Visualizing Impacts of Climate Change on Peak Wildflowers

Rachel Li
University of Washington
Department of Statistics
ryli@uw.edu

Xiaojing Zhu
University of Washington
Department of Statistics
xiaojzhu@uw.edu

Guanming Wang
University of Washington
Department of Statistics
guanmw@uw.edu

ABSTRACT
We develop an animated narrative visualization for the seasonal timing of flowering (i.e. wildflower phenology) in the high mountain meadows of Mt. Rainier to help phenologists understand the biological impacts of climate change. Data was collected by volunteers for 10 plant species at 9 locations along the east branch of the Lakes Trail over a large gradient in elevation from 2013 to 2015. In our visualization, we use animation to show the snowmelt events and the life cycle of wildflowers over time. The viewer watches the wildflower phenology and snowmelts as the animation plays and makes comparison among three years, seeing the relative impact that the climate change has had on the snowmelt date and the wildflower phenology. Our narrative visualization along with other interactive exploration functionalities aim to provide viewers an engaging and effective story-discovering experience along with some insight into the impact of climate change on wildflowers.

INTRODUCTION
Phenology is the study of the timing of recurring life stages (e.g. budding, flowering, fruiting, and releasing seeds), in other words, the biological manifestation of the seasons. In the field of Phenology, people study the life cycle events of plants and animals and how these events are affected by environmental factors, such as variations in climate. Phenology is frequently cued by climatic variables (e.g. snow disappearance, temperature), and thus, will likely be sensitive to climate change. Professor Janneke Hille Ris Lambers from Department of Biology at University of Washington is interested in forecasting the impacts of climate change on the phenology of wildflowers. Previous study shows that the timing of seasonal wildflower displays is strongly linked to snow, and will thus be strongly influenced by climate change. As a result, plant and animals relying on wildflower displays may be affected, as will the management of these natural resources. Although people have made progress in understanding the potential impacts of climate variation on plants, usually these results are not generalizable, i.e. different places could have their own local phenological patterns. In this case, the science project MeadoWatch [3] was established in order to collect information and to gain a thorough understanding of the phenological patterns on Mountain Rainier.

Data was collected by volunteers for 10 plant species at 9 locations, which are along the east branch of the Lakes Trail, over a large gradient in elevation from 2013 to 2015. In our visualization, we design new methods of visualizing the seasonal timing of wildflower phenology in the high mountain meadows of Mt. Rainier to help phenologists understand the biological impacts of climate change.

RELATED WORK
Dynamic Phenology Data Visualization Tool
The USA National Phenology Network [6] is a project that studies the phenology over the entire country. In this project, a dynamic phenology visualization tool is developed so that people can 1) Find out the overall climate pattern, 2) species' and sites' information, and 3) intensity of events. The tool is developed on a zoomable map (Google map). The map on original scale has many state count markers, one for each state, indicating the number of sites within a state. If we zoom in the map, the state count marker will split into many grouped markers, on which a number will tell us the number of status records in that area. If we further zoom in the map, the grouped markers will split into many colored site markers that show the exact location of individual sites. The intensity of color of the marker indicates the density of the data at that site. Mousing over the location also shows a scale indicating the relative density of the data compared to other sites displayed on the map. If we click any site marker, a horizontal bar, which represents phenological activity for selected sites, will appear.

Narrative Visualization
Segel and Heer [5] summarize the design of narrative visualization, and corresponding visualization techniques for telling stories with data. Based on their study, there are roughly seven genres of narrative visualization, including magazine style, annotated chart, partitioned poster, flow chart, comic strip, slide show, and video. Besides, different genres consider varying balance of author-driven and reader-driven experiences. These two story-telling approaches have totally different properties. For author-driven story, it has the properties 1) linear ordering of scenes, 2) heavy messaging, and

This is the report of final project.

