

# Storm Risk Mitigation through Improved Prediction and Impact Modelling: Science Plan



## 1. Summary

Storms are having an increasing social and economic cost and the negative societal impacts are disproportionately influenced by extremes. This has highlighted the need to improve the forecasting of storms and their impacts in the short-term and long-term. This £4.9M NERC programme on *Storm Risk Mitigation through Improved Prediction and Impact* is a response to this need. The programme will be achieved through three integrated science deliverables.

## 2. The Research Programme's Objective

The objective of the programme is to improve short and longer term forecasting of storms and their impacts on catchments and coasts.

## 3. Scientific Background

Storms have had an increasing social and economic cost over recent years and are likely to be the main cause of loss of life or assets in the UK over the next few decades. The negative societal impacts caused by adverse weather are disproportionately influenced by extremes. Furthermore, with climate change, the costs associated with storm impacts are likely to increase. This has highlighted the need to improve the quality of forecasting of storm track and intensity (a) in the short-term (0-48 hours) through numerical weather prediction (NWP) and (b) in the long-term (over decades with evolving climate change) through improved climate prediction. On both timescales there is a need to improve forecasting of impacts.

Several research gaps need to be filled with regard to the prediction of mid-latitude storms, particularly extra-tropical cyclones, to inform short-term mitigation strategies against the impacts of hazardous weather such as high winds and heavy rain. Given the high degree of influence that storms have on other natural hazards—such as riverine, groundwater, pluvial and coastal flooding, ground stability (including landslides) and coastal erosion—in addition to their effects on the built environment, ecosystems and agriculture, there is a requirement for improved linkage with impact models to better inform policy and enable preventative measures to minimise risks associated with such storms. There is a need to improve the way in which information flows between numerical weather prediction, climate models and impacts models.

This programme has been structured into three interconnected deliverables. The first deliverable is particularly focussed on increasing our understanding of, and capability to predict, structures at the mesoscale in extra-tropical cyclones, to help improve quality of forecasting in the short-term through numerical weather prediction. Cyclones have a major role in producing large rainfall accumulations over short periods (the order of a day), leading to fluvial and some pluvial flooding. They are also central to both direct wind damage and coastal flooding through storm surges and waves. The second programme deliverable is focussed on increasing our understanding of the role of key physical processes within extra-tropical cyclones and how these will be affected by climate change i.e. over the long-term. Other storms which also cause serious impacts, such as mesoscale convective systems, are not included in this programme. The third deliverable from the Storms programme will focus on determining how to use more effectively the finest resolution achievable from numerical weather predictions (about 1 km) in order to deal with impact modelling issues such as downscaling and sensitivity of model outputs for catchment or coastal applications, or both.

#### **4. Strategic Context**

The programme has been developed as part of the Natural Hazards Theme and will address the need to increase the capability to forecast the impacts of hazardous weather (in particular heavy rain, and high winds) and thereby contribute to meeting one of the three foundation areas of the Natural Hazards Theme Action Plan: to enable better forecasting and mitigation of hydro-meteorological hazards.

The programme will directly address NERC Natural Hazard strategy challenges relating to storms, floods, coastal erosion, and improvement of integrated risk assessment and scientific advice. The storm challenge has the highest priority in the Natural Hazards Theme Report, and this programme is aimed at improving:

- (i) predictive capability of models with respect to extreme wind and precipitation;
- (ii) knowledge about the change in the frequency and intensity of storms under global warming conditions; and
- (iii) improved knowledge of the coastal sea surface response to extreme storm conditions and how well the current generation of models deal with it.

#### **5. The Research Programme Science Deliverables**

The programme objective (Section 2) will be addressed via three integrated science deliverables.

The science deliverables will be implemented as specified in a separate *Implementation Plan*, which should be read in conjunction with this document.

*Deliverable 1: Numerical Weather Prediction (NWP)*—increased understanding of and capability to predict mesoscale structures in extra-tropical cyclones.

