# A STUDY ON THE FOEHN IN PIEDMONT, ITALY

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**Abstract:** An analysis of the yearly, seasonal and monthly frequency of North and North-West foehn in Piedmont (Italy) has been carried out considering some stations located in the Northern (Ossola Valley) and in the North-Western (Susa Valley) part of the region. The selection has been performed and adopting synoptic mesoscale and punctual recognition criteria. The results show a gradual reduction of foehn frequency with the increase of the distance from the alpine watershed, but a significant occurrence was observed also in the low plain. The monthly and seasonal distribution of foehn episodes and the correlations with synoptic configurations have been investigated. Finally, a detailed analysis has been carried out on the foehn event of December 18th 2004,. selected as case study representative of the analyses.

**Keywords:** *Piedmont, foehn.*

## 1.INTRODUCTION

Piedmont region is located in the extreme north-western sector of Italy, and it is bounded at the northern, western and south-western sectors by the Alpine chain and at the southern and south-eastern sectors by the Apennines. In some meteorological conditions, this orographic configuration enhances the onset of foehn. In Piedmont, foehn can typically occur in the north-western sectors with air flows coming from North, North-West and West, or less frequently in the southern sectors with air flows coming from South or South-West. As in the eastern part of Piedmont there are not any mountains, foehn from eastern sectors are not observed at all. Sometimes, cold and dry winds propagate from North-East or East through the Po Valley reaching the Piedmont: even if, in this case, the weather can be very similar than in the case of foehn (excepting for the very low temperatures), these episodes cannot be classified as foehn. The synoptic configuration favouring the onset of the foehn is a positive difference of atmospheric pressure between the upwind and the downwind sides of the mountains (Whiteman, 2000).

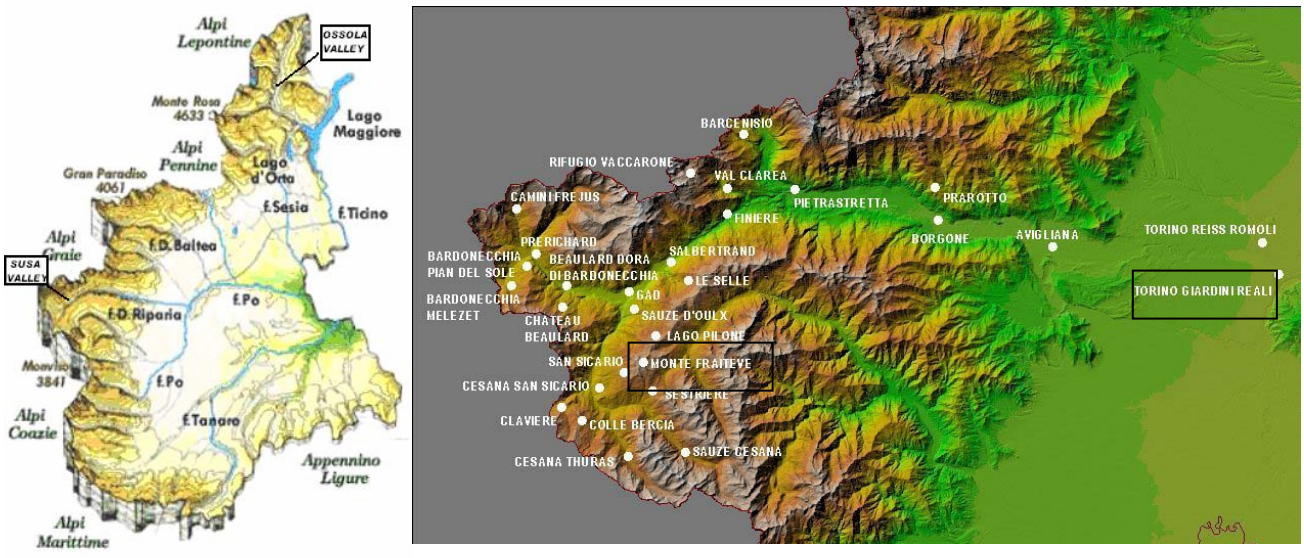


**Figure 1**:Left: Map of the Piedmont region with topography and the location of Susa valley and Ossola valley. Right: Detail of Susa valley, individuation of meteorological stations and evidence of Monte Fraiteve e Torino Giardini Reali stations, used to the study of a typical example of foehn

