AMT-2022-113 / Referee Comments

General comments:

The presented paper is in general well written and has a good structure. The authors have shown an interesting hardware concept to estimate wind using a UAS together with simple mathematical models and algorithms. The authors made good contributions in the analysis of each factor that affects the calculations through stand-alone calibrations and validations against conventional meteorological towers, as well as identifying and overcoming some of the short-comings. Having said that, there are some parts of the paper that deserves more attention in some parts and provide more solid concluding remarks in the Spectra analysis section. The paper can be accepted with minor revisions that must be addressed beforehand and shown below.

1. Does the paper address relevant scientific questions within the scope of AMT?

   Yes.

2. Does the paper present novel concepts, ideas, tools, or data?

   Very thorough study of an idealized case and good contributions in the mathematical analysis of factors.

3. Are substantial conclusions reached?

   Yes, although some parts need more insight and consideration of important factors inherent to the UAS.

4. Are the scientific methods and assumptions valid and clearly outlined?

   Yes. Some assumptions must be declared as belonging to the author’s opinion unless there are citations about it.

5. Are the results sufficient to support the interpretations and conclusions?

   Yes.

6. Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)?

   Yes.

7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution?

   Yes.

8. Does the title clearly reflect the contents of the paper?

   Yes.

9. Does the abstract provide a concise and complete summary?

   Yes.

10. Is the overall presentation well structured and clear?

    Yes.

11. Is the language fluent and precise?

    Yes. Some minor corrections though.

12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used?

    In general yes. Equations 10-12 deserves attention as described below.

13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated?

    See comments below.

14. Are the number and quality of references appropriate?

    Yes.

15. Is the amount and quality of supplementary material appropriate?

    N/A

Other comments:

Line 19-23: There are a few papers that compares conventional meteorological instruments with the UAS-based weather instruments. Please add some references and elaborate a bit more (1 or 2 sentences). Here are some papers as examples (but not limited to):

Pinto, J. O. et al. "The Status and Future of Small Uncrewed Aircraft Systems (UAS) in Operational Meteorology" Bulletin of the American Meteorological Society, 102(11), E2121-2136, https://doi.org/10.1175/BAMS-D-20-0138.1, 2021.

Bell, T. M. et al. "Confronting the boundary layer data gap: evaluating new and existing methodologies of probing the lower atmosphere", Atmos. Meas. Tech., 13, 3855–3872, https://doi.org/10.5194/amt-13-3855-2020, 2020.

Line 31: Edit to say: "The effects of incoming wind on the UAS attitude provides the basis for …". The word dependency sort of contradicts the statement of "fly autonomously without prior knowledge of the wind field" in line 24.

Line 39: Instead of feasible, say something like "more affordable/accessible/simple". Wind tunnels are feasible too, but the presented method requires less "effort" to achieve the same goal.

Line 40: Add the following: "… repeated for different multi-copters under the same conditions".

Table 1: Make first letter upper case to be consistent with the other tables in the document.

Line 67: Please provide the version of ArduCopter used.

Line 70: Since the styrofoam is crutial component in this study, it would be worth describing it more in depth. Please provide with some more properties about the material and a brief description of the construction of the enclosure.

Line 73-75: Table 1 is not referenced anywhere in the text. You may want to mention it here.

Line 105: However, yaw is important for estimating the wind direction. I'm assuming that the reason of doing yaw = 0 here is just for the computation of wind speed which is a function of the tilt only. Please clarify this if so.

Line 114: replace used with applied

Equations 10-12: I understand what you did here. However, many readers will be confused by the appearance of the wind components u and v. To avoid confusion, you can define **V = V**wind **- V**uas **= V**eq **=** {u,v,w} knowing that **V**uas = 0 because of hovering conditions.

