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NATURAL ENVIRONMENT RESEARCH COUNCIL

Probabilistic Coastal Flood Forecasting

Nigel Tozer – HR Wallingford

Peter Hawkes, Tim Pullen, HR Wallingford
Angela Scott, UKCMF / Environment Agency
Jonathan Flowerdew, Ken Mylne, Francois Xavier-Bocquet, Met Office
Kevin Horsburgh, Proudman Oceanographic Laboratory

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IAHR UK Section Technical Meeting, 16 September 2010

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Project context

Parts of the UK coast are vulnerable to flooding

- Extreme water levels (astronomical plus surge)
- Waves (height and period) causing overtopping
- Need to protect against risk to people and assets
  - Mobilisation
  - Warning and evacuation
  - Close areas to pedestrians and vehicles

Margate, England, Winter 2000/01: Photograph courtesy of Peter Barker, RNL

Photograph Ian Davison: Blackpool, Winter 2007/08

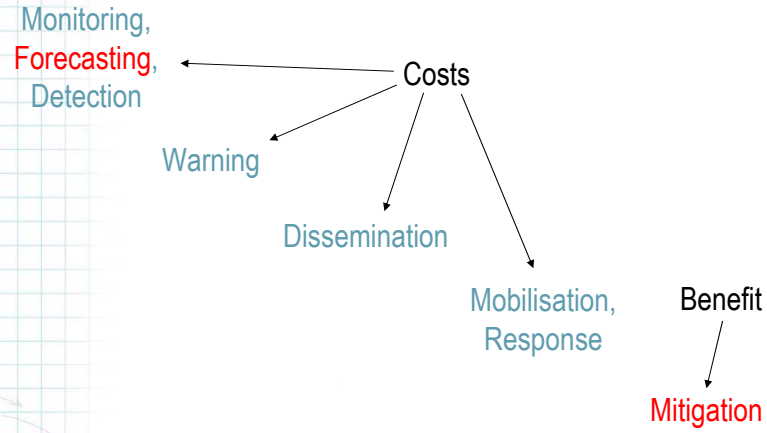
Project context

- **Met Office:**
  - **Runs operational weather, offshore wave and surge forecasting models**
- **Environment Agency:**
  - **Operates the *United Kingdom Coastal Monitoring and Forecast Service* (*UKCMF*)**
    - Provides forecasts of surge levels and waves, and in some areas wave overtopping
  - **Manages response to flood warnings**

