

# The Precipitable Water Project: Using Zenith Clear Sky Temperature to Approximate Precipitable Water in Areas without Nearby Measurements in the Western U.S.

**Vicki Kelsey**<sup>123</sup>

<sup>1</sup>Langmuir Laboratory for Atmospheric Research

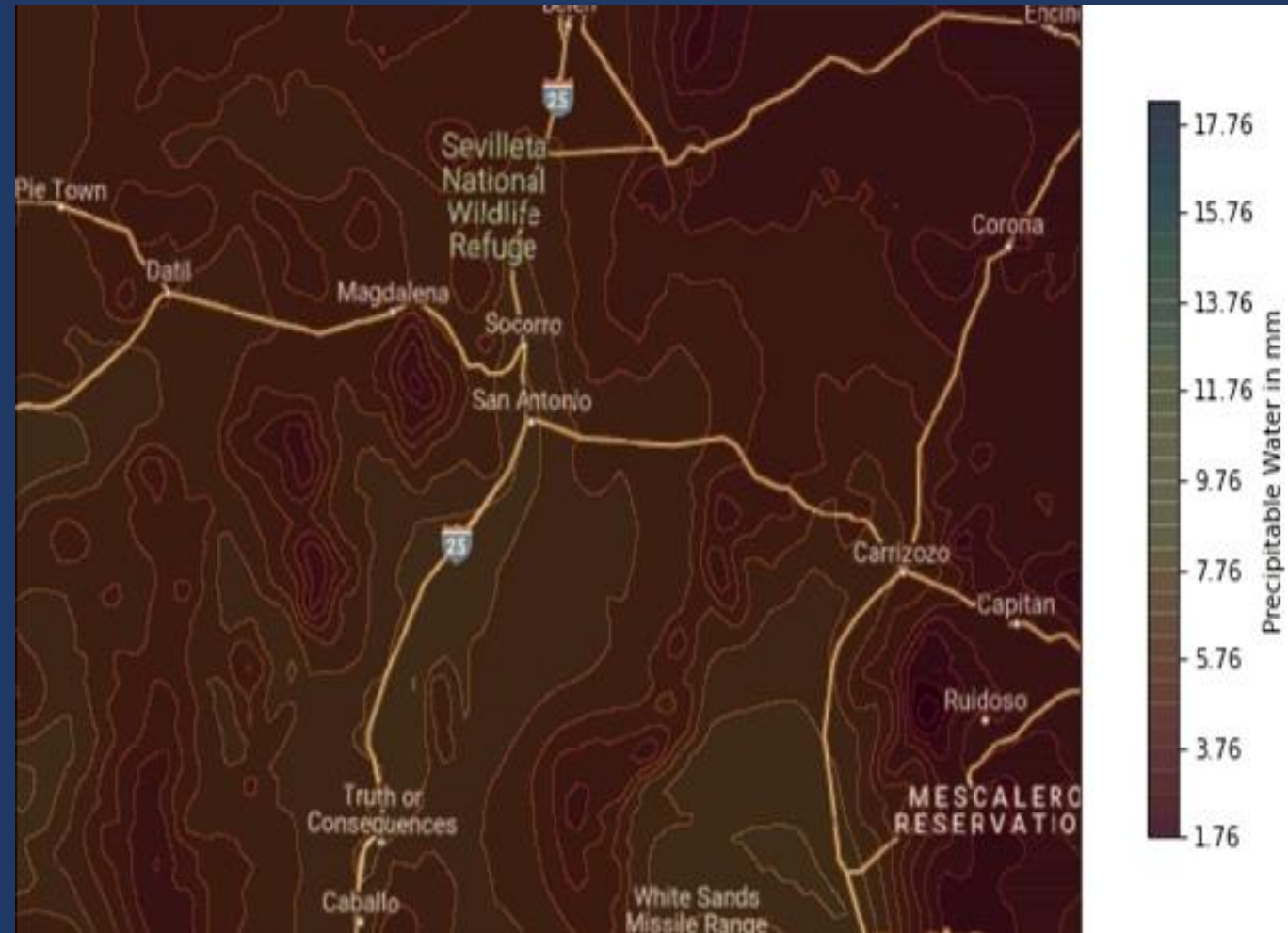
<sup>2</sup>South Dakota School of Mines and Technology

