VASE (Visualized Atmosphere Sounding Exploration)

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Abstract

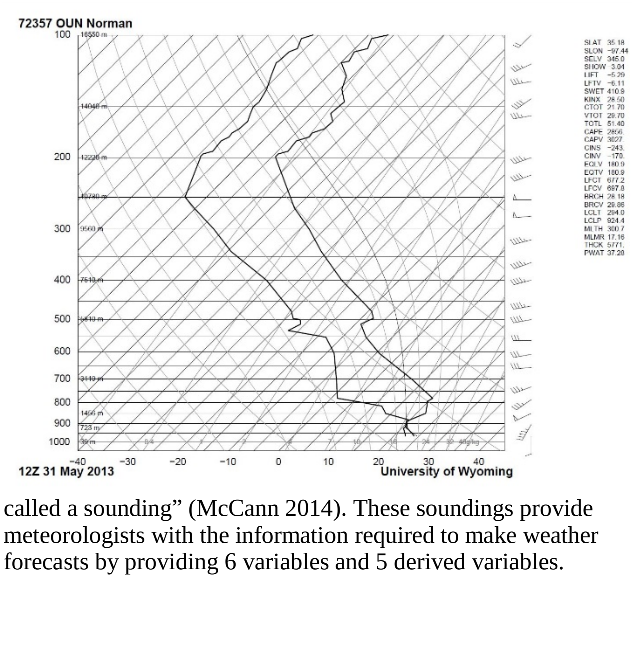
Despite atmospheric science and weather forecasting being relevant data to many fields and corporations, there has not been a lot of innovation incorporating the modern breakthroughs and methods of interactive visualization to the meteorological field. There is a plethora of free atmospheric information valuable on the internet that is being under-utilized. Having a more approachable way to present and explore the information in a browser based application could benefit individuals from a number of fields and make use of the avalanche of data available. Due to the complexity and scope of information from Soundings, VASE, like its predecessor the Skew-T chart, is still slanted towards individuals with meteorological training.

VASE is an attempt to utilize visual variables to redesign the traditional Skew-T chart to be more intuitive and facilitate the comparison of multiple Sounding readings. Even for these experts, Skew-T charts are not particularly effective or efficient for many important forecasting tasks, as the presented format is difficult for comparing two readings side by side to view patterns. VASE attempts to present this information in a way that trained users can innately spot patterns to compare or contrast readings.

Keywords: Meteorology Visualizations, Sounding, Atmospheric data, Skew-T.

1 Introduction

Skew-T charts are formed from data “collected by launching a balloon with an attached sensor and transmission equipment called a radiosonde. The set of data from one balloon launch is



called a sounding” (McCann 2014). These soundings provide meteorologists with the information required to make weather forecasts by providing 6 variables and 5 derived variables.

Weather forecasts have a large audience built up of more than just meteorologists including but not limited to farmers, government authorities, and the military (Schroder 1993), but a traditional Skew-T reading takes a great deal of specialized training to be able to extract information from. There is a vast amount of atmospheric sounding data is widely available for free from sites such as the University of Wyoming’s Department of Atmospheric science, but the data tables or Skew-T formats it is available in are only useful to trained specialists. Even for these experts, Skew-T charts are not particularly effective or efficient for many important tasks, as the presented format is difficult for comparing two readings side by side to view patterns. Additionally many other experts require the use of weather data for predictive modeling, such as the need for power companies to predict power demand, since weather is the primary driver for electricity demand (Treinish 2000).

Most scientific computing utilizes computers for what they do best (simulation, data filtering, and data reduction) in tandem with man’s propensity for pattern recognition and identifying areas of interest, features and anomalies (van Dam et al 2000). But many of the recent breakthroughs in the science and methods of interactive visualization haven’t been widely incorporated into the climate community (Nocke et al 2008). During a two-year long design study involving meteorologists in decision making contexts, Quinan and Meyer found that design flaws in visualizations can lead to misinterpretations and inaccuracy, but that there was very limited support for working with ensemble forecasts (two or more simulation outputs that cover an overlapping geographic area or time frame). Furthermore, it is challenging for meteorologists to attempt to mentally integrate information from sets of visualizations with inconsistent or conflicting coding, but may be necessary to form accurate and holistic predictions (Quinan & Meyer 2015). The same operations must be applied to datasets that need to be fused or correlated for ease of use and understanding (Treinish 2000).

