Simulating Trajectories of Floating Stratospheric Balloons in Support of 2023 and 2024 Eclipse Ballooning Missions

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Abstract

We have modified a free-balloon trajectory prediction script, originally written by balloonists at the University of Colorado Boulder for use with vented latex weather balloon flights, to allow for open-duration "float" flight segments. This work was motivated by the "engineering" (AKA "video-streaming") side of the Nationwide Eclipse Ballooning Project (NEBP), which is considering floating weather balloons to make gravity wave oscillations easier to identify and also to help stabilize the camera platform to assist in taking high-quality video and/or photos. When the simulation program is run, it searches for weather data in a public database from the National Center for Atmospheric Research. The code uses this data to create a choice of files displaying the predicted flight trajectory. The script allows the user to dictate the ascent profile (typically at a constant ascent rate), the vent rate (that is - the rate at which the ascent is slowed), the duration of the float state (or slow ascent or slow descent), the termination condition (typically either a time or a target altitude), and the parachute descent profile (at a rate that is realistic, but non-linear in time). The script may be used to predict trajectories up to 180 hours into the future. Trajectories can also be run using historical data, such as that from Oct. 14 and Apr. 8 (the 2 upcoming eclipse dates), up to 6 years into the past. This prediction tool will be useful for eclipse teams as they select what part of the country to travel to, based in part on trajectories from past years, and also as they decide exactly where to launch from, based on the weather predictions in the days just prior to each eclipse.

Simulation Code

Float predictions are developed using python code originally developed by University of Colorado student Christopher Roseman. The program needs user input for Latitude, Longitude, Altitude, and Launch Time. When the program is run, it searches a public database selected based on the user input from the National Center for Atmospheric Research. The code makes use of this data to create the choice of csv, kml, geojson, html, or png files displaying predicted flight trajectory.

Effect of Venting and Floating on Trajectories

We have generated Altitude vs Time plots for Vent-No-Float, Vent-30-Min-Float, Vent-60-Min-Float, Vent-90-Min-Float, Vent-120-Min Float. – available upon request.

Historical Trajectories

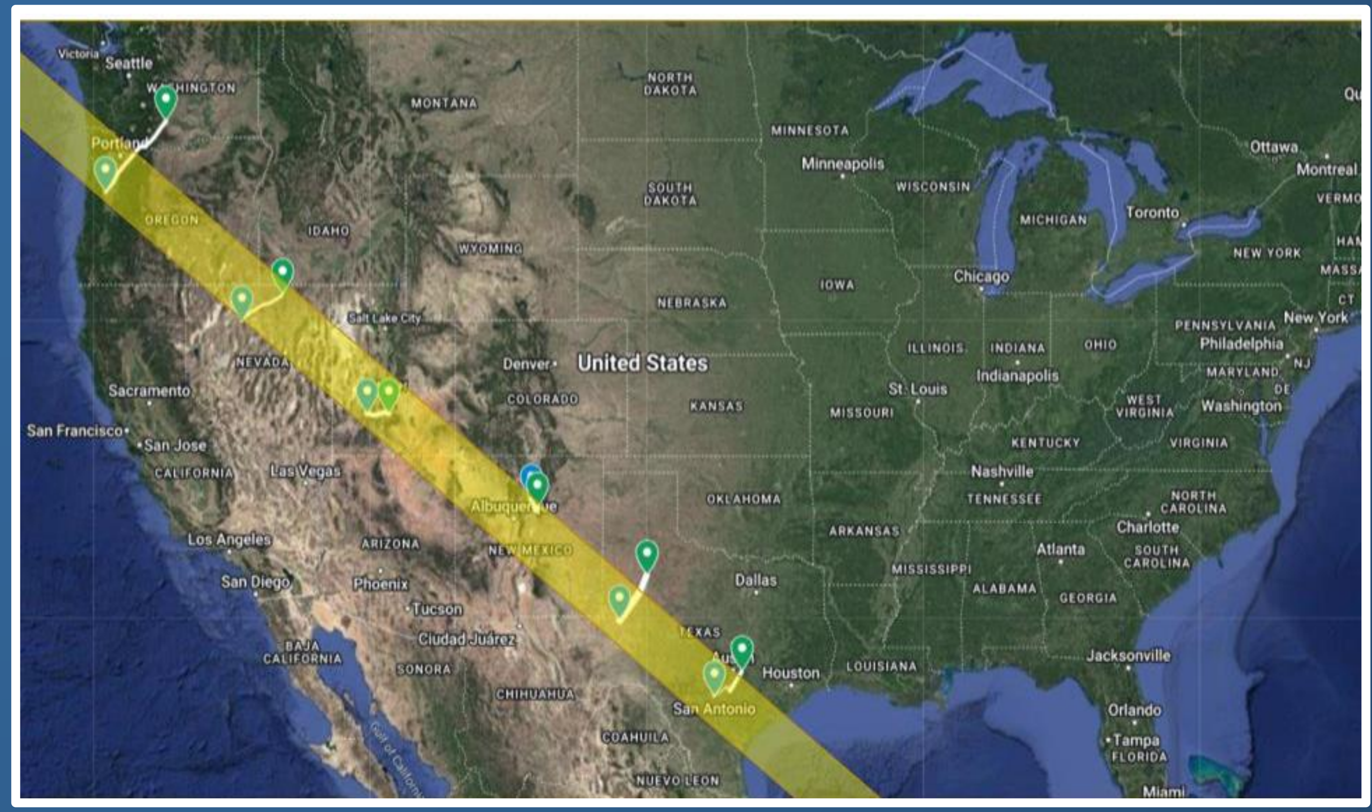
We have generated 3-hour float trajectory maps for Oct 14 for 6 launch locations from within the 2023 eclipse path using data from 2021, 2020, …, and 2016.

