PRIOR WORK SURVEY: DYNAMIC WEATHER-BASED TOOL VISUALIZATION

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1 Project Background

This project aims to create a pixel-art-based dynamic weather visualization app. It will present hourly weather data for up to 16 days, as provided by a free weather API. The app is intended to be visually engaging and interactive, featuring dynamic elements that adjust based on weather data.

This project was inspired by Rainmeter [4], a desktop customization tool for Windows. While Rainmeter offers many weather widgets, it lacks fully dynamic weather wallpapers. Observing this gap led to the idea of creating pixel-art-based dynamic visualizations that combine utility with aesthetics, offering an engaging and innovative experience.

This visualization will use pixel-art graphics to represent weather conditions with several dynamic elements:

- **Season-Based Terrain (Figure 1):**
  The app will feature terrains that change dynamically based on the current season. For Summer, the terrain will resemble a green environment with sandy tones and may include animated tumbleweeds to enhance realism. Winter terrains will showcase snowy landscapes with frost-covered ground, snow buildup, and possibly ice patches or icicles. Spring will display lush green meadows with blooming flowers, vibrant hues, and subtle animations like flowers swaying in the wind. Autumn will represent brown terrains with scattered fallen leaves, muted tones, and optionally, flying leaves animated to reflect wind.

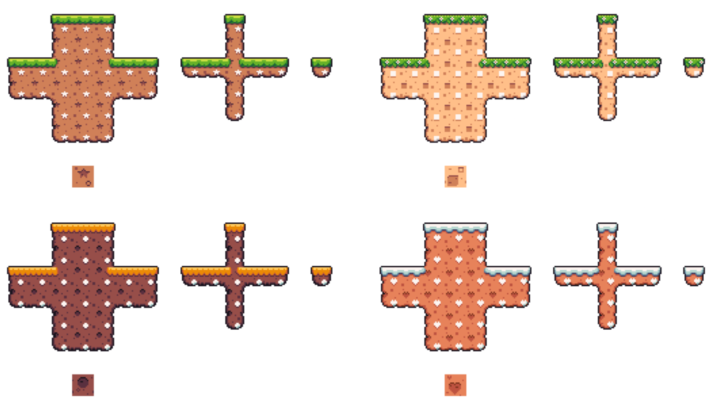

Figure 1: Proposed tilesets for the project. (In clockwise, from top right) Spring, Winter, Autumn, Summer.

- **Dynamic Clouds (Figure 2):**
  Clouds will adjust to the current weather and time of day. Clear skies will feature sparse or no clouds, while partly cloudy conditions will have scattered, fluffy clouds. Overcast conditions will be shown with thick, dense cloud cover, and rainy or snowy weather will feature dark, heavy clouds. During the day, clouds will appear brighter with sunlight highlights, while at night, they will adopt dimmer tones with potential moonlight effects.
- **Terrain Mapping (Temperature-Based):**
  The terrain elevation will change based on the temperature trend over time. If the temperature for the next hour is higher than the current hour, the terrain will slope upward to indicate a rise. If the temperature decreases, the terrain will slope downward to suggest a decline, while consistent temperatures will produce flat terrain. These transitions will be smooth to mimic natural landscapes, with gradient changes visually emphasizing the temperature shifts.
- **Swaying Trees (Wind-Based) (Figure 3):**
  Tree animations will correspond to real-time wind speeds, creating a lively effect. With low wind speeds, trees

will sway gently, while moderate speeds will cause more noticeable motion. High winds will make trees lean significantly, creating a sense of gusty conditions. Additional details, such as falling leaves or broken branches, may be included to reflect extreme winds.

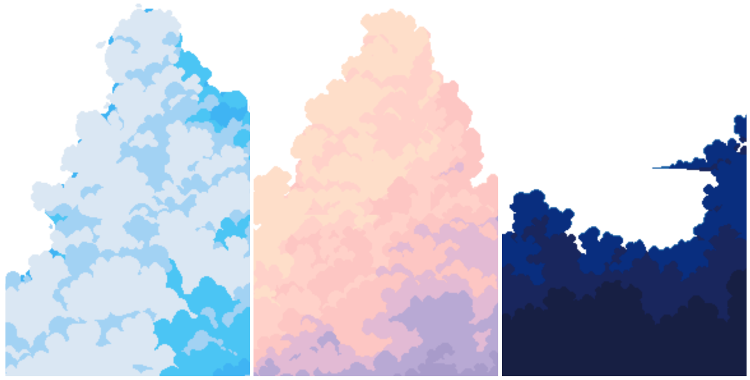

Figure 2: Some clouds for the project. (from left to right) Afternoon, Evening, Night.

