Field Test of Altitude-Controlled Stratospheric Ozonesonde Flight with Vented Balloon during the 2024 Total Solar Eclipse

Kiefer Neumann[a], Aidan Halloran[b], Robert Hibbard[b], Nicholas Babich[b], Tarek Ibrahim[a], Grace Teall[a], and Chong Qiu[c]

Abstract

The concentration of the stratospheric ozone layer is of great interest to the atmospheric science community, since it is critical in blocking the harmful UV radiation from the sun. Typically, regular weather balloons with Electrochemical Cell (ECC) ozonesondes are used to determine the vertical profile of ozone column concentration within a flight time of ~2 hours, with a limited fraction of the data relevant to the ozone layer. Therefore, it would be ideal if ozonesonde flights can be maintained within the ozone layer (~60,000 to 80,000 ft) to maximize the efficiency in data acquisition, especially considering the rising costs of ozonesonding and high-altitude ballooning. We adapted the vented balloon with altitude-control flight capability from the Nationwide Eclipse Ballooning Program (NEBP) for atmospheric ozonesonding and deployed a commercial ECC ozonesonde payload with this approach from Central Texas during the 2024 total solar eclipse in the hope of (1) field testing the performance and application potential of vented balloons in horizontal ozone layer profiling and (2) monitoring the stratospheric ozone layer during the solar eclipse for an extended period of time. The adapted vent valve successfully lowered the balloon from 71,000 ft to 41,000 ft within minutes and demonstrated promising performance in the field. Unfortunately, unexpected radio communication difficulties were experienced from six hours before the totality to two hours after, leaving the second research objective largely unobtainable.

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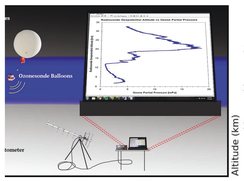
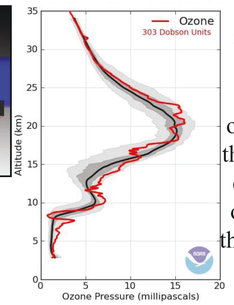
Background

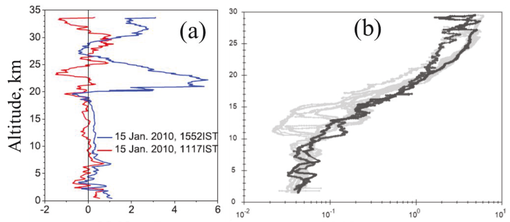




Adapted from NOAA ESRL Global Monitoring Laboratory

Ozonesondes are used to monitor the ozone levels in the atmosphere, especially the ozone layer in the stratosphere.

Previous measurements on the ozone layer during solar eclipses showed inconclusive results



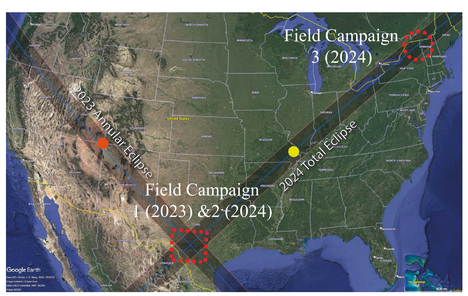
Δ[O3], mPa — 2010 Eclipse over India

Ratnam et al. **2011**, *Geophysical Research Letters*, 38, L02803. doi:10.1029/2010GL045903

[O3], ppm — 2017 the "Great American Eclipse"

Sohl et al. **2017**, *Academic High Altitude Conference*, Session 5. https://via.library.depaul.edu/ahac/2017/session5/2/

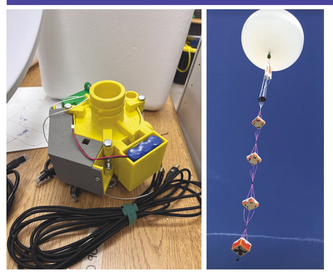
Our plans to conduct stratospheric ozonesonde flights during the 2023 annular and 2024 total solar eclipses



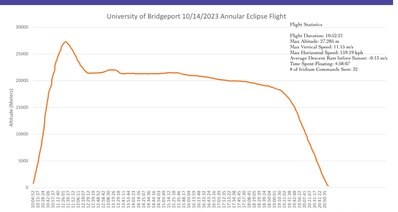
Acknowledgements

We want to thank the technical support from Dr. Joseph, Dr. Mohsen Sarraf, and Mr. Larry Reed. Collaboration with University of Bridgeport eclipse ballooning team led by Dr. Jani Pallis is greatly appreciated. The project was funded by Nationwide Eclipse Ballooning Project (NEBP), Connecticut Space Grant Consortium (P-1840&1846), National Science Foundation (#AGS-1847019) and University of New Haven Buckman Endowed Funds.

Method



Nationwide Eclipse Ballooning Project (NEBP) vent balloon and its performance during the 2023 annular eclipse (Data source: University of Bridgeport).



