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Short communication

Determination of sea-floor seepage locations in the Mississippi Canyon

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ABSTRACT

The ephemeral nature of marine oil and gas seepages and their complex trajectories in the water column make seep sampling difficult and costly. Here we report on how active natural seepage can be detected and located in the water column and at the sea bed in real time through the integration of marine X-band radar, synthetic aperture radar, field observations, high resolution single beam acoustic methods, and meta-ocean data from the marine environment with a simple bubble rise model.

The extent of predictions made using a bubble rise model narrow down the likely seafloor origin point of an observed surface feature to within a radius of 630 m within which clusters of acoustic contacts were detected. Use of averaged deep current velocities and directions narrows the radius to 130 m, and use of a smaller established range of bubble rise speeds from the Gulf of Mexico can narrow the predicted sea-floor origin radius further to 16.5 m. These results are useful for focussing detailed sea bed search patterns for natural seepage and are also suggestive of a seep system with complex water column trajectories associated with Biloxi Dome in the Gulf of Mexico.

1. Introduction

Following the events of the 2010 Deepwater Horizon oil spill, a survey of natural seepage in the Mississippi Canyon of the Gulf of Mexico was commissioned by BP and the Natural Resource Damage Assessment Trustees (NRDA) during late August and September of 2011. The aim of the survey was to sample and characterise active natural seepage on the sea surface, in the water column and at the sea-bed, in the vicinity of the Deepwater Horizon site. The survey area was focused on the salt domes around the site, Biloxi Dome being one of the main target areas located to the south-west. The Biloxi Dome is 13 km long and 5 km wide, elongated in a NW–SE direction and in water depths of approximately 1400 m (Fig. 1). The edges of the dome, especially the south-eastern edges, are characterised by faults and fracture networks.

The *M/V Sarah Bordelon* was the lead vessel of three vessels during the survey, tasked with the role of delineating and sampling surface slicks; determining the location of bubble streams in the water column and identifying seabed locations for further sampling and investigation. Achieving these tasks required the detection of the oil slicks in real time in order to perform efficient sampling, and to understand the spatial relationships between acoustic water column data and sea surface expression. For slick detection, images obtained with Synthetic Aperture Radar (SAR) have been proven to be very reliable tools for the detection of surface oil slicks produced by prolific natural seepage in the Gulf of Mexico, (Garcia-Pineda et al., 2010; MacDonald et al., 2002) therefore, locating the oil slicks on the sea surface using SAR was one of the key elements used for surface slick delineation. Multiple Cosmo/Skymed, and Radarsat-2 images of the study area were provided to the vessel by the Center for Southeastern Tropical Remote Sensing (CSTARS) within three hours of acquisition during the survey. To achieve real time detection of surface oil slicks, the vessel was equipped with an S6 Marine X-band radar system with a standard radar console

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(Rutter Technologies, Canada). Marine X-band radar as a tool for detection of oil slicks has been established during field trials with test slicks (Egset and Nost, 2007), however use has not been widely reported for the detection of surface expression from natural seepage.

For the detection of hydro-acoustic flares in the water column, a 38 KHz echosounder was side mounted on the vessel, with two acoustic Doppler current profilers (ADCP) for profiling the first 500 m of the water column. Surface water sampling and photography was performed for the ground truthing of SAR and X-band features. This information was combined to build simple bubble rise models and to understand the spatial relationships from the sea surface to seabed.

There is a growing debate on the quantification of material released from natural seeps reaching the sea surface and entering the atmosphere, especially in the case of seepage in deeper water (>200 m) (Hu et al., 2012; Solomon et al., 2009). The answer to this debate requires understanding of seep trajectory through the water column to allow simultaneous sampling on the seabed, in the water column and on the sea surface. Submarine natural seeps are primarily detected by acoustic methods. However, establishing the correlation between the oil slicks and seeps from the seabed is not straightforward. The migration path of the oil in the water column is three dimensional, the profile of which can be easily missed by 2D single beam echo-sound systems. Normally, oil droplets rise as bubble streams and their fate and trajectory depends on the initial size and shape of the bubble, ascent velocity, prevailing current and wind directions and the presence or absence of a hydrate stability field (MacDonald et al., 2002; McGinnis et al., 2006; Rahman Talukder et al., 2013; Rehder et al., 2009). In this study, oil slicks observed on the western flank of Biloxi Dome visually from the vessel and in both SAR and X-band imagery were used as a starting point for a prediction of their migration path and likely seafloor origin (Figs. 1 and 2). The proximity and similarity of the X-band and SAR observations indicate a persistent feature associated with the western flank of the dome, during the time of the survey and demonstrate the utility of marine X-band radar for tracking surface slicks from natural seepage.

