Overview of Airborne Oceanic Survey Capabilities of the NOAA Aircraft Operations Center

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ABSTRACT

The NOAA Aircraft Operations Center (AOC) operates a fleet of nine aircraft based in Tampa, FL at MacDill AFB. These aircraft can be configured to meet specific scientific requirements and have been successfully used to conduct a full range of airborne oceanic research around the globe. While best known for its role as "Hurricane Hunters", AOC deploys its planes from the Arctic Ocean to the Tropics in a wide variety of missions. The two WP-3D Orion aircraft have played a key role in oceanic research for nearly four decades. This presentation will provide an overview of the types of oceanic research missions conducted by the four engine turboprop WP-3D, with an emphasis on the capabilities of the Orion as an airborne platform to exploit emerging technologies supporting advances in oceanic survey techniques. Additionally, AOC operates three types of light aircraft that perform a wide range of remote sensing roles (both overland and overwater) along with several experimental unmanned aerial systems (UASs).

The NOAA WP-3Ds first became operational in 1976 but have undergone a number of programmatic upgrades in recent years. Over the next three years both WP-3Ds will undergo a comprehensive 14 month service life extension maintenance project where significant portions of the wings, tail and avionics are being replaced (along with 4 upgraded Rolls Royce engines). This is expected to extend the service life an additional 20+ years.

Each Orion can deploy dozens of Airborne Expendable Bathythermographs (AXBTs) on missions through a combination of external and internal buoy launch tubes. Conductivity Temperature and Depth (AXCTDs) and Current Profilers (AXCPs) can also be launched (but only using an internal free fall chute). More than 70 buoys were deployed on some missions in the Gulf of Mexico in the aftermath of the 2010 Deepwater Horizon disaster. In 1983, oceanographic research flights between Mexico and Ecuador studying El Nino launched over 100 buoys per mission. With the capability to fly at low altitudes for mission durations of up to 10 hours (covering tracks in excess of 3000 km in length), the WP-3D has an unmatched track record of success in its ability to survey the ocean.

In addition to the Orion, AOC operates four de Havilland (DHC-6) Twin Otter aircraft as well as a Gulfstream Turbo (Jet Prop) Commander 1000 (695A) and a Hawker Beechcraft King Air 350ER. Each is a proven remote sensing platform with the capability to loiter at low altitude over the ocean and collect data.

Finally, for the past few years AOC has been operating a small number of unmanned aerial systems (UASs) including the Puma, which has been successfully deployed from NOAA research vessels, and the Coyote launched from the Orion.

I. Improved and Expanded WP-3D Ocean Measurement Capabilities

One important aspect of WP-3D enhancement has been the installation of upgraded Rolls Royce T-56 A-15 Series 3.5 engines. With significant improvement in fuel efficiency over the older T-56 turboprop engine system (with an average of 8 percent less fuel consumption over the full spectrum of flight altitudes) the AOC P-3s will be able to transit to the operational area at a higher altitude, burning less fuel enroute, to have more flight time available for low altitude ocean survey patterns. Once on station, the new engines also burn fuel more efficiently at low altitude further extending loiter time over the mission data collection area. A full avionics upgrade includes the replacement of hundreds of pounds of original copper wiring with much lighter modern cabling, saving weight and thereby further extending time on station.

The Lower Fuselage (LF) radar used for weather research and reconnaissance on the WP-3D has been in service since 1977. This C-band LF radar is being replaced by an X-band multimode system with significant ocean surface scanning capabilities. These include a Synthetic Aperture (SAR) mode employing scatterometry to enable measurement of sea surface roughness and wave heights and an Inverse SAR (ISAR) mode for ice patrol missions detecting and classifying icebergs. Other potential future applications of the new multimode radar system include Marine Sanctuary and Maritime patrol flights, oil spill detection and mapping, oceanic garbage patch gyre surveys and marine mammal detection and tracking.

