CLOUDNET (EVK2-2000-00611) FIRST ANNUAL SCIENTIFIC REPORT.

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ABSTRACT.
This project is concerned with gathering radar and lidar data on clouds, interpreting it and comparing with the cloud representation in operational NWP models, and, in colalboration with industry, defining a GCOS Cloud Remote Sensing (CRS) station. The first two deliverables (0 and 1) - a project publicity brochure and a kick-off workshop report have been completed. The deliverables 2-4 are due in October 2002:

Deliverable 2: - 'Existing data sets and initial analysis'

The data set documentation has been posted on the web site; as have 11 scientific presentation and 11 submitted papers on the analysis. A further seven papers will shortly be placed on the web.

Deliverable 3 'Initial algorithms recommendation'

A document is being prepared based on the output of deliverable 2.

Deliverable 4 - ' User Requirement Document'.

A draft version is being circulated for final comment

Deliverable 5 - 'Establishment of a Web site'.

This is in place - http://www.met.reading.ac.uk/radar/cloudnet. It contains the scientific analyses referred to above, and also some observation data from the three sites and model data from the four models together with a description of data formats. The complete data will be posted when the intensive observation period starts in October 2002.

The intensive observations period scheduled for October 2001-3 has been postponed for one year, following hardware failure of two of the cloud radars. These have been returned to the manufacturer in Canada, but should be functioning in time for the October 2002 observation program from October 2002- October 2004. Two of the sites have been recording a reduced data set for the past year. A one year no cost extension to the project has been agreed.

Considering the work packages:

WP1 - Analysis of existing data sets.

11 scientific papers submitted and 7 in preparation.

WP2 - Operation of three observing stations.

Scheduled to start October 2002. Limited operation over the past year.

WP3 - Development of retrieval algorithms.

The papers address retrieving properties of ice, liquid and mixed phase clouds.

WP4 - Comparison of retrieved profiles with operational models.

Data from two of the four models have been archived over the past year. Archiving of the other two to start in October 2002.

2 papers comparing observation & model ice water content and cloud fraction.

WP5 - Definition of instruments and algorithms for GCOS.

Two papers on new calibration procedures. Others on required sensitivity

Industrial partners have attended our kick-off meeting in KNMI, the workshop in Reading in October 2001 and progress meeting in Paris in May 2002.

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1. INTRODUCTION.

The overall objectives of the Cloudnet project 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.

This involves:
- Development of algorithms for deriving ice and liquid water content from ground based lidar, radars and radiometers.
- Showing that the cloud properties inferred can be usefully compared with the prognostic variables held in the model grid box for four European operational forecasting models and so improve such models.
- Collaboration with European industry so that the instrument techniques and algorithms developed can be implemented to provide operational data for these forecasting models.

The project is organised in the following work packages:
WP1: Exploit Existing Cloud Data Sets
WP2: Operate cloud remote sensing stations.
WP3: Development of Retrieval Algorithms.
WP4 Compare retrieved cloud profiles with values in operational models.
WP5 Definition of instruments and algorithms for GCOS.

A Cloudnet web site htttp://www.met.reading.ac.uk/radar/cloudnet/
has been established, in summary this contains:
i) Overview of the project, aims, and work packages.
ii) Results.
  Minutes of the three meeting.
  (kick-off 9 May ‘01; 1st w’shop 19-20 Nov ‘01; 1st progress 27-28 May ‘02).
  11 Scientific presentations at the meetings.
  11 papers so far submitted for publication.
  Work Package Documents.
  The Completed Deliverables.
iii) Data formats.
  Description of data formats for level 0-2.
  Level 1 definition of NetCDF format for radar and lidar data.
  Model variables to be recorded.
iv)Data Archive. (for four models over the three observing sites)
  Data from ECMWF model from Jan 2001
  Met Office model collected archived since Feb02 will shortly be transferred.
  Cabauw observations (apart from radar - shortly to be transferred).
  Chilbolton radar/lidar observations, 2001 -early 2002 will soon be transferred.
  Meteo France and KNMI model data archiving will start on 1 October 2002

