Real-Time Analysis of Atmospheric Thermodynamic Conditions based on 1DVAR Method using Ground-Based Microwave Radiometer Data

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1. Introduction

Forecasts of convective clouds in summer seasons remain challenging, because there is uncertainty in the numerical model reproducibility of low-level atmospheric thermodynamic structures. Recently, a ground-based microwave radiometer (MWR) data has been used for estimating accurate thermodynamic profiles in the low-level troposphere through a one dimensional variational (1DVAR) technique using the results of numerical model simulations (Ishimoto, 2015; Araki et al., 2015, 2017). For the diagnosis of convective cloud developments, the 1DVAR analysis using the MWR data with time intervals of a few minutes could be of benefit considering the diurnal variations of atmospheric thermodynamic profiles although radiosonde observation data twice a day has been used in the traditional method. In September 2013, aircraft observation campaign was conducted to investigate the effectiveness of ground-based AgI generators in seeding convective clouds developed around the central mountain region in Japan as part of the joint research project for a renewal of ground-based AgI generator at Ogouchi Dam between the Bureau of Waterwork of the Tokyo Metropolitan Government and the Meteorological Research Institute. To support the aircraft observation, we developed a real-time 1DVAR analysis system for the derivation of accurate atmospheric thermodynamic structures using MWR data and results of high-resolution numerical model simulation.

2. Model settings and design of the real-time 1DVAR system

Numerical simulations were performed twice a day by the Japan Meteorological Agency (JMA) Meteorological Research Institute Non-Hydrostatic Model (MRI-NHM) with a horizontal grid spacing of 1 km and a model domain covering the central mountain region during the campaign. Initial and boundary conditions were provided from forecast data of the JMA operational mesoscale model, and the MRI-NHM was run for 12 hours from 00 and 12 UTC. The results of the simulations were used for 1DVAR analysis (Araki et al., 2015) by combining with the observation data from the MWR installed at Ogouchi (35.79°N, 139.05°E, 530 m). We used the ground-based multi-channel MWR (MP-3000A, Radiometrics), which observed the brightness temperature of 21 K-band (22-30 GHz) and 14 V-band (51-59 GHz) microwave channels with a bandwidth of 300 MHz in the zenith direction at time intervals of a few minutes. The results of the simulation were output at 1-hour intervals, and they were interpolated into the time intervals of MWR observations and used for the first guess of the 1DVAR analysis. The 1DVAR retrievals of atmospheric temperature and water vapor profiles were performed every 10 minutes using the latest observation data of the MWR. In this way, we constructed a real-time 1DVAR analysis system for the retrieval of accurate atmospheric thermodynamic structures.

3. Real-time 1DVAR analysis of atmospheric thermodynamic conditions

An example of the real-time 1DVAR analysis is shown in Fig. 1. The real-time 1DVAR analysis system output profiles of thermodynamic profiles and a list of thermodynamic indices such as lifted condensation level (LCL), level of free convection (LFC), convective available potential energy (CAPE), Showalter stability index (SSI), and lifted index (LI) at the time of every analysis. The 1DVAR-derived profile data of temperature, water vapor density, and liquid water content was converted into a format processable in the Universal RAwinsonde OBservation program (RAOB; http://www.raob.com/), and the data were monitored in the form of time-height cross-section as shown in Fig. 2. During the aircraft observation campaign, the real-time 1DVAR analysis system and monitoring system were used for a flight decision of the convective cloud observation. From the viewpoint of predicting convective cloud developments, it would be effective to monitor the thermodynamic conditions of the atmosphere using this real-time 1DVAR analysis system combined with the kinematic conditions of the atmosphere such as operational surface wind and wind profiler observation.

