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ORIGINAL ARTICLE

Assessment of troposphere mapping functions using three-dimensional ray-tracing

Landon Urquhart · Felipe G. Nievinski · Marcelo C. Santos

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Abstract The troposphere delay is an important source of error for precise GNSS positioning due to its high correlation with the station height parameter. It has been demonstrated that errors in mapping functions can cause sub-annual biases as well as affect the repeatability of GNSS solutions, which is a particular concern for geophysical studies. Three-dimensional ray-tracing through numerical weather models (NWM) is an excellent approach for capturing the directional and daily variation of the tropospheric delay. Due to computational complexity, its use for positioning purposes is limited, but it is an excellent tool for evaluating current state-of-the-art mapping functions used for geodetic positioning. Many mapping functions have been recommended in the past such as the Niell Mapping Function (NMF), Vienna Mapping Function 1 (VMF1), and the Global Mapping Function (GMF), which have been adopted by most IGS analysis centers. A new Global Pressure Temperature model (GPT2) has also been developed, which has been shown to improve upon the original atmospheric model used for the GMF. Although the mapping functions mentioned above use the same functional formulation, they vary in terms of their atmospheric source and calibration approach. A homogeneous data set of three-dimensional ray-traced delays is used to evaluate all components of the mapping functions, including their underlying functional formulation, calibration, and compression method. Additionally, an alternative representation of the VMF1 is generated using the same atmospheric source as the truth data set to evaluate the differences in ray-tracing methods and their effect on the end mapping function. The results of this investigation continue to support the use of the VMF1 as the mapping function of choice when geodetic parameters are of interest. Further support for the GPT2 and GMF as reliable back-ups when the VMF1 is not available was found due to their high consistency with the NWM-derived mapping function. Additionally, a small latitude-dependent bias in station height was found in the current mapping functions. This bias was identified to be due to the assumption of a constant radius of the earth and was largest at the poles and at the equator. Finally, an alternative version of the VMF1 is introduced, namely the UNB-VMF1 which provides users with an independent NWM-derived mapping function to support geodetic positioning.

Keywords Troposphere · Numerical weather models · Mapping functions

L. Urquhart · M. C. Santos
Department of Geodesy and Geomatics Engineering, University of New Brunswick, Fredericton, Canada

Present Address:
L. Urquhart (✉)
Nexteq Navigation, Calgary, Canada
e-mail: lurquhart@nexteqnav.com

F. G. Nievinski
Department of Aerospace Engineering Sciences, University of Colorado, Boulder, CO, USA

Introduction

The tropospheric delay is an important error source for precise geodetic positioning as it affects both the accuracy and repeatability of station coordinates as well as causing differences in the annual periodic signals of geodetic time series (Tesmer et al. 2007; Vey et al. 2006). As the troposphere is a non-dispersive medium for Global Navigation Satellite System (GNSS) frequencies, it cannot be removed by observing on multiple frequencies, thus it is necessary to model the delay using external parameters.

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