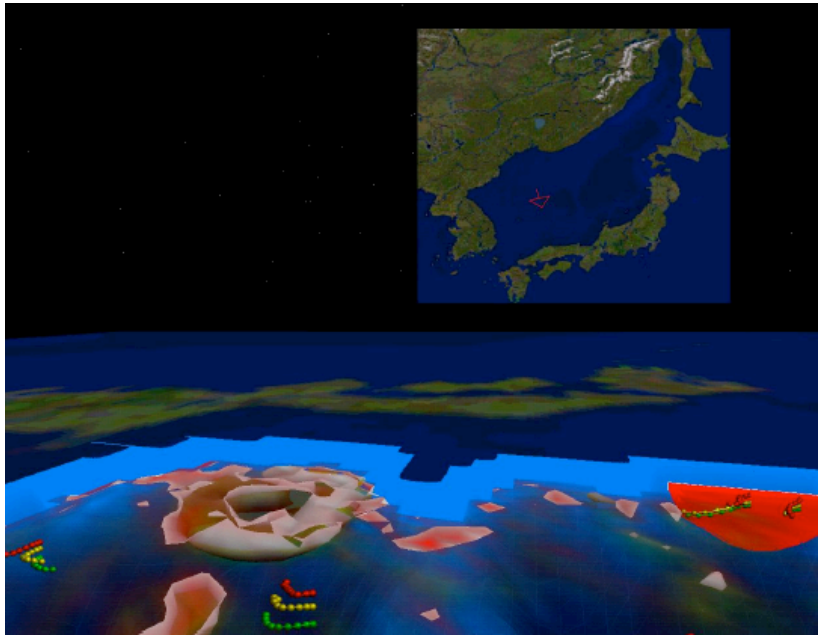
Guidelines for Virtual Environment Design as Explored Through Oceanographic Scientific Visualization

James Creager, Lawton Pybus,
Thomas Stokes, Francis Trowbridge

Scientific Visualization

- Representation of natural phenomenon through visual displays
- Can be 2D or 3D, static or dynamic
- Recently virtual environments (VEs) have been a popular option for display



Benefits of VE & Scientific Visualization

- Presents large amounts of data easily in a way that can be understood better than looking at raw data
- Takes advantage of visual bandwidth
- Use of metaphor
- Capable of showing dynamic data in a understandable way
- Scaling (local and global trends)

Usability Issues with VE/Scientific Visualization

- Frame of reference (FOR) & associated tradeoffs in navigation and judgment
- How do you present symbolic information without occlusion of the visualization?
- How should the scientist be able to interact with the environment (navigation and analysis controls)
- How to render the display at different zoom points

