2.5 COMPARING WATER VAPOR VERTICAL PROFILES USING CNR-IMAA RAMAN LIDAR AND CLOUDNET DATA

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1. INTRODUCTION

Atmospheric water vapor is a key element in the global radiation budget, because it has a main role because of its efficiency as green-house gas. In addition it is involved in the microphysical processes leading to clouds formation and development. On local scale, water vapor has a principal role because of its influence in the local weather especially for what concerns precipitations, with direct effects on the human activities (e.g. agriculture and tourism) and in severe events on human life and security too. Therefore it is important to represent this parameter in model for short term weather forecasts. Moreover, water vapor distribution is characterized by a large spatial and temporal variability, considerably different between troposphere and stratosphere, strongly influenced by both large-scale circulation and localized convection. This high variability in the water vapor field makes necessary a long-term comparison between accurate and high resolution observations and operational forecast models. The EU CloudNET project offers an extended database of water vapor profiles provided by five operational forecast models of ECMWF, the MetOffice, MeteoFrance, KNMI and DWD. On the other hand, at CNR-IMAA accurate vertical profiles of water vapor mixing ratio are provided with very high resolution in a systematic way since May 2002.

2. OBSERVATION SITE

A Raman lidar system for atmospheric water vapor vertical profiling is operational at CNR-IMAA (40°36'N, 15°44'E, 760 m above sea level) since May 2002. This lidar system is based on a Nd:YAG laser equipped with third harmonic generator with a repetition rate up to 100 Hz. Receiving system is based on a Cassegrain telescope (f=5m) and interferential filters are used for spectral selection. The elastic backscattered radiation at 355 nm, the N_2 Raman shifted signal at 386.6 nm and the water vapor Raman shifted signal at 407 nm are acquired each minute. For each wavelength, the signal is then split into 2 different channels for acquisition of both low and high range signals in photon counting mode.

An example of typical water vapor mixing ratio vertical profiles measured with CNR-IMAA Raman lidar is reported in Figure 1 and 2 respectively for nighttimes and day time conditions. In both cases, contemporary and co-located radiosounding profile is also reported. During night time, the profile extends typically up to 12 km a.s.l. with a vertical resolution ranging between 15-150 m and an integration time of 10 minutes. Statistical error is typically within 5% up to 8 km of altitude and stays within 10% in 8-12 km altitude range (Cornacchia, 2004).

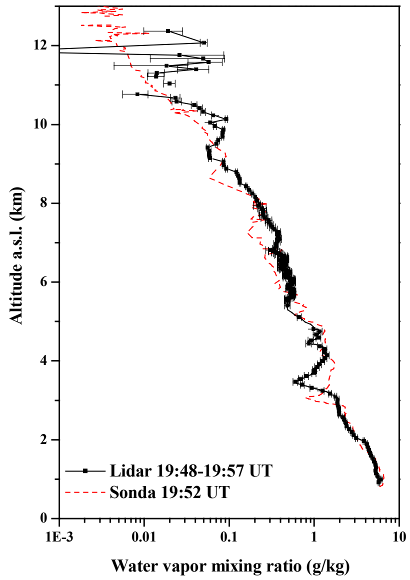

Figure 1: Example of CNR-IMAA water vapor Raman lidar vertical profile in night time conditions (black line). Simultaneous and co-located radiosounding is reported in red.

In daytime conditions, specific humidity vertical profile typically covers the altitude range extending between the surface and 5 km of altitude, because of the low signal to noise ratio of Raman signals. In this case, the vertical resolution is 15-300 m and the statistical error is lower than 5% up to 3.5 km and within 10% up to 5 km when an integration time of 10 minutes is used (Cornacchia, 2004).

