The CARL project : a further step towards the determination of microphysical cloud characterics from active remote sensing.

J. Pelon, P. Flamant, J. Testud (IPSL, France)
M. Quante, O. Danne, E. R. Raschke (GKSS, Germany)

To validate and to improve cloud parameterizations in general circulation models, a detailed information about the cloud characteristics must be available on large scales. Crucial cloud characteristics is the particle size distribution (liquid or ice), and crystal shape which are known to have a strong influence on the radiative property of clouds. Remote sensing measurements are potential candidates to this respect as proposed in the frame of the Earth Radiation Mission by the European Space Agency. An important step towards remote sensing of particle size distributions is proposed in the CARL project by the combination of a cloud radar, backscattering lidars and radiometers on the ground and on an aircraft platform. The main goals of CARL are low level warm clouds and high level cold clouds.

This "multi-wavelength" measurements in optically thick clouds, the "dual beam technique" considered for the radar (successfully used in ASTRAIA, a dual beam airborne weather radar), aims going far beyond the description of cloud layering obtained from a single beam radar, by measuring the radar reflectivity and the specific attenuation, from which it is possible to derive the water content W and the equivalent radius r_e of droplets.

Mapping W and r_e within liquid water clouds suffices to fully characterize the radiative property of the cloud. As shown from previous backscatter lidar measurements performed during EUCREX, the extinction at cloud edge can be derived even in dense clouds. In warm clouds both visible and infrared lidar measurements can be used to derive W and re as shown from ground-based observations. Such informations can be used as an input to radar inversion. For mixed phase clouds additional information is obtained from polarized lidar signal. In the same spirit, in optically thin clouds will lead to informations about size distributions and shape along vertical profile, helping to understand the cloud microphysics and its link to larger-scale cloud properties (in particular with respect to radiative budget) and tropospheric dynamics. It is proposed in the frame of CARL to test these methodologies both from the ground and from an aircraft to allow cloud sampling on larger horizontal scales. Also, using the Doppler capability of the radar, the dual beam technique will allow to better describe the cloud dynamics by measuring two independent components of the air velocity. Combined analysis of the data of all the instruments with respect to above mentioned parameters will be conducted during CARL using a three-dimensional atmospheric model able to represent cloud processes to quantify the impact of measurements on radiation budget.

During the workshop an introduction to CARL will be given. A particular focus will be put on both stratocumulus cloud and thin cirrus cloud analysis by the authors contributing to the CARL project.

Airborne Active Remote Sensors

Lidars :

LEANDRE-1/ARAT /Mystère 20	since PYREX, 1990 INDOEX, March 1999	Backscatter/clouds/aerosols (0.53 µm /1.06 µm/ Δ)
LEANDRE-2/ARAT	ACE-2, 1997	DIAL/Water vapor (0.73 µm)
WIND/Falcon	MAP, Sept.-Nov. 1999	Doppler/wind (10.6 µm)

Radars :

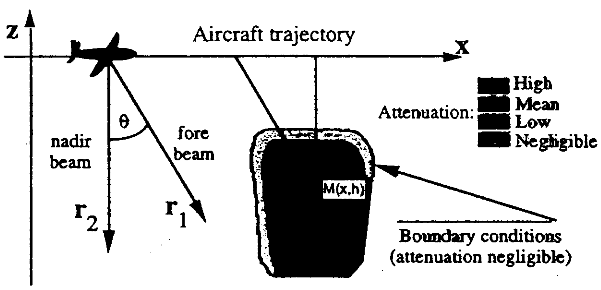
ELDORA/ASTRAIA TOGA-COARE, FASTEX in 1996, MAP in 1999

RALI : Radar/Lidar onboard the ARAT

TRAC, 1998 + CLARE	94 GHz-radar of Wyoming Univ./LEANDRE-2
1999	*94 GH-radar dual beam (CETP)*/LEANDRE-2
2000-2001	94 GHz-radar (CETP)/ *0.53 µm and 10 µm* lidar

THE RALI EXPERIMENT
(airborne RAdar and LIdar)

∞ Instruments :
dual beam 95 GHz radar
backscattering lidar



∞ Scientific goal :
Documentation of microphysical and dynamical characteristics of non precipitating clouds

STEREORADAR ALGORITHM

Kabèche and Testud, 1995

Stereoradar equation : $$\boxed{\frac{dZ_{af}}{dr_1}-\frac{dZ_{an}}{dr_2}=\sin\theta\frac{\partial Z}{\partial x}+(1-\cos\theta)\frac{\partial Z}{\partial h}}$$

