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A new retrieval algorithm for tropospheric temperature, humidity and pressure profiling based on GNSS radio occultation data

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The GNSS radio occultation (RO) technique is an important remote sensing technique for obtaining thermodynamic profiles of temperature, humidity, and pressure in the Earth's troposphere. However, due to refraction effects of both dry ambient air and water vapor in the troposphere, retrieval of accurate thermodynamic profiles at these lower altitudes is challenging and requires suitable background information in addition to the RO refractivity information.

Here we introduce a new moist air retrieval algorithm aiming to improve the quality and robustness of retrieving temperature, humidity and pressure profiles in moist air tropospheric conditions. The new algorithm consists of four steps: (1) use of prescribed specific humidity and its uncertainty to retrieve temperature and its associated uncertainty; (2) use of prescribed temperature and its uncertainty to retrieve specific humidity and its associated uncertainty; (3) use of the previous results to estimate final temperature and specific humidity profiles through optimal estimation; (4) determination of air pressure and density profiles from the results obtained before.

The new algorithm does not require elaborated matrix inversions which are otherwise widely used in 1D-Var retrieval algorithms, and it allows a transparent uncertainty propagation, whereby the uncertainties of prescribed variables are dynamically estimated accounting for their spatial and temporal variations. Estimated random uncertainties are calculated by constructing error covariance matrices from co-located ECMWF short-range forecast and corresponding analysis profiles. Systematic uncertainties are estimated by empirical modeling. The influence of regarding or disregarding vertical error correlations is quantified. The new scheme is implemented with static input uncertainty profiles in WEGC's current OPSv5.6 processing system and with full scope in WEGC's next-generation system, the Reference Occultation Processing System (rOPS).

Results from both WEGC systems, current OPSv5.6 and next-generation rOPS, are shown and discussed, based on both insights from individual profiles and statistical ensembles, and compared to moist air retrieval results from the UCAR Boulder and ROM-SAF Copenhagen centers. The results show that the new algorithmic scheme improves the temperature, humidity and pressure retrieval performance, in particular also the robustness including for integrated uncertainty estimation for large-scale applications, over the previous algorithms. The new rOPS-implemented algorithm will therefore be used in the first large-scale reprocessing towards a tropospheric climate data record 2001–2016 by the rOPS, including its integrated uncertainty propagation.