Project H.A.L.O.

An Effort to Provide Continuous Observation of the April 8th, 2024 Total Solar Eclipse

PRESENTED BY WESLEY TAYLOR OF MILLERSVILLE UNIVERSITY

Background Information

- Boundary Layer: First ~1 km of atmosphere above the surface heavily influenced by surface-air interactions; driven mostly by turbulent atmospheric motions

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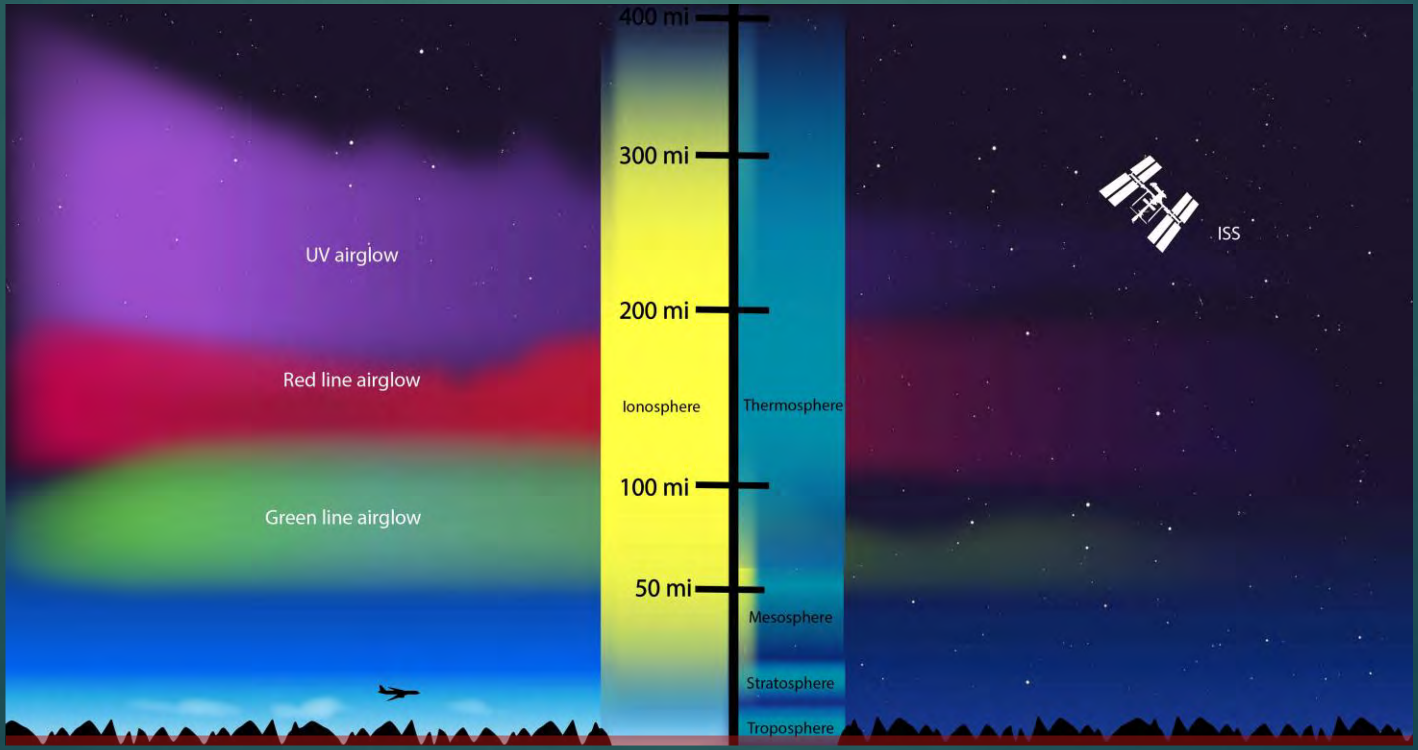
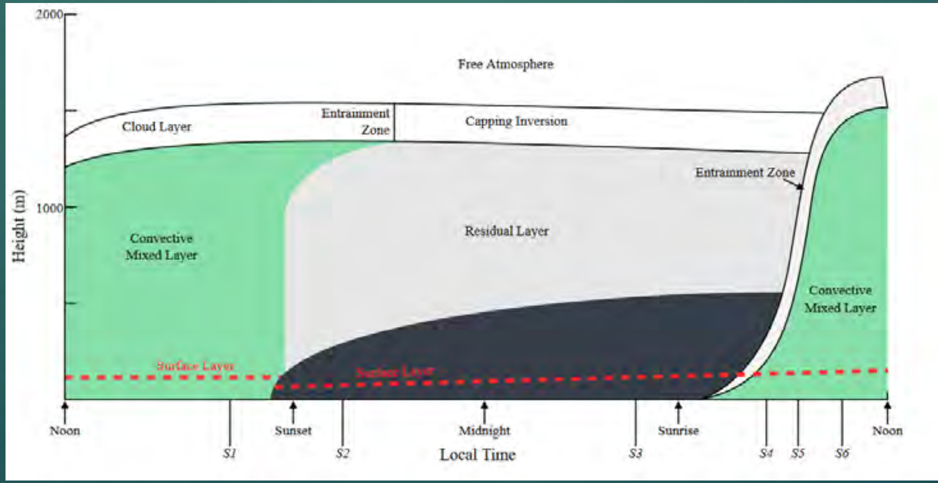


