Mixing layer depth monitoring by lidar and ceilometer networks

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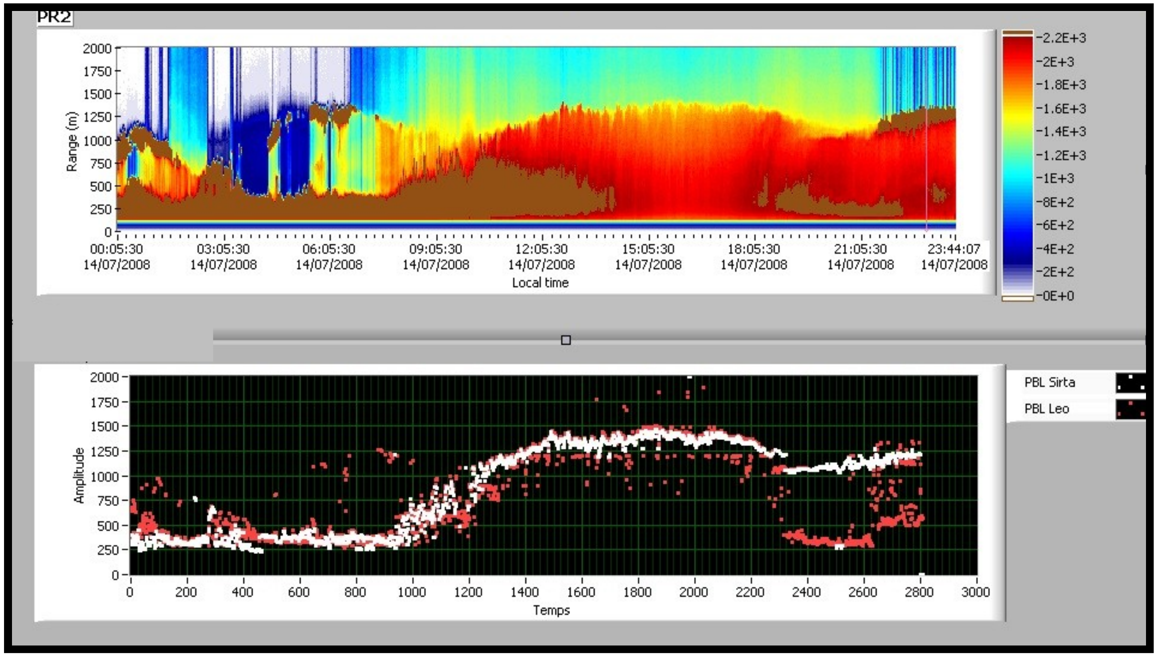
Contribution from I. Xueref-Remy from LSCE/IPSL



NetFAM/EG-CLIMET Workshop
18-20 March 2009 - Oslo, NO

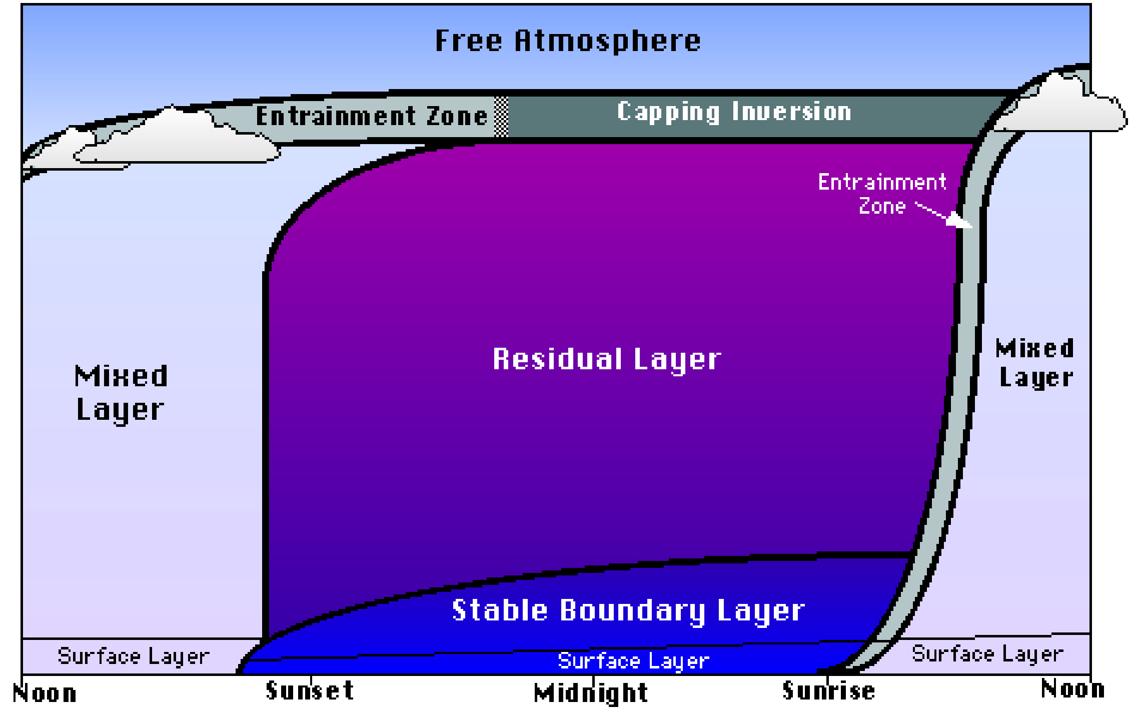
Definition of mixing layer depth

Layer in which heat, momentum, gaseous constituents and aerosols are transported from and to the Earth's surface

"The mixing depth defines the top of the layer near the surface where turbulent mixing is occurring." (White et al. 2009)

