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Increase of Ionizing Radiation at the Pfotzer Maximum over the Southern Appalachians

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Abstract

Verso l'alto is a multi-disciplinary research and development project whose goal is to gain insight into the upper atmospheric electromagnetic environment above the Southern Appalachian Mountains. Using high altitude weather balloons, Verso l'altos' payload carries scientific equipment in order to record cosmic radiation fluctuations and locate gamma rays that produce terrestrial gamma-ray flashes (TGFs). TGF's commonly form in high electrical fields within and above thunderstorms and snowstorms in the troposphere and tropopause; where they produce a shot of intense gamma radiation that is hurled into space. Four successful launches have been completed from October 2012-November 2013. A high-speed camera is also included within the payload to capture images of the region. Live tracking and telemetry of the flight is performed by an amateur radio communications payload, and beacon coordinates are uploaded to aprs.fi for real-time access online. The chase teams consist of three or more licensed mobile amateur radio operators who track and retrieve the payload. New scientific equipment flown in November provided a broader range of data collection, including a temperature sensor and effected radiation dose rate per hour in Sieverts. Data from the November flight concludes that fluctuation peaks within the tropopause was due to the Pfotzer maximum, where incoming primary cosmic radiation components decrease upon entering the tropopause and secondary components increase and radiate near altitudes of 15-20 km. This finding is important to atmospheric space physics, where the maximum spikes in counts are confined to lower altitudes below the stratosphere. This impacts the exposure rate of ionizing radiation to airline travelers, and high altitude scientific airline flights. Atmospheric mixing of solar radiation concluded that the geomagnetic field fluctuation coincides with the radiation counts and is directly related. All flights are coordinated on a specific date to ensure the retrieval of the project by the cooperation between local communities, scientific organizations and academic institutions. Future flights scheduled for 2014 include winter flights and spring thunderstorms. The goal of this project is to better understand the impact of cosmic radiation fluctuations from the ground into the mid-stratosphere, where direct observation is extremely limited. This project brings together interdisciplinary scientists, engineers and students, which further enhances multiple STEM fields throughout the region.

Keywords: Atmospheric radiation, thunderstorms, cosmic rays.

1. Introduction:

Cosmic rays that bombard our planet interact with the terrestrial atmosphere; the troposphere, tropopause, and the lower stratosphere. These cosmic particle showers are modulated by solar wind and the terrestrial weather, which influence the amount of charged particles entering our atmosphere. Muons are the most penetrating part of cosmic ray showers and their large energies provide information on how primary cosmic ray fluxes interact with the atmosphere. They generate from the decay of pions above altitudes of 14 km, (45,931 ft.)

Terrestrial Gamma ray Flashes, (TGFs), are brief pulses of gamma radiation that are generated within the lower troposphere and emit photons out into space.[1] Discovered in 1994 by RHESSI and Fermi satellite detectors, TGFs usually form during a thunderstorm or in intense electrical activity. Typically lasting a millisecond or less, TGFs can have photon energies exceeding 20 MeV.[2] Since gamma-rays are absorbed by the atmosphere; the scarcity of

TGFs seen by satellites might have an obstructed view of their production in the lower troposphere. The distribution of TGFs at intensities below those seen from space does not follow a power law distribution and determining their mechanism of production has posed a challenge to scientists. It is still unclear if these photon energies follow a geomagnetic field line upon escape, or if the moment of origination occurs at the peak of intracloud (IC) lightning as a lag in its tail leading to cloud to ground (CG) peaks.[3] Storm cloud production and height during a thunderstorm, along with atmospheric pressure also pose questions if a single storm system produces multiple TGFs, or how to localize them.[4]

The Pfotzer Maximum occurs between altitudes of 14-25 km, (45,931-82,021 ft.) within the tropopause layer below the stratosphere where primary particles, (pions and hadrons) decrease and secondary particles, (muons) increase. This is an important source of ionization in the Earth's atmosphere. The initiation of an electromagnetic-muon cascade results in the ionization of the ambient air during the release of primary energies by the excitation of air molecules deeper in the atmosphere. In this cascade a fraction of the primary particles reach the ground as high energy secondary particles.[5] The electromagnetic field also interacts with incoming particles, as the sun's solar rays bombard the atmosphere. This mixing is directly related, as deeper into the atmosphere the pressure decreases as the differential absorption rate within tropopause heights vary.

The Southern Appalachian region is geographically located in the south east of the US, with WCU nestled in the Great Smoky Mountains of Western North Carolina. The climate in this region varies from sub-tropical in the summer to harsh, sub-alpine winters in the higher elevations. Weather patterns that traverse the region are diverse, and as a system moves across the mountains its energy is displaced which creates pockets of intense thunderstorm cells throughout the area. Jet stream variation occurs across this region and fluctuates at different altitudes throughout the year. Could these displaced cells harbor a source for gamma radiation? If each peak of radiation is detected at lower tropospheric altitudes, does the Pfotzer Maximum influence TGFs?