<sup>3</sup>National Weather Service ABQ Student Volunteer  
Summer 2021

[vkelsey@pmat.app](mailto:vkelsey@pmat.app)

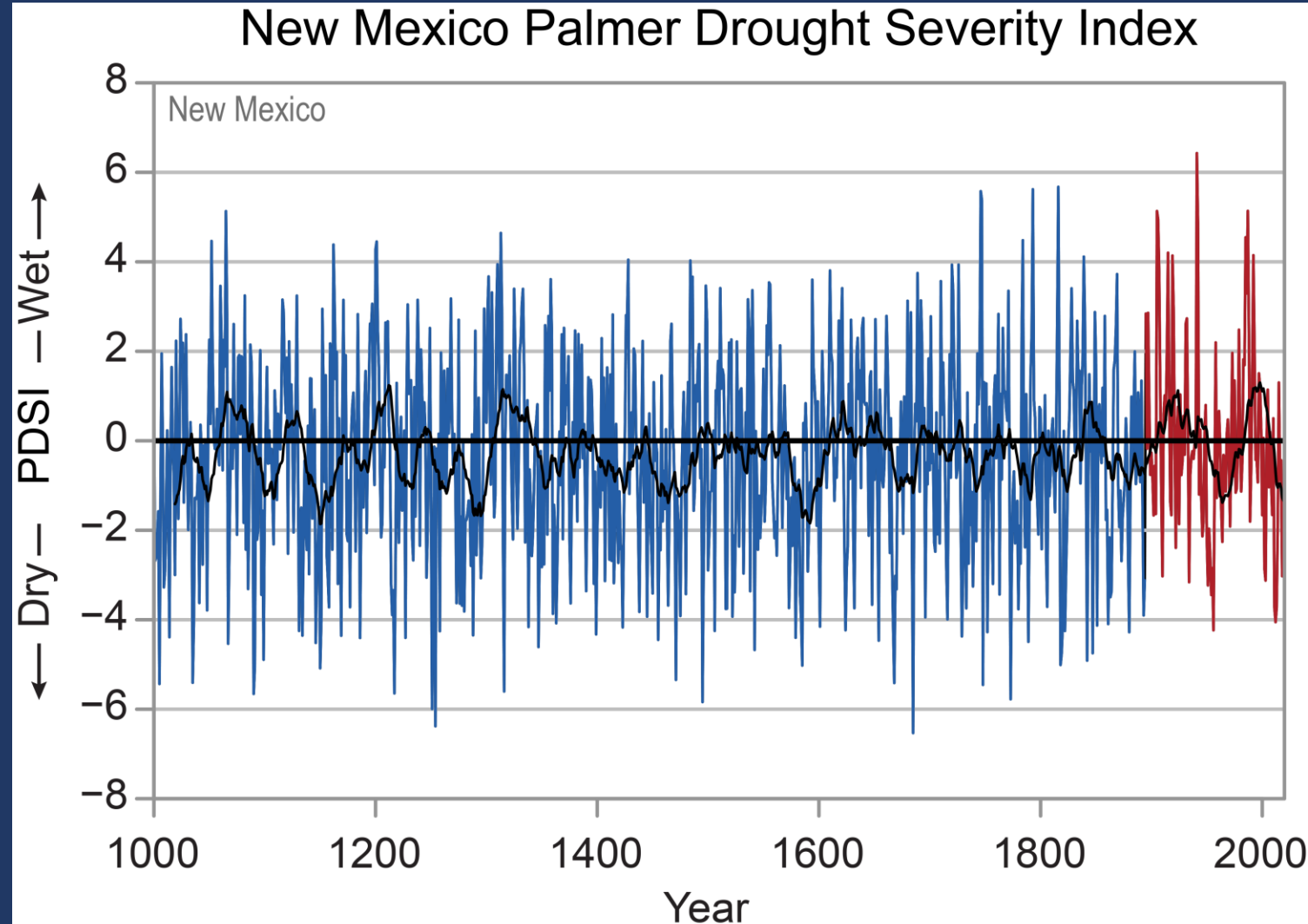
2 April 2022

5th Texas Weather Conference



# PWAT: Drought to Deluge

This project shows how zenith clear sky temperatures can be used to approximate PWAT in higher elevation, arid and semi-arid regions of the west where data is not currently available for forecasting



