

Hurricane Tracking Technology: Advancements and Opportunities

Hurricanes are severe and catastrophic weather events, often causing extensive property damage, infrastructure interruptions, and the devastating loss of human life. In these situations, government agencies and non-profit organizations need fast, sophisticated solutions to forecast hurricanes, monitor the storm's progress, and minimize damage.

Hurricane tracking technology is key to predicting these events, deploying rescue efforts, and restoring critical infrastructure such as telecommunications services. There are several exciting innovations that can save human lives and reduce the risk of property losses.

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The Hurricane Forecasting Process

Before modern monitoring technology, major storms were a surprise to people who live in hurricane-prone areas. Over time, hurricane forecasting has significantly improved, and affected citizens can receive hurricane warnings days in advance of the first rain bands.

The History of Hurricane Forecasting

The [very first hurricane warning service \(https://journals.ametsoc.org/view/journals/wefo/5/2/1520-0434_1990_005_0185_tnhcpa_2_0_co_2.xml\)](https://journals.ametsoc.org/view/journals/wefo/5/2/1520-0434_1990_005_0185_tnhcpa_2_0_co_2.xml) likely came into effect in the early 1870s. Father Benito Vines, the director of the Meteorological Observatory of the Royal College of Belén in Cuba, established a network of observation sites and developed the first method to predict tropical cyclone movement.

Father Vines used these methods to issue the oldest known hurricane warning on August 23, 1873. This alert notified residents in the Northeast United States and Canada about a major tropical storm that would eventually impact Newfoundland.

Modern hurricane forecasting began during the 1950s in the wake of two major technological advancements. First, [computer technology \(https://plato.stanford.edu/entries/computing-history/\)](https://plato.stanford.edu/entries/computing-history/) was in the early stages of its development during this time. Climate scientists wanted to leverage computers to perform statistical and dynamical modeling for hurricane forecasting. As technology has improved, these models have advanced significantly.



Second, governments began using reconnaissance aircraft (https://journals.ametsoc.org/view/journals/clim/25/13/jcli-d-11-00419.1.xml?tab_body=fulltext-display) in the 1940s, primarily in the United States. Satellites support modern hurricane observation, but in the past, pilots helped forecasters monitor storms by flying their aircraft into hurricanes and collecting valuable data. These initiatives helped climate scientists monitor both hurricane track, or its path over a given period of time, and intensity, or the strength of the storm.

Modern Methods for Hurricane Prediction

Today, scientists use several tools to monitor weather events and track hurricanes on the ground, in the sky, and from space. Aircraft, satellites, drones, and unmanned aerial vehicles (UAVs) are only some of the solutions that help forecast and track hurricanes.

Researchers use data from satellites and other devices to develop sophisticated models that predict important factors about hurricanes, such as intensity. Data modeling is necessary to perform accurate hurricane tracking.

There are several data points that inform these algorithms, such as the following:

- Oceanic water temperatures, because hurricanes form when warm moist air rises above water
- Wind speed and direction, which helps determine a hurricane's potential path
- Changes in water temperature and salinity below one thousand feet, which helps researchers predict changes in hurricane intensity
- The presence of El Niño–Southern Oscillation (ENSO), a climate phenomenon that has an impact on hurricane frequency

Advancements in Hurricane Forecasting

Scientists have built upon past advancements in hurricane forecasting to create modern, innovative tracking methods. These solutions support the accurate prediction of hurricane movement, protecting people and structures on the ground and aiding rescue and restoration efforts.

