RASS-Sondierungen zur Verifikation von MLH-Bestimmungen aus SODAR- und Ceilometerdaten

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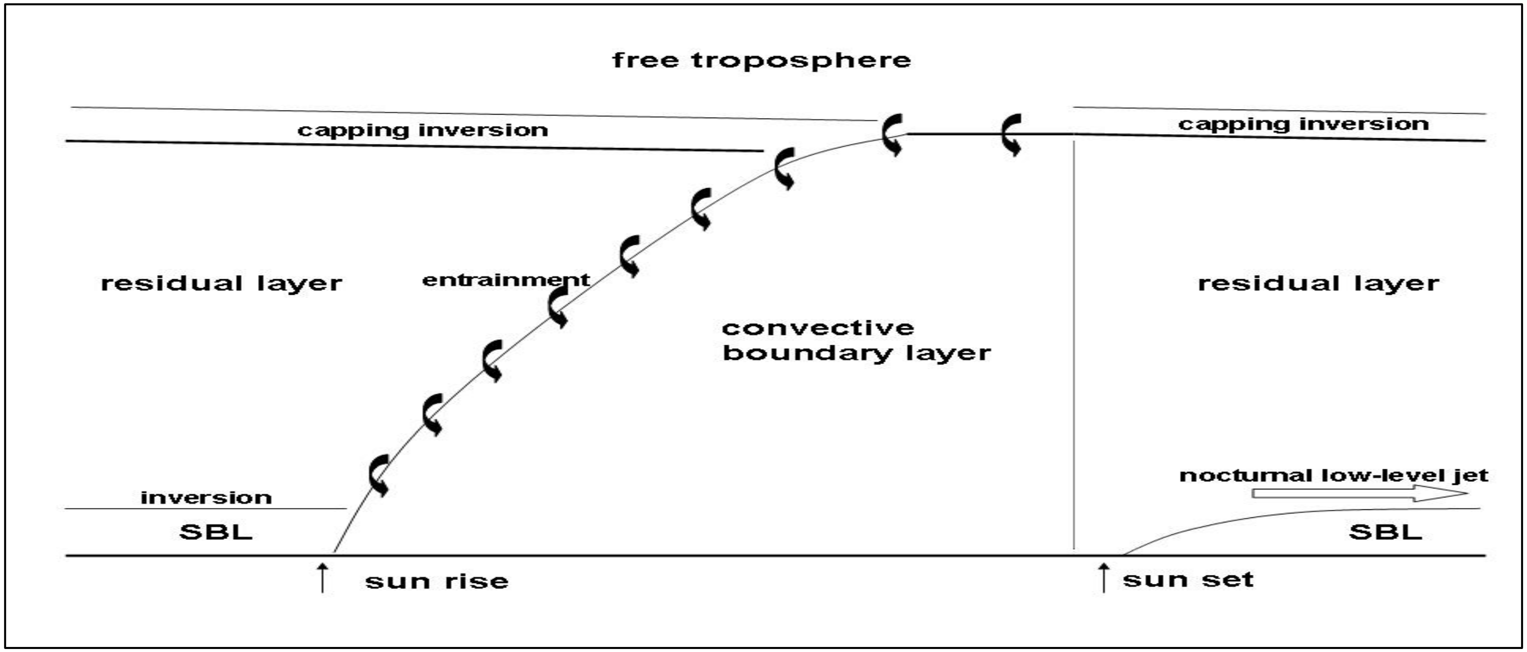
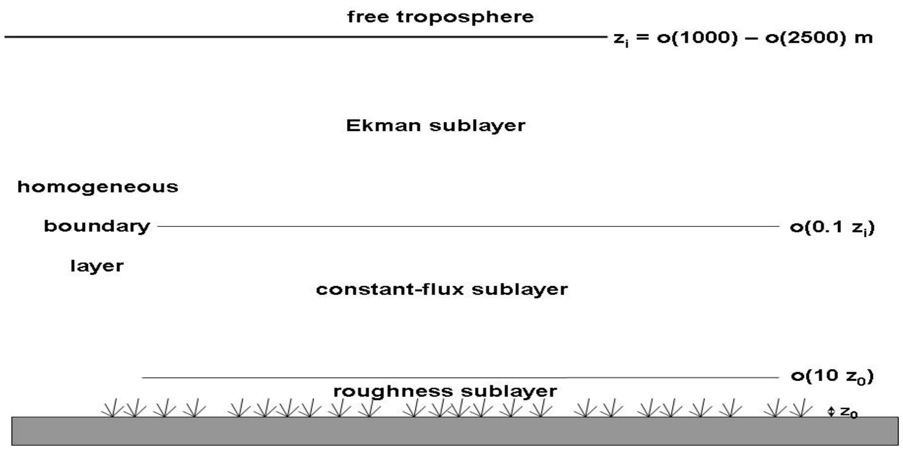
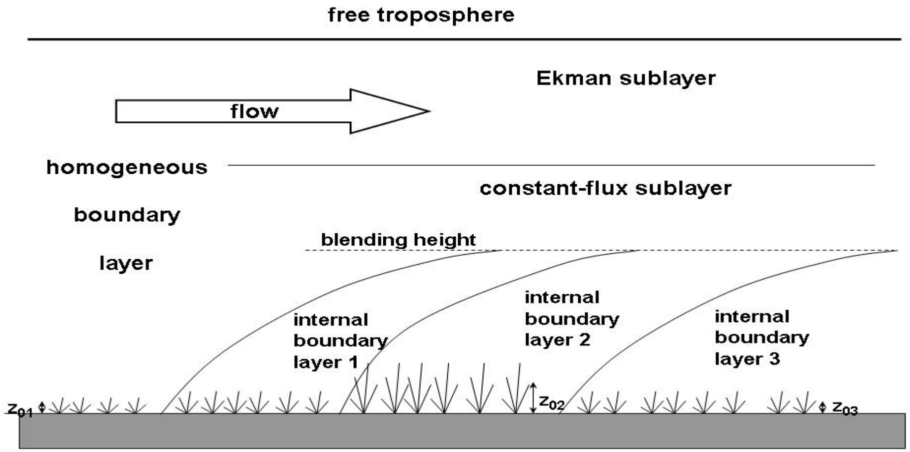
zusammen mit: Klaus Schäfer, Christoph Münkel (Väisälä) und Peter Suppan

diurnal variation of PBL



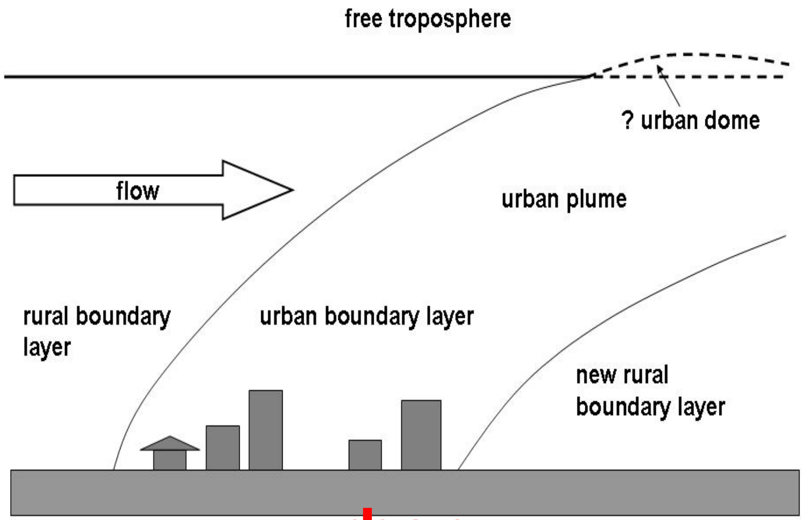


vertical structure of PBL

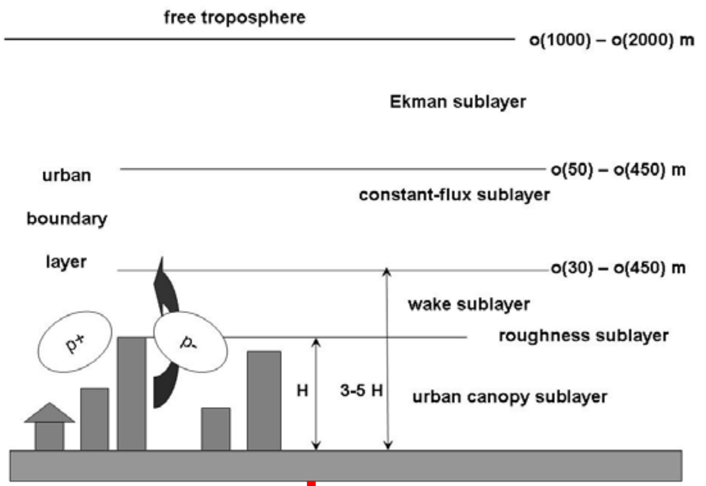


internal layers in PBL

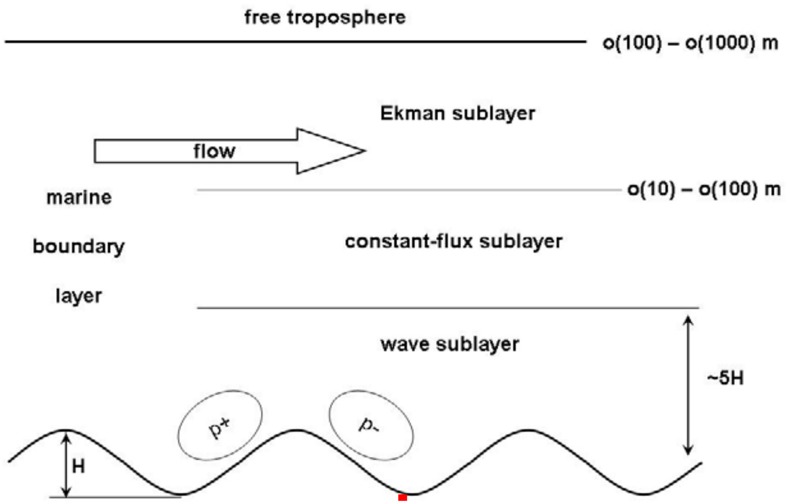
special types of PBL



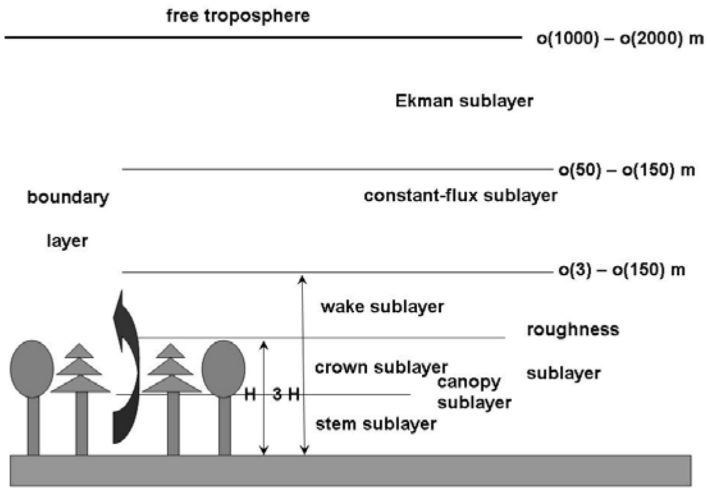
urban



urban



marine



forest

The vertical wind profile

logarithmic law
(with stability correction) $u(z) = (u_*/\kappa)\,(\ln(z/z_0) - \psi(z/L_*))$

power law $u(z) = u(z_A)\,(z/z_A)^n$

New proposal
(Gryning et al. 2007)

$$u(z) = \frac{u_{*0}}{\kappa}\left(\ln\left(\frac{z}{z_0}\right) + \frac{z}{L_{MBL,N}} - \frac{z}{\boxed{z_i}}\left(\frac{z}{2L_{MBL,N}}\right)\right)$$

needs information on the PBL or mixing-layer height

Gryning et al., 2007: On the extension of the wind profile over homogeneous terrain beyond the surface boundary layer. Bound.-Lay. Meteorol., **124**, 251–268.

