Exploring 4D Flow Data in an Immersive Virtual Environment

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About the Project

Ocean models help us to understand and predict a wide range of intricate physical processes that make up the atmospheric and oceanic systems of the Earth. Because these models output an abundance of complex time-varying three-dimensional (i.e., 4D) data, effectively conveying the multitude of information produced by a given model poses a significant visualization challenge.

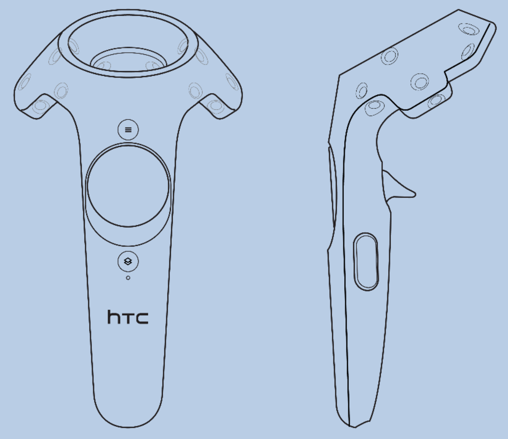
Recent advances in mobile computing have ushered in a new era of affordable, high-fidelity virtual reality (VR) devices. The proliferation of these devices presents a unique opportunity to incorporate their use into scientific workflows; especially those involving geospatial data.

Head-Mounted Displays (HMDs) provide a separate view of the virtual scene to each eye, which changes based on the position and orientation of the HMD in physical space to match real-world viewing. The binocular viewing contributes stereopsis and the head tracking enables motion parallax, both of which convey strong depth cues to the human visual system. In addition, they provide a natural and intuitive way to change the viewing position, a task which is normally mapped to a mouse or keyboard function.

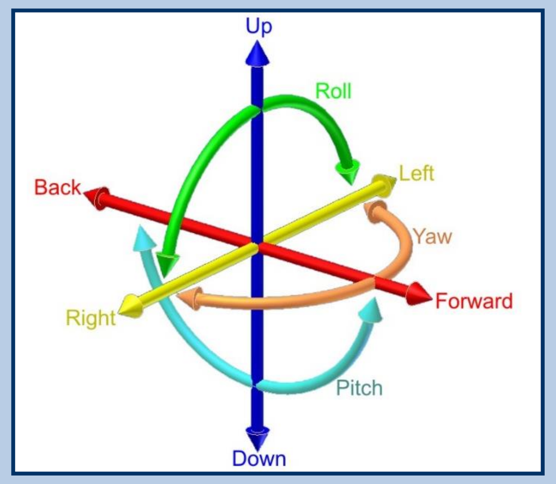
Six-Degree-of-Freedom (6DOF) devices that report their position and rotation with respect to a reference coordinate system. The total degrees of freedom can be determined by counting the principal axes (x, y, z) that a device an be positioned along or rotated around. A traditional computer mouse, for example, only reports the relative x- and y-offsets of the mouse position on a desk or mousepad, yielding 2DOF. A device capable of 6DOF provides data about its position and orientation in 3D space.

The **Kinematic Chaining Model of Bimanual Actions** proposed by Yves Guiard posits that the left and right hands form a kind of kinematic chain and the non-dominant hand forms a local, coarse frame of reference which the dominant hand can leverage for finer, more precise movements.
An example of this type of asymmetric action would be painting a figurine by holding it in one hand and applying the fine details with the other. Past evaluations have found this mode of interaction to be superior over unimanual ones for a variety of tasks in virtual environments .

By combining these superior viewing conditions and interaction techniques, we believe that we can improve the exploration of model results to more quickly and efficiently assess their validity and gain a more holistic understanding of the model.



