ATMOSPHERIC PRECIPITABLE WATER AND ITS CORRELATION WITH CLEAR SKY INFRARED TEMPERATURE OBSERVATIONS

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ABSTRACT

Precipitable water vapor (PWAT) is the vertically integrated amount of water vapor in the atmosphere, and it is a valuable predictor for weather forecasting. Currently, the use of sophisticated instrumentation can limit the number of PWAT measurement sites, which affects the accuracy of forecast models in regards to storm formation, strength, and the potential for precipitation. We have analyzed relationships between PWAT and zenith clear sky temperature measurements for the dry climate zone found in the North American Desert Southwest, specifically over Socorro, New Mexico (34°N, 107°W). Daily measurements of the ground and zenith sky temperatures have been made at Socorro for two complete annual cycles using low-cost infrared thermal sensors. Radiosonde measurements of PWAT from National Weather Service stations located in nearby Albuquerque, and Santa Teresa, New Mexico, are input into our dataset and analysed via a newly developed computational tool. Our results show that an exponential relationship between PWAT and zenith clear sky temperature holds for the Desert Southwest, but with parameters that are different from those obtained previously over the more moist climate zone of the Gulf Coast of Texas. Model simulations can accurately reproduce the observed relationship between PWAT and temperature, and the results suggest that half of the signal in temperature is directly related to changes in opacity due to changes in PWAT, while the other half is due to changes in air temperature that usually accompany changes in PWAT.

PRECIPITABLE-WATER MODEL ANALYSIS TOOL

The analysis was conducted by the **Precipitable-water Model Analysis Tool (PMAT)**, a software suite developed in Python and R that:

- collects NWS atmospheric data from radiosondes and ground stations
- processes infrared temperature measurements
- computes exponential regression coefficients for zenith sky temperature and PWAT
- visualizes the results

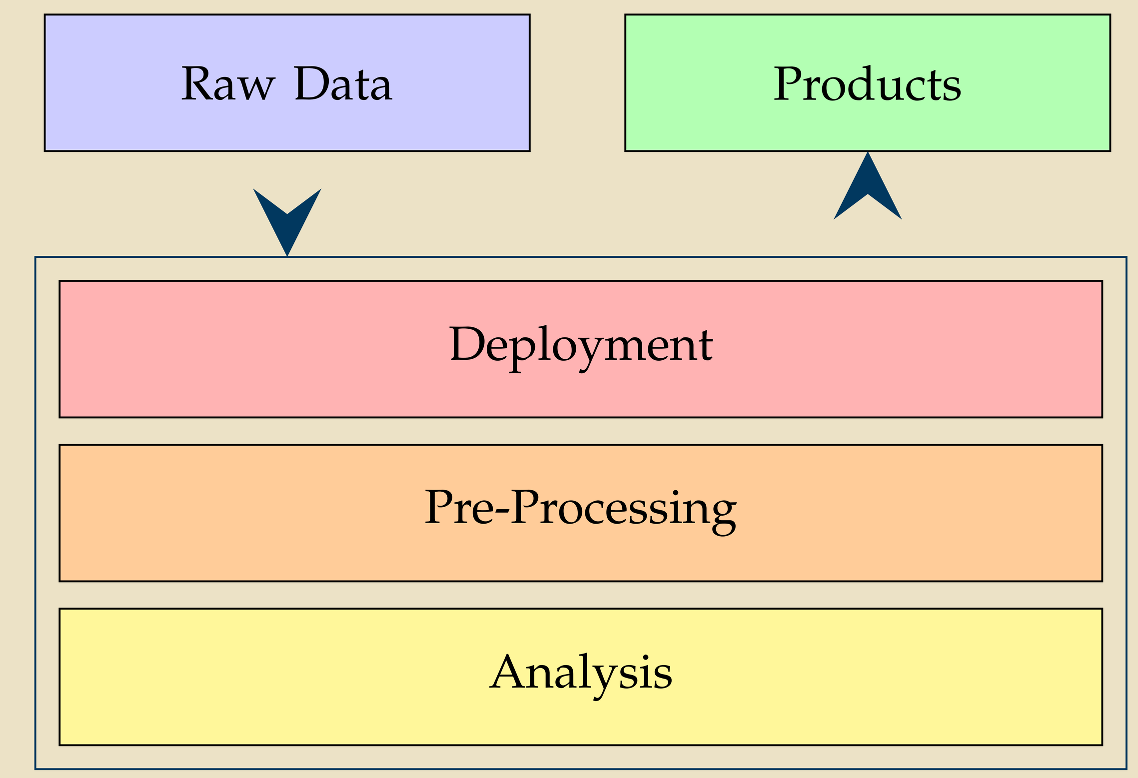

Figure 5: Workflow diagram for the PMAT

DATA COLLECTION

We employed a method that utilizes the relationship between the total precipitable water (PWAT) and the measured brightness temperature (T_b) [1] as,

$$\frac{\mathbf{dT_b}}{\mathbf{dPWAT}} = \frac{\partial \mathbf{T_b}}{\partial \mathrm{PWAT}} + \frac{\partial \mathbf{T_b}}{\partial \mathbf{T}_{\mathrm{air}}}\frac{\partial \mathbf{T}_{\mathrm{air}}}{\partial \mathrm{PWAT}}, \qquad (1)$$

where we define T_{air} as the mean temperature.

