Status and changes in key meteorological variables at the CONECOFOR plots, 1996 - 2005

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Abstract – In this paper, variability of precipitation, temperatures and temperature stress indexes of permanent monitoring plots (PMPs) of Italian CONECOFOR network are analyzed. The study is carried out in 16 Open Field areas over the period 1996-2005. For four areas among these (BOL1, EMI1, VAL1, VEN1) longer time series are considered. An eventual trend in time series is analysed using the Mann-Kendall test, applied to annual and seasonal values, and using the additive stochastic model to separate the seasonal variation, despite the limited number of available data. Both methods do not show clear temperature or precipitation trends on long-term period. Changes in annual climatic parameters for different areas may be related to fluctuations on short-term period.

Key words: *trends, precipitation, temperature, time series.*

Riassunto – Stato e cambiamenti in variabili meteorologiche chiave nel periodo 1996-2005. Questo studio analizza le variazioni di alcuni parametri meteorologici (temperature, precipitazioni e indici di stress termico) per 16 aree permanenti della rete CONECOFOR per il periodo 1996-2005. Per 4 di queste aree (BOL1, EMI1, VAL1, VEN1) sono stati utilizzati dati antecedenti al periodo indicato. Nonostante la limitatezza dei dati disponibili, l'analisi del trend è stata effettuata tramite il test di Mann-Kendall, applicato a valori annuali e stagionali, sia mediante l'uso di un modello stocastico additivo che isoli le variazioni dovute alla stagionalità. Entrambi i metodi non mostrano trend su lungo periodo per le temperature o le precipitazioni. Cambiamenti in alcuni parametri climatici possono essere legati a fluttuazioni di breve periodo.

Parole chiave: *tendenze, precipitazioni, temperature, serie temporali.*

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Introduction

The monitoring of the climate attained a great importance and a public attention in discussions of a possible global warming in the last years. The available observational data indicate the existence of persistent trends in earth climate characteristics during the last century. The planet surface is about 0.6 °C warmer with respect to the beginning of the 20th century and the continental precipitation are 5 to 10 % higher (http://www.met-office.gov.uk/research/hadley-centre). Analysis of surface temperature recorded at meteorological stations shows unprecedented rate of temperature change during the past 25 years (Hansen *et al.* 1999; Folland 2001). The global warming in the European and in the Mediterranean area is stronger over the regions of Central and Eastern Europe and Asia Minor during the winter, and over the regions of Southern Europe and Northern Africa during the summer. The largest increase of annual mean surface precipitation decreases over Southern Europe and the Mediterranean area, whereas it shows a slight tendency to increase during summer (Buermann *et al.* 2003).

The present work focuses on analyzing the behaviour of the thermal variables (maximum, minimum and mean temperatures), the temperature stress indexes (winter index, summer index, late frost index, heat index), the precipitation and precipitation index in the growth season, at monthly or yearly scale for the period 1996-2005.

There are many questions of interest, particularly in connection with climate change, including whether there are any regularities in temperature fluctuations, whether there is evidence of a consistent rise in temperature going beyond natural fluctuations, or an evidence of seasonality in precipitation and a decline in it, whether extreme events occur, *etc.*

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In attempt to investigate this issue, classical statistical analysis and time series analysis such as autocorrelation and additive stochastic model based on monthly monitored data for precipitation and temperatures were used.

Methods

Data collection

In this study, meteorological data collected on 16 permanent monitoring plot (PMPs) are used during the period 1996-2005 (Table 1, Figure 1). We considered only data from Open Field stations, situated in proximity (generally no more than 2 km away) from the monitoring plot. The Open Field stations are in accordance to the World Meteorological Organisation Standards (WMO 1969).

The measured parameters considered in this work are: air temperature at 2 m (AT), the minimum air temperature (AT_{min}), the maximum air temperature (AT_{max}), precipitation at 1.5 m (PR). We also considered some calculated parameters: winter index (WI), number of days with temperatures below 0 °C (N_WI), summer index (SI), heat index (HI), late frost index (LFI), number of days with precipitation (N_PR), precipitation index during the growing season (GPRI). WI, SI, HI, LFI indexes are related to the temperature stress (KLAP *et al.* 1997; CALLEART *et al.* 1997; AMORIELLO and COSTANTINI 2000); we used the periods reported in Table 2 to calculate these indexes.

