Internal Variability Dependence on Cirrus Cloud Structure

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Abstract

Cirrus clouds play an important role in the climate system owing to their interwoven microphysical, dynamical and radiative properties. Using 35 GHz millimeter wave radar observations, we study the broadening of the Doppler spectrum and work on the problem of separating the contributions of different physical phenomena within cirrus clouds. Such a separation will allow us to specify how the roles of atmospheric dynamics and microphysics vary with cloud structure during future data analysis.

Introduction

We report some preliminary results on distinguishing various vertical regions in the cloud that apparently are dominated by different physical phenomena. Investigation of the scaling variability and long-range correlations in the vertical regions of the cloud where the specific different phenomena have been identified will be presented elsewhere. This work adopts a different prospective from that used in earlier studies (Ivanova et al. 2003, 2004).

First, we take advantage of the fact that the three quantities measured with the 35 GHz millimeter wave radar--the radar reflectivity, the Doppler velocity, and the Doppler spectral width--are not independent of one another. That is, the Doppler velocity is the reflectivity-weighted mean particle fall velocity and the Doppler spectral width is its reflectivity-weighted standard deviation, or Doppler spread or Doppler broadening.

Therefore, if we identify regions in the cloud having approximately constant values of radar reflectivity (i.e., backscattering cross section)--or values within a certain range--then, from a mathematical point of view, we could eliminate the weighting factor. As a result, the interpretation from a physical point of view given by any further analysis of the mean velocity and its standard deviation will become more accurate, more straightforward, and more clear. Such partitioning of the regions will facilitate our successfully surmounting the problem of interwoven cloud dynamical and microphysical contributions during subsequent data analysis. Furthermore, we will see that this also leads to the identification of regions in the cloud where different types of stratification exist and where different physical processes are dominant.

Data

We analyze data collected on January 26 and 27, 1997 with a millimeter wave cloud radar (MMCR) that operates at 34.86 GHz at the Southern Great Plains (SGP) Atmospheric Radiation Measurement (ARM) Program site (http://www.arm.gov/docs/sites/sgp/sgp.html) (Figure 1). The radar produces measurements at four modes that are used to obtain a best estimate of the cloud signal following an interpolation procedure described in Clothiaux et al., (2000).

