

VERTICAL DISTRIBUTION OF AIR POLLUTANTS IN THE INN VALLEY ATMOSPHERE IN WINTER 2006

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Abstract: In order to obtain a three dimensional picture of the distribution of air pollutants in the Inn Valley in wintertime, the field campaign INNOX (NO_x-structure in the Inn Valley during High Air Pollution) was carried out in January/February 2006. For this purpose continuous ground based measurements were performed. Additionally, vertical profiles of various air pollutants and meteorological parameters were measured throughout the whole valley atmosphere on six selected days. A tethered balloon was used for carrying meteorological devices and an inlet line attached to ground-level on-line instruments in order to cover the lowest atmospheric layers up to 150 m AGL (above ground level). At higher altitudes a research aircraft from MetAir (<http://www.metair.ch>) was operated. Preliminary results show not only strong vertical but also horizontal gradients in air pollutant concentrations.

Keywords: *air pollution, Alpine valley meteorology, airborne in situ measurements, PTR-MS, tethered balloon*

1. INTRODUCTION

Currently there is much debate on public and political levels how to deal with air quality problems in Tirol. There is clear evidence that traffic contributes significantly to air pollution (e.g. Beauchamp et al., 2004). Being one of the main traffic routes between southern and northern Europe, the Brenner route (eastern Inn- and Wipp Valley) faces high HDV (heavy duty vehicle) traffic density. The traffic volume in the eastern Inn Valley has doubled from 1980 to 2000 (Verkehrsclub Österreich, 2004) and it is predicted to further increase by approximately 40% until 2012 (Thudium, 2003). Although technical progress in car industry reduces vehicle emissions it can not equalize the effect of gradual traffic increase. Therefore additional strategies to improve air quality are necessary. Currently the government implemented a HDV ban during nights and a speed limit (100 km h⁻¹) during the winter season (November - April) for the Inn Valley motorway (A12). The speed limit imposed in 2006 is supposed to reduce the LDV (light duty vehicle) emissions of NO_x and Particulate Matter by approximately 30% (Thudium, 2004; Oetl et al., 2006). However, meteorological conditions that control dispersion and dilution strongly influence immissions of pollutants. The formation of a stable boundary layer during nighttime traps pollutants, which are emitted from the surface. This leads to enhanced concentrations of pollutants in the lowest air layers. Typically the associated low-level temperature inversion breaks up shortly after sunrise, however, in winter it can persist throughout the day (Thudium, 2003). That is why emissions should be minimized during nighttime and especially in winter. The diurnal and seasonal variations are particularly well pronounced in valleys where the topography not only favours the build-up of stable cold pools, but also channels the flow and limits its speed (Dreiseitl and Stöhr, 1991). Additionally, a thermal wind system, that occurs in the Inn Valley on 30% of all days (Vergeiner and Dreiseitl, 1987) leads to a recirculation of polluted air (Griesser, 2003). The strong influence of the valley topography and meteorology cause morning peak concentrations of NO_x in winter being up to nine times higher than over flat terrain with comparable emission source strengths (Wotawa et al., 2000). The goal of the INNOX-campaign is to obtain a detailed three dimensional picture of air pollutant distribution and to study the key transport and dilution processes of pollutants in winter in this specific topographic area.

2. DATA AND METHODS

The INNOX-campaign took place in January/February 2006 near the town Schwaz in the Inn Valley, Tirol, Austria. During this period ground based measurements of certain VOCs (Volatile Organic Compounds) were performed using a PTR-MS (Proton-Transfer-Reaction Mass-Spectrometer) instrument (described in detail by

