Classification of precipitation and volcanic clouds using operational X-band polarimetric radar parameters

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Explosive volcanic eruptions are severe natural phenomena that produce pyroclastic materials, eruption columns, and volcanic ash clouds. During moist weather conditions, volcanic eruption products can be covered with water, resulting in wet ash and/or mixtures of ash and rain. Wet ash, which is heavier than dry ash, increases the risk of towers or poles collapsing, and rain mixed with volcanic ash is a harmful natural phenomenon that threatens human life, infrastructures, economies, agriculture, etc. Optical measurements, which are made with ground-based instruments, cameras, and satellites, have some limitations of their ability to detect volcanic ash clouds and eruption column in cloudy or precipitation conditions. Weather radar is one of the key instruments for studying and monitoring both precipitation and volcanic ash clouds, since it can observe both types of system and can provide valuable information that can discriminate between the two systems through the use of polarimetric parameters. To study the systems, and distinguish between the two, we used an algorithm that produces three-dimensional, constant-altitude, plan-position-indicator data (3D CAPPI), which are high-spatio-temporal resolution volumetric and developed a classification algorithm between precipitation and volcanic ash clouds using X-band polarimetric radar parameters. Twelve volcanic ash cloud events (each more than 3,000 m high) and 46 rain events (included convective precipitations, seasonal rain fronts, typhoons, etc.), which occurred during the period June to November, 2013, were used to develop the algorithm. Using statistical analysis of the two kinds of events, we obtained the characteristics of the polarimetric radar parameters of precipitation and volcanic eruption clouds. The results have been used to make a membership function for volcanic ash clouds and rain, and to make a classification algorithm. The designed algorithm can discriminate between three conditions, which exist separately in both convective precipitations and volcanic ash clouds; convective precipitations alone, volcanic eruption columns alone, and volcanic ash clouds alone. So far, the algorithm cannot discriminate between two further conditions; when both non-convective precipitation and volcanic ash cloud exist separately, and non-convective precipitation alone. The results of this study could help to develop and improve an algorithm applicable to quantitative short-term forecasting for precipitation/volcanic ash clouds (QPF/QAF) and to enhance quantitative estimation for precipitation/volcanic ash clouds (QPE/QAE). This study can also be useful in the creation of hazard maps to protect human life against harmful natural hazard phenomena, such as rain mixed with volcanic ash.

Keywords: Precipitation, Volcanic ash clouds, Polarimetric radar parameters, Three dimensions