In this paper the flights from November 2013, (Cat 6)-June 2014, (Cat X) will be discussed. Presented at NCUR was Cats 6, 7 and 8 flights.

2. Methodology:

Using high altitude weather balloons equipped with two small payloads, each balloon experiment is launched from Jackson County Airport in Cullowhee, NC. (Figure 1) Compressed hydrogen is used to inflate the balloons. Its cargo consists of a scientific payload to record atmospheric radiation and temperature and a Cannon A495 camera programmed to take pictures every 20 seconds. A second payload separated by ten feet is housed with amateur radio equipment for tracking, telemetry and jet stream variation. All balloons are chased after its launch to its impact site, via APRS which shows its trajectory online. An 8 foot parachute safely allows the balloon to coast to its landing destination. Each payload is housed in a small 2 inch thick styrofoam box with additional padding for insulation. Locating the balloon after landing requires the operators to use directional antennae and Radio Directional Finding (RDF). Each operator uses the antenna to tune in the balloon's beacon by sound and direction to locate the payload.

Figure 1: Launching of the balloon at Jackson County Airport and image after take-off.

2.1 Flight Equipment

The scientific payload consists of an Arduino particle detector that records particle counts per minute and a temperature sensor that records atmospheric temperature housed on the outside of the payload. A small glass Geiger Mueller tube is attached to the detector, which is powered by a 12 volt lithium AA battery pack. The detector has a boundary of energies from 3.5 MeV-105.48 GeV, but cannot determine if the particles are positive or negative. For Cat X a barometric pressure sensor was added. (Figure 2a). A Cannon A495 camera is also housed within the scientific payload programmed to capture pictures every 20 seconds.

The communications payload consists of a very lightweight GPS receiver, APRS encoder and VHF/UHF transceiver to determine and transmit the balloons' latitude, longitude, and altitude. (Figure 2b) The APRS encoder is a device which receives GPS coordinates from orbiting satellites and reformats them into an open digital packet radio protocol called Automatic Position Reporting System. The encoder converts these packets into audio tones that are rapidly transmitted by a standard FM voice transmitter operating in the 2 meter amateur radio band. A frequency of 144.39 MHz is used, and automated APRS stations all over the world can listen for packets on this frequency. Packets are automatically uploaded to the internet and are instantaneously available at http://aprs.fi/. (Figure 2c)

Amateur radio frequencies and equipment used to track and communicate with the balloon are licensed and experienced amateur radio operators who have volunteered to engineer and operate the communications systems in accordance with Federal Communications Commission (FCC) rules. The call sign for Verso l'alto is K4WCU-11.

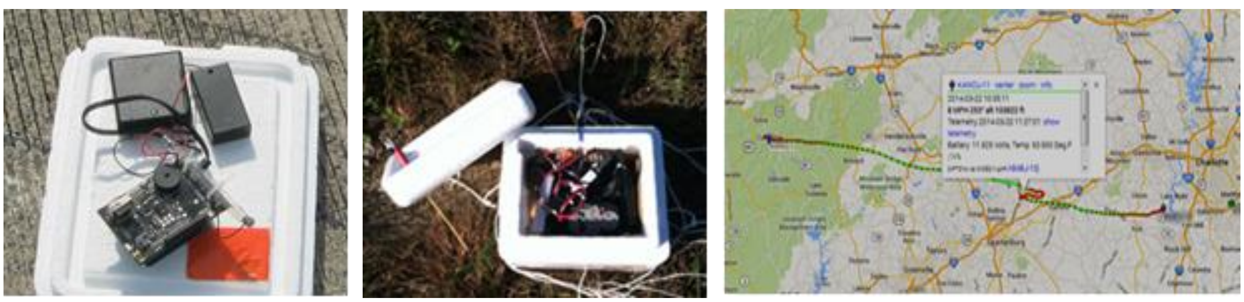


Figure 2: (a) The scientific payload (b) the radio communications payload (c) trajectory of Cat 8 flight on aprs.fi

2.2 Chase Equipment

All amateur radio chase vehicles are equipped with a laptop running APRSICE software, a 2 meter mobile radio and a Byonics Tiny Trak 4 for optimal coverage during flight. APRSICE software is an amateur radio real time tactical display program written for Windows mobile operating systems. For tracking in real time, the program interfaces with a network of servers that are gathered from stations operating on the internet and/or the radio network. Users on the radio network (RF) can operate completely detached from the internet. This is a very useful tool to have during a chase, since most of the area covered is within a dead zone of phone/internet reception.

