Atmospheric Spectroscopy, Infrared and Solar Corona Photography using a High-Altitude Ballooning Platform

Vishnuu Mallik
Department of Aerospace Engineering and Mechanics
University of Minnesota, Twin Cities

HIGH-ALTITUDE BALLOONING AT THE UNIVERSITY OF MINNESOTA

- Funded by the Minnesota Space Grant Consortium
- Students use helium-filled latex balloons to carry their payloads to near-space
- ‘Spaceflight with Ballooning’ offered as a freshman seminar

SPACEFLIGHT WITH BALLOONING

- As a team, our objective was to design, construct and launch a scientific payload into near-space.

Team experiments included:

- Atmospheric and weather studies
- Unique team experiment-Infrared photography

Atmospheric and Weather Studies

- To measure the relative humidity at different altitudes
- To measure the temperature at different altitudes
- To measure atmospheric pressure at different altitudes

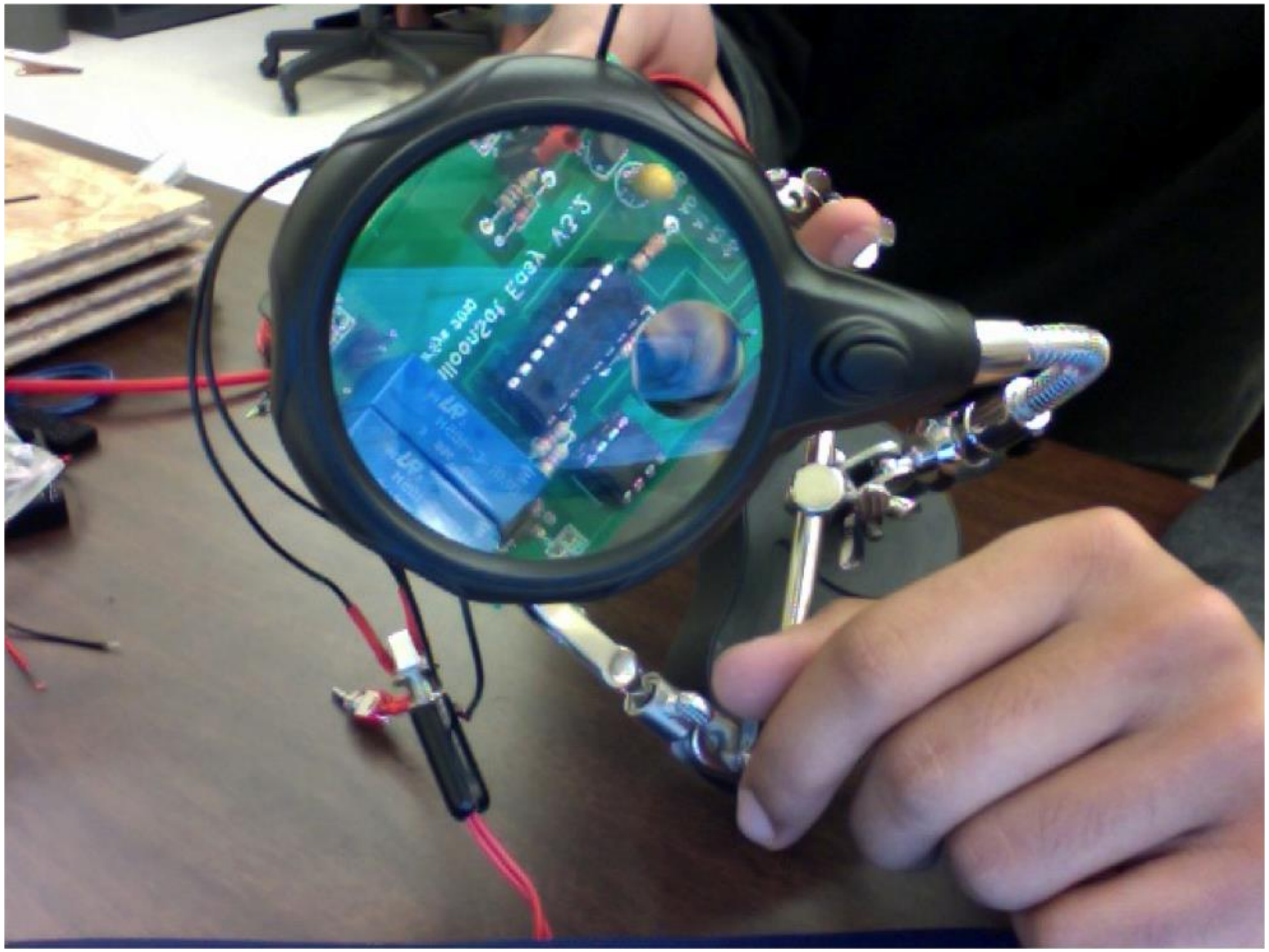
Infrared Photography Experiment

- Comparing infrared (IR) to visible light
- Attempt to see how different ground features absorb/reflect IR light
- Attempt to see which parts of the atmosphere absorb/reflect IR light

PHASES OF THE PROJECT

- Design and Construction of Payload
- Launch and Recovery
- Data Analysis

Design and Construction



Components

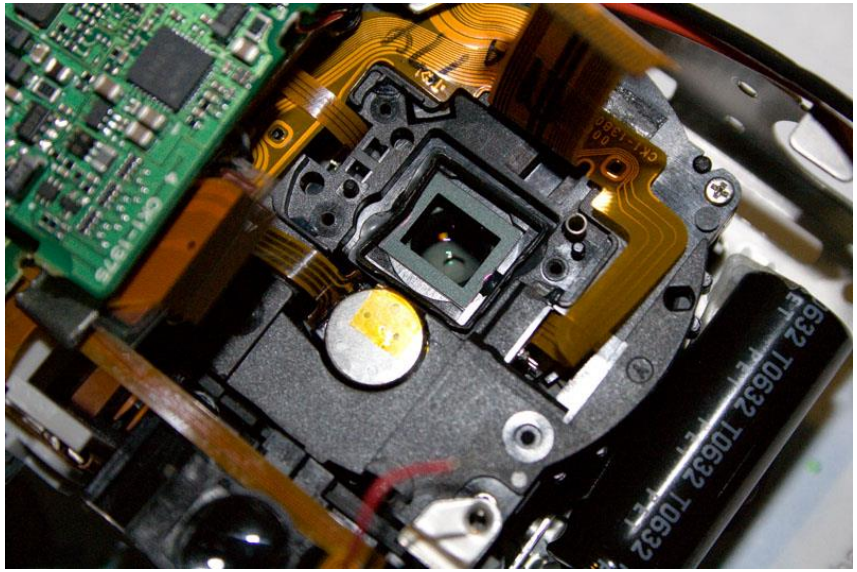
- Paul Verhage BalloonSatEasy flight computer and Near Space Weather Station
- Resistive heater
- HOBO with temperature sensor
- Visible light camera
- Infrared camera