Section 2 outlines the results of the ten papers in the process of being accepted for publication and the seven papers which are to be submitted within the next two months. Section 3 identifies how they relate to WP1 (Analysis of existing data sets). In Section 4 we report progress on WP2 (Operate cloud remote sensing stations). Progress on Work Package 3 (Development of retrieval algorithms) is discussed in Section 5 and the contribution of the 17 papers is categorised. The contribution of the papers to WP4 (Comparison with operational models) is dealt with in Section 6 and progress on WP5 (Definition of a GCOS RCS) in Section 7. In Section 9 the state of the deliverables is summarised and the progress of the project in terms of the timetable is reviewed. Technical difficulties with the two of the cloud radars has resulted in them being returned to Canada, accordingly the operation of the remote sensing stations has been delayed by one year, and a one year no-cost extension to the project has been approved.

2. PUBLICATIONS.

Below we list the papers submitted for publication and those about to be submitted and briefly indicate their salient points.

Papers submitted for publication:

1. R J Hogan, H Flentje, P N Francis, A J Illingworth, M Quante and J Pelon: Characteristics of mixed phase clouds. Part1: Lidar, radar and aircraft observations from CLARE '98. In revision. Q J Roy Meteorol Soc., 2002.

This paper confirms an algorithm for identifying supercooled clouds by comparing radar/lidar observations with in-situ aircraft observations. The observations also show that these supercooled clouds have an important radiative effect.

2. R J Hogan, A J Illingworth, P P V Poiraes Baptista and E J O'Connor: Characteristics of supercooled clouds: Part II A climatology from ground-based lidar. In revision. Q J Roy Meteorol Soc., 2002

Analysis of a two years of observations shows that supercooled layer clouds occur frequently over Chilbolton in the UK. Such clouds have a significant climatological effect on radiation but are not represented in climate models.

3. R J Hogan and A J Illingworth: Parameterizing ice cloud inhomogeneity and the overlap of inhomogeneities using cloud radar data. In revision. J Atmos Sci, 2002.

Analysis of Chilbolton observations leads to an expression for the fractional variance in ice water content in a grid box as a function of grid-box size and wind shear and also an expression for the vertical decorrelation of optical extinction coefficient. Such expression could be incorporated in models to represent cloud inhomogeneity.

4. N Gaussiat, H Sauvageot, A J Illingworth. Cloud liquid water and ice content retrieval by multi-wavelength radar. In revision. J Atmos Ocean Technol, 2002.

Derivation of both cloud liquid and ice content from radar is generally ambiguous. A new method is proposed and validated which uses three wavelengths to separate the differential attenuation caused by the liquid water and the Mie scattering from the ice.

5. R J Hogan, D H Bouniol, D N Ladd, E J O'Connor and A J Illingworth: Absolute Calibration of 94-GHz radars using rain. In revision. J Atmos and Ocean Technol, 2002

Calibration affects water content values derived from cloud radars, but is difficult to obtain to better than a factor of two. A new calibration method accurate to better than 1dB is proposed and validated which exploits the quasi-constant short range reflectivity of rain at 94GHz.

6. Krasnov O and Russchenberg H: An enhanced algorithm for the retrieval of liquid water cloud properties from simultaneous radar and lidar measurements. Part 1: The basic analysis of in-situ drop spectra. In revision. Phys and Chem of the Earth. B. 2002

This paper analyses in-situ drop spectra in terms of the expected radar reflectivity (Z) and lidar extinction coefficient (α). Radar reflectivity is often dominated by drizzle although it contributes little to LWC; relationships between Z/α and LWC are derived in the presence of drizzle.

7. Krasnov O and Russchenberg H: 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 In revision. Phys and Chem of the Earth. B. 2002

Observations of Z/α in stratocumulus with varying amounts of drizzle are compared with observations of LWC and liquid water path from radiometers.

