Atmospheric Precipitable Water and its Correlation with Clear Sky Infrared Temperature Readings: Data Analysis

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Introduction

The goal of this research is to determine the correlation between precipitable water and zenith sky temperature using low-cost instrumentation.

The methods of measuring precipitable water include [2]:

- Radiosondes
- Analyzing signal delay from ground-based Global Positioning System networks.
- Microwave-Infrared radiometers

We can define the relationship between the precipitable water (TPW) and the measured effective temperature (T_{eff}) as,

$$\frac{dT_{\text{eff}}}{d\text{TPW}} = \frac{\partial T_{\text{eff}}}{\partial \text{TPW}} + \frac{\partial T_{\text{eff}}}{\partial T_{\text{air}}} \frac{\partial T_{\text{air}}}{\partial \text{TPW}} . \quad (1)$$

Existing models show that there are equal contributions from both terms in Equation (1), where we define T_{air} as the mean temperature within the lowest 5 km of the atmosphere.

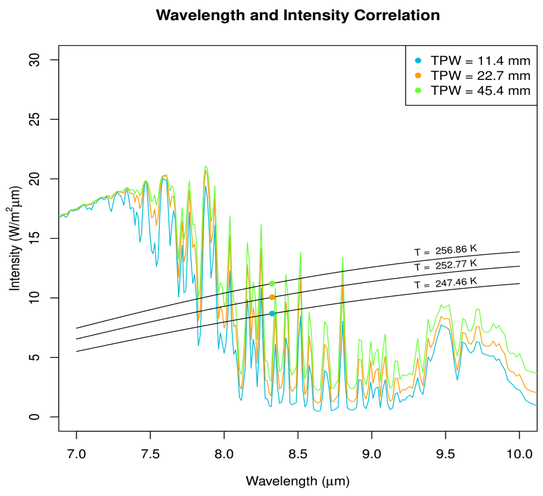

Figure 1: Based on calculations using MODTRAN [1]. Blue, orange, and green curves relate to TPW of 11.4 mm, 22.7 mm, and 45.4 mm, respectively. Corresponding circles represent mean radiance of the spectral band between 7-10 μm. Solid black curves show corresponding black body temperatures.

References

[1] A. Berk, L. S. Bernstein, and D. C. Robertson. MODTRAN: A moderate resolution model for LOWTRAN. Technical report, July 1987.

[2] Vicki Kelsey. Atmospheric precipitable water and its correlations with clear sky infrared temperature readings: field observations. Poster presented at PhysCon, Providence, RI., 2019.

Data Collection

We collect:

- Zenith sky temperature measurements using infrared thermometers [2].
- Precipitable water data from radiosondes at Albuquerque *(ABQ)* and El Paso *(EPZ)*, launched by the National Weather Service.

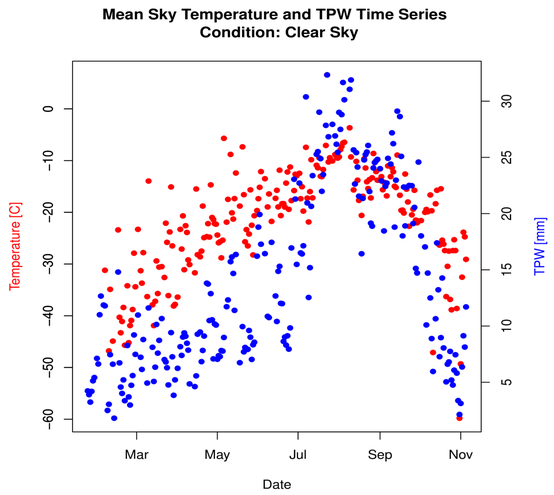

Figure 2: Time series of measured temperature *(red)* and precipitable water *(blue)*.

Computational Methods

We have developed an open source tool in R for analyzing the relationship between precipitable water and temperature. The tool utilizes the numerical methods

- Linearization of an exponential relationship
- Linear regression analysis

The computational tool contains four plot sets to visualize the data collected:

- Time series of average temperature measurements and precipitable water readings
- Analytical plots that show the correlation between temperature and precipitable water
- Individual sensor plots that shows the time series of temperature measurements for each of the infrared thermometers.
- Charts that show the distribution of observation conditions recorded by each of the infrared thermometers.

