Raman Lidar Water Vapor Measurement Validation Using a One-Year Radiosonde Dataset in Payerne

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1. Introduction

Water vapor is a key component of the Earth's atmosphere (IPCC, 2007). Knowledge of the atmospheric humidity profile is of primary importance for meteorological and climatological applications. Since Summer 2008, the Raman Lidar for Meteorological Observations (RALMO) has been installed and tested in the radiosounding station of MeteoSwiss in Payerne, Switzerland (Fig. 1). This instrument provides continuous tropospheric water vapor profiles during day and night at a 30-minute repetition rate. Fig. 2 illustrates how the lidar bridges the gap between radiosonde profiles. With this lidar, short-term humidity changes in time and altitude above Payerne become visible. Here, we validate lidar water vapor profiles using a 1-year collocated radiosondes dataset.

2. Instruments & Dataset

Lidar: custom-designed instrument developed by the Swiss Federal Institute of Technology (EPFL) and MeteoSwiss (Dinoev, 2009). The lidar system uses a trippled Nd:YAG laser that emits laser pulses at a repetition rate of 30 Hz. The average power is approximately 9W.

Radiosondes: SRS-400, equipped with a capacitive Rotronic HC2 humidity sensor. This sensor has recently participated in the international intercomparison 2010 of high-quality radiosondes organized by the World Meteorological Organization (WMO).

Dataset: Data from 1 October 2009 to 30 September 2010. During this 1-year period, the lidar produced profiles 52.6% of the time, which represents a total of 9'086 profiles. Profiles reached an average of 6'879 m at night, and 3'545 m during the day. The radiosonde is launched routinely twice a day at 11:00 UTC and 23:00 UTC. For the year under study, a total of 771 operational profiles have been collected.

3. Results

Longterm drift. Since the recalibration at the start of October 2009, the system remained fairly stable, as illustrated in Fig. 3 which shows the temporal evolution of the difference between radiosonde and lidar at different altitude levels. Over an eight-month period from November 2009 to June 2010, the mean monthly bias shows a slight positive trend of about +0.12%/month at 1 km a.s.l. (+0.51% at 2 km a.s.l.). From July to September 2010, however, a negative trend of -4.4%/month is observed (-5.0%).

Water Vapor Profiles. On average, lidar water vapor mixing ratio was found to be within 5 to 10% of radiosonde values up to 8 km at night (Fig. 4), and within 3% up to 3 km during the day (Fig. 5). Relative humidity results show an agreement within 2 and 5% for day and night, respectively.

Integrated Water Vapor. Integrated water vapor measured with the lidar is compared with radiosonde, microwave radiometer and GPS measurements (Fig. 6). Lidar is found to have a dry bias compared to radiosondes (4.2% on average) and microwave radiometer (6.4%), and a wet bias compared to GPS (5.3%).

4. Outlook

This validation opens the door to the assimilation of lidar profiles into operational models such as Cosmo-2 (COnsortium for Small-scale MOdelling). Lidar data complements regular radiosonde data and gives valuable information on the state of the atmosphere between two radiosonde launches. It can be used to follow the evolution of humidity in the troposphere in near realtime. The next step concerning the development of the lidar is the retrieval of temperature profiles.