Minimization of a functional ⇨ Z

2 estimates of K : $K_f=\frac{1}{2}\left(\frac{dZ}{dr_1}-\frac{dZ_{af}}{dr_1}\right)$ $\quad K_n=\frac{1}{2}\left(\frac{dZ}{dr_2}-\frac{dZ_{an}}{dr_2}\right)$

Minimization of a functional ⇨ K

NO HYPOTHESIS ON THE K-Z RELATIONSHIP

BOUNDARY CONDITIONS $Z=Z_{af}$ or $Z=Z_{an}$ AT THE CLOUD EDGE

DUAL BEAM ALGORITHM

Testud and Oury, 1997

Assumption of a power low relationship: $K=aZ^{b}$

Hitschfeld and Bordan solution (1954): $$Z=\frac{Z_a}{\left(1-0.2\ln 10.b\int Kdr\right)^{1/b}}$$

2 measured apparent reflectivities ⇨ 2 estimates of Z

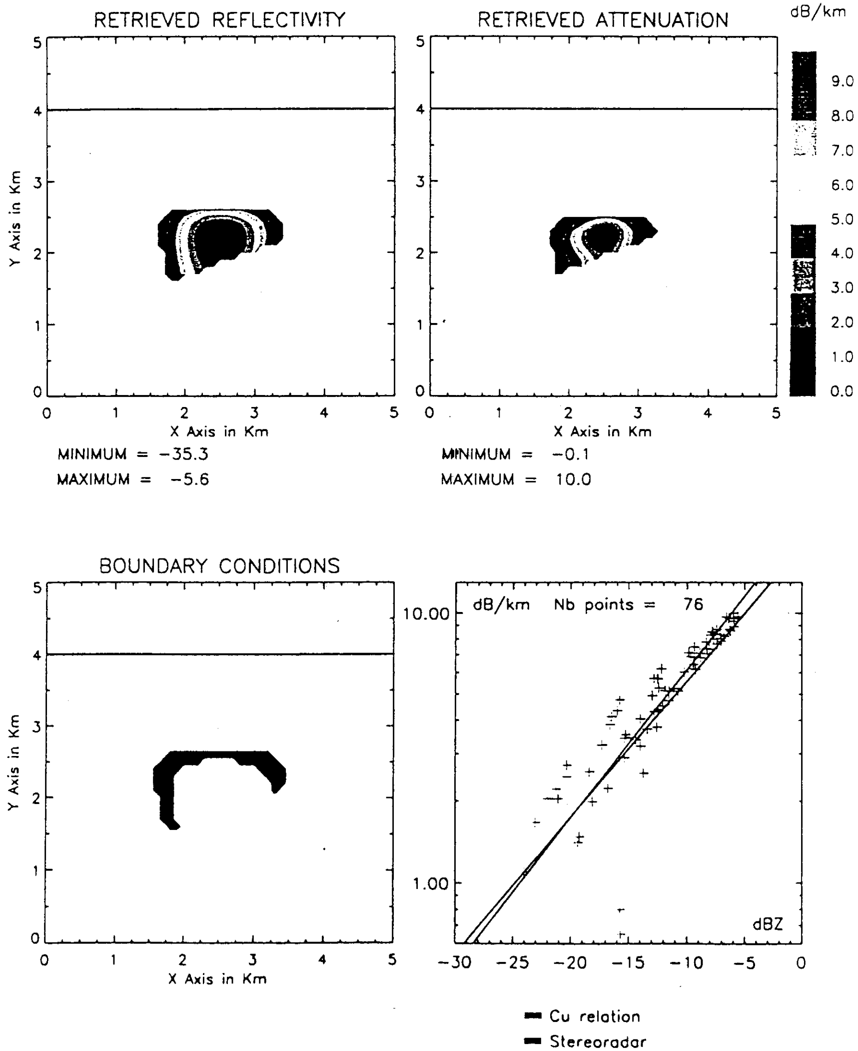
⇨ We impose $Z_f=Z_n$

⇨ Determination of Z, K and a

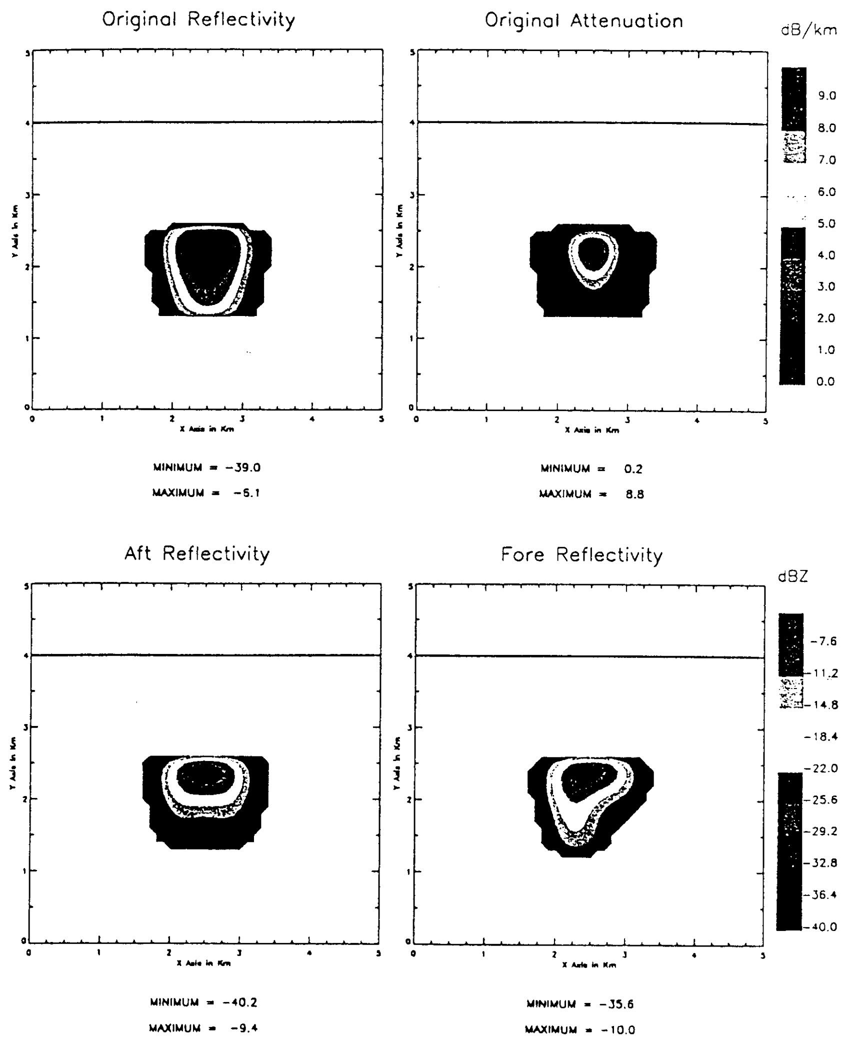
HYPOTHESIS ON THE b COEFFICIENT OF THE K-Z RELATIONSHIP

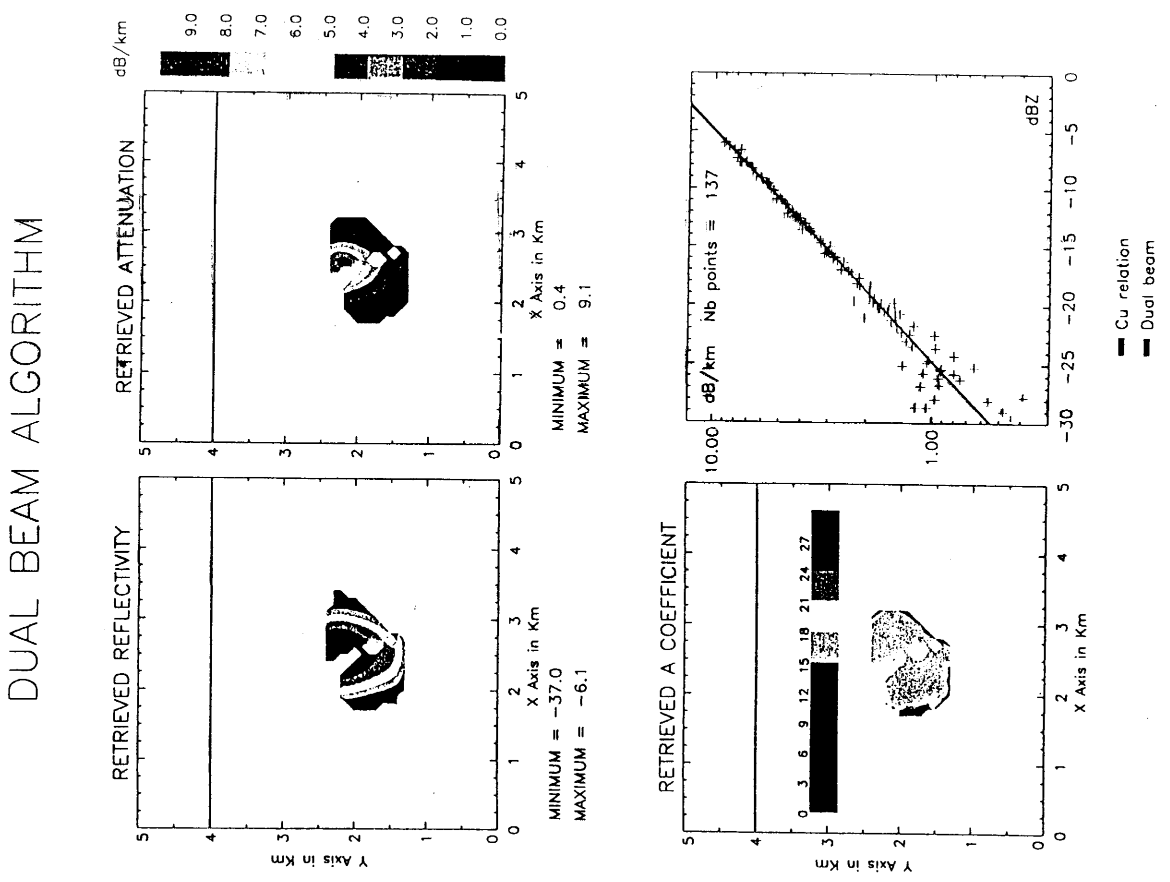
