Adapting NEMO for use as the UK operational storm surge forecasting model

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Existing operational forecasting system

CS3x

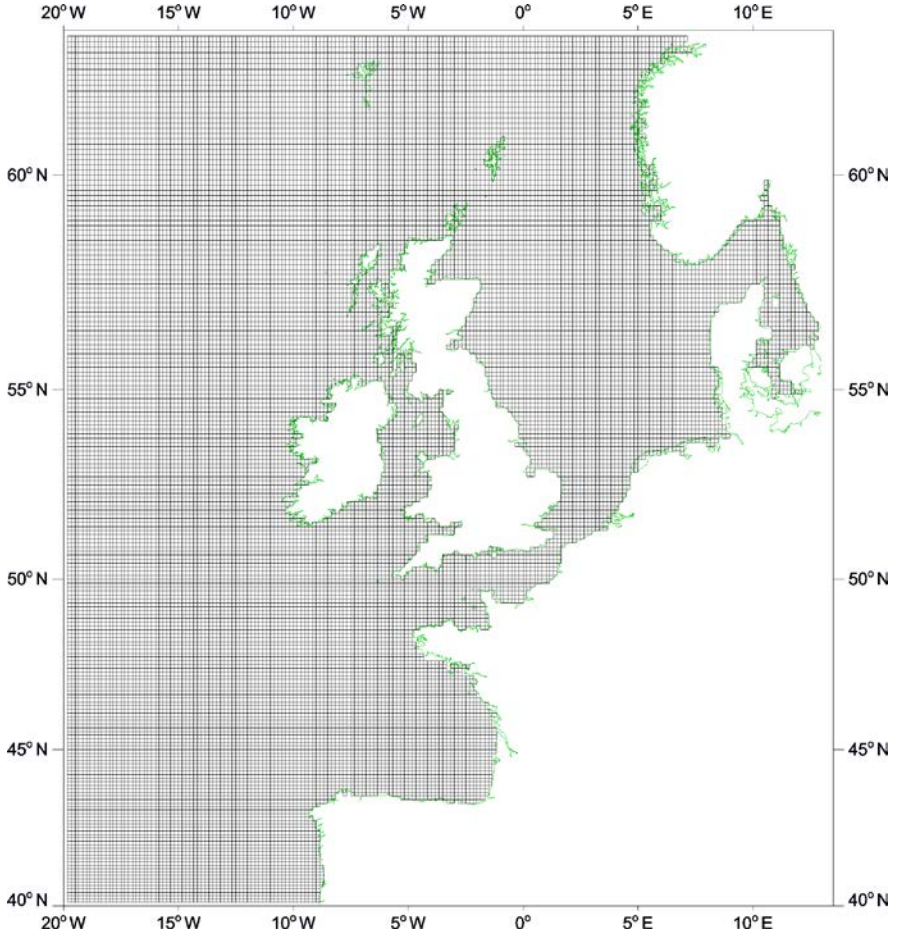
The National Tidal & Sea Level Facility (NTSLF) at NOC developed and maintains tide-surge models based on CS3, which are used to forecast storm surges on the UK coastlines

Single vertical level (barotropic) tide plus surge model, including Flather boundary condition for tides with 26 tidal constituents and Charnock based parameterisation for wind stress

CS3X is the core configuration used in UK surge forecasting run over UK continental shelf domain, resolved at 12km

