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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 RC1 and RC2 and a version of the manuscript highlighting the changes, 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-AC1-supplement.zip

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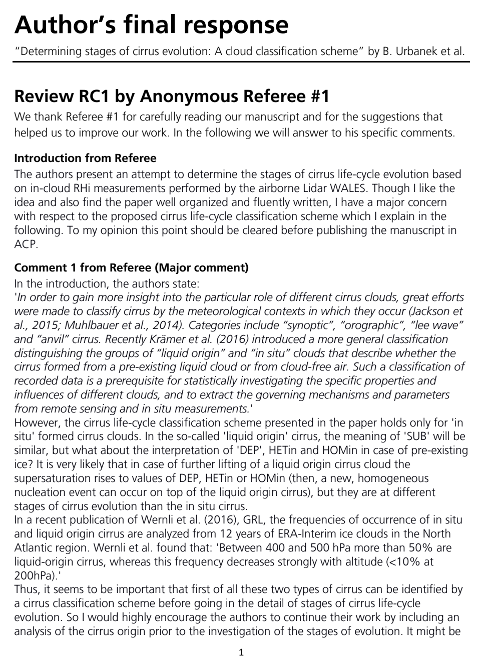

Author's final response

"Determining stages of cirrus evolution: A cloud classification scheme" by B. Urbanek et al.

Review RC1 by Anonymous Referee #1

We thank Referee #1 for carefully reading our manuscript and for the suggestions that helped us to improve our work. In the following we will answer to his specific comments.

Introduction from Referee

The authors present an attempt to determine the stages of cirrus life-cycle evolution based on in-cloud RHi measurements performed by the airborne Lidar WALES. Though I like the idea and also find the paper well organized and fluently written, I have a major concern with respect to the proposed cirrus life-cycle classification scheme which I explain in the following. To my opinion this point should be cleared before publishing the manuscript in ACP.

Comment 1 from Referee (Major comment)

In the introduction, the authors state:
'*In order to gain more insight into the particular role of different cirrus clouds, great efforts were made to classify cirrus by the meteorological contexts in which they occur (Jackson et al., 2015; Muhlbauer et al., 2014). Categories include "synoptic", "orographic", "lee wave" and "anvil" cirrus. Recently Krämer et al. (2016) introduced a more general classification distinguishing the groups of "liquid origin" and "in situ" clouds that describe whether the cirrus formed from a pre-existing liquid cloud or from cloud-free air. Such a classification of recorded data is a prerequisite for statistically investigating the specific properties and influences of different clouds, and to extract the governing mechanisms and parameters from remote sensing and in situ measurements.*'
However, the cirrus life-cycle classification scheme presented in the paper holds only for 'in situ' formed cirrus clouds. In the so-called 'liquid origin' cirrus, the meaning of 'SUB' will be similar, but what about the interpretation of 'DEP', HETin and HOMin in case of pre-existing ice? It is very likely that in case of further lifting of a liquid origin cirrus cloud the supersaturation rises to values of DEP, HETin or HOMin (then, a new, homogeneous nucleation event can occur on top of the liquid origin cirrus), but they are at different stages of cirrus evolution than the in situ cirrus.
In a recent publication of Wernli et al. (2016), GRL, the frequencies of occurrence of in situ and liquid origin cirrus are analyzed from 12 years of ERA-Interim ice clouds in the North Atlantic region. Wernli et al. found that: 'Between 400 and 500 hPa more than 50% are liquid-origin cirrus, whereas this frequency decreases strongly with altitude (<10% at 200hPa).'
Thus, it seems to be important that first of all these two types of cirrus can be identified by a cirrus classification scheme before going in the detail of stages of cirrus life-cycle evolution. So I would highly encourage the authors to continue their work by including an analysis of the cirrus origin prior to the investigation of the stages of evolution. It might be

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

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).

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