FLOODmemory

Multi-Event Modelling Of Risk & recoverY

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Jan 2013 – Dec 2015

EPSRC
Pioneering research and skills

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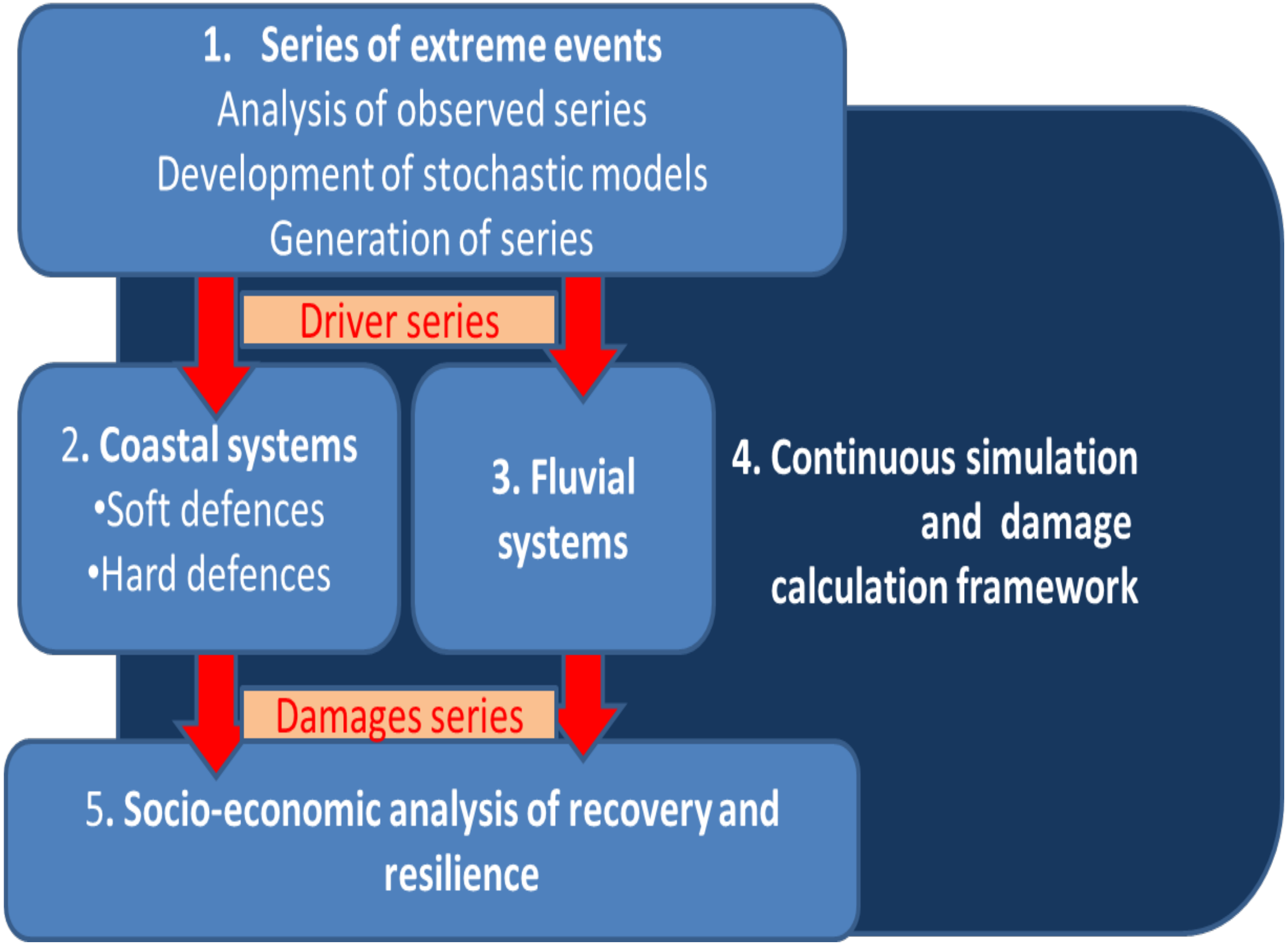
Rationale

- Floods do not occur at regular intervals
- The **vulnerability of receptors** and **performance of pathways** both have memory
- If **repeated shocks** occur within the **memory period** then drastically increased damage may occur

So, we seek to :

- Identify and quantify this under-estimated risk
- Increase resilience by pre- and post-event actions

Project Structure

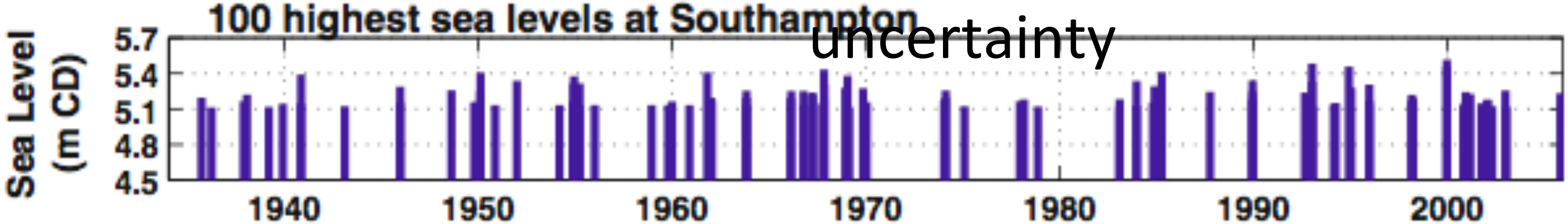


WP1 – Statistics of extreme event series

Combining research in :

