Atmos. Meas. Tech. Discuss., 8, C4720–C4730, 2016
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Atmospheric Measurement Techniques Discussions
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Interactive Comment

Interactive comment on "Observations of water vapor mixing ratio and flux in Tibetan Plateau" *by* S. Wu et al.

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Received and published: 6 January 2016

Thank you for your review of our manuscript. We greatly appreciate the substantial amount of time and effort that you dedicated to this review process. Here we provide the response to you and you can also refer to the mark kept revision of PDF file in "Supplement". Thanks again. Review of "Observations of Water Vapor Mixing Ratio and Flux in Tibetan Plateau" by S. Wu, G. Dai, X. Song, B. Liu, and L. Liu This paper describes unique observations of water vapor and vertical wind speed using Raman and Doppler lidars in the lower troposphere over the Tibetan Plateau. Radiosondes are used for calibration of the Raman lidar. The paper contains novel and interesting data yet is only publishable after major revision because:

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1) The English language is poor, particularly in sections 1 and 2. These two sections must be considerably re-formulated.

A: Thanks, we have rewritten those two sections with improved English.

2) Throughout the paper I miss an interpretation of the data: we see here interesting observations differing substantially from standard atmospheric conditions that have to be better described and understood. I recommend the use of a simple trajectory model, e.g. Hysplit, freely available, to better understand the origin of the air sampled. I am not convinced by the authors' statement that the humidity variations are due to local evaporation variability. Also, additional information such as the weather situation and the lidar backscatter signals are needed to better understand the observed variability, also of the boundary layer height.

A: In the revision, the interpretations of the data measured in the Tibetan Plateau have been added. Please refer to the corresponding section, e.g. Fig. 10 and 11, in the revision. We used the trajectory model HYSPLIT for the analysis of the transportation of the moist air mass and it is found that the high water vapor mixing ratio maybe result from the input of the moist air mass from Southeast Asian warm pool region. Please refer to Fig. 8 and the corresponding discussion in the revision.

3) I am puzzled by the strong discrepancy between lidar and radiosonde humidity in Figure 6: not only are the lidar-derived H2O mixing ratios in the lowest layer, probably the nocturnal boundary layer, persistently larger than the radiosonde values, but also the thickness of this humid layer seems to be considerably smaller in the right half of the lidar plot. This cannot be the effect of noise in the lidar data, which is probably responsible for the high values and scatter at the top of the lidar plot (the authors should discuss this as well, and occasionally reduce their measurement range). It rather looks like a systematic issue that the authors have to find out and to explain.

A: We agree. The water vapor mixing ratio measured by WACAL in the lowest layer is effected by the overlap function. As a result, the values are not accurate and we have

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eliminated the water vapor mixing ratio data below the overlap region (i.e. $\leq$ 200 m) in Fig. 6 of the revision. For the flux analysis below 200 m, we used the data from radiosonde.

The overlap is shown in Fig 1 of the response, also provided in Fig. 4 of the reference:

Wu, S., Song, X., Liu, B., Dai, G., Liu, J., Zhang, K., Qin, S., Hua, D., Gao, F., and Liu, L.: Mobile multi-wavelength polarization Raman lidar for water vapor, cloud and aerosol measurement, Opt. Express, 23, 33870-33892, 2015.

As for "the thickness of this humid layer seems to be considerably smaller in the right half of the lidar plot", we add some new results in the Fig. 6 of the revision. According to the figure, the decreasing trend is not so distinct and we rewritten the statement of the trend. We also find the difference between water vapor mixing ratios measured by WACAL and radiosonde. This difference maybe results from the measurement time difference ($\sim$1.5 h) of the WACAL and radiosonde.

In Fig. 6, the water vapor mixing ratio measured by WACAL and radiosonde are presented. The time serials of water vapor mixing ratio from these two systems are provided in Fig. 6(a) and (c) respectively. And the trend of is shown and two dry or low water vapor content time periods are found. Fig. 6(b) and (d) provides the mean water vapor mixing ratio and the deviation measured by WACAL and radiosonde. The deviation of water vapor mixing ratio from WACAL and radiosonde which is shown in Fig. 6(e) indicates that the water vapor mixing ratio measured by WACAL is about 0.7 g kg-1 smaller than that measured by radiosonde. This result is also consistent with the mean deviation from Fig. 4 and can also explain the different of water vapor mixing ratio between Fig. 6(a) and (c).

Yes, the high values and scatter at the top of the lidar plot are probably because of the noise of the lidar and we have removed the data with low SNR (SNR<10). Please refer to the Fig 6 of the revision.