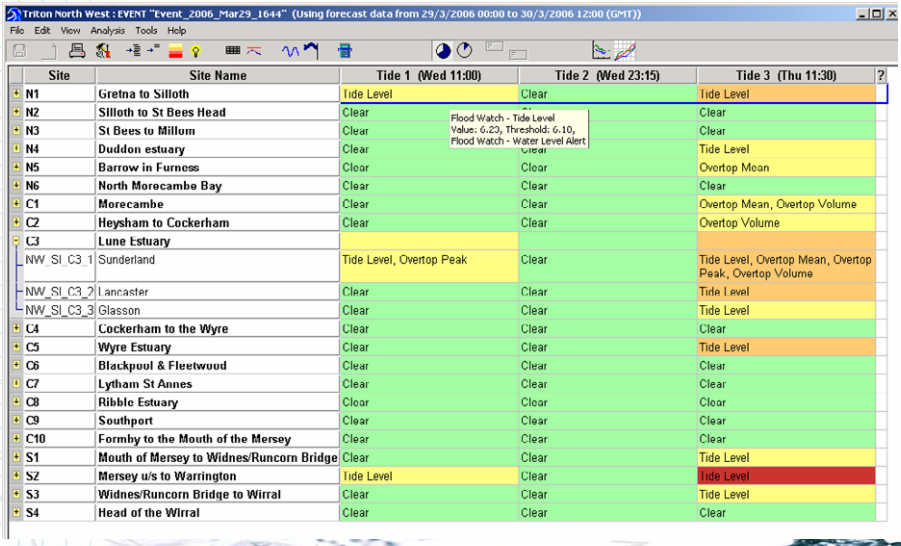
Research Project Outline

- ***Probabilistic coastal flood forecasting***
  March 2006 to December 2008
  - Surge ensemble forecasting
  - Wave ensemble forecasting
  - Probabilistic nearshore wave and overtopping forecasting
  - Forecasting demonstration
  - Field measurements of overtopping (and waves)
- **Higher information content than deterministic forecasts – more reliable / better decision making**
  - Account for uncertainties in surge prediction, wave prediction, wave transformation and overtopping prediction
  - Provide probabilities of threshold crossings

