波線追跡法による大気遅延量推定値のGEONET基線解析への適用
Ray-traced atmospheric total slant delays for GEONET processing

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Introduction:

The Japanese Meteorological Agency (JMA, [4]) is offering numerical weather models (NWMs) at different spatial and temporal resolutions. Since such models are already in use to derive mapping functions for space geodetic techniques (e.g. [2], [5]), it is investigated how numerical weather models can be utilized to take the overall atmospheric delay into account. The mesoscale-model from JMA with a spatial resolution of about 10 km and a time interval of 3 hours between the data-set has been selected as source for all computations

Kashima Ray-tracing Tools (KARAT)

The National Institute of Information and Communications Technology (NICT) has developed a ray-tracing package which allows to derive atmospheric total slant delays by using NWM data. Since these models are limited in their spatial and temporal resolution KARAT includes interpolation algorithms which allow the user to obtain ray-traced tropospheric delays for any site or epoch. Moreover KARATS considers the surface topography by implementing SRTM [3] data, referenced to the WGS84 system. Zenith total delays (integrated from the physical surface up to a height of 86km) are shown in figure 1 as obtained from a model run. Beside the core-modules, KARAT contains also interfaces which allow manipulation of RINEX observation data and it includes an orbit module, which computes the observing geometry from receiver position, time and GNSS satellite number.

