Remote sensing of meteorological conditions at airports for air quality issues

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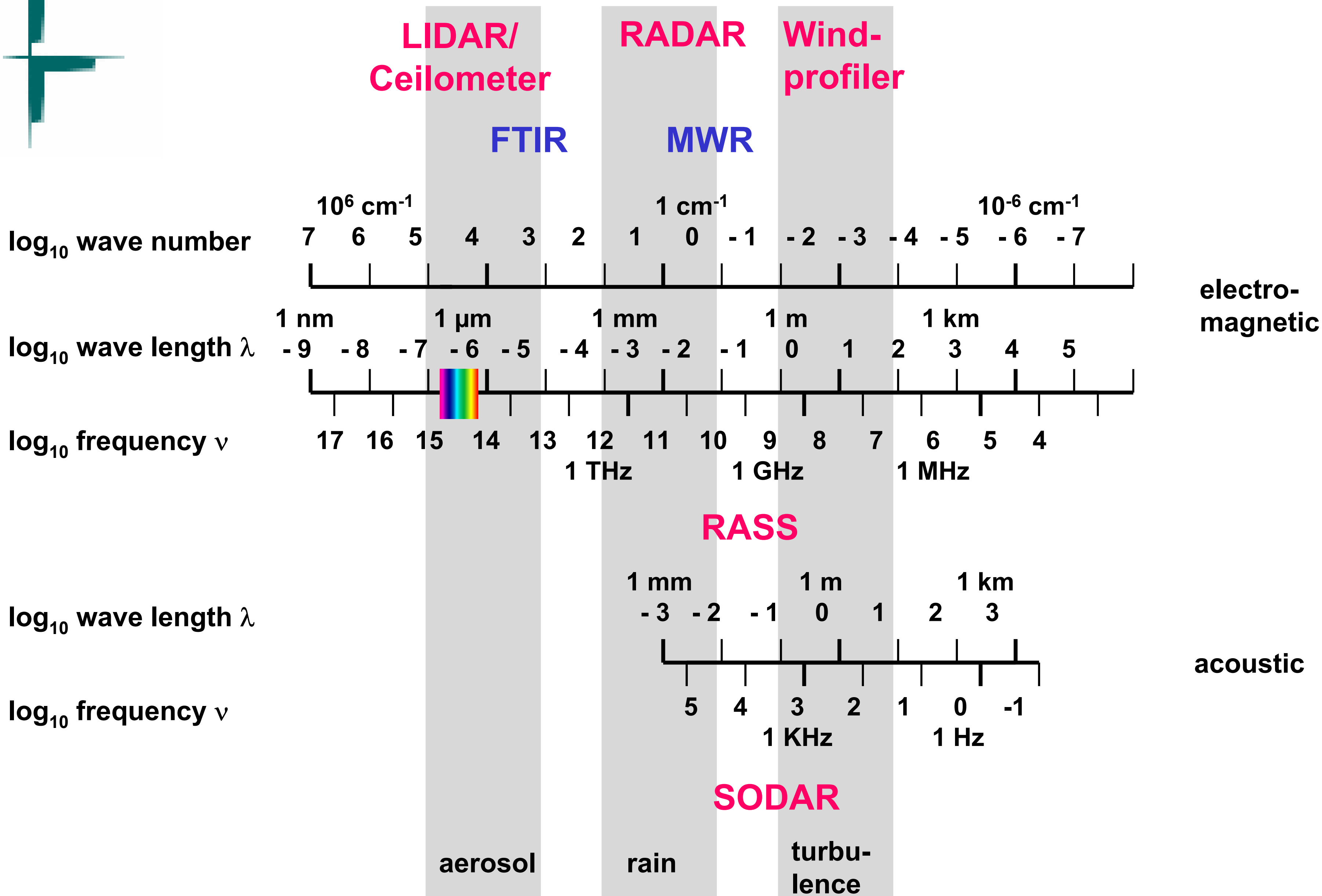
Remote sensing:

basics

and

instrumentation

Typical frequency bands for remote sensing of the atmosphere



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

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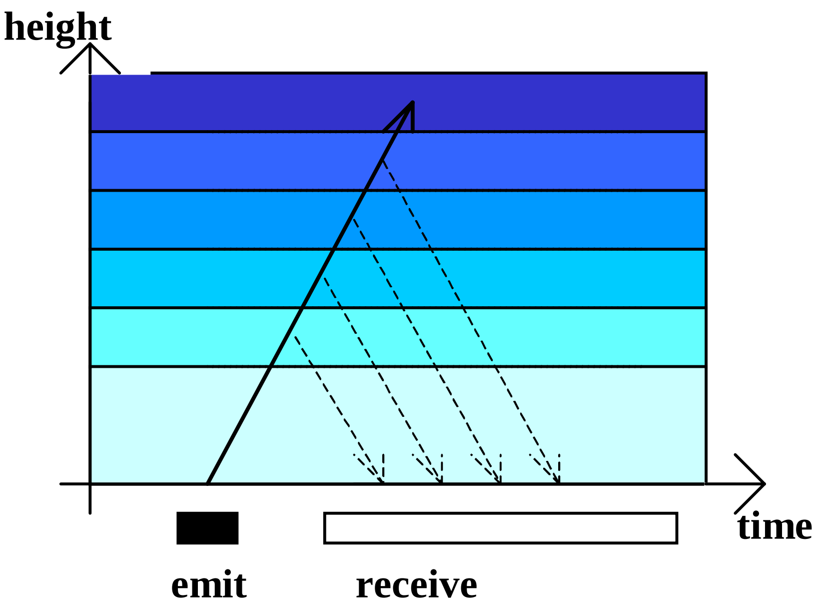
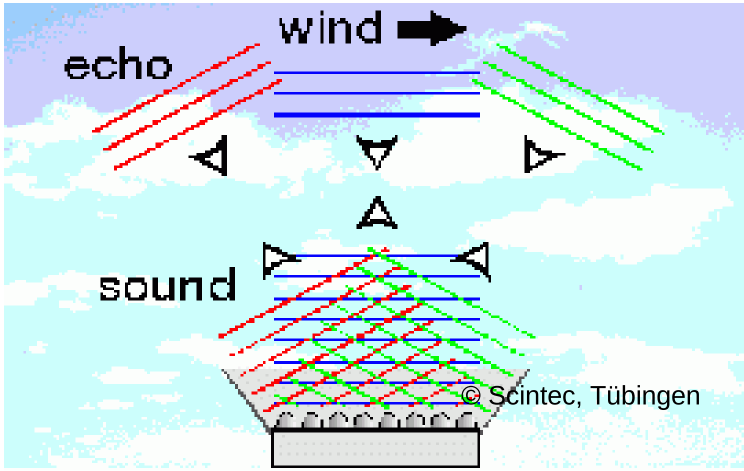
Acoustic Remote sensing:

backscatter at thermal fluctuations and gradients (and large snow flakes) in the atmosphere

monostatic SODAR: measuring principles





deduction:

sound travel time = height
backscatter intensity = turbulence
Doppler-shift = wind speed

Emission of sound waves into three directions:

in order to measure all three components of the wind (horizontal and vertical)

Large SODAR
of IMK-IFU
(METEK DSDR3x7)

frequency: 1500 Hz
range: 1300 m
resolution: 20 m
lowest
range gate: ca. 60 m

size of instrument:

height: 4 m
width: 1,50 m
length: 10 m
weight: 8 t

Reitebuch, O. und S. Emeis, 1998: SODAR-measurements for atmospheric research and environmental monitoring. Meteorologische Zeitschrift, N. F., 7, 11-14.

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mobile trailer (container) with built-in minisodar and data acquisition of IMK-IFU

Aerovironment AV4000 minisodar

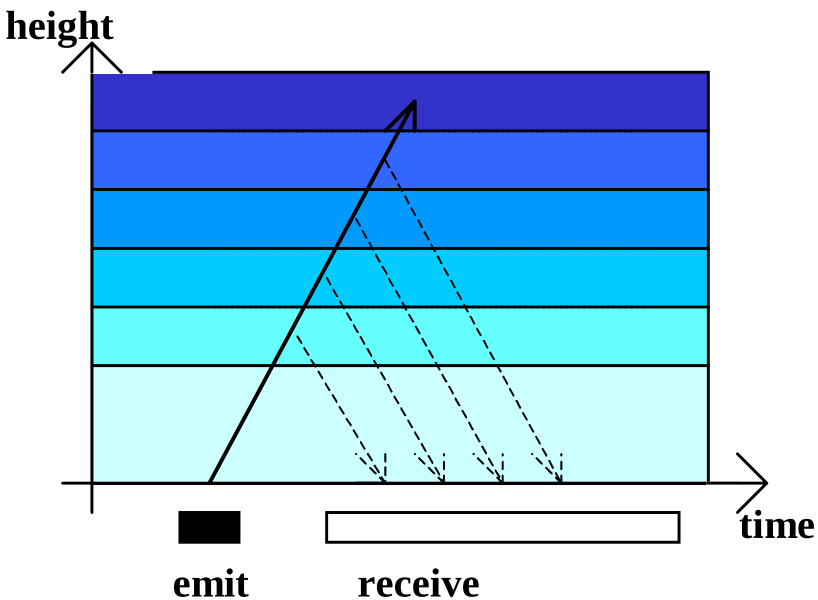
range:	**200 m**
frequency:	**4500 Hz**
vertical resolution:	**5 m**
temporal resolution:	**10 min**

phased-array SODAR

Optical Remote sensing:

backscatter at aerosol particles, insects, water droplets, ice, and snow (fog and clouds are opaque) in the atmosphere

Ceilometer/LIDAR measuring principle



detection:

travel time of signal = height
backscatter intensity = particle size and number distribution
Doppler-shift = cannot be analyzed from ceilometer data
from LIDAR: velocity component in line of sight

ceilometer

about 1 m in size

normally mounted vertically

emits radiation at 0.9 µm (eyesafe)

Difference between acoustic and optical remote sensing

acoustic remote sensing:

SODAR sees

➔ thermal structure of atmospheric boundary layer
➔ wind and turbulence profiles

optical remote sensing:

ceilometer sees

➔aerosol content of atmospheric boundary layer

(often this follows the thermal structure of the boundary layer but not always, advection and secondary formation of aerosols has influence, too)

Examples:

Mixing-layer height

Wind and turbulence profiles

Low-level jets

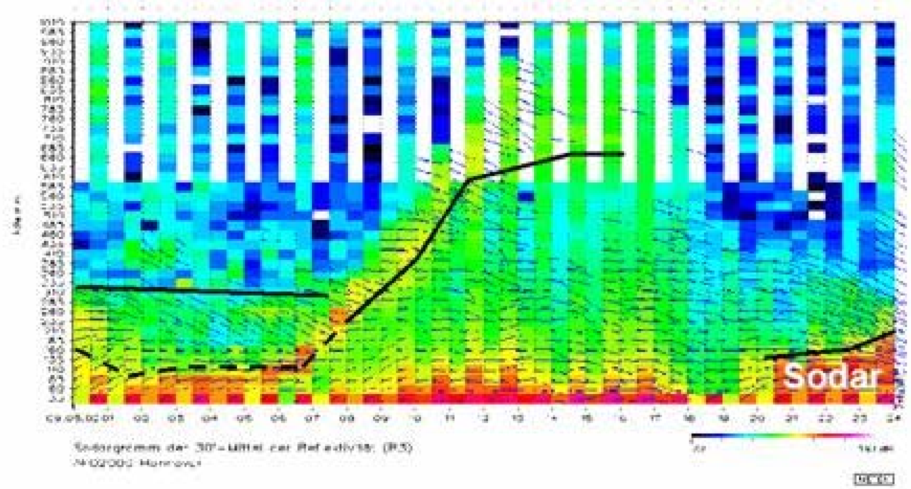
Mixing-layer height

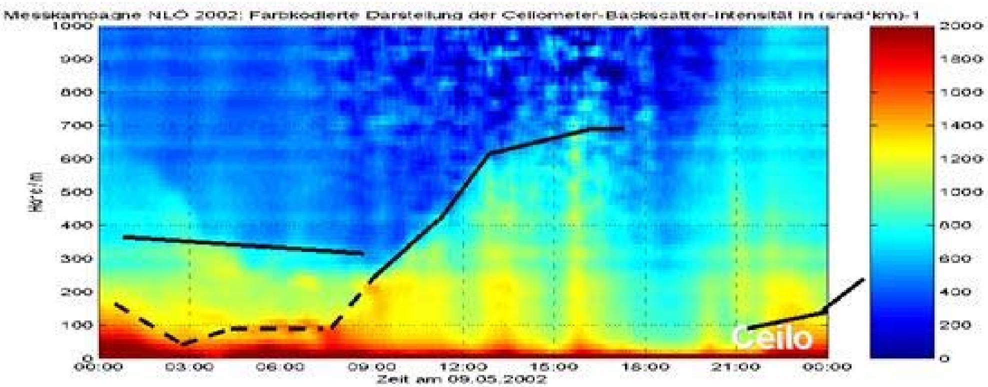
height underneath which the atmosphere is usually well mixed

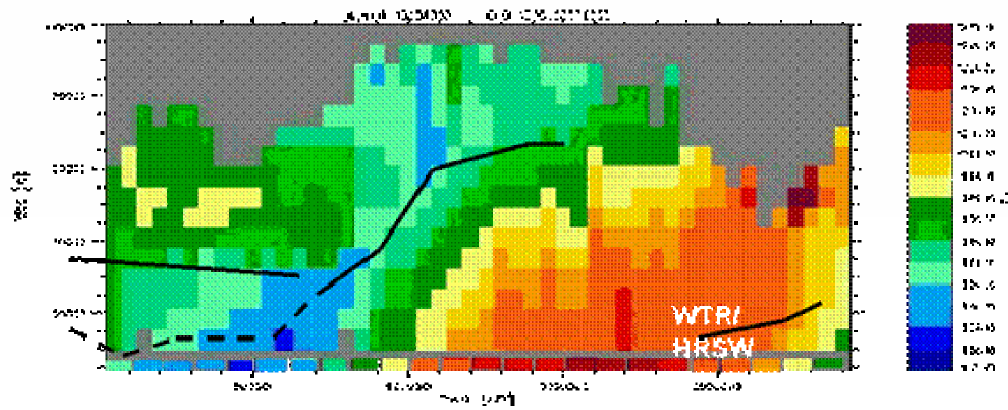
and pollutants are distributed rapidly

Comparison of SODAR measurements with data from a Wind-Temperature-RADAR (RASS) of IMK-ASF and a ceilometer of Vaisala (backscatter at 0.9 µm) for 09 May 2002

Results of MLH retrieval during simultaneous operation partly agree and partly complement each other







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.

SODAR measurement programme for Charles de Gaulle Airport (Paris):

Δt = 30 min, Δz = 20 m, z_{min} = 40 m, z_{max} = 800 m

used variables for the determination of MLH

acoustic backscatter intensity R_z in dB, σ_w in m/s

criteria for diagnosing MLH:

criterion 1 (top of turbulent layer)

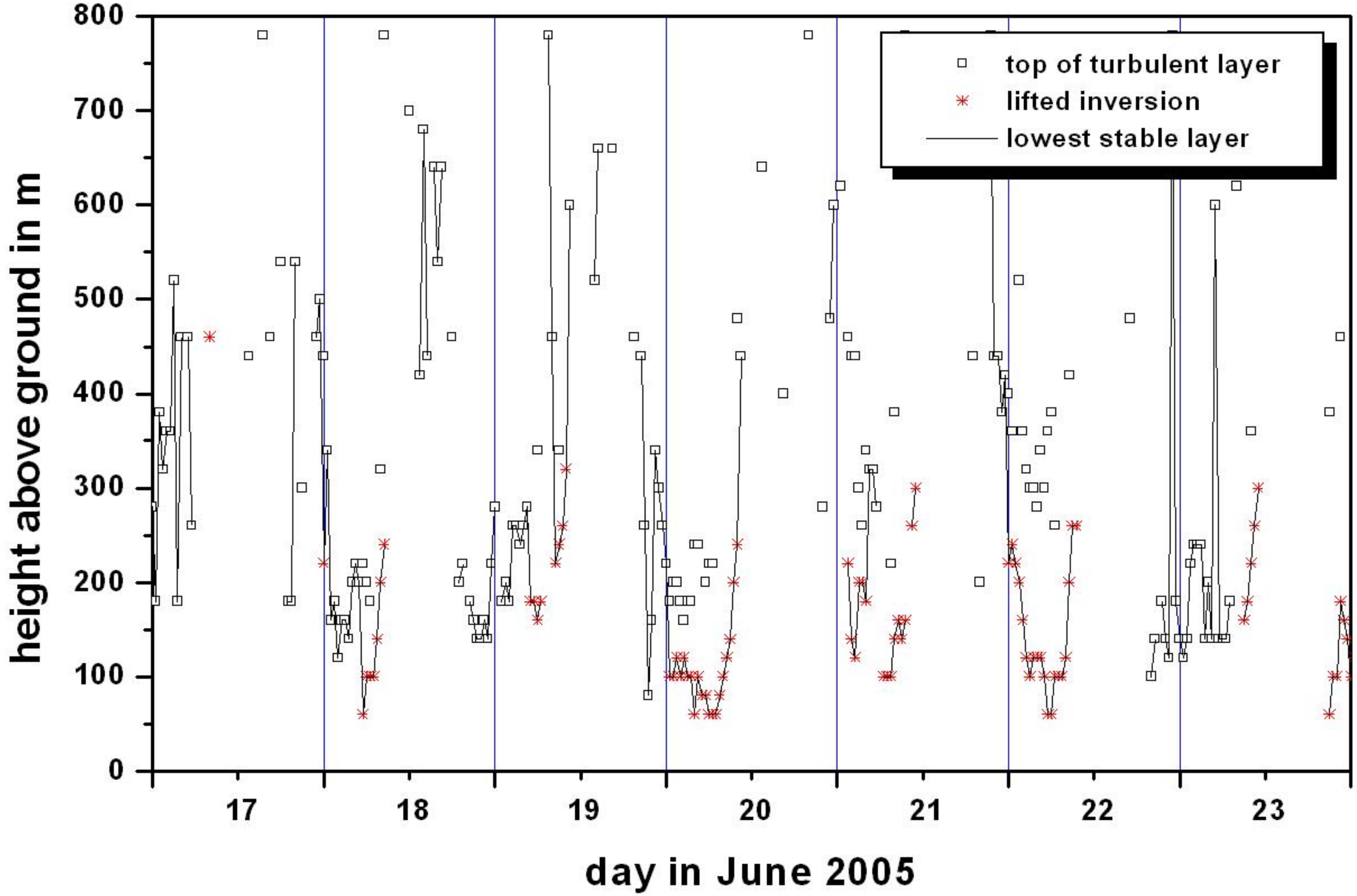
R_z < 88 dB $\wedge$ R_{z+1} < 86 db $\wedge$ R_{z+2} < 84 dB

criterion 2 (surface-based or lifted inversion)

Rz > 105 dB $\wedge$ σ_w < 0,3 m/s $\vee$ dR/dz_{z+1} < 0 $\wedge$ dR/dz_{z-1} > 0 $\wedge$ σ_w < 0,7 m/s

Emeis, S., M. Türk, 2004: Frequency distributions of the mixing height over an urban area from SODAR data. Meteorol. Z., 13, 361-367.

Weekly variation of mixing-layer height (CDG)



clear diurnal cycle of MLH

low values in the morning hours (100 – 200 m)

high values in the afternoon (above the range of the instrument > 800 m)

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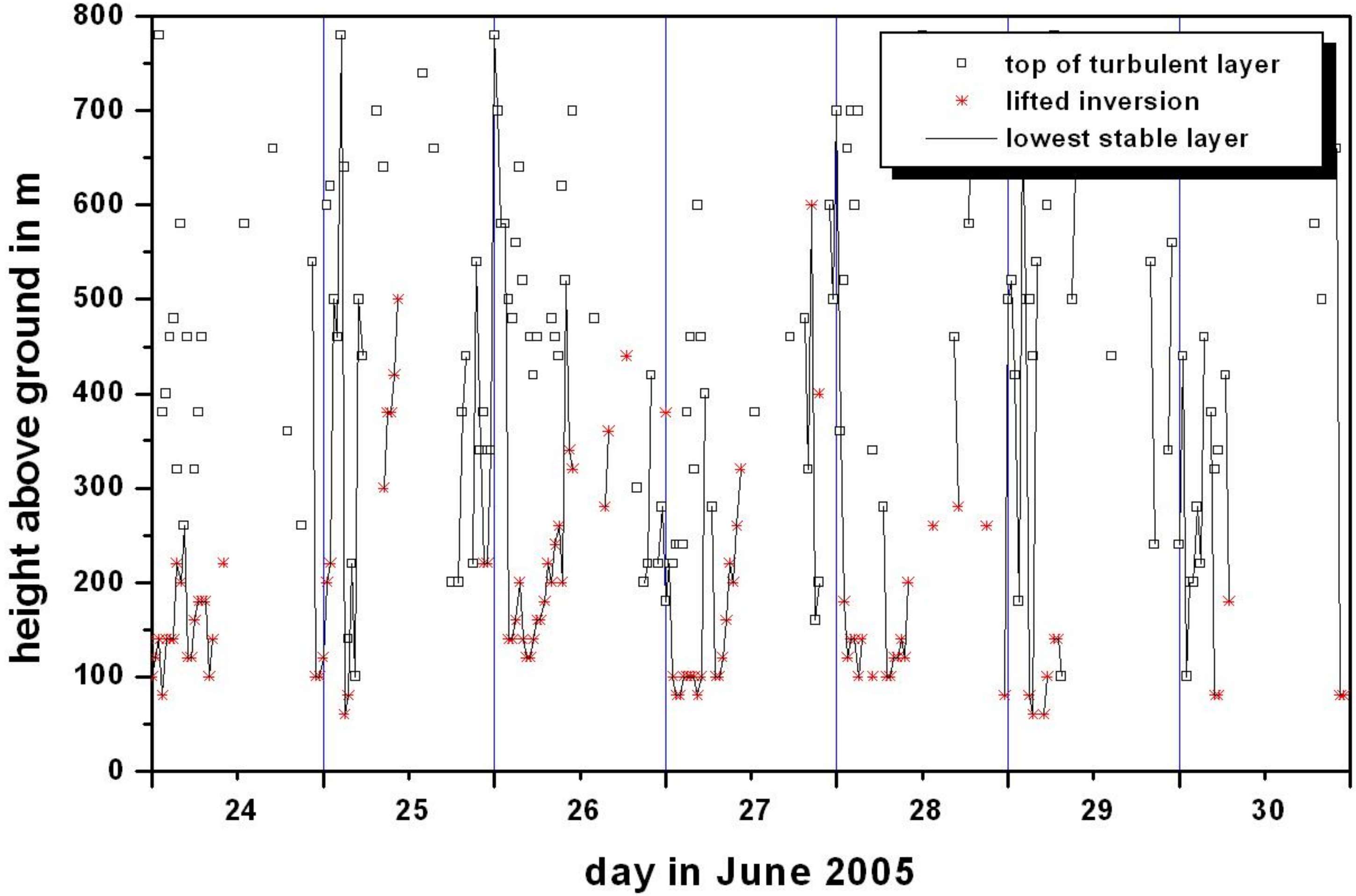
Weekly variation of mixing-layer height (CDG)

