OTEM 2010
4th Workshop on Optoelectronic Techniques for Environmental Monitoring
19-21 October 2010, Romania, Cluj-Napoca

Compact micropulse backscatter lidar: Airborne and groundbased applications

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Motivation

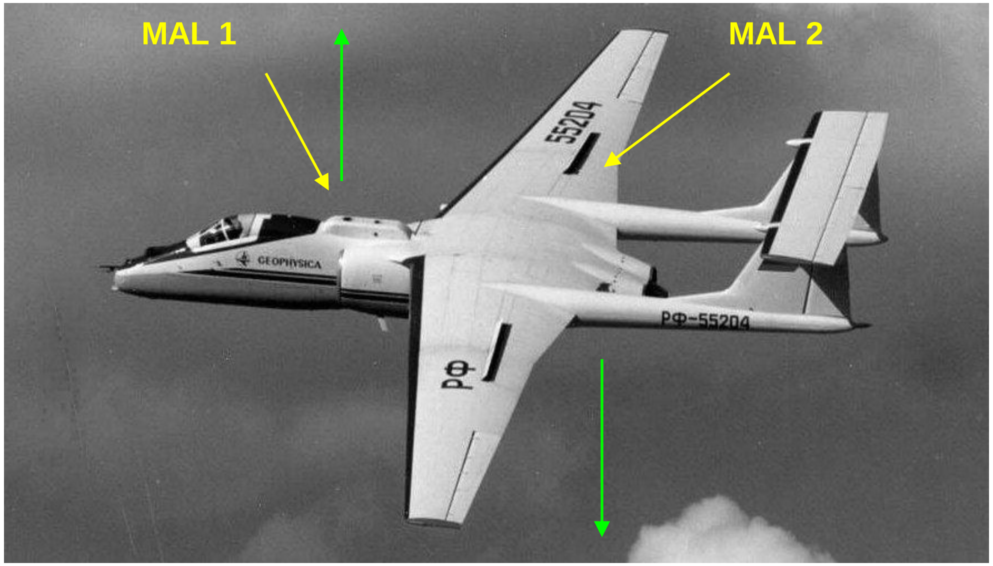
- To realise compact, robust, automatically operating backscatter lidar for stratospheric aircraft, with a sensitivity sufficient for detection of clouds with BR~ 2-5 at 1-2km from the aircraft

- To check its performance for PBL and low troposphere measurements: Aerosol backscatter Coefficient and PBL (mixed layer) top;

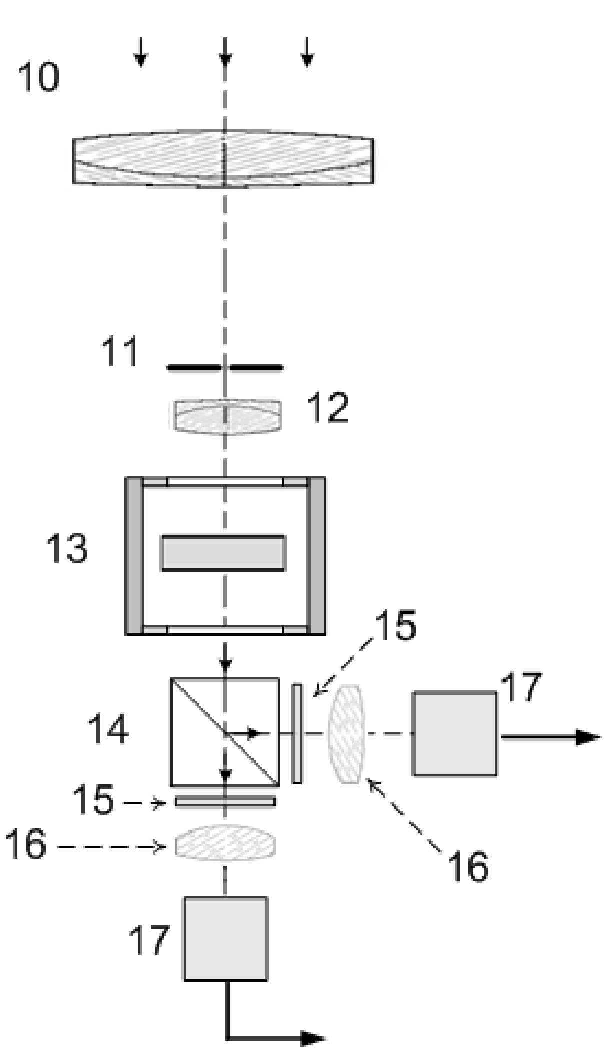
The “Starting point” – lidar for stratospheric aircraft:

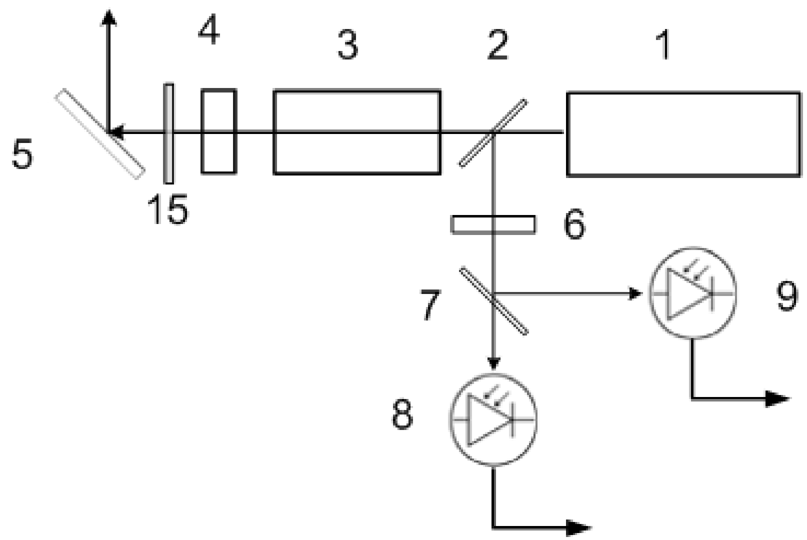
M-55 « Geophysica » (Myasishchev Design Bureau – Russia)

- payloads: 1500 – 2100 kg
- altitude :up to 21-22 km
- flight duration: 5-6 hours
-cruise speed: about 750 km/h
-crew: 1



The Optical set-up:





RECEIVER :

« 10 » - Receiver lens

« 11 » - Field stop

« 12 » - Collimating lens

« 13 » - Interfernce filter in thermostabilisation housing

« 14 » - Polarisation beamsplitter-cube

« 15 » - Polarisation filter

« 16 » - Focusing lens

« 17 » - PMT Module

TRANSMITTER :

« 1 » - Laser

« 2 » - Plate 95%T

« 3 » - Beam expander, x16

« 4 » - λ/2 - Plate

« 5 » - Beam pointing mirror

« 6 » - Glass filter, « green »

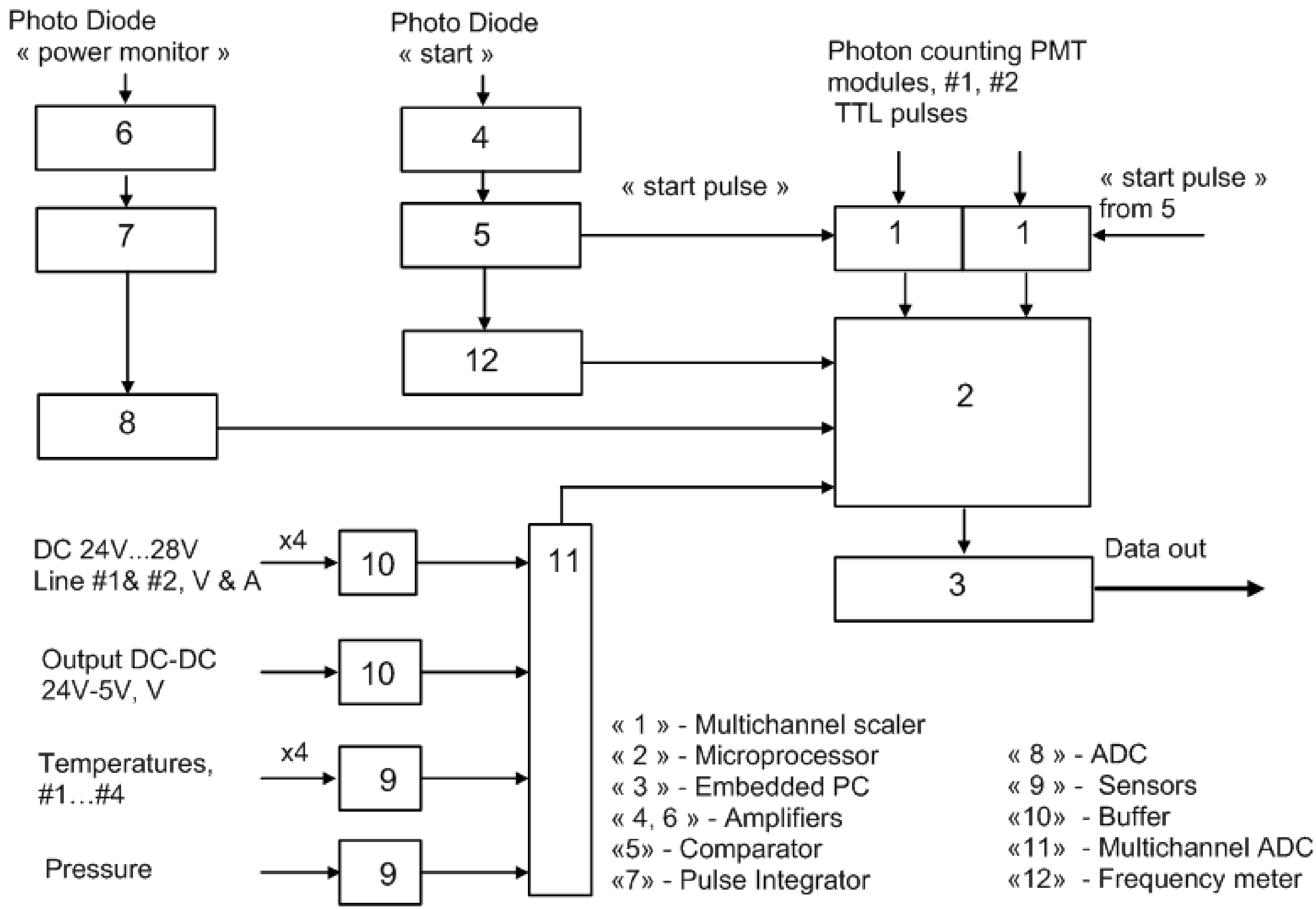
« 7 » - Plate 50% T/R

« 8 » - PIN PhDiode, « start »

« 9 » - PIN PhDiode, « monitor »

« 15 » - Polarisation filter

The Signal acquisition set-up:

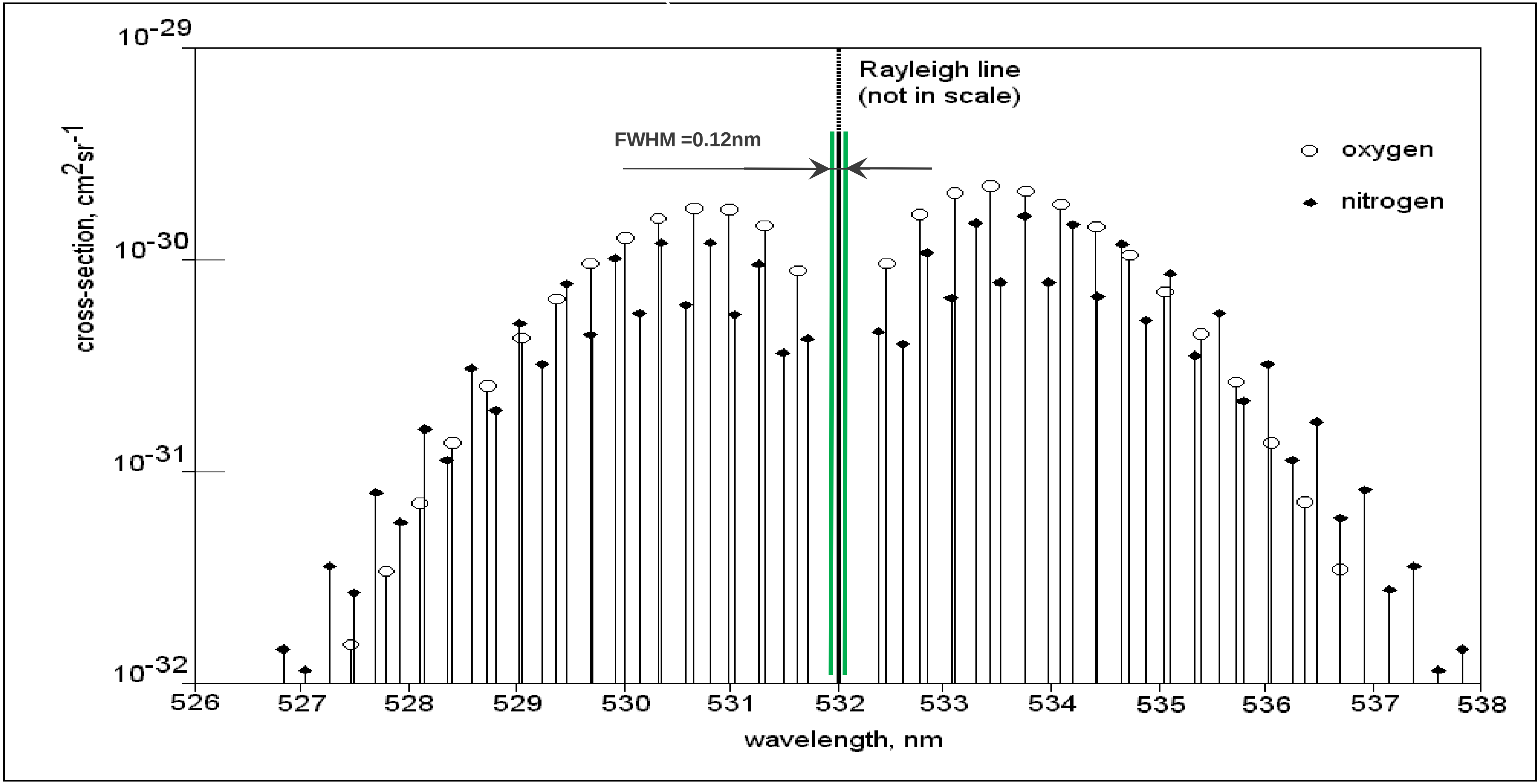


The Sub-systems Specs:

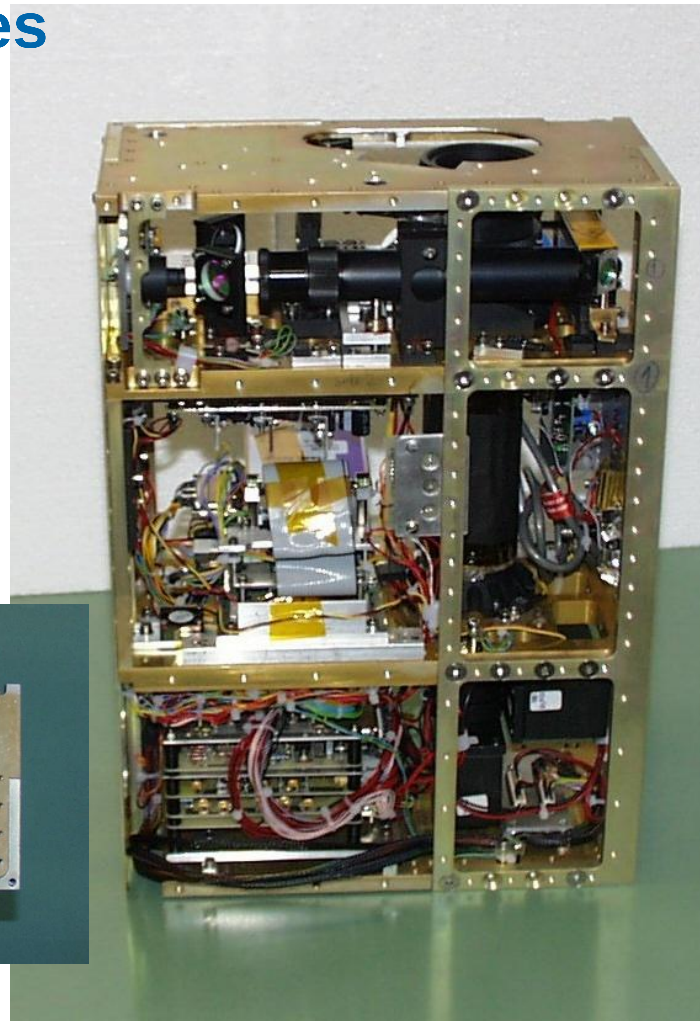
Here only a selected set; Complete set of specs - in the “Handbook of Instruments/30 March 2007;

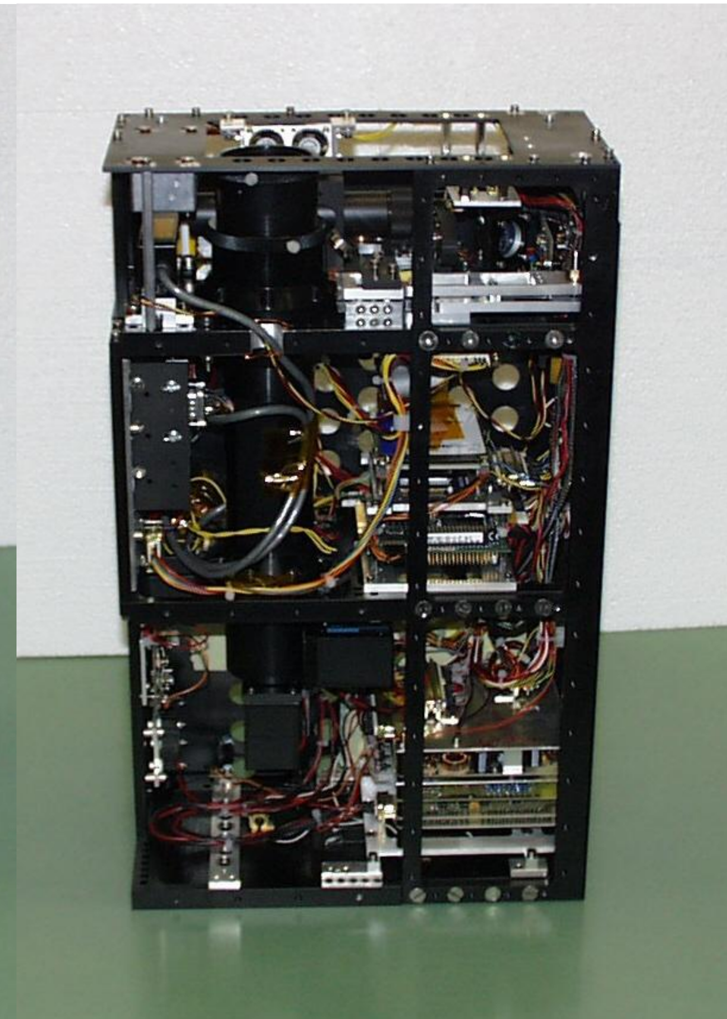
Transmitter		**Detector**	
Laser type	NANOLASE NG-0032x-L05	*PMT (module with SW PMT tube)*	Hamamatsu H6240-01
Wavelength	532nm	*Sensitivity /dark counts (passport data)*	~3.4e5 cps/pW 80/Max 200
Pulse energy/PRR	3.5μJ/5KHz	**Data acquisition**	
Beam Expander	X20	*Type - Photon counting*	Laboratory made multichannel scaler
Beam diam/divergence	8mm/0.25mrad FWHM (+/-0.02)	*Counting rate*	50MHz
Receiver		*Row data time resolution*	6sec
Effective Diameter	48mm	*Row data range resolution*	Adjustable bin: 10m …30m
FOV	0.4mrad	*Number of range bins*	1028 bins
Filter FWHM/TR	0.12nm (Barr)/0.38	*Embedded PC*	486/66 MHz

The filter bandwidth and the depolarisation measurements:



The Assemblies





The Lidars in housings / The campaigns:

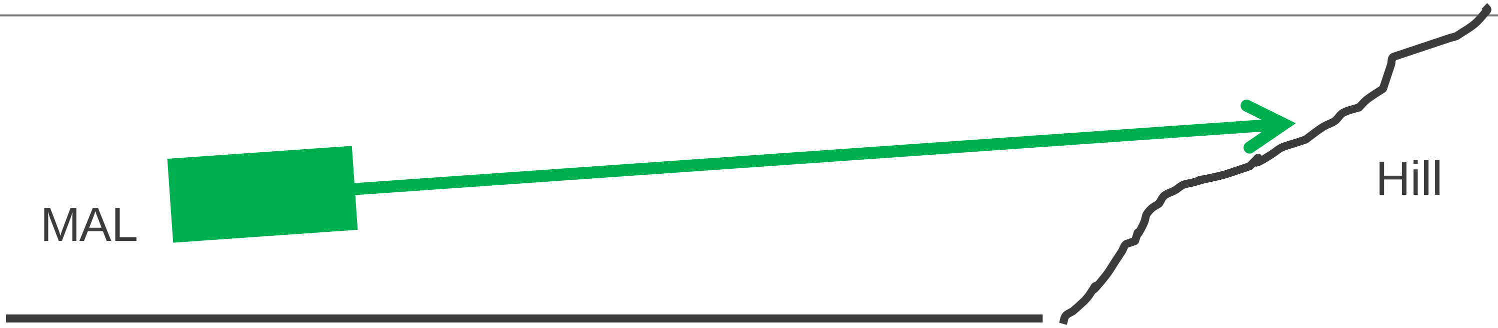
Airborne:

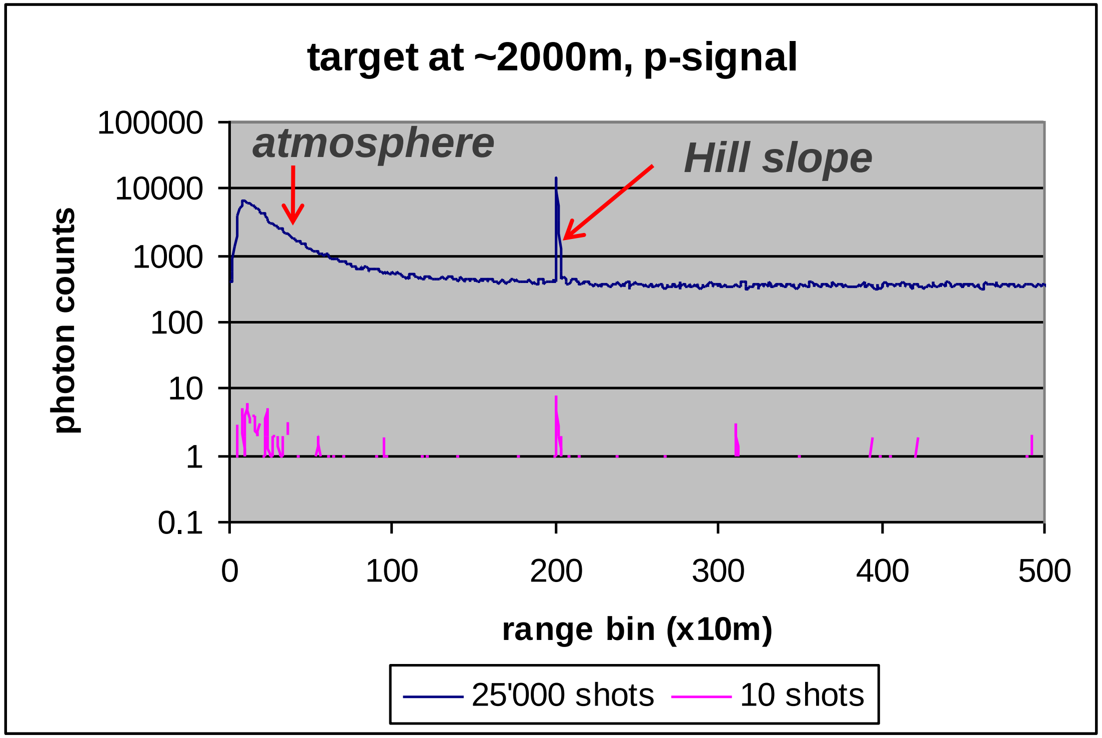
- APE-POLECAR, Rovaniemi – Finland, Dec 1996-Jan 1997
- ETC, Forli - Italy, Dec 1998 – Jan 1999
- APE-THESEO, Mahe – Seychelles, Feb-March 1999
- APE-GAIA, Ushuaya – Argentina, 1996-April 1999 July and Oct 2002
- EUPLEX, Kiruna-Sweden, Jan-Feb 2003
- ENVISAT Validation, Forli July and Oct 2002 Kiruna, Feb-March 2003
- TROCCINOX, Aracatuba- Brazil, Jan-Feb 2005
- SCOUT-O3, Darwin-Australia, Nov-Dec 2005
- RECONCILE, Kiruna-Sweden, Jan-March 2010

