Development of A New Humidity-Retrieval Algorithm from Turbulence Echo

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INTRODUCTION

The behavior of the atmosphere is characterized by various physical parameters. Humidity is one of the most important driving forces of intense atmospheric disturbance via the latent release of heat. Although the amount of water vapor generally decreases with increasing height, it shows large variations in time and space, e.g., with the passage of a front or clouds. It is very important to develop a new and accurate technique for continuously monitoring the humidity profile, regardless of weather conditions. Humidity profiles obtained via advanced measurement methods are useful for studying meteorological phenomena, global environmental change, and disaster prevention.

The turbulence echo intensity observed by wind-profiling radar is closely related to the vertical gradient of refractive index squared (M^2), which largely depends on the vertical humidity gradient in the moist atmosphere. In previous studies, height profiles of humidity have been estimated from these characteristics by determining the sign of the radar-derived $|M|$ using simultaneous complementary measurements. Wind-profiling radar has great potential as a tool for all-weather humidity observations. To put this device into practical use, however, it is first necessary to improve the accuracy and expand the height range.

HUMIDITY RETRIEVAL WITH THE MU RADAR AND LOWER TROPOSPHERE RADAR

The height range of humidity retrieval was expanded by combining data from MU (middle and upper atmosphere) radar with RASS (Radio Acoustic Sounding System) and Lower Troposphere Radar (LTR) operating at 46.5 MHz and 1.3 GHz frequencies, respectively. Reduction of the MU radar receiver sensitivity was undertaken to prevent the leakage of transmission signal to the receiver; this was corrected by comparing the signal-to-noise ratio (SNR) of the MU radar and LTR below 2.1 km height. $|M|$ profiles from the two radars between 1.5 km and 1.95 km height are then merged with a linear weighting function. Specific humidity (q) profiles were successfully estimated from the merged $|M|$ profiles.

HUMIDITY RETRIEVAL USING A ONE-DIMENSIONAL VARIATIONAL METHOD

To achieve a more precise estimate of humidity, a one-dimensional variational method was applied using a wind-profiling radar. A statistical probability for the sign of M is introduced to the cost function of the variational method to determine the optimum result with reduced calculation cost. Humidity profiles were retrieved from the MU radar-RASS data using the first guess calculated from the time-interpolation of radiosonde results. Figure 1 shows time-height variations in the radiosonde-derived q (upper), the first guess (middle) and the analysis result (lower). The time-height structure of the radiosonde-derived q shows remarkable features that are highlighted on the figure by circles. The radiosonde result has a sharp peak below 3.9 km height at 18:00 LT on July 31 and two peaks at 3.0 km height at 09:00 LT and 15:00 LT on August 1. It is also apparent that the radiosonde result below 3.0 km decreased over time between 12:00 LT and 21:00 LT on August 3; however, these structures are not evident in the time-height variation of the first guess calculated from the time-interpolation of 12-hourly radiosonde results. Time-height variations in the analysis result are in good agreement with the recorded variation in the radiosonde result, especially the remarkable peak as shown by circles. This result confirms that the analysis result successfully retrieved detailed humidity variations that cannot be expressed by the first guess. The remarkable improvement over the conventional method is especially evident for the case of a large error in the first guess.

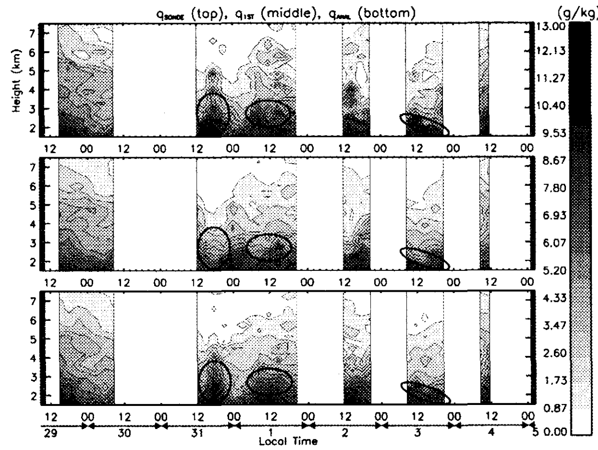

Figure 1 Time-height variation in the radiosonde-derived q (upper), the first guess (middle) and the analysis result (lower). Note that the first guess profiles are calculated from 12-hourly radiosonde results.