# PWAT Data Gaps

## GOES-R limitations

- Angle of incidence
- Topography

## POES limitations

- Orbits
- Frequency

## GPS measurements and Ground based monitoring equipment

- Few measurement sites
- Funding
- Elevation

## Radiosondes

- Large WFO areas
- Large distances between sites

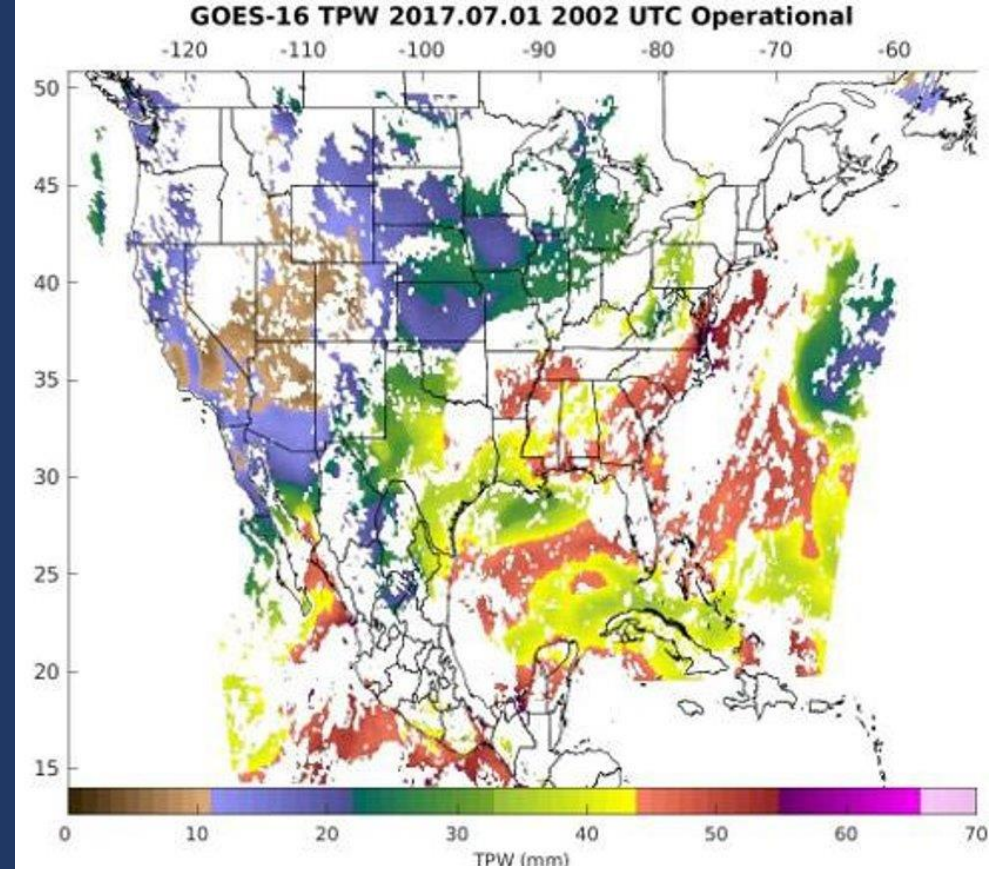
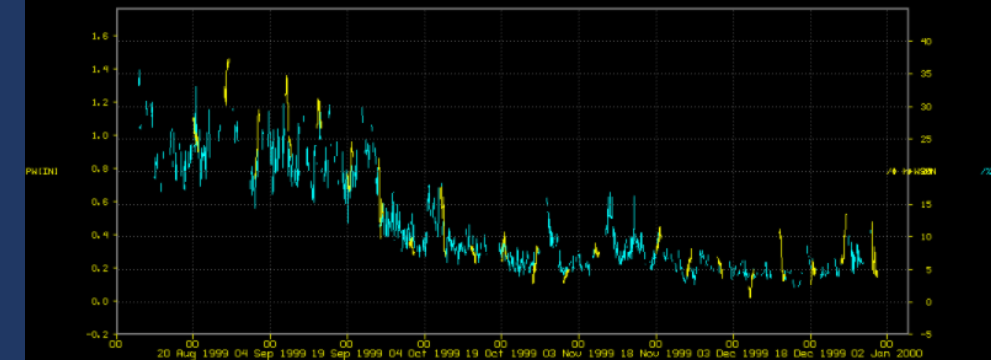