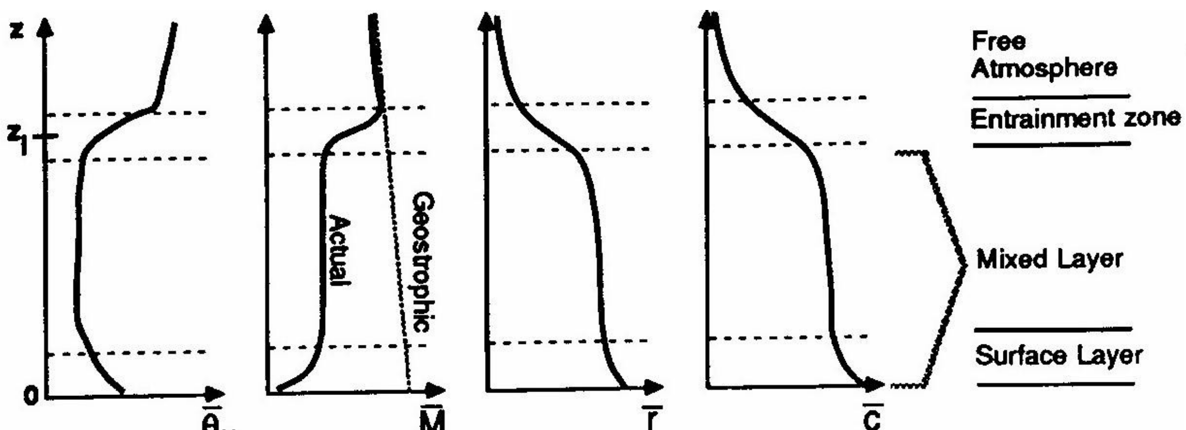
Convective mixing layer: capped by entrainement zone where the vertical heat flux gradient reverses sign

Stable mixing layer: a layer of low and sporadic turbulence

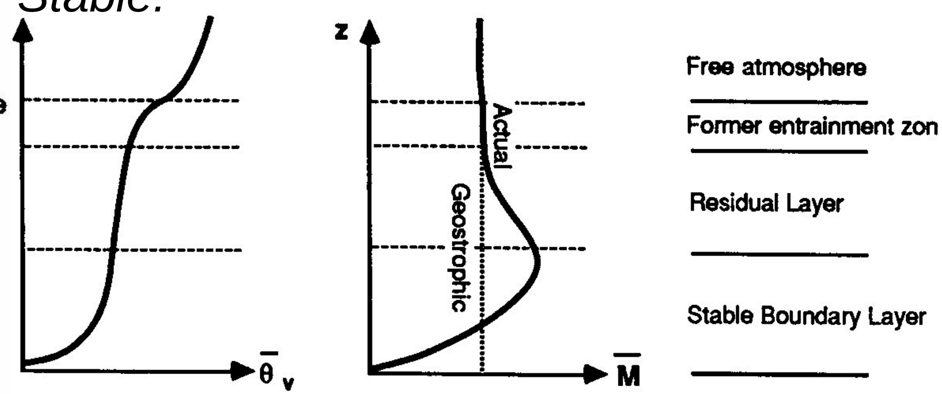


Structure of Planetary Boundary Layer
adapted from Stull, 1988.

Convective:



Stable:



Potential temperature θ_v, wind speed M, water vapor mixing ratio r, and pollutant concentration c

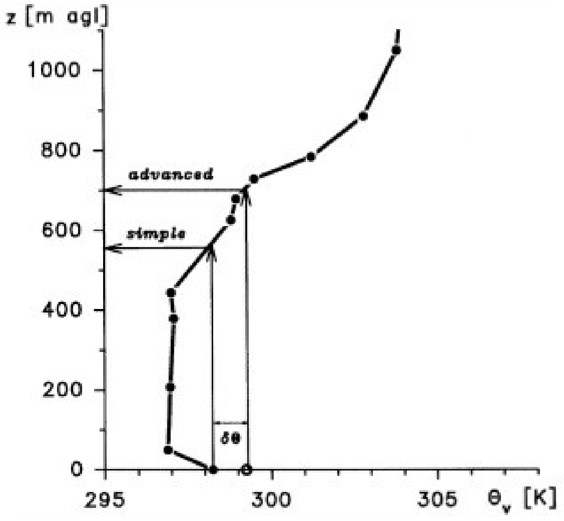
Determination of mixing layer depth

From profiles of temperature, humidity, wind and turbulence parameters:

Parcel method (Holzworth 1972): height of intersection of the actual potential temperature profile with the dry-adiabatic ascent starting at near-surface temperature.

Height where turbulent kinetic energy (TKE) first drops below some fraction of its value at the surface or below some arbitrary lower limit based on experience.

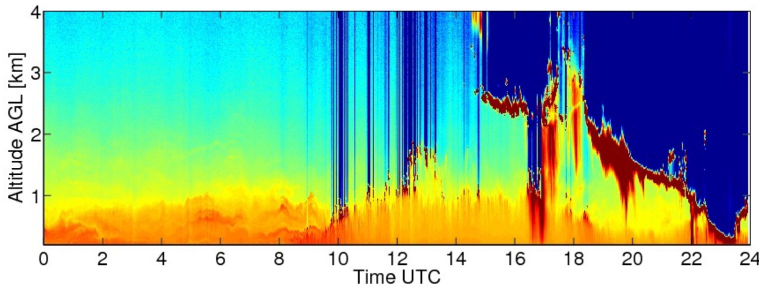
Height where the bulk Richardson number for the model outputs surpasses a critical value beyond which the atmosphere is considered decoupled (0.25 Seibert et al., 2000)



From active remote sensing:

·Radar and Sodar: scattered by temperature inhomogeneities Cn2 (max at top of ML)

·Lidar: scattered by aerosols (strong gradient at top of ML)



Mixing layer depth detection methods using lidar remote sensing - State of the Art

1D methods *(well described in literature)*

- **Vertical gradient** method (1st, 2nd derivative)
- **Temporal variance** method
- **Wavelet** based covariance method
- **Idealized profile** method

2D methods *(not described in literature)*

- **Sobel/Canny gradient** method (~ 1st derivative)
- **LoG « Laplacian of Gaussian »** method (~ 2nd derivative)
- **Wavelet** based method
- **Phase congruency** method

1D methods
- **Vertical gradient method**
- Temporal variance method
- Wavelet based covariance method
- Idealized profile method

