

CLIMATOLOGICAL STUDY OF THE WIND IN PIEDMONT

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Abstract: The object of the following study is to individualize the common anemological features in the Piemonte region. The executed analysis avails itself of a multiannual sample of wind data (from 1990 to 2000) collected by 59 ARPA-Piemonte monitoring network.

The wind statistical analyses have followed different phases:

- analyses of wind frequency and wind directions and spotting of the anemological basins;
- annual and monthly average of wind directions;
- annual monthly and hourly average of the wind force with spotting of breezes;
- analyses of daily and hourly wind calm;
- analyses of the strongest windblasts with records of critical cases;
- analyses of the number of days of föhn and types of weather (Borghi-Giuliacci method).

Keywords: wind speed, wind direction, anemological regime, föhn.

1. INTRODUCTION

The aim of the following study is to individualize the common anemological features in the Piemonte region. This is to be done by a climatological analysis of wind measures in this region, in relation to the annual occurrence and to the meteorological current events, in order to get into a better comprehension of the weather events occurring in this territory. The executed analysis avails itself of a multiannual sample of wind data (from 1990 to 2000) collected by the ARPA-Piemonte monitoring network. The meteorological stations used for the surveys were those equipped with sensors either for speed or direction of the wind, and with a minimum of two years activity (56 in total in Tab.1).

2. DIRECTION WIND, ANEMOLOGICAL REGIME AND WIND FORCE

The annual and monthly frequency of wind directions considers 16 direction sectors and, for every station, it allows to identify, if possible, the prevailing wind directions related with certain characteristics of the site where the instrumentation was located. Observing the results for every station, a classification is effected according to the directional regime of the wind (Tab. 1), defining it *unimodale* if there is one dominant direction, *bimodale* if there are two prevailing directions and *trimodale* if there are three prevailing directions. Therefore the available stations have been classified according to the regime of origin. The classification in zones based on the directional regimes of the wind has given the following results: Zones 1A), 1B) and 1C) – *Unimodale* regime - characterized by the presence of a maximum in the wind direction frequency attributable, for the highest maximum to valley canalization and for the lowest maximum to a meteorological conditioning; Zones 2A), 2B), 2C) – *Bimodale* regime - mainly due to "valley canalization" of the wind, as it happens in Val of Susa (class 2B), in the Ossolano (class 2A), in the Cuneese and in the Saluzzese (class 2C); class 2C occupies the greatest area in the Piemonte and it could be attributable to a "region canalization", related with the orography of the entire Western Alps; Zones 3A), 3B) and 3C) – *Trimodale* regime. The annual average speed has been calculated for each examined station. The highest annual average speeds were recorded at Colle San Bernardo (5,6 m/s), at

Monte Fraiteve (5,5 m/s) and at Capanne di Cosola (5,3 m/s). Followed by Gad, Mombarcaro and Mottarone, that registered 3.6-3.4 m/s.

Table 1. Analyzed meteorological stations, provenance (P), quota (E), latitude (LN), longitude (LE), beginning of the sensors activity (YI), annual average speed (WF), maximum gusts and registration date (SW), number of calm days (WC), prevailing wind direction (WD), anemological origin regime (U= *unimodale*, B = *bimodale*, T = *trimodale*).