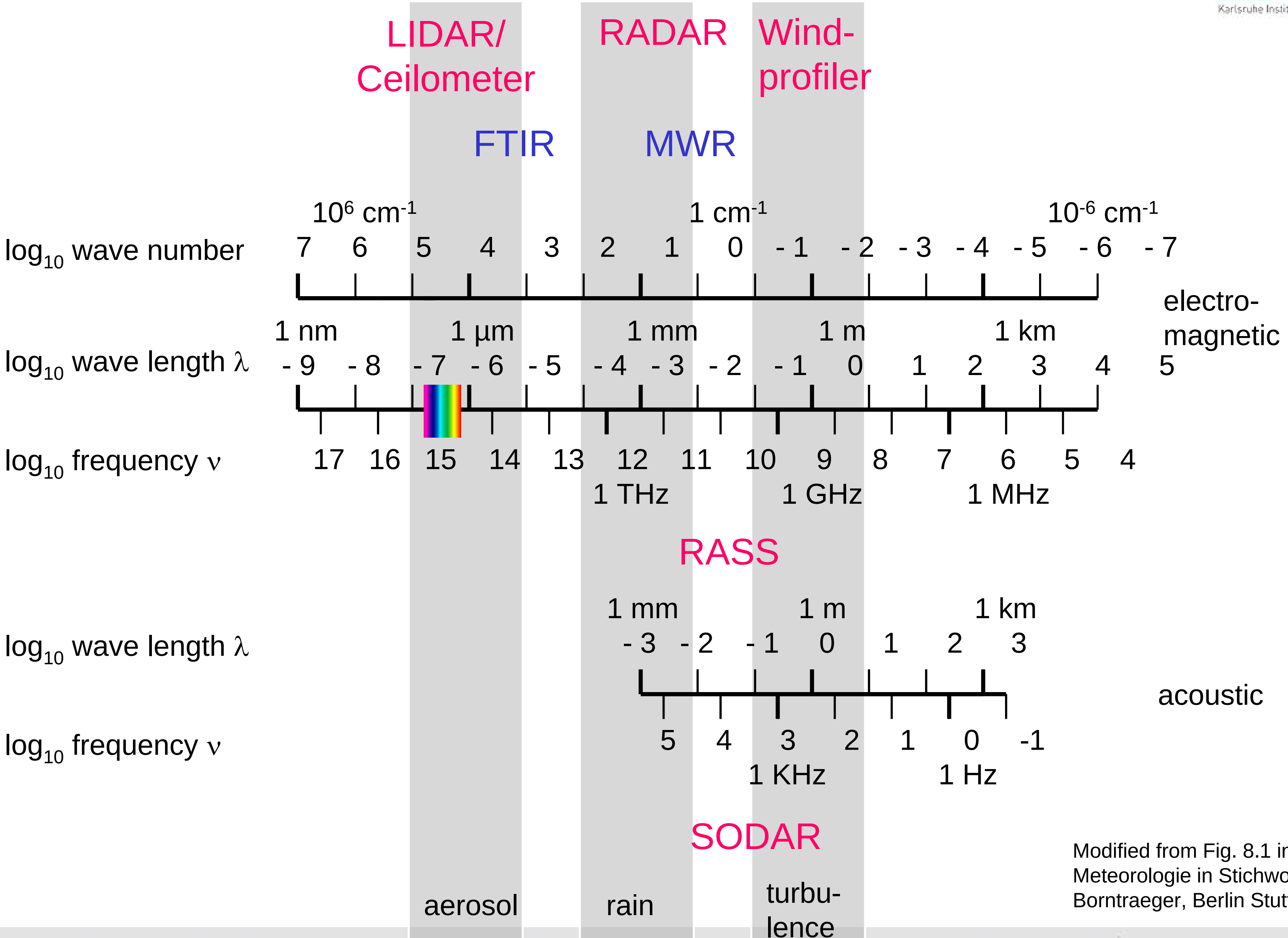
Basic remote sensing techniques

subject of this talk

name	princple	spatial resolution	direction	type
RADAR	backscatter, electro-magnetic pulses, fixed wave length	profiling	scanning, slanted	active, monostatic
SODAR	backscatter, acoustic pulses, fixed wave length	profiling	fixed, slanted, vertical	active, usually monostatic
LIDAR	backscatter, optical pulses, fixed wave length(s)	profiling	scanning, fixed, horizontal, slanted, vertical	active, monostatic
RASS	backscatter, acoustic, electro-magnetic, fixed wave length	profiling	fixed, vertical	active, monostatic
FTIR	absorption, infrared, spectrum	path-averaging	fixed, horizontal, slanted	active, bistatic or passive
	emission, infrared, spectrum	path-averaging	fixed, horizontal, slanted	passive
DOAS	absorption, optical, fixed wave lengths	path-averaging	fixed, horizontal	active, bistatic
radiometry	electro-magnetic, fixed wave length(s)	averaging, profiling	fixed, scanning, slanted, vertical	passive
tomography	travel time, acoustic, fixed wave length	horizontal distribution	fixed, horizontal	active, multiple emitters and receivers

subject of this talk

Typical frequency bands for remote sensing of the atmosphere



LIDAR/ Ceilometer

RADAR

Wind-profiler

FTIR

MWR

10^6 cm^{-1} 1 cm^{-1} 10^{-6} cm^{-1}

$\log_{10}$ wave number 7 6 5 4 3 2 1 0 - 1 - 2 - 3 - 4 - 5 - 6 - 7

electro-magnetic

1 nm 1 µm 1 mm 1 m 1 km

$\log_{10}$ wave length λ - 9 - 8 - 7 - 6 - 5 - 4 - 3 - 2 - 1 0 1 2 3 4 5

$\log_{10}$ frequency ν 17 16 15 14 13 12 11 10 9 8 7 6 5 4

1 THz 1 GHz 1 MHz

RASS

1 mm 1 m 1 km

$\log_{10}$ wave length λ - 3 - 2 - 1 0 1 2 3

acoustic

$\log_{10}$ frequency ν 5 4 3 2 1 0 -1

1 KHz 1 Hz

SODAR

aerosol

rain

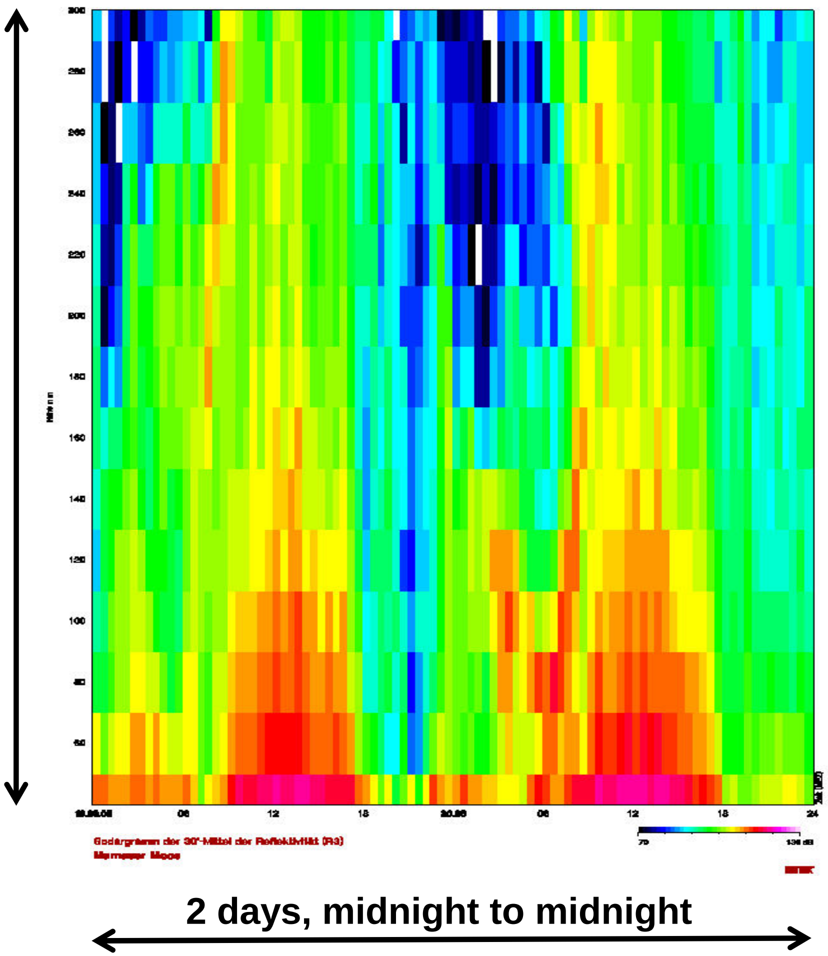
turbu-lence

Modified from Fig. 8.1 in „Meteorologie in Stichworten“, Borntraeger, Berlin Stuttgart 2000