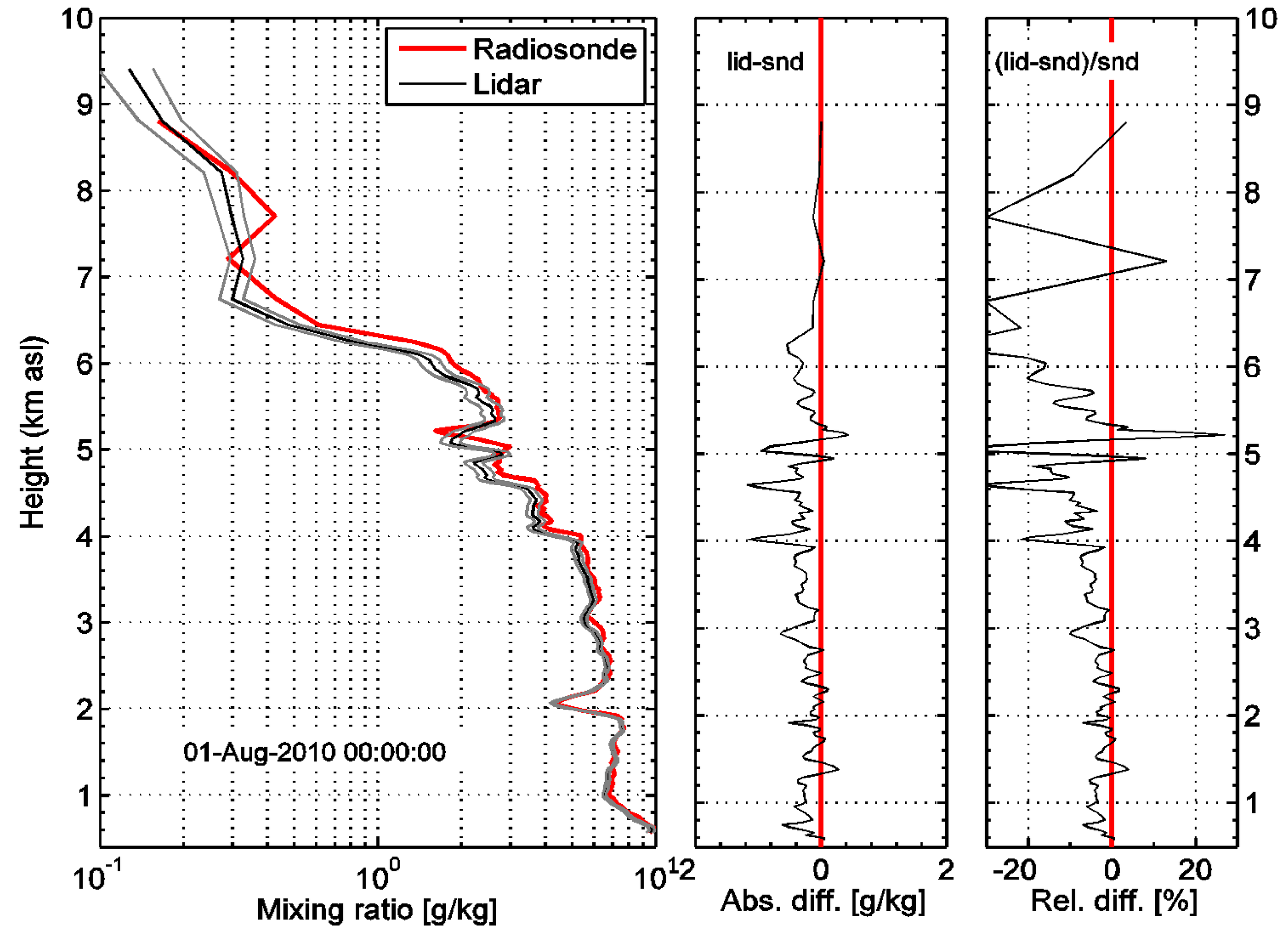

Fig. 1: Example of night-time water vapor mixing ratio profiles from lidar and radiosondes (left). Absolute and relative differences (middle and right).

