Precise Orbit Determination and GNSS Radio Occultation Low-Level Data Processing for Climate Applications

J. Innerkofler[1], G. Kirchengast[1,2], M. Schwärz[1,2]

(1) Wegener Center for Climate and Global Change (WEGC), University of Graz, Graz, Austria
(2) Institute of Physics, University of Graz, Graz, Austria

josef.innerkofler@uni-graz.at

A R S C l i S y s

1 - Introduction

Measurement data from Global Navigation Satellite System (GNSS) radio occultation (RO) (Fig. 1) feature unique properties to provide highly accurate, global, and long-term stable datasets of essential climate variables (ECVs). For serving long-term climate monitoring and analysis, it is indispensable to safeguard the quality of the measurements derived from GNSS signal tracking by RO satellite receivers in low Earth orbit (LEO). It is therefore essential to ensure that LEO orbit solutions meet adequate quality, since they are one of the key inputs for the subsequent derivation of atmospheric excess phases and, further down along the RO processing chain, of ECVs covering the troposphere-stratosphere domain.

2 - Processing setup

The new Reference Occultation Processing System (rOPS) at WEGC (Fig. 2) is now also including a setup for precise orbit determination (POD) and low-level (L1a) data processing. The former routinely and in parallel performs the LEO POD with two independent software packages, Bernese GNSS software and Napeos, and simultaneously employs two different GNSS orbit data products as input. This POD setup enables mutual consistency checks of the calculated orbit solutions and is also used for quantification of estimated systematic and random position and velocity uncertainties (Innerkofler et al. 2020). These quality measures also co-determine the estimated uncertainty of the reprocessed RO excess phase data, that we derive as part of the rOPS L1a processing (Innerkofler et al. 2023), and help to evaluate and ensure its long-term stability.

3 - Results

We provide a detailed evaluation of POD result statistics for CHAMP and Metop covering the period from 2001 to 2022, including intercompaison of the LEO orbit solutions with solutions from other leading orbit processing centers for cross-evaluation (Fig. 3). Additionally, we evaluate the estimated uncertainties of the orbit solution time series data with respect to the LEO orbit uncertainty target specifications for RO (<5 cm in position and <0.05 mm/s in velocity) (Fig. 4), for ensuring highest quality of the retrieved ECVs. The quality of the orbit solutions co-determine the quality of the derived RO profiles, in a first low-level data processing step the excess phases (Fig. 5). This is reflected in the early RO measurement period of CHAMP, where increased differences compared to forward modeled ERA5 excess phase profiles can be observed.

4 - Summary and outlook

The LEO-POD results computed over 2001 to 2022, which serve as a basis for the RO processing at WEGC, show somewhat increased POD uncertainties in the early CHAMP measurement period compared to the later Metop time period. For days with a degraded LEO-POD solution, the estimated uncertainties and derived quality flags allow for quality-controlled use in the subsequent RO processing (see Fig. 5 for example L1a results; for the rOPS L1a algorithms see Innerkofler et al. 2023).
The further reprocessing will include updates to the rOPS-POD subsystem and an extension of the time series up to 2024 including also GRACE and COSMIC-1/-2 data.

