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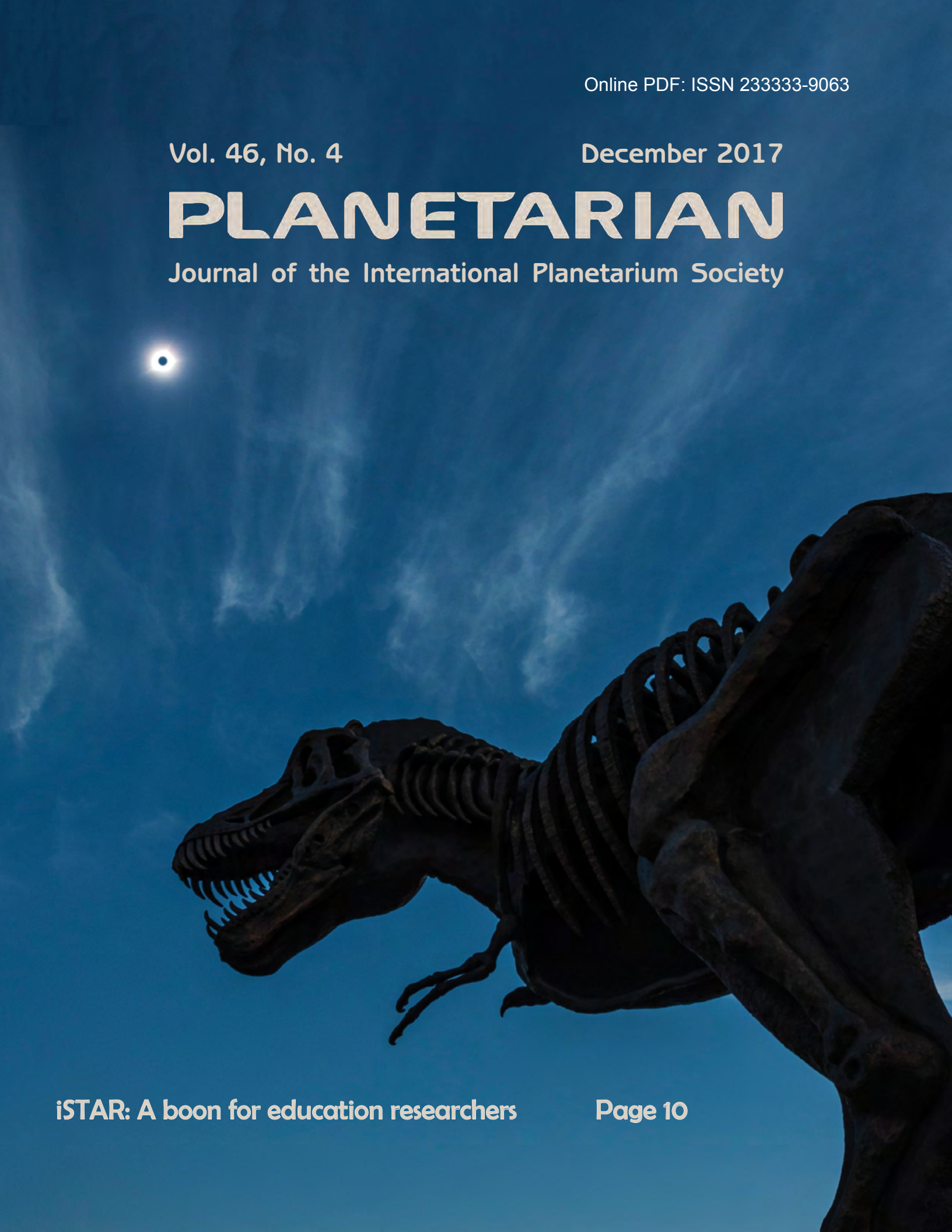

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Final Deadlines
March: January 21
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Articles

On the Cover:

While searching for an eclipse viewing location in Casper, Wyoming, Fred Espenak discovered "this wonderful statue of Tyranosaurus Rex in front of the Tate Geological Museum on the Campus of Casper College. Determining the position of the sun during totality, I chose a compelling composition that would include the T-Rex and the eclipsed sun." You can see more of Fred's photos (and even purchase them) at www.mreclipse.com. ©Fred Espenak

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Columns

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An eclipse expedition, family style

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Abstract

This article describes a project-based learning experience my grandchildren and I shared on our recent family eclipse trip. Besides being motivational and educationally rewarding, this type of informal learning yielded real-world findings that the children could internalize as their own contributions through the discovery method.

