14.12.2020

Review of the article

# "Airborne Lidar Observations of Wind, Water Vapor, and Aerosol Profiles During The NASA Aeolus Cal/Val Test Flight Campaign"

submitted by K. Bedka et al.
**(AMT)**

**Scientific significance: Excellent**
The paper deals with the introduction of two airborne lidar systems for measuring wind and water vapor profiles and demonstrates the possibility of using the data for calibrating or rather validating the first wind lidar in space – Aeolus. Thus, the presented results are rather significant for the lidar community but also for numerical weather forecast centers.

**Scientific quality: Good**
The paper addresses all information that are needed to understand to quality (accuracy and precision) of the measured quantities (wind and water vapor) and discusses all methodologies that are used for the data retrieval.

**Presentation quality: Excellent**
The paper manuscript is clearly structured, all used methodologies are well explained and all figures are clearly visible. Furthermore, the text is well and clearly written.

**Review Summary**
The paper manuscript "Airborne Lidar Observations of Wind, Water Vapor, and Aerosol Profiles During the NASA Aeolus Cal/Val Test Flight Campaign" by Kristopher Bedka deals with the introduction of two airborne lidar instruments by NASA that are used to measure profiles of wind and water vapor. Both instruments were flown during a recent field campaign performed in April 2019 over the Eastern Pacific Ocean aiming at demonstrating the performance of both lidar instruments but also calibrating and validating the Aeolus L2B wind products.
Both, the lidar instruments, the research flights during the campaign, and the methodologies used to retrieve and compare data are accurately explained. It is shown that the DAWN coherent wind lidar at its current state has a good performance measuring tropospheric wind profiles with almost full coverage, almost bias free (< 0.2 m/s) and with a precision of better than 1.6 m/s. The comparison of DAWN and Aeolus data from 5 Aeolus underflights is shown and discussed. It is revealed that the current Aeolus data still has a larger bias of ~ 2m/s and it is discussed that this enhanced bias may arise from thermal variations on the Aeolus telescope mirror and detector hot pixels which are corrected within a re-processed Aeolus data set.
In parallel, water vapor profiles and aerosol optical properties measured by the HALO lidar are shown and used to analyze the particular weather conditions during each of the research flights.
As already stated above, the paper manuscript is scientifically significant and well written. It is suggested to publish it after performing minor revisions as suggested below.

**Detailed comments**

- **Titel:** The title of the manuscript is "Airborne Lidar Observations of Wind, Water Vapor, and Aerosol Profiles During The NASA Aeolus Cal/Val Test Flight Campaign". Thus, the reader expects more or less only measurements that are used for Aeolus Cal/Val. However, the

comparison of DAWN and Aeolus wind data is only a very small (~5%) part of the manuscript. Neither water vapor profiles nor the aerosol optical properties data is used to compare to Aeolus. Thus, the paper mainly demonstrates what is possible with the payload flown during the campaign (also e.g. regarding boundary layer atmospheric conditions, etc.). Thus, it could be thought to make the Aeolus Cal/val less prominent within the title of the paper manuscript. However, if this was the official name of the airborne campaign it is understood that this has to be kept.

- **Introduction (general):** What is a little missing in the introduction is, what is new or rather special for the presented research results. Is it the first time that an HSRL and a DWL are flown on the same aircraft? Or is the performance of the used instruments much better than the one shown by other groups? Are there any other airborne activities to CAL/VAL Aeolus for wind and/or rather optical properties? Such kind of information would help to put the presented work in an international context.

- **Line 44:** A few acronyms, e.g. ALADIN were already introduced in the abstract. Thus, there is no need to introduce the again. The acronym ESA for the European Space Agency is not introduced, however, used in the citations. Thus, it is recommended to introduce ESA.

- **Line 48-49:** "Aeolus observes…LOS". This was already mentioned in the sentence before (at least for the wind field) → skip or harmonize these two sentences.

- **Line 66-68:** "lack hor. And vert. resolution" → It could be helpful to mention which resolutions, coverage, etc. would be required for observations to be useful for NWP (including reference).

- **Line 84-85:** Why do you use "" here? In which of the following references is this sentence written?

- **Line 115-118:** Does this mean that the beam shaping optics improve the SNR similarly than having 250 mJ pulse energy instead of 100 mJ, or just that the missing 150 mJ were partly compensated by the beam shaping optics?