We have generated 3-hour float trajectory maps for Apr 8 fro 6 launch locations from within the 2024 eclipse path for years 2021, 2020, …, and 2016.

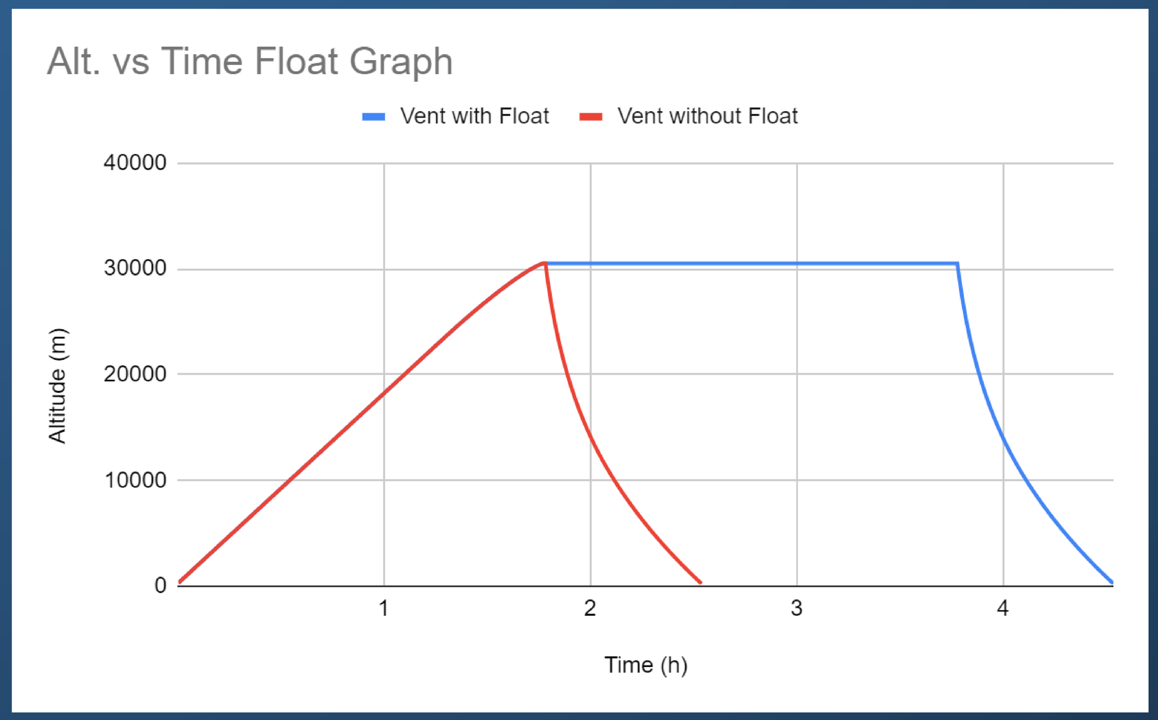
The map below shows trajectory variation for different years from one launch location. The maps at right use 2016 weather for both April 8 (top) and October 14 (bottom), to show trajectory variation with geography.