Credits: NASA's Goddard Space Flight Center/Duberstein

Background Information

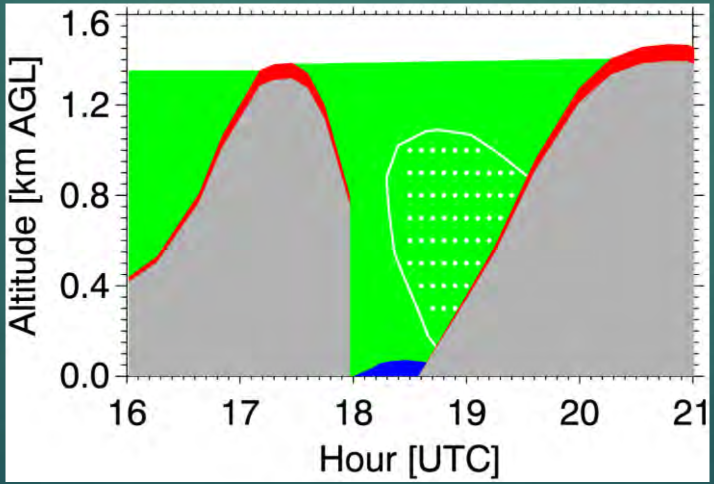
- Over the course of the diurnal cycle, the atmosphere becomes more turbulent or more stable based upon incoming solar radiation (insolation) and lack thereof respectively
- During the daytime, this generated instability helps to contribute to thunderstorm formation; at night, the stable layer that forms contributes to fog development



Credit: NikNaks (Own work, based on [1]) [CC BY-SA 3.0], via Wikimedia Commons

Background Information

- Total solar eclipses (TSE's) reduce insolation at the surface, with the full extent of their effects under extensive research
- The formation of a temporary stable layer has been recorded during the Aug. 21st, 2017 TSE by Turner et al., but the mechanisms by which it operates remains relatively poorly understood



Conceptual Boundary Layer Model, Stable Layer in Blue
Credits: Figure 4, Turner et al. (2018)

What is H.A.L.O.?

