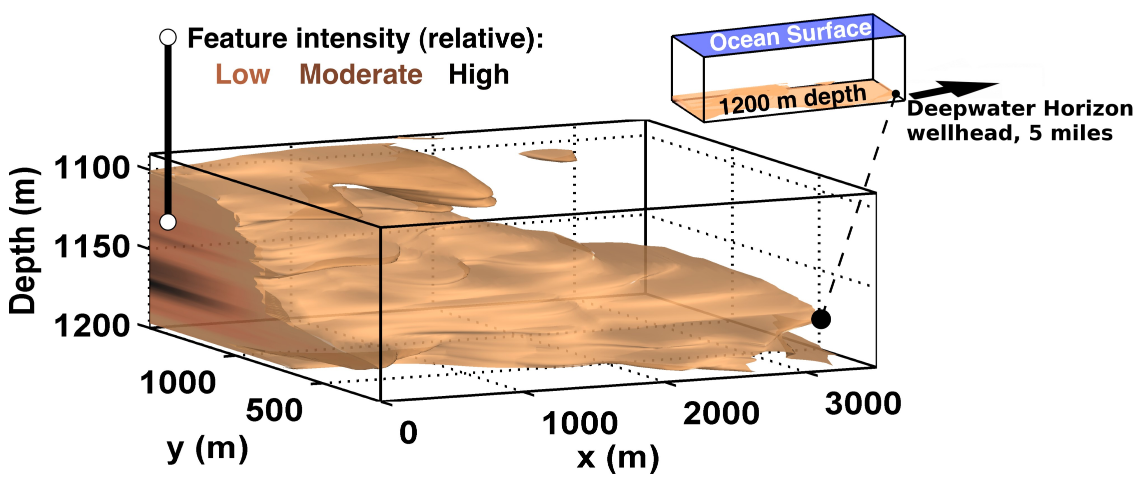
Data Report
NOAA Ship *Gordon Gunter* cruise GU-10-02, Gulf of Mexico
June 2 – 3, 2010 operations of the MBARI AUV *Dorado*

Summary

During a Gulf of Mexico mission of the NOAA Ship *Gordon Gunter* between May 27 and June 4, 2010, a unique autonomous underwater vehicle (AUV) operated by the Monterey Bay Aquarium Research Institute (MBARI) was deployed near the BP Deepwater Horizon wellhead to collect data and samples. The primary purpose of the cruise was investigation of subsurface oil. The AUV deployment site, approximately five nautical miles southwest of the wellhead, was determined based on antecedent observations made by collaborating scientists from NOAA and the University of New Hampshire.

This report summarizes sensor data from AUV surveys conducted on June 2 – 3, when optical and chemical measurements indicated hydrocarbon detection in a plume-like feature below 1000 meters depth. Physical samples were acquired from this feature by ship and AUV sampling systems, and NOAA is managing shore-based laboratory analyses of these samples. When results from these analyses are available, more complete interpretation of the deep feature mapped by the AUV will be possible, including identification of chemical composition, concentration ranges, and source (wellhead or natural seafloor seep).



The illustration above shows the deep plume-like feature mapped by the MBARI AUV *Dorado* on June 3, 2010. The data and methods used to describe this feature are summarized in this report. The brown hues of the feature represent the tea-like colors of Colored Dissolved Organic Matter (CDOM) because CDOM fluorometry was the basis for feature detection, data analysis and visualization.

