SECTION 2: EXECUTIVE PUBLISHABLE SUMMARY, RELATED TO REPORTING PERIOD (12 MONTHS)

Contract n°	EVK2 – 2000 – 00065	Reporting period:	1 APRIL 2003 – 31 MARCH 2004 (YEAR 3)
Title	DEVELOPMENT OF A EUROPEAN NETWORK OF STATIONS FOR OBSERVING CLOUD PROFILES		

Objectives:

In this the third year of CLOUDNET the primary objectives are as follows:

- To test algorithms to derive cloud characteristics from existing data sets.
- To operate the three cloud stations, to quality control and archive the data.
- 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.
- 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.
- To define the instruments and algorithms for a GCOS cloud observing station.

Scientific achievements:

1. *Observational cloud products produced on a web site with errors in near real time.*
   The observed radar and lidar profiles obtained every 30 seconds with 60m resolution are plotted in quasi real time and displayed on the web; derived products of ice water content, cloud fraction, turbulence levels, liquid water path etc with their errors are also displayed, together with the quasi-real time hourly representation of ice and liquid water content, cloud fraction etc from the four operational models.

2. *Objective categorisation of radar and lidar targets.*
   A crucial aspect of the rigorous quality control is the objective categorisation of the targets in terms of liquid and ice clouds, drizzle and precipitation, insects and aerosols, using the radar and lidar characteristics including Doppler and spatial continuity. Quality flags are supplied and of any corrections for gaseous and liquid attenuation is provided. Once this categorisation has been carried out then the various retrieval algorithms to derive cloud properties can be invoked.

3. *Demonstration of the absolute cross-calibration of three ground based cloud radars*. Absolute calibration of the cloud radar return is essential for quantitative retrieval of cloud properties. This is achieved at Chilbolton by simultaneous observations of clouds with precipitation radar which has been calibrated to 0.5dB using polarisation redundancy in precipitation. The RASTA radar from France has been operated along side the Chilbolton cloud radar for several days, and then alongside the Cabauw cloud radar so that all three radars now have an accurate absolute calibration.

4. *Retrievals of ice water contents by three methods and comparison of their statistics.* A simple, but error prone derivation of ice water content from radar reflectivity (Z) alone, has been compared with a second method which uses Z and temperature, and a third, method which uses both the radar and lidar returns to obtain a much more accurate ice water content.

5. *Implications of defining cloud fraction by volume and by area.* Both methods of deriving cloud fraction are displayed on the web site. A comparison of the two methods shows that the cloud fraction by volume, held in the models, is significantly lower than the volume by area, which should be used for computing radiative effects; this introduces a considerable bias in the models computed radiative fluxes.

6. *Derivation of ice density as a function of size through dual frequency radar*. This density function is very important in computing ice water content and radiative effects in ice. Dual frequency radar observations have established which of two proposed functions is the preferred one.

7. *Deriving drop size and concentration in stratocumulus from radar and lidar observations.*
   A new technique using the vertical profile of the radar reflectivity and the lidar backscatter has been used to derive drop size and concentration in liquid water clouds. Different levels of pollution and aerosols lead to changes in these properties with a consequent change in the radiative properties and lifetimes of such clouds.

8. *Improved liquid water path inference from radiometers using model values as a first guess.*
   The liquid water path of clouds when derived from ground-based radiometers is error prone. It has been shown that if the values of temperature and humidity held in the operational forecast model are used as a first guess the retrieved values of liquid water path are much improved.

9. *Normalisation of ice water content and effective ice radius relative to cloud top and base.* Current models fix the ice particle size from the temperature. Analysis of observations has shown that a better parameterisation would be in terms of the relative vertical position of the ice particle within the cloud.

10. *First derivations of the probability distribution functions of turbulence levels in different clouds.* Turbulence has a large effect on the initiation, evolution, dissipation and lifetime of clouds. A new radar technique for inferring turbulence levels within cloud has been developed and statistics derived of the levels of turbulence in various cloud types.

11. *First provision of statistics of model performance for cloud cover and demonstration of improved performance of modified cloud scheme in Meteo France model.* The cloud scheme for the Meteo France model was modified in April 2003. The improved performance was immediately quantifiable from the cloud products produced and displayed on the web.

12. *Comparison of long term statistics of ice water content and effective radius from Cabauw, Chilbolton and Oklahoma.* It has been shown that the size of ice particles as a function of temperature and radar reflectivity is very similar at Cabauw and Chilbolton, but there are significant differences for ice clouds in the US Great Plains. This has significance for global schemes for parameterising ice particle size.

