Analysis of daytime precipitable water vapor time series in L'Aquila (Italy) with long-term sun-photometer, GNSS and radiosondes data

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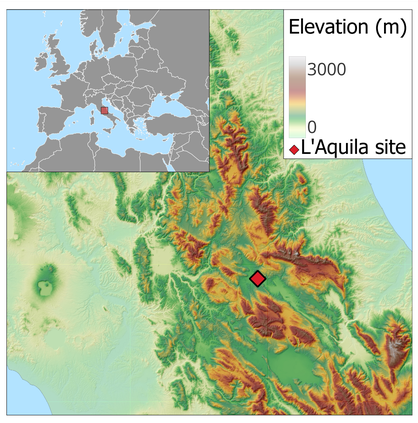
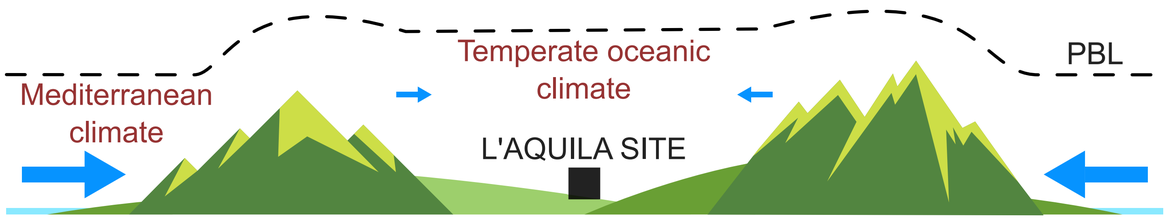
Goal

To characterize the precipitable water vapor (PV) column at the L'Aquila site at various timescale (years up to hours).

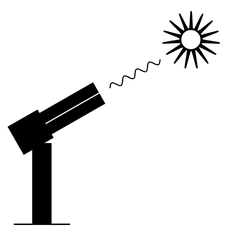
Observation site

- *L'Aquila site:* 42.368° N, 13.350° E, 680 m. ASL.
- The site lies in the bottom of a valley within the Italian Apennines mountain range, and surrounded by high mountains above 2000 meters ASL.



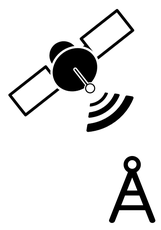


Data and methods



- *Instrument:* Cimel CE318-N (AERONET #856, "LAQUILA_Coppito" site)
- *Data range:* from April 2015 to December 2023
- *Data type:* AERONET Level 2.0 (cloud-free and calibrated) AOD+PV data

- *Instrument:* Leica AR20 + Leica GR30 (currently).
- *Data range:* from April 2015 to December 2023 (instrument operated since 1999).
- *Data type:* hourly Zenith Total Delay (ZTD) observations.
- *Processing:* Zenith Hydrostatic Delay (ZHD) from ERA5 sea-level pressure scaled with barometric formula. Convert the Zenith Wet Delay (ZWD) into PV though Π factor obtained from RS climatology, see [1]. Retain observation if in ± 1 hour from AERONET observation.



- *Instrument:* Vaisala RS-92 and RS-41.
- *Data range:* from April 1994 to December 2023.
- *Data type:* temperature (T) and relative humidity (RH) profile.
- *Processing:* reject the profile if $RH > 95\%$. Convert RH into PV using saturation water vapor pressure and T.

Discussion

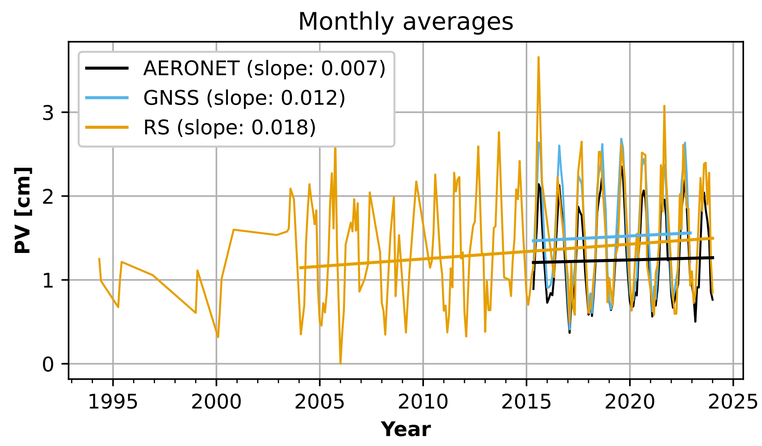
1) Comparison of instruments on co-located PV observations

- Use AERONET/GNSS observation that is nearest to RS launch time in ± 1 hour windows (31 co-located observations).
- All the instruments are highly correlated at statistically significant level.
- AERONET has a negative bias (MBE) respect RS/GNSS, and residuals increases as PV increases.