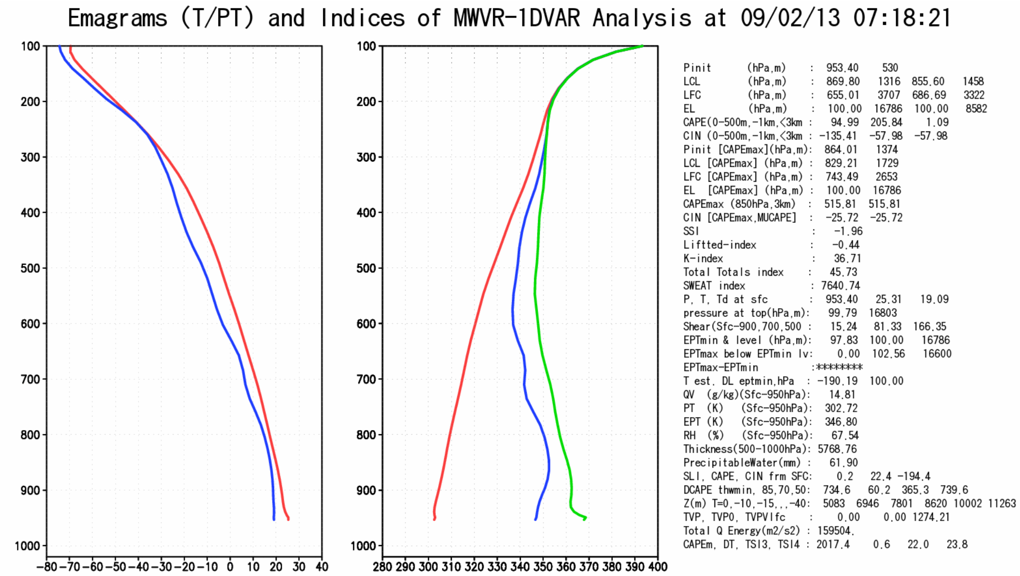

Figure 1. An example of outputs from the real-time 1DVAR analysis system. Red and blue lines in the left panel respectively indicate air temperature and dew point temperature (°C) and red, blue, and green lines in the right panel show potential temperature, equivalent potential temperature, and saturated equivalent potential temperature (K), respectively, at 07:18:21 UTC on September 2, 2013.

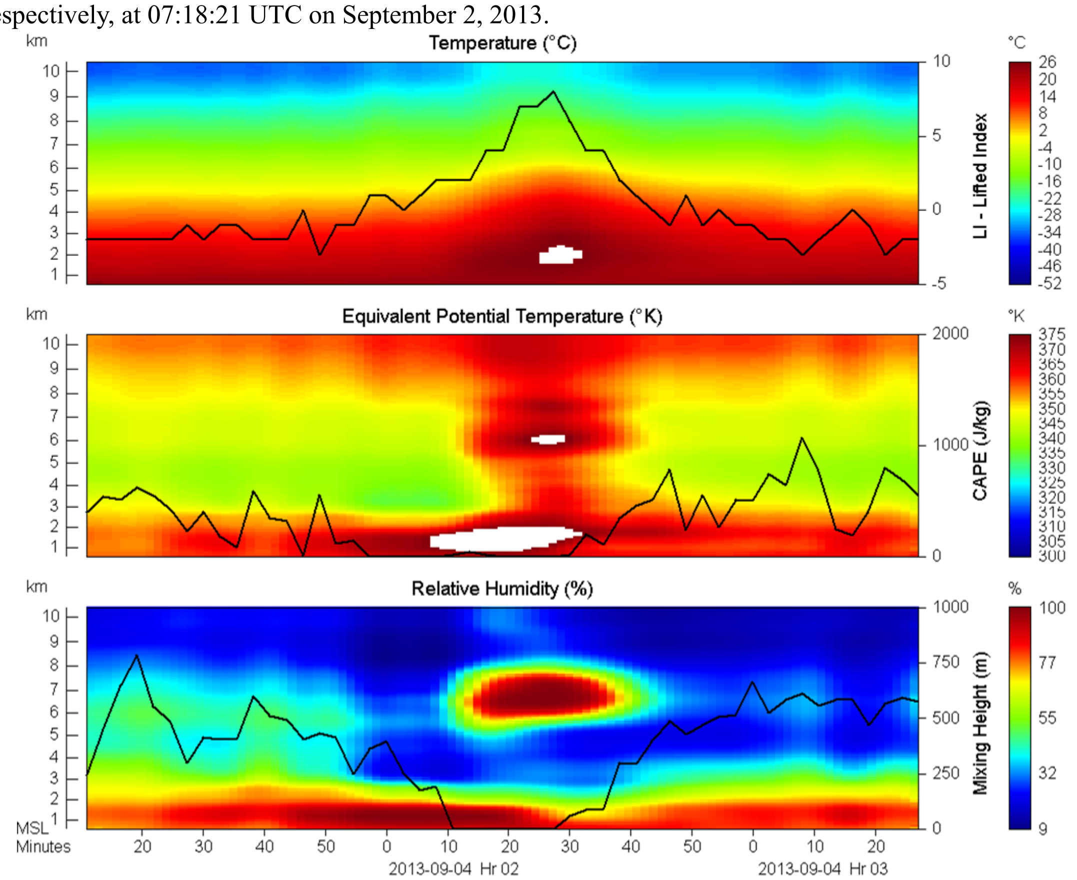

Figure 2. Time-height cross-sections of temperature, equivalent potential temperature, and relative humidity obtained from the real-time 1DVAR analysis system for 02:10:00-03:30:00 UTC on September 4, 2013.

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