image from: <https://www.goes-r.gov/products/baseline-total-precipitable-water.html>

WSHN  
06 Aug 1999/06UTC - 31 Dec 1999/06UTC

Image: <https://www.ssec.wisc.edu/~scottl/calval/whitesands.html>





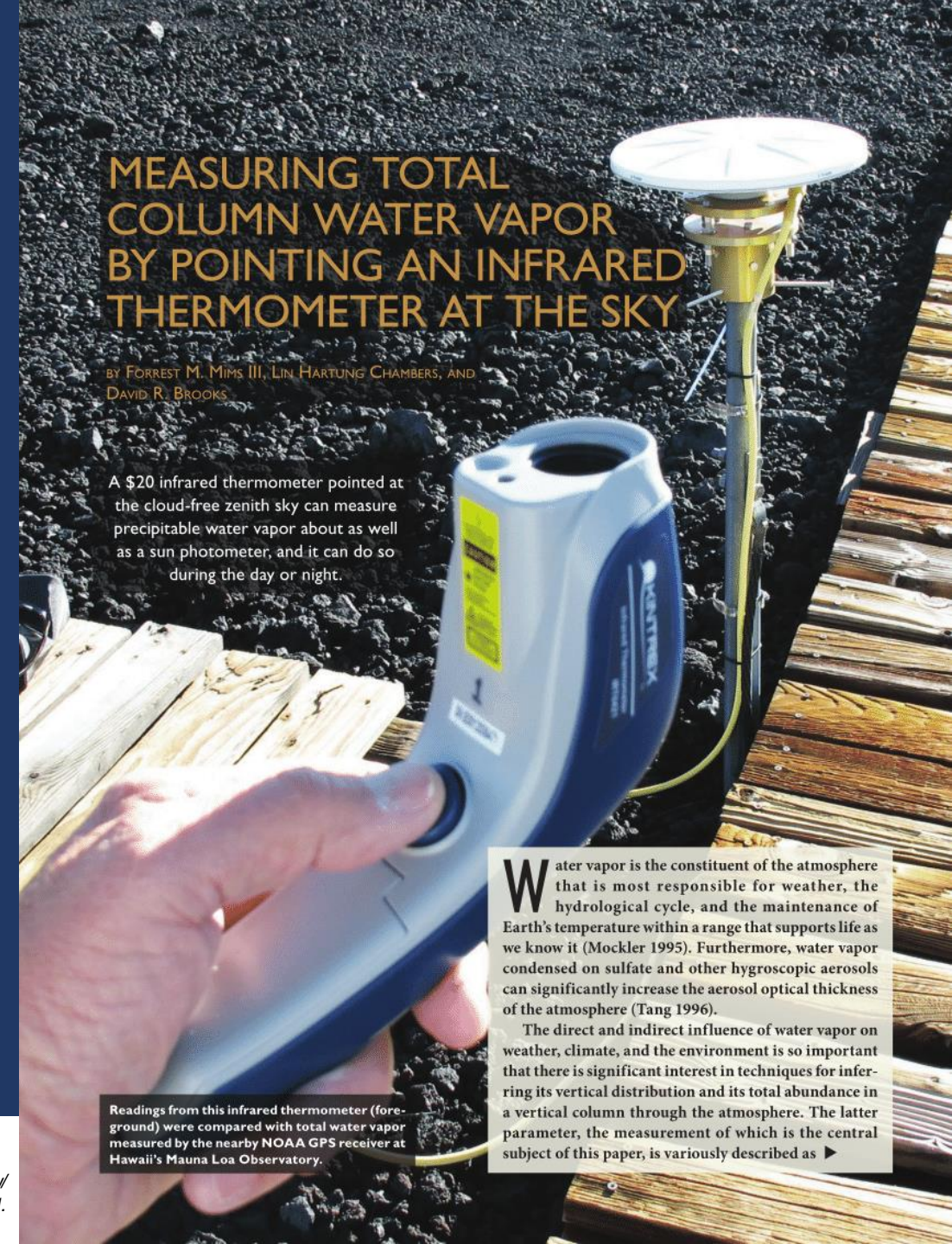
# Previous Works

Smith and Toumi. 2008  
London, UK

Maghrabi and Clay. 2009  
Coastal South Australia

Mims et al. 2011  
Seguin, Texas

Image: *Bulletin of the American Meteorological Society*, 92(10), 1311-1320. [https://journals.ametsoc.org/view/journals/bams/92/10/2011bams3215\\_1.xml](https://journals.ametsoc.org/view/journals/bams/92/10/2011bams3215_1.xml)



## MEASURING TOTAL COLUMN WATER VAPOR BY POINTING AN INFRARED THERMOMETER AT THE SKY

BY FORREST M. MIMS III, LIN HARTUNG CHAMBERS, AND DAVID R. BROOKS

A \$20 infrared thermometer pointed at the cloud-free zenith sky can measure precipitable water vapor about as well as a sun photometer, and it can do so during the day or night.

Water vapor is the constituent of the atmosphere that is most responsible for weather, the hydrological cycle, and the maintenance of Earth's temperature within a range that supports life as we know it (Mockler 1995). Furthermore, water vapor condensed on sulfate and other hygroscopic aerosols can significantly increase the aerosol optical thickness of the atmosphere (Tang 1996).