8. Heijnen S H, H. Klein-Baltnink, H W J Russchenberg, W.F. Van der Zwan; Polarimetric cloud studies at 3.3.GHz. In revision. Phys and Chem of the Earth. B. 2002.

Paper considers the information available on ice crystal habit and melting processes available from polarisation parameters.

9. Protat A, C.Tinel and J Testud. Dynamic properties of clouds and dynamic/microphysical interactions from 94GHz radar and lidar.
In revision. Phys and Chem of the Earth. B. 2002

The dynamics of cloud motions are retrieved using a dual beam radar - forward and vertical pointing cloud radar. Relationships are developed between terminal fall velocity of the icy hydrometeors, and also fall velocity and ice water content and effective radius. this is compared with the expected fall velocity from the radar/lidar retrieved IWC and size.

10. C.Tinel, J Testud, A. Protat, and J.Pelon. Microphysical and radiative properties of ice clouds using a cloud radar-lidar algorithm. In revision. Phys and Chem of the Earth. B. 2002

This paper extends an existing technique for deriving profiles of ice water content and ice effective radius from observed radar and lidar profiles by relaxing the constraint that the normalised ice crystal concentration be constant along the profile.

Papers shortly to be submitted:

11. M E Brooks, R J Hogan and A J Illingworth: The definition of cloud fraction in GCMs by area and by volume. To be submitted to J.Atmos Sci.

Most GCMs assume calculate the cloud fraction as the fractional volume of the grid box full of cloud and calculate radiative effects assuming this is the same as the fractional area of cloud.   Analysis of observations shows there is an important difference between the two definitions, with the cloud fraction by volume on average being 30% lower than the fraction by area.

12 E J O'Connor, R J Hogan and A J Illingworth. Radar detection and climatology of stratocumulus clouds. To be submitted. J Appl Met.

Comparisons of radar and lidar data at Chilbolton shows that the radar fails to see about 50% of the stratocumulus clouds detected by the lidar. Most clouds which the radar does detect have a few drizzle size droplets within them. Statistics of the underestimate of stratocumulus as a function of radar detectability threshold are presented.

13. E J O'Connor and A J Illingworth   Automatic self calibration of cloud lidar.
To be submitted J Ocean Atmos Technol.

A new simple technique for self calibrating lidars is described. It relies on adjusting the calibration coefficient until the observed integrated backscatter profile through a stratocumulus is a known constant.

14. E J O'Connor, R J Hogan and A J Illingworth. Retrieving stratocumulus drizzle parameters using radar and lidar.   To be submitted to J Appl Met.

A radar-lidar retrieval is described to derive a three parameter gamma function to describe the below cloud-base drizzle size and hence drizzle liquid water content, liquid water flux and vertical air velocity.

15. R.J.Hogan and A J Illingworth.   Stratocumulus liquid water content from dual wavelength radar.   To be submitted to J Ocean Atmos Technol.

Observations of differential attenuation between 35 and 94GHz radar reflectivity can be interpreted in terms of a high resolution vertical profile of liquid water content within stratocumulus cloud.

16. M E Brooks, R J Hogan and A J Illingworth. Comparisons of radar derived values of IWC and their representation in operational models of ECMWF and Met Office.

The analysis of one year's data confirms that the mean values of IWC as a function of height in these two models are generally correct to within the accuracy of the radar-derived IWC retrieval. There may be an under-representation of ice above 6km. The probability distribution of IWC and fractional cloud cover is also well captured by the models.

17. D P Donovan: The relationship between lidar/radar effective particle size and Doppler fall velocity of cirrus cloud particles.

Previous work has established that IWC and effective radius of ice particles can be inferred from the profiles of lidar and radar backscatter. These inferred values are then compared with the observed Doppler fall velocity to provide an additional constraint to the ice particle size spectrum.

3. PROGRESS ON WP 1 - EXPLOIT EXISTING DATA SETS.

Documentation of the existing data sets has been posted on the web site.