To carry out a time series analysis with a larger number of years, we considered also data from another dataset of EMI1, coming from a meteorological station placed near the CONECOFOR plot. The excellent overlapping between the common data (1998-2001) of the two stations justified the use of this other dataset to supply lacking data before 1998.

Table 1 - Sampling period and completeness of data for the 16 PMPs.
Periodo di campionamento e completezza dei dati considerati per le 16 aree permanenti.

PMP	Sampling period	Completeness (%)
ABR1	1998-2005	92
CAL1	2000-2005	97
EMI1	1998-2005	100
EMI2	1999-2005	97
FRI2	1999-2005	98
LAZ1	1998-2005	98
LOM1	2004-2005	99
PIE1	2000-2005	100
TOS1	1996-2001	88
TRE1	2000-2005	97
VAL1	1994-2005	95
VEN1	1993-2005	98
LOM2	2002-2005	98
LOM3	2002-2005	85
TOS2	2001-2005	96
BOL1	1990-2005	94

Figure 1 - PMPs equipped with meteorological stations.
Aree permanenti dotate di centraline meteorologiche.

Quality of the data

At first, data availability was defined at each individual plot and sampling year. If possible, the lacking data, due to instrumentation malfunctioning or damages, had to be recovered through the same parameter at different heights, for instance, or through cross controls between all parameters, or through data from the station located in the plot, if present. Logical, climatological and temporal controls gave assurance of estimates goodness.

The completeness of time series, defined as the ratio between the actual and the expected number of records, was carried out for each plot (FERRETTI *et al.* 1999). Low numbers indicate incomplete datasets. Only plots with more than 80 % of data have been considered.

Data had to be homogeneous for each plot. A time series is defined homogeneous if its variations are due only to climate or meteorological weather modifica-

Table 2 - Start of the growing and dormant season of tree species for the 16 areas, estimated by phenological observation.
Inizio della stagione di crescita e di dormienza delle specie arboree nelle 16 aree, stimate mediante osservazioni fenologiche.

PMP	Start of the growing season	Dormant season	Tree specie
ABR1		October 10	*Fagus sylvatica*
CAL1	March 16	October 16	*Fagus sylvatica*
EMI1	April 1	November 1	*Quercus petraea*
EMI2	April 20	October 10	*Fagus sylvatica*
FRI2	April 16	October 16	*Picea abies*
LAZ1	April 1	October 10	*Quercus cerris*
LOM1	April 16	October 1	*Picea abies*
PIE1	April 16	October 10	*Fagus sylvatica*
TOS1	April 16	October 16	*Quercus ilex*
TRE1	June 10	September 30	*Picea abies*
VAL1	May 1	October 16	*Picea abies*
VEN1	April 16	October 10	*Fagus sylvatica*
LOM2	April 16	October 1	*Picea abies*
LOM3	April 20	October 10	*Fagus sylvatica*
TOS2	April 1	October 10	*Quercus ilex*
BOL1	May 1	October 10	*Picea abies*

tions. Data have been rejected, if the consistency was not guaranteed, to the aim of reducing systematic errors during data analysis.

Statistical analysis

The non-parametric Mann-Kendall tests (Mann 1945; Kendall 1975) was used to detect whether a temporal trend exists in annual data (ATmax, ATmin, WI, N_WI, SI, LFI). This test is widely used in environmental science, because it is simple, robust and can cope with missing values and a restricted number of annual values. It has the following important advantages: missing data are allowed, no assumption of normality is required (the data do not need to conform to any particular distribution); it is resistant to outliers; it admits censored data (as only ranks are used).

The Mann-Kendall statistic for a time series (Z_k, k=1,2,...,n) of data is defined as

$$T = \sum_{j<i} \text{sgn}(Z_i - Z_j) \qquad [1]$$

where

$$\text{sgn}(x) = \begin{cases} 1 & x > 0 \\ 0 \quad \text{if} & x = 0 \\ -1 & x < 0 \end{cases} \qquad [2]$$

If no ties between the observations are present and no trend is present in the time series, the test statistic is asymptotically normal distributed with

$$E(T)=0 \quad \text{and} \quad Var(T)=n(n-1)(2n+5)/18 \qquad [3]$$

Temporal trends in monthly data (AT, PR, N_PR, GPRI) are detected with the seasonal Mann-Kendall test, where each data set is adjusted for seasonality (Hirsch *et al.* 1982). This test has all the advantages of the Mann-Kendall test, offering higher power because it removes short-term variability caused by seasonality that would otherwise appear as background noise in a Mann-Kendall test for the whole time series. It is computed by first separating the data into ω subseries, every series representing a season

$$T_j = \sum_{k<l} \text{sgn}(Z_{lj} - Z_{kj}) \qquad [4]$$

where j=1,…, ω. T_j is the Mann-Kendall statistics for season j, which is summed over all seasons to obtain the seasonal statistics

$$S = \sum_{j=1}^{\omega} T_j \qquad [5]$$

Significance threshold of $p<0.05$ is applied to trend tests.

