Drone Advancements in Weather
By Megan Hiykel

Accurate weather forecasting and prediction is important to human safety as well as strengthening knowledge on weather. Previously, meteorologists have used other tools to gather the data on weather that would include satellites, radar systems, ground stations, and weather balloons to collect atmospheric data and forecast weather conditions. However, these tools have their disadvantages like high costs, inaccurate or unreliable data for hard to reach regions, they are also unable to obtain weather conditions at varying altitudes. Now with the modern technology, or Unmanned Aircraft Systems (UAS), is now transforming weather research and forecasting. Drones offer a cost effective and versatile way to collect atmospheric data, and monitor extreme weather conditions all the while filling gaps that the other methods in the past would not be able to accomplish. This Essay will dive into how drones are used in meteorology, their technical advantages, the obstacles with using them, and their growing role in strengthening weather prediction and accuracy.

In the past, weather forecasting relied on ground stations, satellites and weather balloons to collect weather data. Satellites offer comprehensive images of storms, cloud formations, and atmospheric movement; they do not deliver precise data at lower altitudes (National Oceanic and Atmospheric Administration, 2023). Weather balloons can measure temperature, pressure, and humidity as they climb, but their one-time use and ineffectiveness to control its flight patterns get in the way of its efficiency (National Weather Service, 2024). Ground stations offer constant monitoring but cannot acquire data beyond their set locations. Manned aircraft have been sent to fly into hurricanes and collect data from high altitudes. However, flying manned aircraft into storms is expensive, risky, there are not enough pilots to address the potential of various weather issues, and often these pilots are restricted to the most severe weather occurrences (Roza, 2024). In comparison, drones are more adaptable, safer, and are the most cost-friendly and accurate option. Equipped with advanced sensors, drones can follow exact routes the scientists needs, are able collect data at various altitudes, and function in hazardous or hard to reach regions(Luehrs, 2024).

Today drones are used for a variety of operations. With the advancing technology these Unmanned Aircraft Systems (UAS) will only come more versed and capable of more operations in the future. To start, atmospheric data collection Drones are equipped with various sensors which are to detect important factors such as barometric pressure, temperature, humidity, and wind speed (Madokoro et al., 2021). Drones can also capture this information at various altitudes, that information is pertinent for weather modeling. Therefore, helping meteorologists learn about atmospheric profiles. To continue on, storm monitoring and forecasting makes drones the most practical and safest option to gain critical information. This is because Unmanned

Aircraft Systems (UAS) can fly into dangerous conditions such as hurricanes, tornados, and thunderstorms with little risk to life. On the other hand, having a manned aircraft fly into those storms has a big risk of life with human life. For example, drones can fly into the eye of a hurricane and gather life saving data like the trajectory of the storm to save civilian lives. That example leads right into the next topic of current emergency data because in case of a disaster drones can provide critical weather data for emergency services. Meaning they can guide rescue and relief services after a catastrophic event like a hurricane (Batchelor, 2023). In addition, drones are now helping with the climate change efforts. The Unmanned Aircraft Systems (UAS) are doing this by monitoring rising sea levels and melting glaciers (O'Sullivan-Dale, 2024). By the drones gathering this data overtime they can help scientists model long term effects of global warming and be the catapult to finding a solution sooner.

In order to transform weather data it is up to the technology each drone is built with. More specifically in the sensor built into each of the drones . The sensors used for research are temperature and humidity sensors to record differences across altitudes, Anemometers for wind speed measurements, Barometers for pressure readings, Light Detection and Ranging(LIDAR) for mapping and cloud profiling, and thermal cameras for detecting temperature changes (National Oceanic and Atmospheric Administration, 2024). Drones also feature flight systems that enable real-time data relay, autonomous navigation, and endurance in severe weather. For instance, in order to gather vital storm data, NASA and NOAA have tested long-endurance drones that can fly for hours into storms (Person, 2019). The limits of atmospheric science are being pushed by these technological developments.

There are a lot of advantages to using drones for weather monitoring. Drones are a more affordable option compared to satellite launches or manned aircraft deployments (Hilet et al., 2024). With little infrastructure, small teams can quickly deploy and operate the drone.   Drones can contain current and flexible data collection. Drones can be programmed to fly specific flight paths, hover in the same spot, and adjust their location on a need basis for the information they are required to gather. Another benefit is they can relay information back at a fast rate to the scientists involved. Drones are capable of operating in unsafe conditions for humans. Those areas could look like flying above an active volcano, or even just in areas with low visibility (Houston, 2024). The Unmanned Aircraft Systems (UAS) has improved weather forecasting accuracy…

Even though drones have great possibilities they encounter many difficulties when used for weather research. Short battery life and limited distance are major challenges for drones since they can usually fly only for a short time especially in bad weather. Longer missions usually need special drones that can carry heavier loads and have better power systems. Flight regulations can make it difficult to operate drones. In certain areas like cities there are restrictions on where drones can fly. Additionally getting permission to operate drones in bad

weather is often very difficult. Drones are made to work in bad weather but strong winds, heavy rain or very cold temperatures can affect how well their sensors work and reduce the trustworthiness of the data they collect (Duffy et al.,2017).

The long term use for drones in weather research is hopeful. Improvements in technology, such as AI-driven drones and swarm-integrated systems, are improving the previous drones performance (Ushasukhanya et al. 2024). With AI, drones can autonomously change as needed to suit various weather conditions, while swarm drones work together over large areas to gather data (Abdelkader et al., 2021). Improvements also have been made for Battery technology to help increase the amount of time the drone can fly and to go along with that with the introduction of hydrogen-fueled drones, allowing for longer flights (Wang et al. 2021). Additionally, incorporating data collected by drones into weather prediction models will improve forecasting accuracy and enhance disaster readiness. Drones present considerable opportunities for research related to climate change. By looking at events like ice cap melting and deforestation, they will be significant in tracking environmental shifts and shaping global policy decisions.

The use of drones in weather forecasting and research is transforming what we used to be able to accomplish. The benefits we reap from the advanced drone technology is being able to gather weather data at a greater capacity and receiving more accurate data, therefore giving scientists the knowledge to understand patterns in weather. Additionally, all the while keeping pilots safe. Even though there are still some kinks like battery life, flight regulations, and specialized drones for longer missions. With the constant improvement the drone field has made in this recent technology they are set to overcome these challenges. With the constant weather concerns and global warming not looking like it will resolve, drones will play a crucial role in the future to further our understanding and help meteorologists combat these serious issues.

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