Forecasting context

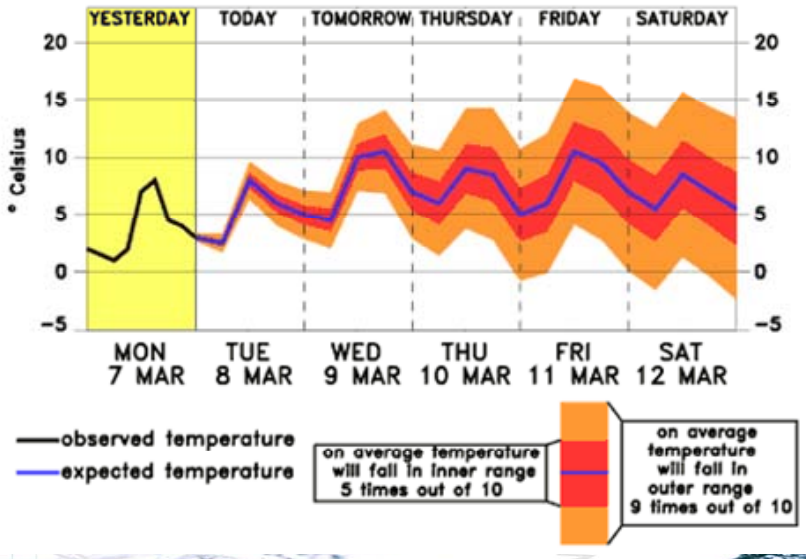


Coastal flood forecasting, NW Region

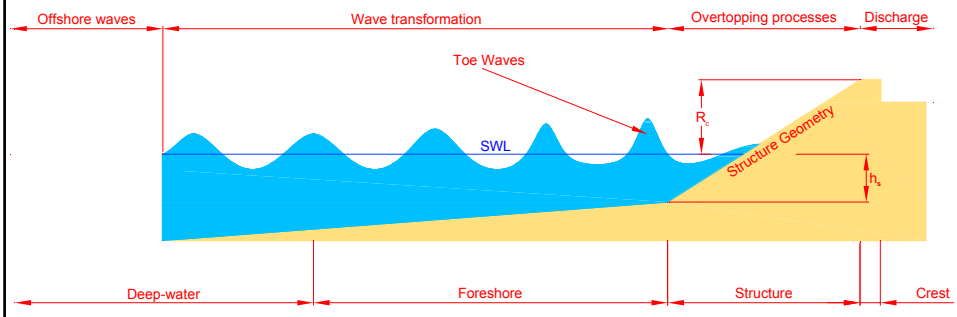


Site	Site Name	Tide 1 (Wed 11:00)	Tide 2 (Wed 23:15)	Tide 3 (Thu 11:30)
N1	Gretna to Silloth	Tide Level	Clear	Tide Level
N2	Silloth to St Bees Head	Clear		Clear
N3	St Bees to Millom	Clear		Clear
N4	Duddon estuary	Clear		Tide Level
N5	Barrow in Furness	Clear	Clear	Overtop Mean
N6	North Morecambe Bay	Clear	Clear	Clear
C1	Morecambe	Clear	Clear	Overtop Mean, Overtop Volume
C2	Heysham to Cockerham	Clear	Clear	Overtop Volume
C3	Lune Estuary			
NW_SI_C3_1	Sunderland	Tide Level, Overtop Peak	Clear	Tide Level, Overtop Mean, Overtop Peak, Overtop Volume
NW_SI_C3_2	Lancaster	Clear	Clear	Tide Level
NW_SI_C3_3	Glasson	Clear	Clear	Tide Level
C4	Cockerham to the Wyre	Clear	Clear	Clear
C5	Wyre Estuary	Clear	Clear	Tide Level
