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High-Altitude Balloons Flights on Total Solar Eclipse

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Abstract:

Students from the University of North Florida (UNF) participated in NASA's Nationwide Eclipse Ballooning Project (NEBP). The UNF team visited Malvern, Arkansas during April 6 -9, 2024. A high-altitude balloon, Innovation, was successfully launched, and after approximately 5 min, another balloon, Osprey-2, was launched before beginning the total solar eclipse from Malvern, Arkansas. The main aims of the flights were to evaluate the performance of the newly designed Innovation Vent and Cutdown System, connectivity with a satellite iridium modem, RFD900, testing new flight data recorder payload, new ozone sensor data logger payload, new Geiger Muller Counter payload, Raspberry Pi camera, 360-degree Insta camera, 170-degree camera, ground station, and new spot tracker.

The variation in the altitude of the Osprey-2 and Innovation balloons with flight time was measured. The Osprey-2 balloon reached the highest altitude at approximately 27896 m, whereas the Innovation balloon reached the highest altitude at approximately 27860 m. The maximum speed over ground for Osprey-2 was 206.57 km/h while for Innovation was 216.4 km/h. Both flights covered the solar eclipse. Our 3-D printed vent system worked well without helium gas leakage on both balloons. We found that the Iridium satellite worked faster to open the vent on the Osprey-2 balloon, while our newly designed vent on the Innovation balloon opened automatically by the geo-fence without using any satellite modem. However, the ascending rate of both balloons was faster than that of the venting helium, and before balloons started floating and closing of the vent command executed, the balloons underwent a burst. The variations in the temperatures inside and outside the payload with time were measured. The ozone concentration was measured using three types of nanocrystalline composite oxide semiconductor thin films. Three sensor boxes, each with eight sensors, were used to monitor the ozone concentration. The concentration of ozone in the stratosphere decreased throughout the solar eclipse. This may be because the amount of available sunlight decreased; hence, ozone formation also decreased. The variation in sunlight during flight supports the results of the ozone sensors. In addition, the Geiger Muller counter payload measures radiation counts per minute (CPM) during the entire flight period. It was found that the radiation counts decreased during the total solar eclipse.

Introduction:

A total solar eclipse is an infrequent and astonishing event that offers students and scientists a unique opportunity to study both atmospheric and celestial phenomena. A solar eclipse occurs when the moon passes between the sun and the earth, casting its shadow upon the earth. During a total solar eclipse, the moon completely blocks the sun's face, creating a "switching the light off and switching the light on" event, and regions affected by the eclipse witness a rapid shift from dusk to dawn due to the moon's shadow significantly decreasing solar radiation.

Ozone constitutes too small a percentage of the atmosphere and serves as a trace component. Despite its small percentage in its limited presence, it exerts a significant influence on ecology, climate, and the environment. Ozone in the stratosphere protects us from the sun's harmful ultraviolet rays. However, ozone in the troposphere, closer to the Earth's surface, is a pollutant and hazardous to human health. The changes in ozone concentration at all heights were closely related to the sudden cutoff of photochemical reactions due to rapid changes in solar radiation during a solar eclipse. Therefore, it is necessary to investigate the variations in ozone during a solar eclipse and the mechanism of the changes in ozone. The amount of ozone in the atmosphere is measured by instruments on the ground and carried payload/aloft on balloons, aircraft, and satellites. Some instruments measure ozone locally by continuously drawing air samples into a small detection chamber. Other instruments measure ozone remotely over long distances using ozone's unique optical absorption or emission properties. Solar eclipses also impact the Earth's ionosphere, the upper part of the atmosphere. Measuring ozone and solar radiation during a total solar eclipse helps advance our knowledge of atmospheric processes and provides valuable data for scientific research.

The University of North Florida (UNF) developed a nanocrystalline thin-film gas sensor array and odor sensor made of nanocrystalline oxide semiconductor materials [1-3]. In collaboration with the University of North Dakota (UND), the UNF team has successfully developed and tested the ozone sensor payload on NASA-High Altitude Student Payload (HASP) balloon flights every year since 2008 [4] and measured the ozone concentration in the stratosphere during day and nighttime flights. The UND and UNF teams [5] attempted to measure ozone concentration during the total solar eclipse on August 21, 2017, from Rexburg, Idaho on high-altitude ballon flight, and observed a decrease in the ozone level during the solar eclipse. The measured observations and data were limited because of the shorter flight time and lower altitude owing to the balloon being affected by solar eclipse-induced atmospheric turbulence and being busted early.

Students from the University of North Florida (UNF) participated in NASA's Nationwide Eclipse Ballooning Program (NEBP) during 2023-2024. The UNF team successfully launched two ballons from Pearsall, Texas, during an annular solar eclipse on October 15, 2023. They measured the decrease in the concentration of ozone in the stratosphere due to the decrease in UV light from sunlight throughout the annular solar eclipse [6-7] and studied how ozone levels change when light is suddenly reduced and then restored. In this paper, we present the results of two balloon flights conducted during a total solar eclipse on April 8, 2024.

Experiment:

The teams of the University of North Florida (UNF) and the University of Central Florida developed and fabricated several payloads and used hardware supplied by the NEBP. The details of the flight line of the two balloons are given in Table 1.