Hansel et al., 1995; Lindinger et al., 1998). A nearby meteorological station provided data of temperature, radiation, wind, etc. during the measurement period. The vertical distribution of various air pollutants was determined on six chosen days. For this purpose several analytical instruments were carried on two platforms: a research aircraft from MetAir AG (Switzerland) and a tethered balloon. The balloon carried a teflon tube up to an altitude of 150 m AGL. Through this tube air was sucked to a PTR-MS and a CO-analyser. Additionally a radiosonde was fixed next to the teflon tube inlet which transmitted meteorological data (air temperature, wind, humidity and pressure) to the ground station. With this setup it was possible to obtain detailed vertical profiles in the lowest atmospheric layers, where the strongest gradients in pollutants concentrations occur. Additionally the diurnal variations of the thermal stratification and pollutant concentrations were observed with up to 10 soundings per day. The research aircraft collected vertical profiles from 150 to 2200 m AGL (crestline). It carried more than 100 kg of measurement equipment including instruments for measuring aerosols, CO, NO_x, VOC, and meteorological parameters. The temporal resolution of up to 10 Hz allowed to obtain a three dimensional picture of the distribution of pollutants in the Inn Valley atmosphere.

3. RESULTS AND DISCUSSION

Figure 1 shows the diurnal variation of shortwave-incoming radiation, temperature and the benzene volume mixing ratio (VMR) near ground on 1 February 2006. Grey bars indicate times when the vertical profiles of benzene VMR and the potential temperature, plotted in figure 2, were measured. A clear diurnal pattern in benzene levels can be seen with highest values during nighttime around 2 ppbv and a daytime minimum, with levels below 1 ppbv. This behavior is contrary to what one expects from the emission source strength (e.g. highest traffic density during the day). It indicates that meteorological parameters are mainly responsible for the diurnal variation of pollution levels by determining dispersion and dilution conditions. During the night a low temperature inversion develops, due to the radiation deficit of the surface. Near-ground emitted pollutants are trapped in so called cold pools. One can see from the vertical profile at 0900 CET, before the sun had reached the valley floor (figure 2 a), how stable stratification prevents the vertical air exchange and pollutants accumulate in a shallow layer. At 100 m AGL benzene levels have already decreased by a factor of four compared to surface values. Two hours later at 1100 CET the low level temperature inversion is much less intense and the benzene VMR has decreased. However there is still a significant benzene gradient within the lowermost 100 m AGL (figure 2 b). On 1 February 2006 the benzene level near ground reaches its minimum at 1600 CET, when the daily temperature maximum occurs. At this time the valley atmosphere is well mixed up to 100 m AGL and benzene is homogeneously distributed within this layer (figure 2 c). Benzene levels on the ground increase again when the radiation balance at the surface becomes negative. A low-level temperature inversion, that reduces the dilution volume, develops and pollutant levels increase immediately (figure 2 d).

Although this vertical soundings provide valuable information on the distribution of pollutants near ground, this local profiles are not representative for the whole valley. Figure 3 shows CO-data from 2 cross sections of the research aircraft, together with CO-data from the tethered balloon soundings. In the morning (figure 3; left) a strong gradient near ground can be seen, consistent with benzene data (figure 2 a). Up to 500 m AGL horizontal differences are observed with concentrations being twice as high along the sunny slopes of the valley compared to the shaded ones. In the afternoon (figure 2; right) levels and gradients of CO have decreased near ground, but have increased aloft. In 1000 m AGL CO-values near the sunny slopes are almost four times higher than background levels which can be seen at the same altitude on the opposite side of the valley.

This asymmetric distribution is most likely due to a vertical transport of pollutants via upslope winds. This either thermally or dynamically driven circulation could not be detected directly by aircraft wind measurements, indicating a very thin upslope wind layer.