2D methods
- Sobel/Canny gradient method (~ 1st derivative)
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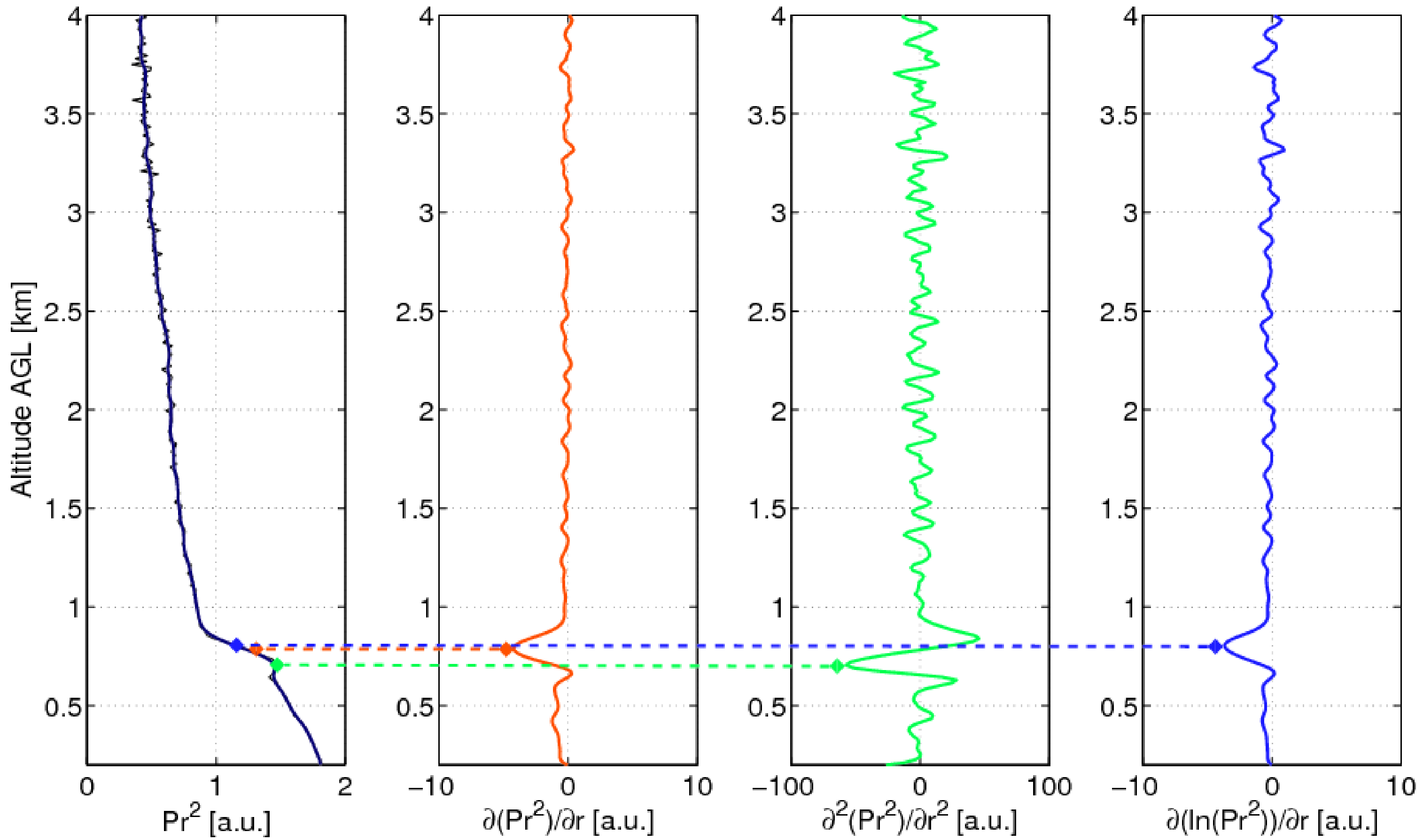
- Phase congruency method

1D methods - **Vertical gradient** method (1st, 2nd derivative)



Lidar signal
-
raw and smoothed

Mininum of 1st derivative of lidar signal

Mininum of 2nd derivative of lidar signal

Mininum of 1st derivative of the logarithm of lidar signal

References:

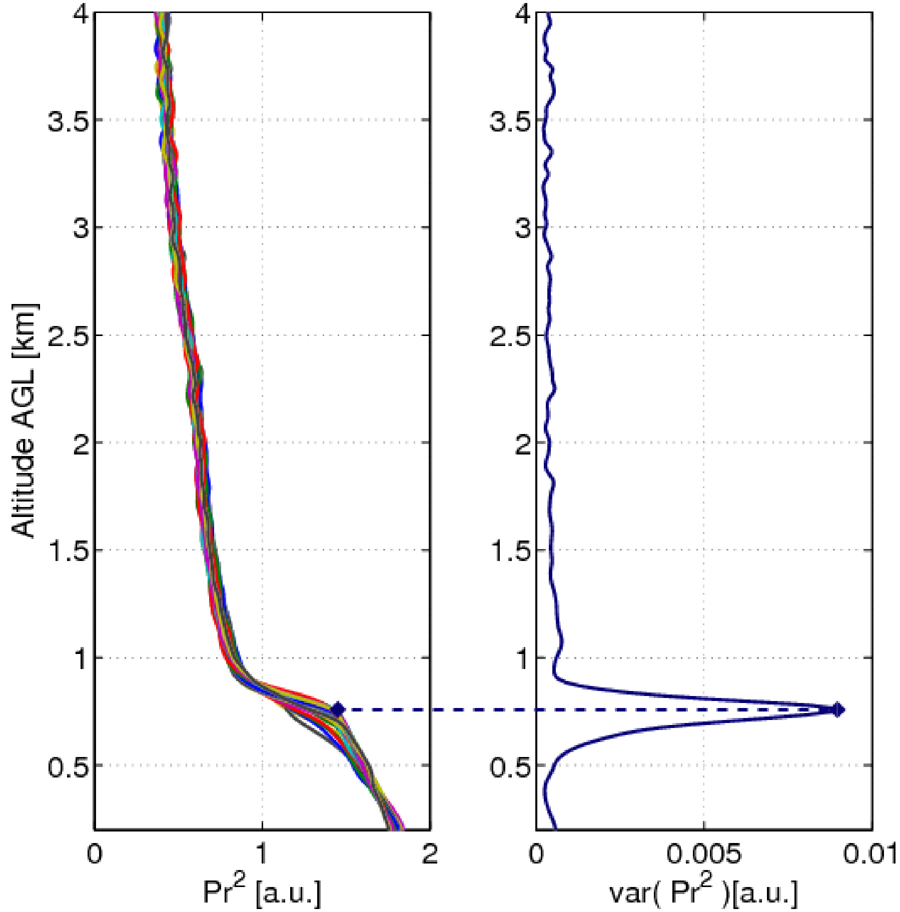
Melfi et al., 1985

Flamant et al., 1997

Martucci et al., 2007
Menut et al., 1999

Sicard et al., 2006

1D methods - **Temporal variance** method



Lidar signal
-
20 profiles

Maximum of variance of lidar signal

References:

Hooper and Eloranta, 1986.

