Development of Digital Thermosonde Instrument for Quantification of Relative Cn2 Estimation Error between NWP Analysis and Thermosonde Measurements

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Introduction

Optical turbulence is the distortion of light waves due to density variation in the atmosphere, and the refractive index structure parameter is a common representation of the optical turbulence in an atmospheric layer. Members of the Space Studies, Atmospheric Sciences, and Electrical Engineering departments at UND are developing a thermosonde to measure this atmospheric optical turbulence, which is caused by temperature differences in a layer.

This NASA-funded student instrument project involves the design and development of the thermosonde instrument, the launching of multiple student-built thermosondes on high-altitude balloons at various locations across North Dakota, and the analysis of the thermosonde data to calculate the refractive index structure parameter for each flight. Comparisons of the thermosonde temperature profiles will be made with forecasted temperature profiles from the National Center for Atmospheric Research (NCAR) Weather Research Forecast (WRF) model and the Rapid Update Cycle (RUC) model to determine the accuracy of the models at predicting optical turbulence.

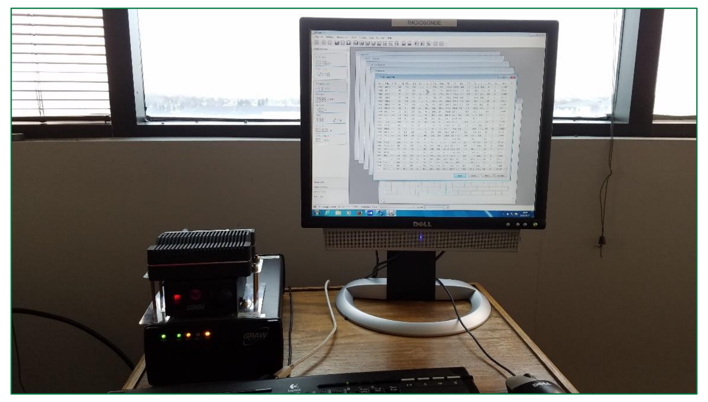
Balloon Flights

Many balloon flights are planned as part of this project. In addition to the three main thermosonde launches, as many as five preliminary launches are planned with only a GRAW DFM-09 radiosonde to practice the balloon filling procedure, the launching, and the tracking of the balloons, as well as gaining familiarity with the GRAWMET radiosonde receiver software.

The GRAW DFM-09 is the standard radiosonde made by GRAW. It provides a wide range of meteorological data, including pressure, temperature, u/v wind components, altitude, and GPS coordinates.

Each radiosonde must be initialized with the GRAWMET software from the GRAW GS-E groundstation, which is located in Clifford Hall. After the radiosondes are initialized and connected to the Clifford receiver, they will be attached to high-altitude balloons and released. The radiosonde sends its data to the groundstation, where it can be viewed in the GRAWMET software. While launching the radiosondes is an important part of the flight procedure, tracking and recovering the package is also a significant task, especially when the thermosonde is launched. The GPS coordinates from the DFM-09 is used to track the radiosonde for the majority of the flight. Other smaller tracking units are attached to the packages as well for easier mobile tracking. After the balloon pops and the radiosonde falls back down, it reaches a distance where it falls under line of sight of the Clifford Hall antenna. At this point, the radiosonde loses its connection with the Clifford Hall receiver, so the radiosonde's GPS data cannot be used to find the exact location of the package once it hits the ground. The smaller trackers are used to locate the thermosonde package on the ground with a smartphone app.

A GRAW DFM-09 radiosonde, like the ones that will be flown for test flights and integrated into the thermosonde package.

