Fernerkundungs-Untersuchungen der Schichtung der unteren Atmosphäre in Alpentälern und deren Einfluss auf die Schadstoffbelastung

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Motivation

High air pollution episodes associated with meteorological conditions like calm winds and low inversion layers occur near major Alpine traffic routes

These situations are typically in deep valleys with high emissions from road traffic, urban areas and industry

Motivation

The dispersion of these exhausts is strongly reduced due to frequent inversions, low wind speeds compared to flat terrain and a limited mixing volume

Consequently the air pollution is high

Background

Several emission reduction measures were successful during the last 20 years but due to increasing amounts of heavy duty vehicles and passenger cars the overall air quality in such regions is even worse

The EU air quality thresholds (European Air Quality Framework Directive 96/62/EC and its daughter directives) of e.g. PM10 and/or NO_2 are too often exceeded not only in these regions

Background

This situation is caused by an ongoing deeper understanding of the health impact of such air pollutants so that new emission standards and ambient concentration thresholds for air pollutants are continuously defined

E. g. currently the new threshold values for NO_2 as of 2010 seem to be too high because there are new research results about the influence of high NO_2 concentrations upon the mortality rate

Background

But also the increasing NO_2/NO_x ratio in traffic emissions is a reason for this situation which is caused by an increased efficiency of Diesel engines and new catalysts as well as an growing number of Diesel cars

AIR QUALITY IN INNER-ALPINE VALLEYS NEAR BRIXEN
RESULTS OF MEASUREMENTS IN SUMMER 1999

Objectives

- **Determination of the wind regime**
- **Height of the boundary layer**
- **Air quality during a summer ozone episode**

Main focus: flow patterns on days with high ozone concentrations

IFU-SODAR: Horizontal wind speed and direction in Brixen July 1999

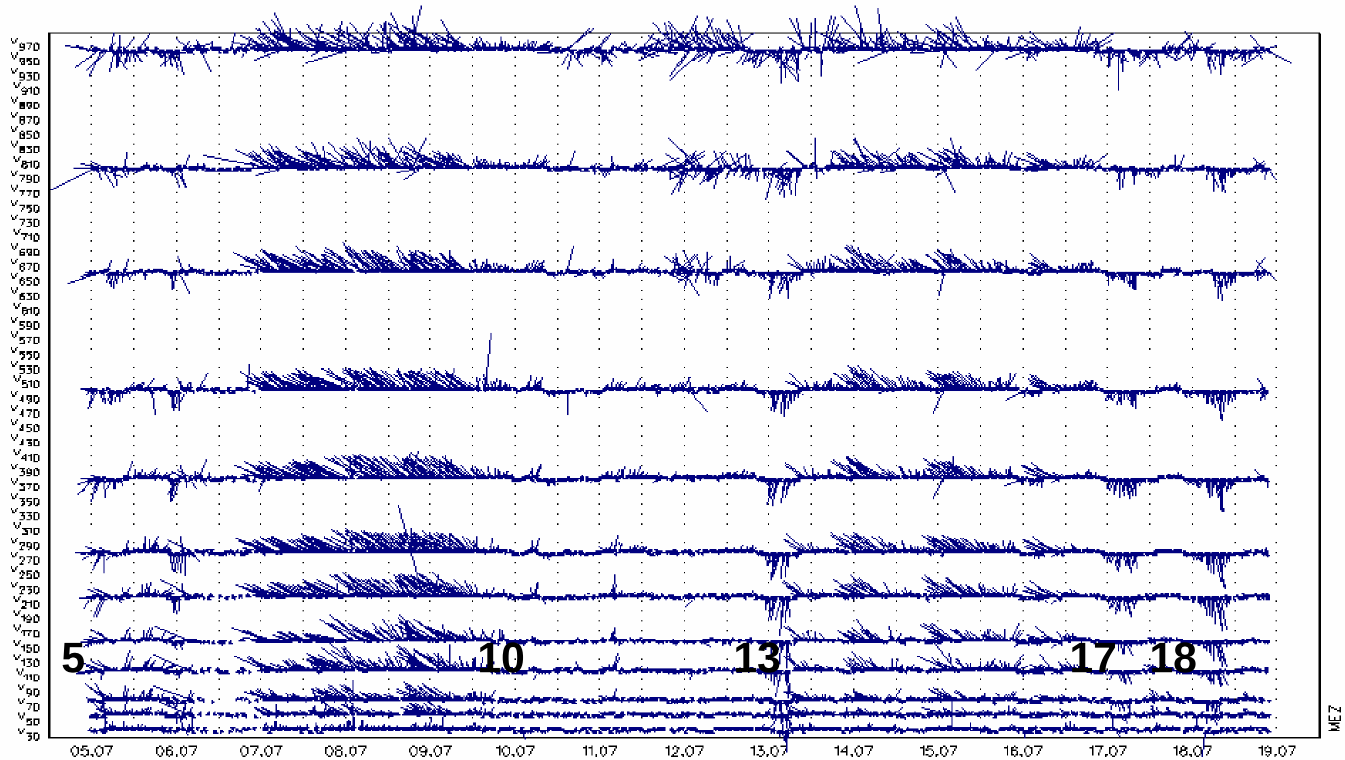


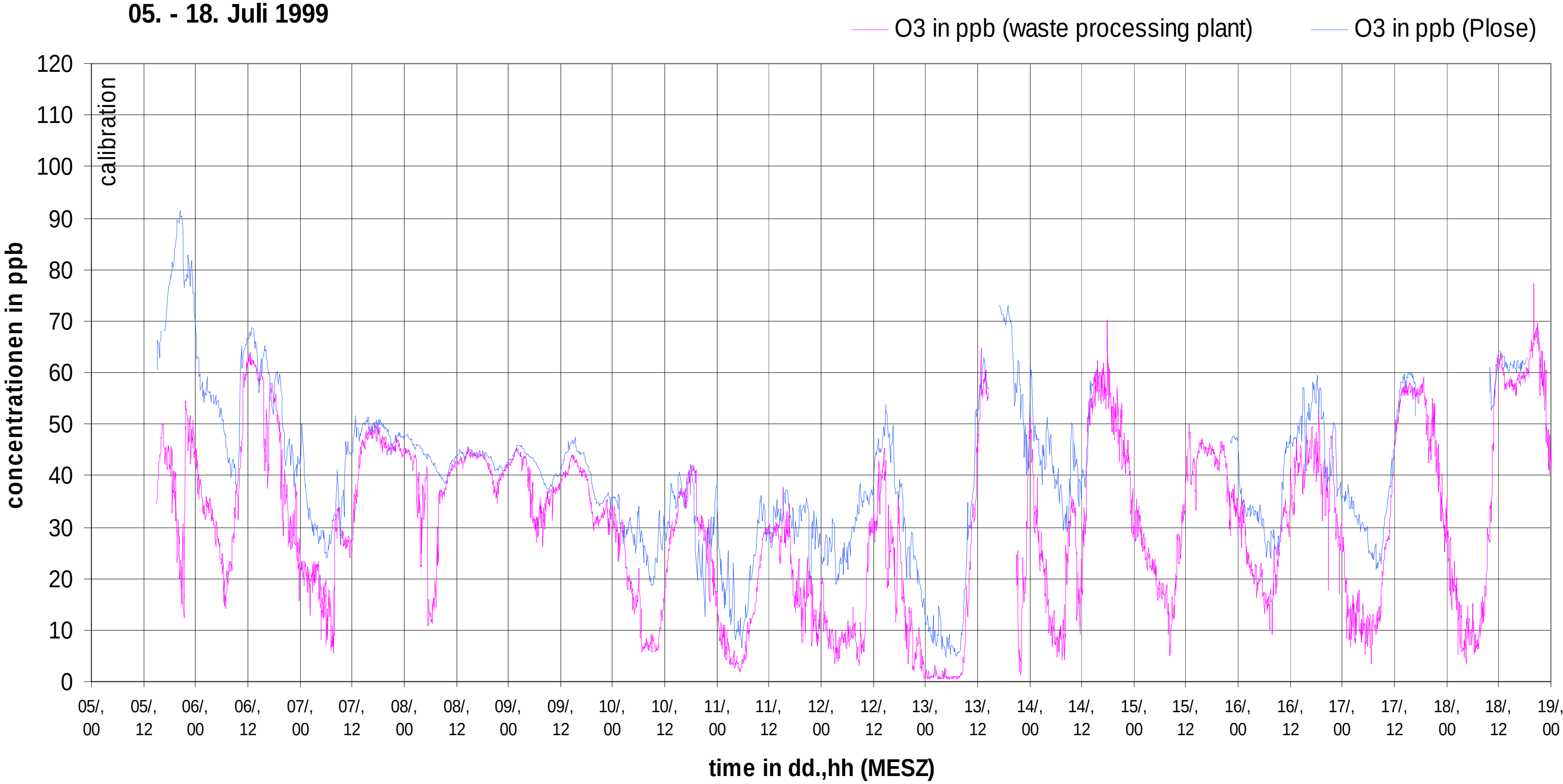
Abb.: 30'–Mittel des Windvektors (v_x) für ausgewählte Höhen (x)
Brixen (Bressanone) Scintec–SODAR Juli 1999