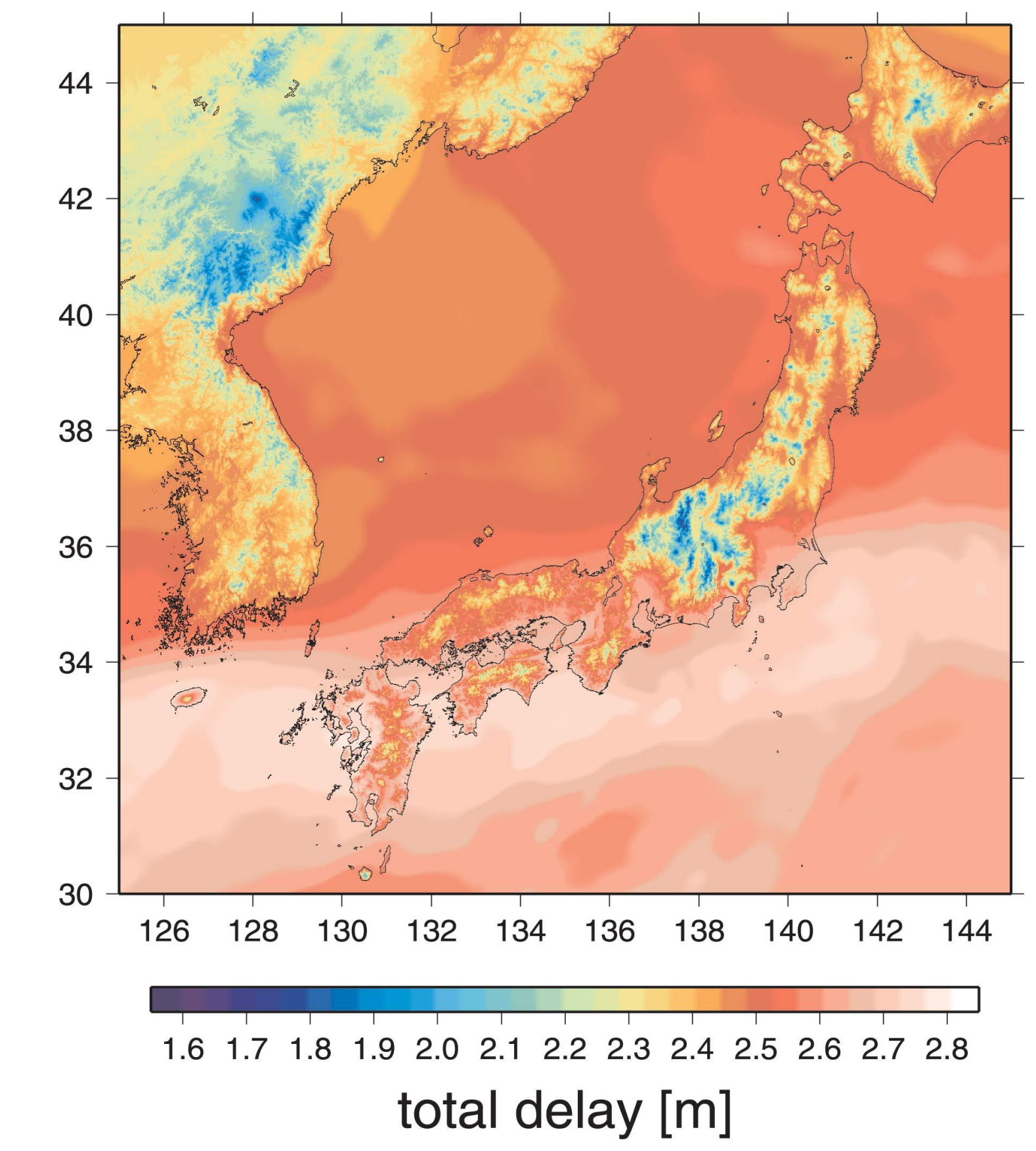

Figure 1: Total zenith delay on July 23, 2006 0UT obtained from ray-tracing through the 10km mesoscale model.

Removal of troposphere delays from GEONET data

In total more than 0.4 billion observations taken by GEONET receivers between July 1st, 2006 and July 15th, 2006 have been processed and the ray-traced delays were subtracted from the original measurements, before the information is written back to RINEX format. Thereafter these troposphere-reduced observations were analyzed by the cluster computation network at GSI in a similar fashion as the standard GEONET solutions are obtained. Thus, the newly computed station coordinates can be compared with a reference solution and the impact of the numerical weather models can be measured qualitatively.

Results:

As the ray-traced data were considered as totally free of atmosphere errors, troposphere estimation has been turned off during the re-processing of the data. Thus deficits of the numerical weather model are expected to translate directly into the estimates of station coordinates. Figure 2 and 3 depict the differences between the standard GEONET solution (computed with Niell mapping functions a linear gradient estimation) and the KARAT solution. It can be clearly seen that the introduction of the numerical weather model shifts (in general raises) the vertical component station coordinate by a few cm, whereas the horizontal components are affected systematically, based on the formation of baselines of the GEONET analysis backbone network. Moreover it has been found that ambiguity resolution performance decreased slightly by about 1 % when the ray-traced data has been applied. This fortifies the theory that still un-modeled atmosphere delays are remaining in the observation data, after the ray-traced troposphere slant delays have been subtracted.

