OIL SPILL SCIENCE

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IN THE AIR AND ON THE WATER: TECHNOLOGY USED TO INVESTIGATE OIL SPILLS

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Oil detection and monitoring are important for managing marine resources and minimizing potential environmental impacts. New technologies complement traditional ship, satellite, and mooring-based data collection techniques, allowing scientists to study all aspects of oil spills. Along with underwater vehicles, unmanned surface and aerial vehicles, as well as satellites, are used to study oil spills at and above the ocean's surface. These technologies allow scientists and responders to understand how oil moves on the ocean's surface. Some have advanced into operational use by the spill response community and others are being tested as response tools.

Unmanned surface/aerial vehicles and satellites help scientists understand the movement of currents and pollutants at the ocean's surface (graphic not to scale). (Anna Hinkeldey)

UNMANNED SURFACE VEHICLES

Unmanned surface vehicles (USVs) operate on the surface of the water without any onboard operators. Scientists are developing new ways to use USVs as research tools.[1] USVs are a cost-effective technology with a wide range of applications, including scientific research, environmental missions, ocean resource

The Saildrone, a type of unmanned surface vehicle, can carry an array of instruments that allow scientists to take atmospheric and oceanic surface and subsurface measurements. (ECOGIG)

exploration, and military uses. Some USVs are lightweight and compact, which makes them easy to maneuver and deploy in shallow water where ships cannot operate effectively. They also have the potential to carry instruments and sensors to conduct monitoring and sampling.[2] Due to USVs not requiring a crew on board,

- there are minor threats of collisions at sea,
- the costs of maintenance and operation are lower, and
- they can perform longer and more hazardous missions than manned vehicles.[2]

Saildrones

Saildrones are exactly what the name describes, sailing drones. They float on the surface of the water to conduct oceanography, fishery, and marine mammal studies.[1,3] Powered by wind and solar energy, they have solar panels on the hull and wing to provide power for command, control, communications, and sensor operations. Scientists launch Saildrones from shore, docks, or platforms. They stay at sea for extended lengths of time while reporting and collecting real-time data with a collection of weather- and water-related sensors.[1]

Natural oil seeps are locations where oil leaks naturally into the ocean through cracks and faults in the ocean floor. Scientists recently used a Saildrone to study oil from a natural seep in the Gulf of Mexico on the surface of the ocean. The study's objective was to estimate how long the oil slick remained on the surface and to determine the importance of winds and surface currents on the movement and fate of the surface oil. Scientists launched the Saildrone from a platform in Louisiana and directed it to a natural oil seep 230 miles offshore. Once it located the seep, it surveyed the area for three weeks and then sailed back to the platform. The instrument was equipped with an **anemometer** and an autonomous Remote Optical Watcher (ROW). A sensor that uses **fluorescence** to detect the presence of oil on the surface of the water, an ROW sends an alarm when it detects oil at a level above a specified threshold. Observations collected by the Saildrone confirmed the changes in wind speed and direction predicted by the computer model during the study were correct.[4] The costs of this operation were much lower and data quality higher compared to other methods.

Drifters

Drifters study ocean circulation patterns by providing scientists with real-time information about how surface currents move. They float on the surface of the water, come in many different sizes, and contain GPS units to track their position as they move with the water. Modern drifters are quite inexpensive so they can be deployed in large numbers, which can reveal the highly complex nature of ocean surface currents. The data gathered from these devices helps scientists develop and evaluate predictions from computer models.

Scientists compare the data from the drifters and the model to make sure the model is predicting what is happening on the water's surface. The computer models help predict climate, weather patterns, currents, and where pollutants might go when dumped or spilled into the ocean. To learn more about computer models and how scientists use them to track oil, read the Sea Grant publication ***Predicting the movement of oil***.[5]

