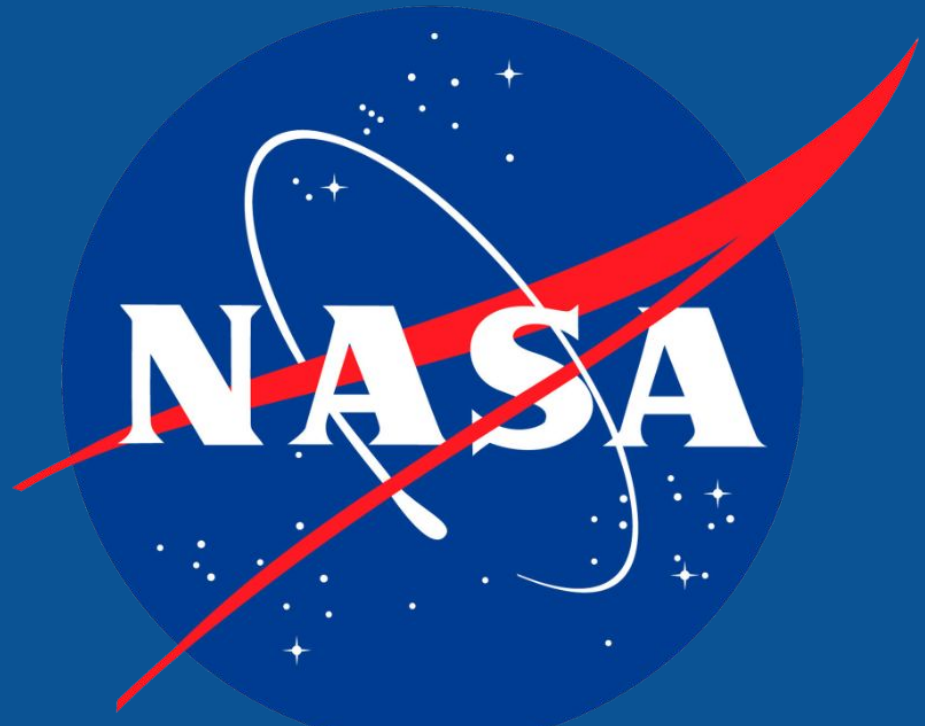


# SpectroSat

## Using a NASA STELLA spectrometer to determine the relationship between the concentration of water vapor and other gases in the lower atmosphere

