Enhanced Geospatial Functionality for NOAA's Ocean Exploration Data

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***Abstract*—National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) is transitioning its suite of ocean exploration geospatial products and services into NOAA's GeoPlatform - an instance of ArcGIS Online. This cloud-based platform supports accelerated data visualization, spatial analyses, collaborative workspaces (e.g., groups), and map product creation. NCEI hosts ocean exploration data access layers, multiple bathymetric image services, and various remotely operated vehicle (ROV) feature services. NCEI also supports near real-time operation tracking for NOAA Ship *Okeanos Explorer* via a web map as well as a 3D web scene compiling all ROV-related services. NCEI plans to build upon these initial services as NOAA Office of Ocean Exploration and Research (OER) expands its exploration efforts.**

Keywords—Ocean Exploration, ArcGIS Online, GeoPlatform, NOAA, Okeanos Explorer, ROV, Deep Discoverer

I. Introduction

National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) works closely with NOAA Office of Ocean Exploration and Research (OER) to ensure that ocean exploration data collections are FAIR (Findable, Accessible, Interoperable, Reusable) to the public. NCEI carefully stewards vital sonar, oceanographic, atmospheric, image, video, and collected specimen data and requisite information that contribute greatly to the scientific understanding of the world's oceans. A key objective of OER's exploration model is rapid and unfettered public data access for purposes of environmental characterization, resource management decisions, and to support the development of hypothesis-driven research [1]. NCEI ensures the long-term preservation of NOAA's exploration data collection by making the distributed data and supporting documents centrally discoverable through the Ocean Exploration Digital Atlas web map. Although effective for data access, the Digital Atlas requires users to download and use their own GIS environment for data visualization and analysis.

NCEI is transitioning its suite of ocean exploration geospatial services and products into NOAA's GeoPlatform, an instance of Esri's ArcGIS Online. This cloud-based platform supports accelerated data visualization, spatial analyses, collaborative workspaces (e.g., groups), and map product creation. This transition not only aligns with NOAA's newly developed Cloud Strategy [2], but hosting data services on NOAA's GeoPlatform will also help put these vital data to work. The initial development of geospatial services is focused on products derived from data collected by NOAA Ship *Okeanos Explorer* and OER's remotely operated vehicle (ROV) *Deep Discoverer*. These ocean exploration data were initially chosen due to consistent naming conventions and file types, sustained collection history, and ease of integration with geospatial services. NCEI plans to expand upon these services to include additional ocean exploration layers as well as other NOAA data sets. Building these geospatial services within a cloud environment also facilitates expansion into unmanned systems [3] and artificial intelligence [4].

II. ArcGIS Online Development

A. Data Access Layers

Since not all OER funded cruises include ship trackline data, cruises are geospatially displayed as points within the Digital Atlas. This point REST service supports data access at a regional level but does not adequately display where data were collected - this is especially true for transit cruises that cover large geographic areas. NCEI now hosts two OER data access feature layers within NOAA's GeoPlatform: an All Points feature layer and a Tracklines Only polyline feature layer for cruises with trackline data. Providing both options allows users to determine which service better suits a specific need. For example, the All

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Points feature layer, which contains a more comprehensive list of OER funded cruises, is primed for attribute joins.

Ship tracklines were constructed by using a Python script (ArcPy) to read ASCII navigation files and output a file geodatabase feature class. The resulting polylines were then generalized using the ArcGIS Simplify Line tool to reduce the number of vertices. The geodatabase was then uploaded to the NOAA GeoPlatform and published as a hosted feature layer. Drawing optimization is enabled on the tracklines layer for a more efficient load time. The ROV dive tracks (described under *ROV Dive Services*) were created in a similar way.

Data access is provided through embedded hyperlinks found within each OER Data Access layer's pop-up (Fig. 1). Pop-ups were configured using Esri's Arcade expression language. Arcade supports custom labeling and data visualizations within the ArcGIS Platform. All links and headings found within the pop-ups are included within the geodatabase used in creating and updating these data access services. Additionally, end users have the ability to view and alter these pop-up configurations within their own ArcGIS environment. Any changes performed by end users, including pop-up configurations, do not affect the authoritative source hosted by NCEI.