In 1989 and 1991, scientists used drifters during four experimental oil spills on the Norwegian coastline. Experimental oil spills are planned, controlled spills that allow scientists and responders to observe the movement of oil in a non-threatening manner. These experiments allow them to study the impacts of weather and sea conditions on the oil and help guide strategies for oil spill planning and response. Scientists deployed nine drifters to help track the movement of the experimental oil and see if the computer model used to map ocean currents represented the oil's movement correctly. They found that the movement of the oil and drifters depended on the weather and sea conditions as well as the condition of the oil.[6] When wind and sea surface were calm, the motions of the surface oil and the drifters were similar. As winds increased and small breaking waves began to appear on the sea surface, the properties of the oil changed. This change caused the oil and drifters to move away from one another.[6]

More recently, two experiments used 1,400 drifters to understand the currents of the Gulf of Mexico. During the first experiment, scientists deployed 300 satellite-tracked surface drifters in the northeastern Gulf of Mexico over the course of a week. Drifters reported their location every five minutes for six months.[7] During this experiment, Hurricane Isaac came through the Gulf of Mexico. This gave scientists an opportunity to collect data and study the impacts of hurricanes on ocean surface currents. Results showed that during Hurricane Isaac, the movement of water particles was six times larger than prior to the hurricane.[8]

During the second experiment, scientists deployed 1,100 drifters to trace the **small-scale** currents in the open ocean environment — the largest experiment of its kind. Scientists designed the drifter to be compact to make it easier to conduct research from small boats in shallow coastal areas such as harbors, lakes, rivers, and estuaries. The experiment successfully measured small-scale ocean currents across a large geographical area using drifters (Figure 1). It also provided information that has allowed scientists to learn more about the speed and movement of surface currents.[9] Computer