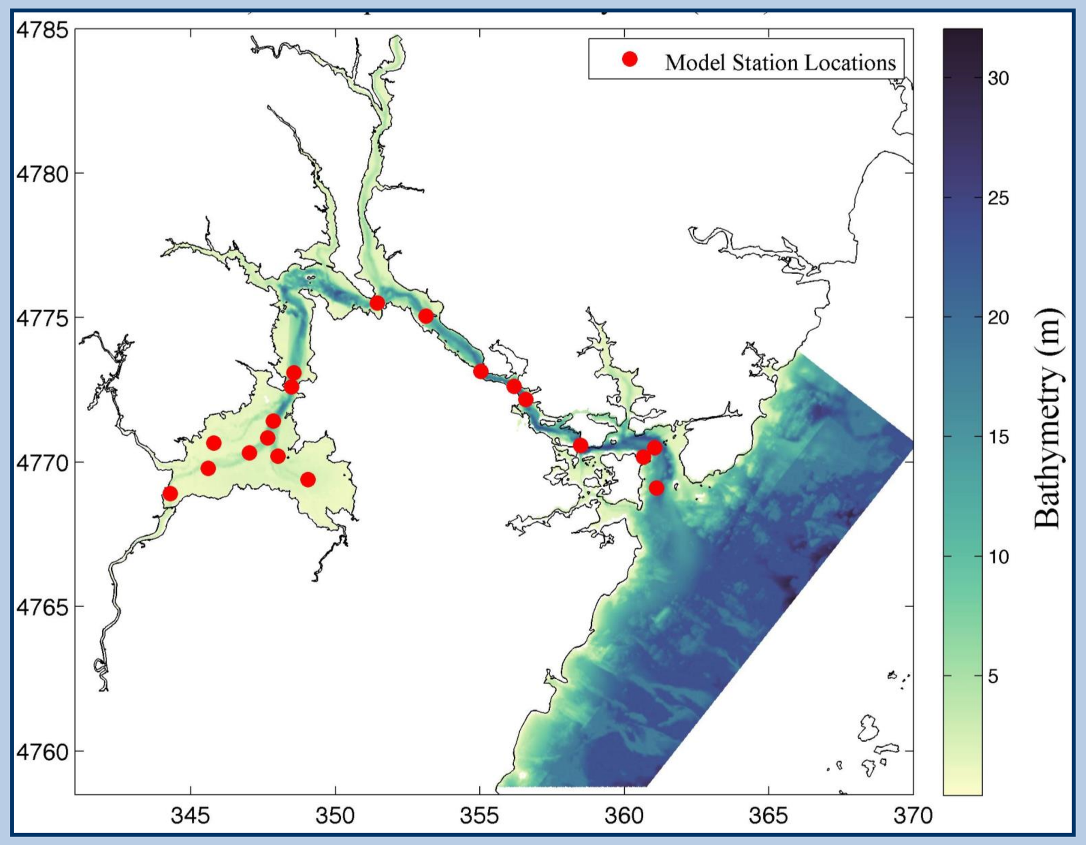
The HTC Vive 6DOF controller. It contains 3 buttons, one analog trigger, and a clickable touchpad for the thumb.



Six Degrees of Freedom (6DOF). Each colored line or arc represents an independent degree of freedom.