→ = 3 m/s Westwind

IFU GAP

Brixen

05. - 18. Juli 1999

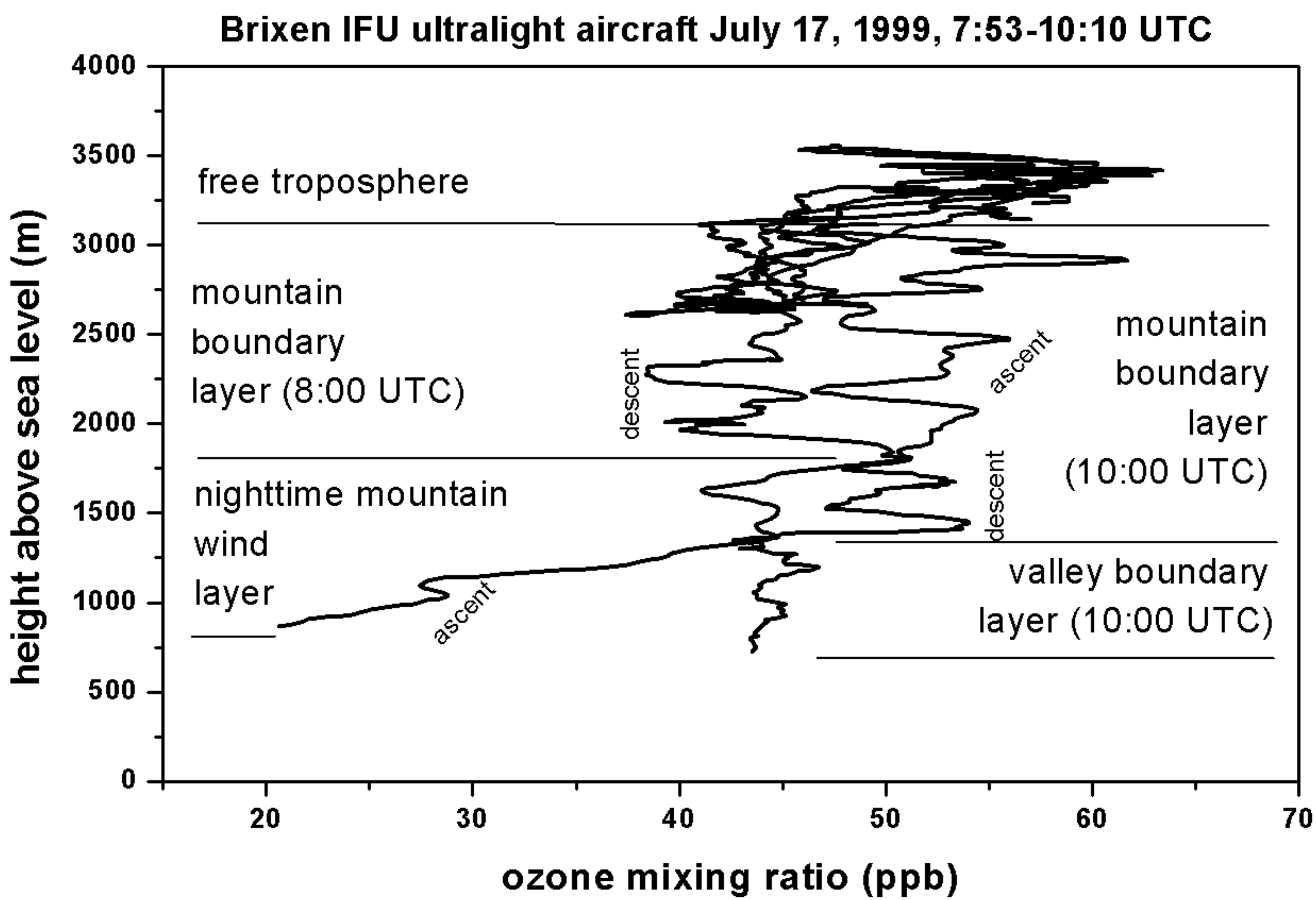


Wind features can be identified also in the surface ozone concentration readings at both measuring sites

At the waste processing plant during the night the concentrations are around 10 ppb

Deposition to the ground and ozone titration due to freshly emitted NO has removed nearly all of the ozone from the cold and stable surface layer

With the start of thermal convection in the morning the concentration starts to rise and reaches nearly 60 ppb on July 17 at the waste processing plant and in Plose because ozone is mixed downwind from the residual layer above


Brixen IFU ultralight aircraft July 17, 1999, 7:53-10:10 UTC
height above sea level (m)
ozone mixing ratio (ppb)
0
500
1000
1500
2000
2500
3000
3500
4000
20
30
40
50
60
70
free troposphere
mountain boundary layer (8:00 UTC)
nighttime mountain wind layer
mountain boundary layer (10:00 UTC)
valley boundary layer (10:00 UTC)
ascent
descent
ascent
descent