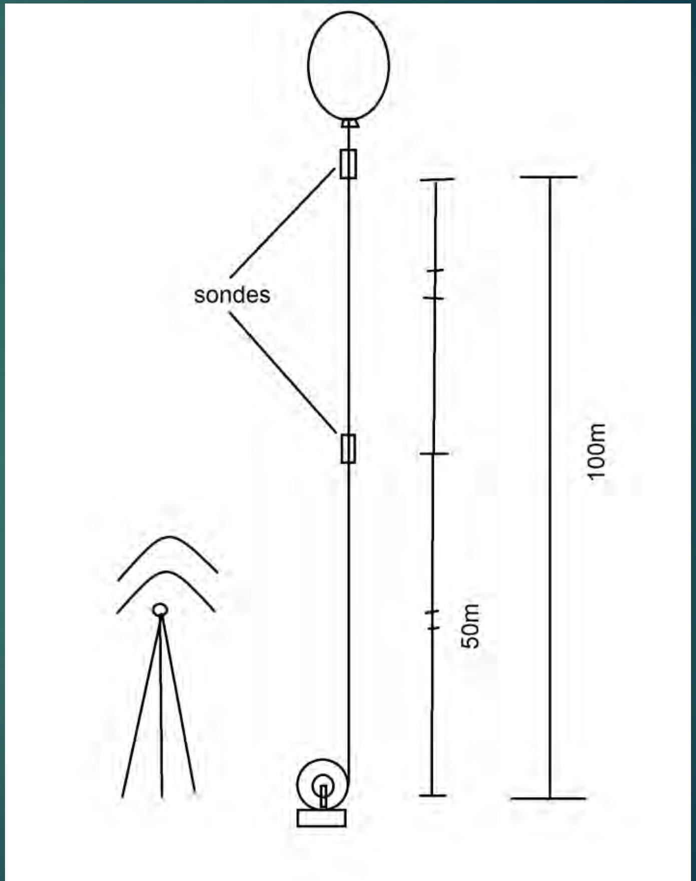
- Stands for "Heliophysical and Atmospheric Analysis of Lunar Obstruction"
- Current Primary Research Objective (P.R.O.): Observe surface and boundary layer conditions under the effects of a TSE with relation to their interactions with the atmosphere and solar angle
  - Expected results would indicate that as latitude increases, the temperature inversion increases with strength as solar angle decreases and atmospheric thickness increases
- The secondary objective would be to create a continuous set of observations of the sun's corona, which will be visible during the eclipse

Current Research
(End of Slideshow)

Proposed Research Plan

Proposed Research Plan

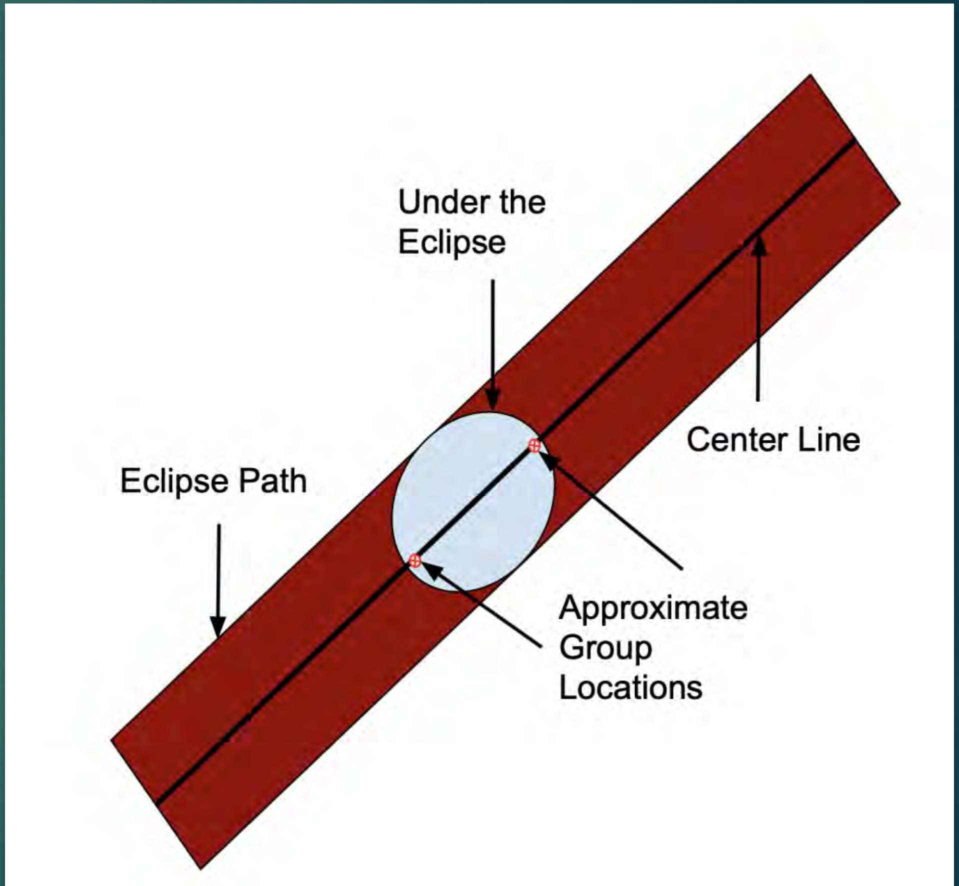
- A nylon rope is to be stretched to 100m
- At the 50m and 100m marks, sondes are to be attached to the rope. A third sonde is placed in a cover at the surface
- The rope will then be lifted into the air by a 100g weather balloon for the duration of the eclipse and for some time afterwards
- The rope can be reeled in after data collection to retrieve the sondes and balloon for future reuse



