Abstract: This paper describes a method for estimating the specific attenuation and equivalent radar reflectivity in a melting layer using a dual-Ka-band radar system. The system consists of two identical, Ka-band radars. When a precipitation system crosses between two radars, the radar observes the system with opposite directions. The radar employs FM-CW type and designed for the measurement of the scattering characteristics of precipitation particles. The pulse echo shows a radattenuation characteristic. The radattenuation due to no attenuation is subtracted by both radars. But by adjusting different measured, radattenuation with range, the specific attenuation can be estimated. After obtaining the specific attenuation, equivalent radar reflectivity is estimated. In the melting layer, specific attenuation and the equivalent radar reflectivity vary largely along the radio path, and the estimated specific attenuation is very sensitive to the setup configuration of the experiment. The accuracy of the estimated specific attenuation is found to depend on the curvature of the equivalent radar reflectivity with respect to range and the distance for the differentiation. The measurement system and actual procedure of data analysis are also described.

Observation
The intensive observation period in Mt. Zao was held from 13 Dec. 2014 to 12 Nov. 2014 (29 days) twice for 40 days. The observation period in the melting layer was from 28 Feb. 2015 to 11 Mar. 2015 (11 days). When the melting layer comes down/up as the temperature decreases/increases, the beams of radars go through the melting layer thus the k and Ze in the temperature decreasing/rising, the beams of radars will also change their direction.

Calibration and Correction of Zm
Even though the system parameters are well specified, calibration is required. Actually, our Ka-radar was found unstable, particularly, in cold season. Zm was adjusted by radar disdrometer, which is a commercial one called Parsivel, and dual total path attenuation. When the melting layer comes down/up as the temperature decreases/increases, the beams of radars go through the melting layer thus the k and Ze in the temperature decreasing/rising, the beams of radars will also change their direction. In the melting layer, specific attenuation is calculated and compared with Ka-radar measurement. Only rain cases are used, because radar reflectivity of rain is much more stable than snow.

1. Estimation of bias of Ka #1: calculating Ze, including Mie scattering effect, from measured DSD by Parsivel and making comparison with Zm(#1) then the bias of SN1 is obtained.
2. The total attenuation along the beam should be the same between Ka#1 and Ka#2. Ka#1 has been adjusted by Parsivel so the discrepancy of SN1 vs SN2 should owe to the bias of SN2.
3. Validating the obtained k-Ze datasets of Ka-radar by k-Ze relationship of Parsivel.

Results
The case of dual-radar observation through melting layer is in total about 54 hours. The method is still developing, however, the preliminary results indicate the characteristic behaviors of k-Ze relationship depends on the position of the melting layer, that is, the state of the melts particle. As the height of melting layer decreases from 420 m below to 300 m high during 30 minutes.

Discussion
Regions in the melting layer is categorized by Ze profile and k and Ze in same range in each cases are fitted as k=αZeβ.

Conclusion
This unique measurement using two same in-wavelength radars viewing a same precipitation volume from opposite viewing angles shows the radar reflectivity(Ze) and attenuation(k) with reduced uncertainty. The k-Ze relationships of rain, melting layer, and snow were successfully measured. The method of the dual-radar sensitivity collection was developed. This result will make it possible to study the connection between the microphysical characteristics of the hydrometeor and the measurable quantity by radar observation.

References