# Extending Operational Satellite Cloud Remote Sensing into the Submillimeter Range: The Challenge of Supercooled Liquid Water Absorption

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**Abstract.** Clouds are an essential part of the climate system determining the distribution of water and energy. Despite their importance their prediction via weather and climate models remains problematic. Upcoming spaceborne observations are envisioned to provide new insights into global cloud characteristics for climate studies and to improve numerical weather prediction via data assimilation. Specifically, the future Eumetsat Polar System – Second Generation (EPS-SG) to be operated within the 2020–2040 time frame will include three passive microwave instruments for enhanced cloud observations. In particular the Ice Cloud Imager (ICI) with eleven channels between 183 and 664 GHz will for the first time exploit submillmeter wave frequencies for operational ice cloud imaging. Furthermore, ICI will target the vertical humidity profile and information on hydrometeors (cloud ice, graupel, snow, rain and cloud liquid). It should be noted that ICI measures at both V and H polarisation with two window channels (243 GHz and 664 GHz) that provide additional insight on hydrometeor scattering.

In order to retrieve cloud properties like ice / snow water path, cloud ice effective radius, cloud altitude and further hydrometeor information from (sub-) millimeter measurements the scattering signal by ice particles that increases with increasing frequency is exploited. However, also water vapor and liquid water absorption increase with frequency and the observed brightness temperatures strongly depend on the vertical structure and composition of clouds. Frequently, layers of supercooled liquid are embedded in or found on top of ice clouds. Xie et al. (2015) could show that the stratification of absorbing (vapor, liquid) and scattering (ice/snow) layers changes both brightness temperatures and polarization difference and that accurate information on liquid water is required to correctly interpret the polarimetric observations.

Microwave radiometers are the basic observational tools used to measure liquid water path (LWP). However, a large fraction of liquid-bearing clouds are supercooled (i.e., Tcloud < 0°C) and only very few laboratory observations of liquid water absorption coefficient in microwave at supercooled temperatures are available. Consequentially, microwave absorption models use semi-empirical models that are derived from laboratory measurements at warm temperatures and extrapolated to supercooled temperatures. Therefore it is not surprising that different models for the complex permittivity of liquid water – among them the frequently used model by Liebe et al. 1991 – differ significantly in particular at higher frequencies leading to uncertainties of up to 80% in LWP (Kneifel et al., 2014).

This lecture will introduce the upcoming ice cloud mission to be launched in 2021 and illustrate the challenges in retrieving cloud parameters from polarimetric measurements up to 664 GHz. In particular the impact of supercooled liquid water will be discussed and new developments to model liquid water absorption based on field observations and older laboratory data will be presented.

**Biography.** Prof. Dr. Susanne Crewell holds the professorship for Meteorology at the Institute for Geophysics and Meteorology and is of the Albertus Magnus Graduate Center of the University of Cologne. Her research is directed on a better understanding of the atmospheric water cycle by exploiting novel observation techniques from space, aircraft and ground and to bridge observations and modeling on different scales.

She obtained her doctorate in 1994 in Environmental Physics at the University of Bremen, Germany. Afterwards she worked as a post-doc at the State University of New York, Stony Brook, and University of Bonn. In 2004, she has been appointed Professor of Experimental Meteorology at the University of Munich.

Since 2006, Prof. Dr. Susanne Crewell established the Jülich ObservatorY for Cloud Evolution (JOYCE) as a member of the University of Cologne. JOYCE is dedicated to the observation of cloud formation and cloud transformation. Further, she is a spokeswoman of Cologne's scientists in the DFG-funded collaborative research center TR32 "Patterns in Soil-Vegetation-Atmosphere-Systems" of the Universities of Bonn, Aachen, Cologne and the Research Center Jülich. She also coordinates the Marie-Curie project "Initial Training for atmospheric Remote Sensing" (ITaRS), a consortium of 19 partners funded by the 7th European Research Framework Program. Moreover, Crewell initiated a range of national and international projects optimizing efficiency and exploring the use of remote sensing for weather forecast and climate modeling.

Susanne Crewell is elected member in a range of committees including the Academy of Sciences, Humanities and the Arts North Rhine Westphalia, the Joint ESA-Eumetsat Microwave Imager & Ice Cloud Imager Science Advisory Group, the Senate Commission of the Helmholtz Association and the Review Board for Atmospheric Science and Oceanography of the National Science Foundation DFG.