Proudman Oceanographic Laboratory
NATURAL ENVIRONMENT RESEARCH COUNCIL

Improving surge forecasts in southern UK using real-time data from Europe

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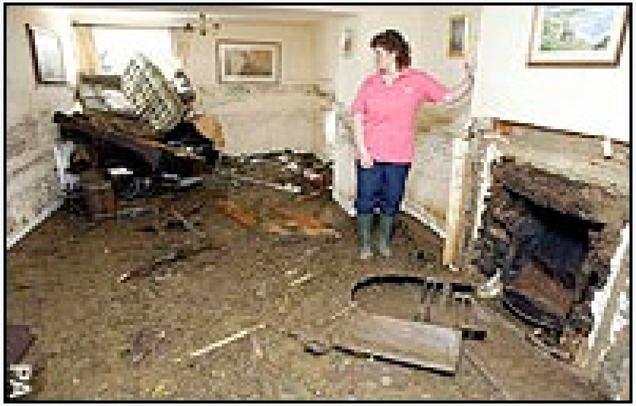
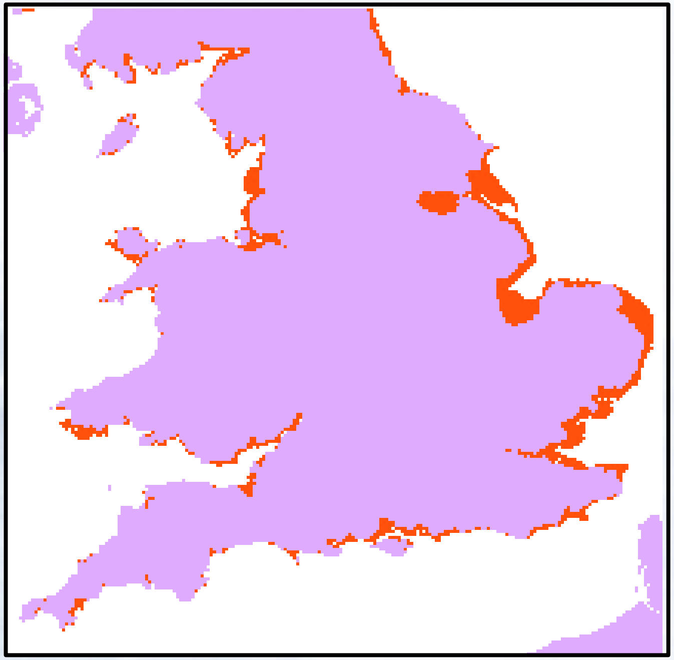
POL

Coastal flooding costs millions and ruins lives

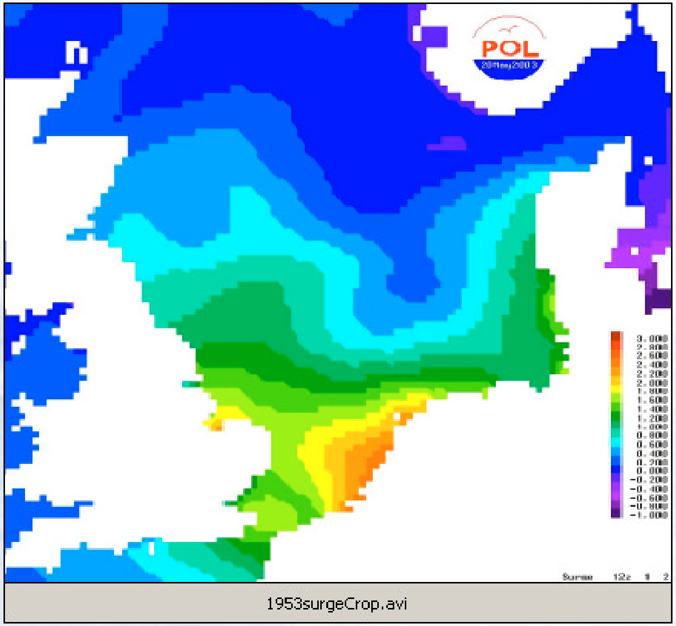
- The UK has 12,400km of coastline
- 5 million people in England and Wales live in flood risk areas
- 41 % of are not fully aware of the threat
- Problem made worse by rising sea level, and the possibility of more extreme events
- By 2100 the 1000 year flood return level (shown here in red) may become a 100 year return level



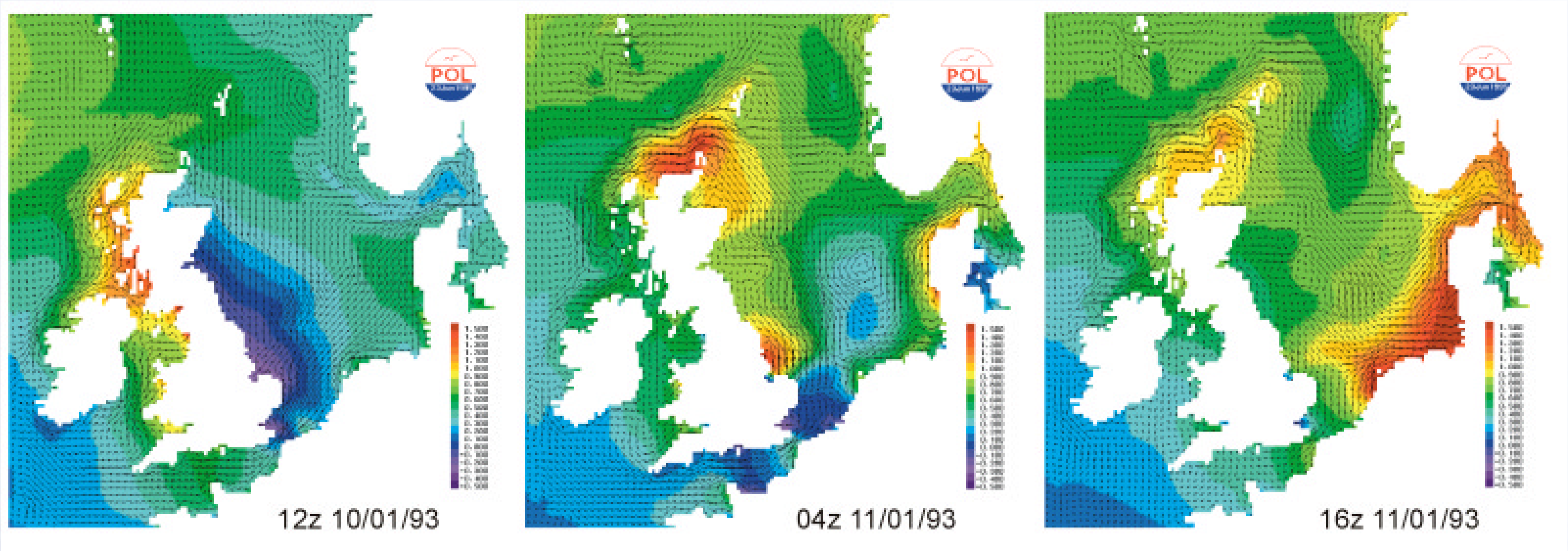


Reasons for an effective forecasting service

- The North Sea storm surge of 31 January - 1 February 1953 caused extensive flooding and loss of life.
- 309 people drowned in southeast England and 1830 died in Holland. Sea level was raised by over 3.5 m in the worst affected regions.
- The floods of autumn 2000 caused damage to 10,000 properties with a total cost of more than £1.3 billion



