

**HIWeather**

**Health impacts outline**

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**Introduction**

High Impact Weather (HIWeather), a research activity within the World Weather Research Programme (WWRP), aims to improve extreme weather event forecasting, both in spatial resolution and predictive lead time. A significant beneficiary of HIWeather products could be decision makers in disaster early warning systems and emergency health care provision, who would be able to use improved forecasting techniques to better prepare for approaching extreme weather.

However, a significant knowledge gap exists in the HIWeather operation plan in terms of **where** and **how** significant health care decisions are made. Further, missing is a detailed awareness of how much lead time is needed for health care decisions. If a significant goal of HIWeather is to improve health outcomes by successful utilisation of its products, the direction of improved HIWeather products must be steered by the awareness and knowledge of the nature of disaster-related health care decisions.

This white paper aims to give an exposition on the process by which health care decision makers build a timeline of required action. The report will be structured around each of the 5 areas of focus of HIWeather.

**The logic of this approach is to begin with the desired health outcome improvements, and work systematically through the processes to where improved HIWeather products could assist.**

In this way, the selection and development of HIWeather products will be able to use health impacts at the heart its direction.

**Structure**

The 5 areas of focus for HIWeather are:

* urban flood
* wildfire
* localised extreme wind
* disruptive winter weather
* urban heat waves and air pollution

The following process will be reported upon for each of the 5 areas of focus:

* Identify key health issues for each sector.
* Identify key quantitative metrics which can be tracked and measured for success of interventions.
* Create timeline of decisions which need to be made by key decision makers
* Explain how decision makers come to trigger disaster-related health action plans
* Identify key gaps in capabilities of forecasting (both in time and space) which can be improved upon to help decision makers make calls.

**Health impacts**

**1. Urban Flood**

**Overview**

Urban floods can arise from extreme thunderstorms or from river overflow. Both rapid rise and slow rise floods can have a significant impact on public health in an urban area.1 Between 1995 and 2015, 3,062 flood events were recorded2. Floods were responsible for the majority (56%) of natural disasters; affecting 2.3 billion people worldwide2. While the adverse health effects of flooding include direct impacts on human health, the pathways can be complicated and indirect.

**Health impacts**

**Disruption to essential health care.** Treatment for serious illnesses, such as cancer, can be disrupted by flooding, due to transport infrastructure being knocked out for prolonged periods of time.3 Lack of availability of routine prescription medicines due to flooding may also impact health.4 Health care practitioners may also become overwhelmed by the increased demand for services.1

**Drowning or physical trauma.** Rapid rise floods can cause sudden changes to the environment, increasing the risk of drowning and injuries.5 Slow rise floods can also be deadly when there is a lack of preparedness.1

**Illnesses.** Diseases can be spread from undisinfected groundwaters by the onset of flooding.6 Increased instances of cholera7, diarrheal diseases7, hepatitis A and E7, leptospirosis7, melioidosis8, respiratory infections9, and typhoid7 have been observed after floods in urban areas.

**Malaria.** Epidemics in the wake of flooding in tropical regions can occur due to clogging of storm water drains, causing stagnant water to allow genesis of vectors of malaria.9,10

**Malnutrition.** Damage to infrastructure caused by flood, and disruption to food systems can cause appropriate food to be unavailable for prolonged periods, with children and the elderly particularly in developing countries vulnerable.11

**Psychological distress.** The mental health effects of a flood can last long after the flood itself, with reports of increased prevalence of psychological morbidity (including depression, anxiety, PTSD) in residents up to 1 year after floods, particularly if residents are displaced at short notice.12,13

**Key deliverables**

**Clear messaging of probability, lead times and spatial scales.** Improving ‘believability’ of flood forecasts can and must be improved upon by having clearer messaging on the predictability and processes of weather systems. The trustworthiness of flood forecasts can increase the changes of appropriate action and response by a vulnerable population.14,15 Such ways to improve trustworthiness are diffuse, but include clearer explanation of uncertainty in forecasts, validation of hazards, among other aspects.

