

# CLLOUDNET

## DEVELOPMENT OF A EUROPEAN NETWORK OF STATIONS FOR OBSERVING CLOUD PROFILES

CONTRACT: EVK2 – 2000 – 00065

1 APRIL 2001 – 30 SEPTEMBER 2005

### SECTIONS 5 AND 6: FINAL REPORT.

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**SECTION 5: EXECUTIVE PUBLISHABLE SUMMARY OF OVERALL SCIENTIFIC OBJECTIVES.**

Contract n°	EVK2 – 2000 – 00065	Reporting period:	1 APRIL 2001 – 30 SEP 2005
Title	DEVELOPMENT OF A EUROPEAN NETWORK OF STATIONS FOR OBSERVING CLOUD PROFILES		
<p><b>Strategic Aspects.</b></p> <p>The representation of clouds is a major cause of uncertainty in numerical models used for weather forecasting and to predict global warming. According to IPCC much of the currently unacceptable broad spread in predictions of global warming is due to difficulties with representing clouds. In weather forecasting the precipitation is now explicitly produced via the clouds, so reliable forecasts of flash floods and extreme weather requires correct representation of clouds. These models represent clouds typically by two prognostic variables per model grid box: cloud fraction and the average mass of liquid/ice cloud condensate within the grid box. Before the CloudNET project there were no reliable observations of vertical profiles of cloud fraction and water content with which to evaluate the cloud performance of these forecast models.</p> <p>The CloudNET project has fulfilled its objectives and provided for the five work packages:          WP1. Analysis of existing cloud data sets. This has laid the basis for the algorithms in WP3.          WP2 Over two years of continuous observations of cloud profiles over three ground stations in the UK, France and NL, together with cloud data over the stations from four operational forecasting models.          WP3. Development of algorithms to derive cloud properties, such as cloud fraction, liquid water content, ice water content on the model grid box with errors from the observed backscatter profiles obtained from vertically pointing cloud radar, cloud lidar and ground based radiometers.          WP4. Comparisons of the observed cloud properties with their representation in operational models and computation of the statistics of model performance together with skill scores on a monthly basis so that improvements in model cloud parameterisation schemes can be rapidly evaluated.          WP5. Specification for a network of cloud observing stations which could provide cloud profiles in real time ultimately for assimilation into forecasts models and advice to industry to implement this specification.</p> <p>In addition to the above objectives the work has been extended:</p> <p>a) From the original three observing stations (Chilbolton, UK; Paris, France, Cabauw, NL) to include Lindenberg (Germany) and, after the recommendations of the GEWEX Cloud and Aerosol Profiling Group, to include the ARM stations of the USA Department of Energy located in Oklahoma, Alaska, together with those in the Western Tropical Pacific at Naru and Manus.</p> <p>b) Extend the four the original operational forecasting models of ECMWF, KNMI (Netherlands, Meteo France and the UK Met Office mesoscale model, to include three further models: the Lokal Modell of DWD (Germany), the RCA model of SMHI (Sweden), and the global version of the Met Office Model.</p> <p>As a result Europe now has the infrastructure to:</p> <p>a) Observe, on a continuous basis, profiles of cloud properties at four ground stations in Europe and four outside Europe, which are then converted into the cloud variables (with defined errors) used in climate and weather forecasting models and archived together with the output of seven operational forecast models for the grid box over the observing station in NetCDF format on a publicly accessible web site.</p> <p>b) Compare the cloud variables derived from observations with the model representation and provide statistics of model performance including skill scores, updated monthly, of the ability of the models to represent clouds. These statistics available on the web site enable new cloud parameterisations implemented on the models to be rapidly evaluated. Climate models essentially use the same cloud parameterisations.</p> <p>c) Manufacture at an economic cost cloud observing stations which could be deployed operationally.</p> <p>d) Enable European scientists to exploit the above advances for the analysis of data from future space missions providing global profiles of cloud characteristics such as the NASA/Canadian CloudSAT cloud radar and the NASA/CNES cloud lidar to be launched in spring 2006, and the JAXA/ESA joint EarthCARE mission which will embark a Dopplerised cloud radar and lidar on the same satellite for launch in 2012.</p> <p><b>Socio-Economic Relevance and Implications for Policy makers.</b></p> <p>Uncertainties in predictions of future global warming are due to difficulties parameterising clouds in climate models. The advances made in CloudNET will enable rapid evaluation of new cloud parameterisation schemes and thus improve these climate models and also lead to improved operational weather forecasts of cloud cover, precipitation and better warnings of floods and extreme weather events.</p>			

**Overall Scientific achievements:** The following breakthroughs listed in order of the work package.

*WP1 – Analysis of Existing Cloud Data Sets.* This provides a basis for the work in WP3.