M B A R I

Introduction

A key goal shared by Gulf oil-spill researchers is to map, sample and analyze subsurface hydrocarbon-enriched plumes in order to understand their distributions, transport, aging and ecosystem consequences. Marine researchers striving to provide useful information for management and mitigation are adapting existing ocean observing capabilities, including traditional and emergent technologies. During May 27 – June 4, 2010, MBARI participated in an oil-spill response cruise sponsored by NOAA and conducted from the NOAA Ship *Gordon Gunter*. MBARI contributed operations of the *Dorado* AUV, which was equipped with (a) sensors capable of detecting optical and chemical signals of subsurface hydrocarbons, and (b) a recently developed subsystem capable of autonomously acquiring samples from targeted features of interest. The relatively fast survey speed and deep-diving capabilities of this AUV were essential for mapping and sampling target features near the BP Deepwater Horizon wellhead. This report summarizes sensor data from AUV surveys conducted on June 2 – 3 (Figure 1), when ship and AUV sensors detected signals of particular interest to cruise objectives. The data are used to illustrate a method to distinguish specific signals of a hydrocarbon-enriched plume from the oceanic background signal. More complete interpretation of the deep plume feature mapped by the AUV will be enabled by the results of NOAA's shore-based laboratory analyses of physical samples from the feature.

