Dear Referee #1,

We appreciate your questions and suggestions for improvements. They have been adopted and/or further discussed as described in the following. All responses are given in italic and green font.

Sincerely yours

T. Ning and G. Elgered

Main comments:

Section 2.2: How to identify the jumps occurring sometimes at the beginning of the 5 min cycle when you estimate the gradients using WVR. And how many observations from WVR were removed or how many observations are used to compare with the gradients estimated from GNSS?

Response: We have added the following details describing how the WVR data were prepared for the GNSS comparison:
"The jumps were identified by viewing the ZWD during each day. The temporal resolution is then sufficient to identify a 5 min long group of data that is discontinuous to the adjacent 5 min periods. The jumps were later found to be caused by vibrations when the mechanical waveguide switch was activated at the beginning of each 5 min period. After removing WVR data acquired during rain, that were unstable because of the jumps, and all 5 min periods where there were less than 40 (of the 52 scheduled) observations (typically caused by large liquid water content) we ended up with 56,612 data points. There are 105,120 possible data points in one year. There were 14,236 periods of 5 min during the time when the WVR was in the lab, meaning that the gradients estimated from 62 % of the time when the WVR was operated were used to compare to the ones from GNSS."

Line 111-112: It is very obvious that the mean and variability of the estimated gradients amplitude increase with an increase in elevation cutoff angle together with its formal error. Why is this?

Response: In order to explain the issue, we have added the following text in the updated manuscript: "When the elevation cutoff angle increases, fewer number of observations were included for the gradient estimation. For GNSS, the geometry of the satellite constellation is also deteriorated for a larger elevation cutoff angle. As a result, the formal error of the estimated gradient increases as well as the variability. In addition, when using a lower elevation, the larger volume sensed by GNSS introduces an averaging effect that reduces the mean amplitude of the estimated gradients (see Elgered et al. (2019)")."

Line 112-114: "The gradient amplitudes estimated by the WVR are approximately twice as large as the GNSS gradient amplitudes at 3◦ cutoff angle but the decreases to around 50% as large for the cutoff angle of 15◦". I do not find the feature from Table 1. Which column of the table can be used to reach the conclusion?

Response: In the updated manuscript we have modified the sentence to "As indicated by column 9 in Table 1, the gradient amplitudes estimated by the WVR (0.99 mm) are approximately twice as large as the GNSS gradient amplitudes at 3◦ cutoff angle, i.e., 0.49 mm for the GRE solution, but they decrease to around 50 % as large for the cutoff angle of 15◦, i.e., 0.69 mm for the GRE solution."

The formal errors of WVR are larger than ones of GNSS in Table 1. Also as is mentioned in line 116-117, the uncertainty in measured sky brightness is unstable. It seems that the uncertainty of WVR is larger than that of GNSS. Therefore, are the comparison results credible?

Response: This explanation is added when discussing Table 1:

"The uncertainty of the WVR gradients are scaled meaning that if the true wet delays in the different directions have deviations from the linear gradient model the uncertainties increase.

Such deviations will be common during convection processes and the assumption of linear changes of the wet refractivity in a layered atmosphere will not be accurate. The gradient uncertainty given by GipsyX is not scaled. Therefore, these uncertainties are likely smaller than realistic values."

Related to these comments we are also motivated to add the following text at the end of Section 2.2 describing the WVR data:

"The study does not need to assume that the WVR gradients are more accurate compared to the GNSS ones. The main advantage of the WVR gradients is that they are independent and by comparing these to the gradients from different GNSS solutions we can assess the different GNSS processing methods. Furthermore, since we want to study the agreement with as high temporal resolution as possible, we do not apply constraints to the individual 5 min gradients in order to have them independent from adjacent estimates in terms of the atmospheric signals."