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Atmospheric Measurement Techniques Discussions

Interactive comment on "Determining stages of cirrus life-cycle evolution: A cloud classification scheme" *by* Benedikt Urbanek et al.

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For the full response to RC3 and a version of the manuscript highlighting the changes, please see the supplement .zip archive.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/amt-2016-332/amt-2016-332-AC2-supplement.zip

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Author's final response

Review RC3 by Anonymous Referee #2

We thank Referee #2 for his suggestions to improve the quality of our work. In the following we will answer to his specific comments.

General Comment from Referee

In this study a classification scheme for stages of cirrus life-cycle is presented. The scheme is based on LIDAR data in combination with meteorological data (temperature and pressure) from ECMWF. In a case study of orographic cirrus clouds as measured during the ML-CIRRUS campaign the scheme is applied and the results are interpreted.
Generally this is an interesting and important contribution to ice cloud research; thus, this study is an appropriate contribution for AMT. However, there are some issues, which must be clarified before this manuscript can be accepted for publication. Therefore, I recommend major revisions of the manuscript. In the following I will explain my concerns in details.

Comment 1 from Referee (Major comment)

Classification scheme and interpretation of results
The general aim of the scheme is not really clear to me. I recommend that the authors give a bit more information about the aim and the possible use of the scheme.
In general, I agree with the discrimination between regions of potential ice nucleation, moderate supersaturation and subsaturation, since this reflects the different thermodynamic states of the system. However, the role of the class HET is not clear to me and seems to cause severe problems:

(a) Since heterogeneous ice nucleation is not well understood, and ice nucleation on solid particles depend on many details, a general nucleation threshold (as e. g. for homogeneous nucleation, but see minor comment below) cannot be determined. This problem is already reflected in this scheme by the use of 2 different parameterisations and their difference of about 20-30%. Therefore, the definition of the class $HET_{in/out}$ is quite arbitrary, since the lower bound is very fuzzy.

(b) For cloud free air the class might be useful, since then the possibility of heterogeneous nucleation cloud be estimated. But again the arbitrary thresholds of heterogeneous nucleation make it very difficult to use this information in a meaningful way.

(c) For cloudy data, this class might lead to severe misinterpretation of the data. In the text it is suggested that for data points of HET_{in} heterogeneous nucleation takes place or even ice crystals in this category stem from heterogeneous nucleation. This suggestion is not correct because of the problem stated in (a): The nucleation threshold is not well-posed, thus it might be that using a low threshold no heterogeneous nucleation takes place (since the IN need higher saturation); thus the interpretation of ongoing nucleation would be wrong. In the case study the lower threshold is used, but it is not clear if this is really the right one.

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Fig. 1. Preview of the authors' response found in supplement .zip archive

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Discussion paper

Determining stages of cirrus ~~life-cycle~~ evolution: A cloud classification scheme

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Abstract. Cirrus clouds impose high uncertainties on climate prediction, as knowledge on important processes is still incomplete. For instance it remains unclear how cloud microphysical and radiative properties change as the cirrus evolves. Recent studies classify cirrus clouds into categories including "in situ", "orographic", "convective" and "liquid origin" clouds and investigate their specific impact. Following this line, we present a novel scheme for the classification of cirrus clouds that addresses the need to determine specific stages of cirrus ~~life-cycle~~ evolution. Our classification scheme is based on airborne Differential Absorption and High Spectral Resolution Lidar measurements of atmospheric water vapor, aerosol depolarization, and backscatter, together with model temperature fields and simplified parameterizations of freezing onset conditions. It identifies regions of supersaturation with respect to ice (ISSR), heterogeneous and homogeneous nucleation, depositional growth, and ice sublimation and sedimentation with high spatial resolution. Thus ~~the whole cirrus life-cycle can be traced~~all relevant stages of cirrus evolution can be classified and characterized. In a case study of a gravity lee wave influenced cirrus cloud, encountered during the ML-CIRRUS flight campaign, the applicability of our classification is demonstrated. Revealing the structure of cirrus clouds, this valuable tool might help to examine the influence of ~~life-cycle~~ evolution stages on the cloud's net radiative effect and to investigate the specific variability of optical and microphysical cloud properties in upcoming research.

1 Introduction

Cirrus play an important role for weather and climate: besides their influence on the water vapor budget in the upper troposphere through condensation and evaporation (Dinh et al., 2014) and dynamics due to latent heat (Spichtinger, 2014), they modify the radiation balance of the Earth and atmosphere. Thin, opaque cirrus clouds transmit most of the incident solar radiation and absorb long-wave radiation from the Earth's surface. As they are typically high and cold, they only emit little long-wave radiation into space, and thus cause a trapping of radiative energy in the Earth-atmosphere system, which eventually contribute to a rising surface temperature. If the cloud is thick, reflection of solar radiation back to space can get greater than the long-wave absorption, and consequently can cause the surface of the Earth to cool (Baran, 2009). This net radiative effect depends on macroscopic cloud properties like optical thickness, ice water content, and geometric extent as well as on its microphysical parameters such as ice crystal number, size, and shape (Schnaiter et al., 2016; Gallagher et al., 2012; Zhang et al., 1999).

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Fig. 2. Preview of changed manuscript found in supplement .zip archive