Accelerating impact-based forecasting through the Weather and Climate Science for Service Partnership programme

What is impact-based forecasting?

Traditional weather forecasts give an indication of what the weather will be, for example 10 centimetres of rain in a 24-hour period in a given location. Impact-based forecasting (IbF), however, considers the vulnerability of people and property to the weather and warns of the associated impacts, such as loss of life and damaged buildings, as well as the likelihood of the impact occurring.

The main benefit of IbF compared to traditional weather forecasts is that it combines hazard forecasts like heavy rainfall, severe wind or temperature, with the elements that are exposed to the hazard such as buildings, transport routes and population distribution, and the vulnerability of individuals, properties or infrastructure. IbF enables an integrated, authoritative message to be delivered to all parts of society so that everyone can take appropriate action to ensure personal safety and protect property.

The World Meteorological Organization (WMO) recognises IbF as best practice[1] and is encouraging its member states to transition towards IbF as a high priority.

The Met Office, the UK's national meteorological service, has been pioneering these techniques for many years, and through the Weather and Climate Science for Service Partnership (WCSSP) programme is supporting the WMO's ambition by accelerating the implementation of IbF to benefit countries around the world.

This brochure provides an insight into each of the WCSSP projects and highlights their progress towards developing fully operational IbF systems.

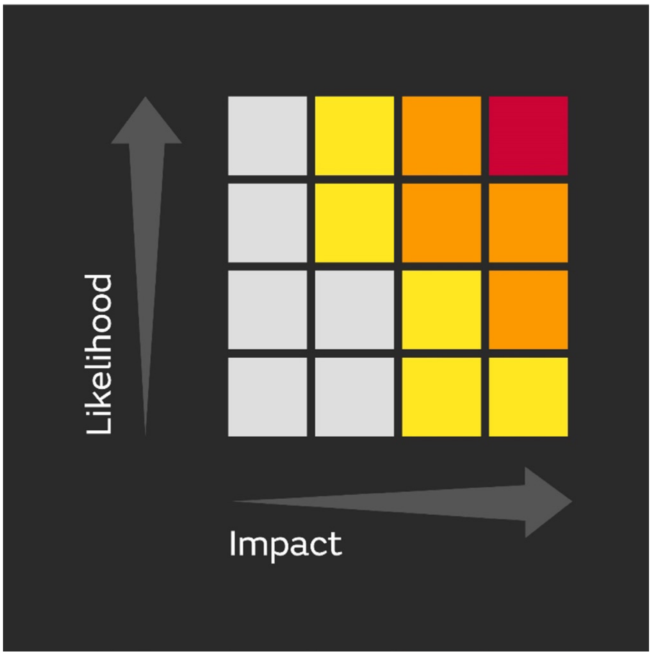
[1] **WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services**

How does impact-based forecasting work?

There are several key steps towards producing impact-based forecasts:

1. Identifying the main hazards such as rainfall, temperature or wind, and impacts such as loss of life, loss of power, damaged buildings, which may differ from region to region.
2. Understanding the needs of the organisations and communities who will receive and act on the warnings.
3. Having the means to forecast the hazard.
4. Calculating the risk by combining the hazard information with vulnerability and exposure data.
5. Communicating the warning to stakeholders and the public.
6. Verifying, validating and improving the warnings based on user feedback.

Impact-based forecasts frequently use a risk matrix to determine the warning level. National Meteorological and Hydrological Services (NMHSs), disaster managers and local communities work together to determine and agree the different warning levels on a case-by-case basis by using impact data from previous extreme weather events.



Example of an IbF risk matrix. Credit: Met Office.

In an IbF risk matrix, the warnings are colour coded depending on a combination of both the impact the weather may have and the likelihood of those impacts occurring.

In this example, a yellow warning is the lowest level and can be issued if it is likely the weather will cause some low level impacts or if the weather could bring much more severe impacts but the certainty of those impacts occurring is much lower.

An amber warning would be issued when there is an increased likelihood of impacts from severe weather which could potentially disrupt plans. There might be the possibility of travel delays, road and rail closures, power cuts and a potential risk to life and property. The advice for an amber warning would be to think about changing your plans and taking action to protect yourself and your property.

