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Interactive comment on "Simultaneous retrieval of water vapour and temperature profiles and cirrus clouds properties from measurements of far infrared spectral radiance over the Antarctic Plateau" *by* Gianluca Di Natale et al.

Anonymous Referee #3

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This paper introduces a new retrieval approach designed to infer water vapor, temperature, and ice cloud properties from ground-based measurements in the far-infrared. The approach utilizes an optimal estimation approach to infer effective diameter and ice water path as well as temperature and humidity at "a few levels" of the atmosphere. The methodology is robust but the implementation lacks sufficient care to address all sources of uncertainty in forward model assumptions limiting the conclusions that can be drawn from the results. Similarly, the evaluation presented is qualitative and does not provide adequate information to assess the performance of the retrieval. The subject of the paper is appropriate for AMT but the following major revisions are required

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Discussion paper

before the work rises to accepted standards for introducing a new algorithm.

Major Comments:

1. Many of the assumptions made are not suitably justified and the associated uncertainty analyses are inadequate to appropriately characterize the performance of the algorithm. For example, the statement “The strongest assumption, which is considered sufficiently reliable, is the approximation of a single uniform layer” is not justified in any way despite the availability of statistics from active sensors. In addition, the uncertainty owing to the assumption of hexagonal columns is not assessed. Also, the potential influence of the presence of super-cooled liquid is not addressed. In fact, other than measurement noise, it appears that only errors in the CO2 profile are actually considered in defining the observation error covariance matrix (Eqn. 10) but this must also account for errors in forward model assumptions.

2. The values of the a priori errors are never actually stated in the paper – they are merely stated to be ‘large enough to not be serious constraints’. In addition, it is assumed that effective diameter and ice water path are uncorrelated and cloud and the atmospheric properties are assumed uncorrelated. In reality observations show that all of these quantities are strongly correlated, larger particles tend to be observed when ice water paths are large and cloud formation is strongly related to relative humidity (supersaturation). Why aren’t these correlations treated in a similar manner to the temperature and humidity profiles on page 10? Curiously, one of the key results of the paper actually involves defining relationships between cloud optical depth and temperature and effective diameter and IWC yet these correlations are not modeled in the algorithm. In addition, the conclusions actually state “This work has shown the capability to perform a simultaneous retrieval of the atmospheric state and the cloud parameters taking into account the possible correlations between the clouds and the atmosphere” yet it is clear from the algorithm description that these correlations are NOT explicitly treated.

3. While it is good that the authors consider the information content of the measurements, the analysis presented in Section 3 lacks sufficient rigor to be informative. First the inadequate characterization of uncertainties noted in (1) and (2) above call the findings into question. In addition, no cloud parameters are actually considered in the analysis limiting their value. In order to adequately characterize the information content of the FIR measurements used in the retrieval, the error covariance matrices must include forward model errors and correlations between cloud and atmospheric properties must be included.

4. The validation of the approach is incomplete and not convincing. Simply noting that residuals are small (page 14) does not provide a measure of the quality of the retrievals. It merely demonstrates that the retrieval has enough degrees of freedom to sufficiently fit the observations. This can always be accomplished in under-constrained problems. A limited number of direct comparisons against radiosondes are presented in Fig. 8 but the paper lacks any quantitative statistical analysis of the accuracy of the retrievals. In addition, no error bars are presented on the retrieved quantities so it is impossible to know whether agreement is achieved within the anticipated retrieval error. In some cases differences between retrieved profiles and soundings exceeds 10 K – is this really "very good agreement"? Finally, the comment "The comparison between the retrieved parameters and statistical correlation laws shows a very good agreement" on page 16 does not rise to the level of evaluating the retrieval performance. On a related note, what exactly is meant by the statement "The comparison of results with radiosoundings demonstrates that the retrieved atmospheric state is not disturbed by the clouds presence" in the abstract?

5. Finally, the reference to energy balance, cloud, and ice particle literature in the introduction is far too narrow and lacks any mention of many important recent papers on the subject. In addition, some literature specific to Antarctic clouds should be added.

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