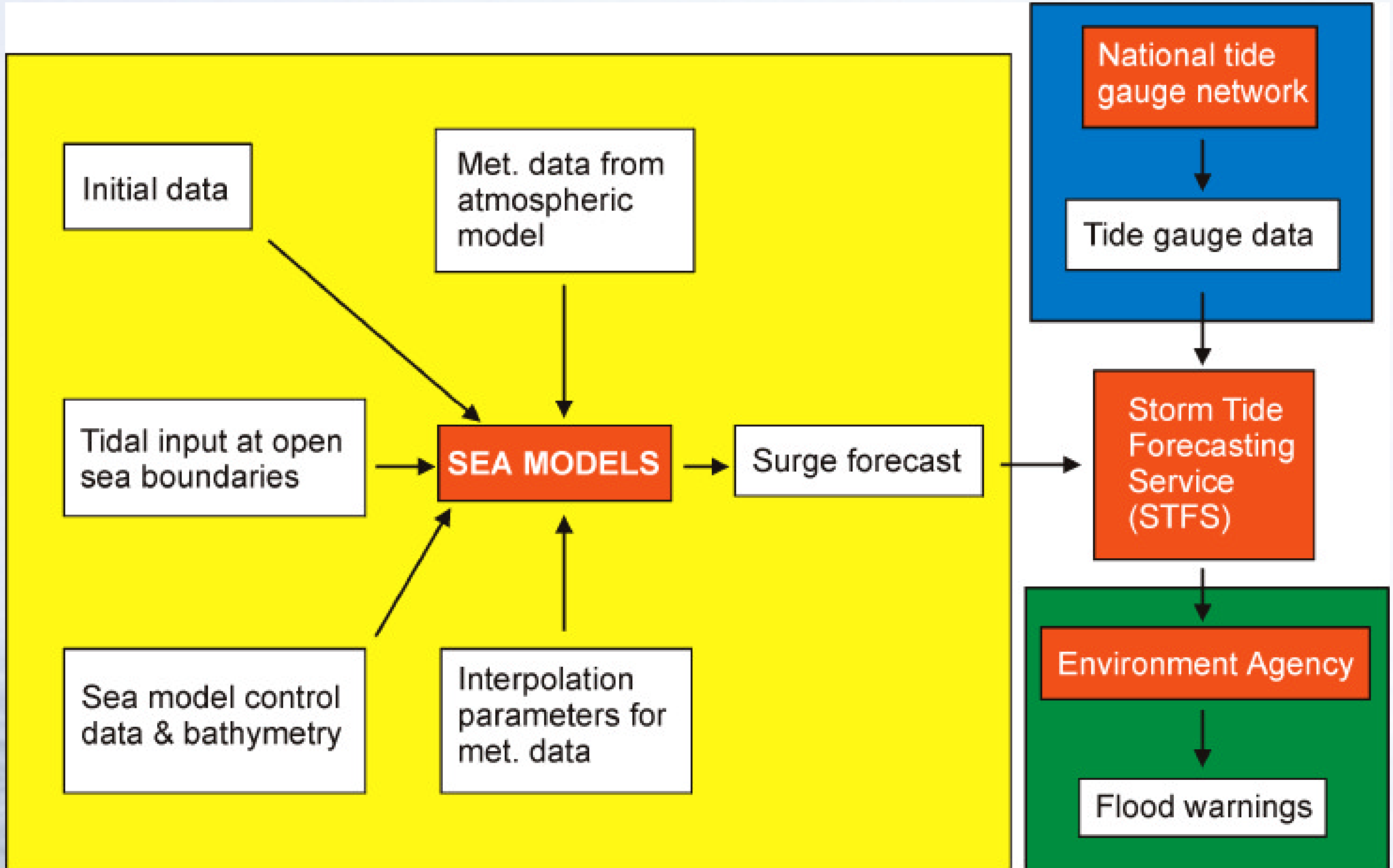
Typical surge propagation around the UK coast



? Externally generated surges move as Kelvin waves, keeping the coastline to their right as they pass into North Sea

? Some regions also experience local enhancement due to local wind forcing

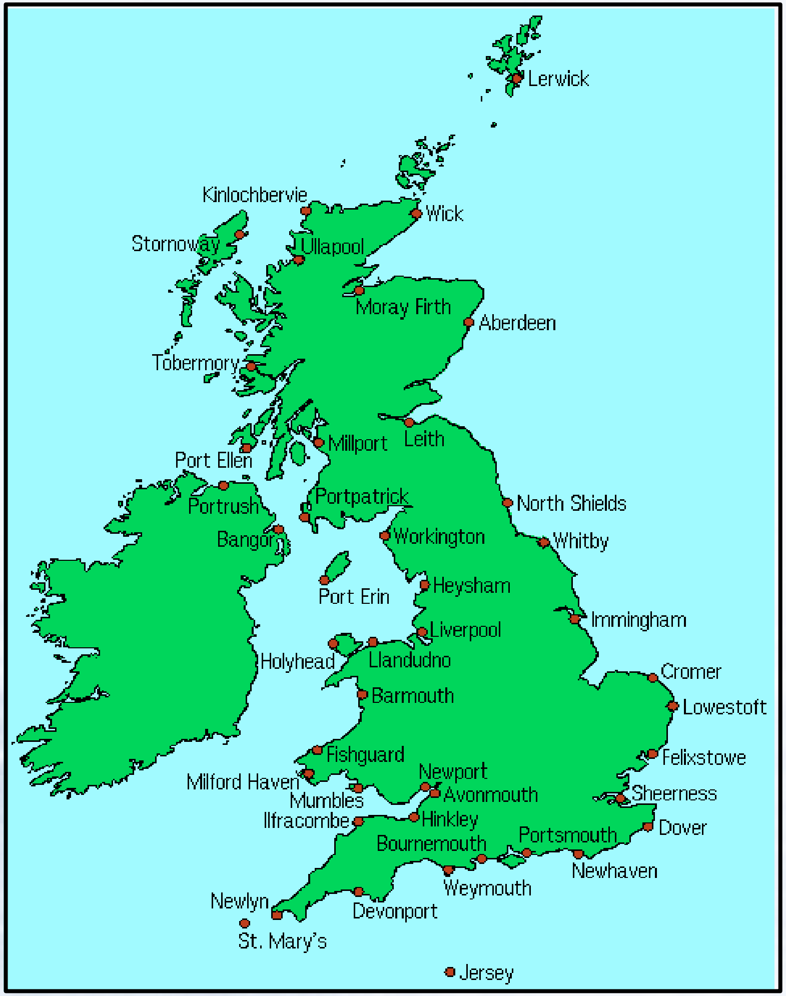
- The Storm Tide Forecasting Service (STFS) was established following the 1953 flooding
- At the same time, a national tide gauge network was set up. POL continues to develop this network both in terms of the measurement and data transfer technology
- POL develops tide-surge models used to forecast storm surges
- The models are run in real-time as part of the forecast suite of models at the UK Met Office. Operational forecasts were first run in 1978 using coarse grid surge and atmospheric models
- Results are transmitted to the Environment Agency along with real-time data from the Tide Gauge Network for coastal flood warning and alerting the public



Components of the UK coastal flood warning system

The UK National Tide Gauge Network

- POL operates the network of 44 stations
- Logging and telemetry systems send real-time 15’ data to the UK Met Office and warning centres
- The data are quality controlled and archived by the British Oceanographic Data Centre (BODC)
- Real-time quality control of the data is required for operational data assimilation in surge models



New technologies and real-time data

- Most tide gauges are pneumatic bubblers or piezoelectric pressure sensors
- Radar gauges are now a promising alternative – relatively cheap, good accuracy, rapid installation
- Gauge data loggers can now interface with a tiny computer which allows remote configuration and broadband transmission of 1 minute sea levels from anywhere in the world

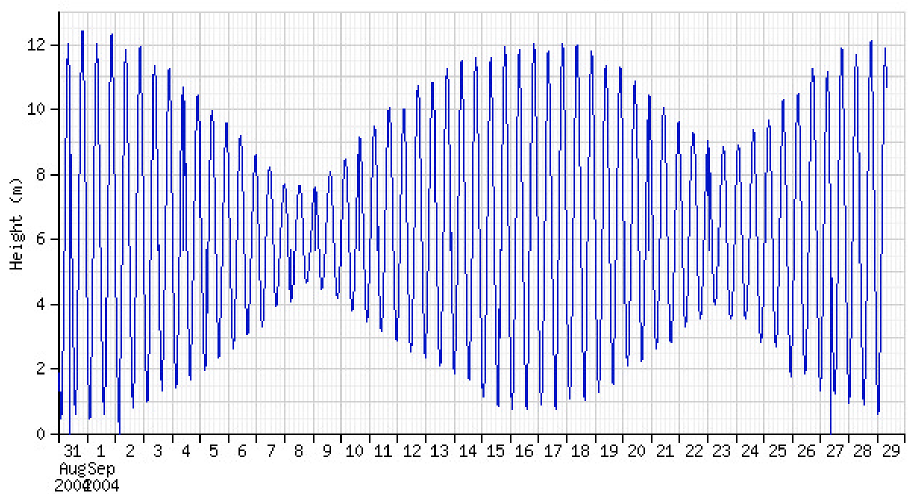
National Tidal & Sea Level Facility

Real/Near-real time data display

Sea level networks | Data availability

Today & Yesterday | Last week | Last month

Tidal elevations for Hinkley Point



WARNING: Plots based upon real-time unchecked data | Disclaimer applies »