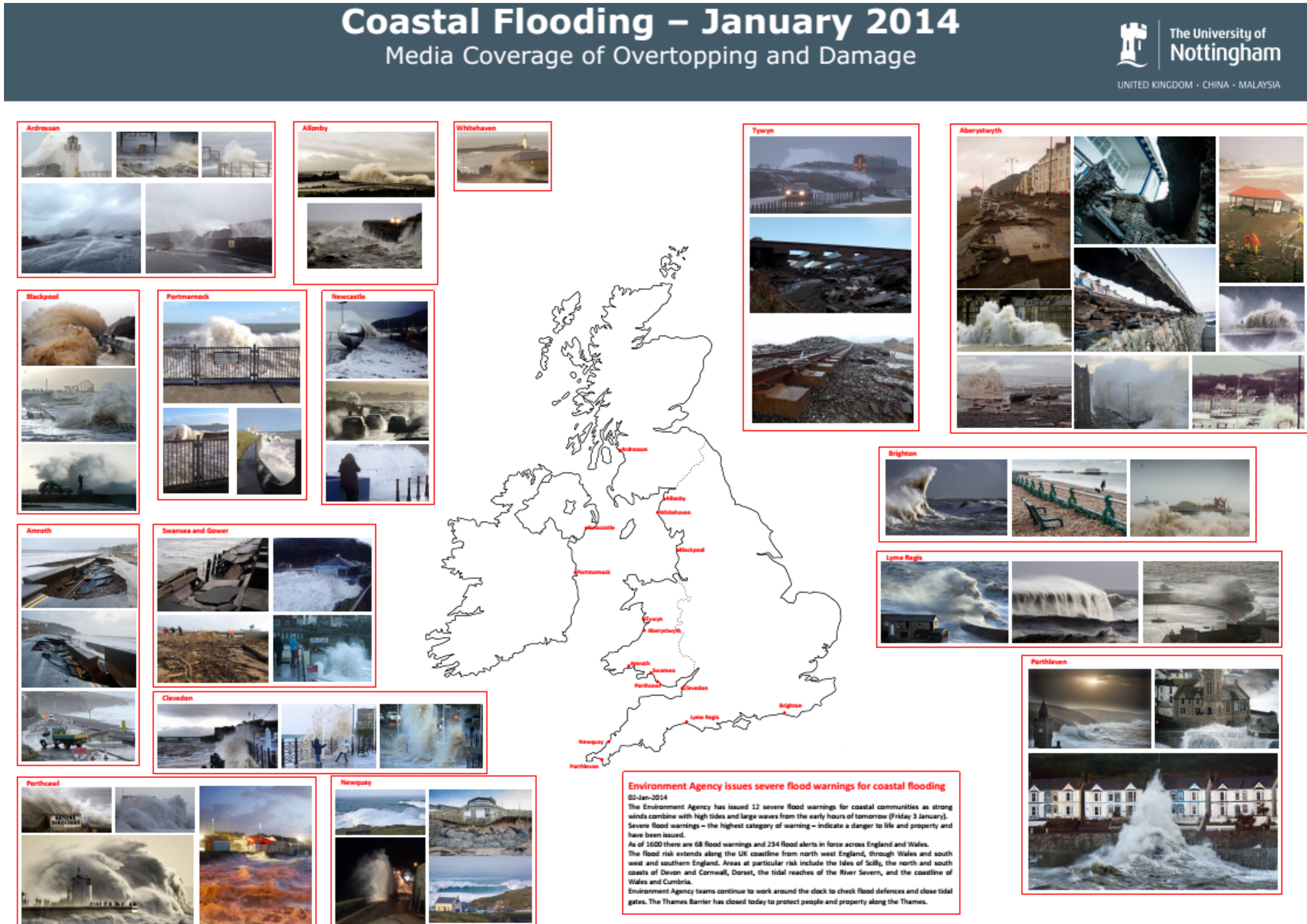
- "super-statistics" and stochastic models of clustering and
- Linking extremes to climate predictors

- Generating series of extremes at multi-timescales
- Accounting for climate change in the mean and clustering in time
- Accounting for non-stationarity and associated uncertainty



Jan 2014 event

- The "perfect storm cluster"
- NOC team preparing database and frequency analysis
- Nottingham team collected damage info



Flood MEMORY WP1: Clustered processes

work done at Queen Mary University of London

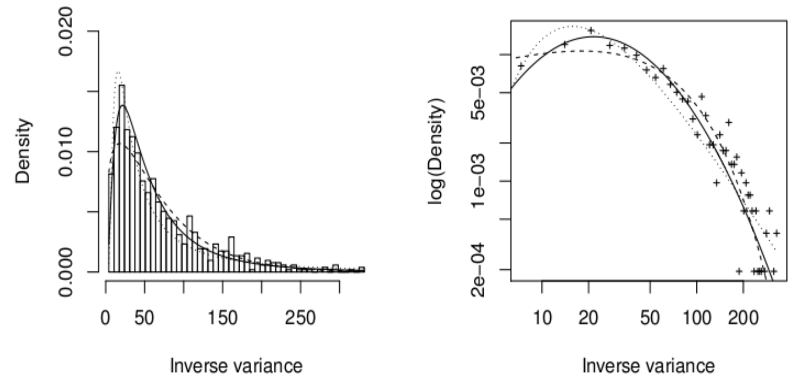
by Christian Beck and Pau Rabassa

Carried out tests on the measured time series and compared the sea-level fluctuations of 5 different UK locations.

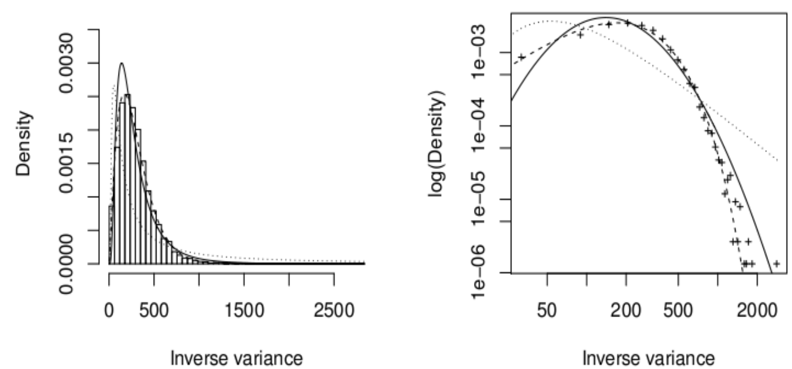
Showed that **fluctuations of sea-levels are well-described by a super-statistical model**

Given the relevant class of superstatistics, can now do extreme value theory for that particular superstatistical dynamics

Next step is to use this information to **construct optimized models for clustering of extreme events**



Extracted probability distibution of the inverse variance for observed sea levels

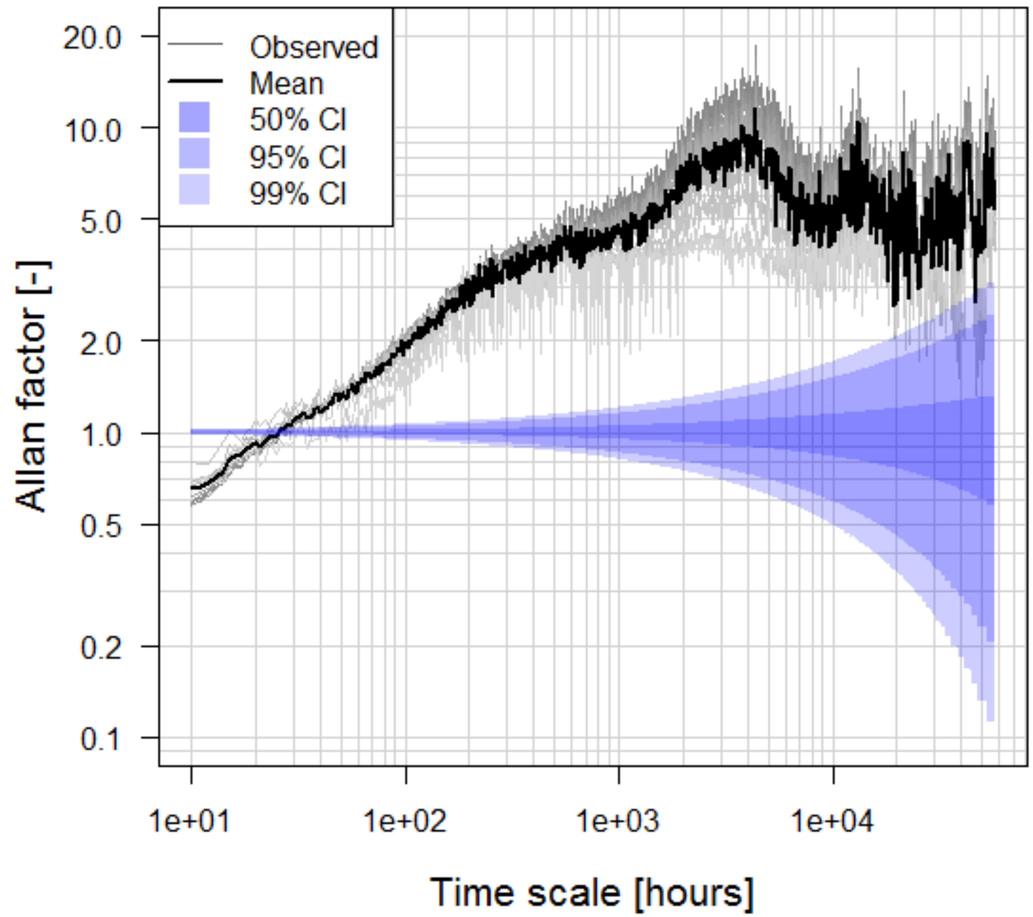


Extracted probability distibution of the inverse variance for observed sea levels differences