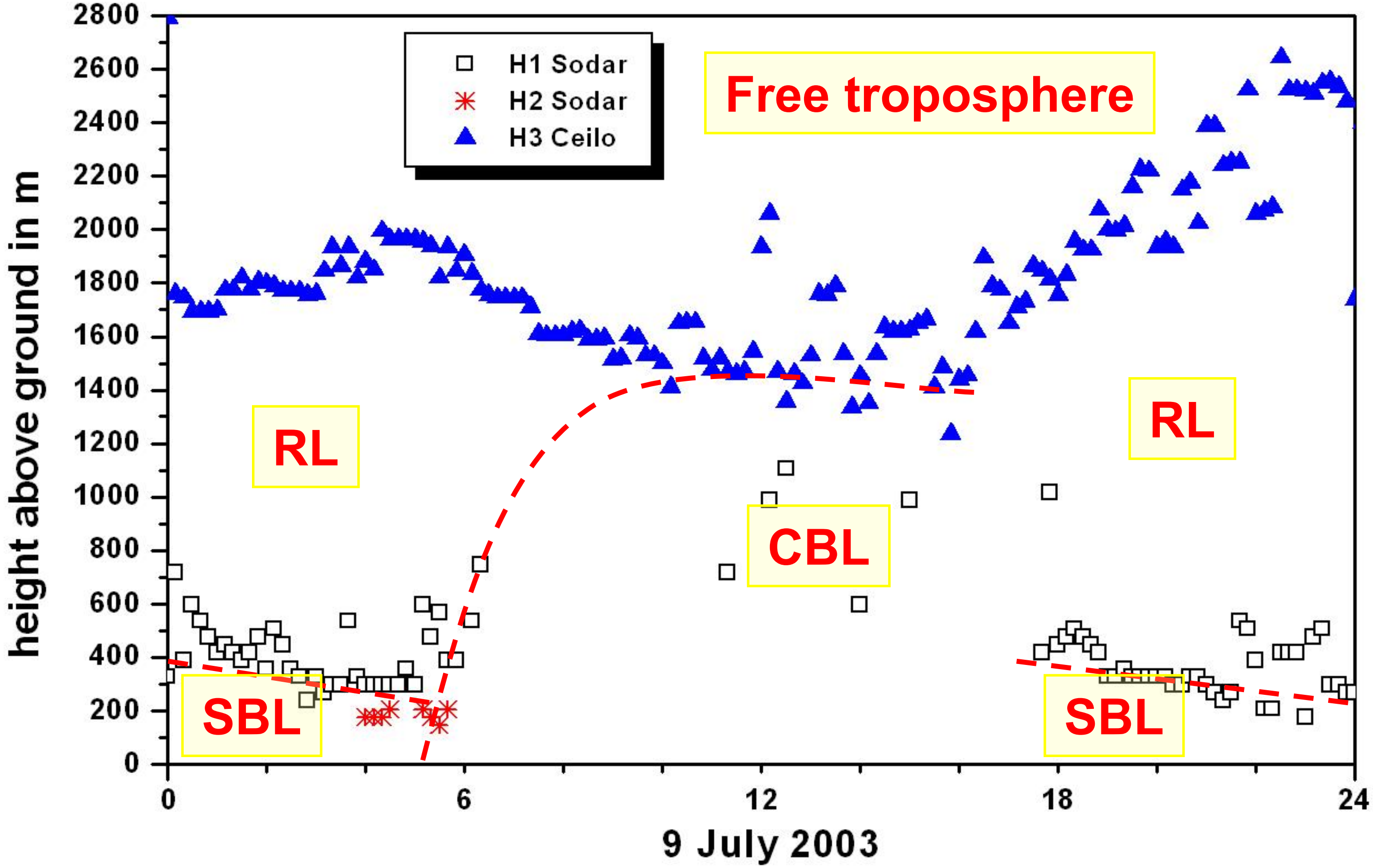


clear diurnal cycle of MLH

low values in the morning hours (100 – 200 m)

high values in the afternoon (above the range of the instrument > 800 m)

Diurnal variation of mixing-layer height from SODAR and Ceilometer data (Budapest)



SBL:

stable boundary layer (usually at night and in winter)

CBL:

convective boundary layer (usually at daytime due to strong insolation)

RL:

residual layer

(usually at night-time)

wind and turbulence profiles

Example from a measurement campaign

at

Paris CDG airport

in

June/July 2005

The sodar has been at position “6”

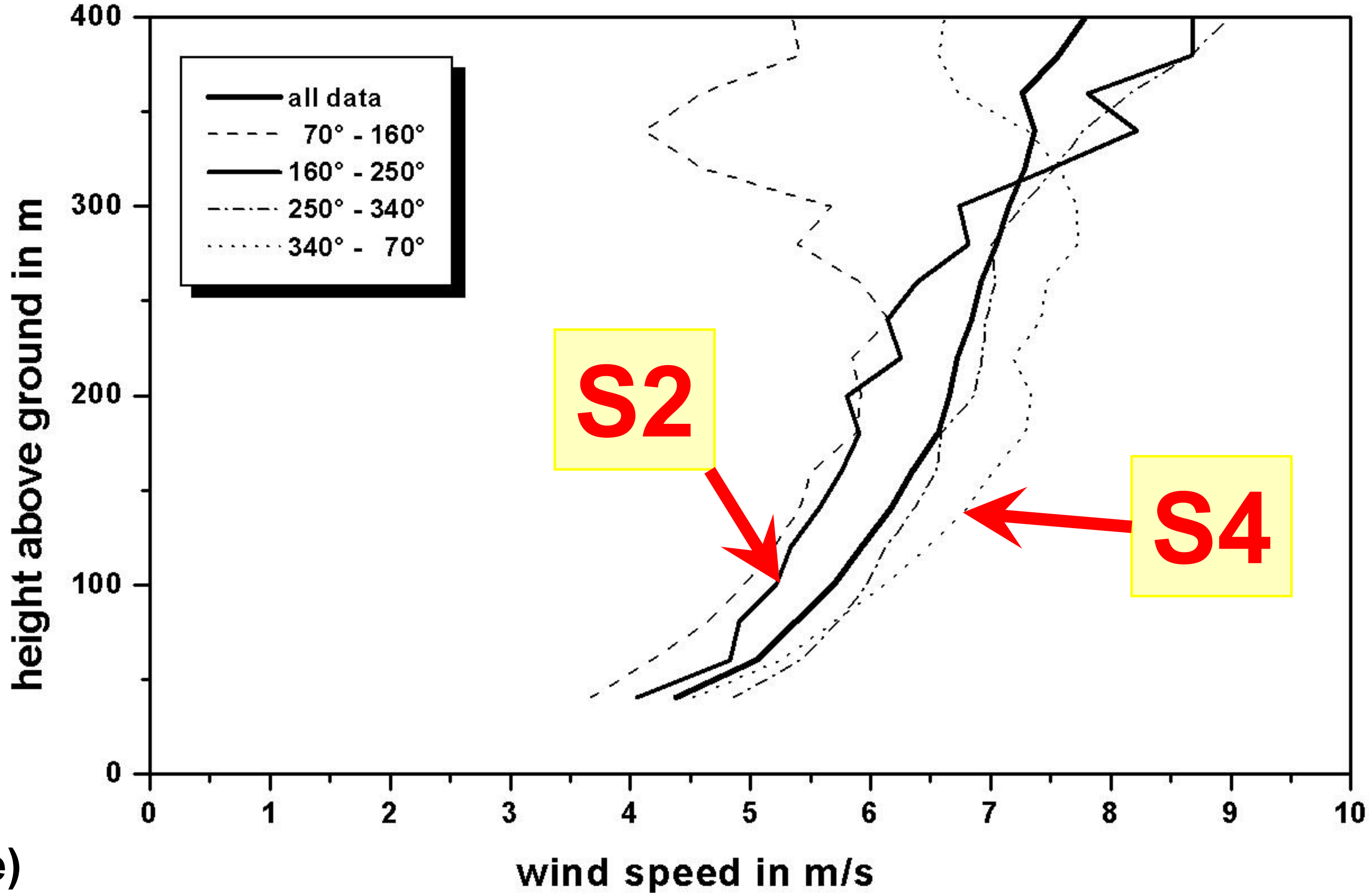
vertical profiles of wind speed u

CDG

June/July 2005

S2: influenced by the airport (lower wind speed over rough surface)

S4: rural profiles (higher wind speed over smooth surface)



