Generating Realistic Images from Hydrothermal Plume Data

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ABSTRACT

Most data used in the study of seafloor hydrothermal plumes consists of sonar (acoustic) scans and sensor readings. Visual data captures only a portion of the sonar data range due to the prohibitive cost and physical infeasibility of taking sufficient lighting and video equipment to such extreme depths. However, visual images are available from research dives and from the recent IMAX movie, *Volcanoes of the Deep Sea*. In this application paper, we apply existing lighting models with forward scattering and light attenuation to the 3D sonar data in order to mimic the visual images available. These generated images are compared to existing visual images. This can help the geoscientists understand the relationship between these different data modalities and elucidate some of the mechanisms used to capture the data.

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1 INTRODUCTION AND MOTIVATION

Hydrothermal plumes form where hot fluids discharge from seafloor vents (commonly called black smokers) on mid-ocean spreading ridges. These hot buoyant fluids entrain the ambient seawater as they rise and are important to understanding the global transport of heat and chemicals in the ocean (which is a factor in climate studies) and to understanding the evolution of sea microbes.

Geologists, acoustical geophysicists and computational fluid dynamicists (CFD) are all involved in the study of seafloor hydrothermal plumes, and they all "see" plumes in different ways. The field geologists, in particular, are used to looking at optical photographs and videos. These are either taken directly of underwater hydrothermal plumes, where the limited visibility constrains the range and features, or are taken in the laboratory during a plume experiment. Geophysicists look at "acoustic" data, and acoustic images are significantly different from optical images. To optical tools, plumes have opaque cores, irregular but sometimes sharp edges, and slowly fading tops. Acoustic imaging sees all the way through the plume core to the other side but sees only gradational edges, because plumes are nearly transparent to transmission of acoustic waves although they do scatter them. Additionally, traditional 3D visualization is largely threshold based so the plume appears to have a sharp top (as an artifact of the chosen threshold). Computational fluid dynamicists see plumes as mechanisms of turbulent transport; they tend to focus on the size and speed of eddies rather than properties of the mean flow. Nevertheless, computationalists are more familiar with looking at isosurfaces within plumes than geologists are because CFD model results are 3D volumes just like sonar data and, hence, visualized with the same or similar tools.

The motivation for this study is to try to create more *realistic* plume images from the acoustic data to help bridge the gap between these fields and help the geologists understand the acoustical geophysicists data. Our goal is to use the particle concentration implicit in the acoustic backscatter intensity to recreate the optical image a camera would see given a particular lighting level.

An additional motivation for visualizing the acoustic data as optical data (i.e., converting acoustic images to optical images) is the greater understanding of the acoustic interaction with the plume and the properties of the plume. Our Vent Imaging and Processing (VIP) group is working to determine the relative roles of different backscatter mechanisms that produce acoustic images of black smoker plumes. We have assumed that Rayleigh backscatter (scattering by particles that are small relative to the wavelength of the acoustic pulses used to ensonify a plume) is the principal mechanism. Other possible backscatter mechanisms are density discontinuities related to turbulent structure and temperature variations within the buoyant plumes. By using visualization techniques, specifically realistic lighting models [7][8][19][25], we can convert the plume image from mechanical waves (sound) to electromagnetic waves (light). The acoustic data are the observed volume backscattering coefficients for Rayleigh scattering and the resulting optical images will model the Mie scattering of visible light. This will, in conjunction with other tests, help us to sort out backscattering mechanisms and their relative importance.

In the next section, we describe how sonar images of plumes are acquired. This is followed by a description of the realistic rendering techniques most relevant to this study. Results of applying the realistic rendering to the acoustical images are described in Section 3. These computed images are compared to "real" images (Figure 1) taken from an underwater cruise [22][21]. Because the lighting techniques are general, different lighting conditions can be simulated by changing the parameters of the model. In Section 4, we apply an IMAX filming based lighting model to the acoustic data and compare these results to images from a recent IMAX film, *Volcanoes of the Deep Sea* [26]. This film captured spectacular images of hydrothermal plume from a site in the Pacific and several sites in the Atlantic; the images shown in Figure 1 are from the RIDGE 2000 Integrated Study Site at 9° N on the East Pacific Rise (EPR) and the vent complex called Snakepit at 23°N on the Mid-Atlantic Ridge. Note the different color of the plumes, which is both a function of the materials present in the plume and the distance of the camera and lights.

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