CSE 512 16 Spring, University of Washington
Instructor: Jeff Heer
Teaching Assistant: Michael Correll, Jane Hoffswell
Course Website: http://courses.cs.washington.edu/courses/cse512/16sp/

3) no interactivity. For reader-driven story, it has the properties 1) no prescribed ordering, 2) no messaging, and 3) free interactivity. Including only one of the approach and excluding the other one will make our visualization work too rigid to illustrate the story. Therefore, in our project, we will find a way to combine these two story-telling approaches.

METHODS

For the phenology data of three years, we would like to develop an interactive visualization that could display the dynamic change of snow disappearance date (SDD) and the timing of flowering for each plant species and plot over the summer season for each year. The challenging part would be how to make users gain an insight from our visualization in a straightforward manner that the wildflower phenology was linked with snowmelt date that was influenced by climate change. By employing the concepts of narrative visualization [5], animation and visual information-seeking Mantra [4], we develop a system that could tell the story with data through both the narrative flow controlled by time variable and the users' interactive exploration.

In this section, we present a detailed explanation of strategies and techniques we used for visualizing the phenology data. Throughout, the design strategies are marked in bold face.

Narrative visualization with animation

We design an **animated narrative visualization** for the phenology data to tell the story of how climate change makes impact on peak wildflowers. We use animation to display the yearly trends of snowmelt and the flowering of each species in each locations (on different latitude) over time. As the days progress in each year when users hit play, users are able to observe the events of snow-covered, snow-disappeared, wildflower blossom, wildflower-disappeared through color change in the graphical elements of our interface. Meanwhile, every event will be marked in the gradually appearing histograms as animaiton plays, which eventually become a static visualization summarizing the information provided in the animation. We also design an input box prompted by Goto Julian day, which enables users to set up the start date of animation as well as just jump into the visualization of any particular day they are interested, which provides a **timeline controlloer**. Also, users are able to pause at any point of the animation for scrutinizing.

The narrative flow is controlled by the time variable, i.e. each day in a year. As the user steps through the animation, the visualization maintains a **consistent visual platform**, changing only the content within each panel while leaving the general layout of the visual elements intact.

Visual Encodings of Impacts

The visualization consists of two parts: the top part is the focal flowers in corresponding sites simply represented by bands and circles; and the bottom part is the histograms documenting the total number of wildflower species observed flowering (i.e. the wildflower season) and the snow-covered or disappeared events. Both top and bottom parts are arrange in three **small multiples** with each representing one year, which allows for direct comparison among years at any given date and serves as a premise for the visual perceiving of climate change impacts.

As time progresses when user hits play, bands turn from light blue to dark green when snow melts from plots, dots turn colored when flowers are observed in plots, and the heights of the bars in the histogram (bottom panel) are stacked by the total number of wildflowers for each species observed flowering. Color encodings for flowers are chosen to be similar to the actual color of most species.

Through such design we can present the phenology data and the snow disappearance date for the three years simultaneously, we hope by which the users could discover the story we are trying to tell: the climate change influences the snow disappearance date, thus making impacts on the phenology of wildflowers.

Visual Information-Seeking Mantra

The Visual Information-Seeking Mantra presented by Shneiderman [4] summarizes many visual design guidelines, several of which are of particular note to us. The **overview-zoom-filter** sequence and the concept of **details on demand** are very important in how we develop our visualization next.

So far, we have established the general system but no details. Users are only be able to perceive the general idea that the climate change have made impact on the phenology of wildflowers in 2015 by making comparison with the year 2013 and 2014. It is naturally for them to wonder how specifically the climate change would make impacts, e.g. they may be interested in questions about 1) which species was most/least affected by the climate change, 2) how would the impacts of climate change on difference species vary upon elevations, etc. We therefore add a filter functionality on the flower species so that users can choose one or more species they are interested in, which provides more **interactive exploration**.

Also, we design several buttons by clicking which users can see the flower gallery, the hiking trail map for the nine sites, the narrative explanation for the visualization as well as more information about the MeadoWatch project. There is also a time converter between Julian day and date. Those features provides **details on demand**.