The focus of this deliverable is on the mesoscale to convective scale (roughly 1-50 km) within extra-tropical cyclones, because this is the scale of many organised structures in such cyclones that are not fully understood. As a result of this, and the paucity of much routine observational data, NWP models currently show relatively poor predictive capability at these scales. This resolution is at the coarse end of that needed for impact models

Therefore, the key scientific questions that will be addressed Deliverable 1 are:

- a. How are potential vorticity and moisture anomalies generated in cyclonic storms, what is their morphology, and what consequences do they have for the weather?
- b. How can these physical processes be parameterized for NWP, both at very high horizontal resolution (~1 km) and at resolutions that are more appropriate for longer-range prediction (10-20 km)?
- c. What is the real-world structure of cyclonic storms at the meso-convective scale?
- d. How can we improve NWP models and data-assimilation methods for better “nowcasts” and forecasts of cyclonic storms at meso to convective scale?

*Deliverable 2: Climate Science*—improved understanding of how climate change and natural variability will affect the generation and evolution of extra-tropical cyclones.

Understanding how climate change will affect extra-tropical cyclones is of crucial importance. There remains large uncertainty in current predictions of storm activity and

limited understanding of the key physical processes involved. Climate change will affect cyclones through background changes in temperature gradients, wind shear and moisture. However, there is considerable uncertainty over these background changes. It will be important to assess the implications of this uncertainty for predictions of changes in cyclone characteristics. In addition, the potential for changes in cyclones to influence large-scale atmospheric circulation is of great relevance.

Therefore, the key scientific questions that will be addressed in Deliverable 2 are:

- a. How will climate change affect the generation and evolution of extra-tropical cyclones? How large are these effects compared to natural variability?
- b. Which physical processes are most important, and which predicted changes are most robust?
- c. How important are the features and processes that climate models poorly represent due to their limited resolution?

Science Deliverable 3: Impacts—improved ability to use numerical weather prediction and climate model output for storms impact modelling.

There is a need to improve the forecasting of storm impacts over both the short term (numerical weather prediction) and longer term (climate projections) timescales. Storm impacts (i.e. the consequences of heavy or persistent rainfall or high wind, such as riverine, groundwater, pluvial and coastal flooding; ground stability, including landslides; and coastal erosion) demand that impact models and storm predictions are better linked in order to better inform policy and enable preventative measures to mitigate risks associated with such storms. Limitations in current modeling techniques include aspects such as (i) the accuracy of extreme wind forecasts used to force surge and wave models for coastal flooding, (ii) incomplete understanding of the air-sea momentum transfer process, and (iii) the appropriate and integrated post-processing of NWP and climate predictions of storm precipitation for riverine flood predictions. Satisfactory solutions will require impact modellers, weather forecasters and climatologists to work together. Development of novel methodologies may be appropriate.

Therefore the key scientific questions that will be addressed in Deliverable 3 are:

- a. What storm impact model (or multi-model cascade) features, and catchment and coastal processes, are the most sensitive to projections of future changes in storms, and thus how robust/uncertain is our understanding of current and future storm impact risk?
- b. How can probabilistic future climate and NWP model outputs best be used for meaningful predictions of storm impacts for catchment and coastal management?
- c. How can storm impact models be improved with next generation NWP and climate models, such as improved prediction of extreme wind for surge and wave modelling or improved extreme rainfall prediction for fluvial flood modelling?

## **6. Relationship to other initiatives**

It is anticipated that this Research Programme will make a significant contribution to the Living With Environmental Change (LWEC) programme, specifically Objectives A - to build effective mitigation, adaptation and resilience to climate change, including preparedness for changes to the intensity and frequency of extreme events; and D – to protect human, plant and animal health by predicting how [...] hazards and other factors will alter

under environmental change. Links to LWEC partners in the delivery of this programme are encouraged, in particular with the Met Office and the Environment Agency.

At a national level the programme will have strong synergies with existing Research Council programmes, such as Flood Risk from Extreme Events (FREE), Changing Water Cycle, and Flood Risk Management Research Consortium (FRMRC/FRMRC2).

The Storms research programme will also seek to engage with international activities; for example, the WMO The Observing system Research and Predictability EXperiment (THORPEX) Programme, the CMIP5 (the Fifth Coupled Model Intercomparison Project), and the EU FP6 project FLOODsite.