## 2.DATA AND METHODS

The method used for selecting the foehn episodes in this paper was that of examining the daily weather bulletins issued by the meteorological service of ARPA Piemonte (Regional Agency Prevention and Environment), which report with high details both in time and space the most relevant phenomena. The period selected is from 2000 to 2005. ARPA Piemonte manages more than 400 meteo-hydrological ground-stations connected in real time to the operative meteorological centre in Torino. Several stations (90 around), located aloft and among valleys, are equipped by anemometer, thermometer and hygrometer. The combined measurements of these sensors are used by ARPA Piemonte forecasters to detect foehn episodes. When a foehn episode begun in Piedmont region, mountainous stations simultaneously observe an increase of wind speed and a rotation of wind direction to western or north-western sectors, while plain stations evidence a wind direction rotation along the valley's axis. Contemporary, the temperature shows a sharp increase (which, in the strongest episodes, can also reach 10°C in 30 minutes) and the relative humidity decreases and reaches values of 15-20% (and sometimes even less).

## 3.RESULTS

To better explain the foehn behaviour in Piedmont, a typical episode is analysed in detail. A NW foehn event involving the western part of Piedmontese region, i.e. the zone comprised between the Western Alps and Turin occurred on 18$^{th}$ December, 2004. As the direction of synoptic flow was western, thus the Susa Valley has been taken as reference valley. Data measured by two meteorological stations displaced along the valley have been compared. The meteorological stations of "Mt. Fraiteve" (2700 m a.s.l.), hereafter MF, and "Torino Giardini Reali" (239 m a.s.l.), hereafter TGR, have been selected as representative of the flow at the crest level (MF) and at the end of the valley (TGR) (Fig.1, right). Since, during a foehn event, the air descends dry-adiabatically in the downstream region, potential temperature can be considered a good tracer for the air mass. In a typical case of foehn, potential temperature at the downstream station should be equal or higher than the one at the reference station (Fig.2).

The trends of temperature, relative humidity and wind speed during the foehn episode in the downwind station of TGR have been examined. The onset of the foehn is revealed by the abrupt variations of temperature (Fig. 5) and relative humidity (Fig. 6) at 09:00 UTC. At the same time wind speed (Fig. 4) reaches 7 m/s (a value which can be considered not normal as the annual mean daily wind speed for this station is about 1 m/s) and the direction was NNW, i.e. almost aligned along the Susa Valley. In the same period the potential temperature of Turin was greater than the one of Mt. Fraiteve. This feature can be explained by turbulent vertical mixing of stably stratified air descending from the crest into the valley.

At 08:30 UTC, the potential temperature of the downstream station reached the one at the reference station. Until 15:00 UTC, the potential temperature in the Turin station remained higher than the one at the reference station: at Turin the maximum value was 287 K, and at Mt. Fraiteve 285 K. After 15:00 UTC, the behaviour of potential temperatures at the two stations was completely different. This event can be regarded as a typical example of western foehn in Piedmont. Northern foehn has more or less the same characteristics, but the temperature increment is sometimes lower, due to the lower temperature of air mass coming by North.

The meteorology forecasters of ARPA Piemonte Regional Weather Centre perform every day a subjective analysis based on the model's maps and on the observations carried out in the hydro-meteorological stations of the regional network. For the detection of foehn, in particular, as "rules of thumb", the following events are investigated:

- Sharp increase in temperature;
- Quasi-simultaneous sharp decrease in relative humidity;
- Quasi-simultaneous sharp increase in wind speed;
- Quasi-simultaneous sharp turn of wind direction along the valley axis and towards down slope.

The number of foehn episodes (hereafter FE) occurred during the six years period examined and the corresponding number of days with foehn (DF) were considered (Tab. 1).The total number of DF was 334, which corresponds to 56±8 DF per year. The duration of a FE can be even larger than 6 consecutive days, but in the majority of cases is limited to 3 days or less. Despite of the correlation with the persistence of the baric situation that generated the foehn (Barry, 1992), it is not rare that local factors cause major alterations like an interruption of the phenomenon.

Each Alpine meteorologist knows very well that every Alpine area has its own foehn climatology. However, the Piedmontese valleys where foehn can penetrate more easily are generally the Susa valley (on W) and the Ossola valley (at North). As it can be seen in Table 2, the Susa valley experiences 19 DF per year and the Ossola valley 13 DF per year, while in other 9 cases per year foehn involve both valleys contemporary, and in other 10 cases per year foehn involves the whole Piedmont. We can also notice as only in 3 cases over a total of 56 (per year) the foehn do not occur in Susa and Ossola valleys.