CONSTRAINT PIA_f-PIA_n FOR THE STABILITY OF THE ALGORITHM

STEREORADAR ALGORITHM



RALI SAMPLING SIMULATION





Small Cumulus Microphysics Study

Florida, summer 1995

95 GHz cloud radar: airborne on the University of Wyoming King Air
side looking antenna

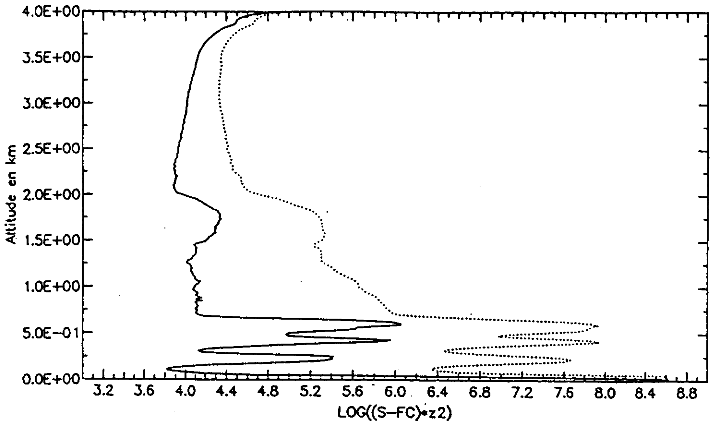
Selection of flight patterns providing at least two viewing angles of the same cloud in order to apply our algorithms

Two flights selected:

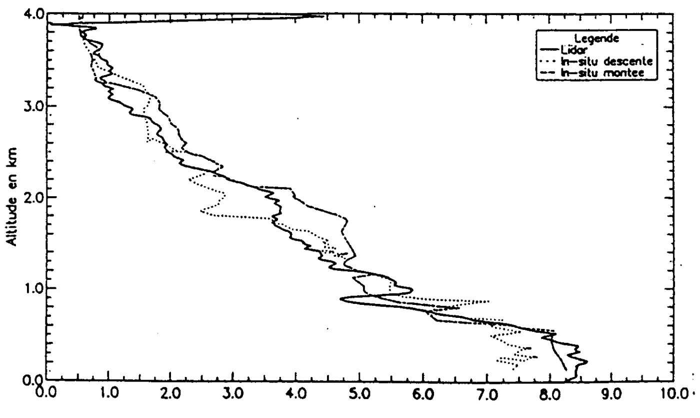
4 August   10 August

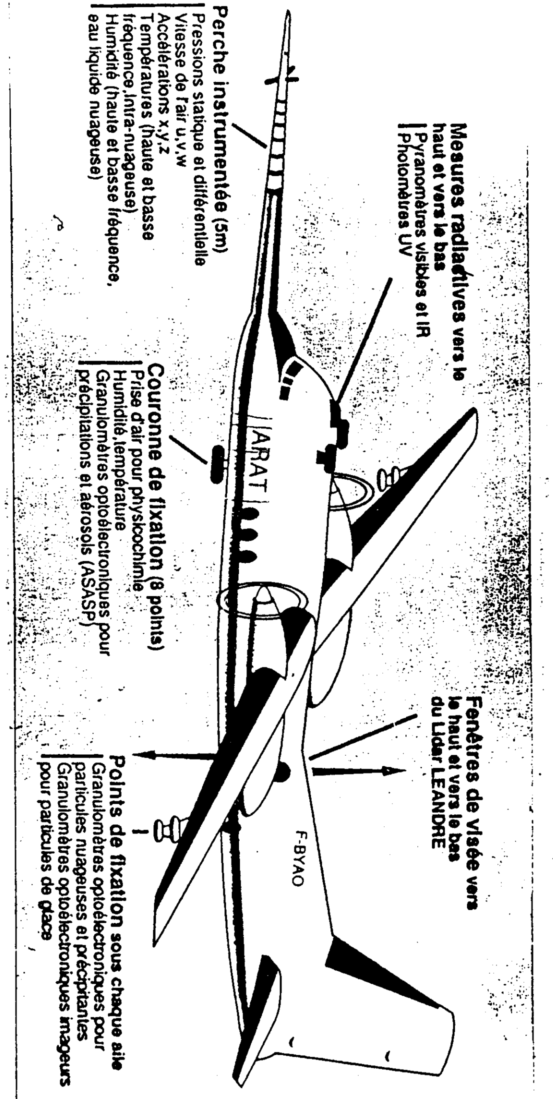
MEASUREMENTS COMPARISON
Flight of Oct. 5 1995

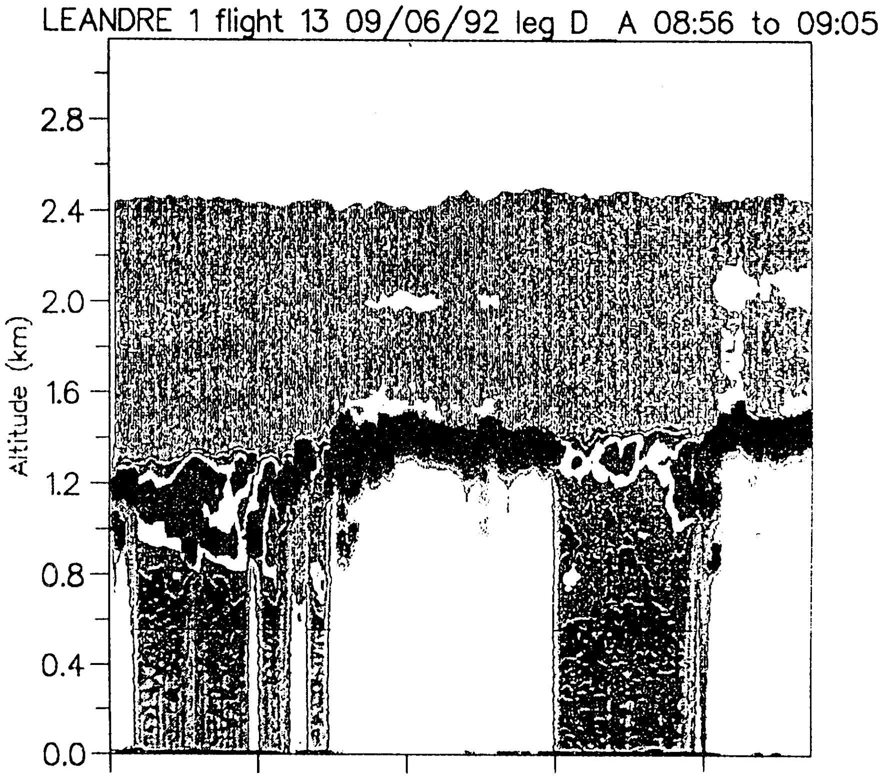
DIAL SIGNALS (on-line and off-line) averaged on 800 shots

