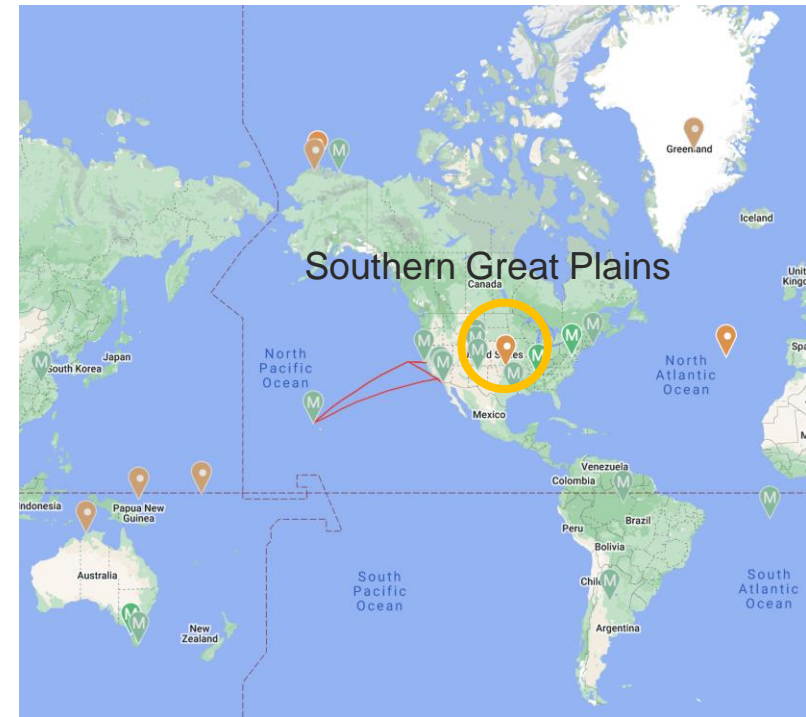


Microwave radiometers in the ARM program

Maria P. Cadeddu, Argonne National Laboratory



- The Atmospheric Radiation Measurement (ARM) program operates 6 facilities (3 AMF and 3 fixed)
- Total of 14 radiometers in the field at any given time
- MWR measurements are focused on PWV and LWP



Overview

Radiometers are procured through a bidding process

Historically we have had different types of radiometers at different sites or even at the same site

Radiometrics 2-channel MWR – Operating at SGP, NSA, AMFs

Radiometrics 3-channel (PR series) – Retired

Radiometrics MP-3000 series – Retired

Radiometrics MP-183 series – Still operating

ProSensing G-band unit – Retired

RPG LWP-90-150 – Retired

RPG LWP 23-31-90 G4 and G5 series – Operating at all sites including SGP



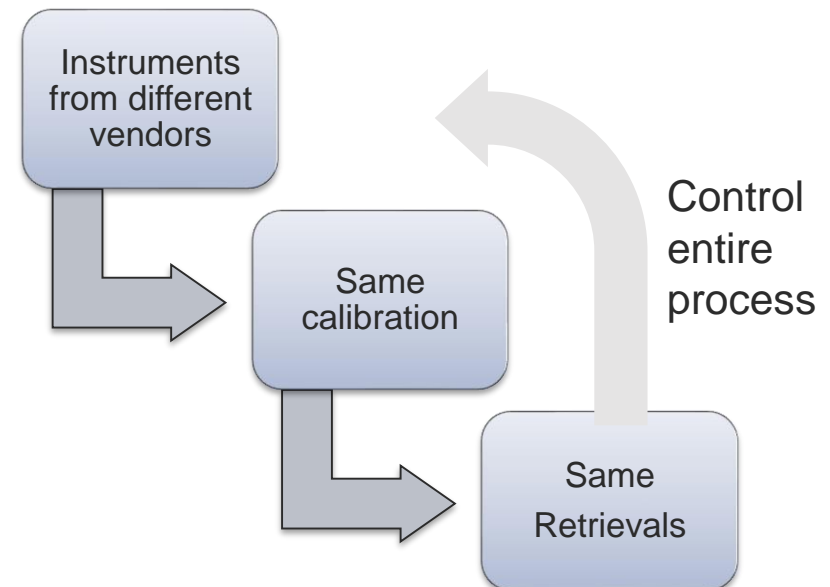
Radiometers in the ARM program

ARM program purpose:

“To provide the research community with the best array of field observations [...] to significantly improve the representation of challenging *atmospheric processes in earth system models*.”

