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Phenomenology of ice formation in INTACC and SUCCESS

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Abstract

An analysis of both the INTACC and SUCCESS data sets is undertaken to assess ice formation phenomenology in light of recent laboratory and field studies. To aid in this analysis, the Asphericity Factor utilized as a threshold indicator for the presence of ice in previous work is now used as a continuous variable to indicate extent of glaciation. The INTACC data yield only one case of homogeneous nucleation. The bulk of the data suggest heterogeneous nucleation is dependent on particle number concentrations in the 0.1 to 0.3 μm size range. The SUCCESS data are in accord with this. A tentative rationalization of this phenomenology in terms of the chemical composition of this preferred size range is offered.

Keywords: Ice nuclei; Cloud glaciation; Nuclei composition

1. Introduction

Ice initiation in the atmosphere could have a potentially profound effect on climate, certainly has an impact on cloud microphysics and precipitation formation, and is poorly understood (IPCC, 2001). This lack of understanding is in part due to the

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complexity of the phenomenon and in part due to a lack of good data. The latter factor is particularly acute with respect to the cirrus clouds of the upper troposphere. Indeed, until relatively recently, only the most limited in-situ data – the most effective type for resolving many issues – were in hand. To address this lack, intensive field campaigns have been mounted including SUCCESS (Subsonic aircraft contrail and cloud effects special study) in 1996 (cf., DeMott et al., 1998) and INTACC (Interaction of aerosol and cold clouds) in 1999 (Field et al., 2001). These two studies have yielded substantial data bases of high quality, which in turn have led to numerous important insights into ice formation in cirrus clouds. However, recent laboratory and some field studies, conducted after the SUCCESS and INTACC analyses, have suggested important conceptual changes in our view of ice formation may be in order (e.g., Koop et al., 2000; Strom et al., 2003). Given the quality of the INTACC and SUCCESS data sets, it would seem that further retrospective analysis, incorporating these concepts, might prove fruitful. We report here the results of one such reanalysis.

2. Methodology

2.1. Data sets

The INTACC data to be utilized have been made available by the courtesy of various INTACC participants and the SUCCESS data set, compiled on CD ROM, is available publicly through the NASA Ames Research Center (contact S. Gaines at gaines@cloud1.arc.nasa.gov). The overall data set and the types of instruments employed in INTACC are well described in Field et al. (2001) while the SUCCESS results have been described in a large number of publications (e.g., DeMott et al., 1998; Heymsfield et al., 1998a,b; Rogers et al., 1998).

Six wave cloud flights were selected from the 10 successful cloud flights undertaken during INTACC. The other flights examined cirrus associated with frontal systems or with wave clouds that were either non-stationary or dissipating during sampling, i.e., they dealt with complex and poorly characterized clouds.

The SUCCESS study was aimed primarily at documentation of contrail microphysics and the impact of aircraft emissions on natural clouds. From the dozen missions flown, we have selected five flights with measurements in substantial “natural” cirrus rather than contrails or cumulus anvils. Two of the five cases were wave clouds previously examined in some detail by DeMott et al. (1998) and Jensen et al. (1998). The other three were upper tropospheric cirrus.

2.2. Instruments

All of the instruments used to obtain the INTACC parameters analyzed in this study are described in Field et al. (2001). Similarly, the instrumentation utilized to obtain the SUCCESS data set has been discussed by Heymsfield et al. (1998a,b), Chen et al. (1998), and Twohy and Gandrud (1998).