Radio Direction Finding, (RDF) is used to locate the balloon once it has landed by tracking the 100mW beacon signal. The antennae tune in on the beacon signal from the payload; the stronger and more frequent the signal is, the closer the payload is to being located and recovered. (Figure 3)

Figure 3: Mobile chase equipment, radio direction finding antenneas and chase into a field for recovery.

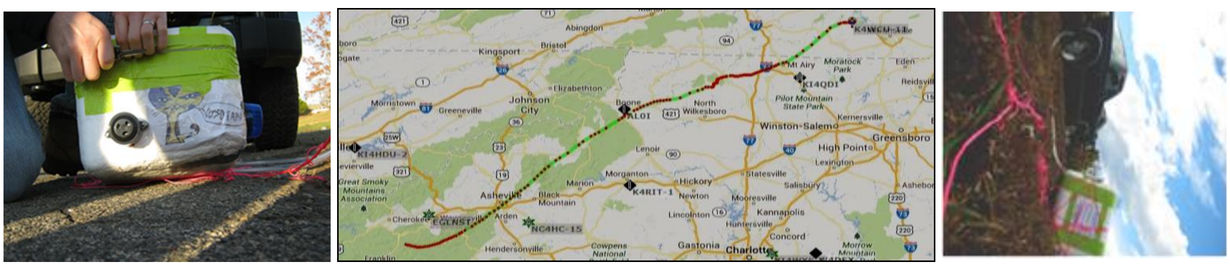
3. Data

3.1 Catamount 6:

Catamount 6 was launched on November 2, 2013 from Jackson County Airport at 12:06 pm. Equipment malfunction the night before the flight occurred with the upgrade to a Tiny Trak 4 within the payload. On the morning of the flight, the team realized the problem and did fix it. The launch was pushed back a few hours, and lift off occurred at 12:06pm. The weight of the payloads was 2.45 kg (5.41 lbs.) with the science payload weighing in at .67 kg (1.48 lbs.) A 1000g balloon was used. The balloon traveled in a northeast direction, with an impact at 3:39pm near Fairy Stone State Park in Virginia. Total flight duration was 3 hrs. 34 min.

Picture 1: Snapshots of the Pfotzer Maximum upon ascent (L) and descent (R).

Cat 6 had the fastest recorded descent from burst at 29.3 km (96,409 ft.) to impact in 27 minutes. This was also the only time the balloon landed in a homeowner's yard on the ground and not in a tree. The radio payload suffered extensive damage from the impact, (Picture 2). New radio equipment was purchased for the next flight.

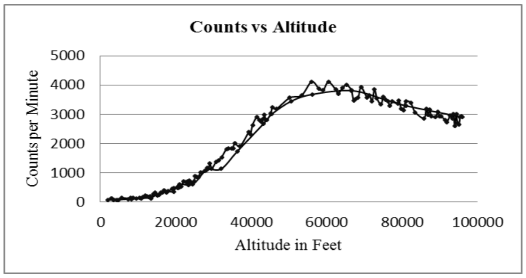


Picture 2: Snapshots of the radio payload damage and impact, center image is the trajectory of the flight.

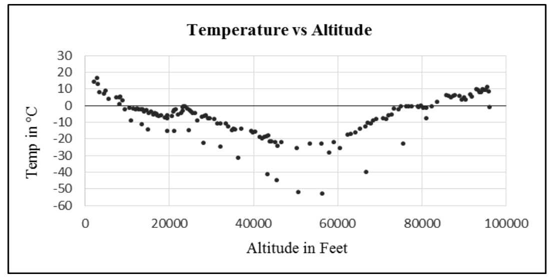
3.1.1 Raw Data:

The detector recorded counts per minute with the highest peak upon ascent at 4158 cpm at 1:58pm at an altitude of 18.7 km (61,470 ft.) over Stone Mountain State Park, NC. A second peak upon descent occurred at 3:05pm with 3978 cpm at an altitude of 21.5 km (70,675 ft.) near Mount Airy, NC. (Picture 1, Figure 4a) Temperature decreased upon altitude with the lowest recording of -28.3°C at 17.6 km (57,983 ft.) upon ascent and -52.6°C at 17.1 km (56,323 ft.) upon descent. (Figure 4b) Both lowest temperature and peak cpm fall within the Pfotzer Maximum. This flight also covered the greatest distance in altitude during maximum counts. (Table 1)

Horizontal speed was recorded during flight with the highest speed reaching 121 mph at an altitude of 6.9 km (22,749 ft.) upon ascent and 147 mph at an altitude of 9.7 km (32,061 ft.) upon descent. The slowest speed recorded was 4 mph at an altitude of 21.7 km (71,439 ft.) upon ascent and at maximum altitude of 29.3 km (96,049 ft.) the balloon was traveling at 61 mph before it burst. (Figure 10)



(a)



(b)

Figure 4: (a) Cat 6 cpm by altitude. The jagged peaks are upon ascent with the smoother lines upon descent. (b) Temperature by altitude, the top is upon ascent and the bottom is upon descent.