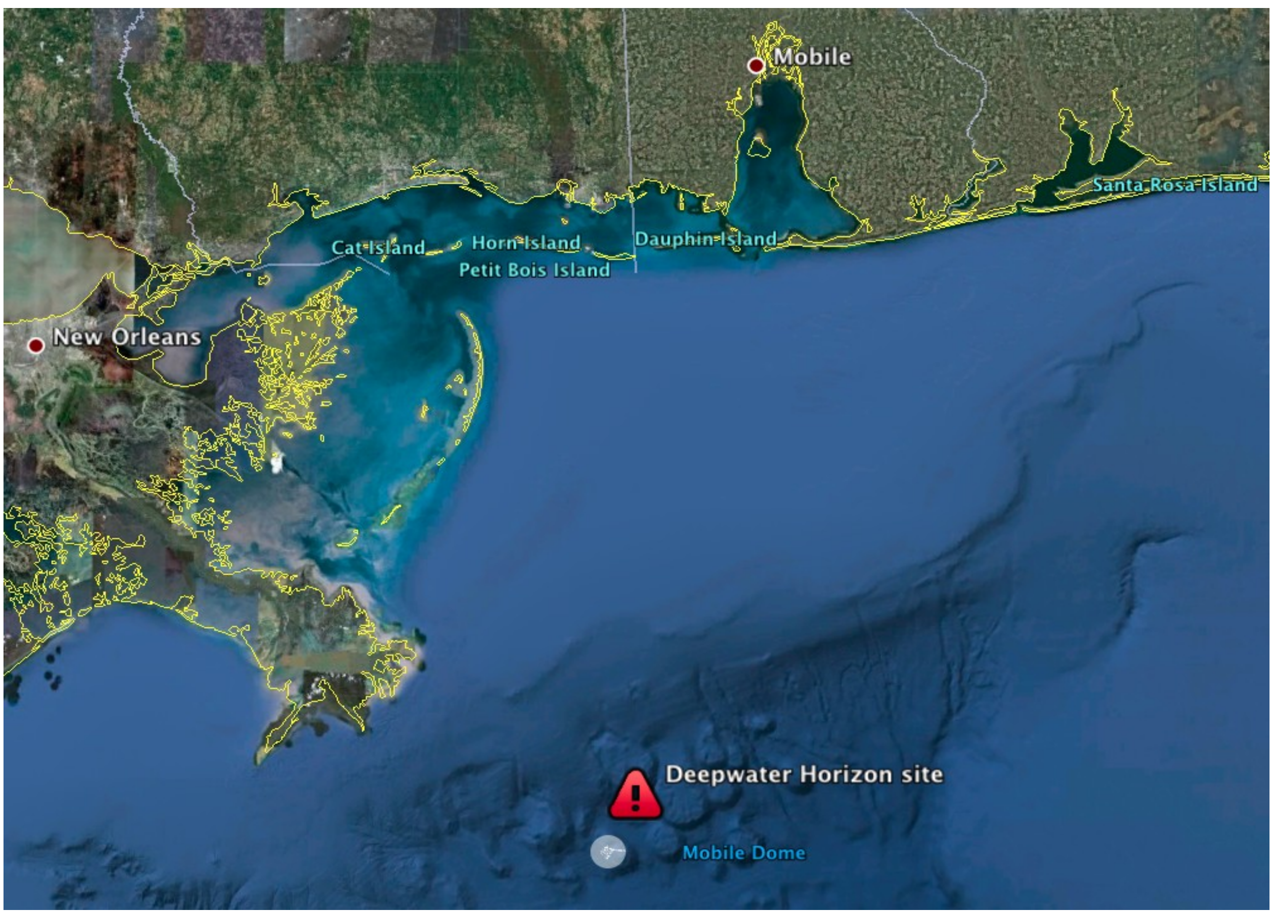


Figure 1. *The map shows the location of June 2 – 3 AUV surveys, in the highlighted area southwest of the Deepwater Horizon wellhead. See Figure 2 for more detail.*

1. AUV sensor measurements

Table 1. Variables measured with sensors on the MBARI AUV

Variables	Sensors
Temperature, Salinity	Dual Sea-Bird Electronics SBE3 temperature and SBE4 conductivity sensors, using SBE25 conductivity, temperature, depth (CTD) board sets
Pressure	Paroscientific Digiquartz 8CB4000-I High Pressure Intelligent Depth Sensor, 0-4000 m range
Density	Derived from temperature, salinity and pressure using the MATLAB seawater analysis toolbox from CSIRO
Dissolved oxygen concentration	Sea-Bird SBE43 oxygen sensor
Colored Dissolved Organic Matter (CDOM) fluorescence	WETLabs ECO-FL CDOM fluorometer 370 nm excitation; 460 nm emission
Optical backscattering at 420 nm	HOBI Labs HydroScat-2
Optical backscattering at 700 nm	HOBI Labs HydroScat-2
Chlorophyll fluorescence at 700 nm (420 nm excitation)	HOBI Labs HydroScat-2

2. AUV survey locations and methods

At a site approximately 5 nautical miles southwest of the Deepwater Horizon wellhead (Figures 1, 2), ship hydrocasts by NOAA scientists measured very high CDOM signals between 1100 m and 1200 m depth. The EK-60 echosounder measurements by University of New Hampshire and NOAA scientists also recorded strong acoustic backscatter. In response, the MBARI AUV was deployed at this site for surveys on June 2 and 3 (Figure 2). The AUV surveys targeted a deep (900 to 1200 m) volume, which was surveyed in a series of vertical sections. The AUV surfaced for GPS acquisition after completing each section, thus also repeatedly collecting profiles between the surface and 900 m depth. Two deep sections were completed during the June 2 survey, and seven sections were completed during the June 3 survey.

