

PlumeViz: Interactive Exploration for Multi-Facet Features of Hydrothermal Plumes in Sonar Images

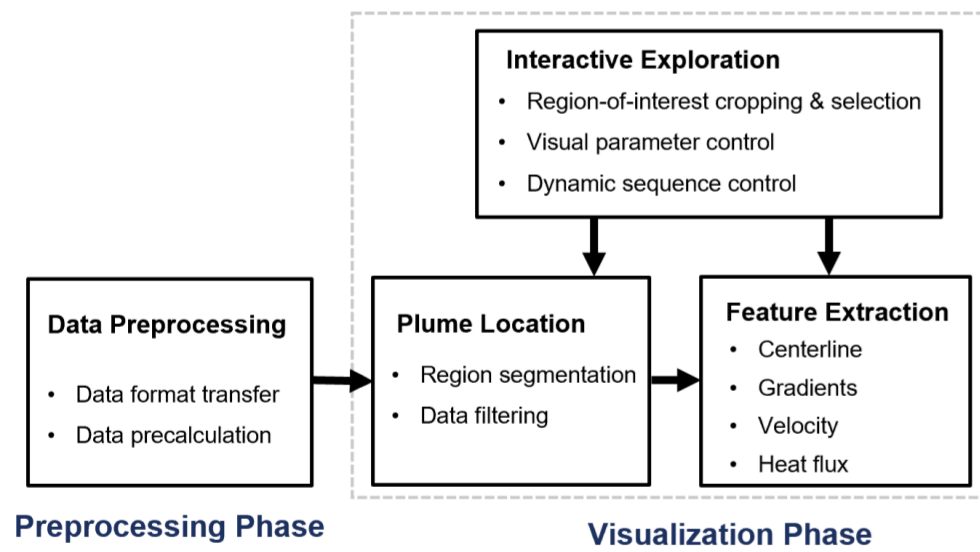
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INTRODUCTION

Submarine plumes serve as essential markers for researchers studying deep-sea hydrothermal systems. Acoustic imaging methods are developed to detect hydrothermal discharges via data with many different facets, such as plume imaging and plume velocity. Visualization techniques play a significant role in analyzing such data. However, due to the undersampled volume and the high dynamic range of volume data in time sequences, it is cumbersome and inaccurate to detect and visualize plumes. Therefore, we propose an interactive system for users to analyze such data and explore multi-facet features with user-interested visual encodings.

