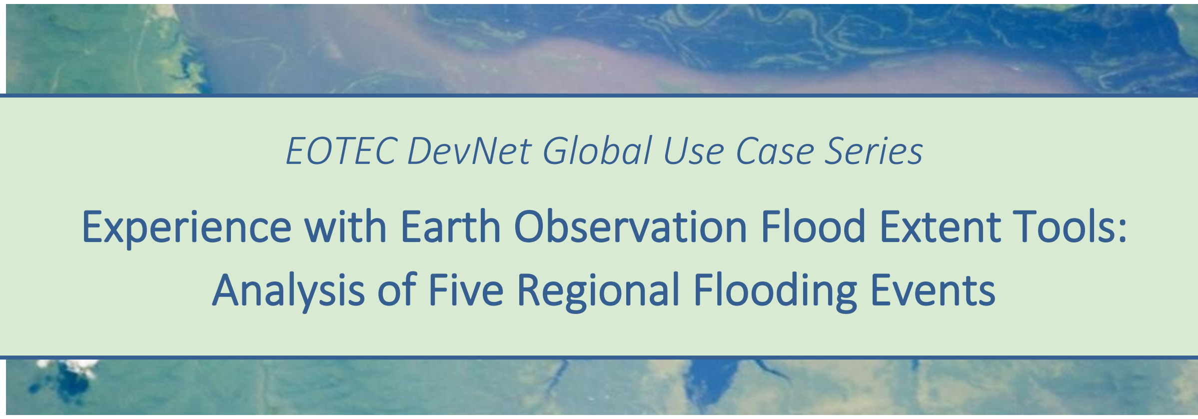

EOTEC DevNet Global Use Case Series

Experience with Earth Observation Flood Extent Tools: Analysis of Five Regional Flooding Events

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See the Annex for a list of regional event analysis writers.

Background

Drawing on five analyses of regional flooding events, this document provides insight on the use of flood extent tools before, during, and after a crisis. Its purpose is to support flood managers and responders in understanding the use of tools and datasets in various circumstances, with attention to Earth observation-related (EO) tools, particularly.

Members of EOTEC DevNet's four regional flood working groups analyzed these five events:

- Central America: Hurricane-related (Eta and Iota) flooding, 2020
- Chamoli district of Uttarakhand, India: Rockfall-triggered flood, 2021
- Ebro River Basin, Spain: Heavy rainfall and snowmelt-triggered flooding, 2021
- Malawi: Cyclone-related flooding (Ana and Gombe), 2022
- Maluku Province (Ambon Island), Indonesia: Heavy rainfall-triggered flooding, 2022

Among the cross-cutting insights in these analyses is the acknowledgement that EO tools contribute data and analysis of that data at every stage of flood management. When the agencies collaborate well and information is properly integrated into meteorological and hydrological models, the results are useful for more timely early warning and more effective disaster management, response, and recovery – all of which save lives and mitigate socioeconomic impacts. Knowledge of EO for disaster risk reduction, however, varies among flood risk managers and professionals, particularly in developing countries. Although EO technologies cannot fulfill every disaster management data need, they can be invaluable in helping meet the challenges. To accelerate their use, we need the involvement and commitment of all to empower capacity building towards multidisciplinary coordination - before a crisis strikes.

[1] EOTEC DevNet is the Earth Observation Training and Capacity Building Network. The network includes communities of practice for Africa, the Americas, Asia-Oceania, and Europe.

Key take-aways from the regional event analyses

Across the five analyses, EO data was a critical link, providing a consistent flow of information before, during and after flooding events.

- Remote sensing and EO data provided a good opportunity for near real-time disaster monitoring.
- The application of EO, in combination with effective local governance, can reduce the risk of disasters as well as the costs of recovery.
- The availability of hydrometeorological data, early warning systems, and online repositories are absolutely necessary to increase resilience.
- EO techniques are quite important for remote areas. The Chamoli, India case, in which flooding caused by a massive rockslide disrupted transportation routes in a high mountain area, reinforces this point. Pre and post event satellite images for damage assessment and for determining changes in river morphology were very useful in providing relief.
- Global response mechanisms contribute significantly to flood response through rapid mapping and other services. Examples from the analyses are found in the Chamoli, India, analysis where the International Charter on Space and Major Disasters contributed to the humanitarian response, and in the Ebro Basin analysis, where the Copernicus Emergency Management Service helped map the extent of flooding.
- EO techniques for flood inundation analysis were mainly used in post-event analysis.
- Overall, satellite imagery is a good resource for the past and future analysis of events including floods.
- There is a need for awareness-raising among decision-makers and capacity building for technical staff to carry out detailed investigation of selected regions prone to flood hazards.