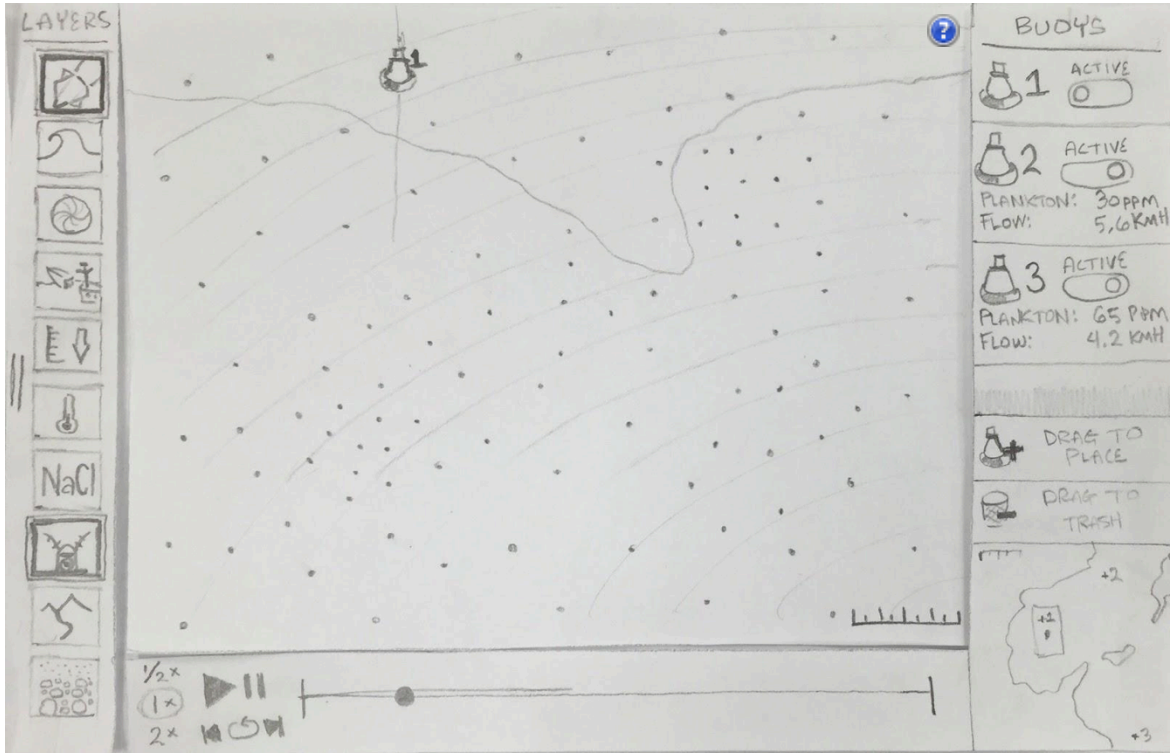
Our Goals

In response to 6 common interface concerns:

- Develop design guidelines for VEs
- Develop design principles for a METOC data visualization context
- Draft an interface that implements the principles

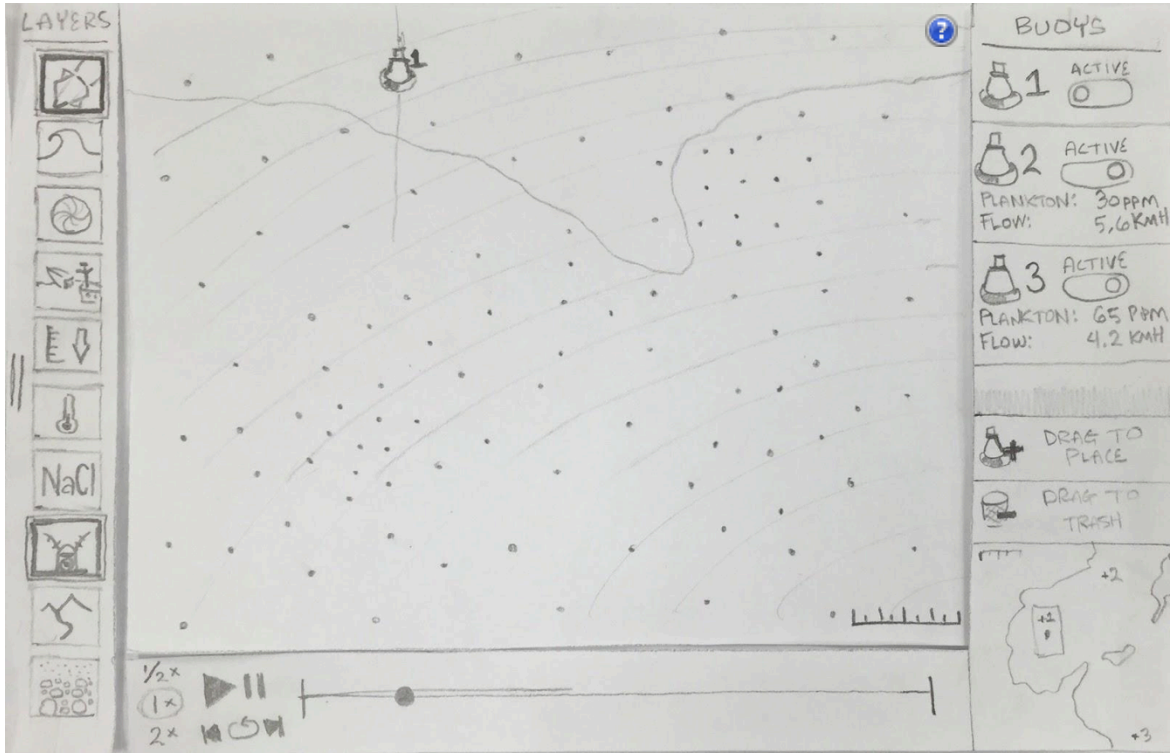
Overview of Display and Controls

- Layers & Filters
- Playback (temporal) controls
- Buoy tackle box
- Overview map
- 3D rendering



