Review "Estimating Beam Pointing of Vertically Pointing Cloud Radars Using Radiosonde Measurements" by Min Deng, et al.

This manuscript addresses a fundamental assumption underlying vertically pointing cloud radar measurements. Such measurements rely on accurate vertical beam alignment so that Doppler velocity observations are not influenced by the horizontal wind component. Although this assumption is commonly adopted, it is not always systematically verified in practice. The manuscript presents a practical method for assessing cloud radar beam pointing using collocated radiosonde observations. Reliable identification and correction of beam-pointing offsets are essential for obtaining accurate vertical Doppler velocity measurements and for the retrieval and interpretation of cloud dynamical properties.

The manuscript features a strong introduction, a generally well-written methodology, and a clear presentation of the results. The figures are informative and effectively support the main findings, while the uncertainties are discussed and explained. Nevertheless, several methodological aspects would benefit from further clarification to improve reproducibility and better justify certain choices. In addition, some concepts and methodological details are repeated throughout the manuscript, which occasionally interrupts the flow. Streamlining these sections would improve the overall structure and readability.

For these reasons, major revisions are recommended before the manuscript can be considered for publication. The study addresses an important practical issue in cloud radar observations, but additional methodological detail is needed to facilitate reproducibility and strengthen the interpretation of the results.

Recommended revisions:

1 Introduction

lines 120-123: "Existing approaches have primarily relied on engineering alignment procedures, statistical characteristics of Doppler velocity, or comparison with independent wind measurements."
Please briefly describe these existing approaches and provide appropriate references. This would help placing the proposed method in the context of previous work.

line 137: "The method exploits the cosine dependence of Doppler velocity on wind direction to retrieve off-zenith pointing angle and to quantify their impact on Doppler velocity observations"
Please clarify whether previous studies have already used the cosine dependence of Doppler velocity on wind direction.

2 Data description

2.1 Cloud radar observations

line 152: It would be helpful to include the range and Doppler velocity resolutions of both radar systems used during CAPE-k.

line 166-170: Some of the points made in this paragraph have already been introduced earlier. Consider shortening or consolidating these statements to avoid repetition.

2.3 Case study of the Vd contribution from horizontal wind

line 201 Please explain why this particular date was selected for the analysis. What makes this case especially suitable compared to other days during the campaign?

line 212: "consistent with expected fall speeds of small ice particles in stratiform cloud conditions." Remind the reader what typical fall velocities of ice particles are.

Fig. 1: Please improve the figure by:
- label the individual panels (e.g., a-e),
- indicating the radiosonde launch time

lines 219-237: The discussion of Fig. 2 and Eqs. (1)-(2) is somewhat intertwined, making this section difficult to follow. Consider separating the description of the figure from the explanation of the equations and referring more explicitly to either Fig. 2 or the corresponding equations in the text.

Eqs. (1)-(2): Please provide a more detailed explanation of the equations. Clarify which terms represent the projected horizontal wind component, particle fall velocity, and vertical air motion.

Fig. 2 and line 230: In Fig. 2, θ_0 appears to represent the elevation angle, whereas in the text it is described as the "zenith angle θ_0". Please clarify this discrepancy and revise either the figure or the text as needed. It may also be worth checking the manuscript for consistency in the use of this angle elsewhere.

3 Beam Pointing Estimation Method

3.1 Sensitivity of Doppler Velocity to Horizontal Wind and Beam Pointing Angle

line 248: "When the radar beam is perfectly vertical ($\theta_0 = 90°$)"
Please make sure that the definition of θ_0 is consistent with Sect. 2.3.

lines 255-257: "For example, when horizontal wind speed is 10 $m\,s^{-1}$, the resulting Doppler velocity magnitude is approximately 0.05 $m\,s^{-1}$."
The values stated here do not appear to be fully consistent with Fig. 3. From the figure, the 10 $m\,s^{-1}$ curve appears closer to 0.1 $m\,s^{-1}$ than to 0.05 $m\,s^{-1}$. Please verify this in the figure.