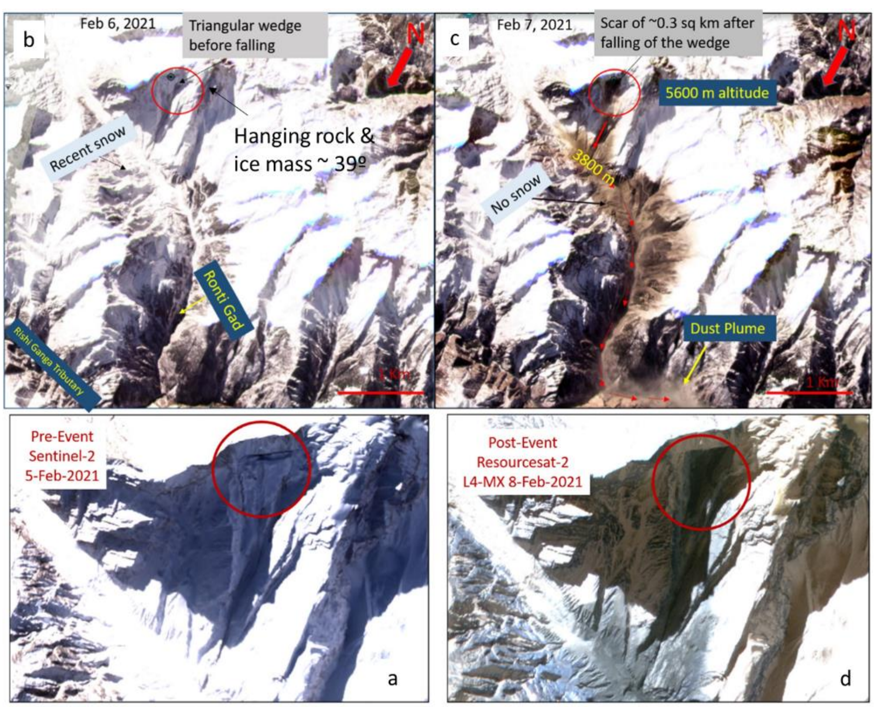


Figure 1: Time series satellite images showing before during and after the 2021 rockslide-triggered flooding event at Chamoli, India.

The analyses highlight the importance of efficient coordination and communication between public administration and civil protection authorities, as well as with researchers and international agencies.

- Governance is a key part of successful disaster management.
    - Collaboration is required at many levels, for example, between local and international agencies as well as among local, regional, and national decision-makers.
    - The Central America case highlighted the importance of the integration of several institutions at various levels - including both international and local agencies - working and promoting synergies to solve a common problem. An existing memorandum of understanding (MOU) between local responders and international agencies led to a prompt response.
    - The Chamoli, India event, which happened outside of monsoon season, highlighted the unexpected nature of events and the need for a coordinated response.
- Early action substantially contributes to disaster risk reduction. The Malawi case demonstrated how early warning can avert loss of life.
- The analyses that most clearly identified the contribution of EO data and tools were those in which partners had long-term EO know-how and experience.