Line 152-154: I think this statement has to be declared as an author's opinion and the approach taken by them, please do so. In my opinion, I believe A(Tilt) can resolve forces of the solid body alone (styrofoam shpere), while the external components (mainly the rotors) need other different approaches, like a different model to describe them, and then combine the results. Please refer to the following paper to understand other points of view in the subject:

Wang, J.Y. et al. "A wind estimation method with an unmanned rotorcraft for environmental monitoring tasks" Sensors, 18(12), 4504, https://doi.org/10.3390/s18124504, 2018.

Rajan, G and D'Andrea, R "Computationally Efficient Force and Moment Models for Propellers in UAV Forward Flight Applications" Drones, 3(4), 77, https://doi.org/10.3390/drones3040077, 2019.

Line 165: Replace "will maintain its position as computed by" with "holds its position assisted by"

Line 174-178: For non-zero wind conditions, an idea that you can try in the future is to let the drone drift by the wind for a period of time. Eventually, the drone velocity will match the wind speed (in other words, wind = ground speed) and you can use that info in a slightly variation of your calculations to obtain the drag coefficients.

Line 188-189: Please also mention authorizations and permissions to fly drones in the area, if any. It is good example to show the reader the efforts made to fly drones legally.

Line 195: Replace “situation” with “conditions”.

Line 236: Replace “A” with “The”, and “end up in obtaining” with “produce”.

Line 236-240: In theory, these “sloped lines” should ideally be just points. You can prove this in simulations within ideal environments. However, your data looks spread out because the drone is tilting back and forth correcting its GS and even flighting turbulence in its way (like its own propeller wash). The lower the GS, the more spread it looks because speed is getting close to the minimum velocity resolution of the GNSS and that introduces errors. The authors continue explaining this in lines 260-264, but without much depth. It would be good to have a physical meaning to all this. Please consider adding it (2-3 sentences more should be enough).

Section 3.2: Have you considered doing circular flights? Since the drone is a sphere and you are assuming isotopic conditions, a circular flight fashion should be valid. This will also help removing errors caused by wind from the calculations by taking the tilt average around the circle.

Line 283: Replace “will offset the real horizontal wind” with “will produce an offset in the horizontal wind estimates”.

Line 287-288: Again, this statement has to be declared as an author’s opinion and the approach taken by them, please do so. Unless you found literature that also supports this, please cite them.

Lines 292: Replace “by” with “described in”.

Line 293: I’m assuming that you are computing the density of dry air since you only mention pressure and temperature variables. If you have humidity data, it is possible to also include the water vapor density for improved accuracy.

Section 5.2: The discussion and analysis of the spectra results are quite consistent and valid. However, there are other factors that are relevant and deserves some discussion too. The propeller wash can very well be within the frequency range of the plateau, injecting energy into the surrounding air. Its effects should be greater when the wind is low since the prop wash doesn’t move away. But this is hard to see in Figure 9 because it shows an “average” of all the flights and wind velocities. GNSS is also another factor, if the position estimation drifts away, the drone will try to follow the wrong position estimate and tilt towards it. The drone is basically rocking back and forth, and this is reflected as increased energy in that range of the spectra.

It is interesting to note that the energy then decreases to levels close to the sonic anemometer spectra, to me this means that the drone’s high frequency wind estimates hasn’t reached the noise floor yet and be as sensitive as the sonic anemometer. Unless there is some kind of artifact in the algorithm. I suggest the authors to explore more on this and come back with conclusions.

Section 5.4: Did you check if the compass measurements are with respect to true north? However, 15deg seems high. ArduPilot offers advance magnetometer calibrations and it compensates for the induced magnetic fields of the electronics. Consider this for the next experiments.

Line 404: replace “usually” with “general”. The word “varying” can be omitted.

Line 408: Correct sentence “since it may not be constant”

Line 414: "Undesired" instead of "spoiled" would sound better.

Line 427: Consider replacing "since it is specific for the mass that the system had" with "since the mass is unchanged during the calibration flights"

Line 455-456: Rephrase "uniforms the aerodynamic forces with respect to the incoming wind's direction" to "helps producing uniform aerodynamic forces with respect to the incoming wind from any direction"