1. Background

The primary aim of the High Impact Weather (HIWeather) project objective is to *"promote cooperative international research to achieve a dramatic increase in resilience to high impact weather, worldwide, through improving forecasts for timescales of minutes to two weeks and enhancing their communication and utility in social, economic and environmental applications".* The HIWeather Implementation Plan highlights case studies – of both successes and failures - as sources of evidence for good practice in warnings.

2. Objectives

To establish the means to evaluate the effectiveness of a whole end-to-end warning chain and to identify an optimal warning chain based on available state-of-the-art components; through the development and exploitation of a database of end-to-end warning chain case study evaluations; and to make recommendations on the evaluation and improvement of warning chains at NMHSs. *Inter alia* the importance of the two-way, cyclic nature of information flows in determining warning effectiveness, will be emphasised.

3. Components

The work will consist of four main components:

A. Case Study Catalogue: collect relevant high impact weather events from case studies, warning assessments (e.g. NWS Service Assessments https://www.weather.gov/publications/assessments), post event reviews, and enquiries (UK Pitt Review – 2007; US Harvey Review – 2017; AUS Black Saturday Review – 2011) etc. Record the information from the study, with links to as much as possible of the following information, referenced to sources in such a way that it can be recovered by subsequent users.
    a. Identifier
    b. name
    c. date
    d. location
    e. impacts
    f. causal hazards
    g. causal weather
    h. forecasts
    i. warnings
    j. exposure (property, people, infrastructure etc)
    k. vulnerabilities identified
    l. interventions
    m. avoided impacts
    n. brief analysis
    o. lessons learned

    Linus Magnusson at ECMWF has produced a database of recent extreme weather events containing information on weather, hazard and forecasts, which will form a useful starting point.

B. Build database & Front End: create a data storage, access and analysis system to store the information and to enable easy use of the information to answer questions identified by practitioners. This component will require identification of one or more host institutions, specification and procurement of hardware, specification and development of software, and agreement of protocols for maintenance and access.

C. Classify Warning Systems: collect information on relevant warning systems, classified by governance, structure and organisation; cross-reference to relevant cases in the database,

with links to documentary evidence underpinning the choices made. Juyeon Bae has produced an index of WMO surveys of weather warnings which will form the starting point for this part of the project.

D. Research & Development projects: analyse events and groups of events that highlight important issues for warning chains, preferably spanning the concerns of multiple task teams, so as to relate the evidence to current understanding of good practice, to assess improvements that current good practice might have brought to the outcomes, and to update our understanding of good practice in the light of these studies. This component will go beyond HIWeather into the research and practitioner communities.

4. Characteristics of a relevant case study?

Relevant high impact weather events include those for which:

- Lessons learned are relevant to current technology and capability. For forecast accuracy this may imply less than 5 years old, whereas for governance, useful lessons may be learned from much older events.
- The event is relevant to HIWeather hazards: including cases involving geological, health or technological hazards if the warning and/or response have relevant characteristics.
- Information is available on many (ideally, but not necessarily, all) components of the warning chain: weather, hazard, impact, forecasts & warnings, response.

5. The main ingredients of a state-of-the-art warning system

A state-of-the-art warning system is designed in partnership with the users to provide the information they require to enable them to take critical emergency response decisions. Work gathered together in HIWeather indicates that the following good practice elements will be included:

i. A governance structure that facilitates design of the system in a partnership between the organisations that are involved (potentially including the NMS, Hazard-specific institutes, Public Health, Infrastructure engineers, Emergency managers, Community groups, and the public)

ii. A hazard monitoring system to record the occurrence of relevant hazards and their impacts

iii. A convection-permitting ensemble weather prediction system initialised hourly with high density observations using a hybrid ensemble/variational data assimilation system to forecast the probability of high impact weather

iv. A coupled ensemble prediction capability to forecast the probability of relevant hazards, including the probability of co-incident hazards

v. A post-processing capability to forecast the impacts of the predicted hazards, including both direct and indirect impacts

vi. A risk-based warning package which includes information on the likelihood and impact of the predicted hazards and including co-designed information on appropriate responses, tailored to the needs of users, and in a variety of formats suited to different users.

vii. A dissemination system that provides the warning information to users whenever and wherever they need it, in a mutually agreed form that enables them to make the appropriate responses.

viii. An evaluation capability that records whether users received the warning, whether it was accurate, and whether they acted appropriately, in a form enabling warning effectiveness to be tracked over time.

ix. A review process, in partnership with the users, to develop system improvements based on the evaluation process.

6. The work

(A) Case Study catalogue

i. Initiation phase in which candidate cases are gathered and fed into an initial database outline (perhaps using an Excel spreadsheet) so as to refine the database structure and objectives.

ii. A team of volunteers to collect information on selected cases that they have access to and to add it to the database. Members may have preferred access to national evidence and/or to specific parts of the warning chain.

iii. A collaborative team activity (perhaps including a workshop) to draw conclusions about the warning chain performance in each case.

(B) Build database and front end

iv. A project team to create a database, that can be accessed by all task team members, formatted to receive the required information and populated with examples from (A).

v. A project team to design and build a front end for the database to enable searches, analysis and evaluation to be undertaken and presented intuitively, and for the results to be archived and shared.

(C) Classify Warning systems

vi. A project lead to identify sources (possibly in or through WMO) of information on national weather-warning systems and to define an outline classification.

vii. A team of volunteers to extract information on selected national weather warning systems that they have access to and to record it in the database.

viii. A collaborative team activity (perhaps including a workshop) to relate the information in the event database to the warning system classification.

(D) Research & Development projects

ix. Scientists or groups of scientists to undertake detailed analysis of selected cases or groups of cases to identify the potential benefits of applying an improved warning chain.