Fig. 3: Please label the individual panels (e.g., a-c)

3.3 Wind dependence of Vd using Radiosonde Observations

lines 307-308: "(typically from ±30 to ±150 minutes)." Please clarify the criteria used to determine the integration period. Under what conditions is a window of ±30 minutes used instead of ±150 minutes?

lines 308-310: A radiosonde typically requires approximately 30 minutes to reach 8 km altitude after launch. Combined with an integration period of up to ±150 minutes, this could result in a temporal separation of roughly 3 hours between the radiosonde and radar observations. How is the representativeness of the environment assessed under these conditions? Wind direction can change substantially over such timescales. Please clarify whether the stability of the wind field during this period is evaluated.

lines 311-315: Earlier (lines 188-190), strong horizontal wind shear is identified as a potential source of uncertainty. Are cases with strong horizontal wind shear filtered out from the analysis? Please explain how these cases are identified.

Figs. 1 and 4: Figure 4 shows the sounding used for this case study. When compared with Fig. 1, the ±30 minute window appears to contain relatively few cloud observations, whereas substantially more observations may be available within a ±150 minute window.
- What integration window is used for this specific case?
- Is there a minimum number of observations required to obtain a robust Doppler velocity estimate?

line 332-334: "Because the contribution of horizontal wind to Doppler velocity depends primarily on wind direction rather than altitude, observations from multiple heights within ice cloud layers can be combined to improve statistical robustness."
Please provide a few more details on how radar and radiosonde observations are matched in height and over what range the data are combined. For example, is each radar range gate paired with the nearest radiosonde observation, or is some form of averaging or interpolation applied?

Fig. 4 Please label the individual panels (e.g., a-d)

4 Results

4.1 KAZR Observations from the CAPE-k

lines 346-347 "The dominant wind in cloud from radiosonde measurement in Figure 5a is in 50 to 150 degrees, which are south-westerly, westerly to north-westerly wind."

This appears to be inconsistent with the definition given in line 233: "measured clockwise from north as the direction toward which the wind flows rather than the direction from which it originates". Based on this convention, 50-150°would correspond to winds directed towards the north-east to south-east sector.
- Please clarify what is meant here
- To avoid confusion, use a single wind-direction convention throughout the manuscript.

line 349 "baseline Vd at approximately -0.8 $m\ s^{-1}$"
How is this baseline determined from Fig. 5b, given that the cosine dependency is

also present in the observations? Was the baseline estimated from the wind directions perpendicular to the beam-pointing offset? Please provide some additional explanation.

4.4 Application to the recent campaigns and fixed sites

lines 482-483 "Considering these factors together, the overall uncertainty in the estimated beam pointing angle is on the order of 0.5°."
How do the uncertainties discussed in lines 465-473 relate to those quantified in lines 476-483? Is the reported overall uncertainty of 0.5° meant to include both sources of uncertainty, or only the latter? Please clarify.

lines 178-181 "Typical uncertainties in radiosonde wind measurements are approximately 0.5–1.0 $m\,s^{-1}$ for wind speed and 5–10°for wind direction, depending on atmospheric conditions and instrument type (Nash et al. 2011; Dirksen et al. 2014)."
A discussion of these uncertainties later in the manuscript is missing. How are the radiosonde wind speed and wind direction uncertainties propagated into the beam-pointing uncertainty estimate?

- Adding a discussion of the following points would improve the interpretation and practical application of the proposed method:
  - Some guidance on when a beam-pointing correction becomes necessary would be valuable. Given the estimated uncertainty of approximately 0.5°, do the authors recommend applying a correction only above this threshold, or is another criterion more appropriate? Practical recommendations would be useful for potential users of the method.
  - What are the likely causes of beam-pointing misalignment at fixed sites over longer time periods? A brief discussion of potential sources (e.g., environmental effects, maintenance activities, frost heaving) would help to understand how frequently beam-point offsets should be checked.
  - It would be interesting to see the corrected Doppler velocity results for the case study. How do the W-band and Ka-band Doppler velocities compare after the beam-pointing correction is applied?
  - How does the method perform when only a limited number of radiosonde observations are available? For example, is it still possible to obtain a robust fit when only a few soundings sample opposing wind directions?
  - Is there a difference between horizontal wind speed and wind direction measured inside and outside of cloud? If differences between in-cloud and out-of-cloud winds are expected, please discuss the potential impact on the beam-pointing retrieval.

5 References

- Some references cited in the text appear to be missing from the reference list. Please check the consistency between in-text citations and the bibliography. In addition, the reference formatting should be standardized throughout.