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Flash Floods

A 2022 victim of flash flooding caused by monsoon rains in India and Bangladesh attempts to save a few of his belongings.

Credit: Nayeemibnmatiur
https://commons.wikimedia.org/w/index.php?curid=147760902

There are many kinds of floods.

River floods develop slowly, water gradually rising over days, providing ample time to evacuate.

Coastal floods come mostly from storm surges, when a hurricane or tsunami makes landfall. Coastal communities also have evacuation warnings. But when not, these can be catastrophic.

Urban flooding happens increasingly as paved areas expand, preventing the land from absorbing rainfall. Flash floods, though often localized, can be the deadliest for their size, simply because they are sudden. They occur when torrential rain falls, snow rapidly melts, or water is forced down a river.

They can send a wall of water tens of feet high hurtling down a channel, faster than people can seek safety. They can sweep away vehicles and roads, making escape impossible. They can carry debris and chemicals, leaving long-lasting devastation in their path.

Despite a few fatal incidents, authorities are improving their ability to predict and react. AI analysis of massive weather data now provides longer lead times for flash floods, especially in the Southwest U.S., Latin America, and Asia.

Meanwhile, smarter urban planning and development include runoff zones to capture floodwaters, and innovative warning systems that alert and prepare the populace.

In the rare case you receive an alert, move quickly to high ground and stay safe.

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Background: Flash Floods

Synopsis: Flash floods are a major natural disaster across the globe and are often devasting, with loss of life and property. New technology is aiding the prediction of these brutal events and may help save live.

- Flash floods are defined as rapid flooding that develops within six hours of heavy rainfall or other triggers such as dam breaks, ice jams, or rapid snowmelt. They are characterized by fast-moving water, often carrying debris.
- Flash floods are very dangerous as they often occur with little to no warning; they can sweep away vehicles, destroy homes and businesses, and cause loss of life.
  - Compared to regular river flooding, flash floods are stronger and more destructive in a short period.
  - River floods typically develop slowly over days or weeks, giving time for evacuation and precautionary measures whereas flash floods are sudden and often catch people off guard.
  - Coastal floods are caused by storm surges, hurricanes, and tsunamis while flash floods typically happen inland and are linked to rainfall and terrain.
  - Urban floods can result from poor drainage and heavy rain but may not involve strong currents compared to the fast-moving and destructive water flow of flash floods.
- Flash floods occur due to a combination of factors.
  - Heavy rainfall from intense thunderstorms or prolonged rainfall saturates the ground, preventing water absorption.
  - Urbanization often results in vast expanses of impermeable surfaces. Cities with asphalt and concrete prevent water absorption, leading to rapid runoff. Drainage systems may become overwhelmed and not be able to direct runoff.
  - Topography plays a significant role in flash floods, with mountainous regions and valleys channeling water rapidly, increasing flood intensity. This is often seen in places like the Appalachian Mountains or slot canyons in the American West.

An estimated 2,200 lives were lost from a flash flood in Johnstown, Pennsylvania in 1889. The South Fork Fishing and Hunting Club, an exclusive and private mountain retreat that included members of wealthy steel, coal and railroad industrialists, had lowered the height of the state-constructed dam on the Conemaugh River to make its top wide enough for a carriage road. Heavy rain caused the dam to be breached and the entire 14.5 million cubic meters (3.8 billion gallons) of water emptied from the reservoir in about an hour's time, all rushing downriver to Johnstown.

Credit: https://web.archive.org/web/20161011084625/http://www.panoramio.com/photo/1931258, Public Domain, https://commons.wikimedia.org/w/index.php?curid=37940074

  - Flash floods could also occur due to sudden releases of water from breached dams or melting ice formations. This was the case in the historic Johnstown Flood (1889), which killed 2,200 people, and the more recent Derna Dam collapse in Libya (2023), with estimates of 5,900 to 20,000 lives lost.
- Flash floods occur across the globe, but some regions are more vulnerable.
  - In the United States, the Southwest and Appalachians are vulnerable due to terrain and storms.
  - Monsoon-driven flash floods occur in India, Bangladesh, and Nepal.

References: Flash Floods

Severe Weather 101 Flooding | National Severe Storms Laboratory, NOAA.gov
Why Flash Floods Are So Dangerous | How Stuff Works.com
Guide to Flood Forecasting | Institute of Electrical and Electronics Engineers
Technology in Action: Urban Flash Flood Warning | Topos Magazine
A Critical Review of Emerging Technologies for Flash Flood Prediction | Water, Volume 16, Issue 14

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Episode **ED 466**

Contributors: Lynn Kistler, Harry Lynch

Background: Flash Floods

- Europe has experienced severe floods in Germany (2021) and Italy (2023).
- In Africa, seasonal floods are worsened due to deforestation and poor drainage.
- Dry regions such as Saudi Arabia and the UAE have experienced deadly flash floods due to sudden storms.

- No matter where they occur, flash floods often have devastating effects.
  - Injuries and loss of life often result due to the sudden onset of the flooding. Typically, there is little warning, people are unprepared and get swept up in the flood water or trapped in vehicles in floodwaters.
  - Infrastructure such as roads, bridges, and buildings are washed away, necessitating costly repairs and causing economic disruption.
  - Soil erosion and the possible destruction of ecosystems often occur in flooded regions.
  - Oftentimes debris and chemicals end up in the fast-moving water, causing pollution.
  - Economically, businesses may close and farmers suffer agricultural losses.
  - Millions are often spent on insurance claims and through government disaster aid efforts.
- With this amount of devastation, can we predict where and when flooding will occur?
  - After o the catastrophic Great Mississippi Flood of 1927, the U.S. government began developing standardized methods to estimate flood probabilities.
  - The Flood Control Act of 1936 directed the U.S. Army Corps of Engineers to conduct floodplain studies and implement flood control measures.
  - This work led to the concept of 100-year and 1,000-year floods, a method based on probability and historical records to estimate flood frequencies. The USGS and the National Flood Insurance Program adopted the 100-year flood standard to determine flood risk zones and insurance rates.