The number of annual values can be less than 10. If it happens, the absolute value of T is compared directly to the theoretical distribution of T derived by Mann and Kendall (Gilbert 1987).

The temporal dependence structure of a univariate time series can be examined statistically through the autocorrelation function ACF (Box *et al.* 1994). The simple autocorrelation analyses quantifies the linear dependency of successive values over a time period. The definition of the correlogram C(k), which outlines the memory of the system, and the slope of the autocorrelation function r(k) are expressed as

$$r(k) = \frac{C(k)}{C(0)} \qquad [6]$$

$$C(k) = \frac{1}{n} \sum_{t=1}^{n-k} (x_t - \overline{X})(x_{t+k} - \overline{X}) \qquad [7]$$

where k is the time lag, n is the length of the time series, x is a single event, $\overline{X}$ is the mean of the events and m is the cutting point. The cutting point is usually determined based on the interval of the analysis. The ACF ranges from -1 to +1, with positive values indicating that a high value would tend to be followed by another high value at lag k. A 95 % confidence interval, around the zero r(k), can be determined using the method of Quenouille (1947), and is dependent upon both the number of data points in the time series, and the absolute value of the autocorrelation coefficient.

If the time series shows a strong interdependency and a long memory effect, the ACF decreases gently and shows a non-zero value over a long time lag. It could mean that a trend is present. If the time series is uncorrelated, the ACF decreases very quickly and reaches a zero value in a short time. If the time series is cyclic, the ACF is also cyclic and has the same cycle length.

The temporal dependence structure of a time series can help understanding if it displays a regular pattern of fluctuations repeated from year to year. This periodic pattern, called seasonality, is very often observed in most climatic elements. The natures of seasonal variations are analyzed in an additive model for temperatures and precipitation. The general model for structure decomposition method is:

$$Y_t = T_t + S_t + \varepsilon_t \qquad [8]$$

where T_t is the trend term, S_t the seasonal term and ε_t the random term. Once seasonal changes are separated from another time series components, it will be clear if a trend occurs.

Results and discussion

Quality of the data

Table 1 shows the sampling period and data completeness for each plot. Altogether almost 10% of the data were recovered for all plots. In particular, precipitation was recovered between cross controls with the amount of precipitation from atmospheric deposition survey.

Completeness of acquired data ranges between 85% (LOM3) and 100 % (EMI1, PIE1). Data from LOM1 for the period 1997-2003 and from TRE1 for the period 1998-1999 were rejected because of not completeness (< 80%) and not homogeneity or malfunctioning of the meteorological station and following replacement.

Climatological characteristics

During the observed period, three events happened in a more or less marked way throughout Italy:

- Cool and rainy summer 2002: in all PMPs the seasonal mean temperatures were lower than the means of the surveyed period, until – 8% at TRE1, whereas the precipitations were higher with a range between + 7% at FRI2 and + 160% at TOS2.
- Very hot and dry summer 2003: in all PMPs the summer mean temperatures were higher, with a range between +7% at CAL1 and + 24% at VAL1 and BOL1, whereas the precipitations were lower with a range between -8% at TRE1 and -62% at BOL1.
- Very cold winter 2004-2005: in all PMPs the winter mean temperatures were lower, with a range between -2% at PIE1 and -72% at EMI2.

Table 3 and Figure 4 show the high interannual and spatial variability for almost all PMPs, and give an idea of the above mentioned events.

Figure 2 shows the mean temperatures plotted against altitude. As expected, the altitude is the most important factor of temperature variation, but not the only one. In fact, FRI2 and EMI2 are at the same altitude but FRI2 has lower values because of its exposure. The mean temperatures range between 4.1°C of BOL1 and 16.0°C of TOS2. The maximum temperature was recorded at EMI1 during 2003 (38.1°C), while the minimum temperature was -27.5°C at VEN1 in 2005.