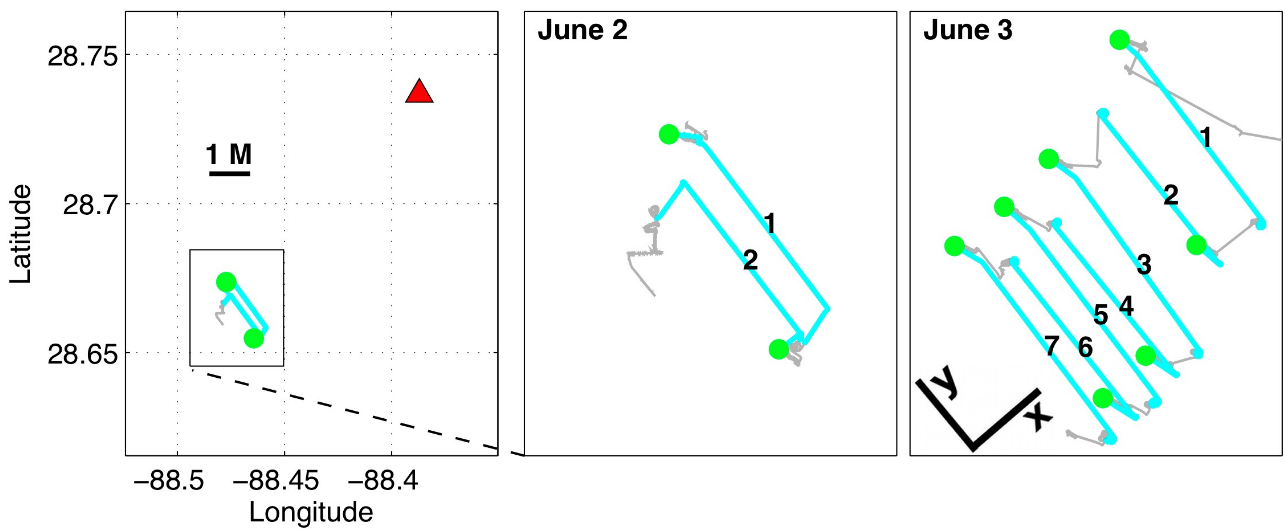


***Figure 2**. Locations of deep vertical sections mapped by AUV on June 2 - 3, 2010. The map at the left shows the Deepwater Horizon wellhead location (red triangle) and the AUV survey domain (inset box); a 1 nautical mile distance reference is shown north of the AUV domain. Portions of the AUV track below 900 m are shown in cyan, and the start of each vertical section is indicated by a green circle. The numerical labels on the sections indicate the order in which they were acquired and the order in which they are later presented. The x-y coordinate-system reference on the June 3 plot defines the orientation of the volume visualization presented at the end of this document.*

3. Deep-water feature definition

Consistent with measurements of other researchers in the Gulf of Mexico, we are using Colored Dissolved Organic Matter (CDOM) fluorescence as a potential indicator of subsurface hydrocarbons. All of the data from the CDOM fluorometer acquired on June 2 – 3 are shown in Figure 3. The maximum CDOM concentration exhibited a linear trend between 200 and 1000 m depth (blue line). To define the expected maximum background levels between 1000 and 1200 m, we extrapolated the linear trend (red line). CDOM fluorescence above the expected maximum value in the depth range of 1000 to 1200 m is defined as signal from the feature of interest. This definition will be used as the basis for (1) examining relationships between CDOM fluorescence and other variables within the feature of interest, and (2) defining threshold values to describe 3-D structure of the feature.

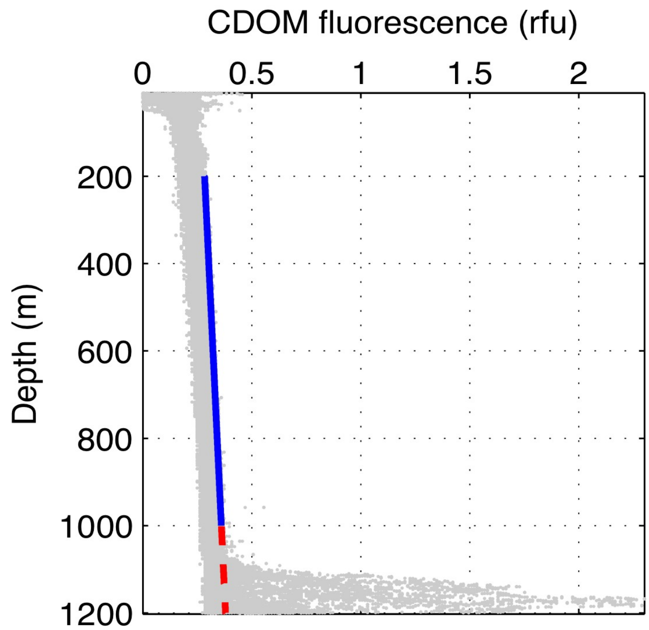


Figure 3*. All data acquired by the CDOM fluorometer (Table 1) on June 2 – 3. The blue line shows the linear least-square fit between maximum CDOM fluorescence and depth, for the depth range 200 to 1000 m, and the red line shows the extrapolation of this relationship to 1200 m depth. The units rfu in this and subsequent plots stand for relative fluorescence units.*

The signal of interest was all below 1000 m; this is consistent with findings from other research efforts in the region. Knowledge of the depth distribution of hydrocarbon signals is valuable for not only scientific research, but also operational planning, specifically with regard to evaluating which platforms can access such deep features. For example, some autonomous gliders may not be capable of reaching this depth.