C6	Blackpool & Fleetwood	Clear	Clear	Clear
C7	Lytham St Annes	Clear	Clear	Clear
C8	Ribble Estuary	Clear	Clear	Clear
C9	Southport	Clear	Clear	Clear
C10	Formby to the Mouth of the Mersey	Clear	Clear	Clear
S1	Mouth of Mersey to Widnes/Runcorn Bridge	Clear	Clear	Tide Level
S2	Mersey u/s to Warrington	Tide Level	Clear	Tide Level
S3	Widnes/Runcorn Bridge to Wirral	Clear	Clear	Tide Level
S4	Head of the Wirral	Clear	Clear	Clear

Met Office example ensemble forecast format

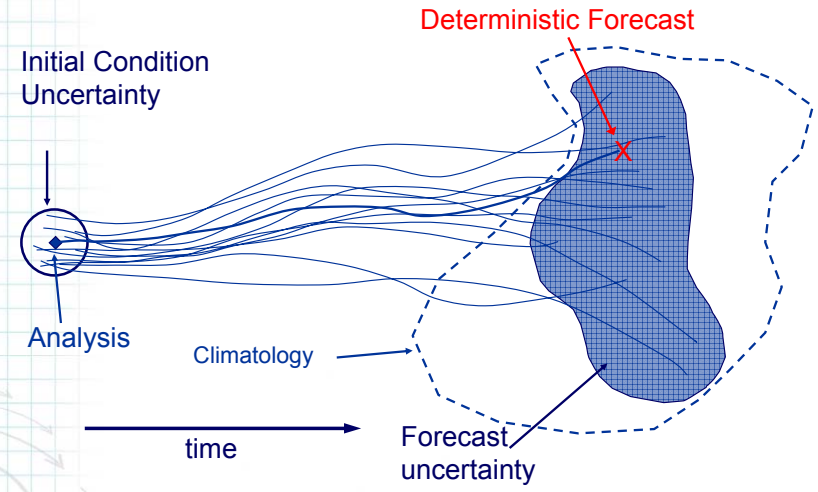


Study and modelling domains



MET OFFICE / POL SURGE & WAVE MODEL	SWAN	SHUTO / GODA	EMPIRICAL WAVE OVERTOPPING
ENSEMBLE MODELLING	MONTE CARLO SIMULATIONS		

Met Office ensemble concept



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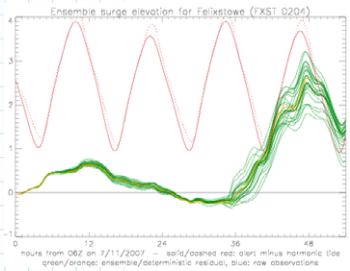
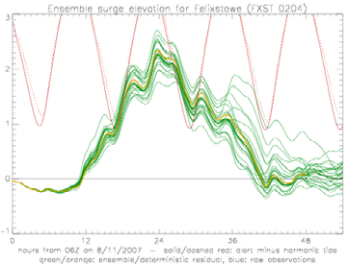
Met Office surge ensemble forecast

