Mixed-phase Cloud Measurements in a High Alpine Environment using Digital In-line Holography

J. Henneberger1, J. P. Fugal2, and U. Lohmann1

1ETH Zürich, Institute for Atmospheric and Climate Science, Zürich, Switzerland
2Johannes-Gutenberg-Universität Mainz, Institute for Atmospheric Science, Mainz, Germany

Motivation
Importance of microphysical studies of mixed-phase clouds:
- Aerosol-cloud interactions are the most uncertain of all forcing agents.
- Level of understanding of mixed phase clouds (MPC) is low because of their complicated structure, dynamics, and heterogeneous ice nucleation.
- Retrieval methods of satellite and ground based remote sensing depend on cloud phase and ice crystal habits.
- Airborne ice crystal concentration measurements have large uncertainties due to scattering.
- Direct measurements of small scale cloud properties are needed for an accurate representation in global and regional climate models.

HOLIMO II - HLOGraphic Imager for Microscopic Objects II
- The measurements were done with a newly developed field instrument HOLIMO II (Holographic Imager for Microscopic Objects II) (Henneberger et al., 2013).
- HOLIMO II uses digital in-line holography to in-situ image ensembles of cloud particles within a well defined sample volume.

Data analysis with HOLOSUITE
A supervised learning algorithm was trained to classify cloud particles based on their shape as circular water droplets, non-circular ice crystals or falsely detected artifacts.

Measurements of mixed-phase clouds
- Mountain-top field measurements from the high altitude research station Jungfraujoch, Switzerland.
- Altitude: 3580 m a.s.l.
- Campaigns at April 2012 and January/February 2013 (CLACE 2013) are presented.
- 16 cloud cases with in total 1800 100-s intervals were analyzed (50 h).
- Cloud criteria: TWC > 10 mg m⁻³

Conclusions
- Successful development of HOLIMO II, a single cloud particle imager, which is using digital-in-line holography.
- Implementation of a classification algorithm to distinguish liquid particle from ice crystals by their shapes.
- Caused by the topography of the Jungfraujoch, two main wind regimes with distinguished cloud properties were observed.
- During northerly wind mixed-phase clouds at the Jungfraujoch were stabilized due to orographic lifting.
- Ice crystal concentrations two magnitude higher than available ice nuclei concentrations

Acknowledgements
- We thank Matteo Reba for his major contribution to the development of the HOLOSUITE software.
- We thank Martin Colladay, Paul Conrad, Keith Bower, Robert Fastharing and Gary Lloyd from the University of Manchester for the support during the CLACE 2013 campaign and the CDP and PVM data.
- We thank the International Foundation High Altitude Research Station Jungfraujoch and Göttingen (HFRI) for the opportunity to perform experiments on the Jungfraujoch.
- This work was supported by MeteoSwiss within the Global Atmospheric Watch (GAW) program of the World Meteorological Organization.

References

Outlook
- Inter-comparison of CLACE 2013 measurements with other in-situ cloud instruments. (University of Manchester)
- Implementation of an ice crystal habit classification algorithm. Comparison to Radar data (EPEL, LTE, Alexis Berne)
- Relate HOLIMO II in-situ measurements to turbulence and ice nuclei measurements (ETH, Yvanne Boose).
- Simulating the Jungfraujoch region using a regional climate model to study the influence of the updraft velocity on the microphysical cloud properties (ETH, Olga Henneberger).
- Build an in-situ cloud measurements system on a cable car system to measure vertical profiles of MPCs (ETH, Alexander Beck).