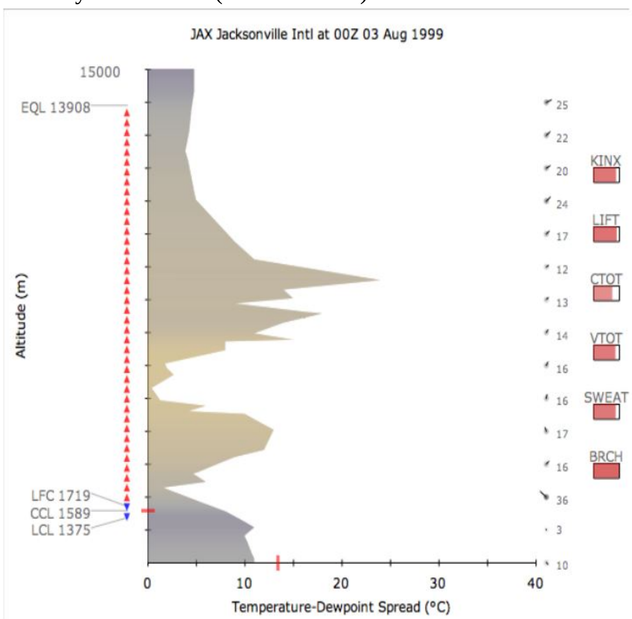
Challenges visualizing weather and climate data specifically are: users come from a wide array of skill levels, ages and disciplines, so tools must account for a range of task variation; alternative visualization techniques are required for analyzing large time-dependent data sets; the heterogeneity of climate data requires many types of visualization to present; and it requires sophisticated technologies to bridge the gap between hefty complex data sets and the users (Nocke et al 2008). Additionally, due to the size of weather simulation data, it tends to be translated into static images which isn’t effective in communicating spatio-temporal data for tracking important features and changes over time. There is also the issue of occlusion problems in regions with a higher station density (Nocke et al 2007).

2 Related Work

For perceiving geographical changes, the form most climate data is presented in, variable size has both the quickest mean response time and first fixation time. Color hue and value also proved to be effective and efficient at communicating geographical data, with variation in orientation being the slowest variable for both response and first fixation (Garlandini & Fabrikant 2009).

Researchers have developed web-based tools to track complex features, such as the Madden-Julian Oscillation in JavaScript using the Google Earth API as the geographical base (Lee, Tong & Shen 2013). These have the potential for a much wider deployment than previous simulations such as TimeMap, GENI and Wildland Fire which required expensive proprietary software's such as ArGIS or MatLab to use (Kannangara, Fernando & Dias 2009). Given the eclectic audience for climate data, it is logical to develop web based tools rather than software based tools, since all they require is for the user to download a free lightweight plug in for their browser.

There have been two previous documented attempts to rework a static Skew-T chart, THETAPLOT during the 1980s and most recently AtmosView (McCann 2014) shown to the left.



Since THETAPLOT was created before most of the modern research on design principles, this project will primarily build off of the work done for AtmosView and attempt to make it have higher learnability and usability for visual comparison, as well as link it to an interactive feature map overlaid on the Google Earth API. AtmosView is a very intuitive and creative rework of the Sounding data, with a strong foundation in psychological and design principles. It is able to present a lot of visual data using a small static image, and has been designed to accommodate for all common types of color blindness. In addition to creating interactive components for the climate data, three aspects of the chart are in need of a rework: it relies on some text that may be difficult to read at the small font size it is displayed in when comparing more than one graph, the graduation of color in the small red glyphs is difficult to discern, and certain aspects aren't initially visible or intuitive.