Stations	P	E	LN	LE	YI	WF	SW	WC	WD	AR
VERCELLI	VC	132	45.19	8.23	1993	1.6	29.5 27/07/98	32	N	U 1 A
DOMODOSSOLA	VB	252	46.06	8.18	1988	1.6	32.1 20/09/97	39	N	B 2 A
MOTTARONE	VB	1491	45.52	8.27	1988	3.4	42.0 28/03/95	1	SW	T 3 C
FORMAZZA	VB	2453	46.26	8.21	1988	2.5	36.1 29/03/95	2	NE	B 2 A
PASSO DEL MORO	VB	2820	45.59	7.58	1988	2.8	44.3 27/02/90	1	S	U 1 A
TORINO BUON PASTORE	TO	240	45.04	7.40	1989	0.8	17.3 26/06/94	75		
RIFUGIO GASTALDI	TO	2659	45.17	7.08	1987	2.5	42.3 27/02/90	6	NW	U 1 A
COLLE BARANT	TO	2294	44.46	7.03	1987	2.5	40.7 22/12/91	2	E	B 2 C
CUMIANA	TO	327	44.57	7.23	1988	1.3	30.8 15/02/90	39	NW	U 1 A
BORGOFRANCO D'IVREA	TO	337	45.30	7.50	1988	2.5	33.7 04/09/92	3	N	U 1 A
BELMONTE	TO	687	45.22	7.38	1988	2.1	40.9 20/12/91	5	SE	U 1 A
PINO TORINESE	TO	608	45.02	7.45	1988	1.8	24.2 15/02/90	8	SE	B 2 B
MONTE FRAITEVE	TO	2701	44.58	6.51	1988	5.5	44.7 26/01/94	2	NW	T 3 B
CAMINI FREJUS	TO	1740	45.07	6.41	1990	1.8	32.7 28/01/94	21	N	T 3 B
SALBERTRAND	TO	1010	45.04	6.53	1990	2.4	27.5 26/01/94	3	NE	B 2 B
PIETRASTRETTA	TO	520	45.08	7.03	1990	3.3	33.5 25/01/93	2	NW	B 2 B
PRERICHARD	TO	1353	45.04	6.43	1990	1.9	22.2 28/03/95	4	N	B 2 B
GAD OULX	TO	1065	45.02	6.50	1990	3.7	29.2 28/03/95	1	NE	B 2 B
FINIERE	TO	813	45.07	6.58	1991	2.8	27.5 22/12/91	1	SW	B 2 B
AVIGLIANA	TO	340	45.05	7.23	1991	1.7	31.8 22/12/91	10	W	B 2 B
BORGONE	TO	400	45.07	7.14	1991	1.9	31.6 22/12/91	13	NW	B 2 B
LE SELLE	TO	1980	45.03	6.55	1991	1.9	34.8 22/12/91	3	N	T 3 B
LAGO PILONE	TO	2280	45.00	6.52	1988	1.7	23.4 27/02/90	7		
CARMAGNOLA	TO	232	44.53	7.41	1993	1.1	19.1 29/03/95	77	NE	T 3 A
BAUDUCCHI	TO	226	44.57	7.42	1993	1.4	33.2 17/01/97	53	E	T 3 A
PIVERONE	TO	230	45.25	8.02	1993	1.0	20.8 10/08/96	65	N	U 1 A
BARCENISIO	TO	1525	45.11	6.59	1994	1.4	30.1 25/12/99	15	W	T 3 B
RIFUGIO VACCARONE	TO	2745	45.09	6.55	1996	3.1	40.9 18/02/99	2	W	U 1 A
COLLE BERZIA	TO	2200	44.55	6.47	1996	1.5	23.5 27/12/99	7	SW	T 3 B
CLOT DELLA SOMA	TO	2150	44.59	6.56	1996	1.3	23.1 20/09/00	12	W	T 3 B
PRAROTTO	TO	1440	45.08	7.14	1997	1.5	23.8 05/02/99	11	E	B 2 B
CAMERI	NO	173	45.32	8.41	1988	1.6	22.2 28/03/95	11	N	U 1 A
COLLE LOMBARDA	CN	2305	44.12	7.08	1987	2.6	38.8 20/09/99	1	N	B 2 C
MONTE MALANOTTE	CN	1735	44.15	7.47	1988	2.9	42.0 31/08/94	3	W	B 2 C
COLLE S. BERNARDO	CN	980	44.10	8.02	1988	5.6	38.1 20/12/91	0	N	B 2 C
MOMBARCARO	CN	896	44.28	8.05	1988	3.6	27.7 15/02/90	0	SE	B 2 C
LIMONE PANCANI	CN	2008	44.09	7.35	1988	2.8	29.0 20/09/99	1	S	B 2 C
BERGALLI	CN	385	44.24	8.10	1990	1.4	19.5 04/04/98	13	SE	B 2 C
FOSSANO	CN	403	44.32	7.47	1993	2.2	23.2 27/03/95	2	SW	U 1 B
BRA	CN	285	44.42	7.51	1993	1.2	20.3 27/03/95	45	S	B 2 C
BALDISSERO D'ALBA	CN	265	44.45	7.55	1997	0.6	15.5 22/02/99	37	N	B 2 C
RIFUGIO MONDOVI'	CN	1760	44.11	7.43	1997	2.3	40.0 26/12/99	1	S	B 2 C
OROPA	BI	1162	45.37	7.58	1988	2.0	32.5 05/02/99	2	NW	U 1 A
MONTALDO SCARAMPI	AT	295	44.49	8.15	1988	2.4	31.4 03/07/98	2	W	B 2 C
CAPANNE DI COSOLA	AL	1550	44.40	9.12	1988	5.3	40.1 28/12/92	0	W	B 2 C
ALESSANDRIA LOBBI	AL	90	44.56	8.42	1988	2.0	25.9 28/06/90	10	SW	B 2 C
CASALE MONFERRATO	AL	118	45.07	8.30	1988	1.8	25.0 08/03/98	10	N	B 2 C
PONZONE BRIC BERTON	AL	773	44.31	8.32	1989	3.3	33.6 29/08/92	0	N	T 3 C
ISOLA S. ANTONIO	AL	77	45.01	8.51	1993	1.9	21.9 16/04/99	11	S	T 3 C
CREA	AL	385	45.05	8.16	1997	1.5	19.8 06/07/99	16	SW	T 3 A
NOVI LIGURE	AL	162	44.47	8.45	1998	1.1	18.3 13/04/00	74	SE	B 2 C
SPINETO SCRIVIA	AL	187	44.49	8.52	1998	1.8	22.1 16/04/99	23	S	T 3 C
SARDIGLIANO	AL	228	44.45	8.54	1998	2.3	25.7 16/04/99	11	E	B 2 C
CASTELLAR PONZANO	AL	146	44.49	8.50	1998	1.9	21.9 18/01/00	30	S	B 2 C
ARQUATA SCRIVIA	AL	325	44.41	8.52	1998	1.4	22.6 29/10/98	33	S	T 3 C
BASALUZZO	AL	128	44.45	8.40	1998	1.4	18.5 11/07/00	48	S	U 1 C