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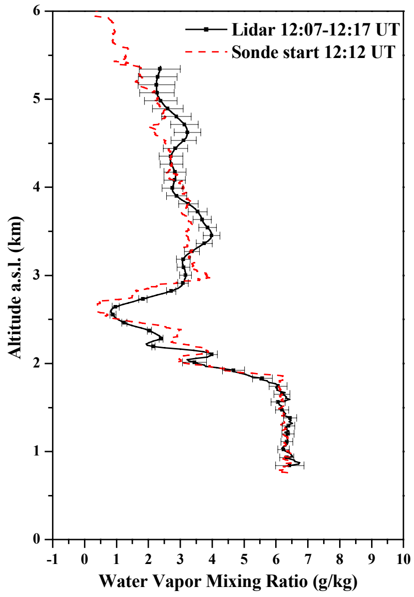

Figure 2: Example of CNR-IMAA water vapor Raman lidar vertical profile in daytime conditions (black line). Simultaneous and co-located radiosounding is reported in red.

Since July 2002, measurements are performed twice a week in an almost systematic way. Additional measurements are performed during special measurements campaigns (e.g. EAQUATE campaign in September 2004 and LAUNCH-2005 campaign in autumn 2005), when typically lidar system runs for many hours providing very long record of measurements (Cuomo, 2004; Cuomo, 2005; Ferretti, 2006).

First intercomparison of water vapor retrieval algorithms were performed within NDSC* (Network for the Detection of Stratospheric Change) (D'Aulerio, 2004). In this retrieval particular attention has to be devoted to the calibration of the Raman lidar system. In principle this kind of system can be absolutely calibrated, but the by the uncertainties on the ratio between the Raman lidar cross-sections of water vapor and nitrogen limits absolute calibration accuracy to about 10% (Whiteman et al. 1992). Calibration with independent water vapor measurements allows to achieve a better accuracy.

CNR-IMAA water vapor Raman lidar is calibrated by means of simultaneous and co-located radiosounding profile: first a devoted calibration campaign was performed in May-July 2002, then radiosoundings are systematically used to check the stability of the lidar calibration constant. Comparison with about 200 radiosounding profiles launched since July 2002 shows that for the same experimental configuration the calibration constant stability is within 5%. Since February 2004, the calibration of the Raman lidar is continuously checked by comparing integrated precipitable water vapor (IPWV) content obtained with the lidar itself and a multichannel radiometric profiles operational 24 hours per day at CNR-IMAA (Madonna, 2005). This allows to overall all the temporal resolution problem related to radiosounding water vapor measurements. Since IPWV is a derived product of the water vapor mixing ratio, when co-located radiosonde is available, calibration is provided by profiles comparison and microwave radiometer data are used to check the stability of the calibration constant on the whole observation period (see for example Figure 3).

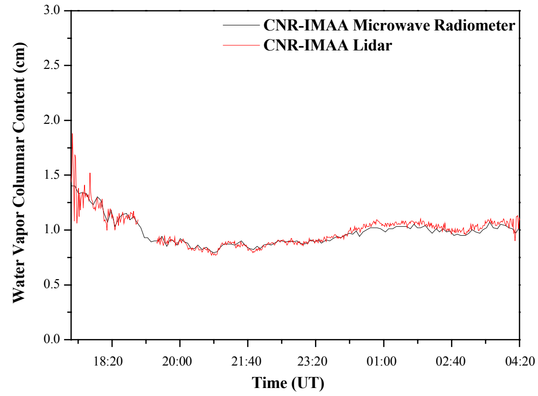

Figure 3 comparison between IPWV microwave radiometer and analogous quantity evaluated starting from Raman lidar water vapor profile calibrated with radiosonde profile.

3. COMPARISON APPROACH

An extended database of atmospheric water vapor is available within CloudNET. At the moment, this database consists of profiles provided by five operational forecast models of ECMWF, the MetOffice, MeteoFrance, KNMI and DWD. The horizontal size o resolution of these models is typically 50 km, and profiles have a vertical resolution between 0.5 – 1 km and a temporal resolution of 1 hour.

For a correct comparison with observational data, lidar high resolution profiles are reduced into a large grid boxes: vertical and temporal resolution are reduced to those of the model, and in this operation the new time grid is calculated on the base of wind speed to take into account the advection time. In all this procedure, only high resolution lidar data with a total error less than 50% are considered. For each box, water vapor mixing ratio mean value and standard deviation and mean error are calculated. In addition, the number of points considered within each box. Because of the 1 hour model temporal resolution, long records of measurements are needed for a significant comparison with the observations. During LAUNCH 2005 international campaign, a long record of measurements of about 30 hours has been collected at CNR-IMAA on 1-3 October 2005.

