National Oceanography Centre

INTERNAL REPORT

The UK Storm Surges of 2023

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Content

This report contains summary plots for the 2023 storm surges from the NTSLF surgeQC data and NEMO surge model. Observational data is from the UK "Class A" Tide Gauge network, operated by the Environment Agency. The data is at 15 min intervals.

Data and Quality Control

UK tide gauge data is quality controlled on a monthly basis at BODC, to GLOSS standards, intended for climate research. A great many gauges do not currently meet these criteria, either because there is no levelling of the gauge to fixed benchmarks or because of unexplained discrepancies between multiple data channels at the gauges. Of the 43 sites, only about 14 are substantially complete for 2023. I have included one plot of this data, for comparison of completeness.

Therefore as part of the monthly data summary, used by the Met Office to assess performance of the model, the tide gauge data undergoes a second quality control step at NOC, which we refer to as the surgeQC. Each month the most complete channel is used at each site, and this may change from the previous month, leading to datum jumps. Data should not drift or jump within the month by more than about 10 cm, but tidal-cycle oscillations between the full-tide and mid-tide sensors are accepted. Radar channels are used where they are substantially more complete than pressure channels. The data to this standard is much more complete, and most surge events are captured at most sites, allowing comparison of spatial patterns of the surge, although the absolute levels may be correct. It is plots of this data that forms the bulk of this report. The data is not currently publicly distributed, but is archived internally at NOC Liverpool.

Note that for statistics of extremes, which may be sensitive to distribution tails, it is recommended to use the climate quality data. No extreme statistics are reported here.

Tide gauge sites

There are 43 named sites (the list includes Jersey, and Islay which is retained for backwards compatibility.) In the timeseries plots they are offset by 1 metre (10 metres for the total water lever plot) and ordered anti-clockwise around the UK starting from Sheerness using the single-nearest-coastline method to include other islands.

Model

The model data here is the deterministic operational UK surge-and-tide NEMO model, as run every 6 hours at the Met Office and provided to NOC. Each model run starts from 6 hours in the past, for a total of 2.5 days. The first 6 hours forward of every run are used here, to provide a single timeseries at every gauge and at every grid point. Model surge residuals are the difference between the tide-and-surge model run and a tide-only run.

Tidal analysis

Observation tide predictions are taken from the Marine Data Products team at NOC Liverpool, and are based on POLpred predictions. These are harmonic tides predictions including up to 115 constituents, and nodal corrections.

Choice of storms

The storms are the named ones as listed on the Met office site, plus Pia from the DMI list, plus those with a skew surge>0.5m in at least 8 sites.

Spring-Neap tides

At most sites in the UK by far the dominant effect on total water level is the tide. During spring tides, the range between high and low water can be metres more than during neap tides, so flooding is far more likely to occur on spring tides. In the following figures the spring-neap cycle is indicated by yellow-pink bars, with a colour scale corresponding to the daily range of the predicted tide at Sheerness. Full and New Moon are marked on the bars as white/black discs.

Acknowledgements

Many people contribute directly or indirectly to the routine analysis of the tide gauge data and surge forecasting. In particular, thanks are due to:

Elizabeth Bradshaw, Polly Hadziabdic, Clare Bellingham at BODC, for regular data processing and quality control at BODC;

Clare O'Neill, Andy Saulter and Breo Gomez at the Met Office, for operational surge modelling and development;

Jeff Polton, Andy Matthews, Sveta Jevrejeva, Angela Hibbert at NOC Liverpool, for project management of this and related projects and many useful discussions;

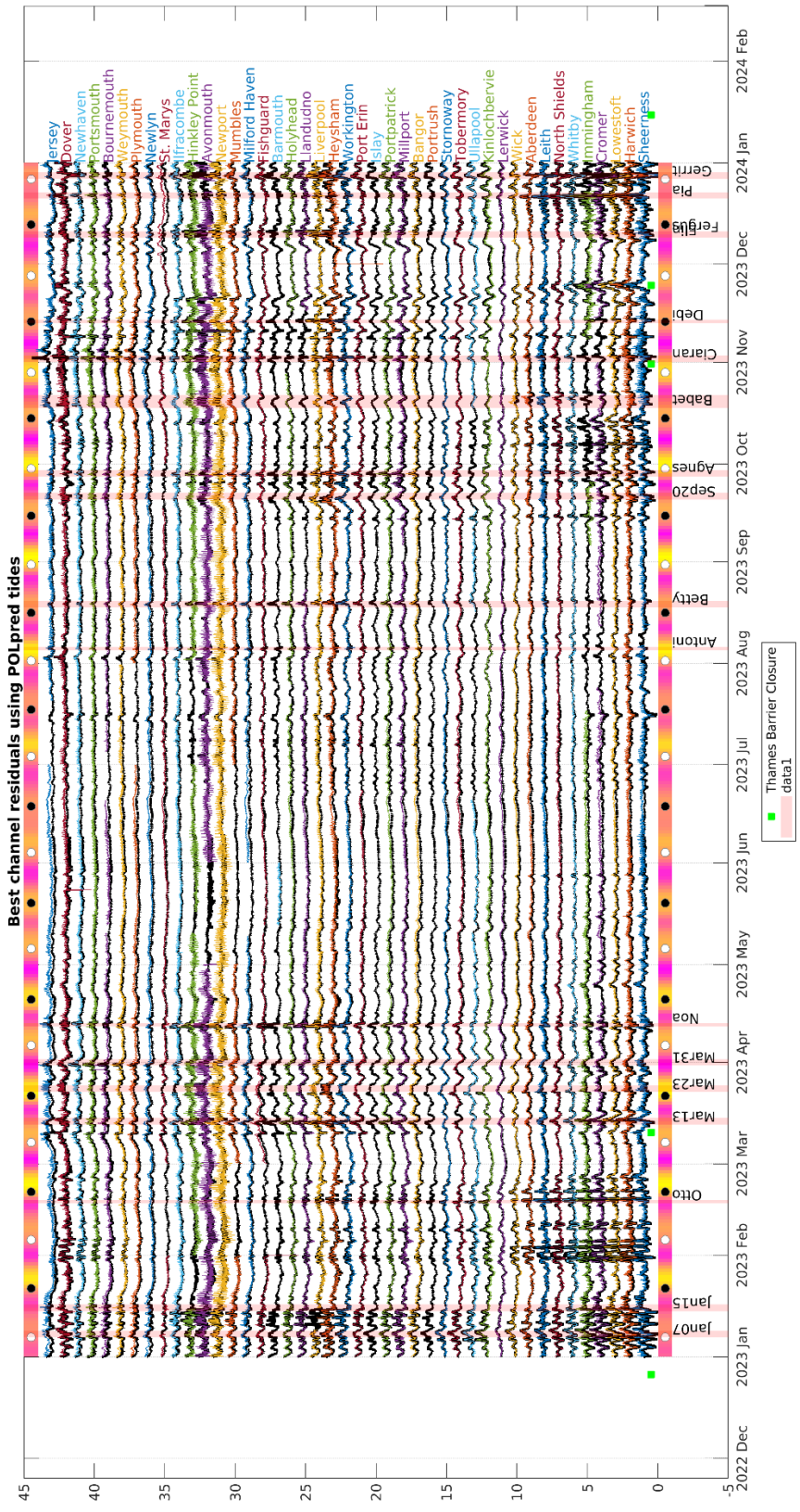
Andy Lane at NOC Liverpool for maintenance of the NTSLF website;

Kelda Low at the Environment Agency for regular updates on gauge data quality and maintenance;

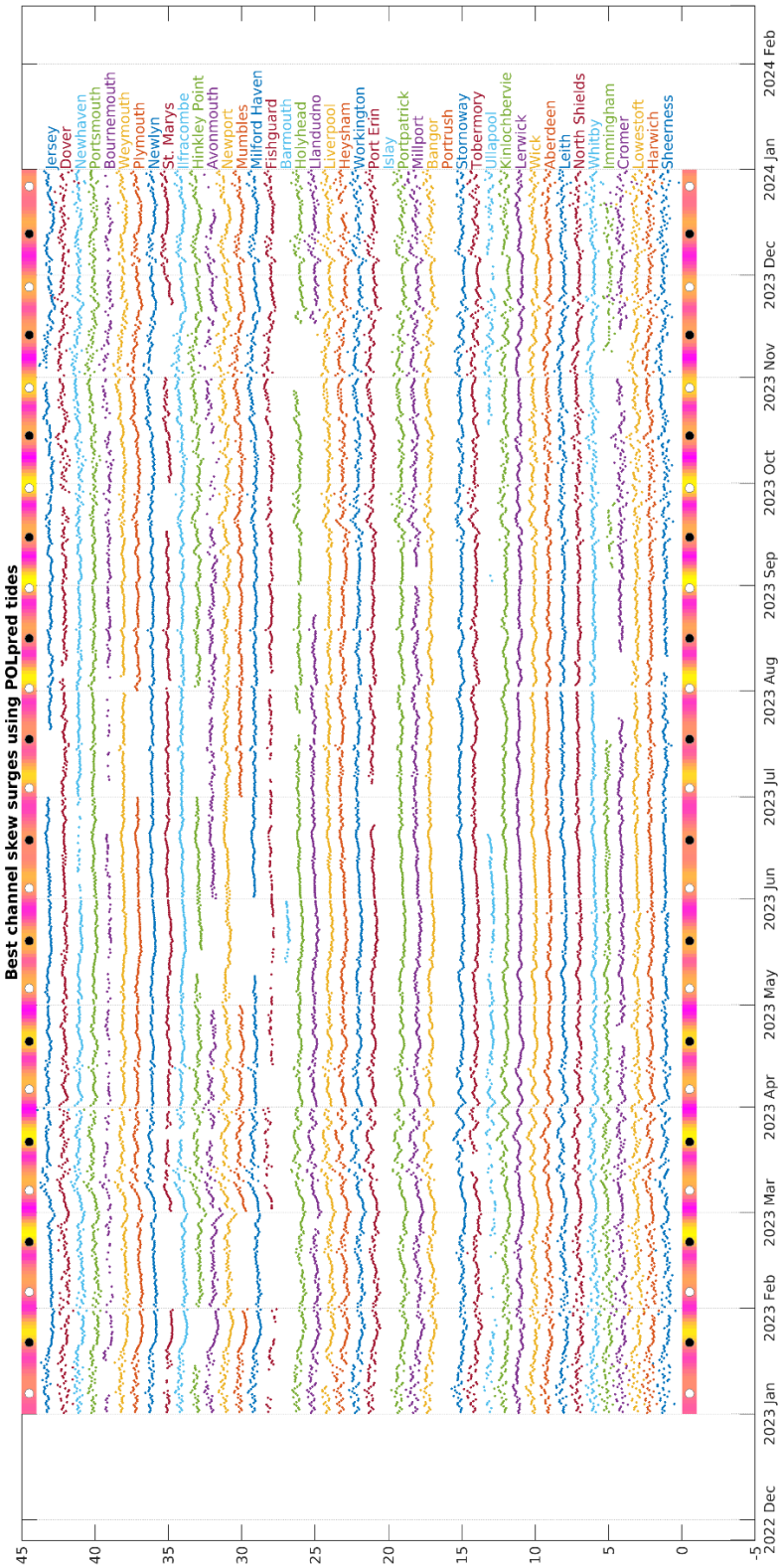
Alan Atkin-Park at the Environment Agency for information about the Thames Barrier closures.

Jenny Sansom, Philip Staley and others at the Environment Agency for helpful discussions.

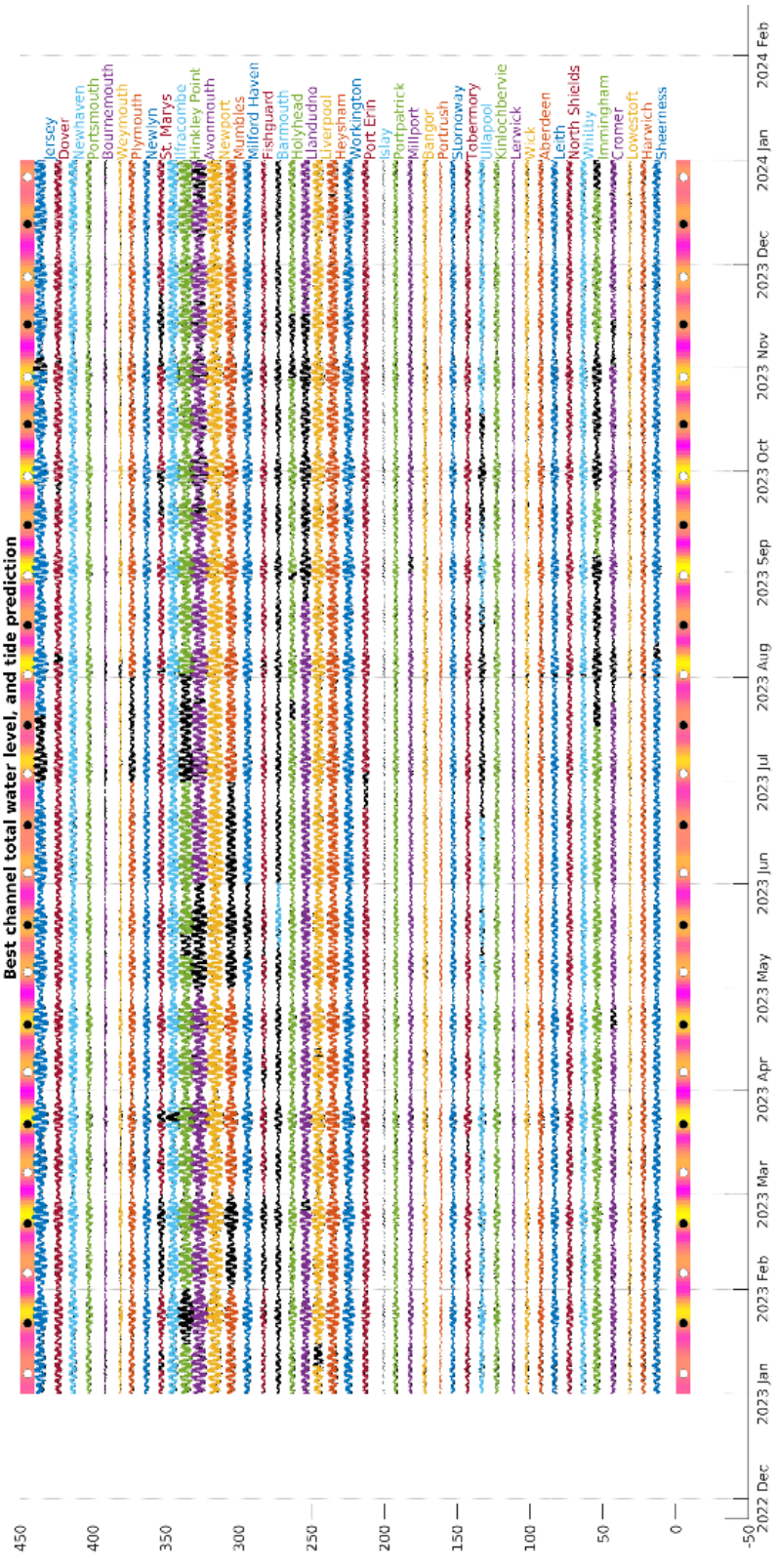
Data from 2023: Surge residual, observations and model



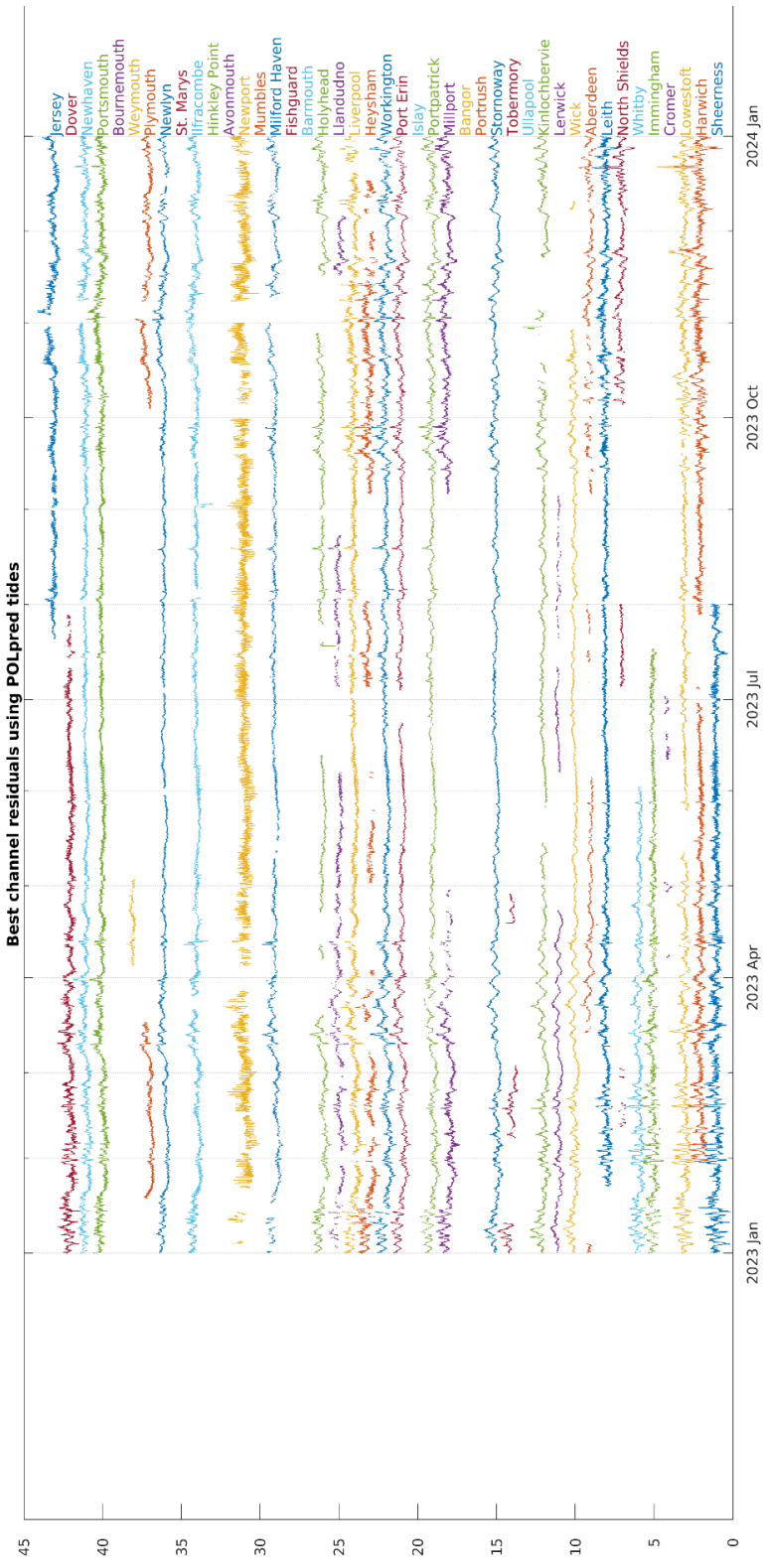
Data from 2023: Skew Surge observations.