Groundbased:

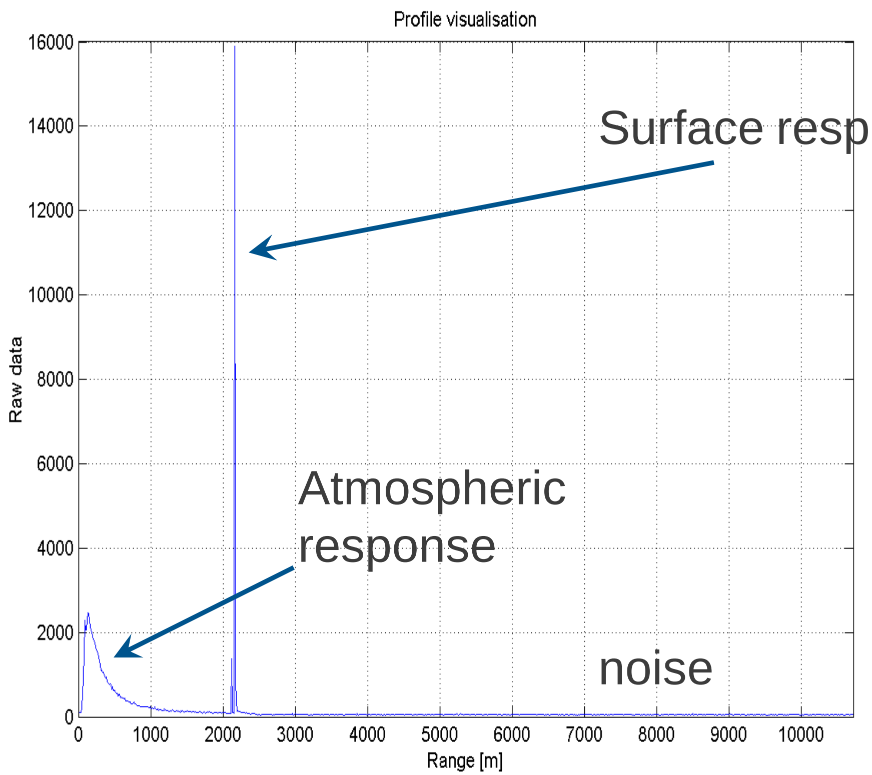
- EARLINET (EC), 2000-2003, intercomparison: Neuchâtel, Paris, Jungfraujoch
- BUBLE (EC, COST715), Basel, Oct 2001- Sept 2002
- EARLINET-ASOS (EC), 2006- Neuchâtel

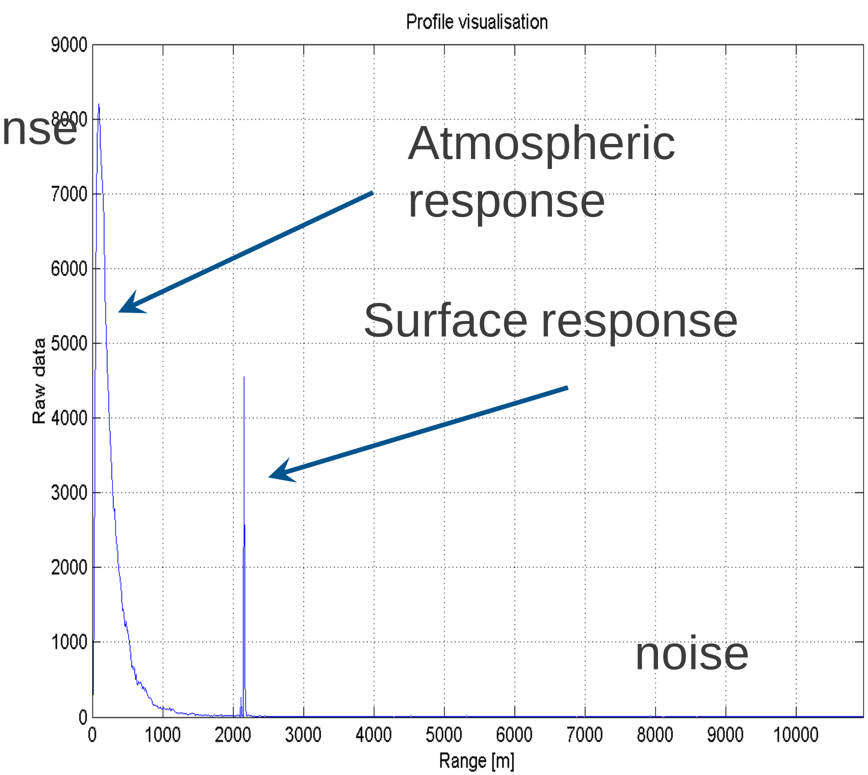
Alignment :


MAL
Hill

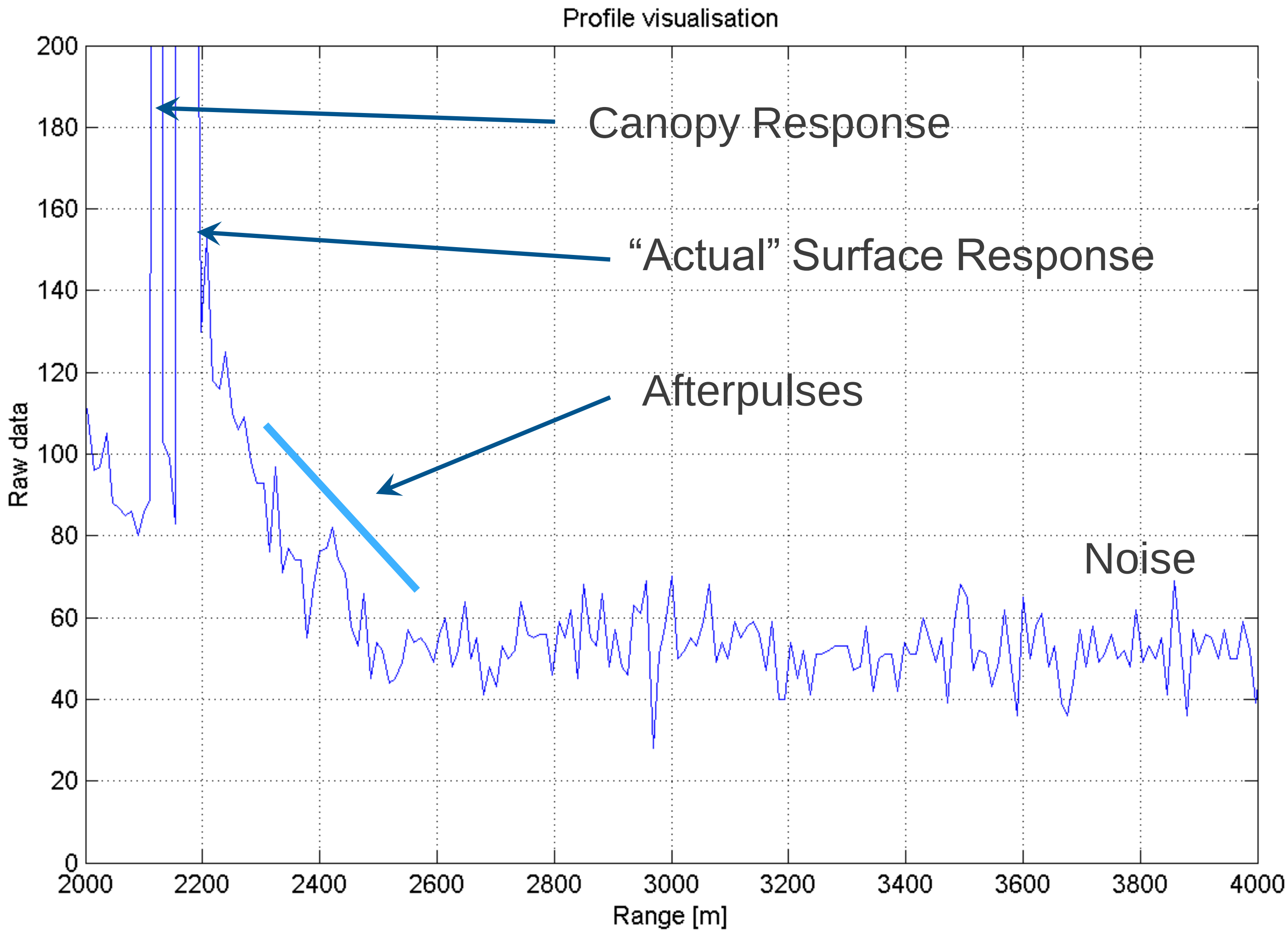

target at ~2000m, p-signal
atmosphere
Hill slope
photon counts
100000
10000
1000
100
10
1
0.1
0
100
200
300
400
500
range bin (x10m)
25'000 shots
10 shots

Alignment +:

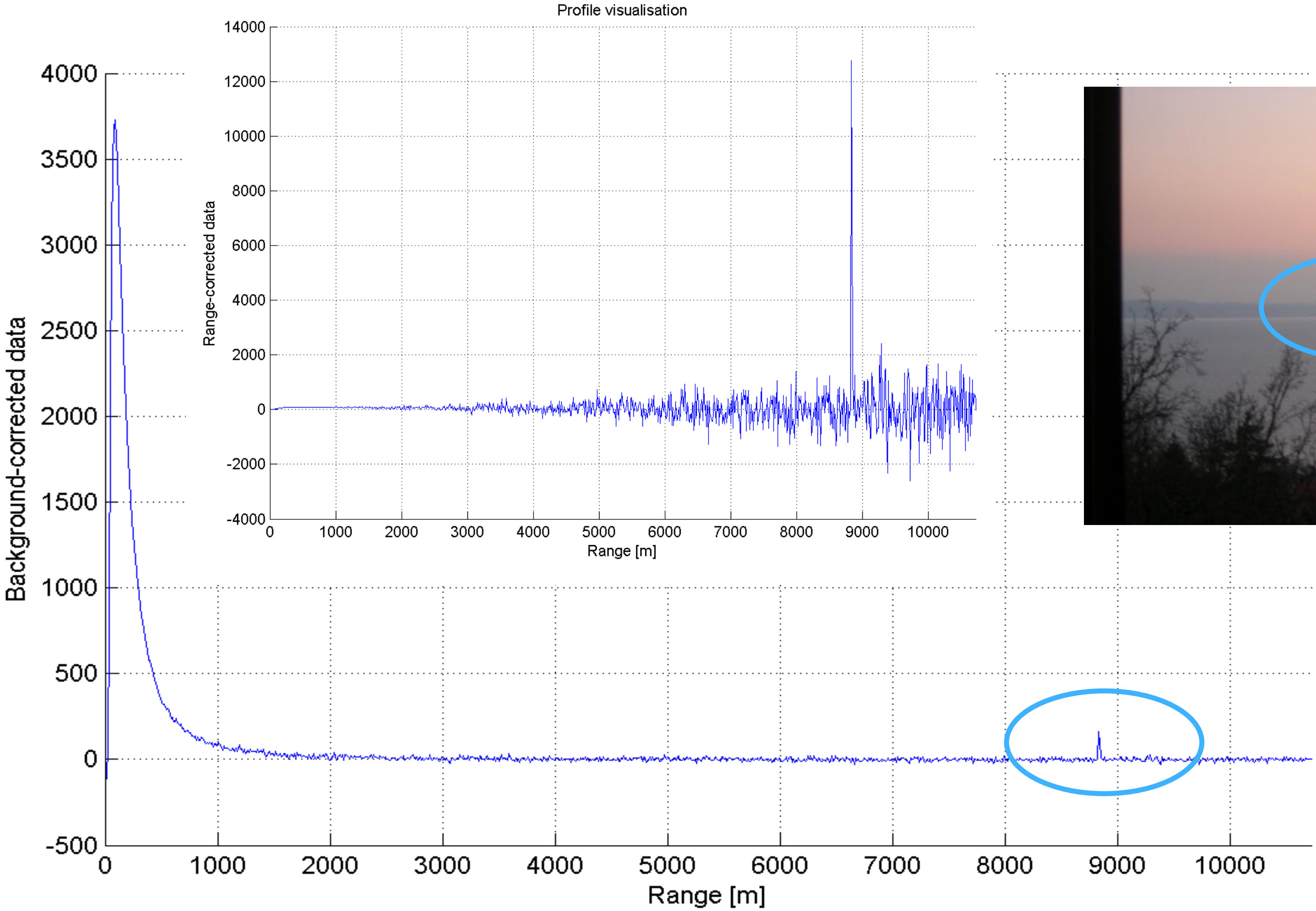

Profile visualisation
Surface response
Atmospheric
response
noise
Raw data
Range [m]
0
2000
4000
6000
8000
10000
12000
14000
16000
1000
3000
5000
7000
9000