13. *Derivation of skill scores for the different cloud schemes in the various models.* The performance of the various models in representing the clouds when compared to the observed clouds has now been expressed as a skill score so the performance can be quantified.

14. *Evaluation of boundary layer schemes in various operational models.* Boundary layers clouds are important for radiative balance and forecasting. An analysis has been carried out of the accuracy with which the models predict such clouds.

Socio-economic relevance and policy implications:

A major objective of CLOUDNET is to develop a network of cloud observing stations and to demonstrate how such stations can improve the representation of clouds used in forecasting the weather and future climate. Clouds play a major role in the production of rain, floods and the hydrological cycle. Difficulties in representing clouds are a major contribution to the current spread in forecasts for future global warming. Achievements 1-3 deal with improved means of observing cloud properties from radar and lidar and displaying them in real time; 4-10 report new techniques for deriving the cloud properties from the radar and lidar signals and 11-14 show how these derived cloud properties can be used to evaluate current representation of clouds with in these forecasting models.

Conclusions:

More than one year's data of cloud profiles taken every 30 seconds with 60m vertical resolution is now archived with quicklooks of raw data and derived cloud properties displayed on the web site in near real time at each of the three sites. The hourly data of cloud profiles held in four operational models over the three sites are also archived and quick looks in near real time available on the web. In addition quicklooks of daily and monthly observations and model data for the past 18 months can be viewed on the web. New cloud products have been developed and error characteristics derived. The first comparisons of observations and model representations have been carried out.

Keywords:

Cloud radar and lidar. Cloud properties. Forecast and climate models. Flooding and the hydrological cycle. Future climate change.

Publications (cumulative list)

Peer Reviewed Articles:

Authors	Date	Title	Journal[1]	Reference
O'Connor E. J., Hogan R. J. and A. J. Illingworth.	2004	Radar detection and climatology of stratocumulus clouds.		To be submitted
Brooks M. E., Hogan R. J. and A. J. Illingworth.	2004	Comparisons of radar derived values of IWC and their representation in operational models of ECMWF and Met Office.		To be submitted
Hogan R. J., Donovan D. P., Tinel D., Brooks M. A., Illingworth A. J. and J. P. V. Poiras Baptista.	2004	Independent evaluation of the ability of spaceborne radar and lidar to retrieve the microphysical and radiative properties of ice clouds.		To be submitted
Hogan R J, Mittermaier MP and A J Illingworth	2004	Retrieving IWC and visible extinction coefficient from radar reflectivity and temperature.		To be submitted
Gaussiat N., Hogan R. J. and A. J. Illingworth.	2004	Stratocumulus liquid water content from dual wavelength radar.	JAOT	To be submitted
Mathieu A., Piriou J. M., Haeffelin M., Drobinski P., Vinit F., Bouniol D.	2004	Identification of error sources in planetary boundary layer cloud forecast using SIRTA observations.	GRL	To be submitted
Bouniol D., Hogan R. J., Illingworth A. J. and A. Protat.	2004	Eddy dissipation rate in clouds from 94 GHz Doppler radar.	JAOT	Submitted
van Zadelhoff G. J. and D. P. Donovan.	2004	Comparing ice-cloud microphysical properties using CloudNET and ARM data.	JGR	Submitted
Tinel C., J. Testud, J. Pelon, A. Protat, R. Hogan, J. Delanoe and D. Bouniol.	2004	The retrieval of ice cloud properties from cloud radar and lidar synergy.	JAM	Submitted
Schutgens N. and D. Donovan	2004	Retrieving radar reflectivity profiles in the case of long radar pulses.	AR	In press
Brooks M. E., Hogan R. J. and A. J. Illingworth	2004	The definition of cloud fraction in GCMs by area and by volume	JAS	In press.
O'Connor E. J., Illingworth A. J. and R. J. Hogan	2004	Retrieving stratocumulus drizzle parameters using Doppler radar and lidar	JAOT	In press.
Donovan D. P.	2004	Ice-Cloud effective particle size parameterization based on combined lidar, radar reflectivity, and mean Doppler velocity measurements	JGR	**108**, No. 18, 10.1029/2003JD 003469
O'Connor E. J., Illingworth A. J. and R. J. Hogan	2004	A technique for auto-calibration of cloud lidar	JAOT	**21**, 777-786
Hogan R. J., Flentje H., Francis P. N., Illingworth A. J., Quante M. and J. Pelon.	2003	Characteristics of mixed phase clouds. Part1: Lidar, radar and aircraft observations from CLARE '98	QJRMS	**129**, 2089-2116