Data from 2023: Total water levels



Data from 2023: Data meeting GLOSS climate-quality QC standards



Highlighted storms.

These events are the storms with names adopted by the Met Office, and also event not covered by the named storms with a skew surge of more than 0.5m at at least 8 sites.

Storm Name	Dates	Storm surge
Unnamed	2023-01-07 to 2023-01-10	Widespread moderate (0.5-1m) skew surge on west and east coasts of UK, but occurred during moderate tides, no especially high levels.
Gerard, France	2023-01-14 to 2023-01-16	Surge mostly in southern North Sea, up to Sheerness 1.0m skew surge.
Otto	2023-02-17 to 2023-02-18	Small <0.5m skew surge in west of Scotland and 0.5-1m skew surge in east coast England later on 17th Feb. Surge residual in the North Sea was mostly due to phase shift and did not result in a substantial skew surge. Neap tide, small total water levels.
Larisa, France	2023-03-12 to 2023-03-14	Surge in Irish Sea, skew surge over 0.5m everywhere and Heysham 0.8m, Newport 1.1m. But due to the date being on neap tides, no high totals.
Unnamed	2023-03-22 to 2023-03-25	Widespread moderate (0.5-1m) surge especially on west and north coast of UK. **Although not the biggest surge, or a named storm, the coincidence of the March 23rd event with the spring tide led to this being the highest recorded level at 18 sites in Scotland and the west coast of England and Wales, as far south as the Severn.**
Matthis, France	2023-03-29 to 2023-04-01	Skew surge approaching 1m in English Channel, and widespread moderate skew surge on west coast of UK. Highest recorded 0.9m (Jersey) but occurred during moderate tides, no especially high levels. Followed by negative surge particularly in Severn (-0.5m negative skew surge at Hinkley, Avonmouth, Newport.)
Noa	2023-04-11 to 2023-04-12	Neap tide, no significant totals. Skew surge in Irish Sea, up to 0.9m at Newport.
Antoni	2023-08-05 to 2023-08-06	No widespread storm surge resulting from this storm.
Betty	2023-08-18 to 2023-08-19	Moderate skew surge (~0.5m) on west and south coasts. Negative surge all week in the Severn.
Unnamed	2023-09-19 to 2023-09-21	Skew surge (<1m) western Scotland and negative skew surge in south east coast of England. Neap tides.
Agnes	2023-09-27 to 2023-09-28	High skew surge in north west England (Workington 0.9m), Scotland (Millport 0.9m, Portpatrick 0.8m) and Northern Ireland (Bangor 0.8m). Agnes led to the highest totals of the year in Northern Ireland where the tidal range is small. Close to 1st October spring tides, ie 3 days later would have been 1m higher at Heysham.
Babet	2023-10-18 to 2023-10-21	Widespread skew surge (0.5-1m) in the west of the UK. This event notable for extreme low waters in the German Bight.
Ciaran	2023-11-01 to 2023-11-02	Widespread moderate (0.5-1m) skew surge on all coasts of UK, however tides were moderate by the day of this storm and the still water level was not significant at most sites. Modelled skew

		surge at Jersey around 1m, and Jersey was severely affected by wave damage but unfortunately no tide gauge data was transmitted during that week. Highest total of the year recorded at Bournemouth.
Debi	2023-11-12 to 2023-11-13	Surge in the Irish Sea, west coast of England and Wales, 0.5-1m skew surge and particularly at Heysham 1m and Workington 1m. However moderate tides so not extreme totals.
Elin	2023-12-08 to 2023-12-09	No widespread storm surge during this event, Fergus followed immediately.
Fergus	2023-12-10 to 2023-12-11	Skew surge 0.5-1m in Irish Sea. Neap tides, no high totals.
Pia, DMI	2023-12-21 to 2023-12-22	Pia had the highest skew surges of the year with >1m widespread across the North Sea (observed 1.2m Cromer, 1.5m Lowestoft, 1.4m Harwich, 1.2m Sheerness, 1m Dover). Neap tide, but still was the maximum total SL for the year at Harwich and Lowestoft in East Anglia.
Gerrit	2023-12-27 to 2023-12-29	Gerrit had widespread positive skew surge (0.5-1m) in the west of the UK, distinctive negative surges (approaching -1m) in the North Sea. Combined with moderate spring tide this event led to the highest levels of the year at Millport (near Glasgow).

Other high levels

Vernal spring tide	2023-02-22	Highest levels of the year at Immingham Coastal erosion at Hemsby
Autumn spring tide	2023-09-30	Highest totals on several east coast sites (Dover, Cromer, Whitby, North Shields) and Newport. No particular storms but on September spring tides.
Autumn spring tide	2023-10-28	Highest totals in south and south west England and Wales (except upper Severn). Milford Haven, Mumbles, Ilfracombe, St. Marys, Newlyn, Plymouth, Weymouth, Portsmouth, Newhaven, Sheerness. Not a named storm but a spring tide, combined with a **sustained period of high sea-level throughout late October and early November**. The causes of this are not yet certain.

Maximums at Avonmouth and Barmouth were not recorded this year, due to frequent gauge problems. In particular Avonmouth is reliant on a radar gauge and does not always record the top of the tidal cycle.

A selection of events, for the State of the UK Climate report

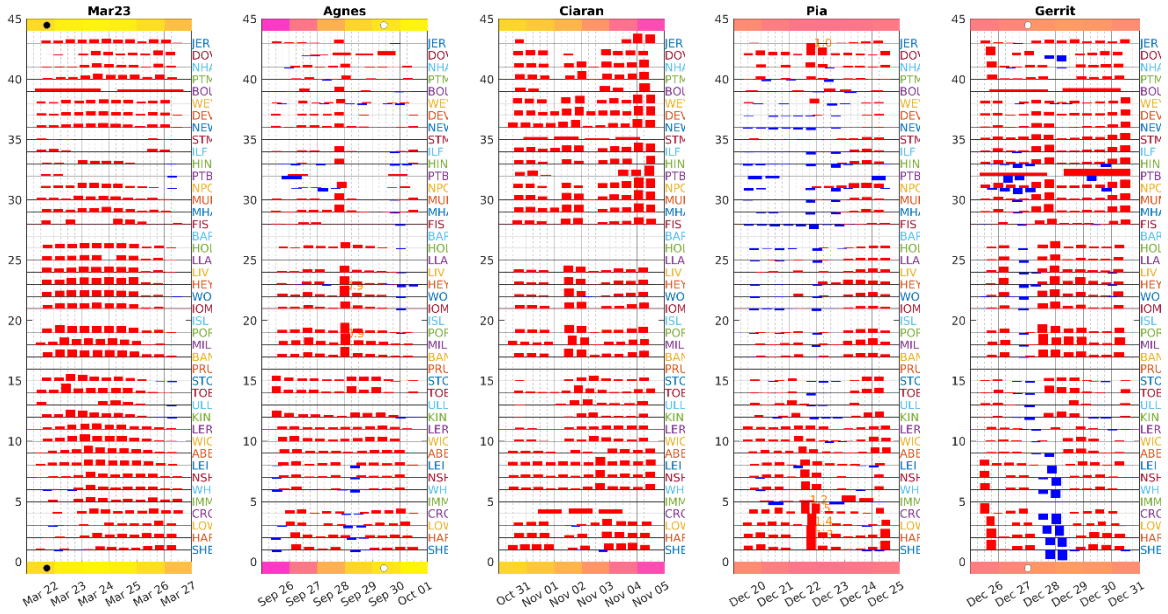


Figure Surges1 Observed skew surges (m) at tide gauges during selected storms on 23rd March, Agnes, Ciaran, Pia, Gerrit. Spring (yellow) and neap (pink) tides are also indicated.

As ever timing of surge events is critical, as for example storm Agnes occurred 3 days before the September spring tide. Some events (Agnes, Pia) were very brief, others (Ciaran, March 23rd) lasted several days. The March 23rd event coincided with the spring tide and led to the highest levels of the year at many Scottish and west coast sites.

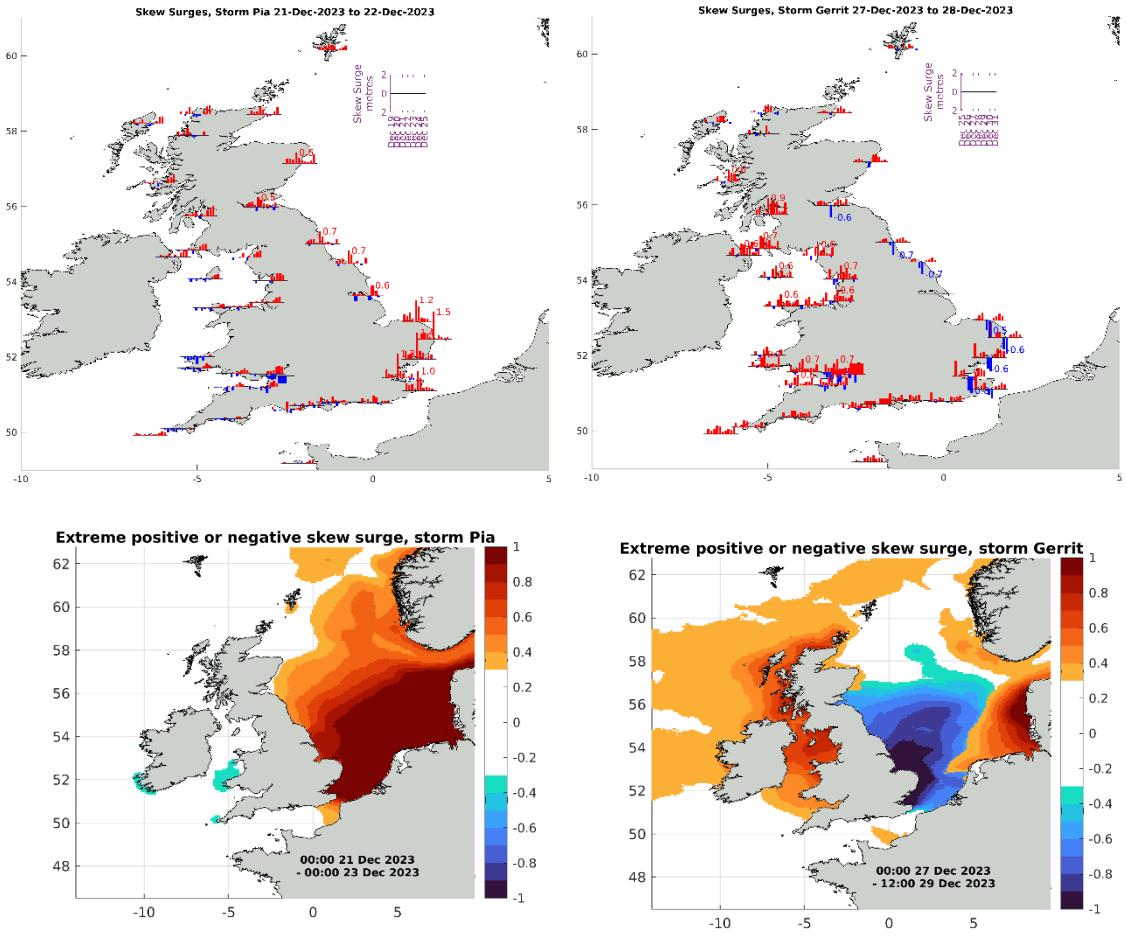
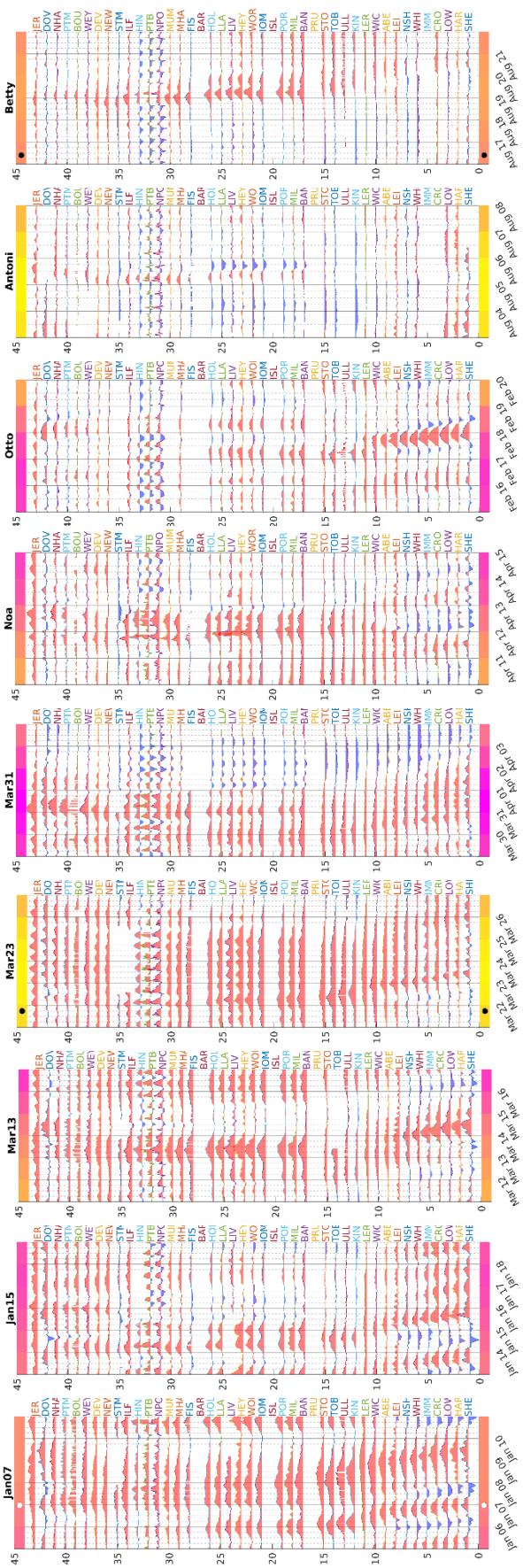
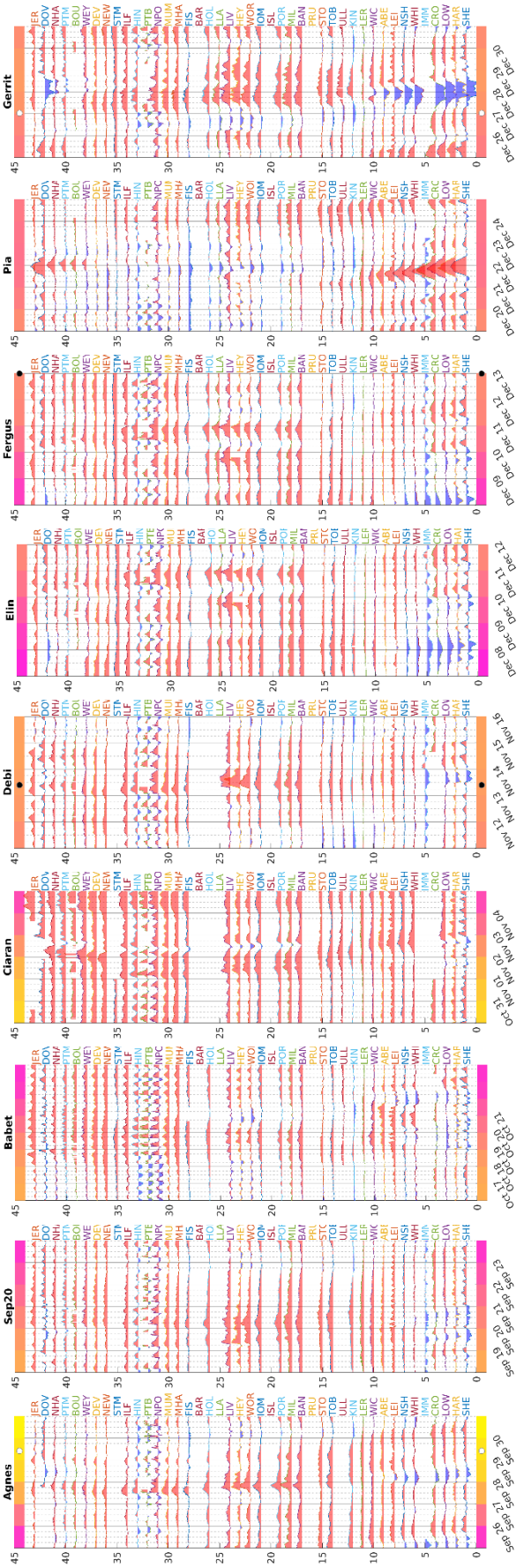


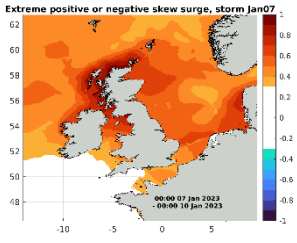
Figure Surges2 Observations (top) and storm surge model (bottom) of storms, Pia and Gerrit. Pia caused high skew surges on the east coast, in the North Sea. Gerrit was high on the west coast and lower levels than the predicted tide on the east. The model here is the NEMO surge and tide operational model, and show patterns of extreme skew surges in open water that correspond well with observed extremes. Model maps show the most extreme positive skew or negative skew during each event (if there are both the positive is plotted).

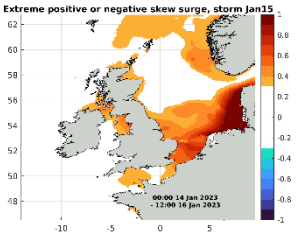
All storms, surge residuals.