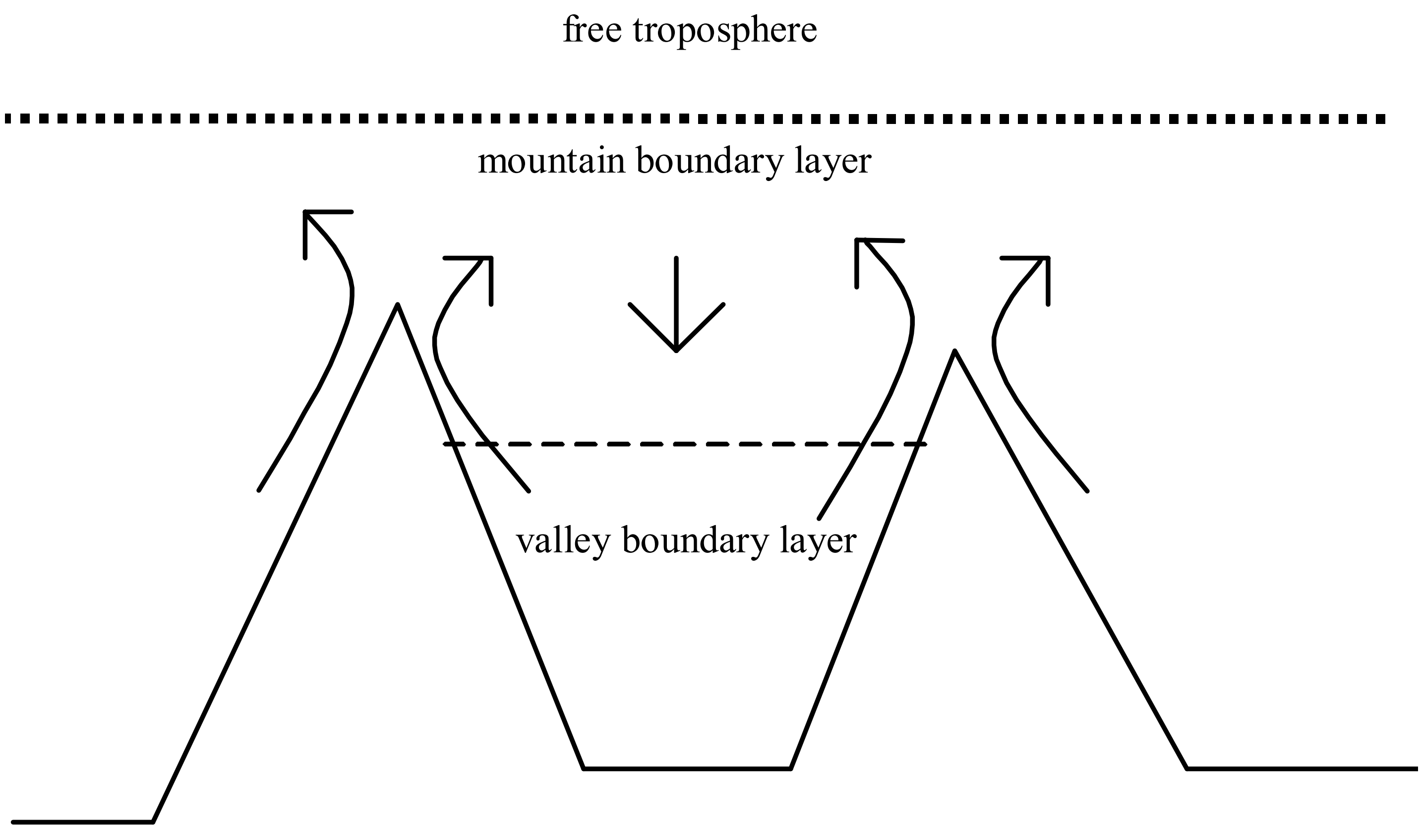
Conclusions

Highest ozone concentrations during the day when thermal mixing took place

Surface ozone maximum in the early afternoon in the order of the concentration in the free troposphere plus a small contribution due to daytime chemistry

Vertical mixing was the most important influencing factor for the peak ozone concentration

Only on the evening of July 18 a clear signal of horizontal advection of ozone from the south could be observed at the two surface measurement stations near Brixen



Boundary layer structure and vertical exchange in an Alpine valley

Threefold structure of the air in the valleys during summer-smog episodes was found:

• There is a valley boundary layer which is shallow and stable in the night (a few hundred meters thick) and well-mixed during the day (1000 – 1500 m thick)

• Above this is the mountain boundary layer which reaches up to 3000 to 4000 m a.s.l.

• This layer is strongly influenced by the mountains

Upslope winds on the slopes transport trace substances from the valley boundary layer into this layer during the day

Above this layer we find the free troposphere

In order to detect the upper boundary of the valley boundary layer, additional meteorological stations should be sited in heights between 1300 m and 2100 m a.s.l.

This would allow to find the top of a valley boundary layer which is 800 to 1600 m thick in the case that the valley floor is at about 500 m a.s.l.

Objectives of the winter campaign 1999

Detection of the height of the stable valley boundary layer in typical winter smog situations in the valleys

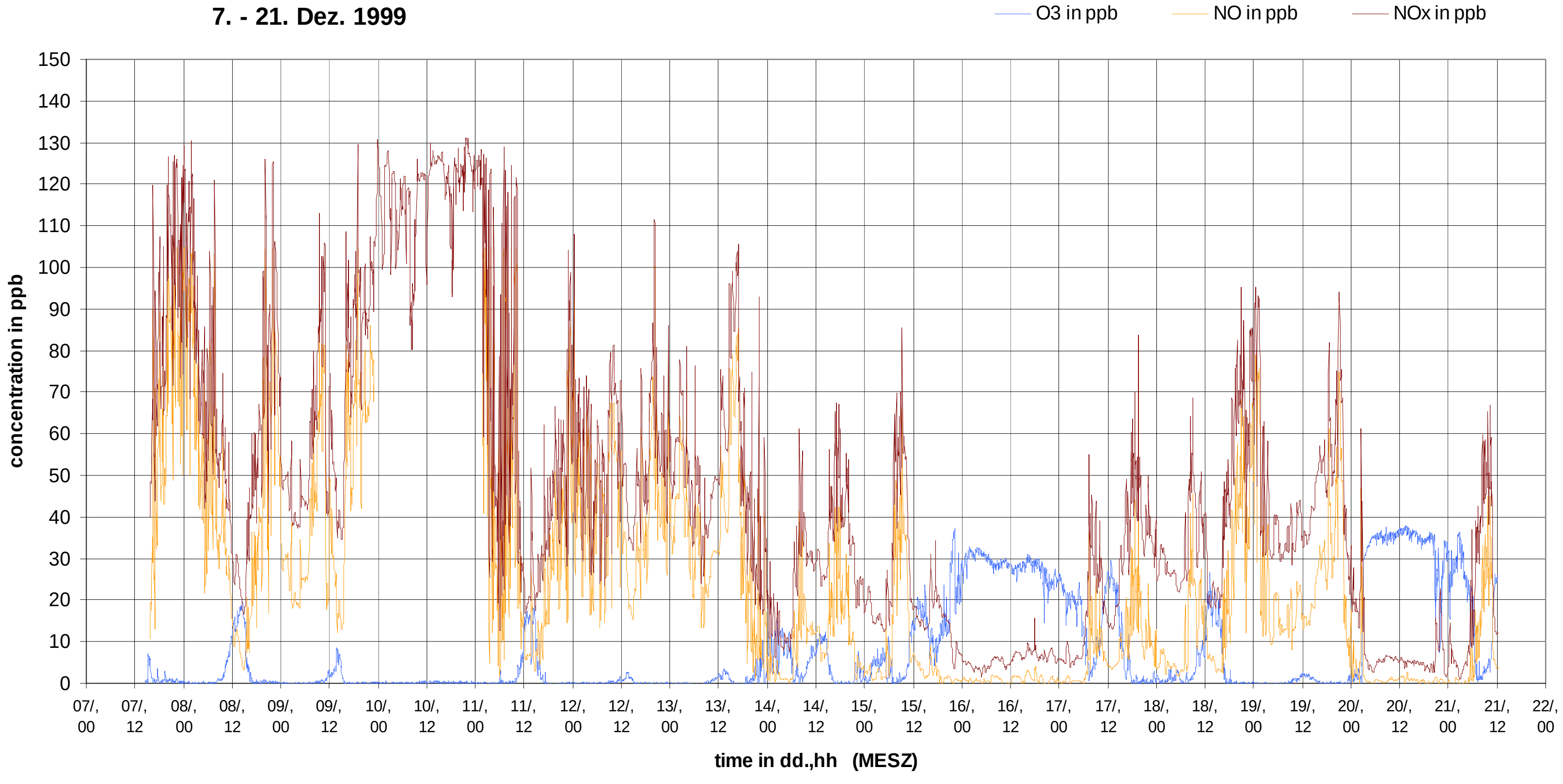
Typical winter smog situations are characterized by clear skies, strong nocturnal radiative cooling, and low wind speeds near the ground