Menut at al., 1999

Hennemuth and Lammert, 2005

ABL detection
-
State of the Art

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- **Wavelet based covariance method**
- Idealized profile method

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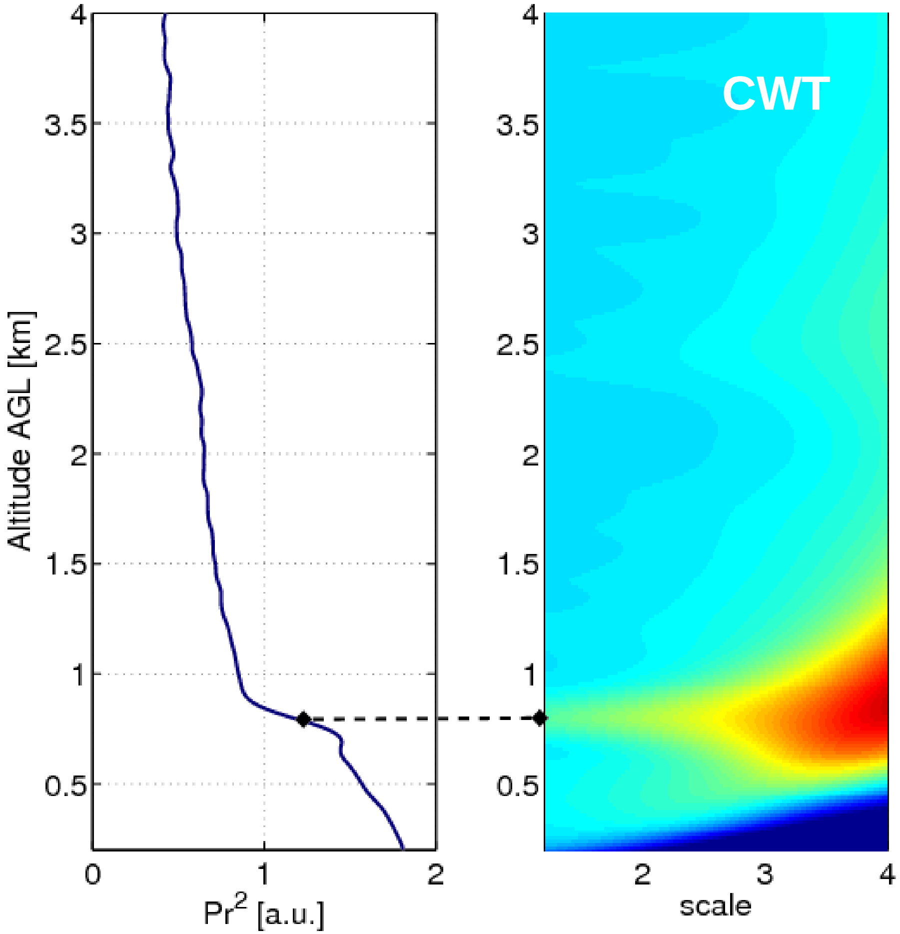
1D methods – **Wavelet** based covariance method



Lidar signal

Maximum Wavelet Coefficient

References:

Baars et al., 2008

Brooks, 2003

Cohn and Angevine, 2000

Engelbart et al., 2008

Haij et al., 2007

Morille et al., 2007

Wauben et al., 2008

"MLH can be derived in about 55% of the cases of which 25% is of a good quality"

ABL detection
-
State of the Art

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2D methods
- **<u>Sobel/Canny gradient method (~ 1st derivative)</u>**
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- Phase congruency method

2D methods – Sobel/Canny gradient method (~ 1st derivative)

1st step : Horizontal and Vertical gradient

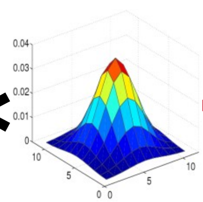
References:

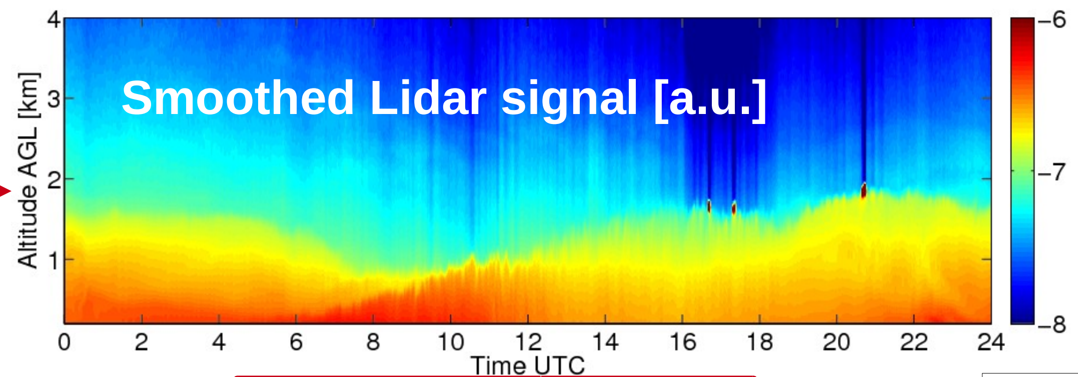
Canny, 1986

Kizhakkemadam, Master of science, 2002

Sobel and Feldman, 1968 unpublished

Lidar Signal *



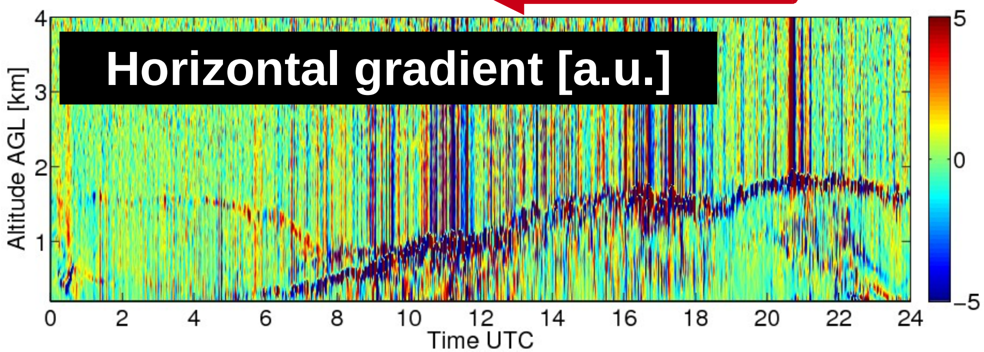


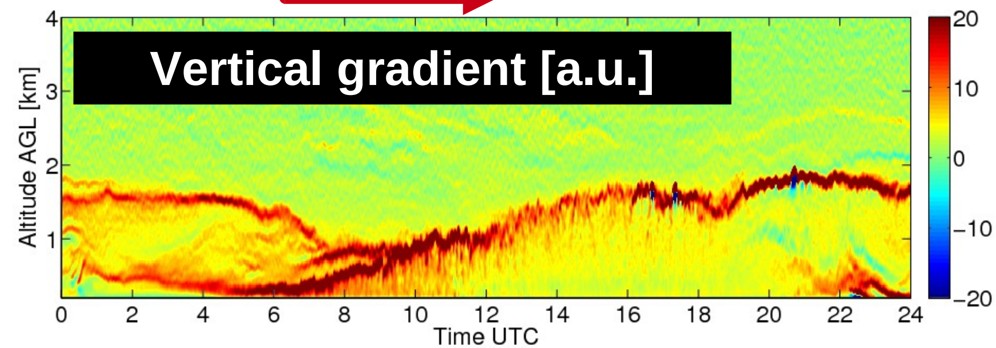
1	0	-1
2	0	-2
1	0	-1

*

*

1	2	1
0	0	0
-1	-2	-1





ABL detection
-
State of the Art

1D methods
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2D methods
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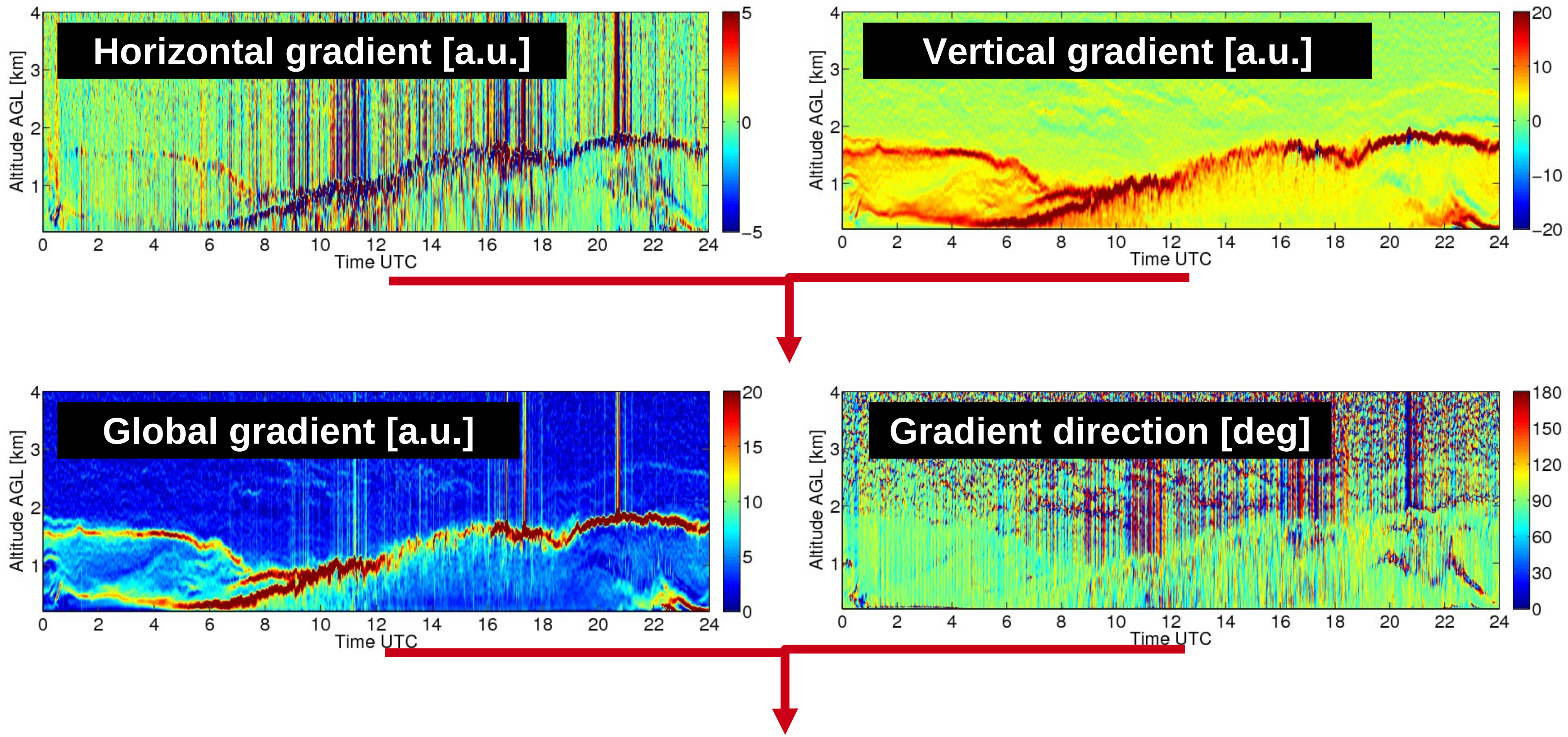
2D methods – Sobel/Canny gradient method (~ 1st derivative)

2nd step : Global gradient and direction



Next steps :
(Under development)

