State of the Science FACT SHEET

Emerging Science for Earth Observations

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • UNITED STATES DEPARTMENT OF COMMERCE

NOAA is using technological innovation -- from autonomous vehicles to smartphones -- to obtain observations in data-sparse regions for improved earth system assessments and predictions while reducing overall costs. New technologies will provide comprehensive coverage to understand the Nation's coasts, oceans, fisheries, weather, and climate. Such efforts are needed to economically provide the integrated large-scale observations required to understand, predict, and prepare for changes in Earth systems.

Uncrewed Systems (UxS)

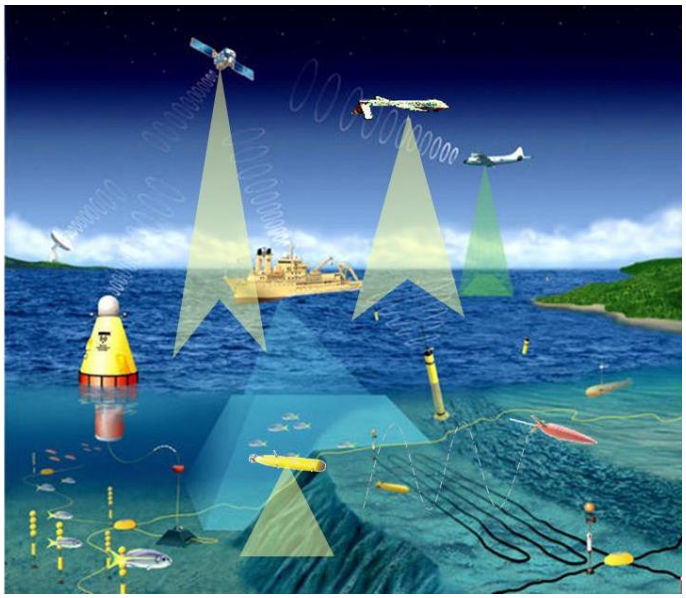
NOAA has relied on remote sensing and in-situ platforms to obtain Earth measurements for decades. Now, the capabilities and reliability of Uncrewed Systems (UxS) also offer the potential for cost-effective and energy-saving solutions for large-scale Earth observations. These systems can travel through water or air, and some can even collect traces of genetic material that have been shed into the environment (environmental DNA or eDNA), all while operating without a crew on board. Some observations, once reliant on manual collection, can now be made with the use of UxS, and many more are being researched and developed, to fill observation data gaps. Advances in computing and artificial intelligence (AI) will bring more real-time processing power to UxS. These platforms will aid missions requiring access to dangerous, inaccessible, or populated areas (e.g., hurricane eye walls, under ice, great ocean depths, cities) and increase the duration and range of traditional, but complementary observing methods.

In the Water

NOAA is developing and, in some cases, utilizing UxS to measure and map conditions in our oceans and Great Lakes. From uncrewed surface vehicles and ocean gliders through autonomous underwater vehicles that can explore the ocean depths, UxS can be used in a wide variety of mission spaces. UxS are being used operationally to: augment crewed surveys, conduct long duration ocean monitoring missions,and to temporarily replace damaged buoys. UxS capabilities in development include: tracking harmful algal blooms, mapping the ocean bottom, monitoring biodiversity (microbes to marine mammals), acoustic monitoring of fish abundance and distribution, and tracking ocean conditions to improve hurricane intensity forecasts.

In the Air

NOAA is working to fill critical information gaps in data limited and remote environments with uncrewed systems that fly, otherwise known as UAS. NOAA is developing and evaluating the use of UAS to improve our understanding of hurricanes, marine ecosystems, polar regions, wildfires, and to gather in situ observations in environments that would be hazardous to human aircrews. NOAA is performing UAS operations to expand marine mammal and turtle abundance surveys, and limited operations to gather atmospheric chemical samples and assess severe storm damage.



Comprehensive Earth Observing System. Autonomous and remotely piloted in situ platforms complement standard ship, aircraft, satellite, and tethered platforms. *Credit: US Integrated Ocean Observing System*

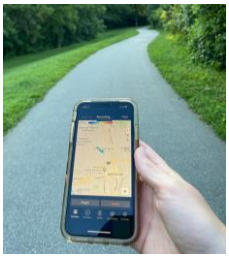
The information gathered by UAS will help scientists make highly accurate maps to understand storm damage, animal habitat, and sea level rise, ultimately leading to improved climate and weather predictions that support the management of marine resources.

