Analysis of Ascent Profiles of 2017 Solar Eclipse

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On August 21, 2017, the NASA Nebraska High Altitude Ballooning group launched three balloons with payloads to monitor the total solar eclipse. Upon analysis of the ascent profiles of two of the balloons, one of them showed a definite slowing of ascent around the tropopause producing a strong "knee" in the altitude vs. time graph and the other one did not. Further examination produced several of these "knee" graphs in other ascents during the eclipse. Statistics of the ascent graphs from the NASA eclipse ballooning project are also presented.

Eclipse | Ascent | Tropopause |

Introduction

As a part of the NASA Eclipse Ballooning Project during the total solar eclipse of August 21, 2017, the NASA Nebraska High Altitude Ballooning Program facilitated three balloon flights launching from very near the centerline of the path of totality at the Stuhr Museum of the Prairie Pioneer in Grand Island, Nebraska. The first balloon had the NASA common payload which streamed video in-flight to a satellite dish base station on the ground and uploaded the files online. The first balloon was launched at noon precisely. The second balloon carried scientific payloads from Metropolitan Community College students and it launched at 12:10 pm. The third balloon was launched by Omaha Public Schools with experiments by their students and it was launched 12:20 pm. Both the second and third balloons used a StratoStar SatCom tracker that uploaded data viewable online during the flight.

Data

While viewing the GPS data from the second of the three balloon flights launched from the Gem Over the Prairie Event at the Stuhr Museum, an examination of altitude vs. time presented an ascent profile graph we had not previously encountered in our many flights. We had flown over 60 successful HAB (High Altitude Ballooning) flights at that time.

Near 40,000 ft. for the MCC balloon (the second one), the ascent slowed considerably, from around 1200 ft./min. average to around 500 ft./min. average. This produced a noticeable “knee” feature in the graph. It looked relatively linear before the feature and relatively linear after the feature.

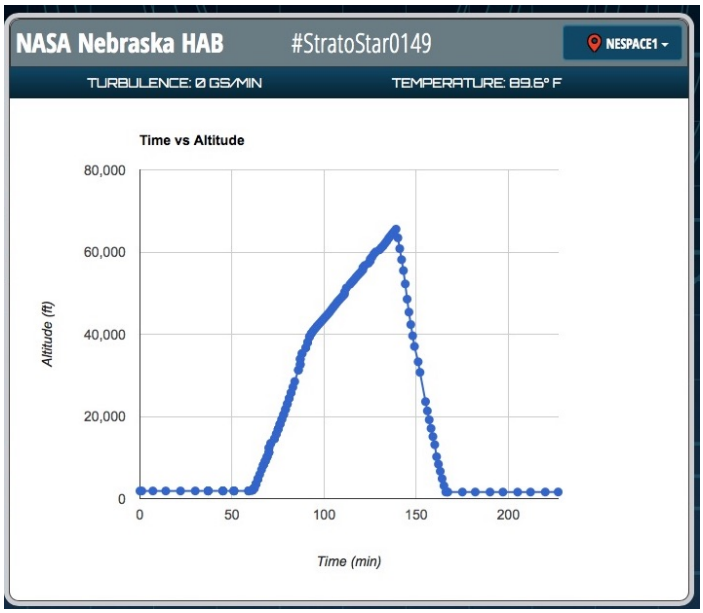

Fig. 1. Altitude profile over time for second balloon

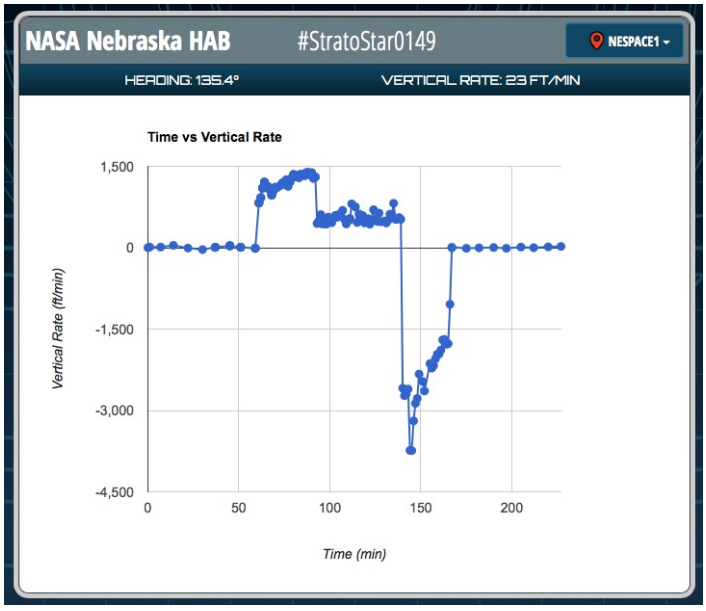

Fig. 2. Vertical rate profile over time for second balloon

This led to an examination of the third balloon's ascent profile.