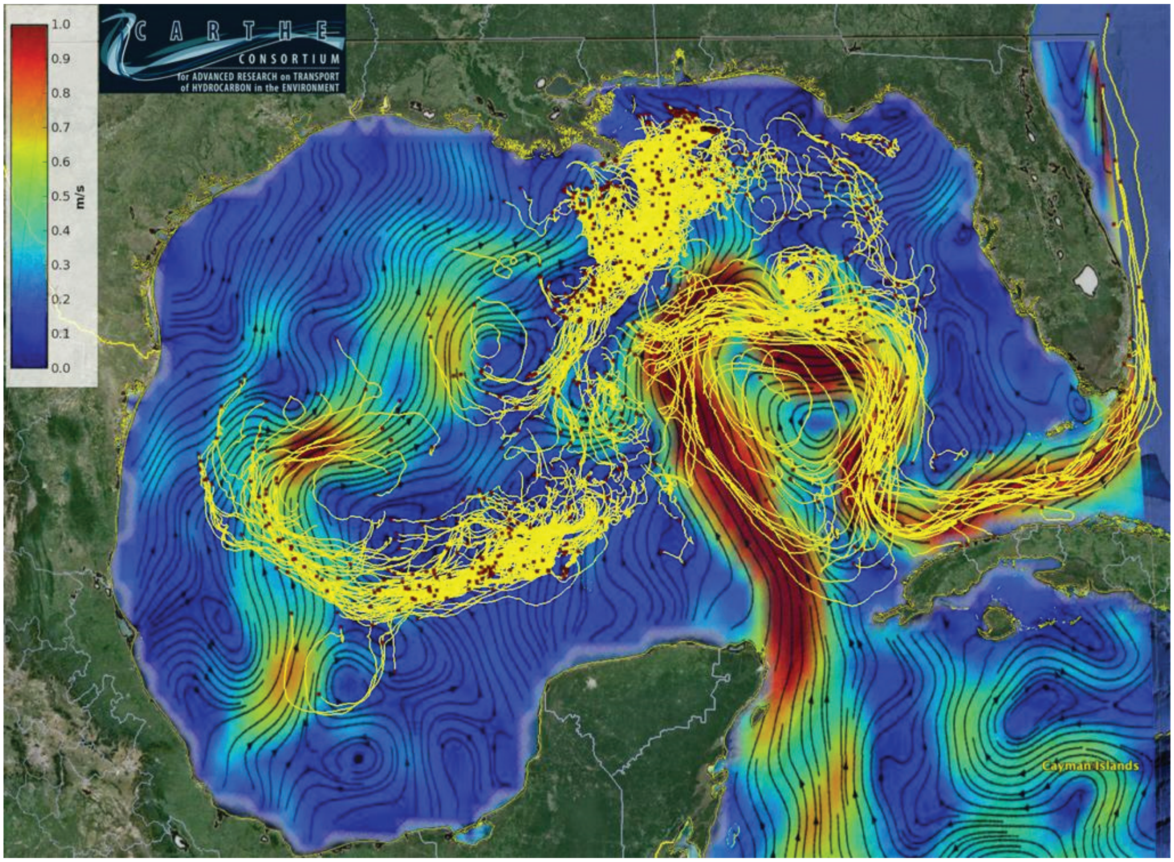

FIGURE 1. *This map shows the movement of the drifters during the 1,100 drifter experiment. The yellow lines show the path of the drifters and the red squares indicate the position of the drifters on March 9, 2016. (CARTHE)*

What happened to all those drifters that went into the ocean?

Scientist invented an environmentally friendly, biodegradable drifter to conduct ocean current experiments. (CARTHE)

Normally, scientists search for and recover as many drifters as possible after an experiment has ended. However, sometimes it is not possible to collect all the drifters due to the length of time they have been in the water and the distances that they have traveled. This causes some to remain in the ocean. Scientists kept this in mind when developing the CARTHE drifter. It is the first environmentally-friendly drifter, built with 85 percent biodegradable material and 15 percent nontoxic electronics. The drifter's body is made of a biodegradable material. Its fasteners are constructed with steel, so they eventually rust away in the ocean. The tubing is natural rubber and the battery packs do not contain lead or mercury and so are not classified as hazardous waste.[9]

models use this information to help make them more accurate when tracking pollutants in the water.

In another study, scientists used two USVs to collect marine mammal acoustic data. The goal of the project was to improve monitoring methods as well as to investigate the impacts of the Deepwater Horizon (DWH) oil spill on nearby marine mammal populations. Each of the vehicles towed tools used to capture a range of sounds made by dolphins, beaked whales, and pygmy and dwarf sperm whales. Because USVs are very quiet, a very wide range of frequencies could be recorded at very long ranges compared to other methods. Scientists identified approximately 30 marine mammals during their study and will continue to monitor activity in the Gulf of Mexico.[10]

UNMANNED AERIAL VEHICLES

Unmanned aerial vehicles (UAVs) are becoming widely used for scientific research, law enforcement, security, natural disaster, environmental monitoring, flood damage assessment, and urban planning.[11,12] They include unmanned aircrafts/drones, multirotor helicopters, and balloons/blimps of different sizes and shapes.[12] UAVs offer a cost-effective way for operators to return to or continue to survey specific sites from the air, observe changes to the environment over long periods of time, and conduct surveys in hard-to-reach areas.[11–13] Strict limits on where and how UAVs can be flown present challenges for use, particularly in the U.S.[12] UAVs have proven to be a reliable technology well-suited for aerial investigation and oil spill response.[13,14]

Scientists control UAVs using remote controls or pre-program them to fly freely, reducing the risk to humans.[11,12] Like USVs, UAVs can be equipped with many different sensors, cameras, GPS equipment, and other meteorological instruments.[11,12] During spill response, UAVs assist in locating the source of a spill to determine proper response action and deliver high quality, real-time information.[11,13] They capture aerial views, detect and monitor marine animals affected by spills, and offer information to aid in shoreline clean-up.[12]

Scientists used drones, like the one pictured here, to capture images of the surf zone. (CARTHE)

Drones

Scientists used drones and **rhodamine dye** to examine the **surf zone** in the Florida Panhandle, putting the dye in the water to see how it moves. For six days, scientists flew drones directly above the surf zone to capture the beach's response to storms and day-to-day changes. They used two drones so they could have one fully

FIGURE 2. *This picture, captured during the surf zone experiment using a small balloon with a camera attached, shows a bird's eye view of the dye that helps scientists see how the water is moving in the surf zone. (CARTHE/ Guillaume Novelli)*

charged and ready to fly over the same location as soon as the other drone's battery began to reach its lower limit. This practice minimized gaps in their data and allowed them to capture multiple images that showed the movement of dye in the surf zone. The drones helped give scientists a better understanding of how water and pollutants move (Figure 2).[15]