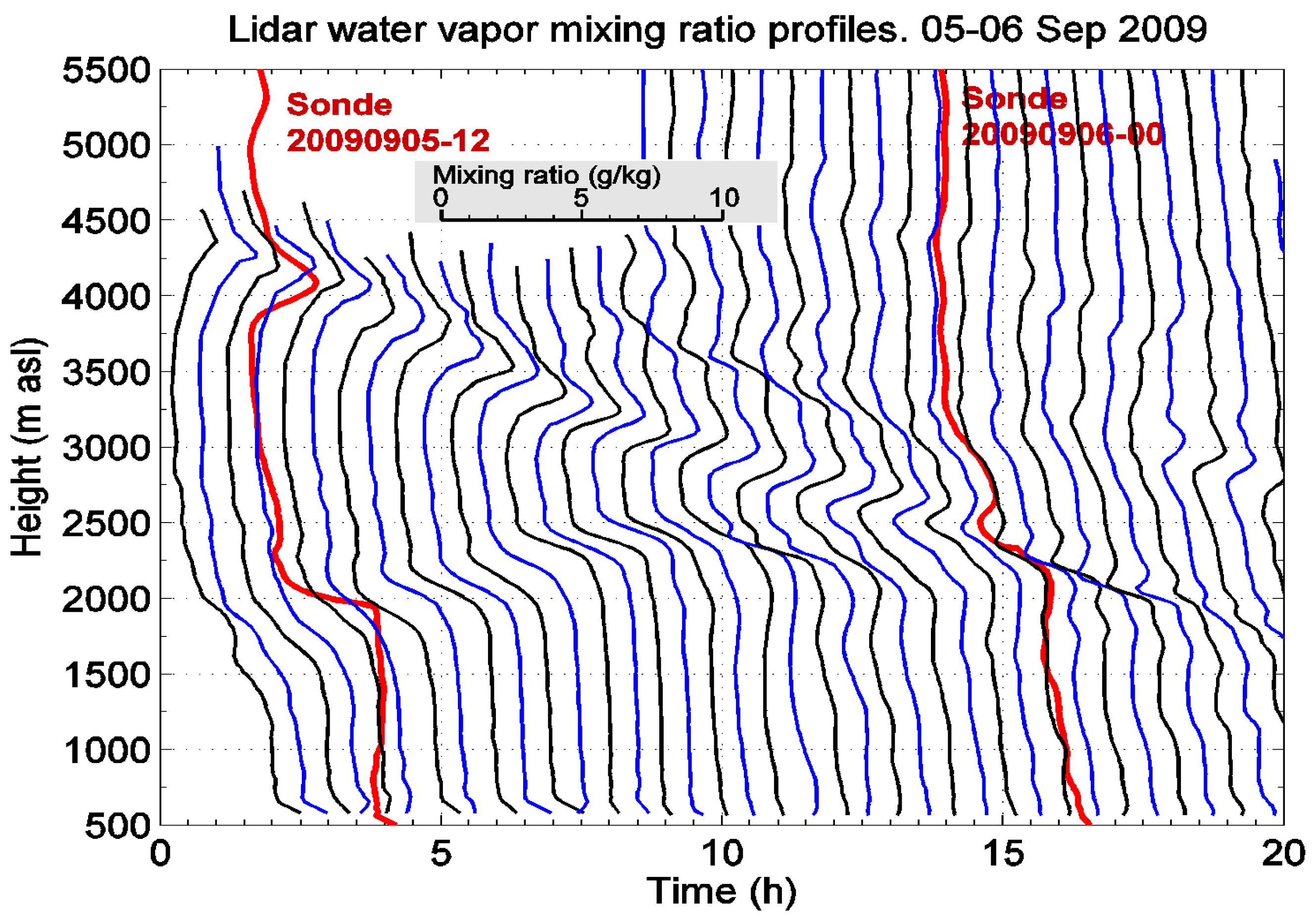

Fig. 2: Lidar water vapor mixing ratio time-series (blue and black) with radiosonde profiles (red).