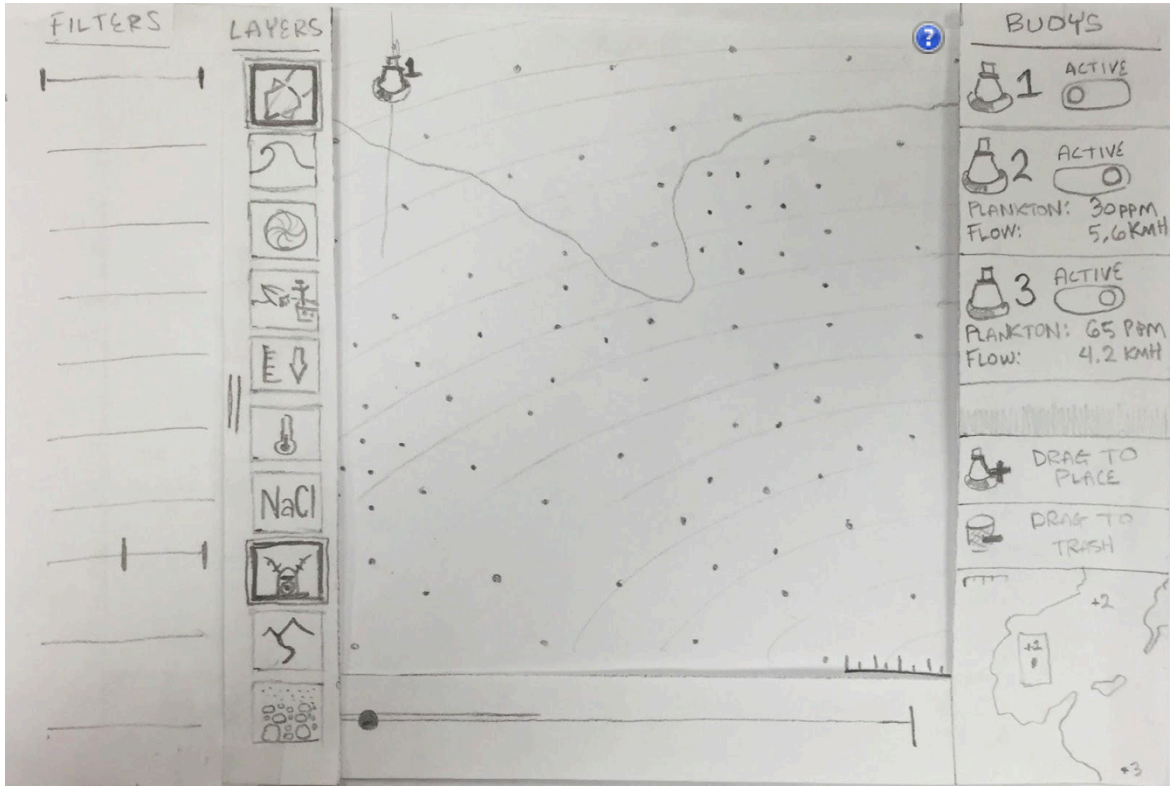
Overview of Display and Controls

- Controlled with a wand and attached joystick (like a Wii-mote)



Overview of Display and Controls

- **Pan:** Grab and move
- **Yaw:** Left-handed joystick
- **Select:** Button on right thumb
- **Zoom in/out:** Two buttons on left hand



How do you represent different physical phenomenon through the VE?

Guidelines:

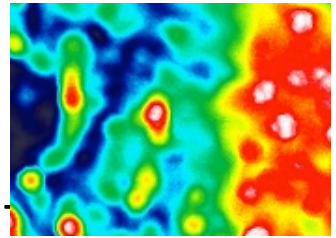
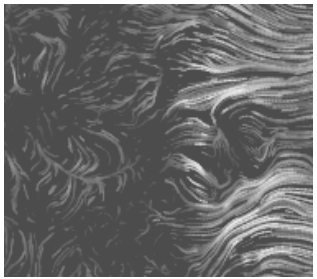
- Data set has information on various features (ocean current, water information, seafloor data, shore features) that can be displayed via layers
  - Each individual layer can be further refined using filters
  - Points on range of filter are visually represented consistently
  - Displaying all features at once can be visually cluttered / increase search & working memory demands

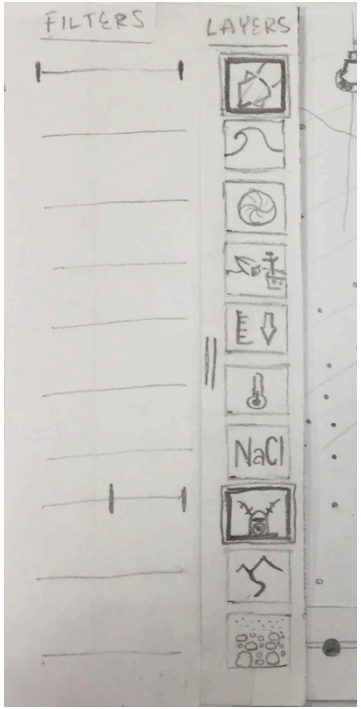
How do you represent different physical phenomenon through the VE?

