Studying a Total Solar Eclipse in Multiple Wavelengths from a Near-Space Platform

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Abstract

The total solar eclipse of August 21, 2017, gave the high-altitude ballooning community an exceptional opportunity to study lighting conditions in the stratosphere during a total solar eclipse across multiple portions of the spectrum. Sensors on balloon platforms flown in Oregon and Nebraska measured changes in the sky's overhead intensity at wavelengths ranging from 940 nm (Infrared A, also know as near infrared (NIR)) to 280 nm (Ultraviolet B, also called UVB) during partial eclipse and totality. The moon's shadow was imaged in near infrared and the Earth's horizon was imaged in thermal infrared, also known as far infrared (FIR).

Intensity measurements at various wavelengths were made using Neulog Light, UVA, and UVB modules, as well using as a LED-based photometer (a Forest Mims design) to study the intensity of eight colors spanning the spectrum from 940 nm infrared to the violet/ultraviolet boundary (400 nm). A Mobius ActionCam was modified for recording NIR, while blocking visible light. A microcontroller/servo combination was use to trigger a Seek Reveal thermal camera for the horizon experiment.

Preliminary analysis suggests that the sky's overhead intensity shows no apparent effect based on wavelength – a somewhat unexpected result. Swinging of the photometer suggests that future measurements should incorporate a sun sensor. The NIR images of the Moon's shadow are very clear – NIR light is more effective at penetrating the haze of the atmosphere than visible light. There is no evidence in the thermal imager of the eclipse shadow affecting the surface temperature of the Earth.

Near Infrared (NIR) and Thermal Imaging

Sunsets and sunrises (and the entire horizon during an eclipse!) have a reddish glow because molecules in the atmosphere are more effective at scattering blue light due to its shorter wavelength than red light. Near infrared (NIR) light, with a still longer wavelength than red light, can often penetrate through the atmosphere even better than visible light. Thus it is beneficial to do imaging from near-space using NIR cameras.

This project made use of Mobius ActionCam digital cameras modified to make them sensitive to NIR [1]. This was done by removing the infrared blocking filter (also known as the "hot mirror") then adding filters that block visible light but still allow NIR through. The cameras were set to record monochrome images and set to take still pictures every five seconds to preserve battery life for the duration of a full balloon flight.

A Seek Reveal thermal imaging camera was used to monitor the horizon to try to document a change in temperature as the eclipse shadow passed.

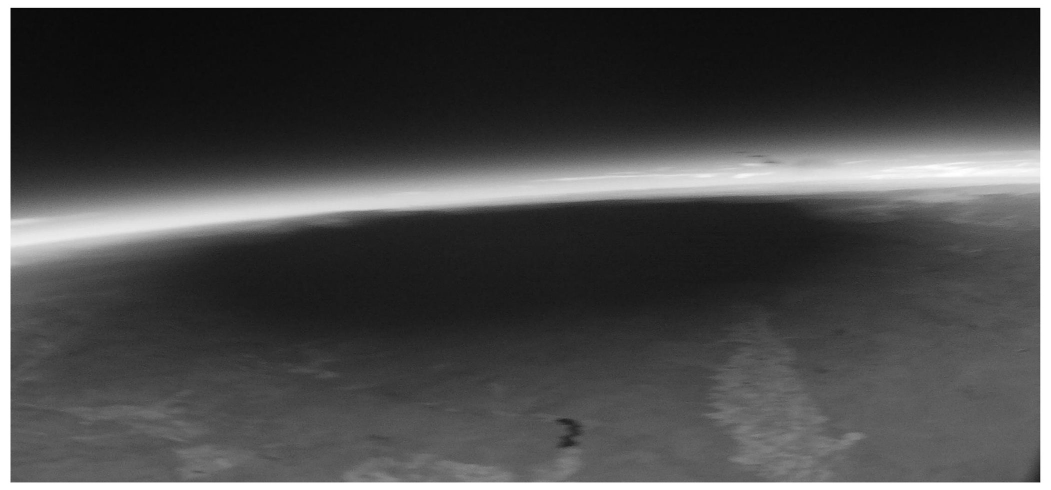

Fig. 1: Shadow of the Moon, imaged in NIR.

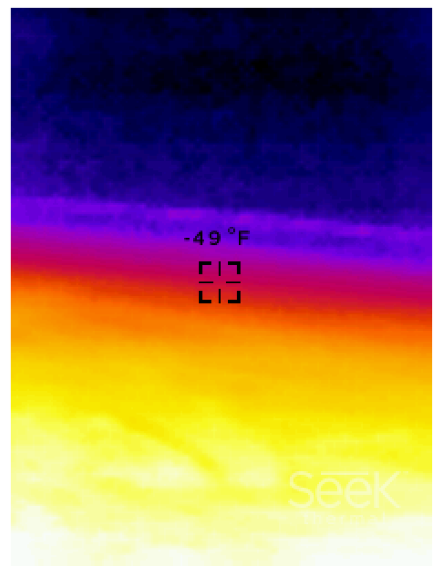

Figure 2: Thermal images of the horizon did not detect any change in temperature as the moon's shadow passed by. Perhaps too much still-warm intervening air.