SODAR

algorithms for mixing-layer height

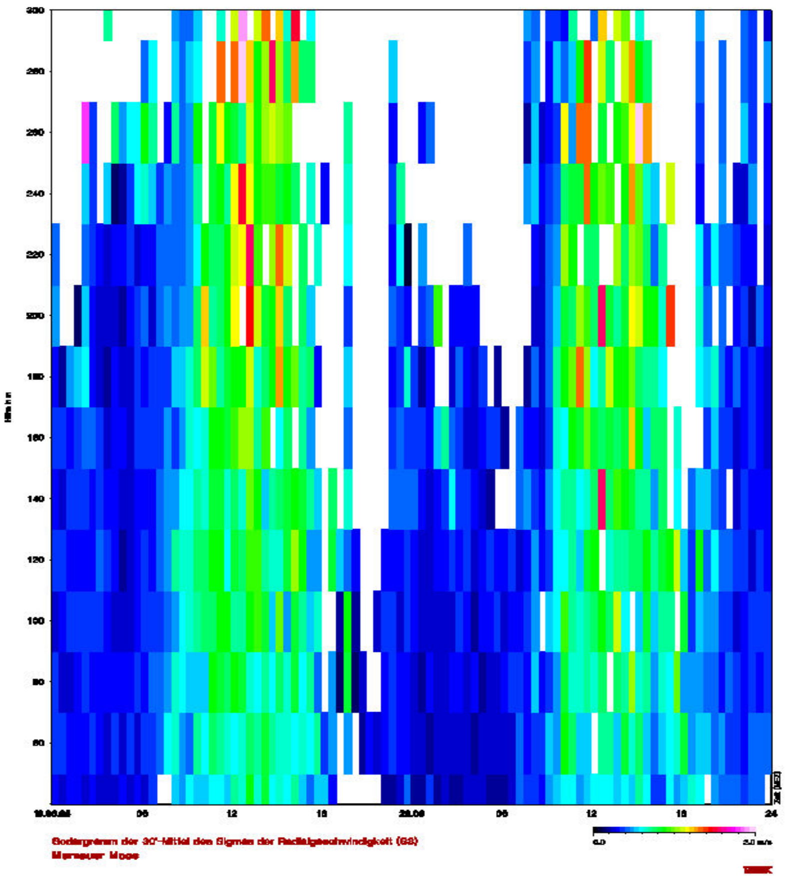
Sample plot SODAR (convective BL at daytime)



acoustic backscatter intensity

40 – 300 m

2 days, midnight to midnight

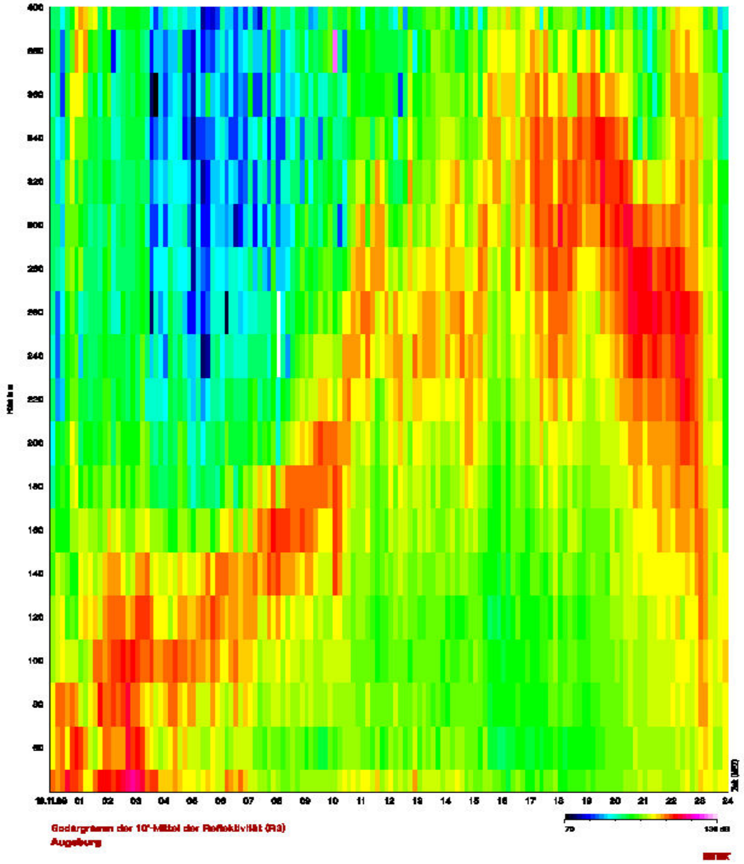


sigma w

Sample plot SODAR (lifted inversion)

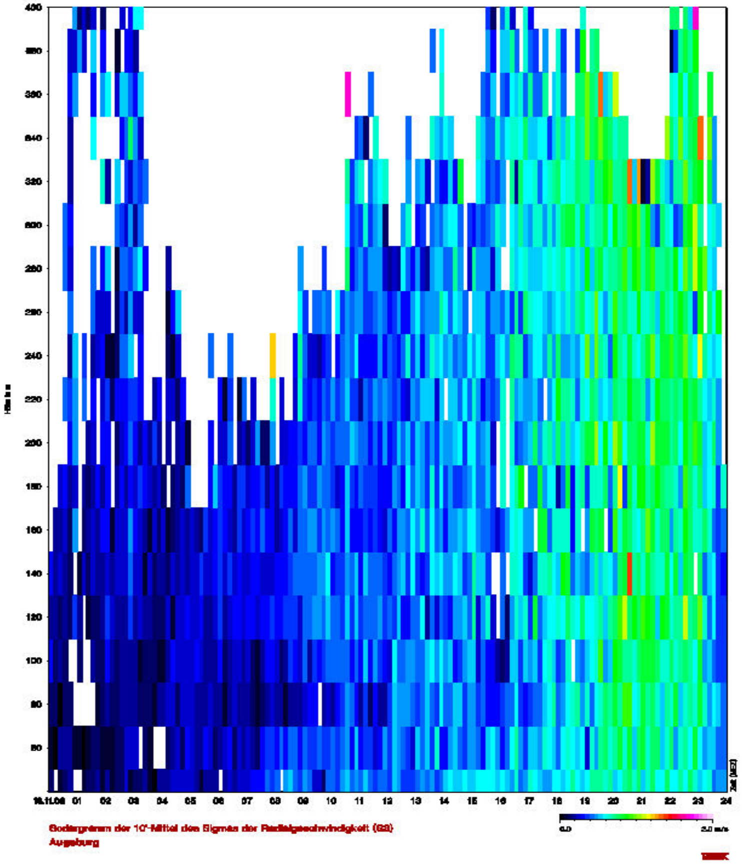
acoustic backscatter intensity

40 – 400 m



1 day, midnight to midnight

sigma w

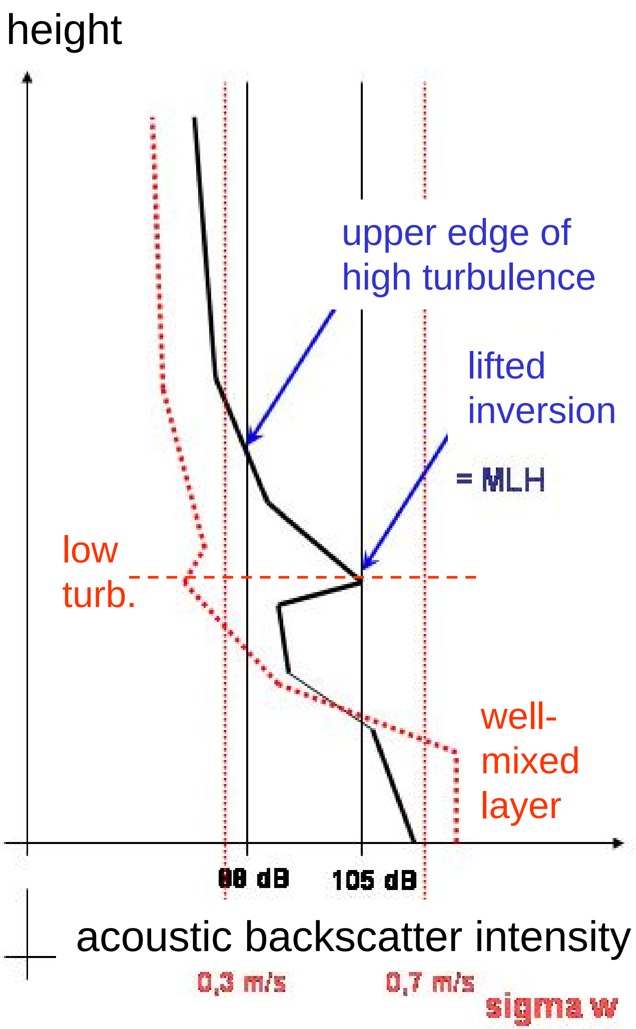


Algorithms to
detect MLH
from SODAR data

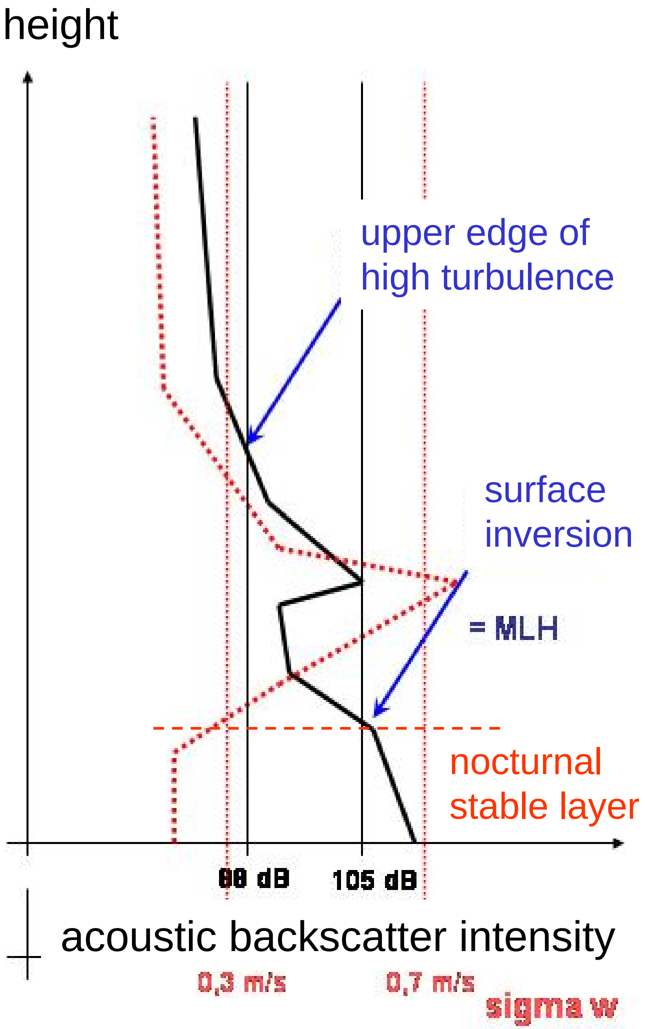
criterion 1:
upper edge of high turbulence

criterion 2:
surface and lifted inversions

MLH = Min (C1, C2)



