6.3 THE EFFECT OF NORTH FOEHN ON BOUNDARY LAYER OZONE CONCENTRATIONS IN THE PO BASIN

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1. INTRODUCTION

The heavily industrialised Po Basin in Italy is a region with high ozone concentrations during the summer months (Prévôt et al., 1997). Ozone accumulates in the atmospheric boundary layer especially when fair weather conditions prevail for several days or weeks, and extremely high levels of ozone can occur towards the end of such periods. Often a significant change in the weather regime is responsible for the termination of high ozone episodes, bringing either a change in air mass or precipitation.

Another cause for the drop of the ozone levels in the Milano area is the influence of north foehn, a regional wind of the Alps that may transport air from the Alpine crest down into the Po Basin. Feeding from a less polluted reservoir higher in the atmosphere, the north foehn advects air containing not only less ozone, but also less primary pollutants for the formation of ozone. Consequently the original highly polluted Po Basin air with ozone concentrations of 70 to 170 ppb is replaced by cleaner free tropospheric air with a low potential for ozone formation.

We present climatological data on the occurrence of north foehn in this area, show the effect of this weather type on the ozone concentration, and try to explain these observations with the boundary layer structure during such events.

2. DATA AND METHODS

This study pursues a climatological approach, investigating 10-year time series (1990-99) of surface observations from the Po Basin near Milano (122 m MSL), Italy, up to the Jungfraujoch (3454 m MSL) at the Alpine crest in Switzerland. Emphasis is put on air quality measurements, especially ozone, which are complemented by meteorological data.

Ozone measurements at the station Mendrisio (350 m MSL) in southern Switzerland were analyzed besides meteorological information from the 4 km distant station of Stabio. The high-alpine station Jungfraujoch provided both types of data. Both stations measured air quality data in half-hour intervals, and meteorological data in hourly intervals. For the statistical analyses the maximum ozone concentrations for each day were determined instead of the daily mean value.

North foehn days were defined as having an afternoon wind direction from the sector between 0° and 36°. Meteorological parameters were averaged for the afternoon, i.e. from 1200 to 1800 h local time. The area of direct foehn influence was determined from 20 air quality stations of the network operated by the Regione Lombardia, Italy. These stations recorded hourly mean values.

More details about data preparation can be found in Weber and Prévôt (2002).

3. RESULTS AND DISCUSSION

It is evident from Fig.1 that the ozone maxima are different during north foehn than on other days. While there is still an increase of ozone concentration with increasing temperature, this increase is quite small and indicates only a weak dependence of ozone on temperature for north foehn days. On the other hand, north foehn ozone concentrations are higher at low temperatures than for the non-foehn days.

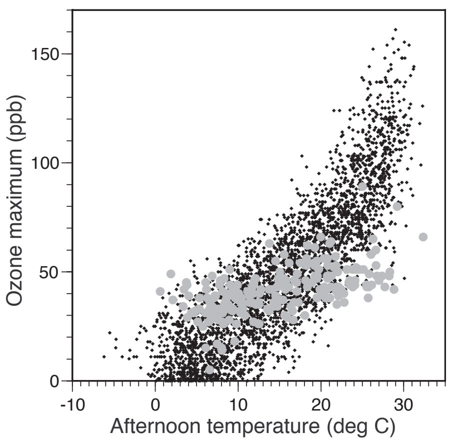

Fig. 1: Maximum ozone concentrations at Mendrisio vs. afternoon temperatures at Stabio for 1990-1999. Grey dots mark cases with north foehn.

The concentrations between 30 and 60 ppb are in good agreement with the annual ozone variation at the Jungfraujoch, representing the background concentration at the lower free troposphere (LFT) of 40 ppb in winter and 60 ppb in summer. These

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results are further supported by an analysis of potential temperature at both stations (not shown). During north foehn the potential temperature differences between the stations are much smaller than during the other days and vary between +4 and –4 K in most cases. The relative humidity is also very low.

Extending this analysis to other stations in the Po Basin, we can determine the area of influence of the north foehn. Fig. 2 shows that this influence reaches to the city of Milano. The stations between Milano and the Alpine foothills exhibit significantly lower ozone concentrations in the afternoon on days with north foehn and high temperatures.

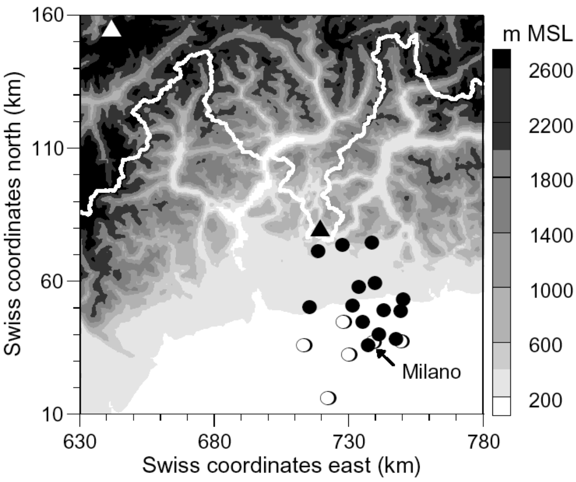

Fig. 2: Area of influence of north foehn in the Po Basin. Black dots: Stations showing significant influence. Open circles: Stations without significant influence. White triangle: Jungfraujoch. Black triangle: Mendrisio.

Two dynamical processes may explain the reduced ozone concentrations in the northern part of the Po Basin. First, the influence of north foehn (and similar flows) is restricted to areas close to mountain ranges. Farther away from the mountains the foehn air is often flowing above the colder near-surface air, especially in winter, and thus surface stations are measuring in a different air mass. Second, foehn air may be mixed with the convective boundary layer air over the plain on summer afternoons, thereby loosing its identity.

This simple, statistical approach reveals that even in the immediate vicinity of Milano the afternoon ozone concentrations during foehn are significantly different from those on the other days. This result needs further investigation, because several photochemical and dynamical processes may interact here.

North foehn occurs on 4 - 6 % of the summer days and on 6 - 8 % of winter days (Weber and Prévôt, 2002). This is a remarkable fraction of time and will influence monthly statistics of ozone and other pollutants.

6. CONCLUSION

During north foehn cases the ozone concentration in the area is substantially reduced to below 60 ppb. Evidence for the origin of this free tropospheric air is given by a similar annual variation at the Jungfraujoch and in Mendrisio, for foehn days, and vanishing potential temperature gradients between the two stations in these cases. This cleansing effect is evident in the region between the southern Alpine foothills and the urban area of Milano.

The geographical setting of the northern Po Basin requires a viewpoint of boundary layer dynamics that includes advection of LFT air besides the development of a convective boundary layer in the afternoon. Ozone concentrations are not only affected by turbulence, where two air masses are mixed, but also by a more or less complete replacement of one air mass by another one. North foehn situations are good examples of this effect.

South foehn does not produce a similar, detectable effect on the north side of the Alps, because ozone concentrations are generally smaller there, considerably reducing the difference between ABL and LFT ozone conentrations (Seibert et al., 2000; Baumann et al., 2001).

LFT air contains significantly less primary pollutants like NO_2 or NO. Transport of LFT air down to low levels changes the ozone precursor concentrations and thus affects the formation of ozone. The secondary production of ozone is reduced in this way, but the effect may only be seen at a later time, i.e. the next day. The present study does not include this effect, but future investigations will.

7. ACKNOWLEDGEMENTS

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