Principles

- Select desired filters (Kaber & Riley, 2001)
- Use distinct visual representations for different features (Kaber & Riley, 2001)

How do you represent different physical phenomenon through the VE?

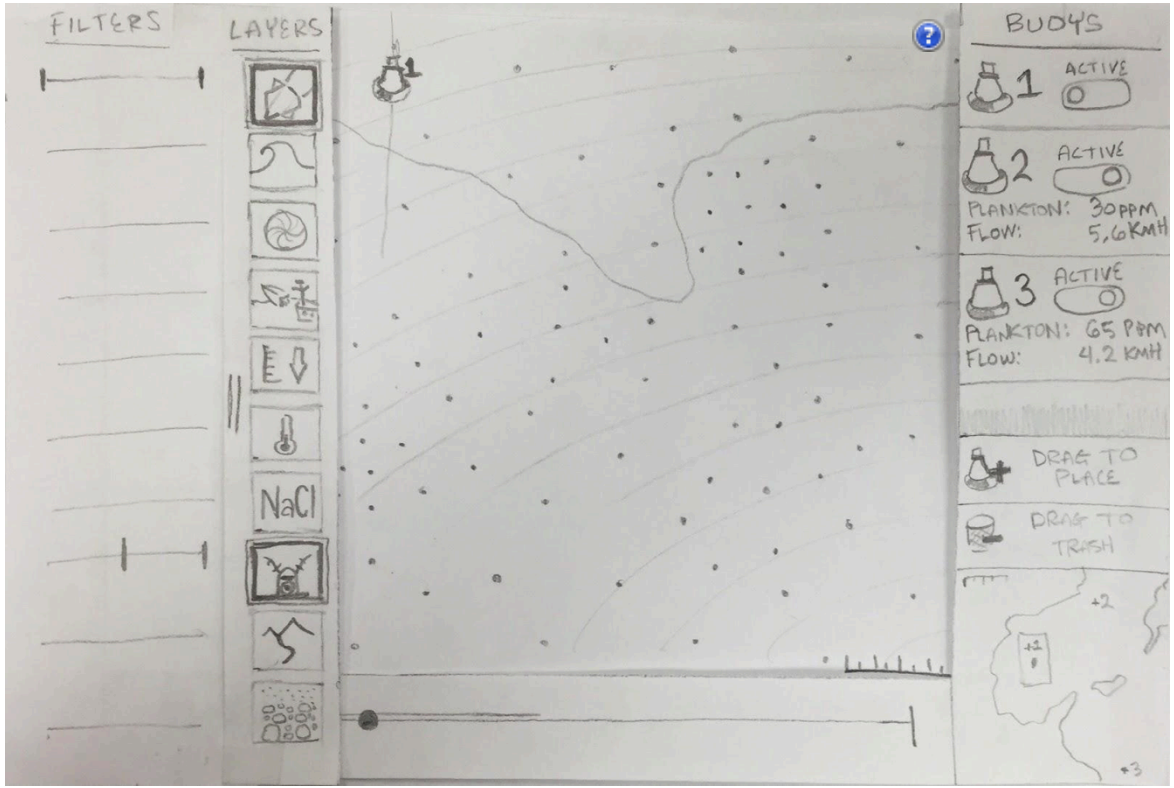
- Layer (examples)
  - Water temperature
  - 
  - 
- Filters



Prototype

- Current flows and plankton filtered here

- Distinct features have different visual representations (flow = moving lines plankton = clusters of dots)



How do you render the features?

Guidelines

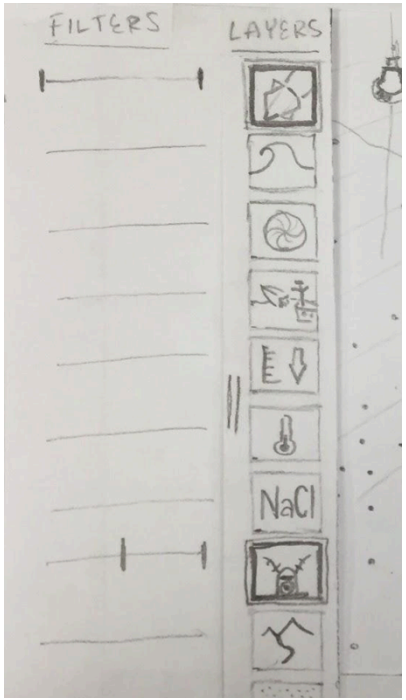
- Render more detail when zoomed in and less when zoomed out to save computational resources (Hornbæk et al., 2002)
- Display only relevant information to save computational resources and reduce cognitive overload to improve usability (Kaber & Riley, 2001; Chen, 2003)