Construction Material

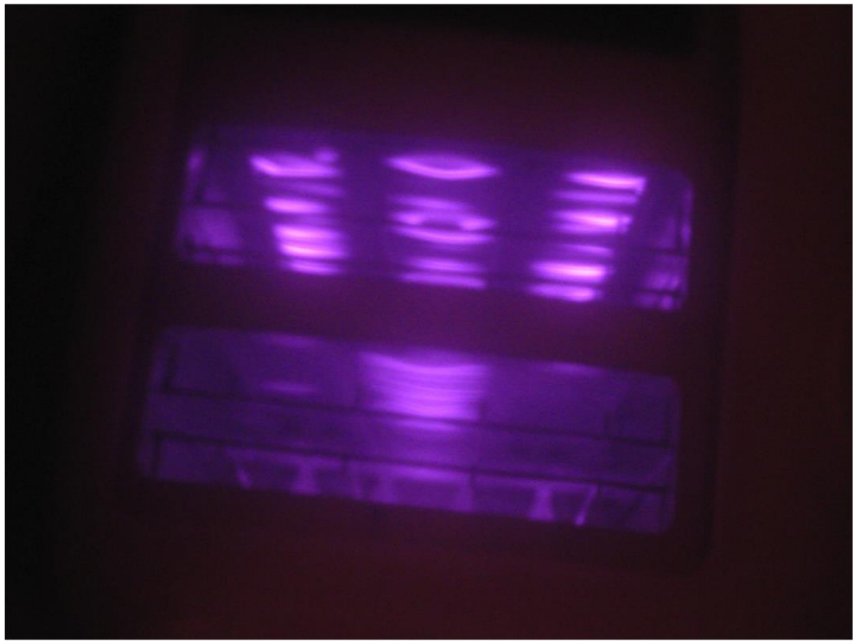
- Foam core
- Insulating black foam
- Hot glue
- Epoxy glue
- Velcro
- Strapping tape
- Rigging strings, key rings, zip ties

Photography Experiment

Because normal cameras are sensitive to IR light, manufacturers install filters in all cameras to block IR from reaching the sensor. Removing this enables the sensor's natural capability.



- Two programmable Canon Powershot cameras were used
- Cameras were oriented for identical fields of view
- Focusing issue with infrared camera

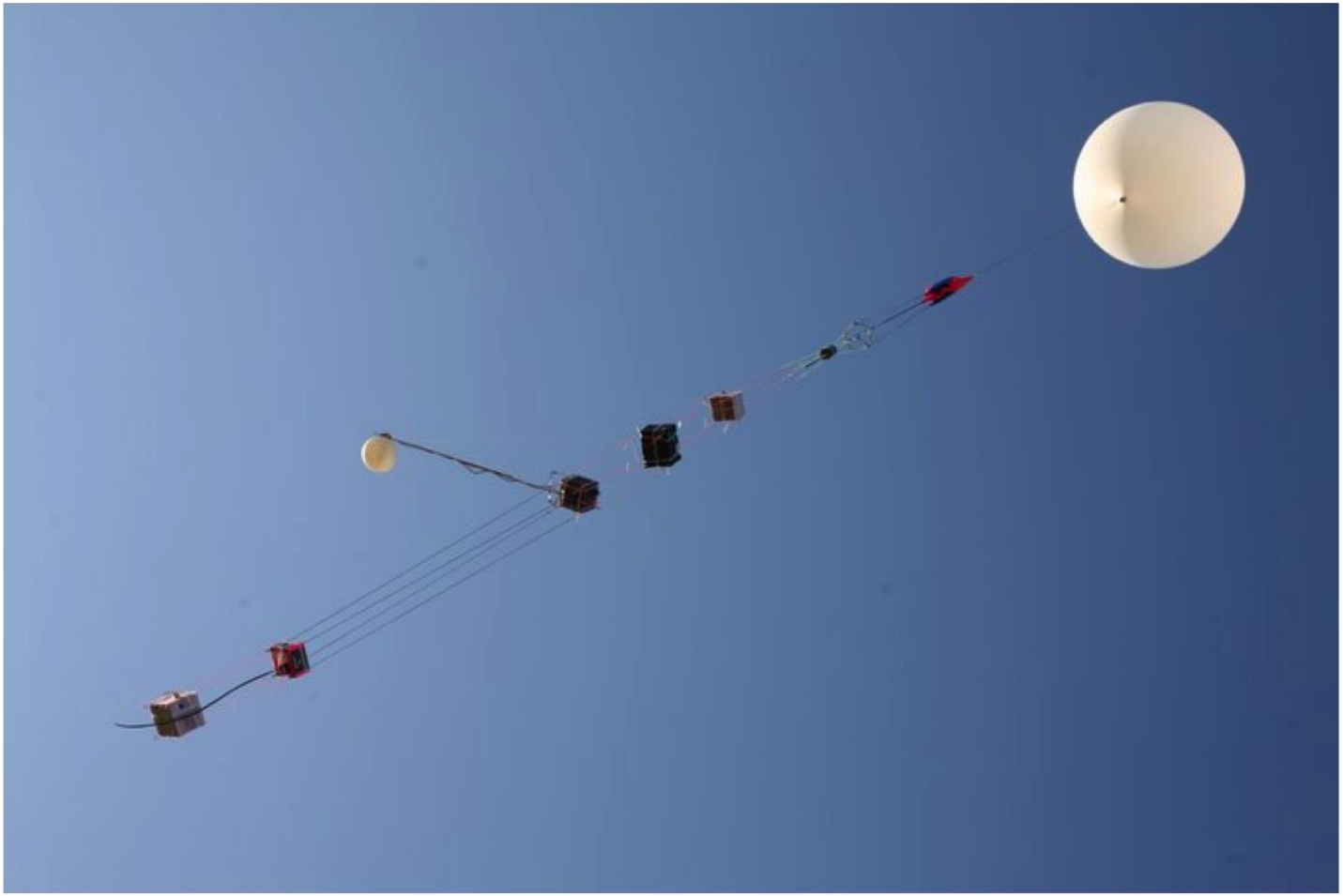


IR photo of toaster. Photo courtesy Seth Frick.

