

**Authors Response  
to  
Reviewer I comments  
on  
manuscript  
acp-2017-567  
Data assimilation of GNSS Zenith Total Delays from a Nordic processing centre  
by  
Lindskog, Ridal, Thorsteinsson and Ning**

**September 2017**

Dear Reviewer I,  
We are very thankful for quick and excellent comments. We have taken action to all suggestions and comments. See our response below in blue. The comments and suggestions were well in accordance with the ones made by a separate Reviewer. We have updated the paper based on the feedback and we feel that we have benefitted by the comments by Reviewer I. The modifications will appear in the revised paper to be submitted shortly after 26 September. The constructive comments and suggestions made by the two anonymous Reviewers were greatly appreciated and we have made a note of that in the Acknowledgements of the revised manuscript.  
Best Regards  
Magnus, Martin, Sigurdur and Tong

**Reviewer I comments and responses**

**General**

This is a nice article assessing the impact of GNSS ZTDs from the Nordic countries (except Iceland) on the quality of forecasts produced with the Harmonie-Arome NWP model. Several strategies for ZTD data thinning and variational bias correction are tested. In addition two types of GNSS ZTD estimation is tested. The manuscript is easy to read, and can be accepted with minor corrections and addons.

Thank you, we are happy to have been notified that Reviewer I is, overall, positive to the content and form of our manuscript.

**Specific**

Be consistent in defining and then using abbreviations. For example you define NWP twice, and the first time it is not when you first write numerical weather prediction. There's a tendency to cite some papers very often. Try to limit yourself to only cite a given paper once in one paragraph.

As suggested, we have reduced the number of citations for a given paper to only once in a paragraph. We think that we are also now consistent in defining and using abbreviations. Also Reviewer II pointed out that we omitted to define at least one abbreviation. We now only define abbreviations once, the first time it appears. The exception is that when abbreviations appear both in the abstract and in the text we define it twice. The reason is that we want both the abstract itself and the text without the abstract to be self-contained. We have tried to avoid abbreviations in the abstract to make it easily readable but GNSS and ZTD appear many times and are important and central to the manuscript. Therefore we defined these abbreviations also in the abstract.

In contrast to most other data assimilated in NWP, ZTD is a parameter that improves with time; as satellite orbits, clock errors etc. become better determined, moving from being based on predictions to being based on observations. For this reason it is good to talk about ZTD being an estimate, not an observation.

*This is true. For simplicity however we have chosen to refer to it as an observation throughout the manuscript. This is now also stated in the introduction.*

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*Good suggestion. We have now mentioned the work by Guerova et al. in the introduction and added a reference.*

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*'The sources of bias in the ZTD observation data with respect to the ZTD model data may be due to several reasons, such as GNSS data-processing algorithms (use of mapping functions, formulation of hydrostatic delay, errors in the conversion of ray path to zenith delay) and systematic errors in both the model fields and the ZTD observation operator. In particular, a low model top will generally result in a systematically too-low model equivalent of the GNSS ZTD observations.'*

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Figures 2 and 3 have been replotted where nga1 and nga2 were compared to the ZTDs obtained from GNSS post processing.

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'The thinning is applied in the form of a static whitelist based on studies of data availability and of observation minus background equivalent statistics from a spin-up period. Thus the thinning is static so that for each data assimilation cycle of observations from the same set of GNSS ZTD receiver stations are used.'

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## Reviewer II comments and responses

### General Comments

This paper is reasonably well written and I find its topic quite interesting in the context of limited-area mesoscale model Data Assimilation.

Anyway, I feel there are a few issues that might deserve a closer look, as discussed in the detailed comments below.

Thank you for your generally positive view on the manuscript and for your constructive comments that are well in line with the comments of Reviewer I. We have revised our text, and suggestions and detailed responses can be found below.

### Specific Comments

#### Introduction

- A so extended explanation of the model used could not be so necessary here due to it is done later in Section 3.

We totally agree and related comments came also from Reviewer II. We have therefore removed several sentences concerned with NWP setup details and made sure these are instead covered in the NWP setup section.

- When it says “and GNSS ZTD from 28 receiver stations are assimilated operationally in MetCoOp” could be explained a little more.

Good suggestion. We have added the following text to explain a bit more about the 28 receiver stations that were assimilated operationally into the MetCoOp system:

'These 28 receiver stations have been selected from the rather few receiver stations over the MetCoOp domain. Often these are supersites, processed by several centres for comparison purposes. MetCoOp operationally uses data processed by the Met Office in the United Kingdom and by the Royal Observatory of Belgium.'