A red warning would be issued when dangerous weather is expected and there is very likely a risk to life with substantial disruption to travel, energy supplies and possibly widespread damage to property and infrastructure. The advice here is to avoid travelling where possible and that you should take action to keep yourself and others safe.

WCSSP South Africa

Southern Africa is severely impacted by extreme weather and climate events. In 2019, tropical cyclone Idai led to over 1000 deaths across Mozambique, Zimbabwe and Malawi, suggesting there are still improvements to be made in the production and delivery of early weather warnings. Extreme weather warnings can be difficult to communicate to the public due to the technical language used. Warnings are also not always translated into all official languages and there is a general lack of public awareness and understanding of weather-related impacts.

The WCSSP South Africa project has been working with the South African Weather Service (SAWS) to launch a new impact-based severe weather warning service in South Africa, which has already delivered significant benefits. By working closely with disaster managers and communities, the warning messages issued by SAWS have been specifically tailored towards the end user. Forecasters have received specific training to ensure non-scientific terminology is used when communicating forecasts and warnings. As a result, disaster managers can understand the warnings issued and take the necessary action ahead of the anticipated severe weather.

An important part of setting up the new service has been the hosting of outreach workshops to ensure the warnings reach the so-called 'final mile'. At these workshops, vulnerable communities are invited to attend and develop communication chains with the National Disaster Management Centre to ensure the warning messages reach their area and that appropriate actions can be taken.

Damage caused by cyclone Idai in Mozambique, 2019.
Credit: Denis Onyodi: IFRC/DRK/Climate Centre

Outreach workshop at East London, Eastern Cape, February 2019. Credit: Met Office

How has the new system performed?

The new system was tested on cases of extreme weather in 2019 before becoming fully operational in 2020. It successfully warned of the high likelihood of flash flooding in coastal areas of Kwazulu-Natal between 22-23 April 2019 and specifically the heightened risk and disruption on the roads. These timely warnings kept people off the roads and enabled disaster managers to evacuate people. Whilst there were still significant impacts from this event - at least 68 fatalities and estimated damages of more than R1 500 000 000 (approximately GB£65 million) – these would have been much higher without the new warning system.

Feedback from users of the new service has been positive. "We find impact-based forecasting to be much easier to interpret than the old warnings," commented the National Disaster Management Centre in South Africa.

Another disaster manager in the Joe Gqabi District in the Eastern Cape said "IbF has significantly improved relationships, especially between emergency response agencies and stakeholders. Disaster Risk Management issues warnings in advance to stakeholders and this enables them to plan their activities especially when there are sensitivities at a particular time. Relations are now good as there is one source of information on weather related matters for the stakeholders to plan, take action and coordinate their activities."

All of the knowledge and lessons learned through the implementation of the new service will be shared through workshops to benefit other developing countries across Southern Africa, supporting the WMO's ambition of a global rollout of IbF.

WCSSP Southeast Asia

The damage and loss of life caused by severe weather in Southeast Asia is a significant barrier to the continued economic development and welfare of the countries in the region. Consultation with our Southeast Asia partners shows there is a clear need for:

1. Improved forecasting of high impact weather;
2. Improved interpretation of those forecasts; and
3. Delivery of better advice and guidance from forecasters to disaster managers and vulnerable communities.

Typhoon Haiyan, known as Super Typhoon Yolanda in the Philippines was one of the most intense tropical cyclones on record. Credit: Ymphotos, Shutterstock.

One of the main aims of WCSSP Southeast Asia is to develop the capacity of institutions in Southeast Asia to issue timely, accurate warnings of high impact weather. This will help promote sustainable economic development, improved social welfare and poverty alleviation in the region.

Despite forecasters in Malaysia, the Philippines, Vietnam and Indonesia following protocol, high impact weather in the countries has often resulted in loss of life and property. After Typhoon Mangkhut in September 2018, the chief forecaster at the National Meteorological Service in the Philippines, noted that they followed all the correct procedures, used guidance from the models and issued warnings as early as they could. Despite this, some of the public did not react to the warnings.

The National Disaster Risk Reduction and Management Council (NDRRMC) reported a total of 82 deaths, 138 injured and two missing in Regions I, II, III, VI, Cordillera Administrative Region (CAR) and the National Capital Region (NCR). Most of the casualties were attributed to landslide incidences caused by prolonged heavy rain, highlighting the need for improved forecasting of high intensity rainfall, and for warnings that clearly highlight potential impacts to communities. Developing the impact-based forecasting approach should enable mitigating action to be taken if similar events were to happen again.

