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An Experimental Campaign for Evaluation of Wet Delay Variations Using Water Vapor Radiometers in the Kanto District, Central Japan

Ryuichi Ichikawa [1], *Y. Koyama* [1], *T. Kondo* [1], *H. Okubo* [1], *H. Hanado* [2], *K. Aonashi* [3], *Y. Shoji* [3], *Y. Hatanaka* [4], *J. Yamamoto* [5], *T. Takamura* [5], *K. Matsushige* [6]

1) *Kashima Space Research Center, Communications Research Laboratory*

2) *Communications Research Laboratory*

3) *Meteorological Research Institute, Japan Meteorological Agency*

4) *Geographical Survey Institute*

5) *Center for Environmental Remote Sensing (CEReS), Chiba University*

6) *National Institute for Environmental Studies*

Contact author: Ryuichi Ichikawa, e-mail: richi@crl.go.jp

Abstract

Anisotropic mapping functions are considered a powerful tool for removing the effects of atmospheric variability from GPS and VLBI analyses. However, the assumption of simple linear form of atmosphere is not always appropriate in the context of intense mesoscale phenomena. Thus, in June 1998 we initiated a field experiment for characterizing water vapor variations using water vapor radiometers (WVRs) in the Kanto district of central Japan. In spite of the relatively short distance between Tsukuba and Kashima (about 54 km) the atmospheric gradients solutions from WVR are significantly different. This result suggests that the mesoscale weather pattern caused these large differences.

1. Introduction

Radio signal delay associated with the neutral atmosphere is one of the major error sources for space-based geodetic techniques such as the Global Positioning System (GPS) and Very Long Baseline Interferometry (VLBI). Recently, several anisotropic mapping functions have been developed for the purpose of better modeling these propagation delays, thereby improving the repeatability of horizontal site coordinates (MacMillan, 1995; Chen and Herring, 1997). The anisotropic mapping function is considered a powerful tool for removing or calibrating the effects of horizontal variability of atmosphere from GPS and VLBI analyses. Atmospheric gradients are assumed to have a simple linear form in the anisotropic mapping function. However, it is suggested that this assumption is not always appropriate in the context of intense mesoscale phenomena such as the passing of cold fronts, heavy rainfall events, and severe storms. Thus, in June 1998 we initiated a field experiment for detecting and characterizing water vapor variations using water vapor radiometers (WVRs) in the Kanto district of central Japan. In this short report we present a preliminary analysis of our findings.

2. Observation

Three WVRs were installed on the east-west line from Kashima to Tsukuba as shown in Figure 1. Dual-frequency geodetic GPS receivers were installed nearby these WVR sites, allowing intercomparison of the atmospheric delay parameters derived using each technique. The delay estimates derived from WVR observations are calibrated in standard fashion by comparing WVR results with those obtained by numerical integration of operational radiosonde profiles observed by the Japan Meteorological Agency (JMA) at Tsukuba (Tateno). Figure 2 shows that calibrated WVR delays are very consistent with the delay derived from radiosonde profiles during the period 28 April - 10 June 1998. GPS-derived delays are also consistent with the other measurements as shown in the same figure.