	r	p-value	MBE [cm]
RS−AERONET	0.983	$< 10^{-5}$	−0.22
RS−GNSS	0.991	$< 10^{-5}$	0.07
GNSS−AERONET	0.981	$< 10^{-5}$	−0.29

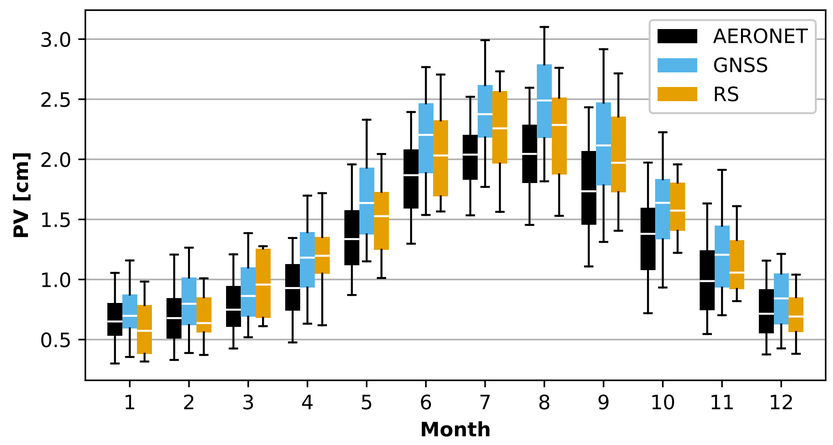
2) Time series analysis of monthly PV

- No clear trend, even if slightly positive for RS/GNSS.
- Mean PV is about 1.4 cm (RS/AERONET) and 1.7 cm (GNSS).



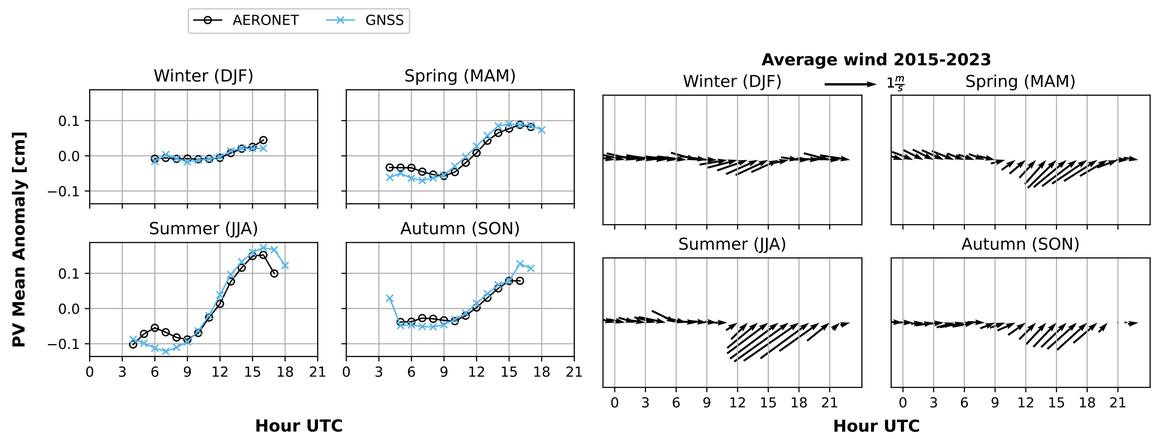
3) Annual cycle of PV

- Typical pattern for northern hemisphere.
- AERONET has lowest mean values (white line inside box), except in Winter.



4) Daily cycle of PV

- Higher variability of PV in Spring/Summer.
- The local minimum around 9-10 UTC is found in other studies, see [2].
- The hourly wind vector does not suggest any strong correlation of local orographic breeze with the local minimum.



Conclusions

- The three observation methods are **highly correlated**, but AERONET tends to provide lower values respect to RS/GNSS, and the residuals increases as PV increases.
- The annual cycle shows a **typical pattern** that can be found also in literature.
- Daily cycle has higher variability in Summer, and a **local minimum** at the end of the morning but this seems not likely due to orographic breeze.

References

[1] P. Basili, S. Bonafoni, R. Ferrara, P. Ciotti, E. Fionda, and R. Arnbrosini. Atmospheric water vapor retrieval by means of both a GPS network and a microwave radiometer during an experimental campaign in Cagliari, Italy, in 1999. *IEEE transactions on geoscience and remote sensing*, 39(11):2436–2443, 2001.

[2] A. Memmo, E. Fionda, T. Paolucci, D. Cimini, R. Ferretti, S. Bonafoni, and P. Ciotti. Comparison of MM5 integrated water vapor with microwave radiometer, GPS, and radiosonde measurements. 43(5):1050–1058, 2005.

We would like to acknowledge the AERONET Network for the sun-photometer data, the Italian Space Agency (ASI) for the GNSS data, and the Italian Ministry of Education for the funds for radiosoundings.

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