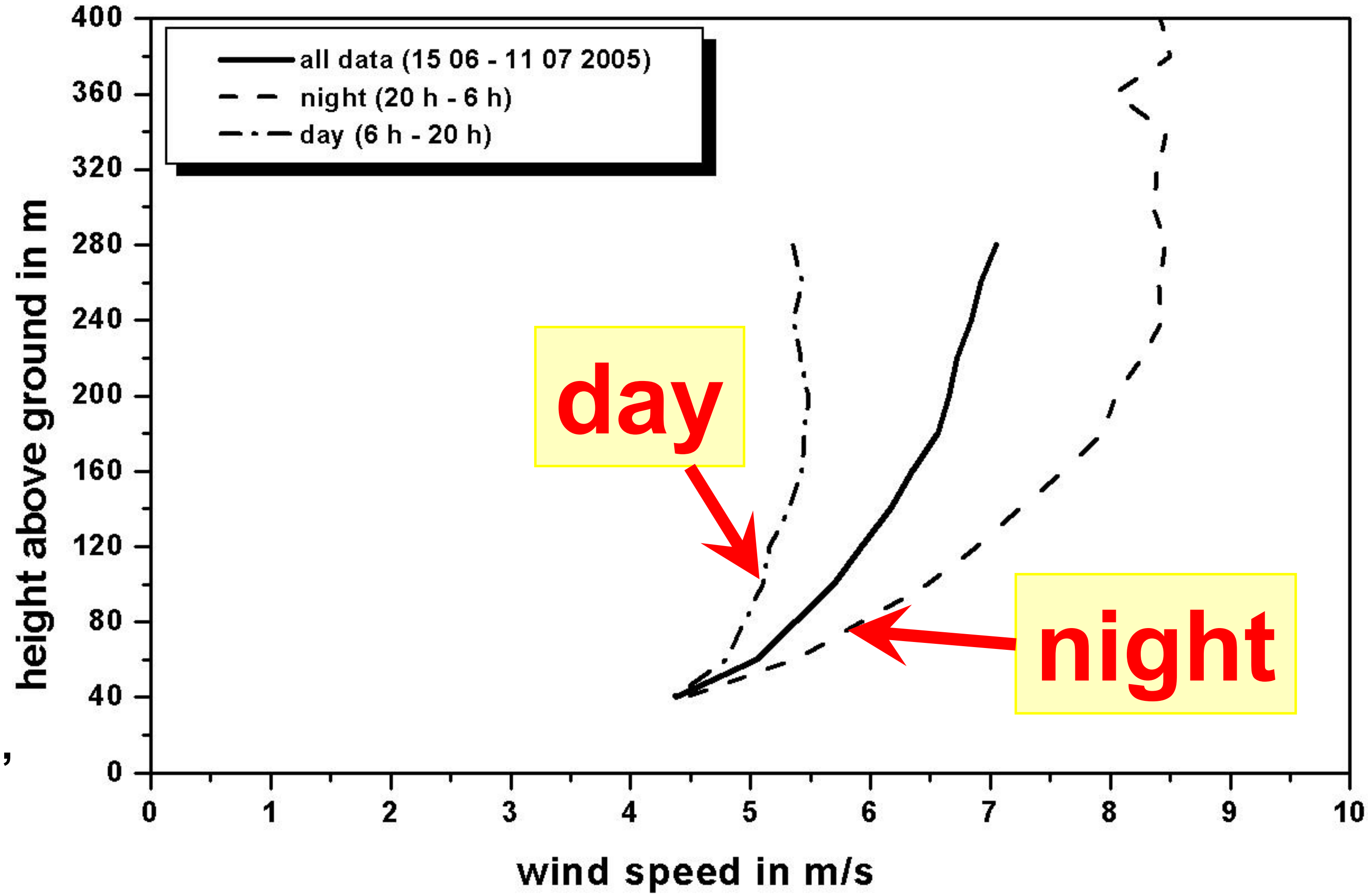
vertical profiles of wind speed u

June/July 2005

CDG

all data

typical difference between daytime and nighttime profiles (small gradient at daytime, large one at nighttime)

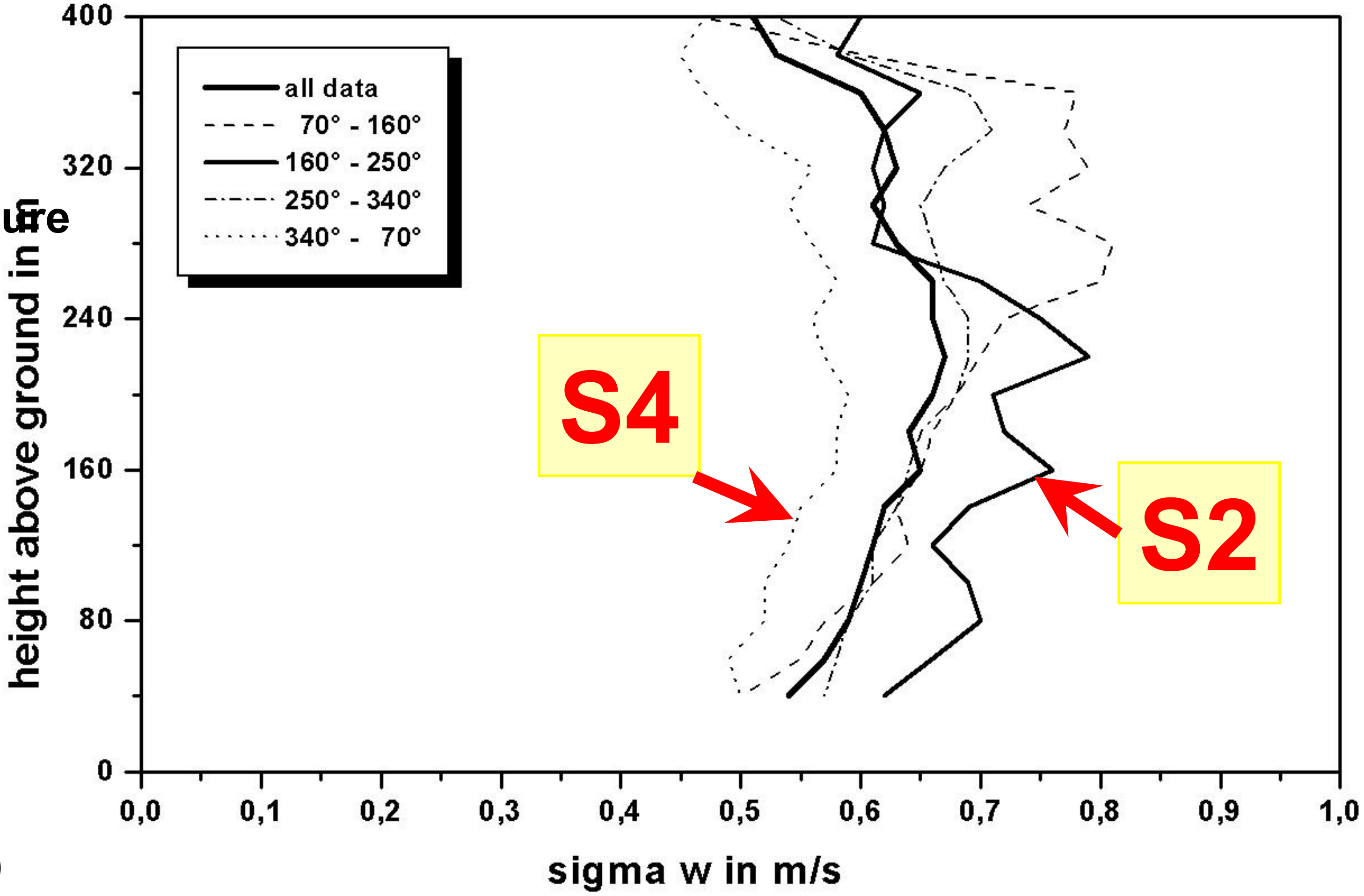


vertical profiles of σ_w

(variance of vertical wind speed, a measure for turbulence)

S2: influenced by the airport (higher turbulence over rough surface)

S4: rural profiles (lower turbulence over smooth surface)



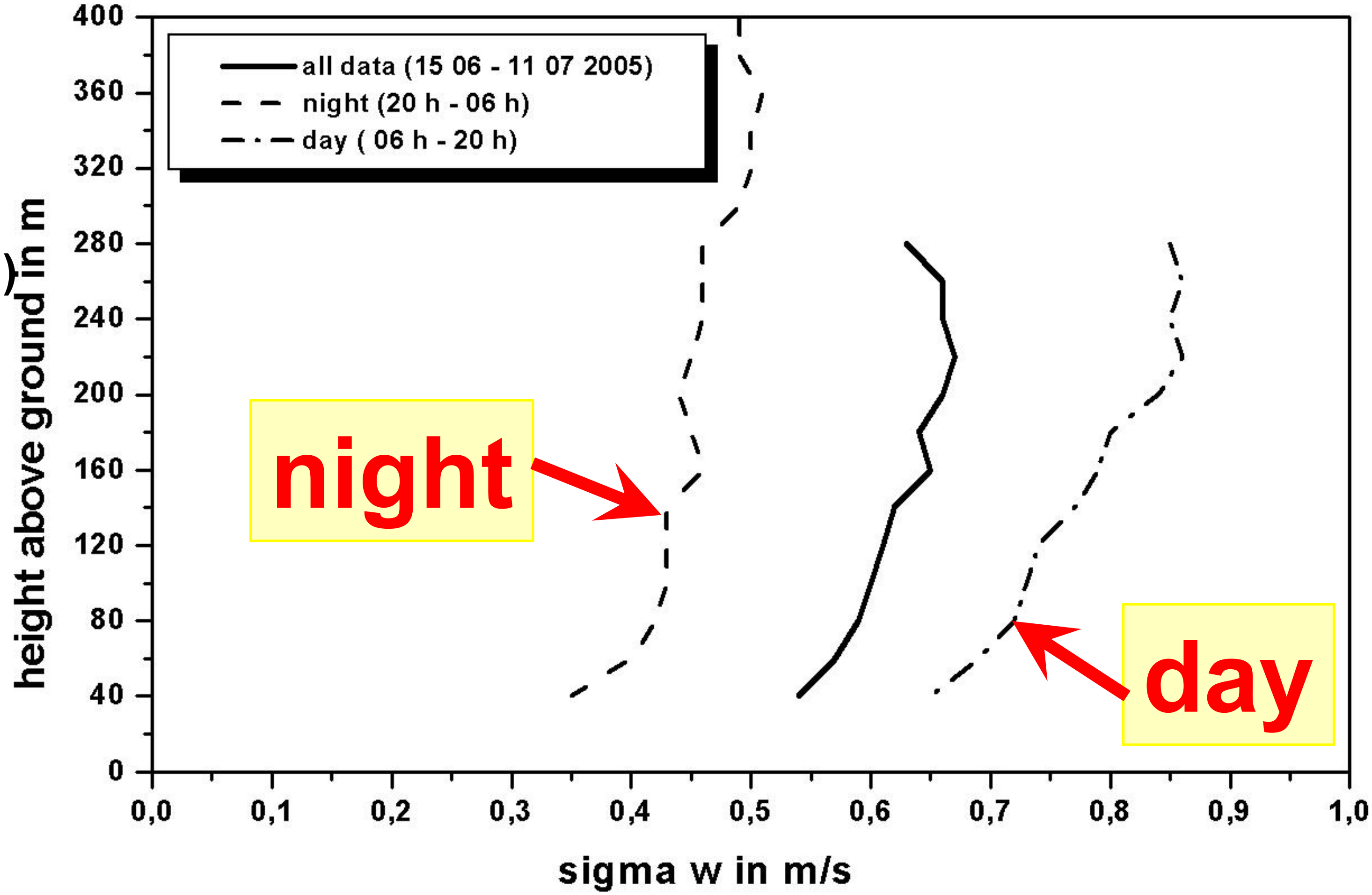
vertical profiles of σ_w

(variance of vertical wind speed)