Through WCSSP Southeast Asia, experiences from the successful implementation of an IbF system in the UK are being shared with forecasters across Southeast Asia. One of the main project outputs will be a handbook for forecasters which will draw together best practice from the project's activities and training. Each country is working on their own tailored version to represent the main weather hazards and priorities for that country.

Project activities include:

- Encouraging the use of ensemble forecasting, this means instead of running a single forecast a computer model is run several times. This allows a greater understanding of forecast uncertainty and therefore can be communicated more effectively to decision makers.
- Encouraging the use of computer models which have higher resolution and are better at capturing the process of convection, which is responsible for many of the extreme weather events in Southeast Asia.
- Gathering data on the impacts of extreme weather across Southeast Asia from sources including the government and media. The database will be used to understand what impacts occur from different events, helping to inform the appropriate warning levels that need to be issued to society.
- Analysing the decision-making process that forecasters go through to issue high impact weather forecasts and understanding how both forecasters and users interpret the warnings. This will ensure that users understand what the forecasters mean when warnings are issued.

Delivering training workshops

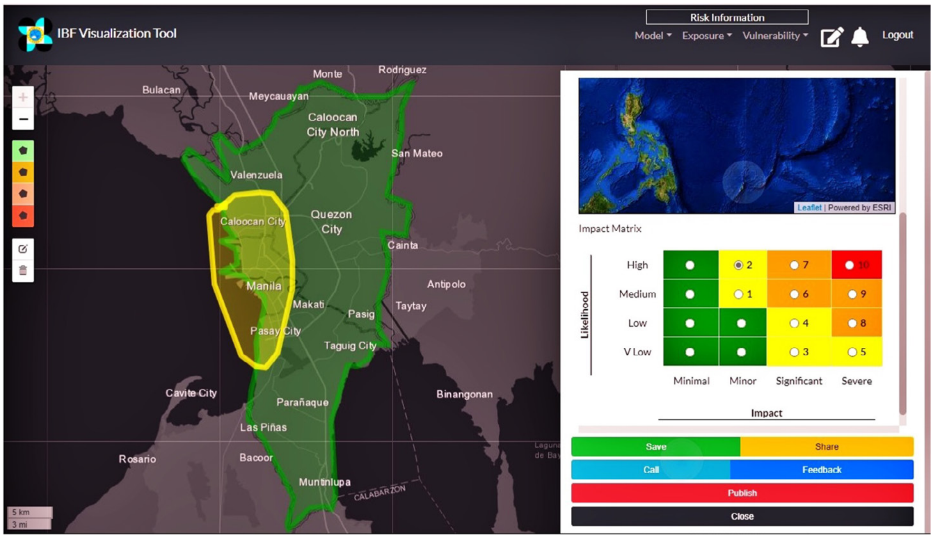
The delivery of training workshops and seminars to scientists and forecasters in Southeast Asia has been a key part of the project. The Weather Testbed was a recent workshop set up between project partners with the aim of encouraging and facilitating collaboration between research and operations to test new science and model changes. A variety of model output was evaluated daily using the latest science configurations developed by the Met Office. This new area of collaboration allowed the project to test the performance of the convective scale models, techniques, and the visualisation of product output. The workshop allowed scientists to explore the level of guidance the model is able to provide, especially when focused on hazardous and high impact weather and the related warnings. Feedback from the workshop participants then allows the model developers to make further improvements.

Find out more > **infographic**

Development of visualisation tools

The project is developing tools and visualisations to aid forecasters. One called FOREST allows forecasters to visualise the forecast output together with real-time observations.

The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), who are responsible for issuing weather forecasts in the Philippines, have been piloting a web-based visualisation tool for Metro Manila. This colour-coded map enables disaster managers and the public to visualise the specific areas that are affected by yellow, amber or red warnings.