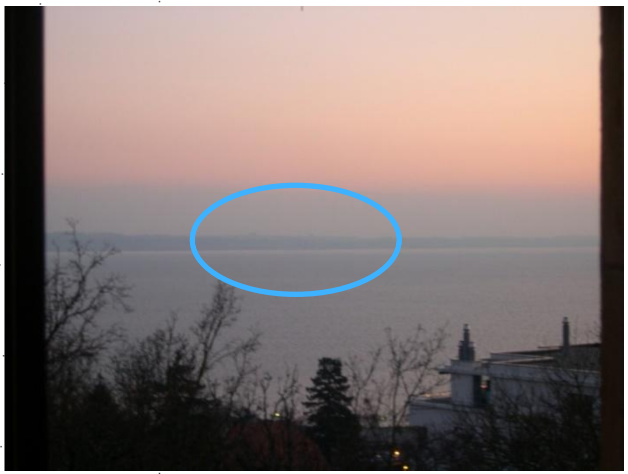

Profile visualisation
Atmospheric
response
Surface response
noise
Raw data
Range [m]
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

Alignment / zoom of the surface response:



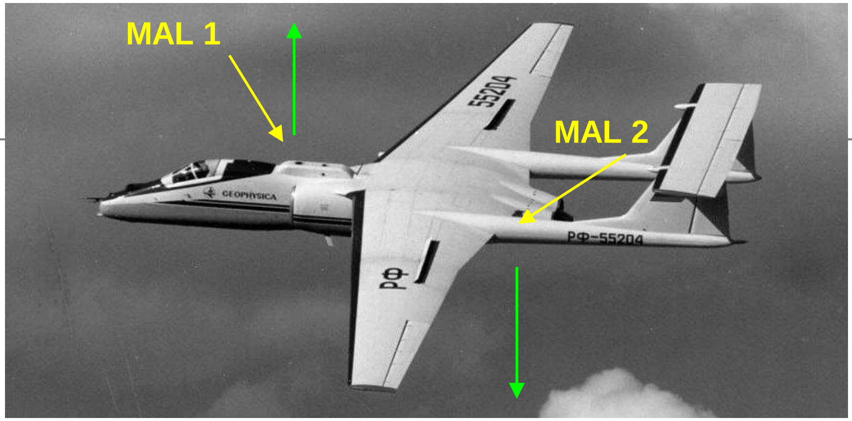
Alignment :

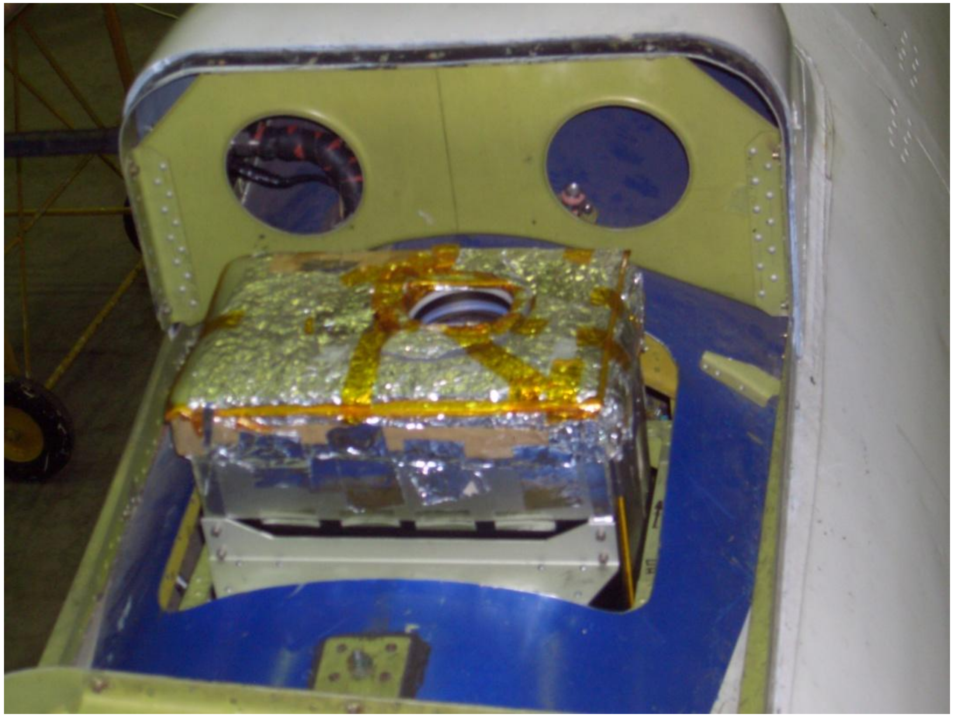

Profile visualisation
Range-corrected data
14000
12000
10000
8000
6000
4000
2000
0
-2000
-4000
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
Range [m]
Background-corrected data
4000
3500
3000
2500
2000
1500
1000
500
0
-500
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
Range [m]

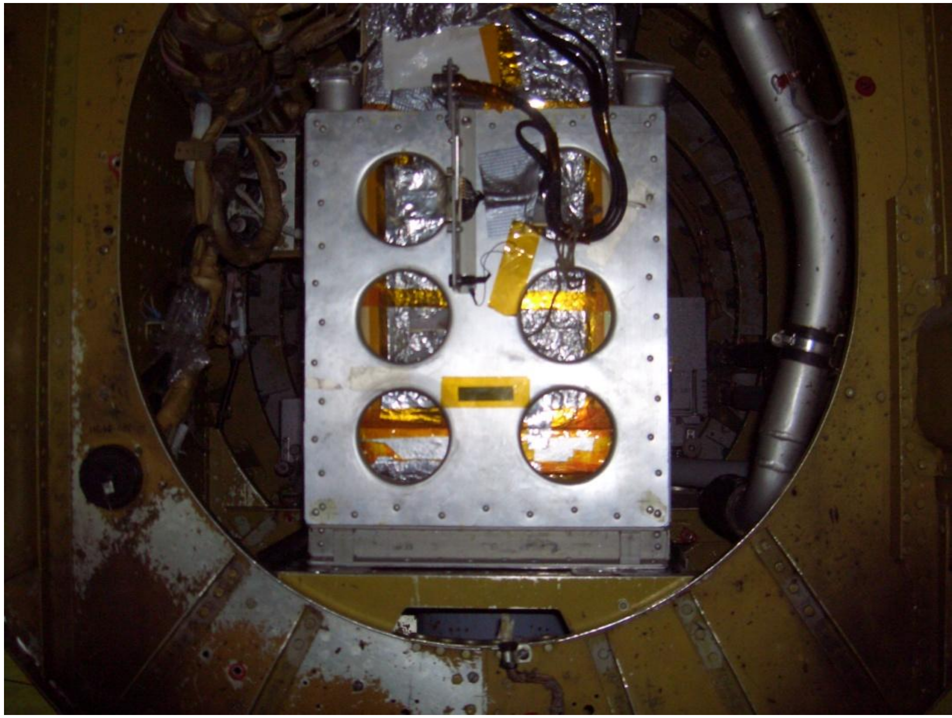


Let us go airborne ....

The Lidars installed on M55:

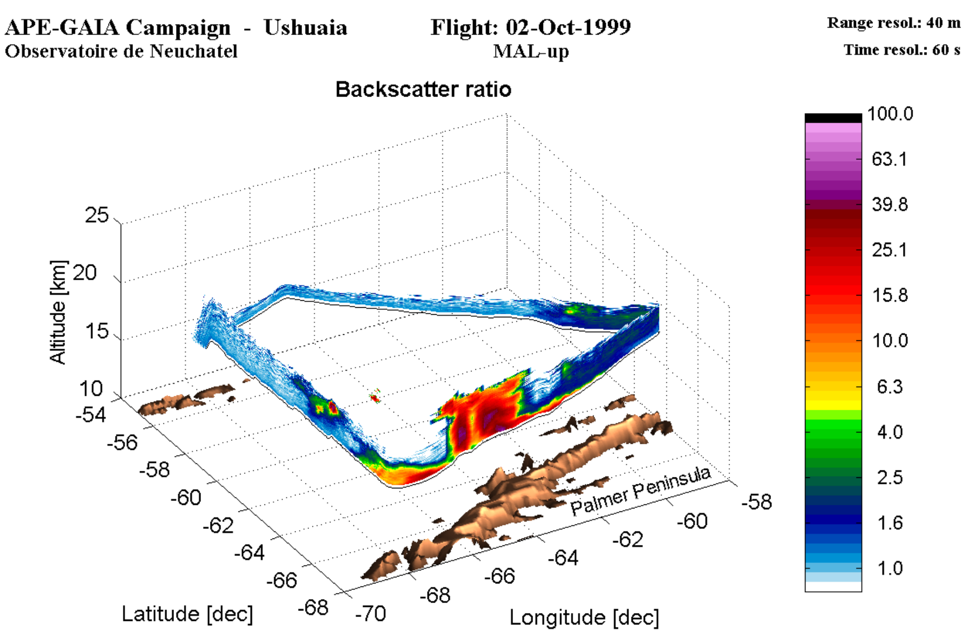


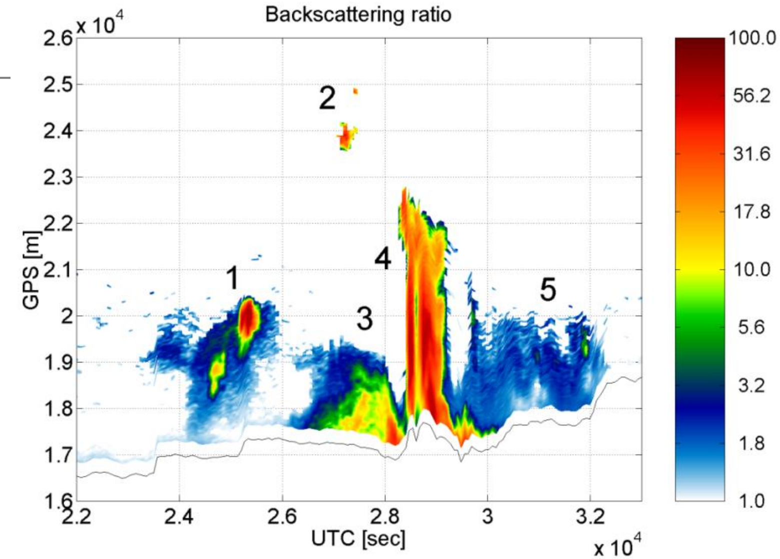


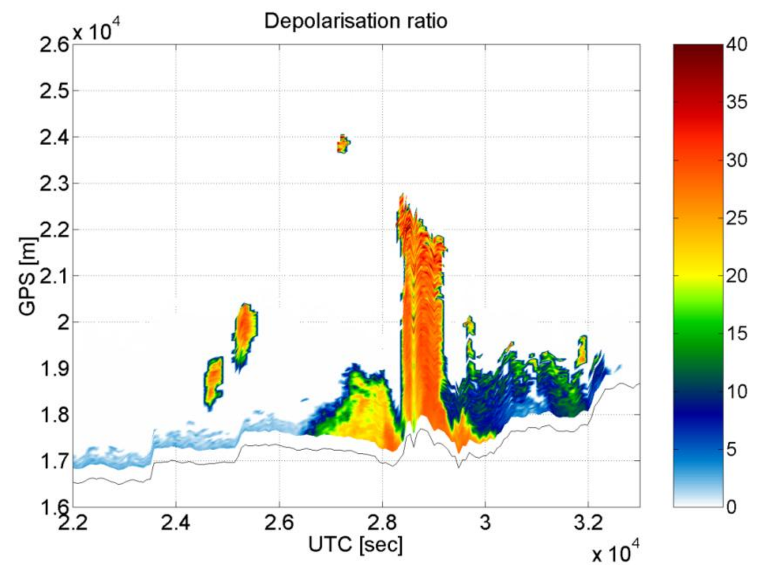


Campaign GAIA/ Over the Antarctic Peninsula from Ushuaia, 1999

Lee-wave PSC type II

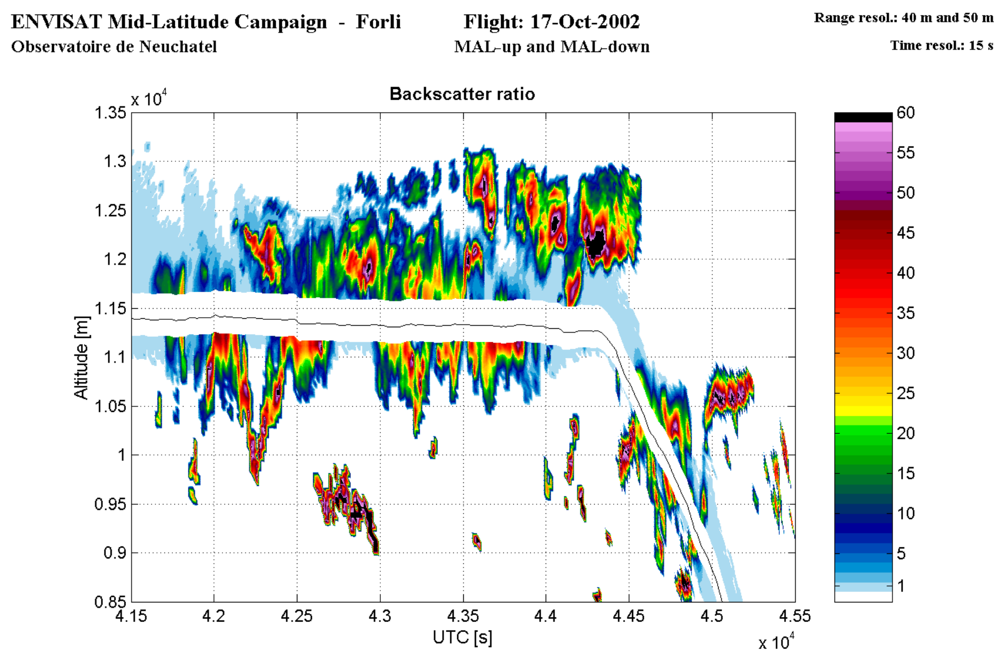


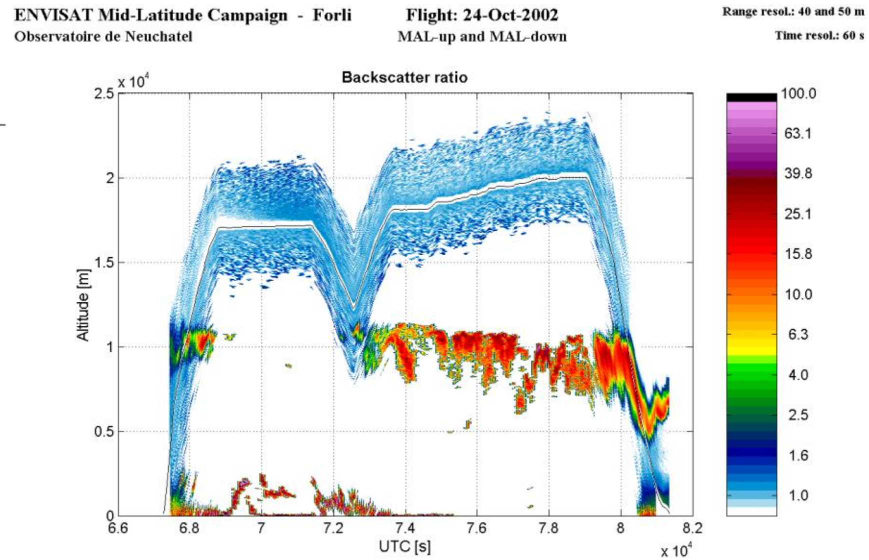


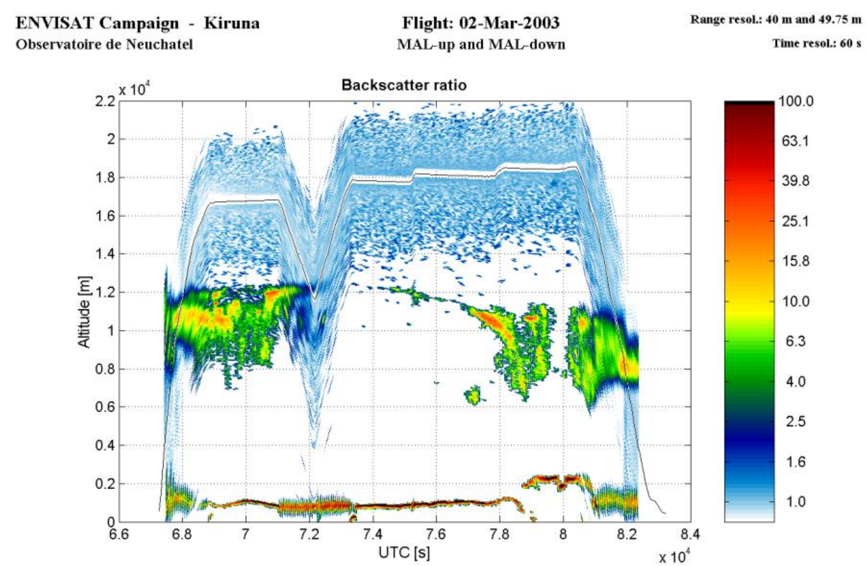


ENVISAT Validation, 2002-2003

Cirrus clouds

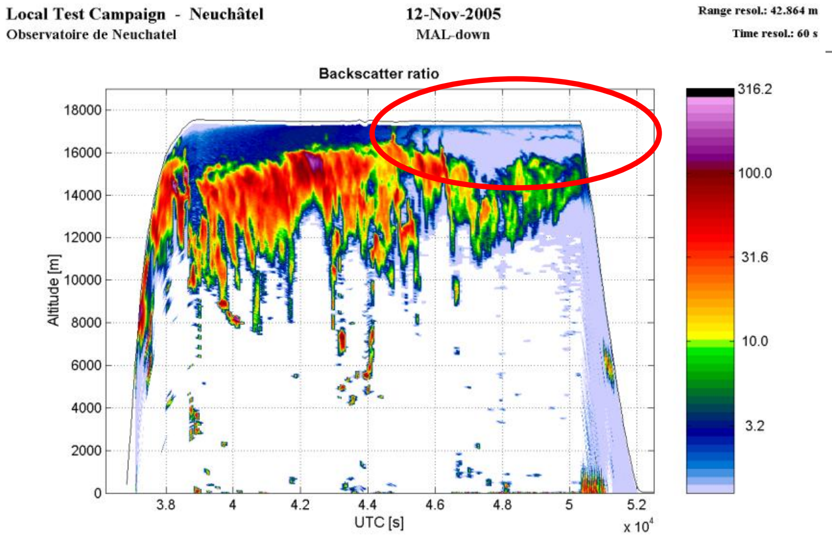


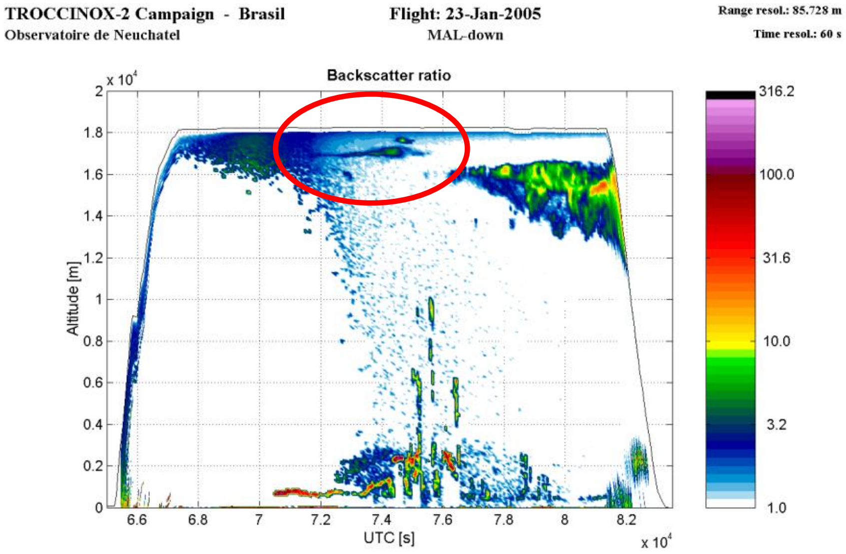


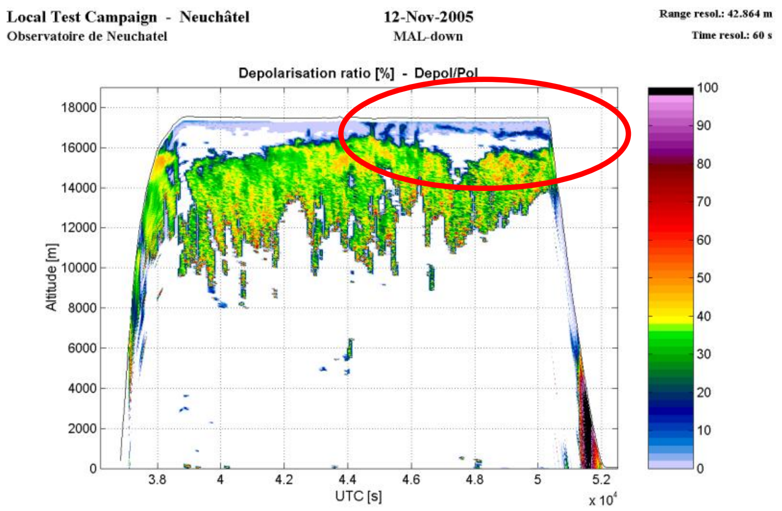


TROCCINOX and SCOUT – O3, 2005

Ultra Thin Tropopause Clouds

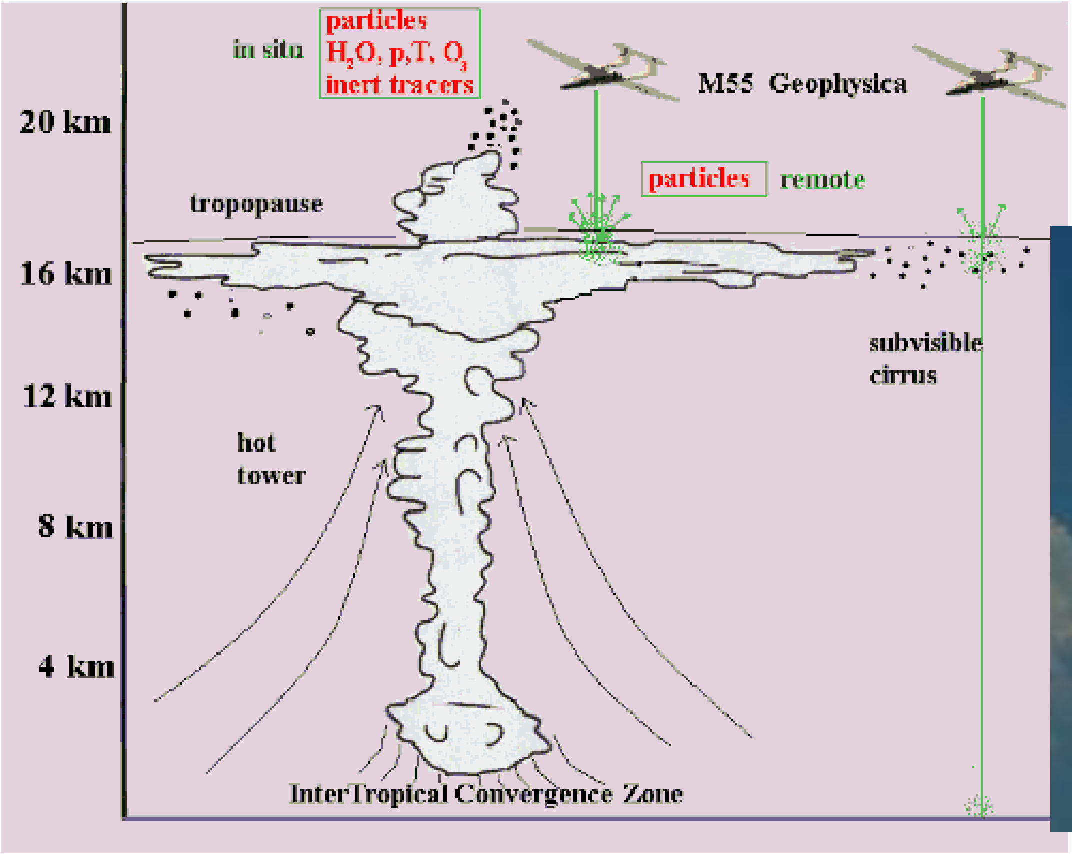