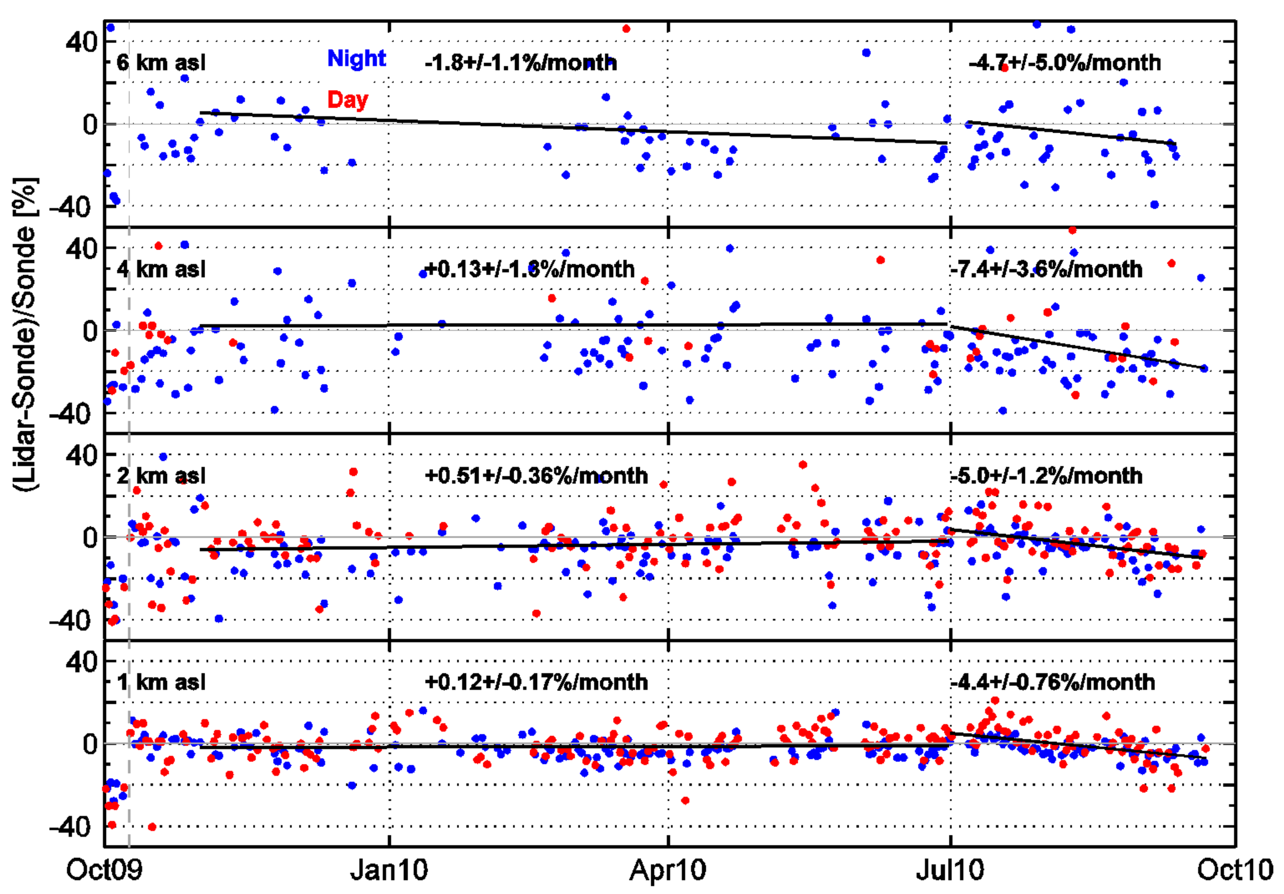

Fig. 3: Temporal evolution of the water vapor mixing ratio differences between lidar and sonde at different altitude levels.