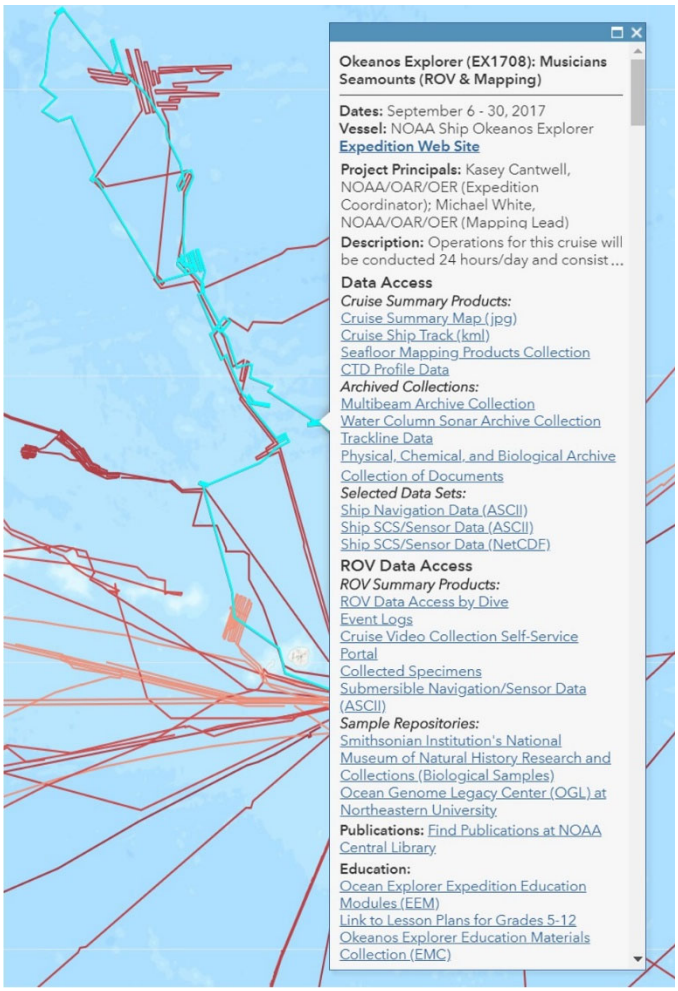

Fig. 1. Esri's Arcade expression language supports custom pop-ups. The pop-up in this figure details available information and data access links for NOAA Ship *Okeanos Explorer* ROV expedition (EX1708) in the mid-Pacific.

B. *Bathymetric Image Services*

Raw and semi-processed ocean exploration bathymetry data are archived in many different file types, some of which require specialized software and expertise to visualize (e.g., .all, .gsf, etc.). Hosting geospatial products - like the bathymetric image services - allows users to readily visualize data, filter out subsets, perform spatial analyses, and create map products without the need for proprietary software.

NCEI developed six bathymetric services for NOAA Ship *Okeanos Explorer*'s multi-beam sonar data to meet various user needs without compromising rendering performance. The Bathymetric Coverage polygon feature layer displays polygon footprints for bathymetric surveys; it is best used for planning and determining where multi-beam data were collected. The Provisional Daily Updates image service displays daily bathymetric products as they are collected. A Python script automatically retrieves the latest daily multi-beam sonar grids from the ship and updates the image service daily. These provisional data are not archived and the service is emptied as the quality controlled versions are made available within the other bathymetric services. The Bathymetric Grids image service provides elevation values and various color ramp visualization options; while the Bathymetric Grids (Subsets) image service supports filtering of data to display subsets (e.g., individual surveys, years, etc.). Image services were implemented using an ArcGIS mosaic dataset to manage and organize the underlying raster data. The Tiled Color Hillshade service supports a more accelerated load time, and can be viewed in conjunction with the Tiled Elevation Layer for a three-dimensional visualization within an ArcGIS Online web scene.

These bathymetric image and tile services are intended for visualization and provisional analysis only. Resolutions vary throughout the mosaic dataset and it should not be used for navigational purposes. Users who wish to download specific multi-beam sonar data should do so through NCEI's Bathymetric Data Viewer which provides access to NCEI's entire bathy-metric data archive holdings.

C. *ROV Dive Services*

ROV *Deep Discoverer* is equipped with high-definition video cameras; two manipulator arms capable of collecting biological and geological samples; a conductivity, temperature, and depth (CTD) instrument; a dissolved oxygen sensor; water collection bottles; and a suction sampler for more delicate biological samples. Spatial coverage of ROV dives are fairly limited and are difficult to identify at regional to global scales. The ROV Dive Locations point feature layer allows users to more easily locate dive sites at global to regional scales, while the ROV Dive Tracks polyline feature layer provides more detailed information at a local scale. ROV dive tracks contain depth values which support data visualization in both two-dimensional maps and three-dimensional scenes. The ROV Entry/Exit Points feature layer signifies where ROV *Deep Discoverer* entered and exited the water, as well as when the ROV began and ended the benthic exploration portion of a dive. Pop-ups were configured with Esri's Arcade expression language to provide data access.

