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ORIGINAL ARTICLE

(Near-)real-time orbit determination for GNSS radio occultation processing

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Abstract The processing of GPS radio occultation measurements for use in numerical weather predictions requires a precise orbit determination (POD) of the host satellite in near-real-time. Making use of data from the GRAS instrument on Metop-A, the performance of different GPS ephemeris products and processing concepts for near-real-time and real-time POD is compared. While previous analyses have focused on the achievable along-track velocity accuracy, this study contributes a systematic comparison of the resulting estimated bending angles. This enables a more rigorous trade-off of different orbit determination methodologies in relation to the end-user needs for atmospheric science products. It is demonstrated that near-real-time GPS orbit and clock products have reached a sufficient quality to determine the Metop-A along-track velocity with an accuracy of better than 0.05 mm/s that was formerly only accessible in post-processing. The resulting bending angles are shown to exhibit standard deviation and bias differences of less than 0.3 % compared with post-processed products up to altitudes of at least 40 km, which is notably better than 1 % accuracy typically assumed for numerical weather predictions in this height regime. Complementary to the analysis of ground-based processing schemes, the potential of autonomous on-board orbit determination is investigated for the first time. Using actual GRAS flight data, it is shown that a 0.5 m 3D rms position accuracy and a 0.2 mm/s along-track velocity accuracy can in fact be obtained in real-time with the currently available GPS broadcast ephemeris quality. Bending angles derived from the simulated real-time processing exhibit a minor performance degradation above tangent point heights of 40 km but negligible differences with respect to ground-based products below this altitude. Onboard orbit determination and, if desired, bending angle computation, can thus enable a further simplification of the ground segment in future radio occultation missions and contribute to reduced product latencies for radio occultation data assimilation in numerical weather predictions.

Keywords GRAS · Metop · Radio occultation · Precise orbit determination · Bending angle · Atmosphere · Real-time processing

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Introduction

Starting with the GPS/MET experiment on MicroLab-1 (Kursinski et al. 1997), atmospheric sounding using opportunity signals from the GPS satellites has evolved into a key application of scientific GPS receivers in space (Yunck 2003). When passing the lower atmosphere, GPS signals experience a deflection that depends on the refractivity along the ray path and results in a modified Doppler shift of the received signal (Fig. 1). Atmospheric conditions can thus be retrieved by comparing the measured GPS signals with those expected for direct signal propagation without an atmosphere. Missions such as GRACE, Metop, COSMIC and TerraSAR-X/TanDEM-X presently collect GPS radio occultation measurements on a routine basis and contribute their data for meteorological and climate research. While radio occultation measurements constitute only a small fraction of the overall meteorological data presently assimilated by the European