**High resolution hazard-exposure mapping** As flood hazard forecasts become more reliable at a higher resolution and longer timescales, hazard-exposure maps (similar to <https://coast.noaa.gov/floodexposure/#/splash)> with detailed overlay of vulnerable groups in flooding (e.g. the elderly, the poor)16 would help to provide targeted aid. This may rely on forecasts of flooding areas being made on the neighbourhood level (~1km resolution for overlay with gridded population datasets like <http://ec.europa.eu/eurostat/data/database)>.

**Vector-borne disease.** Advanced techniques are available for infectious disease mapping with the onset of precipitation, with a one month preparation lead time to adequately prepare medical treatment.17 Working with epidemiologists and infectious disease modellers more closely to understand their needs and wishes would greatly improve their ability to inform medical and emergency services.

**‘Warn on forecast’.** If the forecast skill is significantly improved in a case such as Hurricane Sandy to advance to further days in advance, essential preparations, especially for those less able to move from place-to-place, would be easier and less disruptive. This would require a consistent long-term forecast ensemble, as one of the main reasons Hurricane Sandy was so devastating was due to the conflicting information from competing model forecasts. [ref] This would be especially true for trapped members of the populations, for example those who are stuck in a house to ensure that they have an appropriate amount of food and/or remote medical treatment.

**Improved downscaling of flood forecasts to improve early warning systems.** A study experiment set in Japan demonstrated the benefits improving resolution of flood forecasts for early warning systems.18 This demonstrated that a dramatic improvement in flood forecast downscaling could have significant returns in the preparedness of a population from flood early warning systems.

**Tolerance levels of buildings and drainage systems.** Overflowing sewers and storm drains can lead to flooding and collections of stagnant water, which will both have significant health impacts.1 Under climate change and increasing urbanization, the maximum flows resulting from floods can and should influence design capacity for tolerance of urban storm water. Designing the appropriate drainage system in urbanized areas will depend upon hydro-meteorological characteristics.19 Predictability of long-term maximum estimated flows is therefore an important input of future urban design.

**Preparedness for after the flood** Hurricane Sandy failures in the post-hurricane flood show that more understanding is required by authorities into how the flood will affect infrastructure in the weeks after the flood itself.[ref] Improving modelling of water flows after the flood will result in better infrastructure planning, potentially saving many more lives, and certainly avoiding prolonged distress by a population of displacement without knowledge of return.

**Potential projects with improved forecasting**

**Working with food and medicine supply infrastructure in a developing country with early warning system to map pathways to vulnerable communities** Vulnerable members of Pakistan’s population suffered malnutrition from the devastating floods of 2011.11 Working with authorities there, high resolution flood mapping with adequate lead times could aid planning for stockpiling of food.

**Project to create high resolution disease mapping simulations based on prediction of flood.** In early January 2015, devastating rains hit Malawi, resulting in massive floods across the country. This affected an estimated 638,000 people. There were 79 deaths associated with the floods. An outbreak of cholera resulted in 693 cases and 11 deaths. Advanced techniques are available for infectious disease mapping with the onset of precipitation, with a one month preparation lead time to adequately prepare medical treatment.17

**Long-term hospital infrastructure planning using high resolution flood modelling.** During the 2010 flood emergency in Pakistan, more than 500 hospitals and clinics were damaged or destroyed. High resolution extreme flood modelling could aid the planning of new flood-resistant hospitals and clinics, and help shore up existing treatment centres to enable them to continue to run.

**Education and workshops of key disaster relief stakeholders into understanding how forecasting of floods can be reported.** Often a key reason that appropriate action is not taken by a vulnerable population is that there is not sufficient belief that the flood warning will result in a flood. This is true even in industrialised countries like the USA. A key goal could be to work with practitioners who deploy resources in flood warnings to better understand what kind of information they need with regards to

**2. Wildfire**

**Overview**

Uncontrolled spread of wildfire can originate from bush, vegetation, forest, heath and grass. Wildfires predominantly occur in countries with warmer climates, they have been known to occur from uncontrolled burning of vegetation in temperature climates such as in the UK.20 Many health impacts result from the inhalation of burnt organic material, but other direct effects are evident.