example 1: daytime



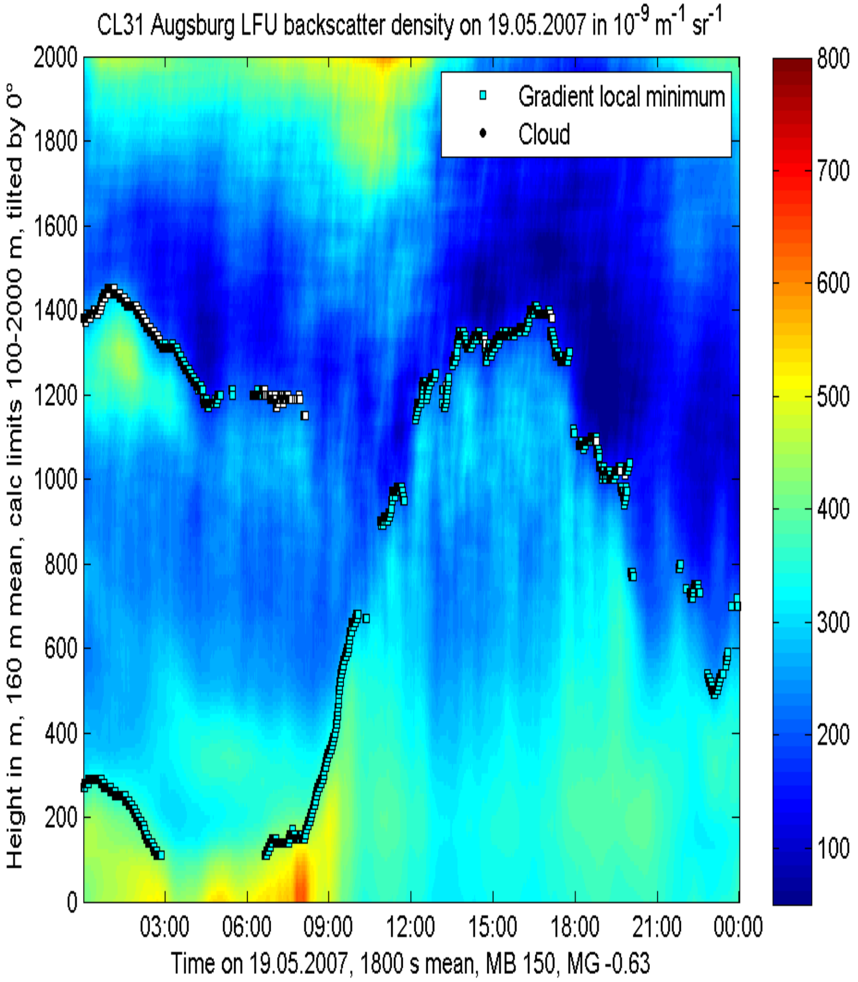
example 2: night-time

Ceilometer

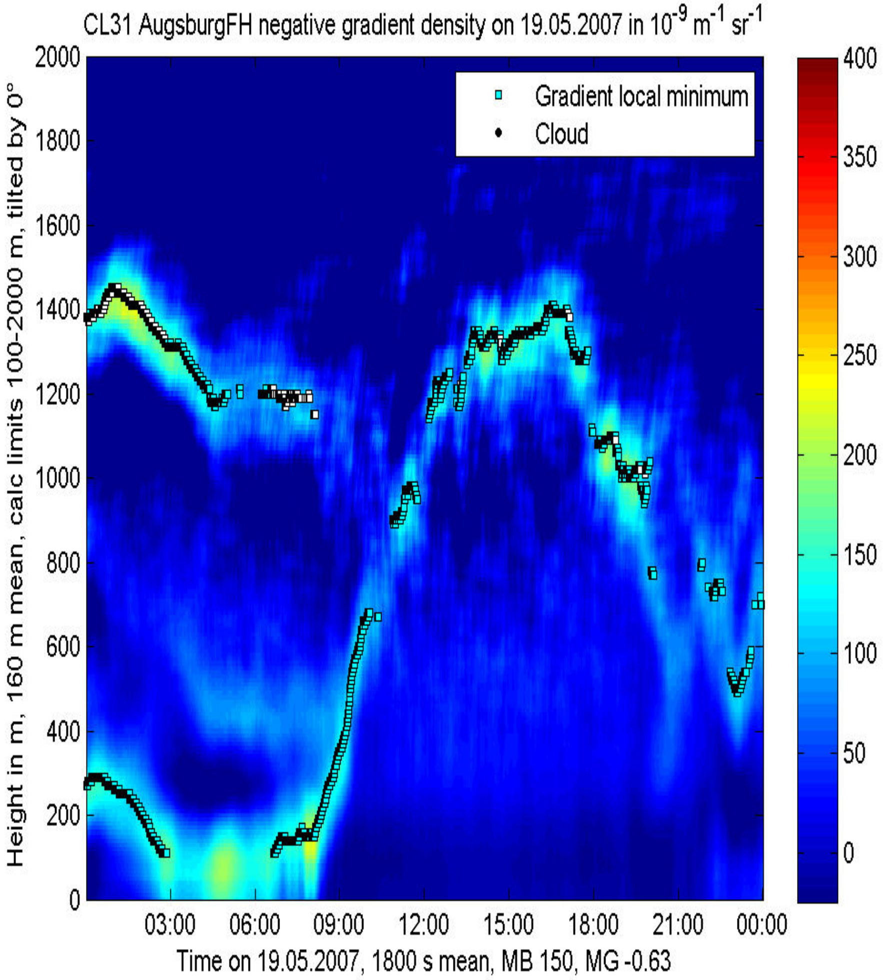
algorithms for mixing-layer height

Sample plot ceilometer (convective BL at daytime)

optical backscatter intensity



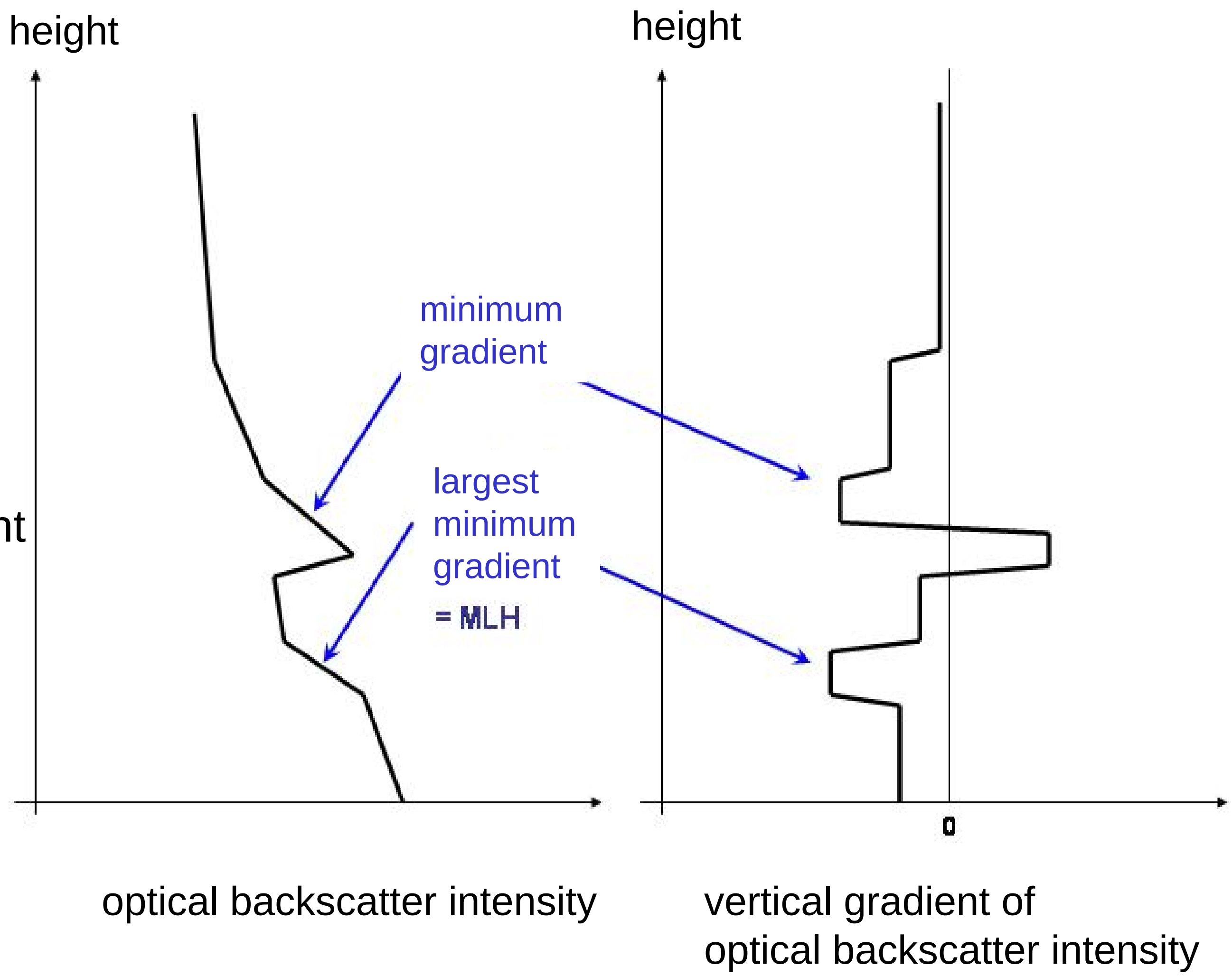
negative vertical gradient of optical backscatter intensity



Algorithms to
detect MLH
from Ceilometer-Daten

criterion

minimal vertical gradient
of backscatter
intensity (the most
negative gradient)