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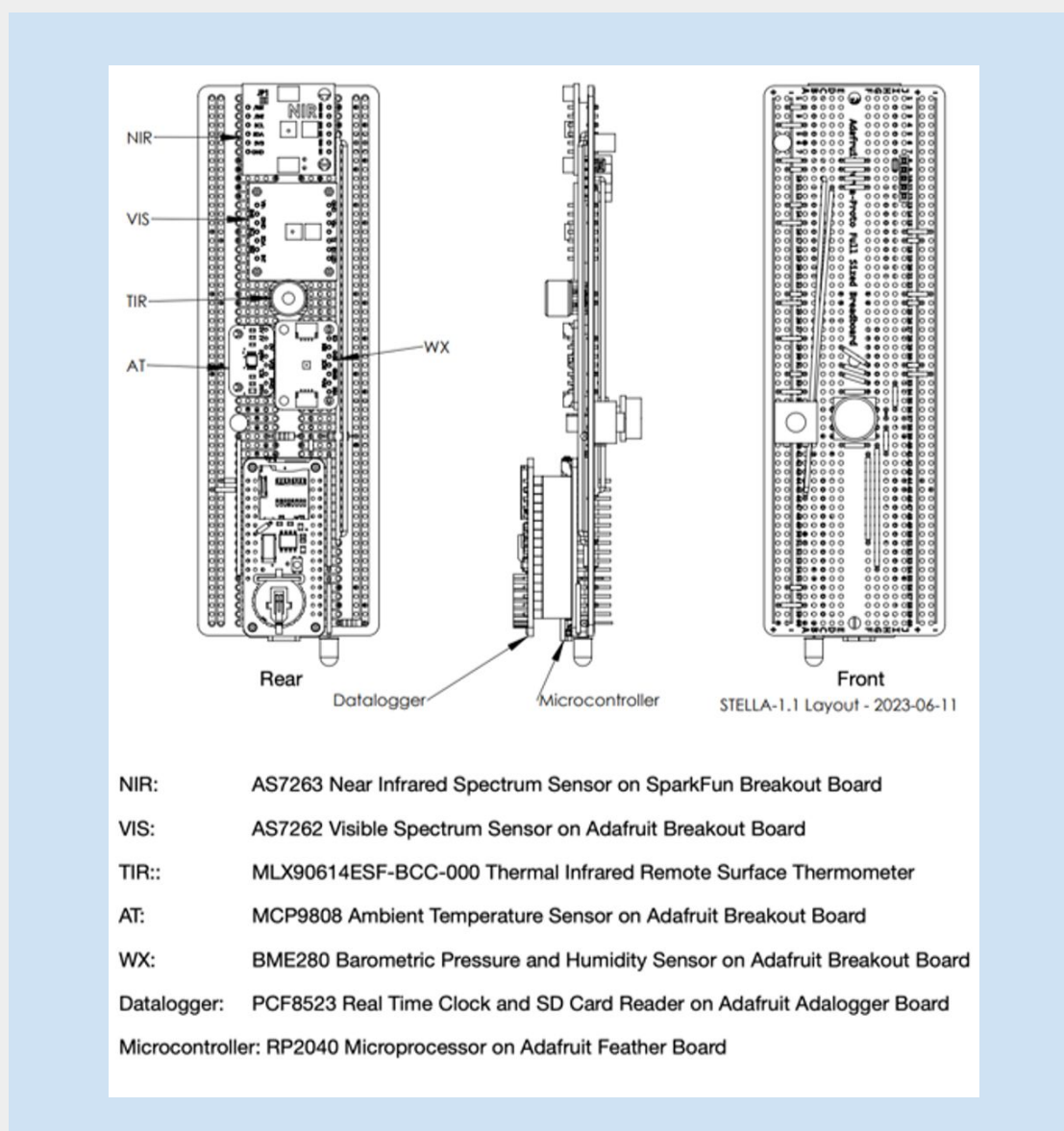