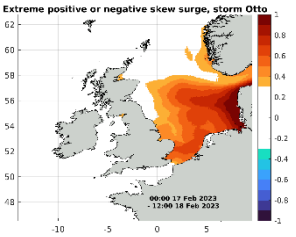


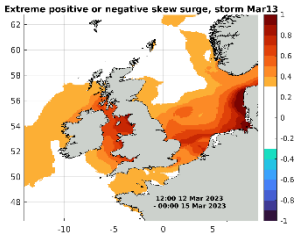


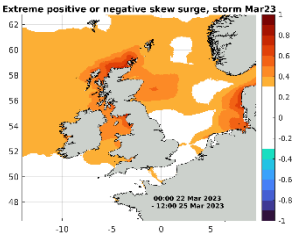
All storms: model skew surge

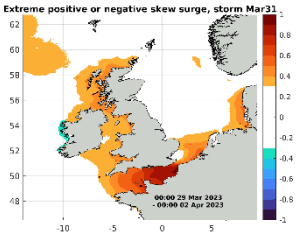


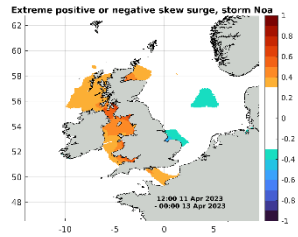


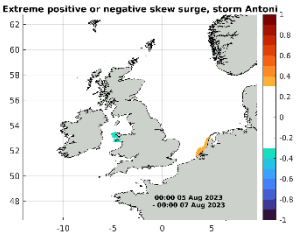


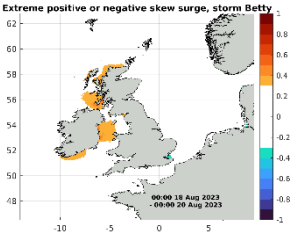


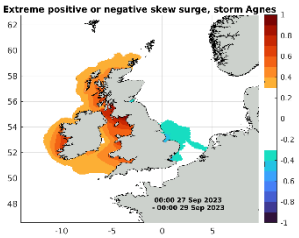


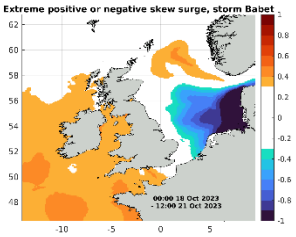


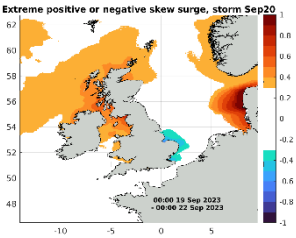


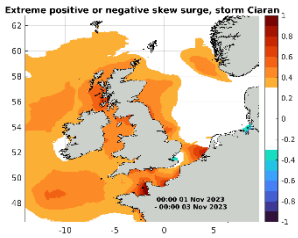


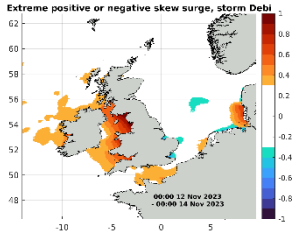


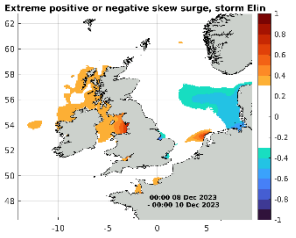


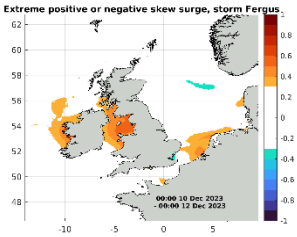


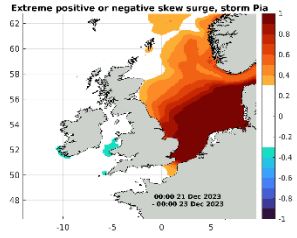


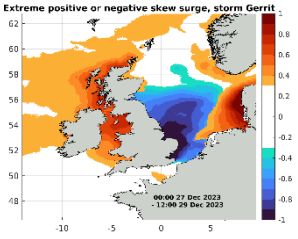






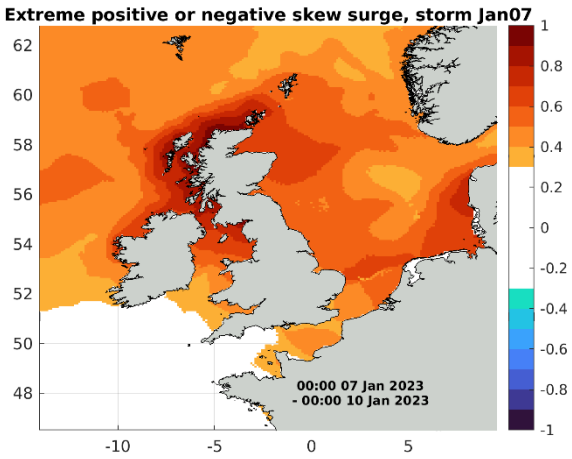


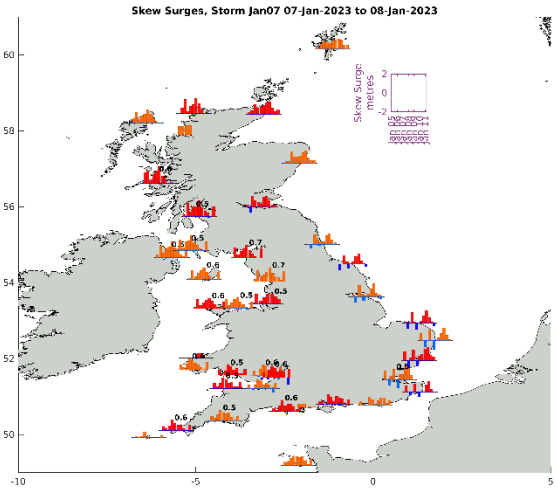


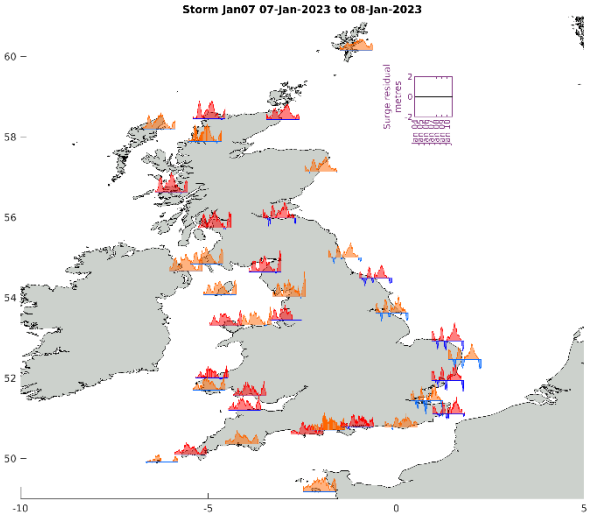


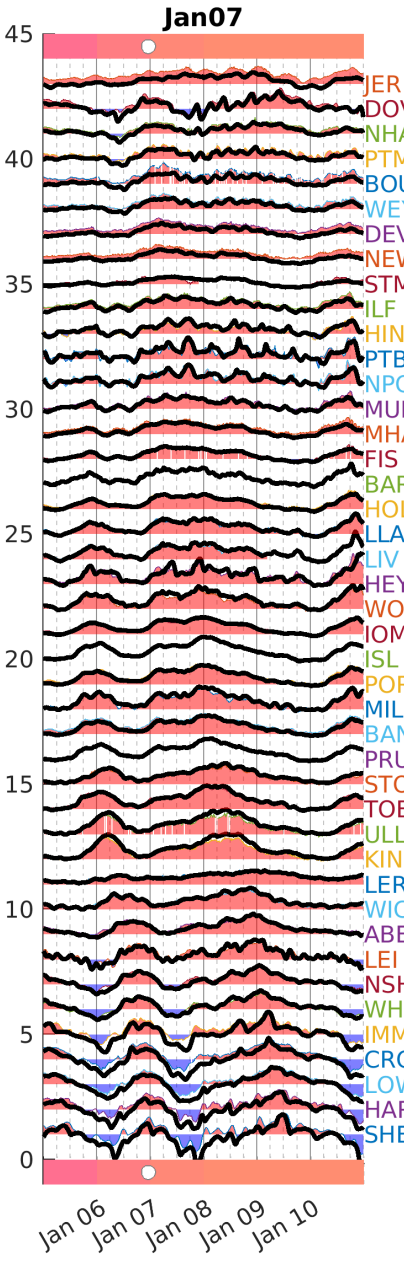
Individual Storms.

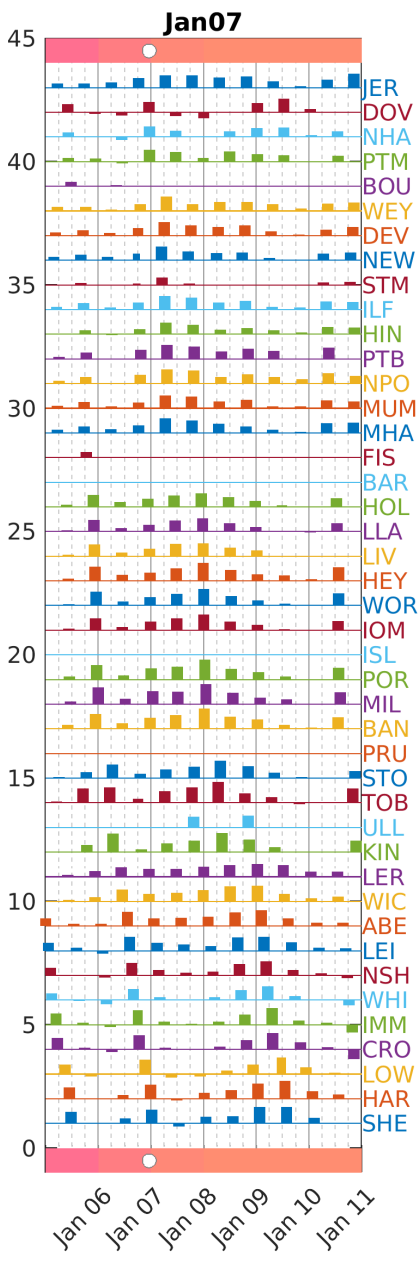
Storm Jan07



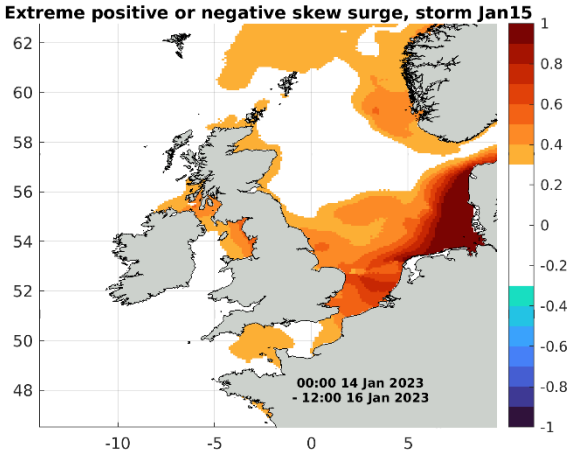








Storm Jan15


Extreme positive or negative skew surge, storm Jan15
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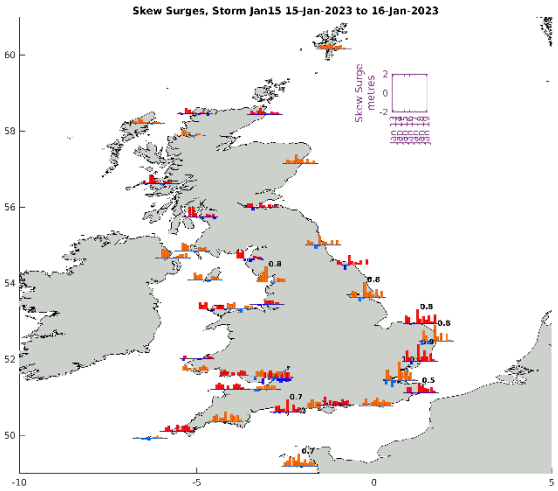
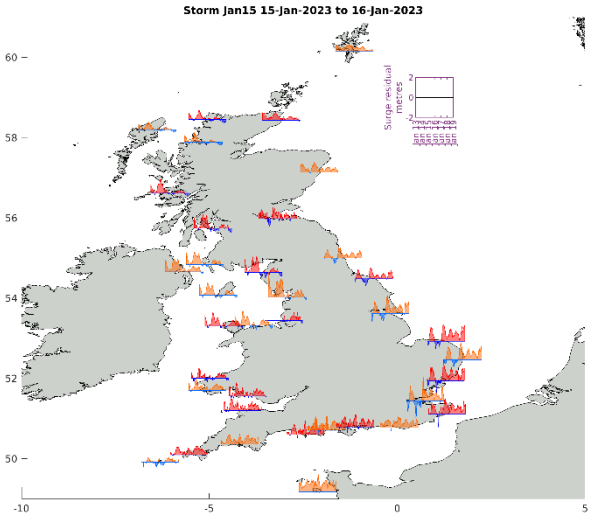
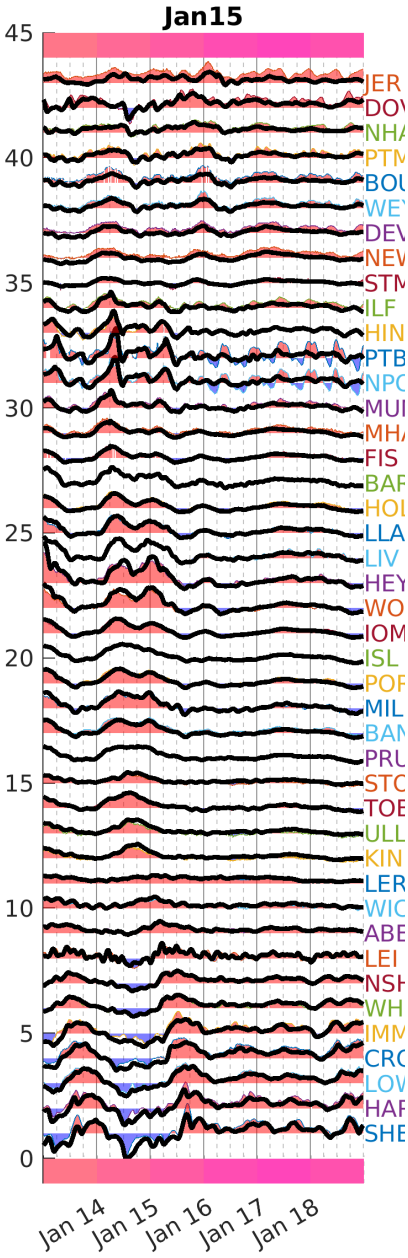
- 12:00 16 Jan 2023


Skew Surges, Storm Jan15 15-Jan-2023 to 16-Jan-2023


Storm Jan15 15-Jan-2023 to 16-Jan-2023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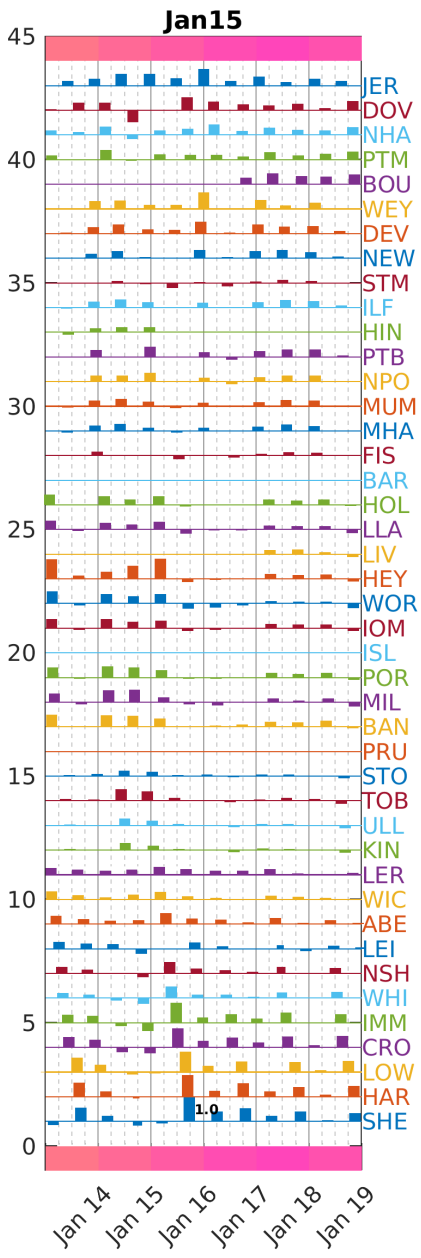
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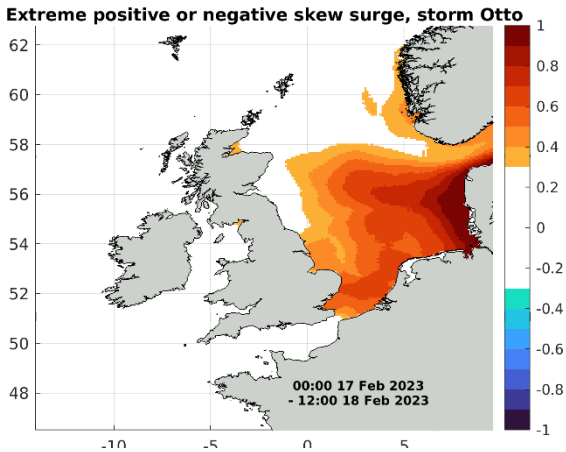
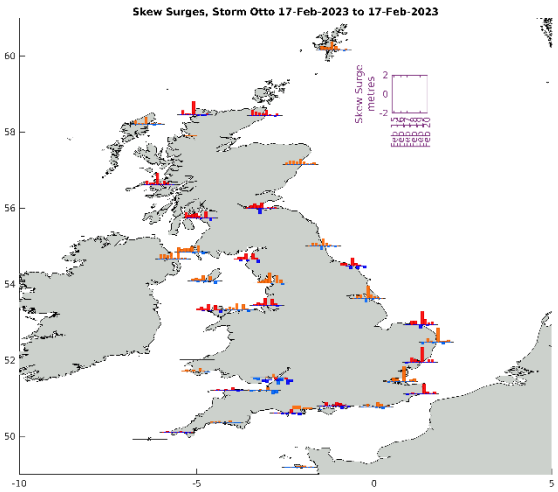
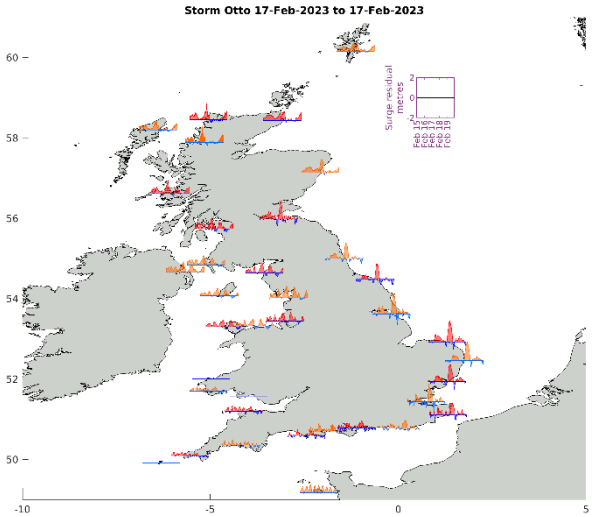
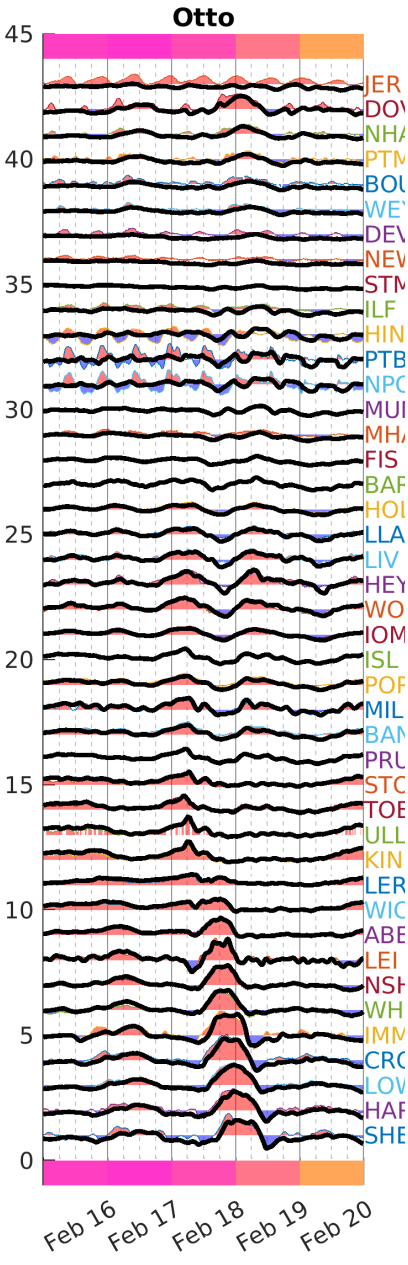
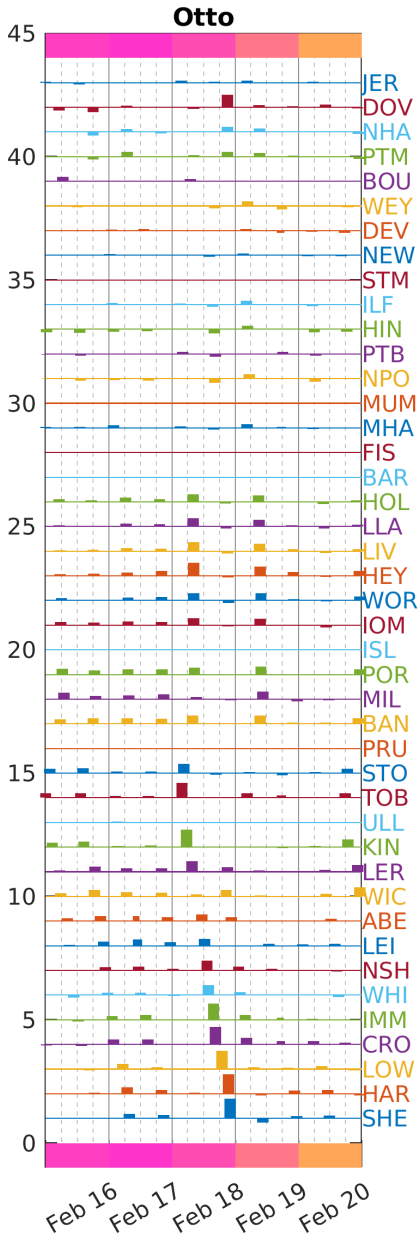
Storm Otto, 17th Feb