The direct and indirect influence of water vapor on weather, climate, and the environment is so important that there is significant interest in techniques for inferring its vertical distribution and its total abundance in a vertical column through the atmosphere. The latter parameter, the measurement of which is the central subject of this paper, is variously described as ►

Readings from this infrared thermometer (foreground) were compared with total water vapor measured by the nearby NOAA GPS receiver at Hawaii's Mauna Loa Observatory.

# Instrumentation

## TE 1610

Field of view:  $4.8^\circ$  Cone  
Low temperature limit:  $-20^\circ\text{C}$   
Target emissivity: 0.95

## FLIR i3

Field of view:  $12.5^\circ \times 12.5^\circ$  Rectangle  
Low temperature limit:  $-40^\circ\text{C}$   
Target emissivity: 0.95

## AMES 12:1

Field of view:  $4.8^\circ$  Cone  
Low temperature limit:  $-50^\circ\text{C}$   
Target emissivity: 0.95



Image taken by Spencer Riley



# Methodology

## Daily zenith sky temperature measurements

- Started January 2019, Socorro, NM
- 1700-1800 UTC or 2300-2400 UTC
- Designation of either cloudy or clear sky
- Ground Temperature measurements taken to check for calibration and drift

## Compare zenith clear sky temperatures with PWAT measurements

- Radiosondes from ABQ and EPZ WFOs
- SuomiNet data (when available)
- AERONET data (when available)