The magnetic field throughout the day fluctuates as recorded from Pisgah Astronomical Research Institute (PARI) ground magetometer during flight. Taken into account the time of day of Cat 6 flight, the peak cpm occurs during a decrease in the magnetic field. (Figure 5).

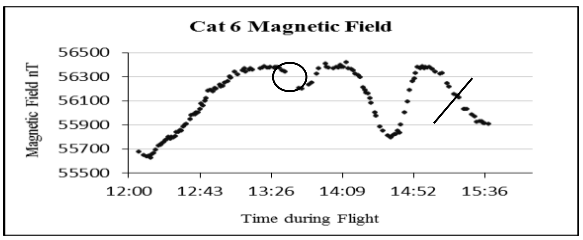


Figure 5: Cat 6 magnetic field from PARI magnetometer. The line indicates where balloon burst. The circle indicates maximum cpm. There was a gap in ground collection time, showing a decrease in nT.

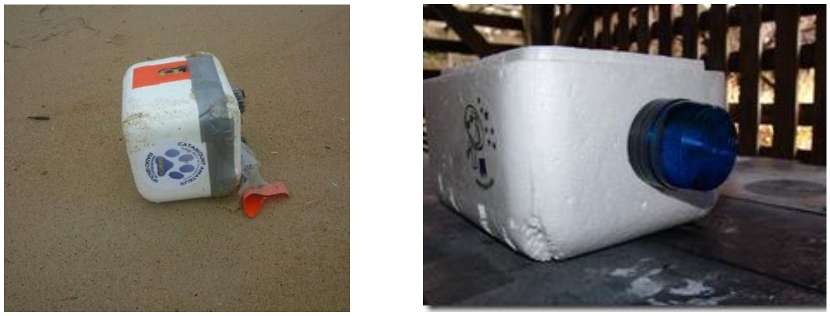
3.2 Catamount 7:

Catamount 7 was launched on February 1, 2014 at 8:46 am from the Jackson County Airport. The total weight of the payload was 2.4 kg (5.34 lbs.) and a larger balloon of 1200g was used A higher altitude was expected since a larger balloon was used, but a small crew of four prepared the launch and under filling of the balloon resulted in a slow ascent. Cat 7 was an epic journey from Cullowhee, NC to impacting northeast of Virginia Beach, south of Delaware two miles into the Atlantic Ocean at 3:25 pm. Chase crews stopped in Statesville, NC to watch the impact online. The balloon reached a max altitude of 27.5 km (90,510 ft.) with a flight duration of 6 hrs. 41 min. (Picture 3)

Picture 3: Cat 7 last picture over the mainland, the trajectory of the flight and the parachute in the ocean.

The Coast Guard and the Cape Charles Marine Police was notified. Further contact was made to The Virginia Institute of Marine Sciences to see if the experiment could be recovered. Low tide and a winter storm previously in the week prevented any recovery from the mainland. Approximately $1500. in equipment was lost. A week later, the science payload washed up onshore at Nags Head, NC. nearly 100 miles from its last packet location. Two middle school Science teachers found the box and turned it in to the Nags Head police. A few days later the empty radio payload was found washed up in Southern Shores, NC. The only identification left on the payloads were the

WCU Catamount Amateur Radio Group (CARGO) logo on the science box and the PARI logo on the radio box. Both boxes were mailed back to WCU, with recoverable data and pictures on the sd cards. That is the power of Science! (Picture 4)



Picture 4: The washed up science box and empty radio box.

3.2.1 Raw Data:

The detector recorded counts per minute with the highest peak upon ascent at 4284 cpm at 1:03 pm at an altitude of 17.7 km (58,203 ft.) near South Boston, VA. A second peak occurred upon descent at 3876 cpm at 2:52pm at an altitude of 16.1 km (52,995 ft.) over Chesapeake Bay. (Figure 6a) Temperature increased upon altitude, with the highest temperature at 31°C at an altitude of 2.8 km (9,407 ft.) The lowest recorded temperature of -28°C at an altitude of 14.4 km (47,348 ft.) upon ascent and -26°C at 27.5 km (90,431 ft.) one minute before the balloon burst. (Figure 6b) Both peak cpm and lowest temperature fall within the Pfotzer Maximum. (Table 1)

Horizontal speed was recorded during flight with the highest speed reaching 130 mph at 15.1 km (49,658 ft.) upon ascent and 135 mph at 15.2 km (50,082 ft.) upon descent. The slowest speed recorded was 3 mph eight minutes after liftoff at 1.1 km (3,734 ft.) and at maximum altitude of 27.5 km (90,510 ft.) the balloon was traveling 121 mph before it burst. (Figure 10)

Upon impact in the Atlantic, the detector kept running and collecting data for an additional 13 hrs. 48 min. The radio transmitted APRS packets throughout the evening and the last packet received was at 10:58pm. The camera took pictures for 19 min after splash down.

