Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2020-147-RC1, 2020
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Atmospheric Measurement Techniques Discussions

Interactive comment on "Generalized Canonical Transform method for radio occultation sounding with improved retrieval in the presence of horizontal gradients" *by* Michael Gorbunov et al.

Anonymous Referee #1

Received and published: 11 June 2020

The derivation of atmospheric refractivity profiles from GNSS radio occultation (RO) observations in the lower and mid troposphere is a challenging task for several reasons, the most important being multipath ray propagation which leads to signal interference effects at the receiver location. To address multipath the present authors over the last two decades have developed bending angle retrieval techniques based on transformations ("canonical transformations") from geometric to impact parameter space. These wave optical techniques, the most advanced being the CT2 algorithm, are based on the assumption, that the atmospheric refractivity field is spherically symmetric. Validation studies on the performance of the wave optical approaches confirmed their superior performance in the mid troposphere when compared to the geometric optics method.

In the lower troposphere, however, horizontal gradients in the refractivity field induce deviations from spherical symmetry, in particular at low latitudes, and the retrieved refractivity profiles may differ by a few percent from corresponding ECMWF data.

In the present study the authors address the lack of spherical symmetry in the lower tropospheric refractivity field by introducing a linear coordinate transformation in impact parameter space such that bending angle is a single-valued function of a generalized "impact parameter". The key feature of this approach ("CT2A") is the introduction of an a-priori unknown parameter β, which needs to be adjusted.

The first two sections of this paper provide an excellent summary of the development from the original "back propagation" to the current CT2 method. The third section describes the generalization of the "canonical transform" method. The introduction of an adjustable parameter to the wave optical retrieval is conceptually a significant step forward, even if the benefit of the CT2A algorithm to the refractivity retrieval is not immediately obvious. At low latitudes the CT2A method appears to improve the data yield within the planetary boundary layer, albeit at the expense of larger deviations from ECMWF. At polar latitudes horizontal gradients are expected to be less pronounced and therefore the CT2A algorithm does not perform better than CT2. In summary, I consider this paper a valuable contribution to the topic of RO retrievals in the lower troposphere and I recommend its publication.

The latitudinal dependence of the fractional refractivity deviation on the choice of the parameter β is an intriguing feature of the present analysis. In the subtropics at altitudes between 1 and 2 km the sensitivity (in particular for $\beta < -10$ km/rad) is larger compared to the latitude band $-10°$S to $10°$N. An obvious question is if this latitudinal dependence is correlated with the latitudinal dependence of strong (horizontal) refractivity gradients extracted from ECMWF meteorological fields. Second, I would suggest to improve the graphical representation of the results by splitting the right panel in Figs. 3 to 11 into two panels, one showing the CT2 results ($\beta = 0$ km/rad) and the other the *difference* between CT2A and CT2.

Technical corrections:

Page 2, line 46:
“a short-wave asymptotical solution” → “a short-wave asymptotic solution”

Page 2, line 51:
Gorbunov et al. (2004) probably should read Gorbunov and Lauritsen (2004b).

Page 3, line 69:
“which is known the Bouger law” → “which is known as Bouguer’s law”

Page 4, line 117:
“although it may have multiple projections to the axis of time t,”
I would suggest instead “although it may not be single-valued with respect to time t,” or similar.

Page 5, line 138:
“instant frequency” → “instantaneous frequency”

Page 7, line 173:
“This transform is performed under the application of the procedure of the stationarization of the transmitting satellite [...]”
I suggest to rephrase this sentence.

Page 7, line 186:
I assume here $\tilde{u}(\xi)$ should read $\tilde{u}(\sigma)$ instead.

Page 8, eqn. 18:
A closing bracket is missing.

Page 9, line 226:
[Gorbunov2004b] probably should read (Gorbunov and Lauritsen, 2004b).

Page 10, line 263:
“The difference in the results of the application of these WO methods is less significant

than the difference coming from other parts of RO data processing systems, [...]”
I suggest to add a reference.

Page 11, line 282:
[Arnold1978] → (Arnold, 1978)

Page 11, line 299 and page 12, line 304:
[Gorbunov2019] is not listed in the reference section.

Page 19, line 407:
“COSMC–ECMWF” → “COSMIC–ECMWF”

Page 21, line 476 and 478:
“Intoduction” → “Introduction”

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