Introduction of the Wide Swath Radar Altimeter (WSRA) onto the WP-3D provides the capability to measure ocean directional wave spectra and significant wave heights as well as the mean square slope of the ocean surface. WSRA data can be fed directly to oceanic forecast centers in the prediction of sea heights for maritime interests and improved storm surge forecast accuracy for land falling tropical cyclones.

For more than a decade, the Orion has carried the Imaging Wind and Rain Profiler (IWRAP) developed and built by the Microwave Remote Sensing Laboratory at the University of Massachusetts, Amherst. IWRAP is a C-band and Ku-band dual-polarized (vertical and horizontal polarization) profiling scatterometer designed to measure the backscattered signal from precipitation and the ocean surface for wind vector retrieval. The Orion based IWRAP is used by NESDIS to provide calibration data for satellite based ASCAT and RapidScat systems in low Earth polar orbits. In January and February of 2015, a prototype antenna developed for the ASCAT follow-on scatterometer (SCA) planned for the EUMETSAT Polar System – Second Generation (EPS-SG) was installed and flown over the North Atlantic on the Orion as part of the NESDIS Ocean Winds 2015 project.

A view of the prototype IWRAP antenna on the NOAA WP-3D which includes a cross polarized receive capability to test the SCA follow-on scatterometer system. This SCA capability is designed to permit more accurate wind vector retrieval in very high wind settings than is possible with the present ASCAT system.

II. Expendable Buoys Deployed from the WP-3D

The Lockheed Martin Sippican MK10A system is used to receive and process AXCP, AXCTD and AXBT data on the AOC Orion. It utilizes the MK21 for real time acquisition and display of probe data and the PMD560 system to record the data. This airborne system is functionally identical to ship based XCP, XCTD and XBT counterparts. The most significant difference between ship and aircraft deployment of expendable buoys lies in strategies that maximize ocean coverage given the significant difference in line of sight data acquisition range of the aircraft versus that of a surface vessel, as well as the much greater speed of the plane allowing for many more buoys to be deployed across an array in just a few hours rather than days.