Anticyclonic weather situations are most likely to produce these smog episodes

Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

Brixen   Station Sarns

7. - 21. Dez. 1999



Conclusions

Highest nitrogen oxide concentrations in winter are during North Foehn periods with clear skies and weak surface winds

Typical height of the stable valley boundary layer in winter is about 350 m

Inn-valley campaign

Objectives

Determination of cross-valley air pollution and meteorological information as well as vertical profiles to determine flow regimes (valley, slope winds), mixing layer height, stability in the boundary layer and emission sources at specific locations

This campaign covered the major part of the winter season 2005/2006

Locations of measurement sites

SOP

Basic site (540 m a.s.l.)

Frundsberg (military helicopter air field), i.e. west of Schwaz:

- MLH: SODAR, ceilometer

Old sporting area west of Schwaz

- PM10
- CO, NO, NO_x, O_3: in situ measurement van

Site at the southern slopes: Arzberg (720 m a.s.l.)

- NO, NO_x: in situ station

Locations of measurement sites

SOP

Highway emission study in Vomp near the measurement station of Land Tirol (570 m a.s.l.), distance to Schwaz 800 m

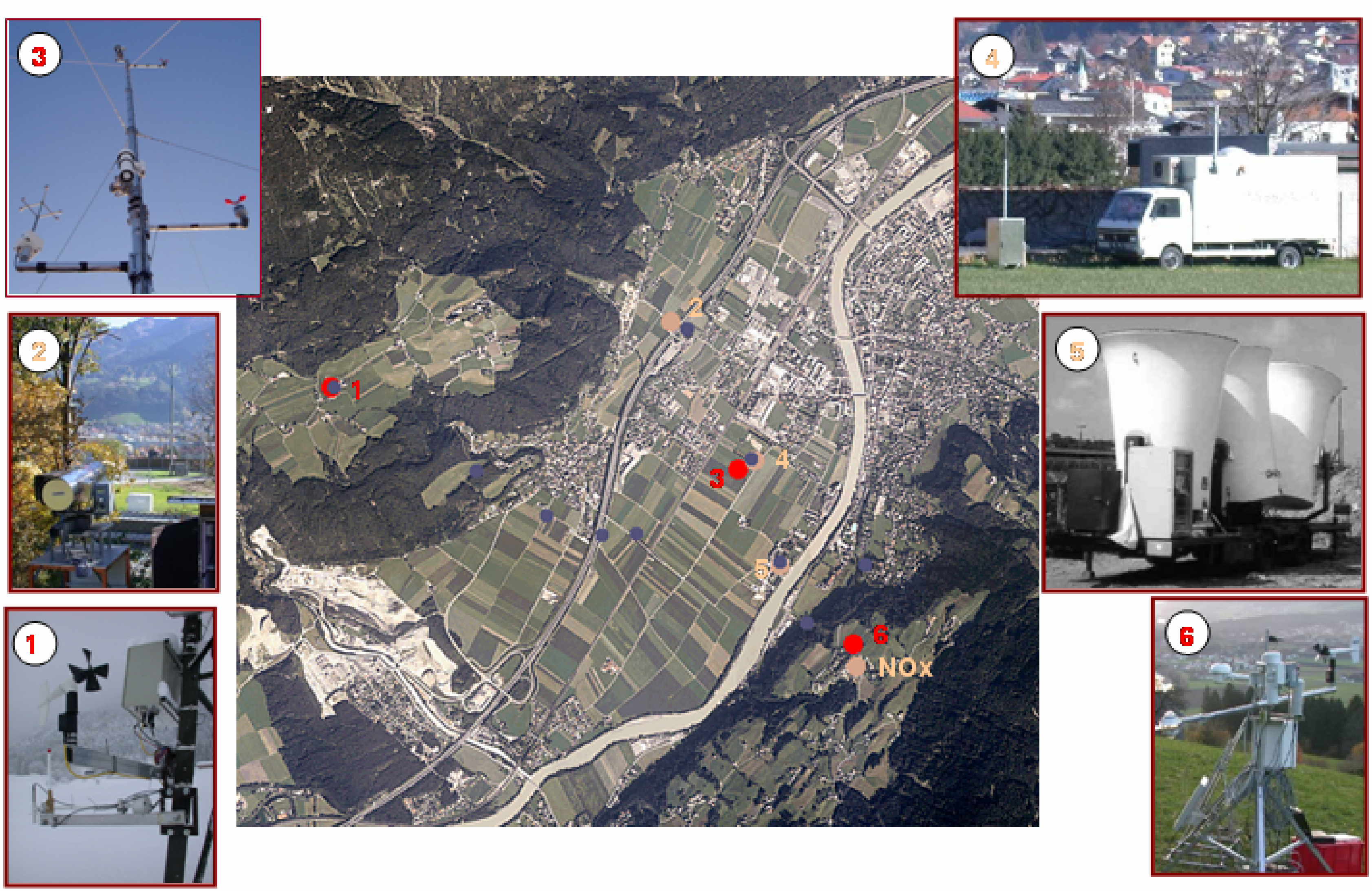
- DOAS with emitter/receiver unit and 3 retroreflectors, retroreflector southerly at a telephone emitter mast on the other site of the highway (120 m) and path about 10 m above highway level, retroreflector easterly parallel to the highway, retroreflector northerly at the slope of the valley and perpendicular away from the highway