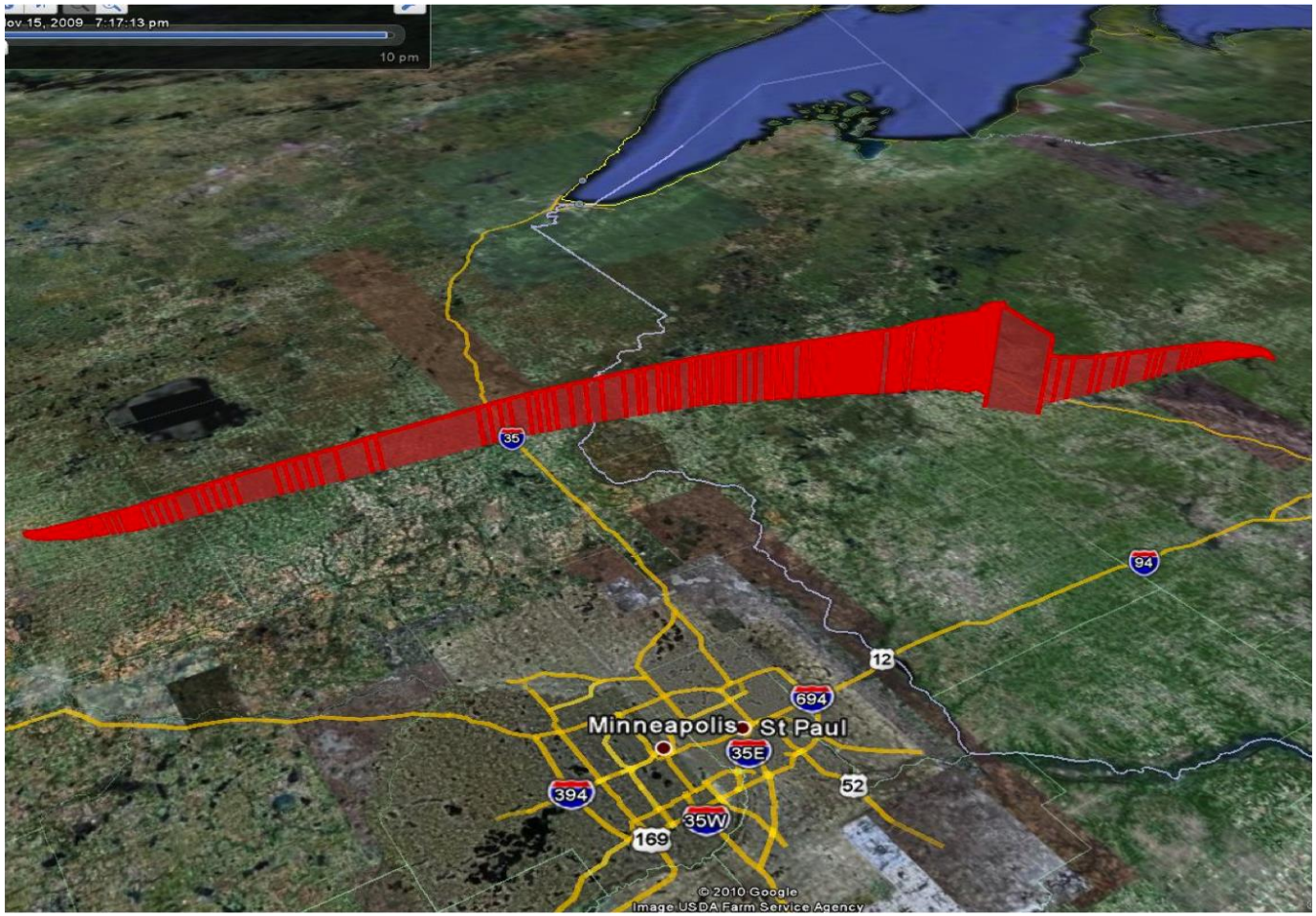
Programming

- HOBO sensors: Every 5 seconds
- Weather Station: Every 15 seconds
- Camera’s: Programmed to take pictures every 30 seconds during flight

LAUNCH!



Ground Tracking



Landing

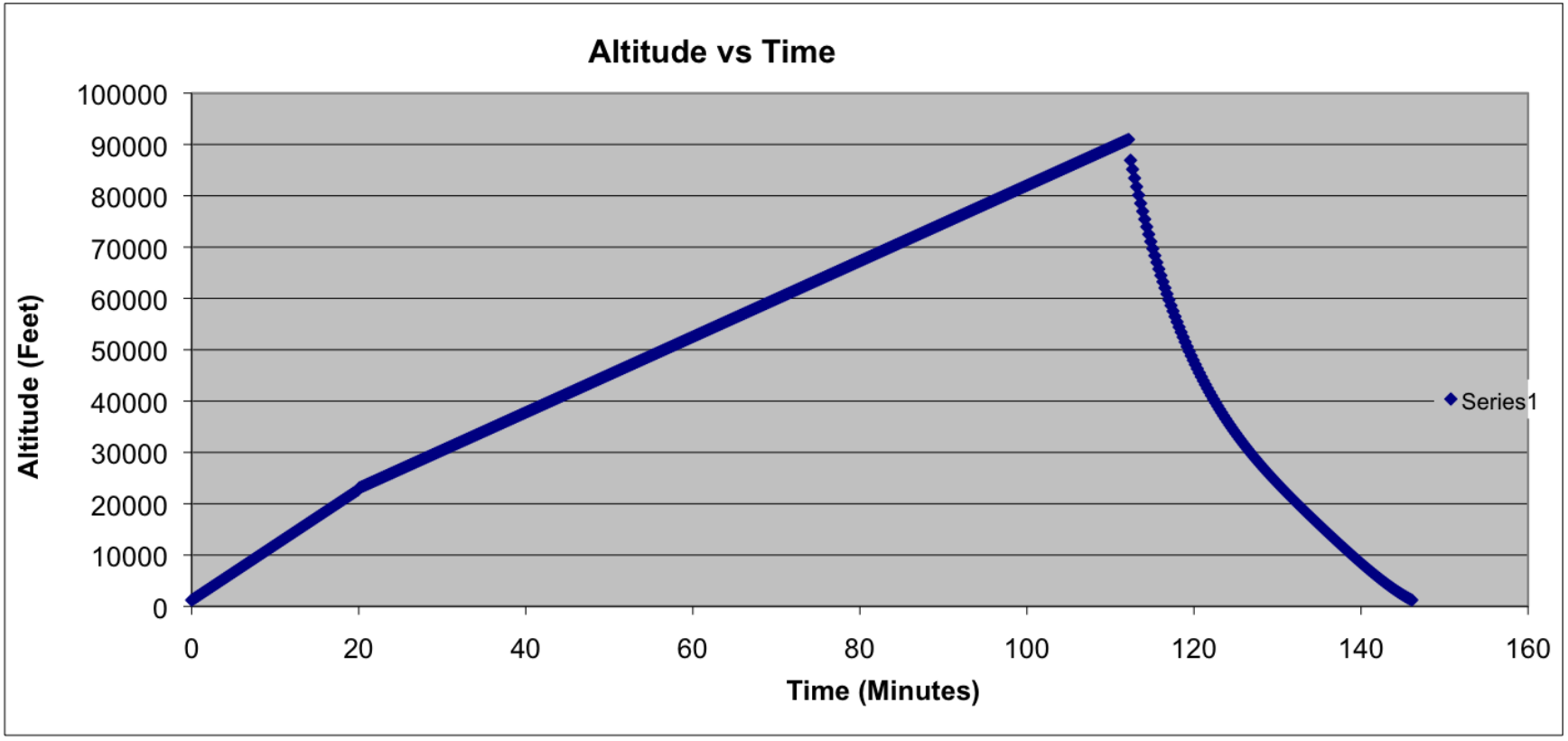
RECOVERY

- When our box was recovered, all was intact and working
- No visible damage on inside or outside
- All things worked for the entirety of the flight
- Everything was still strapped down

