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A study of water vapor within and in the vicinity of cirrus clouds at mid-latitudes

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Cirrus clouds have a large impact on the Earth's climate system. Overall this impact is positive, but depending on their macrophysical and optical properties, the effect of single clouds can be quite different. Thus, cirrus clouds still introduce large uncertainties in climate change predictions. To gain better knowledge of the impact of cirrus clouds, it is of importance to study their macrophysical and optical properties and their dependence on formation processes, environmental conditions, and their evolution with time.
To improve our knowledge, the ML-Cirrus mission took place in March/April 2014. Research flights with the German research aircraft HALO; equipped with remote sensing and in-situ measurements, were performed over Central Europe and over the Northeast Atlantic Ocean. In this study we use measurements taken from the airborne LIDAR system WALES, which is a combined water vapor differential absorption and high spectral resolution lidar. Our main focus is on the humidity distribution within cirrus clouds and in the cloud-free air in their vicinity. For that we use Relative Humidity with respect to ice (RHi), calculated form the WALES water vapor measurements in a 2D field along the flight track together with ECMWF temperature data interpolated to the same grid. We identify cirrus clouds using the following criteria: a) backscatter ratio >= 3 b) linear depolarization ratio >= 20% and c) temperature < 235 K. We further split the cirrus clouds into two main categories according to their formation process: a) in-situ formed clouds and b) liquid-origin clouds.
Overall, we find that, 34.1% of in-cloud data points are supersaturated with respect to ice. Supersaturation is also detected in 6.8% of the cloud-free data points. Regarding their vertical structure, most clouds have higher supersaturations close to cloud-top and become subsaturated near the cloud bottom. When the probability densities of RHi are calculated with respect to temperature, the in-cloud data points seem to have two peaks. One around 225K and close to saturation, RHi=100%. And a second one at colder temperatures around 215K and subsaturated, RHi = 90%. This means, that most cirrus clouds are measured either in a warmer saturated environment or a colder subsaturated environment. These two regions seem to represent the two cirrus cloud categories mentioned above. In-situ formed clouds are mostly cold and unsaturated, with RHi values below the lower threshold for heterogeneous nucleation. Liquid-origin clouds are usually warmer and supersaturated, with RHi values commonly up to the high threshold for heterogeneous nucleation. Finally, regarding the temporal evolution of cirrus clouds, we find that the vertical structure of RHi within the clouds is indicative of their life stage. RHi skewness tends to

go from positive to negative values as the cloud ages. RHi modes are subsaturated in young clouds, supersaturated in mature clouds and return to subsaturated in dissipating clouds.