To achieve this purpose, the ARM radiometers need to provide:

- *Consistently calibrated measurements independently of the instrument model/manufacture*
- Ability to trace back calibration problems and eventually recalibrate
- Full traceability from voltages to retrieval products
- Ability to separate instrumental uncertainty from retrieval uncertainty



The Gordian knot of radiometric observations



Need measurements to validate propagation models



Need accurate measurements for retrievals

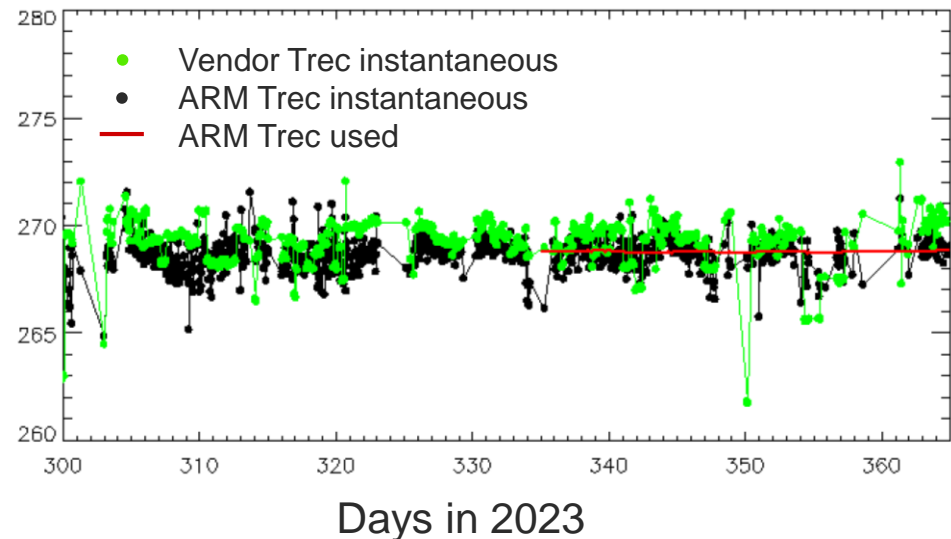
Need propagation models to evaluate measurements

The only way to break the knot is reliable and uniform calibration across time/space/instruments

Calibration principles

- Vendors provided calibration: Not used
- Use LV0 data (voltages) to implement in house calibration
- Follow common calibration principles **for all units** to achieve calibration consistency among all models/sites
- Eliminate human intervention in the calibration process
- Implementation of the calibration differs depending on the model

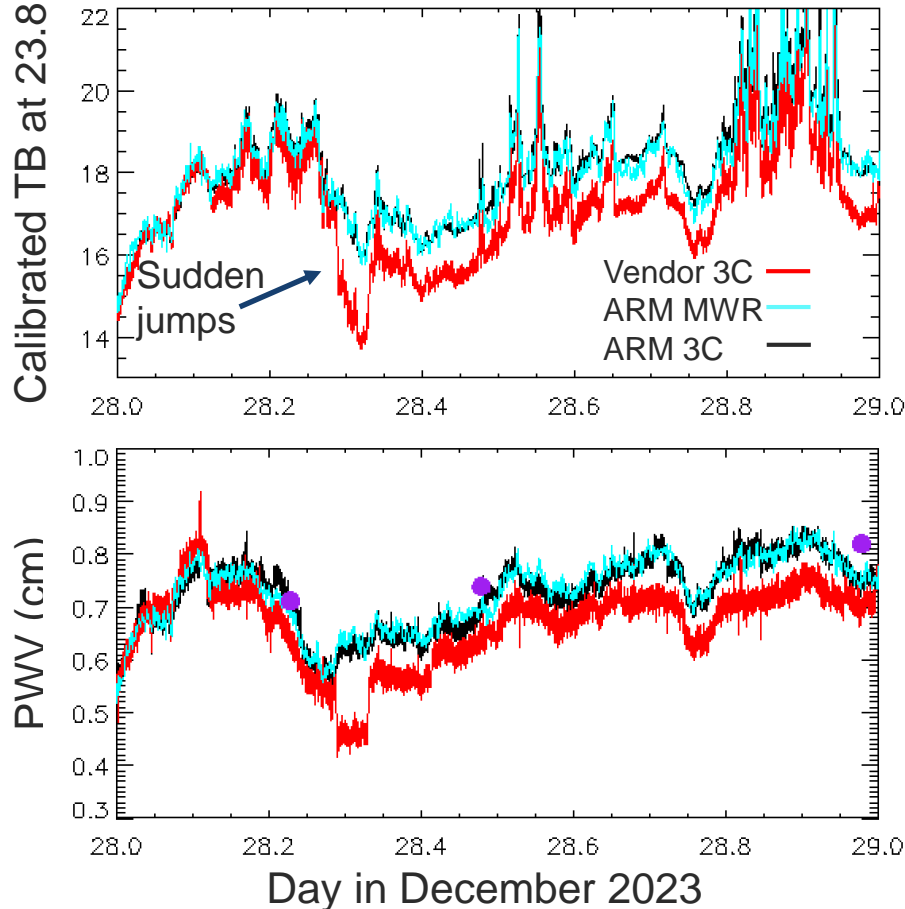
SGP: Trec@23.8 GHz



All vapor radiometers are calibrated using **only tip curves** for absolute calibration

