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Employing GNSS radio occultation for solving the global climate monitoring problem for the fundamental state of the atmosphere

Gottfried Kirchengast, Marc Schwaerz, Jakob Schwarz, Barbara Scherllin-Pirscher, Christian Pock, Josef Innerkofler, Veronika Proschek, Andrea Steiner, Julia Danzer, Florian Ladstaedter, and Ulrich Foelsche

Wegener Center for Climate and Global Change (WEGC) and IGAM/Institute of Physics, University of Graz, Graz, Austria (gottfried.kirchengast@uni-graz.at)

Monitoring the atmosphere to gain accurate and long-term stable records of essential climate variables (ECVs) such as temperature is the backbone of atmospheric and climate science. Earth observation from space is the key to obtain such data globally. Currently, however, not any atmospheric ECV record can serve as authoritative reference from weekly to decadal scales so that climate variability and change is not yet reliably monitored, despite of satellite data since the 1970s.

We aim to solve this decades-long problem for the fundamental state of the atmosphere, the thermodynamic state of the gas as expressed by air density, pressure, temperature, and tropospheric water vapor, which are the fundamental ECVs for tracking climate change and in fact fundamental to all weather and climate processes. We base the solution on the unique SI-traceable data of the GNSS radio occultation (RO) space geodetic observing system, available since 2001 and scheduled long-term into the future. We introduce a new system modeling and data analysis approach which, in contrast to current RO retrieval chains using classical data inversion, enables us to exploit the traceability to universal time (SI second) and to realize SI-traced profiles of atmospheric ECVs, accounting also for relevant side influences such as from the ionosphere, with unprecedented utility for climate monitoring and science.

We work to establish such a trace first-time in form of the Reference Occultation Processing System rOPS, providing reference RO data for calibration/validation and climate applications. This rOPS development is a current cornerstone endeavor at the WEGC Graz over 2013 to 2016, supported also by colleagues from EUMETSAT Darmstadt, ECMWF Reading, DMI Copenhagen, AIUB Berne, UCAR Boulder, JPL Pasadena, and others. The rOPS approach demands to process the full chain from the SI-tied raw data to the ECVs with integrated uncertainty propagation, both of estimated systematic and estimated random uncertainties.

We first briefly summarize the RO promise along the above lines and where we currently stand in quantifying RO accuracy and long-term stability. We then introduce the new concept and design and discuss the development status and early results from the rOPS, with emphasis on its value to provide RO data capable to serve as a reference standard for data validation and climate. We close with an outlook to next steps of work, in particular regarding the integrated uncertainty estimation, and to the first rOPS climate records scheduled to be produced as of late 2016.