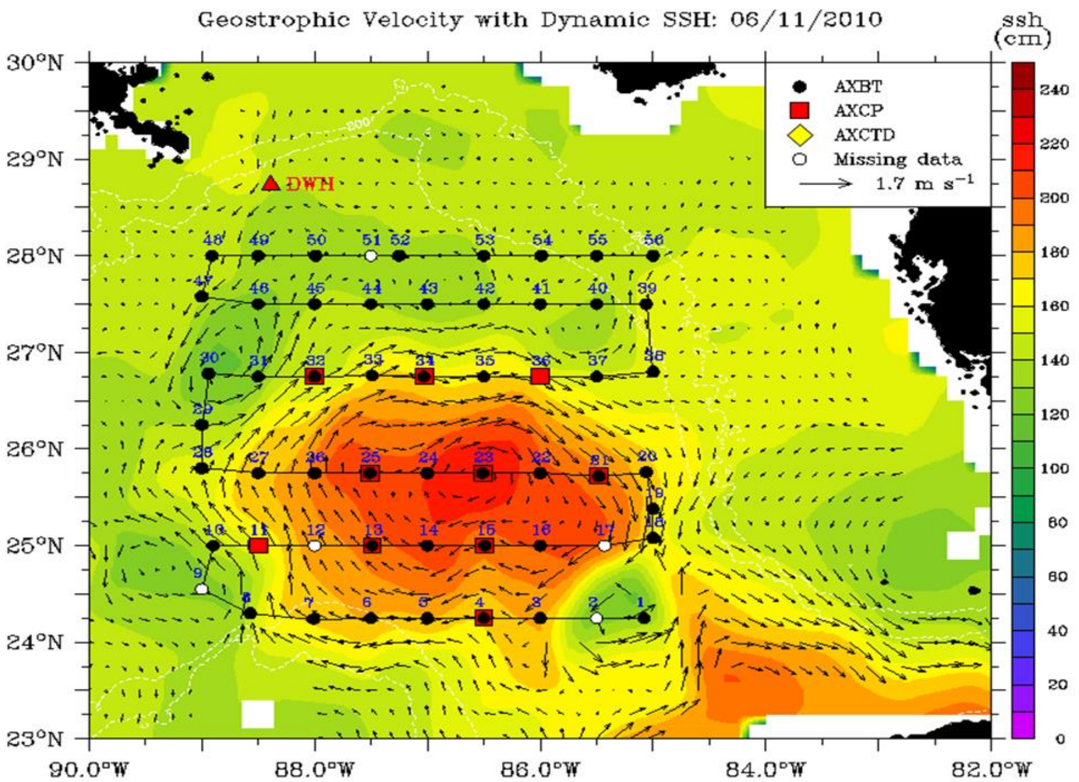
The WP-3D typically flies at approximately 240 knots true airspeed conducting low altitude oceanic science profiles (generally between 1500 and 10,000 feet) when releasing AXBTs. The groundspeed in relation to the Earth depends on headwind / tailwind components but the aircraft dropping BTs is usually moving over the Earth at somewhere around four miles per minute. When deploying AXCTDs and AXCPs the WP-3D slows to an indicated airspeed of less than 200 knots (yielding a true airspeed just over 200 knots). Given the 10+ minute duration that some probes will sample data, the aircraft will often be at a distance of 40+ miles when the buoy at the surface ceases transmitting. At normal survey altitudes this means that the Orion will still have more than ample line of sight geometry to maintain signal connectivity with any deployed AXBT / AXCP / AXCTD through the full duration of its descent (through a maximum of 1500 meters below the surface for CPs). To help ensure optimal coverage with multiple buoys deployed and transmitting simultaneously, the AOC MK10A system utilizes three data channels: Channel 12 (170.5 MHz), Channel 14 (172.0 MHz), and Channel 16 (173.5 MHz).

AOC employs standard A size (36 inch length, 4.875 inch (12.4 cm) width) sonobuoy canisters and launch tubes. AXBTs can either be deployed from an internal free fall chute or they can be pre-loaded before flight into as many as 22 external launch tubes (reduced to 16-17 available external tubes depending on the IWRAP antenna installation and configuration). AXCTDs and AXCPs must be deployed using the internal free fall chute.

There are advantages to externally launching AXBTs (which employ explosive Cartridge Activated Devices or CADs to eject the sonobuoy canister out of the tube). By not employing the internal free fall chute the Orion can fly at higher altitude with the cabin remaining pressurized. This reduces fuel consumption allowing for more time on station. Current AOC operating policy also prohibits flight above 10,000 feet with the cabin unpressurized to reduce the risk of hypoxia. External launches also do not require the operator at Station 5 of the Orion to get out of his seat to manually load the buoy into the free fall chute, thus reducing the risk of injury in turbulent conditions.

After release, the buoy is stabilized by a parachute. Depending on the altitude of the Orion, typically within 60 to 120 seconds an AXBT will splash down and the canister will open deploying the descending probe as well as the floating buoy transmitter, and the MK10A on the WP-3D will begin receiving data. Activation typically occurs within 30 to 40 seconds of splash. The typical length of wire for most AXBTs in the AOC inventory is 400 meters so they will usually transmit ocean temperature for 6 to 7 minutes before the wire breaks. The AN/SSQ-36B has an 800 meter depth capability. AXCTDs (1000 meters) and AXCPs (1500 meter) use the longer wire lengths mentioned earlier so they can transmit for well over 10 minutes. Shown below are the float assemblies for a Sippican AXCP and AXCP and the full AN/SSQ-36B.

The figure below (from a Deepwater Horizon mission) shows the type of coverage employing all three varieties of expendable probes that can be accomplished during a single AOC WP-3D mission.