- **Line 142:** Acronym INS was not introduced.

- **Line 172:** This sentence is not completely clear to me. On the one hand, quantitative numbers are missing. How good is the comparison to in-situ data? On the other hand, DAWN is expected to have no measurements at flight level, right? With a laser FWHM of 180 ns (54 m), the first 100-200 m might be influenced by the outgoing laser pulse which would shift your power spectrum towards 0 m/s. Thus, a comparison to in-situ winds at flight level might not be too meaningful. Could you clarify that?

- **Line 177-179:** It would be worth mentioning that the DLR lidar performance was determined also for airborne measurements (not from ground). So "sondes" are actually dropsondes and not radio sondes. Maybe this can be clarified in the manuscript.

- **Line 184:** "Unreliably". What does unreliably mean here? Is only the 10 Hz data not available all time, or are values corrupt (also in the 1 Hz data)?

- **Line 200:** LASE was not introduced...is it an acronym for the precursor of HALO?

- **Line 208:** “exceeded all expectations”: Concerning what? Reliability? Data coverage? Accuracy? It would be good to provide a short explanation here.

- **Line 231:** water vapor → WV

- **Line 236-237:** Have you ever verified if the WV data precision is Poisson noise limited or if there are other systematic contributions to the random error?

- **Line 239:** water vapor → WV

- **Line 252:** “good agreement” What does "good" and "excellent" mean here? Can you already provide numbers that you are later discussing in section 4.4?

- **Line 262-263:** Can you quantify "favorably" here? What means "show promise" in detail?

- **Line 289:** Water vapor (WV) was introduced before

- **Line 304:** The direction seems to have more outlier than the wind speed (3.57% instead of 0.03%). Can this be related to the fact that DAWN is only measuring 5 different positions in forward direction? Would a full conical scan improve the wind direction determination?

- **Line 321-324:** Different to Aeolus, DAWN is a coherent wind lidar that "only" measures winds by analyzing the narrow-band backscatter signal from aerosols and clouds. But you use DAWN data also for the validation of Rayleigh winds that are measured in almost aerosol-free atmosphere. Can you still justify your approach?
  How do you perform the projection? How accurate do you know the viewing direction of DAWN? In case you are not pointing to the same azimuth direction, your wind measurements would need to be corrected. Did you consider this issue?

- **Line 326:** Is the laser beam pointing really 90° wrt to the heading angle or to the aircraft reference system? Do you control the angle in case the heading angle changes during the flight leg (e.g. due to changing cross wind conditions), or have you verified how constant the heading was during one Aeolus underflight legs?

- **Line 329-331:** Have you tried to use different est. error thresholds in order to verify the sensitivity to these values? This would be an interesting step as other Cal/Val teams reported at the recent Cal/Val workshop that the estimated error calculation seems to vary with time and thus different thresholds might have to be used in different periods. Thus, having the statistical comparison with different thresholds would be interesting.

- **Line 341:** two times “Aeolus”, but the second “Aeolus” should be accumulation…

- **Line 360:** Maybe it would help to introduce all acronyms if not already done before...

- **Line 392:** What does UTC observation hour particularly mean? From which event is it counted? It would be better to plot UTC time in the top-x-axes in order to prevent any confusion...

- **Line 404:** With cirrus cloud(s)?

- **Line 411:** “excellent agreement” → Can you quantify? E.g., largest deviation, accuracy, precision...

- **Line 416:** “along a long” → probably correct but sounds strange and funny.

- **Line 418:** Sometimes, the UTC times are given with “.” sometimes without.

- **Line 425:** Full stop missing at the end of the line.

- **Line 441:** Startocu → Stratocumulus?

- **Line 459-461:** Have you also analyzed the vertical wind speeds in the vicinity of these mountain waves? Do they lead to additional errors in the Aeolus L2B winds which do not consider vertical winds?

- **Line 514:** 21.6 UTC (UTC is missing)

- **Line 517:** was → were (?)

- **Line 528-530:** Can you give quantitative numbers here?

- **Line 611-612:** Can you give quantitative numbers here?

- **Line 631:** “reached up to 30°” → Probably you would have reached larger values, but you consider differences larger than 30° as gross outlier, right? If so, this should again be mentioned here.

- **Line 679-680:** I would also prefer to read quantitative numbers here instead of “excellent agreement”.