* On February 2006, NDSC changed its name to NDACC (Network for the Detection of Atmospheric Composition Change).

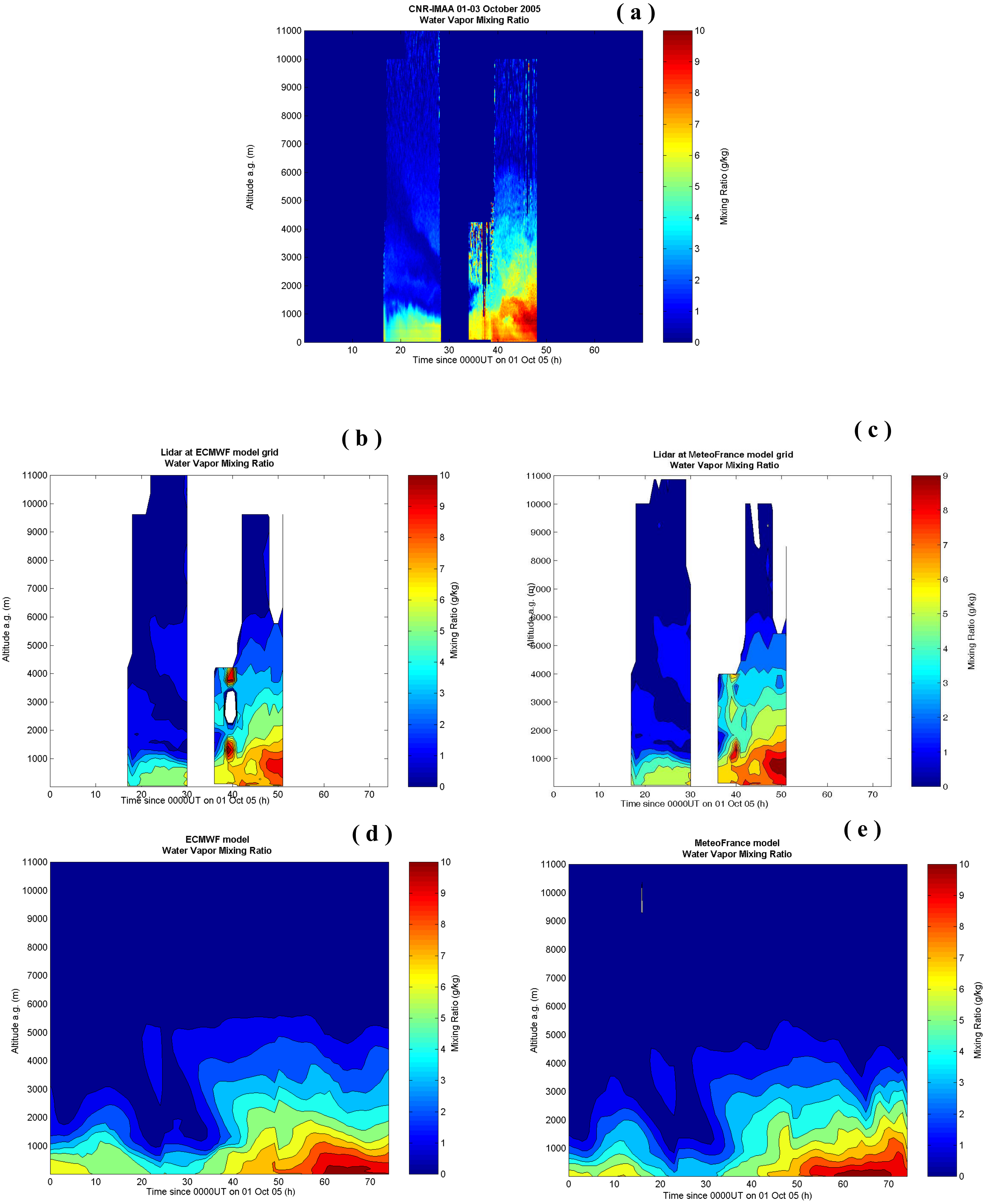

Figure 4: water vapor profiles temporal evolution provided by high resolution lidar data (a); Lidar data at ECMWF and MeteoFrance resolution grid (b -c); ECMWF and MeteoFrance model (d-e).