CDG

all data

typical difference between daytime and nighttime profiles (high at daytime, low at nighttime)

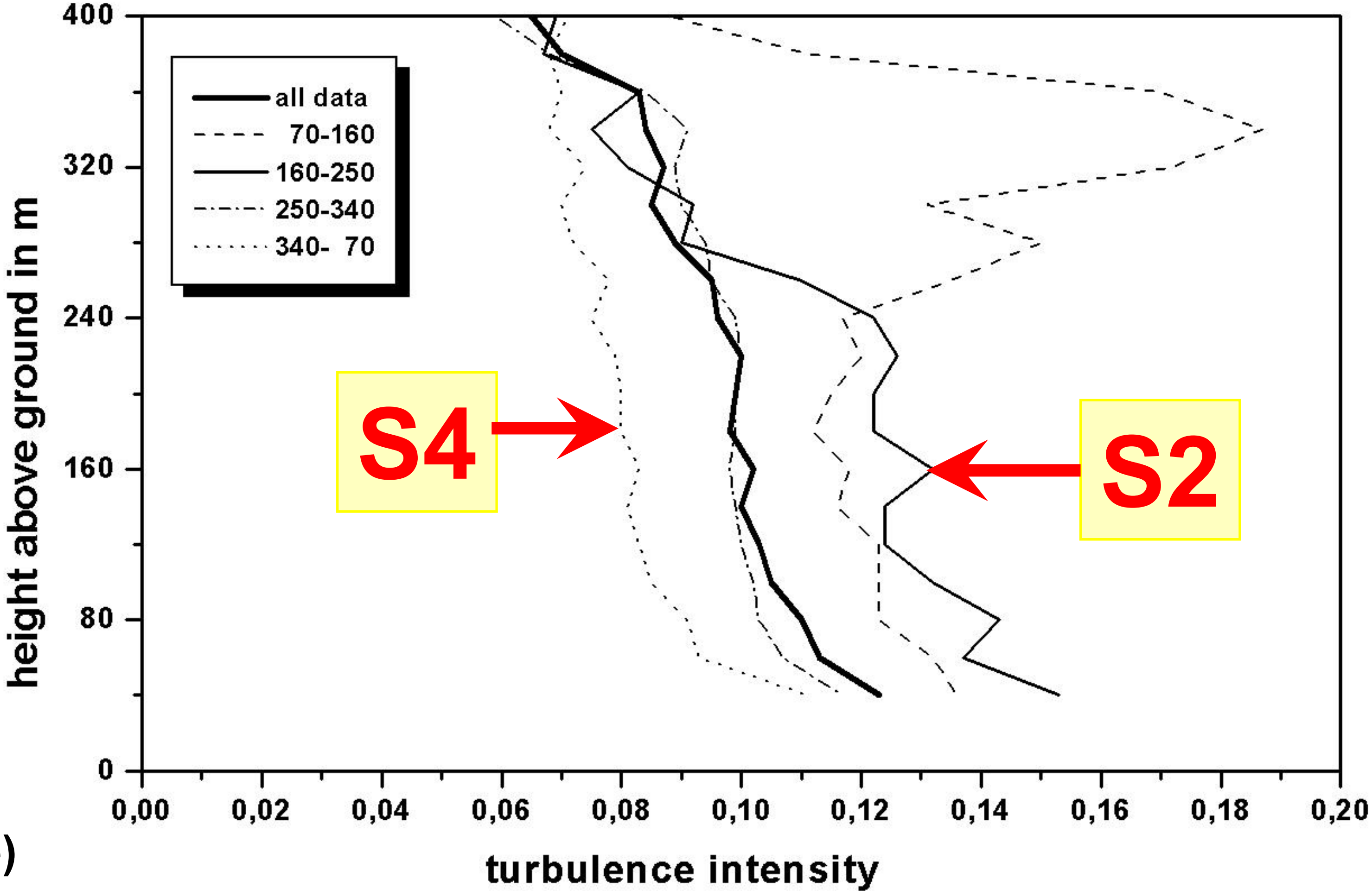


vertical profiles of turbulence intensity (u / σ_w)

CDG

S2: influenced by the airport (higher turbulence over rough surface)

S4: rural profiles (lower turbulence over smooth surface)

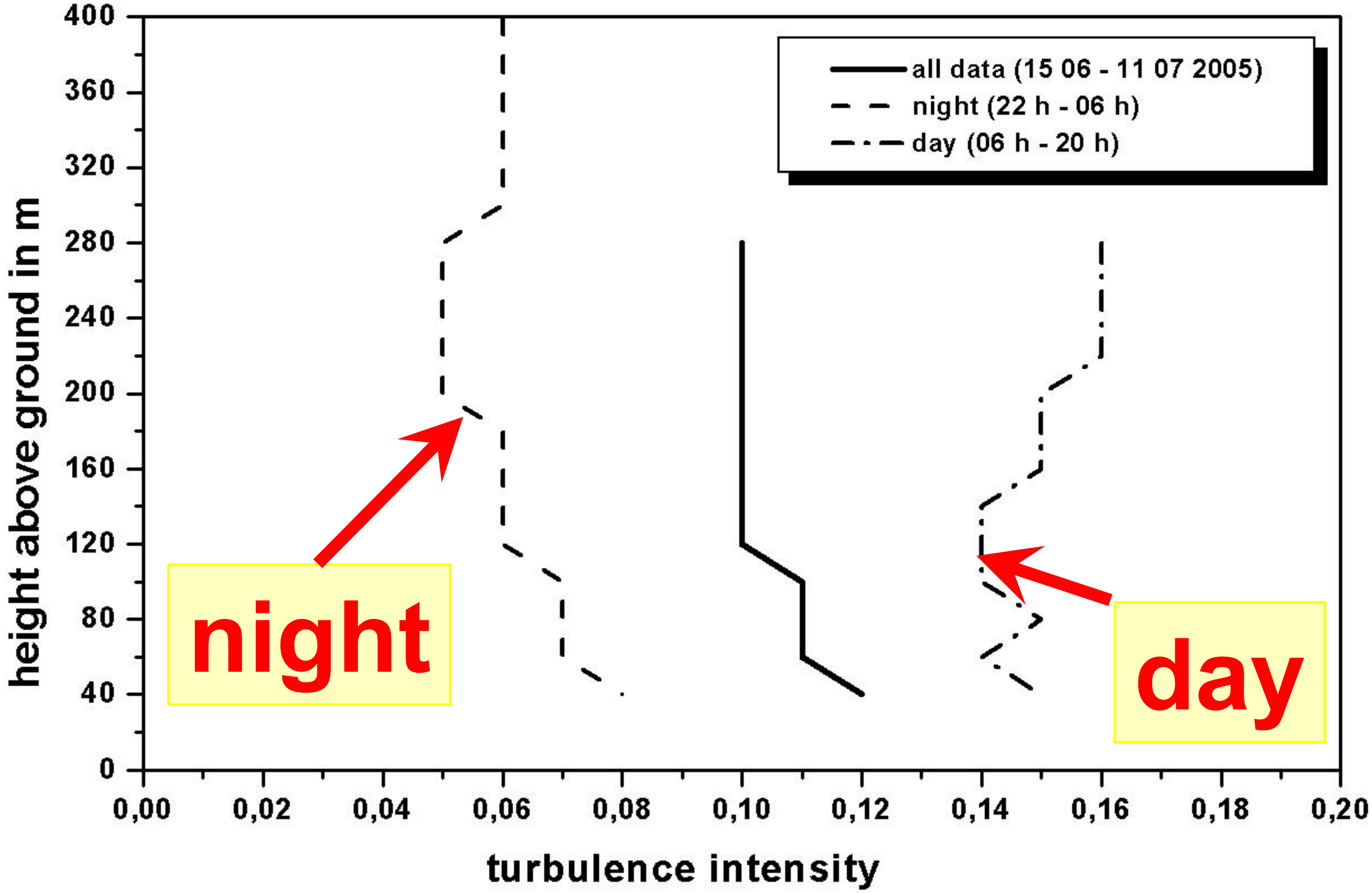


vertical profiles of turbulence intensity (u / σ_w)

CDG

all data

typical difference between daytime and nighttime profiles (high at daytime, low at nighttime)



Low-level jets (LLJ)

maxima of horizontal wind speed a few hundred metres above the ground,
associated with large vertical wind speed and direction gradients

usually form after sun set and disappear at sun rise

appear only in clear nights (no or only few clouds) when a synoptic surface pressure gradient is present

