Review of major CLIWA-NET results

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1. Introduction

The Cloud Liquid Water Network project CLIWA-NET aimed at the improvement of the parameterization of cloud processes in atmospheric models with a focus on vertically integrated cloud liquid water and the vertical structure of clouds. To achieve this goal a prototype of a European Cloud Observation Network (ECON) consisting of ground-based stations and satellite measurements was operated during three enhanced observation phases (EOP) all part of BRIDGE – the major field experiment of BALTEX. The usefulness of these data for the objective evaluation of atmospheric models for weather and climate prediction has been demonstrated. Furthermore, the observations were analysed for their potential as an adequate observing system for the detection of aircraft icing conditions. As microwave radiometry is the most accurate way to measure liquid water path existing radiometers from different partners in Europe should be incorporated in ECON. In order to allow such a system to become operational in the future the design of a *low-cost* microwave radiometer in co-operation with industry was another CLIWA-NET objective.

2. Scientific achievements

The prototype of ECON was successfully implemented during three observational periods. The first two campaigns (CNNI: Aug/Sep 2000, and CNNII: Apr/May 2001) were conducted on the continental scale covering the Baltic catchment, while BBC (Aug/Sep 2001) focused on the regional scale. To achieve ECON, existing observation systems (microwave radiometer and auxiliary instruments) were distributed and operated by the various partners: UNIBE, KNMI, CCLRC, GKSS, HUT, Chalmers, CNRS, DWD, MIUB, IfM and IRE.

Harmonized retrieval algorithms to derive liquid water path (LWP) and integrated water vapour (IWV) were developed for all stations and campaigns. Quality checked time series of LWP, IWV, cloud base height, infrared temperature and different rain flags for all stations during all campaigns were produced.

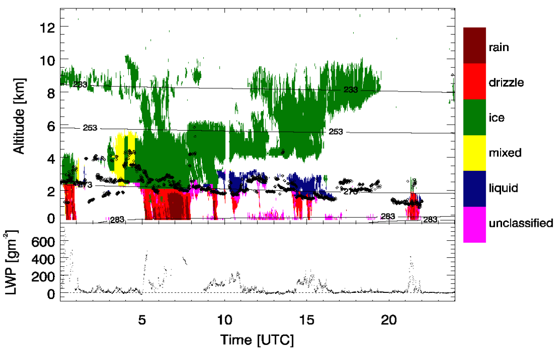

Figure 1. Cloud classification based on the synergy of different sensors and corresponding LWP time series.

The microwave intercomparison campaign (MICAM) performed during the BBC campaign verified the good quality of liquid water path measurements during the previous CNN campaigns. However, the uncertainty of current gas absorption models and the inherent retrieval ambiguities limit the accuracy of standard dual frequency systems to about 30 g m^{-2}. These models need to be further constrained.

The combination of different advanced remote sensing instruments at the Cabauw site during the BBC campaign including cloud radar revealed the complex vertical structure of clouds (Fig. 1). It was found that simultaneous precipitation detection is mandatory for consistent analysis (see also *van Meijgaard et al*., 2004). It also allowed the application of a newly developed synergetic algorithm to derive simultaneously temperature, humidity and liquid water profiles and their respective uncertainties.

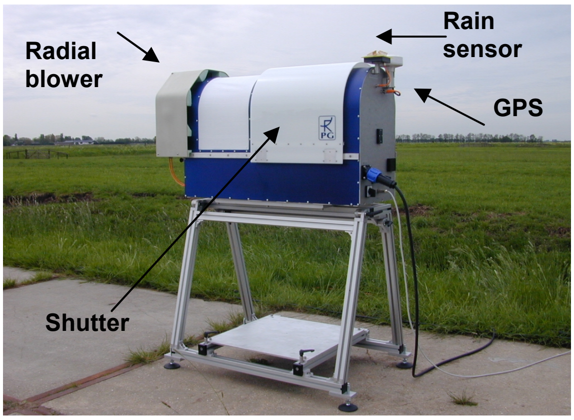

Figure 2. Photo of the low cost radiometer

Based on lidar ceilometer measurements a climatology of super-cooled layers over the Netherlands was derived. The combination with cloud radar and microwave radiometer measurements allowed the identification of some of their properties: Often ice crystals are falling out of thin layers consisting of super-cooled water. Most of these layers contain little water (<25 g m^{-2}). However, measurements within the BBC regional network showed that these layers can extend over more than 100 km and last several hours.

For a future long-term implementation of ECON a low-cost microwave radiometer has been designed. Following a recommendation from the modelling community the instrument was equipped with mechanisms for the detection of and protection from precipitation. Owing to external funding the first systems were already built and sold (Fig. 2).

For the three campaigns about 1400 AVHRR satellite overpasses were processed with the SCANDIA model from SMHI to obtain cloud type classifications. Fields of LWP, optical depth and effective radius were derived from NOAA-AVHRR measurements. Based on quality of the AVHRR instrument, sun elevation and viewing angle, several hundred overpasses were selected for quantitative cloud analysis. The large reference data set from ground-based measurements allowed for a statistical evaluation of the accuracy of the LWP retrieval (*Feijt et al.* 2004). It was found that the newly developed retrieval method using the 1.6 μm channel information is a significant improvement relative to the original KLAROS-scheme used by KNMI. The overall relation between satellite retrieved and ground-based inferred LWP is shown in Figure 3 where ground-based values representing 40-

minute averages around the satellite overpass time are compared with satellite values derived from a 10x10 km^2 area centered around the ground-based site.