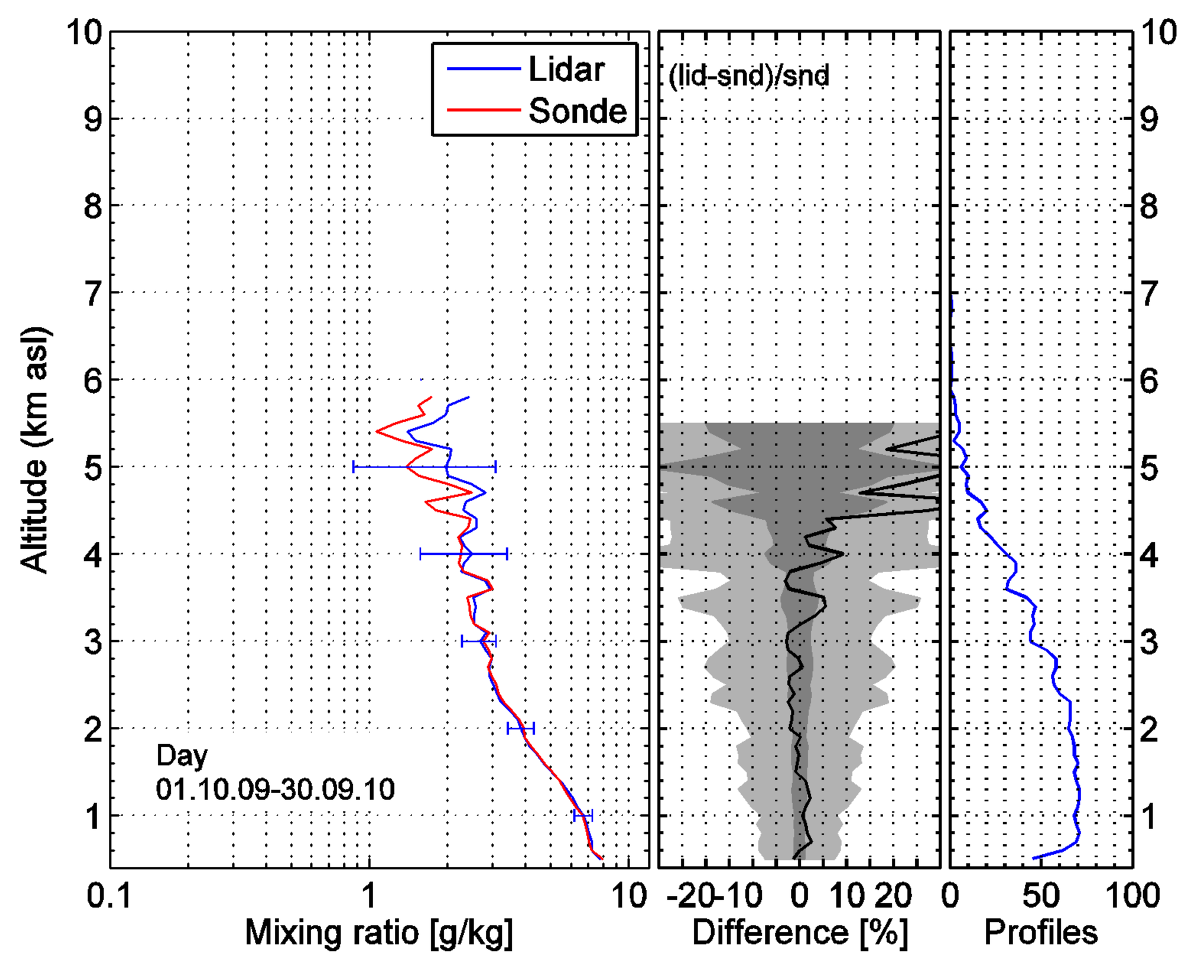

Fig. 4: Mean water vapor mixing ratio (left) and mean bias (middle) during day. Number of profiles (right).

