Comments on "Forward operator for polarimetric radio occultation measurements "

Numbers on left refer to line number in the online preprint:
https://amt.copernicus.org/preprints/amt-2023-132/amt-2023-132.pdf

This manuscript nicely describes early work towards development of a forward operator for the recently developed polarimetric RO measurement. While the presentation is scientifically well presented, I have some minor comments below.

25. The ionosphere also depolarizes the GNSS carrier. Suggest to clarify, eg, "….if a large difference between horizontal and vertical phase shifts is observed (after accounting for ionospheric contributions), that indicates…."

30. Also, India's Navic GNSS system indeed operates at S-band for improved positioning, but with no dual-polarization receive capability (that I am aware of).

Section 1, general. To the less-informed reader, it's not clear what PRO provides "in addition to" standard RO. Suggest making this clear in simpler terms. "PRO complements the standard RO profile of bending angle with a complementary measure heavy precipitation at each vertical level. This is done by measuring the phase delay at two orthogonal (horizontal and vertical) polarizations. This additional measurement provides the path-integrated specific differential phase shift at each vertical level. After inversion, a user therefore has in addition to the profile of temperature, moisture and pressure, a complementary measure of the presence of heavy precipitation along each ray path." Or something like that… Right now, when you say, "…PRO measurements exhibit stronger signals in the presence of heavier precipitation" it is not clear what signal or measure you are referring to.

62. Slight correction: "Since RO measurements represent path-integrated quantities, a positive value of KDP is an indication of the presence of horizontally-oriented hydrometeors somewhere along the ray path".

125. The uncertainty in (3) also relates to the natural variability in the unknown particle size distribution (PSD). Near L-band, Kdp is more related to the mass water content (3rd moment of the PSD), unlike radar reflectivity (6th moment of the PSD). Therefore, Kdp is less sensitive to variations in the PSD and the contributions from the largest drops.

For "flat enough" ice particles, Kdp can actually larger than for (similar water content of) rain media. Since the heavy liquid phase only rain is usually concentrated in a smaller domain than the rest of the (mixed or solid) phase above, a small Kdp integrated over a long path can exceed that from a larger Kdp but integrated over a shorter path. Suggest you cite Fig 11 of Turk et al 2021 to give the reader an idea of the range of values being talked about (pasted below).

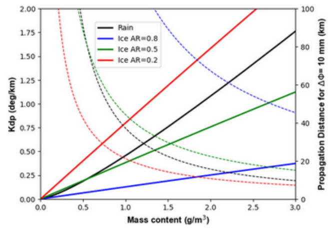

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FIG. 11.

One-way propagation differential phase shift K_{dp} (° km^{-1}, left axis) at 1.4 GHz, as a function of equivalent mass content M (g m^{-3}). The blue, green, and red lines indicate an ice media characterized by oblate spheroids with axis ratios of 0.8, 0.5, and 0.2, respectively, and black is for a rain media with axis ratio following Beard and Chuang (1987). The associated colored dashed lines indicate the propagation distance (km, right axis) through each of these media that would be required for a value of $\Delta\phi$ = 10 mm.

Citation: Journal of Atmospheric and Oceanic Technology 38, 10; 10.1175/JTECH-D-21-0044.1

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138. Presumably the drop size in the IFS representation of LWC are so small, that these are essentially spherical anyhow (and hence contribute little to no to the net ϕ_{DP}).

150. Is the Geer et at formulation for converting vertical mass flux to water content specific to the IFS model, or is this a more general formulation? Readers of this manuscript may want to use this formulation with other models or reanalysis that provide vertical mass flux variables.

156. When you say, "…This configuration is essentially identical to the operational deterministic forecast", is this implying that since the simulation is done with model data so close in time to one of the operational model output time steps, that it is "essentially identical"?

200. Suggest that you cite the work of Murphy et al who earlier suggested this "displacement effect" in their 2019 paper (see their discussion on observation geometry). In fact, you should cite this paper in the very beginning of this manuscript, as their work is the first study on microphysics and PRO.

[1]
M. J. Murphy, J. S. Haase, R. Padullés, S.-H. Chen, and M. A. Morris, "The Potential for Discriminating Microphysical Processes in Numerical Weather Forecasts Using Airborne Polarimetric Radio Occultations," *Remote Sensing*, vol. 11, no. 19, Art. no. 19, Jan. 2019, doi: 10.3390/rs11192268.

230. I would suggest renaming this section to, "Limitations of 1D Operator". This is an important section and these limitations will magnify as model resolutions further shrink.

It's important to mention that this limitation is not only valid for modeling PRO in precipitation (as you show), but in general for modeling of RO, e.g., the bending angle from the water vapor field. In areas of high pressure and fair weather (no clouds), one would expect little different between the bending angle simulated by the 1D and 2D operators as the horizontal water vapor field is rather homogeneous. But near clouds and precipitation, where one wants to maximize the benefit of PRO or RO observations, there are also variations in the water vapor field (eg, dry/moist across frontal boundaries) such that simulated bending angles can be quite different depending upon whether the forward operator was positioned "across" or "along" the weather front.

With a coarse model grid spacing (eg, 1-degree or so), these effects may not matter too much (?). But as model resolutions get smaller and smaller, and resolve clouds and water vapor at km scales, it is important to replicate the actual ray path viewing geometry to being simulations and observations into accord.

325. Referring to “horizontally sparse observations”, if a dense sampling of PRO-like observations were to be available (each PRO viewing from a different relative azimuth angel), do you think that PRO would also be able to better correct for position errors?