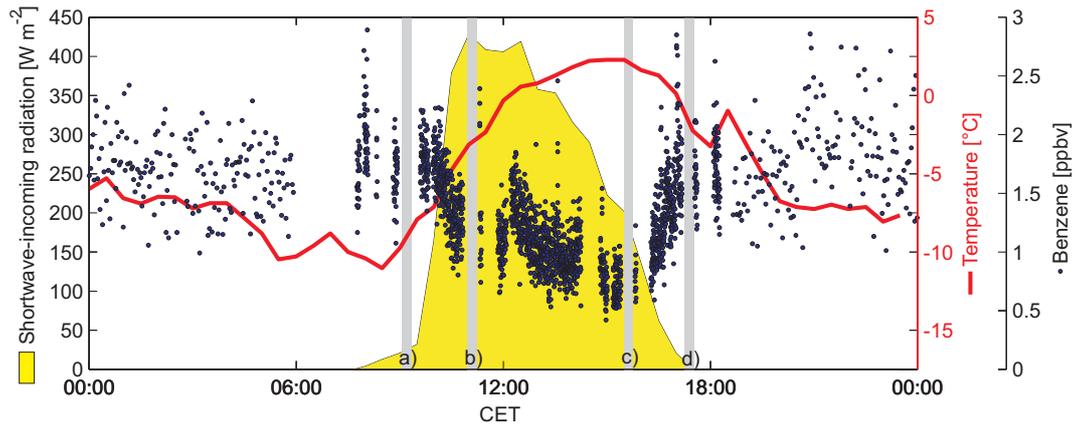


Figure 1: Diurnal variation of ground level benzene VMR (black dots), shortwave-incoming radiation (yellow area plot) and 2 m air temperature (red line) on 1 February 2006. The grey bars indicate times when vertical profiles, plotted in figure 2, were measured.

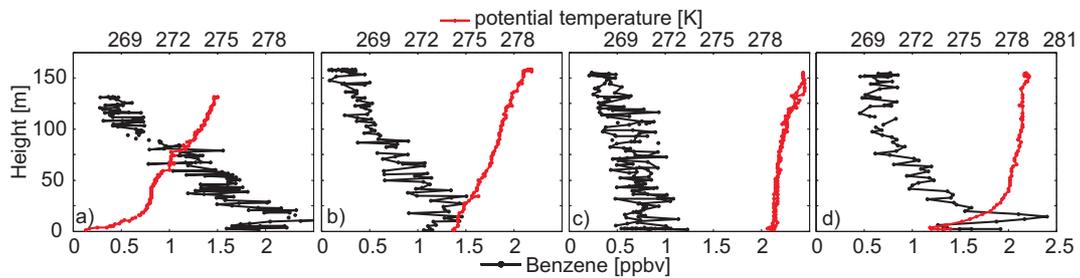


Figure 2: Vertical profiles of benzene VMR (black) and potential temperature (red) on 1 February 2006. Profiles match with times indicated by gray bars in figure 1 (a: 0856 - 0919 CET; b: 1050 - 1107 CET; c: 1523 - 1551 CET; d: 1710 - 1722 CET)