Hogan, R J, A J Illingworth, J P V Poiares Baptista and E J O'Connor	2003	Characteristics of supercooled clouds: Part II A climatology from ground-based lidar	QJRMS	**129**, 2117-2134
Hogan, R J, and A J Illingworth	2003	Parameterizing ice cloud inhomogeneity and the overlap of inhomogeneities using cloud radar data	JAS	**60**, 756-767
Gaussiat N., Sauvageot H. and A. J. Illingworth	2003	Cloud liquid water and ice content retrieval by multi-wavelength radar	JAOT	**20**,1264-1275
Baedi, R.; Boers,R.; Russchenberg, H.W.J	2003	Detection of Boundary Layer Water Clouds by Spaceborne Cloud Radar	JAOT	**19**, 1915–1927
Hogan R. J, Bouniol D. H., Ladd D. N., O'Connor E. J. and A. J. Illingworth	2003	Absolute Calibration of 94-GHz radars using rain	JAOT	**20**, 572-580
Donovan D. P.	2002	First ice cloud effective particle size parameterization based on combined lidar and radar data	GRL	**29**, No. 1, 10.1029/2001GL013731

Non refereed literature:

Authors / Editors	Date	Title	Event	Reference	Type[2]
Bouniol D., Illingworth A. J. and R. J. Hogan.	2004	Deriving turbulent kinetic energy dissipation rate within clouds using ground based 94GHz radar.	3rd European Radar Conference, Sweden.		paper
Illingworth et al.	2004	Observing cloud properties with ground-based mm-wavelength radar.	3rd European Radar Conference, Sweden.		paper
van Zadelhoff G. J. and D. P. Donovan.	2004	Comparing ice-cloud microphysical properties using CloudNET and ARM data.	14th ICCP conf, Bologna.		paper
Wilson D. R., Kerr-Munslow A. M. and A. C. Bushell.	2004	The behaviour of different cloud process parametrizations in a large-scale model	14th ICCP conf, Bologna.		paper

[1] QJRMS: Quarterly Journal of the Royal Meteorological Society; JAM: Journal of Applied Meteorology; JAS: Journal of the Atmospheric Sciences; JAOT: Journal of Atmospheric and Oceanic Technology; JGR: Journal of Geophysical Research; GRL: Geophysical Research Letters.

[2] Type: Abstract, Newsletter, Oral Presentation, Paper, Poster, Proceedings, Report, Thesis

Protat A., Bouniol D. and Martial Haeffelin.	2004	Evaluation of vertical air velocity and its distribution in four operational forecast models using continuous Doppler cloud radar measurements.	14th ICCP conf, Bologna.		paper
Bouniol D., Protat A., M. Haeffelin.	2004	A systematic retrieval of ice cloud microphysical and radiative properties using a synergetic radar/lidar algorithm.	14th ICCP conf, Bologna.		paper
O'Connor E., Hogan R. J. and A. J. Illingworth.	2004	Characteristic of drizzling and non-drizzling stratocumulus as revealed by vertical pointing cloud radar and lidar.	14th ICCP conf, Bologna.		paper
Gaussiat N., Hogan R. J. and A. J. Illingworth.	2004	Cloud water content and cloud particle characteristics revealed by dual wavelength cloud radar observations.	14th ICCP conf, Bologna.		paper
Illingworth et al.	2004	Comparison of observed cloud properties at three ground sites with their representation in operational models: The EU CloudNET project.	14th ICCP conf, Bologna.		paper
Brook M. E. Hogan R. J. and A. J. Illingworth.	2004	A long comparison of cloud properties observed by vertically pointing radar and lidar with their representation in operational NWP models	14th ICCP conf, Bologna.		paper
Agnew J. L. and Hewison T. L.	2004	Comparison of Water Vapour Profiles Measured using a Raman Lidar and a Microwave radiomete at Chilbolton observatory.	22nd ILRC conference, 12-16 July 2004		paper.
Gaussiat N. and A. J. Illingworth	2003	Investigating the density of ice particles using dual-wavelength Doppler data.	31st Int Conf on Radar Meteorology, Seattle.	AMS 2003 Radar Conf Proceedings, pp. 137-139	paper
Illingworth A. J. and D. H. Bouniol.	2003	Improved radar rainfall estimates: What index use in the gamma function for the drop spectrum.	31st Int Conf on Radar Meteorology, Seattle.	AMS 2003 Radar Conf Proceedings, pp. 11-13	paper

