[Responses to the Comment by the Anonymous Referee #4]

>> We deeply appreciate the referee #4 for providing constructive comments. The manuscript is revised following the comments below.

I congratulate the authors for the revisions and improvements they have made to the manuscript based on the comments brought up by this and the other reviewers, and that have alleviated the great majority of my previous concerns with the original manuscript. However, there still is one critical aspect that needs to be addressed by the authors before I can recommend publication of this article. This is related to my previous major comment #2. I have to mention that I appreciate the work the authors have done to compare to a 'true' reference (i.e., a higher-frequency signal) to validate to the EDR estimates out of 1-Hz QAR data.

Comments:

The authors now show 2d-histograms comparing EDR1U, EDR2U, and EDR3U methods to their corresponding estimates using the 20-Hz data, presented in the new Fig. 5. However, these histograms exhibit a clear and systematic underestimation when 1-Hz data is used. Therefore, their claim that: "Based on this result, it can be confirmed that the use of 1-Hz flight data to estimate the EDR is reliable, although the magnitude of the EDR is somewhat underestimated in some cases" [Page 8, lines 26-27], is misleading and not accurate. Eyeballing from the figure, the underestimation is ~0.5 of the 20-Hz estimates. This is a non-negligible difference that can cause significant errors, and that the authors must quantify and include in the manuscript. A simple linear regression should suffice, since the bias seems pretty consistent across the EDR range (i.e., parallel to the 1-to-1 line in log-log space). This is in my view one of the most relevant aspects of the paper (if not the most relevant one), since the authors want to show the validity of 1-Hz data to derive EDR, and therefore need to quantify any biases so these can be taken into account when interpreting EDR estimates from the 1-Hz data. This information needs to be given the importance it deserves and discussed in detail in the corresponding section, as well as included in both the abstract and the conclusions (it is a key point of this work!). Also, I would suggest that the authors do not perform any averaging to obtain the equivalent 1-Hz data from the higher frequency signal, and simply decimate it (i.e., pick every 20th sample), since their averaging could be partially contributing to some of the energy underestimation and subsequent reduced EDR values.

➔ Thank you very much for your good comment. As you suggested, we conducted three additional sensitivity tests on selecting raw 20-Hz data to 1-Hz data (Fig. A1), as follows: 1) Reynolds averaging (approach used in the original manuscript), 2) First pick, 3) Middle pick, and 4) Last pick. Results shown in Fig. A2 are about the energy spectra of the raw 20-Hz (black lines) and the selected 1-Hz wind data (blue lines). The energy spectra of 1-Hz data follow a theoretical slope (-5/3), especially in the overlapped range of frequency (0.1-0.5 s^{-1}). However, near the tail part of the energy spectra the 1-Hz wind data by selecting the arbitrary pick (blue lines in Figs. A2b, c, and d) show relatively larger powers than that of averaged 1-Hz wind (blue line in Fig. A2a) and even that of raw 20-Hz wind (black line in Fig. A2 c). This is likely related to the aliasing problem, which is eventually shown as relatively higher values of EDR2 and EDR3 than the averaged and original EDR values (Figs. 3Ab and c). This feature is not found in the structure function-based EDR1 method, which is consistent with previous study (e.g., Muñoz-Esparza et al. 2018), suggesting that the EDR1 can slightly reduce the uncertainty of retrieved EDR using 1-Hz data. For the Reynolds averaging 1-Hz data, the retrieved EDRs are underestimated systematically regardless of the EDR methods (Fig. A3).

Finally, the results shown in Figs. A4-A6 are about the statistical comparisons of the EDRs based on the structure function (EDR1; Fig. A4) and energy spectrum [EDR2 (Fig. A5) and EDR3 (Fig. A6)] using the 20-Hz raw data (x-axis) to those using the 1-Hz wind data (y-axis). It is found that all 1-Hz (both averaging and arbitrary pick) EDRs are highly correlated to the raw 20-Hz EDRs ($r > 0.92$). However, as already mentioned above, the averaging results of the 1-Hz data show systematic underestimations of EDRs about 8.14% (EDR1), 10.75% (EDR2), and 12.56% (EDR3). In addition, arbitrary pick experiments have systematic underestimations of about 2.17-2.19% in EDR1, and overestimations of about 9.18-9.32% and 10.75-10.91% in EDR2 and EDR3 due to the aliasing problem, respectively.