Table 1 Details of flight line

Balloon Flight	Osprey-2	Innovation
Launch Location	2660 South River Creek Dr., Malvern, AR (34.3943196, -92.8361688)	
Helium Gas Balloon	Kaymont, HAB 1600, 1600g	Kaymont, HAB 1600, 1600g
3-D printed Vent and Cutdown	NEBP/Uni. of Maryland Vent manually controlled by Iridium	UNF-Innovation Vent automatic controlled by geo fence and altitude software program
Parachute	www.The-Rocketman.com 6 feet diameter	www.The-Rocketman.com 6 feet diameter
Radar Reflector	Davis - Deluxe Radar Reflector	Davis - Deluxe Radar Reflector
Payload-1	Iridium Command Module	UNF-Flight Data Recorder (Osprey 2)
Payload-2	UNF-Ozone Sensors (NiCO) S1- Ozone sensors -ITO S2 -Ozone sensors-ITO+WO_3 S3- Ozone sensors- ITO+ZnO	UNF-Ozone Sensors (NiCO) S1-8 Ozone sensors -ITO S2-8 Ozone sensors-ITO+WO_3 S3-8 Ozone sensors- ITO+ZnO
Payload-3	UNF-Geiger Muller counter payload and Spot Trace Tracker	UNF-Ozone Sensors (MigLeo) Ozone sensors-ITO+ Ag_2WO_4
Payload-4	Insta 360 camera, battery backup with selfie stick	170 Action Camera, battery backup and Spot Trace Tracker
Payload-5	RFD 900 and Pterodactyl	UCF-Magnetometer (Barbie)
Payload-6	Raspberry Pi4 130 camera	GPS Tracker (Seculife)
Payload-7	UNF-Flight Data Recorder (Osprey1) and Light Sensor	
NOTAM	HOT 04/008 ZME 04/076	HOT 04/009 ZME/04/076
Recovery Location	(34.9221833, -91.5965666) Near White River Township, AR	(34.9006953, -91.6396163) Near Union Township, AR
Recovery of payloads	Payload- 4, 5, 6 & 7 are not yet recovered.	All payloads were recovered.

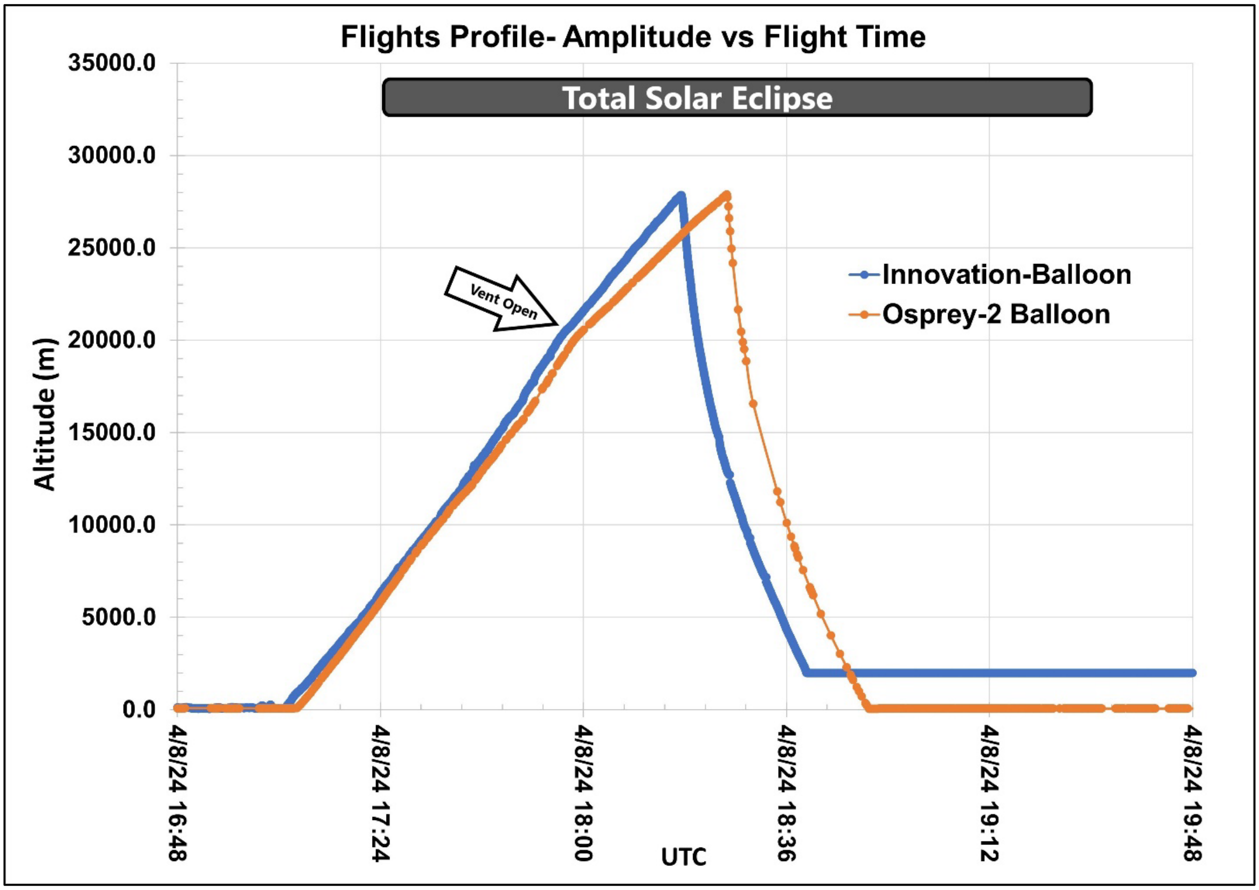
Ozone sensors were fabricated in the Dr. Patel Sensors Lab at the University of North Florida. The ozone sensor payload (NiCO) consisted of three gas sensor arrays fabricated with three different nanocrystalline oxide semiconductor thin films of (S1) ITO, (S2) ZnO+ITO, and (S3) WO_3+ITO.