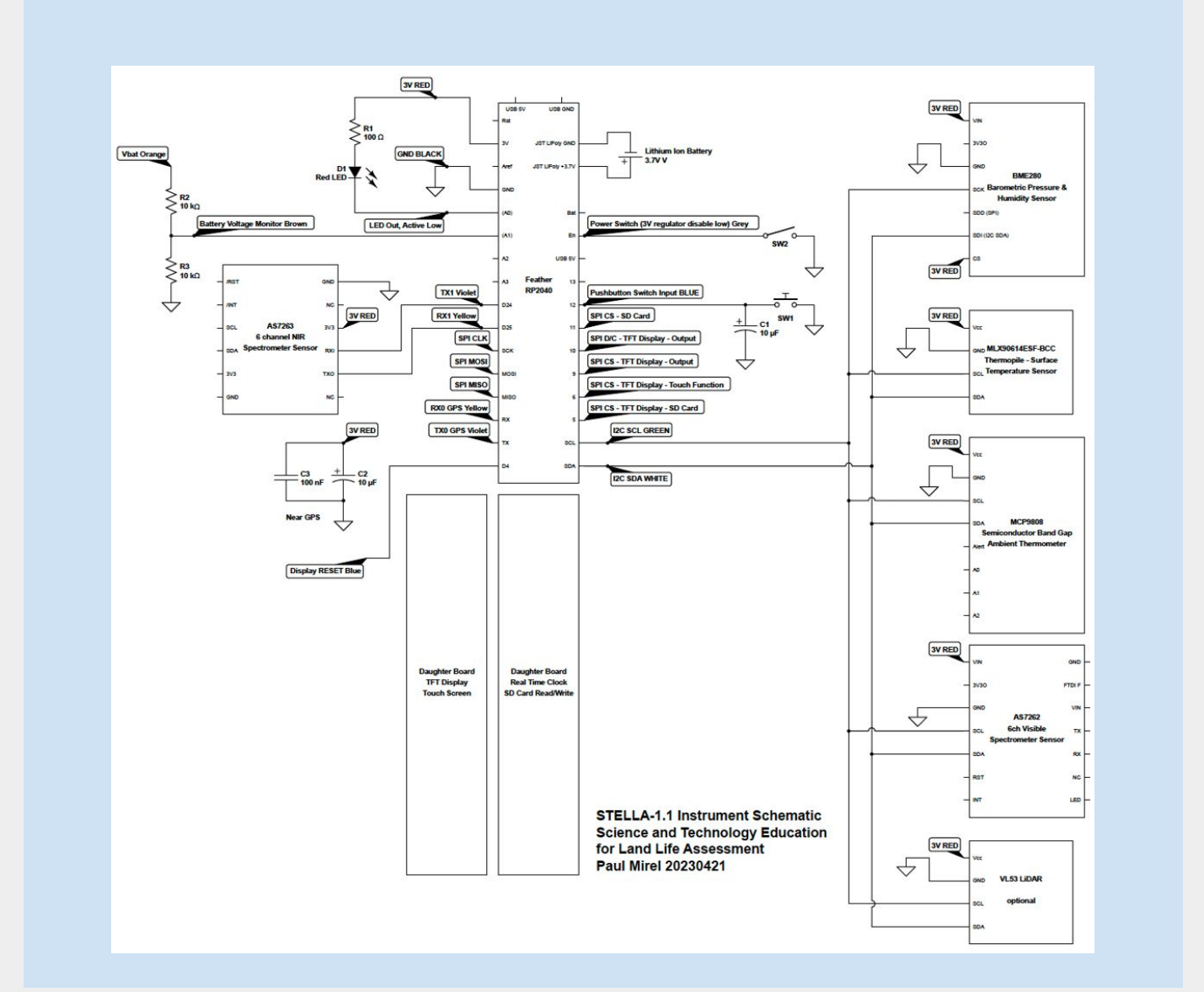
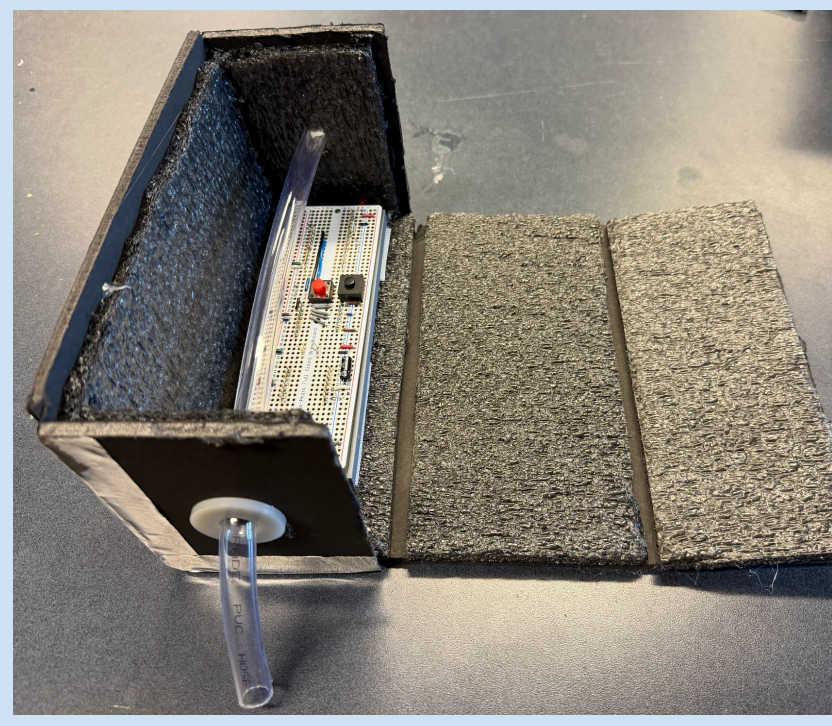