Analysis of number of occurrences

Hourly sea level data :Newlyn 1915-1980

- The analysis is based on the Allan factor
- The diagram clearly shows that the number of occurrences over a wide range of time windows is far from the Poissonian behaviour (blue areas), thus confirming the over dispersion of POT event (i.e. groups of POT events separated by time intervals longer than those expected for Poissonian processes)

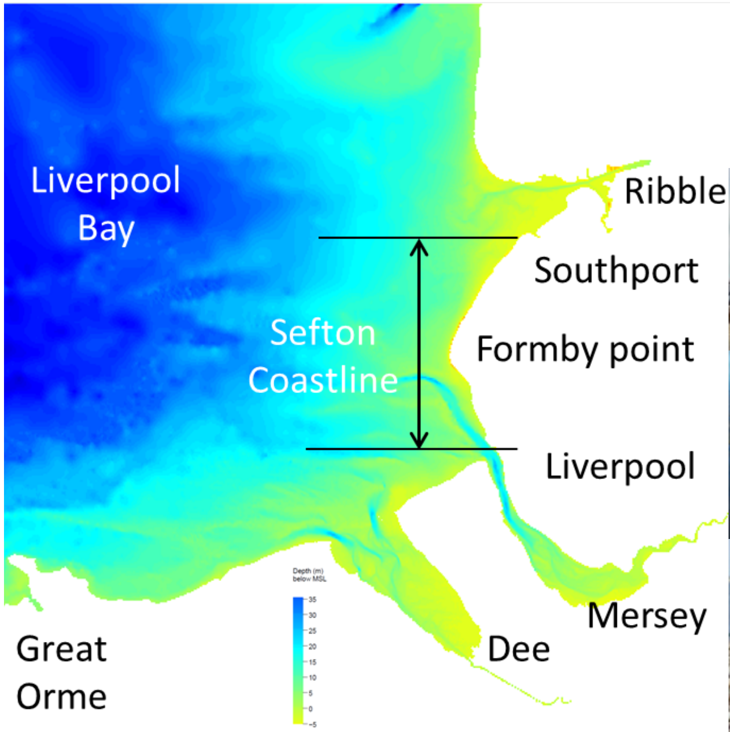


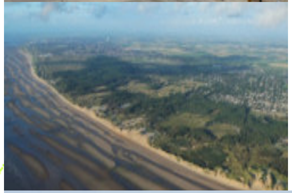
Serinaldi F, Kilsby CG. [On the sampling distribution of Allan factor estimator for a homogeneous Poisson process and its use to test inhomogeneities at multiple scales](). *Physica A: Statistical Mechanics and itsApplications* 2013, **392**(5), 1080-1089.

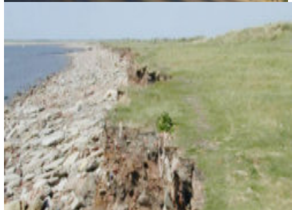
WP 2 – Coastal flood system

- Quantify beach response memory to storm clustering
- Provide quantitative coastal flood predictions
- Provide fragility curves for both engineered and non-engineered beach systems
- Fill the gaps in modelling the effects of subsurface flow on beach morphodynamics

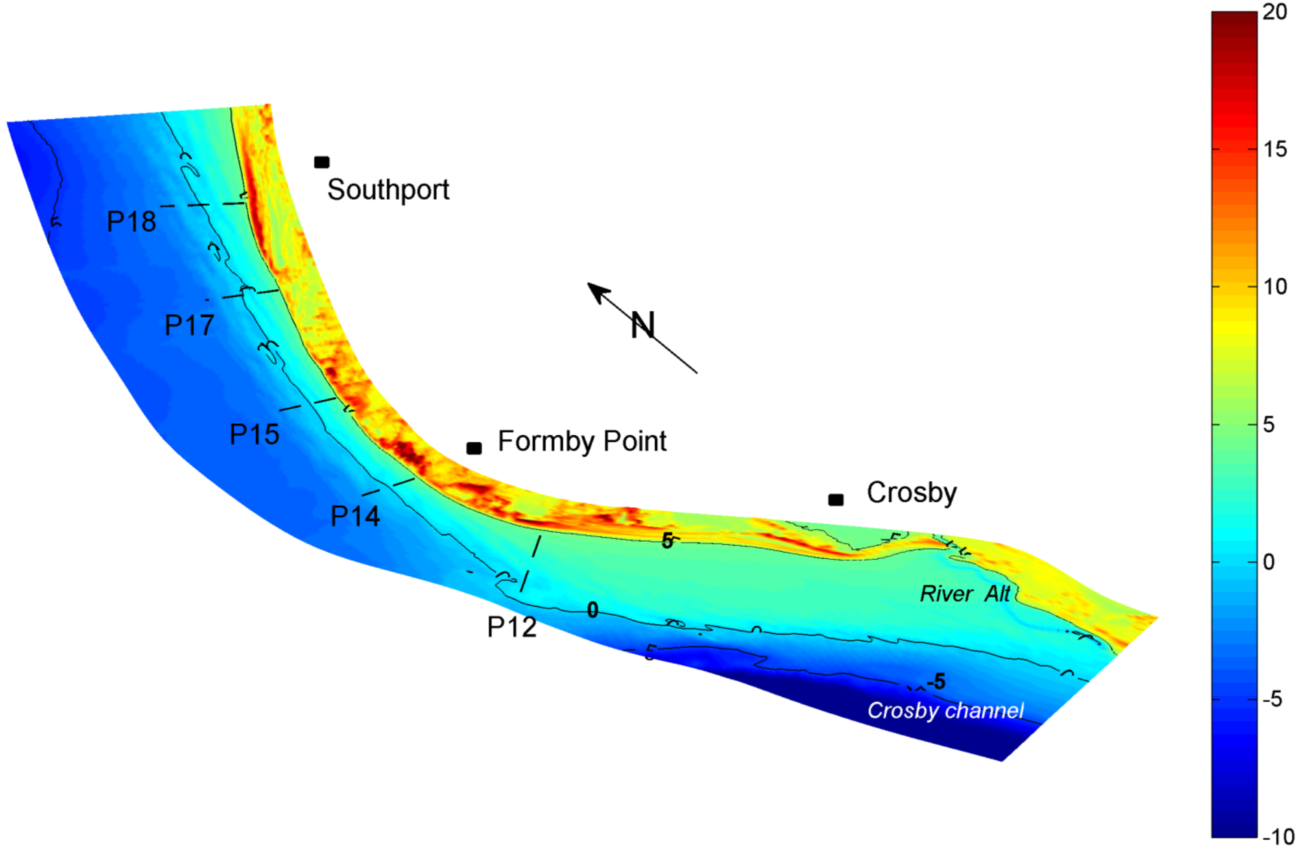
Sefton Coast: Representative of many different UK coastlines