#### Section2:

-The writing (wording) of this section should be revised.

Thank you, we have revised the section.

#### Section4:

-More clarification of the different experiments should be made, for example when talking about A, B or D experiments comment that they are all using 100km thinning, when the experiments are from A, C or D they are using a constant offset, etc. Maybe a table with all the experiments and properties could help.

This is an excellent suggestion. We have added a number of sentences describing what is in common between experiments in different studies. However, in our opinion, after

adding these sentences, it is not necessary to add an additional Table to the manuscript describing the experiments. The newly added sentences are: ' Note that in all experiments of studies A, C, and D only one predictor in the form of an offset value was used. In all experiments in studies B and D a 100 km thinning distance was used. All experiments in studies A, B and C used the operationally used B matrix and all experiments in studies B, C and D used the NGA1 data set, processed with the Bernese approach.'

-Why do you specify the experiment name just on A1, A2, and A3 cases ?

Thanks for pointing this out. It was a mistake and it was inconsistent. We have chosen to remove the specification of experiment names also from A1-A3, since we think these are not needed.

#### Section5:

-The Case study Section was clearly explained but may be not enough to show the improvement of using one thinning distance or other. Supporting those graphics with the use of SAL verification method for example could result in a more complete description of the chosen case study.

We appreciate this comment and also another Reviewer had similar thoughts that supporting graphics would be beneficial. We therefore included one additional Figure in the manuscript showing gauge-adjusted precipitation. Due to the phase error, we have chosen to shift the accumulation period for one hour as compared with the accumulation in the forecasts. We believe that this Figure has improved the illustration of the case study and thank the Reviewer for his suggestion. We have also added text in the case study section related to the newly added Figure. Finally we have modified the radar Figure to show gauge-adjusted accumulated precipitation, rather than instantaneous precipitation as before. Regarding SAL verification, we think that it would be mainly beneficial for an extended period and not just for the one case. Based on that and the fact that we already have several different verification approaches applied in the manuscript we chose not also to include SAL verification

### **Technical Corrections**

#### Introduction

-There are several repeated “they”

Thanks, at one point 'they they' was replaced by 'they' and at another point we simply removed 'they', since it was not needed. Now 'they' appears only once or twice in the section.

-Statistics instead of statistcs

Corrected.

#### Section2:

-NGAA name should be mentioned at the beginning.

It is now mentioned at the beginning of section 2.

-ZTD instead ZTDs

Modified as suggested.

-NRT: explanation is needed when it is used for the first time

Abbreviation is defined the first time it is used. One sentence has been added in order to give a brief explanation about what near real time means in E-GVAP.

2.2. The title could be changed to NGA1 product/ dataset, not just NGA1

As suggested, we have modified the title from 'NGA 1' to 'NGA 1 dataset'.

2.3 The same

As suggested, we have modified the title from 'NGA 2' to 'NGA 2 dataset'.

2.4 Please review the wording. Receiver instead of reciever

The section has been partly re-written and 'Reciever' is corrected to 'receiver'.

### Section3:

-assimilation instead of assi milation

Corrected.

-data assimilation instead of data assimilations

Corrected.

-...control variable vorticity, unbalanced divergence, ... review that sentence

We have now modified the sentence and split it into two sentences, to make it easier to read.

-alleviate instead of elevate

Corrected.

-Last paragraph: review the writing

Thanks, we have now reviewed and improved the wording in the last paragraph of section 3.

### Section5:

5.2- Review the first sentence writing

Thanks, we have now modified the sentence and split it into two sentences, to make it easier to read.

5.3.-

-H+12 and H+24 instead of +12 and +24

Thanks for making us aware of inconsistency between text here and in Figures 6, 8, 9 and 10. However we prefer to write the forecast ranges as '+12 and +24 h'.

-Fig 6: H+12 instead of +12

*Thanks for pointing this out, but again we prefer to write the forecast ranges as '+12 and +24 h'.*

-“For forecasted variables other than humidity...”, review this sentence  
The sentence has been modified to be clearer.

-“.. in the form of NGA1...”, it is not a 'form' but a product or dataset.  
Modified as suggested.

-Review the writing of the last part of the section

As suggested we have reviewed the writing of the last part of the section now modified at some places to make the text clearer and easier to read.

-Fig 8, 9 and 10: H+12 and H+24 instead of +12 and +24

*Thanks for pointing this out but again we prefer to write the forecast ranges as '+12 and +24 h'.*

5.4- Figure 12: 2016 instead 2026

Corrected.