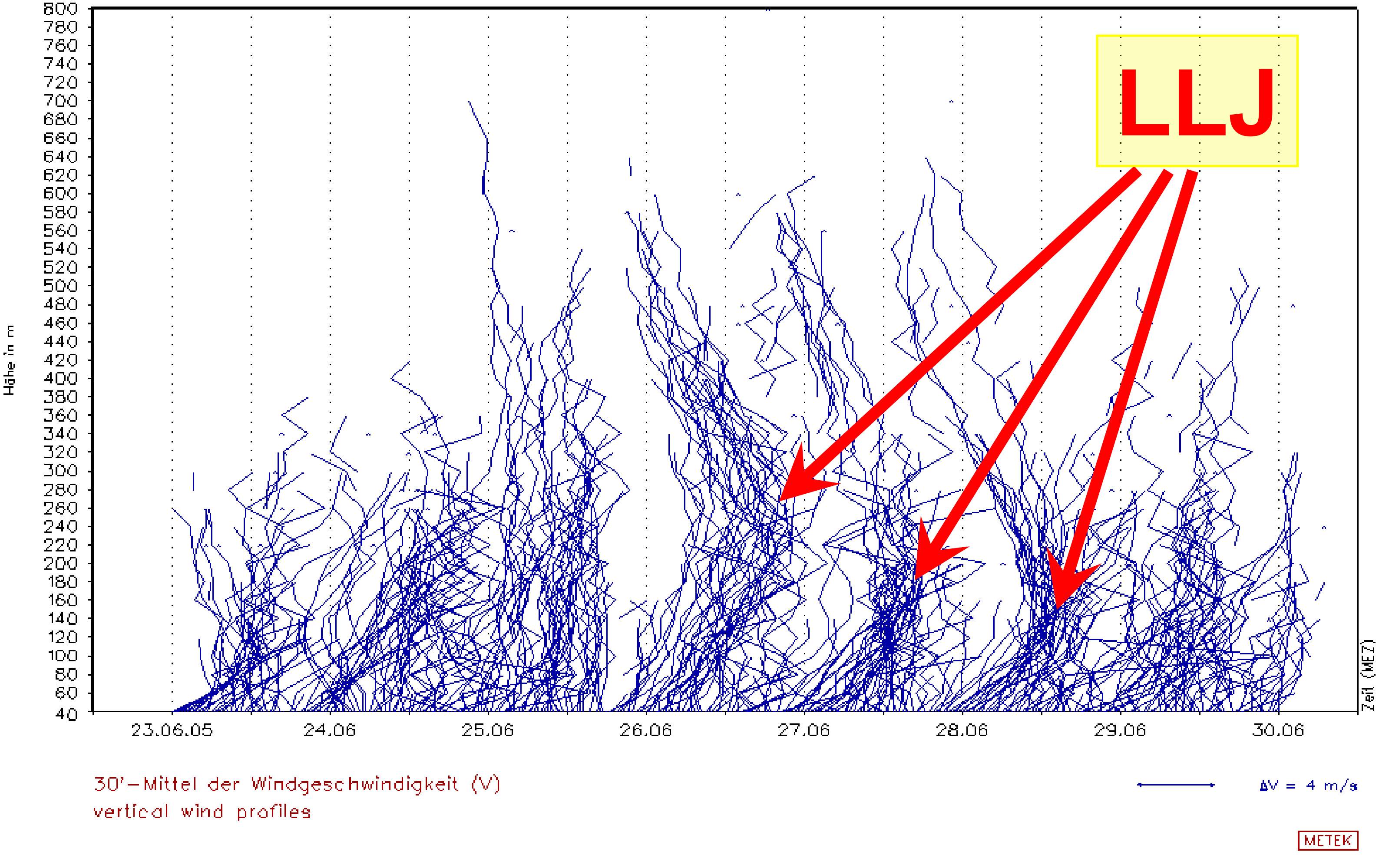
vertical profiles of wind speed

overview

23-30 June 2005

CDG

LLJ especially on June 26 to 28 at 150 to 300 m height above ground



vertical profiles of wind speed

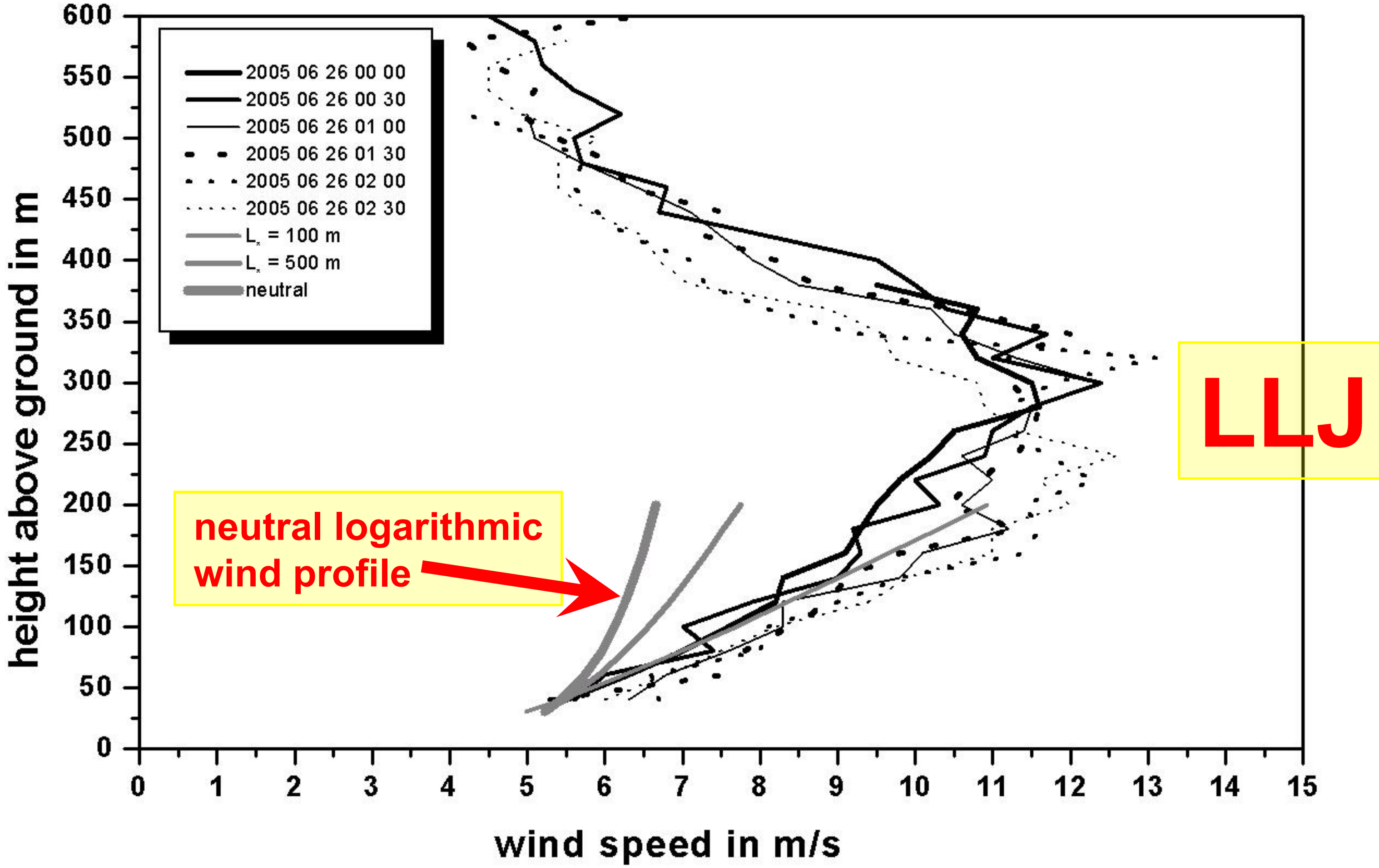
selected 30 min averages

26 June 2005

CDG

LLJ between 200 and 325 m above ground

leads to strong vertical wind shear



vertical profiles of wind direction

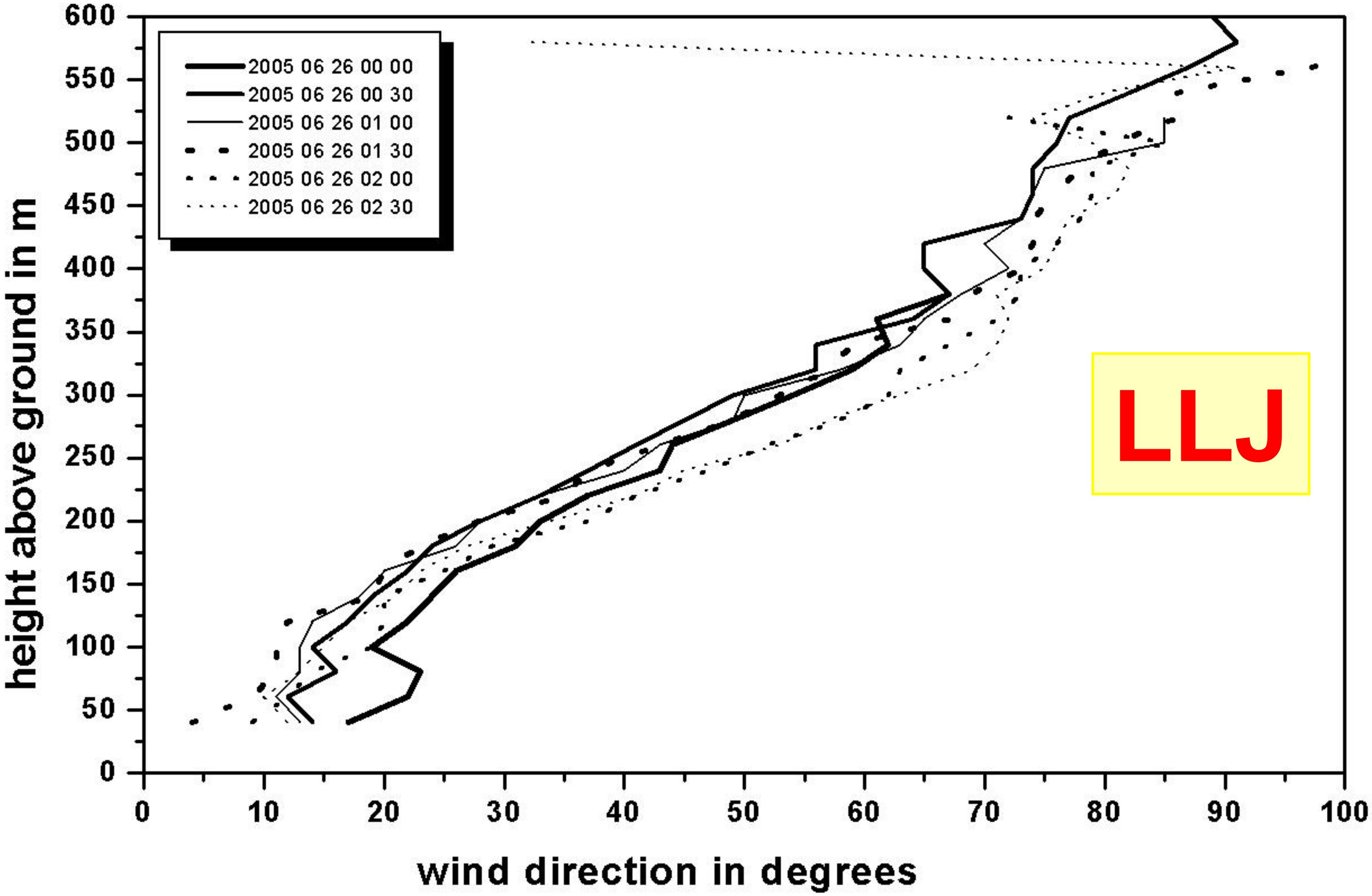
26 June 2005

CDG

selected profiles (same as before)