Some recent innovations in hurricane tracking technology include the following:

- **The GOES-R Satellite System:** The US National Oceanic and Atmospheric Administration (NOAA) developed the GOES-R satellite system (<https://www.ncei.noaa.gov/products/satellite/goes-r-series>), which helps researchers monitor hurricanes and other storms from their early stages. Using this technology's high-resolution imaging and fast refresh rates, meteorologists can issue earlier and more accurate warnings when a hurricane is approaching.
- **The Global Hawk UAV:** UAVs are valuable tools for hurricane forecasting as they allow meteorologists to take measurements remotely. The Global Hawk UAV is an advanced UAV that can fly over severe weather and achieve high altitudes for hours. This remote surveillance aircraft helps track valuable data to predict characteristics such as hurricane intensification.
- **Internet of Things (IoT) Sensors:** IoT devices collect data remotely from various sources, providing a steady stream of valuable information for different use cases. Meteorologists use IoT sensors to monitor the status of hurricanes, collecting data that researchers can use to support modeling and prediction. IoT sensors can also help monitor damage to infrastructure on the ground.

Meteorologists are continually developing new and exciting technologies for hurricane tracking. Potential advances include the expanded usage of deep learning, artificial intelligence, and machine learning in modeling hurricane trajectories and how they evolve, and the deployment of pop-up networks for temporary connectivity. The further integration of satellite and terrestrial networks could also promote connectivity following infrastructure outages.

Common Tools to Track Hurricanes

There are many exciting tools that researchers use to track hurricanes. These solutions collect data from the ground, the atmosphere, and even space via satellites. Some of the most common tools to track hurricanes include IoT devices, UAVs, and dropsondes.

Satellite Networks

Meteorologists typically track hurricanes using satellites, taking important measurements around the storm that help predict how the storm will progress and inform prevention efforts. Satellite data helps estimate important characteristics of ongoing storms, including past movement, the location of its center, and intensity.

Multiple Earth-observing satellites, including those from the GOES-R satellite system, help meteorologists by taking precise measurements of oceanic conditions. For example, satellites measure atmospheric temperatures, moisture levels, and sea surface temperatures. These data points are critical to predicting storms several days before the event takes place.

Satellites also have advanced sensor technology, which helps meteorologists identify key components of the hurricane and predict where the hurricane will likely hit. By analyzing this data, meteorologists can warn those in the storm's path without issuing unnecessary alerts to people outside the affected area.

Many satellites orbit at the same rate as the Earth, meaning that these structures can monitor a hurricane continuously as it forms and progresses. As a result, meteorologists have access to the full view of the storm as it evolves, providing them with more insight on the nature of hurricanes. This data can help inform hurricane model algorithms, further refining and advancing tracking technology.

Dropsondes

Dropsondes are special devices that scientists and government agencies use to monitor hurricane conditions during climate events. These devices are similar to weather balloons and collect data such as wind speed, moisture content, and atmospheric pressure.

During a hurricane, aircraft will drop these balloons above the storm. The dropsondes will collect important data all the way until they hit the ocean floor. Some dropsondes can even collect data in the ocean. All this information helps meteorologists develop more accurate forecasts and inform weather models.

Internet of Things and Sensors

IoT devices have sensors that collect valuable information, depending on where the user places it. For example, an IoT sensor on a wind turbine may collect information such as performance degradation or any damage that occurs to the structure. During a hurricane, these sensors could measure the impact of wind and rain.

By placing IoT sensors on objects and structures on the ground, users can analyze risk and damage without needing to check the integrity of those structures in person. This minimizes potential injury and helps meteorologists analyze the impact of the storm from the ground level.

Environmental sensors may also track conditions such as flood levels, helping researchers and first responders identify the worst-hit areas. Researchers can also use sensors remotely to measure humidity, temperature, rainfall, and other important data points to track hurricanes at atmospheric and ground levels.

Oceanic Gliders

Oceanic gliders collect underwater data below one thousand feet. Meteorologists can feed real-time data from these devices into models to analyze water conditions. By gathering data such as water temperature and salinity, meteorologists can produce intensity forecasts.

Drones and Unmanned Aerial Vehicles

UAVs and drones are some of the most powerful solutions for hurricane tracking. These devices usually have visual capabilities, such as aerial photography. Meteorologists can use these devices to monitor water levels, track the progression of the storm, and analyze ground conditions.