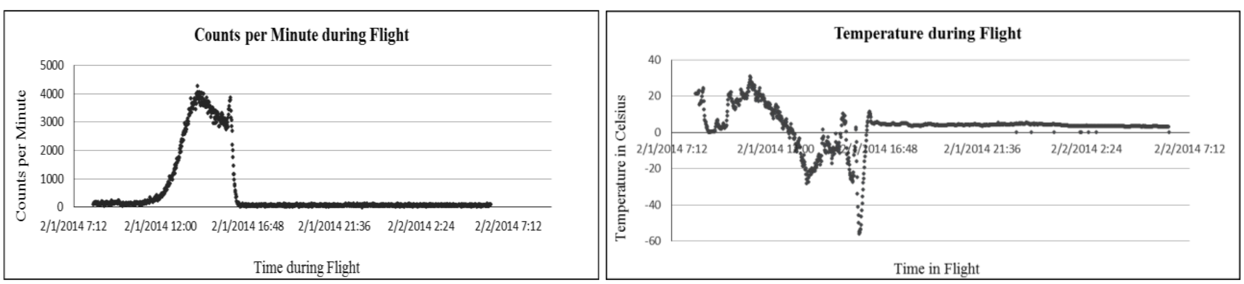


Figure 6: Cat 7 counts per minute (a) and temperature during flight (b)

The magnetic field recorded by PARI ground magnetometer during Cat 7 flight. The peak cpm occurs during a slight decrease in the magnetic field, by mid-day when the sun's rays are the strongest. (Figure 7)

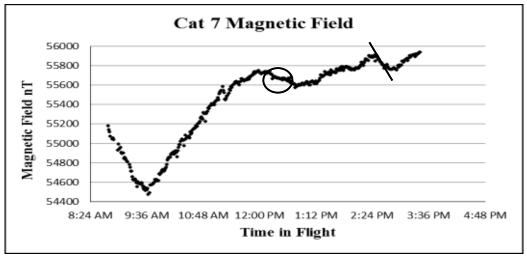


Figure 7: Cat 7 magnetic field from PARI magnetometer. The line indicates where the balloon burst and the circle indicates maximum cpm.

Articles were written of this flight and a small segment was broadcasted on the local WLOS news, as well as the news stations in the Outer Banks, NC. http://thereporter.wcu.edu/2014/02/parts-of-lost-wcu-physics-research-balloon-recovered-in-outer-banks/ http://magazine.wcu.edu/2014/05/learning-by-doing/,

3.3. Catamount 8:

Catamount 8 was launched on March 22, 2014 from Jackson County Airport at 8:37am. New radio equipment and camera was purchased. This flight consisted of testing a lighter version of the previous used communications components in a single payload weighing 1233.8 g (2.7 lbs.) An 800g balloon was used and no scientific data was collected. The balloon traveled in a SE direction, impacting in York, near Lake Wylie, SC. at 11:27 am. (Figure 2 for trajectory) It reached an altitude of 31.6 km (103,822 ft.) with a flight duration of 2 hours 50 minutes. This was the highest altitude achieved, with snapshots of the moon during flight.

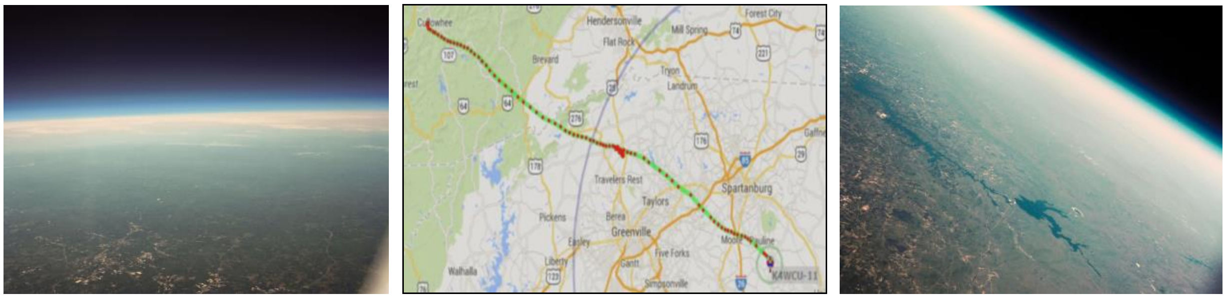
(a)  (b) 

Picture 5: Images of Cat 8 with moon, (a) at 19 km (16,344 ft.) and (b) at 31.6 km (103,822 ft.) falling after burst.