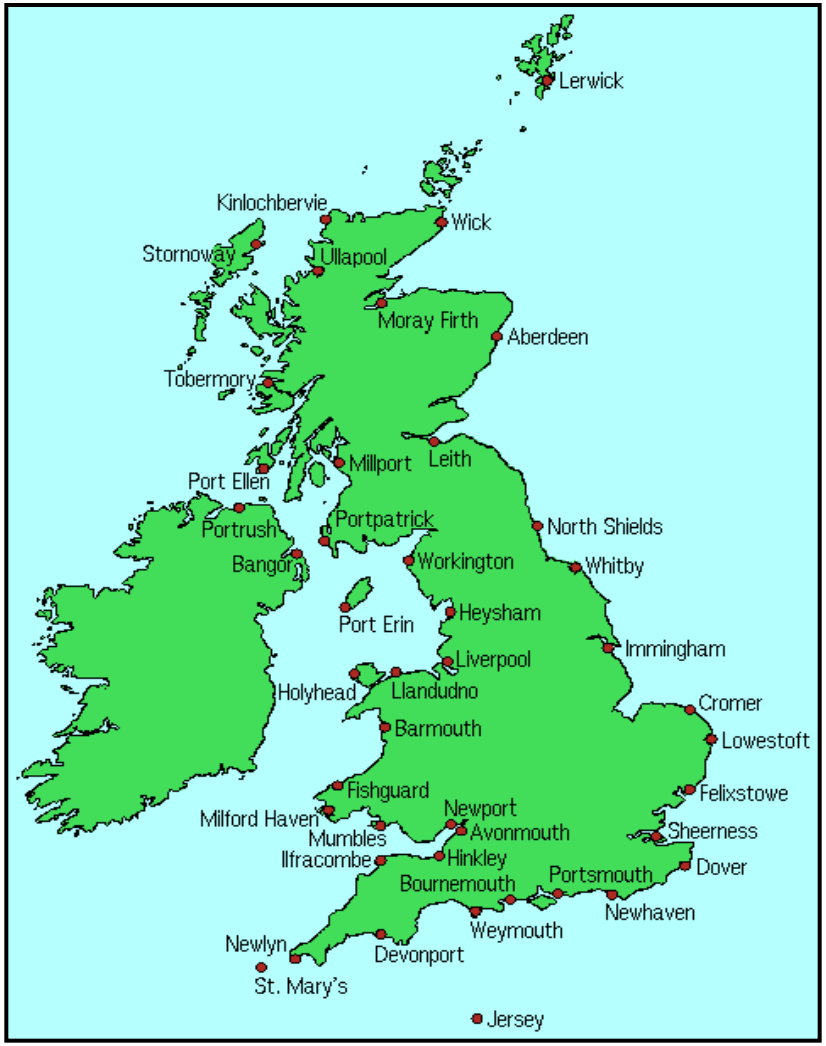
Run as an ensemble prediction system, with 12 ensemble members run 4 times per day, with 7 forecast days

Model is run in both tide+surge and tide-only modes; the tide-only run is subtracted to generate a ‘surge residual’ output which is used by UKCMF, together with data from the National Tide Gauge Network, for coastal flood warning in UK.



