Atmospheric Measurement Techniques Discussions

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Reply on RC1

Chaiyaporn Kitpracha et al.

Author comment on "Validation of tropospheric ties at the test setup GNSS co-location site in Potsdam" by Chaiyaporn Kitpracha et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2022-238-AC1, 2023

First of all, we would like to thank you for your time to read our manuscript in detail and for your insightful comments. We carefully consider your comments and address your points in the manuscript.

General Comments

This is an extended version of the discussion paper / preprint https://doi.org/10.5194/amt-2021-87 which was not published.

It is true that atmospheric ties is an important subject. This is already accepted by the community. The authors should stress what new knowledge this study offers to the community. It is trivial to correct for the extra 2-4 m height difference of nearby antennas. A reasonably good guess of the ground pressure is sufficient. This is shown in Tables 2 and 5 where the only significant impact is when no correction at all is carried out. All models give the same result given the uncertainties. It seems likely that the different biases seen in the ZTD between the different antenna installations are caused by uncertainties in the phase centre of the antenna which indirectly is affected by electromagnetic environment, such as multipath and radomes. "Multipath ties" or "antenna environment ties" would be a better description of what needs to be studied. Although the part covering the so called A20 experiment is correct and readable, it is not meaningful.

Response:

We agree that the majority of effects quantified by this work can be attributed to interactions of the antenna, its phase center and the electromagnetic environment. The study of multipath and antenna environmental effects is indeed in the focus of our work. Furthermore, our work looks at these effects in order to derive conclusions for parameter combination. For the combination of tropospheric parameters, one needs a good guess for all these instrumental effects in terms of systematic and noise like differences. With our

approach, operating various antenna types at quasi the same reference position, we can separate antenna related effects from environmental effects and by installing the same antenna once again we can get an idea about differences caused by individual installations. Practically all groups that study tropospheric parameter combination apply only a height-dependent tropospheric tie and assume no other difference apart from that. This is the motivation of the paper. In our work, we discuss all these effects and think about the consequences for tropospheric parameter combination. For tropospheric parameter ties we suggest to not only use meteorological altitude-dependent differences but also to account for instrumental systematic effects.

In order to make the novelty of this work more clear, we have added a paragraph in the introduction:

"Our novel approach is based on a vertical steering pole that shifts the reference phase center of various antenna types to the same position at the mm level. We ensure that no station height-dependent tropospheric effects are present and all antenna types experience the same multipath effects using this approach. Due to this configuration, all observed differences can be attributed to the type of antenna. In the second experiment, we directly measure the effect of antenna type on tropospheric parameters. For small differences in height, the instrumental effect degrades the observed tropospheric ties. Our research attempts to quantify and assess this in order to obtain more accurate tropospheric ties."

One issue in the 2021 preprint was the five weeks long time series of the A20 experiment (called A20) and that a much longer time series would open up for more detailed studies of long term stability, multipath etc. A second experiment (called A17), roughly eight weeks long is added to the old one in this manuscript. This new experiment does, however, use other antenna installations. The criticism of using short time series is still there.

Response:

The purpose of this work is not to study the long-term stability. The effects that we demonstrate and assess in this work are size of instrumental offsets, effect of antenna multipath, difference when installing the same antenna once again etc., can all be demonstrated on the basis of relative short installations. This is the purpose here. Concerning the stability of a long-term analysis, we conducted such an investigation in one of our previous studies. You may find this information in the introduction, where we write:

"Kitpracha et al. (2020) analyzed long time series (10 years) of the differences in atmospheric parameters at the Wettzell co-location site using three different GNSS observations (e.g., L1, L2, and the ionosphere-free linear combination of dual-frequency, L3) to estimate atmospheric parameters. We found that the instrumental changes cause significant jumps in the time series of the atmospheric parameter differences. Therefore, the impact of instrumental effects are needed to be investigated to improve the combination with tropospheric ties at GNSS intra-technique or inter-technique co-location sites."

Specific comments

Unclear statements in the abstract:

"Additionally, multipath effects at low-elevation observations degraded the tropospheric gradients."

On the other hand on Line 211 you mention that the error increases for higher elevation cutoff angles?