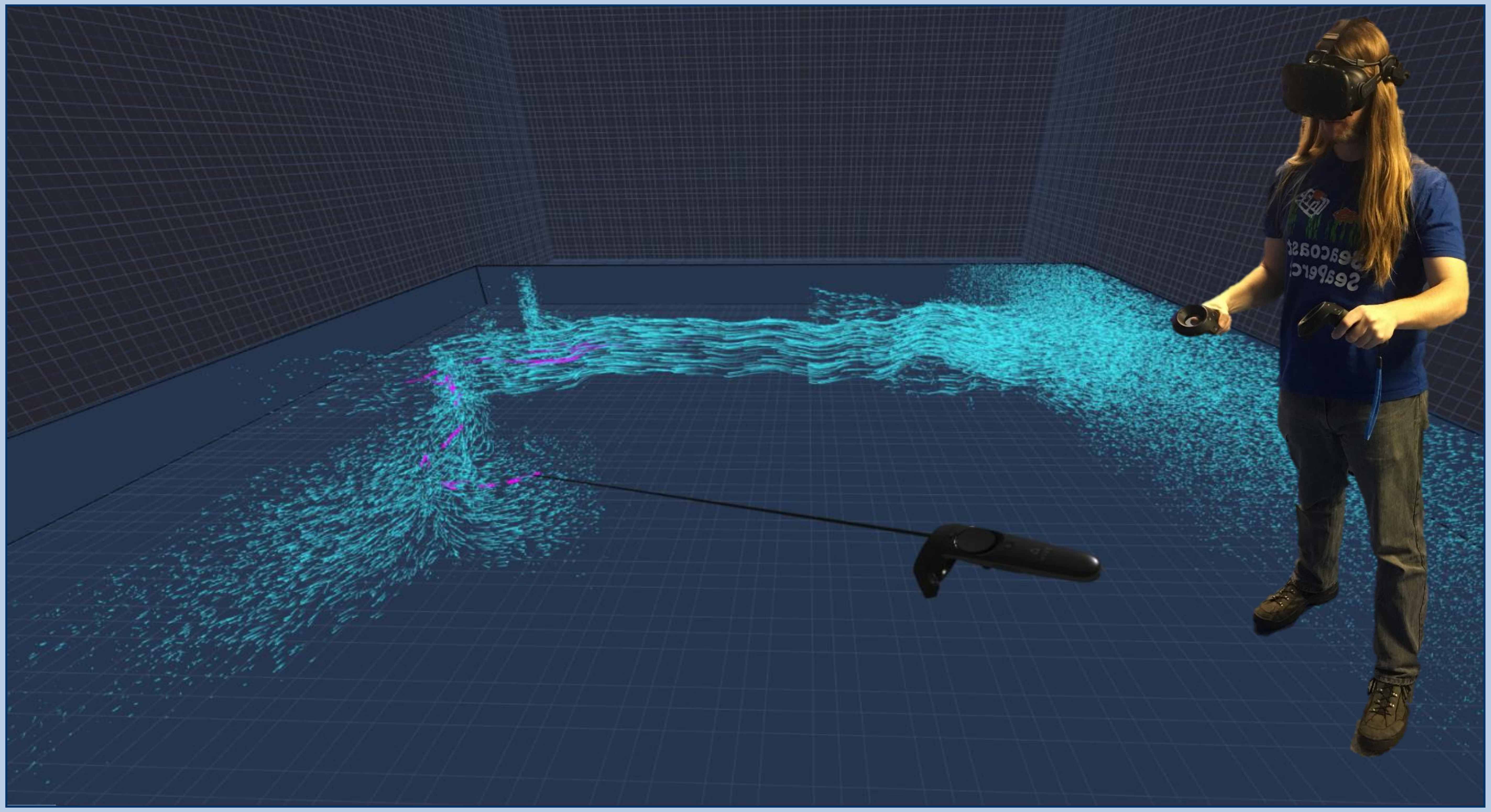
Technical Details

Our dataset is a Regional Ocean Modeling System (ROMS) model representing a 12-hour tidal cycle of the currents within New Hampshire's Great Bay estuary. The model data was loaded into a custom VR particle system application written in C++ using the OpenVR software library.

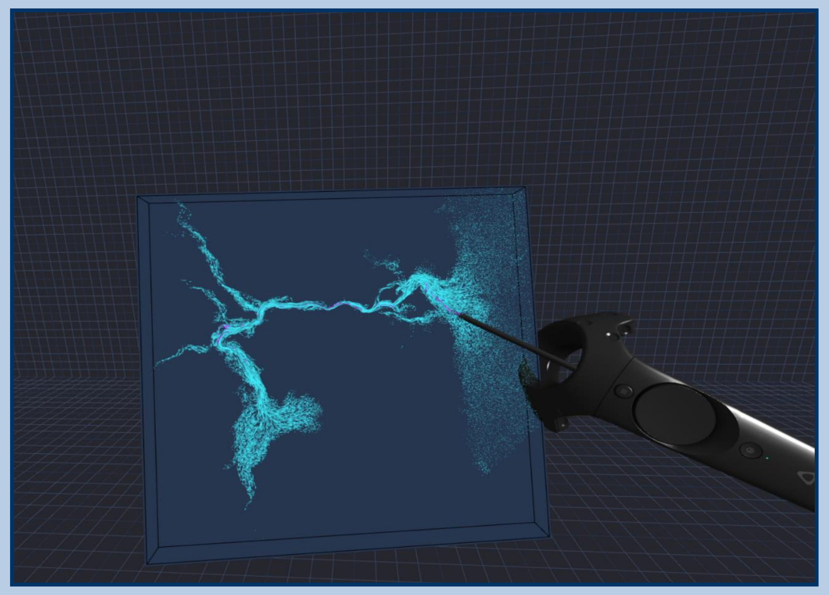


The Piscataqua River-Great Bay estuary is located in southeastern New Hampshire, and is an important economic and ecological resource to the region. It is influenced by the Gulf of Maine, with large semidiurnal tides, a tide range on the order of 2 meters and tidal currents that can reach more than 2 m/s. Observational datasets (1975-2016) exist throughout the estuarine system and give insight to interesting tidal dynamics. A three dimensional hydrodynamic model is employed to better spatially and temporally resolve these tidal dynamics (especially in areas hard to observe – navigational channels and tidal mudflats). [Cook 2016]