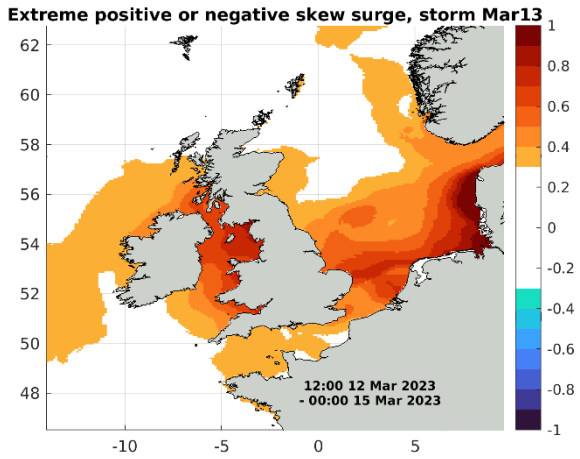


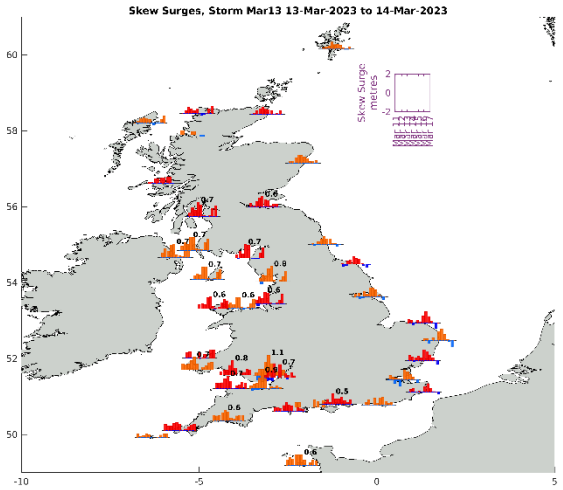


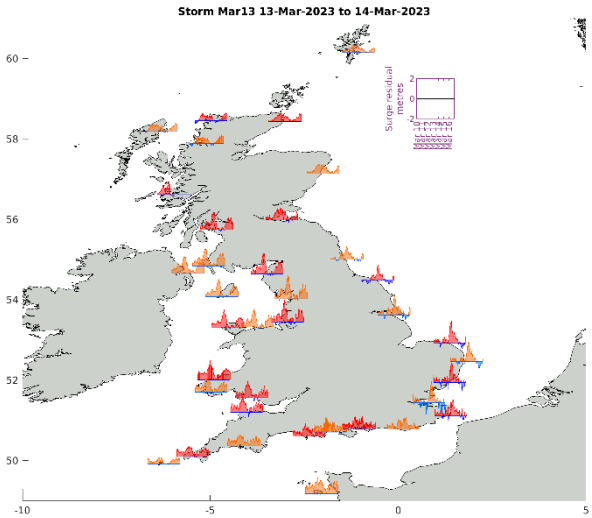


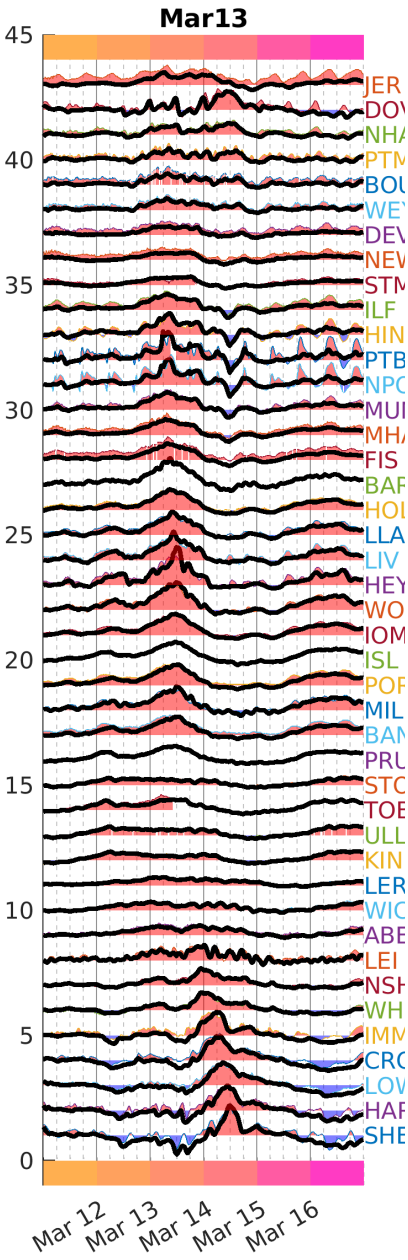


Storm Mar13

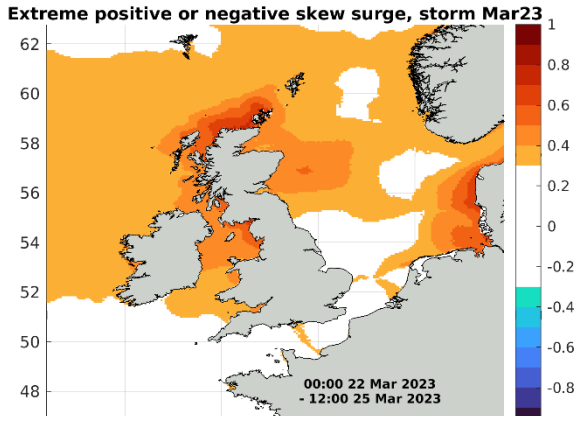

Extreme positive or negative skew surge, storm Mar13
12:00 12 Mar 2023
- 00:00 15 Mar 2023

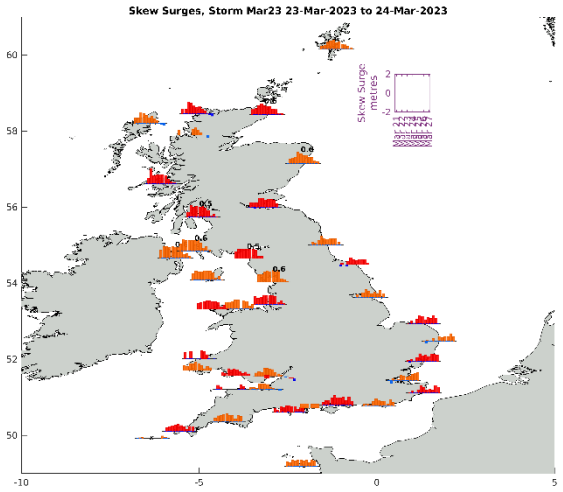

Skew Surges, Storm Mar13 13-Mar-2023 to 14-Mar-2023
Skew Surge metres

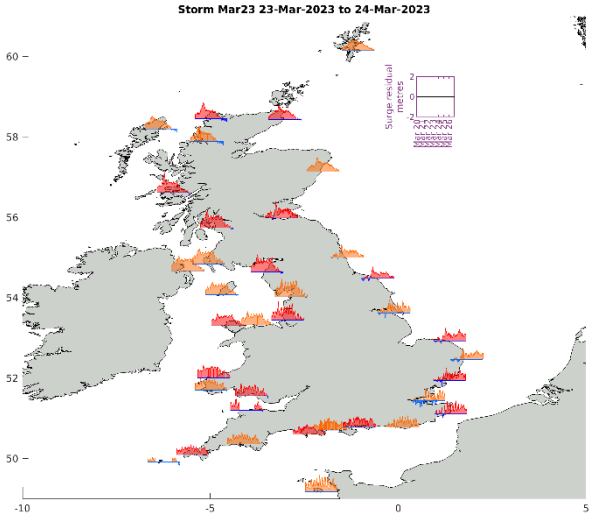

Storm Mar13 13-Mar-2023 to 14-Mar-2023
Surge residual metres

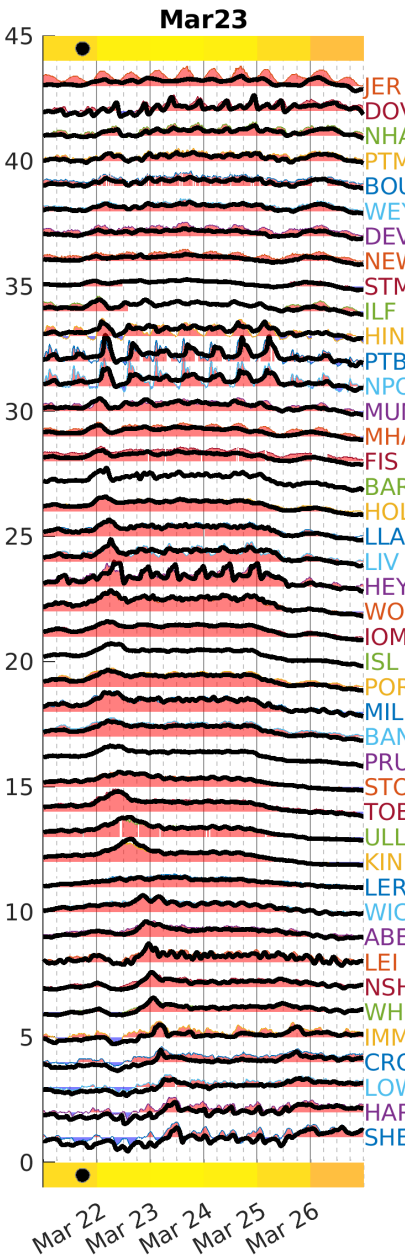

Mar13
JER
DOV
NHA
PTM
BOU
WEY
DEV
NEW
STM
ILF
HIN
PTB
NPO
MUM
MHA
FIS
BAR
HOL
LLA
LIV
HEY
WOR
IOM
ISL
POR
MIL
BAN
PRU
STO
TOB
ULL
KIN
LER
WIC
ABE
LEI
NSH
WHI
IMM
CRO
LOW
HAR
SHE
Mar 12
Mar 13
Mar 14
Mar 15
Mar 16
Mar 17

Storm Mar23

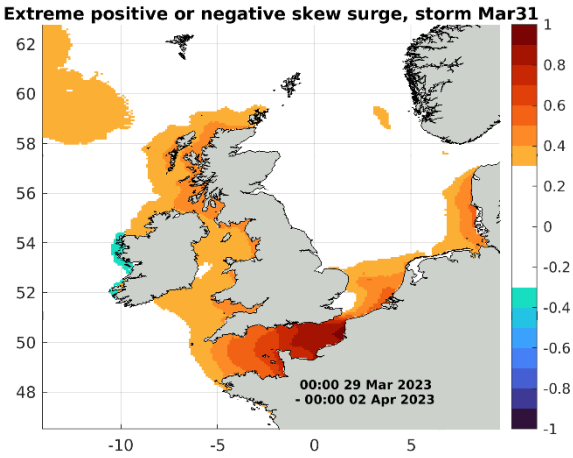

Extreme positive or negative skew surge, storm Mar23
00:00 22 Mar 2023
- 12:00 25 Mar 2023

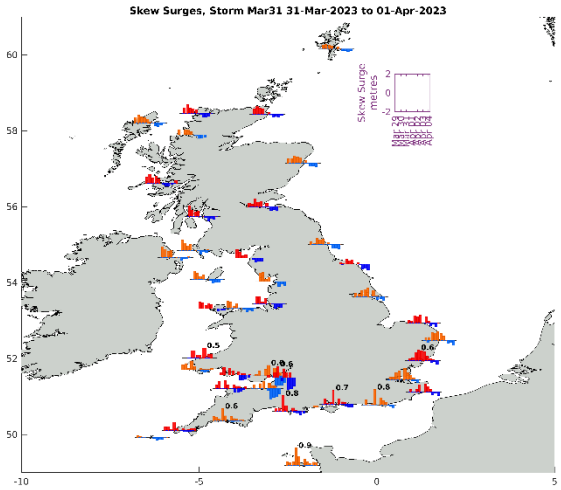

Skew Surges, Storm Mar23 23-Mar-2023 to 24-Mar-2023
Skew Surge metres

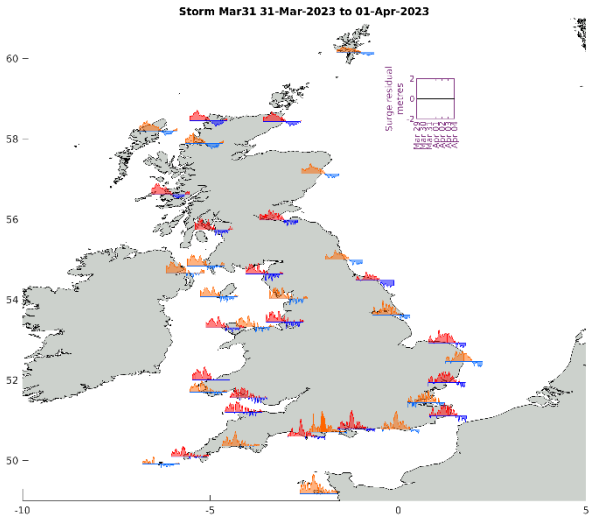

Storm Mar23 23-Mar-2023 to 24-Mar-2023
Surge residual metres

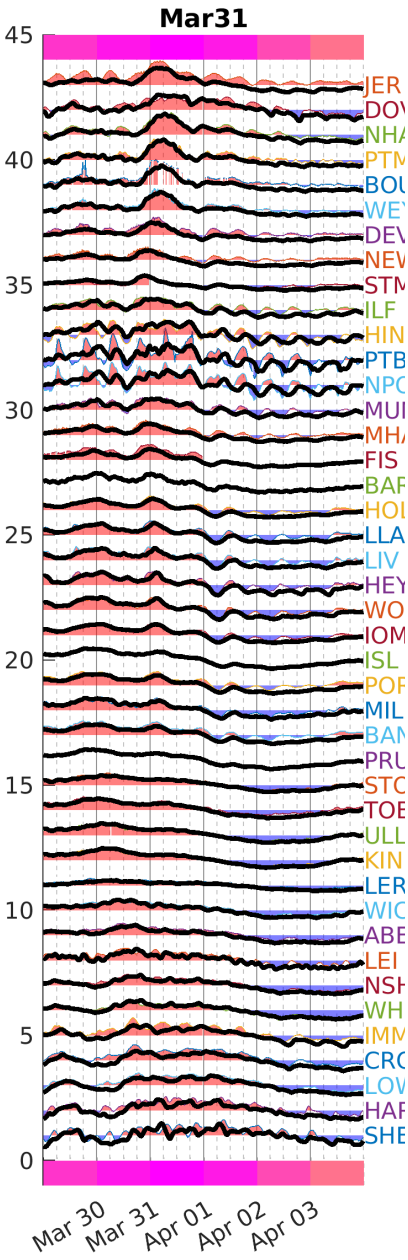

Mar23
JER
DOV
NHA
PTM
BOU
WEY
DEV
NEW
STM
ILF
HIN
PTB
NPO
MUM
MHA
FIS
BAR
HOL
LLA
LIV
HEY
WOR
IOM
ISL
POR
MIL
BAN
PRU
STO
TOB
ULL
KIN
LER
WIC
ABE
LEI
NSH
WHI
IMM
CRO
LOW
HAR
SHE
Mar 22
Mar 23
Mar 24
Mar 25
Mar 26
Mar 27

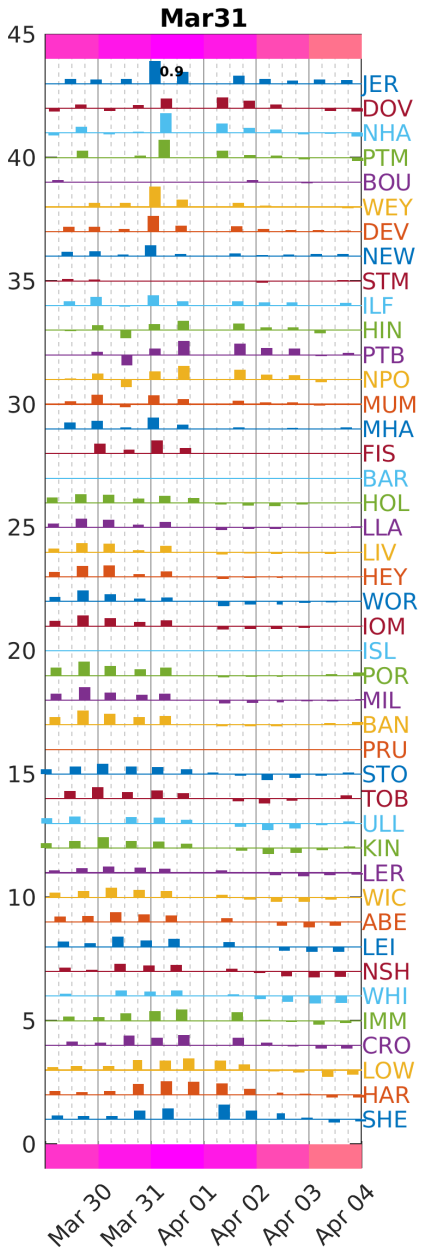
Storm Mar31


Extreme positive or negative skew surge, storm Mar31
00:00 29 Mar 2023
- 00:00 02 Apr 2023