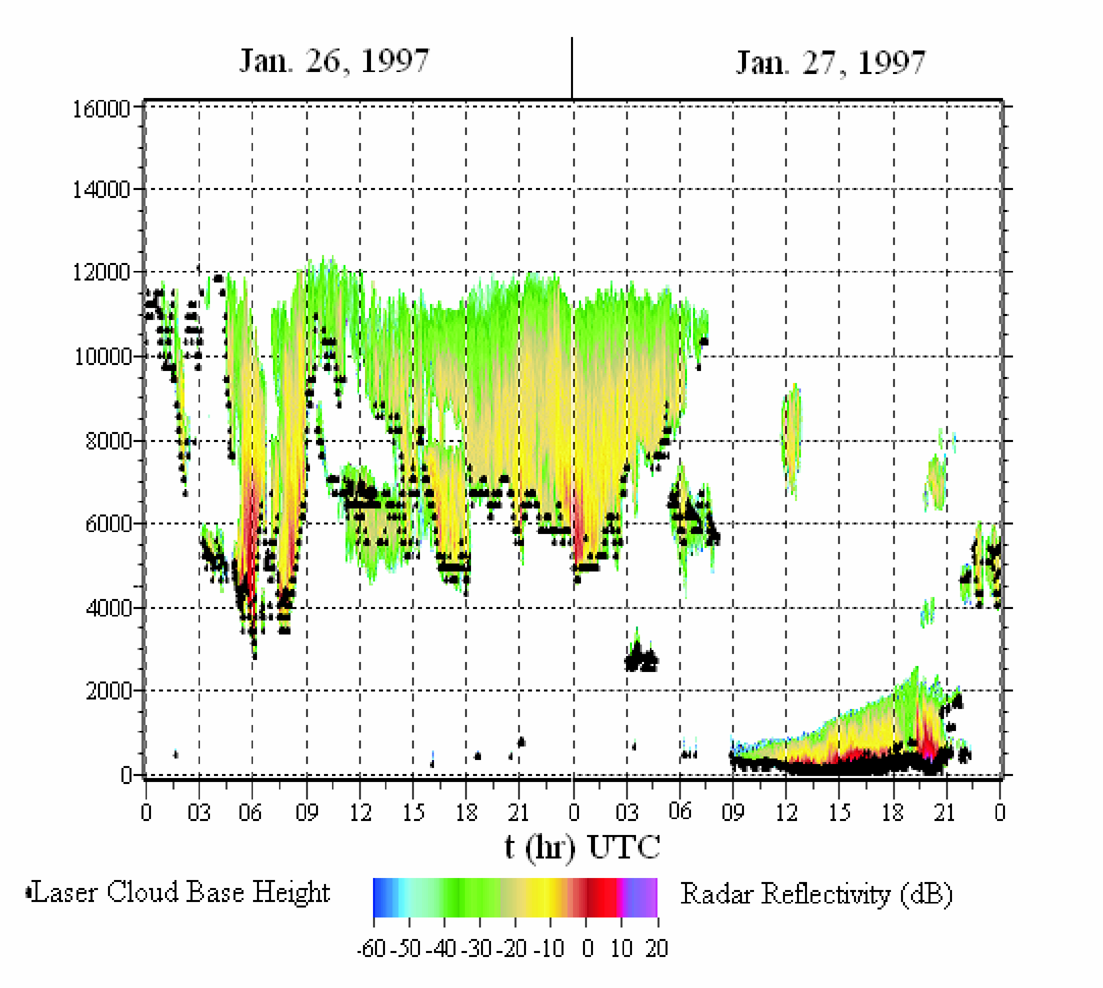

Figure 1. 35mm MMCR data at ARM SGP site on January 26 and 27, 1997.

In order to make an initial estimate of the regions in the cloud as given by radar reflectivity within certain limits, we start by dividing the [-45,+10] dB range of the cloud radar reflectivity into subintervals (Figure 2).