Horizontal speed reached a maximum of 126 mph at 11.0 km (36,214 ft.) upon ascent and 117 mph upon descent at 13.7 km (44,971 ft.) Slowest speed recorded was 1 mph at 22.3 km (73,233 ft.) upon ascent and 8 mph at 25.6 km (84,305 ft.) upon descent. At maximum altitude the balloon was traveling at 8 mph before it burst. (Figure 10)

3.4 Catamount 9:

Catamount 9 was launched from the Jackson County Airport on April 26, 2014 at 9:18 am. This flight consisted of a double payload with a new Ardunio detector and temperature sensor with the total weight of 2100g. (4.63 lbs.) A 1000g balloon was used. The balloon traveled in a SE direction impacting at 11:39 am near Pauline, SC. It reached an altitude of 28 km. (91,910 ft.) with a flight duration of 2 hr. 21 min. The payload landed in a 150 foot tree, and a tree climber was located for retrieval.

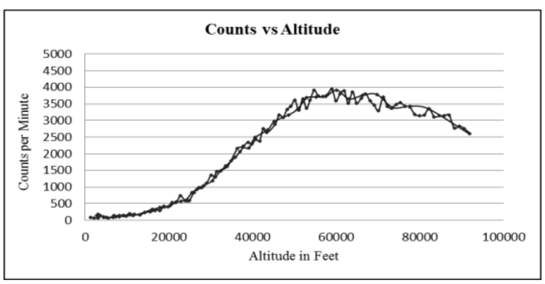


Picture 6: Snapshots of the Pfotzer Maximum upon ascent, trajectory of the flight and Pfotzer Maximum upon descent facing Lake Keowee, SC.

3.4.1 Raw Data:

The detector recorded counts per minute with peak counts of 3942 cpm at 10:09 am at 17.9 km (59,031 ft.) near Marietta, SC. A second peak of 3918 cpm upon descent at 10:48 am at 18.3 km (60,183 ft.) further east of Marietta, SC. (Figure 8a) No temperature data was recorded.

Horizontal speed reached a maximum of 165 mph at 11.3 km (37,105 ft.) and 163 mph at 11.8 km (38,967 ft.) upon ascent. Slowest speed recorded was 6 mph at (83,549 ft.) upon ascent and 4 mph at (77,626 ft.) upon descent. At maximum altitude the balloon was traveling at 17 mph before burst. (Figure 10)

(a) 

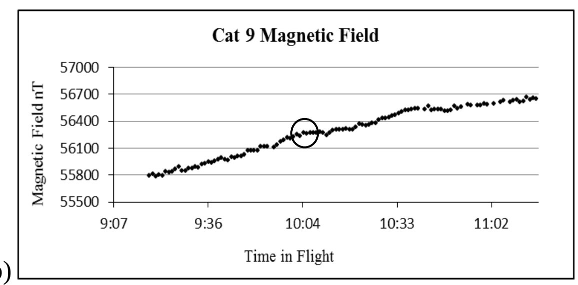
(b) 

Figure 8: (a) Cat 9 cpm by altitude. The jagged peaks are upon ascent with the smoother lines upon descent. (b) PARI magnetic field. The circle indicates maximum cpm where there is a slight increase in the magnetic field.

3.5 Catamount X:

Catamount X was launched on June 21, 2014 from PARI in Rosman, NC at 10:40 am. The challenge of launching from PARI is that the radio transmissions were shielded until after liftoff. The chasers were blind to knowing if the radio transmissions were working properly, and communications on the helipad during liftoff was needed by cell phone. A double payload weighing in at 2108g (4.6 lbs.) was flown with a 1000g balloon. No temperature was recorded, but atmospheric pressure during flight was recorded. The balloon traveled in a SE direction, impacting near Table Rock State Park, SC. at 12:38 pm for a flight duration of 1 hour 58 minutes. It reached a maximum altitude of 24.8 km (81,443 ft.) Burst to impact was 57 minutes.

The Duke TIP program students were a part of this flight, incorporating STEM in their studies at PARI. The 30 students were present for the launch and followed along online, anticipating our return with the payload and shattered balloon. (Picture 7) The experience enhanced the two week program, with the students eager to do the data analysis.

Picture 7: Preparing the launch with the Duke TIP students and trajectory of the flight.