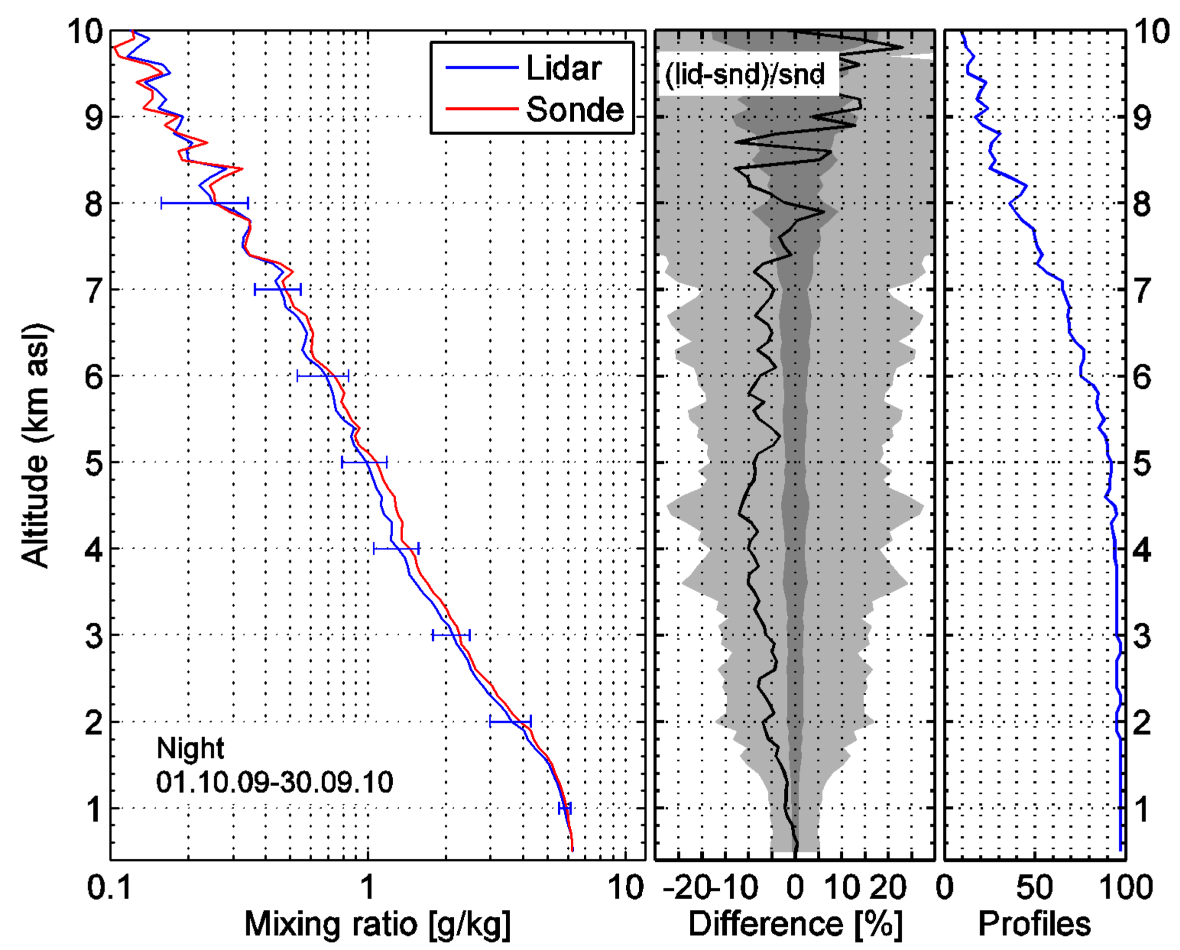

Fig. 5: Mean water vapor mixing ratio (left) and mean bias (middle) during night. Number of profiles (right).