Locations of measurement sites

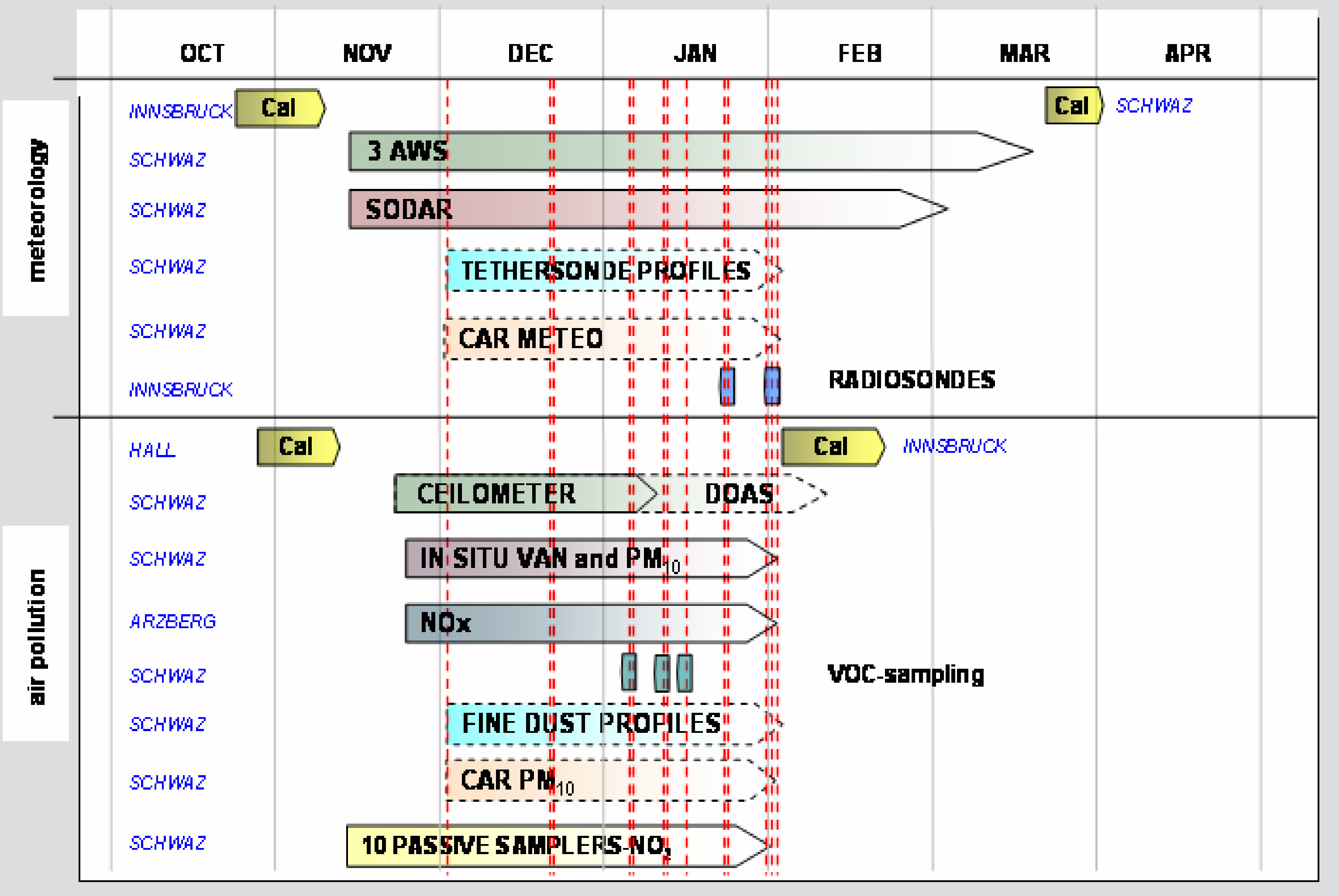
IOP (05:00 – 23:00): 06/07, 12/13, 16 January 2006

Basic site Schwaz

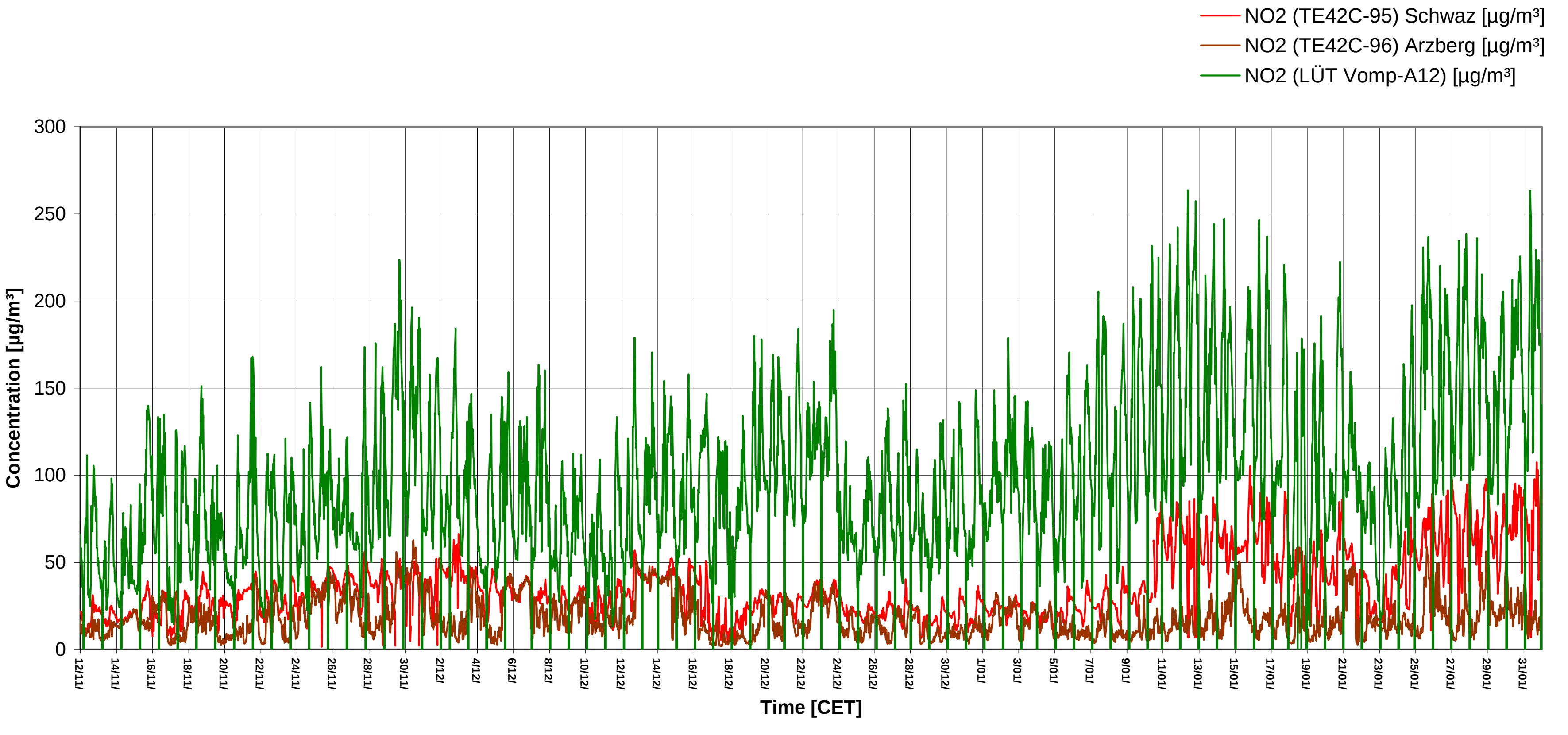
Ambient air sampling for VOC split, daily variation