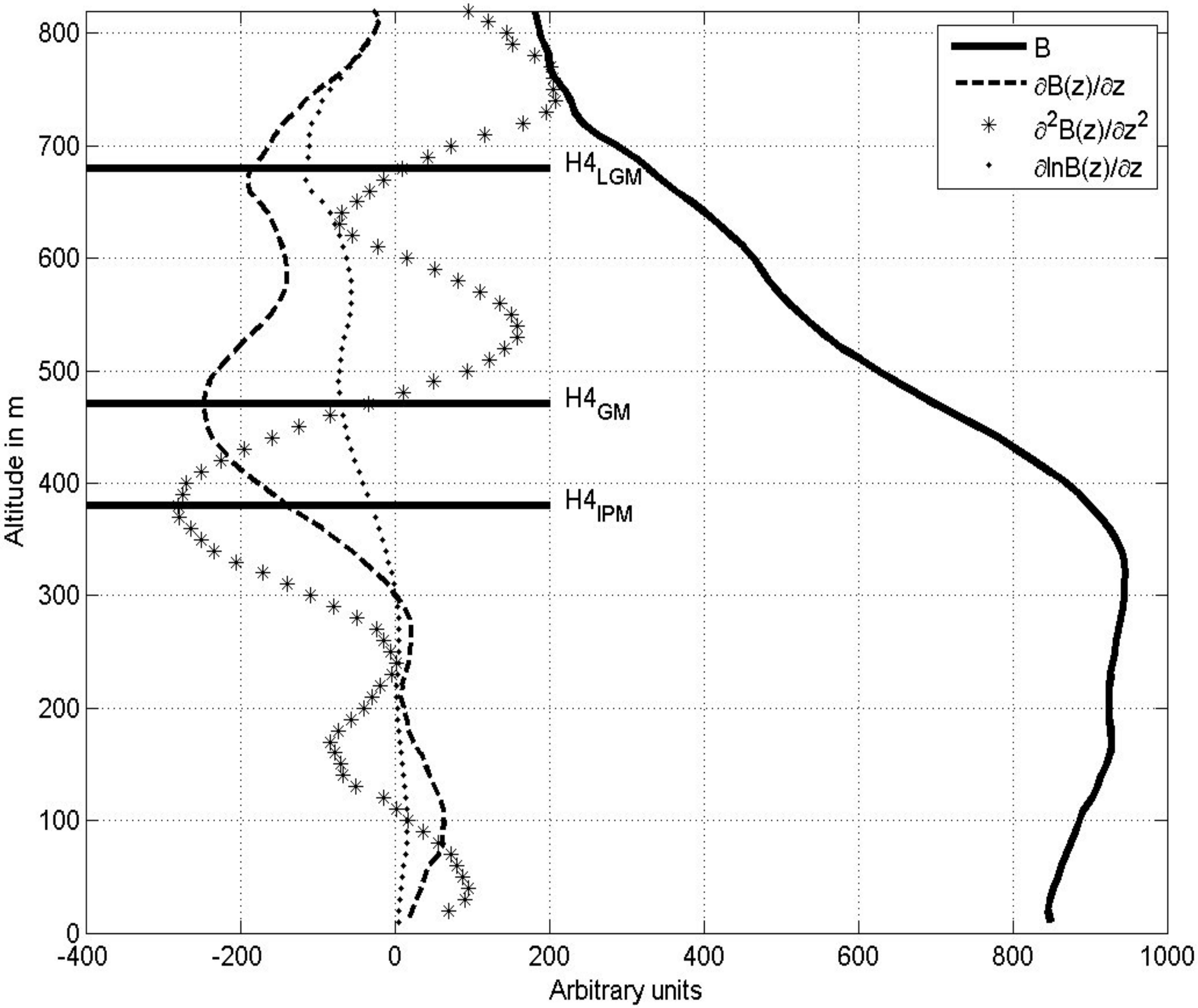


Different gradient methods (see Sicard et al. 2006, BLM 119, 135-157)

logarithmic gradient minimum

gradient minimum

inflection point method
(minimum of 2nd derivative)



RASS

Messprinzip

Vergleiche mit Ceilometer und SODAR

RASS (radio-acoustic remote sensing)

misst vertikale Temperaturprofile

Bragg-RASS: windprofiler plus akustische Komponente

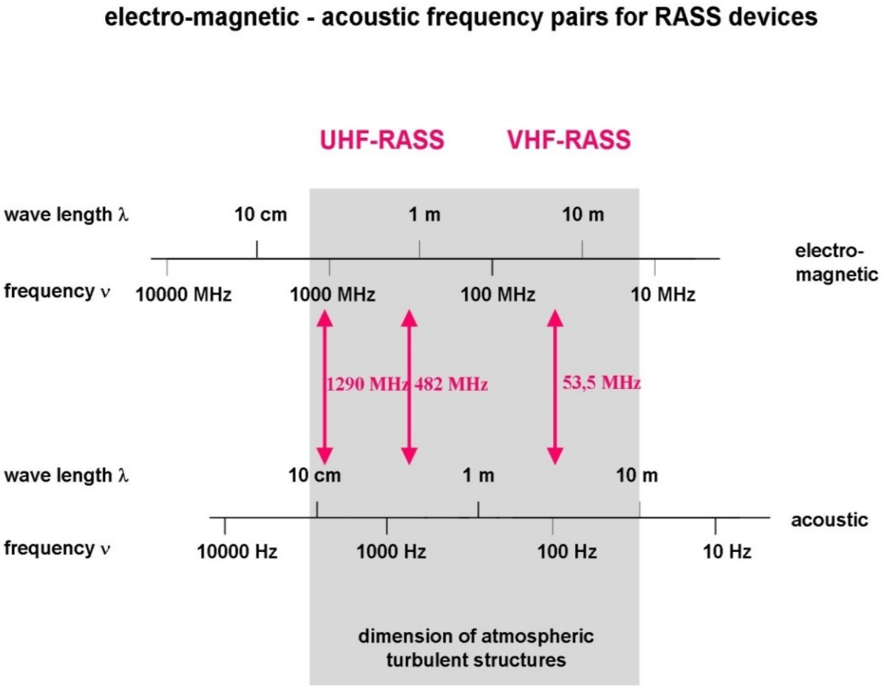
Doppler-RASS: SODAR plus elektro-magnetische Komponente

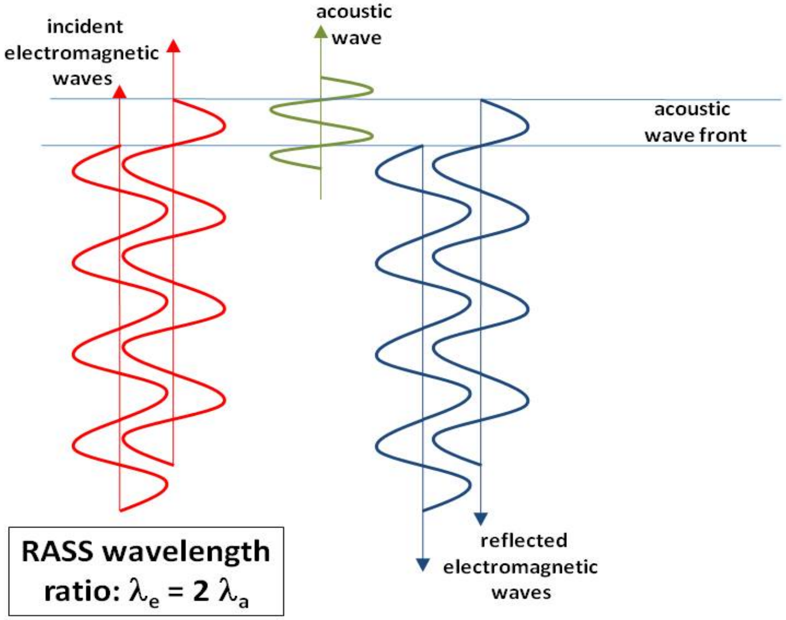
UHF RASS (Grenzschicht)

VHF RASS (Troposphäre)

RASS: Frequenzen

Bragg Bedingung:
akustische Wellenlänge = ½ elektro-magnetische Wellenlänge


electro-magnetic - acoustic frequency pairs for RASS devices



SODAR-RASS
(Doppler-RASS)

(METEK)

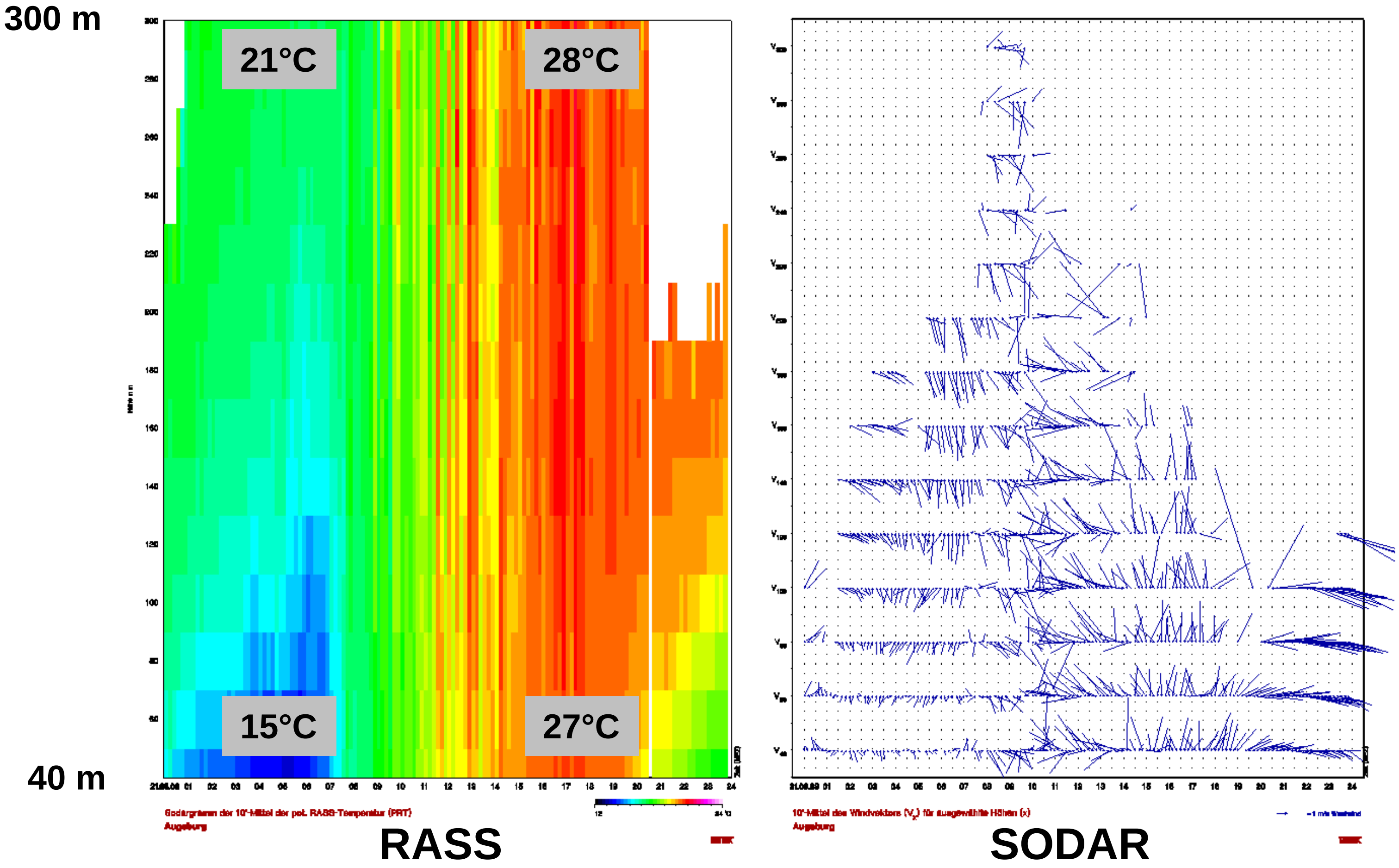
akust. Frequ.: 1500 – 2200 Hz
Radio Frequ.: 474 MHz
Auflösung: 20 m
unterstes
Messniveau: ca. 40 m