Each array has eight ozone sensors, while the other ozone sensor payload (MigLeo) has sensors made of (S4) Ag_2WO_4+ITO. All sensors are n-type semiconductors. The temperature of the ozone sensor array was kept constant at nearly 25±2 °C using a flexible Kapton heater (MINCO) and a temperature sensor (Analog Device TMP36) mounted on the backside and controlled by a digital temperature controller.

Results and Discussion:

Figure 1

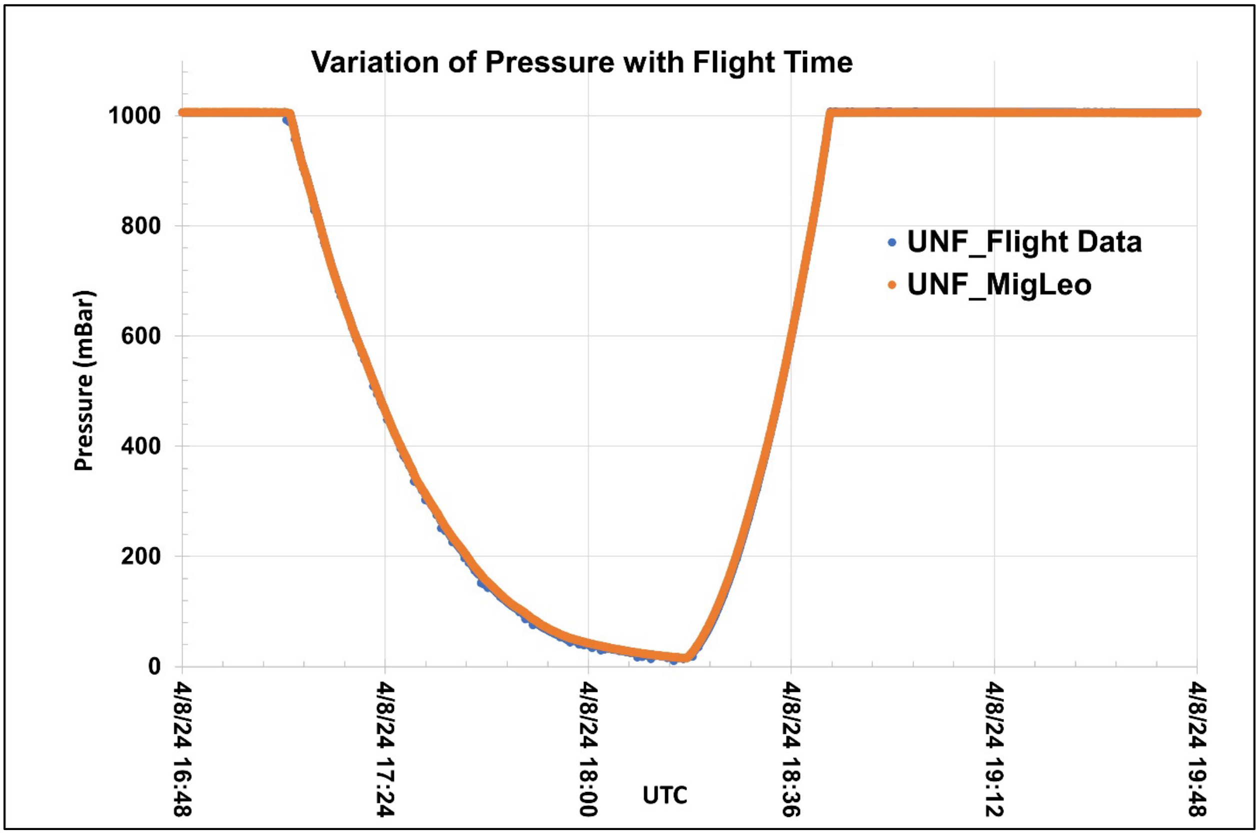
Variation in altitude with flight time for the two balloons.



A high-altitude balloon named Innovation was successfully launched at UTC 17:04, and after approximately 5 min, another balloon named Osprey-2 was launched at UTC 17:09 before beginning the total solar eclipse from Malvern, Arkansas on April8, 2024. Figure 1 shows the variation in the altitude of the Osprey-2 and Innovation balloons with flight time. The Osprey-2 balloon reached the highest altitude at approximately 27896 m, whereas the Innovation balloon reached the highest altitude at approximately 27860 m. The maximum speed over ground for Osprey-2 was 206.57 km/h while for Innovation was 216.4 km/h. Both flights covered the solar eclipse. Our 3-D printed vent system worked well without helium gas leakage on both balloons. We found that the Iridium satellite worked faster to respond to opening the vent on the Osprey-2 balloon, while our newly designed vent on the Innovation balloon opened automatically by the set geo-fence and altitude algorithm, without using any satellite modem. However, the ascending rate of both balloons was faster than the venting rate of helium, and before the balloons started floating and closing the vent command executed, the balloons underwent a burst. We later realized that the pressure was too low at our set altitude of 21000 m; hence, the balloon crossed the limit to burst. We conclude that pressure should also be added with a geofence and altitude in software programming for the automation of the vent valve.

