FLOODmemory

Multi-Event Modelling Of Risk & recovery

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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

1. Series of extreme events
   Analysis of observed series
   Development of stochastic models
   Generation of series

2. Coastal systems
   • Soft defences
   • Hard defences

3. Fluvial systems

Driver series

4. Continuous simulation and damage calculation framework

Damages series

5. Socio-economic analysis of recovery and resilience
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 distribution of the inverse variance for observed sea levels

Extracted probability distribution 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.
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

a. Tide and Surge at ADCP location

b. Wave at WaveNet location

c. Wind at WND location

Storm waves and water levels
Modelling beach change from December 2013 to January 2014 storms

Storm event occurred on the 5-6 December 2013
Evolution of Profile No 14 during storm event D1

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:

\[ E_{\Delta b} = k_{\Delta b} \left( \tau_{\Delta b} / \tau_{bc} - 1 \right) \]

Time - varying erodibility parameter
High-Performance Integrated Modelling System

- 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.