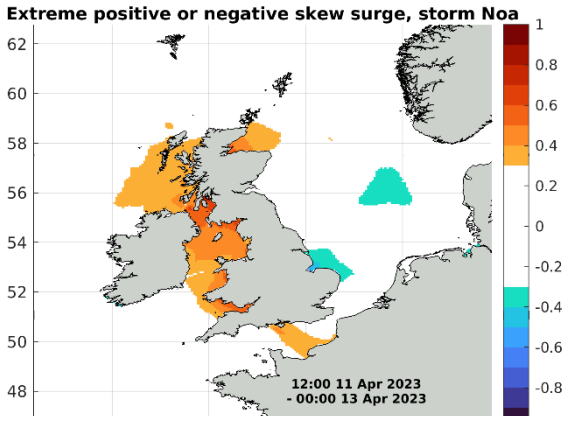

Skew Surges, Storm Mar31 31-Mar-2023 to 01-Apr-2023

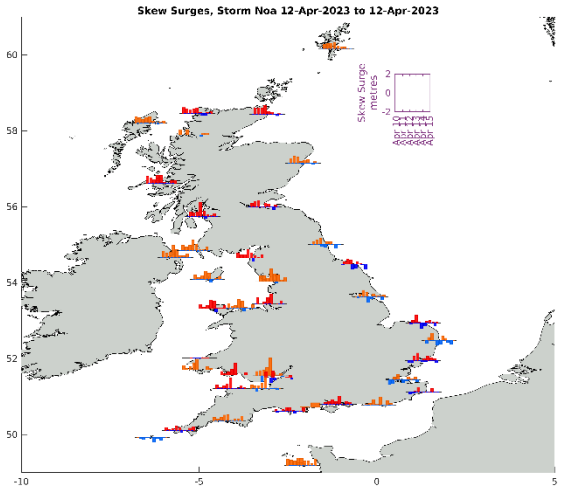

Storm Mar31 31-Mar-2023 to 01-Apr-2023

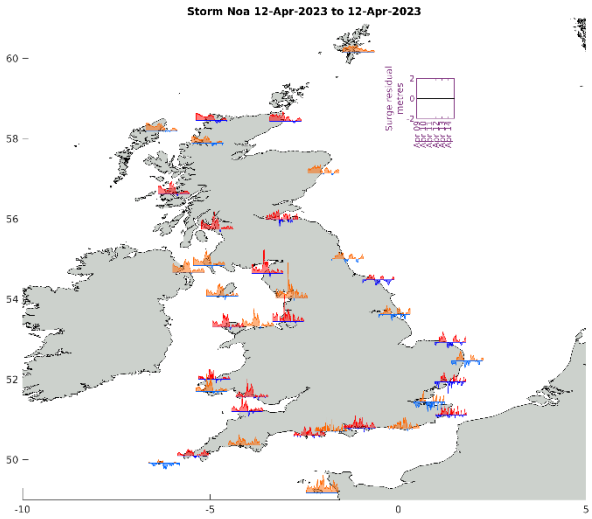

Mar31
Mar 30
Mar 31
Apr 01
Apr 02
Apr 03

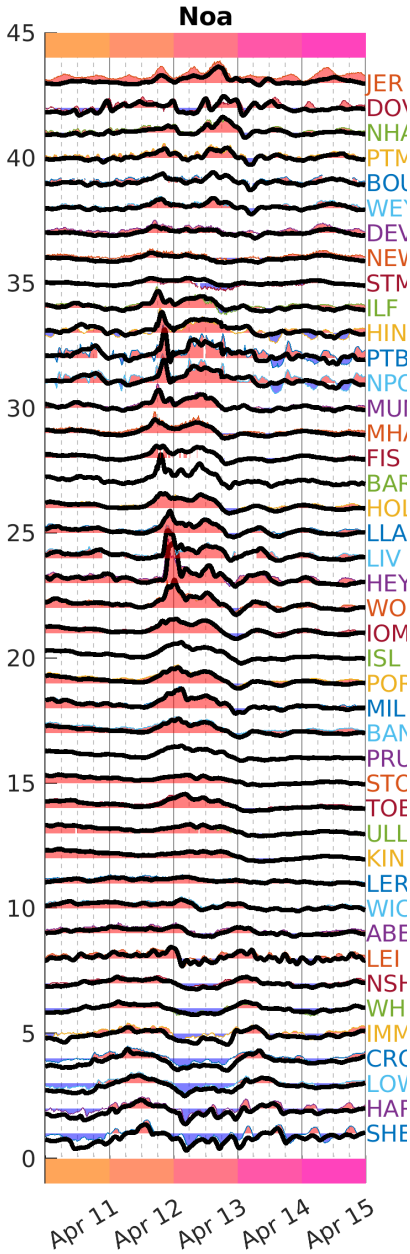

Mar31
Mar 30
Mar 31
Apr 01
Apr 02
Apr 03
Apr 04

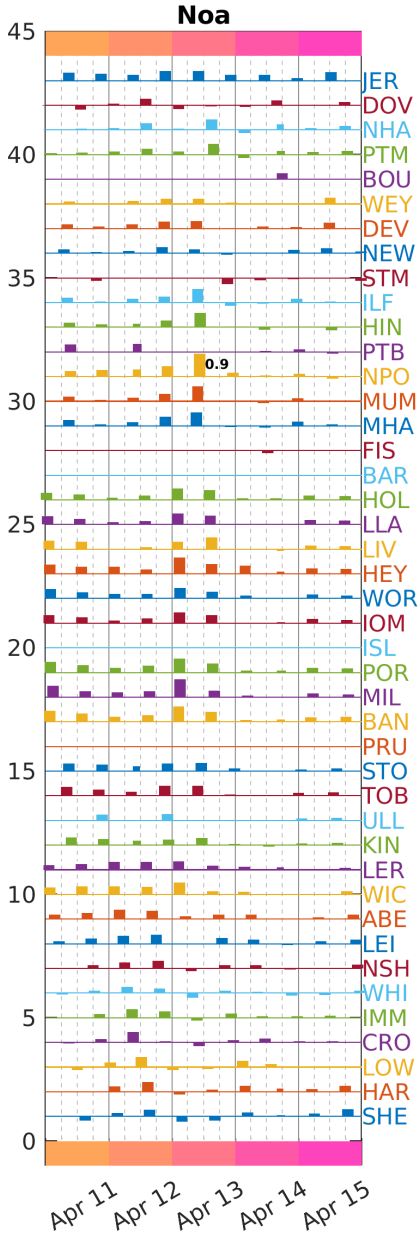
Storm Noa


Extreme positive or negative skew surge, storm Noa
12:00 11 Apr 2023
- 00:00 13 Apr 2023