Figure 2

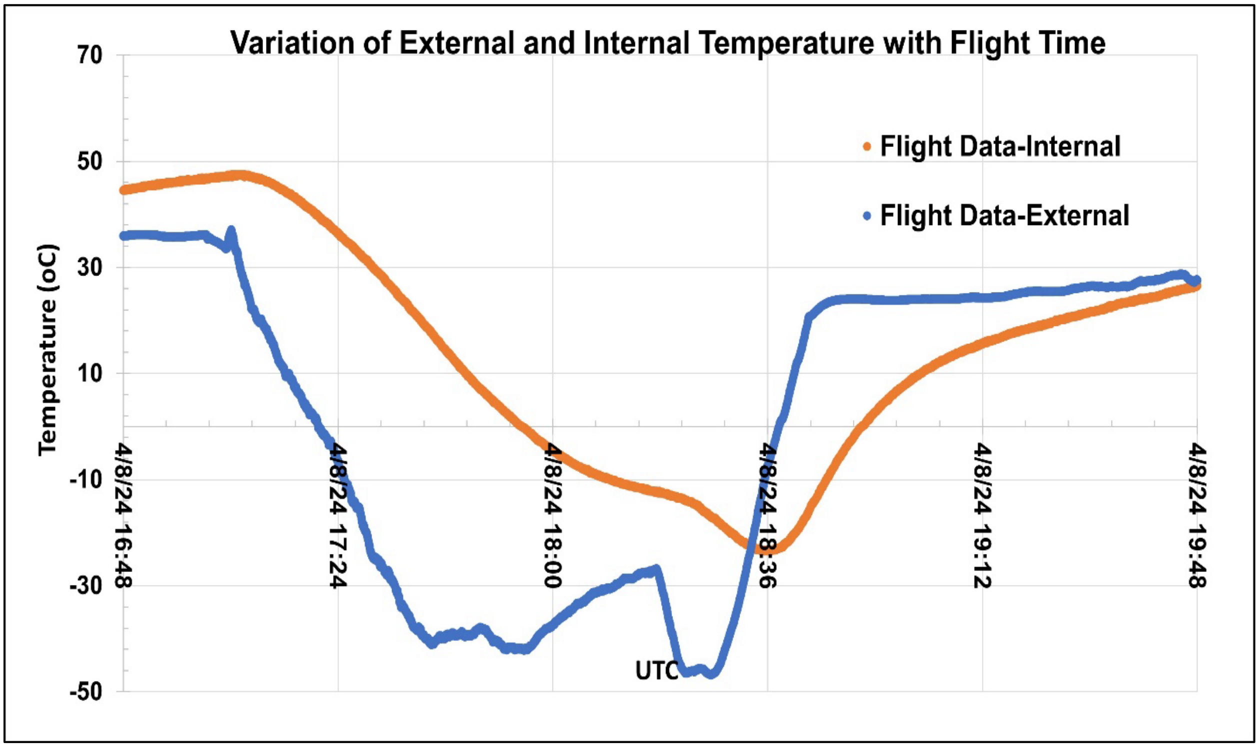
Variation in pressure with flight time.



The variation in pressure with flight time is shown in figure 2. The pressure was recorded using two different payloads: an Osprey-2 flight data recorder and ozone sensors (MigLeo), and identical responses were recorded for both. The pressure was at a minimum when both balloons almost reached the maximum altitude during the total solar eclipse.

Figure 3

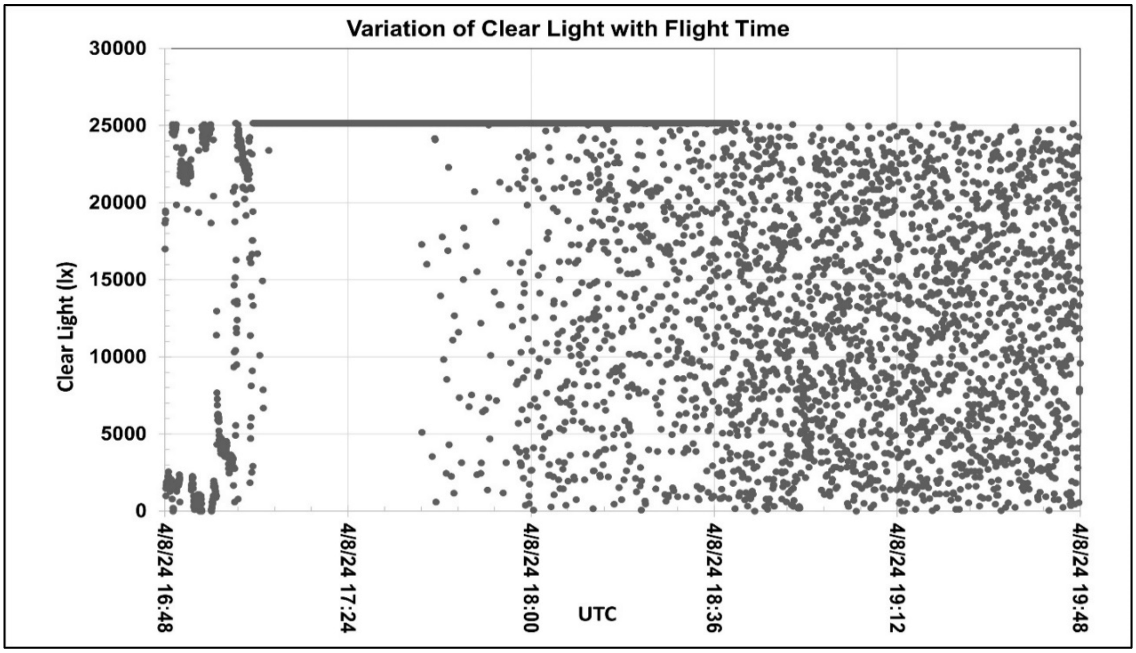
Variation in external and internal payload temperatures with flight time.