### Introduction

SpectroSat's mission objective is to design a system capable of determining the relationship between the amount of water vapor and other gases in the troposphere and stratosphere. If a statistically significant ratio is found between water and another atmospheric gas concentration, the results of the collected data will be able to be used as a reference for future atmospheric studies investigating atmospheric moisture distribution which may be attributed to weather prediction models. The goal of our experiment is to find a link between other atmospheric gases and the relative humidity levels in the upper atmosphere which may be indicative of potential rain. This would allow future atmospheric studies to improve rain prediction models by incorporating correlations between atmospheric gas concentrations and humidity, expanding the range of atmospheric data used in forecasting weather. SpectroSat will be the first test of a STELLA spectrometer on a high-altitude balloon, and a goal of SpectroSat is to determine the feasibility of using STELLA at high altitudes.

### Materials

SpectroSat's main payload is a modified NASA STELLA 1.1 spectrometer. STELLA contains multiple sensors, including: visible light (VIS), near infrared light (NIR), weather (pressure, temperature, humidity), and thermal infrared. The main microprocessor is an Adafruit Feather. Data will be written to a micro SD card using an Adafruit Featherwing Datalogger. The system will be powered by a 3.7 V cylindrical battery, and the data logger will be powered by a 3V button battery. The STELLA will be housed in a cardboard box with foam insulation. The box has holes for sensors and the on/off button.