No dependence from altitude was registered for the precipitation (Figure 3). CAL1, PIE1 and VEN1 showed the highest amount of mean rainfall with 1859, 1846 and 1840 mm, respectively. TOS2 reached

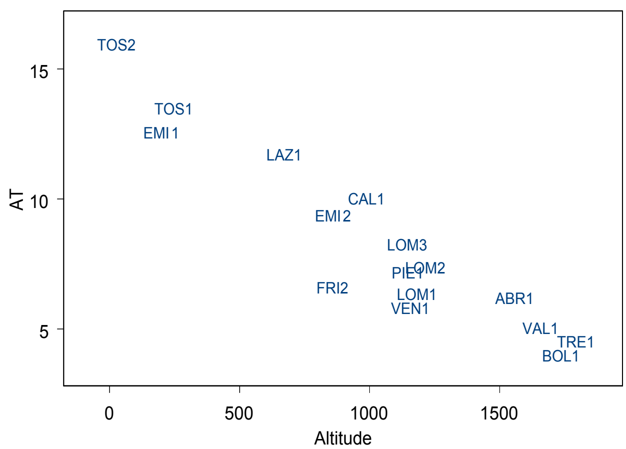

Figure 2 Air temperature against altitude for the 16 PMPs.
Temperatura dell'aria in funzione dell'altitudine per le 16 aree permanenti.

Table 3 - Simple statistics (mean, minimum, maximum and standard deviation) for the variables considered (air temperature AT, maximum air temperature ATmax, minimum air temperature ATmin, winter index WI, number of days with temperatures below 0 °C N_WI, summer index SI, heat index HI, late frost index LFI, precipitation PR, number of days with precipitation N_PR, precipitation index during the growing season GPRI) for all the PMPs.
Statistiche di base (media, minimo, massimo e deviazione standard) per le variabili oggetto di studio per tutte le aree permanenti.

