Meteorology and air pollution in an alpine Valley during two striking different winter periods

Florian Bilgeri[1], Klaus Schäfer[2], Friedrich Obleitner[1] and Stefan Emeis[2]

[1]Institute of Meteorology and Geophysics, Innsbruck University, Austria [2]Institute for Meteorology and Climate Research, Forschungszentrum Karlsruhe, Garmisch Partenkirchen, Germany

IMGI

FZ Karlsruhe

Introduction

During winter essentially, Alpine valleys are frequently prone to enhanced air polution inducing serious impairments of human health and of sustainable development in these regions. This is mainly due to particular topographic and meteorological effects. The measurements of meteorological parameters and air pollution components were performed during two campaigns covering the full winters 2005/06 and 2007/08. The instruments were placed in a cross section at the valley bottom and at different elevations in the lower Inn valley (Tyrol) at nearly the same places during both periods. Meteorological analysis was mainly based on data from routine synoptic stations, non-permanent automatic weather stations and slope-temperature sensors at various heights, which were supported by mixing-height data derived from ceilometer at the valley bottom. Air pollution analysis considered NO and NO_2 and is based on the data from a routine monitoring station of the Tyrolean government and a passive sampler network, distributed in a valley cross section.

Climatology

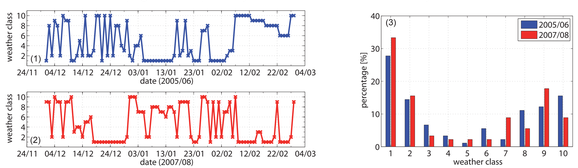
The climatological analysis of the data from Innsbruck shows, that the two investigated periods were completely different regardly the meterological parameters. Compared with the climatological long-term means (1971-2000), the winter 2005/06 (from December to the end of February) was 1,5°C colder, the number of days without a temperature > 0.0°C was higher (+16,4) and there was a long-lasting snowcover. The sum of the precipitation slightly exceeded the mean value. In contrast, the winter 2007/08, with only 8 snowdays and 4 icedays, was about 1,8°C warmer than the mean and it was too dry (-57,4 mm).

data source: ZAMG

	period	Dec.	Jan.	Feb.	mean/sum	difference
temperature	1971-2000	-1,0 °C	-1,7 °C	+0,4 °C	-0,8 °C	
	2005/06	-1,7 °C	-4,6 °C	-0,6 °C	-2,3 °C	-1,5 °C
	2007/08	-1,1 °C	+1,4 °C	+2,6 °C	+1,0 °C	+1,8 °C
precipitation	1971-2000	53,1 mm	43,9 mm	41,4 mm	138,4 mm	
	2005/06	65,0 mm	42,0 mm	37,0 mm	144 mm	+5,6 mm
	2007/08	27,0 mm	37,0 mm	17,0 mm	81 mm	-57,4 mm
days with >1 cm snowcover	1971-2000	16,5	20,3	14,8	51,6	
	2005/06	29	31	28	88	+36,4
	2007/08	2	6	0	8	-43,6

Weather type classification

The investigation of the weather types after the scheme of Steinacker (1991) exhibits, that the relative distribution of the various weather types was nearly the same during both periods, except there were more westerly and southerly flows in 2007/08 (Fig.3). Two long lasting high pressure periods in Jan.06 contrast only one in Dec.07 and one in Feb.08 (Fig.1/2). Especially Jan.08 was characterized by various flow directions (Fig.2).



1	high-pressure, weak gradient	3	north	5	east	7	south	9	west
2	variable, front passage	4	northeast	6	southeast	8	southwest	10	northwest

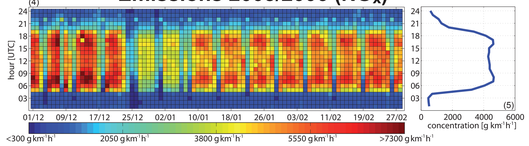
Threshold exceedances

There were more days with threshold exceedances of NO_2 (half hourly mean > 200µg m^{-3}) during the period 2005/06 (24 days) compared to 2007/08 (2 days). Also the number of days with a threshold exceedance of finedust (daily mean > 50 µg m^{-3}) was in winter 2005/06 much higher than in the 2007/08. The threshold of NO (daily mean > 500 µg m^{-3}, half hourly mean > 1000 µg m^{-3}) was only exceeded in winter 2005/06.