LED Photometer Results

In 1992 Forrest Mims reported that LEDs designed to emit light at specific frequencies (i.e. of specific colors) could also be used as narrow-band, frequency specific light detectors [2]. NearSys has used this concept to develop an 8-LED photometer to sense light intensity at specific colors ranging from 940 nm (infrared light) to 400 nm (ultraviolet light) [3]. (See Fig. 1.)

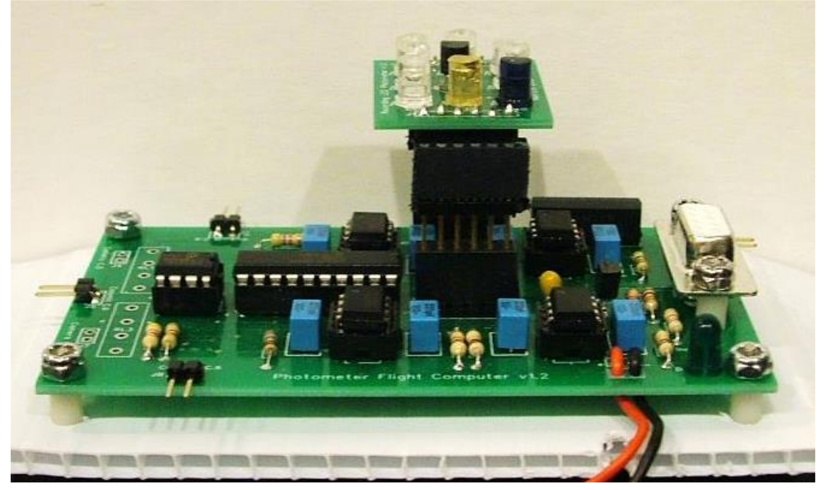

Figure 3: NearSys 8-channel LED-based photo-meter flown during the eclipse.

Fig. 4 shows photometer results at various wavelengths (i.e. various colors). The variation of values in each plot is due to the rotation of the payload, so the sun was not always in view. The balloon was at about 43,000 feet when totality arrived and the intensity signal was temporarily lost in all colors/channels simultaneously.