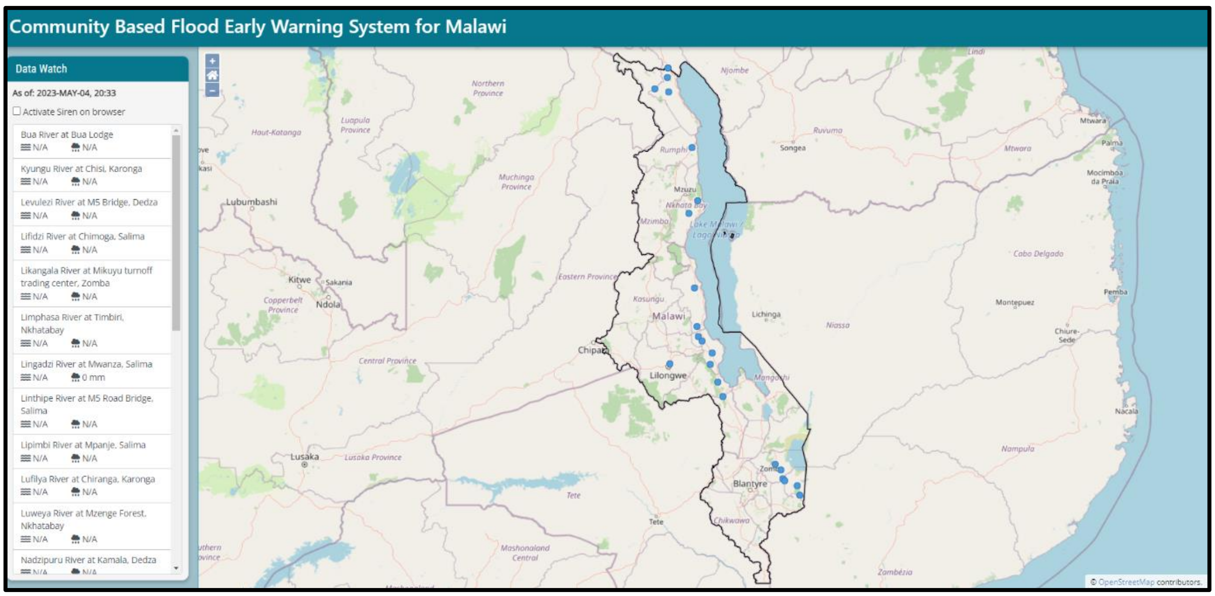
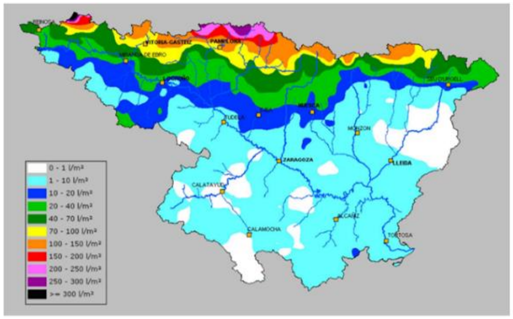


Figure 2: Malawi's Community Based Flood Early Warning Dashboard.

The analyses illustrated the importance of strong public engagement and clear communications.

- The Malawi case demonstrated the quantifiable value of an early warning system that can effectively reach the population at risk. Compared to prior events which resulted in flood-related fatalities, no life was lost in regions that received early warning.
- Transparency and a consistent, steady flow of information are critical when communicating with the public.

- Social media was referenced in three cases. In the Chamoli case, the reference was negative, because social media was a source of rumors and inaccurate information. In the Spain and Indonesia cases, social media were effectively used to disseminate early warning.



Cuenca vertiente a estación de aforo	Precipitación Prevista Harmonie (l/m²)	Precipitación Prevista WRF (l/m²)	Precipitación Observada (l/m²)
A092 Nela-Trespaderne	63	78	98
A074 Zadorra-Arce	74	58	68
A001 Ebro-Miranda	28	38	40
A071 Ega-Estella	90	75	75
A313 Arga-Burlada	135	100	160
A069 Arga-Echauri	120	90	130
A065 Irati-Liédena	110	88	135
A005 Aragón-Caparroso	77	70	99
A002 Ebro-Castejón	48	47	56
A011 Ebro-Zaragoza	32	32	38

Figure 3: Ebro River Basin, Spain, measured and predicted precipitation (8 – 12 December 2021).

Other data-related insights.

- Across the five analyses, the GEOGloWS ECMWF Streamflow Hydroviewer was used the most. Other tools used included the Copernicus Rapid Mapping service tool, European Flood Awareness System, and Hydrologic Remote Sensing Analysis for Floods (HYDRAFloods).
- Satellite and radar-based precipitation forecasts were important for flood modeling across the analyses. Hydroviewer, for example, referenced in the Malawi and Central America cases, uses an ensemble of rainfall forecasts, combined with hydrological modeling, to determine which river reaches are most likely to flood based on decades of historic data. In the Ebro River case, the precipitation forecast was provided by the HARMONIE model of the Spain's Meteorological Agency and WRF of the University of León. It contributed to hydrologic models and, eventually, public warnings.
- Forecasting of hydrological and meteorological variables provided valuable perspectives on preparation for future events.
- In some cases, different tools were used before the event and after the event. For example:
    - In Central America, pre and during the event, the forecast was done using rainfall forecast combined with hydrological modeling. After the event, SAR and optical imagery were used to map flood extent.
    - Similarly, in Malawi, measurements of flow levels using telemetric water level monitoring sensors complemented the streamwise

