We have addressed all of the points raised by the reviewer (copied here and shown in black text), and include our responses to each point below (in blue text). Where there has been a major change in the manuscript we provide the original text (in black italics) and the new text (in blue italics).

1 Anonymous Referee 2

1.1 General comments

The paper presents a practical method for characterizing the "telescope aperture function" of a pulse heterodyne lidar. As explained in the article, this function is required to correct the intensity of the signals recorded by the instrument (termed SNR as it is normalized to the level of white noise in the heterodyne lidar) from the variations of the instrument sensitivity with the range. This function is more complicated than with a direct-detection aerosol lidar as it is not given by the overlap between the laser beam and the telescope aperture, but has more to do with the efficiency of the heterodyne detection. However, an expression exists that predicts how it varies with the range as a function of two system parameters, namely the size of the telescope aperture D and the focal length f. The idea is to tune these two parameters until the corrected signal intensities match the attenuated backscatter measured by a nearby ceilometer. Of course, this method requires the presence of ceilometer nearby, but ceilometers are rather cheap instruments, and are deployed in great numbers in meteorological observation networks. The method opens the possibility to use a heterodyne wind lidar as an aerosol lidar and thus combine with a unique instrument the measurement of wind and aerosol backscatter profiles. This is of great interest for the characterization of pollution transport or the study of the atmospheric boundary layer.

There are several limitations to the method. One deals with the difference of the laser wavelength of a ceilometer (usually close to $0.9\mu m$) and a pulsed heterodyne lidar ($\lambda \approx 1.5\mu m$). The value of the attenuated backscatter are different at the two wavelengths, and the difference is dependant of the nature the aerosols. The method would thus be in trouble if several layers of different aerosols are present in the laser beam. This limitation is clearly discussed in the text. There is, however, a second limitation. The heterodyne efficiency does not depend solely of the instrument parameters, but also on the optical turbulence. This dependency appears in equation (2) of the article with the ρ_0 parameter. It is assumed in article that $\rho_0 >> D$ so that its effect on $A_e(R)$ can be neglected. This assumption is not justified. In practice, it can happen that the turbulence significantly degrades the heterodyne efficiency of the lidar. This is particularly the case when the beam is directed horizontally, a few meters above the ground, on a hot, sunny day. In the article, the vertical (or close to vertical) direction of the beam should alleviate the degradation as the optical turbulence drops very rapidly with the altitude, but it would be worth to have a short calculation of ρ_0 as a function of the range using a typical profile of ${C_n}^2$ and the formulation of Frehlich and Kavaya for ρ_0 (equation 165).

This is a very good point. Discussion of the impact of refractive turbulence has been added as a new subsection 4.3 together with an additional figure (figure 7 in the new manuscript).

So far we have neglected the potential impact of turbulence on $T_f(R)$ arising from the refractive turbulent parameter, ρ_0, in (2). An expression for ρ_0 is given in (Frehlich and Kavaya, 1991),

$$\rho_0(R) = [Hk^2 \int_0^R {C_n}^2(z)(1 - z/R)^{5/3} dz]^{-3/5}, \tag{1}$$

where $H = 2.914383$, $k = 2\pi/\lambda$, and ${C_n}^2(z)$ is the refractive turbulence at range z. We chose 3 profiles with constant ${C_n}^2(z)$, and a realistic vertical profile based on the most turbulent case presented by (Roadcap and Tracy, 2009). Figure 1 shows the impact that these different profiles have on $T_f(R)$, and the resulting re-sampling calculation of $\sigma_{T_f}(R)$ for two Doppler lidar instruments with different $T_f(R)$. Values of ${C_n}^2$ up to $10^{-14} m^{-2/3}$ have negligible impact on $T_f(R)$, and even the realistic profile only showed a slight increase in $\sigma_{T_f}(R)$ for the instrument with a focus set closer than infinity. This suggests that the impact of turbulence can be safely neglected for low values of ${C_n}^2$, and for most applications, can also be neglected when operating in the vertical. Hence, turbulence has no significant impact on the methodology described here for deriving the parameters f and D and their uncertainties from vertical profiles, but can be included for completeness.

However, it is clear that the turbulent impact should not be ignored when measuring at low elevation angles close to the horizon, where a profile similar to ${C_n}^2 = 10^{-13} m^{-2/3}$ may be possible. Fig. 1 shows that such a profile has a major impact on $T_f(R)$, especially in the far range. In these cases, the parameters f and D obtained from vertical measurements are still applicable, but $\rho_0(R)$ must also be calculated or estimated in order to derive the profile of attenuated backscatter, $\beta'(R)$.

An additional paragraph has been added to the conclusion.

The impact of turbulence on $T_f(R)$ was also investigated and was found to have no significant impact on the methodology described here for deriving the parameters f and D and their uncertainties from vertical profiles. However, the turbulent impact should not be ignored when measuring at low elevation angles close to the horizon, as it can modify $T_f(R)$ considerably, especially in the far range. In these cases, the parameters f and D obtained from vertical measurements are still applicable, but the turbulent contribution to $T_f(R)$ should included when deriving the attenuated backscatter coefficient.