The great eclipse experiment

The Great American Eclipse that swept across a diagonal swath of the contiguous United States on August 21, 2017 was reportedly one of the most watched eclipses in human history. In just over 90 minutes, the moon's umbral shadow raced through portions of 14 states where 12 million people reside. Millions more traveled into the path of totality, while even more stayed home to watch this celestial rarity via live broadcasts, thus avoiding the massive traffic jams that followed.

For me, this was a chance of a lifetime to share one of nature's extraordinary splendors with my entire family and connect with my grandchildren on an informal teaching level—much as I do with hundreds of students throughout the year. As a strong proponent of project-based learning (PBL), I realized that the upcoming eclipse offered a unique opportunity to design a real-world experiment for my three oldest grandchildren.

Given that individuals generally spend four times as many years out of school as in, it's no wonder that much of what we know comes from experiences outside of formal schooling. PBL involves scenarios applicable to authentic, real-life problem solving. Besides being motivational and adaptable to a variety of learning styles, this inquiry approach to informal learning supports individual decision-making, collaboration and critical thinking.

I designed this PBL experience to allow the grandchildren[1] to explore the temperature changes that occur during a solar eclipse. Since all three are in primary school, the experiment needed to be basic enough to match their knowledge base, yet challenging enough to spark their inquisitiveness.

Planning the trip

Plans for this trip were made well over 18 months in advance. The last total solar eclipse to touch the US mainland occurred over a generation ago. While a total solar eclipse was visible from Hawaii in 1991, prior to this 2017 eclipse no total eclipse had taken place in any of the 49 continental states since 1979. That was long before personal computers became popular or social media and digital cameras even existed. We fully expected that this long drought of 38 years would heighten visitor interest nationally, necessitating advanced reservations, especially for lodging.

We selected our eclipse site based on three criteria: low cloud coverage, proximity to the central path and an adventurous setting for family to explore. That quickly narrowed our search to the Snake River Valley near Idaho Falls, where average cloud cover is typically 40% in August.

1 Temana Bira Ciotti (grade 2), Jedidiah Pang (grade 4) and Keilana Pang (grade 6). Also joining the team was our daughter Piilani Pang.

Facing page: Composite photo of the Great American Eclipse on 21 August 2017. (photos by Joseph Ciotti and Nainoa Ciotti)

Right: Entire family enjoying the comforts of our home-base eclipse trailer. (photo by Nainoa Ciotti)

Below, left: Nighttime lessons and preparations inside the trailer on the evening prior to the eclipse. Bira, Jedidiah and Keilana checking out their remote datalogger and sensors with their grandfather. (photo Piilani Pang)

Below, right: Observing the partially eclipsed sun with a custom-made pinhole camera. (photo by Ignacio Lobos)

For home base we rented a riverside cabin in Island Park, which gave us easy access to Yellowstone National Park and the majestic Grand Tetons in the days leading up to the eclipse.

For the eclipse, we rented a trailer in Rigby, Idaho, where totality lasted 2 min 15 sec. The trailer was located on private property surrounded by an acre of open land away from Rigby's main thoroughfares. This buffered us from the anticipated high-volume of traffic that was expected that eclipse day, thereby acting as a safeguard for the children while providing a relaxing and unobstructed viewing site for the entire family. The trailer also served as our research base and classroom.

Designing the experiment

Our experiment was based on a similar activity I had conducted at the 2008 total solar eclipse in Altai, China[2]. On that occasion, only temperature readings were collected. For the 2017 eclipse, a photometer was added.

Air temperature variations are complicated by lower atmospheric convection effects, thermal inertial properties of sensors in still versus moving air, and other factors. Given the grade levels of my grandchildren, no attempt was made to account for these in our experiment. Readers interested in learning more about these factors are referred to K. Szalowski[3].

So that the grandchildren could enjoy the eclipse in its entirety without need of manipulating instruments, I selected a remote sensing device that could automatically record data throughout the eclipse's 3-hour duration. Vendors offer several portable devices, such as PocketLab Voyager that can be connected to a smartphone. For our experiment, I selected the Venier LabPro units used in my physics lab. This internal-battery-powered device allows for the connection and simultaneous reading of multiple sensors. When connected to a laptop, this remote unit can be configured to autonomously collect data from any of the sensors at selected sample rates and runtimes. Once the laptop is disconnected, the remote device will operate independently in the field.

The temperature probes were made of stainless steel. These sensors would be used to measure ground and air temperature, with the latter in direct sunlight or shade. These thermistor-based probes have a response time of 90 seconds in moving air[4] and an accuracy of ±0.4°F (±0.2°C).