Blimps and Balloons

Blimps and balloons are low-flying, slow, long-endurance aircrafts that provide a stage to observe an area for a long period of time. Helium gas keeps them floating steady through the air. Blimps and balloons can include cameras, thermal infrared sensors, GPS equipment, and several other meteorological sensors.[12,16] Tethered to a boat out in the water or to a platform on land, they can be easily and rapidly deployed while being controlled wirelessly.[12]

One of the biggest drawbacks from **in situ** burning is that it creates air pollution. During clean-up efforts of the DWH oil spill, scientists used a helium-filled balloon called an aerostat to monitor air quality changes from the smoke plumes caused by burning oil.[17] The smoke produced by in situ burning may contain high concentrations of particles and toxic gases, impacting the health of those who are exposed to them.[18] Scientists launched an aerostat into the plumes of 27 surface oil fires over a period of four days. Its instruments sampled emissions for pollutants and continuously measured **carbon dioxide**. Studies such as this one provide a great representation of emission factors from these smoke plumes and help to insure the safety of responders.[17]

SATELLITES

Satellites are man-made objects placed into orbit around the earth or another body in space. Scientists use them for communications, photography, mapping, and navigation, among other things. Satellites equipped with **remote sensors** gather information about objects or areas from a distance, providing scientists with a new way to study the oceans. These sensors record natural energy, such as sunlight, reflected from the earth's surface. The remotely-sensed data captured by satellites allow scientists to study shoreline changes, ocean surface, ocean currents, waves, winds, **phytoplankton**, and sea surface temperature. Remote sensing plays an important role in oil spill response efforts. By using remote sensing instruments, oil can be monitored at all times. Knowing the location of a slick and its movement helps responders plan accordingly and lessen the impacts of the oil.[19]

During the DWH oil spill, satellites tracked the movement of oil. NOAA's Satellite Analysis Branch supplied more than 300 oil spill analyses using satellite imagery and data sets to map the location of the surface oil.[20] The data collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) and Medium Resolution Imaging Spectrometer (MERIS) helped determine the location and size of the surface oil slick.[21] These satellite images, paired with computer models, created a system for tracking the oil.[22]

Scientists monitored the oil using satellite synthetic aperture radar (SAR). A radar mounted on a satellite, SAR produces a series of high-resolution remote sensing images. This technology identifies and monitors sea surface oil over large remote areas.[23] It can 'see' oil during

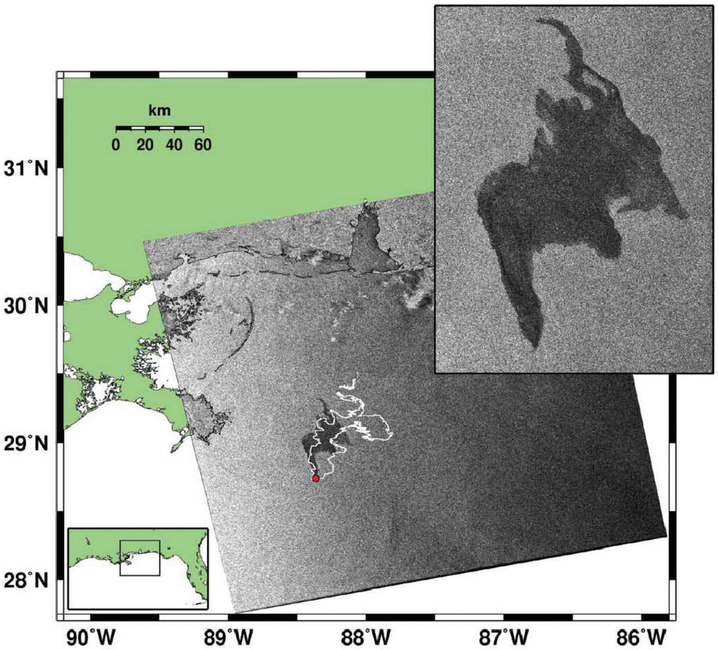

FIGURE 3. *The first synthetic aperture radar (SAR) image of the Deepwater Horizon oil spill, taken on April 23, 2010, shows oil on the surface (black) moving toward the coast. The white outline shows the extent of oil on April 25, 2010. The red circle indicates the location of the wellhead.*[23]

the day or at night, through cloud cover or fog — not a common feature on most satellite sensors.[24]