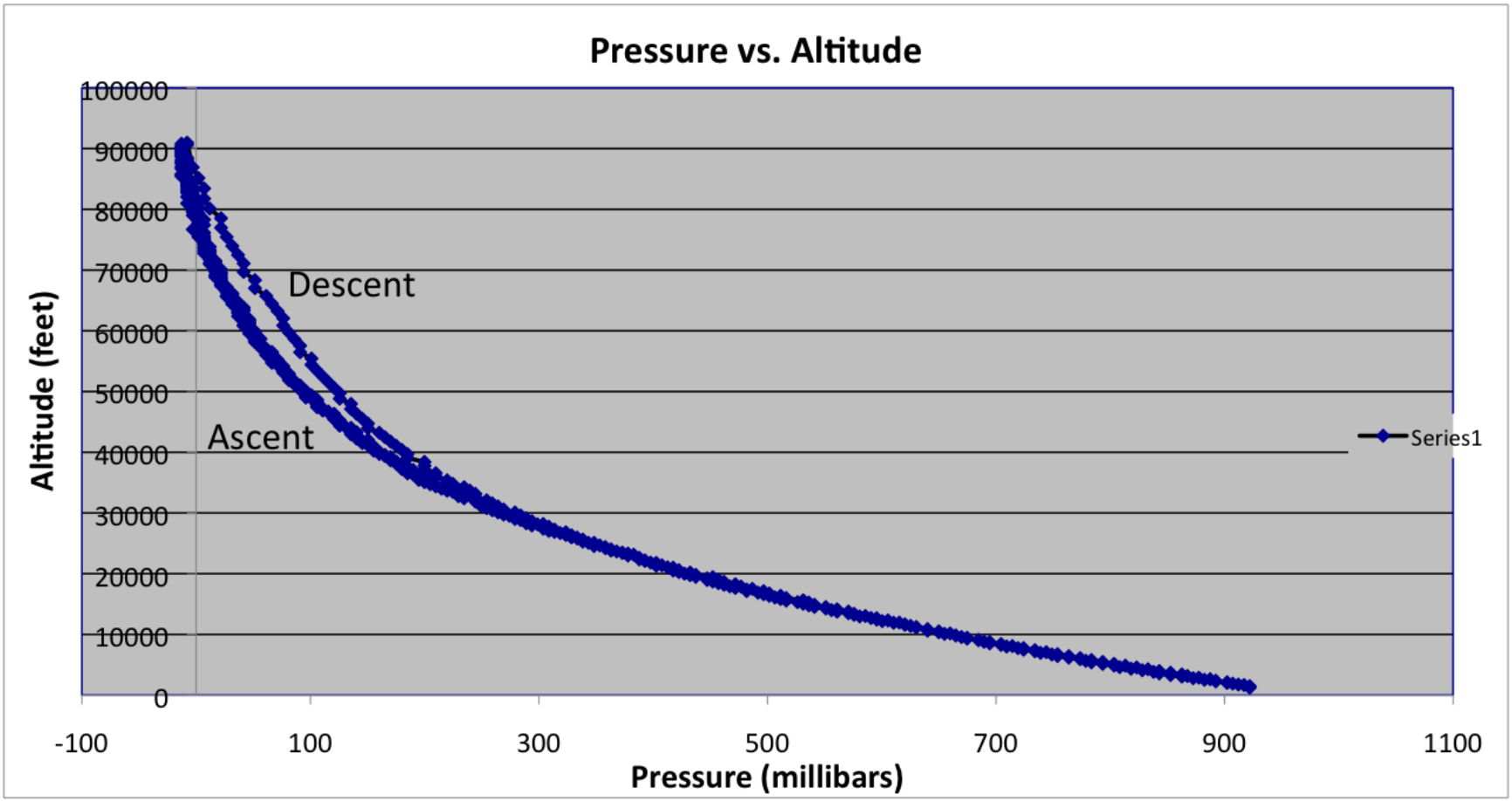
DATA ANALYSIS

- Raw data from flight computer had to be converted
- The final data was then presented on an excel spreadsheet, from which graphs were derived
- The photographs taken in the same time stamps were compared