The variation in the external and internal temperatures of the payload with the flight time is shown in figure 3. The internal temperature of the payload is reasonably higher than the extenral temperature owing to better thermal insulation. The payload body was composed of a thermo-chill double-insulated carton with a foil-insulated bag liner and additional foam. A permanent adhesive vinyl sheet was applied to the external surface of the payload body to render it waterproof.

Figure 4

Variation in the intensity of clear light with flight time.



The variation in the intensity of clear light with flight time is shown in Figure 4. It is clearly observed that the intensity of the clear light decreases as the total eclipse progresses with time until the eclipse ends.

Figure 5

Variation in the UV-A index with flight time.

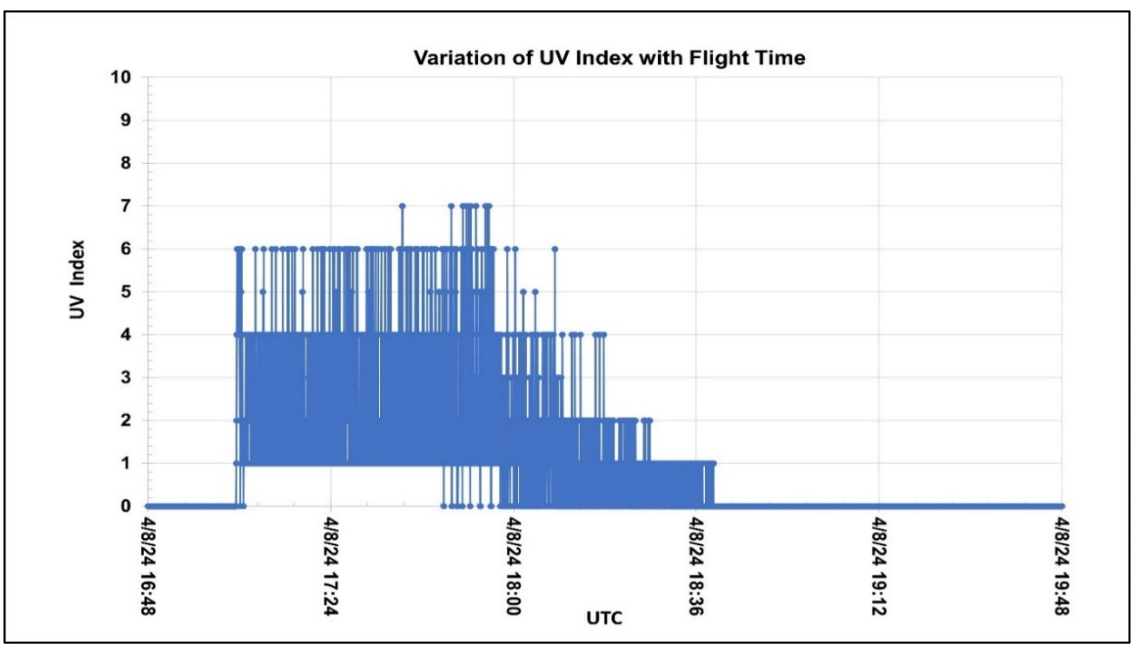


Figure 5 shows the variation in the UV-A index with flight time. It was observed that the UV A index decreased to almost zero during the total solar eclipse. We could not measure the UV-A index after the completion of the eclipse, because the payload power was turned off after impacting the ground. Figures 4 and 5 confirm that UV sunlight was bloked by the Moon to reach the Earth.

Stratospheric Ozone generated in the presence of UV sunlight radiation. UV rays break O_2 molecules into two oxygen atoms. These free O molecules bind to O_2 to produce O_3. When oxidizing ozone (O_3) interacts with the surface of the n-type oxide semiconductor thin film gas sensor, lattice vacanices can be filled by the reaction with ozone. Filled vacanices are effective electron traps, and consequently, the electrical resistance of the ozone gas sensor increases upon reacting with ozone.

Oxygen vacancy (V) + Ozone (O_3) →Lattice Oxygen site (O_0) + O_2

The change in electrical resistance of the sensor array was calibrated with an ozone generator and a standard ozone meter under nearly identical conditions of the startosphere.

Figure 6

Variation in ozone concentration with flight time measured using sensor array S1.