III. Enhanced Visualization of Ocean Exploration Data

A. Live Operations Map

OER prioritizes live interactions with shore-side scientists and the public through the use of telepresence technologies. In response, NCEI supports near real-time ship tracking capabilities for *Okeanos Explorer* within the Live Operations Map (Fig. 2). This web map includes the near real-time Ship Position service, the near real-time Ship Track service, the Provisional Daily Updates bathymetric image service, and other relevant ocean exploration data services. *Okeanos Explorer*'s position is automatically updated using emails sent from the ship at 15-minute intervals. Once the ship position service receives a new set of coordinates, the previous coordinates are automatically appended to the ship track service. These services only need to be manually started at the beginning of a cruise; at which time, all operational updates are automated using a customized Python script.

Due to a future implementation strategy to incorporate near real-time ROV data, NCEI is currently in the process of upgrading the communication protocol from automated emails to a user datagram protocol (UDP) feed. UDP is used for low-latency transmission between computer networks where large volumes of UDP messages are received with minimal delay and is the preferred method for near real-time data transfer. UDP is also loss tolerant and the process receiving the incoming data packets will accommodate any data transmission deficiencies. The UDP feed currently includes ship tracking information (latitude, longitude, speed, heave, pitch, and roll), wind (speeds and direction), air (temperature, pressure, and humidity), water (depth, temperature, salinity, and conductivity). Future integrations will begin to include ROV data within the UDP feed.

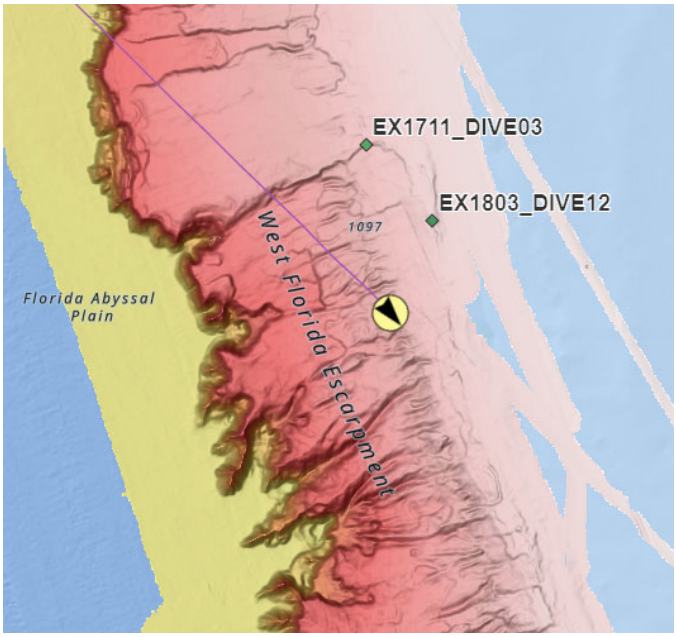

Fig. 2. The Live Operations Map provides shoreside scientists and the public with near real-time ship tracking capabilities. The yellow encircled arrow indicates NOAA Ship *Okeanos Explorer*'s location and heading on March 7, 2020. The Bathymetric Grids image service incorporates multi-beam sonar data products from multiple *Okeanos Explorer* cruises.

In an effort to accommodate the new UDP feed being transmitted from the *Okeanos Explorer*, a development server has been set up at NCEI to integrate a UDP simulator from compiled data packets collected from a previous cruise. There is a background process running on the server that simulates the cruise and sends datagram packets every second. A second background process runs on the server which listens to the UDP port for the incoming datagram packets. Since the UDP is loss tolerant, validation checks are performed on the incoming data feed and successful packets are captured every five minutes

B. ROV Dive Tracks Scene

The ROV Dive Tracks Scene exemplifies how hosted feature services and tiled image services can be combined for enhanced visualization of ocean exploration data (Fig. 3). The scene's ground layer is composed of the Okeanos Explorer Bathymetric Grids (Tiled Elevation Layer) and the GEBCO_2020 Tiled Elevation layer; the Okeanos Explorer Tiled Color Hillshade layer is included for visualization purposes. Essentially, the elevation layer is the data mesh in which the Hillshade visualization is draped. This three-dimensional web scene allows users to interactively explore ROV *Deep Discoverer* dive sites and perform analyses without having to download and process raw navigation data. Due to sensor discrepancies between the ground layer (created from a mosaic dataset of gridded multi-beam bathymetry) and ROV depth values (collected by onboard CTD), all ROV dive services are vertically offset by 10 meters. This offset is for visualization purposes only and does not affect the underlying data.