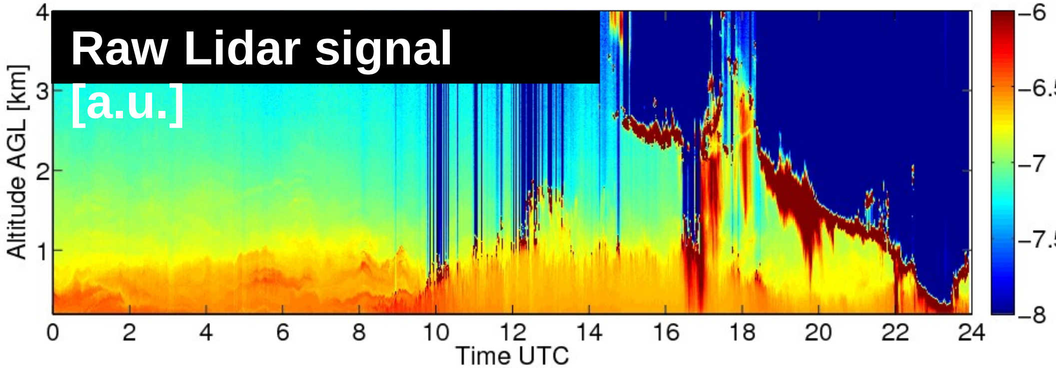
Edge/contour/BL detection
Thresholding

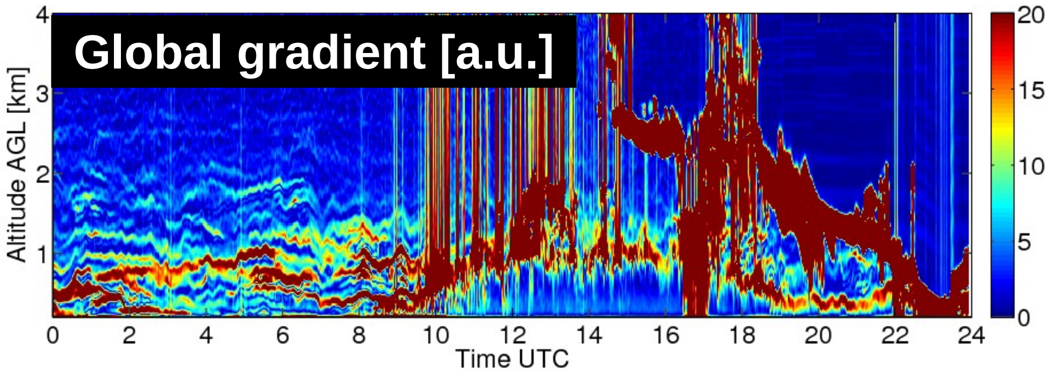
Non maxima suppression
Hysteresis

2D analysis of Lidar and Ceilometer data

Leosphere ALS450 data

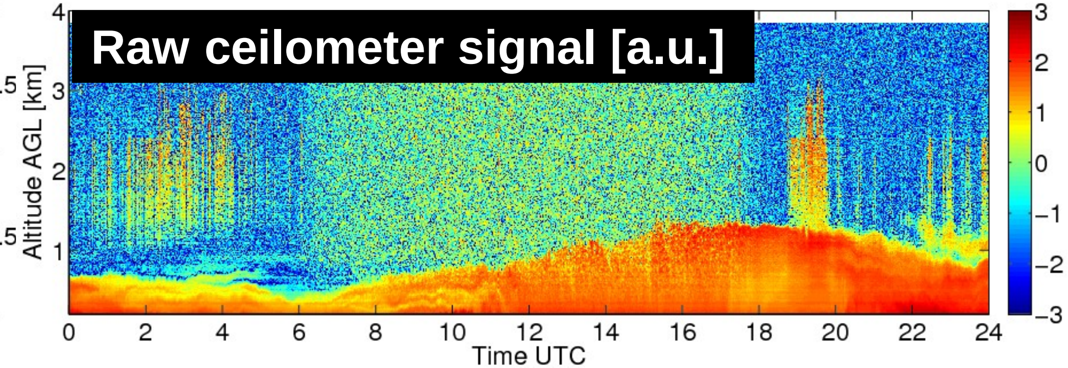
Complex situation including clouds and aerosols

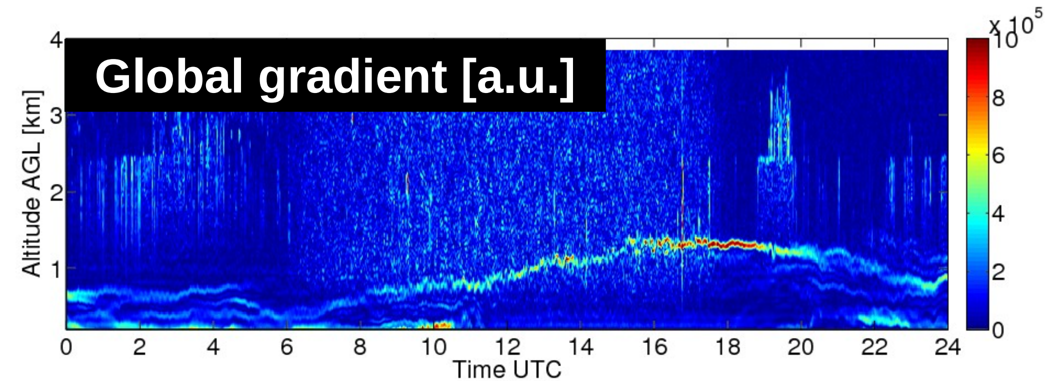




Vaisala (modified) CT25K

Preliminary analysis using 2-D method are satisfactory





<u>Next steps :</u>

Combine with STRAT layer detection (Morille et al. 2007)
Edge/contour/BL detection
Thresholding