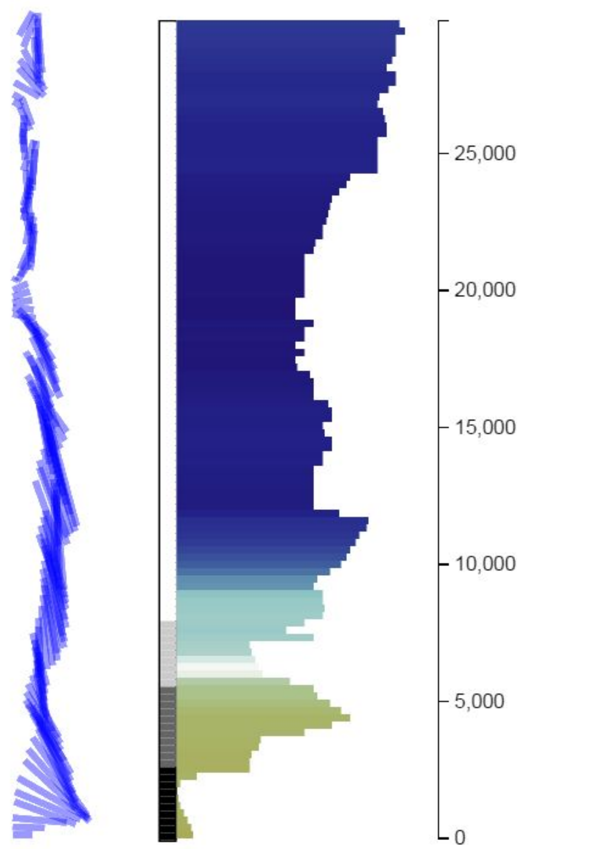
Additionally the charts could be more attractive and use a more intuitive and varied color scheme for displaying data. While yellow is an attention demanding color it also induces more eyestrain than any other color (Fazlul Hoque 2006) and is one of the main colors in the display which is otherwise well conceived. Using two different values to represent factors indicating atmospheric stability within the size chart readings was very well conceptualized and provides much more data than would be expected at an initial glance. Such visual components facilitate visual comparisons between two or more charts.

In the small chart all of Mackinlay's visual variables for quantitative data other than density are utilized well except for color hue. While the use of framed rectangles and color hue variation was well considered, it is nearly impossible to notice the hue variations the paper mentions conveys additional information. Also reducing the width of the framed rectangles is found to be effective in the viewer finding patterns and clusters in the data (Cleveland & McGill 1984). Another strength of AtmosView's design is the absence of distracting "chartjunk", only the minimum, maximum and crucial values are labeled instead of a scale on the side, which gives the user an exact number for any value they may care about (Carson 2009). A way to further refine it would be to have numbers on demand (mouse over) as was implemented in WeaVER. It is difficult to read the values anyways when comparing multiple charts, so just adds more unnecessary clutter to an already very information dense design (Quinan & Meyer 2015).

3 Design Elements

Soundings take readings from the same geographic location at many different altitudes. Each bar represents one geographic location, with the elevation increasing the closer it is to the top of the bar chart. The idea of data-vases combine with AtmosView drove the design, but with altitude being depicted with vertical space rather than time

To make it easier to identify patterns between readings, it



was decided to provide most details on demand (mouse-over) and instead so that the viewer can focus comparing

Soundings and then be able to find specific numbers. Altitude is the variable that all of the elements of the Glyph are positioned by.

3.1 Temperature and Dew-Point Depression

Many studies have been conducted as to how to best use color to represent temperature in Meteorological data. In a 2015 study completed by Quinan & Meyer they propose an optimal color scheme for representing temperature which I utilized in my design. Their color scheme was selected because a) it has been scientifically studied at a greater scale than I had the resources to accomplish and b) their paper mentions the importance of industry standards for colors, cold in particular to determine when a temperature is below freezing. For my color scheme 0*c or freezing, is displayed in white. Not only is the color hue distinct from the rest of the readings, the tonality is noticeable as well. The color scheme used becomes more saturated at extreme temperatures.