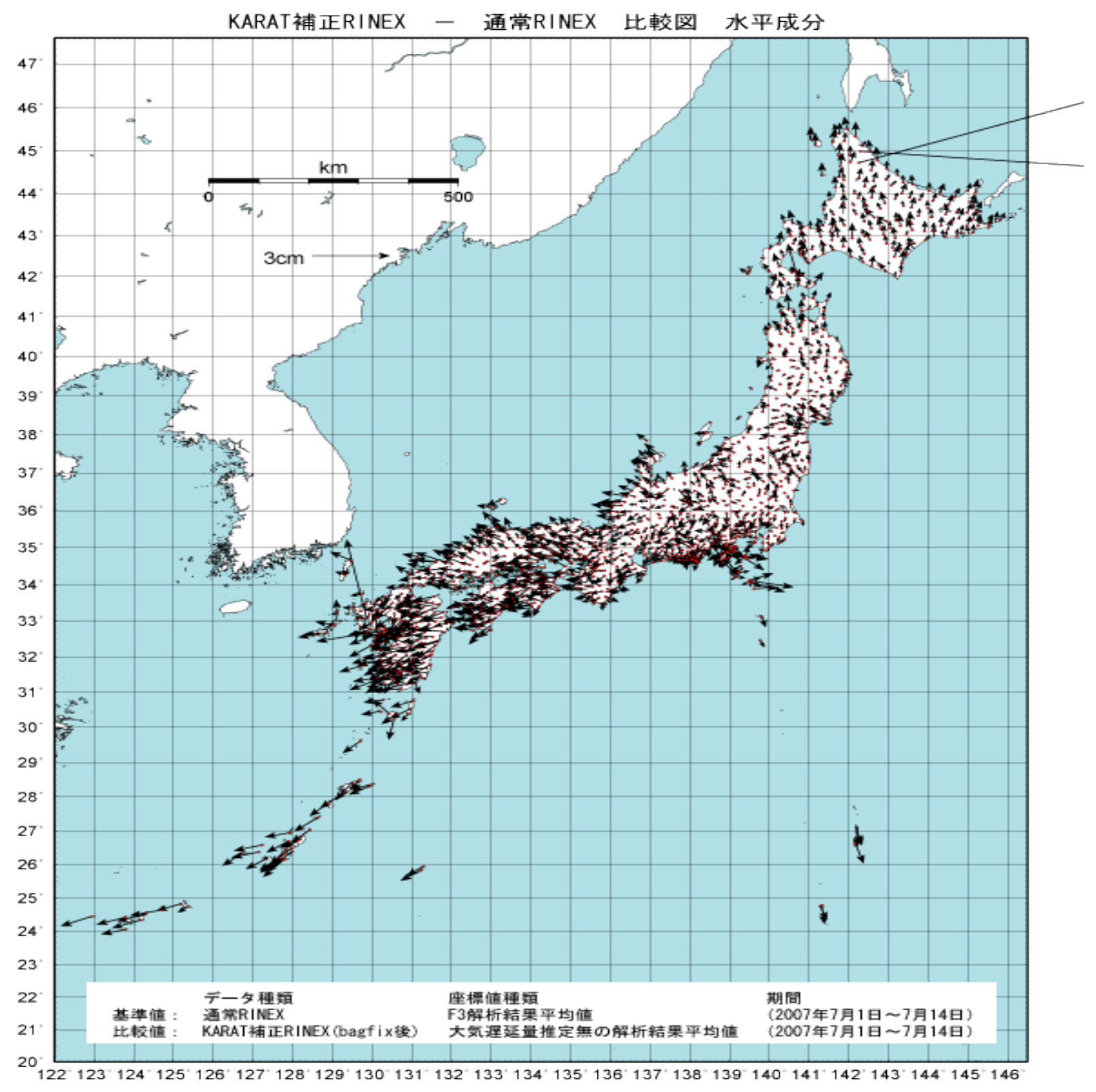

Figure 2: Horizontal differences between the ray-traced results and the reference solution.