Dates are centred upon mid-day

Times in GMT

Time increments 00:00, 04:00, 08:00, 12:00, 16:00, 20:00

NTSLF engineers only

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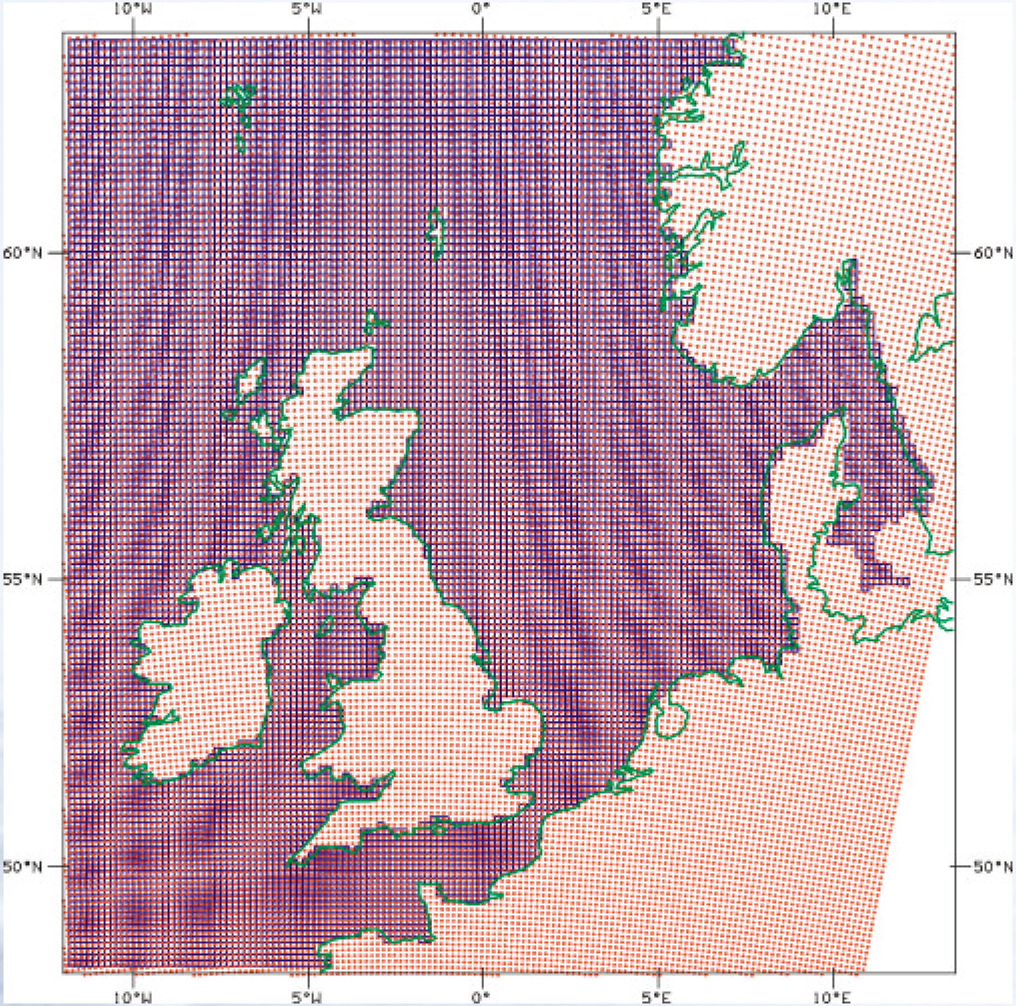
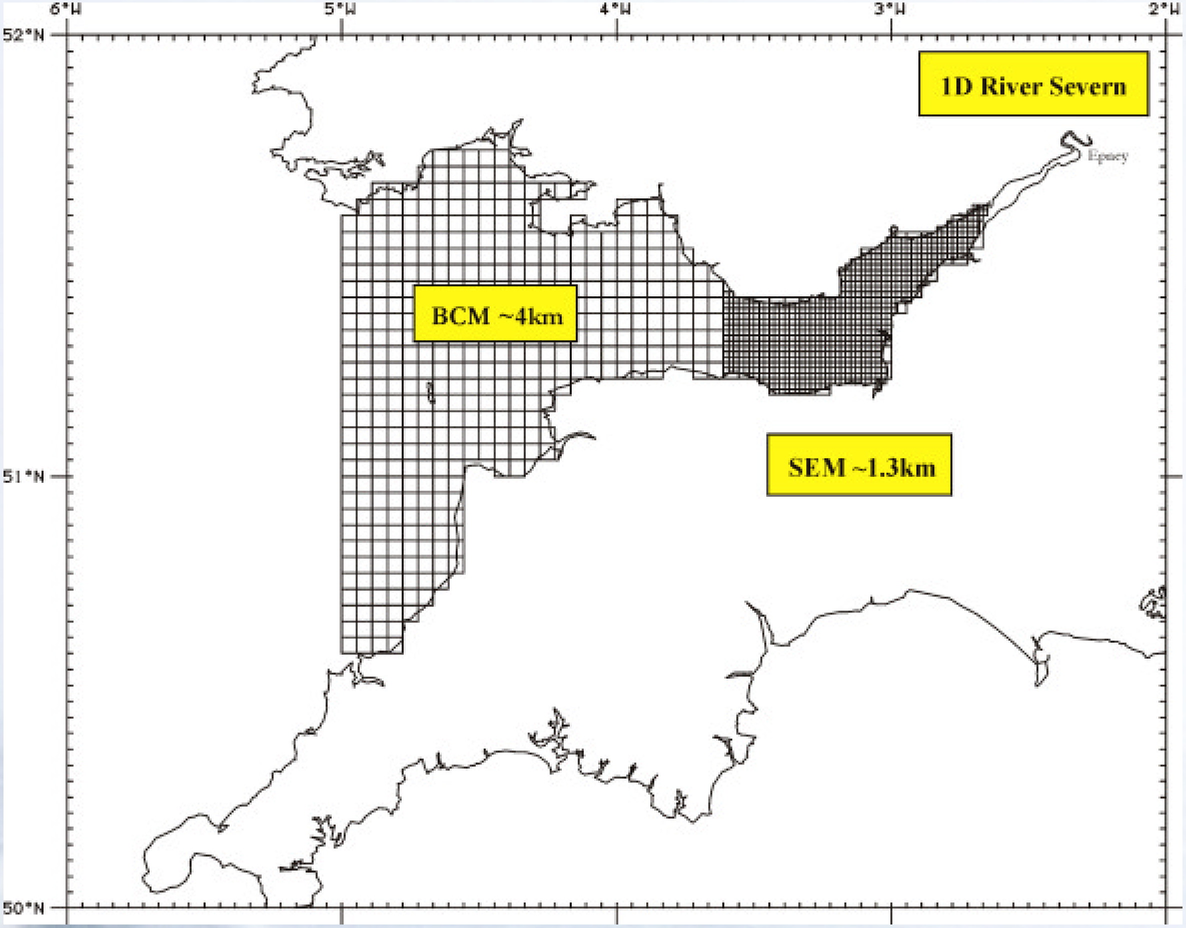
The present tide-surge modelling system

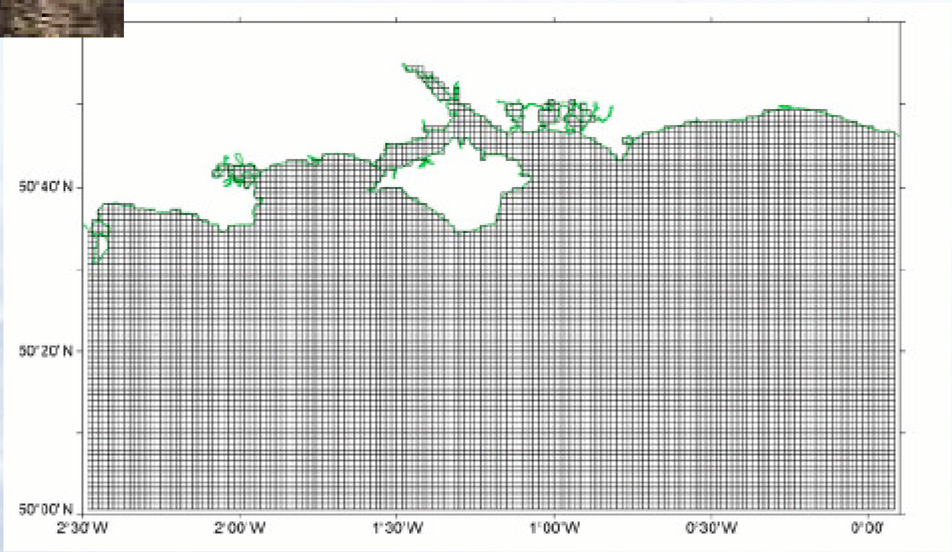
12km barotropic surge model (CS3) shown with grid points of the Met Office's 12km mesoscale 31 level atmospheric model