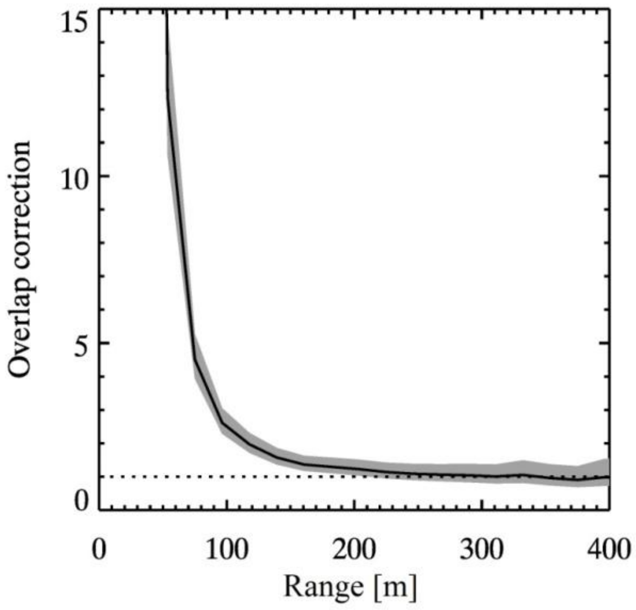
TROCCINOX and SCOUT – O3, 2005

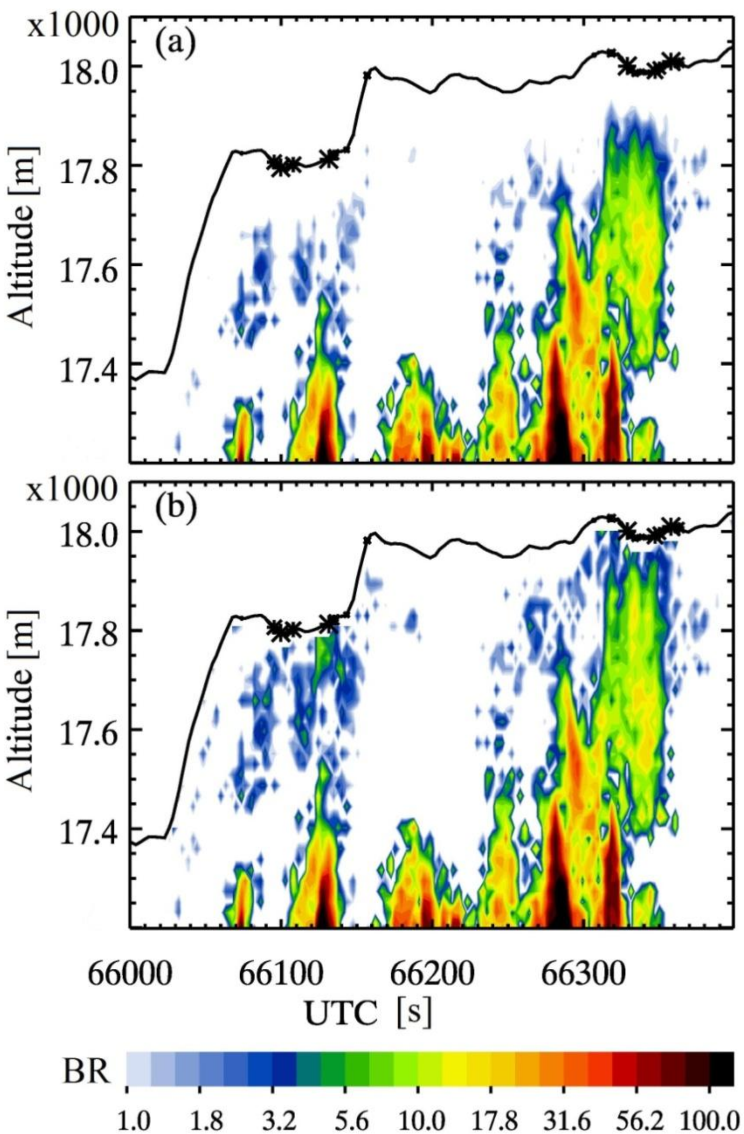
The problem of Tropical convections



TROCCINOX and SCOUT – O3, 2005

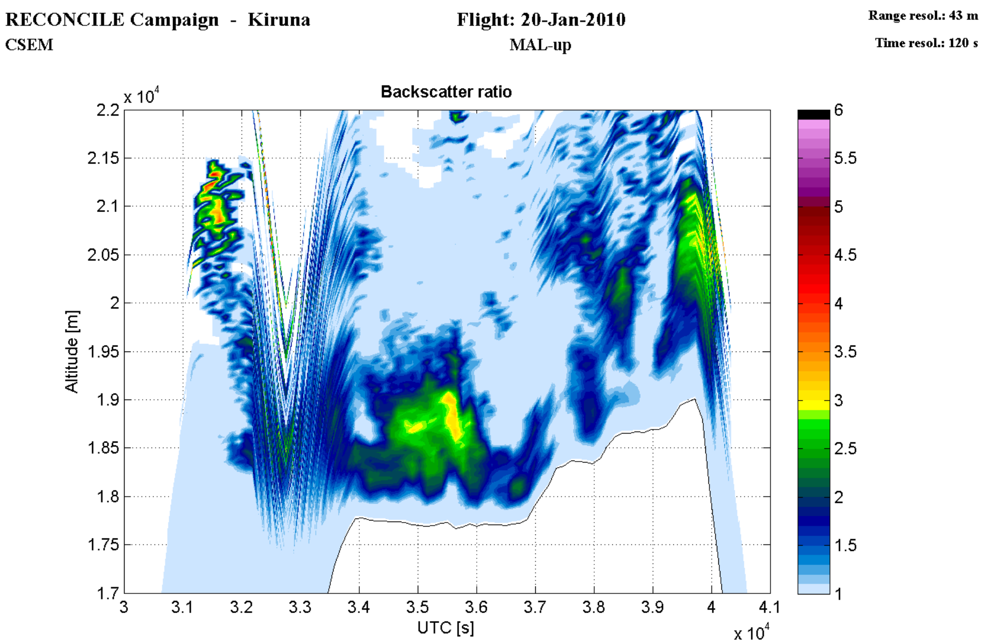
Aerosol layers emerging from the top of high-tropical convection – Correction for the partial overlap using pure molecular backscatter –
Flight on 04 Feb.2005 , TROCCINOX

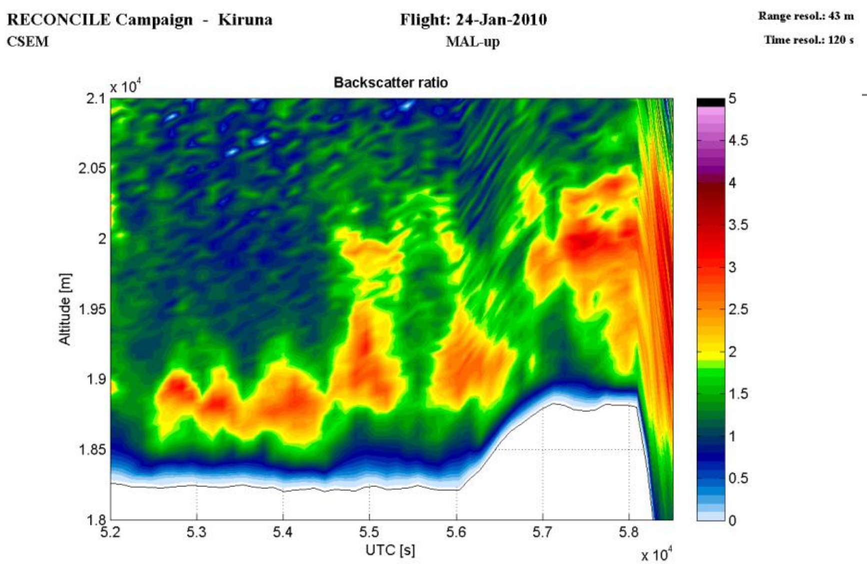


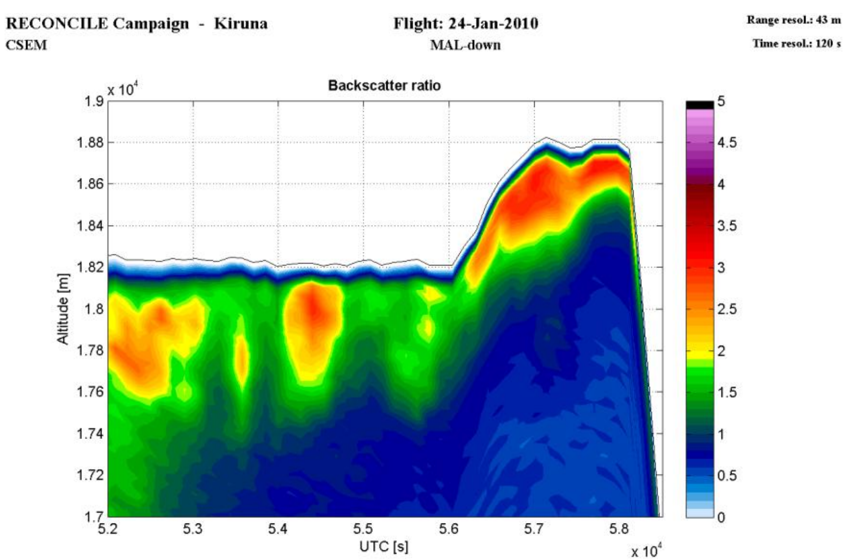


RECONCILE, 2010

Polar Stratospheric Clouds
- synoptic, not lee-wave







Let us come back to the Earth ....