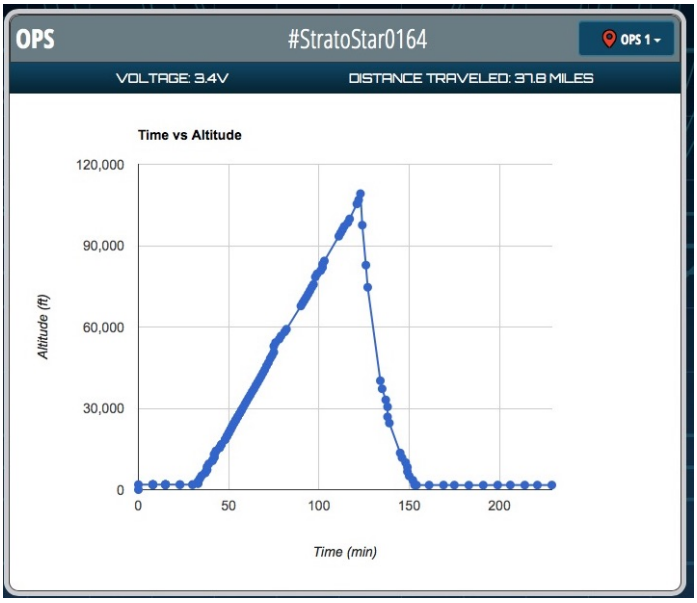

Fig. 3. Altitude profile over time for third balloon

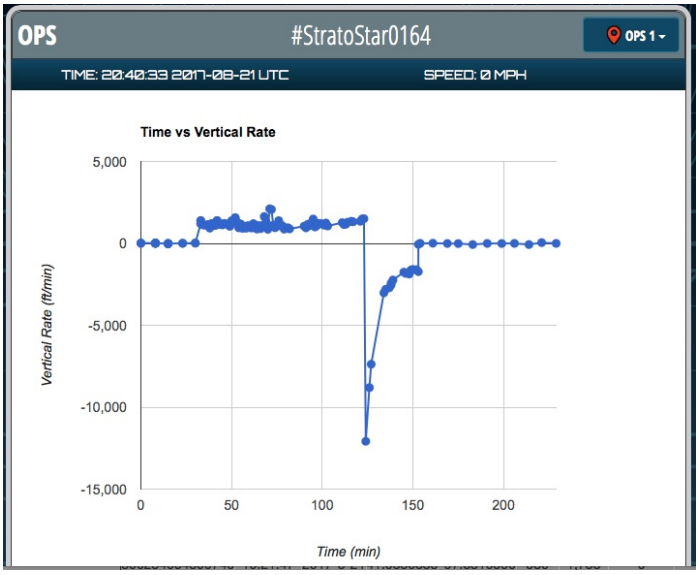

Fig. 4. Vertical rate profile over time for third balloon

The third balloon was launched from the same location 10 minutes after the second balloon and showed no knee feature. If anything, there is a tiny upward bump as it approached 60,000 ft., but kept a fairly constant average ascent rate until burst. This means that the force that caused the slow down on the second balloon was either localized or transient.

This led to an analysis of the data of the first balloon which was launched 10 minutes prior to the one with the strong knee feature. It used an Iridium satellite tracker and the GPS data was graphed in Excel in feet for altitude and UTC for time.

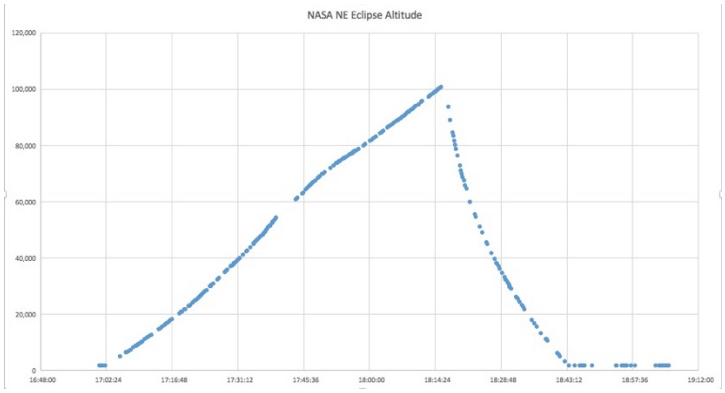

Fig. 5. Altitude profile over time for first balloon

Although not as strong of a feature, there appears to be a slight knee around an altitude of 70,000 ft.