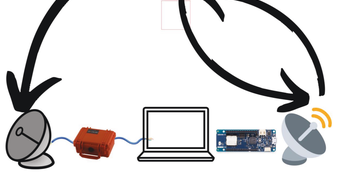
Train Weight: (6+6) lbs; Balloon size: 2000 g
Flight time: ~11 hr; Max Altitude: 27.3 km

Our Objective: Adapt the NEBP vent balloon design to monitor the stratospheric ozone layer at a controlled altitude during the 2024 total eclipse.

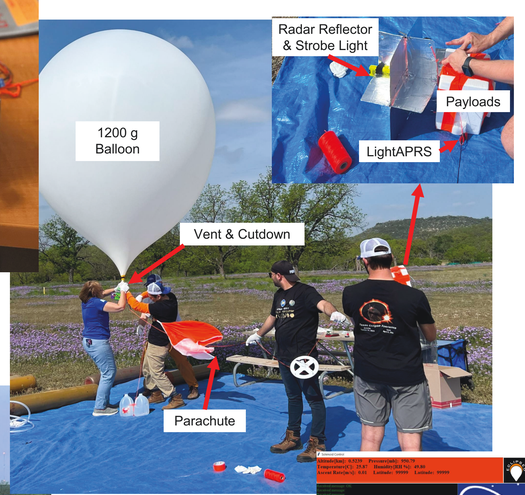
Design Goals:

Train weight 6 lbs (payload 2 lbs); Balloon 1200 g; Flight time 5 hr; Altitude 21 km

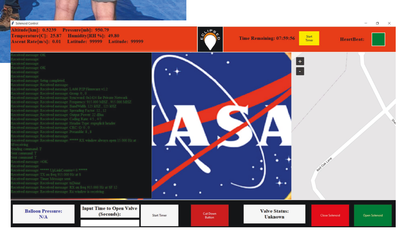
Vent: Arduino Mega, Solenoid vent (on/off), LoRa Modules+unidirectional antenna
Tracking: GPS Modules (NEO-6M), Light APRS tracker (QRP), radiosonde
Safety: Timed vent, timed and emergency cutdown sequence, parachute, radar reflector&strobe light.



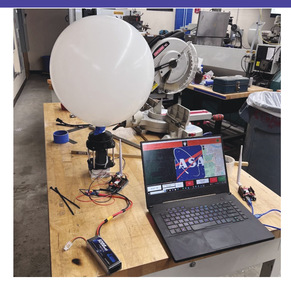
Balloon Train Assembly& Ground Stations



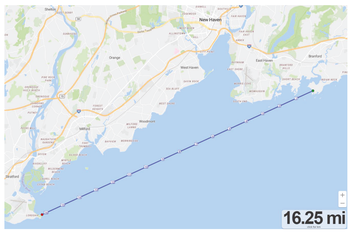
Radiosonde GS based on NOAA ESRL designs



Results&Discussion



Leak, control&comm range tests

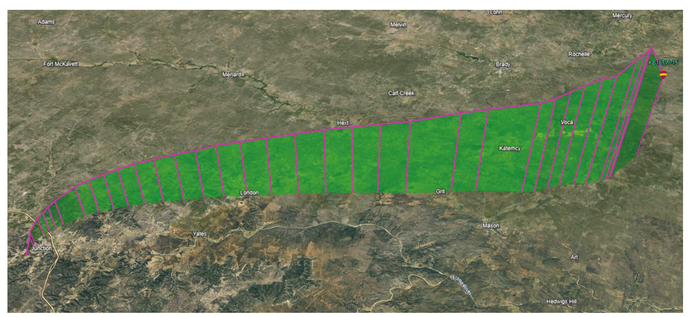


April 8th Flight Data:

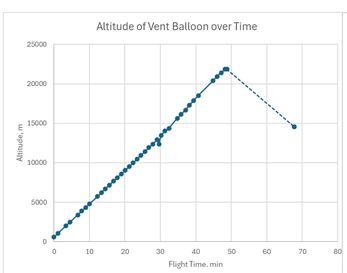
Train weight 6.5 lbs (2946 g); Balloon size 1200 g;
Max Altitude 22 km; Last tracked altitude 14 km
GPS&radiosonde tracking failed at altitude of ~1500 m

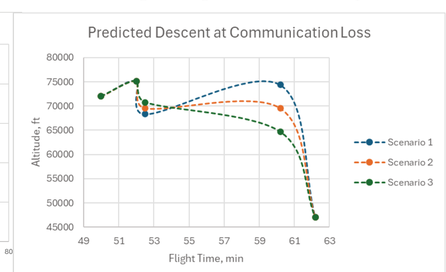
Thoughts: GPS failure also happened to the other teams in the same location. busy wireless comm during the total eclipse? QRP LightAPRS failed after exposure to stratospheric conditions? Needing a better ground station for the radiosonde?

Tracked Flight time: 1.2 hr (by APRS)
Venting sequence: 23 min (10 s), 35 min (15 s), 52 min (30 s), 60 min (120 s)



Vented balloon flight path, via APRS tracking, during the total solar eclipse





Avg. ascent rate: 7.5 m/s
Scenario 1: descent at –3.75 m/s
Scenario 2: neutral buoyance
Scenario 3: ascent at +3.75 m/s

Possible rate change when venting:
(– 45) to (– 69) m/s