## Author's Response to Referee #3

We would like to thank the reviewer for the valuable and helpful comments. Our answers to the comments (quoted in gray) are written in *italic* below each of the comments.

## Reviewer #3 (Comments to Author):

Initial assessment: The manuscript aims to validate the use of ERA5 reanalysis data and radio-occultation (RO) data for long-term monitoring of wind fields. First the geostrophic relation is validated by comparing long-term averages of ERA5 wind speed data with geostrophic wind speed data determined from ERA5 geopotential data and, secondly, geostrophic wind speed derived from radio occultation geopotential data are compared with the ERA5 geostrophic winds. The manuscript concludes that RO determined wind data can provide added value to ERA5 wind data, for the benefit of wind field monitoring.

1) The manuscript is quite well written. I have one basic principal hesitation. As I understand it, and it is also stated on line 44 of the manuscript, RO observation data are assimilated into operational analysis for forecasting purposes as well as into reanalysis. In this case ERA5 data and RO data are dependent and should not be used to validate the potential of RO data to support wind field monitoring. It may even be so that RO data is the dominating observation data source over else data-void areas like oceans. The differences between Figures 7e (Northern Hemisphere winter) and 7f (Southern Hemisphere) support this criticism.

*Thank you for basically finding our manuscript quite well written; we aimed to do everything with due care, science-wise and in the writing.*
*Regarding your "one principal hesitation", we recognize that we apparently have not been clear enough in the introduction of our study design and purpose. We hence will improve on this in the revised manuscript, at several places both in the introduction and the method description, and in fact also plan to improve our what-we-do-term in the paper title from "Validation of…" to "Evaluation of…". On the latter, we realize that we may misguide some readers with using the term "Validation" for actually an evaluation design, where we 'just' test approximations; one physics-approximation (use of local geostrophic equations vs. of full dynamics equations to obtain U,V) and one sampling-approximation (use of 'a-bit-sparse' observational RO sampling vs. of 'full-coverage' space-time-gridded (re)analysis sampling). Given this, the essence of this initial response to your query is that the results of both steps of our "two-steps evaluation method" (quoted from the caption of Figure 1 that introduces our two goals) do very weakly depend on which (re)analysis we use as a reference, as long as it is a state-of-the-art (re)analysis. That is, similar to the cases where we estimated "under-sampling biases" (also termed "sampling errors") and other approximation biases in previous climate-related evaluation studies for various RO variables (e.g., Scherllin-Pirscher et al., 2011, 2014, 2017; https://doi.org/10.5194/amt-4-2019-2011, https://doi.org/10.1002/2014GL061524, https://doi.org/10.1002/2016JD025902), a sound validity of the estimated "approximation-vs.-'true'-reference" bias fields requires a state-of-the-art (re)analysis that represents quasi-realistic atmospheric variability at sub-daily to multi-month time scales at 100-km-scale to large-scale spatial resolution. We most often used ECMWF (re)analyses and/or short-range forecasts (e.g., Steiner et*

*al. 2013, https://doi.org/10.5194/acp-13-1469-2013; Ladstädter et al. 2023, https://doi.org/10.1038/s41598-023-28222-x), but also others were tested. We agree that (re)analysis or short-range forecast fields from assimilation-forecasting systems where RO data would not be assimilated, would be somewhat less quasi-realistic in representing the atmospheric variability in the mass and wind fields, indeed reflecting the positive impact of the assimilated thermodynamic RO data information content. However, since all major state-of-the-art (re)analyses do assimilate RO data since 2006 (start of the "U.S. COSMIC" and "European Metop" RO multi-satellite era), we consider it adequate in this study to quantitatively evaluate the validity of the geostrophic approximation (first goal), and of the RO-sampling sufficiency for providing adequate monthly isobaric-level geopotential fields (second goal), based on using the representative mass and wind field data of the state-of-the-art reanalysis ERA5 (from other studies also involving short-range forecasts, or MERRA2, JRA-55 reanalyses like in von Schuckmann et al. 2023 https://doi.org/10.5194/essd-15-1675-2023, Section 3 therein, we do not expect major differences for the present purpose; we agree, though, we could also test this for a few months for this study, which we so far considered an effort beyond the scope of this initial study). In summary, we hence consider the indirect "dependence" of ERA5 on RO data via assimilation of (some of) the latter data fully compliant with the goals of this study that is actually not including validation in the more strict sense of the term (sorry for the terminological mislead that we will rectify); we plan to improve the revised manuscript to make this clearer.*

