We want to thank the reviewer for their time and careful consideration of the manuscript. They have brought several important points to our attention. Reviewer comments are included below in black and our responses are printed inline in blue. *Italic* text is used to quote text in the manuscript.

Reviewer 1

I find that the author make sufficiently clear that their method of signal processing improves the results from multi-pulse-length LIDAR measurements, in that it enables to merge data obtained from longer and shorter laser pulses and extract a better picture of water vapor distribution in the atmosphere. Therefore I recommend this paper for publication. I have only minor issues that I hope the authors might clarify.

1) Abstract: It is not clear to me why longer pulses should blank the detector. If the energy is distributed over a longer time, the dynamic range of the detector should not be the limit. Please explain it better. Is this only due to the fact that no data can be recorded while the pulse is still on its way out of the laser? Or there are other processes involved (see following point)?

From a simplest, first order perspective the reviewer's description provides an intuitive model for understanding why shorter pulses are needed to see lower. The instrument is effectively blind as the laser pulse exits and therefore a longer pulse forces a higher minimum altitude. Please note that the laser pulses employed by the MPD are much longer than are typical with solid state lasers. Typical MPD laser pulses of 1 μs result in a blanking range of 150 m. However there appear to be some larger complexities that result in a longer time before accurate data can be recovered. At this point, we don't feel that we fully understand all the contributing factors. While we are willing to discuss these factors (and we continue to investigate them), we also want to be clear that they are also beyond the scope of this particular work.

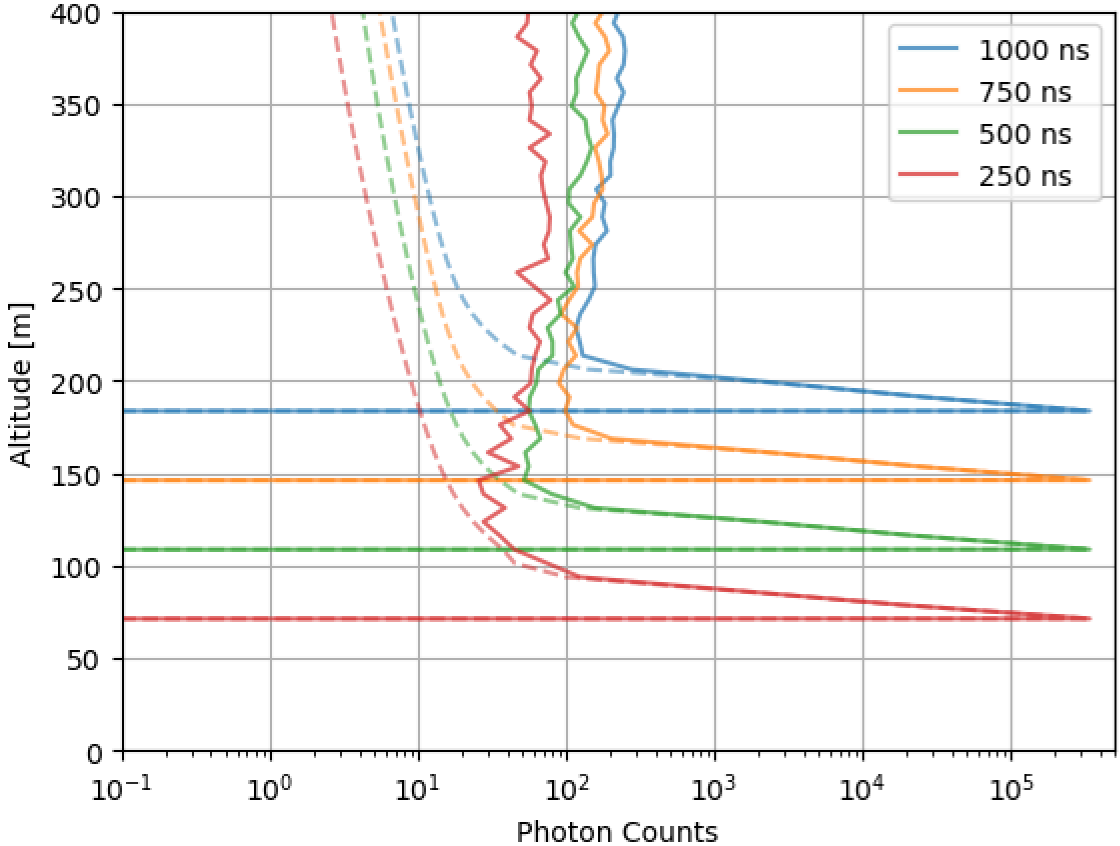
To help clarify this, we have revised the final paragraph in the masking section to read
In addition to masking due to potential errors in the noise model, the long pulse channels tend to experience a bias in the lower altitudes associated with the pulse length and recovery time of the detector. The way these potential errors impact biases in the instrument and ultimately impacts the minimum altitude of data products is discussed in detail in \cite{Spuler2021}. These errors are in part due to the fact that data is not valid while the pulse is exiting and thus the long $1 \mu s$ pulse blanks the receiver (which is electronically gated during the pulse exit) for 150 m. However errors persist in the recovered signals beyond this time and do not appear to linearly scale with the laser pulse length. The exact causes of this "recovery time" effect are still not fully understood and may be related to stray light, detector recovery time after exposure to high optical intensity (while gated), afterpulsing, transient effects of detector gating or a combination of all four. Ultimately, sloping baseline biases and transient detector responses can cause errors in the retrieval, particularly at low altitudes where backscatter signals from the atmosphere are relatively weak due to low overlap (see Figure 11 in \cite{Spuler2021}). The recovery time after the pulse exits does not appear to extend as high with the shorter pulse length. This effect is not encapsulated in the NLL so a heuristic solution of masking data below

500 m on the long-pulse observations and below 65 m or 80 m (for 100 ns and 200 ns pulses, respectively) on the short-pulse channel is employed.