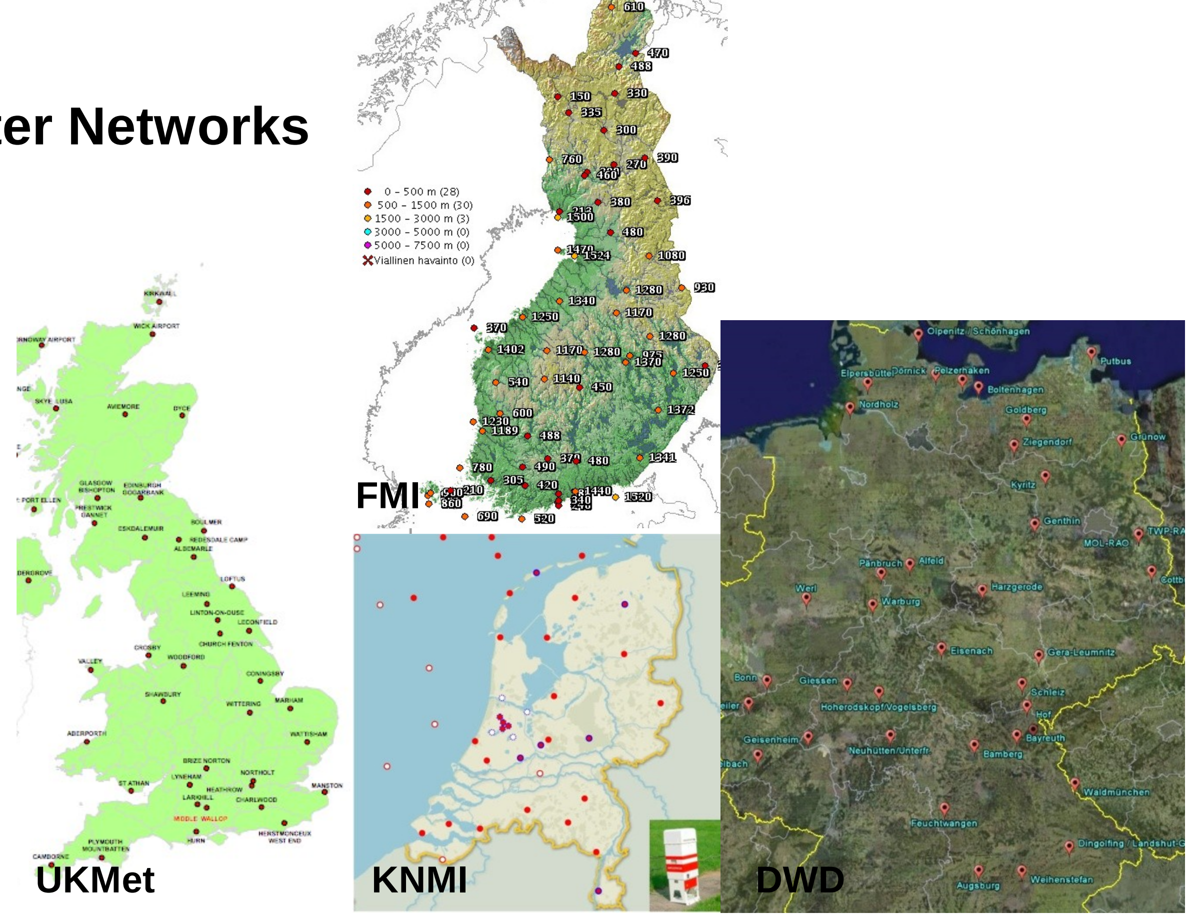
European Meteorological Ceilometer Networks

Ceilometer networks in all (?) European countries

Most systems only provide CBH and VIS (vertical backscatter profile is missing)

WMO TECO 2008 conference, two studies on BLH retrieval from existing ceilometer networks:

- Wauben et al. (KNMI)
- Engelbart et al. (DWD)



Manufacturer	Model / Type	Remarks	Denmark DMI	France France	Iceland IMO	nds KNMI	Sweden SMHI	Switzerlar MeteoSw	Germany DWD	UK UKMet	Finland FMI
Eliasson Engineering AB	CBME80						X				
Vaisala/Impulsphysic	WHX05	Out of production	X	X							
Vaisala	CT25K	Out of production	X	X	X			X		X	X
Vaisala/Impulsphysic	LD40	Out of production	X			X					
Vaisala	CT12K	Out of production	X				X				
Vaisala	CL31	Backscatter profiles	X		X		X			X	X
Jenoptik	CHM 15K								X		

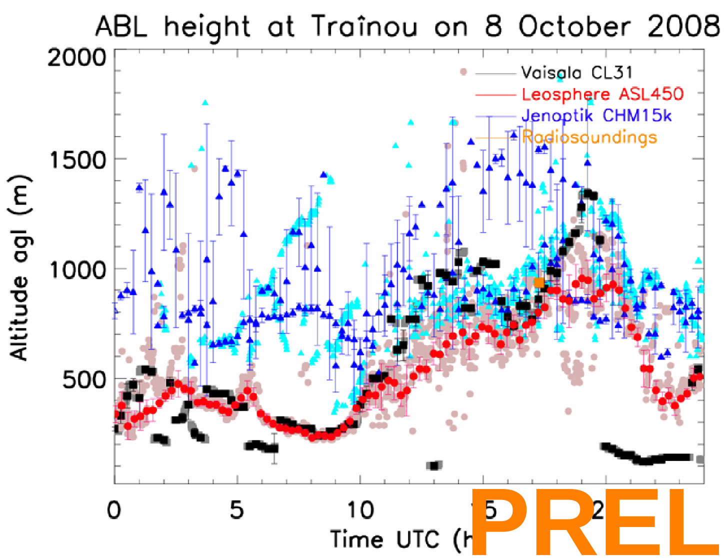
ICOS hABL campaign at Le Traînou (TRN)