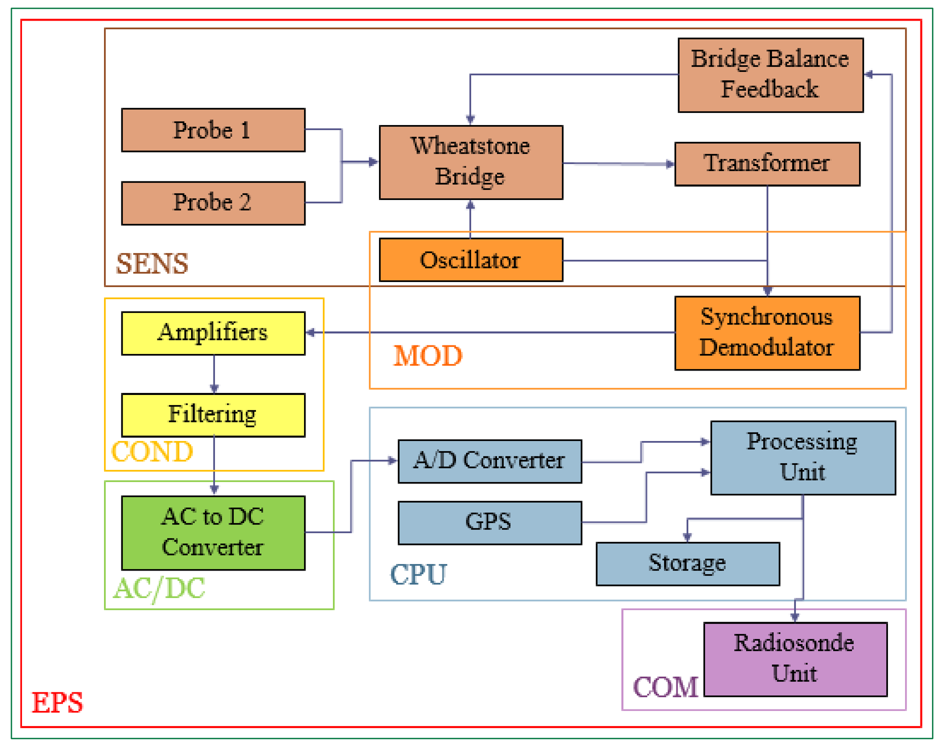


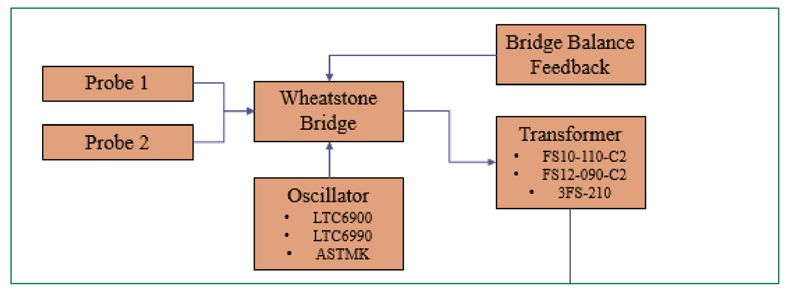
The GRAW GS-E groundstation with the GRAWMET sounding software in Clifford Hall.

Members of the North Dakota Space Grant Consortium launching student-made instruments on a high-altitude balloon, like the one used for this project.

Thermosonde Development

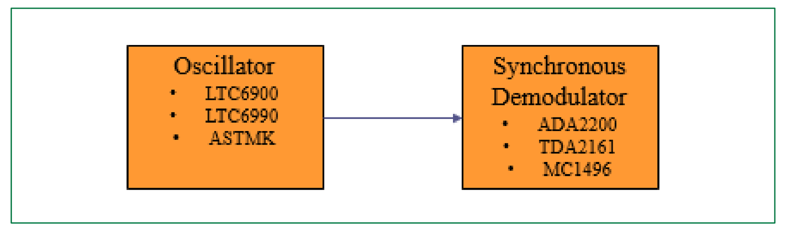
The thermosonde system consists of seven subsystems: the probe system (SENS), demodulator (MOD), signal conditioner (COND), AC to DC converter (AC/DC), processing unit (CPU), radiosonde (COM), and power subsystem (EPS).



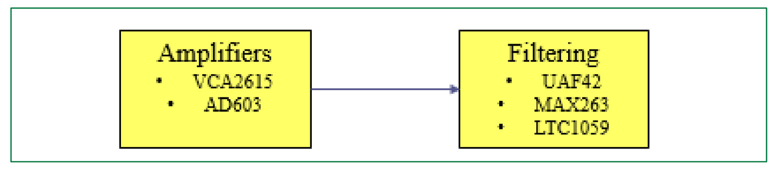


Probe System (SENS):
- Made of 2 um diameter platinum wire
- Oscillator frequency depends on resonant frequency of wires
- Bridge Balance Feedback used to keep Wheatstone bridge values from drifting over time

Demodulator (MOD):
- Synchronous detector AM demodulator modulates the signal and removes the carrier frequency of the oscillator leaving the 1kHz AC signal.

