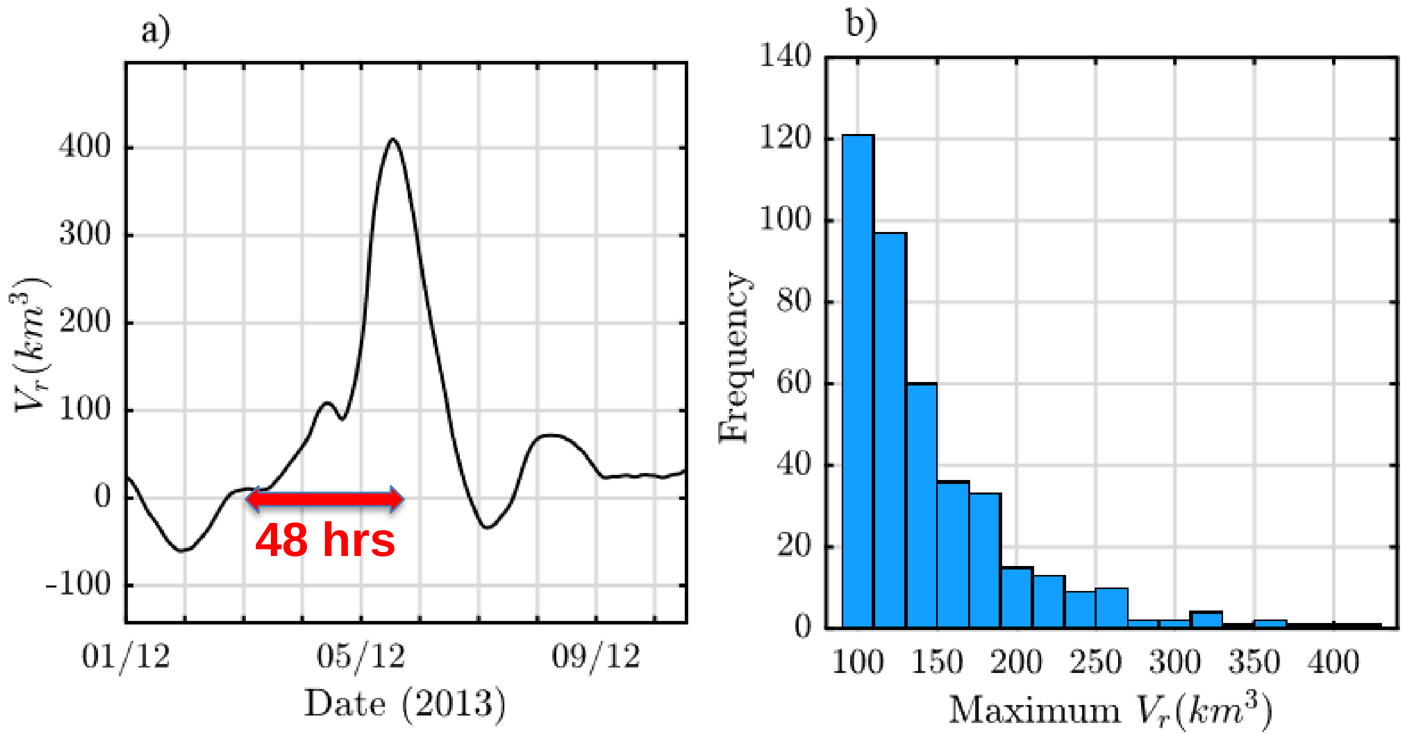
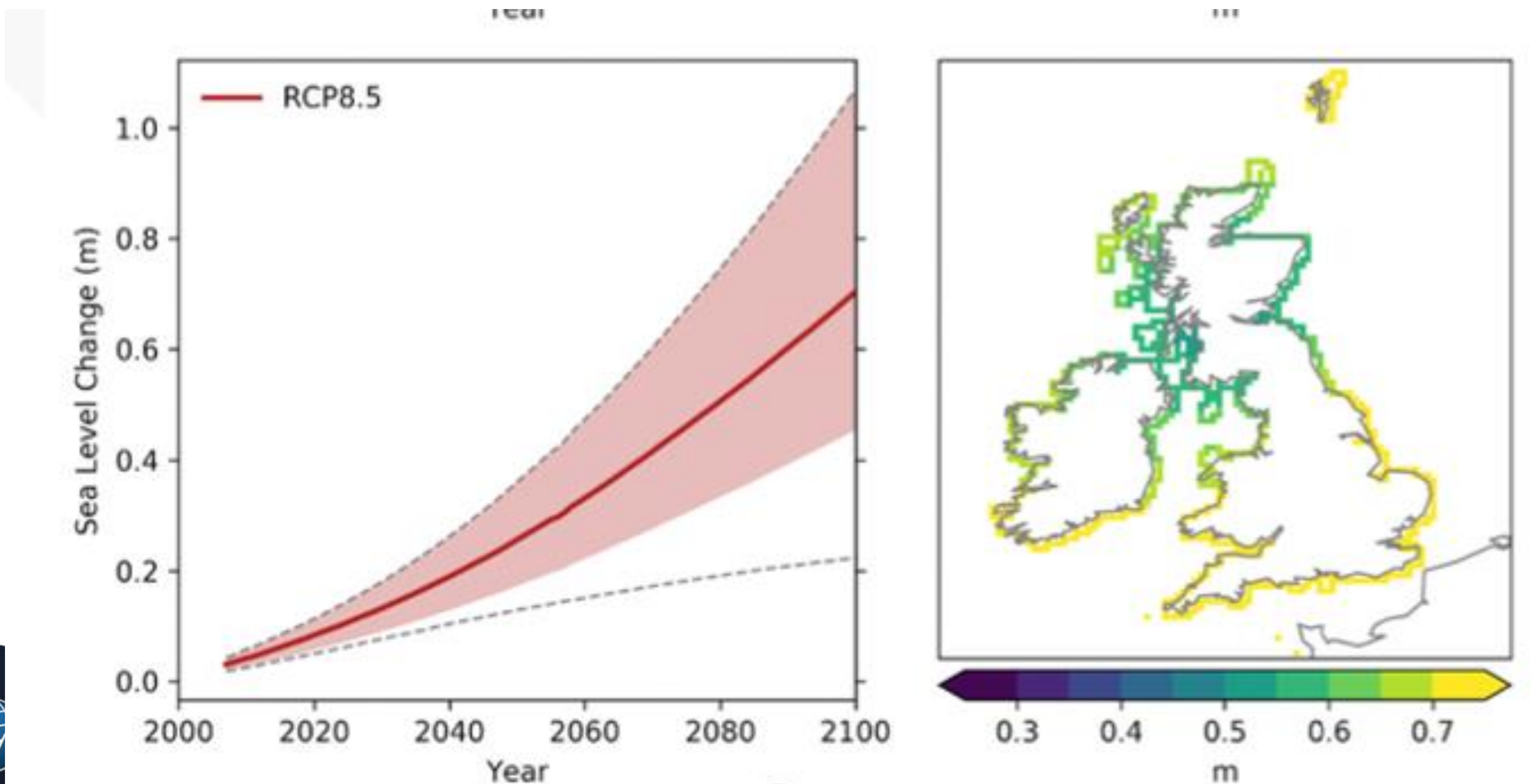


Figure 6.2:* *a) *Residual volume during December 2013 Cyclone Xaver storm surge event. Gridlines for x-axis denote midnight for each day.* ***b)*** *Histogram of independent residual volume peaks over* $100km^3$ *during 2006-2016. Table-6.1 gives some more detail on the peaks over* $300km^3$.

Key messages

Long term mean sea level rise remains an important driver of future coastal flood risk, with the UKCP18 Marine Report advising of (central estimate) sea level rises for the East Coast of the UK of between 0.2 and 0.8m by the year 2100, and the 95% under RCP8.5 of a 1.15m rise (and our synthetic storm surges are comparable with this upper value of future sea level rise).



Key messages

For storm surges and waves, it is well recognised that all projections of future storminess are limited by the current capability of climate models to accurately simulate extreme winds.

The multi-decadal variability of winter storms – and therefore of storm surges – is dominated by natural variability.

For a ~50-year planning horizon it is likely that the greatest threat for coastal extreme sea levels comes from the unobserved variability in storminess.

Our methods only enabled us to synthesise a relatively small number of grey swan storms for the North Sea; further understanding would be gained by developing techniques to synthesise a much larger statistical sample of weather systems; and also studying other European coastlines

Thank you

Volume residual with surge only run