Local models for the Bristol Channel and Severn Estuary

Regional models at Thames Barrier and South coast



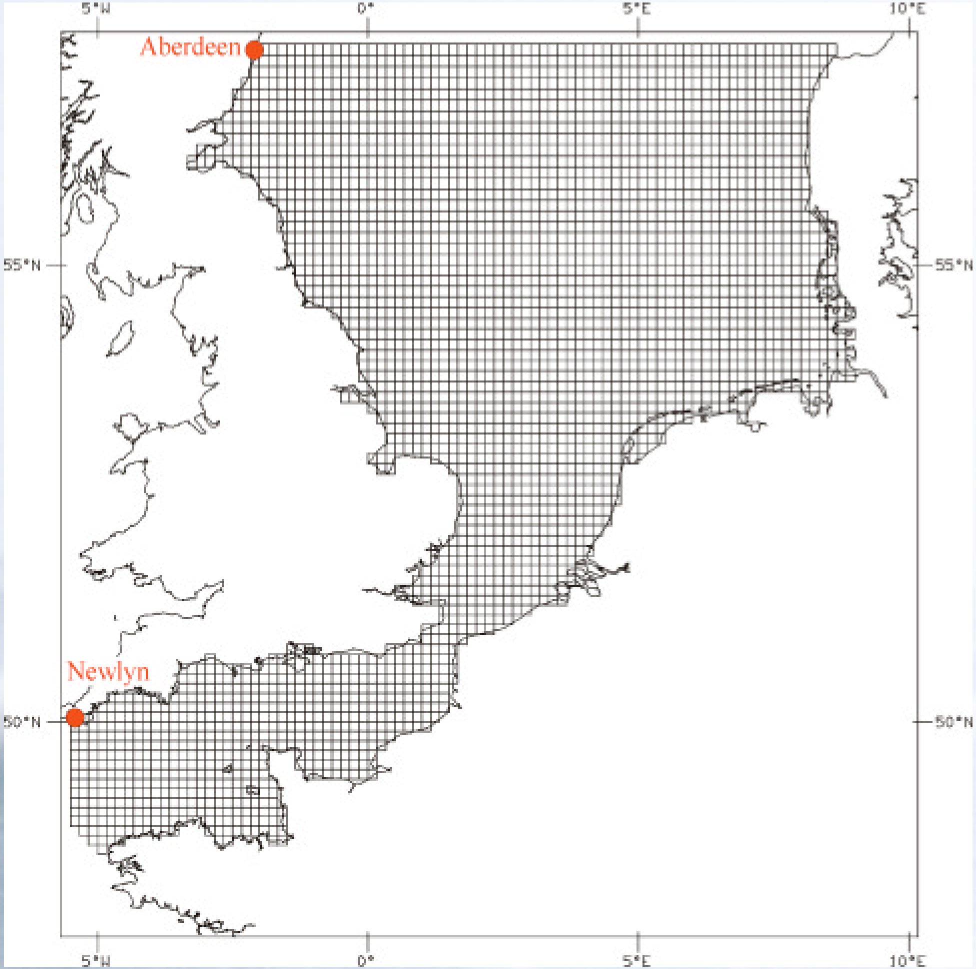
Forecast scheme and performance

- Surge models run four times per day producing forecasts up to 2 days ahead
- The model surge is combined with tide predictions (using the harmonic method) at tide gauge sites to give the best estimate of the total water level
- The local models have been tuned to provide more accurate total water level forecasts
- Model performance is monitored at POL by comparing forecast results with observations every month
- Typical RMS errors are ~10cm. More significant forecast errors are investigated, and the system is in a continuous state of improvement

Data assimilation using real-time tide gauge data

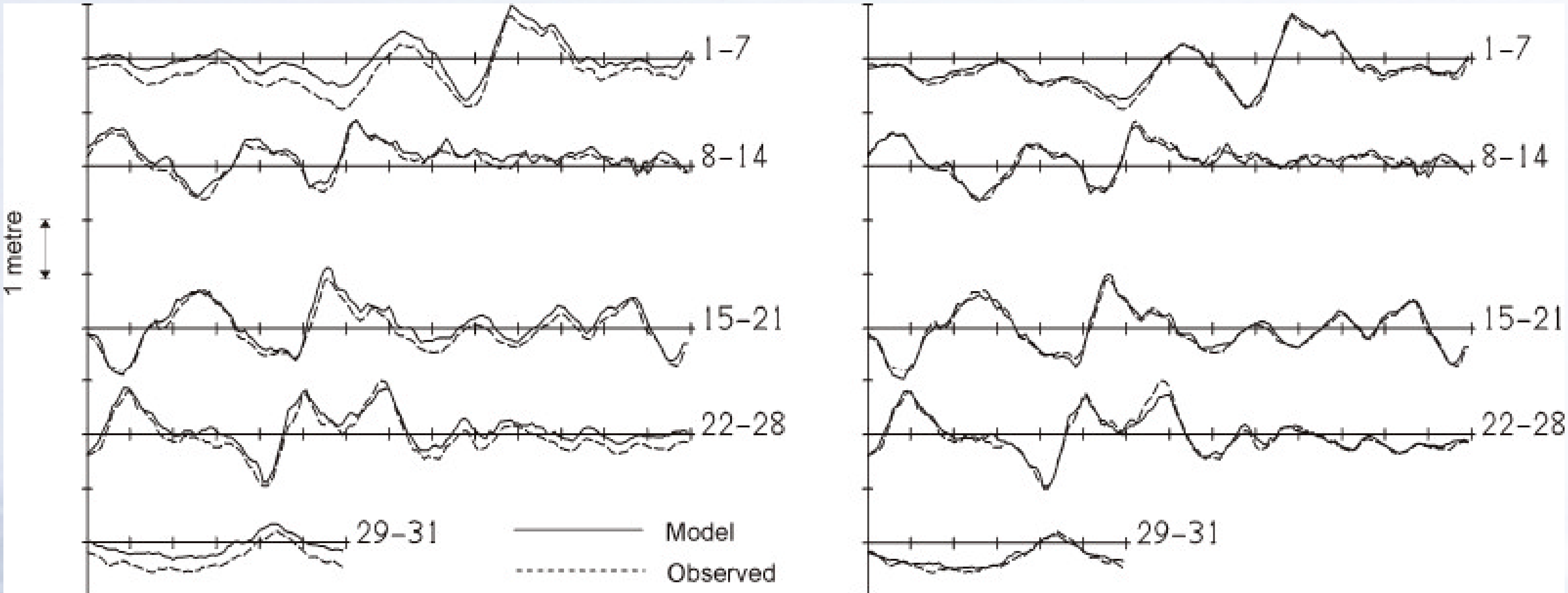
- Assimilating tide gauge data over the 6hr hindcast portion of the model run can improve the models’ initial conditions for the subsequent forecast
- Simple schemes based on successive correction, and optimised interpolation, produce excellent results for hindcasts
- We are experimenting with the relative cost benefits of these simple schemes compared to
  - Ensemble Kalman filters (EKF)
  - Cost function minimisation algorithms (‘model fitting’)
- *If the non-linearity in the meteorology is more important than the initial conditions of the ocean models then the improvement to forecast accuracy is likely to be confined to the early part of the forecast* t = + 0-6 hrs

12km shelf model adjusted by two tide gauge datasets and a suitable radius of influence