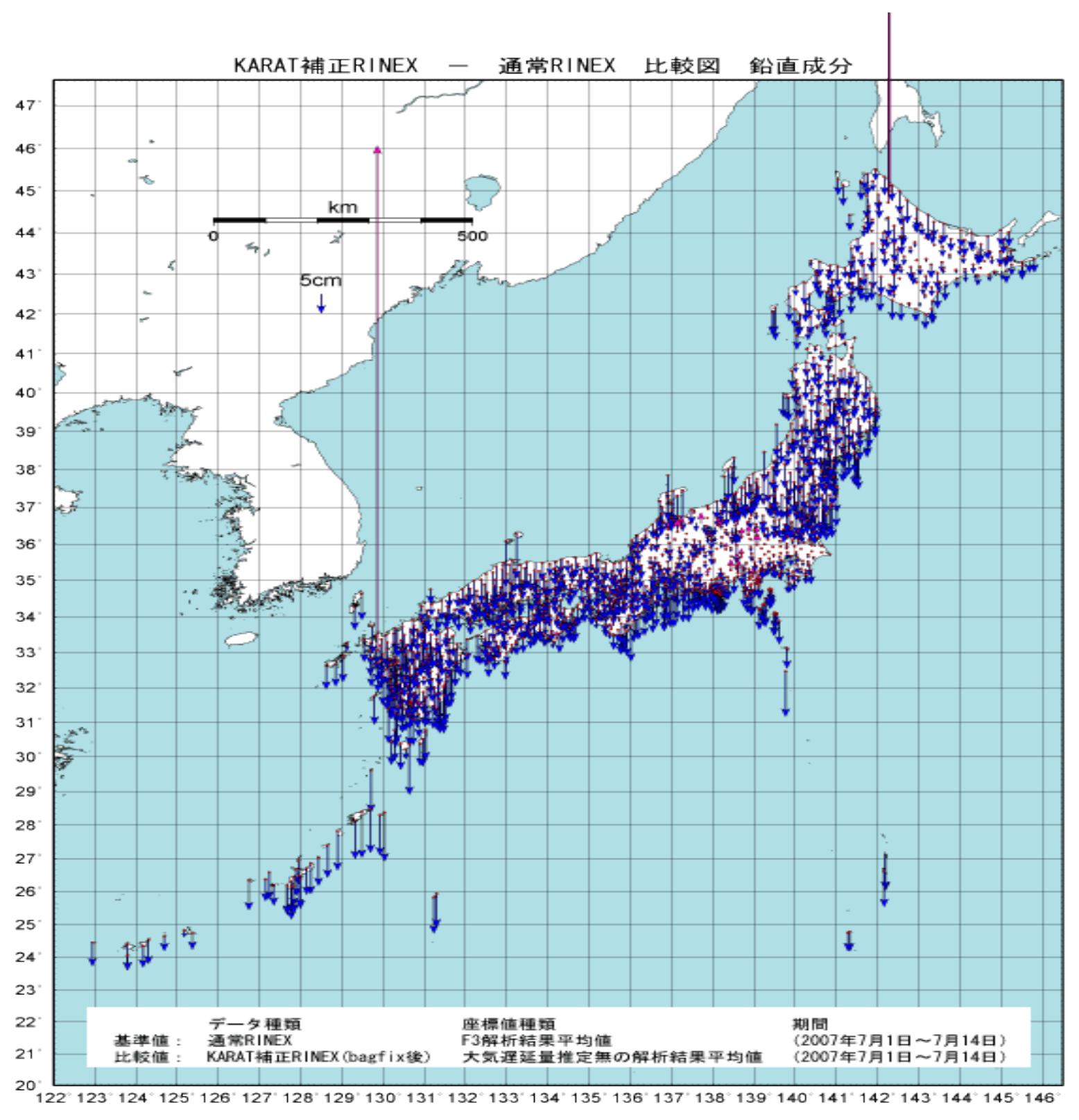

Figure 3: Vertical differences between the ray-traced results and the reference solution.

Interpretation:

In order to check whether deficits of the numerical weather models cause the shift of the station coordinates, zenith total delays from GEONET processing are compared to ray-traced vertical delays. Three stations (Sapporo/Hakkaido, Tsukuba/Kanto and Naha/Okinawa) with their ZTDs are depicted in figures 4,5 and 6 covering a time-span of 2 months. Although the mean ZTDs differences don't exceed the cm level, the height components of stations Naha and Sapporo are affected by more than 5 cm (Note: Tsukuba is kept fixed in both solutions). Since the GEONET solution is obtained from network analysis it has to be considered that errors from the numerical weather models can grow by forming baselines. Additionally it should be considered that one mm error of the troposphere can translate easily into about three mm height component error (see e.g. [1]). The sum of these effects can likely explain the obtained differences between the standard GEONET solution and the ray-traced analysis. Moreover one has to consider that the choice of the mapping function itself has an impact on the reference frame. Thus comparisons between the two strategies will also contain the effect of the mapping function, whereas the ray-traced data is not affected by mapping functions at all, since troposphere contribution is not estimated.