This case has been selected as a first case for the comparison with the model. High resolution lidar data are reported in Figure 4a (15 m, 1 minute). At the beginning of the record, the specific humidity is of about 5 g/kg below 1 km above the ground. Later on, the water vapor content of the low troposphere increases up to 9 g/kg during the night of 2-3 October. On the same night, the water vapor in the 4-5 km also increase (4-5 g/kg respect to 1-2 g/kg for the previous day). A dry layer is evident on 1-2 October night: this structure decreases in altitude from 6 km on 1 October, down to 2 km on 2 October.

At the present, ECMWF and MeteoFrance model data are available for 01-03 October 2005. Lidar data reduced to ECMWF and MeteoFrance resolution, taking into account the advection time, are reported respectively in Figure 4b and Figure 4c. Comparing Figure 4b and 4c, small differences are evident, probably related to different horizontal resolutions (40 km for ECMWF and 23 km for MeteoFrance) and to the different advection times provided by the models.

Figure 4d and 4e show the ECMWF and MeteoFrance model data for the considered period. Even if the models do not capture details in the evolution of water vapor fields, a good agreement is found in term of vertical structure and water vapor content. In particular, both the models see a dry layer intruding from about 5 km a.g.l. down to about 1 km a.g.l. and capture an increase of water vapor close to the surface and in the free troposphere the night 2-3 October. However, the lidar measurements show that water vapor is at least 1 g/kg up to 6 km, while both the models underestimate this altitude of about 1 km. In addition, in average both the models underestimate the water vapor content in the low troposphere, where the influence of local sinks and sources can be very strong, and orography has a big influence, producing differences between the 50 km horizontal resolution models and the punctual lidar measurements.

More quantitative comparison can be carried out in terms of the probability density function (pdf). For example, the pdf calculated for ECMWF (MeteoFrance) data, and for lidar data reduced at ECMWF (MeteoFrance) resolutions in the 0-2 km altitude range are reported in Figure 5 (6).

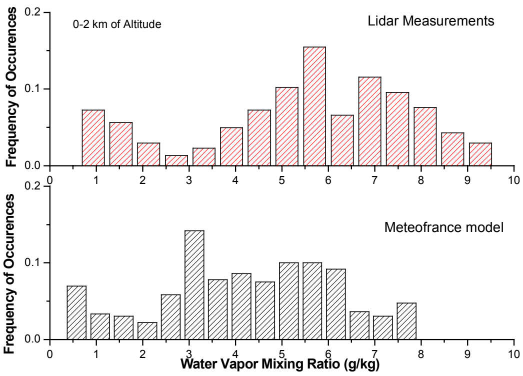

Figure 5: pdf of lidar and ECMWF data in 0-2 km range.

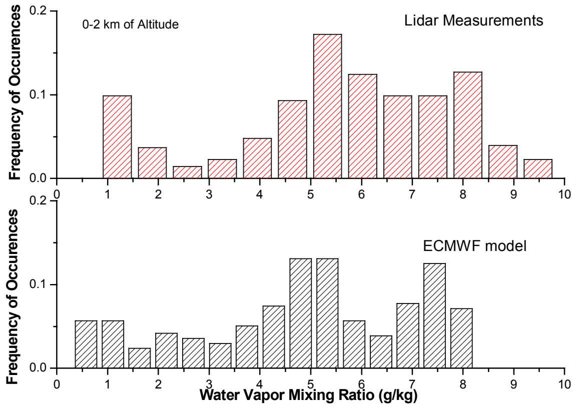

Figure 6: pdf of lidar and MeteoFrance data in 0-2 km range.

In both cases, even if with a shift toward low values, the models well reconstruct the shape of the distribution as a large almost Gaussian distribution with an additional peak around low water vapour mixing ratio values.

The comparison approach here presented for this case, will be applied to long record of measurements performed at CNR-IMAA since May 2002. First results on long term comparison between the 5 models and CNR-IMAA lidar data will be presented at the conference, focusing on the capability of the model to capture mean aspects of the water vapor field as well as on the possible discrepancies between observations and models.

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