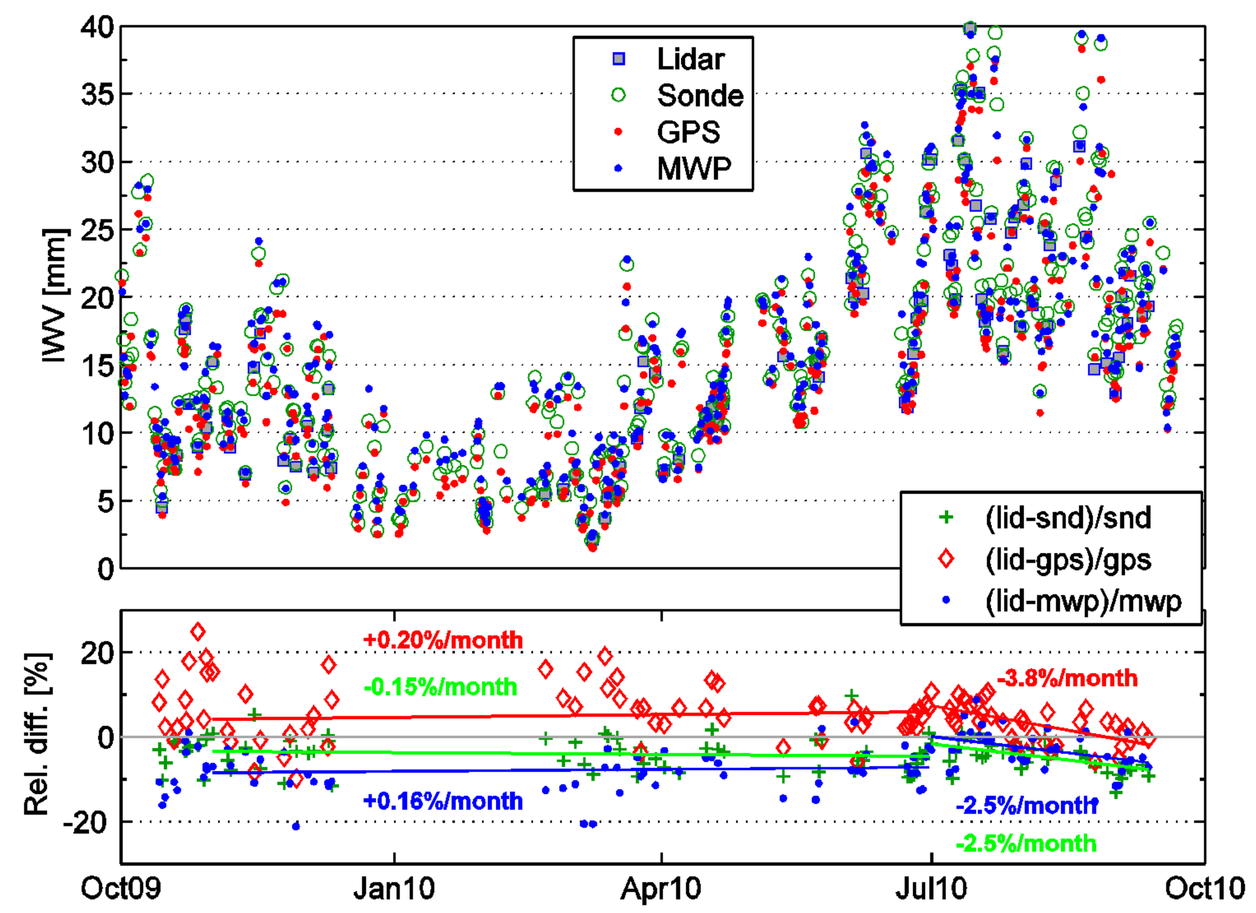

Fig. 6: Top panel: Integrated water vapor time-series above Payerne retrieved from lidar, radiosondes, GPS and microwave radiometer. Bottom panel: Relative difference.

References: IPCC: Climate change 2007: the physical science basis. Contribution of working group I to the Fourth Assessment. Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007.
Dinoev, T.: Automated Raman lidar for day and night operational observation of tropospheric water vapor for meteorological applications, Ph.D. thesis, Federal Institute of Technology EPFL, Lausanne, Switzerland, 2009.

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