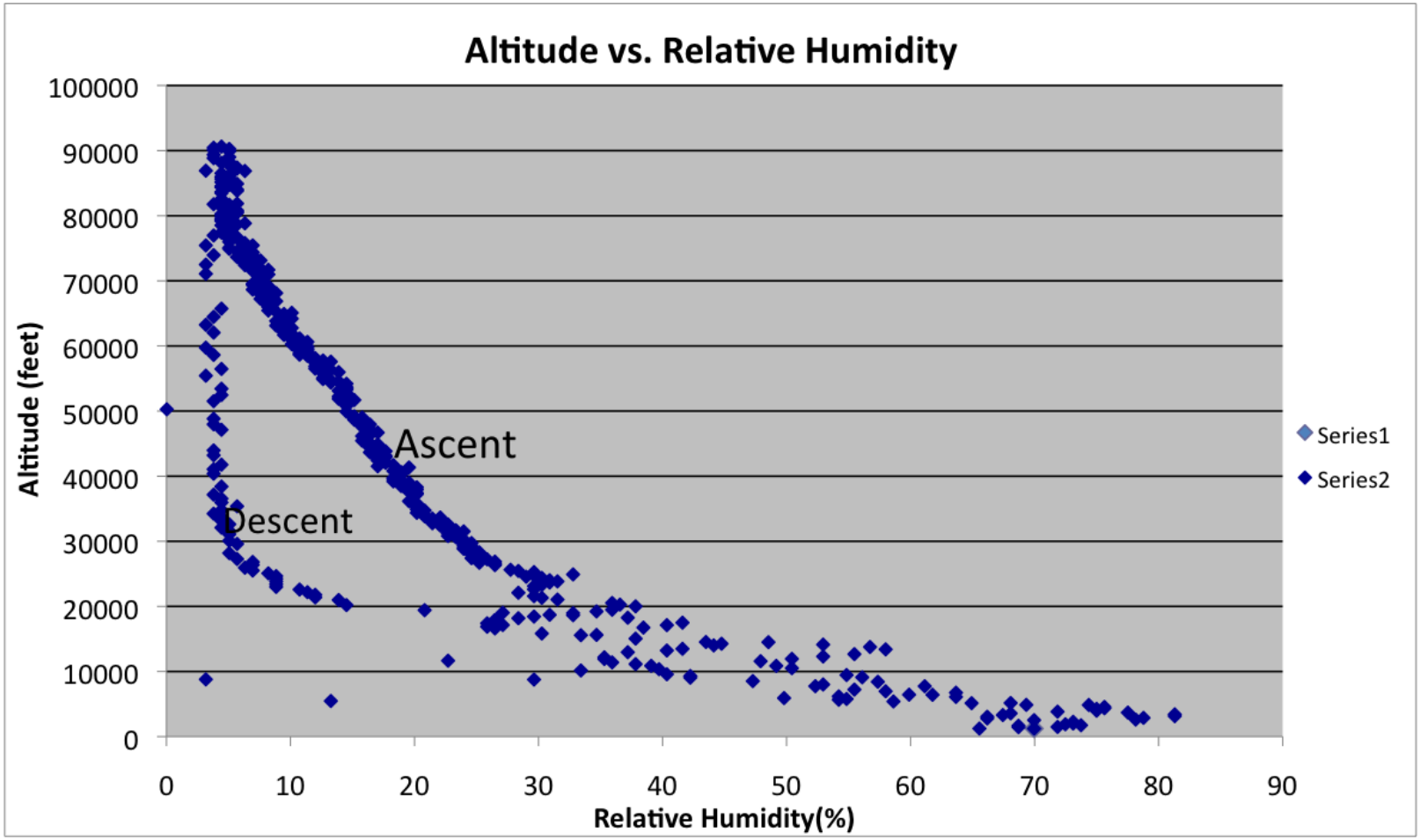
Altitude and Time



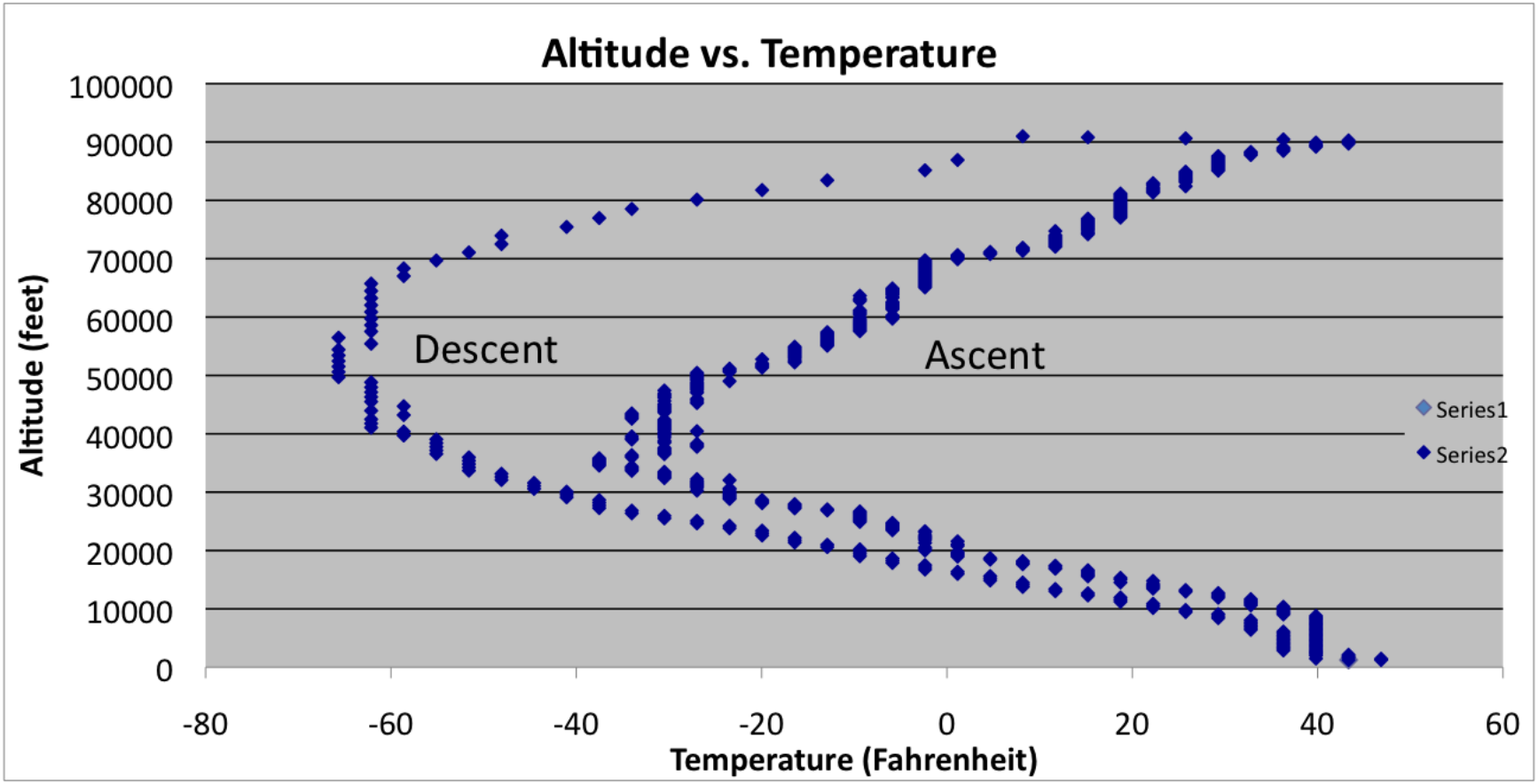
Pressure variations



Relative Humidity Variations



Temperature Variations

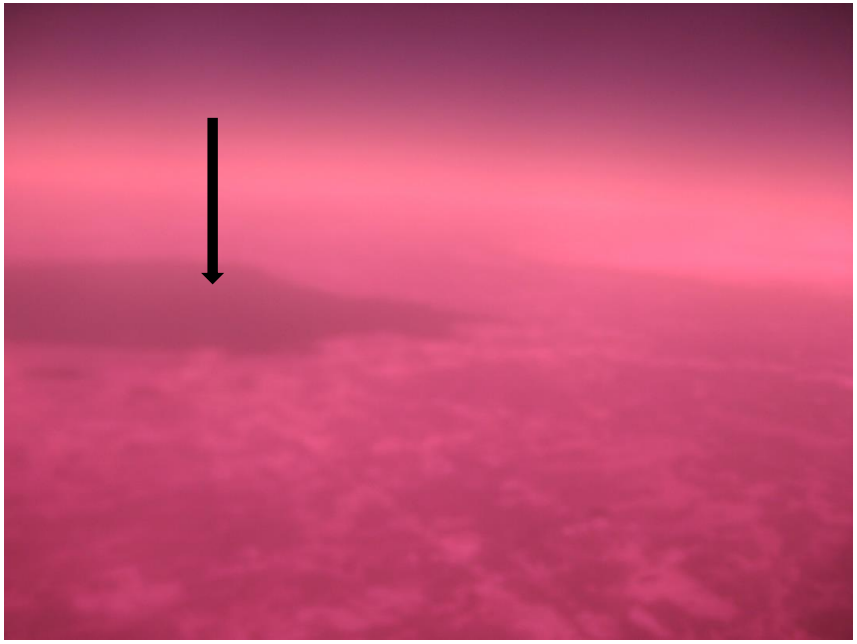


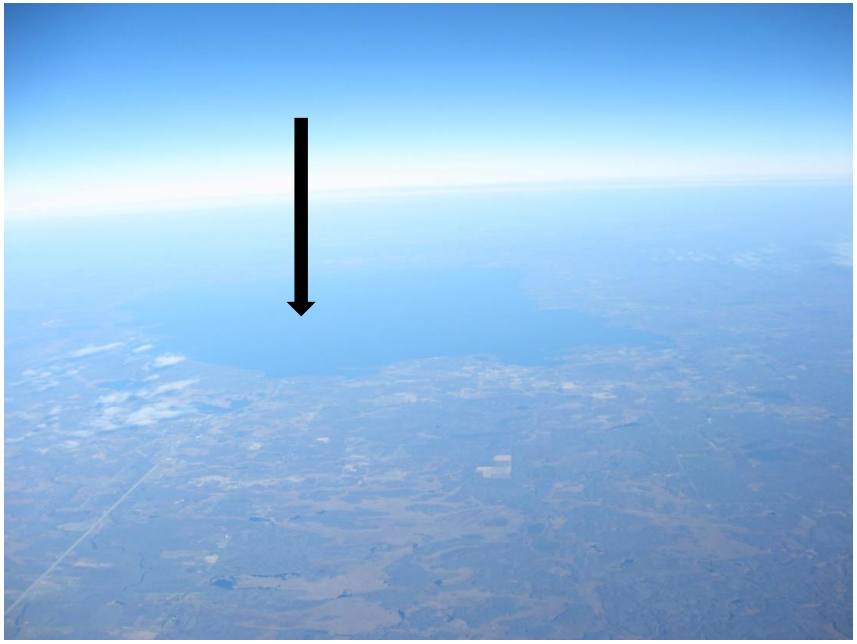
Infrared Light and Water