We used three different types of infrared thermometers to take daily ground and zenith sky temperature readings

Figure 1: *(Left)* The three infrared thermometers used to collect data: (from left to right) 1610 TE, FLIR i3, and the AMES 12:1 Infrared Thermometer.

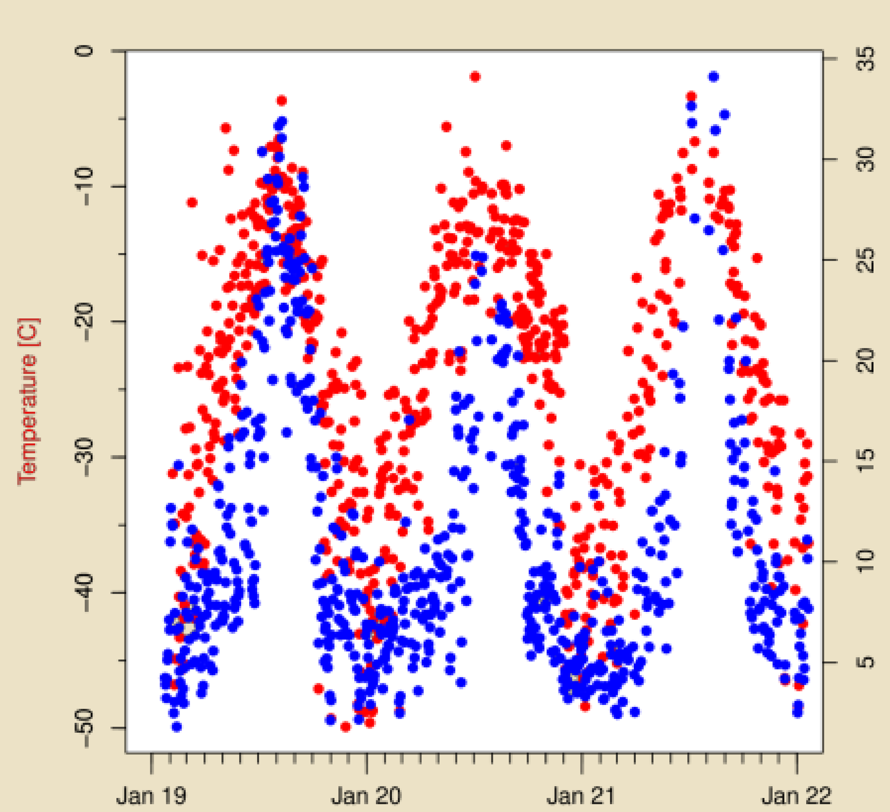

Figure 2: Time series of average zenith temperature (red) and precipitable water (blue) between 19 Jan 2019 and 20 Jan 2022.