### Methodology

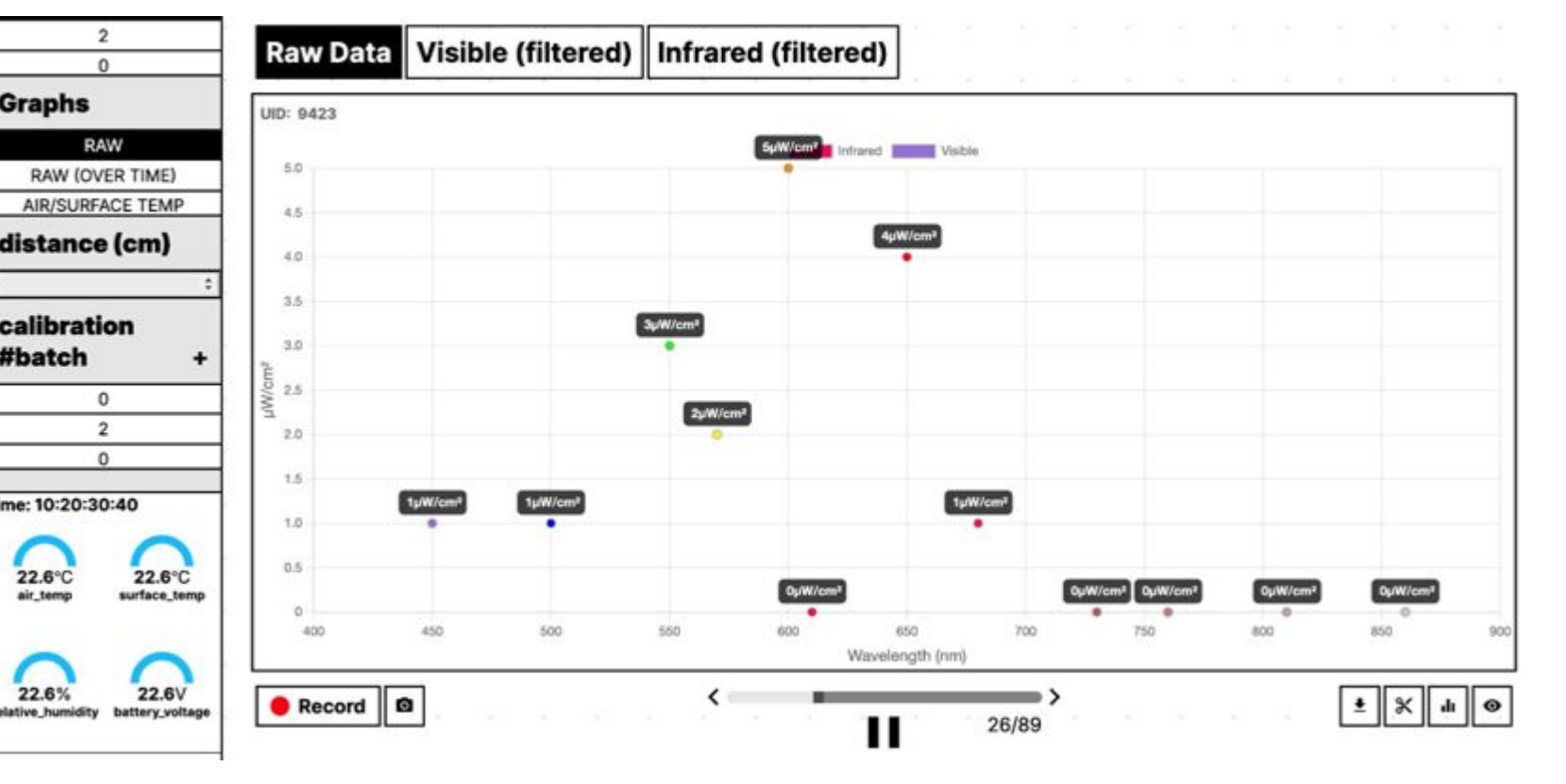
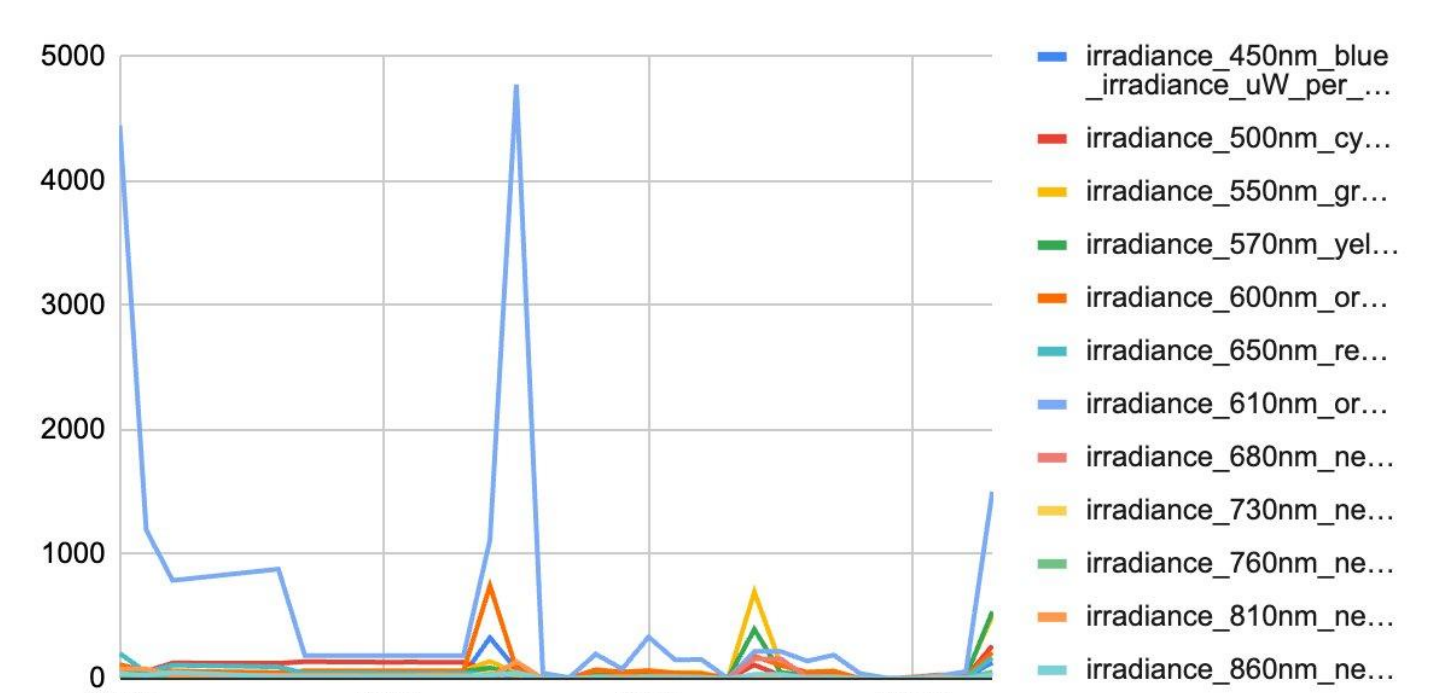
Spectral irradiance measurements will be taken using STELLA's visible light and near infrared sensor. With these two sensors, measurements will cover twelve 20 nm wavelength bands from 450nm to 860nm. All sensors will take measurements in unison every five seconds from launch to landing. The taken measurements will be used to determine the relative quantities of water in the atmosphere in relation to other gasses in the troposphere and stratosphere. The payload will be attached to a high-altitude hydrogen balloon. The balloon will stop ascending at a height of around 80,00-120,000 ft, when the pressure of the external air reaches the balloon's internal pressure.