Improving surge forecasts - simple data assimilation

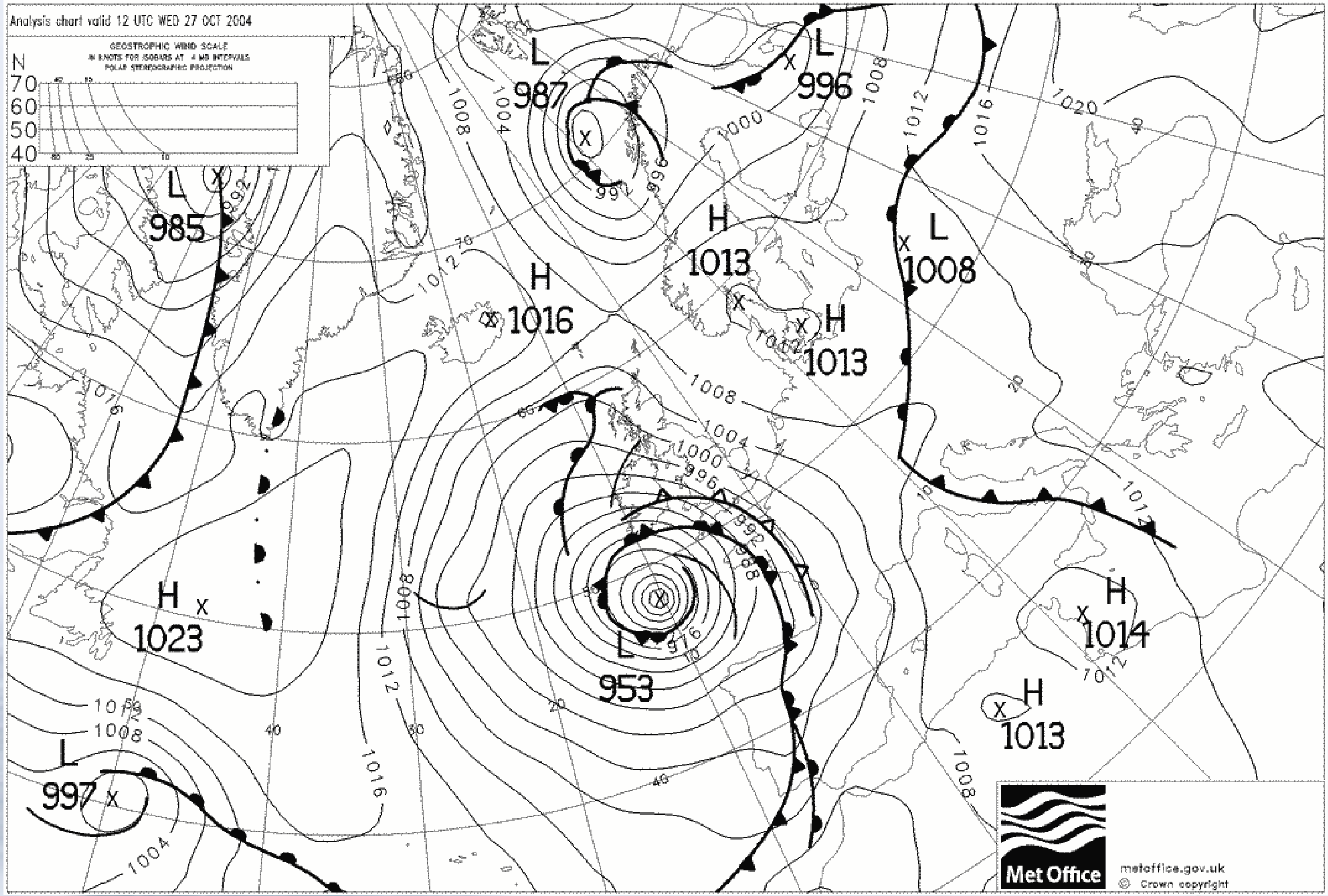
Without assimilation | With assimilation



Effect of data assimilation on surge residuals from the ECNS model for January 1993 at Whitby

Events of 27-28 October 2004

- A severe storm caused flooding and transport disruption on the south coast of England
- A deep depression formed in the southwest approaches and remained anchored for 3-4 days
- Surges were under-predicted by almost 50cm at times, and by 30cm at high water around 1700Z on 27 October 2004
- The meteorological model was analysed and performed well at the time



Analysis chart valid 12 UTC WED 27 OCT 2004
GEOSTROPHIC WIND SCALE
IN KNOTS FOR ISOBARS AT 4 MB INTERVALS
POLAR STEREOGRAPHIC PROJECTION
L 987
L 996
L 985
H 1016
H 1013
L 1008
H 1013
H 1023
L 953
H 1014
H 1013
L 997
Met Office
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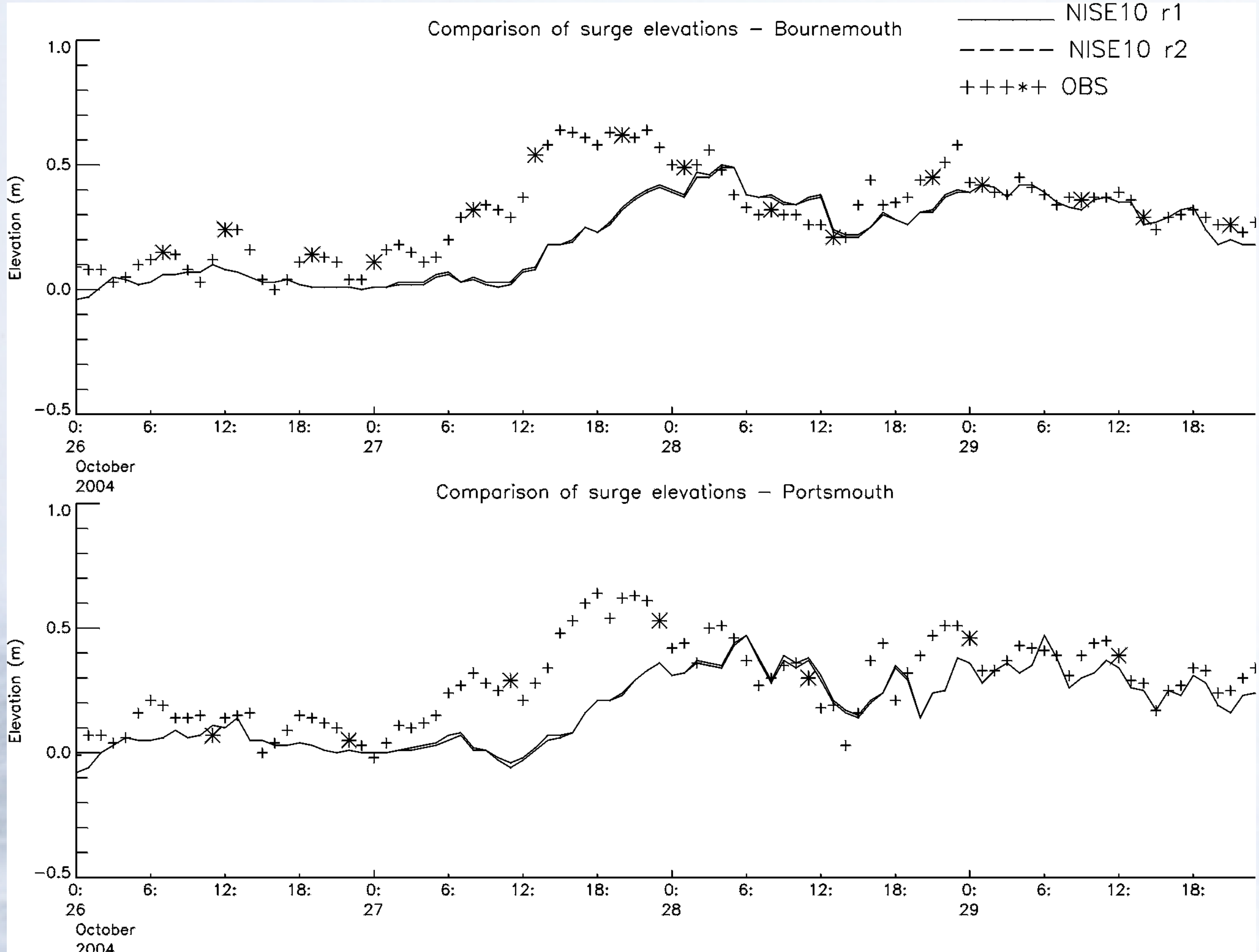
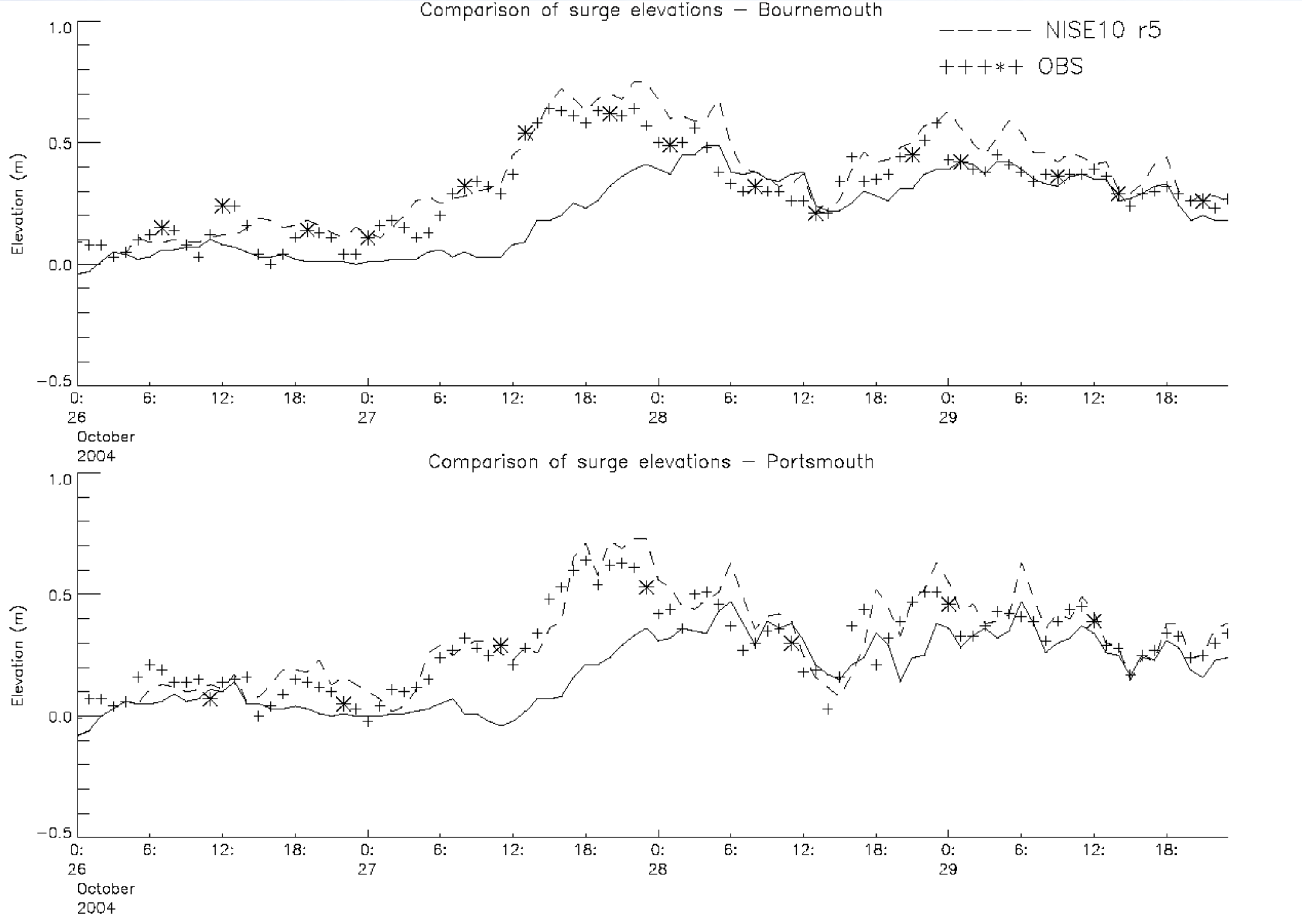