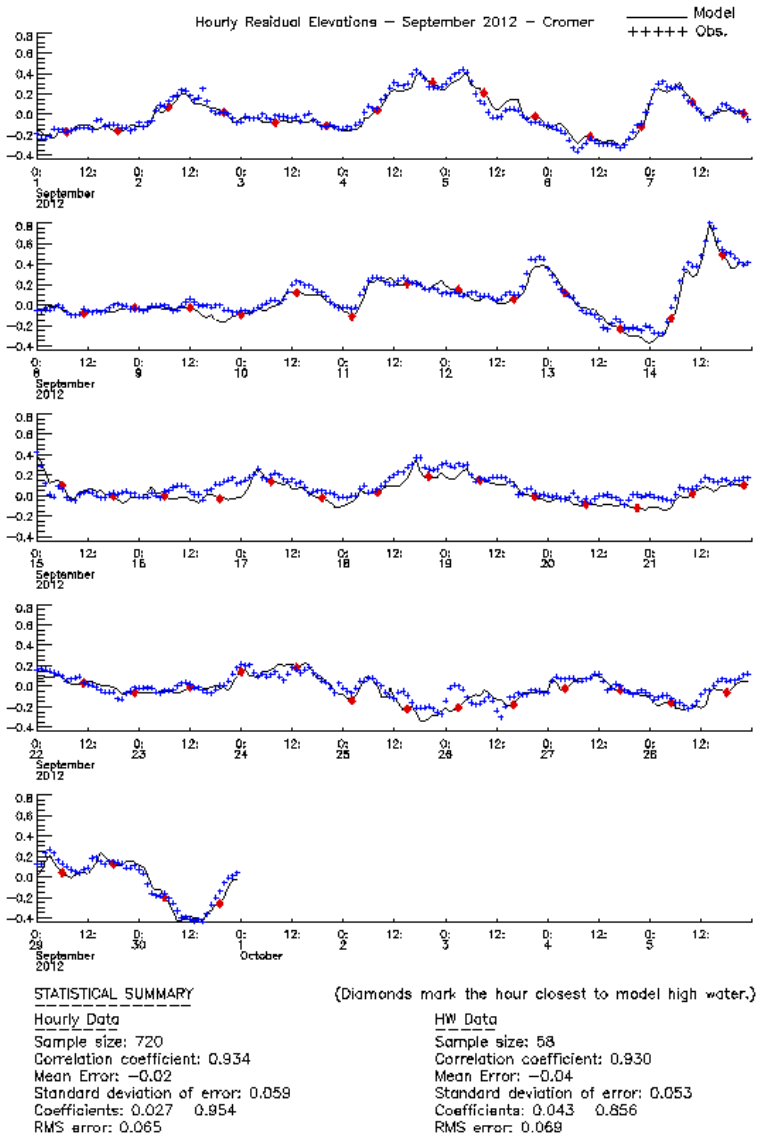
UK Tide Gauge Network

- The NTSLF at NOC operate the network of 44 stations on behalf of EA, SEPA and others.
- Logging and telemetry systems transfer data to the Met Office and then to the EA in near real-time.
- The data are also quality controlled and archived by the British Oceanographic Data Centre (BODC) at NOC.
- Forecasting method is based on summation between model surge residual and port ‘astronomic’ tide generated from harmonic analysis of tide gauge data



CS3x performance

- Validation time series are available on NTSLF web pages
- Surge model statistics are provided as NOC's input to the UKCMF annual report
- Surge model re-run archive spans over 20 years and commercially exploited by Apps Team
- Model performance is monitored at NOC by comparing forecast results with observations every month.
- Typical RMS errors are about 10cm.
- Significant forecast errors are investigated and causes diagnosed so that the system can be progressively improved.