Notice lake's near complete absorption of IR light and significant absorption by freshly tilled soil.

Infrared Light and Water, Cont.

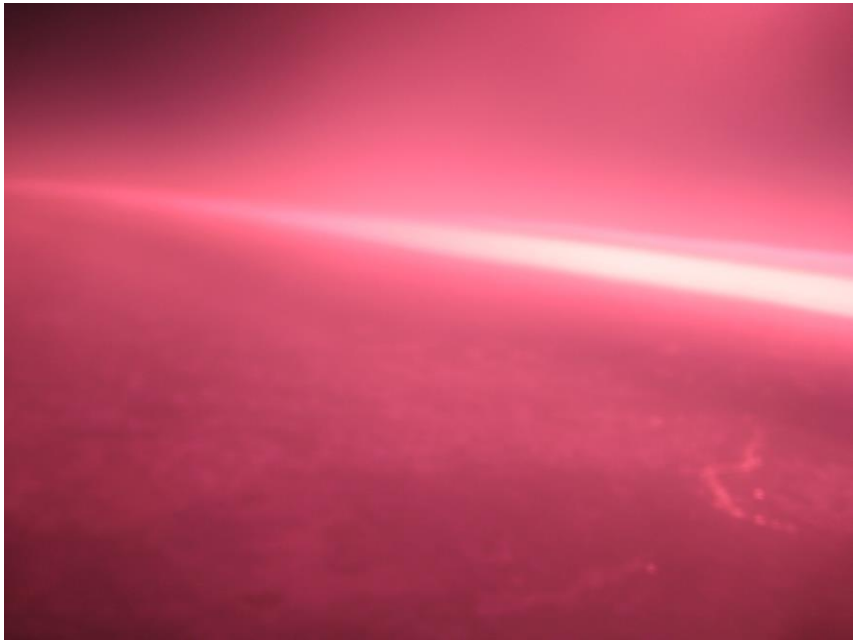
Seen in these photos is Mille Lacs Lake.





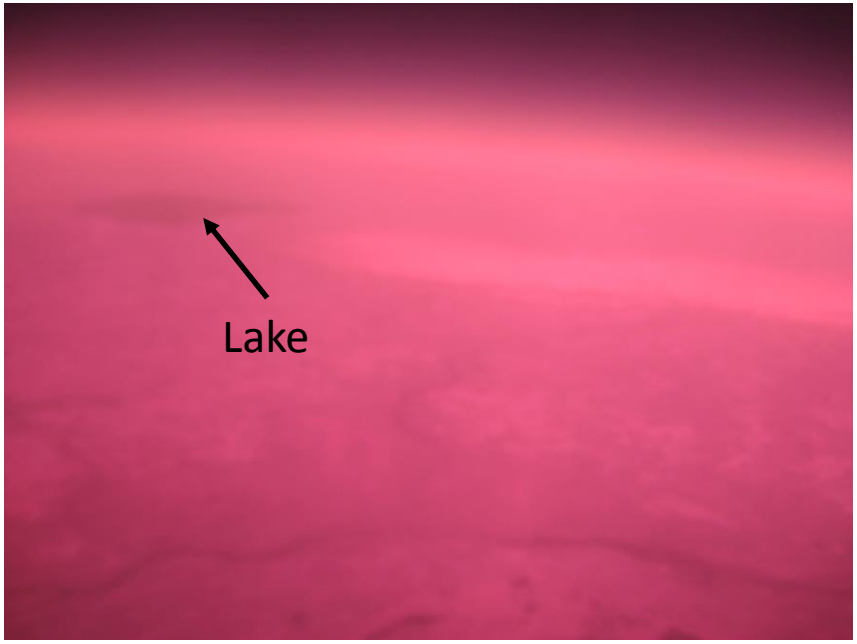
Infrared Reflections

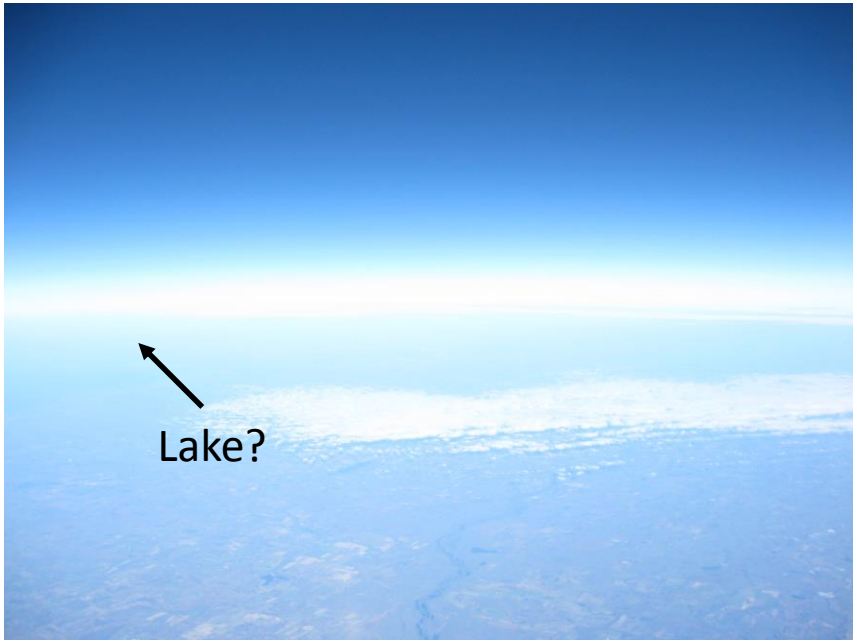
Notice the apparent thinness of the cloud layer when viewed IR.