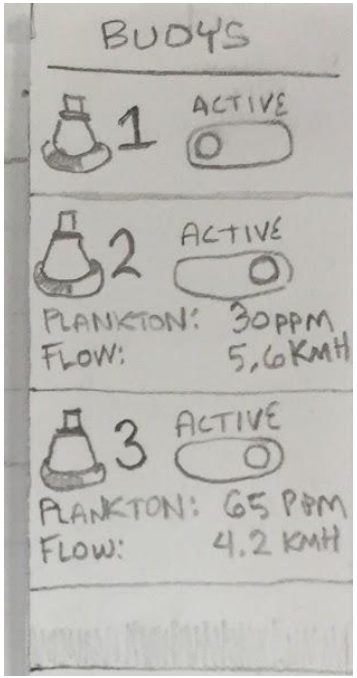
How do you render the features?

Principles

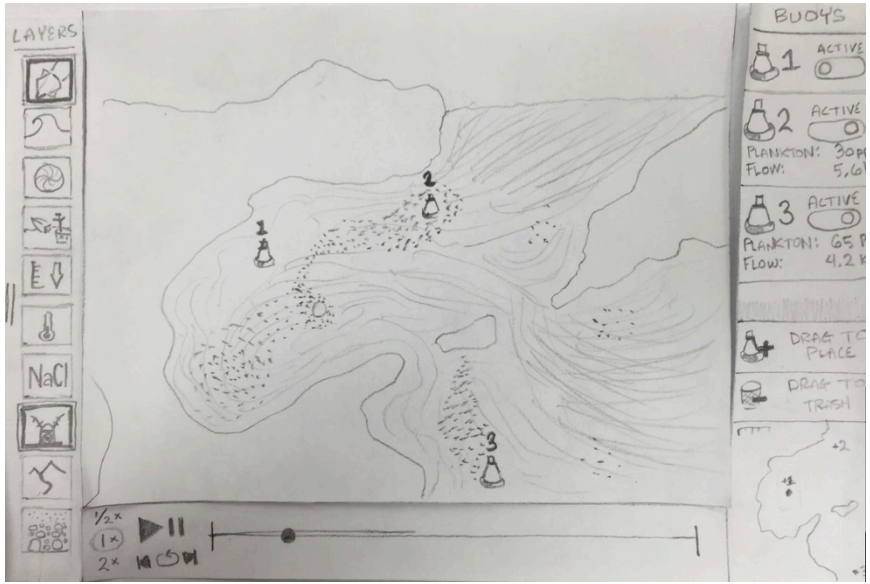
- Layers and filters
  - Data not selected are not computed or displayed
- Active/inactive buoys (selected via toggle)
  - Do not irrelevant display data so only relevant information is visible
- 20 levels of zoom
  - Low levels (1-7): Render static environment textures. Render feature colors and averaged sprite animations, not feature textures or geometries
  - Moderate levels (8-15): Render dynamic environment textures. Render feature colors and sprite animations.
  - High levels (16-20): Render dynamic environment geometries. Render feature colors and sprite animations.

How do you render the features?

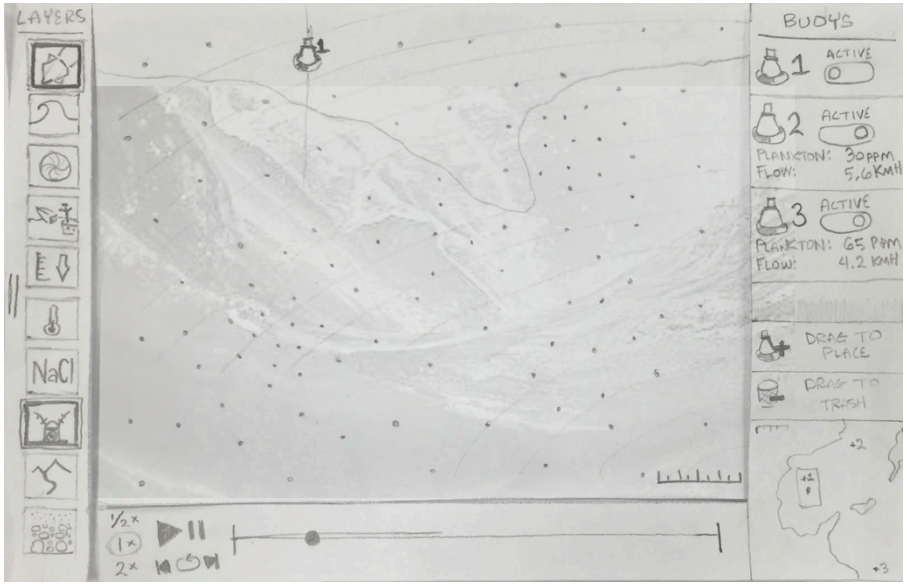




How do you render the features?