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4) I am also puzzled by the high specific humidities observed. The H2O mixing ratios in Figures 5 and 8b are five times higher than the global average, and still at least two times higher than in a typical tropical atmosphere at corresponding altitudes. Here, trajectory analyses may lead to more understanding. Perhaps the air came from the Southeast Asian warm pool region? Was it associated to the monsoon? The authors should also carefully check their thermodynamic calculations. Namely, I found an error in Figure 8b: the absolute humidity is much too high close to the surface, and probably too low at the top of the plot. Using standard atmosphere air density and multiplying with the H2O mass mixing ratio, which gives the absolute humidity, I estimate the absolute humidity to lie between about 7 g/m3 near surface, 3∼4 g/m3 in the middle and 5 g/m3 in the top of Figure 8b.

A: We used trajectory analyses for the understanding of the high water vapor mixing ratios. Four backward trajectories from NOAA HYSPLIT MODEL (Draxler and Rolph, 2003; Rolph, 2003) are provided here in Fig. 2 of the response. The black star represents the observation station of lidar in Nagqu. Base on the figure below, the high water vapor mixing ratio maybe results from the input of the air mass from the Southeast Asian warm pool region. And according to our observation by CDL, the east wind dominates the wind field in Nagqu area, which may indicate the influence of the Asian monsoon. As a conclusion, yes, perhaps the high water vapor mixing ratio is effected by the combination of the moist air mass from Southeast Asian warm pool region and Asian monsoon.

As for the thermodynamic calculations, yes, we have checked them and have corrected the calculation of the vertical water vapor flux according to the reference:

Giez, A., Ehret, G., Schwiesow, R. L., Davis, K. J., and Lenschow, D. H.: Water vapor flux measurements from ground-based vertically pointed water vapor differential absorption and Doppler lidars, J. Atmos. Oceanic Tech., 16, 237-250, 1999.

Since water vapor mixing ratio is the most common unit in boundary layer meteorology,

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we used it to describe the water vapor measurements throughout the work. We have also updated the results of vertical water vapor mixing ratio in Fig. 11. Please refer to the revision. (also you can refer to the Fig. 3 in the response)

5) The section on water vapor fluxes is too short and incomplete, and the data also here need to be better interpreted. Since this is a night time scene, there is likely low or no turbulence, and it is justified to use average values in Eq 14 to estimate the mean local water vapor mass flux. It would be very interesting to see a longer time series, or another measurement on a different night, for comparison. Where are the mentioned rain and clouds in Figures 8 and 9? Is a positive vertical wind directed up or downwards?

A: Thanks for you advise and we have added interpretation and some other explanation in the section on water vapor fluxes. We explained the method used for the preprocess of the water vapor mixing ratio and vertical wind data and interpreted the data of the case study measured on 15 August 2014. We also provided one longtime observation of vertical wind velocity in 24 h in Fig. 9 of the revision. The rain mentioned in Fig 10 and 11 (Fig. 8 and 9 in the original manuscript) began at about 22:00 LST and stopped at about 22:25 LST. The clouds are located at the height of 1.0 km to 1.5 km at time period from 21:40 LST to 22:25 LST. Please refer to Fig. 9, 10, and 11 and the end of the "Observation consequences and discussion" section. We also provide the corresponding figures in Fig. 4 of the response.

"Result from the unique atmospheric characteristics and heating power of the Tibetan Plateau, the longtime observation of vertical wind velocity is required. From this observation, the turbulence, updraft and downdraft at different time period in one day can be detected and analyzed. For this purpose, one case study on 15 July 2015 is provided in Fig. 9. During 0000 LST and 0927 LST, because of the low temperature and rare human and industrial activities, the boundary layer in Tibetan plateau is very low and cannot be detected by CDL with a minimum detection limit of 90 m. During the daytime, the turbulence can be found and the value of the vertical wind velocity is between

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±1 m/s . However, the turbulence in nighttime is rare and the vertical wind velocity is between 0 m/s and 1 m/s , which indicates that the upwelling of the atmosphere on the Tibetan Plateau.

In term of the vertical velocity and vertical water vapor flux, one case study on 15 August 2014 is presented below. Figure 10(a) shows the time serials of range correction signal measured by WACAL and Fig 10(c) is the time serials of the vertical velocity profile of 164 minutes obtained from the Coherent Doppler Wind lidar. By combining the water vapor mixing ratio (Fig. 10(b)) and vertical wind velocity, the vertical water vapor flux can be calculated and the temporal development is shown in Fig. 11. The temporal resolution (dt) and spatial resolution (dr) of the vertical wind velocity is 22 s and 13 m respectively. And the original dt and dr of the water vapor mixing ratio is 10 min and 3.75 m respectively. However, in order to sample the turbulent processes, the simultaneous observations with high and same dt and dr by WACAL and CDL are required. For this purpose, the dt and dr of WACAL are adjusted to be equal to those of CDL by means of interpolation.