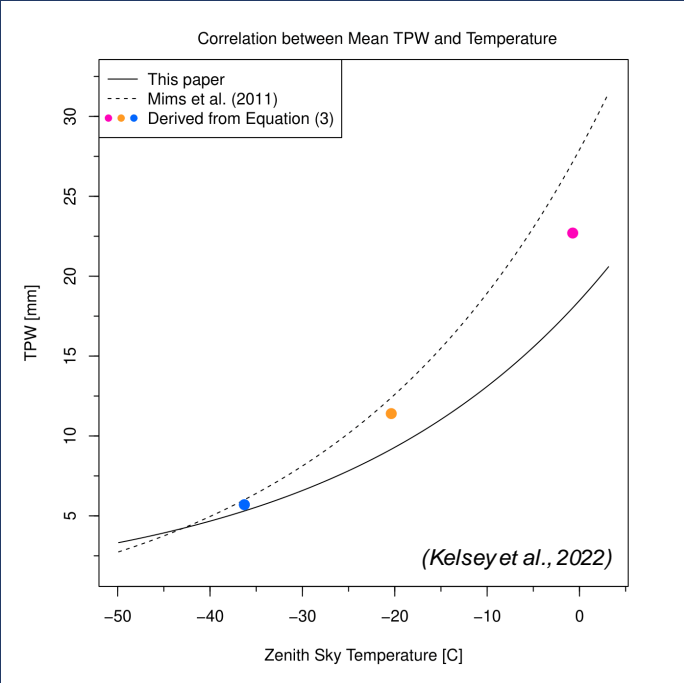
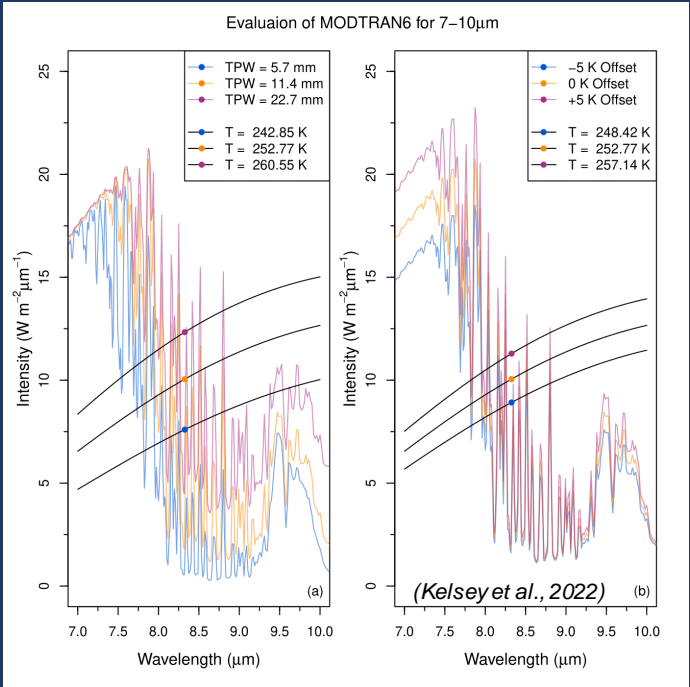