Lower troposphere - Signal processing and output values:

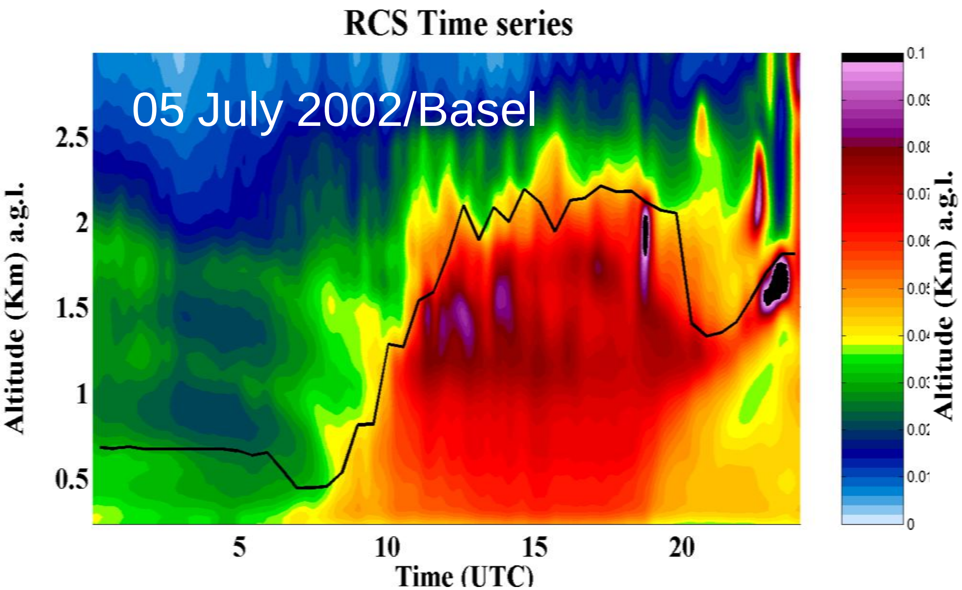
- Aerosol Backscatter Coefficient: Fernald method, “lidar ratio”=50; reference values for molecular atmosphere: radiosonding (Meteoswiss – Payerne, 20km) or SIRA; SR reference values:~1.0-1.2@5500m-6000m

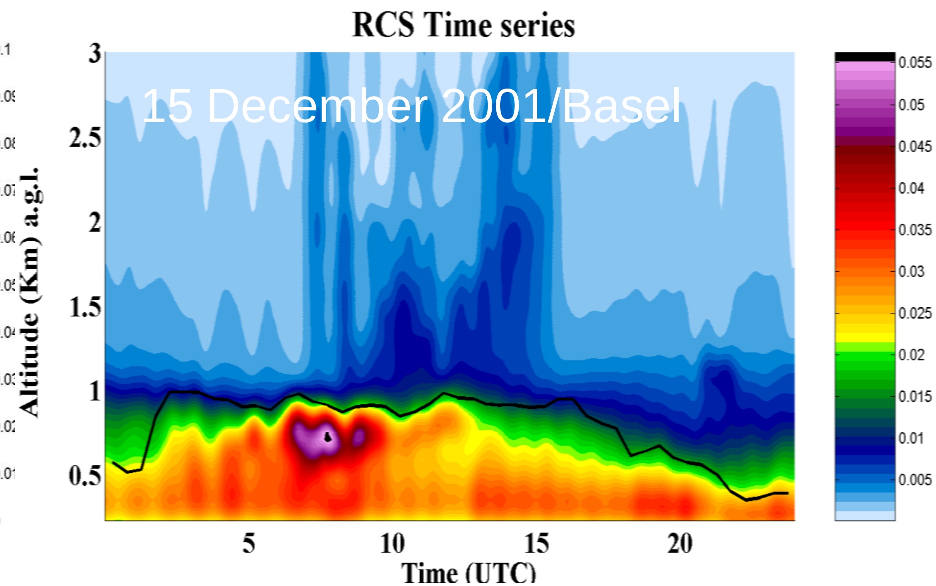
- ABL top: Log-derivative

- Depolarisation Ratio:

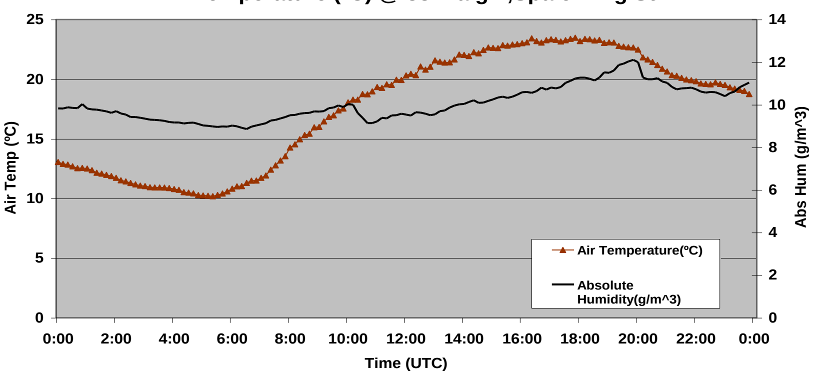
Linear Volume DR; Calibration by 45° method and/or non-polarised light source (special cloud situation found to be very useful);

ABL (mixing layer) top altitude

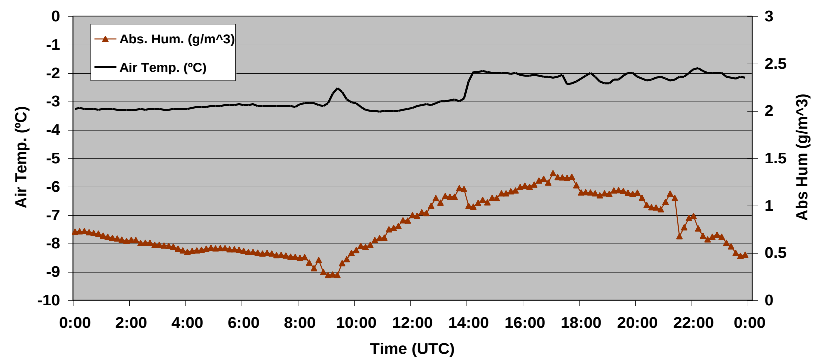




Absolute Humidity (g/m^3) @ 40m a.g.l. in Leonhard St. and Air Temperature (ºC) @ 33m a.g.l.,Spalenring St.

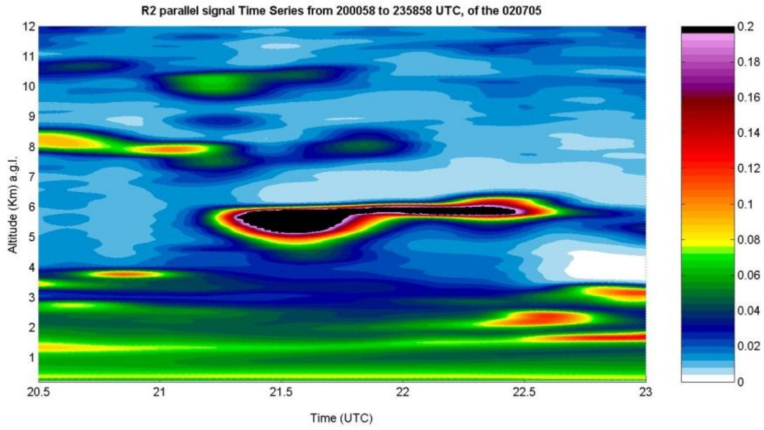


Absolute Humidity (g/m^3) @ 40m a.g.l., Leonhard St. And Air Temperature (ºC) @ 33m a.g.l., Spalenring St.