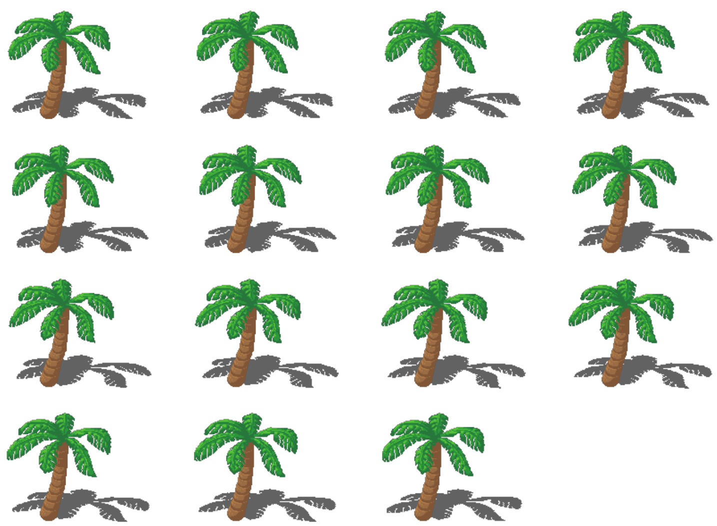

Figure 3: Example of an animated tree spritesheet (15 frames)

- **Rain and Snow (Precipitation-Based):**
  Rain and snow will be animated based on precipitation data. Rain will be depicted with falling raindrops at varying speeds, possibly forming puddles on the ground. Snow will feature flakes of different sizes gently falling, with snow accumulating over time during prolonged snowfall. The intensity of the rain or snow will reflect the data, ranging from light to heavy precipitation.
- **User Selection Dashboard (Figure 4):**
  The dashboard will allow users to select their location and customize the hour of displayed weather data. It will fetch real-time data for the selected region, and users can adjust settings, such as enabling or disabling features like clouds or precipitation, as well as tweaking animation speeds or toggling interactivity for a personalized experience.

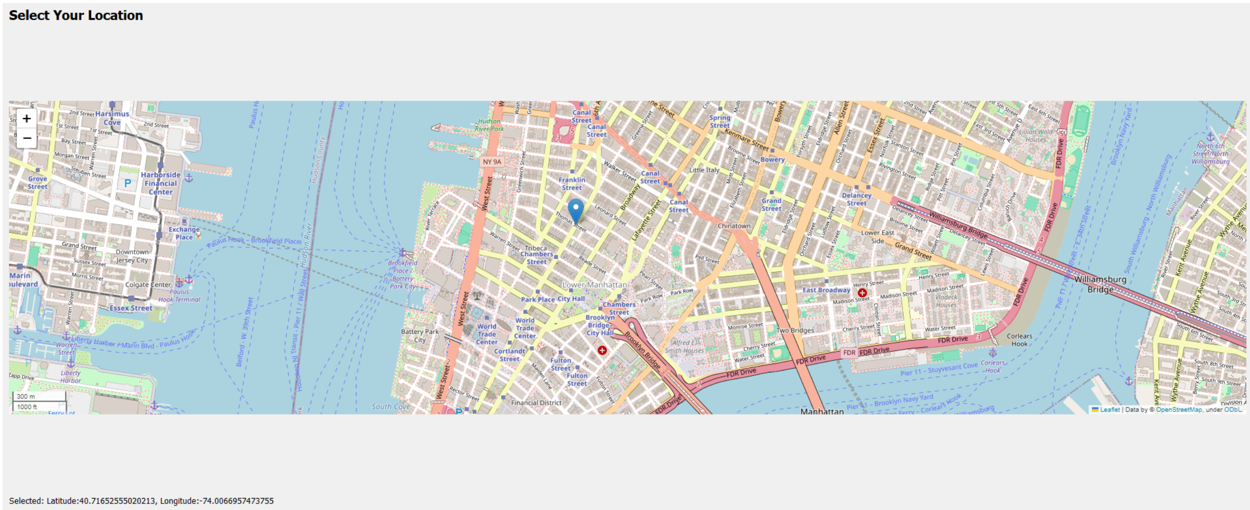

Figure 4: A Skeleton of the location selector dashboard that we are working on.

2 Survey of Prior Work

Dynamic weather visualizations have seen various applications in academic, professional, and consumer settings. While no existing solutions specifically address dynamic wallpapers (the visualization that we are working on), there are several tools, papers, and technologies that provide valuable insights into geospatiotemporal weather visualization.