FRAMEWORK

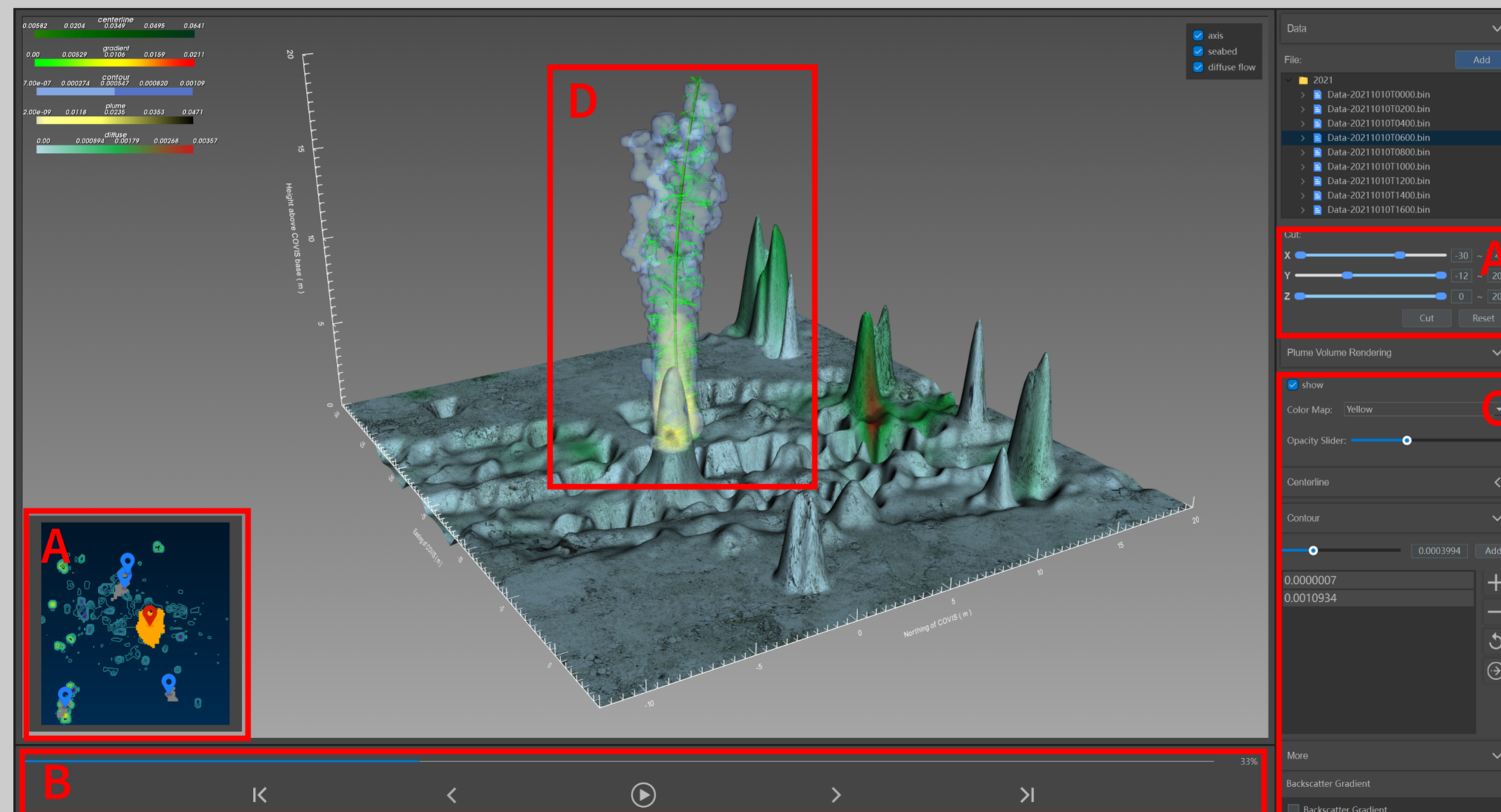
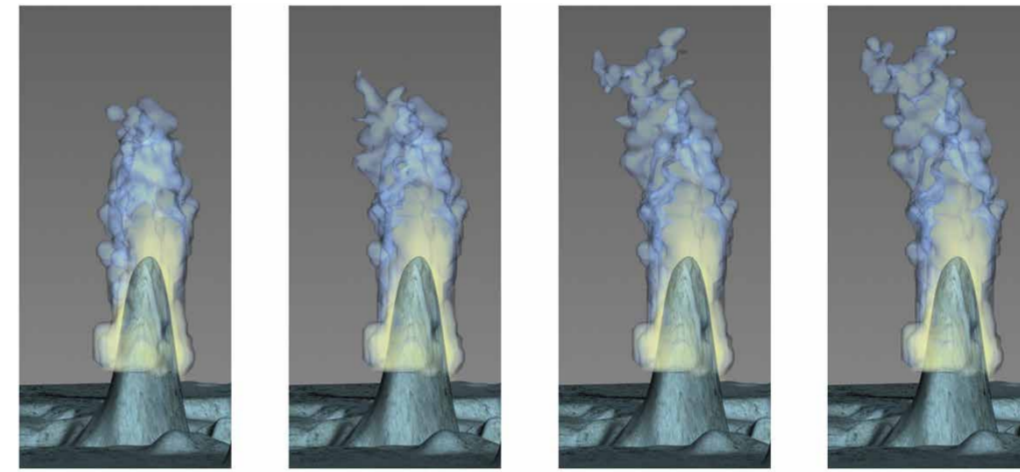


(A) ROI SELECTION

Given the extensive range of plume imaging data and noise present in extracted plume regions, we offer both cropping and region selection tools to facilitate user exploration. The cropping tool enables users to define the desired area by adjusting axis sliders, with the 3D crop displayed dynamically. For more focused analysis, the region selection tool allows users to pinpoint specific plume regions by clicking on corresponding areas within a 2D navigation map.

