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The potential of polarization measurements from space at mm and sub-mm wavelengths for determining cirrus cloud parameters

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Abstract. The millimeter and sub-millimeter waves have been attracting a lot of attention recently in the cloud remote sensing community. This is largely because of their potential use in measuring cirrus cloud parameters with airborne or space-borne radiometers. In this study, we examine the possibility of using polarization measurements in this frequency range to get information on the microphysical properties of cirrus clouds. By using a simple radiative transfer model, we calculated the brightness temperature differences at the vertical and horizontal polarization channels for the following seven frequencies: 90, 157, 220, 340, 463, 683, and 874 GHz. The ice crystals in cirrus clouds are modeled with nearly spherical particles, circular cylinder, and circular plate, as well as with mixtures of these types. We found that the polarization difference signal shows a unique "resonance'' feature with the change of ice particle characteristic size: it has a strong response only in a certain range of ice particle size, beyond that range it approaches zero. The size range where this resonance happens depends to a large extent on particle shape and aspect ratio, but to a much less extent on particle orientation. This resonance feature appears even when ice clouds are composed of a mixture of ice crystals in different shapes, although the magnitude and the position of the resonance peak may change, depending on how the mixture is made. Oriented particles generally show larger polarization difference than randomly oriented ones, and plates have larger polarization difference than cylinders. However, the state of particle orientation has a significantly stronger effect on the polarization difference than the particle shape (cylinder or plate). This makes it difficult to distinguish particle shapes using millimeter and sub-millimeter radiometric measurements, if there is no information available on particle orientations. However, if the state of particle shape mixture can be predetermined by other approaches, polarization measurements can help to determine ice particle characteristic size and orientation. This information, in turn, will benefit our retrieval of the ice water path of cirrus clouds.

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