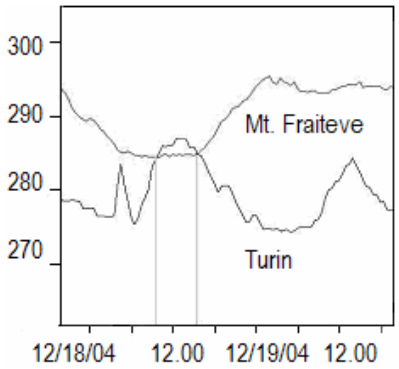


**Figure 2**: Trend of potential temperature (in K) during the foehn episode of 12/18/2004. The vertical lines indicate the beginning and the end of the foehn episode in Turin.

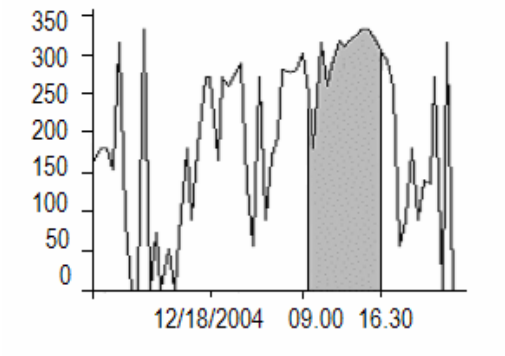


**Figure 3**: Trend of wind direction (in degrees) during the foehn episode of 12/18/2004. The vertical lines indicate the beginning and the end of the foehn episode in Turin. Hours expressed in local time (1 hour more than UTC).

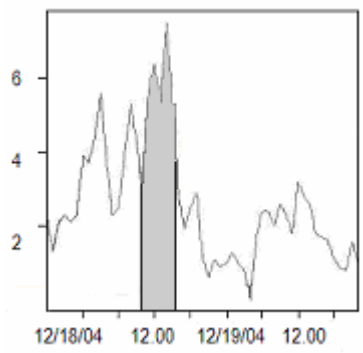


**Figure 4**: Trend of wind gusts (in m/s) during the foehn episode of 12/18/2004. The vertical lines indicate the beginning and the end of the foehn episode in Turin.

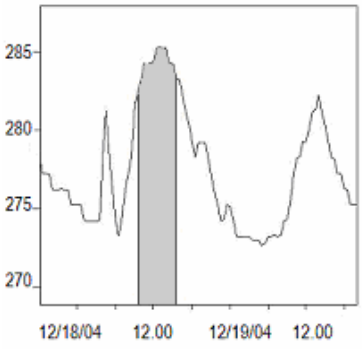


**Figure 5**: Trend of temperature (in k) during the foehn episode of 12/18/2004. The vertical lines indicate the beginning and the end of the foehn episode in Turin.

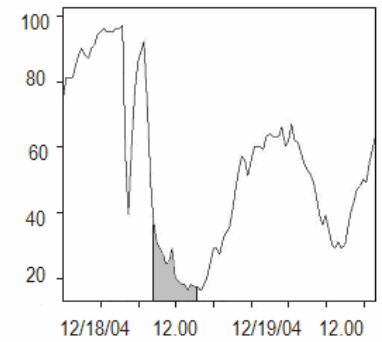


**Figure 6**: Trend of relative humidity (in %) during the foehn episode of 12/18/2004. The vertical lines indicate the beginning and the end of the foehn episode in Turin.

**Table 1**: Number of days in which foehn has been observed in the specified areas. The numbers referred to the row "Susa valley" indicate the cases in which foehn has been observed only in Susa valley.

| Areas concerning foehn | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Average | Sigma |
|---|---|---|---|---|---|---|---|---|
| Susa Valley | 20 | 12 | 24 | 16 | 24 | 17 | 19 | 4 |
| Ossola Valley | 16 | 13 | 6 | 11 | 17 | 14 | 13 | 4 |
| Susa and Ossola Valley | 26 | 3 | 12 | 8 | 11 | 8 | 9 | 7 |
| Other Valleys | 4 | 4 | 3 | 2 | 5 | 1 | 3 | 1 |
| Extended To Piedmont | 4 | 9 | 10 | 11 | 6 | 12 | 10 | 3 |
| Sum Of Days | 70 | 46 | 55 | 48 | 63 | 52 | 56 | 8 |

Regarding the seasonal distribution of DF, foehn episodes are seldom extended to the whole region, but they often concern only determined Piedmontese areas. The most affected zones are mainly north and west, mostly in winter, followed by north-west, mostly in autumn (Tab. 2). The southern sector is affected by very sporadic foehn events which never occur in Spring (3 days). As a general rule, the season with highest DF is winter, followed by autumn (Tab. 3). DF from North have their maxima in Winter and Autumn, with the

flowing of polar air masses from north or north-west, but they can also occur in the other seasons. The foehn affecting the Turin plain can be described as a western fresh wind, due to the West-East orientation of the Susa valley.