Nemo Based Surge model

Transition to NEMO

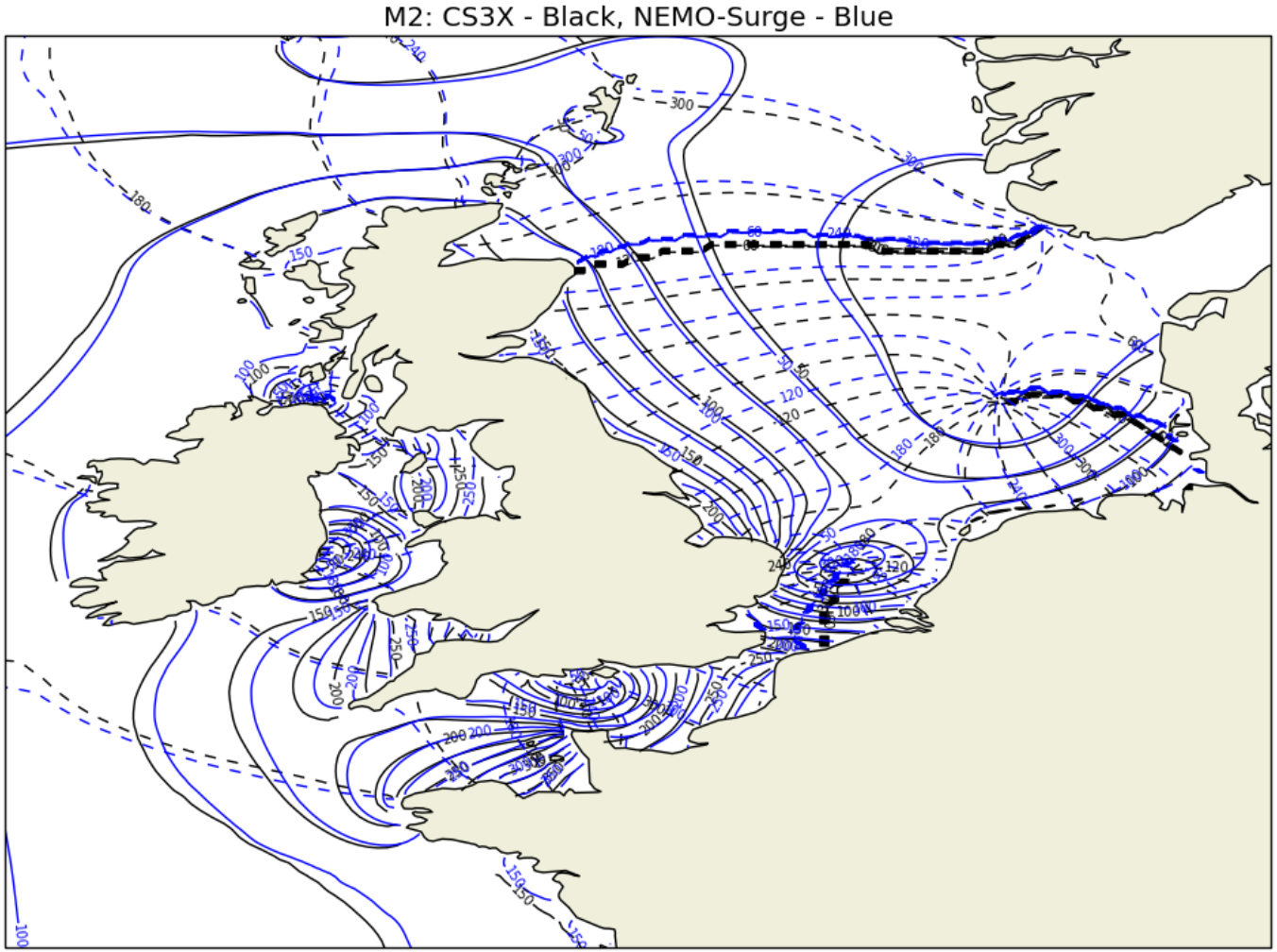
- CS3X is based on legacy code – well tuned and effective UK configuration but limited development opportunities and potential long term support issues.
- NEMO is an ocean model developed by a european consortium with a wide variety of uses, covering operational forecasting and research, global and coastal modelling, and short term and climate timescales
- Working with NEMO will enable use of better supported and configuration managed code, plus access to science developed in a wider international community.
- Synergies with existing Met Office and NOC projects and model configurations, e.g. MyOcean (AMM7, AMM15), coupled model development (UKEP).
- NEMO development will focus on tuning and improving surge related processes, particularly bottom friction and surface momentum flux, along with increasing efficiency by reducing the model to a one layer barotropic model.