Response:

According to the results, multipath effects were found in low-elevation observations at A203 and at A204 stations in the A20 experiment. These degrade the quality of the tropospheric gradients. The text in Line 211 is a general statement about using different cut-off elevation angles **when there is no multipath effect**.

"we set up another experiment with three GNSS stations and four different antennas"

This statement is confusing if you do not explain that you change antennas at a specific station.

Response:

We updated the sentence as:

"To investigate the instrument effect, we designed a second experiment involving three GNSS stations (two permanent stations and one experiment station). At the experiment station, four different types of antennas were utilized to demonstrate the instrumental effects."

"... and tropospheric gradients agrees with the result of the previous experiment in this study."

In what sense to they agree, when it is different gradients during different time periods?

Response:

Here we report differences of estimated parameters between a test station and a reference station. The differences obtained during different time periods do not show systematic effects. Hence, we can conclude that the time-dependent differences are sufficiently followed by both stations. Consequently, the time series of parameter differences agree across time. An example for the agreement between the two experiments is that the mean values of the east gradient differences are larger than the ones of the north gradient differences for both experiments. We rephrased the sentence as follows:

"The bias on GNSS-derived zenith delays and tropospheric gradients differences agrees

with the result of the previous experiment in this study."

As mentioned above all models applying a correction for troposphere (S1-S4) result is the same value. When the height differences are as small as 2 m and 4 m it is sufficient just to use the pressure. A potential improvement, for larger height differences, would be knowledge of the vertical gradient in the wet refractivity, which none of these models take into account. Therefore, the focus shall be on multipath models rather than on the method for tropospheric ties.

Response:

Thank you very much for the interesting suggestion.

We agree with your suggestion about how to improve the meteorological part of the tropospheric ties. However, in our experiment we do not include co-locations with large height differences. This is not the topic of our work. Hence, there is no indication to extend this manuscript adding a discussion of vertical gradient of wet refractivity. We are exactly interested in small height differences up to 4 meters for two reasons: 1) many IGS stations show height differences at that level and 2) the height-dependent effects and instrumental effects are about at the same level for these height differences.

One may, for example, remove A201 for a month and compare the offsets between the other three antennas, and then do same analysis removing A202 for one month.

Thank you very much for the interesting suggestion. Purpose of our experiment is to demonstrate and quantify the instrumental effects including multi-pathing. What you suggest here would be an attempt to mitigate multi-pathing. Nevertheless, at other famous sites, such as Wettzell for instance, there are also several GNSS antennas operated next to each other, e.g. the ones mounted on the balcony railing. These antennas are installed and run as permanent stations and they certainly affect each other. Removing one of these antennas would also be no option. Concluding, your suggestion is interesting but when mitigating the effects we cannot quantify them.

This may be a relevant explanation to the effect mentioned in the last sentence in the caption to Figure 8? Along the same lines, A203 and A204 are located very close to each other. Both are manufactured in metal and one issue to investigate at what level they affect each other?

This is another very interesting suggestion.

Please mind, our target is not to explain the source of the multi-pathing such as addressing it to a certain obstacle in the antenna environment. This is beyond the scope of our work. Instead, we want to quantify the multi-pathing. Accordingly, we set up identical antennas at different heights, relative close to the platform and a few meters above. On the other hand, your idea to explain the source of multi-pathing sounds convincing. Hence, we decided to include the following sentence into the caption of figure 8:

“As shown in the photo of the experiment setup (fig. 1) there are several obstacles in the vicinity of the antennas that can cause the observed multi-pathing. It is also very likely that the antennas affect each other.

For example Figure 1 shows that there are metal structures both to the left and to the right of the A203 and the A204 antenna installations. What is the impact of these?

The impact is demonstrated in the sky plots, where the reader can see the artificial slant delay effects caused by multi-pathing in the left and right directions.

The conclusion would benefit from being much shorter. The text in the section is more like a discussion of the results.

One sentence in the conclusion:

"In comparison to zenith delays, the parameterization of gradients a longer time intervals should be applied."

is difficult to understand. Do you mean that the gradients shall not be updated as frequent as the ZTDs in the estimation process? If so, why? The large gradients are typically caused by variations in the water vapour vapour that are short lived.

Response:

We have removed this sentence.

Technical Corrections

Pages 9 and 12, Figures 3, 4 and 5 have problems with axis labels and legends.

Response:

Done