**Table 2**: Frequency (%) of foehn events according to the direction of arrival of flow and the season. DJF refers to winter, MAM to spring, JJA to summer and SON to autumn.

| | NORTH | | | | WEST | | | | N-W | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DJF | MAM | JJA' | SON | DJF | MAM | JJA' | SON | DJF | MAM | JJA' | SON |
| 2000 | 37,0 | 28,3 | 21,7 | 13,0 | 41,5 | 22,0 | 24,4 | 12,2 | 40,0 | 0,0 | 10,0 | 50,0 |
| 2001 | 40,9 | 13,6 | 13,6 | 31,8 | 46,7 | 20,0 | 6,7 | 26,7 | 0,0 | 0,0 | 20,0 | 80,0 |
| 2002 | 27,3 | 13,6 | 22,7 | 36,4 | 37,5 | 15,6 | 18,8 | 28,1 | 8,3 | 33,3 | 16,7 | 41,7 |
| 2003 | 33,3 | 22,2 | 11,1 | 33,3 | 42,3 | 3,8 | 19,2 | 34,6 | 44,4 | 11,1 | 22,2 | 22,2 |
| 2004 | 34,5 | 34,5 | 6,9 | 24,1 | 44,4 | 22,2 | 11,1 | 22,2 | 19,0 | 33,3 | 33,3 | 14,3 |
| 2005 | 30,0 | 10,0 | 40,0 | 20,0 | 60,0 | 15,0 | 15,0 | 10,0 | 52,9 | 17,6 | 23,5 | 5,9 |
| Average | 33,8 | 20,4 | 19,4 | 26,4 | 45,4 | 16,4 | 15,9 | 22,3 | 27,5 | 15,9 | 21,0 | 35,7 |
| Sigma | 4,9 | 9,6 | 11,8 | 9,0 | 7,8 | 6,9 | 6,3 | 9,6 | 21,4 | 15,1 | 7,8 | 27,3 |

**Table 3**: Seasonal and monthly trend of the total number of foehn events.

| Year/period | DJF | MAM | JJA | SON | Year | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 22 | 19 | 16 | 13 | 70 | 6 | 10 | 12 | 3 | 4 | 4 | 10 | 2 | 8 | 3 | 2 | 6 |
| 2001 | 17 | 9 | 5 | 15 | 46 | 4 | 4 | 6 | 3 | 0 | 1 | 2 | 2 | 10 | 0 | 5 | 9 |
| 2002 | 17 | 9 | 9 | 20 | 55 | 6 | 9 | 6 | 2 | 1 | 3 | 1 | 5 | 2 | 10 | 8 | 2 |
| 2003 | 16 | 10 | 7 | 15 | 48 | 9 | 3 | 2 | 3 | 5 | 0 | 4 | 3 | 4 | 10 | 1 | 4 |
| 2004 | 22 | 17 | 12 | 12 | 63 | 12 | 7 | 7 | 4 | 6 | 2 | 3 | 7 | 5 | 2 | 5 | 3 |
| 2005 | 21 | 9 | 17 | 5 | 52 | 9 | 6 | 4 | 2 | 3 | 2 | 8 | 7 | 1 | 0 | 4 | 6 |
| Average | 19 | 12 | 11 | 13 | 56 | 8 | 7 | 6 | 3 | 3 | 2 | 5 | 4 | 5 | 4 | 4 | 5 |
| Sigma | 3 | 5 | 5 | 5 | 9 | 3 | 3 | 3 | 1 | 2 | 1 | 4 | 2 | 3 | 5 | 2 | 3 |

## 4.CONCLUSION

The study of the frequency of occurrence of foehn from northern and western sectors in Piedmont (Italy) has been carried out considering some stations located in the Northern (Ossola Valley) and in the Western (Susa Valley) part of the region. The method used adopted synoptic mesoscale and punctual recognition criteria. The results obtained show a gradual reduction of foehn frequency with the increase of the distance from the alpine watershed, even if a significant presence of this wind occurs also in the low plain. There is also evidence of a reduction of contribution of summer period to total yearly events, because synoptic-scale pressure gradients tend to be weaker in summer.

In the detailed analysis of the foehn event of December 18$^{th}$, 2004, it has been found that a good indicator of the occurrence of foehn could be the analysis of the potential temperature of a downstream station compared with the one measured at a reference station representative of the flow at crest level. In particular, when the former is equal or larger than the former, there is occurrence of the foehn. We have verified that, in this period, in the downwind station there is a sharp increase in temperature, a decrease in humidity and that the wind is gusty and aligned along the reference valley axis. The potential temperature seems thus to be a good tracer on the lee side of the mountain during a foehn episode.

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