The light sensor uses a silicon photodiode that approximately replicates the spectral response of the human eye and is capable of being set for various illumination situations. For our purposes, we selected the outdoor sunlight setting that allows for a range of 0-150,000 lux. Since we had no mechanism to compensate for diurnal motion, these photometers were fixed to give sky illumination readings at the zenith.

2 During the Altai eclipse I had recruited the grandson of then Planetary Society President Louis Friedman, both of whom were on the trip, to join me in this temperature experiment using a PASCO Xplorer GLX datalogger. The air temperature for that late afternoon eclipse in 2008 was found to drop approximately 7°F (4°C), while the ground temperature fell about 13°F (7°C) from their expected values.

3 Szalowski, K. (2002). The effect of the solar eclipse on the air temperature near the ground. *Journal of Atmospheric and Solar-Terrestrial Physics*, 64, 1589-1600.

4 Response time for still air is about 400 seconds.

Our plan was to set up four independent eclipse stations—one for each grandchild and a fourth for our daughter, who joined our eclipse team. Each station would have a dedicated remote device and a set of sensors, consisting of two temperature probes and a photometer. This allowed for individualized experiments and a way of comparing results.

Above, left: Station setup showing the locations of the three temperature probes, photometer and remote unit for recording data. (photo Joseph Ciotti)
Above, right: All four stations fully set up minutes before the countdown to start the experiment's 200-minute run. (photo by Ignacio Lobos)
Right: Setting up the experimental stations and sharing the learning experience with their parents on the morning of the eclipse. (photo by Ignacio Lobos)

Preparing for the eclipse

During the days leading up to the eclipse, the entire family had numerous occasions to talk and ask questions, like what determined the duration of totality and why did the moon's shadow travel from the west to east coast despite the earth's eastward rotation. The casual settings that surrounded us—whether on the porch watching the Buffalo River flow lazily by or at a campfire roasting marshmallows under a canopy of stars—allowed freedom for questions and answers to percolate uninhibited by the time and testing constraints of a formal classroom.

The evening before the eclipse my wife and I drove our grandchildren and daughter to the planned observation site in Rigby to spend the night at our rented trailer. This gave us time to discuss the experimental procedures as a team and make sure we were ready to start early the next morning. It also gave the children a night out and their parents a night off.

One distinctive feature of PBL is that students quickly learn the meaning and consequences of meeting deadlines. Postponement of the eclipse was not an option. We had to be ready. That evening was spent becoming more familiar with the sensors and recording system.

Checking the equipment

The remote units and probes were connected to a laptop to verify their operation. We created graphical readouts that visually showed how the temperature sensor worked by alternately cooling it down with ice and warming it up with body heat. We repeated this for the photometer by aiming it at bright and dim light sources in the trailer.

Without going into depth, we briefly talked about the temperature probe's response time, something they could visually see on the stripchart as it plotted out in real time. By likening this to their own reaction time with a stopwatch, they realized that the eclipse's temperature graph should show a lag both because the senor doesn't respond instantaneously and the air takes time to cool off and heat up.

All three grandchildren already had some form of formal graphing in their schools, although not as complicated as the charts they were about to record. As a way of practicing how to read these graphs, we examined the baseline[5] graphs (Graph 1) we made earlier that morning at the cabin. The temperature and light baseline profiles were recorded for nearly identical start and end times as our eclipse experiment.

The children took turns interpreting the baseline graph of the temperature and illumination readings, and forecasting what the eclipse graphs might look like. By tracing their finger along each curve, they were accurately able to predict a dip in the upcoming eclipse's profile. This convinced me that they had a good understanding of how graphs are read.

Setting up the eclipse stations

Early sunrise broke under a perfectly cloudless sky and would remain that way throughout the eclipse. After breakfast, we programmed the four remote units to operate on internal battery. Since we had only two temperature probes per remote unit, each child decided which two of the three temperature readings (air-direct sunlight, air-shade and ground) they would collect. They also determined the sample rate for their own experiment.

Once their parents arrived, they joined us in completing the setup of our experimental stations on a large open field. This also gave the children time to explain their experiment to their parents. The main housing of each station consisted of a cardboard box obtained from a local supermarket. The remote recording device was sheltered inside along with the air-shade thermometer, which was positioned horizontally through the box's side.