30 min averages

showing vertical wind direction gradients

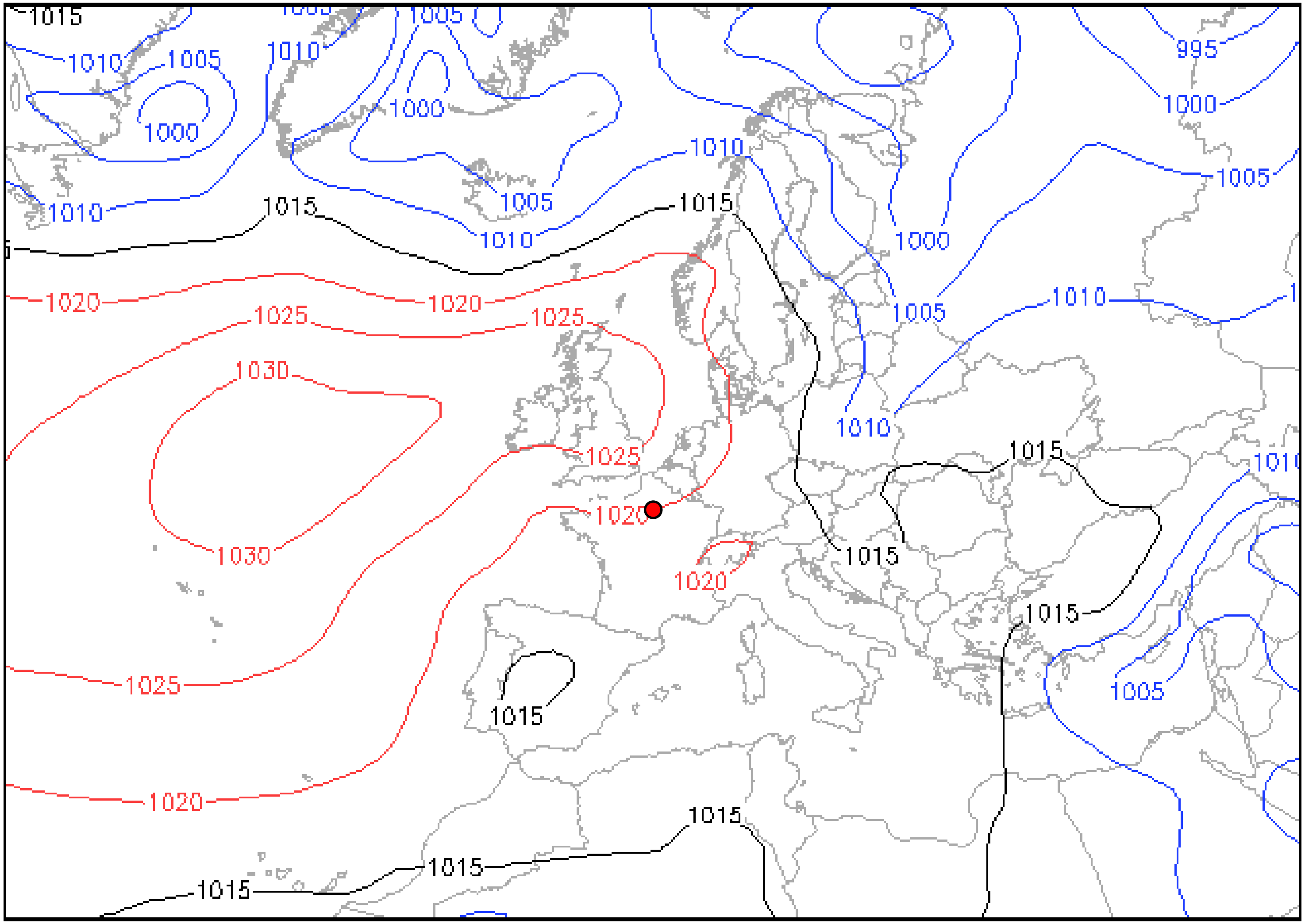


weather map showing a typical weather situation for LLJ at Paris CDG

surface pressure 00 GMT

26 June 2005

Paris CDG lies at the edge of a high pressure system (leading to clear skies) with noticeable horizontal surface pressure gradient



Bodendruck GFS (hPa)

So 26.06.05 00 GMT (So 00 + 24)
WetterOnline

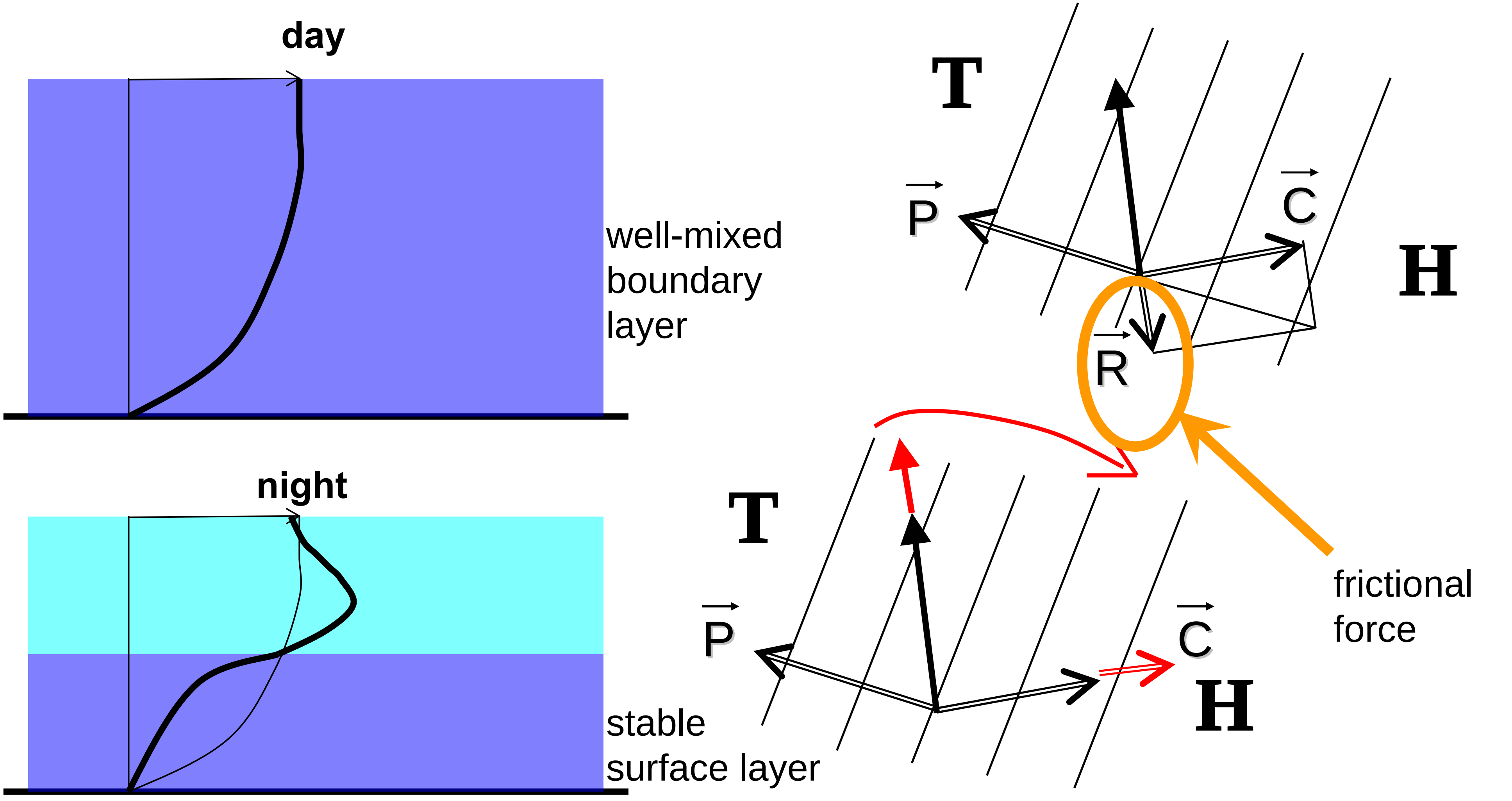
Typical weather conditions for the formation of nocturnal low-level jets (LLJ):

- clear skies
- dry air masses (low thermal radiation from the atmosphere back to the ground)
- non-vanishing synoptic pressure gradient
- low to medium synoptic wind speeds

Physical mechanism:

- rapid thermal cooling of the surface after sun set leads to the formation of a cool stable surface layer with low turbulence
- missing turbulence leads to a decoupling of the layer above the surface layer from the frictional influence of the ground on the atmospheric flow
- vanishing frictional influence leads to an acceleration of wind speed in the decoupled layer
- during the night: inertial oscillation (turning of wind direction of LLJ)
- next morning: destruction of the phenomenon due to thermal mixing from below

Nocturnal low-level jet (LLJ) and turning of wind direction with height

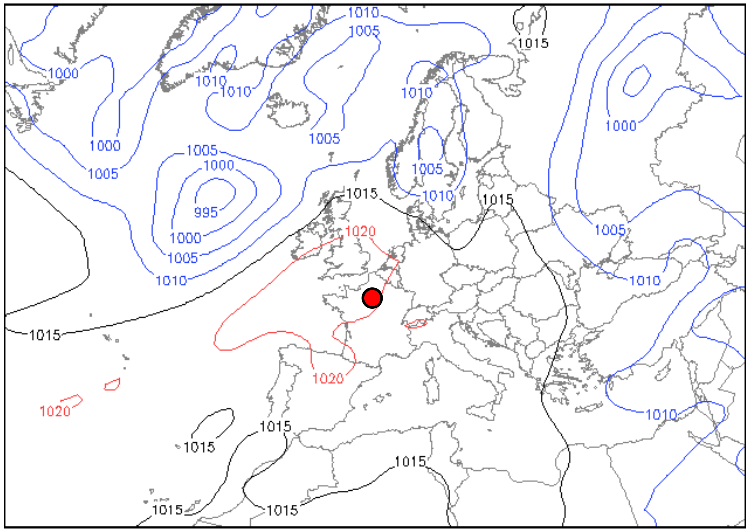


further eamples:

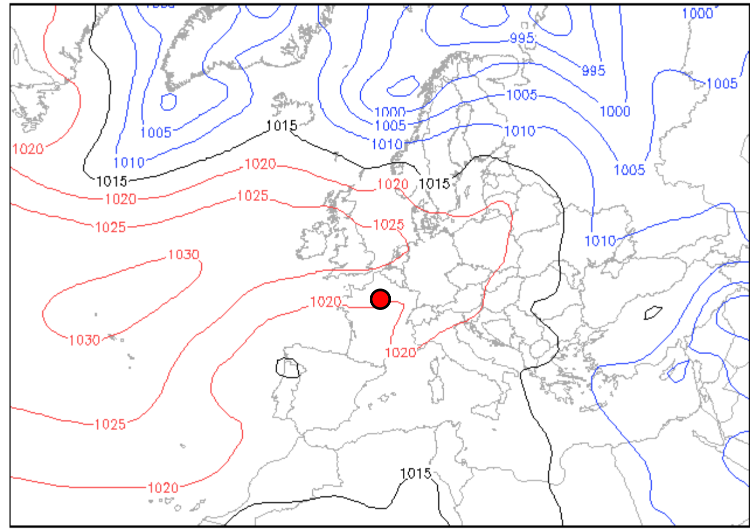
surface pressure
00 GMT

22, 27, 28 June,
10 July 2005

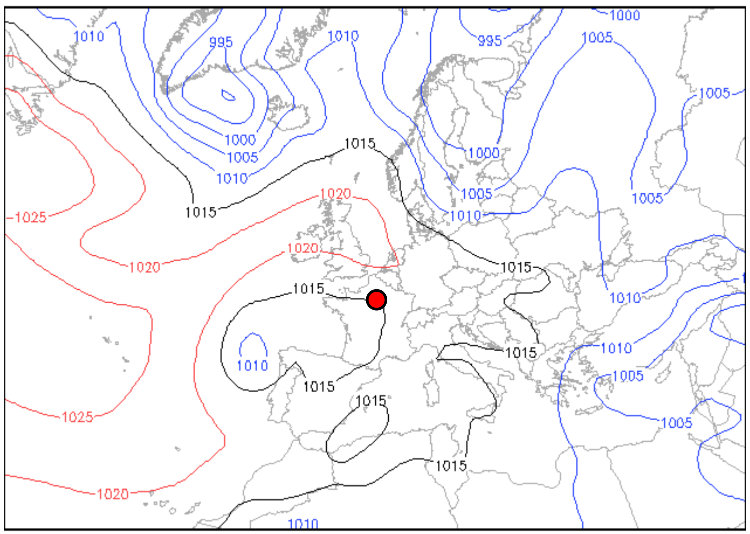
(nights with LLJ at Paris CDG)



