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The origin of midlatitude ice clouds and the resulting influence on their microphysical properties

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Ice clouds are known to play an important role in the radiative balance of the atmosphere. The nature of this role is determined by the macrophysical and microphysical properties of a cloud. Thus, it is crucial that we have an accurate understanding of properties such as the ice water content (IWC), ice crystal concentration (Ni), and ice crystal size (Ri). However, these properties are difficult to parameterize due to their large variability and the fact that they are influenced by a number of other factors such as temperature, vertical velocity, relative humidity with respect to ice (RHice), and the available ice nuclei. The combination of those factors ultimately establishes whether heterogeneous or homogeneous nucleation will lead to ice crystal formation.

The aforementioned factors are largely determined by the dynamics of the environment in which the ice cloud forms, collectively contained in a meteorological situation. Ice clouds have been observed in a variety of situations such as frontal systems, jet streams, gravity waves, and convective systems. Most recently, the concept of the influence of large-scale dynamics on midlatitude cirrus properties has been demonstrated in the work of Muehlbauer et al. (2014). In the work presented here, we explore this concept further by examining how differences in dynamics are translated into the differences in IWC, Ni, and Ri that are found within and between datasets. Data from two American-based campaigns, the 2004 Midlatitude Cirrus Experiment (MidCiX) and the 2011 Midlatitude Airborne Cirrus Properties Experiment (MACPEX), as well as some European-based campaigns, the 2004 and 2006 CIRRUS campaigns, the 2013 AIRTOSS-ICE campaign, and the 2014 ML-CIRRUS campaign are combined to form a large, and more latitudinally comprehensive database of Northern Hemisphere in-situ, midlatitude ice cloud observations.

We have divided the data by meteorological situation and explored the differences and similarities between situations in the IWC, Ni, and Ri observations. This allows us to make inferences on how the dynamics influenced the nucleation process. For example, it is clearly observed that homogeneous freezing dominates in gravity wave cirrus clouds, while heterogeneous freezing dominates in high pressure, warm front cirrus. Additionally, we have found that the origin of the cloud is a key piece of information needed to explain the observations. On the one hand, in situations such as convection and warm conveyor belts, the ice clouds exhibit a higher than expected IWC, and a high Ni of large Ri. This is likely due to the fact that the ice crystals that were observed originated in the liquid or mixed-phase environment and were transported to the cirrus environment. Conversely, we have also observed cirrus in which the IWC, Ni, and Ri values are more consistent with what we expect from cirrus that formed heterogeneously or homogeneously in the native cirrus environment. Through comparisons to modeling work, we are able to confirm the existence of these two types of ice clouds. We suggest that this new information brings into question the way in which we should define cirrus clouds.