During DWH, satellites took the first SAR image on April 23, 2010 (Figure 3). By that time, the oil had spread toward the northern Gulf coastline. When the wellhead was sealed on July 15, 2010, satellites had already passed over the Gulf more than 700 times, giving responders many images to monitor the spill.[23] SAR data helped scientists calculate the total amount of surface oil and predict where it might move. To do this, they analyzed 166 SAR images collected by multiple satellites. The scientists compared these SAR results to calculate the amount of oil coming from the well and observe the impacts of response techniques. From these images, scientists determined that over the 87 days, the oil slick covered a surface area of approximately 4,300 square miles.[25]

Scientists also use SAR images to get an accurate estimate of oil slicks caused by natural seeps, production and transportation of oil, and spills in the Gulf. They reviewed 177 pollution reports from 2001 to 2012 and, using 137 SAR images, found that oil slicks caused by the production and transportation of oil are often larger than reported.[26]

More recently, scientists used another satellite instrument known as Visible Infrared Imaged Radiometer Suite (VIIRS) to track an oil tanker's pathway and location. On January 6, 2018, an Iranian oil tanker collided with a grain freighter in the East China Sea, causing major fires and oil spills. After the collision, nighttime imagery collected by VIIRS helped to monitor the drifting tanker as well as the fires associated with the collision. Once the tanker sank, the instrument showed three separate fire sources the following night, indicating the drifting of floating oil on the water's surface.[27]

Technology continues to evolve and help scientists test, discover, and view the environment from different perspectives. The Gulf of Mexico Research Initiative (GoMRI) funds several of these ongoing studies. Emerging information is available on GoMRI's website at ***http://gulfresearchinitiative.org***. To access other oil spill-related publications or view the references in this publication on Sea Grant Oil Spill Science Outreach Program website, ***www.gulfseagrant.org/oilspilloutreach***.

GLOSSARY

Anemometer — An instrument that measures and records wind speed and direction at the water's surface.

Carbon dioxide — A colorless, odorless gas found in our atmosphere.

Fluorescence — A substance absorbing light that re-emits the light as a different color.

In situ — Observations made at the location or original place of an incident.

Phytoplankton — Microscopic algae that drift or float in bodies of water.

Remote Sensor — A sensor attached to a satellite or aircraft that collects data and detects/classifies objects or areas on Earth.

Rhodamine dye — A harmless, water-soluble dye used as a water tracer.

Small-scale — Ocean currents that occur on spatial scales on the order of 100 meters to 10 kilometers, and times scales of day(s).

Surf zone — The area of the beach in which waves break.

TECHNOLOGY PROS AND CONS

Scientists must consider a number of factors when determining which unmanned surface or aerial vehicle will best suit their study.

Unmanned Surface Vehicles	Advantages	Disadvantages
Saildrones	• Long range and duration for data collection of up to 12 months • Fast — travel up to 10 knots (11.5 mph) • Durable — sturdy, long-lasting, and reusable • Collect high quality data in real-time • Can endure rough weather conditions • Wind and solar powered, no use for batteries • Can include many sensors	• Cannot sample water at depth • Require specialist to operate
Drifters	• Come in many different sizes, allowing deployment from multiple locations • Contain GPS units to track position	• Difficult to recover after deployment • If not biodegradable, can pollute the ocean environment • Must deploy many at a time
Unmanned Aerial Vehicles	**Advantages**	**Disadvantages**
Drones	• Can be equipped with many sensors • Come in many sizes	• Strict limits on where and how they can be flown • Duration limited by battery power • Sensors compact due to limited space • Cannot operate in windy conditions • Difficult to operate at night
Blimps and Balloons	• Observe changes over long periods of time from various altitudes • Can be equipped with many sensors • Free of vibration, which is better for images	• Height of flight limited by length of cable and flight path restrictions • Use helium to stay inflated so occasionally need to be brought down and refilled

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