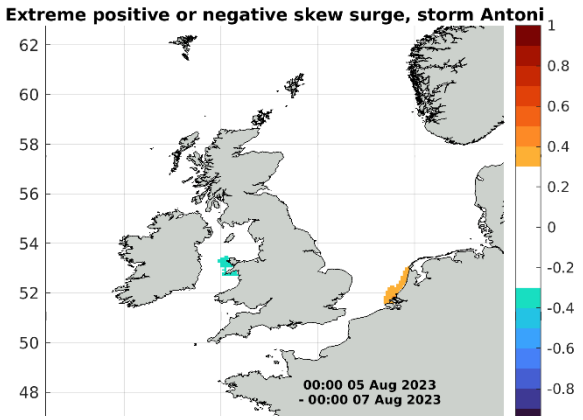

Skew Surges, Storm Noa 12-Apr-2023 to 12-Apr-2023

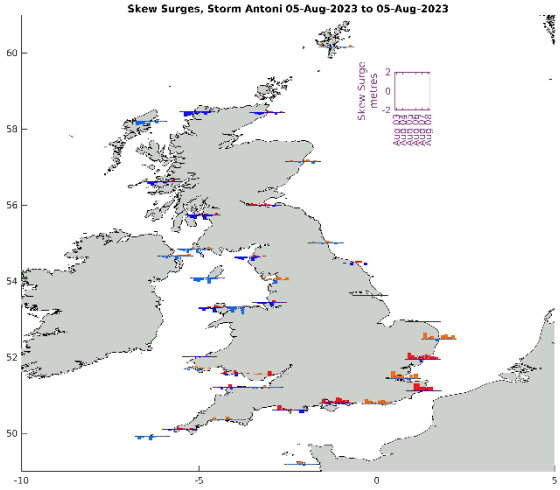

Storm Noa 12-Apr-2023 to 12-Apr-2023

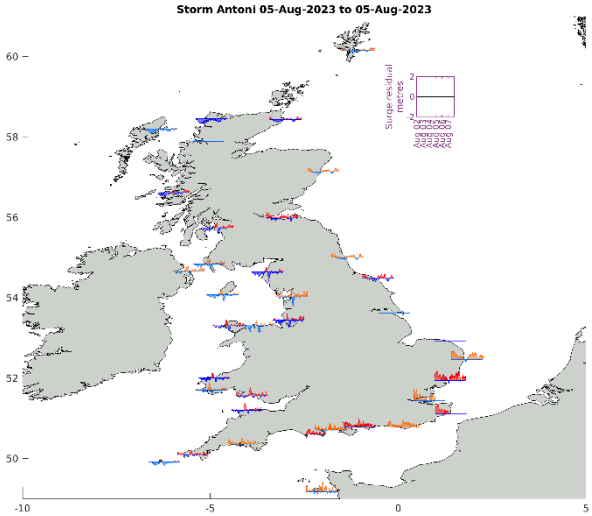

Noa
Apr 11
Apr 12
Apr 13
Apr 14
Apr 15

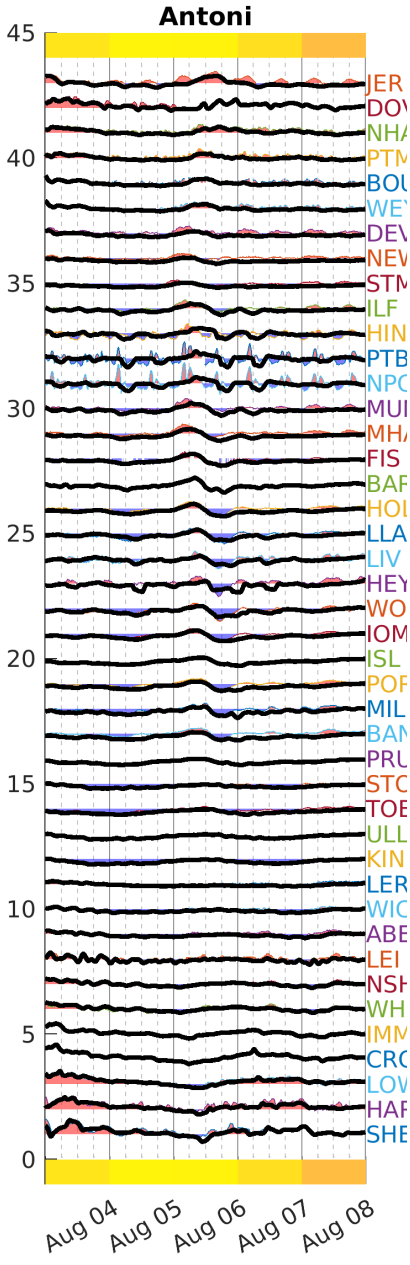

Noa
0.9
Apr 11
Apr 12
Apr 13
Apr 14
Apr 15

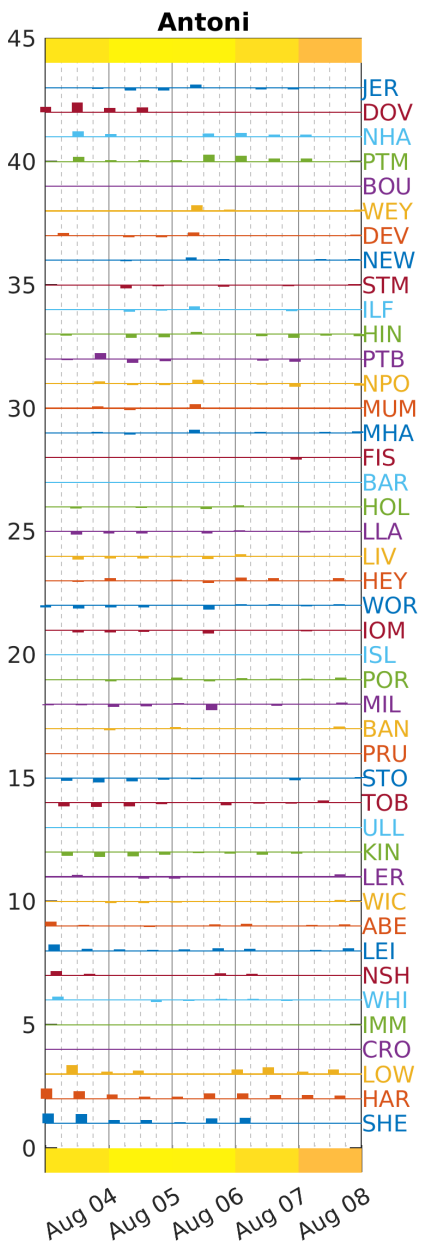
Storm Antoni, 5th August



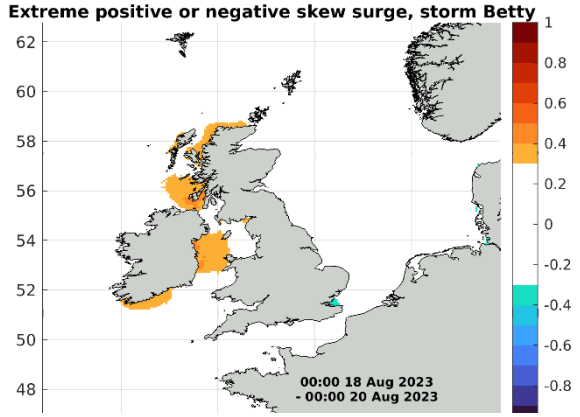


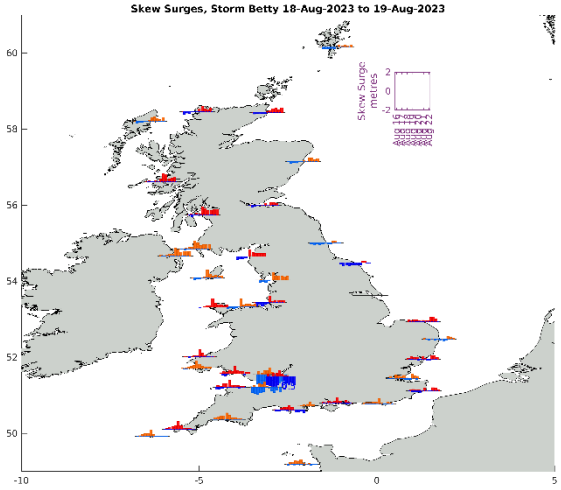


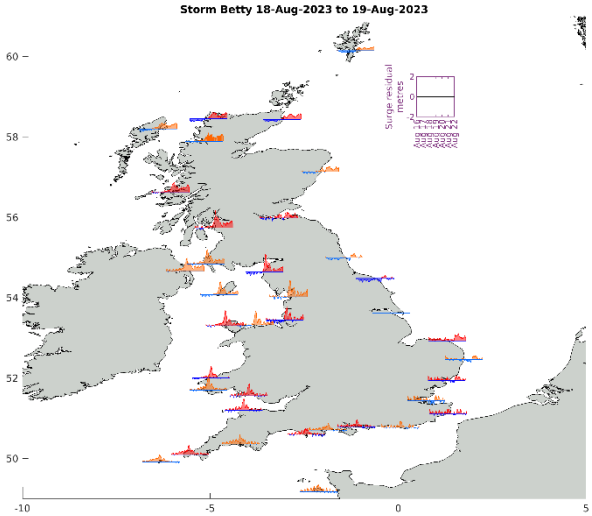


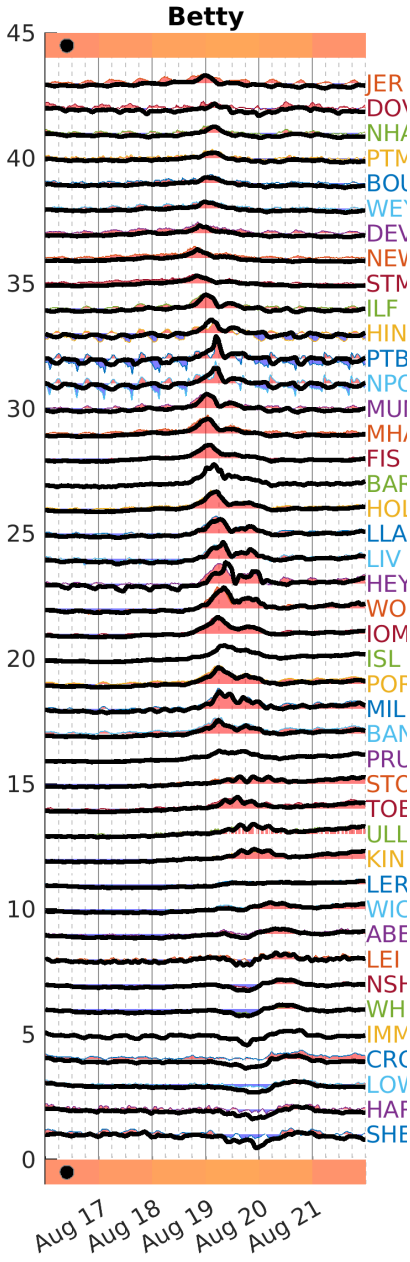


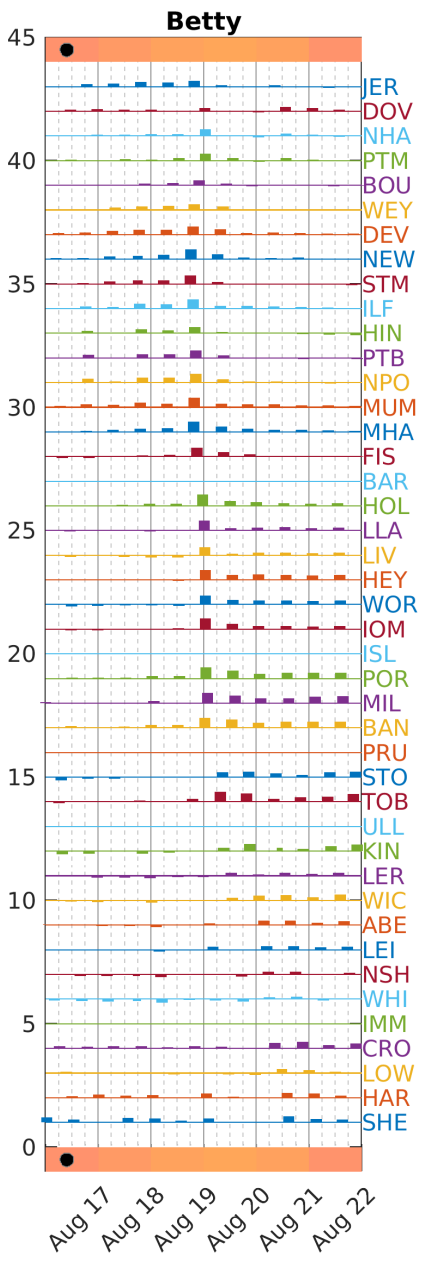
Storm Betty, 19th August



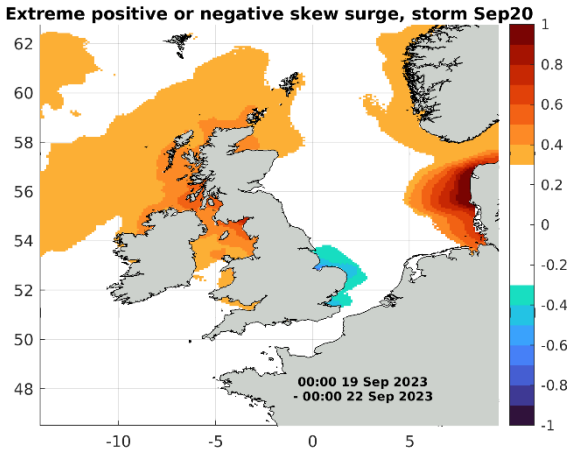


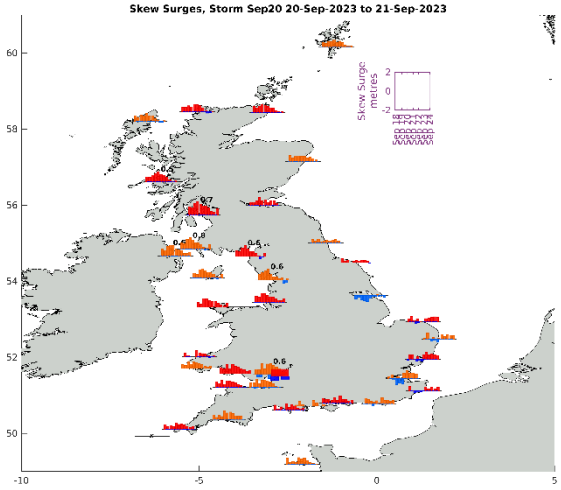


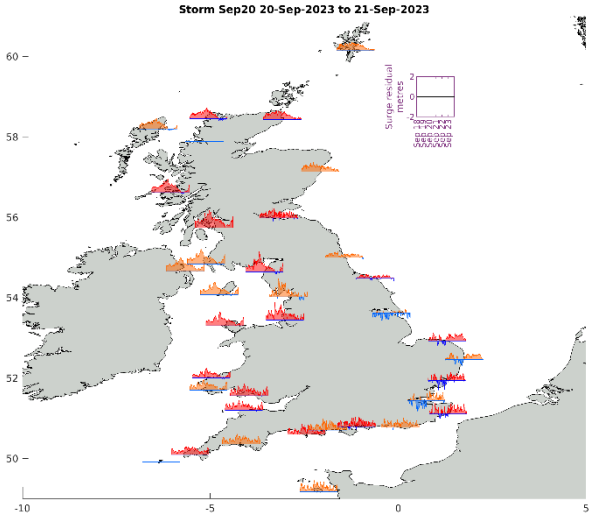


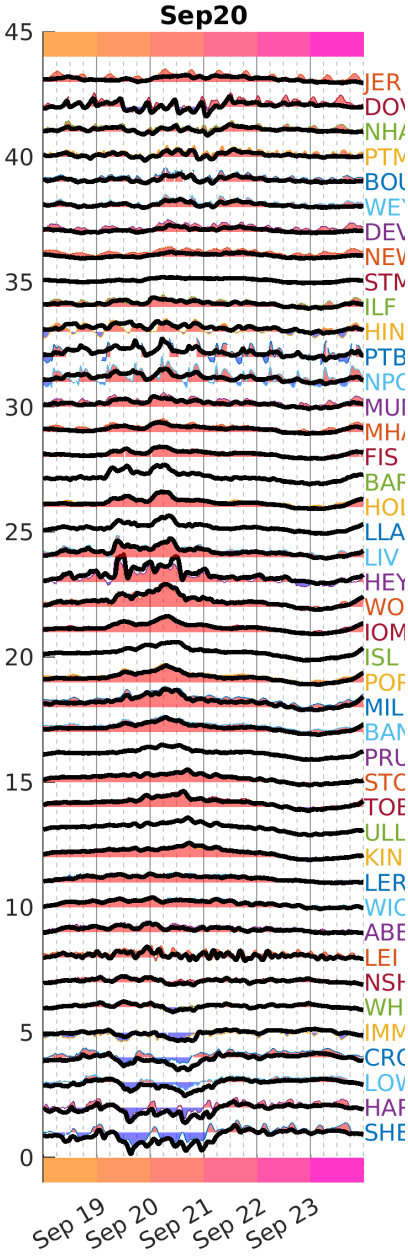


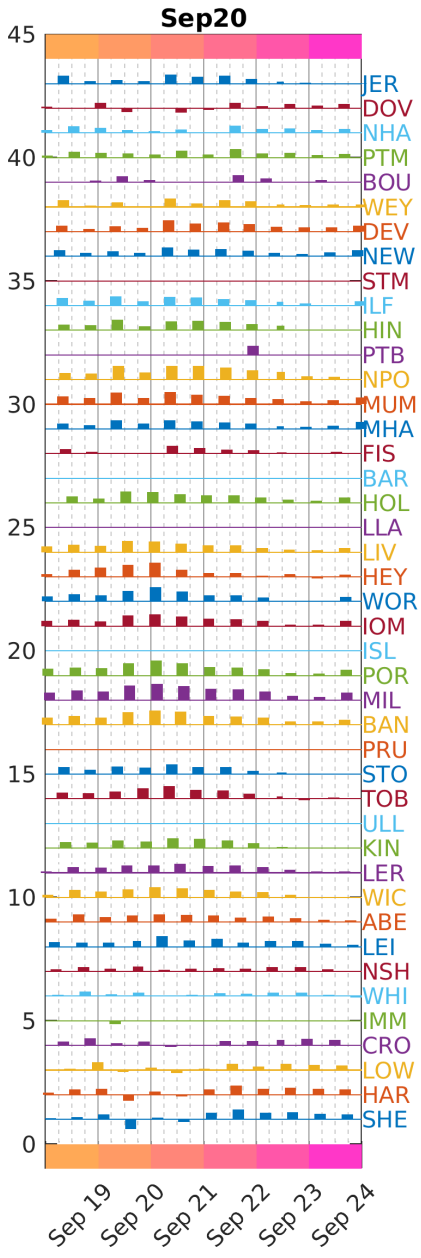
Storm Sep20


Extreme positive or negative skew surge, storm Sep20
00:00 19 Sep 2023
- 00:00 22 Sep 2023