To accumulate more data of balloons that flew during the eclipse, we had access to the Iridium GPS coordinates of balloons from the 55 teams who participated in the NASA Eclipse Ballooning Project. Teams were to launch their balloons about 1 hour prior to totality so the balloons.

Results

Out of the 62 Iridium payloads that recorded data on 8/21/17, 3 of them had no flight, 4 of them had a maximum altitude less than 32,000 ft., and one of them had data missing above 60,000 ft. Out of the remaining 54 flights which had data available, 20 of them showed no knee in the ascent graph (37%), 24 of them showed a slight knee in the ascent graph (44%), and 10 of them showed a pronounced knee in the ascent graph (19%). If you combine the slight knee and the pronounced knee graphs, 63% of balloon flights prior to the eclipse showed this feature. Examining the profound knee features to find common traits, the average altitude of the knee was 50,242 ft. and the average time difference was 17.8 minutes prior to the eclipse.

State	Alt. of Knee (ft)	Time difference between Knee and Total Eclipse
Kentucky	60,000	1
Kentucky	44,813	9
Nebraska	42,264	23
Wyoming	44,170	6
Wyoming	44,570	54
Oregon	45,755	7
Tennessee	58,953	13
Nebraska	53,104	12
Idaho	53,761	10
Illinois	45,427	53
Nebraska	59,841	8
	Average Knee	Average time (min.)
	50,242	17.8

Fig. 6. Strong knee data

The slight knee data showed the knees occurring prior to total eclipse, but two of them occurred after totality. The average altitude of the knee feature in these cases was 58,550 ft. at an average time of 14.6 minutes prior to totality.

State	Alt. of Knee (ft)	Difference between Knee and Total Eclipse
Tennessee	51,355	22
Tennessee	55,620	4
Oregon	61,818	30
Nebraska	66,280	11
South Carolir	59,836	9
Tennessee	60,082	27
Missouri	61,677	12
South Carolir	58,619	11
Tennessee	59,524	-19
Kentucky	58,684	-22
Kentucky	57,306	2
Kentucky	58,192	7
Kentucky	85,474	27
Wyoming	35,541	33
Illinois	51,437	48
Nebraska	55,354	32
	Average	Average time
	58,550	14.6

Fig. 7. Slight knee data

In examining how often these features occur when an eclipse is not occurring, we had a perfect control experiment in a dry run that took place two months prior to the total eclipse. As a part of the NASA Eclipse Ballooning Project, teams were supposed to do a “dress rehearsal” as well as they were able at that time. Some teams just did bench tests, but many were able to do a full flight.

Out of the 43 Iridium GPS systems that were activated on June 20th, 2017, 23 of those did bench tests alone (on the ground). Therefore, 20 flights were in the air. Of those, 2 burst early. Out of the 18 remaining flights, 15 of them showed no knee feature at all and 3 of them showed a slight knee (at 58202 ft., 64213 ft., and at 53038 ft. respectively). So, 3/18 (17%) of the flights on our practice day showed a slight knee feature. This sounds more like our past experiences. There might have been a small decrease in the ascent rate, but if you weren't looking, you might not even notice.

Conclusions

Many balloon flights (63%) launched prior to totality during the 2017 total solar eclipse experienced a sudden slowing of ascent around the tropopause, the boundary layer between the troposphere and the stratosphere. This effect is either short-lived, localized, or both. This presumably occurred because of the cooling effect from the eclipse creating either a strong down draft or temperature differential producing a deceleration of the balloon. During a trial run on a day where no eclipse occurred, only a few flights (17%) showed a slight slowing in the ascent rate around the tropoause.

If another large-scale balloon launch occurs for the total solar eclipse on April 8, 2024, we would be interested in analyzing the ascent profiles as we predict more of these knee profiles would occur than normal balloon flights experience. Until that time, we may consider doing flights at sunset and sunrise to simulate the changing light that the eclipse produces.

Acknowledgments

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