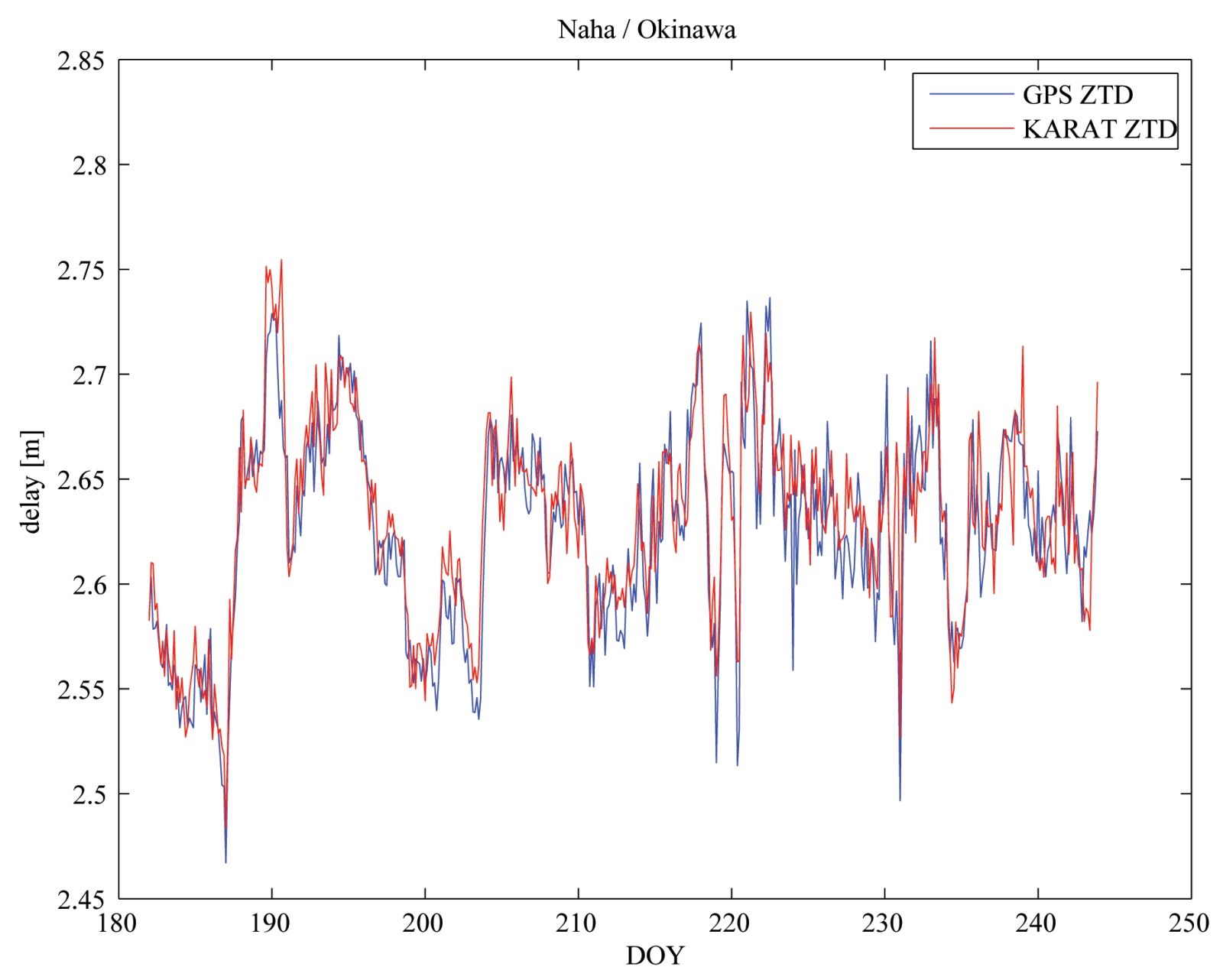

Figure 4: ZTDs for station Naha/Okinawa. Mean bias (GPS minus NWM) -0.0054m.