Reichweite: 540 m

Vergleich mit SODAR-Wind

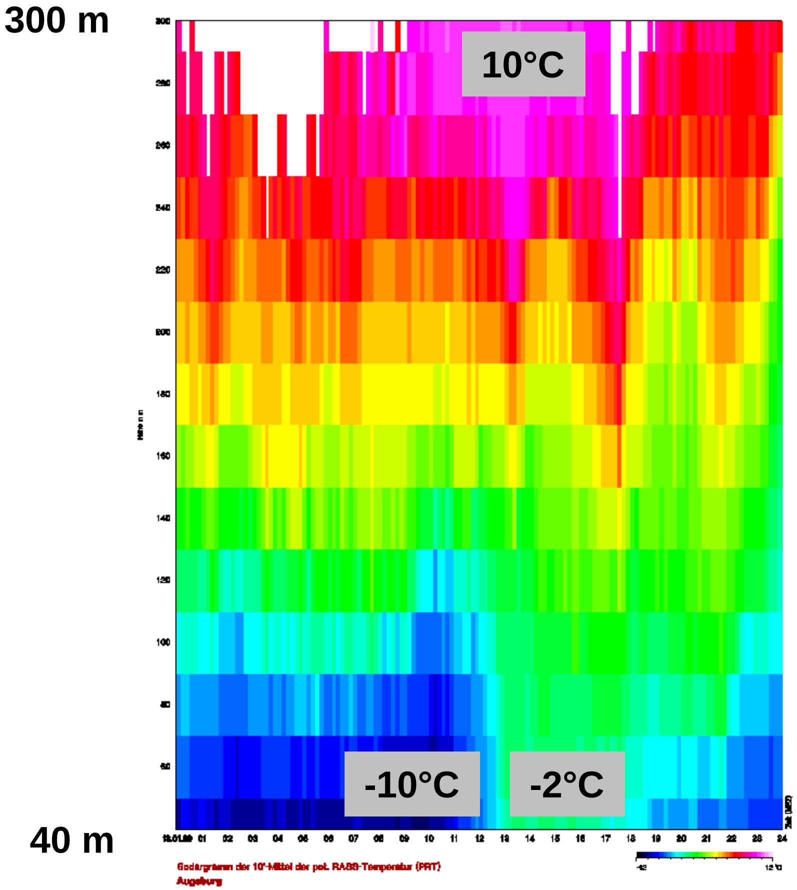
Sommertag

potenzielle Temperatur (links), horizontaler Wind (rechts)

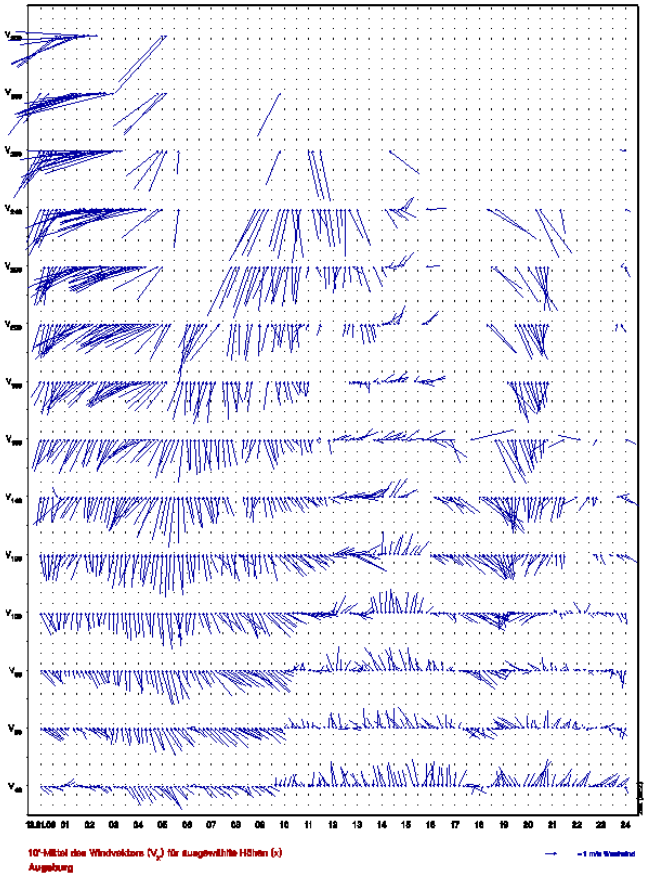


Vergleich mit SODAR-Wind

Wintertag
potenzielle Temperatur (links), horizontaler Wind (rechts)



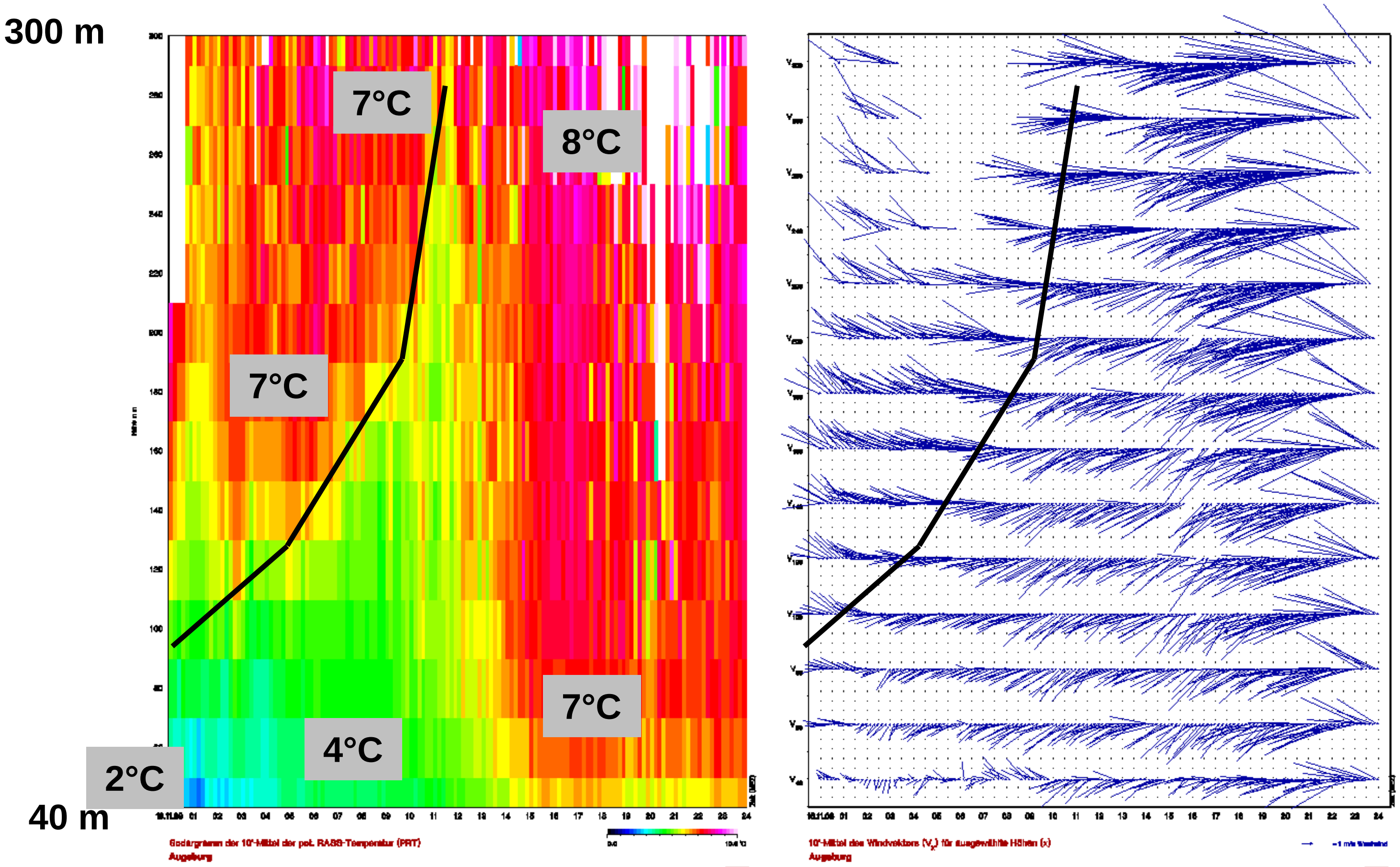
RASS



SODAR

Vergleich mit SODAR-Wind

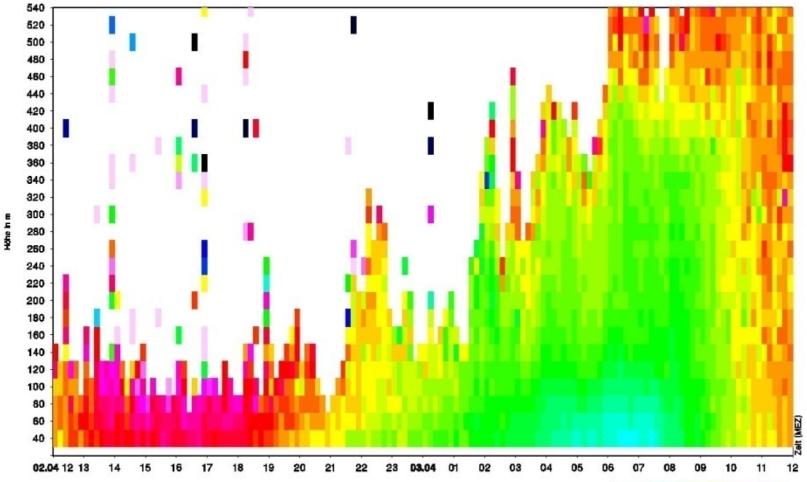
Inversion
potenzielle Temperatur (links), horizontaler Wind (rechts)