**Health impacts**

**Burns.** Direct flame and thermal burns can result from a wildfire. The great increase in burns victims in a short time puts significant pressure on health care burns units, which can overwhelming these specialist centres.20

**Carbon monoxide poisoning.** This is mainly a risk to those who are in the immediate vicinity of the fire, such as firefighters. It can cause hypoxic injury, nervous system damage, and death.

**Eye irritation.** Those living close to the wild fires can experience eye irritation, as well as reduced general visibility due to ambient smoke, which can make vehicular accidents more likely.21 Corneal abrasions can also result from the eyes’ exposure to wildfire smoke.22

**Heat-induced illness.** Working in hot and humid conditions can cause many health issues (see ‘Urban Heat Waves and Pollution’). Firefighters can be particularly vulnerable when attempting to deal with the controlling the extent of the fires.

**Particulate matter inhalation.** Burning of organic material can produce several varieties of particulate matter. PM10 (particles under 10µm in diameter) can pass through the upper respiratory tract and are deposited in airways.20 PM2.5 (particles under 2.5 µm in diameter) can penetrate even deeper into the lungs and deposited where gaseous exchange takes place.20 Short-term exposure leads to increases in hospital admissions for respiratory conditions.23 Exposure to particulate matter will cause long-term health problems, and is a known risk factor for cardiopulmonary and lung cancer mortality.24,25

**Psychological distress.** Wildfires can cause the complete destruction of homes and livelihoods. This in turn can lead to depression, anxiety, and PTSD.26

**Respiratory complications.** Breathing in bushfire smoke will exacerbate breathing problems for both children and adults. [ref]

**Water and land contamination.** Large concentrations heavy metals (such as arsenic, cadmium, copper, and lead) have been found deposited in soil from ash debris after a wildfire, which can cause various long-term health effects.27

**Deliverables**

**Potential projects with improved forecasting**

**Example of Manitoba, Canada.**

**3. Localised Extreme Wind**

**Overview**

28 **Health impacts**

**Injuries from debris.** Buildings and trees

**Road accidents.**

**Psychological distress.**

**Sea spray.**

**Deliverables**

**Potential projects with improved forecasting**

**4. Disruptive Winter Weather**

**Overview**

**Health impacts**

**Deliverables**

**Potential projects with improved forecasting**

**5. Urban Heat Waves and Air Pollution**

**Overview**

Heat waves, or hot weather that lasts for several days, can have a significant impact on society and are associated with a rise in morbidity and mortality. [ref] The impact of heat waves on human health can be catastrophic, as seen in the tens of thousands of excess deaths recorded in Europe during the summer of 2003,[ref] and in the Russian Federation in 2010 [ref]. Between 1994 and 2013, extreme temperatures affected 93 million people and caused 160,000 deaths around the world. It is also clear that exposure to more frequent and intense heat waves is increasing, with an additional 125 million vulnerable adults exposed to heatwaves from 2000 to 2016.[ref] Those living in urban areas may also experience an amplified heat wave, as the urban heat island phenomenon can increase temperatures significantly compared with the surrounding non-urban area.29

Air pollution is characterized by a contamination of the indoor or outdoor (ambient) environment by any agent that modifies natural characteristics of the atmosphere.[ref] Air pollution causes several million deaths each year and is a leading environmental health risk affecting everyone. Nearly 4.3 million premature deaths per year are attributable to indoor air pollution and roughly 3.7 million premature deaths are thought to be caused by outdoor air pollution.[ref] Adverse health impacts result from particles in the air such as dirt, dust, soot, and smoke. These pollutants are released by both human natural and sources, such as through the burning of fossil fuels for electricity and transport, industrial processes, agricultural practices, or forest fires, volcanic eruptions, and wind-blown dust.

Air pollution is known to act as an aggravating factor on the health effects of heat waves. As such, it is important to consider air quality levels when considering the impact of a heat wave on a vulnerable population.