It is written in the abstract that the method proposed in the article is applicable to Halo Photonics heterodyne Doppler lidars. It is clear that it is tested on data from Halo Photonics lidars, but I do not see why it could not be ap-

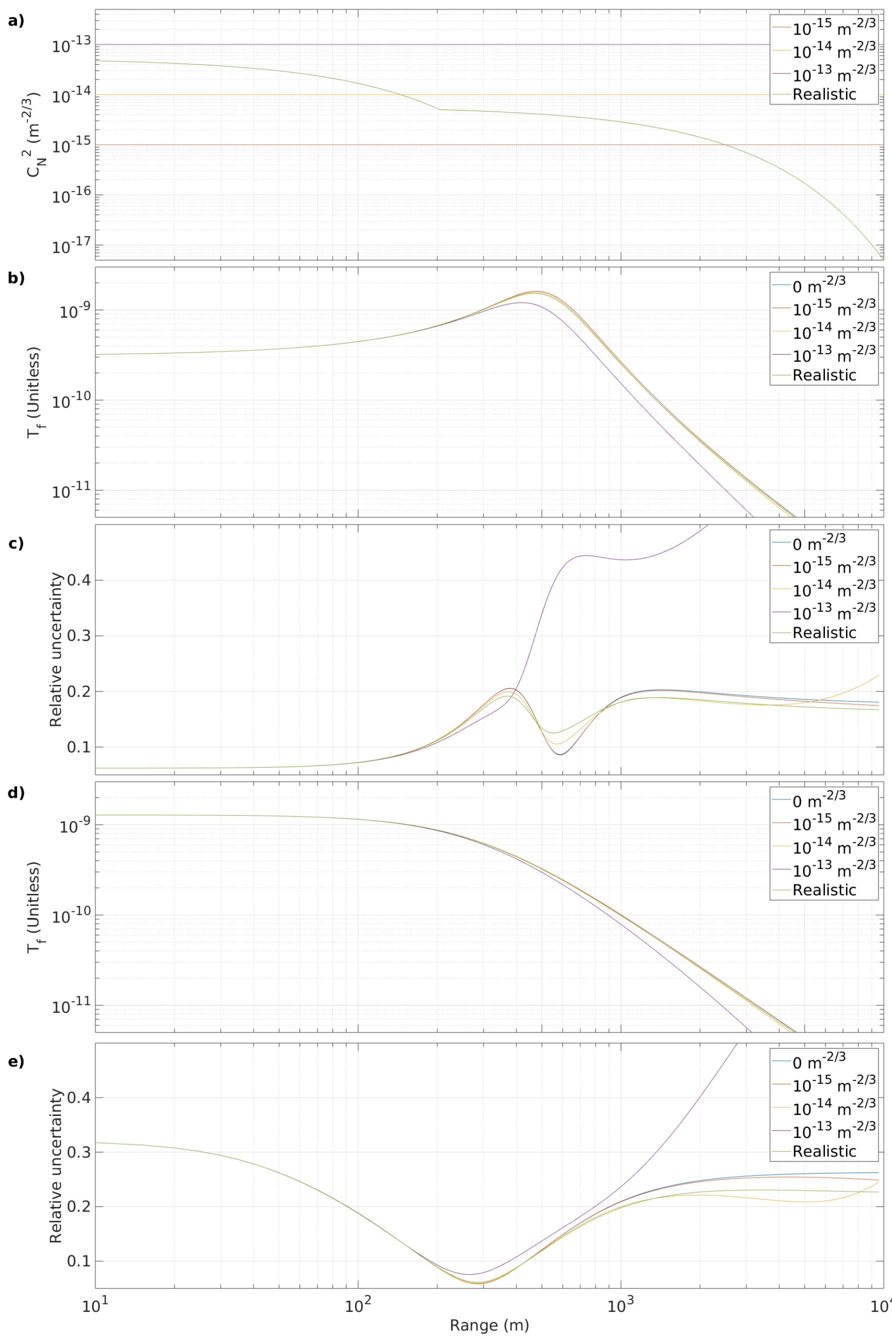

Figure 1: Impact of turbulent parameter, ρ_0, on telescope focus function, $T_f(R)$ and relative uncertainties, $\sigma_{T_f}(R)$, for different ${C_n}^2$ profiles. a) selected profiles of ${C_n}^2$ with range; b) $T_f(R)$ and c) $\sigma_{T_f}(R)$ for Darwin, 21 June 2011 to 22 July 2012; d) $T_f(R)$ and e) $\sigma_{T_f}(R)$ for NSA 30 July 2014 to 31 December 2017.

plicable to heterodyne lidars from other manufacturers as long as they provide measurements of SNR. If that is true, it would be worth mentioning it in the abstract as it widens the applicability of the method.

This is correct, and is now mentioned in the abstract and the conclusion.

Here, we present a methodology for deriving the telescope focus function using a co-located ceilometer for pulsed heterodyne Doppler lidars. The method was tested with Halo Photonics Streamline and Streamline XR Doppler lidars, but should also be applicable to other pulsed heterodyne Doppler lidar systems.

We have developed a method for deriving the telescope focus function and its uncertainty for pulsed heterodyne Doppler lidars, and applied the method to Halo Photonics Streamline and XR Doppler lidars.

1.2 Specific comments

1. In the paragraph that follows equation (1), the meaning of the η term is not explained.

   η is the detector quantum efficiency has been added to the text.

2. Equation (5): the equation applies to relative uncertainties. This shall be made clear.

   We have clarified this in the text.

3. Line 28: why this -22.2dB SNR threshold?

   The threshold is based on the SNR limit in Manninen et al.(2016) as the data we used has been processed with the same method. This threshold is based on the expected noise floor for the instruments considered here (Halo Streamline and Streamline XR) and should probably be modified for different instruments. A citation for the threshold has been added.

4. Table 4 on page 13: the meaning of b in N(f-2, b) and N(f, b) is not explained in the legend.

   The term b was a mistake, it is supposed to be D. This has now been corrected.