3
2
1
4
5
6
NOx

Inn valley measurements



Brenner north field campaign



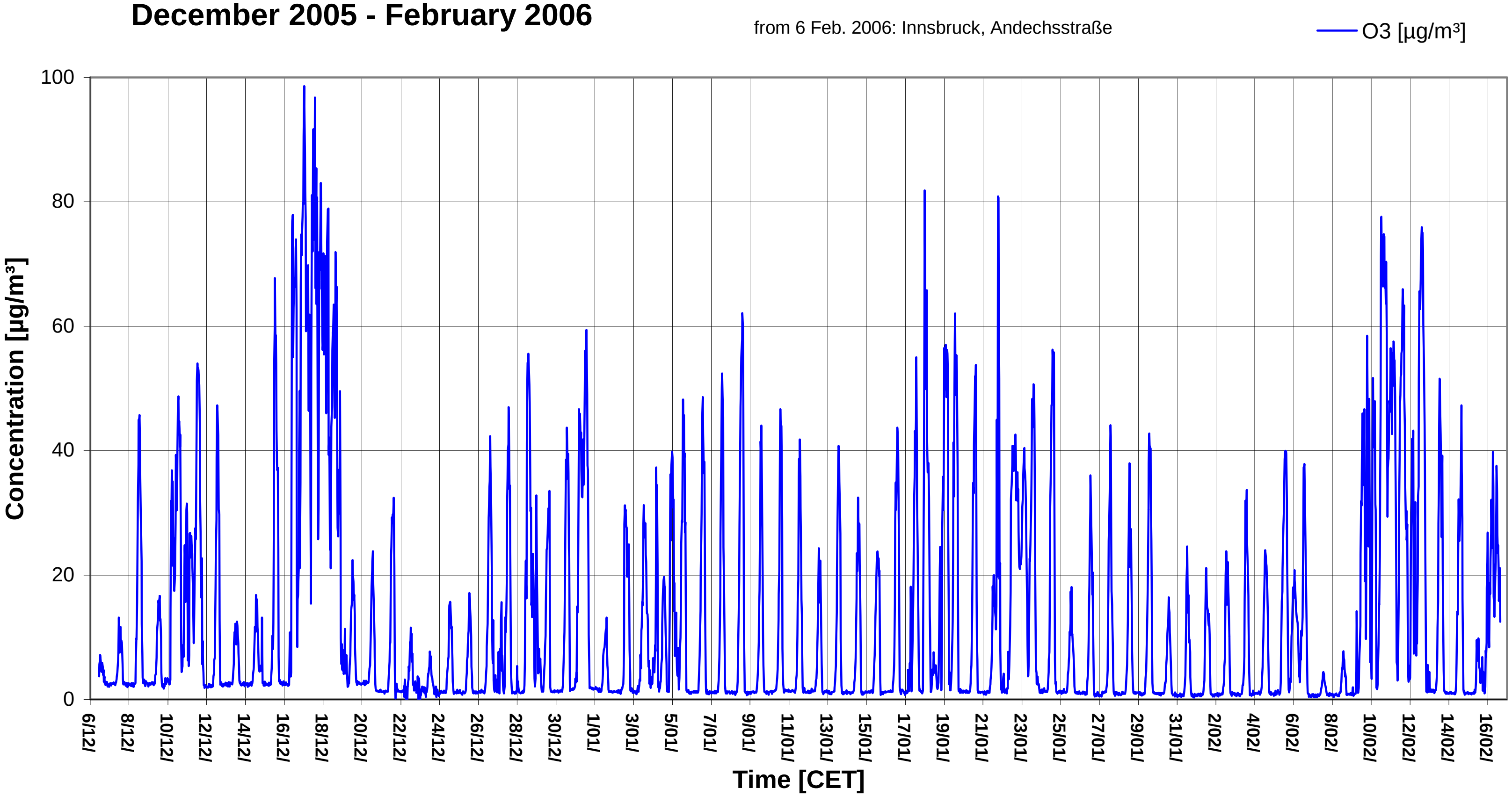
Brenner north field campaign

Inn valley near Schwaz

Ozone

In situ HORIBA APOA-350E, *half-hourly means*

December 2005 - February 2006



Results

The exceedances at the valley floor as compared to the slope station are basically related to a stable layering of the valley atmosphere during nearly all the time

From November until January the NO_2 concentrations increased significantly

Outstanding high pollution episodes were found during 20 – 24 December 2005, 09 – 22 January and 25 January – 02 February 2006

Results

The stable layering of the valley atmosphere was interrupted during the time periods 29 – 30 November 2005, 03 – 07 December 2005 and 12 – 14 December 2005

This was connected to foehn events (29 November) or air mass exchange due to frontal passages (03 and 05 December cold front from west, 01 December warm air from the south)

High ozone concentrations 09 – 12 December 2005, 15 – 18 December 2005 and 21 – 24 January 2006

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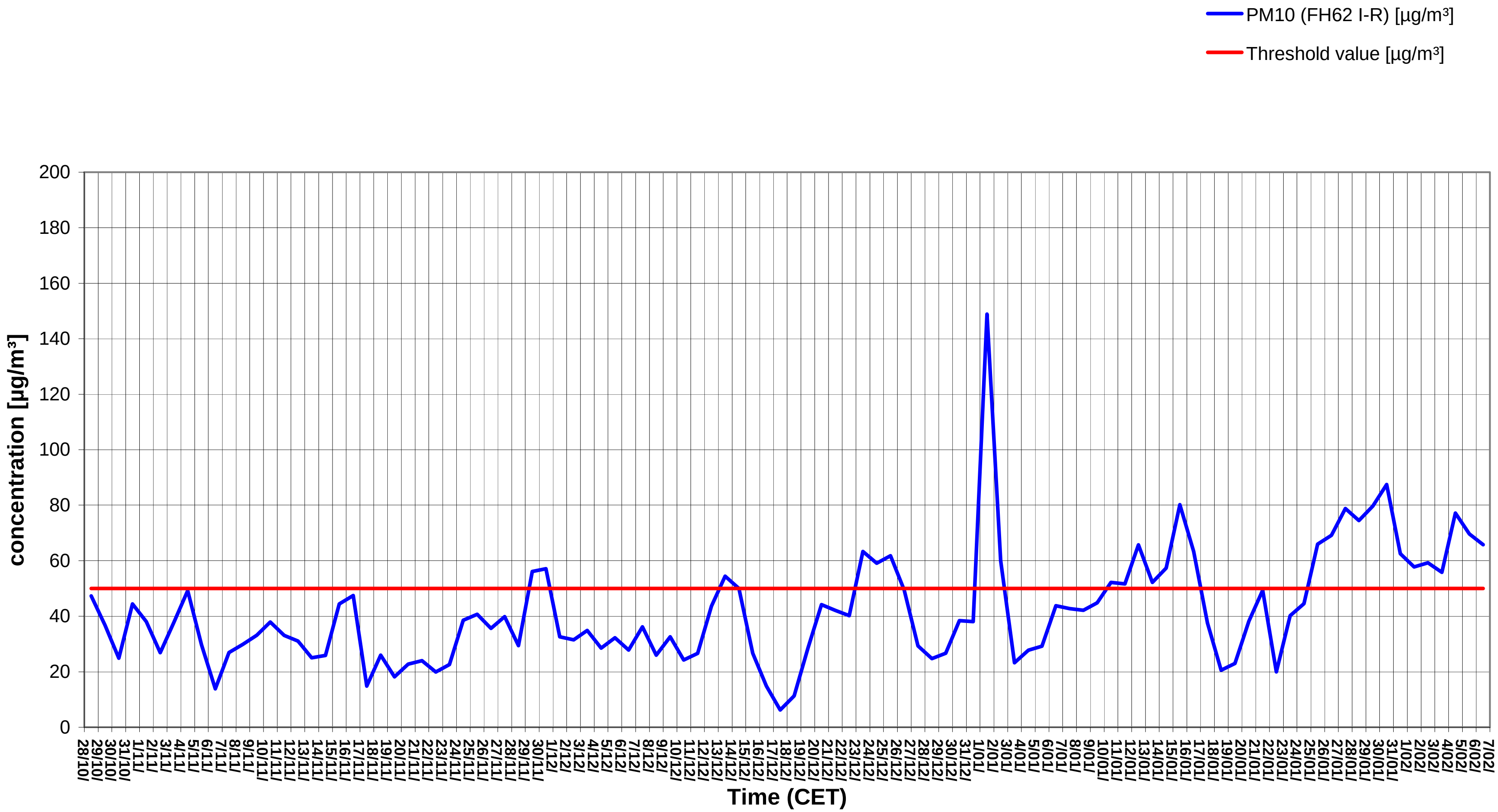
Results