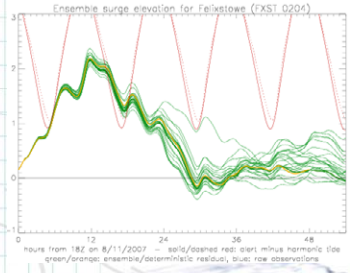


< a.m. forecast 7th November <

> a.m. 8th >

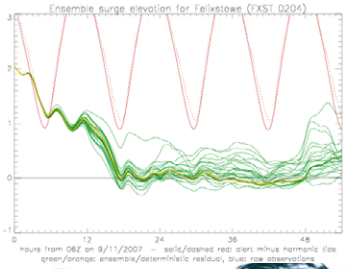


Surge at Felixstowe on 9 November 2007. The oscillatory line represents astronomical tide, a crossing of which indicates crossing of a sea level flood risk threshold.



< p.m. 8th <

> a.m. 9th >



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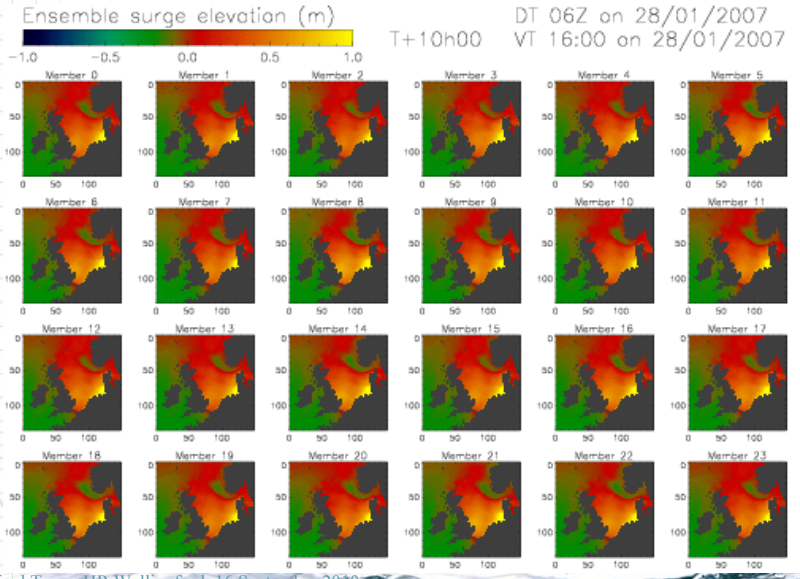
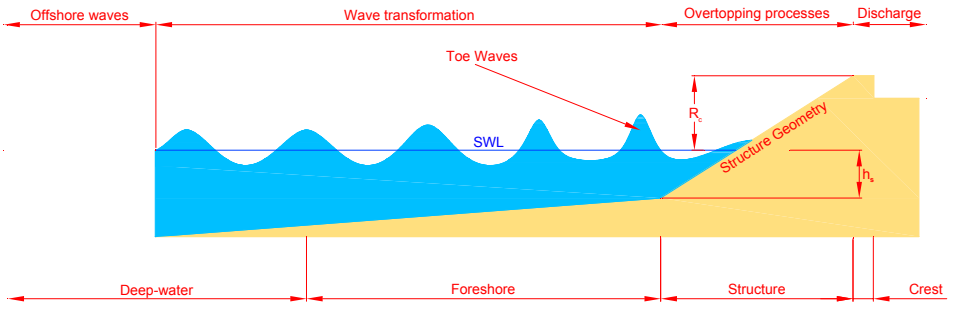
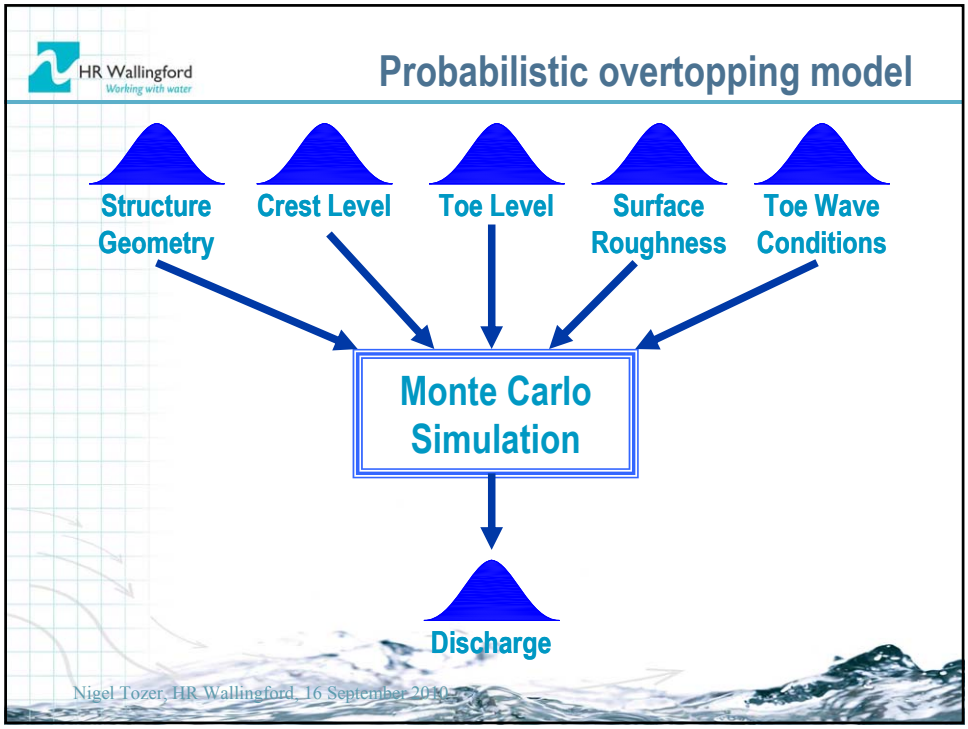
Met Office surge ensemble forecast