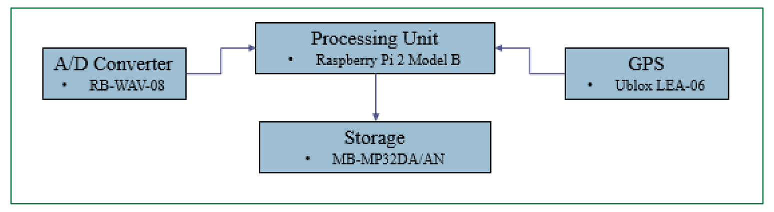


Signal Conditioner (COND):
- Low noise amplifier will amplify the signal without degrading the signal to noise ratio
- Band pass filter filters noise from 1kHz signal



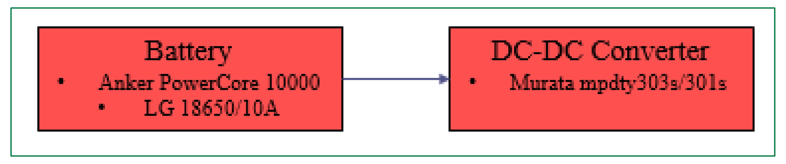
AC/DC Converter (AC/DC):
- The AD637 chip chosen due to fast settling time to a value without reasonable error
- AD8436A chip also considered but did not reach required settling time for expected frequency

Processing Unit (CPU):
- Raspberry Pi 2 Model B chosen for availability and functionality between ADC and GPS
- RB-WAV-08 A/D converter chosen for 24-bit resolution and compatibility with Raspberry Pi



Radiosonde (COM):
- DFM-09 required by NASA due to availability of ground receiver, open source XData protocol, 24 bytes/second transmission rate, and built-in GPS

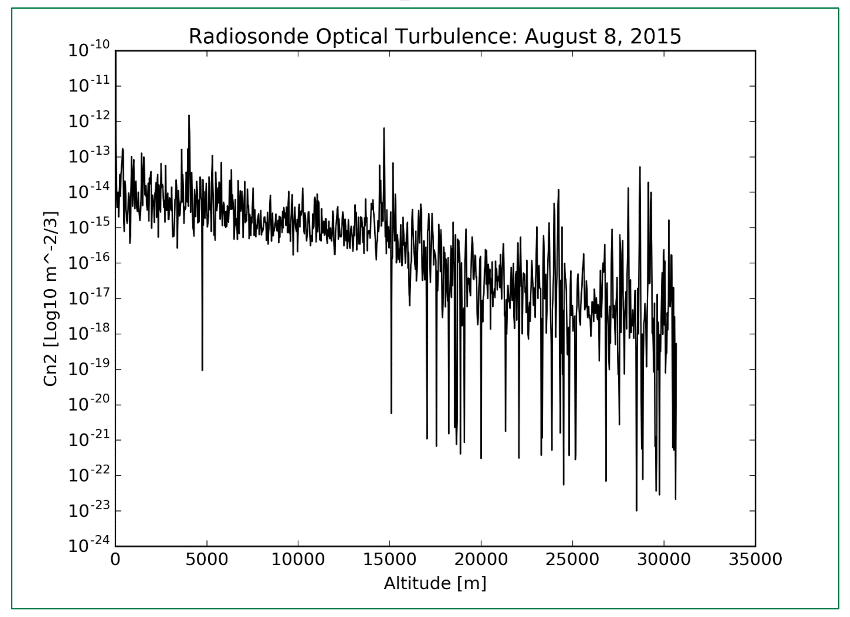
Power Subsystem (EPS):
- Battery decision based on noise level of Raspberry Pi's 5V and 3.3V rails, and possible need of DC-DC converter



Analysis

Once the thermosonde development is complete, multiple thermosondes are planned to be flown at sites across North Dakota. After the flights, comparisons between the thermosonde and radiosonde temperature measurements of optical turbulence will be done. Other comparisons will be done with National Weather Service balloon launches, as well as WRF and RUC model output.