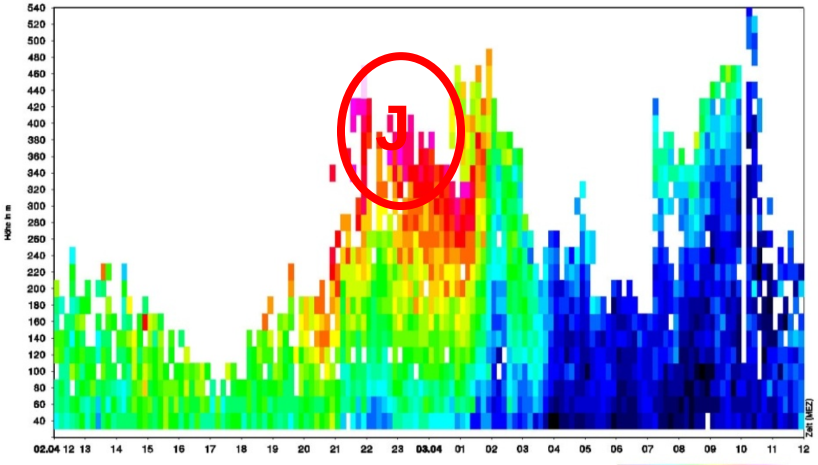
RASS

SODAR

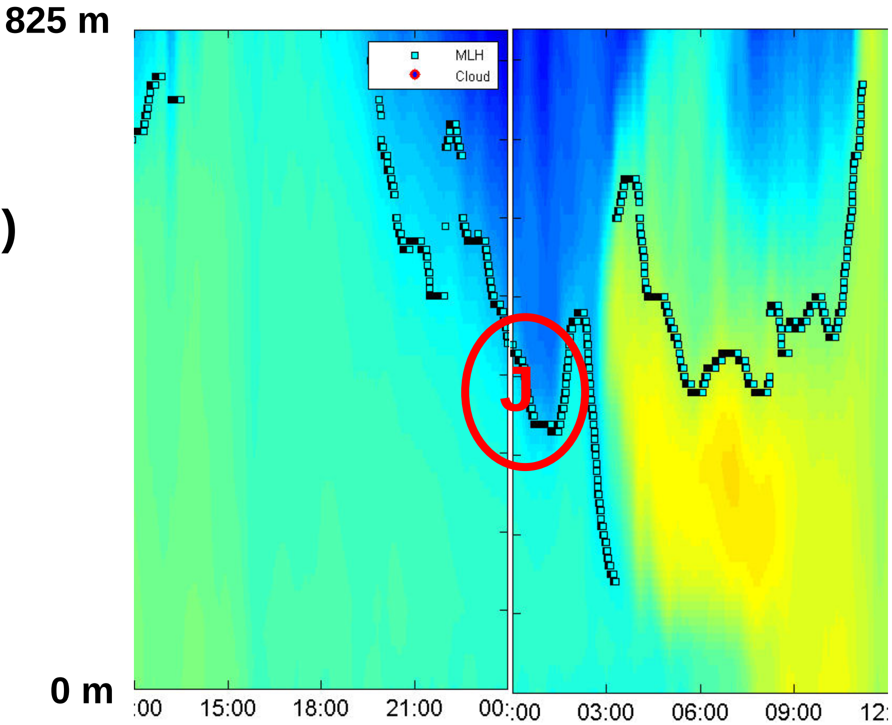
Einfluss eines nächtlichen low-level jets



RASS pot. Temp. (max. ca. 25°C)



RASS (Sodar), mittlere horizontale Windgeschwindigkeit (max. 20 m/s)

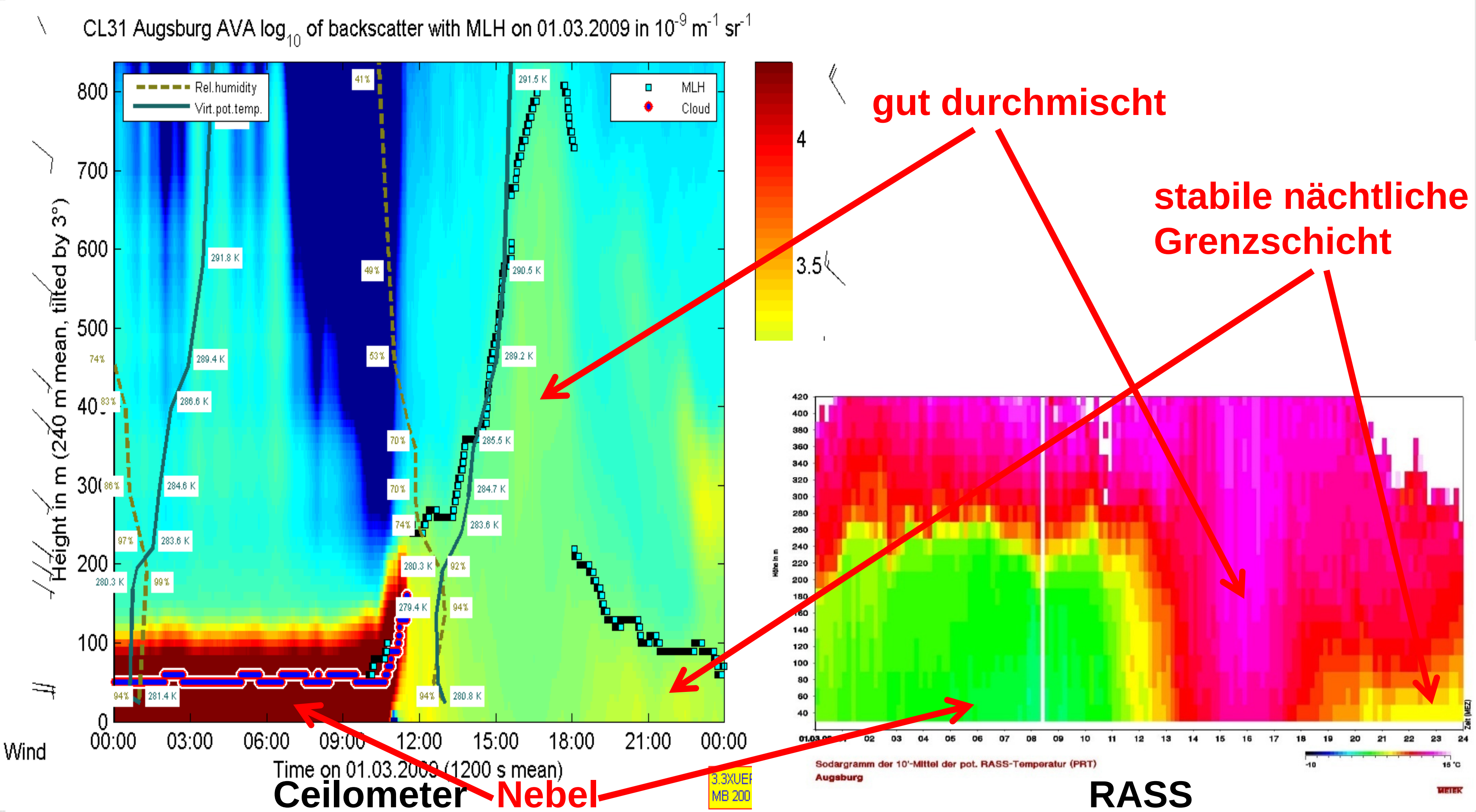


Ceilometer optische Rückstreuintensität (log. Skala)

22 | Prof. Dr. S. Emeis | IMK-IFU Garmisch | 03.07.2009

Temperaturprofil und Luftqualität

Aerosolrückstreuung (links), potenzielle Temperatur (rechts)