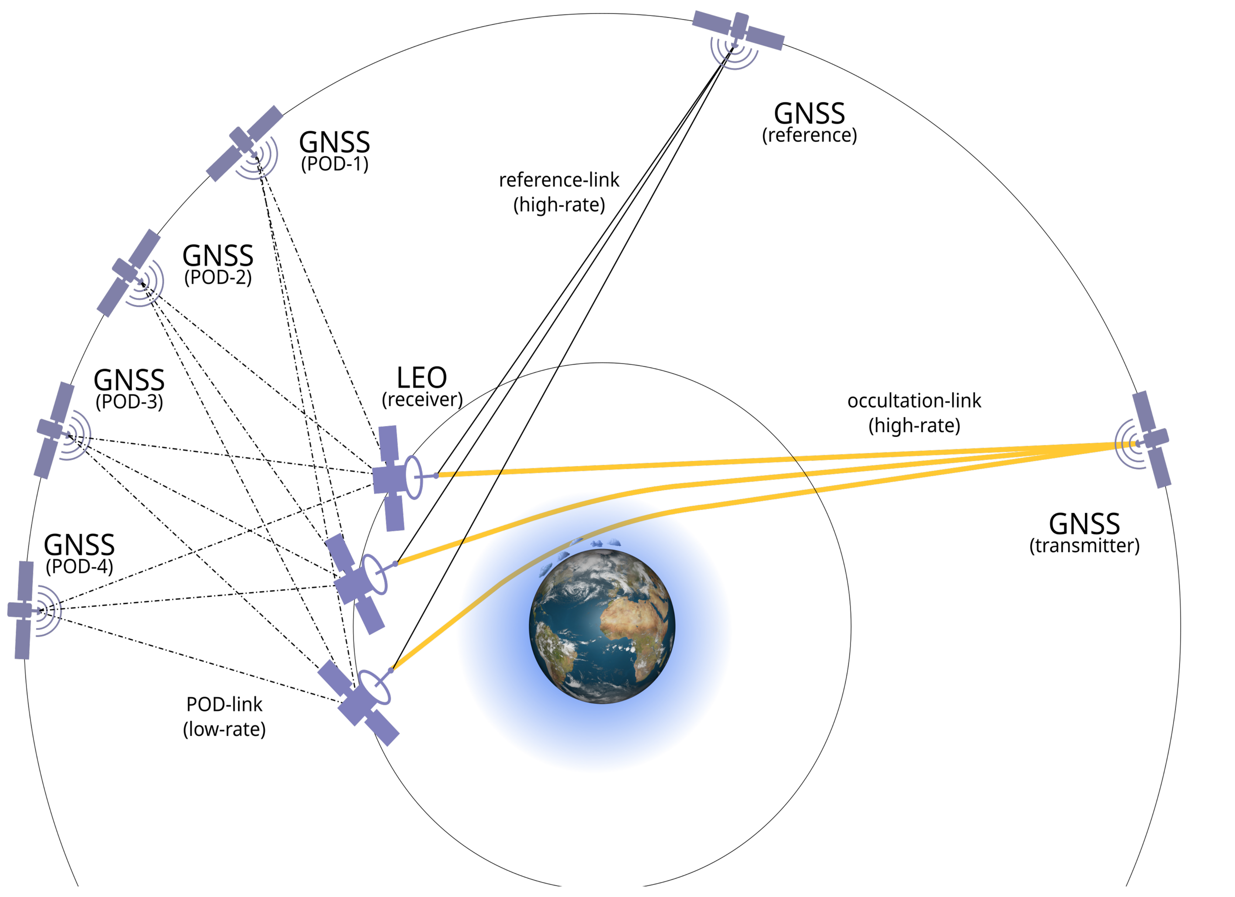

Fig. 1: Schematic view the of the RO measurement principle. Radio signals from the occulting GNSS satellite pass through the atmosphere and are refracted on their way to the faster moving LEO receiver satellite. Depending on the RO differencing method applied, additional measurements of a GNSS reference satellite are employed. The LEO POD is based on measurements obtained from the LEO zenith antenna.