Study and modelling domains



MET OFFICE / POL SURGE & WAVE MODEL	SWAN	SHUTO / GODA	EMPIRICAL WAVE OVERTOPPING
ENSEMBLE MODELLING	MONTE CARLO SIMULATIONS		



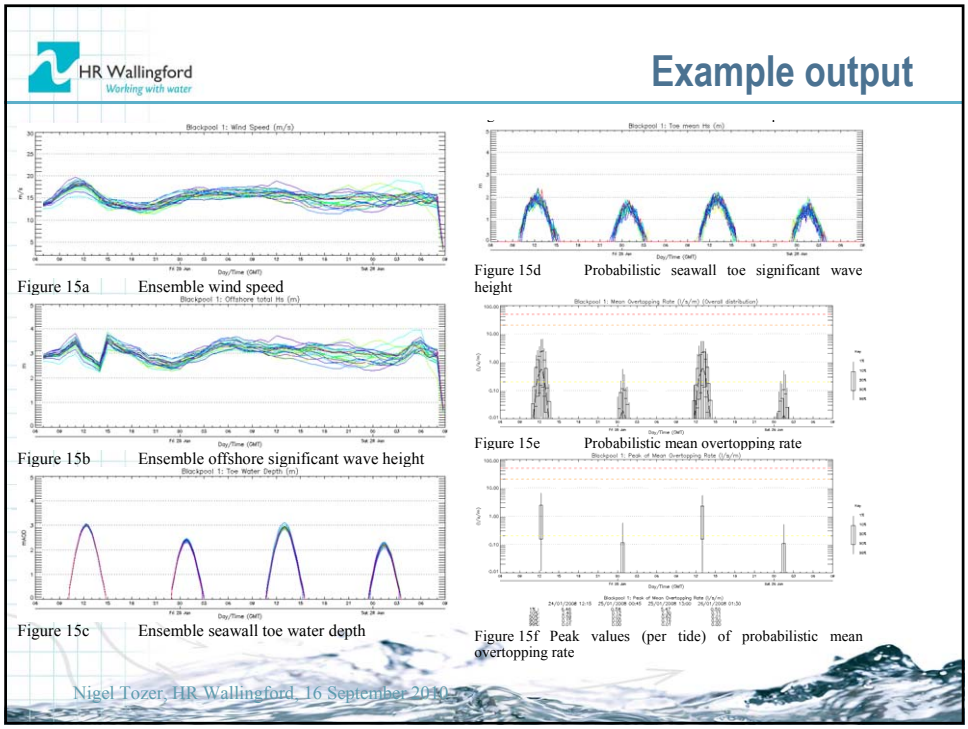


Figure 15a Ensemble wind speed

Figure 15b Ensemble offshore significant wave height

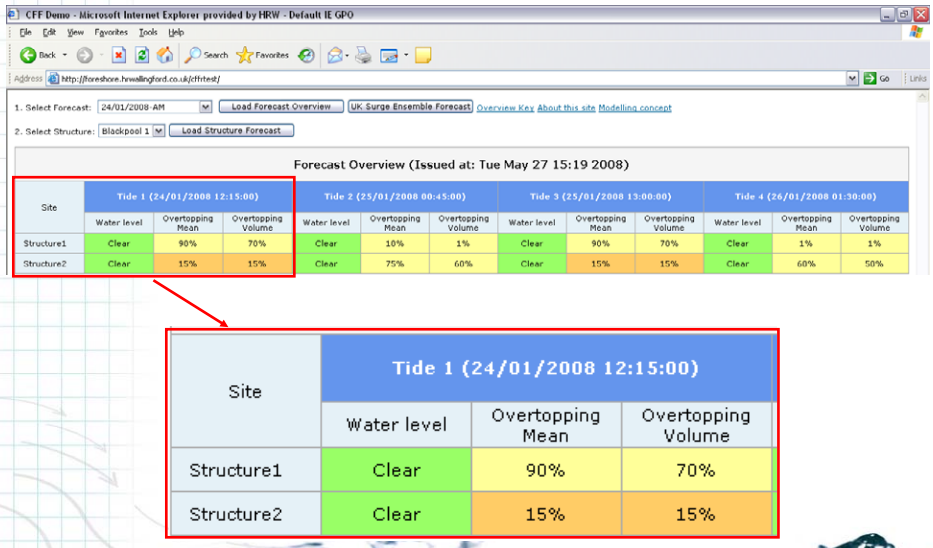
Figure 15c Ensemble seawall toe water depth

Figure 15d Probabilistic seawall toe significant wave height

Figure 15e Probabilistic mean overtopping rate

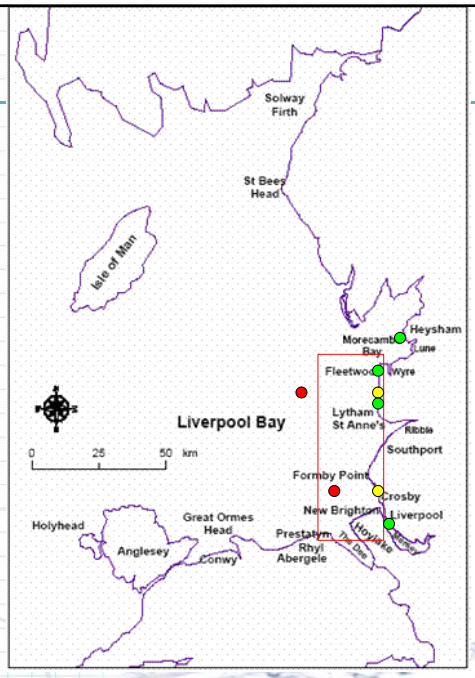
Figure 15f Peak values (per tide) of probabilistic mean overtopping rate