Given the situation that we do not know whether the 1-Hz QAR data used in this study is the averaged value or arbitrary picked one from the raw flight data, the uncertainties found in this study should be considered when we use the retrieved EDR values from the low frequency (1-Hz) flight data for investigating turbulence encounters. Accordingly, we have modified our original manuscript: in the abstract (Page 1, Lines 14-18), in main section (Page 8, Lines 17, 19, 21-30, 33-34; Page 9, Lines 1-6; Figure 5), in summary section (Page 15, Lines 15-23), and supplementary figure (Fig. S1).

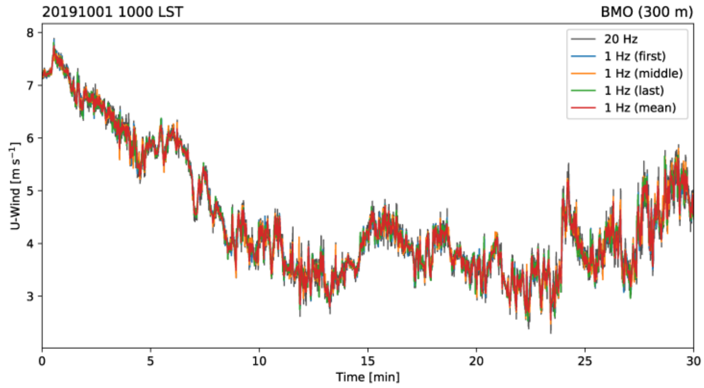

Figure A1. Timeseries of streamwise component of wind data (U) obtained from the BMO between 1000 LST and 1030 LST 1 October 2019 at 300 m AGL. Raw 20-Hz BMO (black) data are subsampled to the 1-Hz wind data (a) using Reynolds averaging (red) and by picking every (b) first (blue), (c) middle (orange), and (d) last (green) sample.