PMP		AT (°C)	ATmax (°C)	ATmin (°C)	WI (°C)	N_WI	SI (°C)	HI (°C)	LFI (°C)	PR (mm)	N_PR	GPRI (mm)
ABR1	mean	6.3	26.6	-13.0	-248	73	1248			878	101	341
	min	5.2	23.1	-15.4	-393	52	1085	0.0	-12.4	728	88	233
	max	6.8	28.5	-10.4	-125	85	1544	0.0	-1.5	1145	124	533
	s. dev	0.5	1.7	1.8	91	15	141			145	11	110
CAL1	mean	10.1	31.7	-7.5	-29	19	1898			1859	123	780
	min	9.2	30.5	-8.9	-46	3	1797	0.0	-7.3	1541	99	404
	max	10.5	33.6	-4.2	-2	36	2039	0.0	-2.0	2449	140	1079
	s. dev	0.5	1.1	1.7	16	12	103			351	18	243
EMI1	mean	12.6	34.7	-6.2	-22	16	2802			843	79	531
	min	11.4	33.5	-9.1	-30	9	2592	0.0	-2.2	613	68	330
	max	13.4	38.1	-4.8	-13	20	3083	18.4	0.0	1028	90	684
	s. dev	0.6	1.5	1.3	7	4	141			156	8	115
EMI2	mean	9.4	31.9	-12.7	-112	39	1745			1448	104	494
	min	8.5	28.3	-15.9	-155	18	1078	0.0	-8.7	1022	87	302
	max	9.9	34.0	-10.5	-48	53	2091	0.0	-0.1	1879	120	795
	s. dev	0.5	1.9	2.3	33	11	317			356	12	167
FRI2	mean	6.7	30.8	-15.8	-339	85	1504			1704	115	1020
	min	6.0	29.0	-19.7	-437	50	1408	0.0	-10.9	1371	99	924
	max	7.3	33.1	-14.1	-194	106	1703	0.0	-2.1	2041	139	1183
	s. dev	0.5	1.3	2.0	73	18	101			249	14	82
LAZ1	mean	11.8	35.0	-7.8	-26	15	2287			970	89	437
	min	11.2	32.1	-10.1	-48	5	2130	0.0	-6.2	820	78	324
	max	12.4	37.5	-5.2	-4	21	2565	11.9	0.0	1181	103	551
	s. dev	0.4	2.0	1.6	16	7	129			141	11	79
LOM1	mean	6.4	29.0	-13.2	-270	88	1362			1126	101	628
	min	6.3	28.5	-14.8	-322	84	1305	0.0	-2.8	987	91	596
	max	6.5	29.5	-11.5	-218	91	1420	0.0	-2.3	1264	110	659
	s. dev	0.1	0.7	2.3	73	5	81			196	13	45
PIE1	mean	7.2	25.7	-11.3	-169	55	1383			1846	107	1147
	min	6.5	23.7	-14.4	-255	41	1264	0.0	-8.0	1229	93	610
	max	7.8	28.2	-9.1	-90	72	1697	0.0	-1.8	3025	124	1857
	s. dev	0.5	1.9	1.9	67	13	160			754	12	488
TOS1	mean	13.6	34.3	-3.8	-4	2	2523			853	73	348
	min	12.7	31.7	-6.0	-14	0	2355	0.0	-0.6	615	38	269
	max	14.0	35.8	-0.3	0	4	2590	1.2	0.0	1177	104	466
	s. dev	0.4	1.6	2.1	5	2	89			249	23	73
TRE1	mean	4.6	27.9	-17.0	-367	93	811			1027	103	411
	min	3.7	22.2	-20.4	-502	78	597	0.0	-4.2	827	80	302
	max	5.4	30.7	-11.7	-278	114	1020	0.0	0.0	1297	127	579
	s. dev	0.6	3.2	2.9	91	13	157			199	18	112
VAL1	mean	5.1	26.3	-15.4	-337	89	1070			816	97	470
	min	4.1	24.3	-18.7	-440	69	977	0.0	-7.2	526	69	298
	max	5.7	28.6	-12.4	-218	113	1384	0.0	-1.5	1075	125	674
	s. dev	0.5	1.5	1.9	74	13	112			195	17	129
VEN1	mean	5.9	26.6	-20.0	-368	87	1292			1840	112	1045
	min	4.9	24.1	-27.5	-573	57	1139	0.0	-14.2	1291	71	705
	max	6.8	30.4	-13.3	-207	110	1535	0.0	-0.7	2795	133	1442
	s. dev	0.6	1.5	3.3	109	17	102			356	16	257
LOM2	mean	7.4	29.3	-11.0	-152	53	1465			1216	122	704
	min	6.9	28.1	-14.9	-202	39	1329	0.0	-7.9	1135	108	502
	max	8.1	31.9	-8.8	-117	62	1744	0.0	-0.3	1368	138	821
	s. dev	0.6	1.8	2.8	45	13	189			131	15	139
LOM3	mean	8.3	29.2	-9.9	-124	44	1653			1356	99	660
	min	7.4	27.8	-13.5	-189	32	1534	0.0	-8.7	1173	90	448
	max	9.2	30.8	-7.9	-67	53	1903	0.0	-0.5	1690	118	778
	s. dev	0.7	1.2	2.6	50	11	170			290	16	184
TOS2	mean	16.0	32.9	-1.4	0	0	2854			651	65	262
	min	15.1	31.3	-2.4	-1	0	2579	0.0	-0.8	496	55	159
	max	16.9	35.9	-0.4	0	1	3264	2.3	0.0	871	79	453
	s. dev	0.7	1.8	0.7	0	1	263			140	10	128
BOL1	mean	4.1	21.8	-15.2	-396	96	871			899	90	478
	min	2.6	19.8	-18.2	-526	83	783	0.0	-7.2	529	64	266
	max	4.9	24.6	-12.3	-310	110	1153	0.0	-0.9	1116	112	663
	s. dev	0.7	1.6	2.1	87	10	127			168	16	123

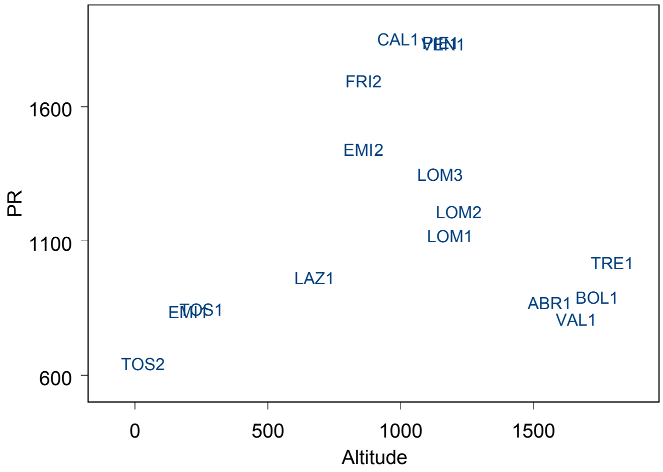

Figure 3 - Precipitation against altitude for the16 PMPs.
Precipitazioni in funzione dell'altitudine per le 16 aree permanenti.

the minimum value of 651 mm. The box plot of PR (Figure 4) showed a high interannual variability inside the same plot. The 2004 was the rainiest year while the 2003 the driest one.