CURRENT ANALYTICAL RESULTS

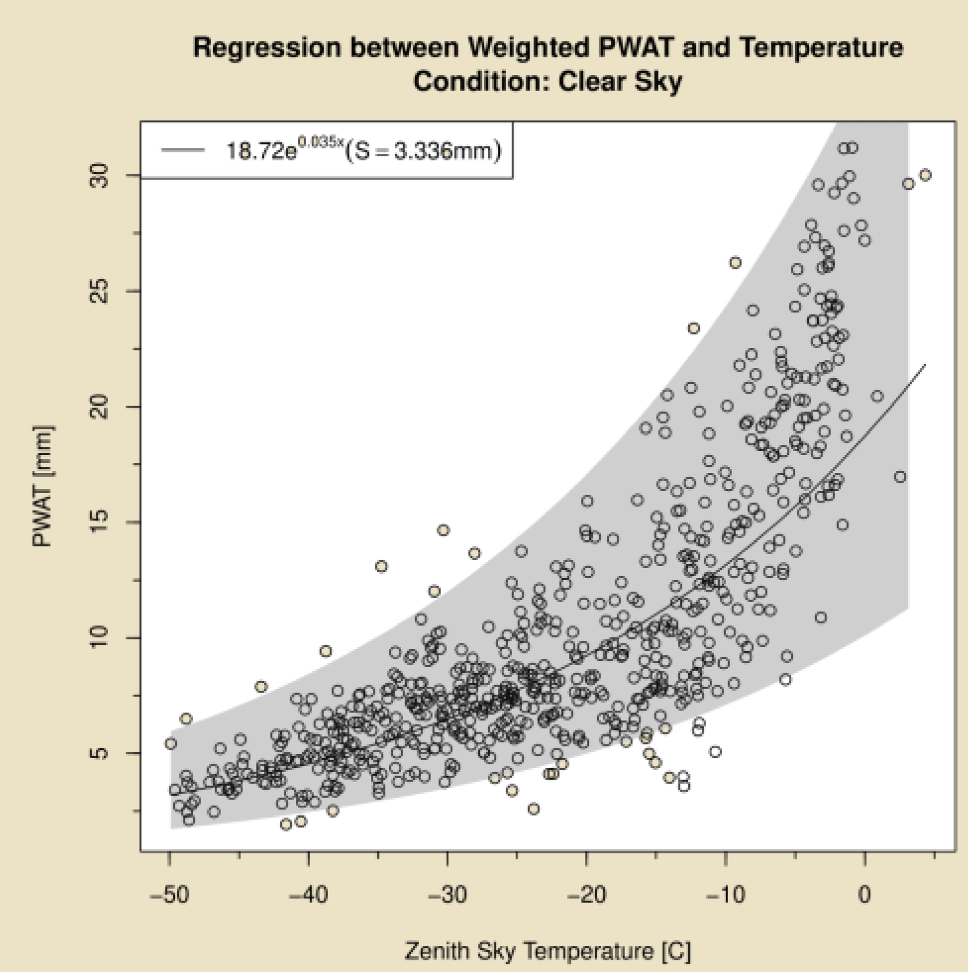

Figure 3: Exponential regression between average temperature and precipitable water, with the averaged best-fit for a 5000 step run represented as the solid black line.

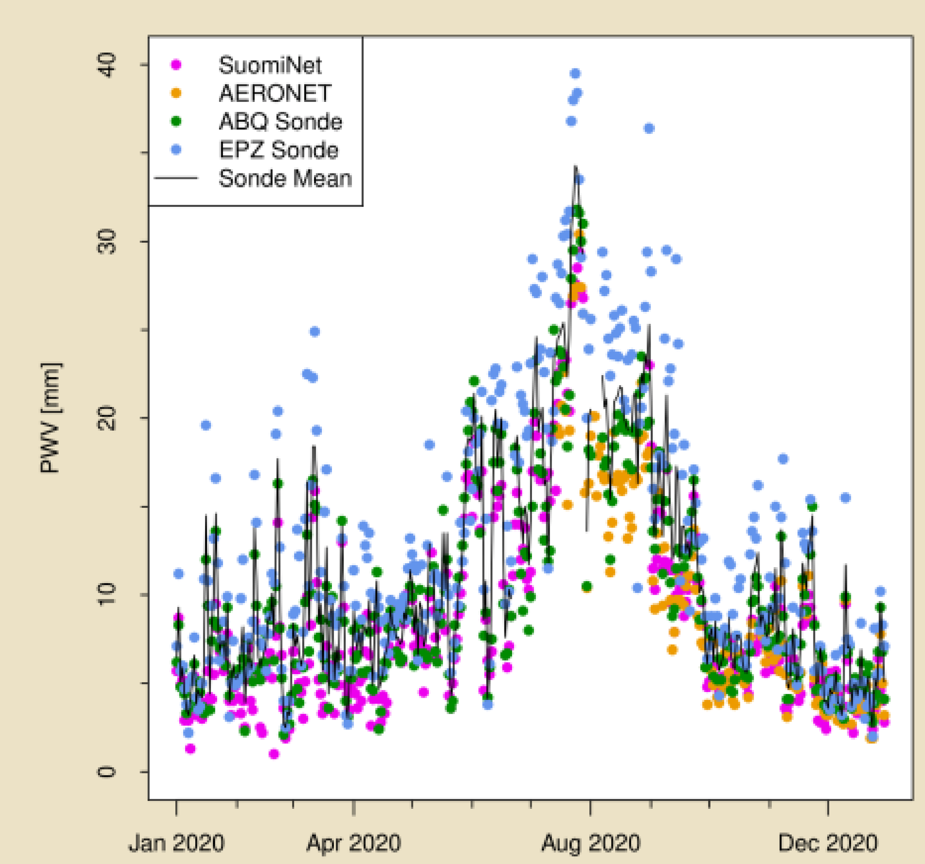

Figure 4: Time Series comparison between NWS radiosondes, AERONET, and SuomiNet for 2020 [2].

DISCUSSION

From 19 January 2019 to 20 January 2022 we have collected 1094 days of data, based on our analysis we report the following.

- **Root Mean Squared Error** is 3.308 mm.
- **Standard Deviation** is 3.336 mm.

The **sources of error** in our dataset include:

- Temperature measurements do not exactly coincide in time or location with TPW measurements.
- Aerosols, subvisible clouds, and other atmospheric phenomena may have introduced measurement bias.
- Angular variation in the downward radiance field and finite field of view

The AMES instrument was best suited for measuring zenith clear-sky temperature and deriving precipitable water at this location.

There are two contributing factors to changes in PWAT with respect to temperature:

- changes in **opacity**
- changes in **air temperature**

In the **next steps** of the project, we aim to

- automate the measurements
- coordinate citizen science / GLOBE projects
- make hourly data available to NWS

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