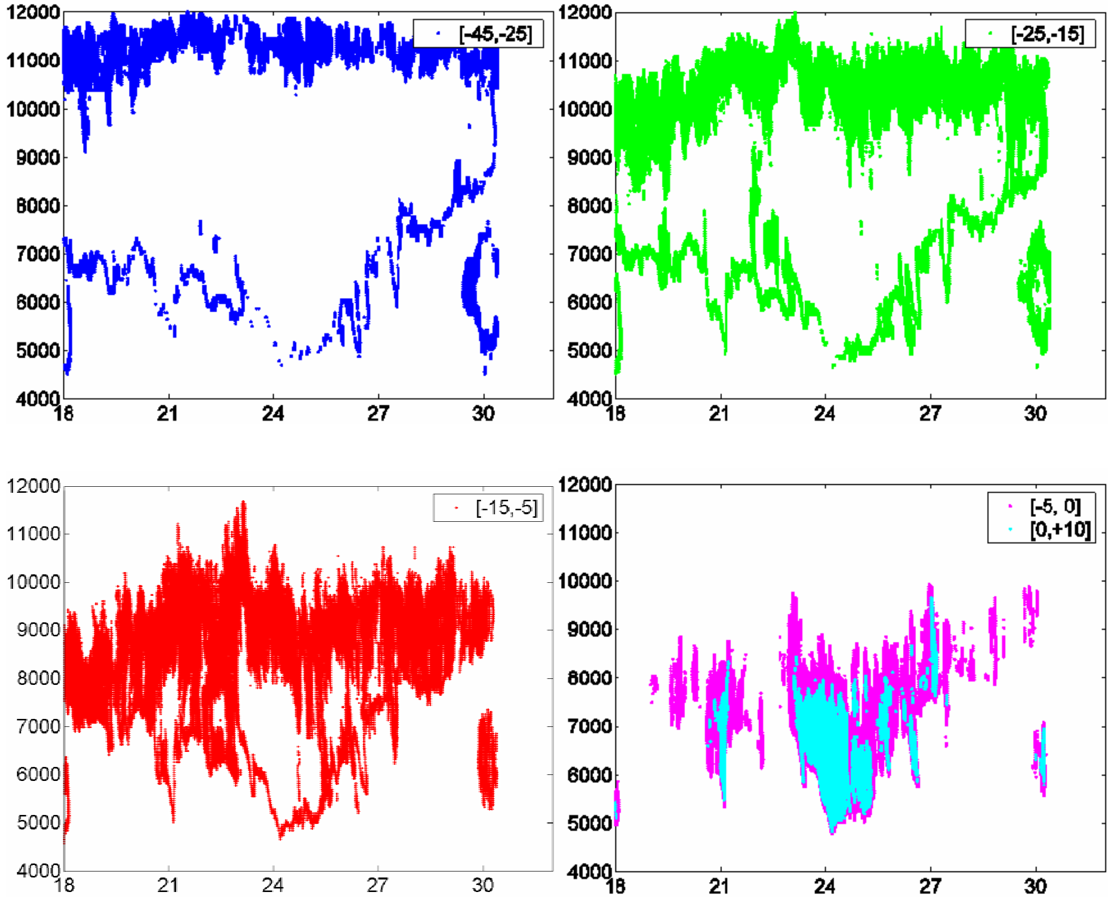

Figure 2. Regions in the cloud with radar reflectivity in certain range.

For the purpose of further analysis, we will consider the data in the [-45,-5] dB range separately from the data in the [-5,+10] dB range. Our hypothesis is that different processes are taking place in these two regions of the cloud.

Making Use of the Radiosonde Measurements

In order to test our hypothesis, we have studied the consequences of the vertical stratification in cirrus clouds through contour maps of equivalent potential temperature calculated from the radiosonde measurements of temperature, pressure, and ice/water mixing ratio (Figure 3).

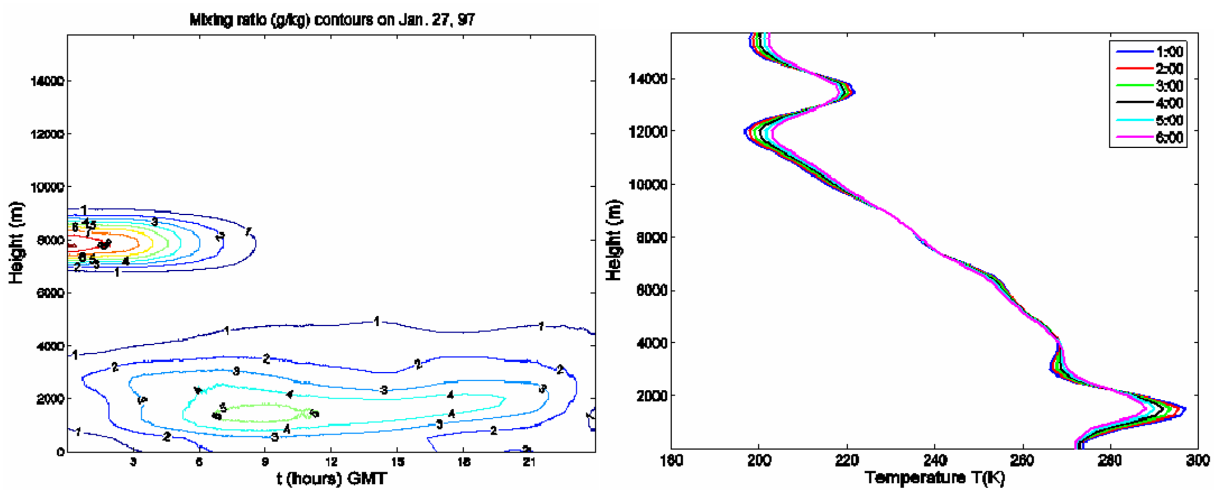

Figure 3. Mixing ratio (g/kg) contours on January 27, 1997 (left panel) and temperature (K) profiles at 1:00,…,6:00 UTC on January 27, 1997 (right panel).