The time serials of water vapor mixing ratio shown in Fig. 10(b) indicates that the water vapor mixing ratio inside clouds which are located at the height of 1.0 km to 1.5 km at time period from 21:40 LST to 22:25 LST is higher than in atmosphere around. The water vapor mixing ratio in the cloud is around 8.63±1.66 g/kg . According to Fig 10(a), it started to rain at about 22:00 LST. From these figures, it is noted that the water vapor kept upwelling and depositing and the flux is about 1.20 ±2.48 g/kg×m/s during 21:03 and 22:00 LST before the raining. Meanwhile, in the process of raining, the water vapor inside the clouds kept depositing and the flux is about -3.37±2.24 g/kg×m/s . Note that because of the coverage and blocking of the raindrop gathered on the windows of WACAL, the water vapor mixing ratio measured during the time period of 22:05 LST to 22:10 LST should be used carefully and is removed during the calculation of the flux. Consequently, a small-scale water vapor cycling was formed partly and the upwelling and deposition of the water vapor were monitored."

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/8/C4720/2016/amtd-8-C4720-2016-supplement.pdf

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Interactive comment on Atmos. Meas. Tech. Discuss., 8, 11925, 2015.

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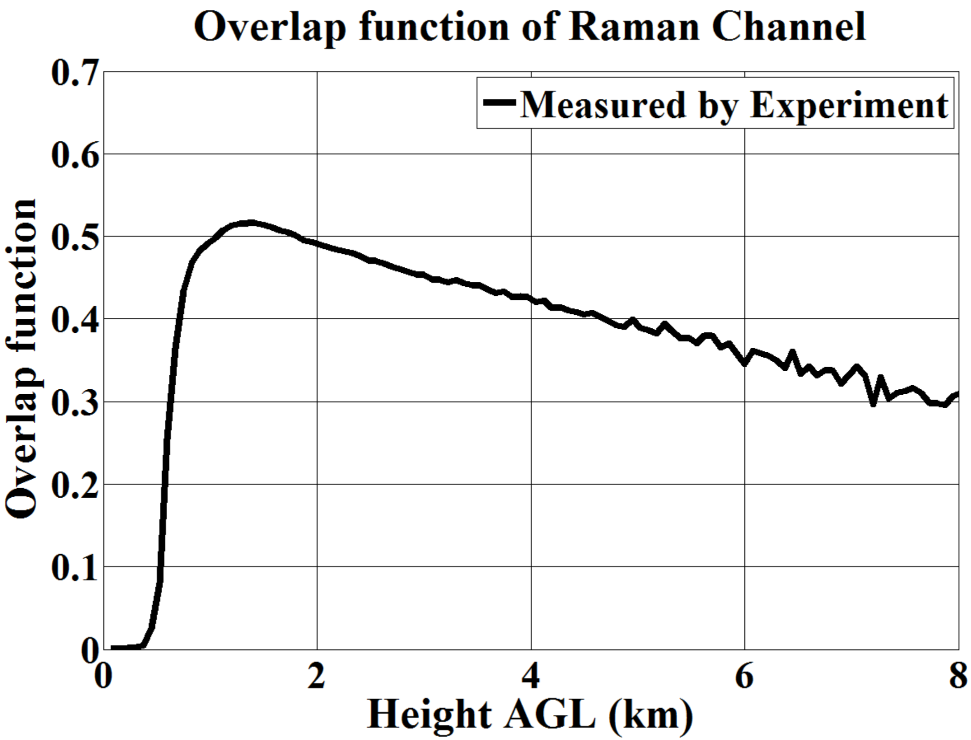

Fig. 1.