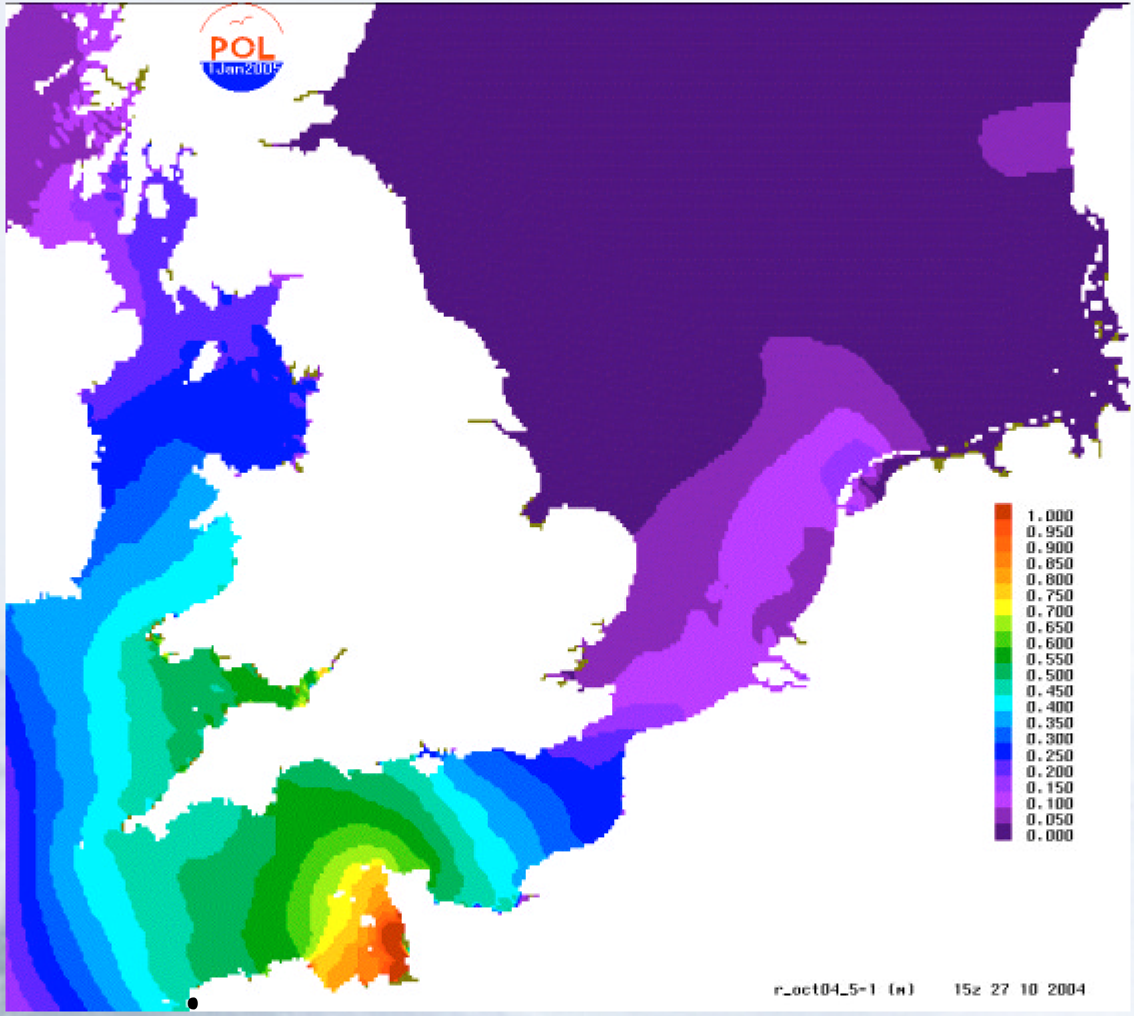
Comparison of surge elevations – Bournemouth
NISE10 r1
NISE10 r2
+++*++ OBS
Elevation (m)
1.0
0.5
0.0
−0.5
0:
26
October
2004
6:
12:
18:
0:
27
0:
28
0:
29
Comparison of surge elevations – Portsmouth
Elevation (m)

- Since the meteorological variables forcing the surge model were reasonably accurate, the most likely reason for poor performance was the development of significant surge in the Bay of Biscay
- Data from EPSHOM was analysed to provide assimilated residuals for the model (our thanks to Guy Woppleman & M. Lucas)
- The improved results demonstrate the value of real-time data from French sites, and also motivated a widening of our outer model domain

Assimilation of data from Le Conquet



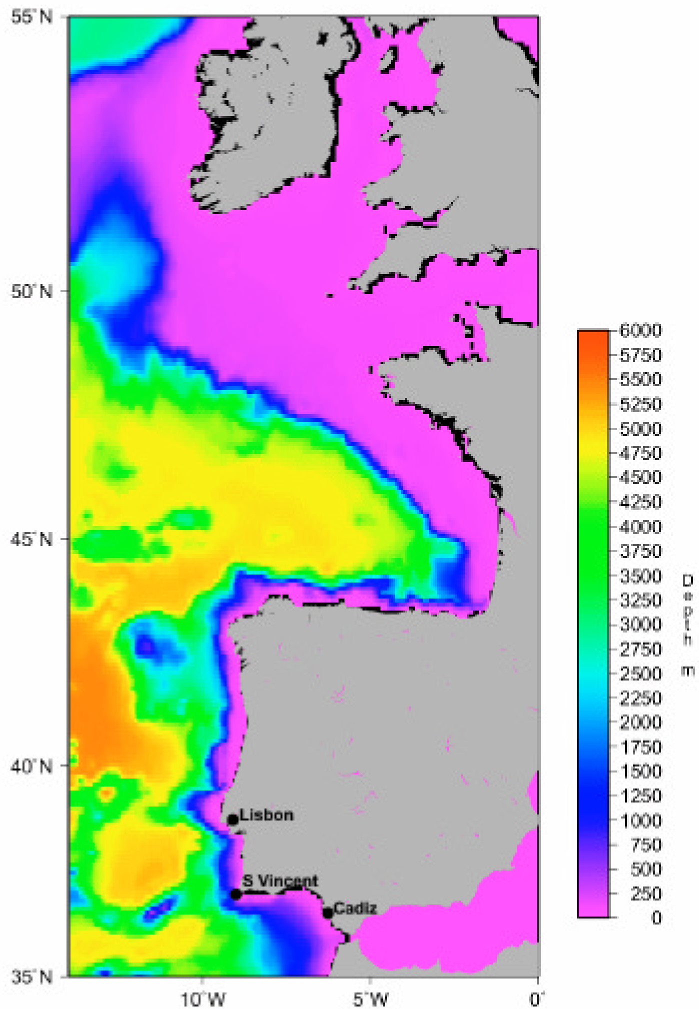
October 27 2004 : influence of data from Le Conquet