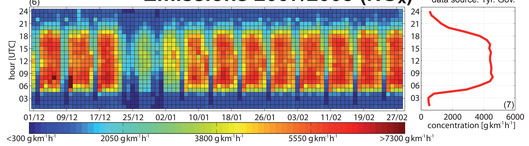
data source: Tyrolean government

	Dec. 05	Jan. 06	Feb. 06	Dec. 07	Jan. 08	Feb. 08
IG-L: threshold NO_2	0	18	6	1	0	1
VDI: threshold NO	0	8	5	0	0	0
IG-L: threshold finedust (PM10)	10	23	13	6	0	0

Emissions 2005/2006 (NO_x)

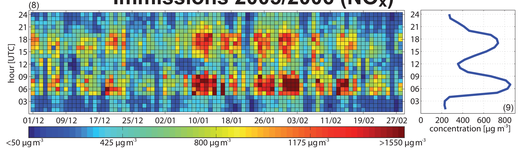


Emissions 2007/2008 (NO_x)

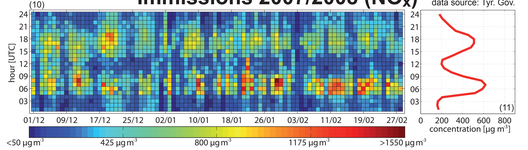


The emission data, which were calculated from permanent traffic counts, show a characteristic daily and weekly cycle (Fig.4-7). The emission rates are high from Monday to Saturday afternoon with two small peaks at each day, one in the morning and one in the late afternoon. On weekends, holidays (especially during Christmas holidays) and during the early morning the emission rates are smaller because of less traffic and various driving bans for trucks. In summary, there is no big difference between the two investigated periods.

Immissions 2005/2006 (NO_x)

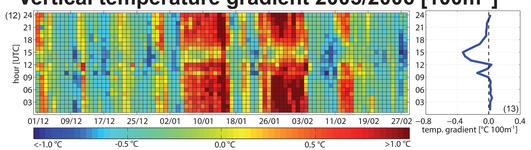


Immissions 2007/2008 (NO_x)

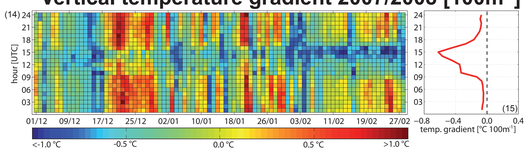


In contrast to the emission-analysis, the measured immissions of nitrogen oxide (NO_x) indicates a difference between the winters 2005/06 and 2007/08 (Fig.8-11). Especially in Jan.06 high concentrations of NO_x appeared, which were associated to high pressure. In general, the measured immission rates are less in 2007/08 as compared to 2005/08. The daily variations, with one peak in the morning and one in the afternoon, reflect the course of the emission rates, chemical reactions and partly on transports of NO_x.

Vertical temperature gradient 2005/2006 [100m^{-1}]

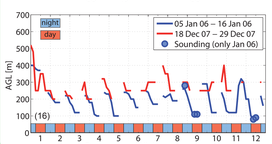


Vertical temperature gradient 2007/2008 [100m^{-1}]



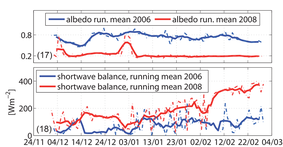
The link between the emissions and the immissions is may be described by the meteorological parameters, especially by the stability of the valley atmosphere. The pseudo-vertical temperature gradients at the southern slope (Fig.12-15) show very stable periods in Jan.06, congruent with the high pressure events. The stable period in Dec.07 was weaker than in 2006, additionally there were only seperated days with high stability in 2007/08. The mean daily variations show the more stable valley atmosphere in 2005/06 as well (Fig.13/15).

Mixing layer height during high pressure events



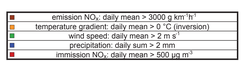
Subjective analysis of the mixing layer height from ceilometer backscatter intensities during high pressure events illustrates the daily variation of them. Typically, the MLH is lower in the evening/night and higher from noon to afternoon (Fig.16). Generally, the mixing layer 2005/06 was lower than in 2007/08.

