Arctic Explorer: Visualization of Sea-Ice Concentration along Arctic Shipping Routes

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ABSTRACT

The Arctic seascape plays an important role in North American trade and defense; however, over recent years, the Arctic has undergone radical changes, altering current shipping routes and opening up new previously blocked paths. This work presents Arctic Explorer, a tool to visualize sea-ice concentration along paths over time. Arctic Explorer could be used to circumnavigate areas expected to be blocked with ice and discover new routes that may have opened up.

Keywords: Geovisualization, Environmental Visualization, Temporal Ordered Spatial Matrices, Arctic Oceanography.

Index Terms: H.5.2 [User Interfaces]: User-centered design;

1 INTRODUCTION

The Arctic Ocean has experienced increased international interest due to various drivers: discovery of arctic oil [1], increases in trade [2], and U.S.-Russia competitiveness [3]. At the same time, the Arctic seascape has experienced radical change due to a rapidly changing climate [4]. Such changes have altered historical transportation routes and opened up avenues of commercial travel through areas previously blocked by ice. This was most noticeably seen when the Northwest Passage opened for transit of ships without an ice breaker in September 2007 for the first time. This passage opening had a tremendous impact on trade as it provided a shipping route that didn't require ships to travel south to the Panama Canal.

Given the interest in understanding the Arctic seascape for both trade and defense, we present Arctic Explorer, a tool to visualize sea-ice concentration along paths over time. Arctic Explorer allows users to draw and edit a path, and from the drawn path, the ice concentration values are visualized through a temporally ordered spatial matrix (TOSM). Arctic Explorer visualizes data to better answer questions such as "When are certain routes blocked by sea ice?" or "Are there points along the route that we may be able to circumnavigate to avoid sea ice?"

2 RELATED WORK

The development of Arctic Explorer was informed by two previous visualization publications: OceanPaths [5] and Temporal Ordered Spatial Matrices (TOSM) [6].

Arctic Explorer uses a modified layout similar to the dual map and analysis interfaces used in OceanPaths. Both tools contain a map interface that users can use to draw paths. In the case of OceanPaths, the paths represent an ocean current that can also branch. The branching paths is represented through a scatterplot network visualization which visualizes measurements close to the

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path, such as water temperature or salinity. In contrast, in Arctic Explorer, interaction with the map changes the TOSM visualization (Figure 2 B i). The use of a TOSM instead of a scatterplot matrix is one of the main differences between the OceanPaths and Arctic Explorer tools.

2.1 Temporal Ordered Spatial Matrix Visualization

TOSMs are visualizations that were developed to demonstrate how a certain attribute of interest (in this case, sea-ice concentration) changes over time. TOSM's have been used successfully in other visualizations [7] to convey other spatio-temporal datasets. Points along the path (drawn on the Map Interface) are interpolated at a regular interval, and the sea-ice concentration at these points is then plotted on the TOSM as a column. Historical data of ice concentration along these points is then visualized as additional columns along the TOSM.
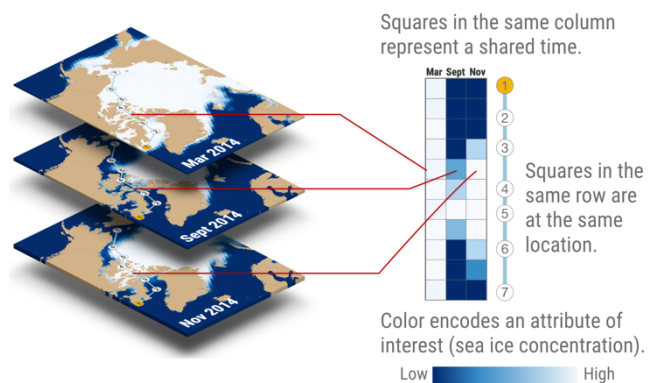

FIGURE 1: The TOSM visualization explained with a cross section of three time points at various months in 2014.

3 DOMAIN PROBLEM AND DATA

Arctic Explorer was created out of a desire from arctic researchers to analyze how sea ice concentration changes over time. From interviews with researchers, the tool needed to fulfill two main requirements: the tool needed to communicate 1. aggregated statistics of overall sea ice concentration and 2. sea ice concentration along a path.