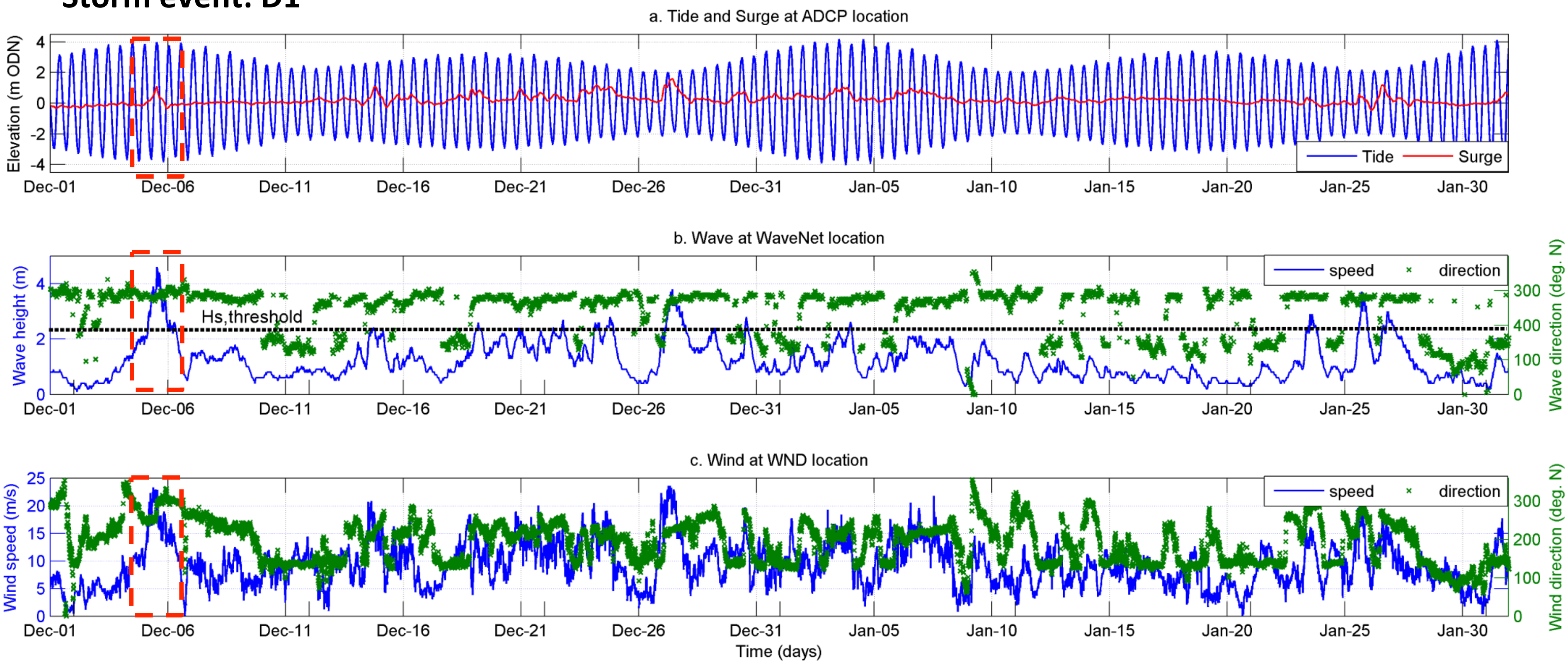
Study Site – Sefton Coast, Liverpool Bay



Profile survey locations

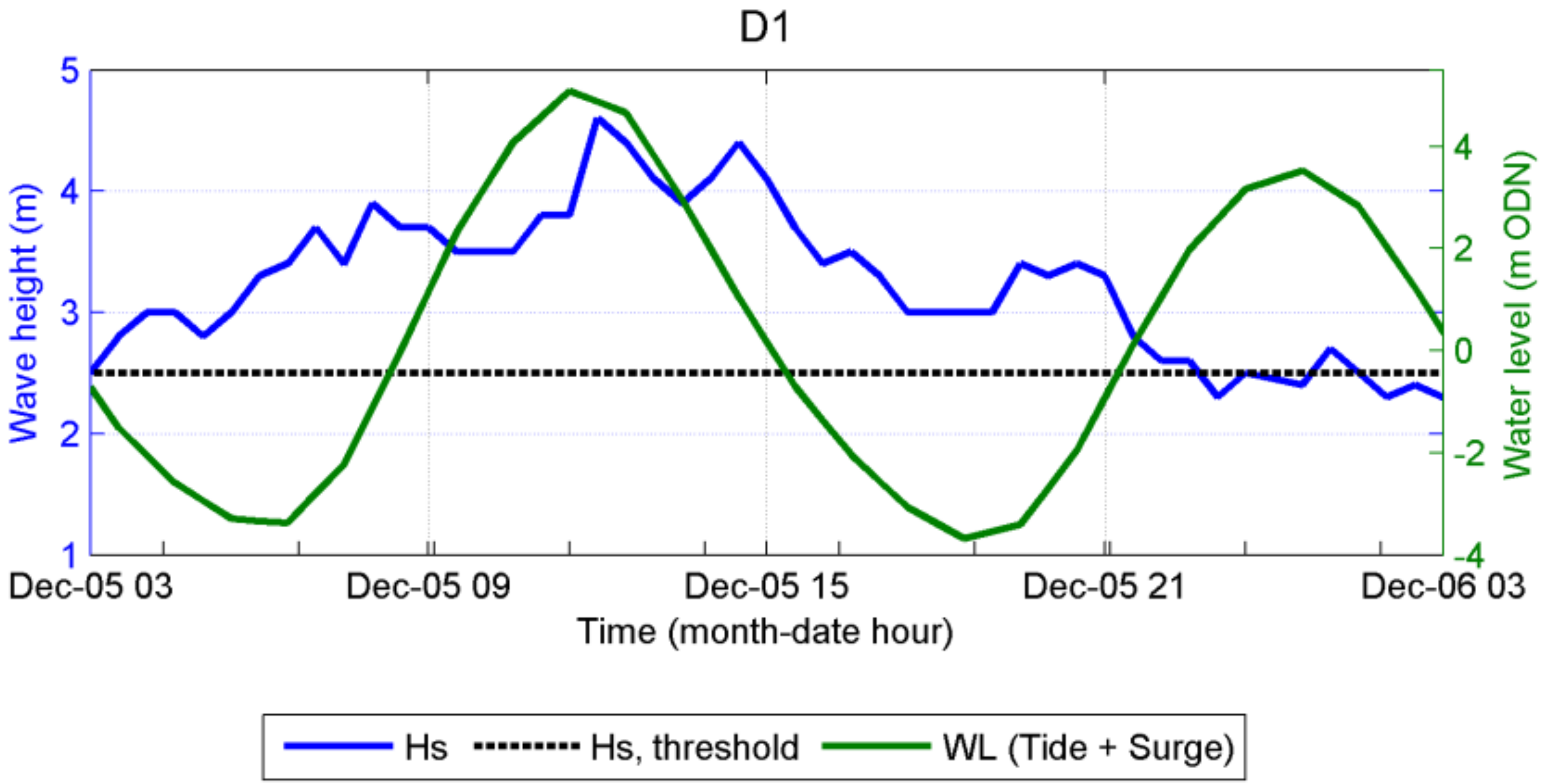
Modelling beach change from December 2013 to January 2014 storms