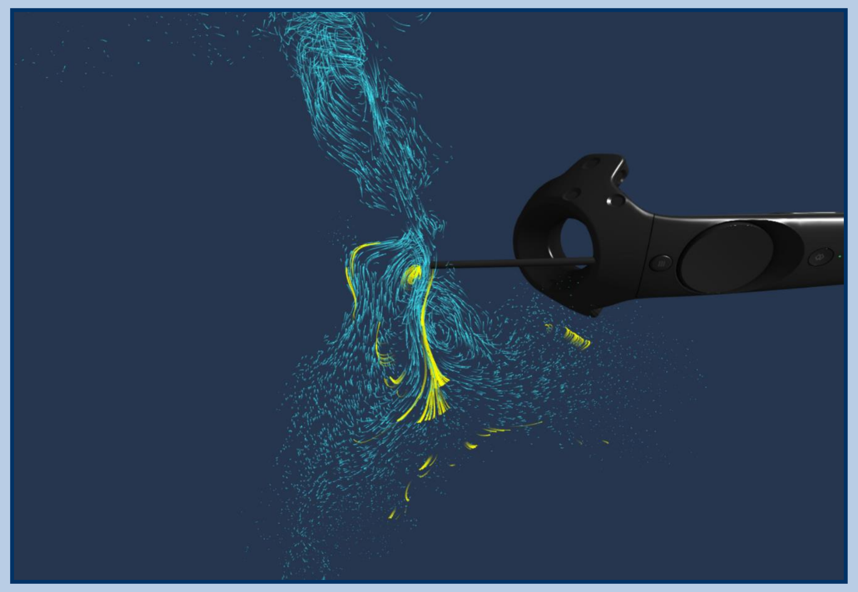
Visualizing the Great Bay Estuary, New Hampshire



The flow model is spread across the floor and the dye-emitting probe has been extended to reach into the volume from across the room. A user actively engaged in exploring the dataset is superimposed onto the virtual world to illustrate both the system in use as well as the "presence" and immersion the virtual environment can create. Our virtual environment allows the user to select preset layouts for the data volume to rapidly move between common viewing setups; the user can also directly grab, manipulate, and scale the particle system volume in any way they please. Dye emitters attached to the two tracked controllers allow colored particles to be released into the flow field to interactively explore its features.



The user could also use a World in Miniature (WIM) style interaction, where a scaled-down model of the particle system can be held and manipulated using the non-dominant hand and the dominant hand can do more precise work, like placing dye pots in areas of interest or probing the flow velocity at ground-trothed locations to quickly assess the model's quality. Any visualizations or interactions occurring on the WIM would also be displayed in the larger particle system in the virtual environment.



Here, the user has walked *into* the particle system volume to get a closer look at the Back Bay area of the model. They hold the model with their non-dominant controller (not pictured) and use the dominant controller to place purple dye particles and emitters into the flow field. Since this is a time-varying flow field, it is possible to visualize the dye particles as the move in and out of the region with the ebb and flow of the tides. Particle colors and parameters (density, buoyancy, etc.) could also be adjusted to emulate pollutant releases, oil spills, and other particles of interest.

About CCOM

Based at the University of New Hampshire, The Center for Coastal and Ocean Mapping (CCOM)/ Joint Hydrographic Center is a national center for expertise in ocean mapping and hydrographic sciences, operating in partnership with NOAA's National Ocean Service, with projects funded by the USGS, ONR, NRL, DARPA, NSF and private sector partners. The centers educate a new generation of hydrographers and ocean mapping scientists, while conducting research to develop and evaluate hydrographic and ocean mapping technologies and applications.

Within CCOM, The Data Visualization Research Lab studies and develop-s advanced interactive visualization techniques that can be applied to ocean mapping and ocean technologies in general. The Science of Data Visualization is a major part of founder Colin Ware's research, grounding data visualization in theories of human perception and cognition. This approach provides theories of what makes visualizations effective thinking tools.

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