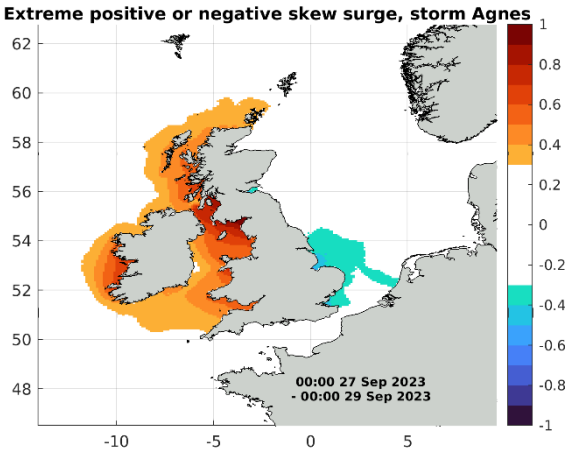

Skew Surges, Storm Sep20 20-Sep-2023 to 21-Sep-2023
Skew Surge metres

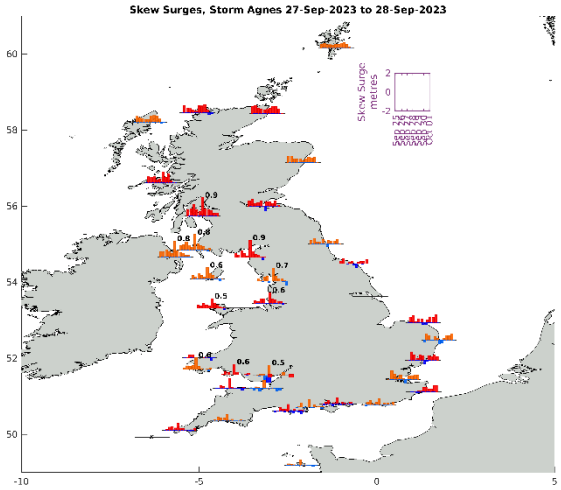

Storm Sep20 20-Sep-2023 to 21-Sep-2023
Surge residual metres

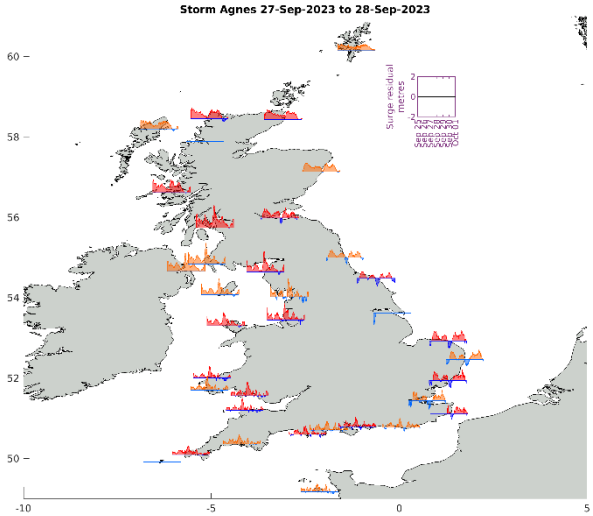

Sep20
Sep 19
Sep 20
Sep 21
Sep 22
Sep 23

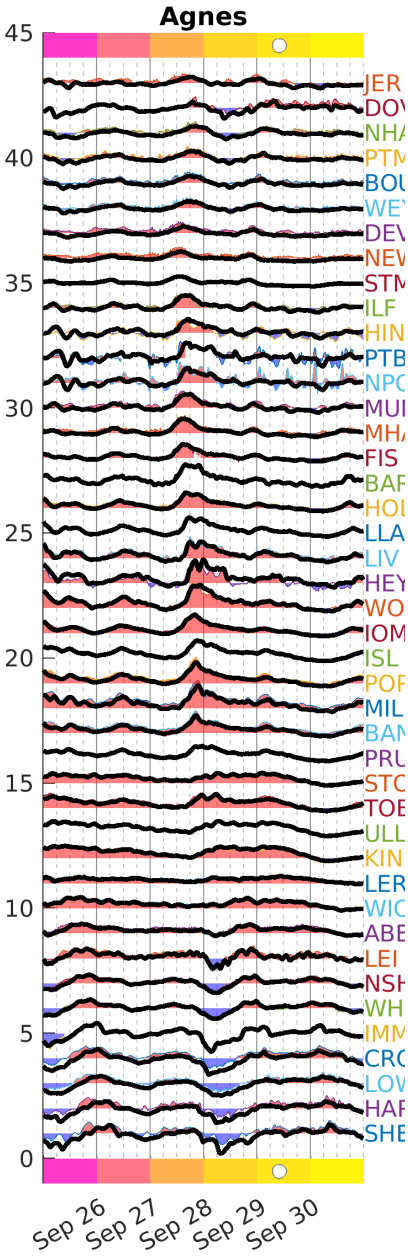

Sep20
Sep 19
Sep 20
Sep 21
Sep 22
Sep 23
Sep 24

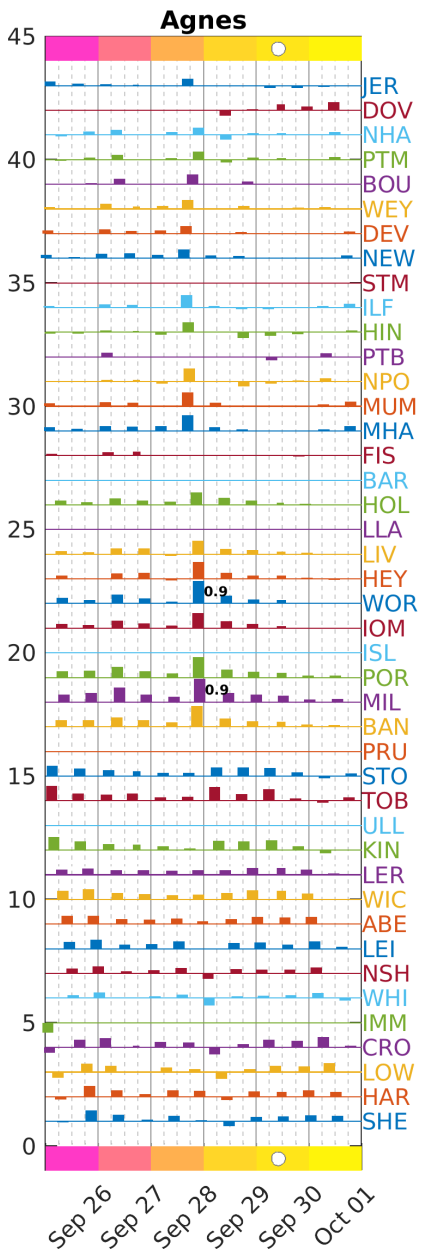
Storm Agnes, 28th September



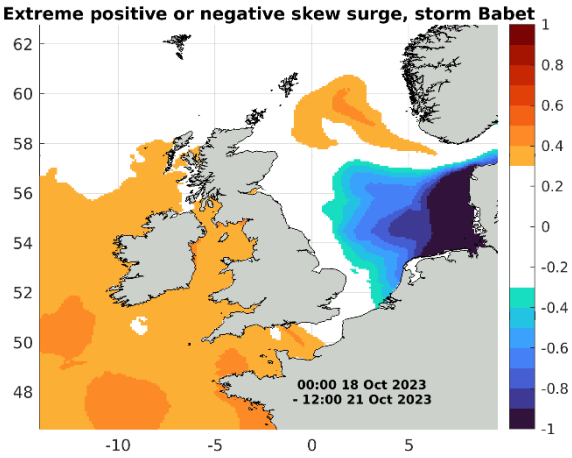


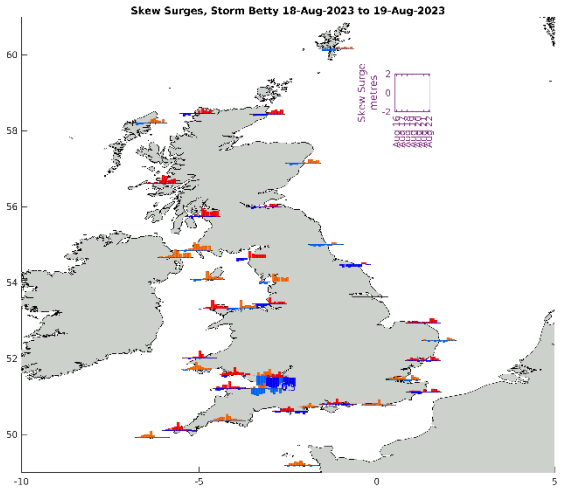


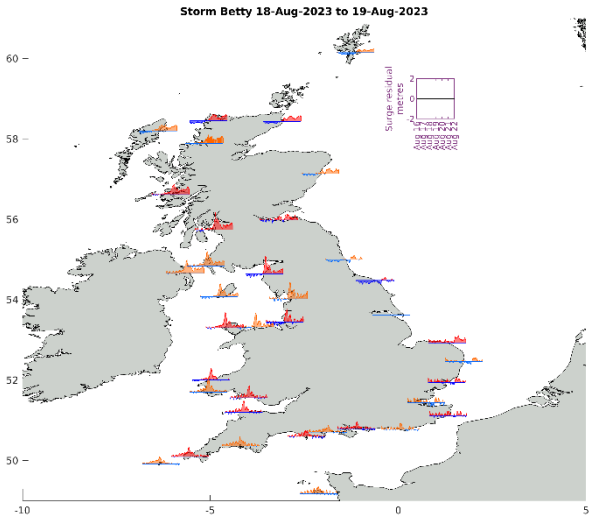


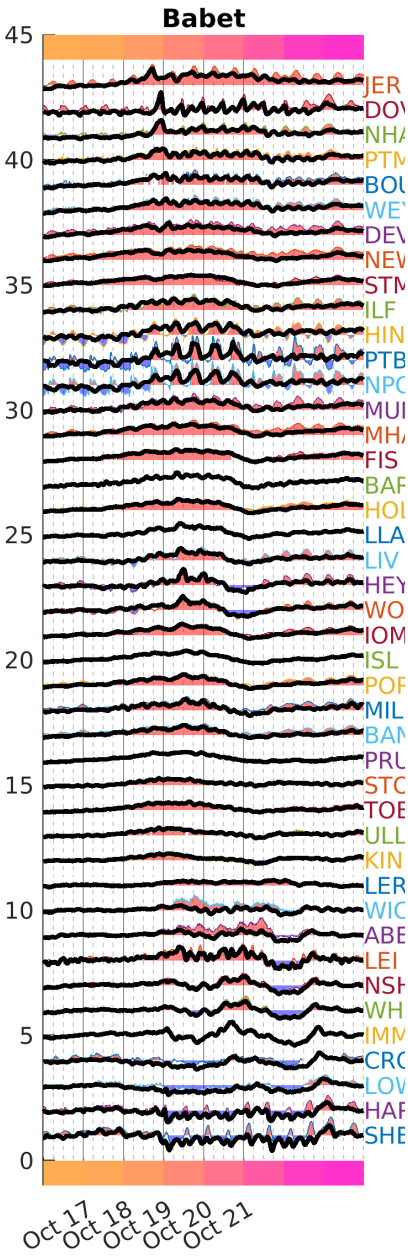


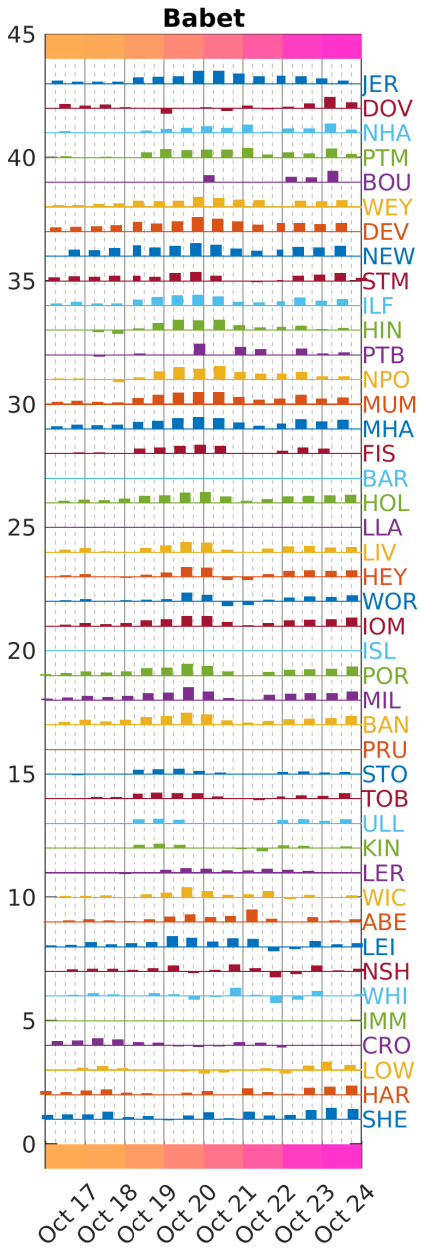
Storm Babet, 19th October



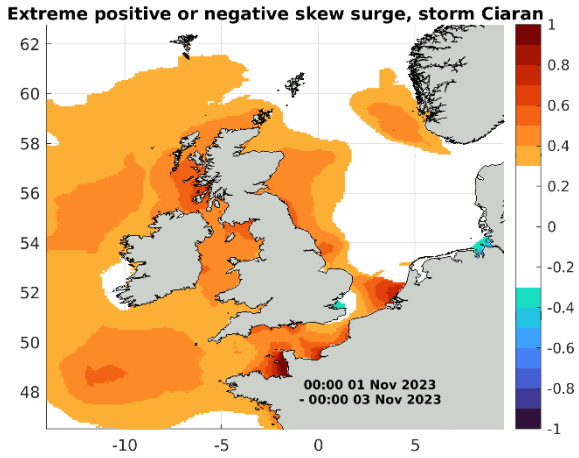


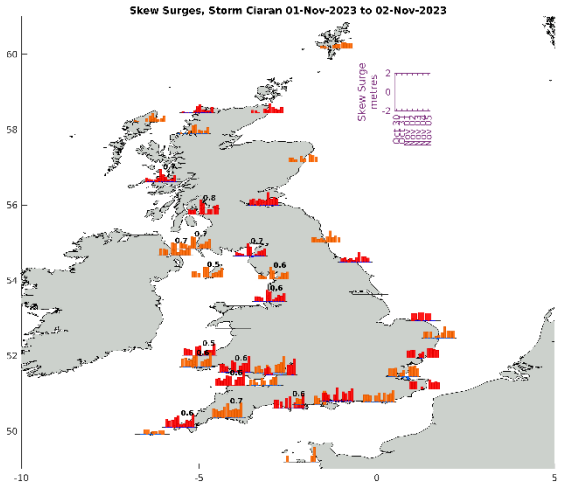


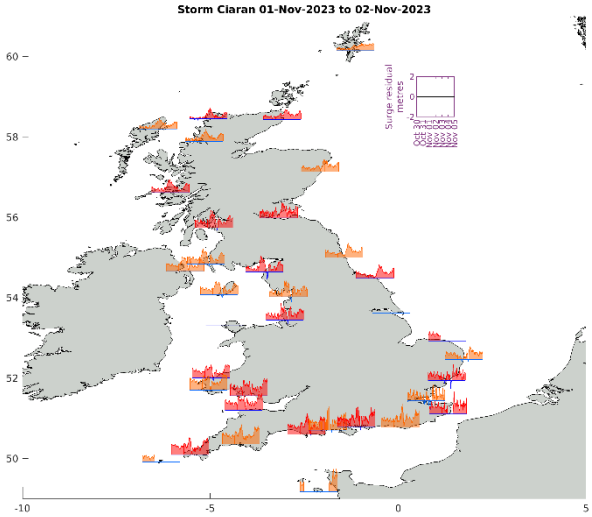


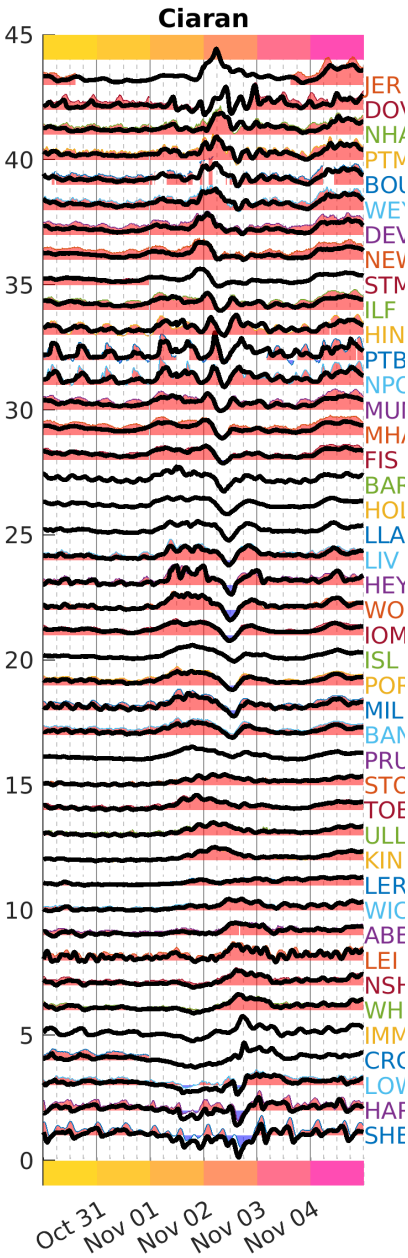


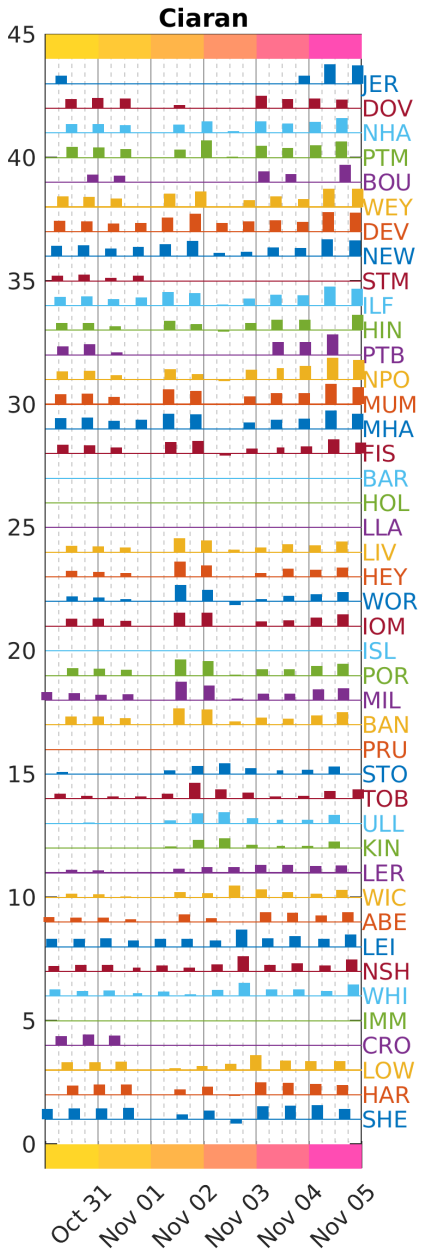
Storm Ciaran, 2nd November



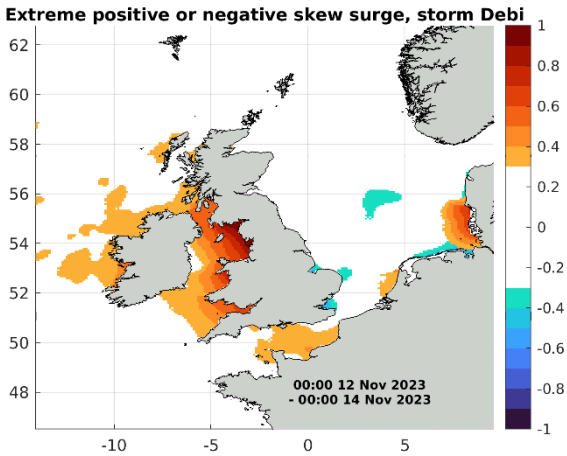


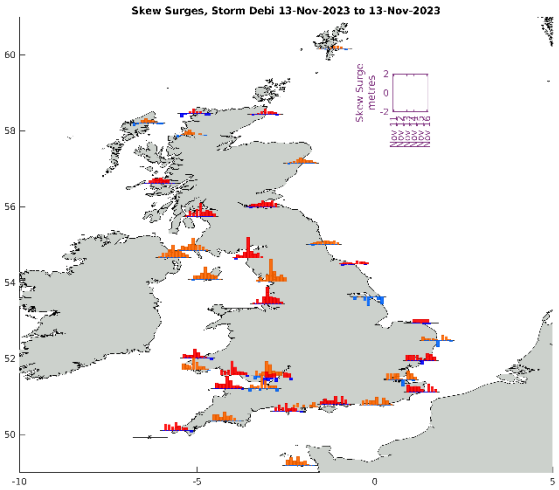


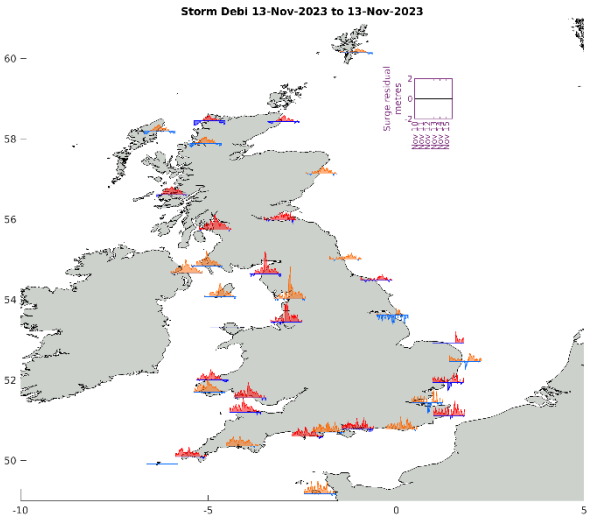