4. Vertical profiles

Vertical profile plots of all AUV data from June 2 – 3 show the feature of interest, below 1000 m depth, in 5 of the 8 AUV sensor measurements (Figure 4). The feature is identified by elevated fluorescence at 460 nm (CDOM) and 700 nm, elevated optical backscattering at 420 nm and 700 nm, and depressed oxygen concentrations. Fluorescence at 700 nm, excited at 420 nm, is typically used to quantify chlorophyll fluorescence, and the shallow (<100 m) signal in this variable is consistent with a phytoplankton layer, unlike the deep, stronger signal.

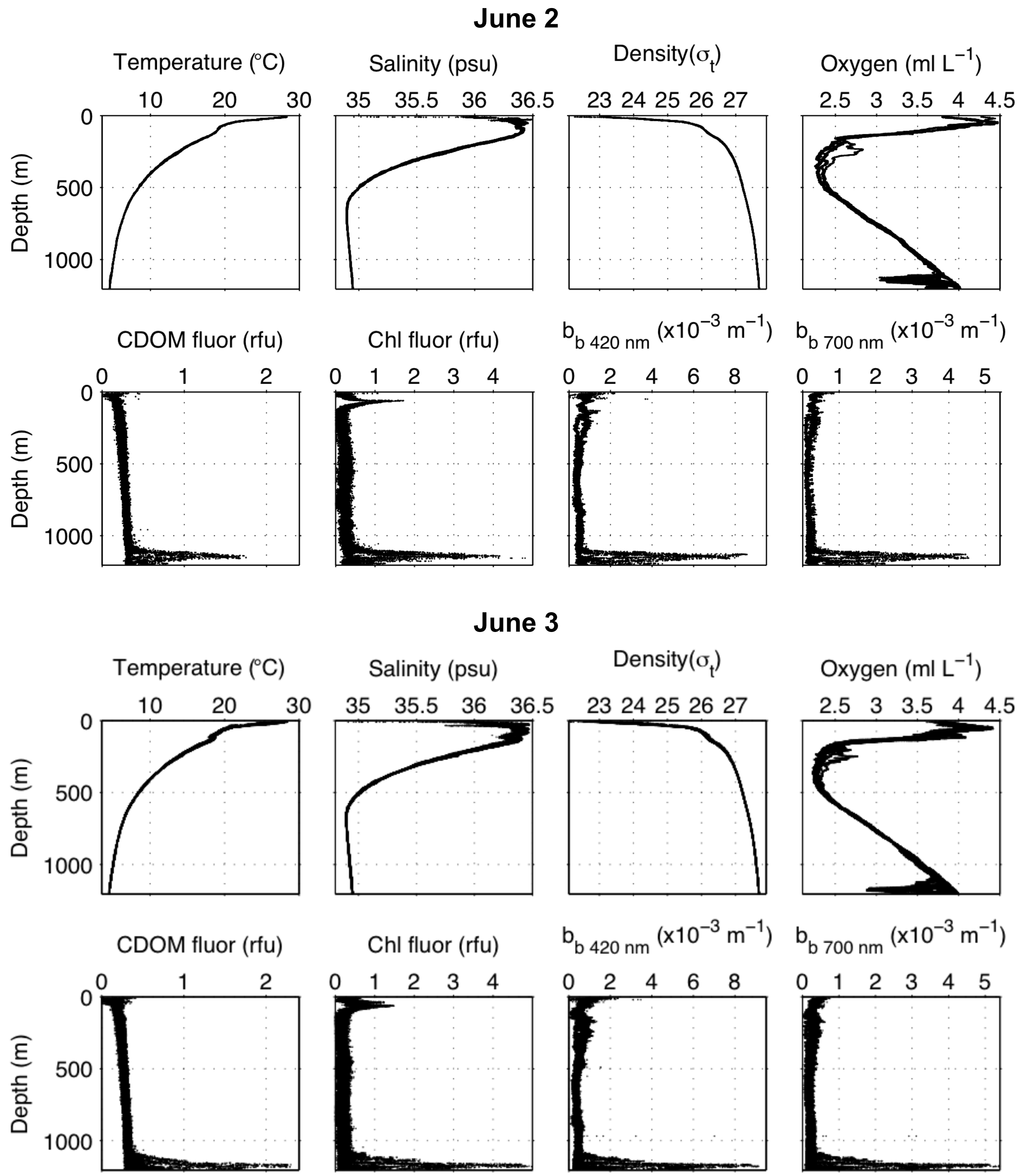


***Figure 4**. Profile plots of all AUV data collected during the June 2 – 3 surveys.*

5. Vertical sections

Synoptic vertical sections, shown for 4 of the 8 variables, exhibit corresponding structure in chemical and optical properties in the deep feature of interest on both days (Figure 5).

