Global Precipitation Measurement (GPM) core satellite on-orbit is the follow-on mission of the Tropical Rainfall Measuring Mission (TRMM) satellite and was jointly developed by United States and Japan. Following the successful observation by the TRMM Precipitation Radar (PR), it was launched on 28 February 2014 carrying Dual-frequency Precipitation Radar. We have been greatly utilizing 3-dimensional precipitation information obtained from those spaceborne radar in weather forecasting, and in global map-type precipitation dataset such as GSMaP as a calibrator.

Despite these great contributions, spaceborne precipitation radars still have some drawbacks to overcome. One big issue is its scan width. With current scan width of 250km, GPM/DPR manages to cover 90% of the surface of the earth in about 14 days, which is not appropriate enough for disaster monitoring compared to the coverage of microwave imager. In addition, capturing whole structure of the typhoons or hurricanes can be quite probabilistic matter under this narrow scan width.

After completing designed life time of GPM on 21 June 2017, in response to these discussions, Japan Aerospace Exploration Agency (JAXA) started feasibility study for wider swath observation assuming future spaceborne precipitation radar. In this paper, we show the results of wide swath observation experiment simulating doubled swath width (500km) and analysis on the mainlobe clutter height which is one of the critical issues when widen the radar swath width.

Due to the limitation of the radar system, we cannot directory widen the swath width of the DPR. In order to simulate the observation with doubled swath (500km) under this condition, scan pattern was changed from normal symmetric scan of 250km to from nadir to 250km scan so that we can at least know the scan status in the one edge of the scan with 500km.

In the experiment DPR successfully caught precipitation echo at wider edge of the scan (almost 250km from nadir) while the normal scan only provided the information for at most 125km from nadir. However, it cannot be immediately said that wide swath observation is applicable for the future scan because mainlobe clutter (surface echo power) height grows up along with the scan incident angle. Due to this constraint, we need to carefully analyze the mainlobe clutter height in order to retrieve precipitation echo properly.

To analyze mainlobe clutter height statistically, vertical profile of the received echo power in each angle bin was examined. Overall, echo power in near nadir incident angle is higher over ocean than over land due to the strong specular reflection. However, peak echo power level over ocean and land are reversed as the incident angle increases because ground surface scattering becomes dominant.

Another point worthy of special mention is that strong signal is found apart from mainlobe clutter only in KuPR. This is caused by strong back scattered power which contribute to the received signal along the antenna sidelobe and it is more prominent in KuPR than in KaPR. In addition, wide swath observation brought us grating lobe clutter effect in some angle bin wider than around No. 40 for KuPR observation especially over land.

In order to examine mainlobe clutter height independently, it is inevitable to reduce sidelobe and grating lobe effect. In this study, clutter-free observation data is extracted based on following procedures; 1) extract observed range bins above mainlobe clutter; 2) extract observed range bins under non-precipitation condition from 1) based on the Kubota et al. (2016); 3) extract observed range bins that satisfy |received power – averaged noise power| < 2 sigma of the noise power from 2). Note that this procedure was applied only for KuPR observation since sidelobe and grating lobe clutter is not prominent in KaPR observation as above mentioned.

By applying those procedure, clutter effect is properly eliminated for range from surface to the sky. With this echo profile, thresholds of -110.0dBm for Ku and KaHS, -107.5dBm for KaMS were set to decide the maximum clutter height in each incident angle (typical noise power is about -111.0dBm for KuPR and KaHS, -108.5 dBm for KaHS).
For KuPR, clutter height is increasing almost linearly along the incident angle both over ocean and land. Maximum height is around 4 km over ocean and 5 km over land. However, there are some suppression of clutter height growth when using looser threshold, especially over ocean. Basically, those tendency is consistent with wide swath experiment result of TRMM/PR while it has clearer suppression of clutter height in larger incident angle. Strange echo peak at incident angle of +4° is due to the incomplete judgement of mainlobe clutter free bottom. KaPR shows more gentle increase trend compared to the KuPR. The maximum clutter height is around 3.5 km over land although linear increase trend is the same as KuPR. Interestingly, clutter height over ocean takes its maximum of about 2.5km at around +27° and turns to show decreasing trend for larger incident angle. This is because of the relatively weak surface echo power due to large incident angle and attenuation by long distance from the surface.

These results indicate that despite relatively shallow and weak precipitation is hard to detect by wide swath scan because it will be masked by the tall mainlobe clutter, there still some possibilities for intense rainfall to be detected. Assuming exactly the same radar system as DPR for future radar with wide swath scan, KaPR will be the key to get the information for lower precipitation where KuPR does not work well.