**Health impacts**

**Heat waves:**

**Cerebrovascular accidents.** A stroke is caused by coagulation of blood in the brain, and studies have suggested that the blood of heat stressed individuals coagulates more readily..30

**Heat edema.** Manifests itself as soft tissue swelling in those who are less acclimatised to heat being experienced.31 Cramps are more likely when exercising in hot and humid environments, but especially during exercise.32

**Heat exhaustion.** Common symptoms include headache, dizziness, goose flesh, nausea, vomiting, diarrhoea, irritability, and loss of coordination.32

**Heat rash.** Also known as ‘prickly heat’ or ‘milaria rubra’, heat rash results from sweating which saturates the skin surface, clogging the sweat ducts.31

**Heat stroke.** Clinically defined as when the body’s core temperature is at least 40.6C.33 A life-threatening condition, with a severe elevation of body temperature with central nervous system dysfunction that often includes combativeness, delirium, seizures, and coma.34

**Heat syncope.** Fainting from heat due to elevated body temperature.Syncope can indicate that someone is undergoing heat stroke.32

**Severe dehydration.** Profuse sweating can occur during a heat wave episode. This can lead to dehydration, which depletes electrolytes and causes sodium losses.32

**Key metrics to track performance**

Cf Lancet Countdown

**Timeline of key decisions**

**1-2 days:**

**3-5 days:**

**1 week:**

**S2S:**

**Decision making process for action plan**

**Who are the decision makers in the process?**

**What are the key pieces of information a decision maker will need?**

**How are heat early warning systems activated?**

**Key gaps in capabilities**

**Which parts of the world are lacking information?**

**Which timescales need to be improved?**

**What level of skill is required?**

**References**

1 Hajat S, Ebi KL, Kovats RS, Menne B, Edwards S, Haines A. The human health consequences of flooding in Europe: A review. *Extrem Weather Events Public Heal Responses* 2005; : 185–96.

2 UNISDR, CRED. The human cost of weather-related disasters 1995-2015. *UNISDR Publ* 2015; **1**: 30.

3 Bennet G. Bristol floods 1968. Controlled survey of effects on health of local community disaster. *Br Med J* 1970; **3**: 454–8.

4 Ochi S, Hodgson S, Landeg O, Mayner L, Murray V. Disaster-Driven Evacuation and Medication Loss: a Systematic Literature Review. *PLoS Curr* 2014; : 1–24.

5 French J, Ing R, Von Allmen S, Wood R. Mortality from flash floods: a review of national weather service reports, 1969-81. *Public Health Rep* 1983; **98**: 584–8.

6 Miettinen IT, Zacheus O, Bonsdorff C-H von, Vartiainen T. Waterborne epidemics in Finland in 1998-1999. *Water Sci Technol* 2001; **43**: 67–71.

7 Watson JT, Gayer M, Connolly MA. Epidemics after Natural Disasters. *Emerg Infect Dis* 2007; **13**: 1–5.

8 Munckhof WJ, Mayo MJ, Scott I, Currie BJ. Fatal human melioidosis acquired in a subtropical australian city. *Am J Trop Med Hyg* 2001; **65**: 325–8.

9 Baqir M, Sobani ZA, Bhamani A, *et al.* Infectious diseases in the aftermath of monsoon flooding in Pakistan. *Asian Pac J Trop Biomed* 2012; **2**: 76–9.

10 Srivastava A, Nagpal BN, Saxena R, *et al.* Malaria epidemicity of Mewat region, District Gurgaon, Haryana, India: A GIS-based study. *Curr Sci* 2004; **86**: 1297–303.

11 Brabant M. Six months after floods struck, malnutrition hits hard in affected areas of Pakistan. UNICEF. 2011. https://www.unicef.org/emergencies/pakistan\_57553.html.

12 Munro A, Kovats RS, Rubin GJ, *et al.* Effect of evacuation and displacement on the association between flooding and mental health outcomes: a cross-sectional analysis of UK survey data. *Lancet Planet Heal* 2017; **1**: e134–41.

13 Waite TD, Chaintarli K, Beck CR, *et al.* The English national cohort study of flooding and health: cross-sectional analysis of mental health outcomes at year one. *BMC Public Health* 2017; **17**: 129.