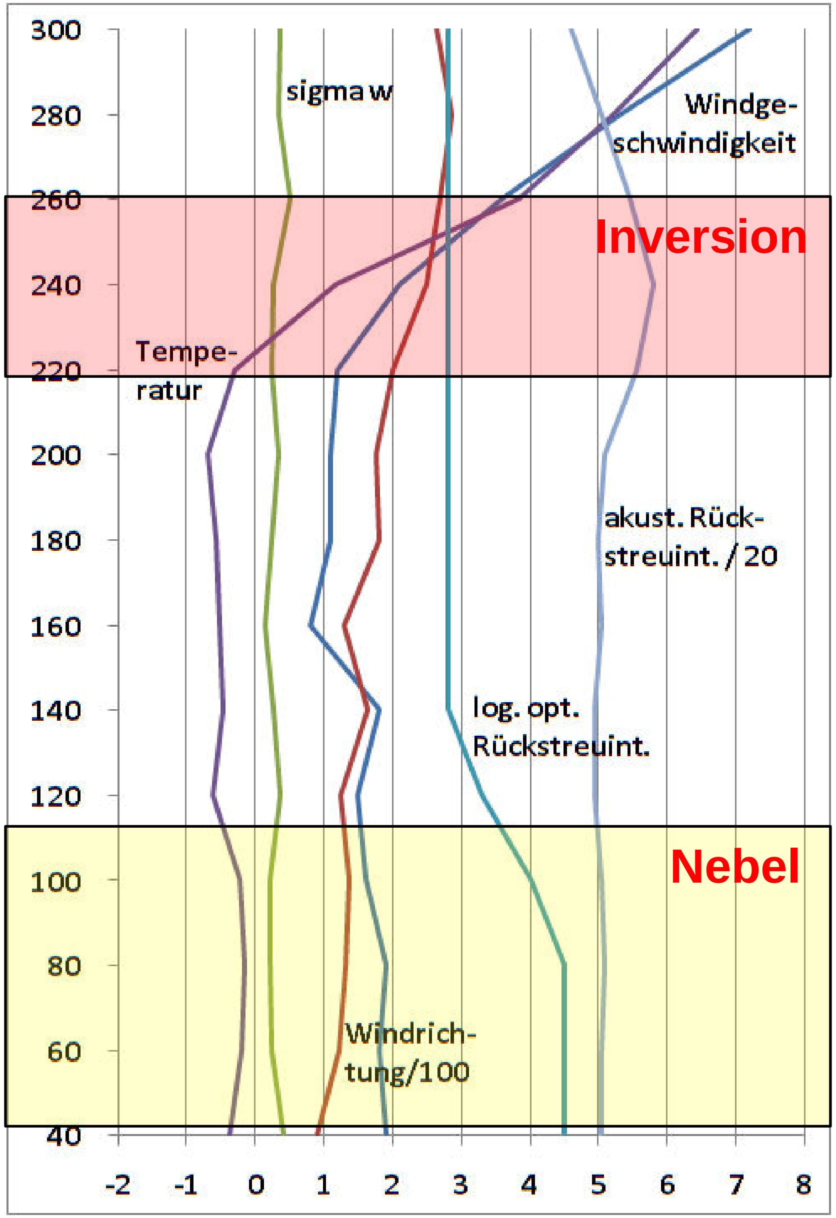


gut durchmischt

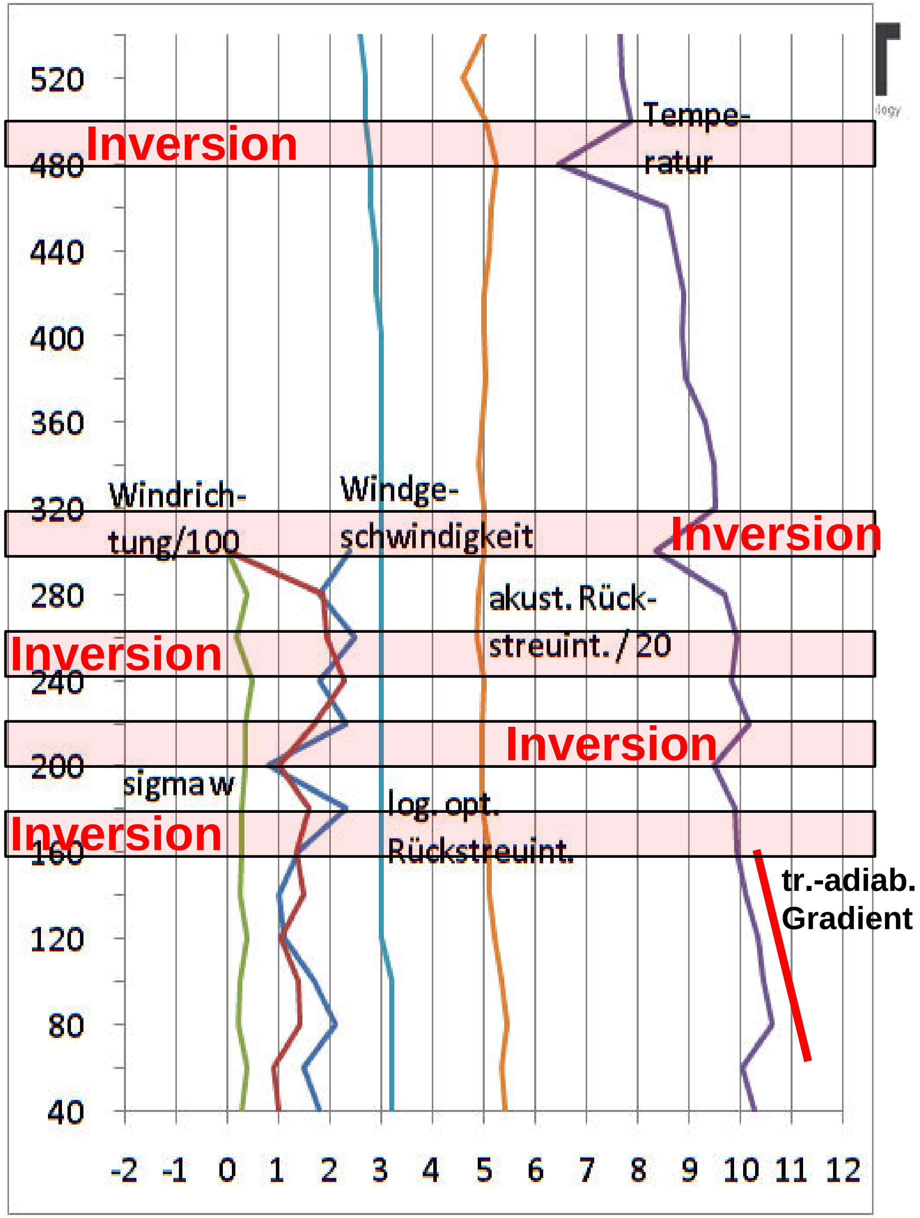
stabile nächtliche Grenzschicht

Ceilometer **Nebel**

RASS



2009 03 01 06 Augsburg



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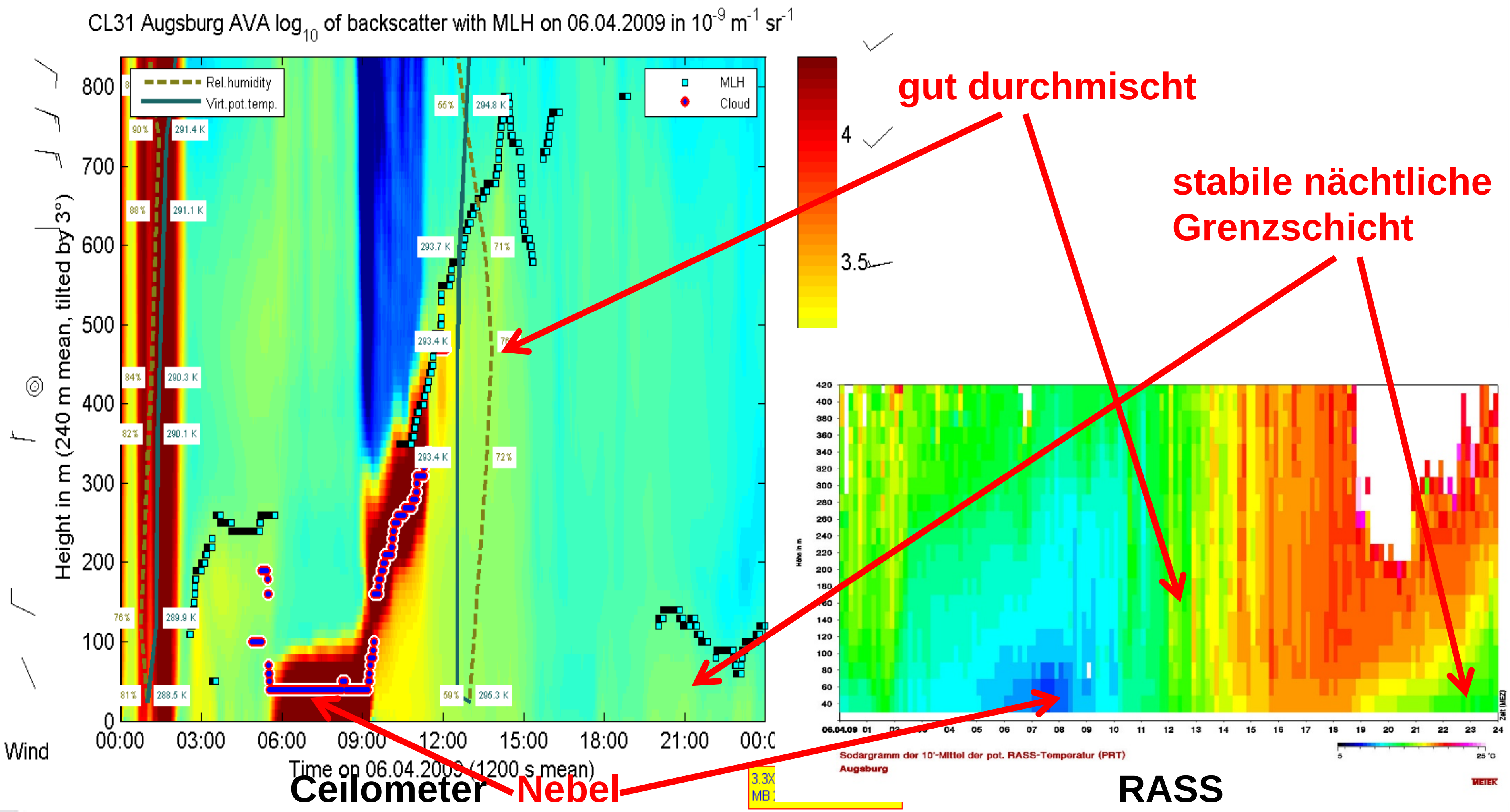
Temperaturprofil und Luftqualität

Aerosolrückstreuung (links), potenzielle Temperatur (rechts)



gut durchmischt

stabile nächtliche Grenzschicht

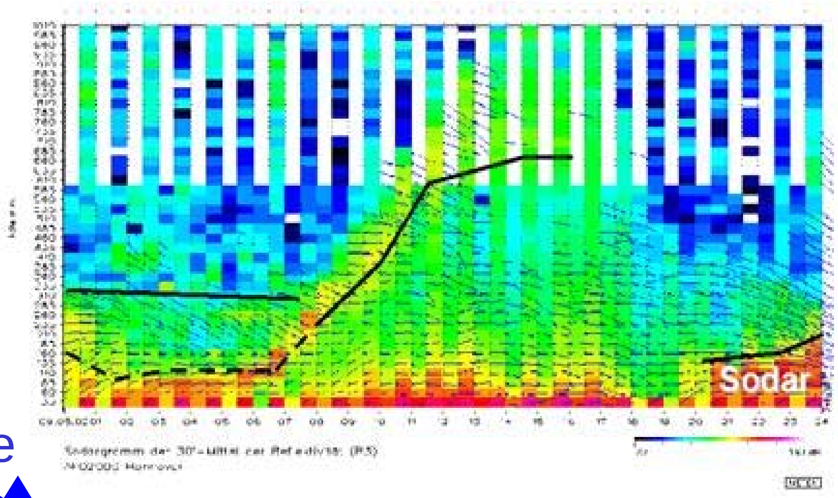
Ceilometer

Nebel

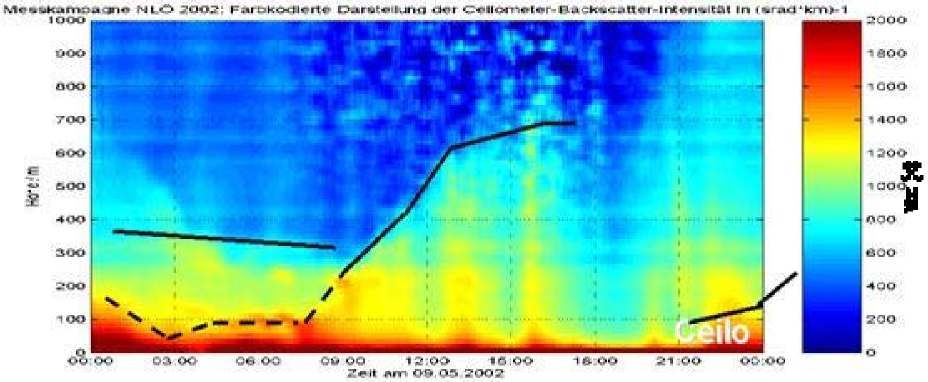
RASS

Comparison of MLH retrievals with three different remote sensing techniques

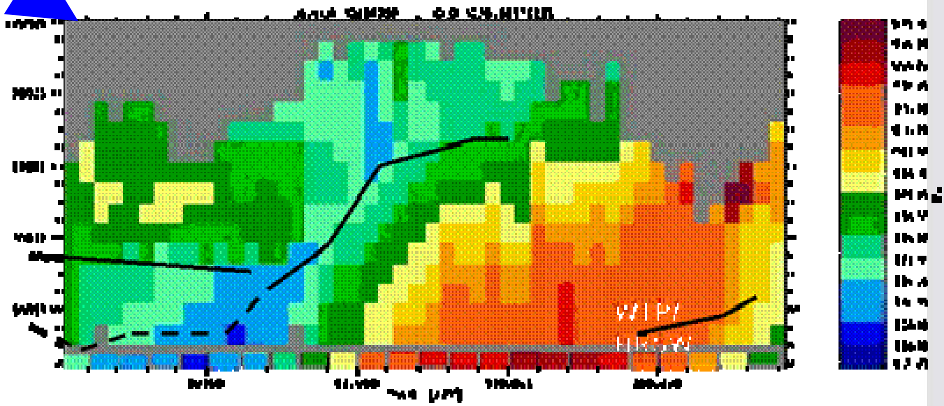
SODAR
acoustic backscatter



ceilometer
optical backscatter



RASS
temperature



Emeis, S., Chr. Münkel, S. Vogt, W.J. Müller, K. Schäfer, 2004: Atmospheric boundary-layer structure from simultaneous SODAR, RASS, and ceilometer measurements. Atmos. Environ., 38, 273-286.

Schlussfolgerungen

RASS-Sondierungen stützen die Interpretation von SODAR-Messungen

- Vertikale Windgradienten können über die Temperaturschichtung erklärt werden.

- Windsprünge können als Temperaturinversionen verifiziert werden.

RASS-Sondierungen stützen die Interpretation von Ceilometer-Messungen

- Obergrenzen hoher Rückstreuintensität können als Obergrenzen gut durchmischter Schichten identifiziert werden.

- Gebiete geringer Rückstreuintensität fallen gelegentlich mit Windmaxima (LLJ) zusammen.

- Einfluss der Luftfeuchtigkeit kann nicht mit RASS erfasst werden. Vergleiche mit Radiosondendaten deuten auch hier auf einen Zusammenhang hin.