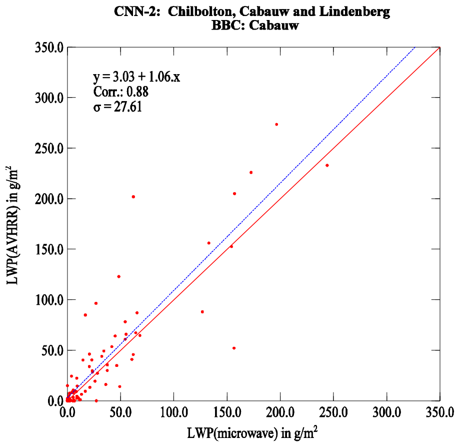

Figure 3. LWP as retrieved from NOAA-16 AVHRR versus LWP as derived from microwave radiometers at the sites Cabauw, Chilbolton, and Lindenberg for CNN-2 and for Cabauw for BBC. The blue line results from linear regression; the red line is the equality line.

Methodologies focusing on the evaluation of model predicted cloud parameters (ECMWF, DWD-LM, SMHI-RCA, and KNMI-RACMO) with CLIWA-NET inferred observations have been developed and examined in various applications, e.g. a statistical evaluation of LWP and the representation of vertically distributed liquid water content based on ground-based observations (*van Meijgaard et al*., 2004), and a comparison of a model predicted LWP-field with satellite retrieved spatial distributions.
The sensitivity of cloud and precipitation parameters on the horizontal resolution in the range of 10 to 1 km has been examined by conducting numerical experiments with the Lokal-Modell (MIUB). Domain averaged LWP, and, in particular, precipitation are found to be strongly enhanced by increasing horizontal resolution. Figure 4 shows that horizontal refinement indeed improves the statistical behaviour of clouds, in particular the intermittency. Size distributions of model resolved convective cells, however,

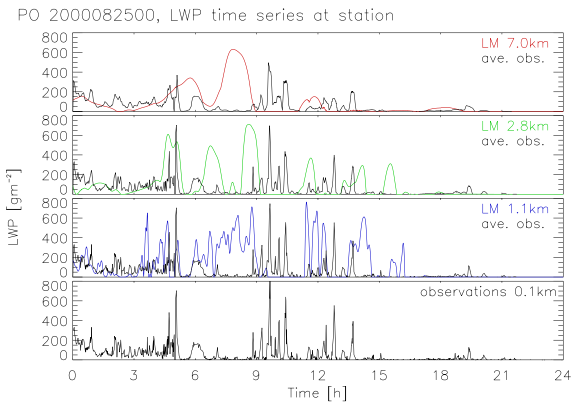

Figure 4. Time series of LWP at station Potsdam. Microwave radiometer measurements (black lines) are filtered with the advective timescale to be representative for each model resolution.

are found to strongly depend on the employed horizontal resolution indicating that a form of parametrized convection is still required at these grid spacings.

Total cloud amounts derived from two satellite systems, i.e. ISCCP and AVHRR, are found to be significantly different for the BALTEX area with the ISCCP cloud amount being much larger than the AVHRR cloud amount. The AVHRR amounts, in turn, are found to be larger than ground-based (synop) estimates. Model predicted cloud amounts from different cloud schemes appear to be closer to the AVHRR amount or even lower.
Refinement of the vertical model mesh results in a better resolution of cloud processes. In general, it also results in a better representation of macroscopic cloud parameters like cloud amount and the vertical distribution of clouds (*Willén*, 2004). Typical errors, however, like a tendency to simulate cloud base height at too low altitudes are not remedied completely.
A detailed overview of the results from the entire CLIWA-NET project is given in the Final Report (*Crewell et al.,* 2003).

3. Conclusions and Perspectives

Within CLIWA-NET we have successfully operated the prototype of a European Cloud Observation Network during three enhanced operational campaigns. A low-cost microwave radiometer was designed and a first prototype is built. The data from the measurement campaigns allowed the evaluation of the full cloud cycle in numerical models along with cloud interactions with other portions of the water and radiation cycles. Guided by the observations certain deficiencies in the representation of clouds in numerical models could be identified. A clear outcome from the model evaluation studies was the need for long-term and comprehensive observations.
In future, the CLIWA-NET observations will form a key dataset for a number of applications: to further develop and test parameterization techniques for clouds and cloud interactions in models for weather and climate prediction; to develop and test algorithms for ground-based and space borne remote sensing; to study super-cooled water layers, to derive statistics for attenuation at higher microwave frequencies; etc. In this perspective, the Eurat initiative is worth mentioning which strives for continuation of CLIWA-NET and related projects in a (semi) permanent framework. The low-cost microwave radiometer offers the potential to make a European Cloud Observation possible.

References

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