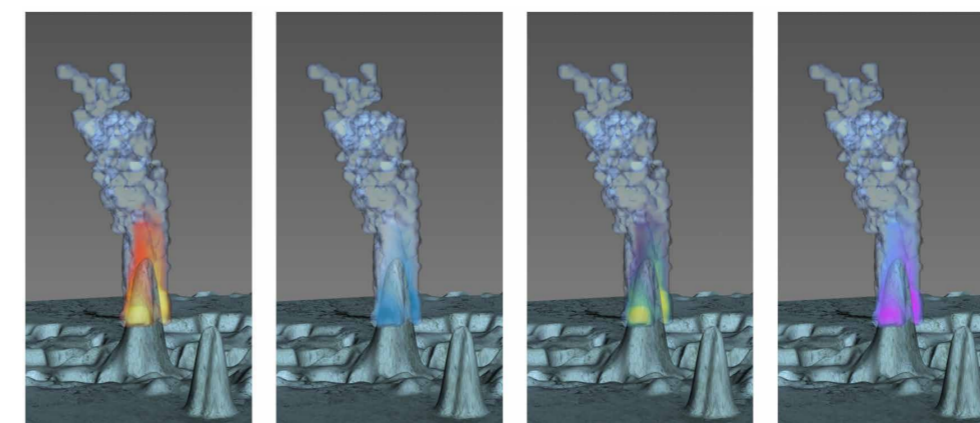
(B) DYNAMIC SEQUENCE CONTYROL

To address the issue of long time intervals between plume data points, we apply linear interpolation to create smooth transitions between consecutive time steps, resulting in a more continuous data evolution. Users can leverage the dynamic sequence control tool to play the sequential data and observe the dynamic evolution of the selected plume.



(C) PARAMETER CONTROL

Our tool integrates a diverse range of continuous color maps from Python's Matplotlib library. Users can choose their preferred color maps, and our tool will automatically adjust the color distribution to align with the data distribution. Additionally, users have the flexibility to modify the opacity function to enhance the visualization of the inner plume structures of interest.



(D) MULTI-FACET FEATURE EXTRACTION

In order to help domain expert to better understand plumes' behavior, we extract multi-faceted plume features, including plume centerline, backscattering intensity gradients, plume velocity and heat flux.

(a) Plume Centerline

Specifically, we identify the line connecting points of maximum concentration within each plume cross-section along the z-axis. These connecting points are then fitted with a smooth quadratic polynomial function. After this operation, we obtain a smooth curve representing the centerline of the plume.

(b) Backscattering Intensity Gradients

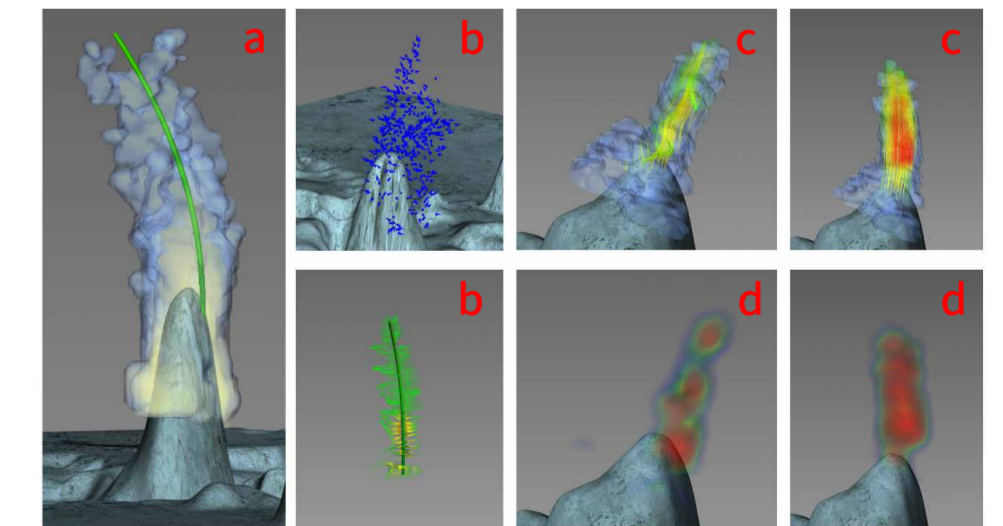
We calculate backscattering intensity gradients using central differences and represent them as either small arrows or streamlines.

(c) Plume Velocity

Plume Doppler data enable us to describe the motion of the plume. Based on existing works, we calculate the plume velocity from the doppler data and then draw streamlines to represent it.

(d) Heat Flux

Heat flux is a crucial factor in studying dynamic hydrothermal discharges. After determining the plume velocity, we can calculate the plume heat flux and use volume rendering to visualize it.



More details about our tool and source code can be found on:
<https://syiming123.github.io/plumeviz/>

