Responses to Review #2

The authors would like to thank the reviewer for his valuable comments which helped improving the quality of the manuscript. Our point-by-point responses to the reviewer's comments appear in bold below.

Comment on the general areas for improvement:

While the technical aspects are thoroughly addressed, a stronger emphasis on the broader implications of the data for climate science and weather forecasting would enrich the paper. Connecting the results more explicitly to their potential impact could enhance the manuscript's significance.

The authors understand this comment to strengthen the implications of the lidar data for climate science and weather forecasting. The purpose of this ESSD article is to describe the WaLiNeAs database and how we retrieve the water vapor mixing ratio. The instrumental error budget is described and the errors are provided in the database.

A paragraph explaining the meteorological conditions encountered during the two WaLiNeAs campaigns has been added to section 2.2.2. This paragraph explains the different meteorological situations encountered during WaLiNeAs, enabling the different water vapor contents stored in the database to be associated with the meteorological context.

"Looking back over the campaign, the first part of the WaLiNeAs field campaign during the autumn and winter of 2022/2023 was characterised by two distinct periods. A fairly wet period was observed between October and mid-November corresponding to the period of HPEs (Flamant et al. 2021). However, no HPE occurred during this period. This was followed by a dry period from mid-November to mid-January 2023, during which the atmospheric water vapor content was very low, with values below 10 g kg^{-1} in the lower troposphere. In Toulouse, the summer of 2023 was marked by two significant meteorological situations. The first occurred in June 2023. It was characterised by thunderstorms and heavy rainfall with a cumulative rainfall water of 131.9 mm near Toulouse, which is a record for the last 10 years (https://www.infoclimat.fr/climatologie-mensuelle/07630/juin/2022/toulouse-blagnac.html, last access 10/08/24). The second was in August 2023, when a record heatwave hit the whole of southern France and the Mediterranean basin. July and September 2023 were within seasonal norms."

The detailed discussion of calibration and instrumentation, though important, somewhat overshadows the practical outcomes related to weather events, which are the primary goal of the study. A more balanced focus would improve clarity.

We think that the discussion on the calibration method and instrumentation is very important because these results are new and could lead to advances in lidar technology in the future. However, we are considering improvements in the construction of the text as detailed above. It is worth noting that for users of the database, it is very important not only to know what the error bars are, but also how they were obtained. This is also one of the focus of the ESSD articles.

Specific comments:

Abstract:

Comment on line 12

The two main objectives stated in the abstract have been adressed, however with varying degrees of completition. The first one ("Investigating the water vapor content during heavy precipitation events (HPEs) in the Western Mediterranean coastal regions") has been fully addressed, while the second ("Assessing the impact of high spatio-temporal WVMR data on numerical weather prediction forecasts using assimilation techniques") is partially achieved, with further work on data assimilation still pending. While the paper discusses the potential for these high-resolution datasets to be assimilated into models like AROME to improve weather forecasts (line79), it does not yet include a completed analysis of this assimilation's impact. The authors emphasize that the lidar data fills critical observational gaps, particularly in the lower troposphere, and mention plans for further assimilation work. However, they don't present results demonstrating the improved prediction accuracy within this paper.

The assimilation process is not in the focus of ESSD. WaLiNeAs is a project in partnership with Météo-France, who is responsible for assimilating the lidar data and quantifying their impact using AROME. This work is ongoing. The WaLiNeAs database is open to the international scientific community and can be used by other meteorological groups.

Comment on line 15

The claim of being the first program in Europe to provide network-like, simultaneous, and continuous water vapor profile measurements should be reconsidered. Existing networks like PollyXTNet, EARLINET, and RAMSES have similar capabilities. Please consult these references: …

The authors have added some references to the text and would like to thank the reviewer for these. However, the references given relate either to lidar networks but for the study of aerosols, or to instruments that are indeed for the measurement of water vapor but not deployed with other instruments as part of a project like WaLiNeAs, especially in Europe. The references Reichardt et al.2012 and Foth et al. 2015 have therefore been added to present other lidar instruments and to present the calibration method using a microwave radiometer as it is indeed relevant to mention it.

For WaLiNeAs, it is the deployment of multiple lidars measuring simultaneously water vapor over a period of several months that is unprecedented. The following sentence has been modified to precise the exact measurement period: "WaLiNeAs is the first program in Europe to provide network–like, simultaneous and continuous water vapor profile measurements over a period of 3–4 months."

Comment on line 18

Although the paper mentions continuous monitoring for three months, the three lidar instruments did not operate simultaneously during this entire period. Please clarify this aspect.

The text has been modified to clarify the fact that the lidars were not working simultaneously: "This measurement setup enabled the monitoring of the water vapor content within the low troposphere over a period of three months over autumn – winter 2022, with some interruptions, and four months in summer 2023".

Introduction

Comment on line 36: Clarify the sentence regarding "humid air masses from the Saharan regions over the Mediterranean Sea." It seems the authors intend to convey that air masses become humid as they traverse the Mediterranean Sea, rather than originating as humid over the Sahara.