Flash floods very often cause extensive and expensive damage to infrastructure such as roads and bridges. This is damage from a flash flood to a roadway located in Fort Payne, Alabama in 2022. Storms brought 15-20 inches (38-51 cm) to southeast Alabama, causing widespread destruction.

Credit: United States Congress, Office of Robert Aderholt https://twitter.com/Robert_Aderholt/status/1249709924940165122, Public Domain, https://commons.wikimedia.org/w/index.php?curid=92399309

  - These classifications are still widely used in zoning laws, building regulations, and insurance policies. However, changes in precipitation patterns and extensive urbanization have made these models less reliable, as extreme floods are occurring more frequently than past data predicted.
- Fortunately, technology is providing valuable tools and information to reassess flood models and predictions and assist in planning for proper emergency response.
  - Through advanced weather forecasting and modeling, meteorologists are able to use high-resolution satellite imagery, Doppler radar, and computer models to track storm systems.

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- NASA's Global Precipitation Measurement Mission provides real-time precipitation data worldwide and helps identify areas at risk of flash flooding.
- The European Centre for Medium-Range Weather Forecasts uses AI and machine learning to refine flood predictions and offers early warnings to countries prone to extreme rainfall.

- Flood early-warning systems use networks of rain gauges, river sensors, and hydrological models to help detect rising water levels, primarily for river flooding.
  - The Global Flash Flood Guidance System, used in over 60 countries including India, South Africa, and Brazil, helps meteorologists provide timely warnings to local communities.

Credit: StickyChannel92
https://commons.wikimedia.org/wiki/File:When_Flooded_Turn_Around,_Don%27t_Drown_Sign_USA.png

  - The U.S. National Weather Service Advanced Hydrologic Prediction Service uses river gauge data to issue flood alerts.
- Artificial Intelligence (AI) and Machine Learning are becoming extremely useful tools that can analyze vast amounts of weather data to detect patterns that may indicate an impending flash flood.

One cause of death from flash floods is people attempting to drive across flooded roads and bridges and they get swept away by the rising and swift waters.

Credit: Marvin Nauman Public Domain
https://commons.wikimedia.org/w/index.php?curid=8070666

  - Google's AI-Based Flood Forecasting was launched in India and Bangladesh, where monsoon floods are common. The technology uses historical flood data along with real-time satellite imagery to send alerts via Google Search and Maps.
  - IBM's Watson Decision Platform for Disaster Management uses AI to analyze weather, terrain, and hydrological data with the goal of helping emergency responders anticipate the severity of flash floods.
- For cities, including smart infrastructure and flood-resistant urban planning also reduces risk. Absorbing rainwater and preventing runoff can be accomplished by using permeable concrete and green spaces.
  - Rotterdam in the Netherlands uses "Water Squares" that temporarily store excess rainwater, preventing flash flooding.
  - Singapore's Smart Drainage System uses real-time sensors to monitor and redirect floodwaters with the implementation of AI-controlled stormwater drainage systems.
- Ample warning is also key to saving lives during flash flood events. Governments and organizations use text messaging, push notifications, and sirens to warn residents.

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    - Japan uses the J-Alert System, a nationwide emergency broadcast system to send both flood and earthquake alerts to cell phones and public loudspeakers.
  - Once flooding begins, drones are providing aerial surveillance of flooded areas, allowing rescue teams to assess damage and locate stranded individuals.
    - After cataclysmic destructive flash flooding from Hurricane Helene (2024) in North Carolina, the state is expanding their drone program to improve emergency response and recovery efforts.
  - Mobile Apps such as FloodTags (Indonesia and the Netherlands) or MyCoast (U.S.) allow anyone to submit photos, descriptions, and data to officials in real time, helping to monitor rapidly changing conditions and adjust response and recovery efforts.

Flash floods are a challenge for urban areas with impervious concrete surfaces. Benthemplein, a city near Rotterdam in the Netherlands developed a solution called "Waterplein" (water square). When heavy rains occur, stainless steel gutters channel water into one of three retention ponds, the largest of which only fills with extremely heavy rains. When dry, which is most of the year, the ponds can be used as amphitheaters, basketball and volleyball courts, and skateboarding.

Credit: https://www.publicspace.org/works/-/project/h034-water-square-in-benthemplein

- While technology is transforming our ability to forecast and respond to flash floods, the way we design our cities can help prevent them.
  - Smarter urban planning that replaces hard concrete with permeable pavements, green roofs, parks, and restored wetlands allows rainwater to soak in rather than rush away.
  - These nature-based strategies, combined with advanced modeling and real-time monitoring, help communities manage stormwater before it becomes a disaster.
- It is impossible to stop the devastation of flash floods, but technology including AI, smart infrastructure, and real-time alerts is saving lives and reducing damage.
  - Countries and communities that invest in flood mitigation technology are better prepared for extreme weather and advancements in climate modeling; urban planning will further improve flood resilience

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