1. Objective evaluation of radar/lidar retrieval of ice particle size and ice water content.
2. First climatology of ice particle size as a function of ice water content and temperature.
3. Characterisation of ice particles using both radar reflectivity and Doppler velocity.

*WP2 – The three cloud stations have been operated 24 hours each day for over two years.*

4. Development of a new technique using the rain return to calibrate the 94GHz cloud radars.
5. Development of an auto-calibration technique for lidars each time there is low level water cloud.
6. Demonstration of absolute cross-calibration for the three cloud radars at the three stations.

*WP3 Development of retrieval algorithms:*

7. Correction of the 30second/60m backscatter profiles and mapping on to the operational model grid.
8. Target classification into different types of cloud (e.g. ice, liquid water) so that the correct algorithm to convert backscatter signals into the variables held in the models can be invoked.
9. Derivation of cloud fraction by mapping observations on to the operational model grid.
10. Establishment of cloud phase (liquid, ice, mixed phase) using lidar depolarisation.

*For targets classified as liquid water we have new techniques for deriving:*

11. Accurate liquid water path (lwp) from dual frequency radiometers using clear sky periods identified with the lidar when lwp is zero to optimise the radiometer calibration factors.
12. Liquid water content profiles by comparing the adiabatic liquid water content profile from observed cloud top and cloud base and then scaling the profile to give the liquid water path observed in 11.
13. Liquid water content from the profile of the radar return and the lidar extinction at cloud base.
14. Drizzle parameters below stratocumulus (Sc) cloud base such as droplet size, concentration, liquid water flux, air velocity – drizzle controls the evolution of Sc clouds which are important to the earth's climate.

*For ice targets, new techniques using the radar reflectivity (Z) to derive ice water content (iwc) using:*

15. Z combined with temperature: capturing changes in particle size and concentration with temperature.
16. Z combined with the Doppler velocity – to derive ice particle densities and size and thus better iwc.
17. A comparison of the iwc derived from different retrieval methods.

*WP4. Comparison of cloud observations with representation in operational models.*

For the first time it has been possible to make an objective comparison of the variables held in the model grid box such as cloud fraction, cloud and ice water content with the observed values. Highlights are:

18. First evaluation of cloud fraction showing, for example, the improved representation of low clouds after 2003 by ECMWF, and the difficulty of the Met Office scheme in filling grid boxes 100% with cloud.
19. Model liquid water content is generally good with the prognostic scheme of the Met office best. All models have difficulty representing supercooled clouds; such clouds have a significant radiative impact.
20. The model iwc is on average rather well represented, at least for clouds below 8km. This is in stark contrast to the worrying order-of-magnitude spread in mean iwc for climate models reported by AMIP.
21. High cloud occurrence. Initially it appears that the model has too much high cloud, but once the data is corrected for the thin clouds not detected by the radar and lidar, the model agreement is satisfactory.
22. The difference in expressing cloud fraction as a volume of the grid box or as a projected area of the grid box has been quantified as has the effect of wind shear on the pdf of iwc within the box.
23. Analysis of model performance classified by weather regime reveals specific failings of the model.
24. Cloud fraction skill scores from 2002 to 2005 quantify model improvements during this time.
25. Confirmation of the improvement of the Meteo-France cloud scheme introduced after the 1999 storms,
26. Testing of proposed Met Office 'PC2' cloud scheme by comparing with cloud statistics from CloudNET
27. Parameterisation of ice effective radius in terms of distance from cloud top instead of temperature has been implemented on the KNMI RACMO model.

*WP5. Specification of a standard cloud observing station.*

28. An economic combination of cloud radar with a simple ceilometer and low cost radiometers.
29. The use low power FM/CW mm wave cloud radars and an X-band pulsed cloud radar.
30. Relaxation of radiometer specification: algorithm 11 can tolerate 5K drifts in brightness temperatures.