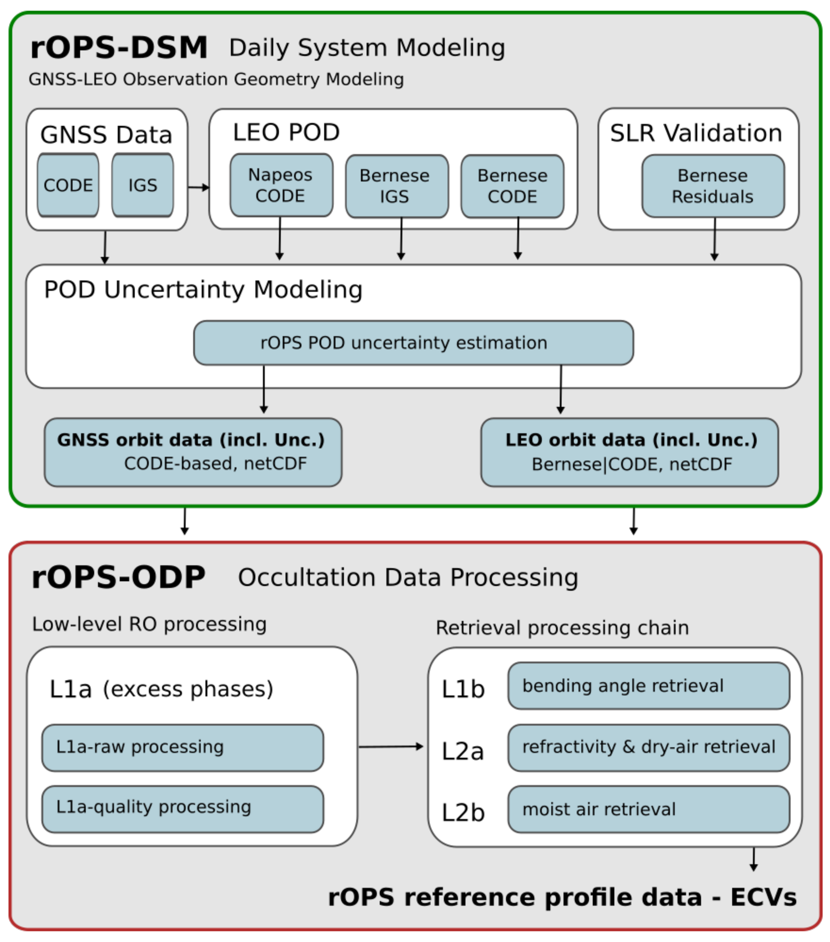

Fig. 2: Schematic overview of parts of WEGC's rOPS relevant to this study, comprising the daily system modeling (DSM; top), and the occultation data processing (ODP; bottom) with focus on the RO low-level data processing.

