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Prof. Witold Rohm
Institute of Geodesy and Geoinformatics
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PhD Thesis Evaluation Elzbieta Lasota

Dear Prof. Rohm,

It is a great pleasure to serve as a reviewer for the doctoral thesis on “Use of GNSS ground-based and satellite observations for tropospheric refractivity investigation” by Ms Elzbieta Lasota. Before being invited to review this thesis, I haven’t met Ms Lasota in person or collaborated in any project. I am aware of her research through her five peer-reviewed publications.

The thesis is written in English with the abstract in both English and Polish. It consists of three chapters. Main scientific results were presented in her five closely related, peer-reviewed publications and only summarized in the thesis including Introduction, Summary and Conclusions. Five manuscripts are included in Appendix A. The main scientific objective of the dissertation is to utilize the properties of propagating space- and ground-based GNSS signal, refractivity and bending angle, to advance monitoring and modelling of the troposphere, in particular during severe weather events. The thesis subject is very important and has huge, significant societal and economic benefits. As the Earth’s climate is getting warmer, there are more severe, high-impact weather events, such as tropical cyclones and hailstorms studied in this research. Therefore, it is essential to better monitor, understand and monitor those events. I appraise Ms Lasota and her advisors for tackling such an important and challenging topic. The thesis investigates the small part of the atmospheric refractivity caused by hydrometeors, which is often ignored but has increased magnitudes during severe weather events, such as heavy rains and thick clouds. This makes the study unique and clever. The methodology is clearly and concisely presented in the schematic diagram in Fig. 1.8 through five closely and logically connected Work Packages (WPs).

The research presented in the thesis produced original and significant scientific results. This is partially due to the fact that all five publications have been peer-reviewed and deemed original research. I also briefly summarize my view on this. Publication A.1 represents the first attempt to evaluate the cloud contribution to RO retrievals after considering the uncertainties of bending angle retrievals. The results have huge potential application to better assimilate the GNSS RO data to the NWP models and thus improve the TC forecasting. Publication A.2 studies the impact of TC hydrometers on ground-based GNSS delays. Although it was just done for one storm (Typhoon Meranti), it has huge implications on assimilation of STDs and inclusion of hydrometeors’ contribution in ZTDs and STDs. Publication A.3 is more technical and results in a dataset with complete set of RO profiles co-located with TC tracks. This dataset is the main input

of publications A.1 and A.4. Publication A.4 represents the first step to use combined space- and ground-based GNSS observations to study two hailstorms. Publication A.5 evaluates four ML models for retrieving meteorological profiles using GNSS RO profiles without input of NWP models and shows promising of ML in GNSS RO physical parameter retrievals.

I have the following comments to help Ms Lasota improve her final thesis.

1. Abstract: The first three paragraphs are all introductions or motivation for the study. Only the fourth paragraph is about main results of this Ph.D. study. I would recommend that Ms Lasota expands the last paragraph to include more specific and significant results especially emphasizing the originality of the research.
2. The thesis is presented in an unconventional way since it mainly summarizes five individual publications and attaches them in the appendix. The author did a good job in Section 1.7 to try to connect five publications. However, they are totally separated in Section 2. One question is about the order of them (see #9 below). Another question is about the relationship and connection among them. It would be good to try to connect each subsection with others.
3. Section 1, “Introduction”: Overall this section needs some additional references. I listed a few examples below. The candidate can find more.
4. Young et al. (2015) reference is wrong. You left the first author out (J. Wang). It should be **Wang, J., K. Young, T. Hock, D. Lauritsen, D. Behringer, M. Black, P. G. Black, J. Franklin, J. Halverson, J. Molinari, L. Nguyen, T. Reale, J. Smith, B. Sun, Q. Wang and J. Zhang, 2015: A long-term, high-quality, high vertical resolution GPS dropsonde dataset for hurricane and other studies. *Bull. Amer. Meteor. Soc.*, **96**, 961–973. doi: <http://dx.doi.org/10.1175/BAMS-D-13-00203.1>**
5. You can add some references for Section 1.2. For example, you can add the following reference after the first sentence. “Kunkel, K.E., Karl, T.R., Brooks, H., Kossin, J., Lawrimore, J.H., Arndt, D., Bosart, L., Changnon, D., Cutter, S.L., Doesken, N. and Emanuel, K., 2013. Monitoring and understanding trends in extreme storms: State of knowledge. *Bulletin of the American Meteorological Society*, 94(4), pp.499-514.
6. Section 1.2.2 Hailstorm: It would be useful to briefly discuss how hails might affect GNSS signals.
7. Page 35, 2nd paragraph: correct this sentence “The obtained difference quantify the magnitude of the clouds’ impact ...”.
8. Publication A.2: There has been this unexplained mystery of the dry bias in GNSS-derived IWV at high IWV values (i.e. cloudy or precipitation conditions) comparing with radiosonde, MWR and other measurements (e.g. Ciesielski et al. 2014). Just wonder whether ignoring the impact of hydrometers in GNSS IWV retrieval might explain the dry bias. Ciesielski, P. E., H. Yu, R. H. Johnson, K. Yoneyama, M. Katsumata, C. N. Long, J. Wang and others, 2014: Quality-controlled upper-air sounding dataset for DYNAMO/CINDY/AMIE: Development and corrections. *J. Atmos. Oceanic Technol.*, 31, 741-764.
9. Section 2.3 (Publication A.3): Since the dataset from Publication A.3 is the main input of publications A.1 and A.4. I wonder whether it is better to move Section 2.3 to Section 2.1 or make references to Publication A.3 in other sections. In current flow, it seems that Section 2.3 is out of order.
10. Section 3.2: Change “not negligible” to “non-negligible”.

Overall assessment

There is no doubt that the candidate provided original solutions of a few scientific questions and acquired deep but also broad knowledge in the topic of the thesis. The layout of the dissertation

is acceptable although I have some suggestions (see #9 above) to improve it, the bibliography is mostly complete, the methods used in the analysis are well described. The discussion of the results and potential applications of the obtained results are sound and solid. Thus, the final conclusion for evaluation of the thesis is ***Positive (sufficient) with honors (outstanding)*** given its scientific originality and significance, high scientific can technical quality and potential future applications, and Ms Lasota's tremendous amount of high-quality work on diverse topics.

Final recommendation

In my opinion, Ms Lasota's doctoral dissertation fulfils the requirements for a doctoral degree in particular under Article 13 of the Act of March 14, 2003 Ustawa o stopniach naukowych i tytule naukowym oraz o stopniach i tytule w zakresie sztuki (Dz.U. 2003 Nr 65 poz. 595 z późn. zm.).

Please let me know if you have any question.

Yours sincerely,



Dr. Junhong (June) Wang