The maximum gusts interesting the Piemonte were verified 01/26/94 at Fraiteve (44.7 m/s) and 02/27/90 at Passo del Moro (44.3 m/s) and at Rifugio Gastaldi (42.3 m/s). On the other hand, the stations were divided by quota in order to individualize the presence of standard trends. For synthesis some examples are shown of the stations placed at over 2000 m of quota (Fig.1). It is possible to underline that in all

stations there is a maximum in the month of December, as well as elevated speed values in February. In all the stations there is a minimum of intensity in the months of May and August, except in the case of Colle della Lombarda, with its minimum in July. Besides, it was possible to evaluate the annual wind speed trend depending on the time and the month. As an example, the graph related to the station of Domodossola (VB) whose data distribution clearly underlines a valley breeze regime, with a general increase of the wind intensity in correspondence with the warmest hours of the day and its maximum in the month of July. At nighttimes, during the whole year, the speed is less than 1 m/s. Besides, November, December, January never exceed of 1,5 m/s (Fig. 2). It is possible to identify a breeze regime.

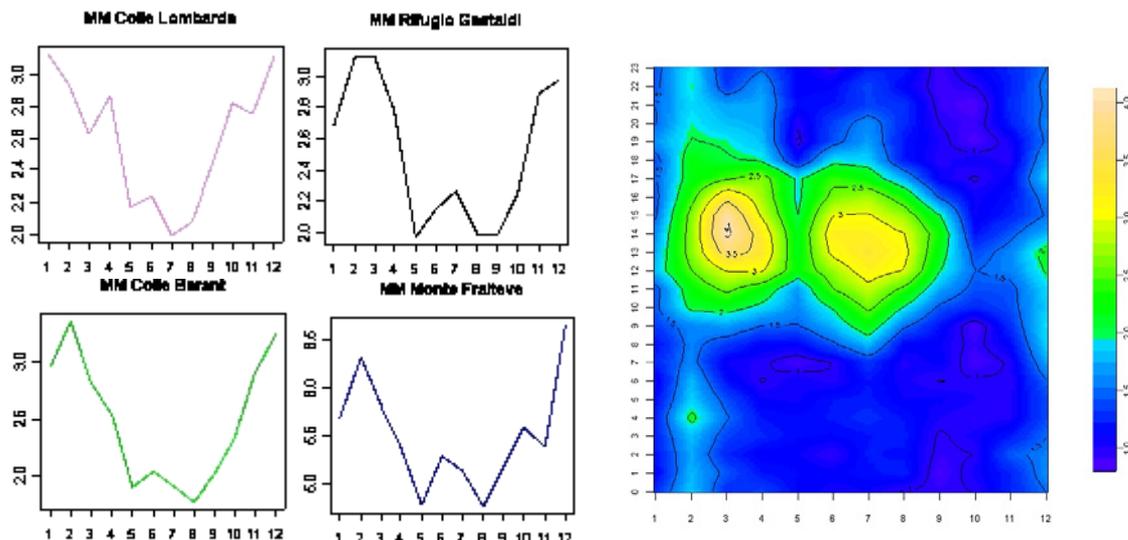


Figure 1. (left) Annual wind speed for some stations above 2000 m.

Figure 2. (right) Representation by isolines of the average speed during the year (in m/s), related with the hour (Y axis) and the months (X axis), at the station of Domodossola.

