Meso-gamma scale Water Vapor Distribution Associated with a Thunderstorm Calculated from a Dense Network of GPS Receivers

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The Tsukuba GPS Dense Net campaign that took place in the autumn of 2000 and in the summer of 2001 measured the meso-gamma scale distribution of water vapor. As part of the campaign, 75 GPS receivers and 20 automatic meteorological observation systems recorded water vapor variations associated with a thunderstorm on 1 August 2001. The three-dimensional water vapor distribution in the area was estimated from slant water vapor (SWV) data derived from GPS receivers using tomographic methods.

SWV is the total amount of water vapor per unit area between a GPS receiver on the ground and a GPS satellite. The SWV data used in this study were obtained with sufficient accuracy by carefully removing multi-path effects, phase center variations of the GPS antenna, and other error sources. SWV was converted to a value that was projected onto the vertical direction (VSWV) so that the influence of the elevation angle on the slant path was removed. VSWV values from adjacent receivers to individual satellites were strongly correlated with each other. Variations in VSWV depended on the GPS receiver positions relative to the developing or moving thunderstorm. Our results indicate that SWV data can provide useful information about the water vapor distribution in the vicinity of thunderstorms. Correlations between the variation of VSWV and the precipitable water vapor (PWV) distribution around the GPS receiver were also calculated. The directions of the large values of VSWV corresponded to regions of high PWV.

The three-dimensional water vapor distribution, estimated tomographically, agreed well with Doppler radar-observed reflectivity. Regions of high water vapor near the surface occurred on the northern side of a region of intense reflectivity. The more humid regions above 3 km corresponded to regions where reflectivity increased. The water vapor distribution estimated from the GPS showed an increase of water vapor above a height of 1 km, which preceded the appearance of radar echoes by about 20 minutes during the thunderstorm formation.