Discussion

We find that the occurrence of neutral stratification coincides with the upper part of the cloud (layer A in Figure 4), where comparable contributions from particles with similar sizes is more likely. The unstable region (B) in the cirrus cloud coincides with the convective region in the cloud where it is more likely that the largest particle size contribution dominates the radar reflectivity. Finally, a stable region (C) is identified via the positive vertical derivative of the equivalent potential temperature that we found to coincide with the region that has been identified by radar reflectivity values within the [-5,+10] dB range (Figure 2). Our findings are in agreement with previous work on cirrus clouds by Gultepe and Starr (1995).

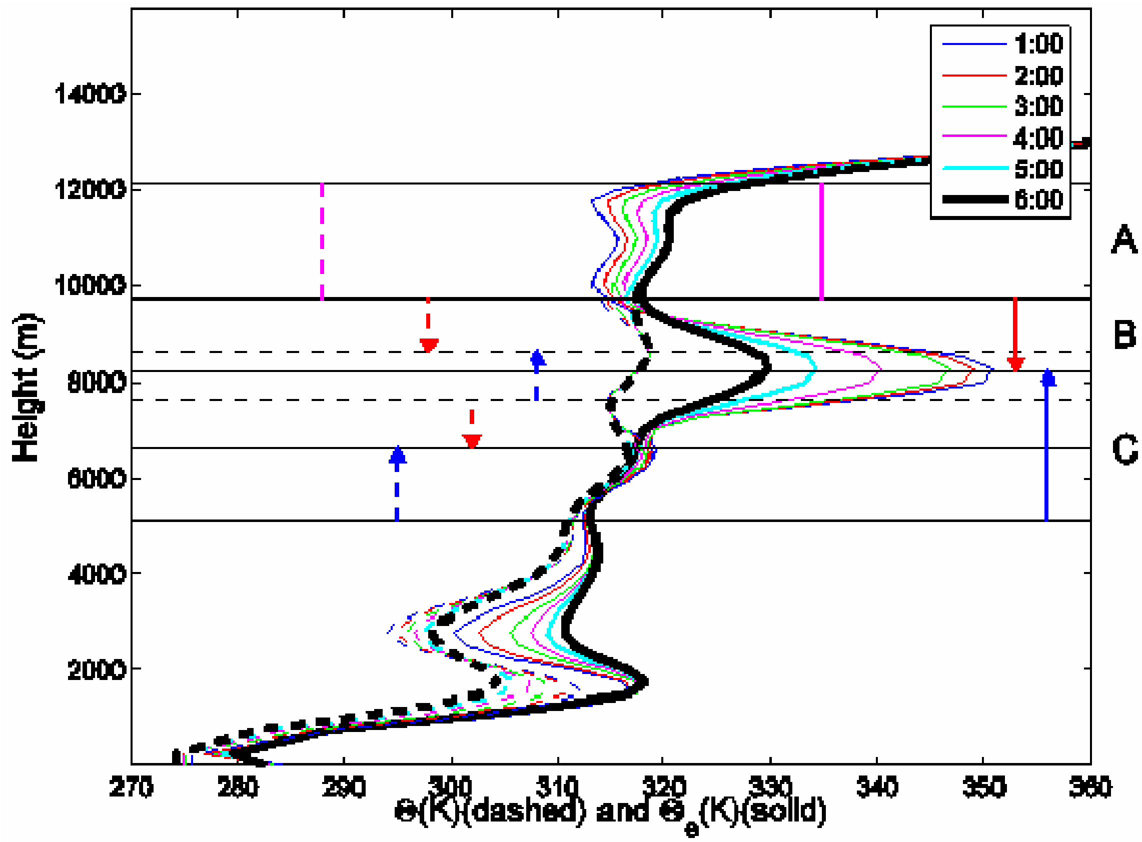

Figure 4. Potential temperature (dashed) and equivalent potential temperature (solid) profiles at 1:00,…,6:00 UTC on January 27, 1997.

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