The number of rainy days is rather constant at all PMPs and follows the trend of precipitation. The extreme events (PR > 100 mm/day) were recordered as follows:

- 1 in 2003 at ABR1;
- 2 in 1999 1 in 2000, 1 in 2001, 2 in 2003, 1 in 2004 at CAL1;
- 1 in 2000, 1 in 2003 at EMI2;
- 2 in 2000, 1 in 2002, 2 in 2003, 1 in 2004 at FRI2;
- 6 in 2000, 8 in 2002, 1 in 2003, 1 in 2004 at PIE1;
- 2 in 2000 at VAL1;
- 2 in 1996, 2 in 1997, 2 in 1998, 2 in 1999, 4 in 2000, 1 in 2001, 5 in 2002, 3 in 2004 at VEN1;
- 1 in 2003, 1 in 2004 at LOM3.

The spatial variation in temperature stress indexes, calculated for 16 plots, is given in Table 3 and is well represented through the box plots in Figure 4.

Winter index WI is an indication of severeness of

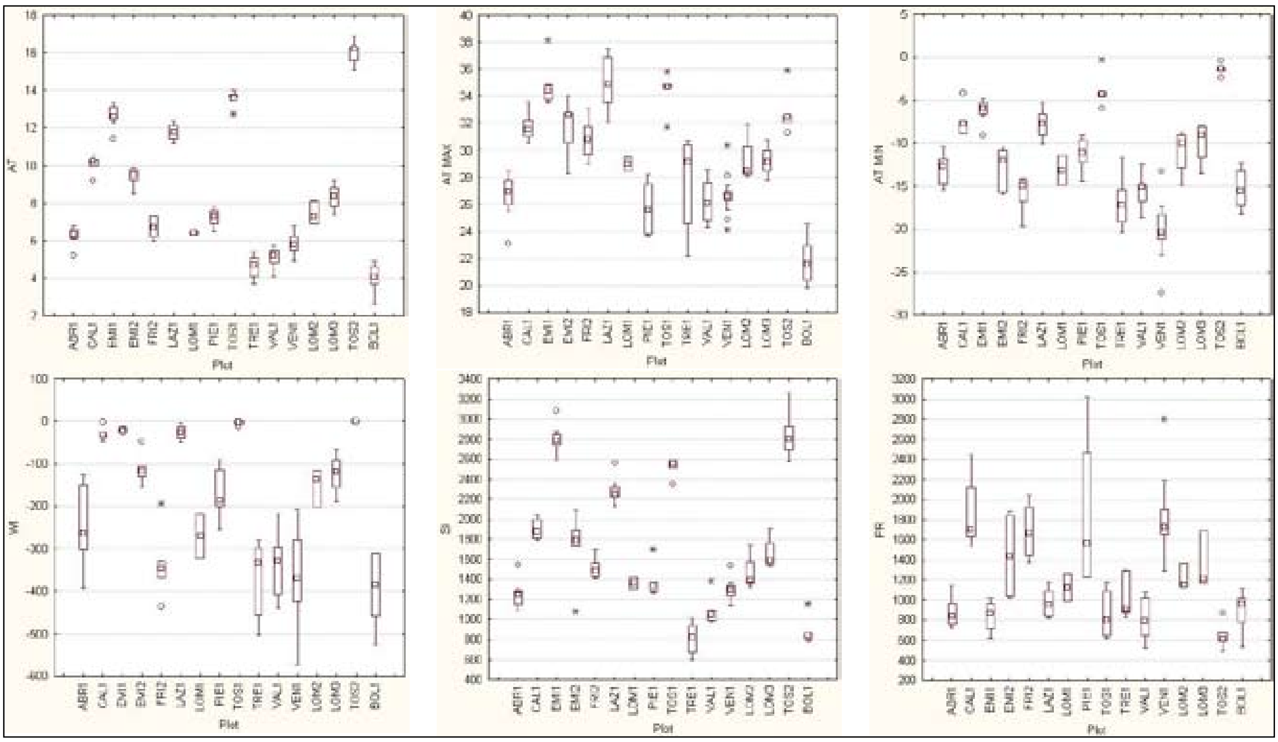

Figure 4 - Box plots of a few surveyed variables (air temperature AT, maximum air temperature AT_{max}, minimum air temperature AT_{min}, winter index WI, summer index SI, precipitation PR).
Box plot di alcuni parametri oggetto di studio.