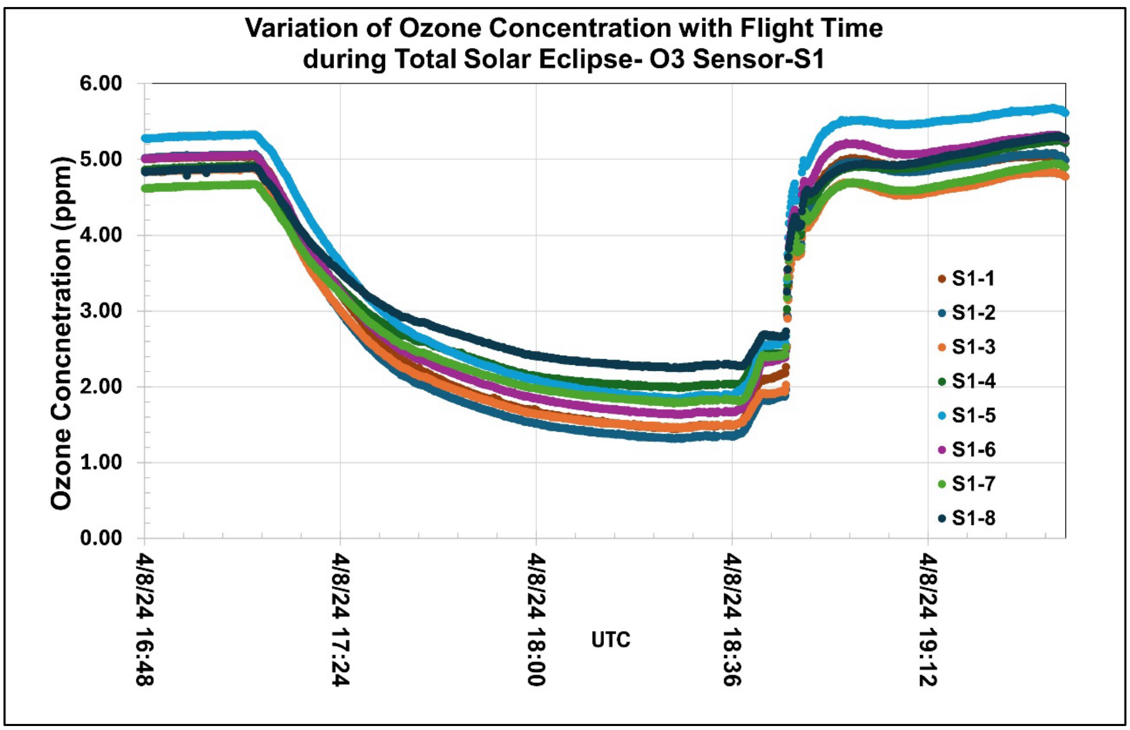


Figure 7

Variation in ozone concentration with flight time measured using sensor array S2.

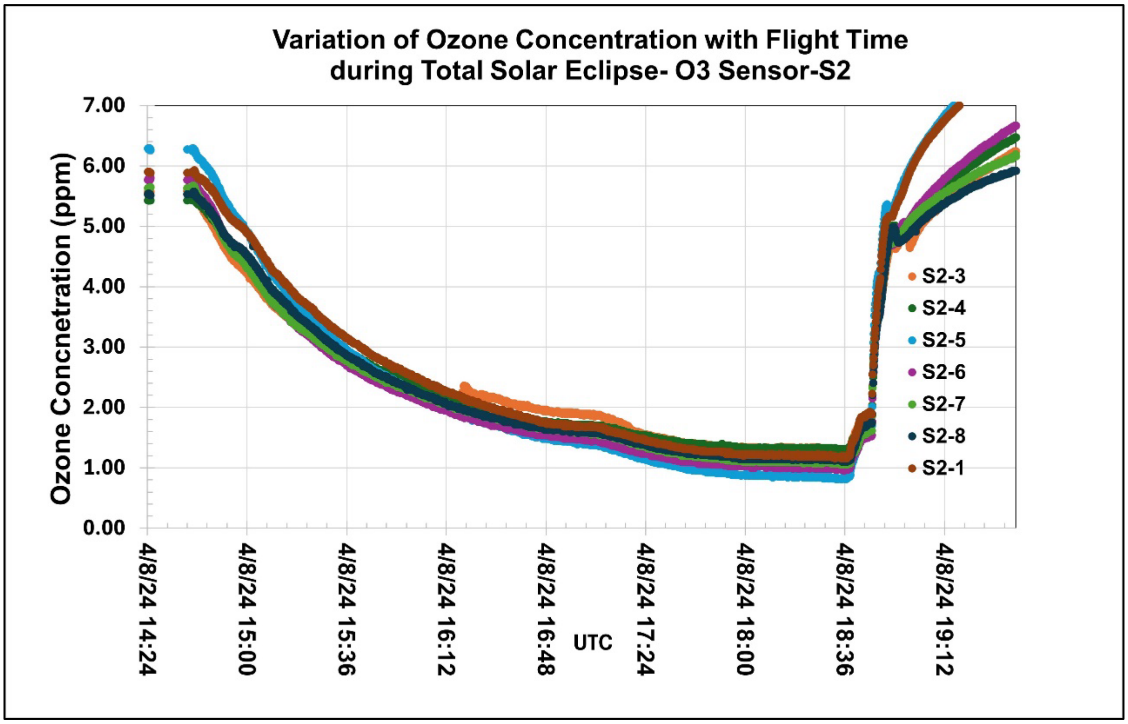


Figure 8

Variation in ozone concentration with flight time measured using sensor array S3.