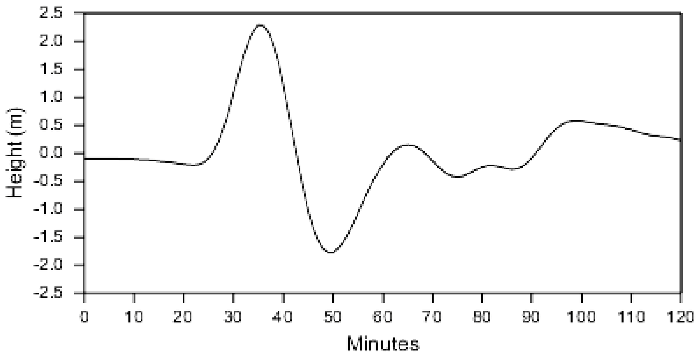


UK research towards a tsunami warning system

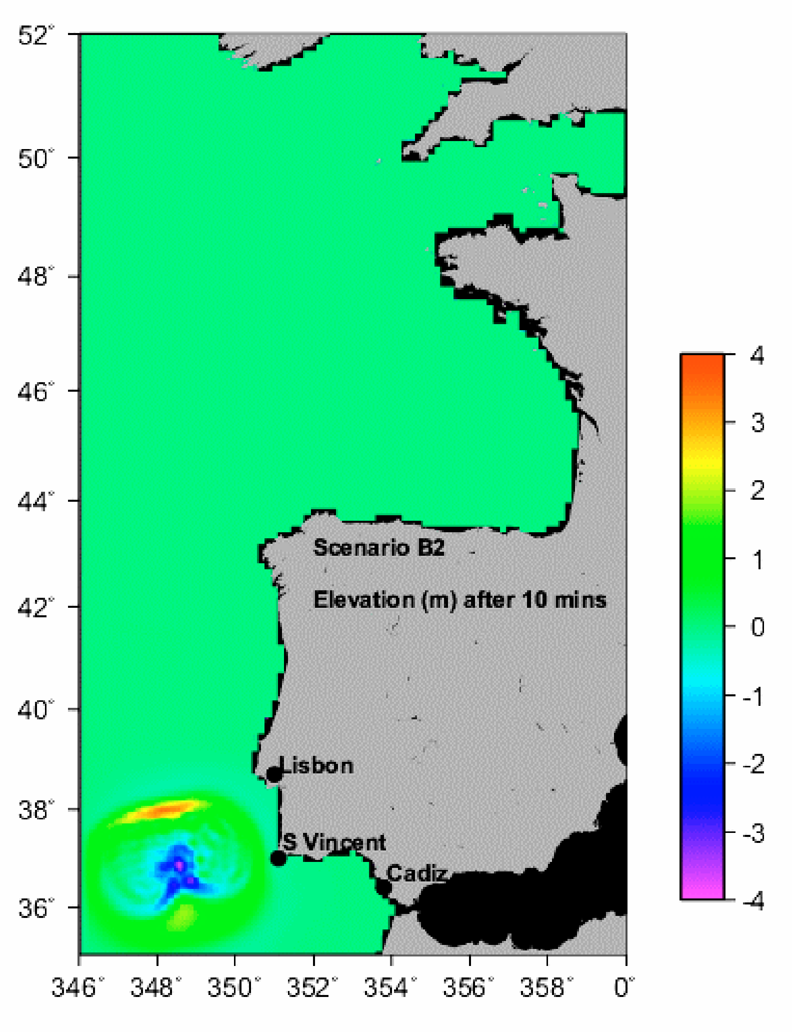
- The tsunami of 26 December 2004 prompted many governments to consider the risk (however small) from tsunamis
- POL, BGS, UK Met Office and HR Wallingford were involved in assessing risk to the UK in a joint modelling study
- The most credible seismic source (for the northwest shelf) is a fracture zone west of Portugal that caused the November 1755 Lisbon earthquake

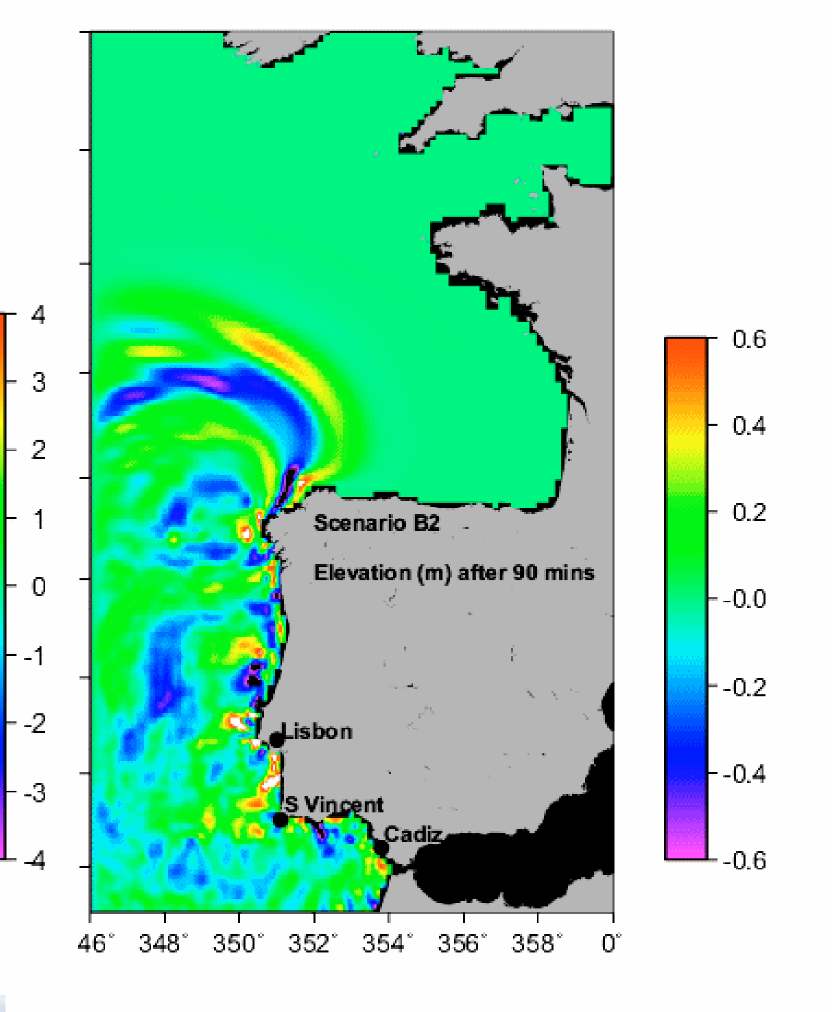
- We extended the12km POL operational storm surge model southwards to 34°N and westwards to 14°W (to accommodate the complete sea surface disturbance)
- TELEMAC finite element model was nested for finer resolution at the UK coastline
- Run B2 examines the source location north of the Gorringe Bank proposed by Johnston (1996).
- The Mw 8.7 event gives rise to tsunami amplitudes approaching the UK shelf approximately 50 cm
- Arrival times at Lisbon and Cape St Vincent are consistent with the best interpretation of literature surrounding the 1755 event (Baptista et al., 1988).





Time series of elevation at model point nearest Oeiras (38.67°N, 9.32°W) for the B2 8.7 Mw scenario


52°
50°
48°
46°
44°
42°
40°
38°
36°
346°
348°
350°
352°
354°
356°
358°
0°
Scenario B2
Elevation (m) after 10 mins
Lisbon
S Vincent
Cadiz
4
3
2
1
0
-1
-2
-3
-4


46°
348°
350°
352°
354°
356°
358°
0°
Scenario B2
Elevation (m) after 90 mins
Lisbon
S Vincent
Cadiz
0.6
0.4
0.2
-0.0
-0.2
-0.4
-0.6

- None of the Mw 8.3 models would produce waves with any consequences for the UK.
- Even allowing for local amplification, the wave amplitudes are an order of magnitude smaller than storm surges
- The Mw 8.7 seismic events all produce a similar wave (~0.5m) at the steep bathymetry that marks the UK continental shelf break, approximately 2-3 hours after the initial disturbance
- The rapid change of depth to the southwest of the UK ensures that propagation times across the Celtic Sea are a further 3-4 hours, allowing well-positioned instrumentation to provide effective warning for emergency response.