# Checking our data against MODTRAN6 and Mims et al.

Zenith Sky Temperature matches  
Brightness Temperature data from  
MODTRAN6

Planck function evaluated

Our fit more in line with MODTRAN6  
points than Mims et al. achieved



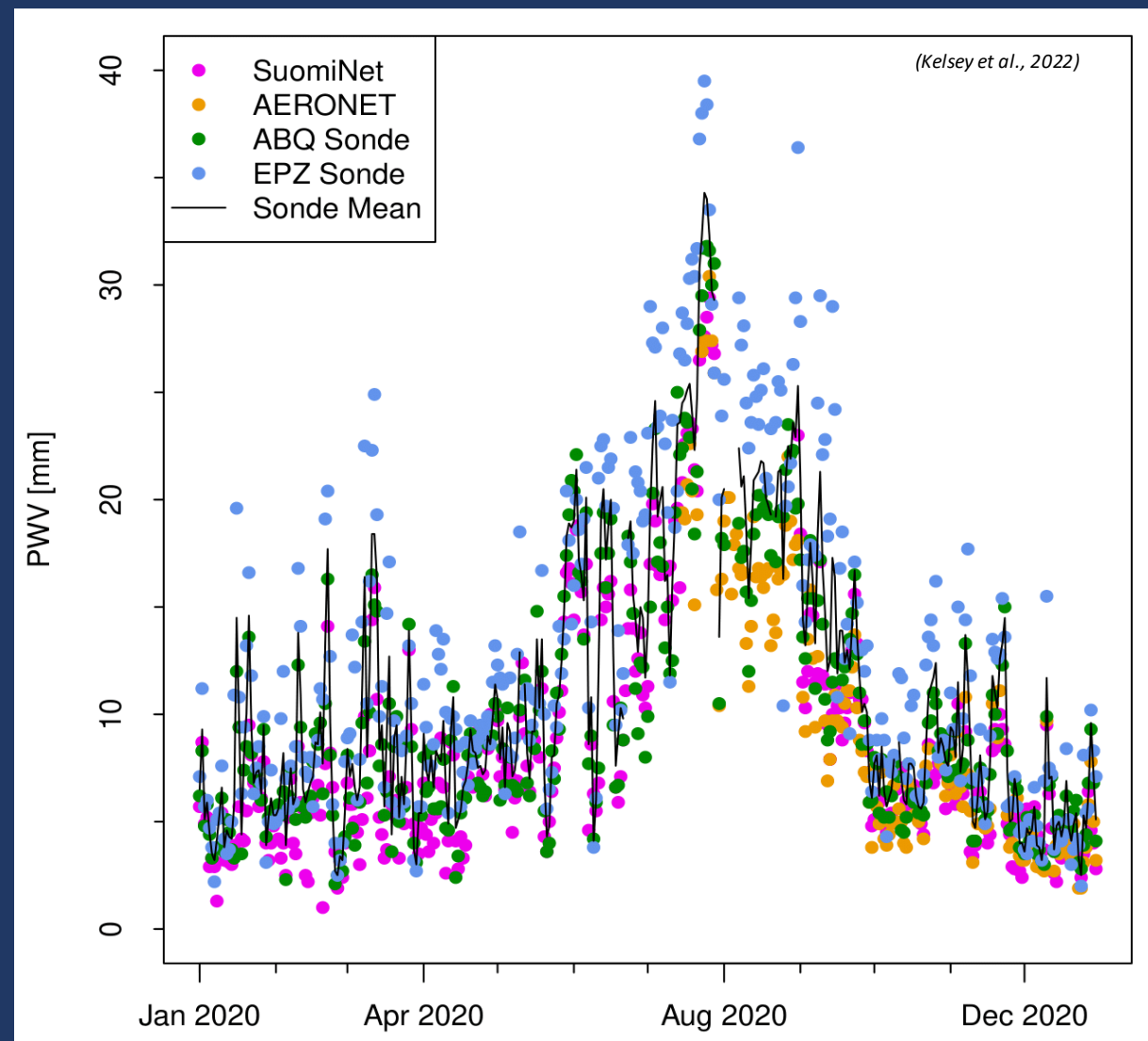
# Local PWAT measurement comparisons

## SC01 SuomiNet

- On M Mountain
- Satellite GPS
- ~2600 ft difference in elevation
- Not online ~50% of the time since Jan 2019

## AERONET

- Sevilleta National Wildlife Refuge
- Sun Photometer
- 22 miles north
- similar elevation
- online 5 months/year





