Monitoring system for atmospheric water vapor with a ground-based multi-band radiometer -- an application of radio astronomy technologies into meteorology

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In order to prevent meteorological disasters such as local heavy rainfalls and significant tornadic storms, temporally high-resolution estimation of thermodynamic environments and cloud microphysics is required. For the purposes of short-term forecasting and nowcasting of severe storms, we propose a novel ground-based measurement system which observes radiative intensities in the microwave range and estimates the thermodynamic environments in the atmosphere. There have been some commercial systems [1]. However, their receiver noise temperature is higher than the atmospheric radiation temperature (≈ 20 K in the case of Japanese winter) because they are the ambient temperature system. Low temperature system is required to reduce the noise in radiometric observations. Our multi-band receiver system is designed to identify a rapid increase of water vapor before clouds generation. At the frequencies between 20 and 30 GHz, our system measures water vapor as a broad absorption peak at 22 GHz and cloud liquid water. Another 50 -- 60 GHz band provides supplement information from an Oxygen radiation which contains vertical profiles of physical temperature of molecules in the atmosphere.

Our system has a simple transport optical system which has main mirror and wire grid to separate the RF signal into lower and higher frequency band. For the construction of the cold receiver system, novel technologies which developed for CMB (cosmic microwave background radiation) observation are applied. In particular, a technology to operate a cryocooler on a rotating system [2] and a radio-transparent thermal insulator [3] are key seeds, e.g., protection of dew condensation in the optical path. The input atmosphere signal is amplified by a HEMT which is maintained below 10 K, spectrum shape is simply measured by using a signal analyzer. Cold black body calibration source of 30 K is implemented inside of the cryostat. The calibration signal is also transported to each receivers via the wire grid whose rotation switch the optical path; either the atmosphere signal or the calibration signal. Our system is designed to be less than one cubic meter and low electrical consumption (less than 2 kW). Therefore, it is easy to deploy the system on top of high buildings, mountains, and on a deck of ship.

We developed a prototype receiver, and sufficient receiver noise temperature (≈ 50 K) was confirmed based on Y-factor measurements with 77 K cooled black body. We also demonstrated the monitoring of water vapor in the atmosphere in the zenith direction. The opacity of 20 GHz band observed by our system was consistent with the result of the radiosonde observations. Developments of the prototype system and its test results will be presented in this conference.

[1] http://radiometrics.com/, http://www.radiometer-physics.de/rpg/html/Home.html
[2] S. Oguri, J. Choi, M. Kawai and O. Tajima, Rev. Sci. Instrum., 84, 055116, (2013).
[3] J. Choi, H. Ishitsuka, S. Mima, S. Oguri, K. Takahashi and O. Tajima, Rev. Sci. Instrum., 84, 114502, (2013).