Edge Computing and Artificial Intelligence

Increasing data volumes and the development of AI algorithms are steering NOAA towards edge computing, where computing resources are dispersed or otherwise in the field, for efficient, real-time, data-driven decision making. Example use-cases for edge and cloud computing include UxS on-board processing of images, video, or genetic sequences. AI and edge computing both have the potential to greatly increase operational efficiency, providing a positive return on investment.

UxS Integration into Agency Operations
NOAA's Uncrewed Systems Strategy outlines actions to accelerate research, development, and transition into operations of platforms with proven functionality. The UxS Operations Center supports UxS training, policies, acquisition, technology transition, and operation of particularly complex or multi-mission UxS. NOAA is working to accelerate . The NOAA Uncrewed Systems Research Transition Office works to ensure NOAA's broad mission is enhanced by these emerging capabilities. With the incredible pace of innovation, UxS research and development is essential to ensure NOAA's place as a global leader in earth observations and environmental science.

Observations in your Hands



Smartphones can be employed to provide mobile earth system observations. There are around 7 billion smartphones active globally, offering an opportunity to supplement existing observing systems. Through citizen science and application development, NOAA can expand connections to this vast network. For example, users of the Meteorological Phenomena Identification Near the Ground (mPING) app are able to report critical weather observations anywhere, at any time. Apps such as CrowdMag can tap directly into mobile phone instrumentation to passively collect environmental data. This app uses integrated magnetometers to enhance observations of Earth's magnetic field. Both of these examples provide NOAA with information that fills important data gaps that cannot be collected easily with other techniques. With mobile apps providing ever-increasing capabilities and ease of use, their potential for harnessing the power of volunteer contributions continues to grow.

Research Application Highlights

- **Hurricane Intensity Forecasts**: Innovative science at NOAA is testing the ways that UxS can be used to improve hurricane forecasting. NOAA has deployed multiple UxS platforms including Saildrone Uncrewed Surface Vehicles (USVs), ocean gliders and UAS to monitor and study tropical systems to obtain ocean conditions and air-sea interactions to improve hurricane intensity forecasts.

- **Resilient Communities and Blue Economy**: NOAA mapping applications for small uncrewed aircraft systems include assessment of post-storm and flood damage, critical salmon habitat, and high accuracy documentation of changing coastlines. In the water, NOAA is operationalizing the use of the Drix USV. In some applications, ship-USV teams combine fishery and hydrographic mapping sonars. The aim is to increase the productivity of fishery acoustic and ocean mapping surveys compared to ships alone.

NOAA Ship Thomas Jefferson underway with the DriX unmanned surface vehicle. *Credit: ENS Patrick Faha*

- **Marine Mammal Surveys and Health Assessment**: NOAA routinely uses uncrewed aircraft systems to estimate the size of critical cetacean and pinniped populations and to evaluate marine mammal health and condition.

- **Biodiversity and Harmful Algae Monitoring**: NOAA is advancing biological monitoring through autonomous eDNA collection and measurement of algal toxin using public-private partnerships.

- **Exploration:** NOAA's Ocean Exploration is working with Cooperative Institutes to implement multi-vehicle uncrewed sampling missions; automate processing of video data from autonomous platforms, landers, and autonomous underwater vehicles. The work also includes delivering learning opportunities to underserved communities that grow a capable, diverse workforce ready to implement the technologies needed to meet mission objectives.

- **Fire Management** NOAA is developing UAS to help monitor and understand wildfires, prescribed burns, and weather conditions that will impact their behavior. Particularly important to this effort is developing UAS for use at night, when it is much more dangerous to have crewed aircraft near a fire.

- **Accessible Science**: Citizen Science brings the power of the public to earth observations. CrowdMag has been downloaded to over 17,750 cell phones using both the Google and Apple application stores. The program has collected over 100M data points from around the world. To learn more about CrowdMag and how you can get involved click here.