Bouniol D., Illingworth A. J. and R. J. Hogan.	2003	Deriving turbulent kinetic energy dissipation rate within clouds using ground based 94 GHz radar.	31st Int Conf on Radar Meteorology, Seattle.	AMS 2003 Radar Conf Proceedings, pp. 193-195	paper
D.P. Donovan	2003	Effective ice cloud Size distribution parameterization using combined lidar, radar reflectivity and Doppler velocity measurements	EGS-AGU-EUG Joint assembly, Nice, France		Oral
D.P. Donovan	2002	Effective particle sizes in Cirrus derived from combined lidar, radar reflectivity and Doppler velocity measurements.	European Conference on Radar Meteorology, 18 - 22 November 2002, Delft, The Netherlands.	ERAD 2002 Proceedings, Vol. 1 - pp. 173 – 178	paper
Krasnov O and Russchenberg H	2002	An enhanced algorithm for the retrieval of liquid water cloud properties from simultaneous radar and lidar measurements. Part I: The basic analysis of in-situ drop spectra.	European Conference on Radar Meteorology, 18 - 22 November 2002, Delft, The Netherlands.	ERAD 2002 Proceedings, Vol. 1 - pp. 173 – 178	paper
Krasnov O. and H. Russchenberg	2002	An enhanced algorithm for the retrieval of liquid water cloud properties from simultaneous radar and lidar measurements. Part II : Validation using ground based radar, lidar and microwave radiometer data	European Conference on Radar Meteorology, 18 - 22 November 2002, Delft, The Netherlands.	ERAD 2002 Proceedings, Vol. 1 - pp. 179 – 183	paper
Heijnen S. H. Klein-Baltink H., Russhenberg W. J. and W. F. van der Zwan	2002	Polarimetric cloud studies at 3.3.GHz.	European Conference on Radar Meteorology, 18 - 22 November 2002, Delft, The Netherlands.	ERAD 2002 Proceedings, Vol. 1 - pp. 117 – 121	paper
Protat A, Tinel C. and J. Testud	2002	Dynamic properties of clouds and dynamic/microphysical interactions from 94GHz radar and lidar.	European Conference on Radar Meteorology, 18 - 22 November 2002, Delft, The Netherlands.	ERAD 2002 Proceedings, Vol. 1 - pp. 155 – 158	paper
Tinel C., Testud J., Protat A., and J. Pelon	2002	Microphysical and radiative properties of ice clouds using a cloud radar-lidar algorithm	European Conference on Radar Meteorology, 18 - 22 November 2002, Delft, The Netherlands.	ERAD 2002 Proceedings, Vol. 1 - pp. 184 – 187	paper

Illingworth A. J., Hogan R. J., Brooks M. E., and E. J O'Connor.	2002	The use of cloud radar and lidar data for validating clouds in operational forecasting models.	2nd Workshop on Spaceborne Cloud Profling Radar and Lidar, July 02, Tokyo, Japan		Oral
Krasnov O and H. Russchenberg	2002	The Comparative Study of the Relation Between Cloud Microphysics and Radar-to-Lidar Ratio for the Different Geographical Regions and Field Campaigns	Open Symposium on Propagation and Remote Sensing, 12-15 February 2002, Garmisch - Partenkirchen, Germany	URSI Commission-F, 12-15 February 2002, Garmisch-Partenkirchen, Germany 10 pp	paper
Krasnov O. and H. Russchenberg	2002	The relation between the radar to lidar ratio and the effective radius of droplets in water clouds: An analysis of statistical models and observed drop size distributions.	11th Conference on Cloud Physics, 3-7 June 2002, Ogden, Utah, AMS.		Proc. on CD-ROM
Krasnov O and Russchenberg H	2002	Use of simultaneous radar and lidar data for the retrieval of microphysical parameters in low-level water clouds.	15th Symposium on Boundary Layer and Turbulence, 15-19 July 2002, Wageningen, The Netherlands.	AMS, pp. 88-91.	paper
Krasnov O and Russchenberg H.	2002	Comparison of multiple-wavelength cloud radar observations in the BBC campaign	27th General Assembly of the International Union of Radio Science, Maastrich, The Netherlands.	Conference CD of URSI (2002).	Proc. on CD-ROM