Example probabilistic forecast overview

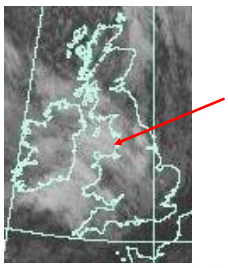


Site	Tide 1 (24/01/2008 12:15:00)		
	Water level	Overtopping Mean	Overtopping Volume
Structure1	Clear	90%	70%
Structure2	Clear	15%	15%

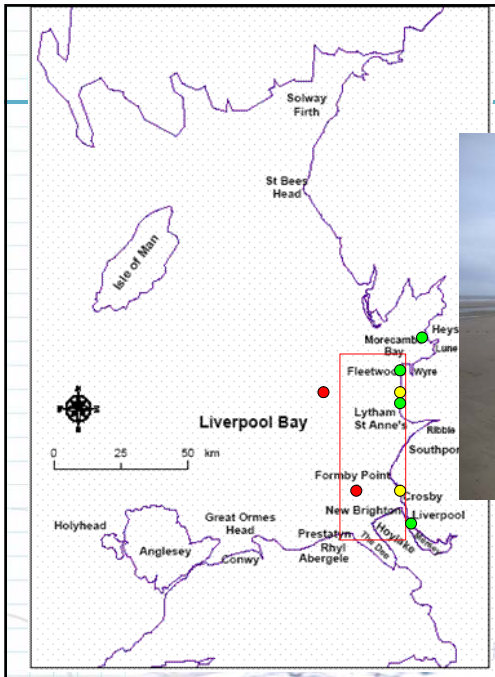
Demonstration area



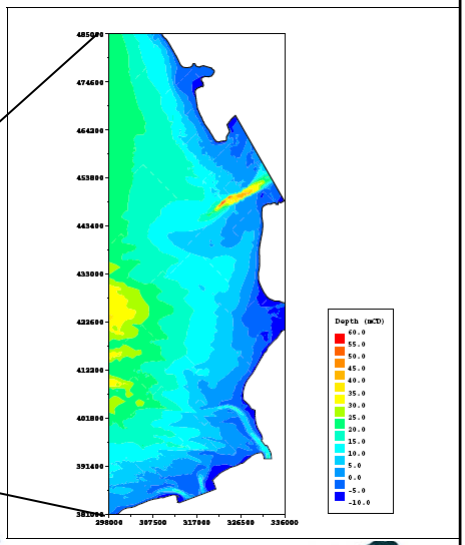
- Green dots: tide measurement
- Red dots: wave measurement
- Yellow dot at Blackpool: overtopping measurement