Reducing complexity to increase efficiency

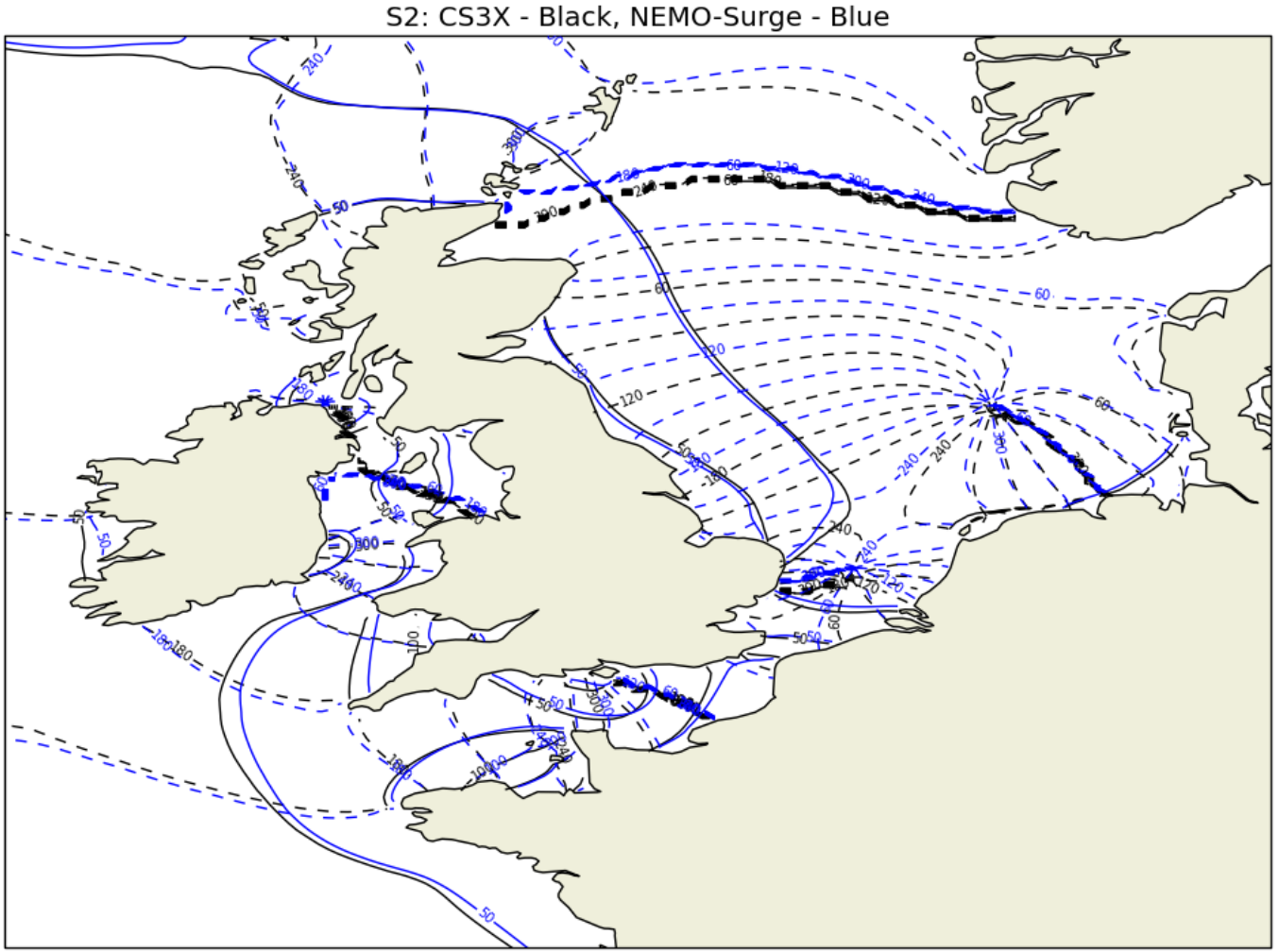
- All vertical processes removed
- All tracer processes removed
- Horizontal pressure gradient scheme revised to allow model to run with one active vertical level
- Run times and computational costs for 9 month constant density runs showed below

	Total CPU (days,h:m:s)	**Elapsed time (running on 128 processors) (seconds)**	**Total memory (Mb)**
50 levels	13,1:07:26	10720	43852
3 levels	4, 20:58:57	4009	30068
1 level (amended code)	4, 7:18:09	3535	29190