RESULTS

Screenshots of Visualization

Figure 1 shows a series of screenshots of our visualization, ending at the final view of the visualization (i.e. the last day of each year). The readers will have a better sense of it by viewing it at `http://cse512-16s.github.io/fp-racheryl-xiaojzhu-dennis418szsy/`. Figure 2 shows the filter functionality, Figure 3 shows the animation control panel and Figure 4 shows the time converter. Figure 5, Figure 6, Figure 7 show the details-on-demand information.

Figure 1. A series of screenshots of visualization. Both mountains and histograms are arranged in small multiples for each year, which allows for direct comparison between years at any given date. As time progresses when user hits play, bands turn from light blue to dark green when snow melts from plots, dots turn colored when flowers are observed in plots, and the heights of the bars in the histogram (bottom panel) document the total number of wildflower species observed flowering (i.e. the wildflower season). The histograms show up gradually along the time axis as the animation plays. Every change in the process of animation will be marked in such histograms, which will eventually become a static visualization summarizing the information provided in the animation. Users can also type in the start date of the animation on the left side.

Figure 2. Leftside part shows the color legend for the 10 species, which were chosen to be similar to the actual color of most species. This legend could also functions as a filter on flower species so that people can choose certain types of flowers they are interested in, which is illustrated by the right-side part. Upon selecting on the species, the focal flowers in corresponding sites and the histograms will change accordingly.

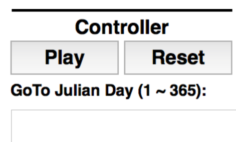

Figure 3. The animation control panel.

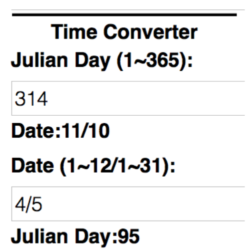

Figure 4. Timer converter between Julian day and date.

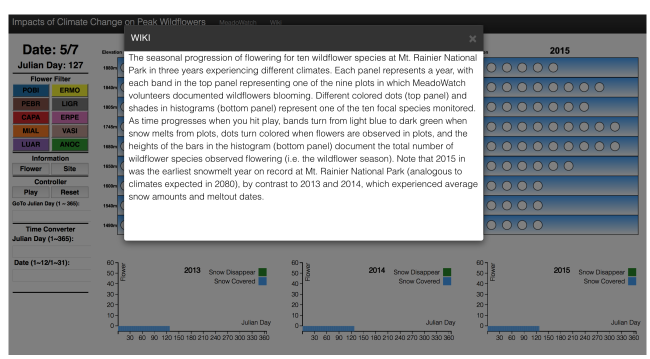

Figure 5. The information box for the narrative legend

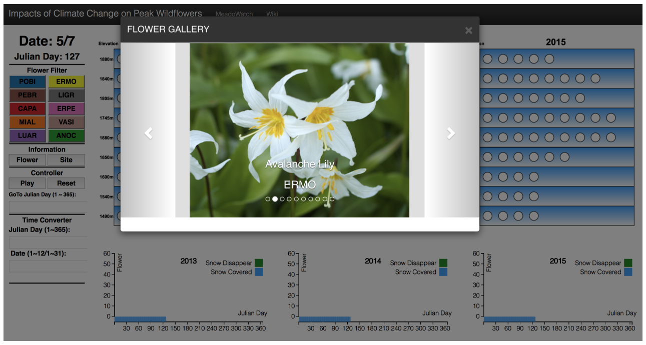

Figure 6. The flower gallery for detailed species information.

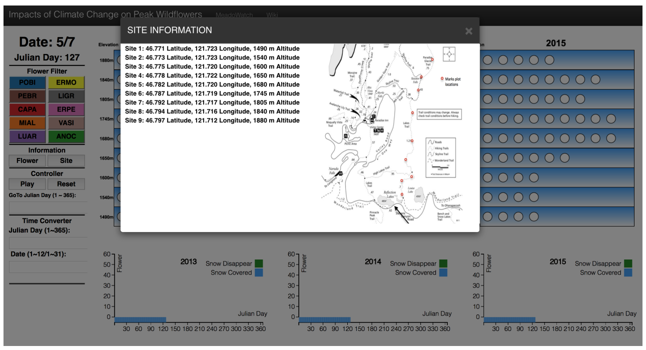

Figure 7. The hiking trail map for more site information.