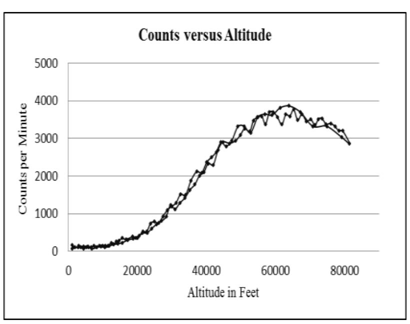
3.5.1 Raw Data:

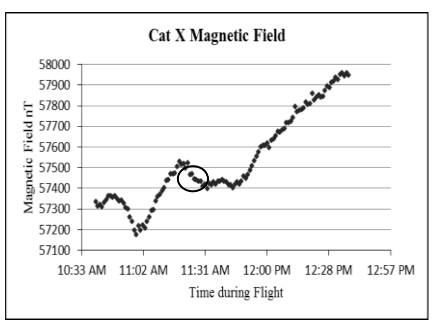
The detector recorded counts per minute with peak counts of 3768 cpm at 11:28 am at 19.9 km (65,290 ft.) near Cold Mountain Branch, NC. A second peak occurred during descent of 3816 cpm at 11:47 am at 18.7 km (61,366 ft.) near Claypole Branch, NC. This was the first recorded second peak of cpm higher than the first peak. (Figure 9)

(a)  (b) 

Picture 8: Snapshots of the Pfotzer Maximum upon ascent (a) and descent. (b)

Atmospheric pressure decreased upon altitude, with the lowest values less than 1.0 kPa within altitudes of 23.8-24.1 km (78,358-79,243 ft.) before and after burst in a 4 minute duration. At the P-max the atmospheric pressure was 5.1 kPa. (Figure 9)





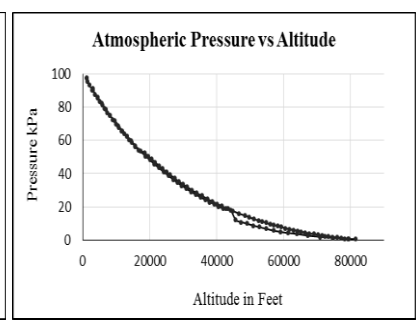


Figure 9: Cat X cpm, showing jagged peaks upon ascent, smoother lines upon descent. Magnetic field with circle representing max cpm. Atmospheric pressure upon altitude, the lower line is upon descent.

The magnetic field trended upward throughout the day, with the P-max occurring upon the second decrease in the magnetic field. Cat X flight was also the Summer Solstice.

Horizontal speed reached a maximum of 32 mph at 5.2 km (17,203 ft.) upon ascent and 35 mph at 13.4 km (44,259 ft.) upon descent. Slowest speed recorded was 4 mph at 19.9 km (65,290 ft.) upon ascent and 4 mph at 6.25 km (20,535 ft.) upon descent. At maximum altitude the balloon was traveling at 11 mph before burst. (Figure 10) This was the slowest velocities recorded for horizontal speeds throughout the eight flights.

3.6 Jet Stream Variation:

The jet stream in the Southern Appalachians varies greatly by altitude, time of day and seasonally with each flight recording a fluctuation of horizontal speeds. Maximum speeds, greater than 70 mph, occur in altitudes ranging from 6.0-15.8 km (20,000-52,000 ft.) This is the transition into the tropopause, (12.8 km/42,240 ft.) where stratified turbulent kinetic energy increases and convective dynamics are located near Earth's surface. Cat 7 recorded the fastest speeds in the stratosphere, nearly the same velocities as in the tropopause. Cat X on the Summer Solstice recorded the slowest speeds, not showing variation between the atmospheric layers. The graphs by altitude show ascent and descent, with some overlapping, following the same trend. Free falling before the parachute catches increases the velocity of descent, and once the chute catches wind, the descent rate slows. Each flight shows the differential complexities of seasonal jet stream occurrences. (Figure 10)

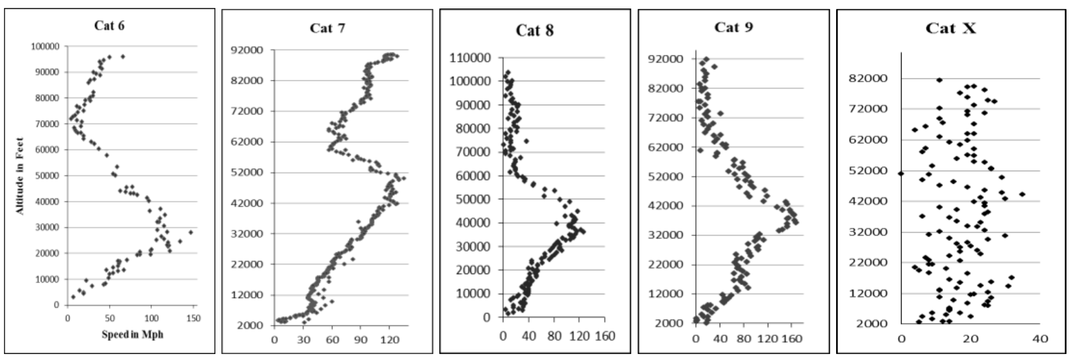


Figure 10: Jet steam variation, altitude vs speed by flight.