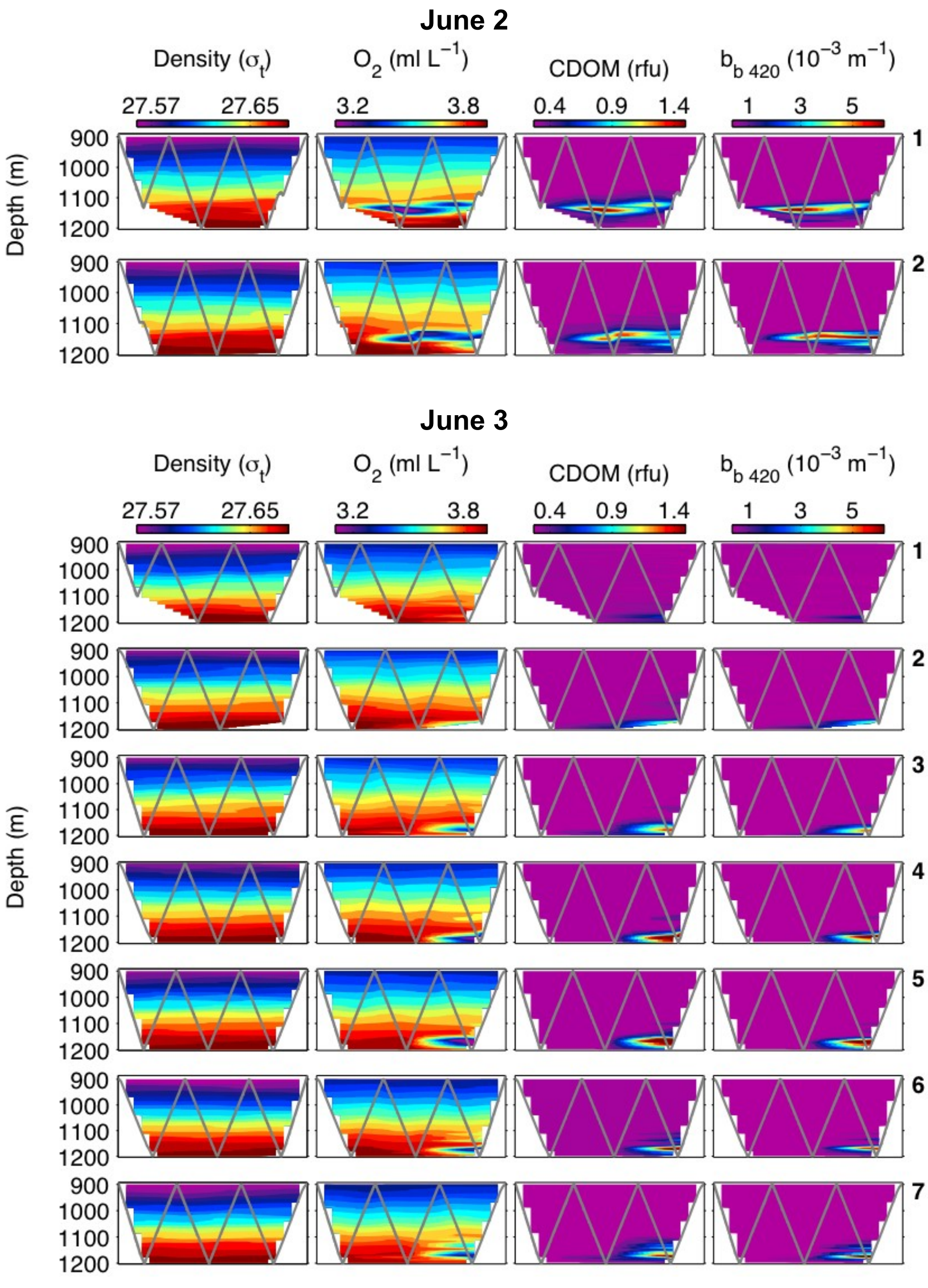


Figure 5. *Vertical sections of a subset of properties (Table 1). The AUV survey track is overlaid on each section (gray lines). The unlabeled x-axis is time; North is to the right. Numbers along the right edge correspond with section identification in Figure 2.*

6. Property-property relationships