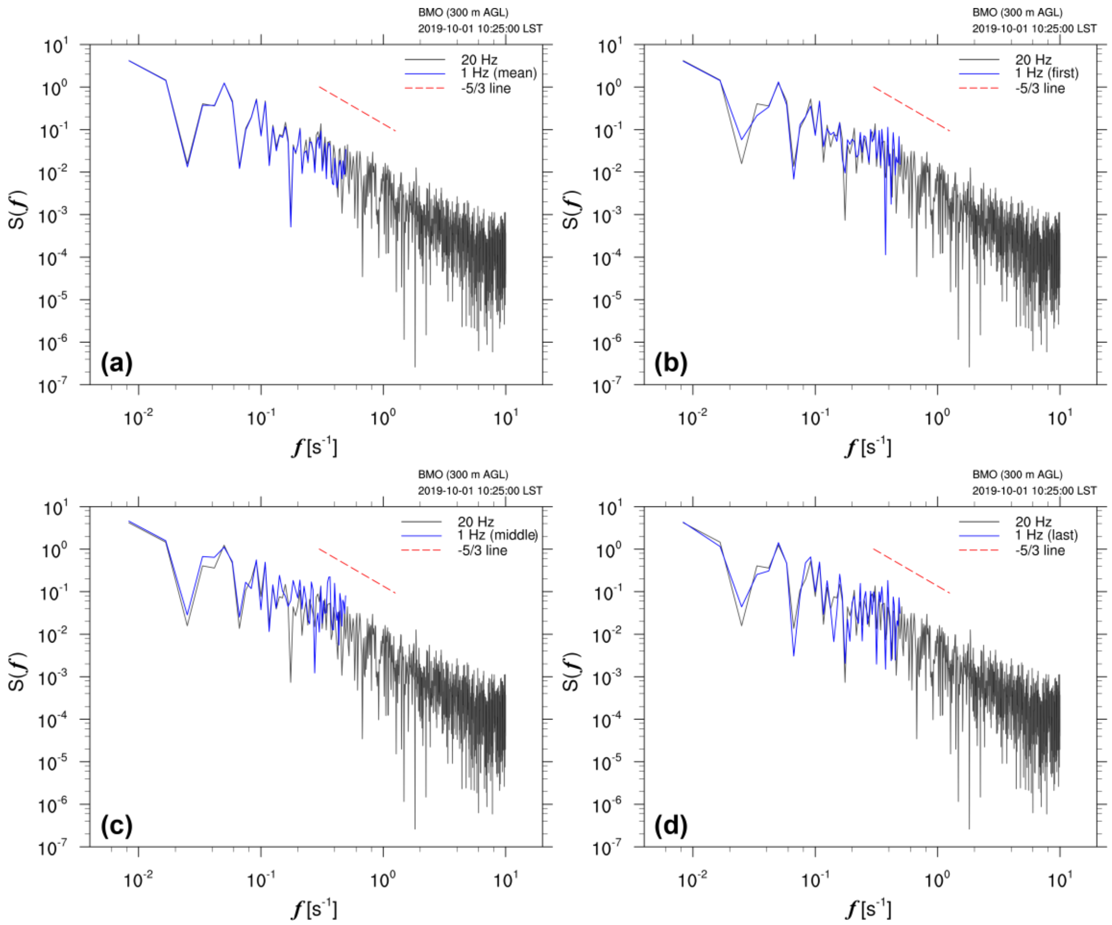

Figure A2. The energy spectrum of U-wind obtained from raw 20-Hz (black) and subsampled 1-Hz (blue) BMO data at 1025 LST 1 October 2019 at 300 m AGL. The dashed line represents the theoretical slope ($f^{-5/3}$) in the frequency domain. Raw 20-Hz BMO data are subsampled to the 1-Hz wind data (a) using Reynolds averaging and by picking every (b) First, (c) Middle (10th), and (d) Last (20th) sample.

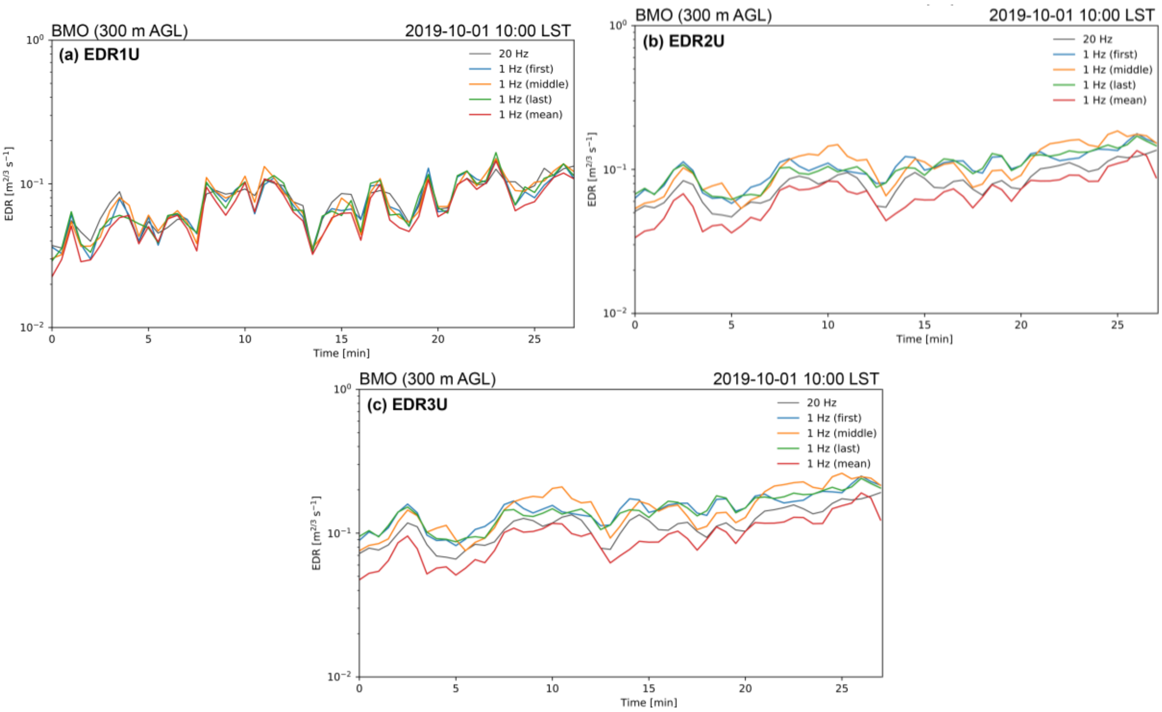

Figure A3. As in Fig. A2, but for the (a) EDR1s, (b) EDR2s, and (c) EDR3s.