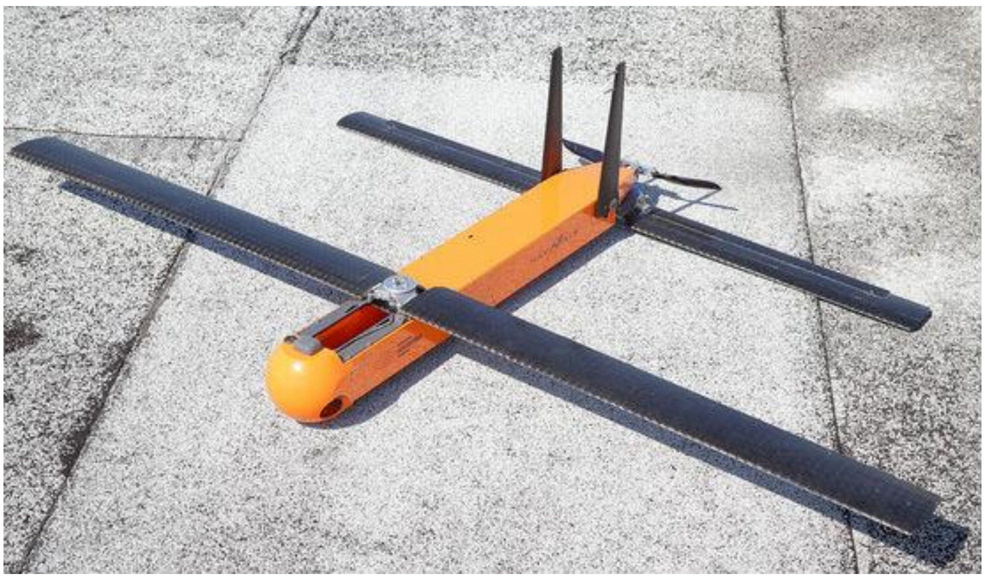
Flight Track and buoy deployment points for the WP-3D Deepwater Horizon mission flown on 11 June 2010. The tracks and points are overlain above a warm core eddy detached from the Loop Current in the eastern Gulf of Mexico (Figure from AOML / University of Miami RSMAS).

III. Future Capability in Ocean Sensing

Over the past two years, a prototype dropwinsonde has been successfully tested at AOC which uses an infrared sensor to scan below as it falls. Within a few seconds of splash the IR sensor has demonstrated the ability to accurately measure ocean skin temperature. Given sufficient wind and mixing, this reading should be reasonably representative of a one meter sea surface temperature. Heading into the 2015 Atlantic Hurricane Season, AOC has retrofitted 169 of the standard Vaisala production inventory AVAPS II sondes with this modification to include the IR sensor. Intercomparison with AXBTs in a variety of ocean conditions and wind regimes over the next year should allow for a determination to be made as to the suitability of this new technology with regard to augmenting expendable buoys in mapping SSTs.

AOC has been launching Puma Unmanned Aerial Systems (UASs) from NOAA research vessels and US Coast Guard ships for the past two years. This small (13 lb) aircraft with a wing span of 9 feet is battery operated and hand launched with a flight duration of two hours. While video camera recording of marine mammals in support of NOAA's Marine Sanctuary program and related missions has been the primary role of this aircraft, it holds potential to carry a variety of payloads including remote sensing of the ocean and coastal waterways. The same is true of the Coyote UAS. Coyote was successfully launched from a WP-3D (through the buoy free fall chute using the same standard A size canister discussed earlier) into Hurricane Edouard in September of 2014. Multiple Coyotes were deployed in two different missions. One aircraft flew for 68 minutes, which included an extended period at very low altitude prior to the battery life being reached. While the Coyote is currently envisioned as a meteorological platform for study of the atmospheric boundary layer it can readily be adapted to hold remote sensing instruments for ocean study.

NOAA Puma UAS being hand launched from the deck of a US Coast Guard vessel.



Coyote UAS