Reply to Reviewer 1

We thank the reviewer for his review and his detailed comments.

Below you will find the reviewer's comments in bold and our replies.

1 Introduction

L 16: Abbreviation ALADIN not introduced.

We will add the meaning of this abbreviation.

Please revise the citations for the Aeolus mission. E.g. Lux et al., 2021, is a paper on a very specific topic on laser frequency stability and probably not a good reference for the whole Aeolus mission. A good overview of the Aeolus mission is given e.g. by ESA (2008).

We revised the citations related to the Aeolus mission. As suggested, we added ESA (2008) as a reference for the Aeolus mission.

In line 24f, you motivate the WIVERN radar as a complementation of current global wind measurements in cloudy conditions. However, you do not clearly state the limitations of the other observation techniques, especially Aeolus, before. This could be added e.g. in line 21.

Two sentences have been added to the paragraph to add context.

Aeolus only measures winds in clear sky (so called ``Rayleigh winds'') and at inside thin clouds (``Mie winds''). Scatterometer measurements can also provide complementary observations at the surface, with significant progress being recently achieved even in presence of strong winds near heavy rain (Polverari, 2022). Similarly, winds at cloud top can be derived from successive satellite images of clouds and humidity, the so-called Atmospheric Motion Vectors. However, apart from sporadic and sparse radio soundings and aircraft penetrations, no wind observations are currently available inside thick clouds and precipitating systems.

2 Mispointing errors

Your whole paper is based on equation (1). Could you please add a proper derivation of this very important equation?

We will add a better derivation in the manuscript. The hydrometeor Doppler velocity, v_D, is obtained by subtracting the component of the spacecraft velocity, v_{SC}, along the antenna boresight form the measured Doppler velocity, v_{mD}. Thus, $v_D = v_{mD} - v_{SC}\sin(\theta)\cos(\varphi)$, where θ and ϕ are the elevation and azimuthal pointing angles, respectively, and with the second term of the equation representing the projection of the spacecraft velocity along the antenna boresight. If the actual pointing of the antenna has a mispointing of δθ and δϕ in the elevation and azimuthal angle respectively, the mispointing error will be: $\delta v_{mis} = [v_{mD} - v_{SC}\sin(\theta)\cos(\varphi)] - [v_{mD} - v_{SC}\sin(\theta+\delta\theta)\cos(\varphi+\delta\varphi)]$

$$\frac{\delta v_{mis}}{v_{SC}} = [\sin(\theta+\delta\theta)\cos(\varphi+\delta\varphi) - \sin(\theta)\cos(\varphi)]$$

$$= \left[(\sin(\theta)+\cos(\theta)\delta\theta)\big((\sin(\varphi)+\cos(\varphi)\delta\varphi)\big) - \sin(\theta)\cos(\varphi)\right]$$

$$\delta v_{mis} = v_{SC}[-\sin(\theta)\sin(\varphi)\,\delta\varphi + \cos(\theta)\cos(\varphi)\,\delta\theta]$$

3 Doppler correction methods

Eq (2): The variable $H_{S/C}$ is not introduced.

$H_{S/C}$ is the spacecraft altitude. We added the meaning of it in the text. Also changed notation to H_{SC}.

L 79: Why “therefore”? Maybe better “unfortunately”?

We agree with your suggestion, and we replaced “therefore" with “unfortunately”.

L 87: blue -> orange dashed

Corrected.

L 88: How is the noise subtracted? Does this noise subtraction method have an impact on the precision of your correction method(s)?

The noise subtraction is via a standard procedure (e.g. description in Kollias et al. 2022, added). Here we have first simulated noise according to the Wivern spec (and add to the signal generated by the surface), then the noise level is estimated by averaging clear sky bins; finally, this estimate is subtracted from the total signal.

L 140: Why 0.4 m/s? In the introduction you state that it should be below 0.3 m/s.

In the introduction we are saying that previous studies have considered mispointing errors negligible (i.e. lower than 0.3 m/s). This is not the case anymore. Additional text has been added to explain what the current requirements are. In order to fulfill the mission requirements, when counting for the other contributions (pulse pair estimator error, non uniform beam filling, wind shear) the pointing contribution of the random LoS Doppler velocity error budget must be of the order of 0.4-0.6 m/s whereas the requirement for the systematic contribution has to be smaller than 0.3-0.6 m/s.

L 151f: Why do you choose these box sizes?

Because they correspond roughly to from (500 m x 500 m) to (500 m x 5 km), which are the instantaneous WIVERN footprint and the area after 5 km integration, respectively.

Figure 7: What is the difference between dashed and solid lines? Description is missing.

The solid lines are referred to the forward pointing case (azimuthal angle = 0 degrees), while the dashed lines are referred to the side view pointing cases (azimuthal angle = +-90 degrees). We will add the description in the caption of the figure.

L265: The method is in detail described by Weiler et al. 2021. So maybe this is a better reference here.

We replaced the reference as you suggested.

Figure 13: Is this Figure really necessary?

Yes, we think that this figure is important because it explain how winds can be reconstructed and properly sampled in in-cloud region with reflectivities exceeding about –15 dBZ from the CloudSat database.

L 182: Why only between -65° and 65° latitude?

Since we want to compare the winds retrieved at side views during the descending orbits with the ones retrieved at side views during the ascending orbits, we preferred to exclude latitude close to the orbital inclination because those latitudes mark a transition for side LoS winds from zonal to meridional winds.

Figure 14: Difficult to see the difference between solid and dotted lines. Please adapt line style.

All lines are solid but have different markers now.

4 Summary and conclusion

L 332: And on which time scales can such models be considered unbiased? What about the wish to have model-independent measurements?

In our study we used ECMWF, which can be considered unbiased at global scale probably on weekly time scales. Comparison with radiosoundings and aircrafts suggest expected bias <0.3m/s with standard deviations around 2.5m/s.

In the introduction you motivate your study with phase 0 industry studies showing mispointing errors above 0.3 m/s particularly for slow varying components. Are the time scales of your methods sufficiently fast to correct for these? So, what exactly are "slow varying components"? This should be addressed either here or in the introduction.

Different error contributions have been classified and assigned to systematic or random errors according to the split frequency of 1.16e-5 Hz, which corresponds to 1 day period. Thus, "slow varying components" are the mispointing power spectral density components characterized by a period larger than 1 day. Time scales of method #1 and #2 are enough fast to correct these errors. Method #3 is slower than the previous two and can be used to correct slowly changing mispointing errors. Time scale of method #4 is driven by the time scale at which the reference model can be considered unbiased; in our analyses we used the model provided by ECMWF and it looks very effective to correct these errors. We will address this in the introduction.