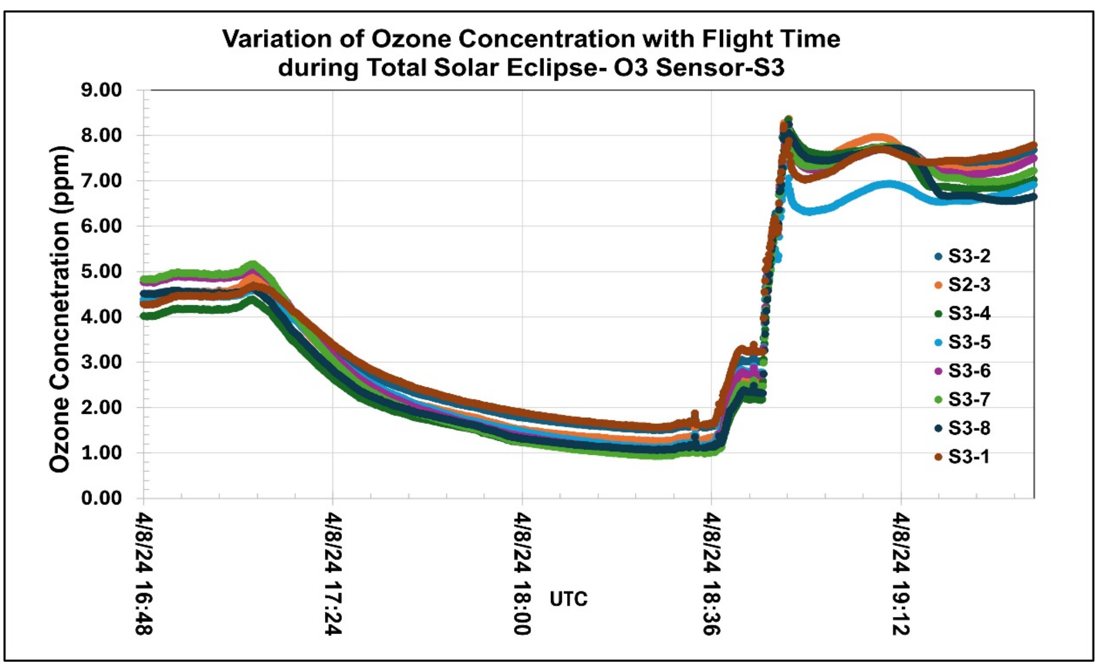
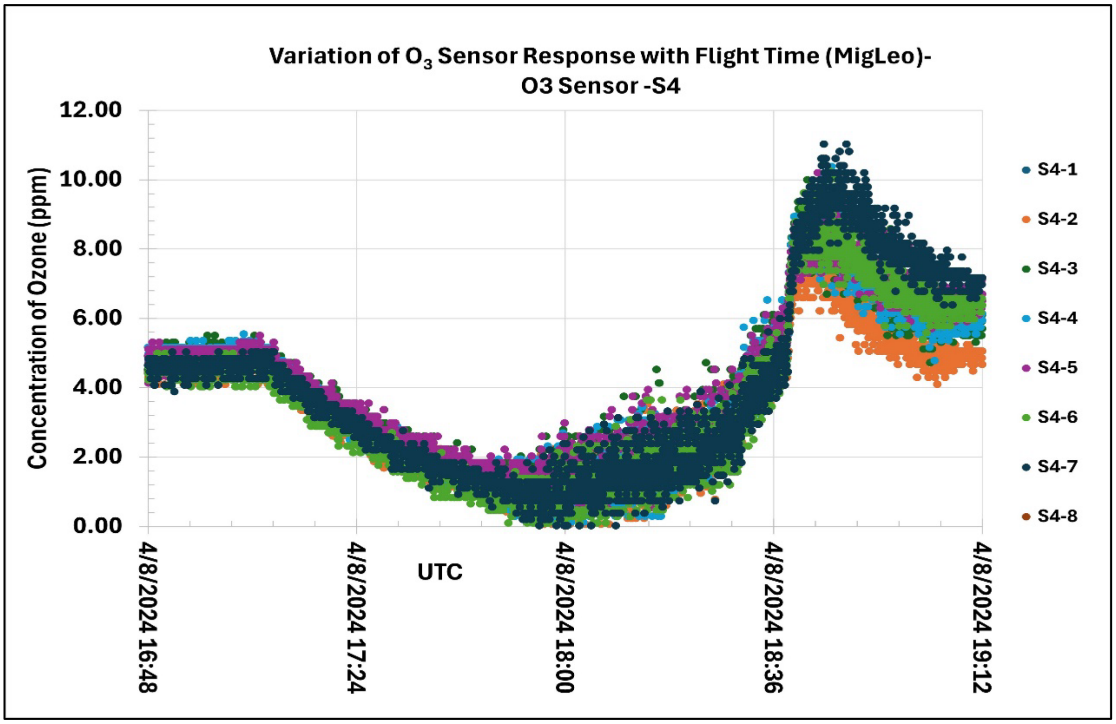