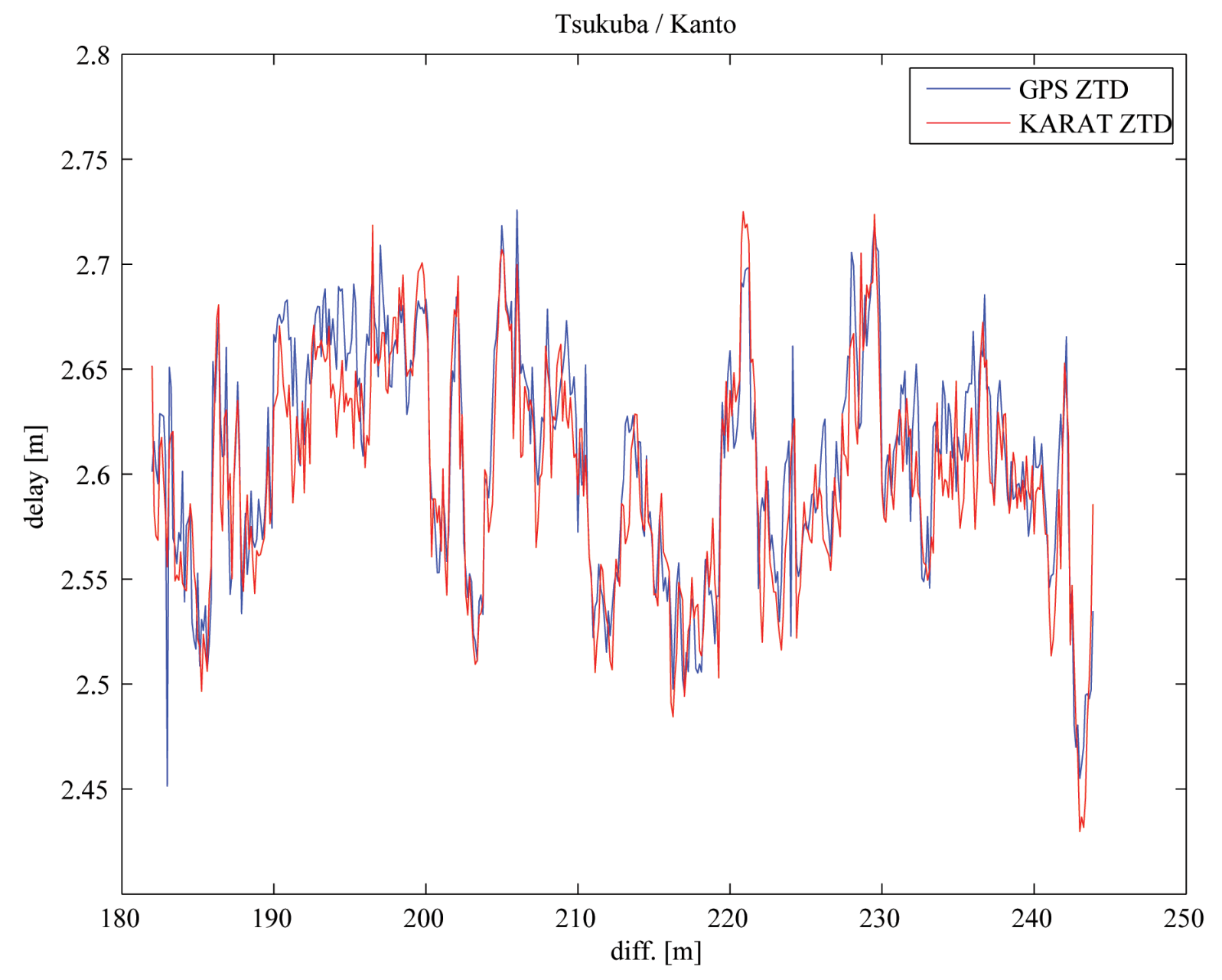

Figure 5: ZTDs for station Tsukuba/Kanto. Mean bias (GPS minus NWM) 0.0085m.

Outlook:

In order to account for the un-modeled residual troposphere delays it is necessary to parameterize these biases like normal troposphere parameters. Assuming that azimuthal asymmetry is considered properly by the numerical weather model a simple mapping function (e.g. 1/cos(z)) can be used to estimate the un-modeled fraction of the troposphere in zenith direction. Such an analysis strategy requires modifications of existing software packages since troposphere has to be turned off in some modules (e.g. code-clock synchronizations) whereas other modules should estimate residual (un-modeled) troposphere delays. Moreover the application of precise point positioning (PPP) techniques is expected to prevent to growth of the errors, as it happens during formation of baselines within network analysis.