The air-direct sunlight thermometer was located vertically through the top of box, while the ground thermometer was inserted horizontally under about 0.5 inch (1 cm) of soil. Each photometer was mounted vertically through the top of the box. To prevent the box from moving, three metal kabob skewers were staked into the ground and taped to its sides.

Observing the eclipse

The remote units were manually started at 10 a.m. MDT and ran autonomously for 200 minutes, automatically stopping at 1:20 p.m. MDT. The children could verify that their equipment was operating by checking the remote unit's LED, which blinked at their chosen sample rate. Each child was also given a field notebook to jot down comments and

(Continues on next page)

5 The baseline data was collected at our cabin in Island Park, Idaho, which is located 65 miles northeast of Rigby where the eclipse was observed. The sky for the baseline data was mostly clear with less that 10% scattered clouds.

reminded to approach the stations cautiously to avoid stepping on buried thermometers or casting unwanted shadows.

Since the equipment was recording autonomously, the children could enjoy the entire eclipse with their family, whether gazing through sun peeps, bouncing on a trampoline in the slowly dimming morning light or checking out the crescent sun's image that was projected from a simple pinhole camera they made. As an exercise in creativity, they each punched out their own imaginative constellation of pinholes in aluminum foil that was mounted in a poster board frame.

We set up an additional experiment by placing a sheet of white foam board on the grass for a possible glimpse of the elusive shadow bands. During the ten minutes preceding totality, the sky rapidly dimmed to an eerie orange-red. It was as if nature were allowing our eyes to dark-adapt for totality's brief splendor. In fact, the moon had covered all but the sun's limb-dark edge, bathing us in an unworldly sunset. A minute before totality, shadow bands began rippling across our makeshift screen and were captured on our smartphone[6].

The fleeting dazzle of the diamond ring was soon followed by a stunning totality that inspired spontaneous cheers and applause. It was a magical time to share with the family.

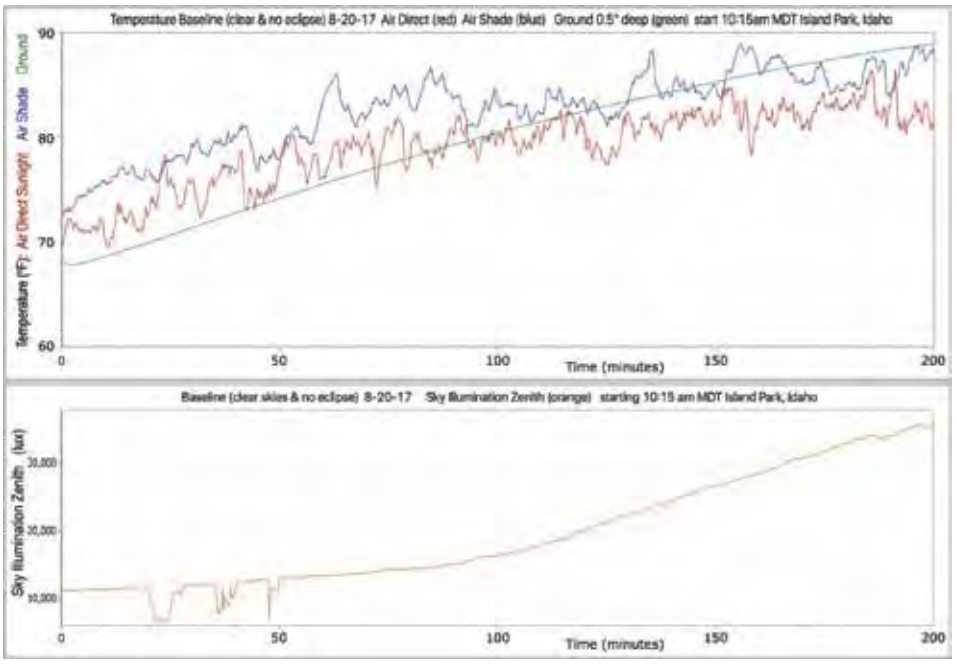
Results and lessons Learned

After disassembling our stations, we reconnected each remote device to our laptop, which instantly graphed the downloaded data. The various profiles from each station were virtually identical, confirming the reliability of our setup. This immediate feedback verified the grandchildren's earlier predictions and gave them a satisfying sense of achievement.