Figure 9

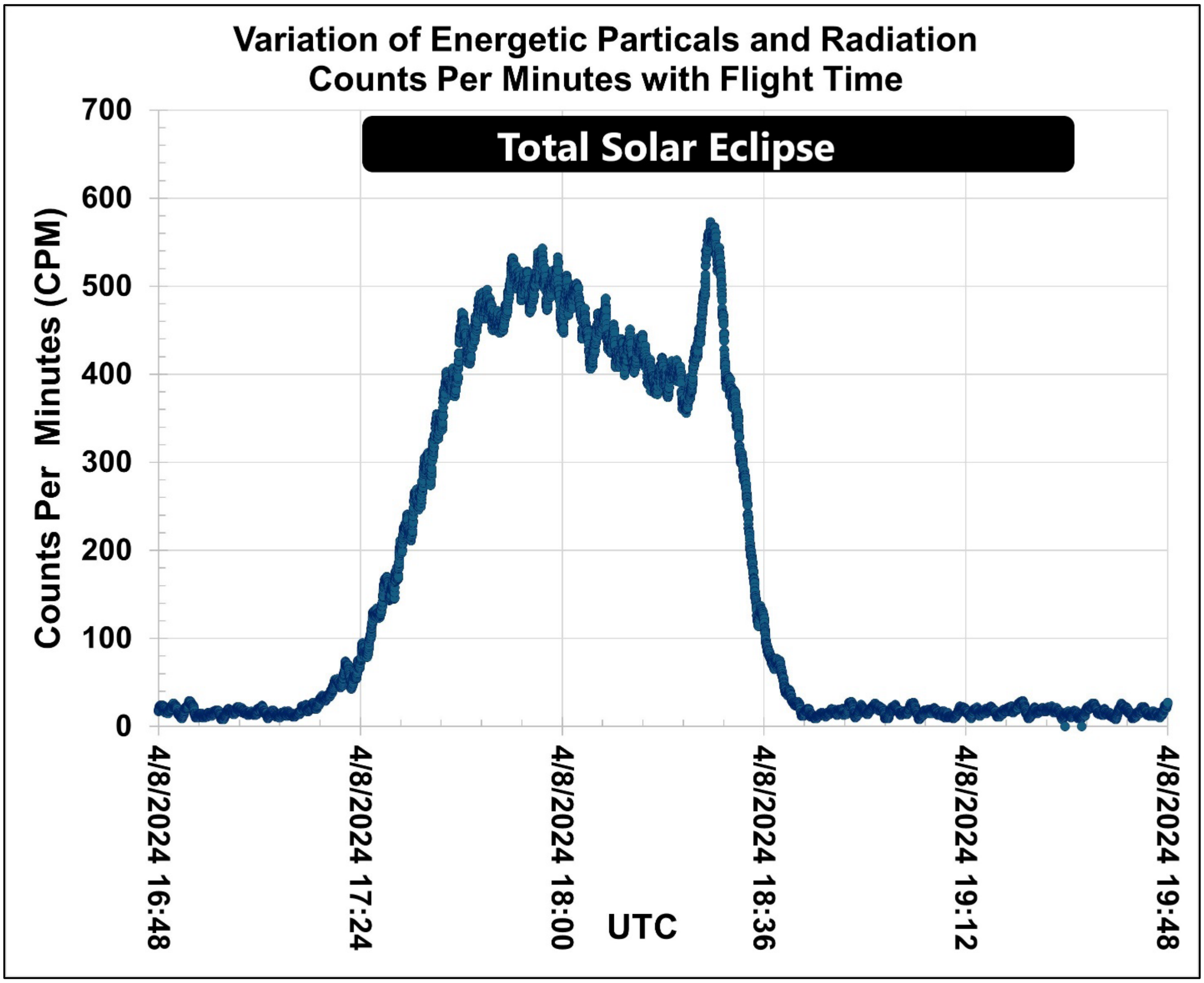
Variation in ozone concentration with flight time measured using sensor array S4.



The variation in ozone concentration with flight time during the total solar eclipse measured by three different sensor arrays S1, S2, and S3 of the UNF ozone sensor payload (NiCO) mounted on the Osprey-2 balloon are shown in figure 6, 7, and 8, respectively. The variation in ozone concentration with flight time during the total solar eclipse measured by sensor arrays S4 of the UNF ozone sensor payload (MigLeo) mounted on the Innovation balloon is shown in figure 9. Each type of ozone sensor array has different sensor characteristic properties, such as sensitivity, selectivity, stability, speed of response, reversibility, and interference with other polluting gases. Both ozone sensor payloads on the two different balloons show nearly similar responses. The ozone concentration decreased as the solar eclipse progressed and reached a minimum when the balloon reached its highest altitude around the total solar eclipse. Then, the concentration of ozone started increasing and then turned stable, Sensor arrays S2, S3, and S4 showed little increase in ozone concentration at the end due to the possiblity of interference effect of the accumulation of polluting gases. The decrease in ozone concentration during the total solar eclipse is mainly due to the non-avalablity of UV sunlight, as observed in fig. 4 and 5. We observed a similar reduction in ozone concentration due to reduction of UV light at night on the NASA-High Altitde Student Payload (HASP) balloon flight of previous years.

Figure 10

Variation of energetic particles and radiation counts per minute measured using a Geiger Muller counter with flight time.



The variation in energetic particles and radiation counts per minute measured using a Geiger Muller counter with flight time is shown in figure 10. The counts per minute reach a maximum at UTC about 17:54, and that time balloon altitude was about 20,000 m, then counts per minute falling down due to progress of total solar eclipse and decrement of UV sunlight. At approximately 20,000 m altitude, a region experiences the highest concentration of secondary cosmic radiation and is known as the Pfotzer-Regener [8] maximum altitude in the stratosphere, where cosmic radiation intensity is greatest. During a total solar eclipse, we observed a decrease in radiation counts, leading to a reduction in radiation counts of secondary cosmic ray flux measured at the Earth's surface. This phenomenon has interesting implications for high-altitude aviation and space tourism. The reduction in radiation counts and UV light during the eclipse supported the observation of a reduction in ozone concentration during the total solar eclipse.

Conclusion:

Several scientific payloads were successfully launched on two high-altitude balloons to study the total solar eclipse. The vent valve of both balloons worked to open the vent, but before getting float and closing the vent, balloons burst. We successfully observed that the ozone concentration decreased during the total solar eclipse due to a decrease in UV sunlight. We also observed a similar decrease in radiation counts during the total solar eclipse. Our students obtained the best learning experience, knowledge, and training from space science and engineering of the NEBP.

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