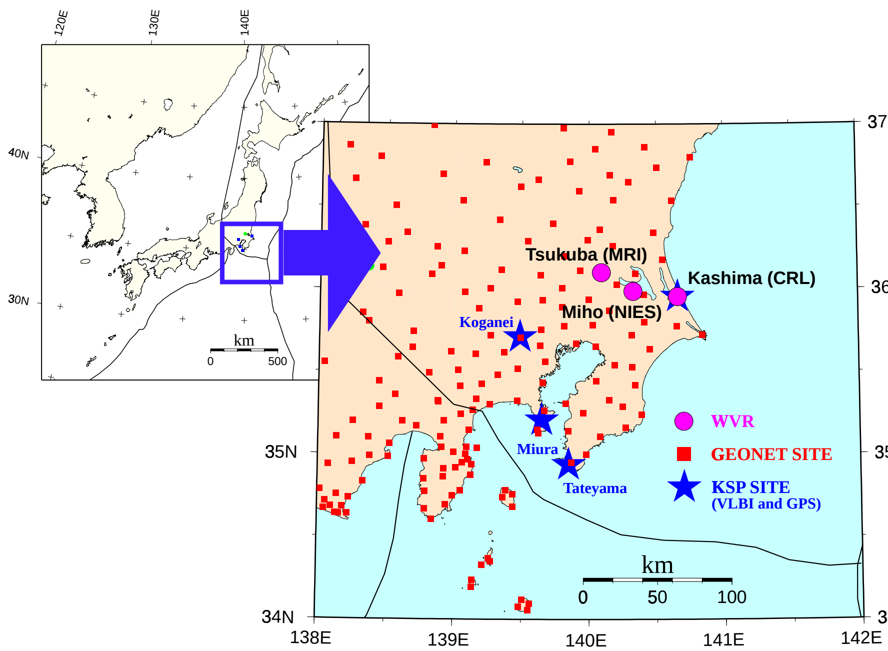

Figure 1. Map showing the WVR and GPS stations operated during the field experiment.

3. Results

Time series of atmospheric gradients estimated by WVR slant delays at Tsukuba and Kashima are compared to each other as shown in Figure 3.

In this figure we show the estimates of the EW (upper) and NS (lower) gradient delay during July 1998. Here, the gradient vector was estimated as a piecewise linear function with three-hour intervals. Both series of the EW and NS gradient components are smoothed with a 24-hour window. In spite of the relatively short distance between Tsukuba and Kashima (about 54 km) the atmospheric gradients solutions are significantly different. The magnitude of the NS gradient component at Kashima is approximately several times larger than that at Tsukuba during 3–4, 9–10, and 30–31 July 1998. We investigated the zenith wet delay (ZWD) field retrieved by the permanent GPS array of the Geographical Survey Institute (GEONET), by constructing maps in which ZWD is represented as a continuous spatial function (by interpolating between the GPS stations). In the vicinity of Kashima, for the period 3–4 July 1998, the ZWD field had a strong NS gradient of up to 1 cm/10 km (see Figure 4).

But the gradient in Tsukuba during this time period was very much smaller. This result

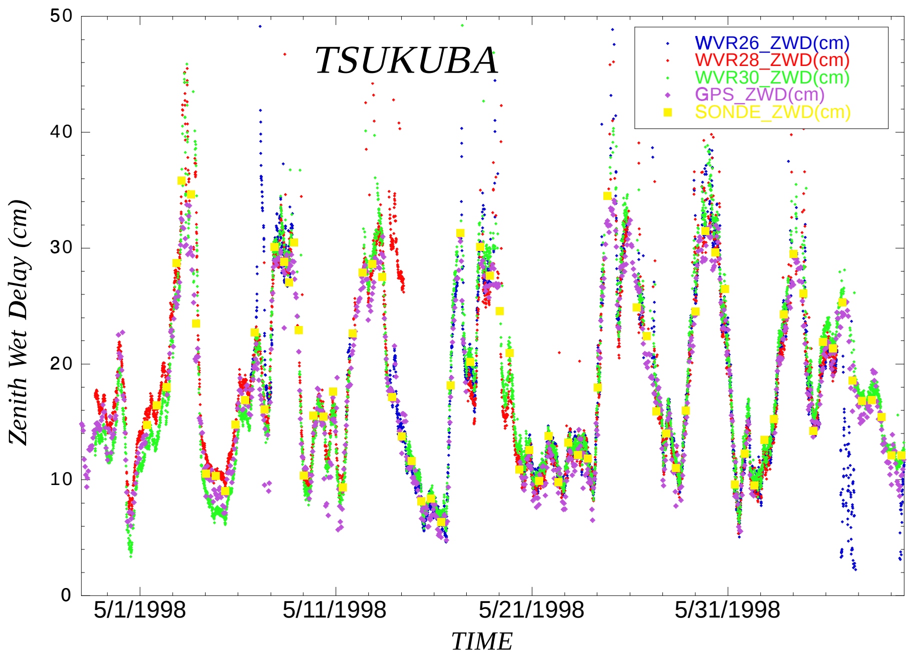

Figure 2. Zenith wet delay at Tsukuba as measured by WVR, GPS, and radiosondes from 28 April to 10 June 1998. The WVR wet delay is calibrated by comparing with the delay based on the radiosonde data.

suggests that the mesoscale weather pattern caused large differences to develop in the NS gradient (between Kashima and Tsukuba). We are now analyzing the output of high resolution numerical weather prediction models in order to investigate these results more deeply.

