Responses to Reviewer 2

We thank the reviewer for the insightful comments. Below is a point-by-point response to their review.

All new major modifications are highlighted in yellow here and in the main manuscript.

The objective of this study is to assess and compare the performance of relaxed eddy accumulation (REA), disjunct eddy-covariance (DEC), and a mixing length parameterization labelled A22 in comparison to the eddy covariance (EC) technique using high-frequency measurements collected at two sites. The high-frequency measurements of scalars were filtered to supply scalar quantities that were then used with high-frequency wind speed measurements to compute the REA and DEC fluxes. I concur with Referee 1 that by low-pass filtering the scalar signal, the authors unrealistically deteriorated it for input into both the REA and DEC flux calculation. Fast valve switching is done in REA, and fast (instantaneous) sampling is done in DEC, in order to avoid apparent biases as are depicted in Figure 2. As such, I recommend that the authors undertake a major revision of the work in this manuscript.

Response:

We thank the reviewer for bringing up these important points and the shared references which were instrumental for the revised version. To address the reviewer's concern here, we are recapping below the original flow of the paper and showing the modifications we made.

The main purpose of the paper was to evaluate the performance of different models in estimating the scalar turbulent fluxes under **stable** conditions across two contrasting sites (Q1). The second motivation was to test these models under scenarios for which fast sensors are not available or where slow/medium response sensors are technically and/or economically the only viable option (Q2). To that end, we revised the paper, adjusted the approach, and incorporated the necessary modifications to address these questions/motivations in a clearer way. (Q1)'s approach stays the same. In addressing (Q2), we are explicitly considering scenarios where only slow-response sensors are deployed. Our original text may have been confusing since we indeed agree that REA apparatuses can be fast and give results comparable to our REA results with fast sensors; this is now made clearer though the caveat of this need for speed is underlined. DEC grabs instantaneous samples fast but at large intervals, and while this does indeed miss contributions from a range of small scales, it does not give identical fluxes to a filtered signal, so we have removed any analyses of DEC directly.

But we still aim to examine the application of an REA approach that does not require a mechanical apparatus, as now explained and motivated more clearly. Hence, we give our proposed model another name when we apply filtering (**VEA**: Virtual Eddy Accumulation instead of **REA**), i.e., when using the slow-response scalar signal and when a mechanical experimental apparatus to separate the flows is not involved. VEA **recovers** an REA system when filtering is not applied.

The **observed filtered** fluxes with the slow sensors are now referred to as **LEC** fluxes (LEC: Large eddy-covariance), instead of **DEC**. Hence, the DEC is no longer referred to as a benchmark to compare to in the analysis, and REA is only used and referred to when dealing with the **high-frequency** signal sampled in a way that mimics a fast, flawless mechanical flow separation device..

As such, the **main** elements that have changed in the paper are listed below:

1. Abstract:

   Conventional and recently developed approaches for estimating turbulent scalar fluxes under stable atmospheric conditions are evaluated, with a focus on gases for which fast sensors are not readily available. First, the relaxed eddy accumulation (REA) classical approach and a recently-proposed mixing length parameterization, labelled A22, are tested against eddy covariance computations. Using high-frequency measurements collected from two contrasting sites (the frozen tundra near Utqiagvik, Alaska and a sparsely vegetated grassland in Wendell, Idaho during winter), it is shown that the REA and A22 models outperform the conventional Monin-Obukhov Similarity Theory (MOST) utilized widely to infer fluxes from mean gradients. Second, scenarios where slow trace gas sensors are the only viable option in field measurements are investigated using digital filtering applied to fast-response sensors to simulate their slow-response counterparts. With a filtered scalar signal, the observed filtered eddy-covariance fluxes are here referred to as large eddy-covariance (LEC) fluxes. A virtual eddy accumulation (VEA) approach, akin to the REA model but not requiring a mechanical apparatus to separate the gas flows, is also formulated and tested. A22 outperforms VEA and LEC in predicting the observed unfiltered (total) eddy-covariance (EC) fluxes; however, VEA can still capture the LEC fluxes well. This finding motivates introducing a sensor response time correction into the VEA formulation to offset the effect of sensor filtering on the underestimated net averaged fluxes. The only needed parameter for this correction is the mean velocity at the instrument height, a surrogate of the advective timescale. The VEA approach is very suitable and simple to use with gas sensors of intermediate speed ($\sim$ 0.5 to 1 Hz), and with conventional open or closed path setups.

2. Introduction:

   Highlighted in the paper.

3. Subsection 2.5: VEA: Virtual eddy accumulation flux model

   New Subsection Highlighted in the paper.

4. Subsection 2.6: LEC: Large eddy covariance model

   New Subsection Highlighted in the paper.

5. Subsection 4.2: Simulating a slow scalar sensor for model testing

   Highlighted in the paper.

6. Subsection 4.3: LEC, VEA and A22 model evaluation using simulated slow sensor data

   Highlighted in the paper.

7. Subsection 4.4: A sensor-response correction for the optimal VEA coefficient β_v

   Highlighted in the paper.

8. Conclusions:

   Highlighted in the paper.

The correction factor in the new model (**VEA**) is now referred to β_v instead of β_s

All relevant figures were **updated** to reflect these modifications.