We currently believe that potential contributing factors related to corruption in the backscattered signals at low altitudes are related to combinations of scattering in the instrument, detector afterpulsing, nonlinear optical amplifier response to drive current, residual deadtime errors, detector response to the gate and detector illumination while gated.

Factors such as scattering can cause the exit pulse to extend beyond the actual "on" duration due to increased optical path length, but we presently believe that scattering probably just dictates the *amount* of corrupting pulse signal coupled into the receiver. Extended tails in the response are believed to be the product of afterpulsing in the detector AND nonlinear responses in the optical amplifier (after the current is turned off, similar to afterpulsing, trapped carriers recombine to continue to emit a weak, decaying signal which can be scattered into the receiver). These tails, because they are not constant in range, and atmospheric signals are comparatively low, can cause biases in DIAL retrievals. Gating the detector significantly decreases the amount of afterpulsing from the detectors, but the detector still may experience some recovery time after the gate is reenabled, resulting in a sloping baseline response effect. Additionally, the baseline response of the detector does appear to be influenced by the light exposure even while the gate is applied. Finally, deadtime, while corrected using more advanced methods (see Kirchhoff et al 2025) may not be adequately addressed due to insufficient range resolution at the steepest parts of the baseline response curves.

Many of these terms will tend to dominate the backscatter signals nearest the instrument where signal photon counts are low and thus contribute significant errors. Note that removing these terms relies on accurate estimates of the baselines, doesn't account for some of the stated potential factors, and poor correction can increase errors. The figure below shows some example data of a system transmitting 4 different laser pulse lengths along with the associated measured baseline calibrations (dashed lines). While it's clear that the shorter pulses produce valid data at lower altitudes, the exact location where that data is valid is likely beyond the point where the detector gate is turned on (something seen circumstantially based on the fact that the retrieval is biased).



In order to push retrievals lower, we will need to better understand these kinds of effects and how they can be characterized and modeled to provide corrections or uncertainty estimates. This is an area we are actively working on, but for now, leveraging a combination of multiple pulse lengths appears to help address the problem without comprehensive knowledge of it.

2) Page 7: "In addition to masking due to potential errors in the noise model, the long pulse channels tend to experience a bias in the lower altitudes associated with the pulse length and recovery time of the detector (the exact causes of this effect are still not fully understood and may be related to stray light, detector recovery time, afterpulsing or a combination of all three)."

How is the dependency of this effect on the pulse length. Can you give a quantitative answer?

As per our response above, we don't fully understand the factors involved. For example, it appears that the nonlinear response of the optical amplifier is different for different pulse lengths. But we have also noticed that the detector response after the gate is reenabled seems to change based on the amount of illumination while the gate is disabled. To avoid over speculation, we have not made any changes to the manuscript in response to this comment.

3) Figure 5, bottom right panel. The authors discuss the noisy data (blue line), but the average value of the blue line seems to be much shifted toward higher humidity as well. Can they explain it?

As discussed starting at line 313 in the text, the retrieval appears to suffer from poor regularizer selection on this day, possibly due to improperly tuned masking criteria (highlighting a drawback of optimizing regularizers for every scene). We don't really agree that the blue line is "much shifted toward higher humidity". The visible data is approximately 0.5 g/m^3 higher than the other profiles, but a lot of the lower swings have been masked based on the QC masking criteria, so the masked view tends to be slightly biased.

We have added some clarifying language to better explain this near line 313.
In this dataset, the short pulse and the combined retrieval (with optimized regularizer) are both very noisy. This suggests that some of the processing criteria are not necessarily well tuned for this configuration (e.g. masking criteria and minimum altitude of long pulse). The forward model of the 100 ns short pulse may also be less accurate as the rise time of the amplifier output is not necessarily negligible at this short of a pulse length. However the excessive noise likely stems from improper regularizer selection, as the combined processing using a fixed regularizer is not nearly as noisy and appears to recover the water vapor structure relatively well. This demonstrates how optimization of the regularizer may not always produce the best results when corrupted data is used to estimate the optimal values. It also demonstrates how further work on establishing optimal pulse length combinations would be highly useful for establishing the best mode of operation for this multi-pulse-length technique.

4) What happens if instead of short and long pulses one used only short pulses with more or less energy? I understand that this might not be possible with the present setup, but what if?

For improved signal to noise ratio, higher pulse energies are generally better, but we don't really know how this might alter the aforementioned corrupting terms that extend beyond the laser pulse length.

We are not sure what the reviewer asks is physically possible, but engaging in the hypothetical: One advantage of short pulses is that the pulse length need not be deconvolved from the observations if they are very short (standard Nd:YAG pulses being on the order of a few ns). In a perfect world, modulating the power but leaving the pulse length constant would make more standard image fusion techniques (combining lower power noisier pulses with higher power less noisy pulses) more practical. As it stands, PTV is doing double duty by both denoising the image and deconvolving the pulse width from the observation.