Storm event: D1



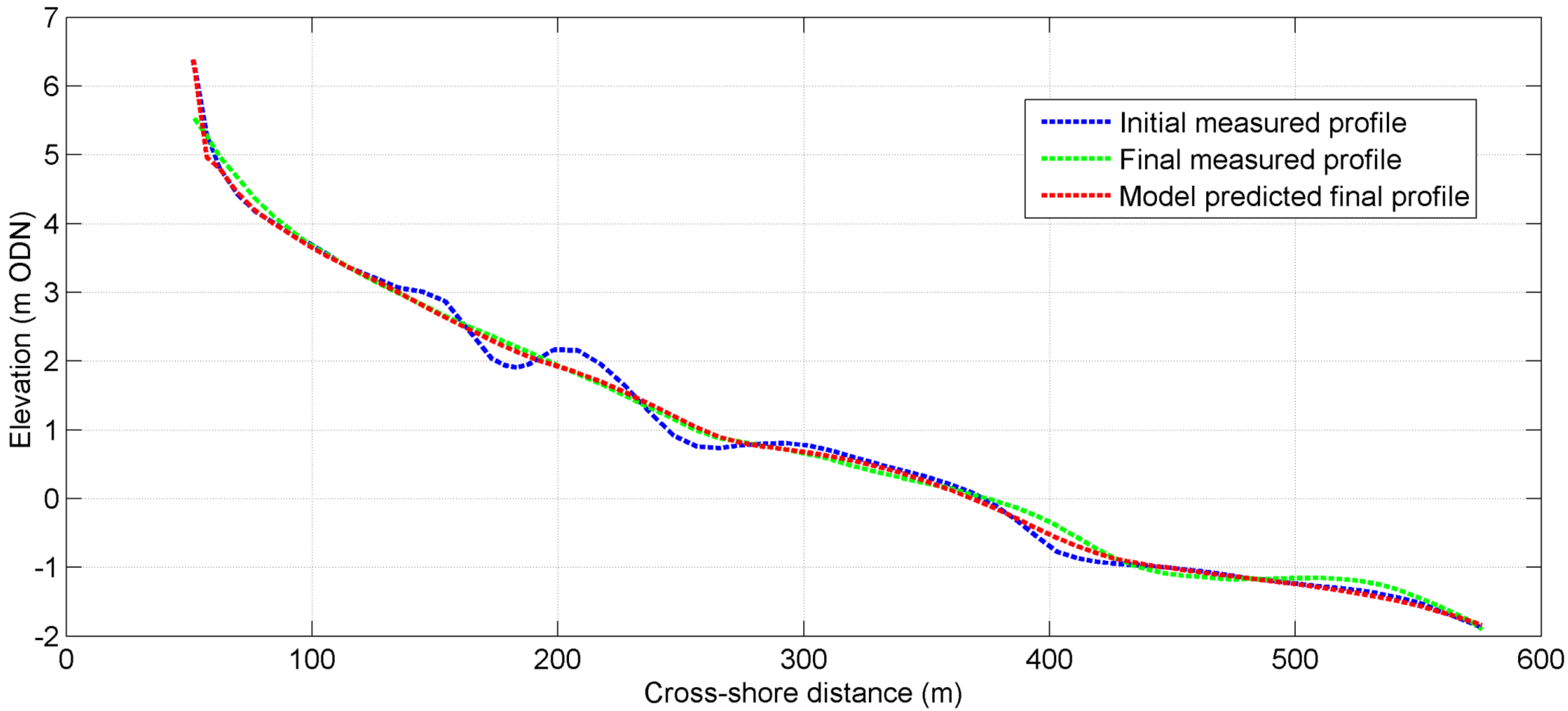
Storm waves and water levels

Modelling beach change from December 2013 to January 2014 storms



Storm event occurred on the 5-6 December 2013

Modelling beach change from December 2013 to January 2014 storms

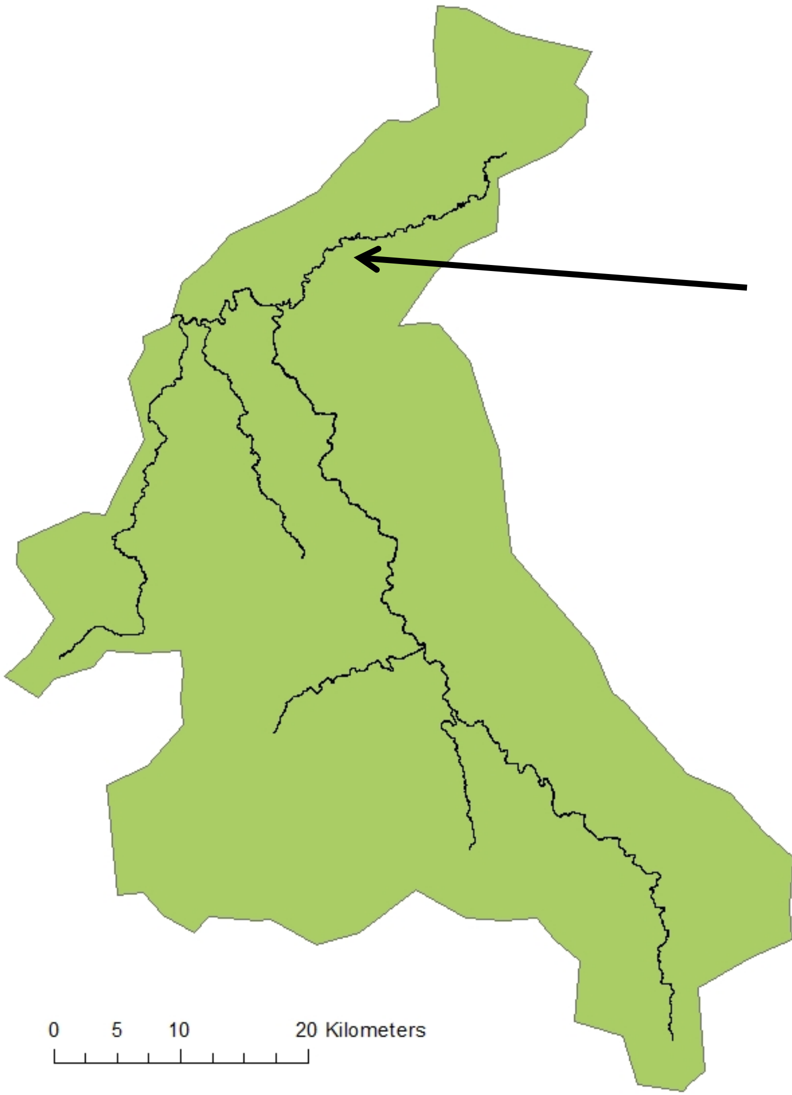


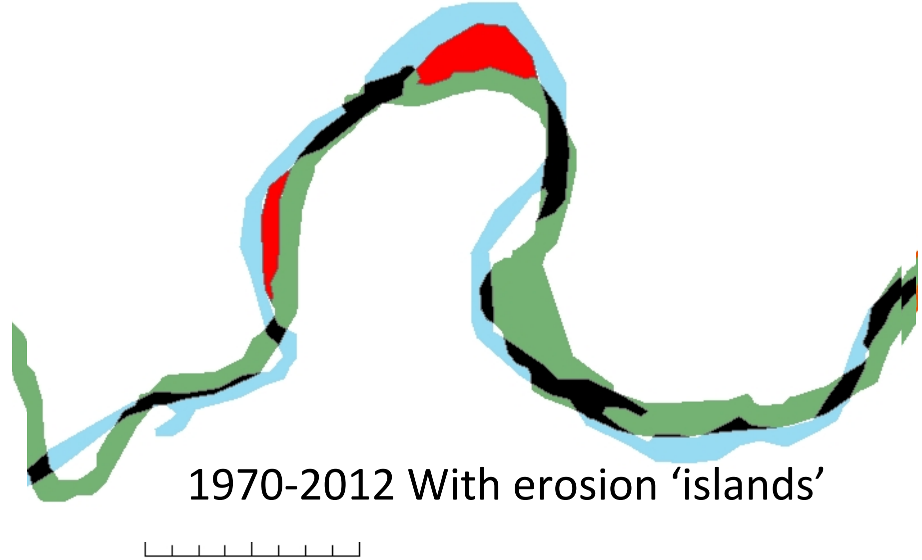
Evolution of Profile No 14 during storm event D1