Results

Concentrations of PM10 show no typical variation during the week but typical peak before noon

Exceedences of 50 µg/m^3 threshold value of PM10 at background station

Dominant peak in PM10 concentration from the night of 31 December 2005 up to the night at 01 January 2006

Influence of reconstruction works at the old sporting area in Schwaz in CO, NO and NO_x from 13 up to 15 February

Results

The DOAS results show

a slight decrease of NO_2 concentrations from the path across the highway over the path parallel to the highway up to path perpendicular away from the highway but

a dominant decrease of NO in this direction

Results

The concentrations of NO and NO_2 above the highway are clearly dominated by the traffic volume

Higher concentration values were found during week days than during the weekend (significant temporal period of 7 days with peak values at Saturday) was well as typical peaks in the morning and in the evening

Mixing layer height

The thermal layering of the atmospheric boundary layer is an important condition for the development of episodes of high concentrations of air pollutants which can be harmful for people and ecosystems

The quantitative knowledge of the height of the mixing layer is essential for the vertical dispersion of air pollutants because they determine and limit the speed and the range of vertical dispersion

Mixing layer height

Inside of valleys in mountainous areas, due to secondary thermal circulations within these valleys (upslope winds and the corresponding sinking motion above the centreline of the valley), mixing layer height is often much lower than over level terrain

Usually the mixing layer height remains the whole day below the crest heights of the surrounding mountains

Methodology

SODAR: Height of a turbulent layer (H1) characterized by high acoustic backscatter intensities due to thermal fluctuations and a high variance of the vertical velocity component (σ_w)

Height of a surface-based and up to five lifted inversions (H2_1 to H2_5) characterized by high acoustic backscatter due to a sharp increase of temperature with height and simultaneously low σ_w