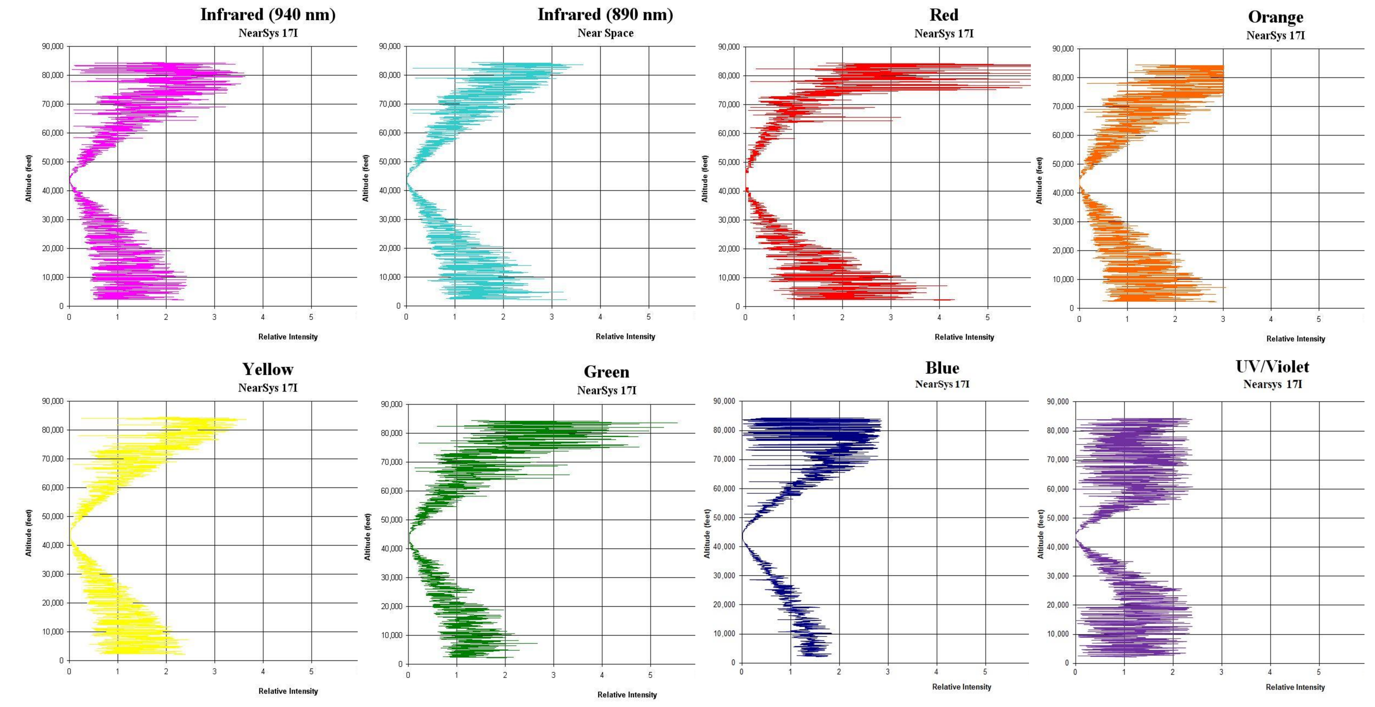

Figure 4: LED photometer intensities versus altitude.

References

1. Verhage, L. P., "The Near Space Eclipse," Nuts and Volts, Oct. 2017, pp. 10 – 13
2. Mims, F. M., "Sun photometer with light-emitting diodes as spectrally selective detectors," Applied Optics **31**, 1992, pp. 6965-6967
3. http://www.nearsys.com/catalog/balloonsat/bsatphoto.pdf
4. https://neulog.com/

Neulog Light, UVA, & UVB

Neulog plug-and-play modules [4] offer a wide range of easy-to-use sensor/loggers, some of which are well-suited for stratospheric ballooning use. The U of MN team flew (Visible) "Light", "UVA" (320-370 nm), and "UVB" (280-320 nm) modules during the eclipse. (See Fig. 5.) The modules were angled to directly face the sun but did so only when the payload was correctly oriented as it spun while in flight.

Figure 5: Chain of 3 light-sensing Neulog modules: visible to ultraviolet.

Fig. 6 shows Neulog module results for light intensity at various wavelengths. Like Verhage's photometer plots, the intensity variation associated with payload rotation is very evident. The data maxima show the decrease in light intensity at all wavelengths as the sun is eclipsed. The balloon carrying these modules was at about 90,000 feet when totality began.

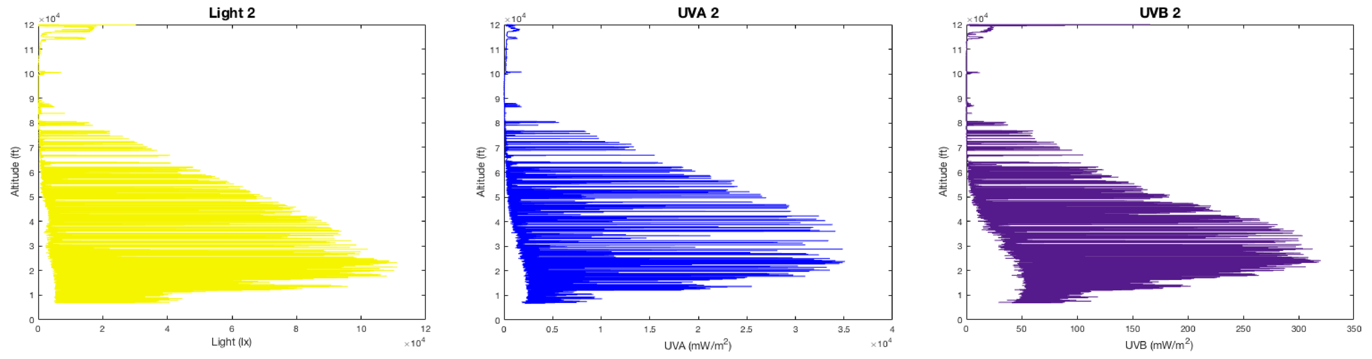

Figure 6: Neulog module intensities versus altitude.

One striking difference between these results and Verhage's is an almost total lack of intensity post-eclipse. This was not due to the payload stopping rotating – one idea we considered – but because the balloon grew so large that it shaded the sensors (see Fig. 7). Light sensors need to be kept out of balloon shadows!

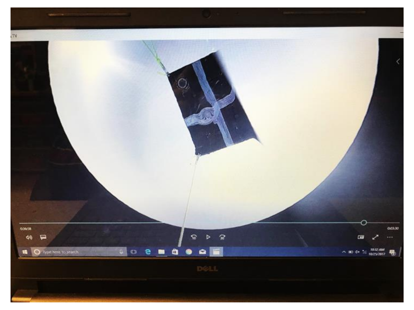

Fig. 7: Up-view within a balloon shadow.

Peak light intensity reduction agreed with geometrical calculations of the sun area blocked, for both sensor sets.

Acknowledgements

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