Comparison of 3-hour-float missions if launched from Buffalo, NY, on April 8 in 2016 – 2019.

2016 trajectories for 3-hour floated balloons launched from cities inside the 2024 eclipse path



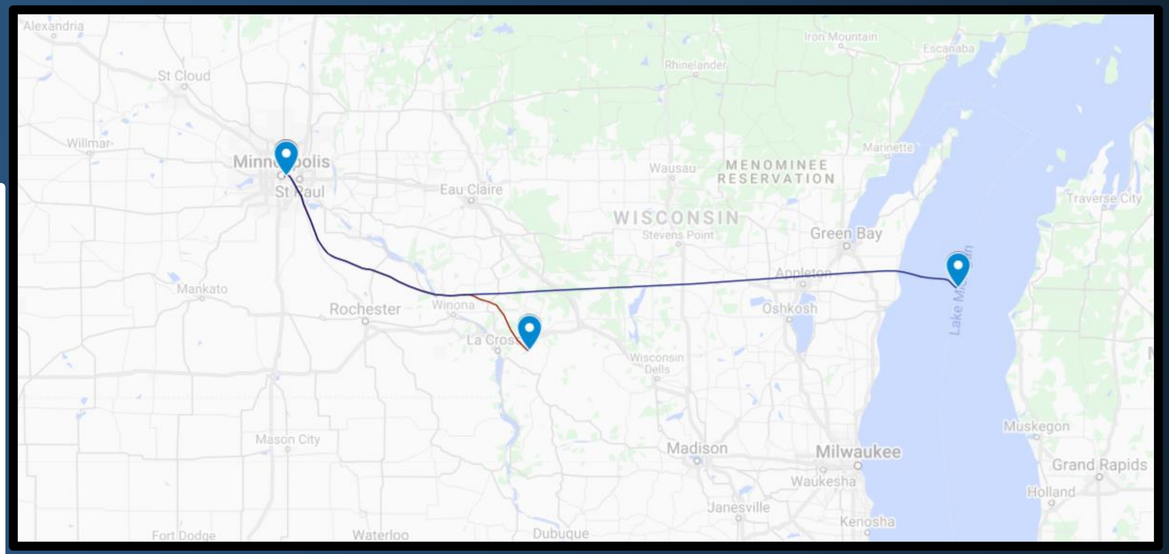
2016 trajectories for 3-hour floated balloons launched from cities inside the 2023 eclipse path



Altitude vs Time graph for a 2-hour-float (at ~30 km) prediction, and no-float at the same altitude.

Conclusions

Using float trajectory software, we are able to simulate flight paths with various float durations using historical weather data from eclipse dates from multiple locations along both eclipse paths. These results may help teams decide where to travel to, along the eclipse paths, and approximately what to expect if floating balloons for various lengths of time on the two eclipse dates. In particular, we are considering the effect of float on flight length (in distance) and on recovery terrain (since getting the payloads back is crucial for the video-streaming eclipse ballooning missions).



Simulation showing the difference in trajectory between no float and a 3 hour float, if launched from the University of Minnesota in Minneapolis (not on an eclipse path).

Acknowledgement

We particularly want to thank Christopher Roseman of the University of Colorado Boulder, who originally developed trajectory code the the HYFLITS MURI research project, for generously allowing us to use (and tweak) his code for doing eclipse/float trajectory predictions.

References

- CUSF Landing Predictor 2.5, https://predict.habhub.org/
- C. Roseman, D. Lawrence, J. Pointer, S. Borenstein, and B. Argrow. "A low-cost balloon system for high-cadence, in-situ stratospheric turbulence measurements", 2021 AIAA Aviation Forum, AIAA 2021-2691, https://doi.org/10.2514/6.2021-2691.

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