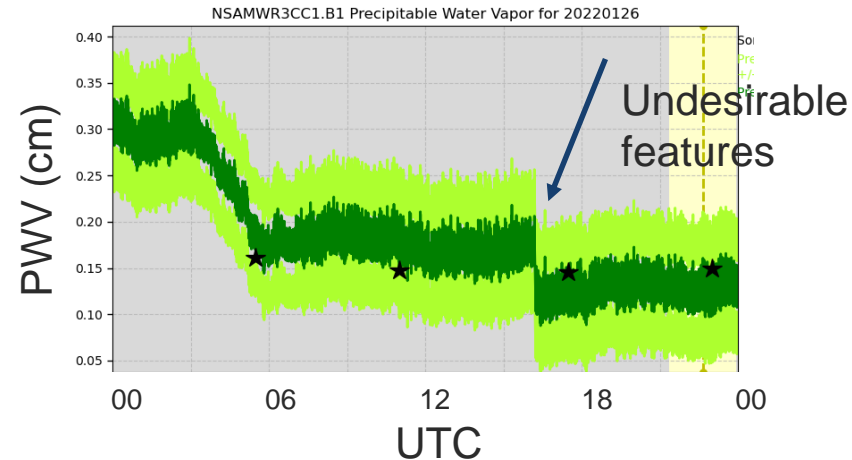
Calibration consistency

SGP: TB and PWV comparison



Inconsistent calibration yields undesirable features in the retrievals

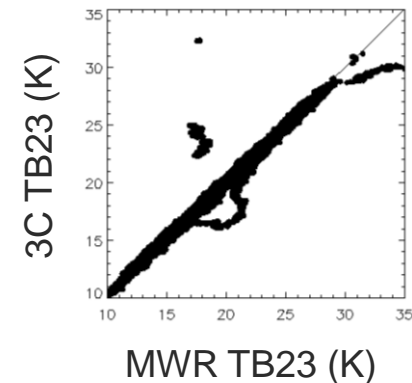
North Slope of Alaska



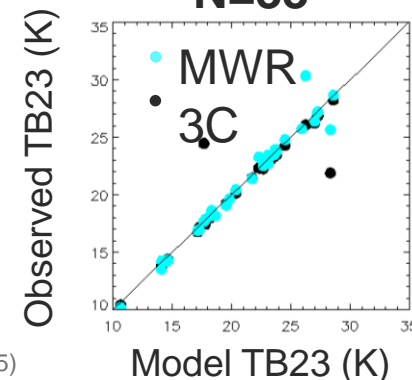
Instruments monitoring

- Instruments are continuously monitored for quality
- Automated checks –first screening
- Human review
- Review of calibration (# of tip collected, stability of absolute calibration, receiver noise, noise diode or receiver temperature, etc.)
- Comparison of independently calibrated instruments-Redundancy
- Comparison with model calculations

SGP Dec 2023 co-located MWR-3C N=47862



SGP Dec 2023 RS and model N=33



Retrievals

The main radiometric products for the ARM program are *precipitable water vapor and liquid water path*