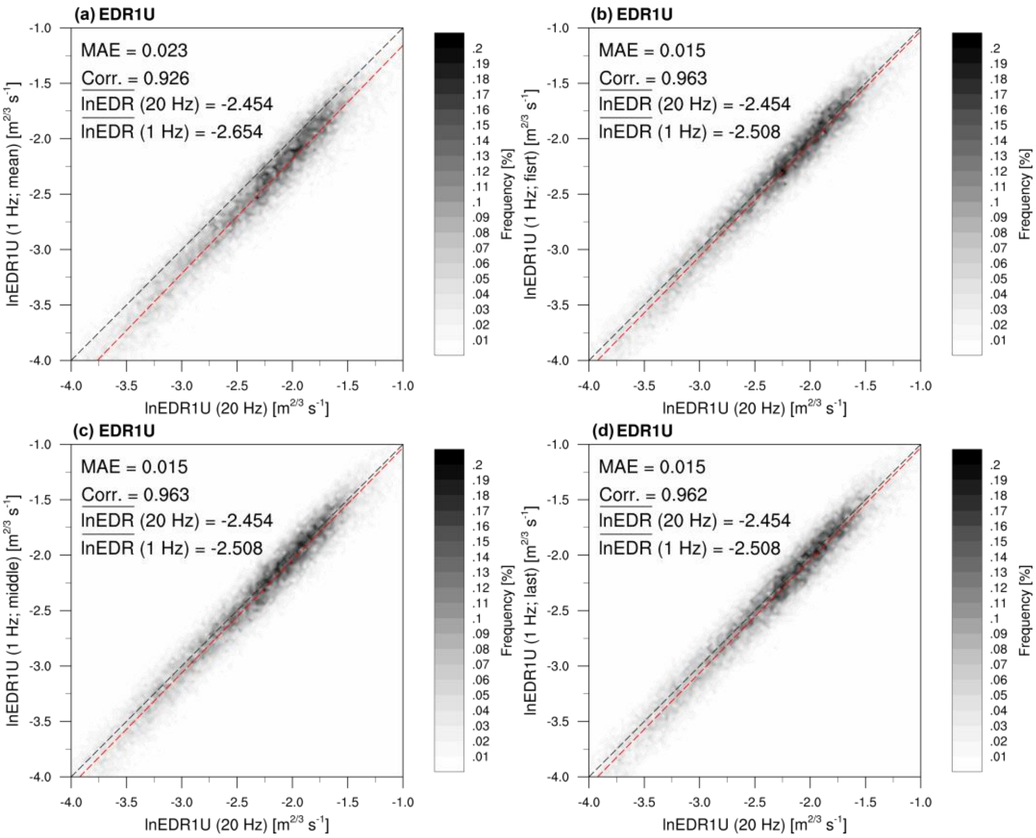

Figure A4. Scatter density plots of the EDR1 calculated using the 20-Hz wind data (x-axis) and the 1-Hz wind data (y-axis) with linear regression line (red dashed line). Raw 20-Hz BMO data are subsampled to the 1-Hz wind data (a) using Reynolds averaging and by arbitrary selections from (b) first pick, (c) middle pick, and (d) last pick within each time window.