WP3 Fluvial flood risk

- Clusters in flood hydrograph – due to storm clustering and antecedent rainfall
- Sediment routing is continuous with long term memory
- Aggradation/degradation changes channel capacity
- Fragility curves used for natural system and structural defences

Erosion and Sediment model for Eden – SHETRAN





1970-2012 With erosion ‘islands’

Section of River Irthing 1970
with 3.5m buffer outline

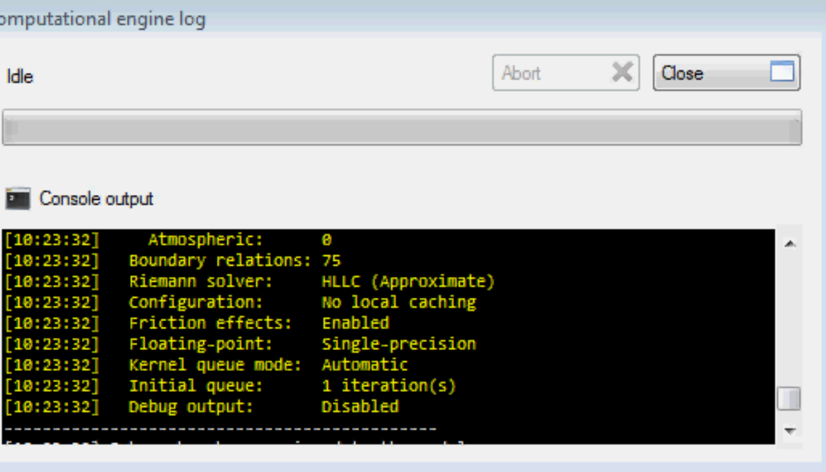
1970 (with buffer) and 2012

Section of River Irthing 1970

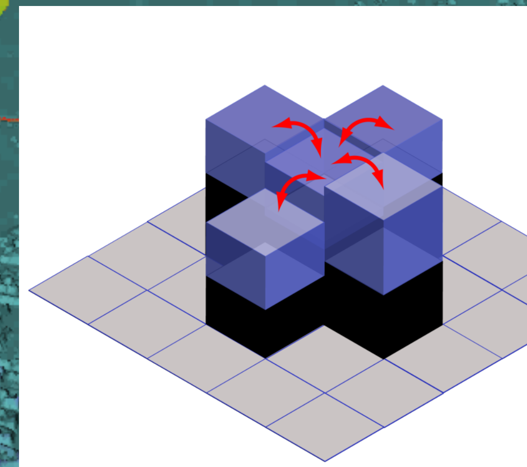
Current representation of bank erosion within SHETRAN:

$$E_b = k_b\left(\tau_b / \tau_{bc} - 1\right)$$

Time - varying erodibility parameter



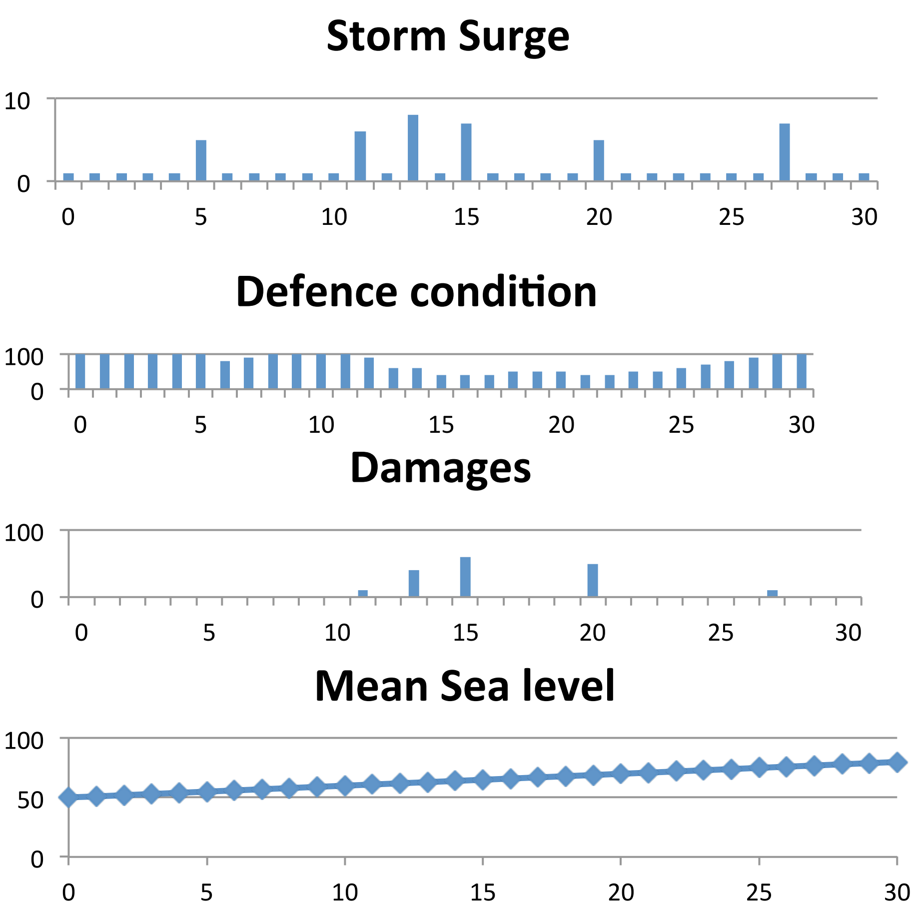
Inundation modelling Hi-PIM

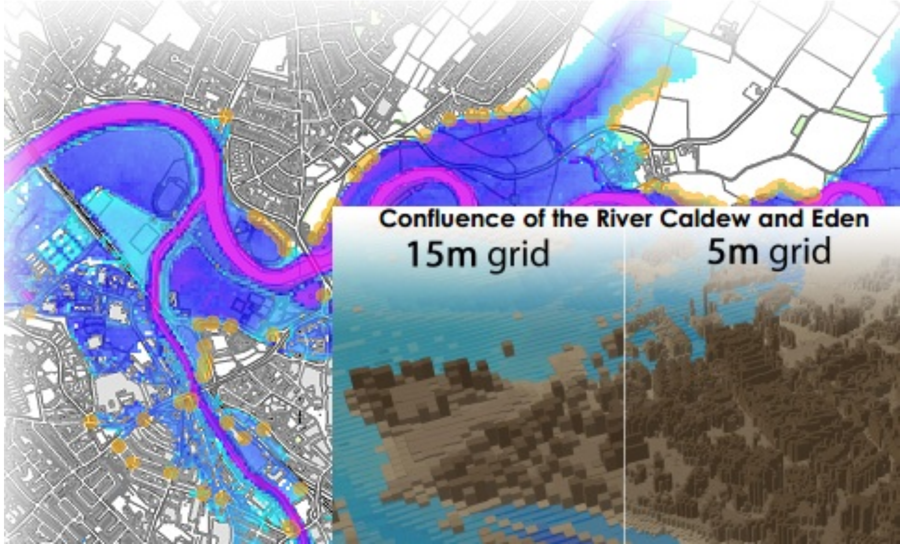


- <u>Hi</u>gh-<u>P</u>erformance <u>I</u>ntegrated <u>M</u>odelling <u>S</u>ystem
  - Three numerical schemes
    - 1st-order Godunov-type scheme, 2nd-order Godunov-type scheme, Simplified inertial approximation
  - OpenCL-based
    - cross-platform
    - cross-architecture
    - flexible modelling framework
  - Any modern CPU or GPU