References

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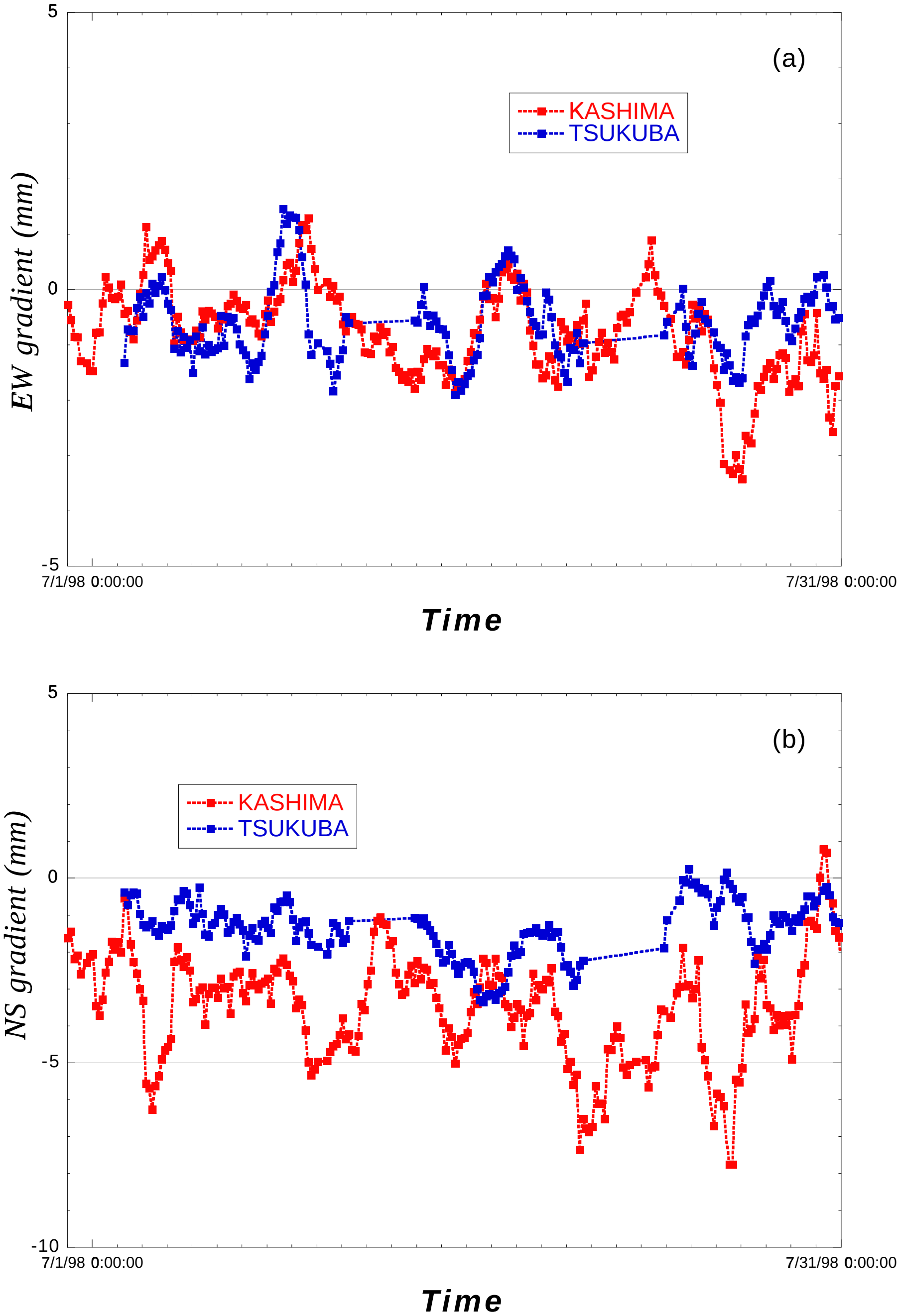

Figure 3. Estimates of the gradients at Tsukuba and Kashima obtained by WVR slant path delays in (a) the east-west direction and (b) the north-south direction. The gradient components estimated with three-hour intervals are smoothed with a 24-hour window.