According to the feature-of-interest definition (Section 3), examination of feature indicator variables showed similar relationships on both days (Figure 6). All optical variables were positively correlated with the primary indicator (CDOM), while oxygen was negatively correlated.

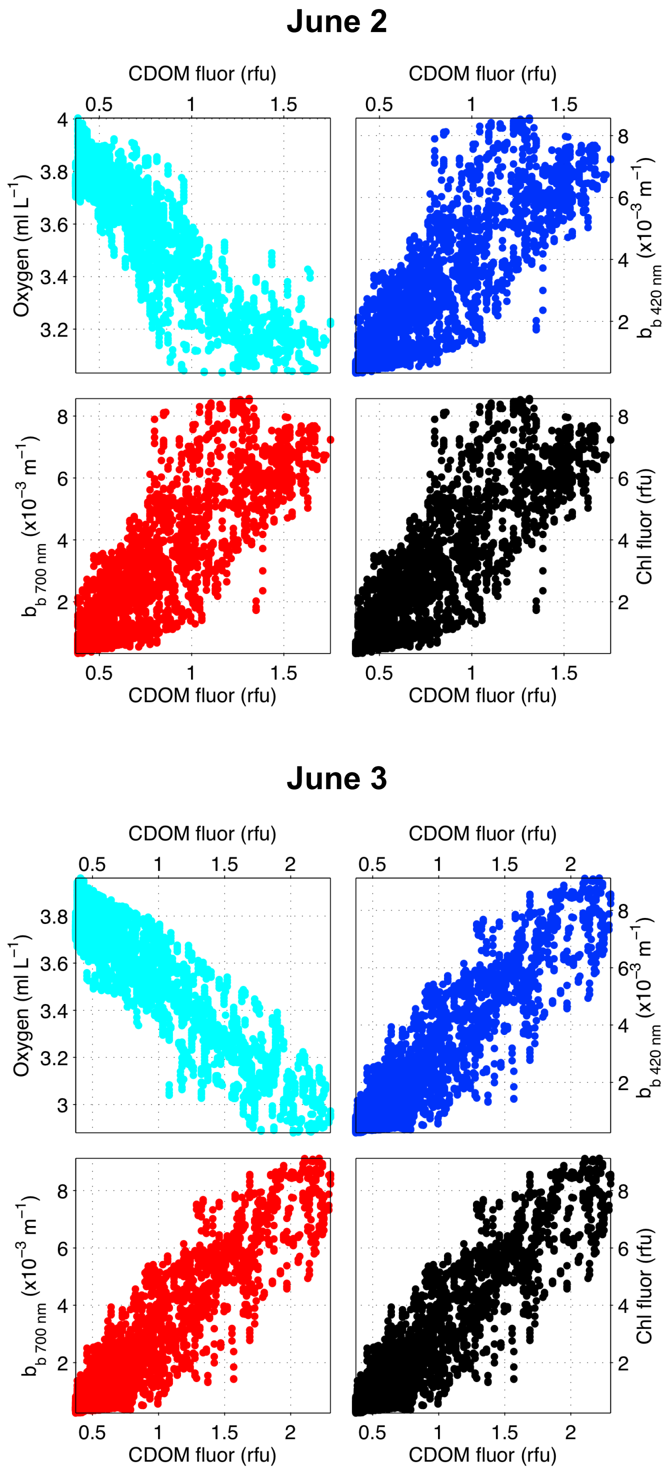


Figure 6*. Relationships between feature-indicator variables, with CDOM as the primary reference.*

