

## REVIEW NUMBER 1

*This is a very fine overview article, providing a short overview of the GNSS4SWEC ES 1206 Cost action, an extensive, detailed overview of the selection and handling of data for the GNSS4SWEC benchmark campaign, and some first results from the inter comparisons of GNSS and NWP derived ZTDs and ZTD gradients.*

*It is clear the benchmark data have been carefully screened and processed, providing a very useful dataset for further studies. Among the most interesting results are that GOP and GFZ results agree well (network versus ppp), that higher resolution NWP seems to agree better with the GNSS, and that GFS NWP is biased with respect to the other solutions.*

*The the NWP community the finding of significantly larger gradients from the GNSS processing than found in NWP is very interesting, and potentially useful as an added data source. Likewise the finding that in certain situations the contribution from liquid water and ice is not negligible (estimated from NWP based calculations).*

*In my view the manuscript is almost ready for acceptance. I would recommend correct points 1 and 3 below before acceptance, while point 2 might be better suited by an online comment from the authors, given that this type of manuscript does not contain many details.*

*A few more detailed comments:*

1) Many places in the text a reference to section 0 is given. Presumably that's the annex (judging from the numbering of the equations there), but the annex has no number.

*Manuscript changed (all cases corrected: Sect 2.3, Sect 3 and Sect 5.3).*

2) A bias for GFS ZTD is found. There could be several reasons, some of which are related to how the numerical integrator for NWP ZTD is made, regarding both interpolation (different vertical resolutions) and extrapolation (top of the model).

*Manuscript changed (Sect 5.2 completed). A possible explanation for the systematic deviation between NCEP's GFS and ECMWF's ERA-Interim ZTDs is the low vertical resolution of the NCEP GFS data (available on 26 pressure levels). In fact, the bias in the ZTD stems from a bias in the ZWD. For a comparison between all the NCEP GFS and ECMWF ERA-Interim tropospheric parameters see Zus et al. 2015 ('WG1 model sub-group summary', ES1206-GNSS4WEC COST Meeting, Wroclaw, September 28 – October 1, 2015). Note that a comparable bias between NCEP and ECMWF ZWDs was reported by Urquhart et al. 2011 ('Generation and Assessment of VMF1-Type Grids using North-American Numerical Weather Models', presented at XXV IUGG General Assembly, Melbourne, Australia, June 28th – July 7th, 2011, available at <http://unbvmf1.gge.unb.ca/Publications.html>). We also note that the interpolation routine, that is used to compute the refractivity at arbitrary points, is the same for both NWMs. Therefore the low vertical resolution of the NCEP GFS data also implies larger interpolation errors.*

3) Equation 0.6, for the effect of the hydro meteors, contains numbers on the right hand side, which seem to call for units. Is what is called "mass content" of hydro meteors another word for their mass density?

*Manuscript changed (more clear explanation added, Sect 5.5).  $M_{lw}$  is the mass content per unit of air volume of liquid water hydrometeors (e.g. cloud water and rainwater) and  $M_{ice}$  the mass content per unit of air volume of icy hydrometeors (e.g. pristine ice, snow and graupel).*

Speaking about units there is on the other hand no need to provide units for the density, pressure, temperature and gas constants further up page 19, as long as no values are given for the constants in equations 0.4 and 0.5.

*Manuscript changed (units deleted from equations in Sect 5)*

The idea to include the hydro meteor contribution in the NWP cost function (if the NWP contains the relevant parameters) mentioned in the conclusion is interesting. In reality it is very complicated, since they are normally not variables in the same sense as specific humidity of the NWP, and the NWP can be far of regarding their size. But pointing out that hydro meteors do sometimes contribute significantly to what appears otherwise to be ZWD is important.

*Thank you for this comment.*