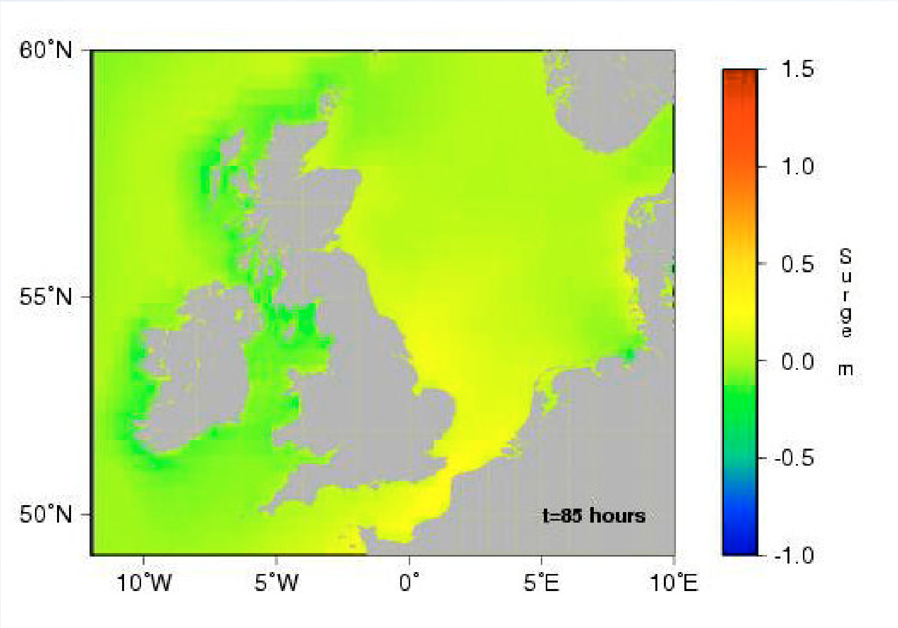
Further tsunami related work in the UK

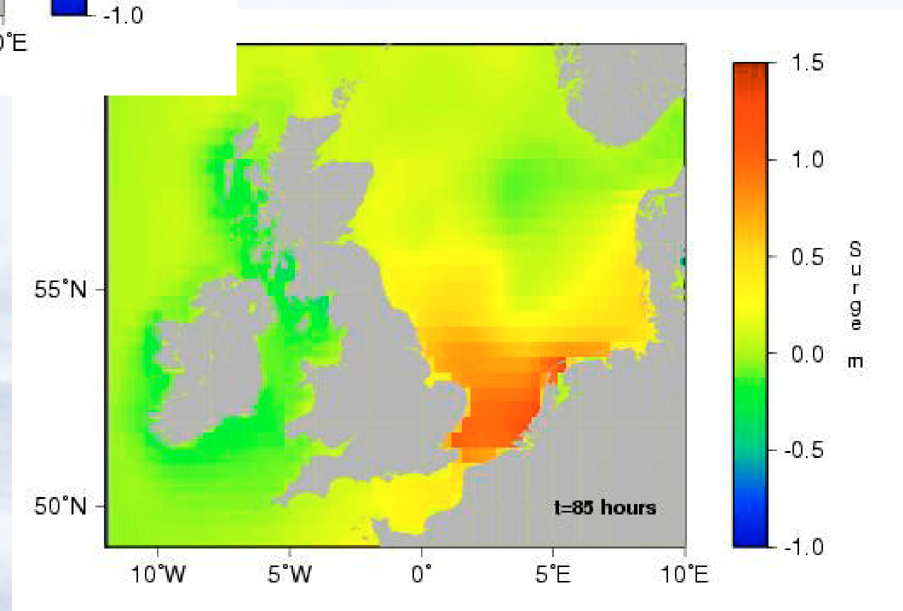
- The report generated by the modelling consortium concluded that risks to the UK were very small, but non-zero
- UK government (Defra) have requested further scoping/demonstrator projects
  - Integration of tide gauge data from European maritime countries (UK/France/Spain/Portugal)
  - Modelling scoping study with real-time validation from tide gauge data
  - High frequency (1 Hz) sampling and 1 minute broadband transmission from selected UK tide gauges

Concluding remarks

- Incremental improvements to flood forecast accuracy can lead to large savings in government spending
- A good multi-hazard warning system is well-used
- Real-time tide gauge data is essential for
  - optimum model initialisation
  - effective updating of flood forecasts
  - tsunami warning systems
- **The reciprocal availability of tide gauge data from all European countries is mutually beneficial in all of these areas**
- Improved initial conditions via data assimilation will improve model forecasts, and quantification of uncertainty is best approached through ensemble forecasts

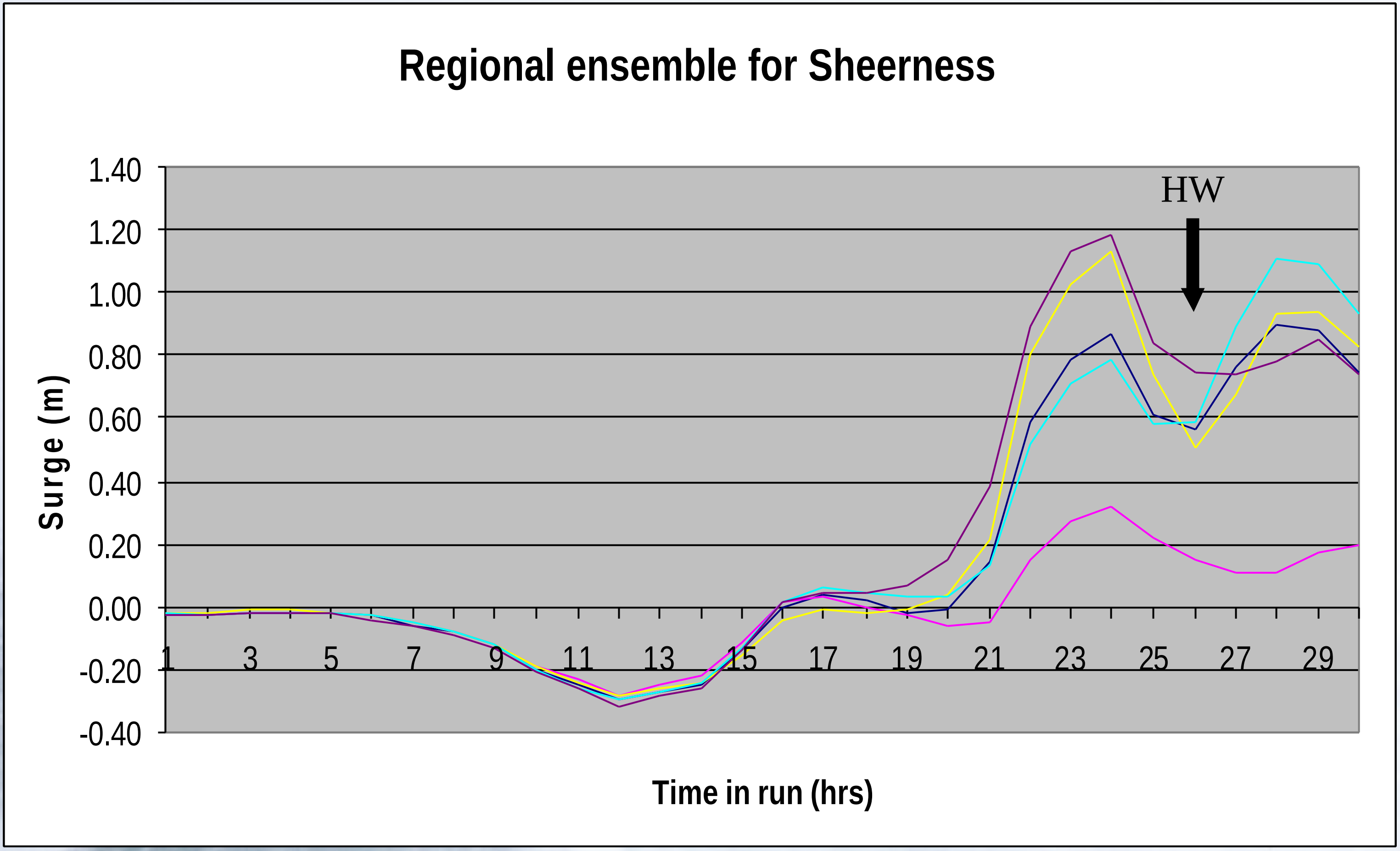
Improving forecasts, reducing uncertainty





Prototype ensemble forecasting in 2006

- Uncertainty (both the meteorology and subsequent sea level response) can be reduced through ensemble forecasts
- Varying a range of initial conditions to reflect the magnitude of analysis error
- Ensemble of 24 members
- The range (spread) of the ensemble provides a confidence measure in the forecast
- A prototype ensemble surge system is being developed with the Met Office in the winter of 2006-2007
- It is equally important to consider how the ensemble information is to be delivered to the warning agencies, or the public



Regional ensemble for Sheerness
HW
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
Surge (m)
Time in run (hrs)