WP4 Continuous simulation and inundation modelling

- Novel approach using an updating framework in continuous time
- With more detailed simulations of inundation and dynamic system performance during storm events

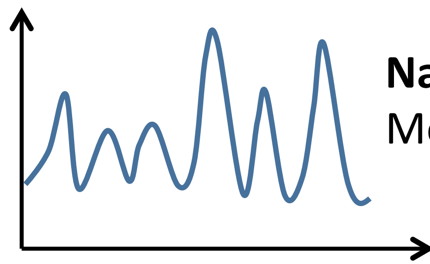




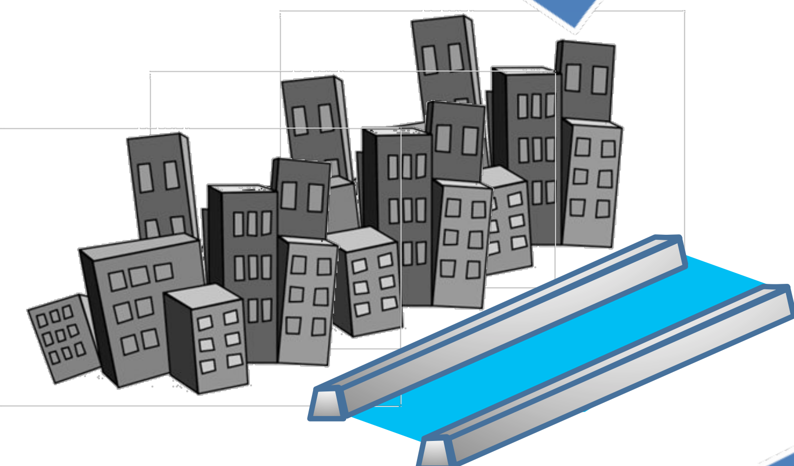
Coupled Human and Natural Systems

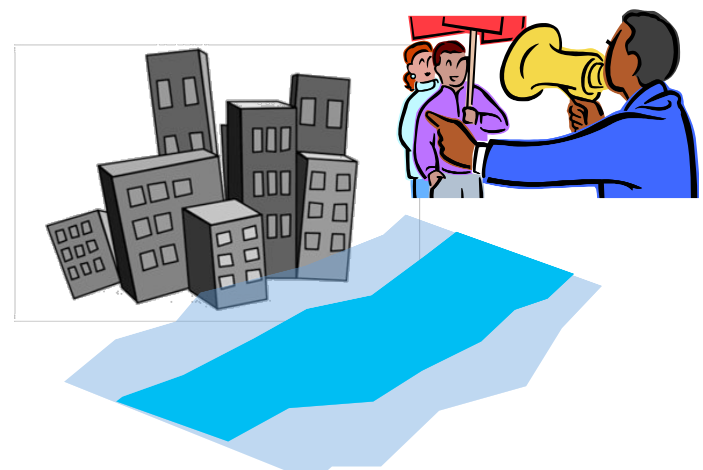
for Flood Protection Investment

Levee effect following investment:
Increased urbanisation
=>hydrological impacts



Natural System
Memory: flood rich / poor



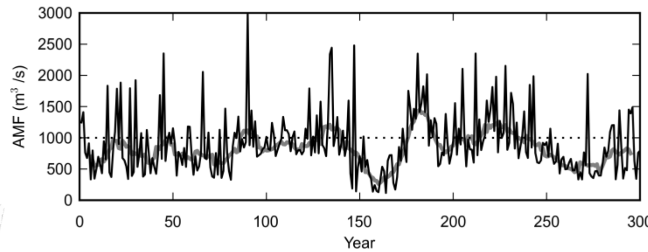


Flood protection investment:
Proactive / reactive
Allocation of scarce resources

Human System:
Flood memory imparted into community
Communities campaign for investment

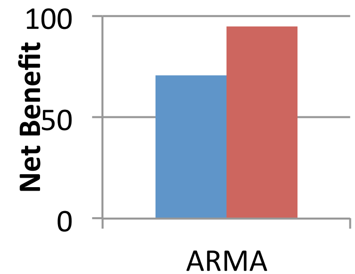
Coupled Human and Natural Systems

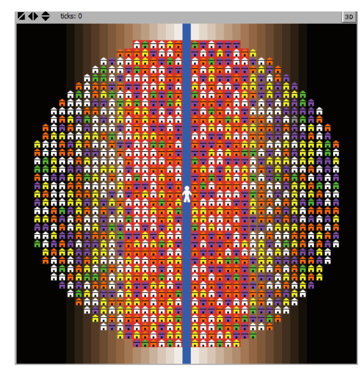
for Flood Protection Investment

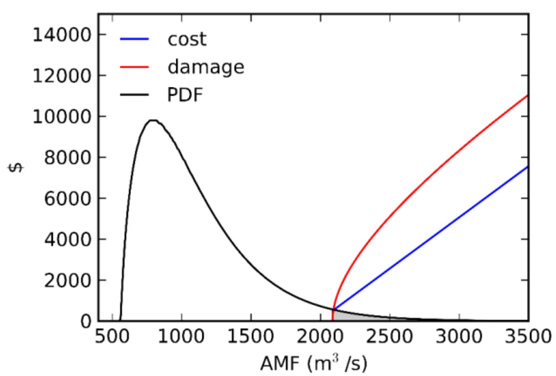


Natural System
ARMA modelling / persistence

Value for Money







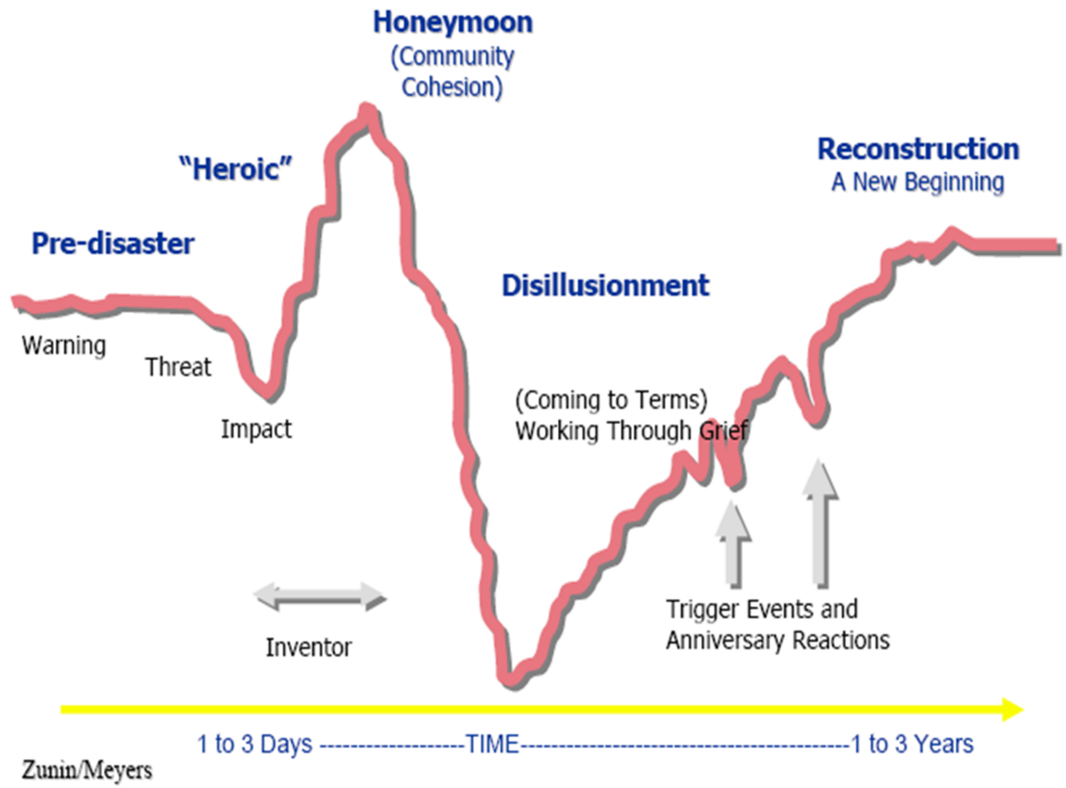
Flood protection investment
Cost:benefit analysis