This was the area I assigned a great deal of consideration for in my color choice, though that came at the cost of having less subtle variations visible at extreme temperatures. Since a great deal of the upper atmosphere is quite cold, there is less variation in color with this refinement than the default, but there is much more apparent variation in the more prevalent lower atmospheric temperatures. After consultation with my meteorological source I refined my color scheme to convey more nuance at the lower altitudes that were much more important for weather forecasting.

Independent from AtmosView I reached the same conclusion, that the lengths of the bars are best used to represent dew-point depression as it is a very important variable that doesn't have a natural variable fit, and size is unused. When I noticed AtmosView utilized the same visual variable, it reinforced my confidence in the representation. The larger the bar is, the greater the difference in the absolute value between temperature and dew point. If this value is less than 6, the altitude is considered saturated, the larger bars represent dryer spaces.

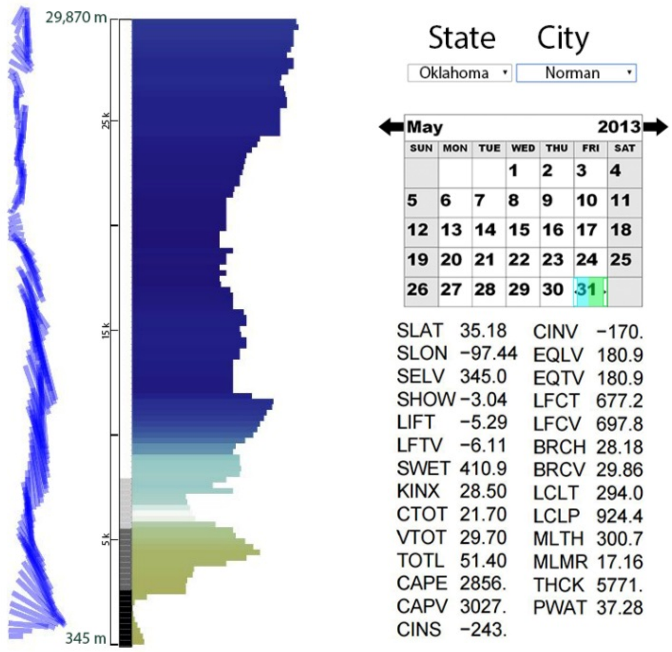
3.2 Pressure Bar

The atmospheric pressures relevant to common forecasting needs are between 500 and 1000 hPa. For purposes of easy comparison, to the left of the temperature and dew-point depression graph the pressure/ thicknesses for commonly referred to pressure ranges are denoted. The range between 1000 and 850 is denoted in light grey, between 850 and 700 in medium grey and between 700 and 500 in black. I've found most users who aren't meteorologists don't notice the presence of this small bar, but the expert users find it useful.

3.3 Wind Glyph

The angle of the line display is the angle and direction of the wind from the data. It made sense to use angle as the variable for wind, given its nature as a strong visual variable for quantitative data, and the benefit of being intuitive. The length is represented at 1 px per knot. I choose to utilize a partially transparent color for the wind glyph because it is much easier to see the direction and speed of the variables nearby as well. The angles of wind seemed rather erratic and it would have wasted a lot of white space to create a wind glyph with no overlap. Additionally it seemed like a strong stylistic choice to represent the nature of wind and differentiate it from the rest of the chart. Most users instantly identify the temperature glyph because of the color scheme, so I wanted to create something else that conveyed the information while being simultaneously familiar and unfamiliar.

3.4 Design for Next Phase



Future plans include the ability to search by city and day (or the averages of several days), as well as the data table featured on Skew-T charts that includes data derived from these variables. Meteorologists rely on those for short cuts to easily interpret the chart data and identify areas of interest. After the stage pictured above is reached by the prototype, additional design will be done as to what other forms the derived variables in the table could take. In the current design plan, all information to the right of the glyph will be hide able so it doesn't distract from comparing multiple visualizations.