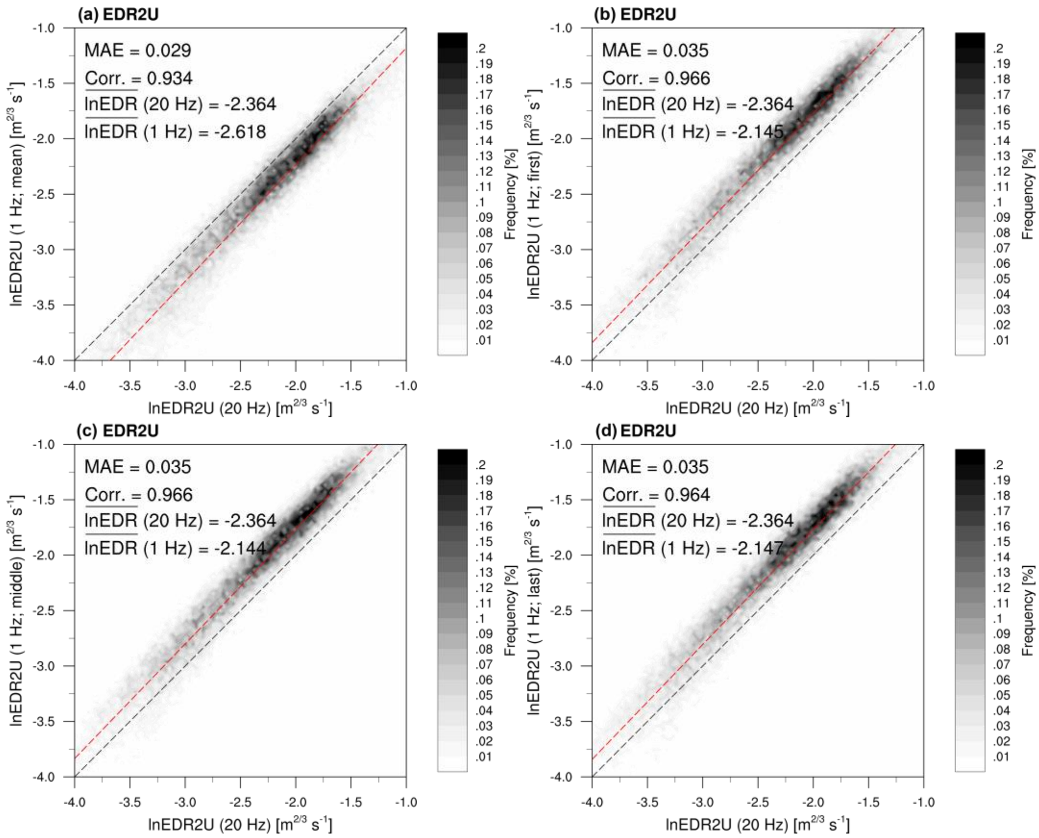

Figure A5. As in Fig. A4, but for the EDR2.

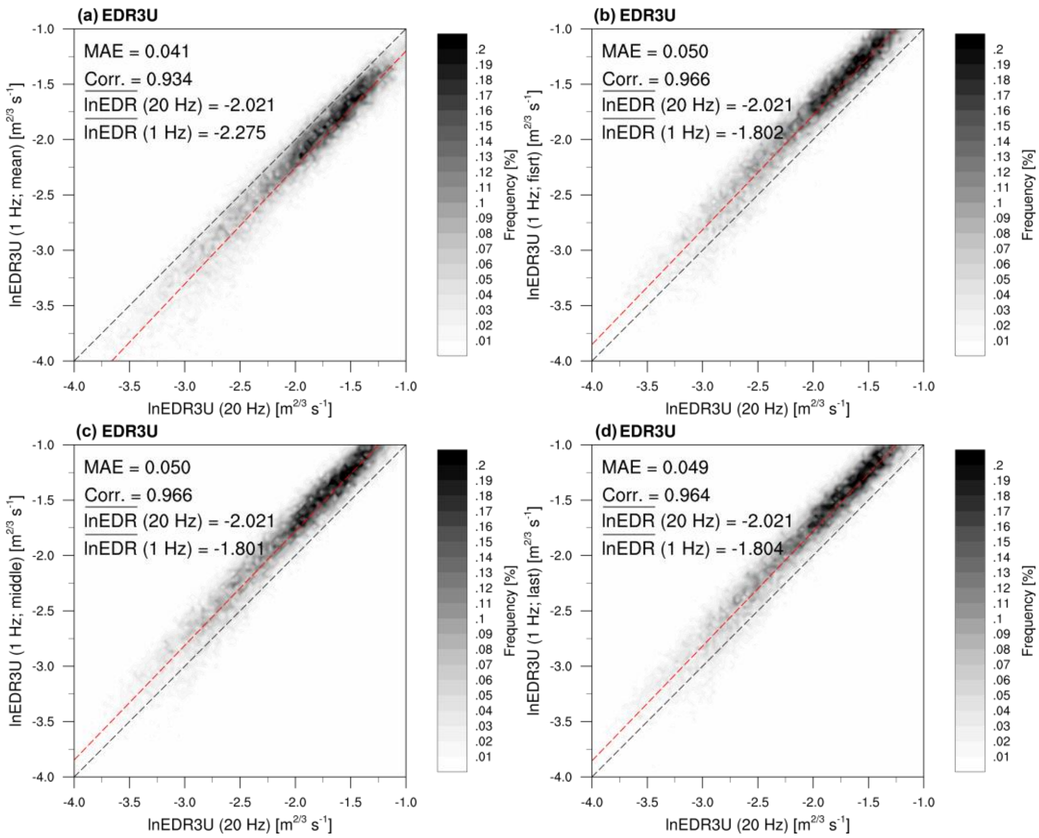

Figure A6. As in Fig. A4, but for the EDR3.

References

Muñoz-Esparza, D., Sharman, R. D., Lundquist, J. K.: Turbulence dissipation rate in the atmospheric boundary layer: observations and WRF mesoscale modelling during the XPIA field campaign, Mon. Wea. Rev., 146, 351-371, 2018.