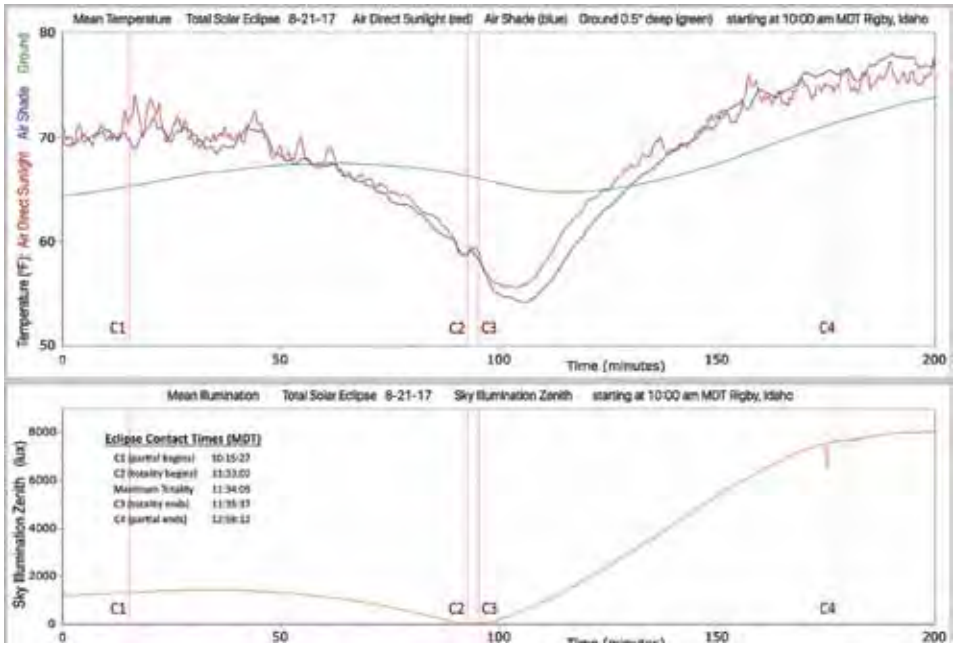
The mean readouts for all four stations are shown in Graph 2. We could easily identify the expected lags in all three temperature curves by comparing them with the illumination graph.

While they had expected the ground to show a different temperature profile than the air, the difference in degree was an interesting discovery for them. One surprise finding was how closely matched the shaded air readings were with those for air in direct sunlight.

Based on the projected temperature[7] that would have occurred without an eclipse, we estimated that the drop in air temperature for direct sunlight was 18°F (10°C). The shaded air cooled down 20°F (11°C), while the ground decreased by 4.5°F (2.5°C). It would be interesting to examine any effect an eclipse-generated wind might have on these results by including an anemometer at a future eclipse.



Graph 1. Temperature and illumination profiles for baseline data taken one day before the eclipse.



Graph 2. Mean temperature and illumination profiles for data collected from the four stations.

Overall, the project's authenticity gave everyone better insight into this celestial phenomenon. The experience of physically making the connection between sunlight and temperature was especially striking. Not only did the children sense the temperature and brightness changes subjectively, they had also recorded them quantitatively with objective, verifiable agreement.

The rewards in the affective domain were just as powerful as the scientific knowledge gained. Some were even unexpected. None of us had ever stayed in a trailer, which added to the excitement and novelty of the experience. Our daughter commented that moving there the night before the eclipse was a good mental switch that helped everyone focus without distractions, while simultaneously building anticipation for the next day.

Our granddaughter remarked that holding night class in the trailer was especially fun. She added that during the daytime with all the eclipse and recreational activity going on, "it was hard to get bored."

(Continues on page 30)

6 The video clip of the shadow bands can be viewed at aerospace.wcc.hawaii.edu/ShadowBands.html

7 The projected temperature values without an eclipse were based on a simple linear fit between the temperatures recorded at C1 and C4.

(iSTAR, continued from page 14)

Detailed information requests about iSTAR should be addressed to the iSTARdatabase.org Coordinator Dr. Michael T. Fitzgerald from the Institute for Education Research at Australia's Edith Cowan University at psyfitz@gmail.com.

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Projected images of the crescent sun from one of the constellation-like patterns punched into the aluminum foil camera. (photo by Ignacio Lobos)

(Eclipse expedition, continued from page 26)

The aesthetic experiences were equally as memorable for all. Some were caught completely off guard and emotionally overwhelmed with the beauty of totality and able to connect with the world in a broader, spiritual sense.

Hearing these and other comments, such as "it was like we were on a very exclusive National Geographic-led tour," made this family-style eclipse expedition extra special.

As one of our sons noted, there are things your children want to learn from their parents and other things that are better learned from a teacher. Learning from their grandparents is a wonderful middle ground. They're already asking about the next eclipse adventure. ☆