Table 1: A 13 minute average of each flight, showing variance in collection over the P-max.

	Cpm	Alt/Ft	Temp °C	Alt/Ft/Min	Mph		Cpm	Alt/Ft	Temp °C	Alt/Ft/Min	Mph		Cpm	Alt/Ft	Alt/Ft/Min	Mph		Cpm	Alt/Ft	Alt/Ft/Min	Mph
Cat 6						**Cat 7**						**Cat 9**					**Cat X**				
	2796	44146	-21.62	1040	65		3450	56044	-19.62	302	93.21		3378	52926	869	65		3696	58237	1164	6
Covered	3024	45186	-22	437	77	Covered	3654	56346	-21.44	305	89.76	Covered	3606	53795	975	54	Covered	3702	59401	1184	7
Altitude	3234	45623	-24.19	1000	69	Altitude	3996	56651	-17.25	354	87.46	Altitude	3912	54770	1007	72	Altitude	3570	60585	1256	17
6.1 km	3180	46623	-21.87	3577	57	1.4 km	3804	57005	-19.69	364	86.31	3.6 km	3738	55777	1106	63	4.3 km	3372	61841	1148	19
20075 ft	3564	50200	-25.31	3163	59	4630 ft	3834	57369	-18.62	450	86.31	11997 ft	3726	56883	928	78	14204 ft	3636	62989	1175	11
	3648	53363	-22.94	2668	50		3930	57819	-19.19	384	77.10		3768	57811	1220	65		3594	64164	1126	21
Peak	4116	56031	-22.75	1952	47	Peak	4284	58203	-18.44	364	71.35	Peak	3942	59031	929	33	Peak	3768	65290	1154	4
	3876	57983	-28.31	1125	43		4050	58567	-17.75	361	69.05		3588	59960	968	35		3486	66444	1206	7
	3822	59108	-21.94	1362	37		3978	58928	-15.25	387	64.44		3798	60928	1023	7		3648	67650	1353	12
	4104	60470	-25.62	1930	32		3888	59315	-15.75	443	56.39		3894	61951	971	50		3456	69003	1266	11
	3852	62400	-17.56	669	28		3972	59758	-15.94	456	59.84		3516	62922	1027	50		3510	70269	1168	19
	3702	63069	-17.06	1152	19		3810	60214	-13.25	460	58.69		3864	63949	974	31		3354	71437	1004	19
	3906	64221	-15.94		19		4050	60674	-12.25		58.69		3528	64923		35		3516	72441		11
Average:	3602	54494.1	-22.1	1672.9	46.3	Average:	3900	58222.5	-17.3	385.8	73.7	Average:	3712	58894.3	1000	49.1	Average:	3562	65365.5	1183.7	12.6

4. Conclusions:

Verso l'alto has proved successful in collecting atmospheric data. The Pfotzer Maximum is present, concluding that in the tropospheric layer higher amounts of ionizing radiation is naturally occurring. Each flight is different in launch time, duration, collection of maximum counts, range of altitude in count collection and horizontal speed during collection. Muonic activity in the lower atmosphere has been confirmed with a threshold transition into pions above 3000 cpm at altitudes above 13.7 km (45,000 ft.) Only a fraction of particles are penetrating through the detector during flight, and it is uncertain what the full absorption of MeV is. There is a power law that the values follow at a particular altitude and latitude, which could correspond with seasonal changes during the peaks of each P-max recorded. The thickness of atmospheric depth of counts range in each flight, with the P-max existing at altitudes of 16.6-19.9 km (54,494-63,365 ft.) This is due to seasonal conditions in the troposphere, as collection ranges from 1.4-6.1 km (4,630-20,075 ft.) over the 13 minute average of the P-max. The magnetic field for each flight generally showed an increased trend, as the sun's rays inflitrated the atmosphere. During P-max collection the magnetic field decreased before reaching the maximum nT of the day. This observation is directly related on each flight. Temperature reached its coldest during the P-max peaks, coinciding with particle scattering in the upper troposphere. Further flights are scheduled for 2015, including an infrasonic array sensor, in hopes of a spontaneous thunderstorm flight.

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