# Approximation based on Correlation

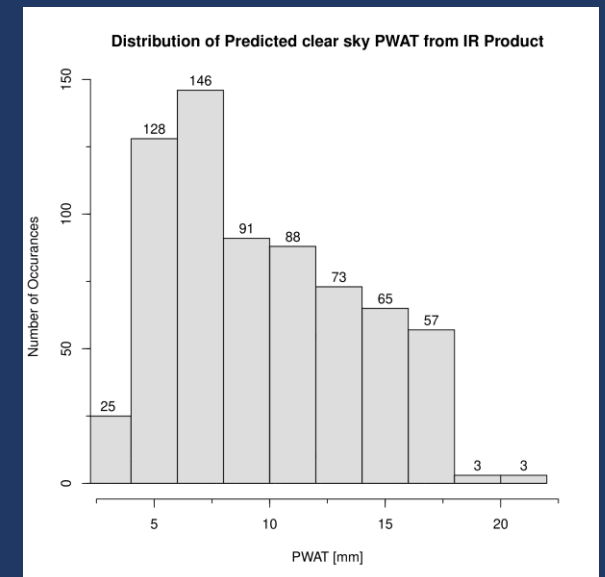
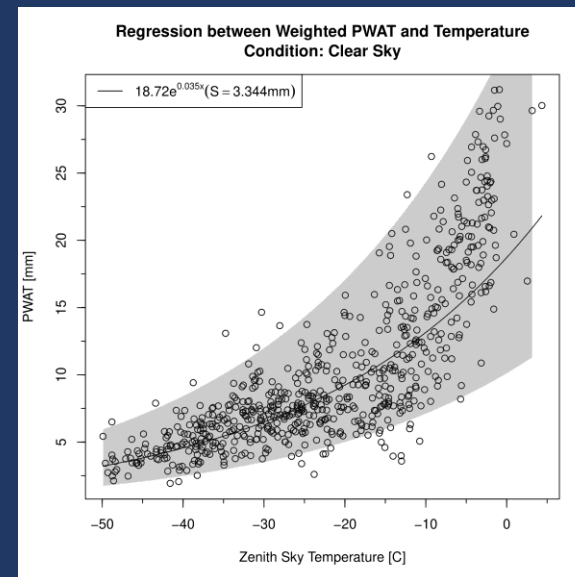
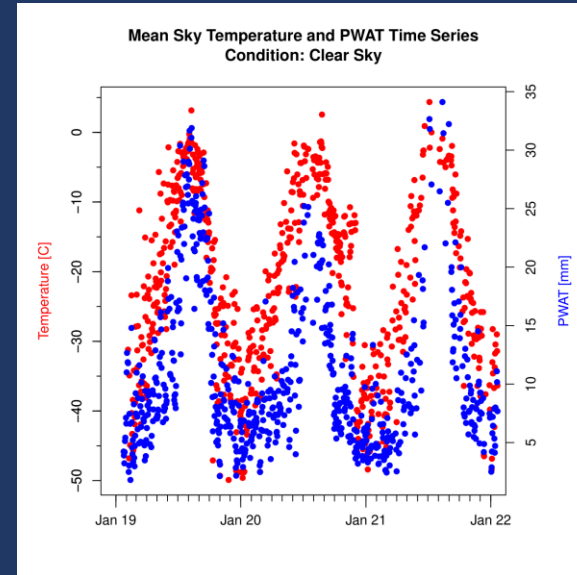
Seasonal Trends

Spatiotemporal average with best-fit line

Correlation proved first, then PWAT values approximated

If GPS based satellite readings or POES data is available, it should be used

Approximation provides insight where there are no PWAT measurements available



# Next steps

## Automation

- Have measurements taken on an hourly basis to be useful to NWS

## Citizen Science / GLOBE Project

- Manual measurements at rural locations

## Data

- Automated Surface Observing System (ASOS)
- Advanced Weather Interactive Processing System (AWIPS)

## Continued development of PMAT

- Open source software
- Full access to our dataset

<https://docs.pmat.app/>



# Any Questions?

Thanks for coming and hearing about the Precipitable Water Project today!

**Vicki Kelsey**  
vkelsey@pmat.app

**Spencer Riley**  
sriley@pmat.app

**Kenneth Minschwaner**  
kminschwaner@pmat.app

For more info, please see our paper (published 18 March 2022)

Atmos. Meas. Tech., 15, 1563–1576, 2022  
<https://doi.org/10.5194/amt-15-1563-2022>  
© Author(s) 2022. This work is distributed under  
the Creative Commons Attribution 4.0 License.



Atmospheric  
Measurement  
Techniques



**Atmospheric precipitable water vapor and its correlation with  
clear-sky infrared temperature observations**

Vicki Kelsey<sup>1,4</sup>, Spencer Riley<sup>2</sup>, and Kenneth Minschwaner<sup>2</sup>