7. Volume visualization

The June 3 survey provided reasonably dense sampling within the target volume, acquiring more than 65,000 CDOM measurements within the 900-1200 m depth range, along seven sections (Figure 2), in 9.3 hours. Interpolating between the vertical sections (Figure 5) provides a model of the CDOM signal variation within the volume. Applying the definition of the subsurface feature of interest (Section 3) to this model allows a description of the three-dimensional shape of the feature of interest (Figure 7). The signal was clearly from a feature larger than the domain surveyed.

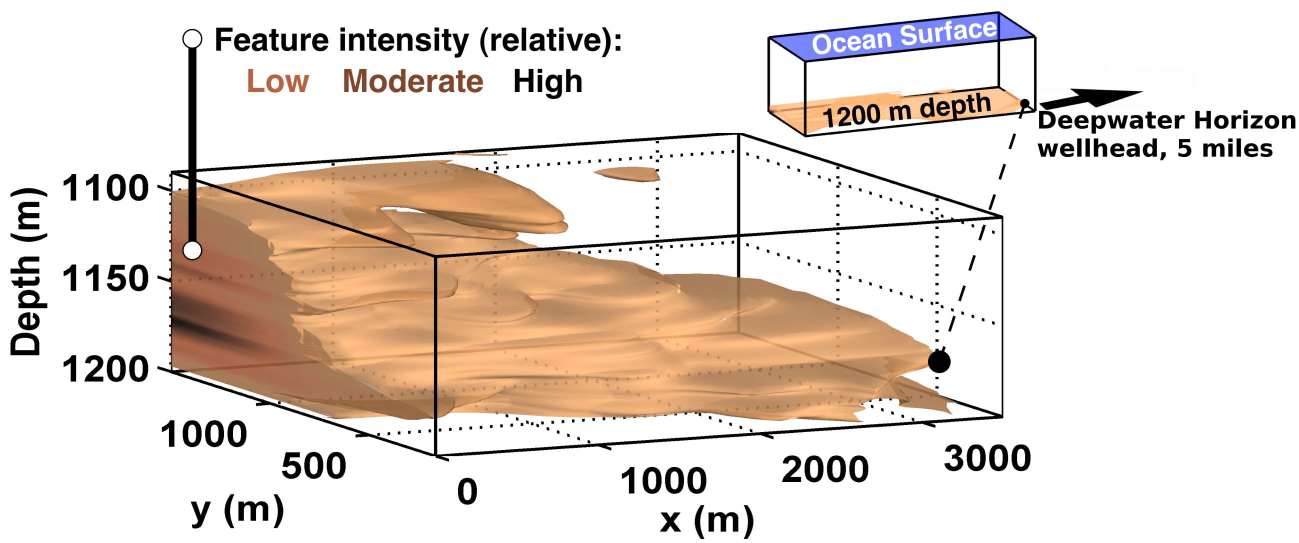


Figure 7*. Three-dimensional structure of the deep feature of interest, as defined by analysis of CDOM fluorometer data (Section 3). The horizontal coordinate system is shown in Figure 2, and the view is from the south and above. The Deepwater Horizon wellhead is northeast of the volume (Figures 1, 2). Shown at the upper right is the proportionally accurate spatial representation of the volume surveyed and the deep feature within the volume. Shown below this reference volume is a magnified view of the feature's structure. The black dots connected by the dashed line identify the same point within the volume. The semi-transparent surface describes the shape of the feature boundaries within the volume. Striated color variation along the left face of the volume illustrates variable intensity (concentration) within the feature.*