Zoomed out



Zoomed in

How should users interact with the VE?

- Modal in some places, mostly **modeless**
  - One mode for navigation and visualisation of all active filters
  - Separate modes for buoy dropping and filter tuning (navigation disables)
- Modified **WIMP**
  - Overview and field of view windows
  - Icons for features
  - Menus and drawers to filter features
  - Spatial pointer ‘wand’
- Navigation controls:
  - Movement with trigger pull pans
  - Left hand joystick controls yaw and zoom features
  - Selection *button* moves around on mini-map, and selects buoy and filter menus

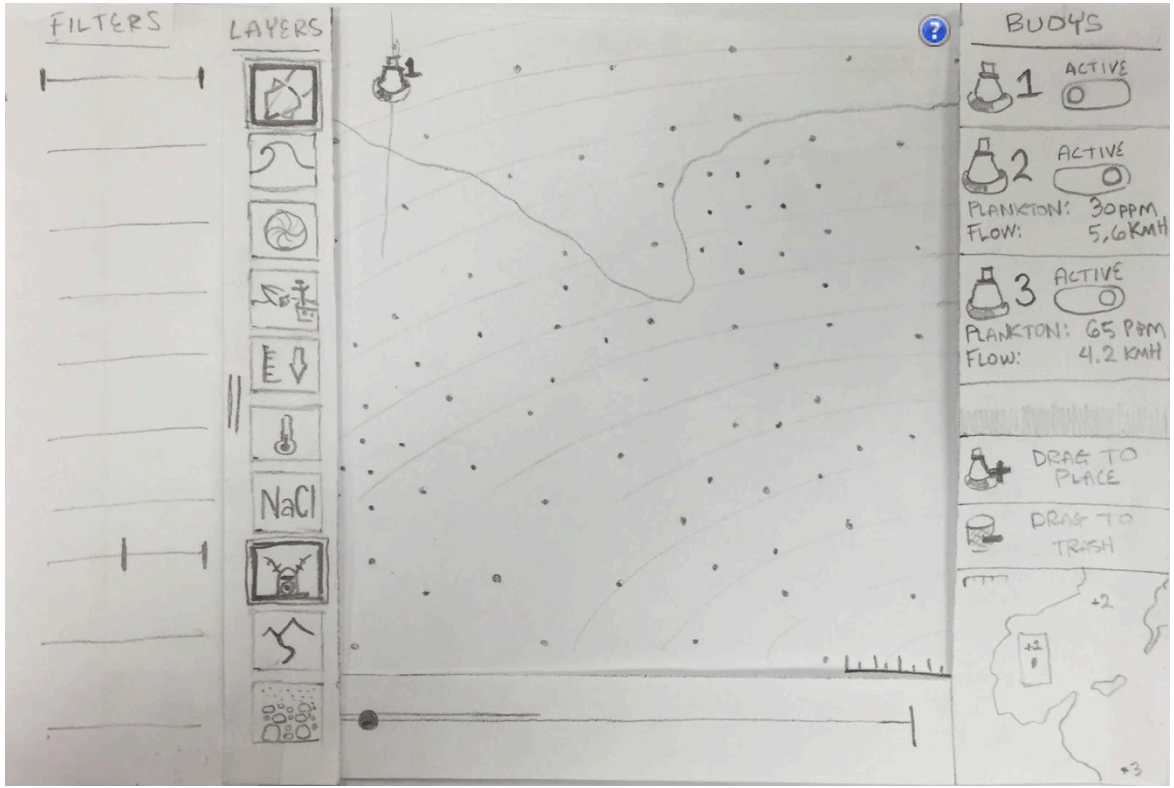
How should users interact with the VE?