Current Analytical Results

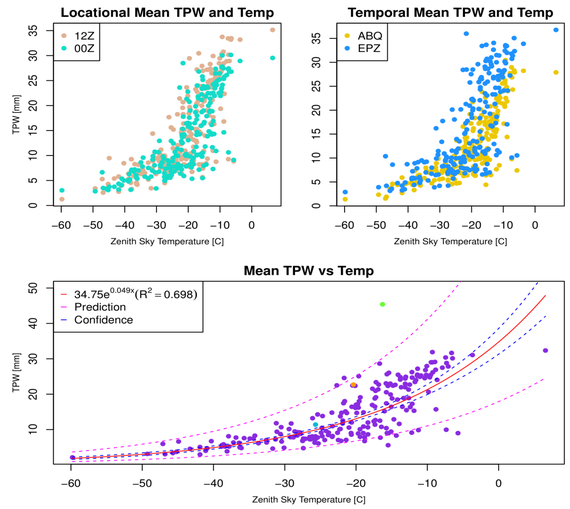

Figure 3: *(Top Left)*: Temperature and TPW based on averaged ABQ and EPZ radiosondes. *(Top Right)*: Temperature and TPW based on averaged 12Z and 00Z radiosondes. *(Bottom)*: Temperature and TPW based on total mean. The *blue, orange,* and *green* circles correspond to results of Figure 1.

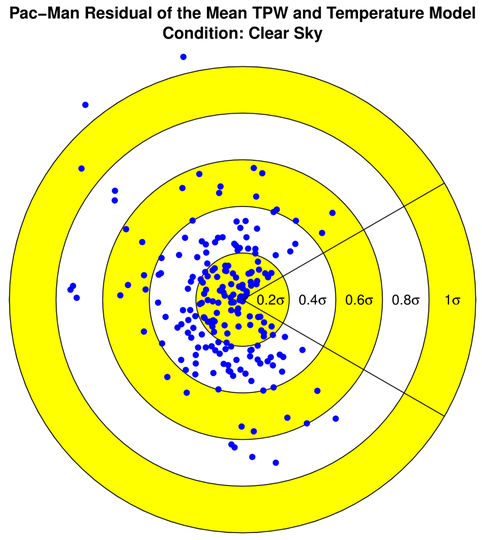

Figure 4: Pac-Man residual plot.

Discussion

Using the computational tool, we have experimentally verified the exponential relationship between precipitable water and zenith sky temperature.

We also have determined that there is a moderately strong correlation between the amount of precipitable water and the temperature at the zenith ($R^2 = 0.698$).

The results of our analysis show that the data fits within $\sim 1\sigma$, as seen in Figure 4.

We suspect that the sources of error include:

- Slight variations of measurement time and location
  - Temperature measurements taken at about 1100 in Socorro while measurements in Albuquerque and El Paso are taken at 0500 and 1700 local time *(MST)*
- Atmospheric phenomena may have introduced bias into the temperature readings

Ongoing Research

We plan on using machine learning techniques to predict whether or not a day is overcast or clear sky.

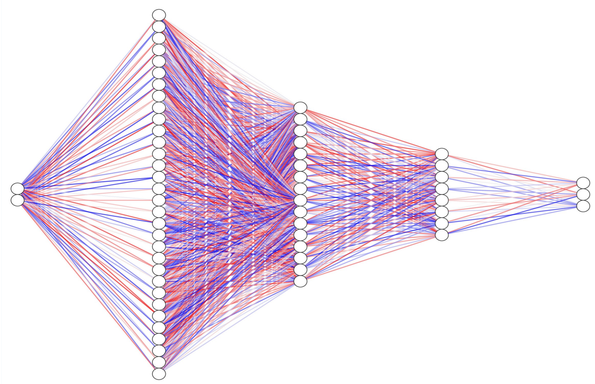

Figure 5: Current machine learning network configuration.

We are currently developing a method to automate the temperature measurement process. This would allow more consistency in the data collection process in addition to the potential of deployment anywhere

Acknowledgement

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Documentation Page: `https://git.io/fj5Xr`