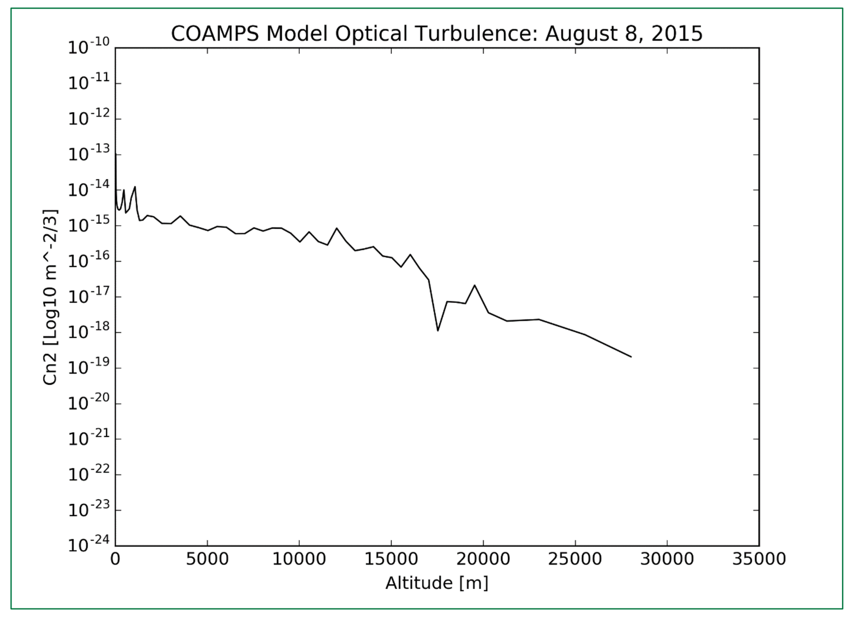
Python scripts are used to calculate the optical turbulence profiles from the thermosonde, radiosonde, and model data. This plot shows the refractive index structure parameter calculated for a radiosonde launched at Cape Canaveral, Florida on August 8, 2015. The lower atmosphere had the highest amounts of optical turbulence, due to the higher number of temperature variations.



The refractive index structure parameter calculated from a radiosonde launched at Cape Canaveral, Florida on August 8, 2015. Cn2 is plotted in logarithmic units.

Model Profiles

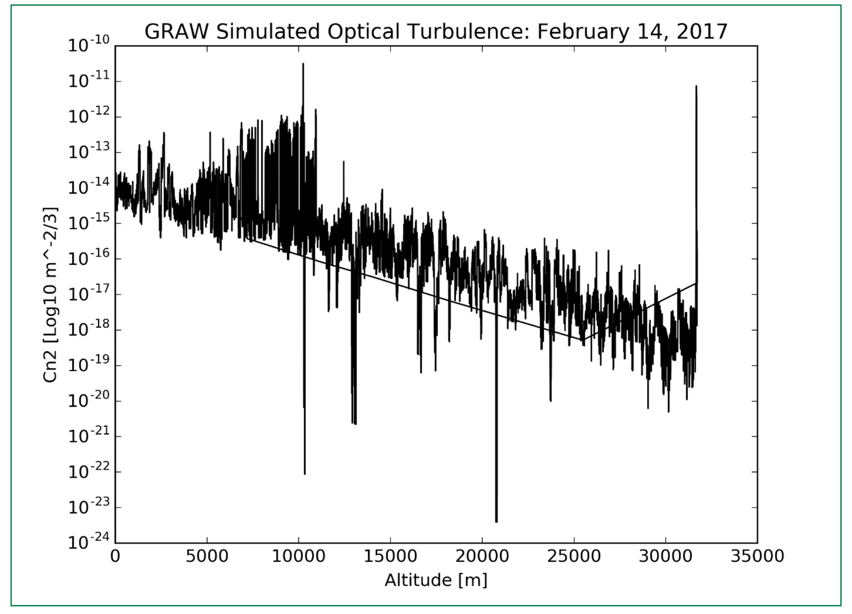
The same method used for calculating C_n^2 for the radiosonde data are used for the WRF and RUC model output. This plot was generated with a COAMPS model sounding, which should look similar to the WRF and RUC output. Despite the relatively few data points, the profile was similar to radiosonde data above. The model also had much less variability in the upper atmosphere than the radiosonde.



The refractive index structure parameter calculated from a COAMPS model sounding for Cape Canaveral on August 8, 2015.

GRAW Radiosonde Profiles

The data from the DFM-09 radiosonde in the thermosonde package is used to find the optical turbulence for each flight. This plot was made with an archived GRAW sounding file, which is very similar to the data generated from the flights with the thermosonde. This turbulence profile exhibited the same exponential decrease through the atmosphere as the previous two profiles.



The refractive index structure parameter calculated from a simulated GRAW sounding on February 14, 2017.

Future Work

- The thermosonde will be completed.
- Thermosondes will be flown at sites across North Dakota, and model data gathered.
- The thermosonde, radiosonde, and model data will be used to calculate C_n^2.
- The three datasets will be compared to find error in the models.

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