Logistics

Observation Team Location Planning

- One group site will be underneath the eclipse during the entirety of the eclipse throughout the United States.
- An important note: the more north the observatory, the more stretched out the Eclipse, which means the sites in the northern states will be spread out further than those in the southern states.



Approximate Locations of Sites

- Minimum Total of Teams: 32
- By State:
  - Texas: 9
  - Oklahoma: 1
  - Arkansas: 4
  - Missouri: 2
  - Illinois: 2 or 3
  - Indiana: 2, 3 or 4
  - Ohio: 2 or 3
  - Pennsylvania: 1
  - New York: 3
  - Vermont: 1
  - New Hampshire: 1
  - Maine: 2

https://www.greatamericaneclipse.com/april-8-2024

Potential Biases

- As the eclipse progresses, the length of the totality decreases with time. The further into the event observations are taken, the less radiational cooling a location will experience
- Topography may also influence the effectiveness of how the boundary layer responds
- Inclement weather patterns are also of consideration
- Lake-effect weather may reduce the efficiency of observations taken downwind of the Great Lakes
- Clouds may affect temperature variation, but a modulus could be applied as a result of Dodson et al.'s work to reduce the effect

The Future of HALO

Why is the P.R.O. Important?

- Solar eclipses have been shown to have a marked impact on solar panels. HALO will provide further research towards determining how latitude affects twilight solar panel efficiency
- Applying the same concept to the ionosphere, it may be possible to analyze ionospheric reactions to the eclipse as a function of latitude as well, e.g. the ionospheric bow wave as detected in 2017 by Zhang et al. (LSTID)
- If integrated into the project, HAM radio signal detection could also be utilized to monitor the effects of any temporary atmospheric ducting that occurs, allowing for a secondary means of validation
- Data can provide critical initialization information for weather model development which would be otherwise difficult to obtain

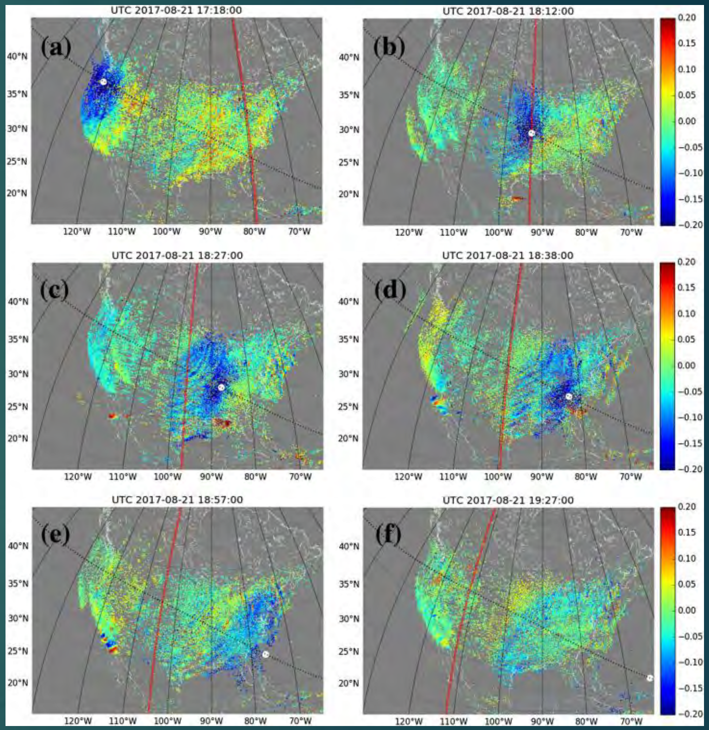


Figure Above: TEC LSTID's as detected on Aug 21st, 2017
Credit: Zhang et al. (2017)

How can HALO be Expanded?