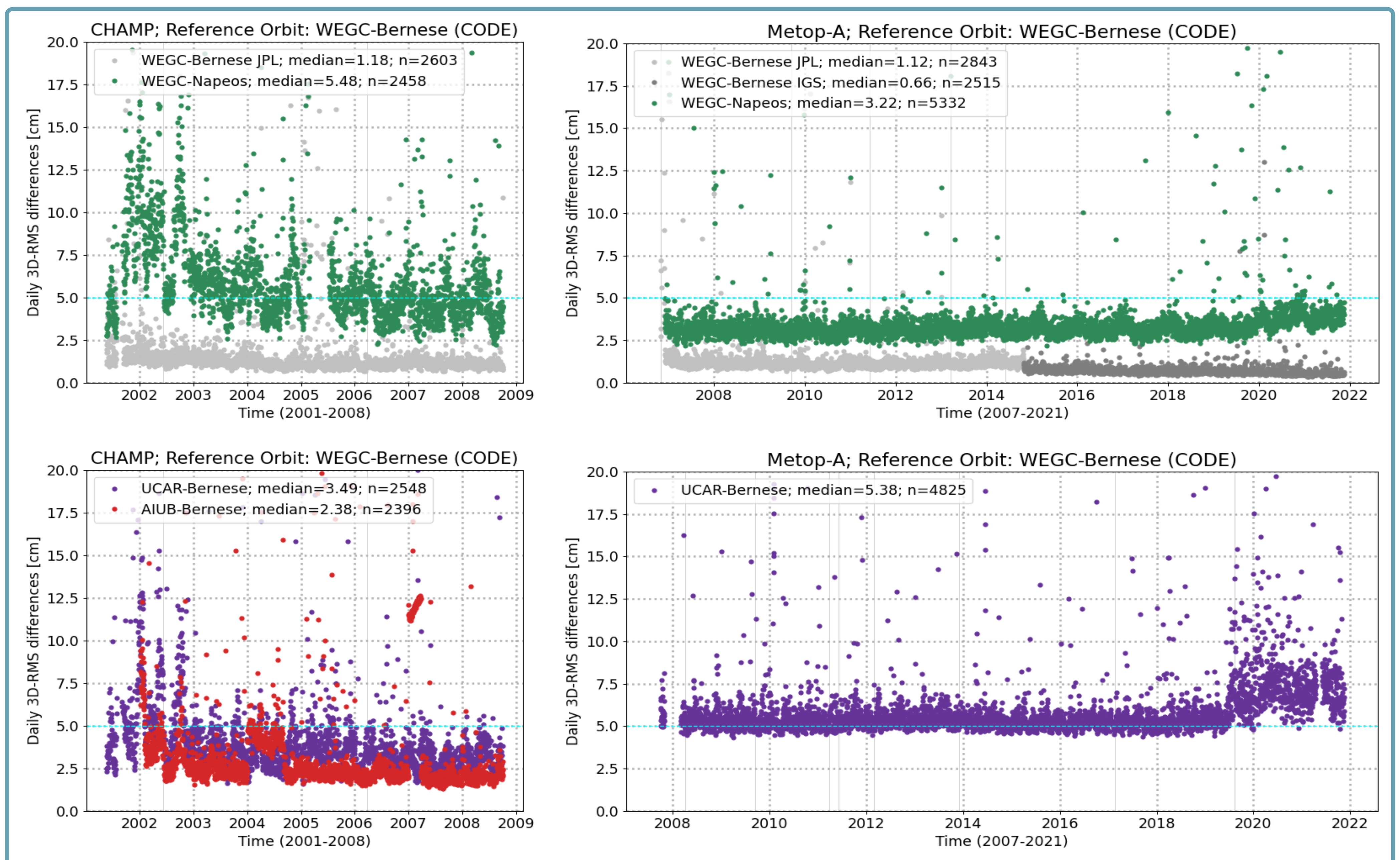

Fig. 3: Daily RMS position differences calculated at WEGC (rOPSv1.1, with Bernese and Napeos) for CHAMP and Metop-A satellites as examples, using GNSS orbits from CODE, IGS, and JPL as input (top row). Evaluation comparing WEGC-Bernese (CODE) baseline solution against solutions of other processing centers (UCAR, AIUB) for CHAMP and Metop-A (bottom row). The number of total days per period is denoted by "n".

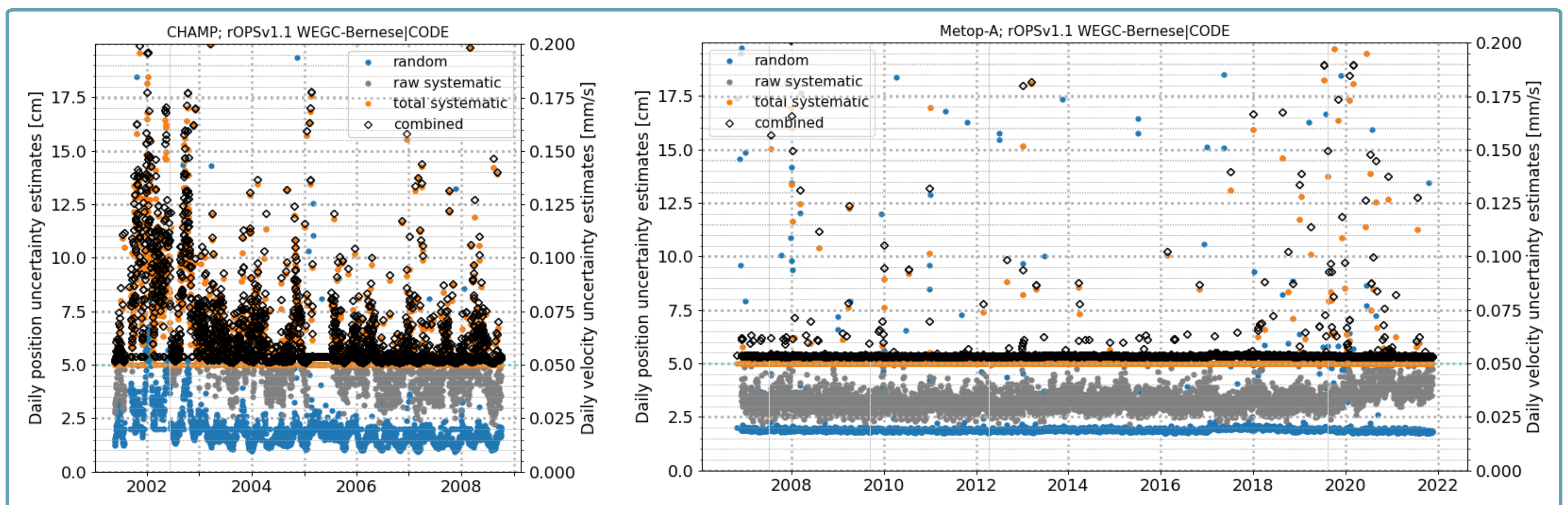

Fig. 4: Daily position and velocity uncertainties for the WEGC-Bernese (CODE) baseline solution for CHAMP and Metop-A. The "raw systematic" values denote the estimated systematic uncertainties before applying the conservative bound while the "total systematic" values show the estimates including this low-bounding (for processing details see Innerkofler et al. 2020).