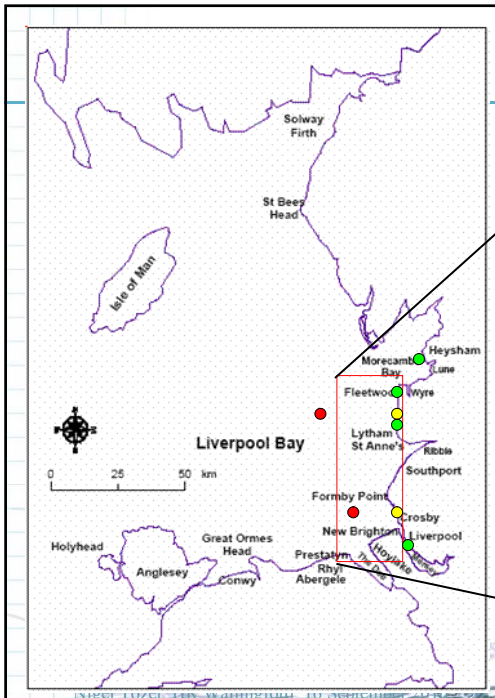


Demonstration area



SWAN model





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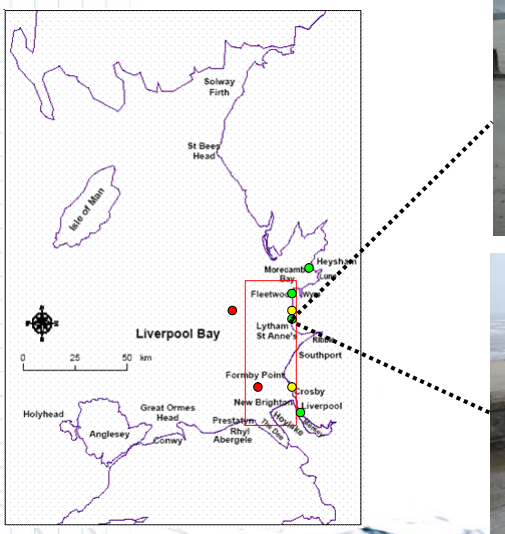

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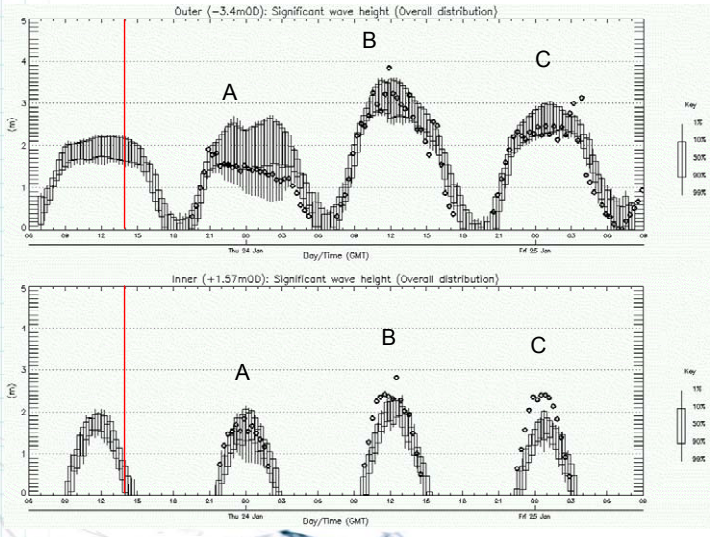
Significant wave height

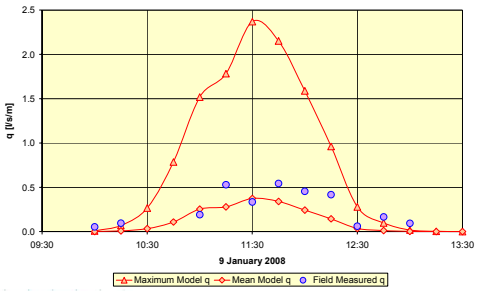


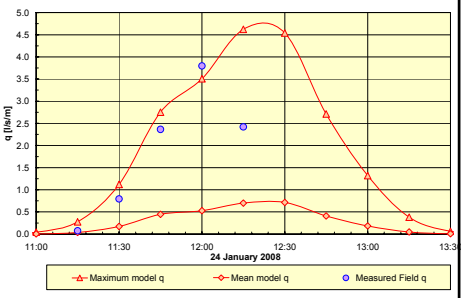
Offshore location

Nearshore location

Wind Speed 15-20m/s, H_s Offshore 3-4m, T_p 7-9s, Surge ~20cm

Mean overtopping rate





Conclusions and recommendations

- Proof of concept for:
  - surge ensemble forecasting, nationally
  - wave ensemble forecasting, SE Irish Sea
  - probabilistic nearshore wave and overtopping forecasting, SE Irish Sea
  - Accurate, Reliable, Timely and potentially Useful
- Recommendations:
  - surge ensemble forecasting (now operational)
  - refinement of astronomic tide predictions and flood thresholds
  - discussion, documentation and training in the use of probabilistic forecasts
  - pilot study of wave ensemble forecasting
  - pilot study of probabilistic coastal wave and overtopping forecasting

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Video Clip