The reviewer is right. The text has been changed as indeed the air masses become humid as they traverse the Mediterranean Sea: Saharan air masses, absorbing moisture from the Mediterranean Sea and air masses for the Atlantic Ocean are advected over the western Mediterranean Sea and reach the coast of southern France, which leads to HPEs".

Comment on line 42: Rephrase to avoid confusion: "leading to an increase in water vapor content up to 5 km in the free troposphere" could be improved by citing Chazette et al. (2016), which suggests the moistening occurs progressively up to 5 km.

The sentence "leading to an increase in water vapor content up to 5 km in the free troposphere" has been changed into "which leads to a progressive increase in the water vapor content up to 5 km in the free troposphere."

Comment on line 64: The lidar calibration at the Météo-France site in Toulouse occurred after the campaign, which raises questions about timing. Was there a reason this validation was not conducted before the campaign, and how did this sequencing affect the results?

The same comment has been made by the other reviewer. The term "validation" has thus been removed. In fact, the authors found that it was not correct to present the Toulouse campaign in this way. The Toulouse campaign is part of the WaLiNeAs project as a second field campaign measurement. The authors specify in the text that there was an opportunity to validate the calibration of the HORUS-2 lidar in Toulouse, but it was not the purpose of the second campaign in Toulouse.

Comment on line 68: Harmonize the references to the AERIS database across the manuscript and ensure that the access date is provided for both links.

The references to the AERIS database across the manuscript have been harmonized following the reviewer's advice.

Section 2:

Comment on line 91:

While discussing the Raman lidar sites, mention that they provide continuous, high-resolution water vapor profiles at specific, localized points, and cannot capture broader spatial variations.

We add the fact that "the Raman lidar sites provide continuous, high-resolution water vapor profiles at specific, localized points, but cannot capture broader spatial variations".

Comment on Figure 2:

Enlarge and change the colors of the labels (“a, b, c, d”) for better visibility.

The modification of the labels (“a, b, c, d”) has been made.

Comment on Figure 3:

Including a photo of the WALI instrument would enhance reader comprehension, alongside the existing truck station image.

We understand the reviewer's comment, but a picture of the lidar inside the truck would not contribute to a better understanding of the lidar. The optical scheme shown in Figure 4 provides more and better information.

Comment on line 175-176:

Elaborate on how acquiring both N2-Raman and H2O-Raman channels for each telescope improves the signal-to-noise ratio, as this is a critical point.

More precision has been provided to justify a better SNR has more photons are acquired: “as twice as many photons are received”.

Comment on line 178:

Specify if the lidar is operational during precipitation events, and discuss any limitations.

More precision has been provided to explain how lidars are acquiring during precipitation events: “It is important to note that rain does not prevent the lidar from acquiring data, although the range of the lidar is reduced”.

Comment on line 179:

Explain how the sky background can affect signal acquisition and potentially degrade measurement quality.

More information has been provided to explain how the sky background can affect signal acquisition and potentially degrade measurement quality: “Indeed, during daytime, the sky background does not represent a usable part of the signal and thus limits the range of the lidar for measuring water vapor.”

Comment on line 194-195:

For better readability, move the sentence "Table 2 provides an overview of the system’s key characteristics for each lidar" to the end of the paragraph.

The sentence has been moved to the end of the paragraph.

Comment on Table 2:

Define the acronym "(AC)" in the last row for clarity.

The term "AC" has been removed as it does not provide useful information.

Comment on Figure 4:

Include additional explanation in the text about "3ω" and "2ω" and the "seeder input", as well as the implications of WALI's unique configuration with the rotational and vibrational Raman Polychromator.

The term "3ω" has been added next to the sentence "The three lidar systems use pulsed frequency–tripled" for a better understanding of this notation. The sentence: "Unlike HORUS, the WALI laser has an injector (seeder imput in Figure 4b) to stabilise the wavelength, which is essential for good temperature measurement" has been added in the text to explain the purpose of the seeder.

Comment on line 217:

Consider adding "on-site" after "manually" for better clarity.

The words "on site" have been added.

Comments on Figure 6:

• The blank spaces for HORUS-2 from 5/11/22 to 12/01/23 should be marked as "no data" and highlighted in red for consistency.

- **The blank spaces for HORUS-2 have been put into red to better highlight the fact that there was no data after 5/11/2022.**

• Standardize the timeline format—either daily or monthly—for both periods of the campaign (Oct22-Jan23 and May23-Sept2).

- **The comment is difficult to apply. Indeed, it is important for us to show the daily availability of the data during the first part of the WaLiNeAs campaign. These data will be used by Météo-France to test the impact of lidar data assimilation in the AROME mesoscale model. They therefore need the daily data availability for each lidar. Concerning Toulouse, the lidar was off during a few days at the beginning of July 2023 as explained in the text. Including all the days from 31 May to 25 September 2023 in the table would make it even more difficult to read.**

• If you choose the daily basis, I would make the squares smaller, so the timeline fits in a small space (ideally in one-line timeline) for a better readability (e.g. consider naming the days only with a number instead of the full date to make the squares smaller and in the interest of clarity).

- **As explained above, the format of the figure is difficult to change.**

• In case you choose to show the month name, use abbreviations "Jan." and "Dec." instead of "janv." and "déc".