Real Time

MWRRET VAP

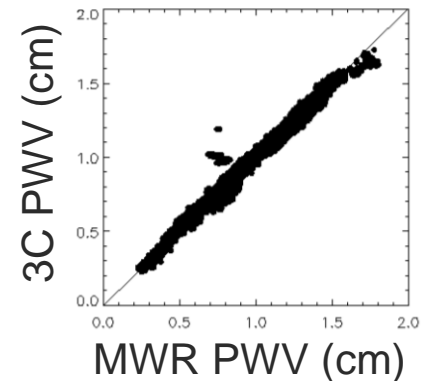
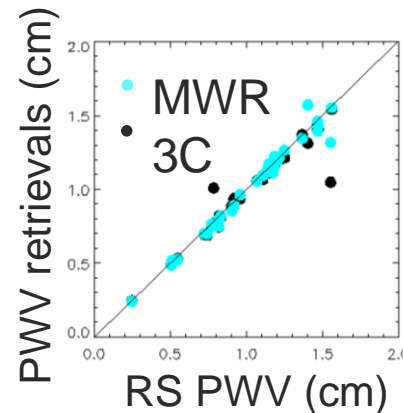
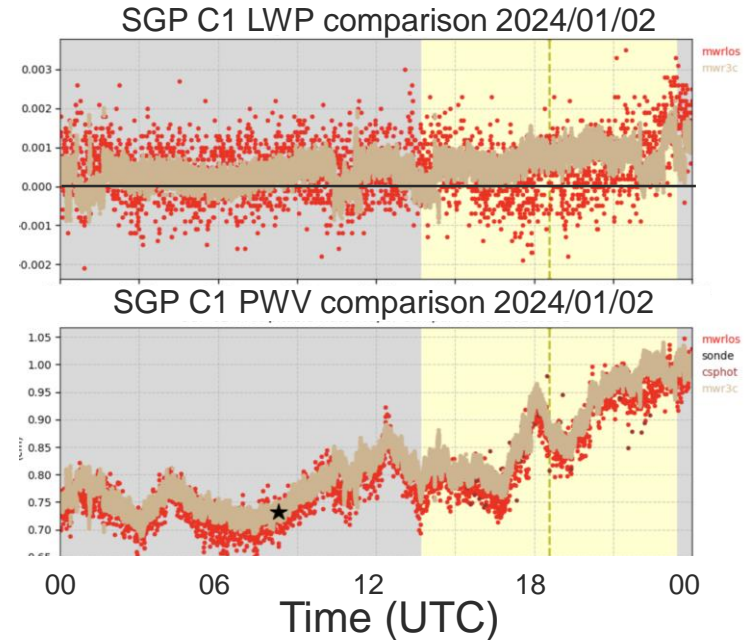
Provided in the .b1 datastream Instantaneous Uncertainty: RMSE	Provided in the c1 and c2 datastreams Time lag Uncertainty: Individual error bar 1-sigma
2-channel – Statistical regression 3-channel until 1/1/2021 – Neural network 3-channel after 1/1/2021– Statistical regression Regression coefficients are derived at each location	2-channel – Optimal estimation 3-channel – Optimal estimation Some de-biasing implemented

The largest systematic uncertainty in the retrievals is due to calibration

Real time retrievals

Routine *daily* comparison of real time retrievals
 Early detection of issues, anomalies, diurnal dependencies
 Utilized by users of AMFs until VAPs are available

Routine monthly comparison of real time retrievals
 Useful to identify biases and long-term drifts

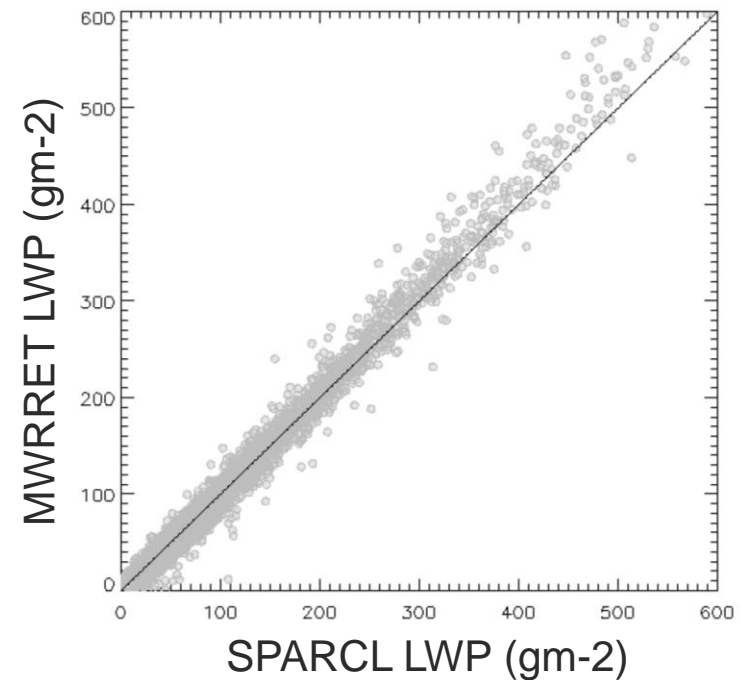


VAP retrievals

- The MWRRET VAP is run at several locations including the SGP.
- Uncertainties are provided in the form of 1-sigma error bar.
- Frequencies: 23-30-90 GHz Turner et al. (2007)
- For optimal estimation there is a bias removal before using the data.

LWP comparison between 2 OE methods

Eastern North Atlantic



SUMMARY

The ARM logo consists of the letters "ARM" in a bold, blue, sans-serif font. Below the letters is a blue curved line that starts under the 'A', goes under the 'R', and ends under the 'M', resembling a stylized horizon or a wave.

- ▶ Historically the ARM program has operated a variety of ground-based radiometer
- ▶ Because of the importance of maintaining time/space consistency the units are post calibrated – Eliminates inconsistencies due to vendor related approaches
- ▶ Full control of calibration enables to better understand uncertainty of retrievals. In-house calibration provides ability to recalibrate all the way back to tip curves
- ▶ Traditionally the ARM programs provides real-time statistical retrievals and VAP (optimal estimation) retrievals with a time lag
- ▶ Calibration is the single most important source of systematic uncertainty in retrievals