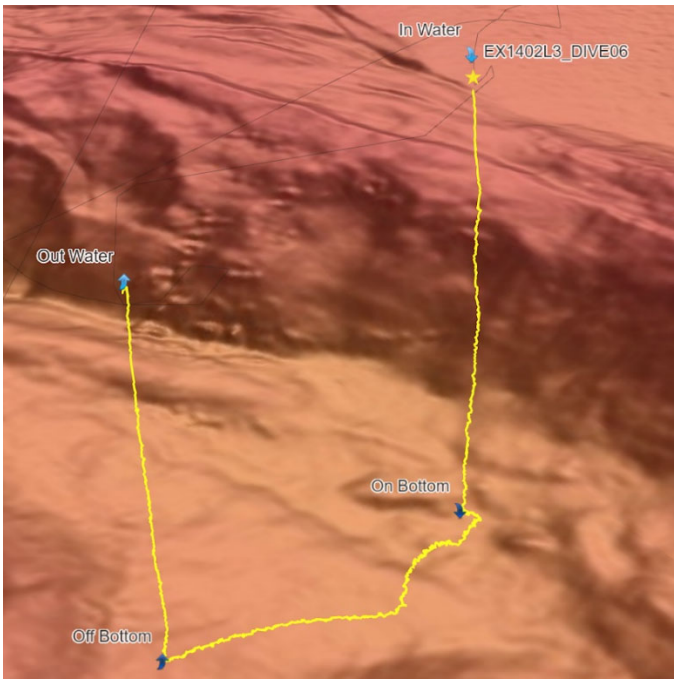

Fig. 3. The ROV Dive Tracks Scene allows users to interactively explore ROV *Deep Discoverer* dive sites three-dimensionally within a cloud-based, geospatial environment. This figure exhibits Dive 06 from NOAA Ship *Okeanos Explorer* expedition (EX1403L2). The ship track (thin black line), ROV dive location (star), ROV dive track (yellow), and ROV entry/exit points (blue arrows) can all be viewed along with the underlying seafloor bathymetry. The ground layer is generated from the Tiled Elevation service and visualized with the Tiled Hillshade service; both services incorporate multi-beam sonar data products from multiple *Okeanos Explorer* cruises.

IV. Summary

For nearly two decades, NOAA NCEI has supported the management and preservation of NOAA's ocean exploration data. NCEI's transition of geospatial services into NOAA's GeoPlatform strengthens this support through improved data access layers, seamless bathymetric image and tile services, near real-time operation tracking, and three-dimensional visualization of ROV dive sites. These ocean exploration data services provide NOAA, the ocean exploration community, and the greater public with visualization tools that will save resources spent on data search, download, preprocessing, and spatial analyses. Each web service has been developed with multiple use cases in mind. These services are geospatial building blocks that can be used in a variety of applications (e.g., expedition planning, hypothesis-driven research, machine learning, etc.) by many different users. All services are interoperable through the ArcGIS REST API. Additionally, most services are accessible via Open Geospatial Consortium (OGC) Web Map Service (WMS), Web Coverage Service (WCS), and Web Feature Service (WFS) specifications. NCEI will continue to develop and update web services in support of NOAA's ocean exploration endeavors.

NCEI is also investigating the ArcGIS Experience Builder and the ArcGIS API for Javascript for a future ocean exploration platform that can provide OER and the public with a centralized environment for data discovery, visualization, and analysis. Centrally displaying where oceanographic data, sonar, image, video, and specimens were collected provides NOAA with a comprehensive view of current ocean exploration data holdings while also highlighting data poor areas. This would allow NOAA and partners to prioritize and systematically plan where to focus ocean exploration expeditions, helping NOAA meet the 2019 Presidential Memorandum [5] and 2020 National Strategy [6] to map, explore, and characterize unknown regions within the United States' Exclusive Economic Zone.

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