Data was obtained from the NOAA Arctic Sea Ice Dataset and was analyzed to create the aggregated statistics. This data was then transformed to increase lookup speed for visualization. Through initial talks with users, the tool helped researchers identify patterns in how sea ice concentration changes over time and can be used to demonstrate historical events such as when the Northwest passage first opened to ships without ice breakers back in 2007.
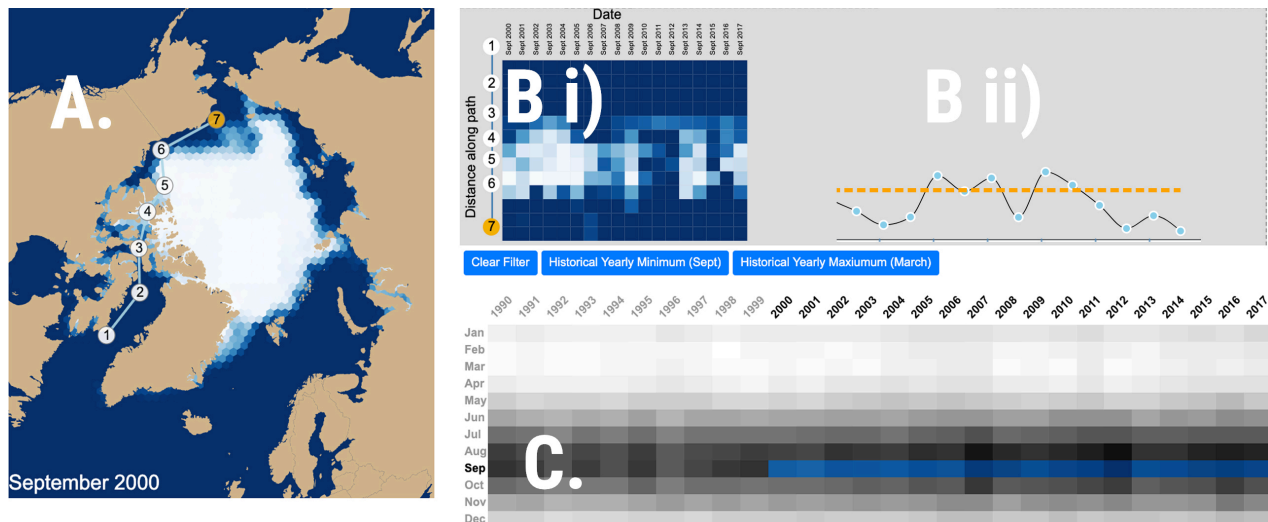
FIGURE 2: A View of the Path Navigation mode in Arctic Explorer. A. The Map Interface containing a path that is drawn representing the Northwest passage. B. i) The Analysis Interface containing a TOSM of the path drawn in the Map Interface. B. ii) When the overview mode is selected, a simple time series is shown showing total sea ice concentration over time. C. The Time Selector Interface used to select the dates of September from 1990-2017 to be shown.

4 ARCTIC EXPLORER DESIGN

Arctic Explorer has three primary views: a map interface (Figure 2A), an analysis interface (Figure 2B), and a time selection interface (Figure 2C). Additionally, a user can select one of two modes: an overview mode and a path-navigation mode. The overview mode changes the Analysis Interface to display aggregated statistics (Figure 2B ii) such as the mean ice concentration. When the tool is swapped to path navigation mode, the interface becomes a TOSM visualization as seen in Figure 2 B i. As the contributions of this poster focus on design decisions for the TOSM matrix, the rest of this sketch will focus on the navigation mode.

4.1 Map Interface

The Map Interface visualizes the sea ice in the Arctic at a given point of time. Interaction with the map is used to draw the path of interest through the addition of support points. These numbered points can be changed through drag and drop (Figure 2 A).

4.2 Analysis Interface

The Analysis Interface displays a TOSM visualization for the path drawn on the map. The main contribution of Arctic Explorer is the path legend present on the left side of the TOSM. The irregularly spaced nodes (numbered circles) serve as landmarks for where along the path a given area on the TOSM is situated. Additionally, through clicking on one of the points along the map, the highlighted node is changed, allowing the user to better understand how rows on the TOSM correspond to spatial locations.

Additionally, a path highlight interaction and a tool tip are present when the user hovers over a cell on the TOSM. The tool tip displays the value of the ice concentration, and the path highlight is visualized on the Map Interface to show which location corresponds to the cell that is hovered over. These interactions can be seen in the demo video inside of supplemental material.

4.3 Time Selection Interface

The time selection interface allows a user to change the date that is currently visualized. This interface contains a heat map where rows represent shared months and columns represent a year. Through brushing on the heat map, a user changes the data shown on the

Map and Analysis Interfaces. We chose this interaction modality as it easily allows a user to look longitudinally (how sea ice concentration changes over multiple years) and cross sectionally (how ice concentration varies over one year).

5 DISCUSSION AND FUTURE WORK

The development of Arctic Explorer demonstrated how interactions and a coordinated path legend improve the comprehension of a TOSM. Initial user feedback indicates these interactions help analysts understand how locations correspond to cells on a TOSM.

In future work, we plan to formally study how other interaction or layout design choices impact the comprehension of the TOSM visualization. Additionally, we would like to further explore how to incorporate uncertainty visualization into TOSM visualizations. Such steps could make TOSM visualizations more accessible and useful to both expert and non-expert users.

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