Development of a real-time monitoring system for precipitable water vapor using a dense GNSS receiver network for GNSS/QZSS

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Because of global warming, the frequency and intensity of extreme weather events are projected to increase, leading to serious hydrological hazards such as landslides, unexpected increases in river level. Torrential rains in urban areas, resulting from the sudden development of a strong thunderstorm associated with sudden heavy rainfall, are becoming a serious problem. The horizontal scale of local heavy rainfall is as small as a few kilometers; it is difficult to predict such rainfall from the current numerical weather forecasts. Weather radar can detect a cloud only after the event becomes evident. An observation system to monitor the behavior of water vapor before the formation of clouds is, hence, necessary.

A Global Navigation Satellite System (GNSS), represented by a GPS, is now widely used for the precise determination of coordinates. The ultimate error in satellite positioning arises from the propagation delay of the GNSS radio signal within the atmosphere. The delay can, however, be related to the accumulated water vapor along the signal path, which can be mapped in the vertical direction to estimate the precipitable water vapor (PWV). This is the basic concept of GPS meteorology.

In a conventional GPS meteorological method, all available GPS satellites above an elevation angle of 5–10° are used to estimate PWV; therefore, the horizontal resolution of GPS-PWV is as wide as about 20 km. We here propose to use GNSS satellites at high elevation angle only, thus improving the horizontal resolution of the PWV estimates considerably. In particular, we will employ the Quasi-Zenith Satellite System (QZSS), which was launched in September 2010 by JAXA. One of the QZSS satellites is positioned over Japan continuously for about 8 hours daily, and hence, it is suitable for monitoring PWV with a better horizontal resolution than in conventional methods.

We have installed a dense GNSS receiver network (10–15 GNSS/QZSS receivers) with a horizontal spacing of 1–2 km around the Uji campus of Kyoto University. Comparison tests between GPS-derived PWV, radiometer PWV, and radiosonde PWV were carried out during July and August 2011. Within the range of 1–4 mm, the GPS-PWV PWV agrees with the PWV derived from radiosondes and the radiometer. We will employ this system to study extreme weather events in the tropical regions in future.

Acknowledgements

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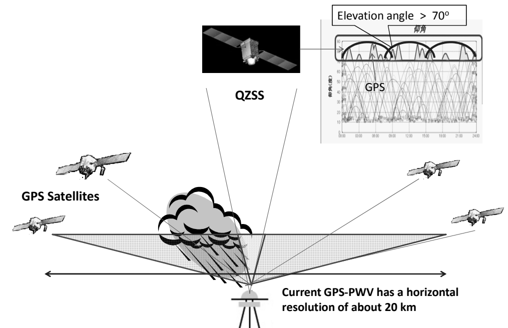

Figure 1. A horizontal water vapor monitoring system employing a GPS and the QZSS.

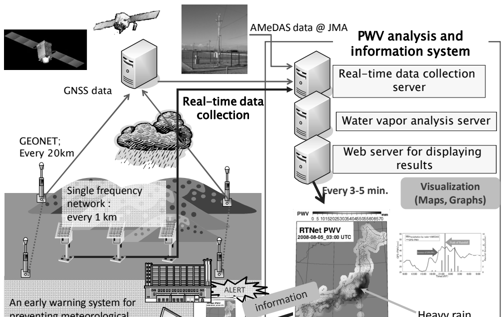

Figure 2. A schematic of a GNSS-based weather forecast early warning system