Infrared Penetration

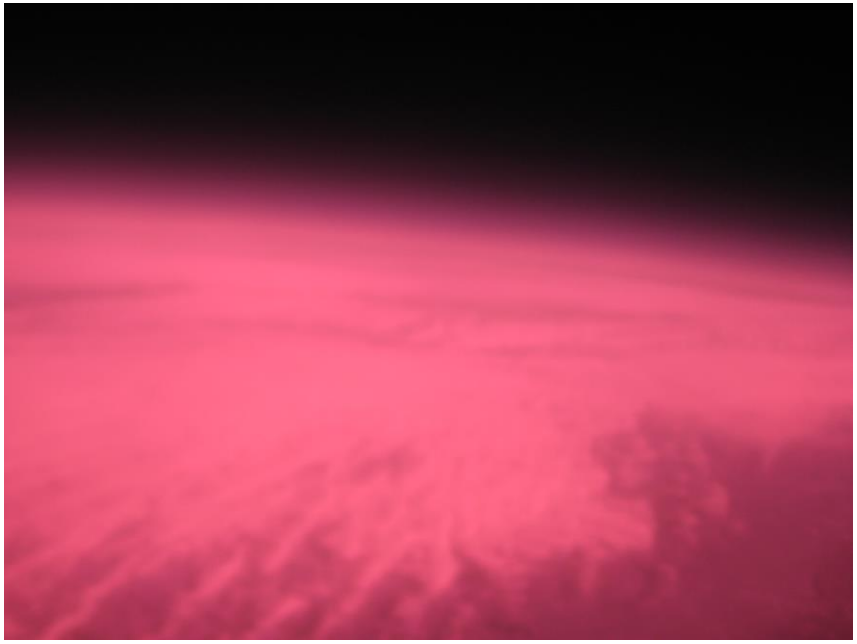
By this point in the flight, Mille Lacs Lake is completely invisible to the naked eye, although IR light gets through just fine.





Right Before Burst

Taken from 88,000 feet. Notice the lack of glow in the upper reaches of the atmosphere in the infrared photo.



Summary of Results

- External temperature in the atmosphere follows a decreasing trend till about 35,000 feet above sea level, and then increases till about 90,000 feet.
- Atmospheric pressure decreases with an increase in altitude.
- Relative humidity increases in areas where cloud layers are found, and decreases with altitude in the rest of the places in the atmosphere up to about 90,000 feet.
- Infrared light can reveal some distinct features in the atmosphere and on the earth’s surface, such as water bodies.

UROP

- Undergraduate Research Opportunities Project (UROP) funded by the University of Minnesota
- Project on Atmospheric Spectroscopy and Solar Corona Photography from a high-altitude ballooning platform

UROP project will attempt to

- Take solar corona photographs using a shadowed still camera
- Do spectroscopy using a simple home built spectrograph or a commercial Red Tide Spectrograph
- May involve the use of a telescope and a light sensing active pointing mechanism

SOLAR CORONA PHOTOGRAPHY

- Solar Corona
- Encircles the Sun
- Relatively faint
- Is most visible from the Earth during a total solar eclipse of the Sun

