Review of acp-2017-567: Data assmilation of GNSS Zenith Total Delays from a Nordic processing centre, by Lindskog, Ridal, Thorsteinsson and Ning.

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.

Specific
Be consistent in defining and then using abreviations. 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.

In constrast 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.

p 2 Either here, or in the section on the NWP model setup, provide at short, conceptual explanation how radar rain rate/reflectivity is turned into humidity.

p 2 Consider refering also to the recent review by Guerova et al (the GNSS4SWEC review paper).

p 3 top of page, and again p 9: How do you know the biases handled with VarBC are biases of the GNSS ZTDs? NWP also have biases. In addtion observation operators might include short cuts, for example regarding the corrections for the offset between model orography and GNSS antenna, which will also show manifest themselves as biases.

p 3 4. line from bottum. Precis -> Precise

p 5, section 2.4 : On the intercomparison of nga1 and nga2. Why not compare also to ZTD estimates obtained in GNSS post processing, serving as "truth".

p 5+, section 3: Regarding the NWP setup there is too much sharing of whole sentences between the introduction and section 3. Reduce the amount of duplication.

p 5 last line: I presume you use 6 or 12 hourly ECMWF forecasts with one hour time resolution as boundaries?

p 7 3. line: assi milation -> assimialation

p 8 ".. bias correction, error specification" -> "..bias correction, and error specification"

p8 You use a fixed sigma_O for all sites and seasons, and discuss using Desroziers method to determine

sigma_O instead. Have you considered also looking at the O-B distributions and give preference to those GNSS sites that are "most Guassian" in this regard?
In this connection, is the data thinning a random thing, or is it always ZTDs from the same sites that are assimilated?

p 8, 3. last line: To elevate -> To alleviate

p 10. Please provide a few words about the DFS signal per observation.

p 15, figure 9. Use markers for 6 or 12 hours, to be consistent with your NWP cycling and verification frequency.

p 15, figure 10. Notice that automated cloud cover measurements from some instruments have systematic problems at the very highest and lowest values.

p 16, figure 11. Use markers for 6 or 12 hours.

p 16. The selection of the case study is a bit unfortunate. The area with strong precipitation is quite close to the boundary of your NWP area, and the atmospheric flow in the period is from South-West toward North-East, ie. into your area near the main precip. In addition you have for some reason not included GNSS ZTDs from the E-GVAP Dutch, German, and Polish processing centers, which would have provided plenty of additional ZTDs for assimilation. As heavy local precip in Southern Sweden and Denmark is often related to humid air arriving from South-West, these are probably important observations to include in your operational NWP.

Figure 12. I strongly recommend to provide maps of observed 3 hour precipitation for comparision to the NWP 3 hour precip. maps. Either raingauge adjusted radar precip, or raingauge based precip. The instantanuous radar rainrate images are misleading. Alternatively the NWP precip should be for a much shorter period.
For the type of heavy precipitation 12 h to 18 h is a long forecast, and you might excuse yourself and provide observed versus modelled precip with an offset in time. You have already mentioned a phase error in the text. Looking at synop precip data in our database it appears to me the precip your NWP dumps between 0 and 3 UTC actually fell between 19 and 23 UTC the day before.

Figure 12. The year is 2016, not 2026.