Human System:
Agent-based modelling of virtual cities / communities

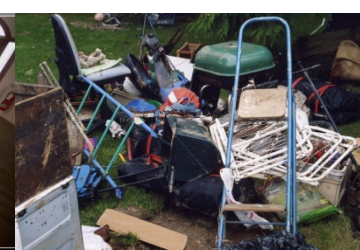
WP5:Socio-economic analysis of recovery and resilience

Novel analysis of recovery and resilience using outputs of simulations allowing much wider range of conditions to be studied than available from empirical cases

Can consider :
- Health
- Security
- Development
- Homes
- Education
- Livelihoods
- Communities
- Finance
- Economy







WP5:Socio-economic analysis of recovery and resilience

Working definition of flood memory:

"The term memory can be expressed as the differential level of vulnerability caused by the antecedent effect of the damage within the natural/built environment as a result of flooding within the limited window of recovery time between events."

(Bhattacharya-Mis and Lamond, 2014 , ICBR, accepted)

Working on

1. **Reviews of state of the art of memory studies in Mental Health, Socio-Economic Systems and the Built Environment. Towards developing fragility mapping for frequently flooded case study areas (outputs below).**
2. **Analysis of frequently flooded locations to identify the impact of memory within property markets (ongoing)**

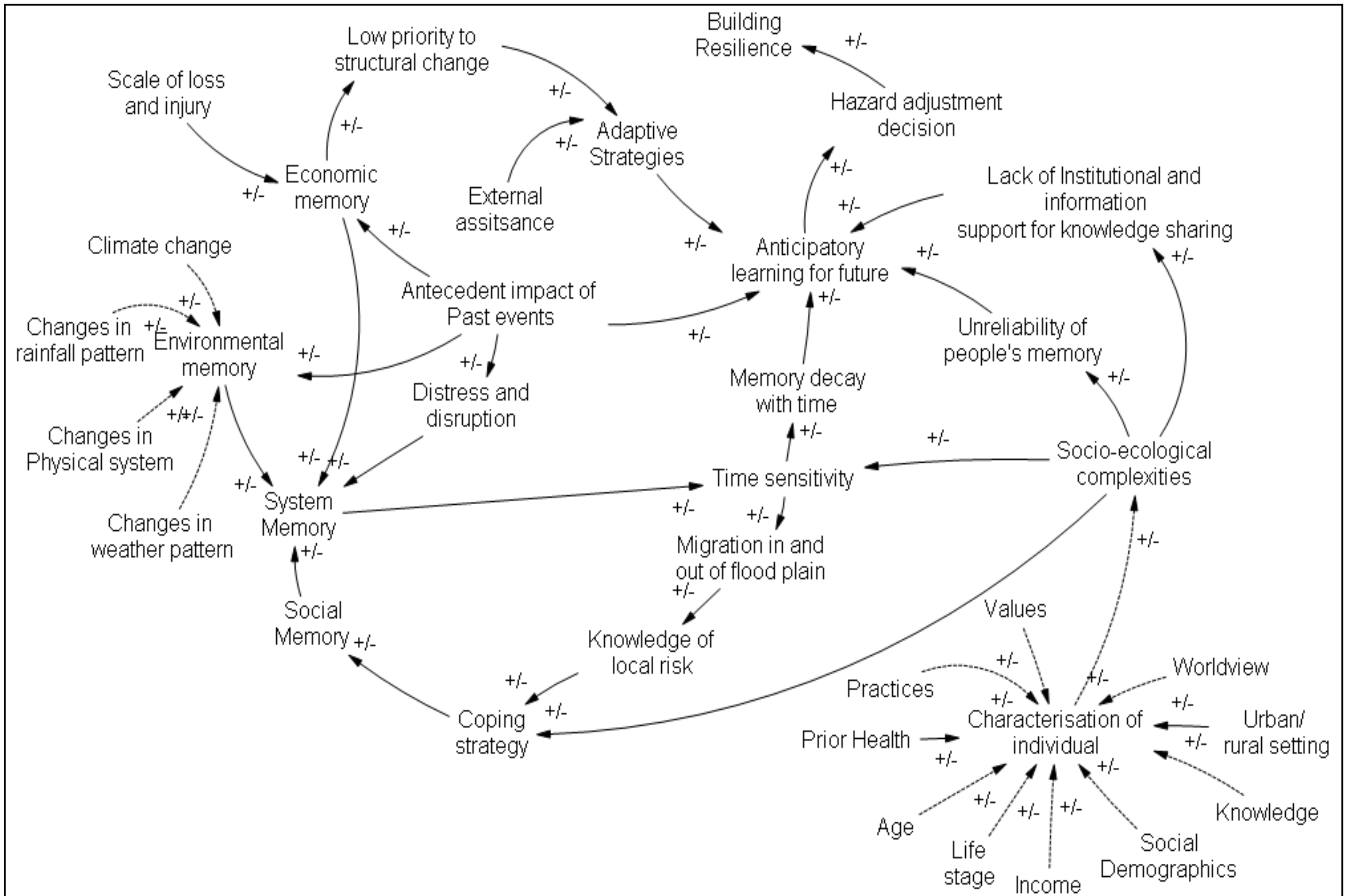
Work package outputs:

Academic outputs:

1. The role of flood memory in the impact of repeat flooding on mental health (*FRIAR, 2014*)
2. Socio-economic complexities of flood memory in building resilience: An overview of research (*Procedia Economics and Finance*)
3. Towards an integrated framework for building resilience using flood memory in the built environment (Prepared for *USAR, 2014*)

Mapping the theory

Memory can be distributed into two broad themes in a socio-ecological system: environmental and social. The environmental memory deals with the physical or natural part of the system while the social memory concerns the people and society as a whole.



Conceptual map illustrating interrelationship between memories within a system (Bhattacharya-Mis and Lamond, 2014)

Outputs

- **New combination** of climate, "super-statistics" and flood system models, including "memory", all within a novel continuous/event simulation framework to inform socio-economic analyses
- **Information and strategies** for dealing with "multiple shocks" which may be "blindspots" in UK flood risk
- **Myth busting** of return periods and stationarity: replacement of inadequate conventional analyses