Animation Running Speed

We set the animation speed to be 1 second per day. Even though users can specify the start date of animation, we set the default start date to be at Julian day 127, i.e. 7th of May in that the first snowmelting event starts at 2 days after that. Therefore, users do not need wait for the long winter time to observe the first change in the visual elements. One issue of our final visualization is that the histogram part on the bottom seems blinking a lot, which makes the animation not quite smooth. Another issue is that if we set the animation speed to be faster, there would be a problem with the histograms in that the rendering of which for each day takes time. If the animation speed was too fast, the histograms would disappear in the process of the animation and only show up in the end. The top part was implemented by canvas element in JavaScript, which changes quite smoothly in the animation, while the bottom histogram part was implemented via D3, which seems to have some speed issues.

DISCUSSION

Overall, our visualization achieves its goal of providing an engaging experience along with some insights into the impact of climate change on peak wildflowers. It is quite obvious during the animation that the snow disappearance and peak flowering dates were very early in 2015 compared with 2013 and 2014. Although a full user study is outside the scope of this paper, we were able to have several viewers experience our visualization during poster sessions and many valuable feedbacks were collected from them.

In general, the viewers respond positively to seeing the snowmelting and flower-appearing over time. All of them were able to quickly perceive the early flower blossoming in year 2015 and link that with the high temperature and early snowmelt. And people like the part that pulling out the flower gallery or site map will not affect the running of animation. However, most of them felt the bottom histogram part is not updating as animation processes and they tended to miss the filter functionality on species. One idea that people mentioned most is about the interaction exploration. They would like to see more interactive functionality after the animation is finished. Another feature that could enhance the effectiveness of the story is the more aligned layout for each species in the mountainpanels, which would make the visual track of each species easier.

FUTURE WORK

As more data is collected in the meadowatch project, we need to generalize this visualization to phenology data of more than three years. Users can select years among which that they are interested in comparing, thus having easy access to the historical phenology record for each focal species and locations. In order to display more years in one page, some rearrangements of the layout for the display panels are required. One idea would be that we can make either the ”mountain” panel or the histogram panel foldable so that extra room would be obtained for more years of data. It would be better if those panels are dragable so that users can rearrange the layout themselves.

For the interactive exploration part, we would like to enable more interactive functionalities in both the top ”mountain” part and the bottom histogram part, among which the users could do some linked interactive exploration.

In term of visualizing phenology data, we would like to include more phenophases not only flowering stage, but also the other three stages: budding, ripening fruit and releasing seed. The visual encoding of each stage would then be very challenging.

REFERENCES

1. Phenology visualization tool. `https://www.usanpn.org/nn/connect/visualizations`.
2. J. Hille Ris Lambers. Glacier basin species identification and plot location pamphlet, 2013.
3. J. HilleRisLambers. *The MeadoWatch Project*. Available at `http://www.meadowatch.org/`.
4. C. North and B. Shneiderman. Snap-together visualization: a user interface for coordinating visualizations via relational schemata. In *Proceedings of the working conference on Advanced visual interfaces*, pages 128–135. ACM, 2000.
5. E. Segel and J. Heer. Narrative visualization: Telling stories with data. *Visualization and Computer Graphics, IEEE Transactions on*, 16(6):1139–1148, 2010.
6. N. G. Society. Fieldscope - project budburst. `http://budburst.fieldscope.org/`.

7. E. Theobald, A. Ettinger, H. Burgess, L. DeBey, N. Schmidt, H. Froehlich, C. Wagner, J. HilleRisLambers, J. Tewksbury, M. Harsch, et al. Global change and local solutions: Tapping the unrealized potential of citizen science for biodiversity research. *Biological Conservation*, 181:236–244, 2015.