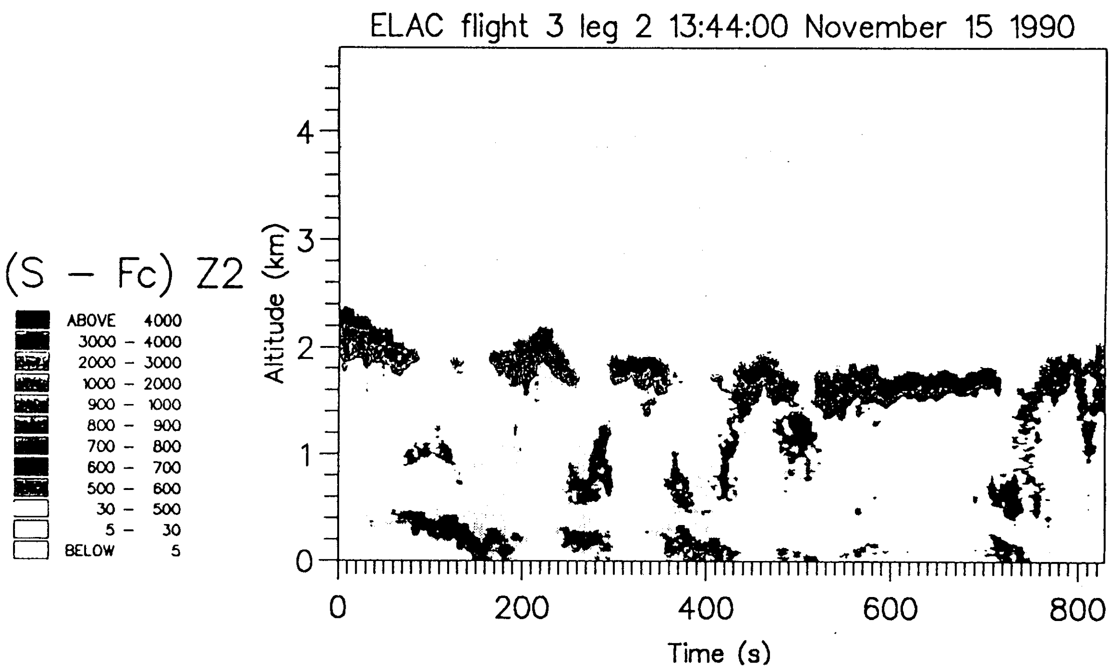


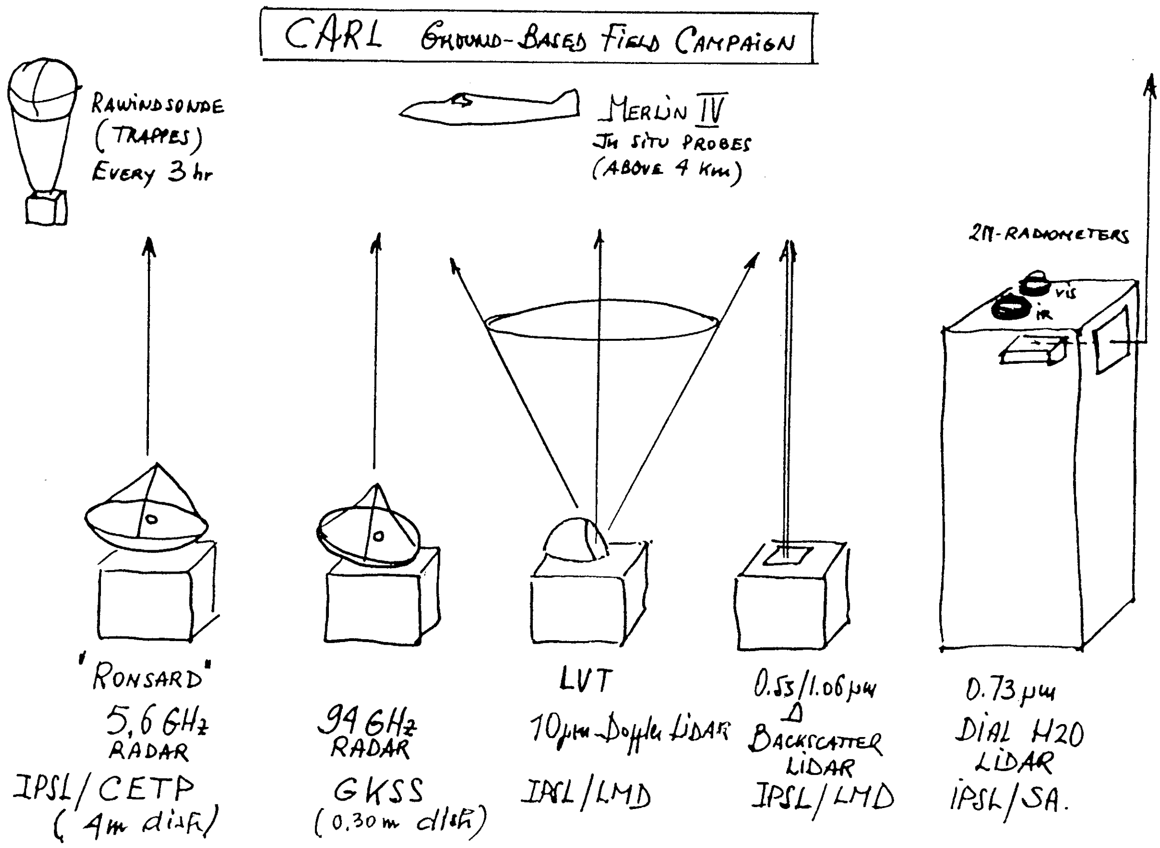
WATER-VAPOR MIXING RATIO (DIAL and In-Situ)