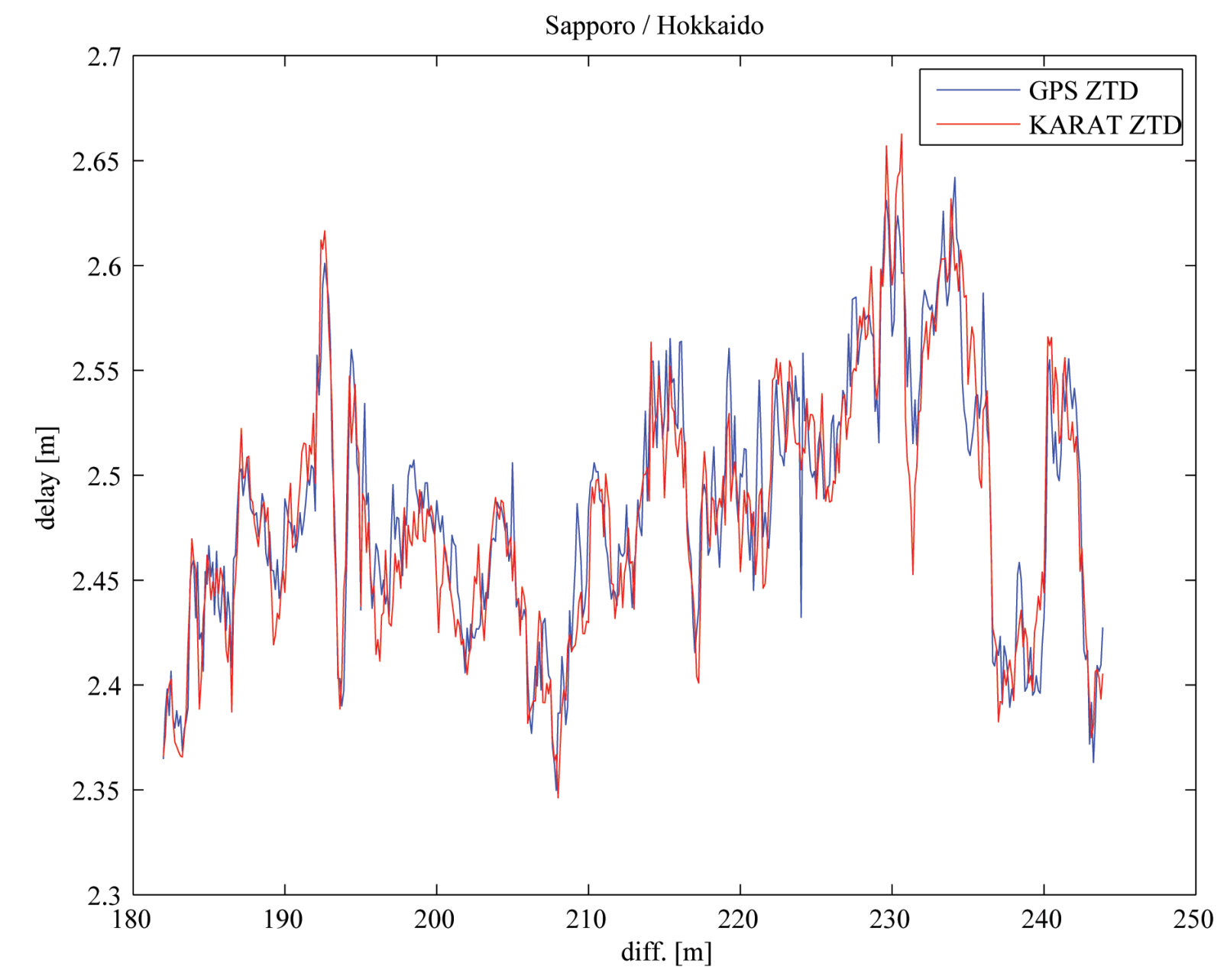

Figure 6: ZTDs for station Sapporo/Hokkaido. Mean bias (GPS minus NWM) 0.0031m.

Acknowledgements:

We would like to deeply thank the Geographical Survey Institute (GSI) for providing computation time and GEONET data. The first author is grateful to the Japan Society for the Promotion of Science (JSPS) for supporting his research (project P-06603).

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