**Conclusion:** Participating National Met Services have expressed the wish that the CloudNET infrastructure continues to operate and provide them with objective and timely evaluations of clouds in their models.

**Keywords:** Cloud radar and lidar. Microwave profiling. Cloud representation and properties. Forecast and climate models. Flooding and the hydrological cycle. Future climate change.

## 6.1 Background.

According to IPCC much of the currently unacceptable broad spread in predictions of global warming is due to difficulties with representing clouds. In a future warmer world if there are more low clouds they will reflect sunlight and tend to counteract the initial forcing due to carbon dioxide, whereas if high clouds increase then this will enhance the initial warming further. At present it is thought that these two effects of clouds almost cancel out so the net effect of clouds is a slight cooling. Current predictions of global warming range from 2 to 5K, but, rather worryingly, this range is virtually the same as it was ten years ago. Policy makers require more accurate predictions. One of the first steps is to verify that the current models are at least representing the vertical profiles of clouds correctly for the present climate. The second is to evaluate and improve the cloud parameterisation schemes in the models.

In weather forecasting the precipitation is now explicitly produced via the clouds, so reliable forecasts of flash floods, extreme weather and general representation of the hydrological cycle relies on correct representation of clouds. Weather forecasting and climate models essentially use the same cloud parameterisation schemes. These models represent clouds typically by two prognostic variables per model grid box: cloud fraction and the average mass of liquid/ice cloud condensate within the grid box. Before the CloudNET project there were no reliable observations of vertical profiles of cloud fraction and water content with which to evaluate the cloud performance of these forecast models. Ground based observations only give cloud base and satellites only see the top of clouds: information on the vertical structure is absent.

CloudNET aims to provide observations of the vertical profiles of clouds using new active radar and lidar technology. This will enable for the first time the representation of the vertical profiles in the operational models at a particular time to be compared with the observed values. The project is organised in five work packages

- WP1 - Exploit Existing Cloud Data Sets.

The first stage will be to look at the limited amount of cloud data from radar and lidar which exists.

- WP2 - Operate three cloud remote sensing stations.

These stations will be operated continuously to provide a two year sample of all the clouds likely to be encountered. The data will be quality controlled, and archived in a standard format. The model data from operational models will also be archived.

- WP3 - Development of retrieval algorithms.

These algorithms will convert the backscattered signals from radars and lidars into model variables and remapped on to the grid of each model, to enable direct evaluation of model variables such as cloud fraction and cloud mass condensate.

- WP4 - Compare retrieved cloud profiles with operational models.

The performance of the models in representing the clouds will be evaluated using objective statistical tests to identify the strengths and weakness of current parameterisation schemes.

- WP5 - Definition of instruments and algorithms for GCOS.

To define the optimal combinations of instruments, algorithms and data formats for a practical GCOS stations for measuring clouds. Forecasting centres are already planning how to assimilate such cloud observations into their models, so ultimately the data from a network such stations would be used to improve weather forecasts.

## 6.2 Scientific/technological and socio-economic objectives.

The overall objectives of CLOUDNET are:

- To optimise the use of existing data sets to develop and validate cloud remote sensing synergy algorithms.
- To demonstrate the importance of an operational network of Cloud Remote Sensing stations (CRS-stations) to provide data for the improvement of the representation of clouds in climate and weather forecast models and for the use of GCOS.

The objectives of the five work packages are:

WP1 – Exploit Existing Cloud Data Sets

- To organise the existing data in to a format accessible by other partners.
- To test first versions of algorithms to derive cloud characteristics from the data set.
- To analyse the in-situ cloud aircraft data to validate the retrievals.

WP2 – Operate three cloud remote sensing stations.

- To operate the stations for a minimum of one week per month for two years.
- To quality control and archive the data.
- To archive the model forecast data over each of the sites.

WP3 – Development of retrieval algorithms.

- To develop algorithms for retrieving macroscopic cloud properties, and liquid ice and mixed phase cloud properties from radar and lidar observations and consider the technological implications of implementing such algorithms.

WP4 – Compare retrieved cloud profiles with operational models.

- To compare the macroscopic cloud properties, and liquid ice and mixed phase cloud properties inferred from radar and lidar observations with the values held in four European operational forecasting models.

WP5- Definition of instruments and algorithms for GCOS.

- To define the optimal combinations of instruments, algorithms and data formats for a practical GCOS stations.