- **WindVis2 (Figure 5)**
  WindVis2 [6] is a comprehensive weather visualization package developed at the University of New Hampshire's Data Visualization Research Lab. It's designed to display the latest weather forecast model data from NOAA NCEP, specifically the North American Mesoscale (NAM) model. The key features of this tool are:

  - **84-hour forecast display:** Shows a complete 84-hour forecast in 3-hour time steps with automatic updates every 6 hours.
  - **Multiple view options:**
    * Temp. & Pressure: Displays surface temperature (color), atmospheric pressure (texture), and surface winds (traces and numbers).
    * Pressure & Jet Stream: Shows atmospheric pressure (texture), surface winds (small dark traces), and jet stream winds (large white traces).
    * Precip. & Cloud Cover: Illustrates precipitation (color), cloud cover (texture), and surface winds (traces and numbers).
  - **Interactive elements:** Users can click on the map to get detailed information about specific points, including temperature, pressure, precipitation, cloud cover, and wind data.
  - **Time control:** Features a time bar with play/pause functionality and the ability to manually adjust the displayed time.
  - **Automatic updates:** Can be configured to automatically download updated forecast data at regular intervals.

  This tool's focus on interactivity and multi-parameter integration serves as the base inspiration for designing intuitive user interfaces for our dynamic weather tool.

- **Chyron Weather (Figure 6)**
  Chyron Weather [1] is a professional-grade, end-to-end weather visualization suite designed for broadcast environments. It offers a comprehensive set of tools for creating visually rich and informative weather presentations.

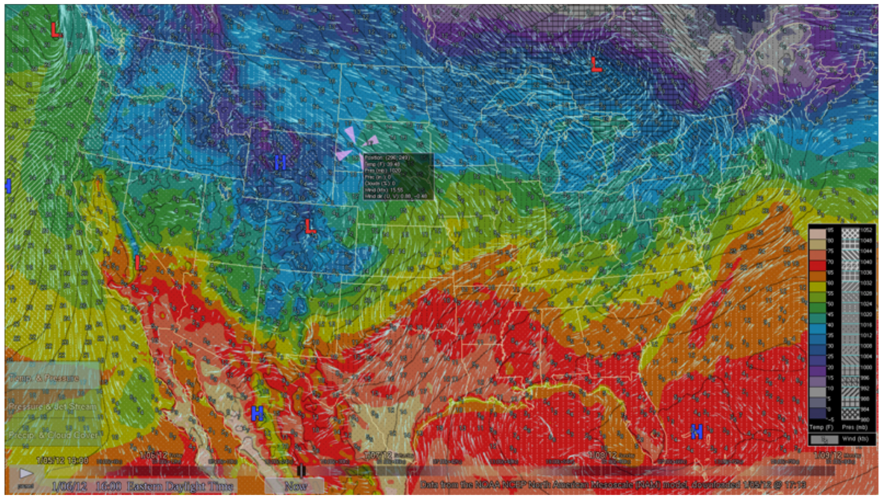

Figure 5: A still snapshot of the primary view design as implemented in a public display. Temperature is represented by color, while atmospheric pressure is given by contours and a sequence of textures. Animated wind traces show the wind direction and speed. Numbers show wind speed at sample points.

The key features of this tool are:

- **Data integration:** Allows for the combination of various meteorological data sources to create a comprehensive weather story.
- **Customizable visualizations:** Offers flexible authoring tools for designing and stylizing maps, graphics, and forecast assets to match specific branding requirements.
- **Real-time forecasting:** Enables live weather presentations combining map-based graphics, global analysis, and lifelike 3D scenes.
- **3D visualization:** Can create lifelike 3D scenes with true elevation models and high-resolution textures for special weather events.
- **Scalable architecture:** Can be deployed on-premises, in the cloud, or in virtualized environments, making it suitable for various operational scales.
- **Multi-platform output:** Capable of addressing live playout across numerous screens and studios, as well as handling high-volume rendering for web and social media.

While its complexity exceeds the requirements of this project, its scalable architecture and focus on real-time updates offer valuable lessons for dynamic content generation.

• **Visualization Techniques in Literature**
This paper [3] provides a comprehensive overview of various methods used in environmental data visualization, including weather data. Some key points from this survey include:

- **Classification of visualization techniques:** The paper presents a classification system based on the number of different factors that can be visualized.
- **Tool assessment:** It offers an overview of popular visualization tools and assesses their capabilities for handling large environmental datasets.
- **Data types:** Discusses various data types used in environmental visualization, such as 1D, 2D, 3D, multidimensional, temporal, tree, and network data.