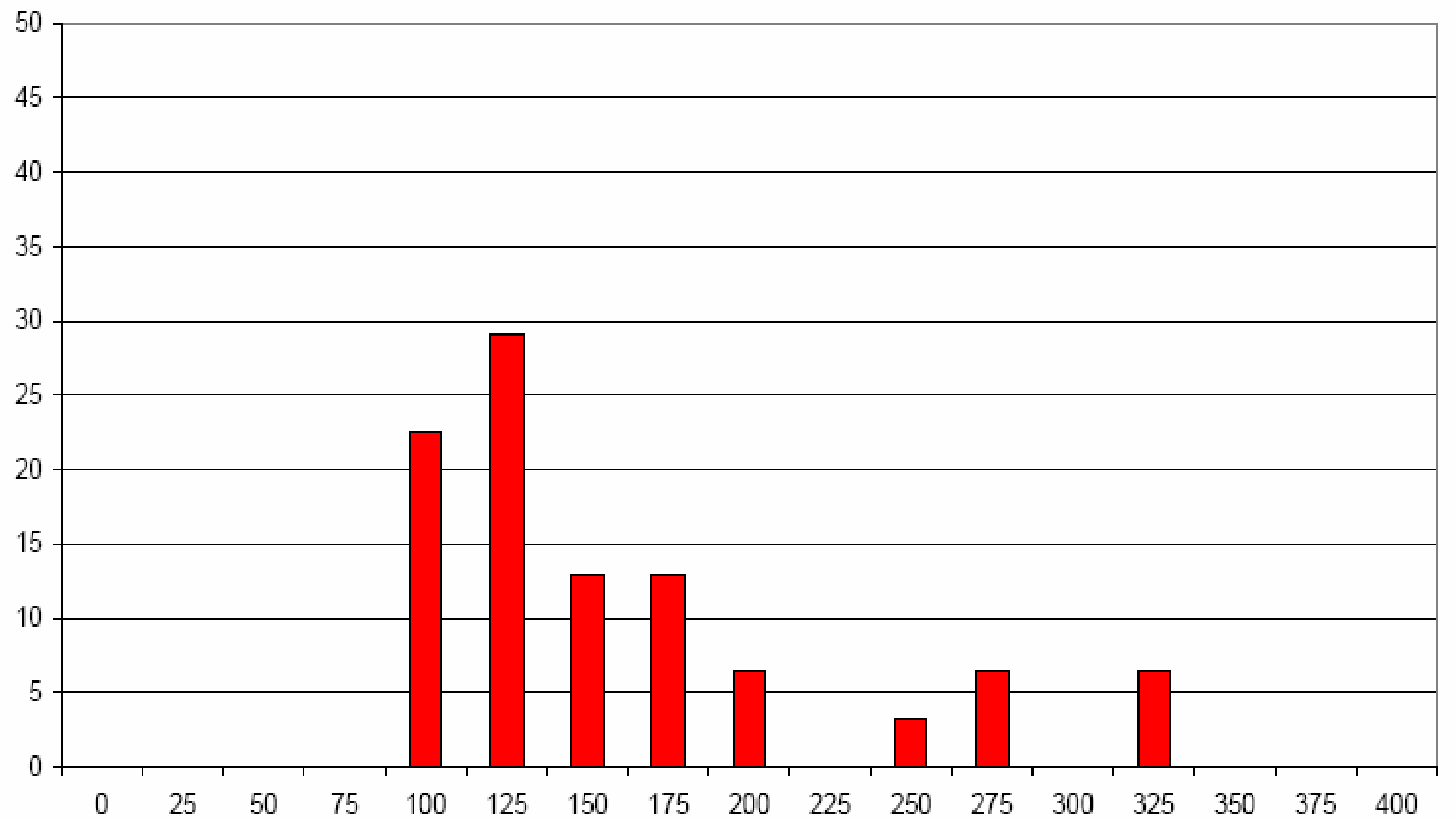
Methodology

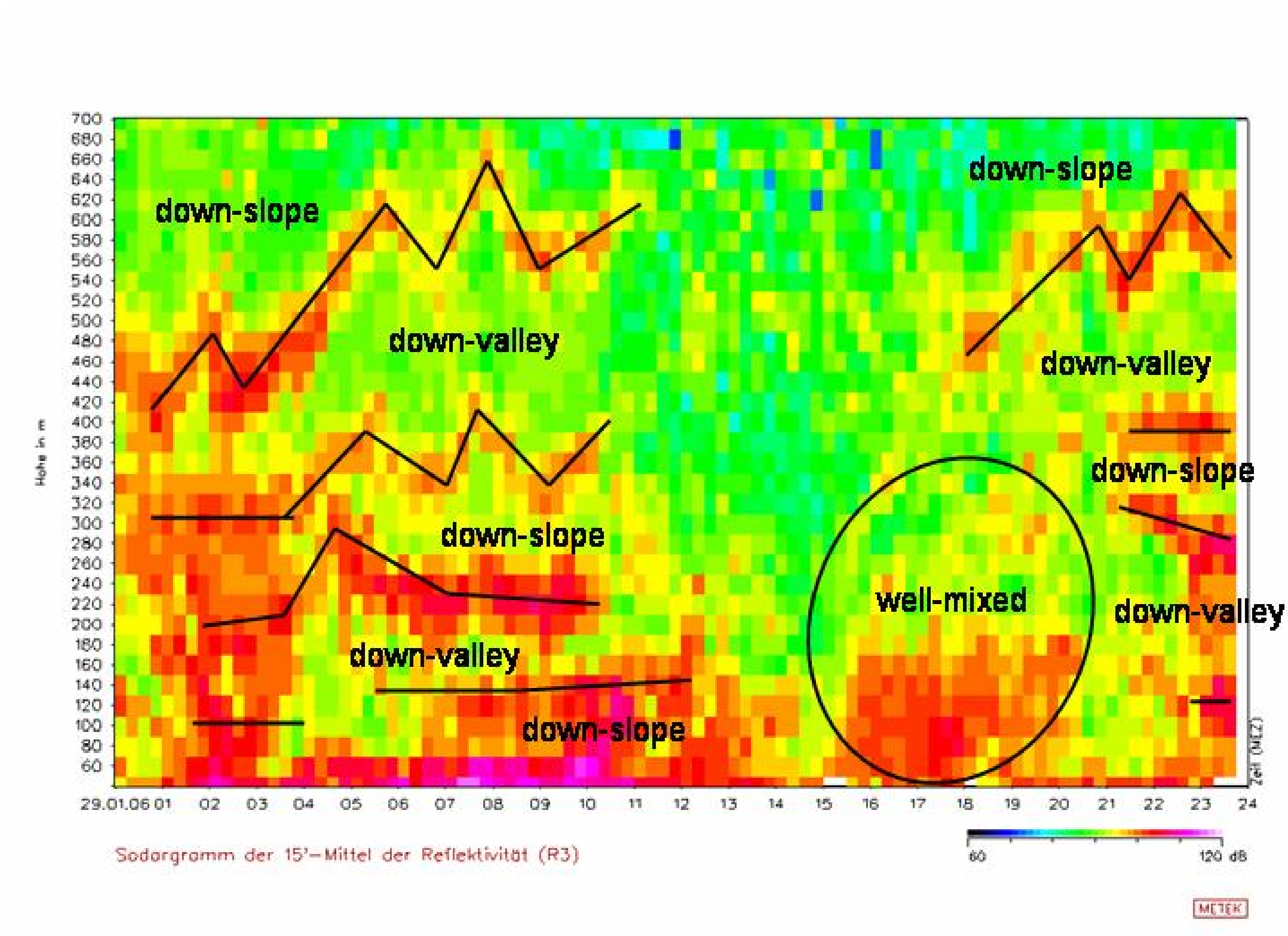
LIDAR / ceilometer: Height of the near surface aerosol layers (H3_1 to H3_5) characterized by the maximum of the vertical gradient of the optical backscatter intensity

Results

Lowest lifted inversion H2_1 usually persists during late afternoon break-up period

The daily mean mixing layer height varies between 100 m and 325 m with a peak frequency of about 29 % at 125 m above the valley floor


50
45
40
35
30
25
20
15
10
5
0
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400


down-slope
down-valley
down-slope
down-valley
down-slope
well-mixed
down-slope
down-valley
down-slope
down-valley
Höhe in m
Zeit (MEZ)
29.01.06
Sodargramm der 15'-Mittel der Reflektivität (R3)
60
120 dB
METEK

Results

Nocturnal down-valley flow and nocturnal down-slope flows are nearly laminar due to their small flow speed and high thermally stable stratification

Therefore the interaction between the different layers is very small and the layers can persist for hours without dissipating each other by friction

This can be derived from the wind directions in the several layers: valley-parallel flow and flow slightly crossing the valley axes

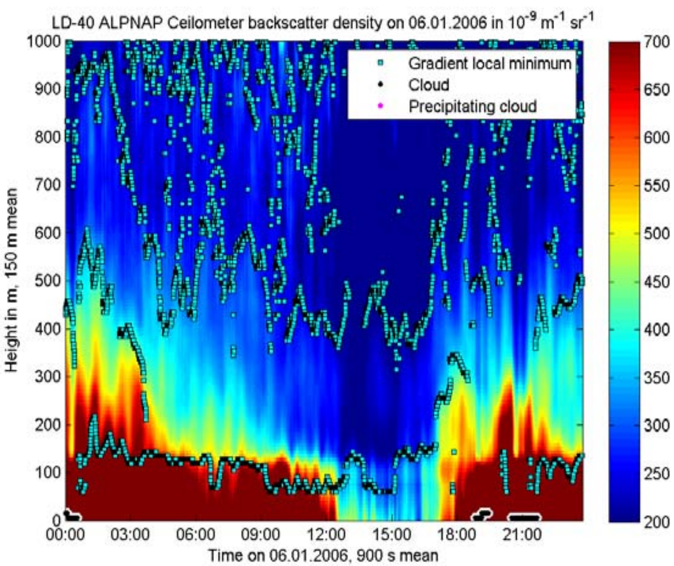
Results

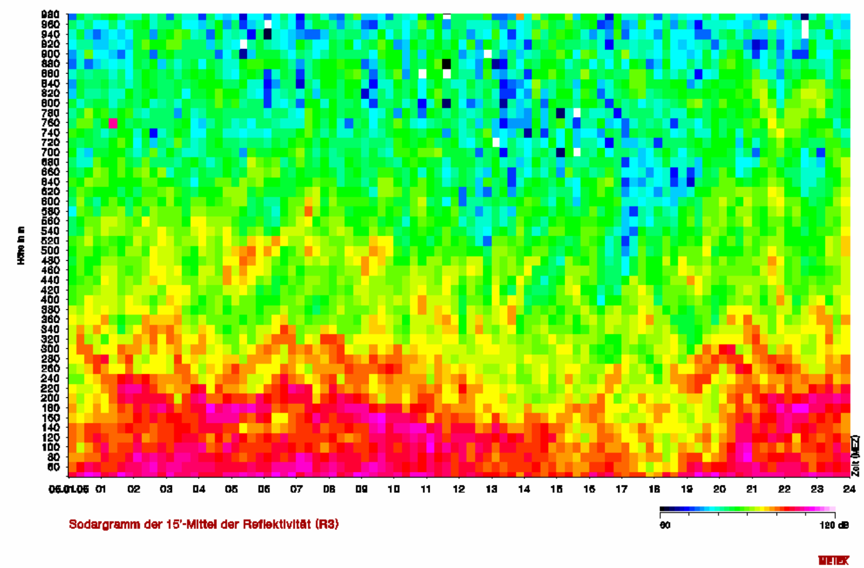
Determination of the occurrence frequencies of multiple layering in the Inn valley

Only in 20 % of all 15 min time periods in January no lifted inversion could be detected

Most common (28 %) are two lifted inversions within the first about 600 m above ground

Four and five layers together still appear in about 10 % of the time


LD-40 ALPNAP Ceilometer backscatter density on 06.01.2006 in 10^{-9} m^{-1} sr^{-1}
Gradient local minimum
Cloud
Precipitating cloud
Height in m, 150 m mean
Time on 06.01.2006, 900 s mean
1000
900
800
700
600
500
400
300
200
100
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
700
650
600
550
500
450
400
350
300
250
200


Sodargramm der 15'-Mittel der Reflektivität (R3)

Results

The surface-based stable layers are in good agreement for both methods

Lifted inversion are determined by both methods but the altitude values differ

The ceilometer values seem to be higher

We like to thank the Provinzverwaltung Bozen for financial support and the company Aquater S.p.A., Italy, namely Antonio Levy for effective cooperation.

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We like to thank Johannes Vergeiner, Esther Griesser, Friedrich Obleitner and Julia Wittig from the Institut für Meteorologie und Geophysik, Universität Innsbruck for fruitful cooperation as well as Julia Porcham from the ASFINAG (Austrian highway company) for providing the traffic data