Other views:

2) Line 13: Also the use of ERA5 wind analysis data to compare and validate ERA5 geostrophic wind data based on ERA5 geopotential data is questionable. The ERA 5 wind and geopotential analysis increments are coupled via near-geostrophic linear relations. For this reason ERA5 wind and geopotential data are deterministically dependent, although the long term mean increment may be very small.

*Thank you, please see the answer above. We agree that the 3D-gridded U,V wind field results of ERA5 outputs, obtained from the ECMWF model dynamics&physics underlying the data assimilation in ECMWF's integrated forecasting system (IFS), will (hopefully!;) be physically consistent, hence "deterministically dependent", with the isobaric-level geopotential fields at the appropriate space-time scales. But as you hint, we focus in this study on monthly-means-based long-term wind field monitoring, at highest horizontal resolution no finer than several 100 km (2.5° x 2.5° sampling, order 5° lat x 5°/cos$\varphi$ lon resolution), i.e., we look at quite strongly space-time-filtered wind fields, where most of ageostrophic components are attenuated quite strongly. We consider ERA5, and the underlying ECMWF IFS, in the context a state-of-the-art atmospheric analysis asset that is capable to provide us with quasi-realistic dynamics&physics, properly bridging from 6-hourly analyses per day to monthly-mean fields at the synoptic- to large-scale horizontal resolution of interest.*

3) Line 73: In my view, in case RO observations were used already, they cannot provide any further "added value".

*Thank you, your view indicates that we may also not have made it sufficiently clear so far that the key phrase for the "added value" is, as explicitly included in the title, "…the potential of long-term radio occultation data…". That is, what RO may deliver as "added-value" based on its rather unique*

*combination of high accuracy and long-term stability (=multi-year to multi-decadal stability), is the capacity to accurately keep long-term consistency also over certain months and times where reanalyses (like ERA5) experience inhomogeneities due to changes in observing systems, i.e., in the combination of assimilated data sets in observation type, amount, quality, and space-time coverage. We in fact found in this study indication of one such "inhomogeneity year" (2016) in ERA5. A more long-term stable monthly-mean RO data record might hence cover, say, the 15 years 2006 to 2020 wind-field record more stably than the corresponding record from ERA5, which would be an added-value for climate change-related studies like long-term gradual shifts of the Hadley cell, jet stream patterns, etc. We will carefully recheck the text, to make sure we improve the description of what "added-value for long-term monitoring" means, where found needed. By the way, a good example for such added value was recently published in a climate change-related study based on RO-derived long-term temperature fields (Ladstädter et al. 2023, https://doi.org/10.1038/s41598-023-28222-x).*

4) Line 80: It is stated that a latitude-longtude grid of 2.5 degrees resolution is used for ERA data. Please inform whether 2.5.degrees is also the resolution of the input spectral ERA5 data.
Furthermore a latitude-longitude grid is not optimal for calculation of geostrophic winds in polar areas. Alternative Grids should be considered, at least in polar regions.

*Yes, the ERA5 data are from T42 spectral, consistent with the 2.5° grid (and various settings in the technical fine details how to do this, based on the original model level fields, have been tested very carefully as part of various previous studies). Regarding RO, we do in fact use equal-area cellsize selection around each grid-cell center location; hence the 2.5° x 2.5° sampling grid does not imply that we get, due to meridian convergence, smaller-and-smaller cell areas towards the poles. But thanks for mentioning this; we will recheck our description of these method details and improve as needed.*

5) Lines 104-108: The sentence "RO data show …. 2019)". is a bit un-clear.

*Ok, thanks, just looked at it – agreed, yes, we need to polish this one a bit to make it more clear…we will do so.*