All seventeen papers discussed in section 2 have used existing data sets. We now identify which paper used which data set.

CLARA - 1996 - Netherlands

CLARE - October 1998 - UK

1. Hogan et al.	6&7. Krasnov and Russch.	15. Hogan&Illling.

C^2 - Continuous monitoring at Chilbolton since 1998

2. Hogan et al.	3. Hogan et al.	4. Gaussiat et al.
5. Hogan et al.	11. Brooks et al	12. O'Connor et al
13. O'Connor et al	14. O'Connor et al	16. Brooks et al.

CARL1 (May 99) and CARL2 (Autumn 2000/March2001) - France

9. Protat et al	10. Tinel et al

ARM On going in the USA
17. Donovan.

Cliwa-net - Aug-Sep 2001 NL.
8. Heijnene et al.

4. PROGRESS ON WP 2 - OPERATE CLOUD REMOTE SENSING STATIONS.

Technical difficulties with two of the 94GHz cloud radars has resulted in them being returned to the manufacturers in Canada. The French cloud radar was returned to Paris during the summer and appears to be working satisfactorily. The tube of the 94GHz at Chilbolton failed in February 2002. A new tube which is integrated with the modulator is being shipped from Canada to the UK at the end of this month (September 2002). Accordingly a revised contract has been negotiated. The intensive period of operating the cloud remote sensing stations will start 1 October 2002 for two years. A one year no-cost extension to the contract has been agreed. In summary the situation at the three observing stations is as follows.

Cabauw: This station has been operating continuously for the past year. The 35GHz radar and lidar are operating satisfactorily. Data from Cabauw for the lidars, radiometers and fluxes has been placed on the KNMI Cloudnet ftp site. The radar data will be transferred shortly to the KNMI site.

Chilbolton: Cloud radar data has been recorded continuously for the past three years up to the failure of the radar tube in early March 2002. The radar should be operational within two weeks of the repaired tube being returned from Canada. Ceilometer lidar data has been recorded continuously throughout this period. All this data is currently archived at Reading and will shortly be transferred to the Cloudnet web site.

Palaiseau: The cloud radar has been returned from Canada this summer and is working satisfactorily. The current research lidars at Palaiseau can only operate when a researcher is present and cannot be left unattended in case rain falls on the optics. A loan of a spare lidar ceilometer from KNMI (similar to those being operated at the other two stations) has been arranged and this is being set up for continuous operation in Paris.

We are confident that following the one year delay continuous operation can begin at all stations on 1 October 2002.

5. PROGRESS ON WP 3 - DEVELOPMENT OF RETRIEVAL ALGORITHMS.

This package started in October 2001. The following advances have been made using existing data sets. The brackets refer to the 17 papers listed in section 2.

i) An algorithm for identifying supercooled cloud layers has been tested and validated with in-situ aircraft (1. Hogan et al).

ii) Retrieval algorithm in i) for supercooled water has been used for two years of data to develop a climatology of such clouds. (2. Hogan et al).

iii) Retrieval of sub-grid scale ice cloud inhomogeneity and its parameterisation (3. Hogan and Illingworth).

iv) Retrieval of both liquid and ice water content using triple wavelength radar (4. Gaussiat et al).

v) Technique for calibration of radar - crucial if radar values are to be used in any retrieval. (5. Hogan et al)

vi) Algorithm for retrieving liquid water content from radar and lidar in the presence of drizzle. (6. Krasnov and Russchenberg)

vii) Validation of the algorithm in vi). (7. Krasnov and Russchenberg).

viii) Retrieval of ice and melting ice parameters using polarisation (8. Heijnen et al).

ix) Derivation of dynamics and ice water content from radar/lidar backscatter combined with radar Doppler velocity. (9. Protat et al).

x) Deriving ice water content and ice particle size from radar and lidar relaxing the constraint of constant normalised particle concentration. (10. Tinel et al).

xi) Methods of retrieving cloud fraction from data - comparing the volume and area approaches for defining fraction. (11. Brooks et al).