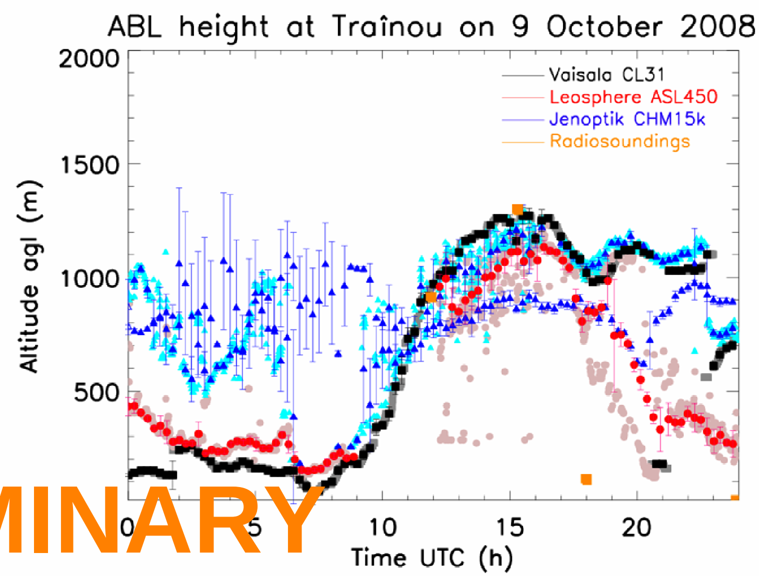
3-21 October 2008

I. Xueref-Remy et al (*irene.xueref@lsce.ispl.fr*)

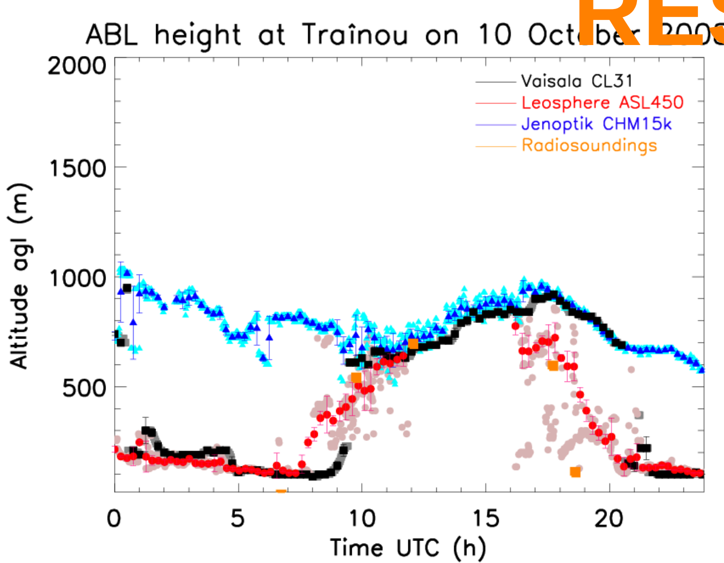
PRELIMINARY COMPARISON WITH RADIOSOUNDINGS

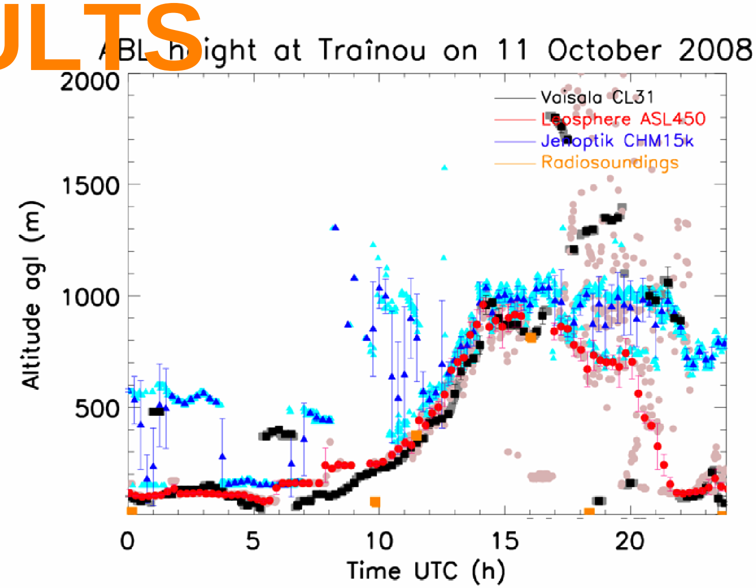
Method: [Menut et al 2000] ĞNeeds a visual quality check

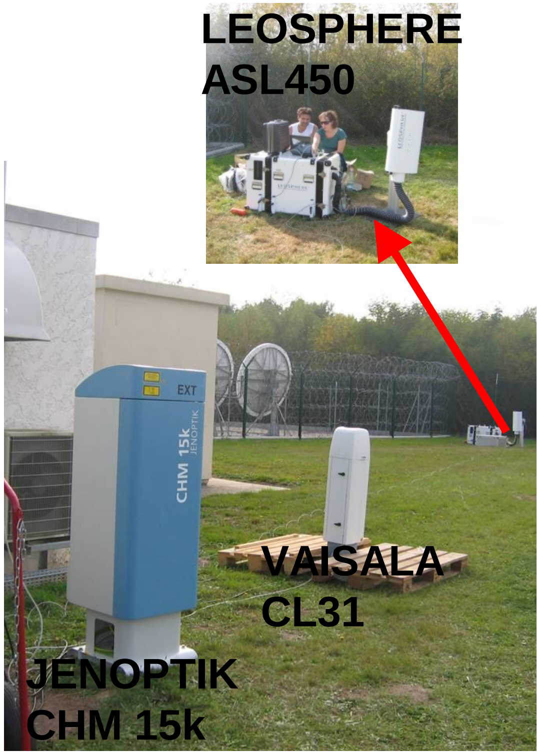




PRELIMINARY RESULTS





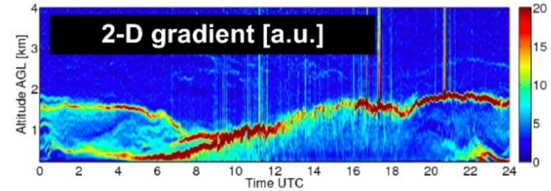


Summary:

- Mixing layer depth is key parameter
- Extensive literature on MLD retrieval
- Lidar and ceilometer backscatter from aerosol are suited to trace MLD
- 3-D nature of Lidar signal --> image processing
- New lidar/ceilometer network in Europe provide monitoring of the backscatter profile
- Good opportunity for STSM to implement new 2-D image processing technique on a ceilometer network

EG-CLIMET Short Term Scientific Mission

Retrieval of mixing layer thickness from existing ceilometer/lidar networks in Europe
Proposed by M. Haeffelin, Institut Pierre Simon Laplace



The atmosphere boundary layer is characterized by turbulent fluctuations. The determination of its thickness is crucial in meteorology to study energy and water fluxes exchanges between the surface and the atmosphere. It is determined either (1) using temperature, humidity and wind profiles from in-situ vertical profiles or (2) by tracing gradients in atmospheric constituents or structures using remotely sensed vertical profiles (lidar, radar, sodar).

Lidars or ceilometers provide vertical profiles of backscatter from aerosol particles. Aerosols are predominantly concentrated in the mixing layer, and hence lidar signals can be used to trace the thickness of the mixing layer. We reviewed more than 20 papers describing methods to retrieve mixing layer thickness and application to ceilometer networks.

As Lidar/ceilometer data are 3-dimensional in nature (vertical, temporal and intensity), we reviewed 2-D image processing methods. We show that these methods have a great potential for retrieving mixing layer thickness from lidar/ceilometer signals – using both temporal and vertical gradients.

We propose a short term scientific mission (STSM) to test and implement a Sobel/Canny 2-D image processing method on a ceilometer network in Europe. As studies have been conducted recently by KNMI (Wauben et al., 2008) and DWD (Engelbart et al., 2008) on applying 1-D methods on ceilometer networks to retrieve mixing layer thicknesses, we propose to conduct a STMS through a collaboration between IPSL and either KNMI or DWD during summer 2009.

Participants:
IPSL: M. Haeffelin, Y. Morille
KNMI: H. Klein Baltink, …
DWD: D. Engelbart, …
Duration: 2-3 months (summer 2009)