- Interaction guidelines:
  - Allow modeless navigation of different data model features by including layers in one navigation mode
  - Don't allow navigation when navigation is not part of the user's task (e.g. selecting layers, dropping buoys on a specific spot)
  - Don't map all movement of the user on to movement in the VE. (e.g. user pulls trigger to begin panning, moves joystick to control yaw, presses buttons to zoom)
  - Include an overview feature, which increases user satisfaction (Hornbæk et al., 2002). Data visualization VE's should be 'walk-up-and-use' (Kaber and Riley, 2001), and user satisfaction is important for novice users (Hornbæk et al., 2002)
    - Changes in overview window coupled with changes in FOV (Hornæk et al., 2002)

Prototype

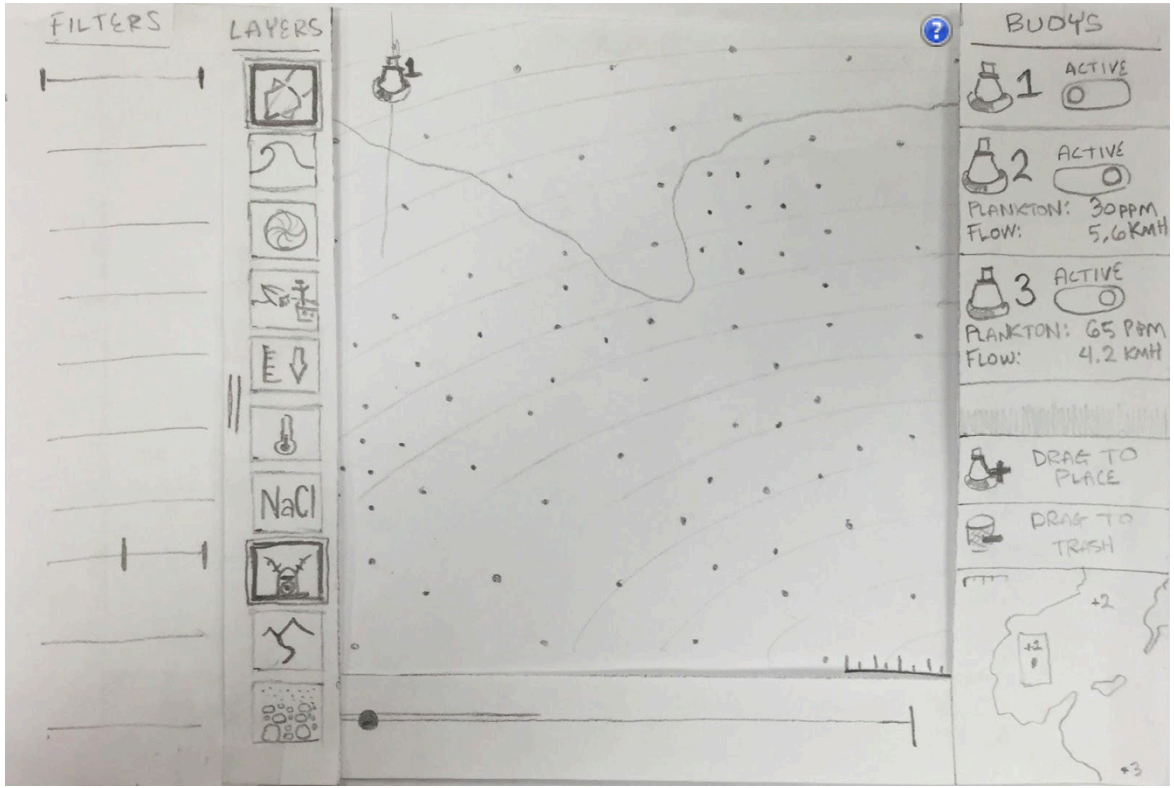
- While navigating, users will see visual representation of all features filtered on

- Users will also see specific data from the model at active toggled buoy locations



Prototype

- The filter drawer is pulled out, so navigation is disabled
- Navigation also disabled while dropping buoys
- Tasks don't require navigation