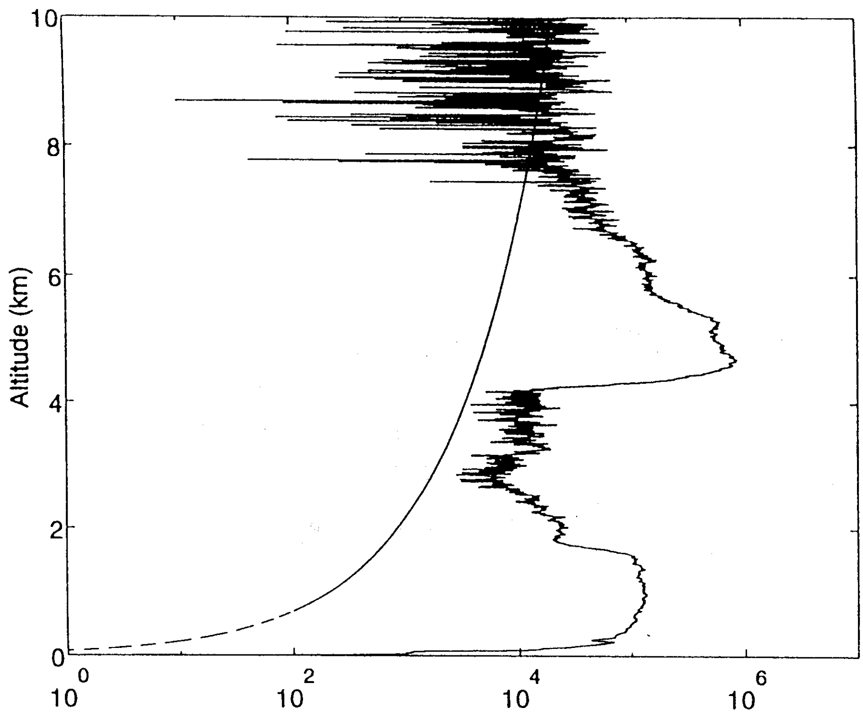





LEANDRE 1 flight 13 09/06/92 leg D A 08:56 to 09:05
Altitude (km)
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0


ELAC flight 3 leg 2 13:44:00 November 15 1990
(S – Fc) Z2
ABOVE 4000
3000 – 4000
2000 – 3000
1000 – 2000
900 – 1000
800 – 900
700 – 800
600 – 700
500 – 600
30 – 500
5 – 30
BELOW 5
Altitude (km)
4
3
2
1
0
0
200
400
600
800
Time (s)


CARL Ground-Based Field Campaign
Rawinsonde (Trappes) Every 3 hr
Merlin IV In situ probes (above 4 km)
2Π-Radiometers
'Ronsard' 5,6 GHz Radar IPSL/CETP (4m dish)
94 GHz Radar GKSS (0.30m dish)
LVT 10μm Doppler Lidar IPSL/LMD
0.53/1.06μm Backscatter Lidar IPSL/LMD
0.73μm DIAL H2O Lidar IPSL/SA.


Altitude (km)
Square range corrected signal
10
8
6
4
2
0
10^0
10^2
10^4
10^6