2. Methods

2.1. Wind data

Wind speed and direction vectors acquired from in situ platforms and a satellite scatterometer showed light to moderate winds primarily from the east at about 5 m/s on the 25th, shifting to the northeast on the morning of the 26th of August before shifting to the northwest during the evening (Fig. 1, Supporting Information Figures S1 And S2, Table 1).

2.2. Water column current profile data

During the observations on the western flank of the Biloxi Dome, current profiles were collected along the vessel track to a depth of 500 m (bin depths of 21, 77, 157, 253 and 453 m respectively). At a depth of 21 m, the average current speed was 0.37 m/s,

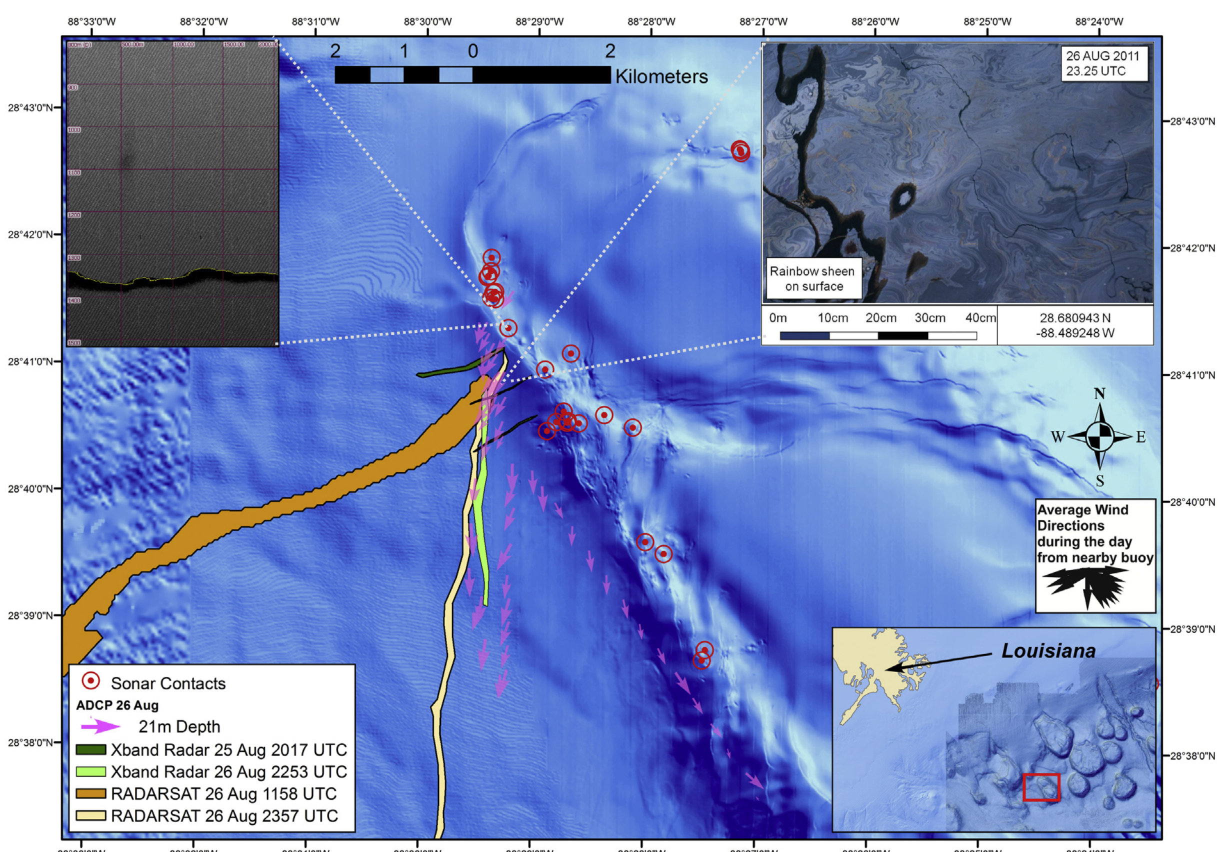

Figure 1. A map of the Biloxi Dome survey area. The main inset shows an AUV derived high resolution multibeam bathymetry relief map of the Biloxi Dome. Overlaid are the Synthetic Aperture Radar (SAR) slick areas for the 26th August. The shipboard X-band radar surface slick data from the 25th and 26th August is also shown. The photographic inset top right shows observed sheen observed in to location of SAR and X-band surface slick anomalies on the 26th August. Acoustic current Doppler profiles of surface waters to 21 m, and averaged wind speed from a buoy 28 nm to the SSW indicate wind direction and surface current were predominantly to the south during the 26th August. The multiple acoustic contacts were identified on the dome throughout the survey are also shown and the inset shows the acoustic contact within the water column.