IbF visualisation tool. Credit: PAGASA

Case study: Typhoon Ulysses, Manila, Philippines, November 2020

With support from WCSSP Southeast Asia there have been pilot runs of IbF during recent periods of high impact weather. In November 2020, PAGASA released two warnings for typhoon Vamco (known in the Philippines as typhoon Ulysses) for Metro Manila – an amber warning for heavy rainfall and amber for severe wind.

Warnings included a list of expected impacts for a range of different sectors including power, water supply, communications, and infrastructure. Through good communication between PAGASA and city stakeholders, two pre-disaster risk assessment meetings were held before the expected landfall of the typhoon, which triggered an early response across Metro Manila. Based on the Situational Report No. 29 from the National Disaster Risk Reduction and Management Council (NDRRMC), over 123 emergency alert and warning messages were sent to the public via mobile phones and social media. School classes were suspended, police officers were notified their assistance would be needed and vehicles were on standby for transporting medical supplies and food[2].

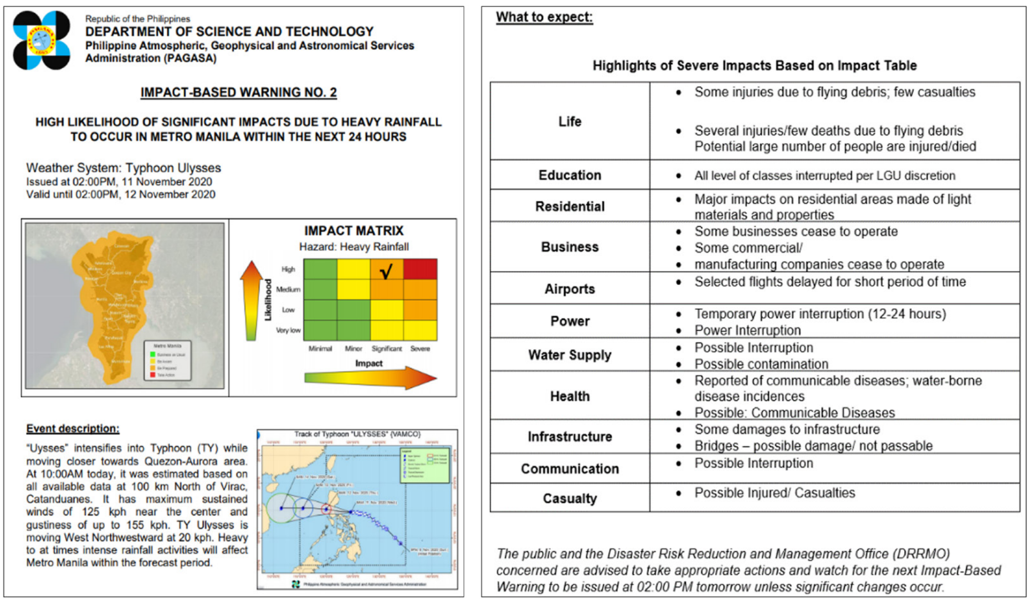
Bryan Españo, of the Makati City Disaster Risk and Reduction Management Office, commented "At the time the IbF system showed amber warnings for heavy rainfall, we acted swiftly. We coordinated the public officials to reposition their assets over the flood-prone areas of the city and warned the community living near the water channels of possible overflowing".

After the warnings were issued disaster managers in Metro Manila were asked to validate the accuracy of the warnings based on the impacts that occurred on the ground. Disaster Managers in Quezon City, Malabon City and Makati City confirmed that most of the forecast impacts did materialise, especially the ones described in the severe wind warning.

Most stakeholders in Metro Manila who were involved in the pilot provided positive feedback on how the IbF system worked during typhoon Ulysses. Bryan Españo said "Overall, the IbF helped us to lessen the impacts of the severe weather. We prefer IbF because it is easy to understand, unlike the traditional forecast system which sometimes has terminologies that can be too difficult to interpret by the public."

Despite this good progress challenges do remain, such as translating the warnings into all local languages and adopting this approach more widely across the country. Therefore more pilots will be needed to improve and fine tune the process before it's rolled out operationally across the Philippines.