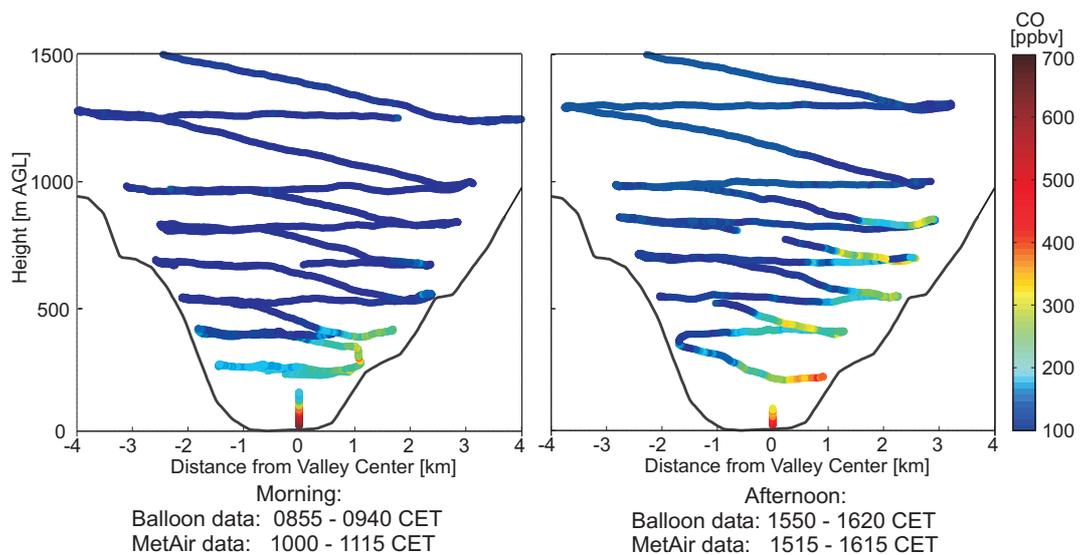


Figure 3: Vertical transect of CO VMR across the Inn Valley (oriented from southeast (left) to northwest (right)) near the town Schwaz in the morning (left) and in the afternoon (right) on 1 February 2006. Data were collected with a tethered balloon that carried the inlet line of a CO-analyser. Data from 150 m AGL up to crest height they were measured by a research aircraft.

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REFERENCES

- Beauchamp, J., Wisthaler, A., Grabner, W., Neuner, C., Weber, A., Hansel, A., 2004. Short-term measurements of CO , NO , NO_2 , organic compounds and PM_{10} at a motorway location in an austrian valley. *Atmospheric Environment* 38, 2511–2522.
- Dreiseitl, E., Stöhr, D., 1991. Emission - Meteorologie - Immission. Studie im Auftrag der Tiroler Landesregierung.
- Griesser, E., 2003. Quantitative Simulation des NO_x -Konzentrationsverlaufes während der Belastungsepisode im November/Dezember 1999. Master's thesis, Universität Innsbruck.
- Hansel, A., Jordan, A., Holzinger, R., Prazeller, P., Vogel, W., Lindinger, W., 1995. Proton transfer reaction mass spectrometry: on-line trace gas analysis at the ppb level. *International Journal of Mass Spectrometry and Ion Processes* 149, 609–619.
- Lindinger, W., Hansel, A., Jordan, A., 1998. On-line monitoring of volatile organic compounds at pptv levels by means of proton-transfer-reaction mass spectrometry (PTR-MS) medical applications, food control and environmental research. *International Journal of Mass Spectrometry and Ion Processes* 173, 191–241.
- Oetl, D., Hausberger, S., Rexeis, M., Sturm, P., 2006. Simulation of traffic induced NO_x -concentrations near the A 12 highway in Austria. *Atmospheric Environment* 40, 6043–6052.
- Thudium, J., 2003. Szenarien der Entwicklung des Schwere Güterverkehrs 2002 - 2012, Auswirkungen des Nacht-fahrverbots auf der A12 Oktober 2002 - Jänner 2003. Ökoscience, im Auftrag der Tiroler Landesregierung.
- Thudium, J., 2004. Luftschadstoffemissionen im Unterinntal 2003. Ökoscience, im Auftrag der Tiroler Landesregierung.
- Vergeiner, I., Dreiseitl, E., 1987. Valley winds and slope winds - observation and elementary thoughts. *Meteorol. Atmos. Phys.* 36, 264–286.
- Verkehrsclub Österreich, 2004. Verkehr ist wachsendes Gesundheitsproblem. <http://www.vcoe.at/start.asp?pg=detail.asp?ID=1531>.
- Wotawa, G., Seibert, P., Kromp-Kolb, H., Hirschberg, M.-M., 2000. Verkehrsbedingte Stickoxid-Belastung im Inntal: Einfluss meteorologischer und topographischer Faktoren. Endbericht zum Projekt Nr. 6983 Analyse der Schadstoffbelastung im Inntal des Jubiläumsfonds der Österreichischen Nationalbank.