Three-dimensional radar imaging of atmospheric structures using multiple receivers and multiple frequencies

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Abstract

Multi-receiver and multi-frequency imaging techniques of UHF/VHF atmospheric radar have been applied to reconstruction of the three-dimensional irregularity structure of refractive index (termed three-dimensional/3D radar imaging), providing a chance of observing small-scale structures in the radar volume. In this study, simulations of 3D radar imaging for various irregularity structures were carried out. Spatial weighting effect arising from radar beam pattern, range weighting function, and other factors were considered in the computation, showing the importance of the spatial weighting effect on the imaging result. Practical usage of 3D radar imaging has been carried out with the Middle and Upper atmosphere Radar (MUR; 34.85^{o}N, 136.10^{o}N) in Japan. The MUR possesses the capabilities of 5 frequencies, ranging from 46 MHz to 47 MHz, and up to 25 receivers to achieve the imaging techniques. In this study, the Capon method was employed for the process of imaging, and the 3D structure imaging of a wavy layer and turbulent structure was obtained. Information such as echo center and structure morphology in the 3D structure imaging was then extracted for further examination. For example, the location distribution of echo centers in the radar volume could imply the traveling orientation of the wavy layer, which was consistent with horizontal wind direction. This study has demonstrated an advanced application of 3-D radar imaging to practical atmospheric phenomena.

Keywords: Interferometry, Instruments and techniques, Turbulence