I choose to use a traditional forms view because I noticed when I was using the tool that a lot of the information I had were dates and states. Most states only had 1 or 2 weather stations that gathered data, but for larger states with more the option should be given to select that area the meteorologist requires data for. I am still considering using a timeline bar (to select ranges) rather than a calendar view, but could see that as being difficult to use since most of the time there is a specific date in mind, and there are decades of Sounding data available free of use.

More variation in the color hue of the upper atmosphere that comprises most of the Glyph is another area I plan to refine. It seems like there would be a way to maintain the current color scheme, but add in more shades of blue in the upper atmosphere areas that currently have less differentiation.

4 Scope and Limitations

Due to the nature and timeframe of this project, the VASE prototype has still not reached a level of sophistication worth conducting formal testing. A lot of refinement and improvements have already been identified by members of the meteorological and visualization fields. Due to the small sample size of experts I have worked with so far, it is entirely possible VASE would not be so widely appreciated as hoped. After further refinement of the prototype, I plan to seek out additional experts in the meteorological field both in Maryland and Oklahoma to ensure that the information and tasks they base decisions on are included in the visualization. My assumption is that meteorologists will have similar variables that are important to them, but different methods for examining those variables. Further insights into forecasting would be helpful to refine the design of VASE and ensure maximum efficiency.

In its current state VASE is a proof of concept, that there are more approachable ways to present weather data while maintaining its complexity. The goal is not just to provide a tool to make the forecasting more efficient and effective for experts, but also to make the field a bit more approachable for novices. While VASE still requires meteorological knowledge for the data to be meaningful, my hope is that having Sounding data presented in a more colorful, interactive and intuitive way will encourage more people to learn about weather science.

5 Future Directions

While I utilized many research design principles to try and make a more intuitive way to understand and compare atmospheric data, there is still a great deal of work to be done in learnability. Utilizing the visual variables of colors, shapes and position rather than mere charts is a step in the right direction, but further work needs to be done with both the usability of VASE as well as finding ways to convey the vast amount of information contained in small print on Skew-T charts.

The learnability suffers from the same shortcomings as its predecessors. Simply, making meaningful connections from Sounding data requires a great deal of training. In a matter of minutes the average user could learn to extract variable values from the Glyph, but it is only meaningful in the hands of a trained expert. The positive feedback I received from the meteorologist I consulted with indicates that there may be a place for more interactive and visual tools for meteorological data. But throughout the course of the project it became clear to me that in order to develop a tool that would be used by meteorologists, I would need to spend more time consulting with those professionals and more deeply understanding their needs.

VASE is still in its early stages of development. Before it would be ready to test with professional meteorologists the following issues must be addressed: conversion to a fully SVG model, mobile device compatibility, data marking the highest altitude clearly on the axis, the pressure at ground level marked next to the 0 altitude mark, and the ability to aggregate data to show averages for a single location over time. An interactive map showing the US readings over a single time period would be a nice presentation format if time allows. However, the meteorologists' perspective is that seeing the averages of one location over a time period is much more informative for making weather predictions. While the intention to provide meteorologists with a tool to compare Sounding readings with visually was well conceived, the initial impression of geography being the independent variable was misplaced, and future efforts will be focused primary on providing tools with time as the primary variable.

Additionally, to be accessible and useful, a tool such as VASE should be a fully web based tool with the ability to retrieve sounding data daily, with users having access to a plethora of dates and a range of sounding locations. While I do not have the data to back that claim up, many of the suggestions given to me (and tools employed most regularly) from the meteorologist I consulted with shared this common theme.

Even though in its current state VASE isn't the optimal tool, meteorology could benefit from more research being done in visualizing data, primarily for comparison purposes, for experts as well as novice users. Currently many of the most used tools and charts employed by meteorological experts are archaic static graphs.

The basic usability tests I performed indicated, unsurprisingly, the two user groups had very different information needs and desires. Novice users found VASE visually appealing, but were not able to glean meaningful information from the content even after exploration. In contrast the handful of subject experts found the system easy to learn, their suggestions for improvement mainly centered around including more information in the design, mainly the derived variables featured on the Skew-T chart tables

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