Flooding in Makati City due to heavy rainfall from Typhoon Ulysses. Credit: Makati City



Republic of the Philippines
DEPARTMENT OF SCIENCE AND TECHNOLOGY
Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)

IMPACT-BASED WARNING NO. 2

HIGH LIKELIHOOD OF SIGNIFICANT IMPACTS DUE TO HEAVY RAINFALL TO OCCUR IN METRO MANILA WITHIN THE NEXT 24 HOURS

Weather System: Typhoon Ulysses
Issued at 02:00PM, 11 November 2020
Valid until 02:00PM, 12 November 2020

Event description:

"Uysses" intensifies into Typhoon (TY) while moving closer towards Quezon-Aurora area. At 10:00AM today, it was estimated based on all available data at 100 km North of Virac, Catanduanes. It has maximum sustained winds of 125 kph near the center and gustiness of up to 155 kph. TY Ulysses is moving West Northwestward at 20 kph. Heavy to at times intense rainfall activities will affect Metro Manila within the forecast period.

What to expect:

Highlights of Severe Impacts Based on Impact Table

Life	• Some injuries due to flying debris; few casualties • Several injuries/few deaths due to flying debris Potential large number of people are injured/died
Education	• All level of classes interrupted per LGU discretion
Residential	• Major impacts on residential areas made of light materials and properties
Business	• Some businesses cease to operate • Some commercial/ • manufacturing companies cease to operate
Airports	• Selected flights delayed for short period of time
Power	• Temporary power interruption (12-24 hours) • Power Interruption
Water Supply	• Possible Interruption • Possible contamination
Health	• Reported of communicable diseases; water-borne disease incidences • Possible: Communicable Diseases
Infrastructure	• Some damages to infrastructure • Bridges – possible damage/ not passable
Communication	• Possible Interruption
Casualty	• Possible Injured/ Casualties

The public and the Disaster Risk Reduction and Management Office (DRRMO) concerned are advised to take appropriate actions and watch for the next Impact-Based Warning to be issued at 02:00 PM tomorrow unless significant changes occur.

Impact-Based Warning No. 2 for heavy rainfall issued by PAGASA, a day before Typhoon Ulysses affected Metro Manila. Credit: PAGASA

[2] http://ndrrmc.gov.ph/attachments/article/4138/SitRep_no_29_re_TY_Ulysses_as_of_13JAN2021.pdf

WCSSP India

WCSSP India is a research project building and harnessing strong, sustainable science and innovation partnerships between the UK and India. It is a collaborative initiative between the Met Office – supported by the UK Government's Newton Fund - and the Indian Ministry of Earth Sciences (MoES). A core activity of WCSSP India is to collaboratively develop the underpinning science for impact-based forecasting tools which can support the Indian Meteorological Department (IMD) as they transition towards operational IbF.

In 2019 an impact-based forecasting workshop was held at the Indian Institute of Tropical Meteorology, Pune, bringing together researchers and operational meteorologists to discuss the challenges associated with impact-based forecasting. Based on this workshop a set of priority areas were identified: research and development of impact models; socio-economic impact data collection; and communication and dissemination of warnings.

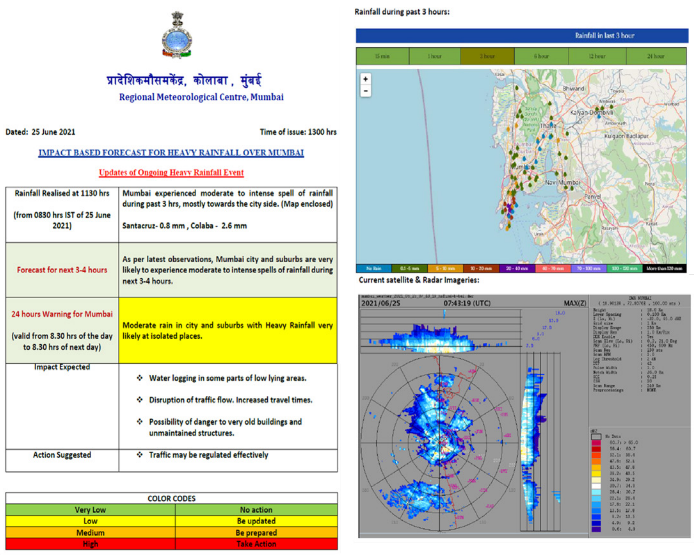
As part of the work, WCSSP India has identified a set of weather patterns which represent all the main phases of the Indian climate throughout the year, such as the active or retreating monsoon phases. These are being used to develop forecasting prototypes for different hazards such as heatwaves, heavy rainfall, and landslides. This project has shown that many of these weather patterns have good forecast skill at least 15 days ahead.