- Although the P.R.O. is the highest priority, the hope is to create a multidisciplinary research endeavor branching out from just meteorology
- High priority topics include:
  - Continuous monitoring of the solar corona
  - Atmospheric compositional dynamics
- Other topics include:
  - Ionospheric anomalies
  - Animal behavior
  - Gravitational anomalies
  - ...and other potentially relevant studies

Non-Research Benefits of HALO

- Provides an excellent platform for public communication about atmospheric weather and space weather sciences
- Grants research experience and materials for those at every level of professional experience
- Provides a medium for collaboration between various sectors under the meteorology umbrella – including HamSCI

What Could the Future of HALO Look Like?

- Ideally, we want our project to be a coalescing endeavor
  - Alone, we lack the resources and manpower to execute HALO
- As of now, HALO is planned to be a student-organized event
  - We are not unopposed to giving another the mantle if interest is expressed
- Utilization of surface-based publicly gathered data may help validate measured changes
- All team-gathered data is planned to be made public through some medium so that others may study what is recorded

Acknowledgements

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  - Alex Colgate
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  - Allison Krantz
  - Joshua Kinsky
- Millersville Meteorology Professors
  - Dr. Richard Clark
  - Dr. Sepideh Yalda
  - Dr. Greg Blumberg
- Event Organizers

Sources:

- Bozic, N. (2003). *Total Solar Eclipse on August 11th 1999 Observed at Kelebija*. ADSABS. Retrieved January 11, 2023, from https://articles.adsabs.harvard.edu/full/2003POBeo..75..105B/0000105.000.html
- Cherniak, I., & Zakharenkova, I. (2018). Ionospheric total electron content response to the Great American Solar eclipse of 21 August 2017. *Geophysical Research Letters*, *45*(3), 1199–1208. https://doi.org/10.1002/2017gl075989
- Dodson, J. B., Robles, M. C., Taylor, J. E., DeFontes, C. C., & Weaver, K. L. (2019). Eclipse across america: Citizen science observations of the 21 august 2017 total solar eclipse. *Journal of Applied Meteorology and Climatology, 58(*11), 2363–2385. https://doi.org/10.1175/jamc-d-18-0297.1
- Hanna, E. (2018, March 7). *Meteorological effects of the 20 March 2015 solar eclipse over the United Kingdom*. Retrieved January 11, 2023, from https://eprints.lincoln.ac.uk/id/eprint/26439/
- MacPherson B., González S. A., Sulzer M. P., Bailey G. J., Djuth F., Rodriguez P. (2000). Measurements of the topside ionosphere over Arecibo during the total solar eclipse of February 26, 1998. *Journal of Geophysical Research, 105*(A10), 23055 – 23067. https://doi.org/10.1029/2000JA000145
- Ritson, R., Ranglack, D., & Bickford, N. (2019). Comparing social media observations of animals during a solar eclipse to published research. *Animals, 9*(2), 59. https://doi.org/10.3390/ani9020059
- Salah, J. E., Oliver, W. L., Foster, J. C., Holt, J. M., Emery, B. A., & Roble, R. G. (1986). Observations of the May 30, 1984, annular solar eclipse at Millstone Hill. *Journal of Geophysical Research, 91*(A2), 1651. https://doi.org/10.1029/ja091ia02p01651
- Turner, D., Wulfmeyer, V., Behrendt, A., Bonin, T. A., Choukulkar, A., Newsom, R. K., Brewer, W. A., & Cook, D. R. (2018). Response of the Land-Atmosphere System Over North-Central Oklahoma During the 2017 Eclipse. Geophysical Research Letters, 45(3), 1668–1675. https://doi.org/10.1002/2017gl076908 (incl. Figure 4 on Slide 2)
- Thomas, Michael E, 'Optical Propagation in Gases and the Atmosphere of the Earth', Optical Propagation in Linear Media: Atmospheric Gases and Particles, Solid State Components, and Water (New York, 2006; online edn, Oxford Academic, 12 Nov. 2020), https://doi.org/10.1093/oso/9780195091618.003.0012, accessed 15 Mar. 2023.
- Zhang, S., Erickson, P. J., Goncharenko, L. P., Coster, A. J., Rideout, W. M., & Vierinen, J. (2017). Ionospheric Bow Waves and Perturbations Induced by the 21 August 2017 Solar Eclipse. Geophysical Research Letters, 44(24). https://doi.org/10.1002/2017gl076054 (incl. Figure 2c. on Slide 13)

Thank You!