xii) Radar sensitivity threshold and stratocumulus detection. (12. O'Connor et al)

xiii) Technique for calibration of lidar - crucial for quantitative use (13. O'Connor)

xiv) Retrieval of drizzle parameters in Sc using Doppler radar & lidar .(14. O'Connor)

xv) Radar retrieval of liquid water content in drizzling and non-drizzling stratocumulus. (15. Hogan).

xvi) Retrieving IWC values from radar reflectivity. (16. Brooks et al).

xvii) Better retrievals of ice using Doppler radar and lidar (17. Donovan)

If we consider the details of WP3 then the relevance of the papers is as follows:

WP 3.1 Macroscopic Cloud Properties.
Methods of retrieving cloud fraction. 11.

WP 3.2 Liquid Water Clouds.
Radar/lidar retrieval of LWC in cloud in presence of drizzle. 6.
Validation of 6. algorithm. 7.
Doppler radar/lidar retrieval of drizzle below cloud. 14.
Dual wavelength radar retrieval of LWC profile. 15.

WP 3.3 Ice Water Clouds
Sub-grid scale inhomogeneity. 3.
Use of radar polarisation diversity. 8.
IWC, air flow and terminal velocity. 9.
IWC and particle size radar/lidar. 10.
IWC and particle size from Doppler radar and lidar. 17.

WP 3.4 Mixed Phase Clouds.
Radar/lidar identification of supercooled clouds 1.
Climatology of supercooled clouds. 2.
Triple Wavelength radar identification of IWC and LWC. 4.

WP 3.5 Technological Implications.
Auto-calibration of radar. 5
Radar sensitivity and Sc detection. 12.
Auto-calibration of lidar. 13.

6. PROGRESS ON WP4 - COMPARISON WITH OPERATIONAL MODELS.

Technically this package does not start until January 2004, but work has been done using the existing archive of ECMWF and MetOffice model data over Chilbolton.
Climatology of supercooled clouds. 2.
Sub grid scale ice cloud inhomogeneity 3.
Definition of cloud fraction. 11.
Climatology of stratocumulus. 12.
Comparison of IWC and cloud fraction with ECMWF and MO models. 16.

WP4 4.1 - Co-ordinate model outputs.
The format for the recording of model data and the model parameters to be recorded have been agreed and are posted on the web site. Taking the four models in order:

A. ECMWF. Model data over the three sites has been archived routinely since Jan 01. Data up to March 02 is on the Cloudnet web site.

B. Met Office. Model data from the three sites has been stored routinely since Feb 02. Transfer of this data to the Cloudnet web site archive is imminent.

C. KNMI and D. MeteoFrance.
Data archiving over the three ground based sites will start on 1 October 2002.

7. PROGRESS ON WP 5- DEFINITION OF A GCOS REMOTE CLOUD SENSING STATION.

This package does not start until April 2003. However the papers itemised under WP 3.5 are leading to the radar and lidar specification for sensitivity of such a station.

8. THE DELIVERABLES AND SUMMARY OF PROGRESS.

Taking the deliverables in numerical order.

0. Project Publicity Brochure - due July 01.
   - Complete. Copies have been distributed. A copy is also available on the web site.

1. Kick-off workshop report. - due summer 01.
   - Complete. Available on the web.

2. Existing Data sets and Initial Analysis. - due Oct 02
   Documentation of data sets is on the web site.
   11 scientific presentations and 11 submitted papers are on the web site.
   A further 7 papers will shortly be posted on the web.

3. Initial algorithms recommendations - due Oct 02.
   This document is being prepared - based on the work in deliverable 2.

4. User Requirement Document - due Oct 02.
   A draft document has been written and is being circulated for final comments.

5. Clounet web site - this is in place and described in Section 1.

No other deliverables are due until October 2003. The three ground based observing stations are ready to start their intensive two year observations program in October 2002. The four models will all be archiving model data above these stations from the same date.