14 Morss RE, Mulder KJ, Lazo JK, Demuth JL. How do people perceive, understand, and anticipate responding to flash flood risks and warnings? Results from a public survey in Boulder, Colorado, USA. *J Hydrol* 2016; **541**: 649–64.

15 Lazo JK, Bostrom A, Morss RE, Demuth JL, Lazrus H. Factors Affecting Hurricane Evacuation Intentions. *Risk Anal* 2015; **35**: 1837–57.

16 Rufat S, Tate E, Burton CG, Maroof AS. Social vulnerability to floods: Review of case studies and implications for measurement. *Int J Disaster Risk Reduct* 2015; **14**: 470–86.

17 Pasetto D, Finger F, Rinaldo A, Bertuzzo E. Real-time projections of cholera outbreaks through data assimilation and rainfall forecasting. Adv. Water Resour. 2016; **0**: 1–12.

18 Yu W, Nakakita E, Jung K. Flood Forecast and Early Warning with High-Resolution Ensemble Rainfall from Numerical Weather Prediction Model. *Procedia Eng* 2016; **154**: 498–503.

19 Chen CF, Liu CM. The definition of urban stormwater tolerance threshold and its conceptual estimation: An example from Taiwan. *Nat Hazards* 2014; **73**: 173–90.

20 Finlay SE, Moffat A, Gazzard R, Baker D, Murray V. Health impacts of wildfires. *PLoS Curr* 2012; : 1–23.

21 Hänninen OO, Salonen RO, Koistinen K, Lanki T, Barregard L, Jantunen M. Population exposure to fine particles and estimated excess mortality in Finland from an East European wildfire episode. *J Expo Sci Environ Epidemiol* 2009; **19**: 414–22.

22 Shustermann D, Kaplan JZ, Canabarro C. Immediate Health-Effects of an Urban Wildfire. *West J Med* 1993; **158**: 133–8.

23 Morgan G, Sheppeard V, Khalaj B, *et al.* Effects of bushfire smoke on daily mortality and hospital admissions in Sydney, Australia. *Epidemiology* 2010; **21**: 47–55.

24 Pope III CA, Burnett RT, Thun MJ, Calle EE, Krewski D, Thurston GD. Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution. *J Am Med Assoc* 2002; **287**: 1132–41.

25 Katsouyanni K, Touloumi G, Spix C, *et al.* Short-term effects of ambient sulphur dioxide and particulate matter on mortality in 12 European cities: results from time series data from the APHEA project. Air Pollution and Health: a European Approach. *BMJ* 1997; **314**: 1658–63.

26 American Psychological Association. Recovering From Wildfires. 2011. http://www.apa.org/helpcenter/wildfire.aspx.

27 Wittig V, Williams S, DuTeaux SB. Public Health Impacts of Residential Wildfires: Analysis of Ash and Debris from the 2007 Southern California Fires. *Epidemiology* 2008; **19**: S207.

28 Goldman A, Eggen B, Golding B, Murray V. The health impacts of windstorms: A systematic literature review. *Public Health* 2014; **128**: 3–28.

29 Tan J, Zheng Y, Tang X, *et al.* The urban heat island and its impact on heat waves and human health in Shanghai. *Int J Biometeorol* 2010; **54**: 75–84.

30 Semenza JC, McCullough JE, Flanders WD, McGeehin MA, Lumpkin JR. Excess hospital admissions during the July 1995 heat wave in Chicago. *Am J Prev Med* 1999; **16**: 269–77.

31 Howe AS, Boden BP. Heat-related illness in athletes. *Am J Sports Med* 2007; **35**: 1384–95.

32 Beltran GW. Heat-related illness. *Emerg Med Serv Clin Pract Syst Overs Second Ed* 2015; **1**: 358–62.

33 R, Donoghue E, A, Graham M, M, Jentzen J, D, Lifschultz B, Luke JL. Criteria for the diagnosis of heat-related deaths: National Association of Medical Examiners. Position paper. National Association of Medical Examiners Ad Hoc Committee on the Definition of Heat-Related Fatalities. *Am J Forensic Med Pathol* 1997; **18**.

34 Leon LR, Bouchama A. Heat stroke. *Compr Physiol* 2015; **5**: 611–47.