2. 1 Wind Calms and days of Föhn

The phenomenon of wind calms plays a great role in favouring the concentration of pollutants in the atmosphere, preventing normal remixing; it is therefore of interest for the air quality monitoring.

With the purpose of elaborating an analysis of the annual wind calm phenomena, the days that register an average speed of <math><1.0\text{ m/s}</math> were considered wind calm days and when datum was present, a maximum gust <math><3.4\text{ m/s}</math>. The sites with a greater number of annual average wind calm days are Carmagnola (77 days), Torino Buon Pastore (75), Novi ligure (74) and Piverone (65). On the other hand, the stations with no wind calm are Passo del Moro, Colle San Bernardo, Capanne di Cosola and Mombarcaro.

From the analysis of the calms it is underlined, as a common characteristic to all the considered sites, the concentration of the phenomenon in the first hours of the day and the evening and an increase recurrence from September to January. The phenomenon is sporadic during the spring and summer months and almost absent in the central and warmer hours of the day. A correlation analysis was developed between the daily wind calms and the types of weather. The classes of meteo-synoptic weather with a greater number of wind calms are: 140 (21%), 90 (14%) and 150 (10%).

The period of time between 2000 and 2003 was studied for the analysis of the number of days of föhn. In these four years there were 218 days of föhn, with an annual average of 55 days. The season with the most numbers of days of föhn is winter (20 days). Föhn can interest the entire Piemonte or only certain areas. The most frequent areas (Tab. 4) are the North (Val d'Ossola) and the West (Val Susa). In the N, W and NW sectors the greatest number of days of föhn is verified during the summer and the autumn. In the East zone and especially in the South zone föhn phenomena are rare; in particular, in the autumn there

are never wind episodes coming from the South. In general, in all the areas of the Piemonte the season with the greatest number of events is the winter.

The correlation between föhn episodes and synoptic configurations has been evaluated, individualizing the most frequent types of weather during such events. In the 75% of the days of föhn the kinds of weather that occur are 100 (16%), 90 (15%), 80 (13%), 31 (11%), 40 (10%) and 110 (10%).

	W	S	S'	A	YEAR
2000	28	11	20	11	70
2001	15	5	14	14	48
2002	21	6	8	20	55
2003	15	8	12	16	45
Sum	79	30	54	55	218
Average	20	8	14	14	55

Table 2. Total number of days of föhn. Winter (W), Spring (S), Summer (S'), Autumn (A).

	J	F	M	A	M'	J	J'	A'	S	O	N	D
2000	6	10	12	3	4	4	10	2	8	3	2	6
2001	5	4	6	4		1	2	2	10		5	9
2002	6	9	6	2	1	3	1	5	2	10	8	2
2003	10	3	2	3	5		4	3	5	10	1	5
Sum	27	26	26	12	10	8	17	12	25	23	16	22
Average	7	7	7	3	3	3	4	3	6	8	4	6

Table 3. Monthly trend on the total number of days of föhn. January (J), February (F), March (M), April (A), May (M'), June (J), July (J'), August (A'), September (S), October (O), November (N), December (D).

	N					W				NW				E				S							
	W	S	S'	A	Tot	W	S	S'	A	Tot	W	S	S'	A	Tot	W	S	S'	A	Tot	W	S	S'	A	Tot
Average	18	7	12	10	47	18	5	11	11	45	8	2	6	7	23	4	2	2	1	9	1	1	0	0	2

Table 4. Number of föhn days related with the season and the wind direction. Winter (W), Spring (S), Summer (S'), Autumn (A).

5. CONCLUSIONS

First of all, it is important to underline how complex it is to individualize some well defined characteristics in the wind behavior, in order to produce classifications. Nevertheless, this study has permitted to trace some good anemological basins. The wind in Piemonte is more intense in the winter and in the spring, decidedly weaker in the summer. Wind calms are rare in spring, more frequent in the autumn and in the winter. The wind in Piemonte reaches its maximum intensity along the borders. This phenomenon surely depends on the territory orography: in fact, in the mountainous zones (Northern and Western part) and in the open plain (as in the Eastern and Southeastern part of the Piemonte) wind calms phenomena are rarely verified. The most critical area in the Piemonte, regarding the meteorological factors concerning the air quality is the central part of the region. In such area the wind intensity is always low and the wind calms are more frequent, not allowing a remixing of the air. The Piedmontese provincial capital is located in this critical area: in fact, the Hills of Turin contribute to a scarce circulation of the air, in comparison with the rest of the region. In particular, the central-southern part of the province of Turin is enclosed by the Alpine Arc to the West and by the Hills to East and Southeast. Above all, this result is important for possible evaluations on the characteristics of air quality at a regional scale.

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