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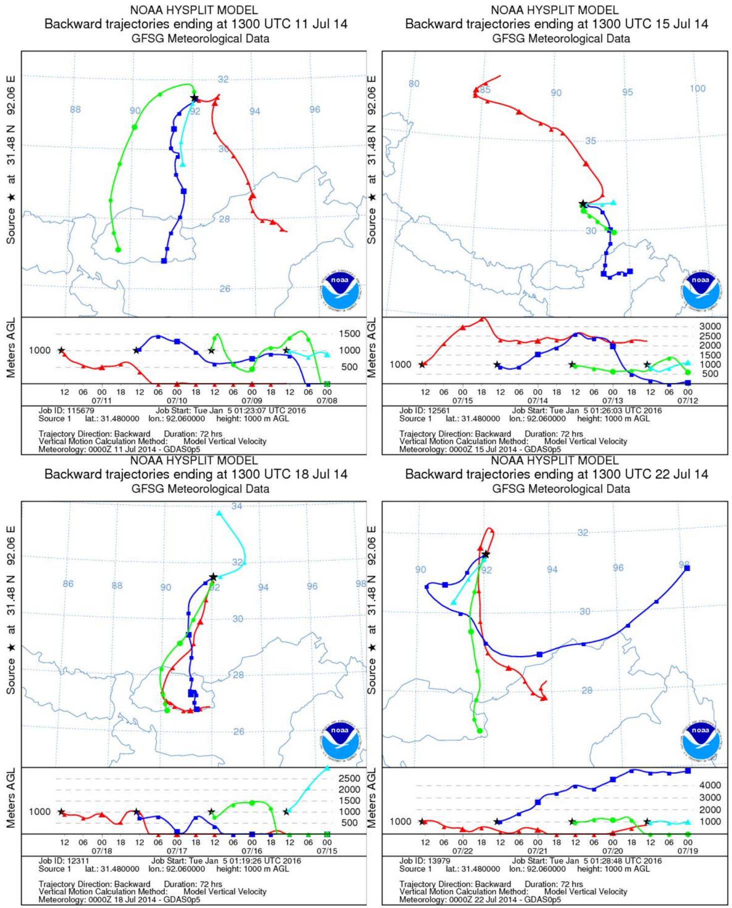

Fig. 2.

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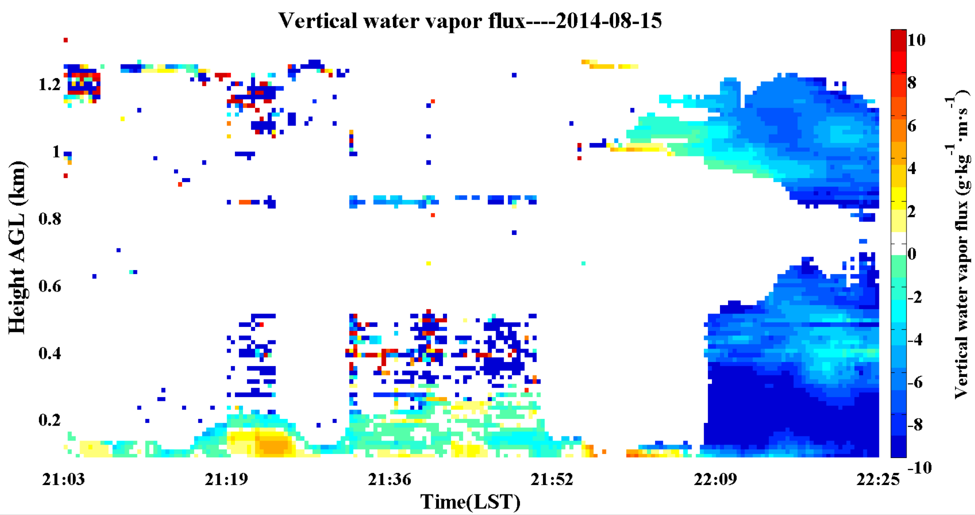

Fig. 3.

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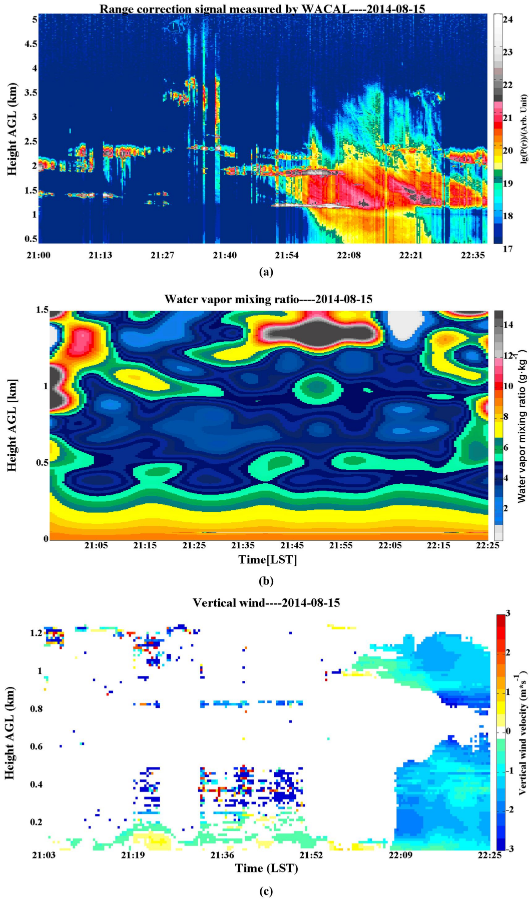

Fig. 4.

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