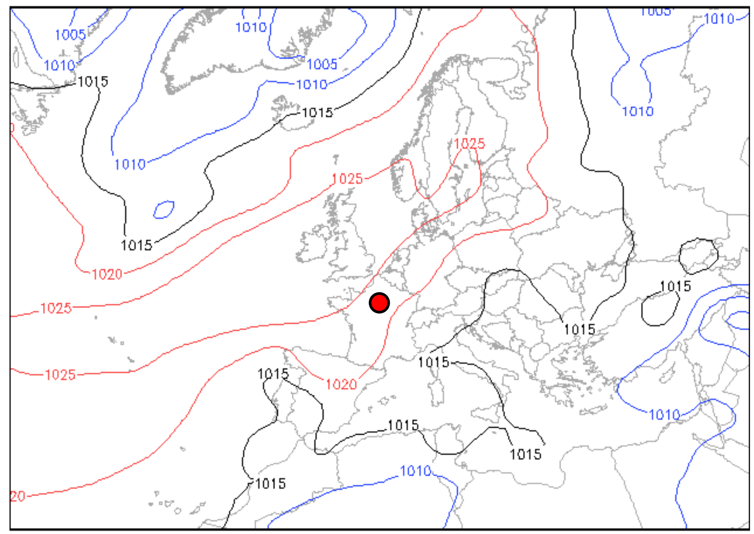
Bodendruck GFS (hPa) Mi 22.06.05 00 GMT (Di 00 + 24)
WetterOnline



Bodendruck GFS (hPa) Mo 27.06.05 00 GMT (So 00 + 24)
WetterOnline



Bodendruck GFS (hPa) Di 28.06.05 00 GMT (Mo 00 + 24)
WetterOnline



Bodendruck GFS (hPa) So 10.07.05 00 GMT (Sa 00 + 24)
WetterOnline

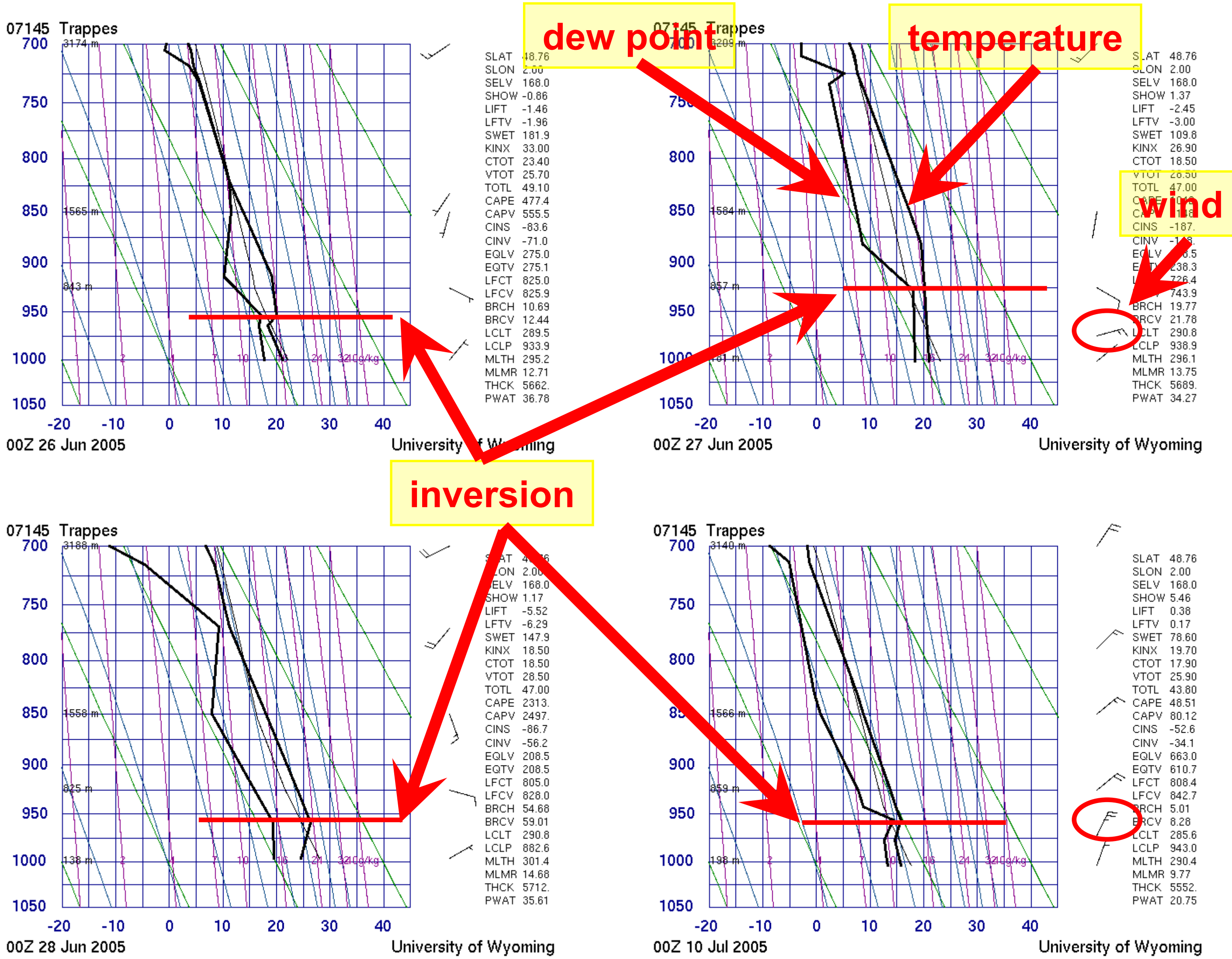
vertical structure of the lower troposphere

radiosonde soundings in Trappes 00 GMT

for heights below 3000 m

26, 27, 28 June, 10 July 2005

(nights with LLJ at Paris CDG)

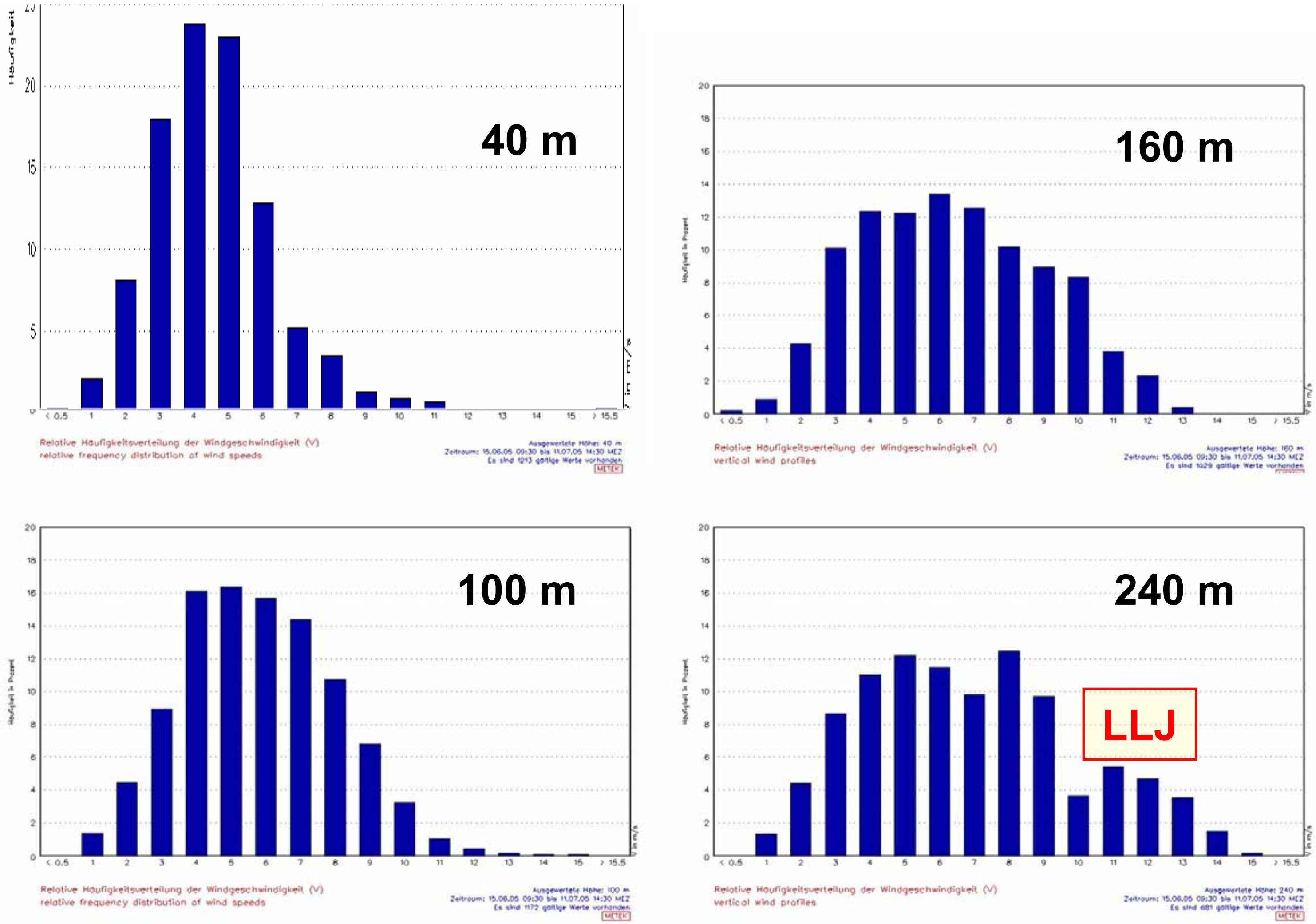


statistical evaluation of sodar wind measurements

wind speed frequency distribution with height

June/July 2005

CDG




Let’s take off …
Thank you for your attention
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