- **The comment has been applied. We there use abbreviations “Jan.” and “Dec.” instead of “janv.” and “déc”.**

Section 3:

Comment on line 243:

There is inconsistency regarding the native time resolution (1 minute (Table2) vs. 50 seconds (line 243). Ensure this is harmonized across the manuscript (also in Fig. 9 it is said “approximately 1 min”).

The authors understand the confusion. Correction has thus been made. The time resolution of the lidar has been harmonised to 1 min throughout the paper.

Comment on line 244:

Clarify whether the lidar acquires range-corrected Raman signals or if this is done post-processing.

Correction has been made to clarify how we acquired range-corrected Raman signals. We specify that the lidars “directly” acquire range-corrected Raman signals. This is not done post-processing.

Comment on Equation 1:

Please add the definition for Oi(z) in the text.

Information has been added in the text to explain the term Oi(z), which represents the overlap factor.

Comment on Equations 4 to 11:

Use consistent nomenclature for the water vapor channel throughout the manuscript, e.g., “H2O” in Equation 4 vs. “H” in later equations.

The use of “H_2O” has been replaced by “H” to harmonise the text.

Comment on Equation 6:

Please consider adding more information and development on how you came up with equation 6 from equations 1 and 2.

More information has been provided to explain how we obtain Eq.6 from Eq 1 and 2 : “By calculating the ratio of the two channels H and N from equation 1 and using equation 2 we can then calculate r_H from the lidar profiles according to the relationship:”

Comment on line 275-288:

More information has been provided on the refractor telescope used in WALI in Table 2.

Comment on line 300:

Provide more details on εm and εa to aid reader understanding.

More details have been provided on εm and εa : "where the relative bias associated with correctly estimating the optical thicknesses and Angström coefficients of molecules and aerosols is given by ε_m and ε_a."

Section 4:

Comment on line 335-336:

Clarify how the calibration between a ground site station and a lidar measurement at 200 m a.g.l. is performed. Why was radiosonde (lines 421-423) data not used for calibration, given the vertical profile data they provide? Is the 45 km distance the limiting factor?

The sentence: "This section shows the results of the method described in section 3.3" has been added to better understand what is the calibration method employed here (section 4.1). Concerning the use of radiosonde for the calibration, we want the radiosonde to serve as a validation for the calibration. Initially we had not planned the Toulouse campaign. We therefore had to find a method of calibrating our lidars without radiosondes. The method using the PTU is the one employed to calibrated our lidars. We think that this method is innovative, although it does have its limitations, and calibrating our lidars in this way will allow us to carry out future studies on lidar calibration, with the pros and cons of each method. The Nîmes radiosonde used for HORUS-1 was 50 km away, which is a long way to go to obtain two comparable atmospheres. However, it was the only radiosonde we had to try and validate our calibration method for HORUS-1. The result shows that the calibration is not aberrant.

Comment on line 346-347:

Please elaborate more the sentence "This shows that therefore, the cross-calibration method is relevant".

The sentence has been changed for clarity: "This linear relationship allows a cross-calibration between the two telescops as the ratio of the calibration constants of T1 and T2 is constant."

Comment on Figure 8:

There is no reference in the manuscript to the "Periods used for calibration" mentioned in Fig. 8.

- **Reference has been added in the text to better understand the "Periods used for calibration" in the figure.**

The phrase "correspond to each other" is unclear. Please rephrase to clarify the meaning.

- **The sentence "correspond to each other" has been changed for clarity: “Examples of time series during which lidars and ground–based weather stations WVMR were almost the same are given on figures…”**

In the text it is used the acronym “RMSD“ instead of “RMS deviation”.

- **“RMS deviation” has been changed for “RMSD”**

Comment on line 366:

I guess the authors mean to refer to Figs. 10a and 10b instead of 11a and 11b.

The reviewer is right, correction has been applied to refer to figure 10 instead of 11.

Comment on line 396:

typo in the word “conside” should read “consider”.

Correction has been applied for the word “consider”.

Comment on lines 426-428 and line 434:

please clarify if you are describing “mean differences” or mean “RMSD”.

We changed the text to clarify that we are describing “mean differences”.

Comment on line 428:

Soften the statement "This can be explained by..." to "This could be explained by..." since this has not been definitively proven.

The words "This can be explained by..." have been changed to "This could be explained by...".

Comment on line 433:

what was the effect of the radiosounding drifting in these measurements?

The sentence: ‘This drift implies that the water vapor field may have been different from what would be expected if the radiosonde had ascended in a straight line. This problem represents one of the limitations of radiosondes for lidar calibration. Its impact is very difficult to quantify.’ Has been added to explain the effect of the radiosonde drift.

Comment on Table 4:

is there a typo in the flollowing WALI ranges?

There is no typo in the Table. The numbers are right.

Section 5:

Comment in Table 5:

Provide more information regarding the “file_version” in the dataset name format.

More information has been provided in the description of Table 5 regarding the “file_version” in the dataset name format : “The “file-version” term in the first line indicates whether the file version is the first (1), second (2), etc... If a new version of the file is uploaded, the file version changes.”