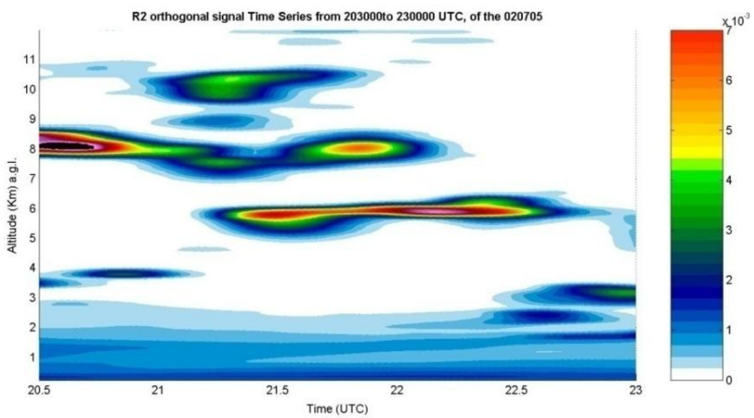


Depolarisation Ratio

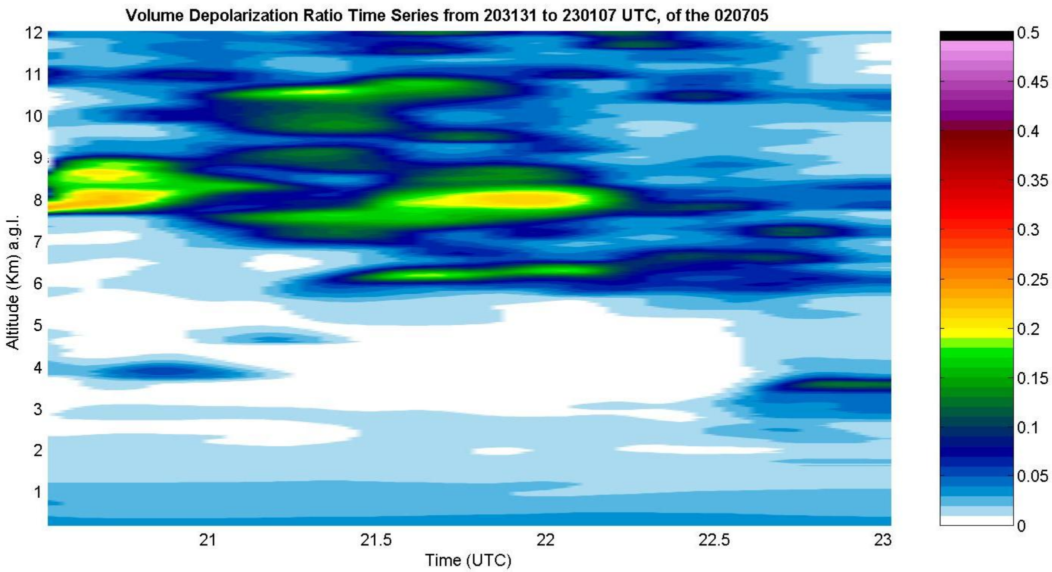
P-polarisation- RC signal



S-polarisation - RC signal

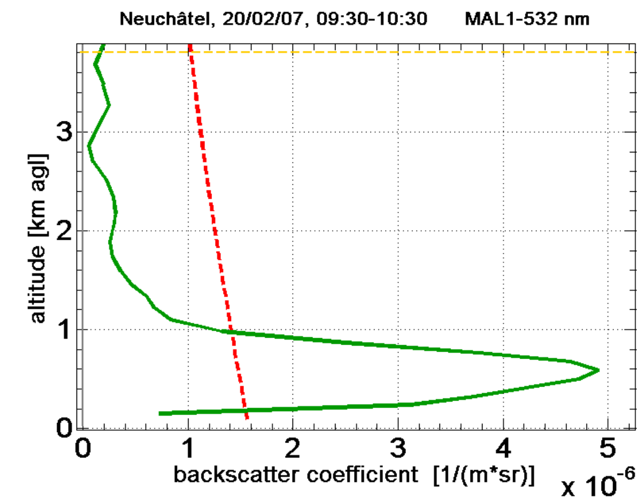


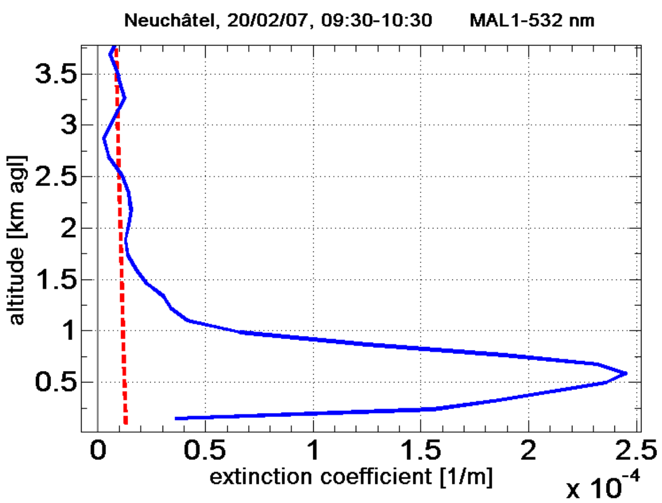
Volume Depolarisation Ratio

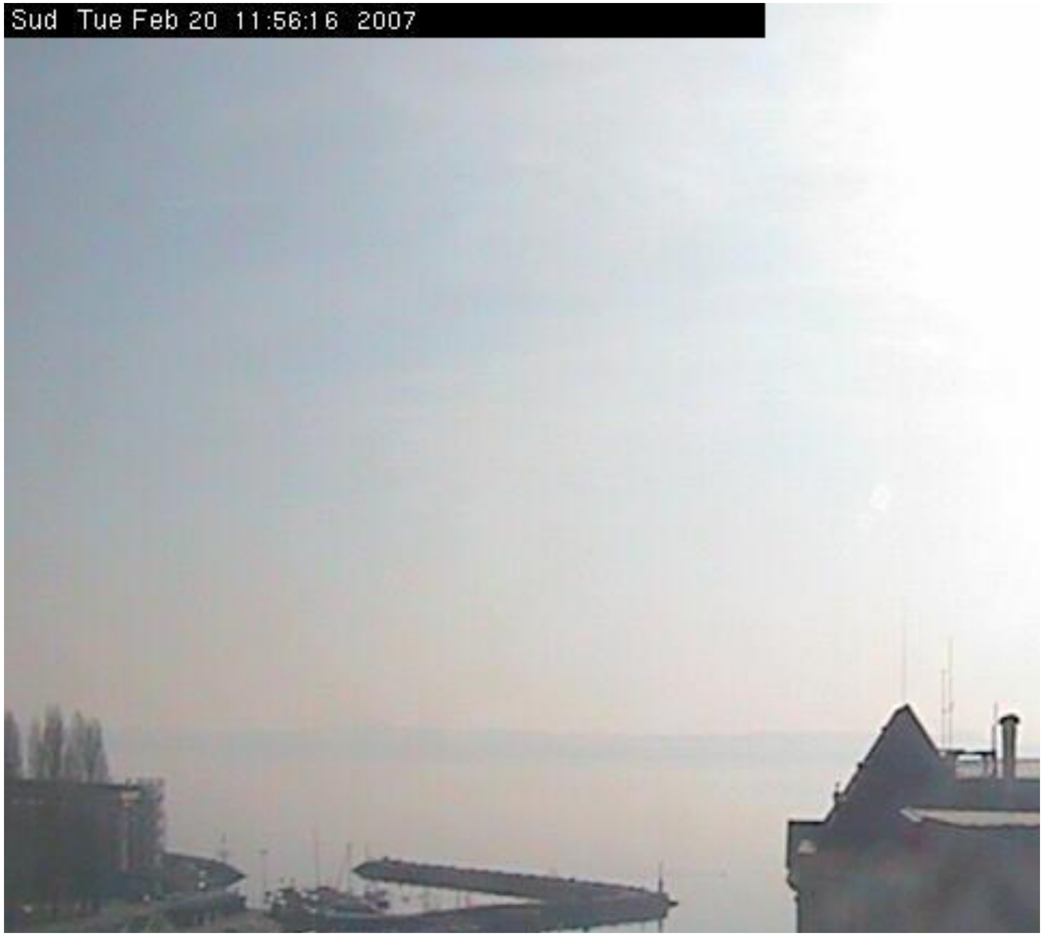


Aerosol Backscatter Coefficient ...

versus the Visibility Range

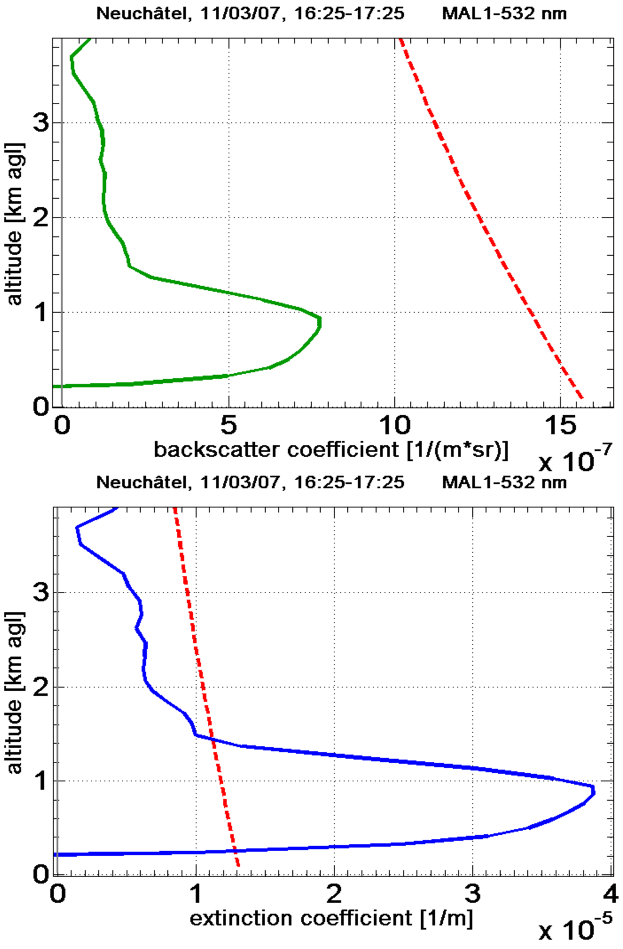


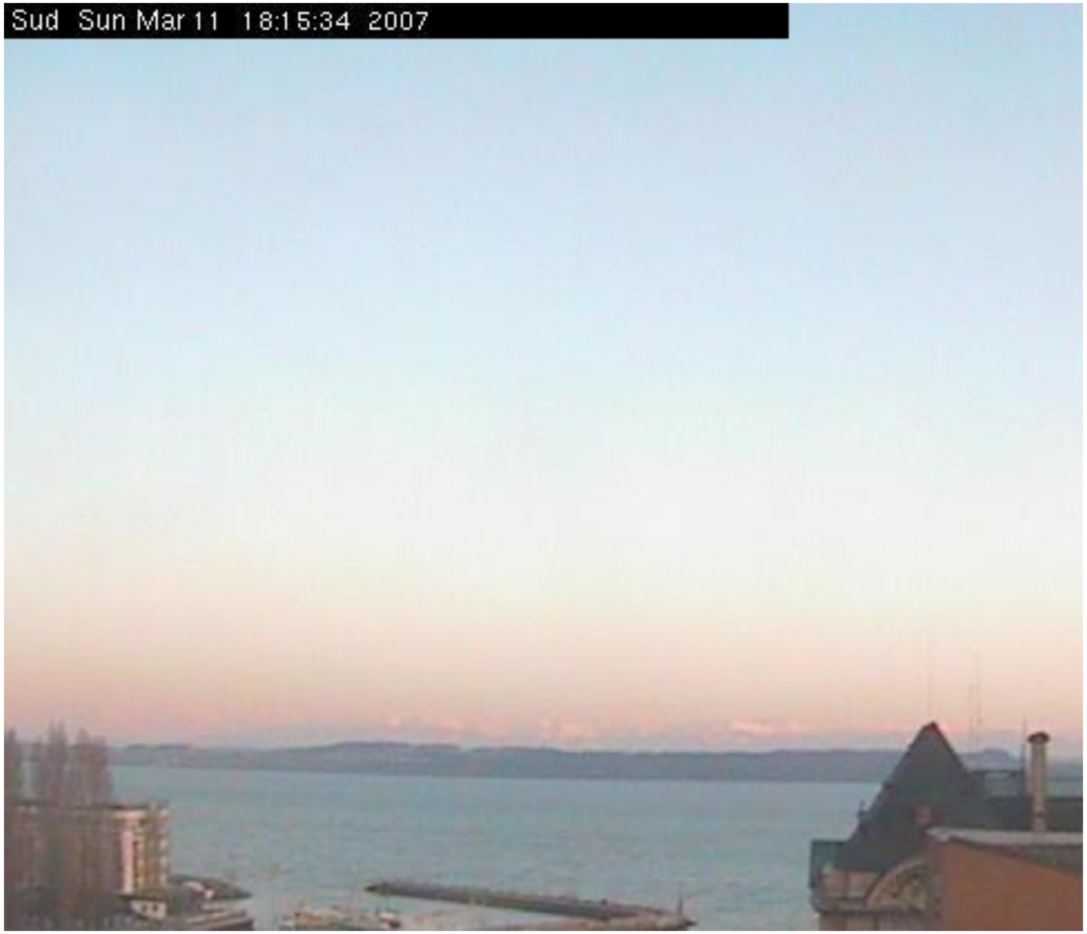




Aerosol Backscatter Coefficient ...

versus the Visibility Range





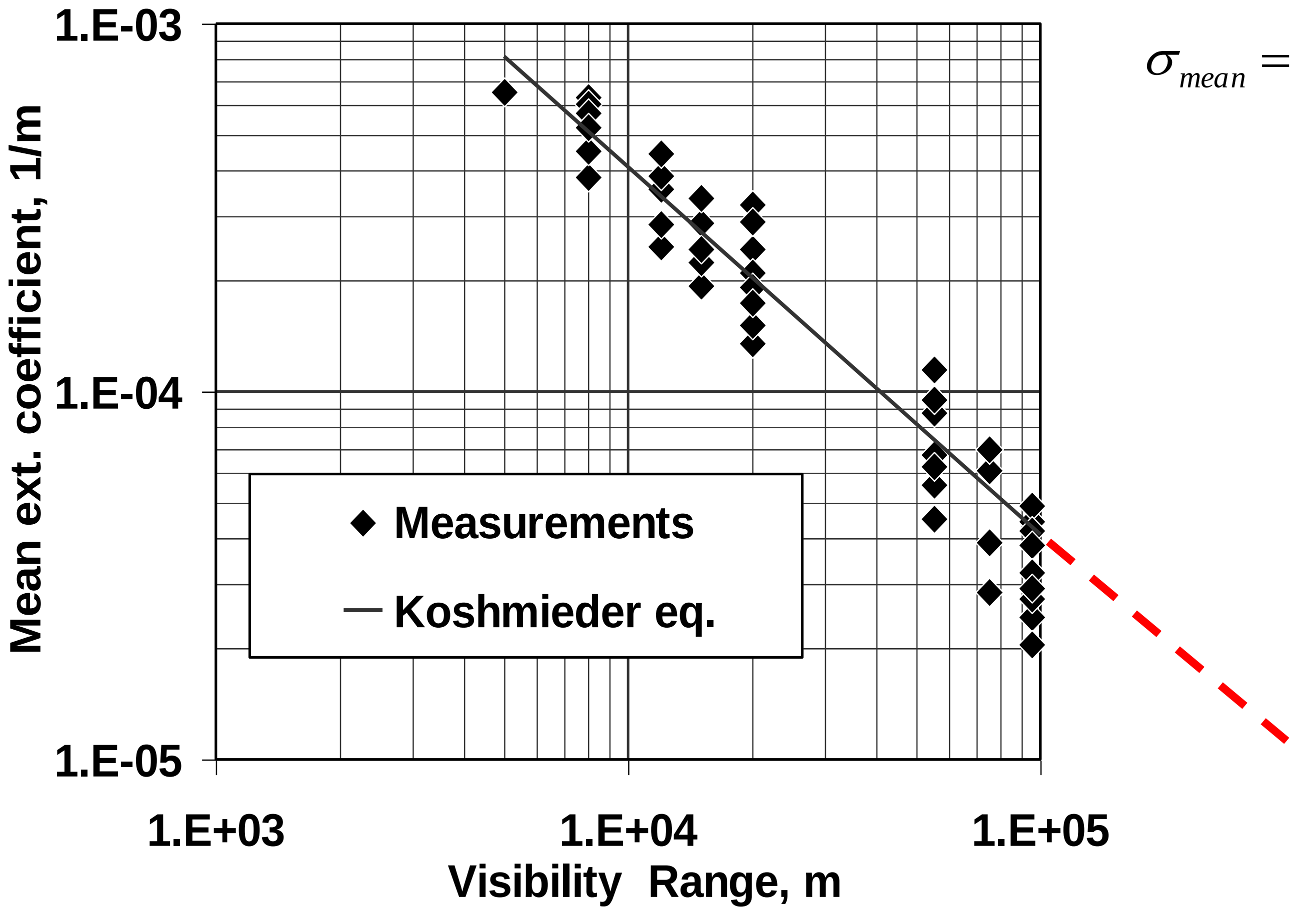
Koschmieder equation

$$R_V = \frac{3.912}{\sigma_{mean}}$$

$$\sigma_{mean} = \frac{\sigma_{PBL}}{R_T} R_1 + \frac{\sigma_{Tropo}}{R_T} R_2$$

No	Topography object, altitude (asl)	Range
1	Opposite shore of lake Neuchâtel (approx 450m)	8 - 12 km (by azimuth)
2	Mt Vully (653m)	15 - 20 km (by azimuth)
3	Mt Ochen (2184m) and Mt Stockhorn (2195m) - Fribourg	55 km
4	Mt Wildstrubel (3243m) and Mt Balmhorn (3698m) - Fribourg	75 km
5	Mt Jungfrau (4158m) and Mt Mönch (4099m)	95 km

... And the two together



$$\sigma_{mean} = \frac{\sigma_{PBL}}{R_T} R_1 + \frac{\sigma_{Tropo}}{R_T} R_2$$

Conclusion:

There is a lidar technology, ready to fill the gaps, where "big " lidars can not go