This paper [5] focuses on advanced visualization methods, particularly 4D meteorological visualization. Key insights from this article include:

Figure 6: A snapshot of the Chryon integration with the CAMIO newsroom that helps weather presenters have minute control over the details of their display and the elements they show.

- **Spatio-temporal data handling:** Discusses methods for processing and visualizing weather data that has both spatial and temporal components.
- **Data formats:** Covers various data formats used in weather visualization, such as NetCDF, HDF, and GRIB.
- **Visualization technologies:** Explores technologies like WebGL and GPU-based rendering for creating dynamic, interactive weather visualizations4.

These studies emphasize the importance of multi-dimensional data handling, temporal visualization, and technologies like WebGL for rendering dynamic, interactive displays. Techniques for effectively visualizing uncertainty and handling diverse data formats such as NetCDF and GRIB were particularly relevant to our project.

3 Trends and Patterns in Prior Work

We notice several trends in the surveyed works for this domain:

- **Visualization Techniques:** Integrating multiple parameters into cohesive displays is a common feature, as seen in WindVis2. Additionally, technologies like GPU-based rendering are increasingly utilized to enhance interactivity and detail, as well as computing speeds.
- **Data Representation:** Geospatial mapping remains a dominant approach for the visualization of weather data. While multi-dimensional data representation is on the rise, the effective depiction of uncertainty is still a challenge.
- **User-Centric Design:** Tools often target distinct user groups, balancing complexity for experts and simplicity for public users. Customization options for tailoring visualizations to specific needs are gaining prominence.

Despite advancements in this domain, there are persistent limitations. Many visualizations are inaccessible to non-expert audiences due to their complexity. Uncertainty representation remains underdeveloped, and large datasets can present processing challenges.

4 Gaps and Future Exploration

The surveyed works highlight several areas for future exploration:

- **Simplified Uncertainty Visualization:** Many tools struggle to represent forecast uncertainty in intuitive ways, especially for non-expert users. Developing simplified models to convey uncertainty could improve user trust and understanding.
- **Long-Range Forecasting:** Accurate visualizations for subseasonal forecasts (3–4 weeks) remain limited and present opportunities for innovation by using advanced prediction models such as [2].
- **Personalized Interfaces:** Creating dynamic interfaces that balance sophistication with ease of use could make weather visualizations more accessible and engaging.
- **Procedural Landscape Generation:** Using weather data to generate interactive or game-like environments remains an underexplored avenue, offering potential for novel user experiences.

This project addresses several of these gaps, particularly through its focus on dynamic, user-friendly visualization. The integration of pixel-art elements, real-time updates, and user interactivity distinguishes this initiative from existing work and sets a foundation for further innovation.

References

[1] *Chyron Weather™ - Weather Visualization Suite - Chyron — chyron.com*. https://chyron.com/products/specialty-content/weather-broadcasting-software/.

[2] Remi Lam, Alvaro Sanchez-Gonzalez, Matthew Willson, Peter Wirnsberger, Meire Fortunato, Ferran Alet, Suman Ravuri, Timo Ewalds, Zach Eaton-Rosen, Weihua Hu, Alexander Merose, Stephan Hoyer, George Holland, Oriol Vinyals, Jacklynn Stott, Alexander Pritzel, Shakir Mohamed, and Peter Battaglia. "Learning skillful medium-range global weather forecasting". In: *Science* 382.6677 (2023), pp. 1416–1421. DOI: 10.1126/science.adi2336. eprint: https://www.science.org/doi/pdf/10.1126/science.adi2336. URL: https://www.science.org/doi/abs/10.1126/science.adi2336.

[3] Romal Bharatkumar Patel. "A Survey of Visualization Techniques and Tools for Environmental Data". In: *Technology and Investment* 14.3 (2023), pp. 153–159.

[4] *Rainmeter, desktop customization tool — rainmeter.net*. https://www.rainmeter.net/.

[5] Roman Rudenko, Ivan Miguel Pires, Margarida Liberato, João Barroso, and Arsénio Reis. "A Brief Review on 4D Weather Visualization". In: *Sustainability* 14.9 (2022). ISSN: 2071-1050. DOI: 10.3390/su14095248. URL: https://www.mdpi.com/2071-1050/14/9/5248.

[6] *WindVis2 | Data Visualization Research Lab — ccom.unh.edu*. https://ccom.unh.edu/vislab/tools/windvis2/.