Visualizing ENSO

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Abstract

The El Niño Southern-Oscillation (ENSO) has long been known for its strong influence on global weather. Although localized to the Pacific Ocean, its effects can be seen across the globe, with notable effects around the Mississippi River valley. In 2017, Muñoz and Dee found that the warm phase of ENSO preconditions the Mississippi valley to flood vulnerability.[1] Given the economic costs associated with natural disasters in this heavily populated region, understanding the connection between ENSO and flooding is of paramount importance—visualizing this connection is the focus of this paper.

Keywords: ENSO, climate change, geospatial visualization.

1 Introduction

The Mississippi River valley is one of the most heavily engineered and navigated river valleys in the world. It is a key driver of the American Midwest economic engine, and its historical susceptibility to flooding has been known for its costliness.

The El Niño Southern-Oscillation (ENSO), although reasonably well-understood by climatologists and meteorologists, continues to show a surprisingly notable impact on regions across the globe. In 2017, its connection to the lower Mississippi river valley was made clearer than ever after the publication of, "El Niño increases the risk of lower Mississippi River flooding," by Muñoz and Dee.[1] This study showed that the warm phase of ENSO showed a clear, causal impact on the susceptibility of the lower Mississippi to flooding. More specifically, in the 6-12 months preceding a given flood within the region, the authors found that El Niño's addition of abnormally high rain levels in the region reduced the capacity for soil infiltration by water. At the time a flood occurs, there is little room for excess water capacity from extreme rains to drain, leading to devastating flooding throughout the lower Mississippi.

Although this paper was crucial in illustrating the connection between ENSO and lower Mississippi flooding, the public understanding of the connection and political responses to it have been limited. In order to make its findings more tangible and accessible, we worked to develop an interactive web-based visualization that allows users (citizens, policymakers, and scientists) to geospatially explore the complex connections between El Niño and the lower Mississippi. By making this phenomenon more accessible to the public, we hope to highlight the critical importance of building a more resilient Mississippi infrastructure that is prepared for the growing impact of climate change.

2 Related Work

For our project, we have consulted sources related to the climatic science behind ENSO, lower Mississippi flooding, and geospatial visualization in related contexts.

1) El Niño increases the risk of lower Mississippi River flooding[1]

This report, written by Muñoz and Dee and published in *Nature*, is the cornerstone of our project and the basis for our visualizations. It describes the climatic relationship between ENSO and lower Mississippi River valley flooding, which we hope to better visualize.

2) Climate Reanalyzer[2]

The Climate Reanalyzer is a University of Maine Climate Change Institute website that contains a large set of geospatial visualizations related to climatology and weather. It includes interactive visualizations and other techniques that model climates variables over time, and will be helpful in the process of deciding how to visualize a certain concept or phenomenon.

3) Real-time 3-D El Niño/La Niña visualizations and animations from the TAO buoy network in the Tropical Pacific[3]

This paper, published by IEEE, tackles one aspect of the project that we hope to address – how to visualize the spectrum between El Niño and La Niña. It relies on a different data set than our cornerstone paper and we plan to visualize the phenomenon differently, but the paper itself is a good exploration of the techniques and technology needed to make it happen.

4) El Niño[4]

This is a NASA comprehensive guide on the El Niño phenomenon. It is thorough and contains numerous visualizations and explanations of the phenomenon that will both inform and inspire our visualization decisions

5) Interactive web access to real-time El Nino/La Nina data from the TAO buoy network in the tropical Pacific[5]

Similar to the previous IEEE paper, this explores a tool made to interactively visualize El Niño and will be a useful reference as we plan how to demonstrate this phenomenon geospatially.

6) Importance-Driven Time-Varying Data Visualization[6]

Published in IEEE Transactions on Visualization and Computer Science, this paper suggests different visualization techniques for different temporal trends illustrated by the importance curve of the data, which is derived from analysis of time-varying data features. It provides mathematical backing to different time-based visualization techniques based on the data used.

7) Correlation Study of Time-Varying Multivariate Climate Data Sets[7]

Published in IEEE Pacific Visualization Symposium, this study also focused on temporal curves, and used time-varying multivariate climate data sets in its analysis, which is the same data space we are interested in. They used clustering and segmentation, pointwise correlation, and CCA as effective methods to explore correlations in these types of datasets.

8) Visualization of Geospatial Time Series from Environmental Modeling Output[8]

From the Eurographics Conference on Visualization (EuroVis), this research introduces an approach for visualizing large geospatial time series, where techniques designed for smaller series such as small multiples and map animation fall short. It is based on clustering to display prominent spatio-temporal patterns in a compact manner, and results in two components: a spatial configuration view for spatial patterns and a sequence view to display their occurrence over time.

9) Geospatial information visualization[9]

This is a chapter from Meeks's book, D3.js in Action. It provides detailed information on how to visualize geospatial data using JS D3, and will act as a crucial guide as we build our visualizations.

10) D3.js: Introduction to Mapping[10]

Similar to the previous reference, this source is a thorough guide on using D3 to visualize geospatial data. Written by Hanson and Seeger, it is an Iowa State academic paper highly relevant to our visualization goals. Although it utilizes JSON data, different from our netCDF source data, it is nevertheless a useful guide for visualizing complex geographic information.

3 Partner

Our partner for this project is Dr. Samuel Muñoz, author of "El Niño increases the risk of lower Mississippi River flooding" and assistant professor at the Northeastern Department of Marine and Environmental Sciences. We are collaborating with Dr Muñoz in order to augment the work of his lab in better understanding the connection between ENSO and Mississippi River flooding. By creating an interactive, publically-available visualization of this phenomenon, we are hoping to improve the accessibility and visibility of his group's research.

4 Data

Data used for the El Niño project is sourced from the National Oceanic and Atmospheric Administration (NOAA) and the United States Geological Survey (USGS) and is publically available. File format of the data is NetCDF, however, Dr. Muñoz has an R script available to flatten the file into a more readable format.

Additionally, Dr. Muñoz has provided us with several data sources that could potentially be utilized for our project: historical sea surface temperatures (NOAA), historical precipitation (GPCC via NOAA), historic soil moisture (CPC via NOAA), and Mississippi river levels (USGS).

5 Execution Plan and Preliminary Work

Plan of execution follows from our goal of creating an effective and immersive visualization to display the effects of El Niño and La Niña. We will be creating the visualization using Data-Driven Documents (D3.js), which is a JavaScript library that binds data to the DOM and applies transformations and events using HTML, CSS, and JS.

Considering most of the data is geospatial, we are in the midst of planning out our views, interactive events, and transitions using task analysis and task abstraction in order to effectively display this data for our target user. Utilizing libraries D3 provides to transform geospatial data (GeoJSON, TopoJSON) may be helpful as well as using functions to create Mercator, Mollweide, orthographic, and satellite projections in D3[11].

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