Drones and UAVs can also help establish important communications with command/control centers during emergency situations. This technology can monitor damaged property, pop-up network infrastructure, and critical infrastructure such as power lines, dams, and bridges, helping agencies prioritize and plan emergency response.

The Impact of New Technology on Tracking Hurricanes

Hurricanes can deliver significant damage, especially if organizations and governments fail to take preventive measures. However, tracking technology can help minimize damage to humans, property, and critical infrastructure during a hurricane. It is vital to adopt new technologies to support affected areas during these events.

How New Technology Improves Hurricane Tracking

New technology allows for better data analysis and more accurate early warning systems before, during, and after a catastrophic hurricane. The more data that meteorologists collect, the more that they can refine models to study, track, and measure the movement of hurricanes. Better technology supports data collection, providing researchers with more information on the nature of hurricanes and their sometimes-erratic movements.

By accurately monitoring a hurricane's progression and mapping its path, meteorologists can collaborate closely with first responders to help residents evacuate affected areas safely, minimizing human loss. Additionally, advances in hurricane tracking technology can help local agencies and first responders identify where people may need emergency assistance.

For example, pop-up mobile networks can help establish temporary connectivity during a hurricane. People in distress can then use these networks to provide or ask for help quickly, reducing rescue delays that could otherwise lead to devastating losses.

Stakeholders can also predict at-risk structures using hurricane tracking technology, supporting the planning and deployment of preventive measures and restoration efforts. With these solutions in place, organizations can implement key protections to minimize the damage that critical infrastructure may sustain under unprotected conditions.

The Importance of Pop-Up Networks

Low latency connectivity is key to providing faster restoration and rescue operations, as well as tropical storm warning systems. However, this connectivity may be extremely scarce following a hurricane, especially if critical infrastructure sustains damage. It can be difficult to obtain the backhaul that is typically necessary to establish connectivity.

This is where pop-up networks can help. Pop-up networks provide temporary wireless connectivity, helping organizations carry out important operations such as rescue efforts and medical care. Using a network of flying platforms, first responders and agencies can deliver wireless infrastructure to ensure temporary connectivity.

Drones, UAVs, and tethered balloons are some of the tools that first responders can deploy to enhance network quality of service and improve network resilience under emergency scenarios. These devices carry free-space optical communication transceivers with extended battery life and [5G technology](https://futurenetworks.ieee.org/industry/7-experts-forecast-what-s-coming-for-5g-in-2020) (<https://futurenetworks.ieee.org/industry/7-experts-forecast-what-s-coming-for-5g-in-2020>) capabilities. These flying platforms deliver temporary connectivity to support disaster relief activities and to enable device-to-device communications. These capabilities are critical when important communications infrastructure, such as cellular networks, suffers damage.

The devices may fly at various altitudes with different functionalities. For example, low-altitude devices may deliver access networks for users on the ground. Airborne devices operating at high altitudes can offer backhaul networks through satellites.

5G networks are also useful given their reliability, low latency, high bandwidth and support for massive connectivity. This combination of features makes 5G very useful for large sensor networks that need to transmit enormous quantities of data in real time.

Insights from hurricane tracking technology can help meteorologists identify which areas may require pop-up networks, supporting planning efforts. If they are working in the affected area, meteorologists can also use pop-up networks to monitor atmospheric and ground conditions following the hurricane event.

Building Hurricane Tracking Technology for the Future

Hurricane tracking technology has the potential to save human lives, reduce the risk of property loss, and restore critical infrastructure and services after a disaster. As researchers continue to develop dynamic, sophisticated weather forecasting solutions, it will become easier and faster to deploy critical restoration and rescue efforts.

To learn more about tracking and forecasting hurricanes using advanced technologies, check out [this article](https://ieeexplore.ieee.org/document/9096717) (<https://ieeexplore.ieee.org/document/9096717>) from the 2020 Third International Conference on Computer Applications and Information Security (ICCAIS).

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