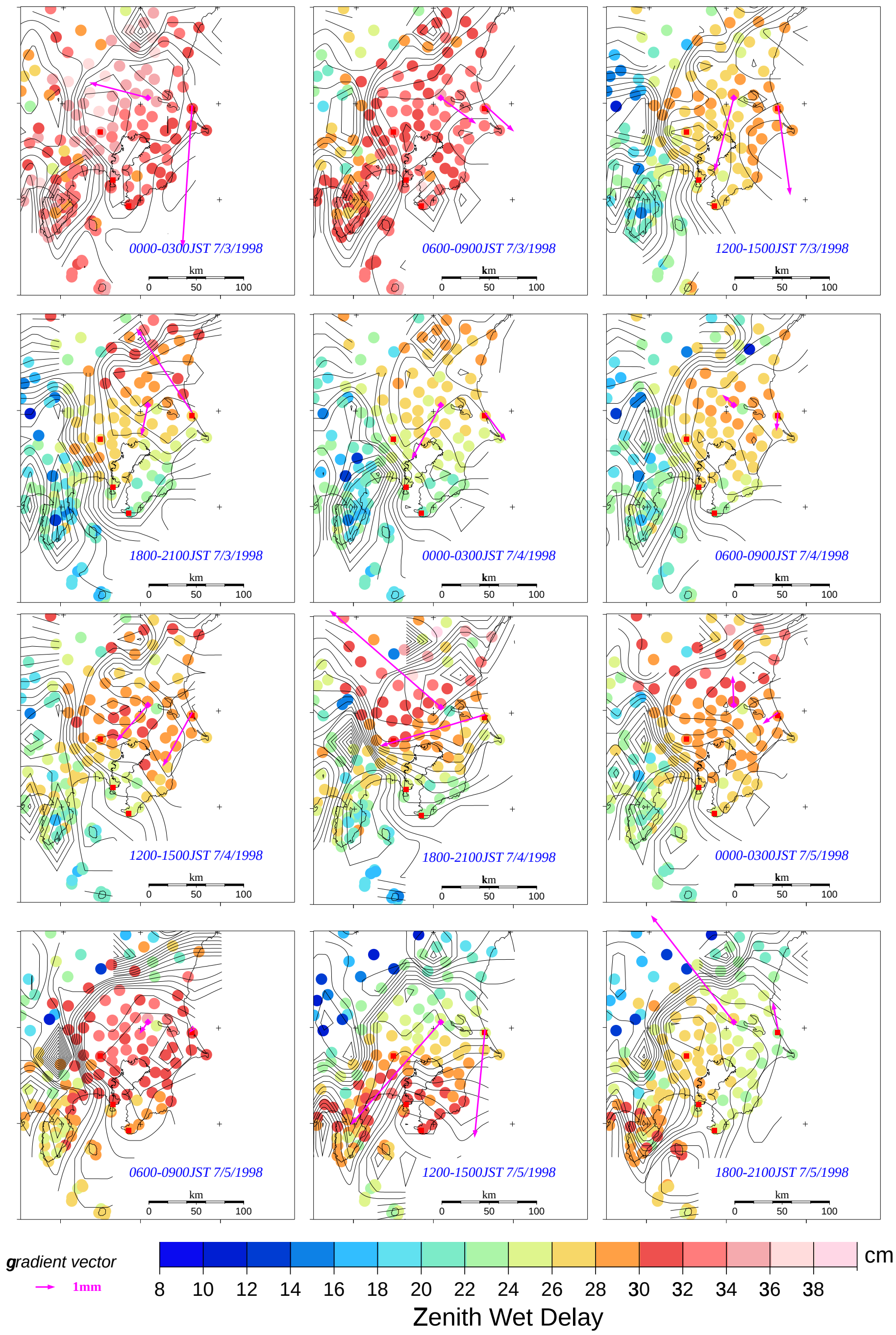

Figure 4. Zenith wet delay images retrieved from the Geographical Survey Institute (GSI) GPS array during 0000 JST July 3–2100 JST July 5, 1998. Contour Interval is 1 cm. Gradient vectors estimated from slant path delays using WVRs are also indicated in this figure.