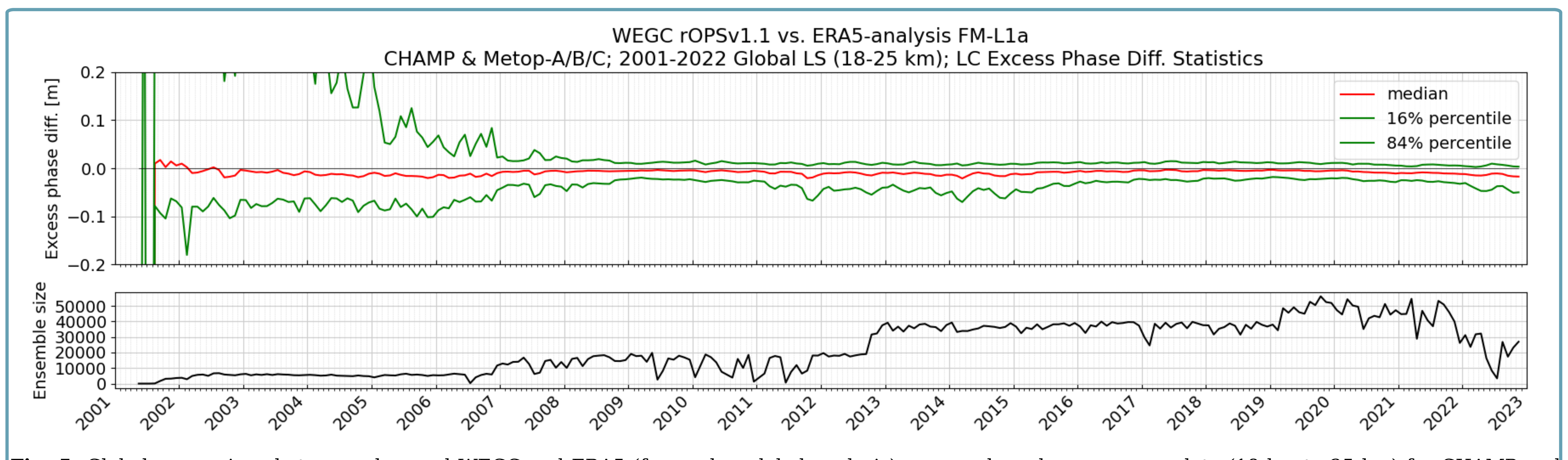

Fig. 5: Global comparison between observed WEGC and ERA5 (forward modeled analysis) excess phase layer average data (18 km to 25 km) for CHAMP and Metop-A/B/C on Straight Line Tangent Point Height (SLTH) grid from 2001 to 2022.

References:
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Acknowledgments:
The work was funded by the Austrian Space Applications Programm ASAP (main projects ATROMSAF1&2, ROMSAF4CLIM) endowed by the Federal Ministry BMK and managed by the Austrian Research Promotion Agency FFG, partly as EUMETSAT ROM SAF CDOP 4 partnership funds (project ROMSAF4P), and by the Austrian Science Fund (FWF) under research grant W 1256-G15 (Doctoral Programme Climate Change – Uncertainties, Thresholds and Coping Strategies). EUMETSAT (Darmstadt, Germany), UCAR/CDAAC (Boulder CO, USA), JPL (Pasadena CA, USA), and GFZ (Potsdam, Germany) are acknowledged for the provision of LEO navigation tracking, attitude and orbit data; We also thank AUIB/CODE (Bern, Switzerland) and the IGS (Pasadena CA, USA) for making GNSS orbit and clock data available.

9-A