The capability has been packaged into a tool and shared with partners to help provide forecasters with an earlier indication of potentially impactful events. Workshops with landslide experts and disaster management authority representatives are helping to inform the usefulness of the weather pattern landslide forecasting application and ways it can be further enhanced. This application is being used to issue landslide bulletins during the monsoon season to provide communities with more time to act and reduce the impacts of such events.

Other activities include:

- Delivering workshops, webinars and training on existing IbF methods and their applicability for different users and/or sectors. As well as providing information on methods to enhance forecasts and warnings to increase preparedness before potentially impactful events.
- Gathering data on the impacts of hydro-meteorological events across India from a variety of sources including Government, private sector and social and traditional media. This database will be used to understand what impacts occur from different types of extreme weather, helping to inform the appropriate warning levels to be =issued to society.
- Developing the basis of a real-time forecasting system for flood hazard and impacts, building on the knowledge already in place in India and utilising best practice from the successful Surface Water Flooding Hazard Impact Model which is operational in the UK. The Flood Hazard Impact Model for India is being developed for use by forecasters to provide guidance on upcoming flood events and their associated impacts which will support impact-based warning issuance.
- Using earth observation data from satellites to identify the impact of flooding on crops, buildings and infrastructure across India. This data will be used to improve the computer models that produce flood-related impact-based forecasts and evaluate the effectiveness of impact-based warnings.
- Comparing impact-based forecasting methods to understand the value of different approaches for different user needs and demonstrate which methods might be most favourable.

Extreme rainfall led to flooding iin Dhemaji, September 2020. Credit: India Red Cross Society.



प्रादेशिकमौसमकेंद्र, कोलाबा , मुंबई
Regional Meteorological Centre, Mumbai

Dated: 25 June 2021 Time of issue: 1300 hrs

IMPACT BASED FORECAST FOR HEAVY RAINFALL OVER MUMBAI

Updates of Ongoing Heavy Rainfall Event

Rainfall Realised at 1130 hrs (from 0830 hrs IST of 25 June 2021)	Mumbai experienced moderate to intense spell of rainfall during past 3 hrs, mostly towards the city side. (Map enclosed) Santacruz- 0.8 mm , Colaba - 2.6 mm
Forecast for next 3-4 hours	As per latest observations, Mumbai city and suburbs are very likely to experience moderate to intense spells of rainfall during next 3-4 hours.
24 hours Warning for Mumbai (valid from 8.30 hrs of the day to 8.30 hrs of next day)	Moderate rain in city and suburbs with Heavy Rainfall very likely at isolated places.
Impact Expected	❖ Water logging in some parts of low lying areas. ❖ Disruption of traffic flow. Increased travel times. ❖ Possibility of danger to very old buildings and unmaintained structures.
Action Suggested	❖ Traffic may be regulated effectively

COLOR CODES	
Very Low	No action
Low	Be updated
Medium	Be prepared
High	Take Action

An example of IbF operational at India Meteorological Department for the city of Mumbai. The bulletin provides warnings in terms of water logging, traffic flow and danger to old buildings due to heavy rain. Credit: Regional Meteorological Centre, Mumbai.

Supporting the Sustainable Development Goals

The implementation of impact-based forecasting through the WCSSP programme is closely aligned to the aims and ambitions of the UN's Sustainable Development Goals, particularly goal 1 (no poverty), goal 11 (sustainable cities and communities) goal 13 (climate action) and goal 17 (partnerships for the goals).

About the WCSSP Programme

Under the Newton Fund the **Weather and Climate Science for Service Partnership (WCSSP) programme** is developing a global network of partnerships that help build weather and climate science and innovation capacity to support long term sustainable growth, economic development and social welfare.

The Newton Fund is a consortium of outstanding research and innovation partnerships between the UK and select countries in Africa, Asia and Latin America to support economic development and social welfare, tackle global challenges and develop talent and careers. The fund is managed by the UK's Department for Business, Energy and Industrial Strategy, and delivered by UK and international partners.

For additional information visit **www.newton-gcrf.org** and follow via Twitter: @NewtonFund