Shortwave radiation

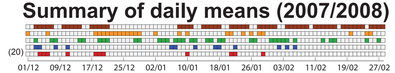


Due to the long lasting snow cover in 2005/06 the mean value of the albedo was 0.70. In contrast, the mean albedo 2007/08 was near 0.20 (Fig.17). Accordingly, there was more energie available in 2007/08 for heating the lower levels of the valley atmosphere, mainly during the high pressure events in Dec.07/Feb.08.

Summary of daily means (2005/2006)



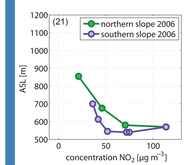
Summary of daily means (2007/2008)

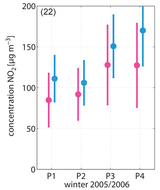


The Fig.(19) and Fig.(20) show the connection between the daily means of emission/immission, the temperature gradients, windspeed and precipitation. Higher immission values were almost based on high emission rates and a stable layering. Sometimes this was disturbed by precipitation or stronger winds (middle of Jan.06). In general, there were more days with high wind speeds in 2007/08 than two years before. Notice, that during Christmas 2007 immissions were low, despite of stable layering.

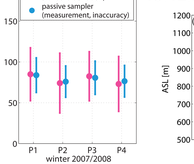
Local variability - NO_2-passive samplers

20.12.2005-31.01.2006

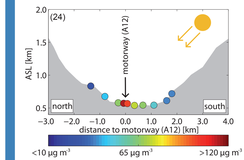


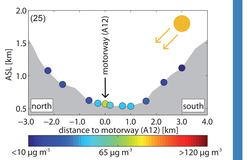


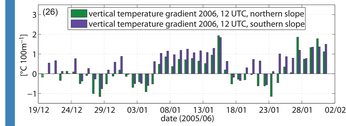
19.12.2007-30.01.2008

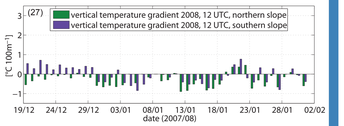


The comparison of one passive sampler with the reference station (Fig.22) demonstrates striking differences in their perfomances. The correspondingly corrected values of the samplers indicated a assymetrie of NO_2 in the valley cross section (Fig.24/25). Higher concentrations were found at the sunny slope each period. This is mainly due to local slope winds and the proximity to motorway. Maximum values were measured at the valley bottom and near the motorway.









The local variability of the temperature gradients is shown in Fig.(26/27). First, there were more days with a stable layering at noon in 2005/06 on both valley sides compared to 2007/08. But the gradient at the northern slope was always weaker than the one at the opposite, especially during the high pressure event in Dec.06.

Summary and Conclusion

The weather-type analysis showed almost the same distribution of the larger scale atmospheric patterns during both periods.There were even more high pressure events in 2007/08, but in 2005/06 the values of air pollution were considerably higher than in winter 2007/08. This difference was based on the lower emission rates during the high pressure event in Dec.07 and on the long lasting snow cover 2005/06. This induced rather stable layering in the lower atmosphere during winter 2005/06, whereas due to the lower albedo values in 2007/08 the atmosphere could be heated and mixed more efficiently. To be added, there were more southerly flows in 2007/08, causing more days with foehn events than in 2005/06. However, during both periods we found higher values of NO_2 at the sunny slope than at the opposite side of the valley. This was a result of the different stability at the slopes, normally the shady side was more stable.

Acknowledgements

This work is partly based on data that have been collected within the ALPNAP project, which is funded by the EU-"Interreg III B Alpine Space" programm, the Tyrolean government and Innsbruck University. In particular the immission and the calculated emission data are kindly allocated by the Tyrolean government. We also like to thank Wolfgang Gurgiser and Florian Karner (IMGI), members of the measurement group.

References

Heimann, D. et. al. (2007): A Guide for Authorities and Consulters. ALPNAP comprehensive report. Universitá degli Studi di Trento, Italy, pp.335
Steinacker, R. (1991): A weather type classification for the eastern alps, IMGI, Innsbruck. pp.16
Weber, A. (2005-2008): Monthly air quality reports tyrol. Tyrolean Government. www.tirol.gv.at/luft
ZAMG (2008): Climatological data from Austria, 1971-2000. www.zamg.ac.at