Changes in light levels in absorption bands of different gasses will be used to determine general trends in levels of atmospheric gasses. Near-infrared measurements will be used to analyze water vapor. Because water vapor absorbs in wavelengths above 800 nm (Lenoble et al., 2013), intensities at 810 nm and 860 nm will be used to determine relative levels of water vapor. The 760 nm channel, corresponding an absorption band of oxygen which has strong and narrow absorption bands (Lenoble et al., 2013), will be used as a reference for comparison, as oxygen levels are expected to remain steady. Visible wavelength data will be used to investigate trace gases. Due to nitrogen dioxide having a broad absorption band around 450 nm (Vandaele et al., 2002), the 450 nm band will be used to examine absorption by Nitrogen dioxide. Ozone absorbs in Wavelengths between 500–650 nm (European Space Agency, n.d.), and these bands will be used to determine relative Ozone levels.

### Expected Data

Table with 19 columns representing various atmospheric and spectral data points, including surface temperature, humidity, pressure, altitude, and irradiance at multiple wavelengths (450nm, 500nm, 550nm, 600nm, 610nm, 650nm, 730nm, 760nm, 810nm, 860nm).

We expect the data collected during flight to roughly follow the format shown above. While all 19 columns represent different measurements, some of the measurements will not be relevant to our research and will serve only as baselines. This includes the 500nm, 600nm, and 610 nm wavelengths as they do not align with any of the strong absorption features we are interested in and are mostly affected by sunlight intensity and scattering.



To the left is the compilation of our trial data as viewed through the STELLA Data viewer. Through this program we are able to observe the intensity of each wavelength played in chronological order. Each time the figure changes is a new measurement every five seconds during flight and then read off of a chip once on the ground.

### Summary

SpectroSat is a high-altitude balloon experiment designed to investigate the relationship between atmospheric water vapor and other gases using spectral measurements. By utilizing the NASA STELLA 1.1 spectrometer, the system collects visible (VIS) and near-infrared (NIR) irradiance data alongside environmental measurements such as altitude, pressure, temperature, and humidity. As the payload ascends through the troposphere and into the lower stratosphere, changes in spectral intensity at specific wavelengths are analyzed to identify patterns in atmospheric absorption and scattering.

Rather than directly detecting individual gas molecules, this project focuses on identifying correlations between spectral features and atmospheric conditions. By comparing relative intensity ratios across key wavelengths, particularly in the near-infrared region, SpectroSat aims to track how water vapor levels vary with altitude and how these changes relate to broader atmospheric composition.

The results of this experiment will contribute to a better understanding of vertical atmospheric structure and the interaction between water vapor and other atmospheric components. By analyzing wavelength-specific irradiance ratios, the project evaluates the effectiveness of low-resolution spectral data in approximating atmospheric absorption behavior. These findings may support the development of simplified retrieval methods for estimating atmospheric properties using compact instrumentation. Ultimately, this work explores the feasibility of using low-cost spectrometers to supplement existing atmospheric datasets and improve the resolution and coverage of inputs used in weather and climate modeling.



### Conclusions

SpectroSat demonstrates the potential of using a compact, low-cost spectrometer system to investigate composition and spectral irradiance in the atmosphere. As the first test of the NASA STELLA spectrometer on a high-altitude balloon, this project also evaluates the feasibility of deploying STELLA in near-space conditions, marking an important step in expanding its applications beyond ground-based use.

By collecting synchronized spectral and environmental data throughout flight, this project establishes a framework for identifying correlations between wavelength-specific irradiance patterns and changes in atmospheric composition. Although the study focuses on detecting trends rather than directly measuring individual gases, the results highlight how broad relative spectral intensity readings can serve as useful indicators of gas composition across different altitudes.

If statistically significant relationships are confirmed, this approach could improve future atmospheric research and weather prediction models. Overall, SpectroSat provides a promising step toward more affordable and accessible atmospheric monitoring while advancing our understanding of moisture distribution in Earth's atmosphere.

### Future Directions

If the project is successful, we would find a statistically significant trend between water vapor and another atmospheric gas. This would promote further testing with more advanced equipment focusing on atmospheric gases that indicate the trend. Should further research conclude there is not only a clear and quantifiable trend between water vapor and another atmospheric gas, but a simple and cost effective approach to providing wide range accurate measurements, weather forecasting models would have additional data in providing the most accurate predictions possible.

By including correlated gas data as a supporting parameter, models could improve accuracy in regions where humidity measurements are sparse or difficult to obtain, such as over oceans or at high altitudes. Improved forecasting accuracy would enhance the prediction of precipitation events, severe weather systems, and long-term climate patterns. This could have significant real-world impacts, including better preparation for extreme weather events, improved agricultural planning, and more efficient water resource management.

### Acknowledgements

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### Citations

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