How EO Data Informed Decisions in Chamoli

In February 2021, a massive rockslide triggered a catastrophic flood in the Chamoli district of Uttarakhand, India, causing some 200 deaths and destroying a hydroelectric project, a highway, and five bridges. Initially, the event was thought to be a glacial lake outburst flood. Multi-temporal satellite images played a critical role in visualizing and deciphering what actually happened. These inputs were critical to agencies providing response, rescue, and relief work on ground. The analysis supported these questions:

- Was the event a glacial lake outburst flood (GLOF)?
- What was the volume of material dislodged?
- What was the precise location of wedge failure?
- What was the slope and elevation of the area?
- Was the valley prone to such events in the past?
- Was the event triggered due to any seismic activity?
- What was the spread, flow depth and flow velocity?
- Was there any cascading event triggered due to the main event?
- What were the changes in valley and river morphology due to the event?
- What major hydropower projects/infrastructure was damaged?
- What was the chronology of the events?

forecast service. Warnings through sirens were triggered when water levels exceeded predefined thresholds.

- The Sentinel-1 satellite provided useful data in more than one of the cases. In the future, however, it would be beneficial to expand usage to include products that have higher temporal refresh rates. (Sentinel-1 has limited repeat cycles.)
- Online repositories for disaster awareness are a steppingstone to a better understanding of events as they happen.
- The availability of data post-disaster provides means for evaluation and recovery to prepare for future events.
- Standardization of methodologies is needed. For now, standardization based on EO techniques is covered in some way through services provided by institutions such as Copernicus Emergency Management Service, NASA Disasters program, or NASA Jet Propulsion Laboratory.
- Nevertheless, a bigger challenge is to localize risk management across a disaster's lifecycle through scenario planning, recovery planning (utilizing local hydrometeorological data), early warning systems, existing and needed human and technology capacities, and the integrity of governance. Capacity development or extended capacities for using EO not only enhances resilience to climate change but also many other areas supporting systemic risk management.
- In general, disaster management agencies are sometimes dependent on partnerships with others to access EO data and derived information. The good thing is that lives and property were saved; the drawback is that the disaster management community is not able to manage the complex analysis on its own.

Continued capacity building must be a major priority.

- Capacity building plays a major role in training individuals in the various areas of disaster management. There is a particular need for capacity

Figure 4: Flood and landslide-affected areas in Ambon, 08 July 2022, courtesy of Indonesia Agency for Meteorology Climatology and Geophysics (BMKG)

building on managing risk systematically throughout the disaster management cycle. In particular:
  - Local-level technical and human capacity building is very important. Even with good collaboration with international agencies, national and local services dealing with floods should be reinforced technically and be autonomous in urgent management situations.
  - Training in EO data access and related flood analysis is needed. A website with manuals in multiple languages on hydrological models would be useful. It should indicate which data/products are required as inputs and where they can be found.
  - Simulated flood scenarios, with the participation of EO and disaster management specialists, would be helpful.
- For flood forecasting, in-depth capacity building on hydrological models is required, with continuous follow-up to deepen skills.
- Along with flood managers, communities must be beneficiaries of training, hands-on activities such as simulations, and other engagement.
- Capacity building and development on flood risk management should be constantly strengthened by taking into account the possibilities offered by EO and new technologies.
- As current geographical EO satellite data cover and lack of high-resolution images are challenges in certain areas, especially mountainous areas or small islands, training on complementary techniques is needed. (Unmanned Aerial Systems are an example.)
- Resilience to climate change does not only require EO capacity development but also for many other areas related to comprehending systemic risk.

Data and analysis are critical to effective and efficient disaster management decisions.

- The availability of accurate information at the right time and right place is key for the right decision-making. This was noted across case studies both before and during flood events.
- Reliable, easily interpreted information - through online geospatial portals, rapid and risk and recovery mapping, weather forecasts, or other sources - was key to helping decision-makers.
- Early warning systems can inform decisions that will reduce fatalities and economic losses. In Malawi, for instance, cyclone-related financial losses were estimated to be 40% less due to the existence of a reliable warning system.
- To avoid the spread of inaccurate information, it is important to be transparent and communicate with the public actively and clearly.

Figure 5: Maps capturing flooding in San Pedro Sula Airport in Honduras are examples of products created by the NASA Disaster Program support responders in Central America during

ANNEX: Regional Event Analysis Contributors

Central America: Hurricane-related (Eta and Iota) flooding, 2020

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Ebro River Basin, Spain: Heavy rainfall and snowmelt-triggered flooding, 2021

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Malawi: Cyclone-related flooding (Ana and Gombe), 2022

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Ambon Island, Maluku Province, Indonesia: Heavy rainfall-triggered flooding, 2022

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