Initial results



Initial results



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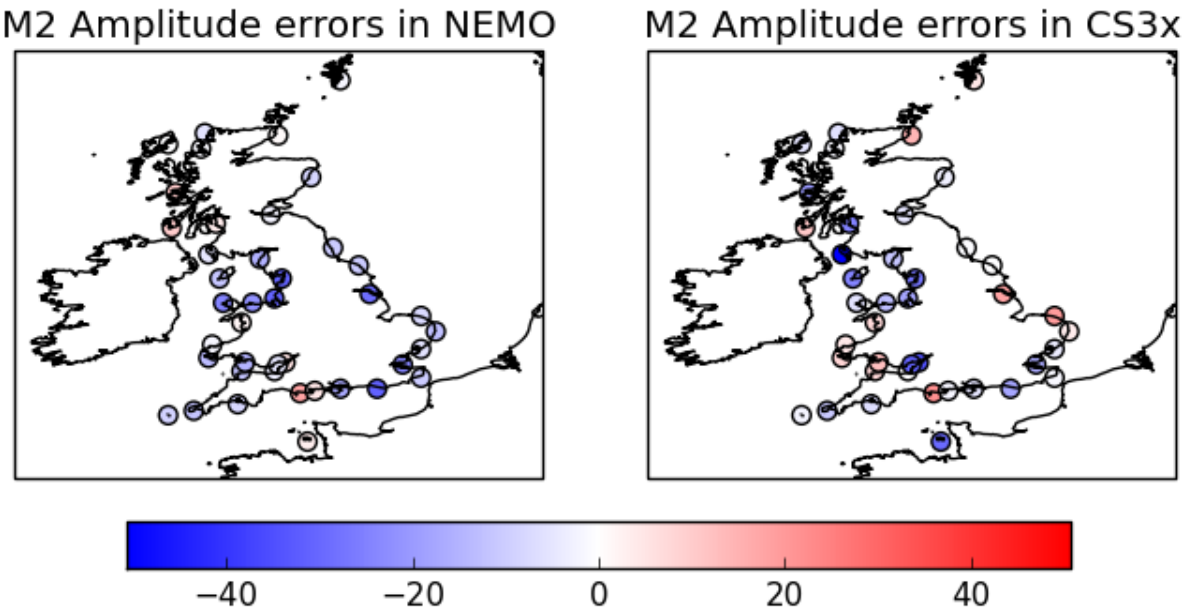
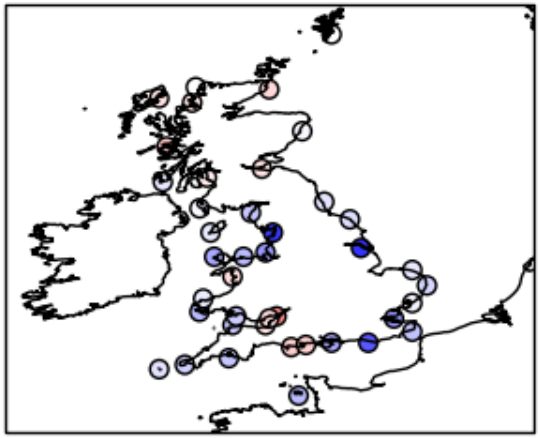
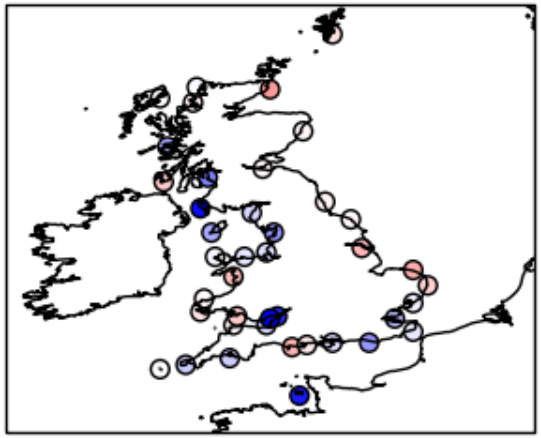