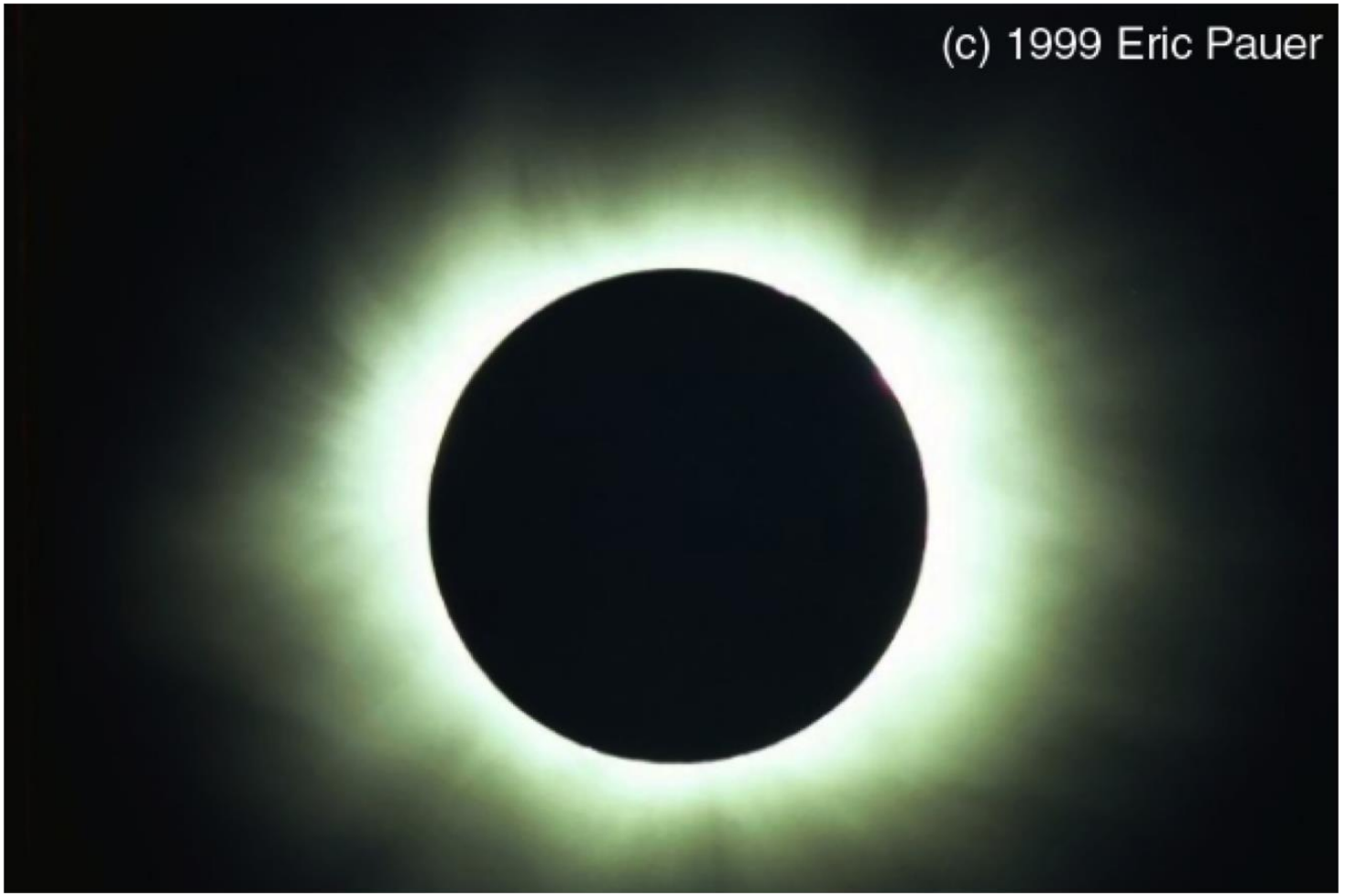


Photo by Eric Pauer; http://www.pauerhome.com/eclipse99/eclipse99.html

Camera modifications for Solar Corona Photography

Shadowed Still Camera

- To block off the bright disk of the Sun
- It's size will need to be determined

Possibility of using filters

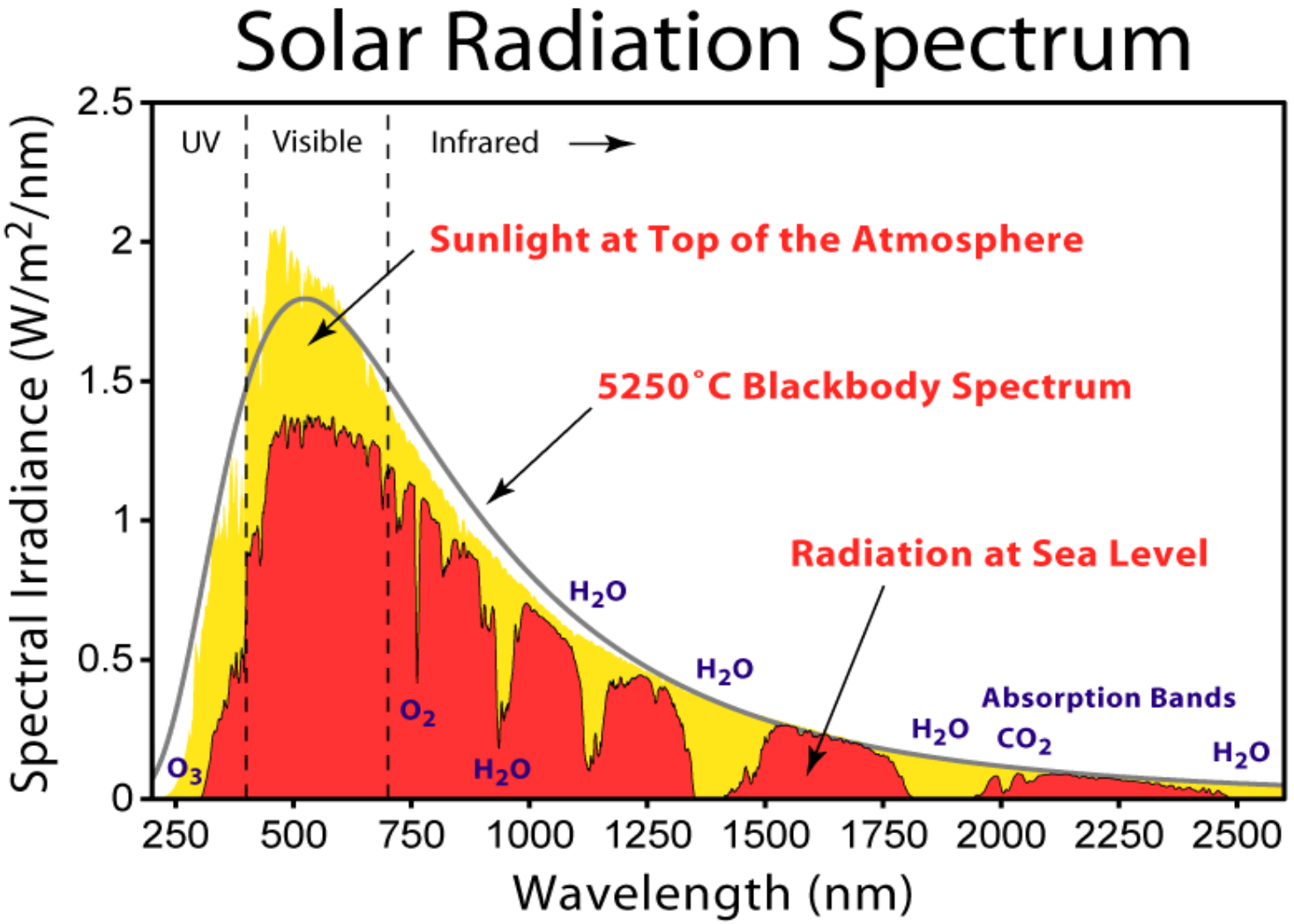
- Polarizing filters will only make the faint part fainter
- May try shooting in ultraviolet or infrared light

ATMOSPHERIC SPECTROSCOPY

Entails studying the wavelengths of light emitted by the Sun.

Some of the reasons the process is complicated:

- Light comes from specific elements of the Sun
- Certain wavelengths are absorbed in the Sun's atmosphere and some are absorbed by the Earth's atmosphere



http://en.wikipedia.org/wiki/File:Solar_Spectrum.png

Home Built Spectrograph (plans taken from volume 24 of Make magazine)

Materials needed:

- ABS plastic pipe and pipe coupling (2” in diameter and 15” long)
- Cardboard and Black construction paper
- Rubber cap and hose clamp
- Holographic diffraction grating film

http://sci-toys.com/scitoys/scitoys/light/spectrograph/spectrograph.html

- Digital Camera at one end will capture the spectrum.
- The photos can then be analyzed using a spectrum analyzer, available on the internet.

http://www.make-digital.com/make/vol24/?pg=60#pg60

Challenges:

- Swinging and Spinning of the payload during flight
- Active pointing mechanisms for the camera

Relevance of the project

Solar Corona studies are important due to

- Effects of coronal mass ejections, space weather, and solar wind on Earth

Spectroscopy will be useful in

- Learning about the atmosphere of the Earth
- Learning about the composition of the solar corona

ACKNOWLEDGEMENTS

- Dr James Flaten, for his continued guidance and for serving as the faculty mentor for the UROP
- Student members of the High-Altitude Ballooning Team at the University of Minnesota
- Minnesota Space Grant Consortium, for funding the freshman seminar project
- University of Minnesota, Twin Cities, for providing funding for the UROP

QUESTIONS?