Use of 2D and 3D elements

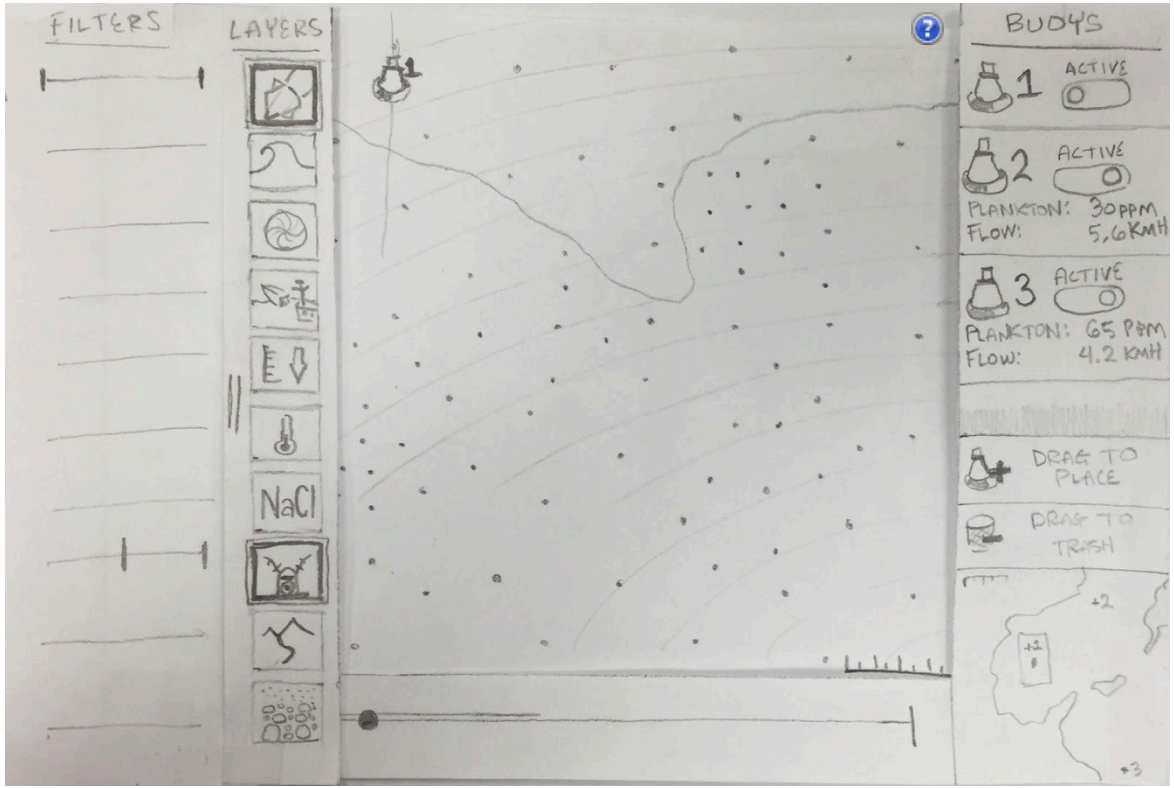
- Use of 2D menus and windows, icons (drawers, buoys and their information, overview map)
  - Add 2D symbolic data, increases usefulness and insights (Chen, 2003)
- No pop-ups
- 3D rendering of physical world/dataset

Use of 2D and 3D elements

- Guidelines:
  - Use 2D Icons, menus, and overview maps, to enhance interpretability. (Data visualization is not part of the task)
  - Use 2D information to convey symbolic (non-visualization) data, to increase usefulness (Chen, 2003)
  - Render the data model in 3D to speed data visualization, and avoid user needing to mentally combine information from 2D models (Kaber and Riley, 2002)

Prototype

- 2D menus, playback controls, navigation in overview window
- 3D FOV navigation and data visualisation



What design metaphors could be used?

- Buoys: data probes
- Tackle box: grab new buoys from here
- Fish net: collect deployed buoys from water (delete them)
- Map: exocentric view for situational awareness and navigation (Hornbæk et al., 2002; McCormick et al., 1998)
- Globe: latitude and longitude lines as spatial reference points (Kaber & Riley, 2001)

How can this be intuitive?

- Use of labels and affordances
- Use of design metaphors
- Modeless for navigation, visualizing active filters, and making local judgements at various buoy locations

User-centered design process to know the expectations of the user (Kaber & Riley, 2001)

- Novice support
  - Quick help icon

Guidelines (Metaphors & Intuitiveness)

- Provide an overview map and markers (e.g. latitude & longitude lines) (Hornbæk et al., 2002, Kaber & Riley, 2002)
- Organize and present task-relevant controls and displays in task-oriented language (Dix et al., 2004)
- Prevent user errors with a modeless interface where possible, and forcing functions where modes are required
- Use labels and affordances to make functionality visible (Norman, 1995)

Usability Principles Addressed

- Users are unaware options, and how to transition between display modes (1)
  - Modeless display of features eliminates need to transition between different data types (e.g. current and plankton concentration)
  - Feature display filters always visible
  - Easy to discern and toggle which filters are active at any time by viewing, pointing, and selecting
- Access to specific model information is limited by interface functionality (7)
  - Buoys afford gathering more specific readings from the data than is presented in the data visualization

Usability Principles Addressed

- Data model information is often dropped from visualizations when transitioning between display modes (8)
  - Filter function allows user to see all data model information desired in a modeless navigation
- The working memory load of users in terms of remembering model information when working with system is excessive (10)
  - Buoy metaphor allows the system to carry information from areas of interest outside of current field of view to allow for comparisons of data

Contact

James Creager
jhcreage@ncsu.edu

Alex Trowbridge
fatrowb@ncsu.edu

Lawton Pybus
lrpybus@ncsu.edu

Thomas Stokes
tastoke2@ncsu.edu