We would be glad to hear your feedback now or at ProjectHalo2024@gmail.com

Current Research

Salah et al. (1986)

- Studied the Millstone Hill, Vermont total solar eclipse of May 30, 1984
- Used data from both a zenith-fixed and steerable antenna
- Measured the effects of the eclipse on the ionosphere and thermosphere
- There was an overall decrease in electron density and temperature during the eclipse.

Bozic (2003)

- Studied the Aug. 11th, 1999 total solar eclipse in Kelebija, Yugoslavia
- Data was accumulated from different groups in an expedition team
- It was found that temperature dropped, humidity increased, and animals and plants exhibited abnormal behaviors during the duration of the eclipse

Dodson et al. (2019)

- Collected millions of citizen observations across the U.S. during the total solar eclipse of Aug. 21st, 2017
- This project was entitled Eclipse Across America (EAA)
- Citizens gathered cloud observations and temperature measurements during the eclipse
- There were many temperature depressions observed in the areas of eclipse totality, which can be compared to the relationship between temperatures and clouds

Ritson et al. (2019)

- Used social media and scientific research to create database
- Difficult to gather data because a given location will experience total darkness only once every 350 years for a three-to-seven-minute duration
- Leads to many potential data collectors
- Scientific and social media data mostly aligned
- Downsides to social media are unclear qualifications, if a species is identified correctly, and less detailed plans

Hanna (2016)

- Caused drop in temperatures, average was 0.55 C – 0.83 C
- Important for solar and wind turbine industries
- Average lowest temperature was reached 15 minutes after maximum eclipse due to thermal lag
- Wind lull during eclipse, which has been noted in past experiments
- Lack of any eclipse-related air-pressure signature
- Solar radiation depleted by about 25% of its normal peak
- Thick clouds lessen magnitude of temperature drop
- Stressed further research needs to be done especially regarding micrometeorological influences, topography, land-surface type, and synoptic meteorology

MacPherson et al. (2000)

- Electron temperature decreased by 600 K at 400 km, but magnitude decreases with increasing altitude
- H^+ ion temperature was 200 K less
- Little variation in O^+
- During the eclipse, the transition altitude fell by 200 km and took 2 hours to recover
- Magnetic activity low before and after eclipse
- Electron density decreased by 25% 30 minutes after eclipse starts
- O^+ decreases by 40% 30 minutes after , H^+ by 42%
- O^+ has smaller temperature change of 75 K
- Electron temperature decrease has a higher lag the higher the altitude is

Zhang et al. (2017)

- Aggregated large amounts of ionospheric observations to determine the detection of ionospheric bow waves during the Aug. 21st, 2017 total solar eclipse
- Utilized total electron count (TEC) differentials detected by GNSS receivers to calculate TEC variations across various locations, revealing the bow waves, ie Large-Scale Travelling Ionospheric Disturbances (LSTID's)
- The waves in question had a 370 km wavelength, 25 minute periodicity, and had a phase velocity of 280 m/s along the eclipse's path

Thomas, “Optical Propagation in Linear Media: Atmospheric Gases and Particles, Solid State Components, and Water” (2006)

- Describes atmospheric ducting in relation to light wave propagation
- Analyzes wavelength absorption and reflectivity constants relative to pressure and temperature
- Mathematically determines the optical horizon, as well as how it can be altered under various conditions

Turner et al. (2018)

- Examined boundary layer interactions during the Aug 21st, 2017 TSE
- Utilized three sites to measure and compare changes that occurred
- Experienced a 800 W/m^2 decrease in insolation during the eclipse, having measured effects on wind speed, wind direction, water vapor mixing ratios, and temperature
- Conceptual model of ecliptic stable layer development model generated through results of study