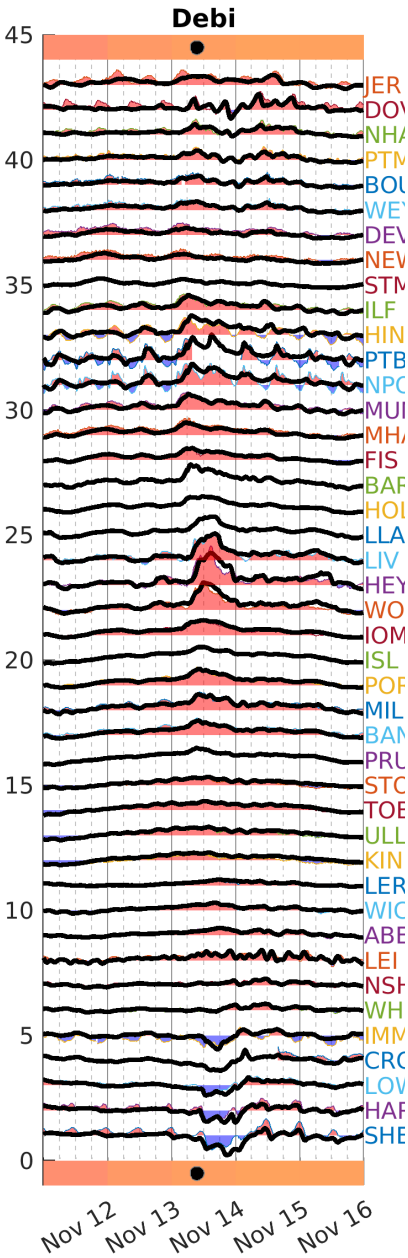


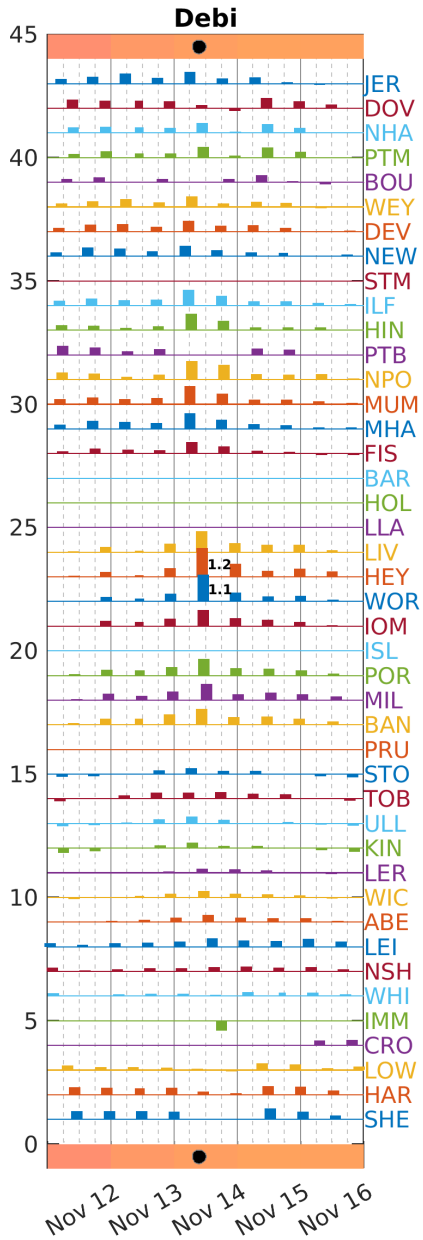
Storm Debi, 13th November



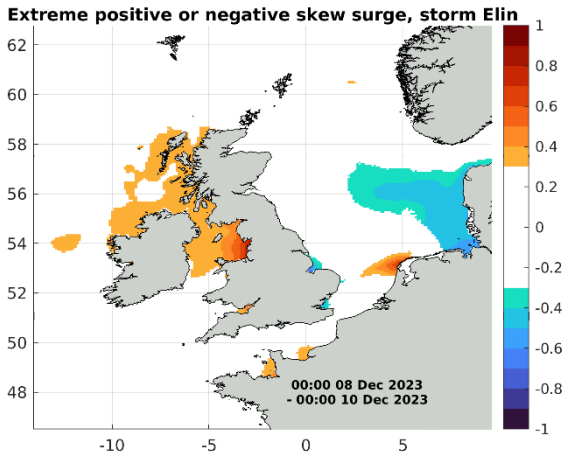


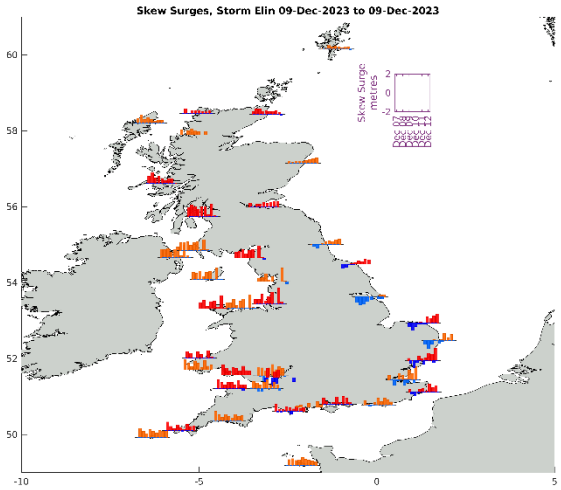


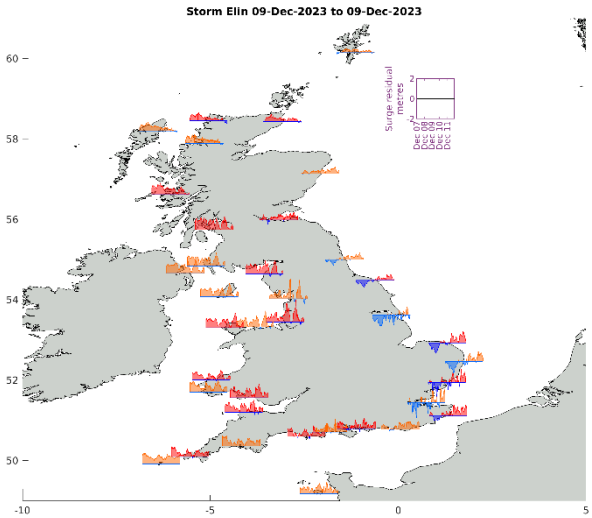


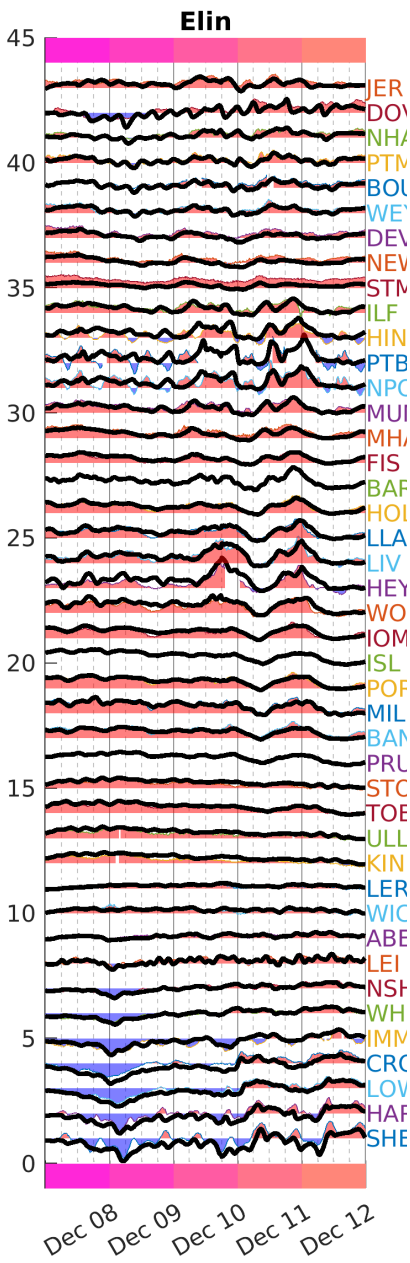


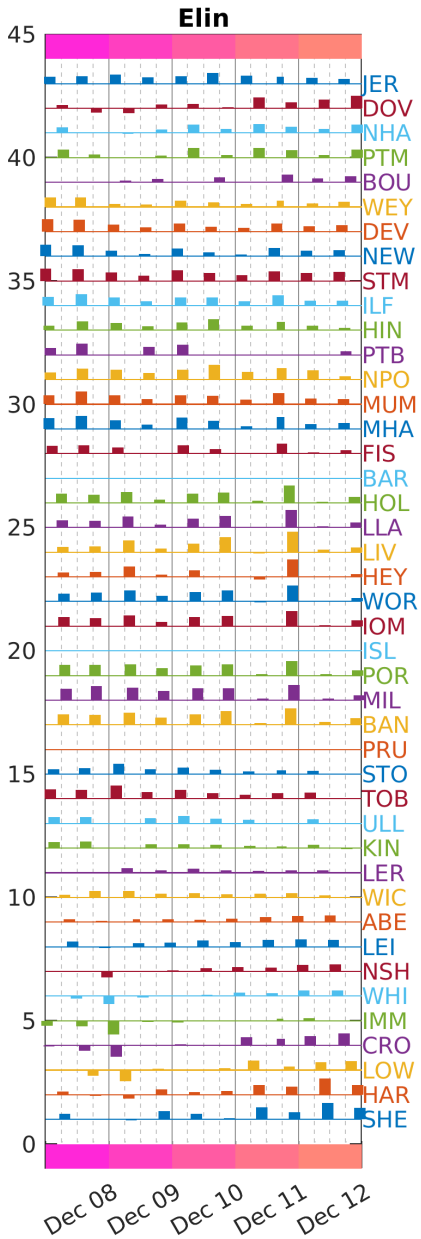
Storm Elin, 9th December



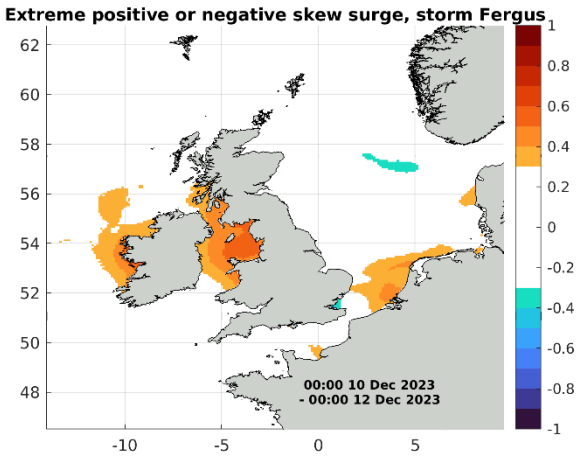


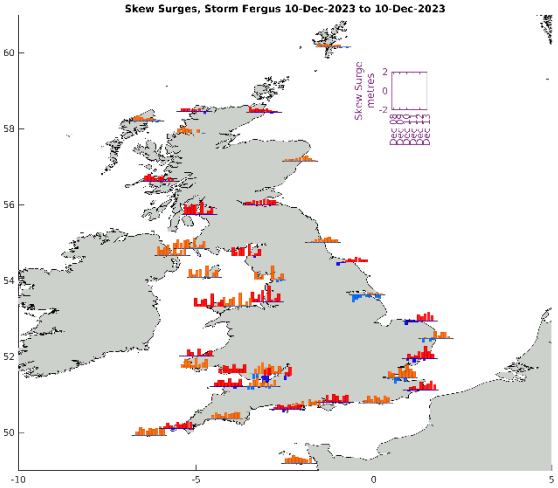


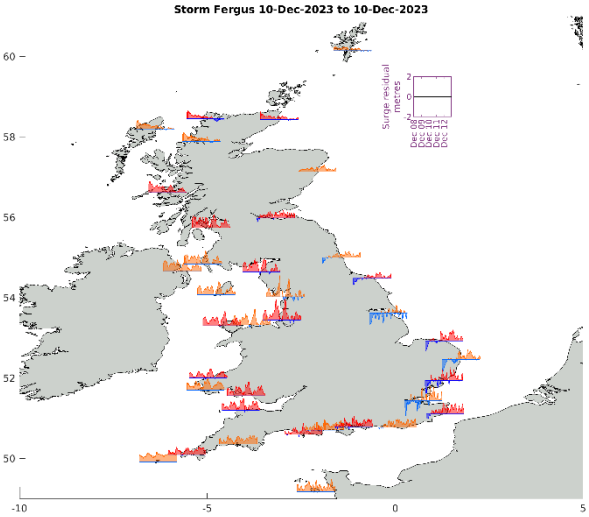


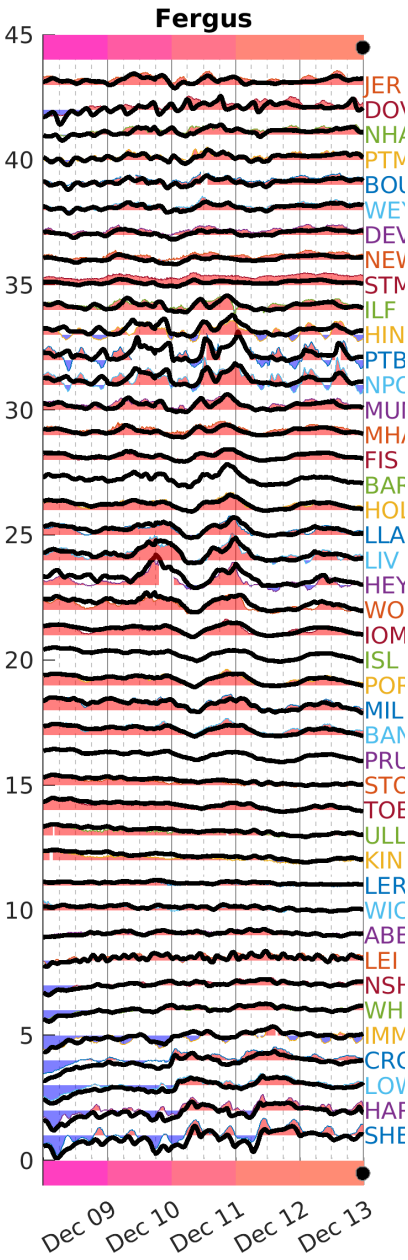


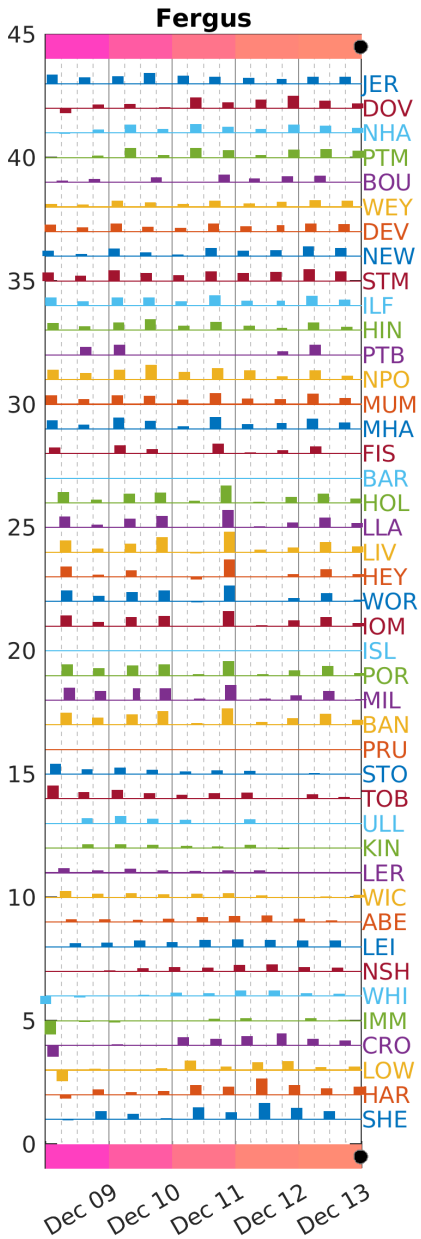
Storm Fergus, 10th December



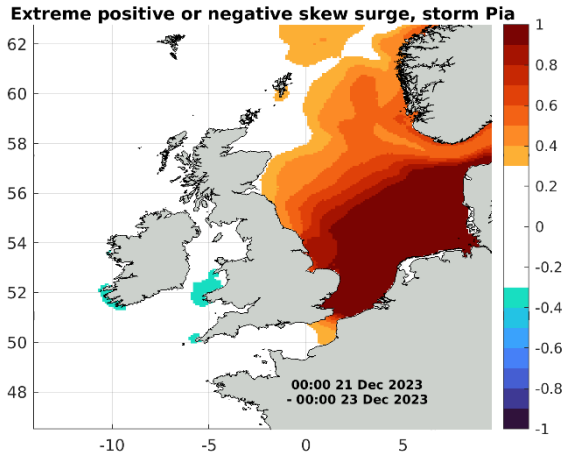


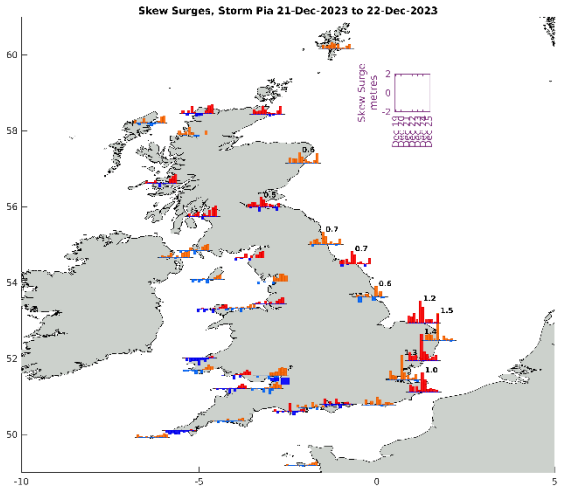


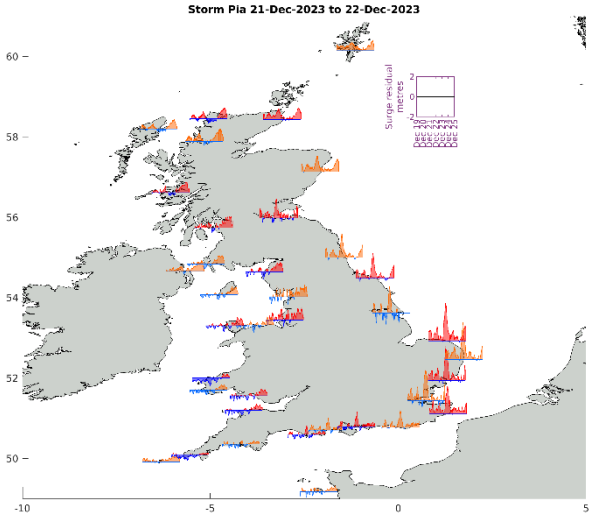


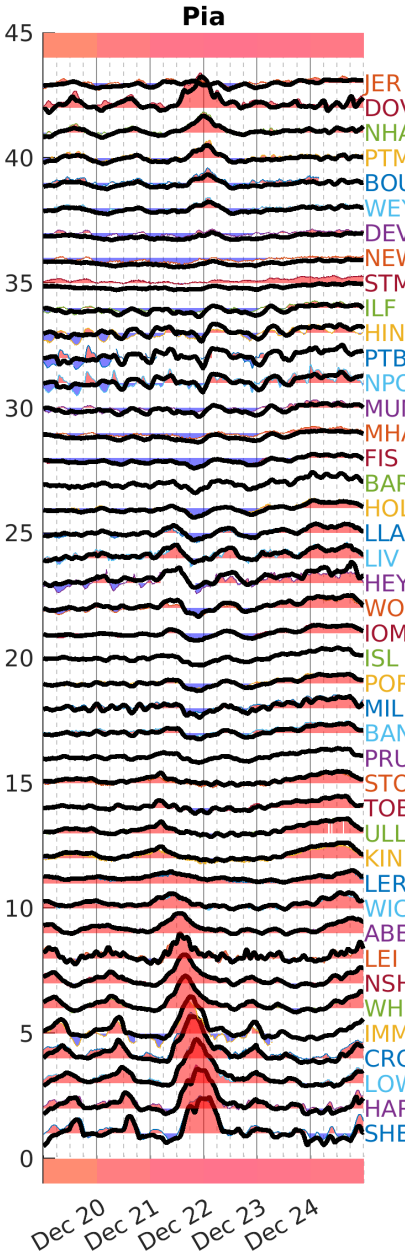


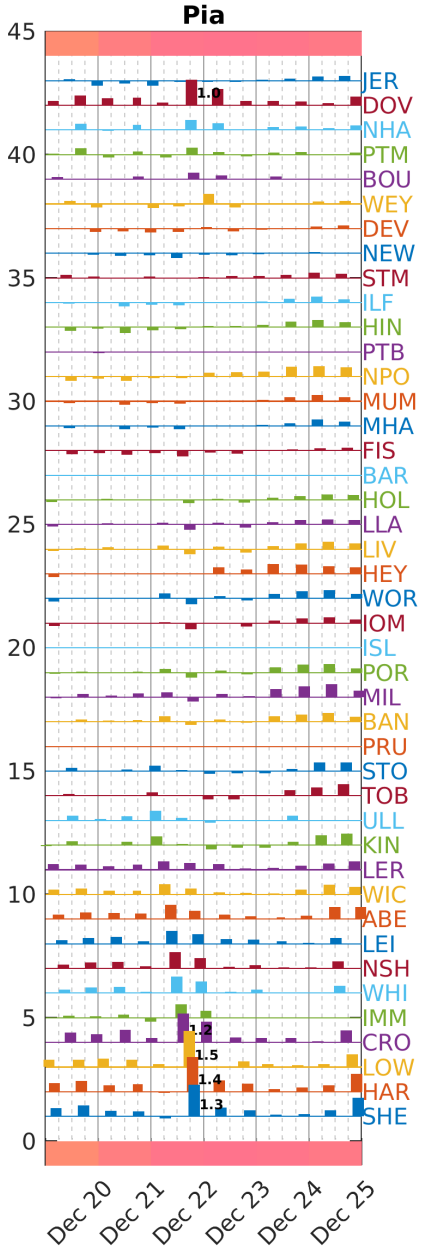
Storm Pia, 22nd December



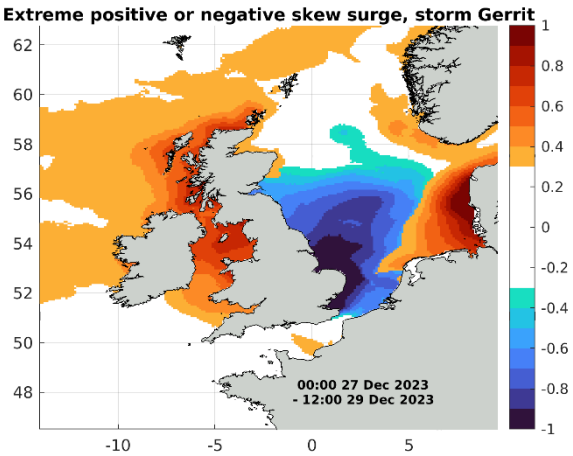


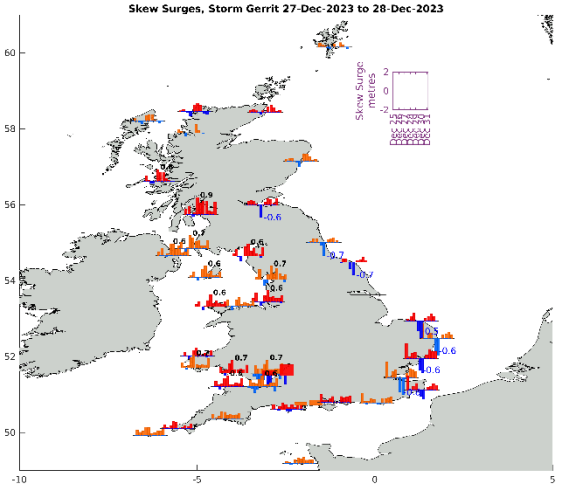


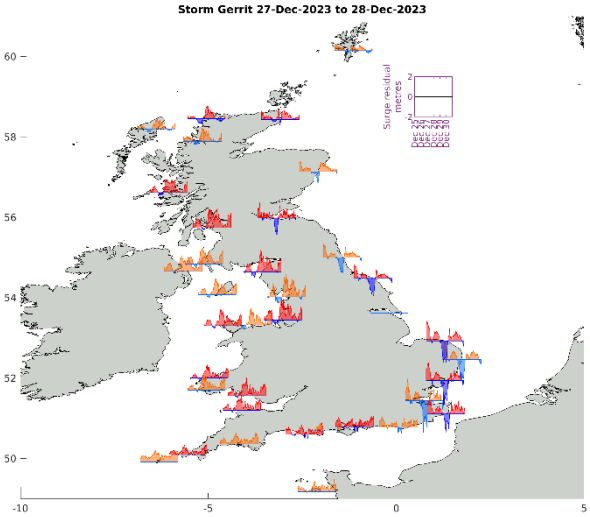


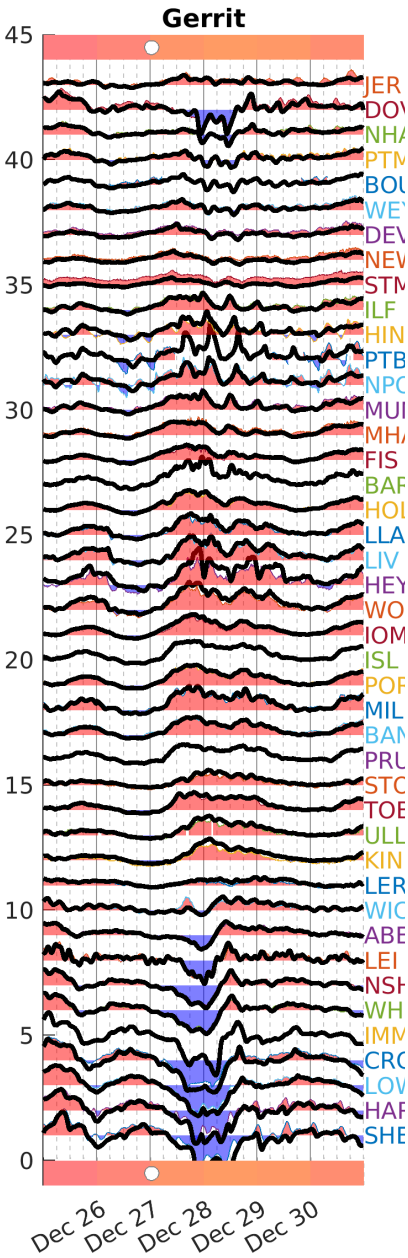


Storm Gerrit, 28th December









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