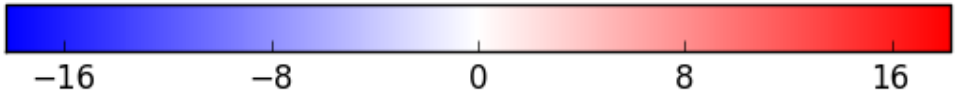
Initial results

S2 Amplitude errors in NEMO

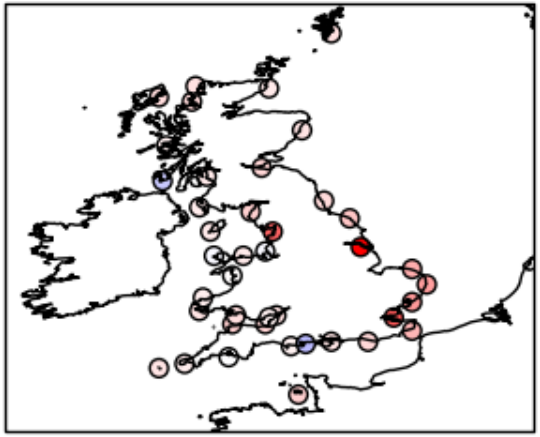


S2 Amplitude errors in CS3x

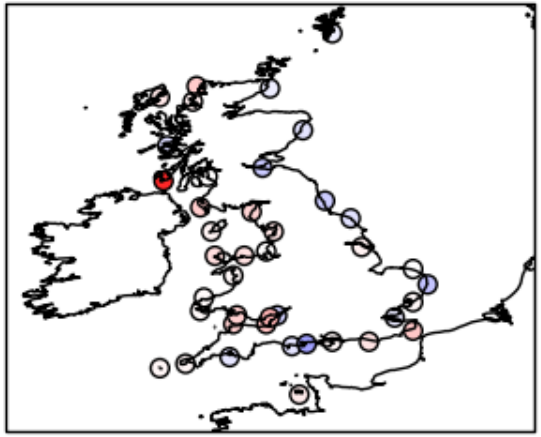


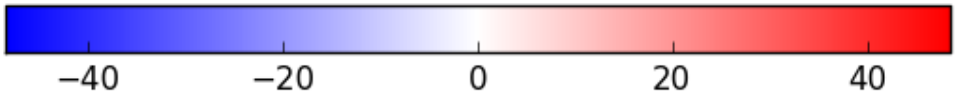


S2 Phase errors in NEMO



S2 Phase errors in CS3x



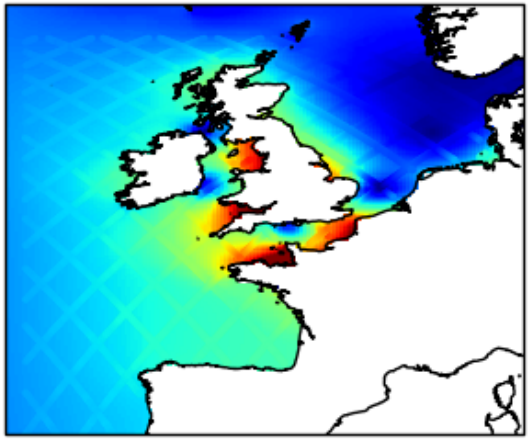


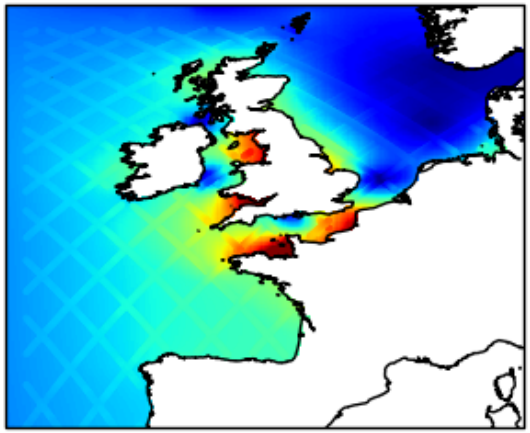
Initial results

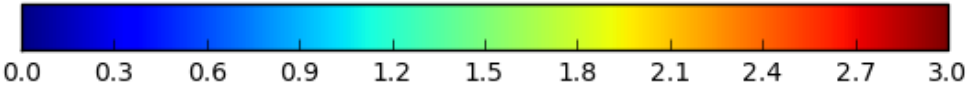
Name	NEMO RMS Amplitude (cm)	CS3X RMS amplitude (cm)	NEMO phase error (deg)	CS3X phase error (deg)
Q1	0.69	0.50	8.76	-6.77
O1	1.13	1.64	10.94	5.77
P1	0.52	0.46	0.70	-9.57
K1	1.47	1.01	-0.33	5.02
2N2	2.08	2.27	-14.61	-11.27
MU2	2.70	3.72	10.90	4.68
N2	3.38	4.12	8.11	3.89
NU2	0.82	0.77	-2.00	1.43
M2	14.04	16.66	4.78	1.08
S2	5.15	6.46	7.59	1.83
K2	1.65	2.45	7.20	2.25
M4	9.34	5.82	36.43	22.85
MS4	6.74	4.46	32.6	2.82
M6	2.48	2.51	27.69	20.70

Initial results

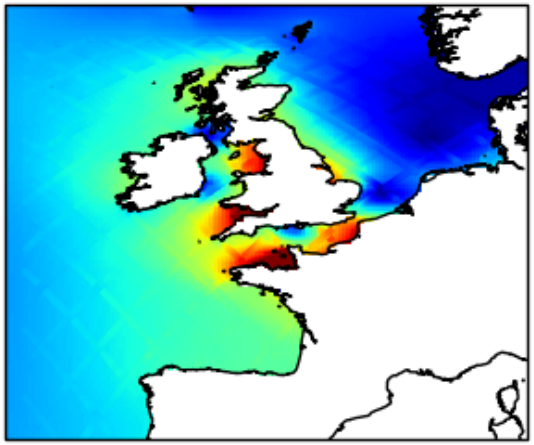
M2 constituent

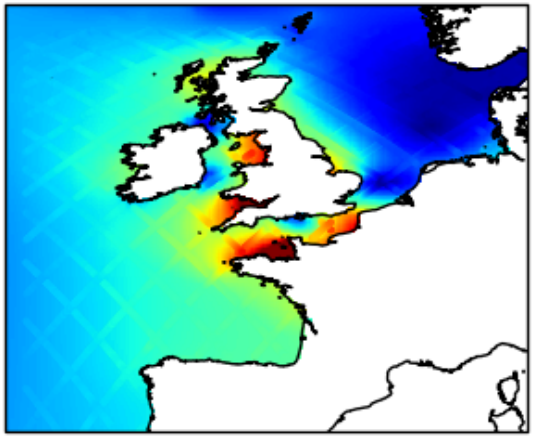


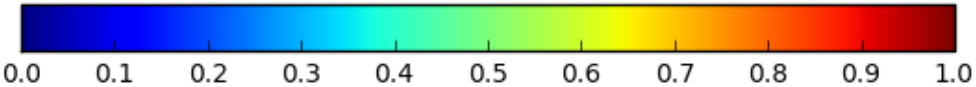




S2 constituent







Comparison of tidal amplitudes from harmonic analysis of models and from satellite data. CS3X on left, NEMO on right

Future plans

- Tune the bottom friction coefficient
- Test EMODnet bathymetry
- Run the model with atmospheric forcing, using the Charnock coefficient for wind drag parameterization, and tune this.
- Thorough testing, to include parallel use by forecasters.
- Implement wetting and drying within the surge configuration
- Implement and assess use of a varying coefficient for bottom friction formulation.
- Coupled wave ocean processes
- Data assimilation.

Summary

- The CS3X storm surge model developed by NOC-L and run by Met Office is a mesoscale configuration, tide plus surge model run in an EPS out to 7 days ahead.
- Surge residuals from the EPS are combined with port harmonic predictions to provide total water level forecasts
- To ensure future support and development of the UK surge model, NOC and Met Office are collaborating on a transition to a NEMO based code
- Initial tidal testing shows amplitudes are well represented in the model, but that there is a bias in the tidal phases, further tuning is needed
- Post transition we will aim to examine effects including 2D varying bottom friction, wetting and drying, coupled wave ocean processes and data assimilation.