the winter. The mean values range between -396°C at BOL1 and 0°C at TOS1. Low temperatures, below 0°C, were recordered in all plots of Northern Italy, especially at BOL1, TRE1 e VEN1. The mean number of days with temperatures below 0°C (N_WI) was very high: it exceeded 50% of dormant season days in many Alpine areas. The minimum value was detected at VEN1 with -573°C in winter 1999-2000. Generally the plots located at a low altitude, like TOS1, TOS2 and EMI1, did not suffer winter freezing nor tree damages.

Late frost index LFI is an indication of frost severeness in spring, when growth has just started. The values range from 0°C to -14.2°C at VEN1. In spite of the rather low minimum temperatures reached, no phenological evidence indicated a non tolerance of the trees to this stress.

Summer index SI is an indication of the quality of the growing season. The mean values varied from 811°C at TRE1 to 2854°C at TOS2. The minimum value was 597°C at TRE1 in 1997 and the maximum value was 3264°C at TOS2 in 2003.

Heat index HI is an indication of the possible occurrence of damage by high temperatures. Only TOS1, TOS2, EMI1 and LAZ1 plots reached values above 35°C. In particular, the maximum value of HI (18.4°C) was reached at EMI1 in summer 2003, in confirmation of an exceptionally hot summer.

Variability and trends analysis

To determine whether there is a linear trend in annual data sequences from 16 areas, the Mann-Kendall test at 5 % significance level was applied to AT_{max}, AT_{min}, WI, N_WI, SI, LFI, GPRI datasets without gaps.

The results are given in Table 4. No trends were found for almost all parameters and plots, with some exceptions. A positive significant trend was found for AT_{max} at BOL1 and TOS1, with a correspondent positive trend for SI at TOS1, and a negative trend for AT_{min} at VEN1. PIE1 exhibited a significant negative trend for WI and a positive trend for N_WI; it means that a decrease in the sum of temperatures below 0°C and an increase in the number of days reaching these temperatures occurred. Besides, a negative trend of GPRI was found at TRE1: the annual amount of precipitation was constant but the rainfall during the growing season decreased.

Trends in monthly data of AT, PR and N_PR were tested through the seasonal Mann-Kendall test at 5% significance level. CAL1 showed a negative trend for AT and a positive trend for PR and N_PR.

At last, the number of rainy days of FRI2 significantly decreased.

The autocorrelation functions of monthly temperatures (Figure 5) for the 4 plots having a sufficient number of data to compute this analysis (BOL1 1990-2005, EMI1 1977-2005, VAL1 1995-2005, VEN1 1993-2005) showed a sinusoidal pattern implying, as expected, that a high short-term autocorrelation was present due to a seasonal factor.

The autocorrelation function of monthly precipitation (Figure 6) showed the same sinusoidal behaviour of temperatures, even if strongly marked for BOL1 in

Table 4 - Results of the Mann-Kendall test for 10 parameters (ns: trend not significant; ↑ and ↓ downward and upward trends, respectively, at 95% confidence level).
Risultati del test di Mann-Kendall per 10 parametri (ns: trend non significativo; ↑ and ↓ trend positivo e negativo, rispettivamente, a 95% livello di confidenza).

PMP	AT	AT_{max}	AT_{min}	WI	N_WI	SI	LFI	PR	N_PR	GPRI
ABR1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CAL1	*↓	ns	ns	ns	ns	ns	ns	* ↑	*↑	ns
EMI1 (98-05)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
EMI1 (77-05)	ns	-	-	-	-	-	-	ns	ns	-
EMI2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
FRI2	ns	ns	ns	ns	ns	ns	ns	ns	*↓	ns
LAZ1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
LOM1	-	-	-	-	-	-	-	-	-	-
PIE1	ns	ns	ns	*↓	* ↑	ns	ns	ns	ns	ns
TOS1	* ↑	* ↑	ns	ns	ns	* ↑	ns	ns	ns	ns
TRE1	ns	ns	ns	ns	ns	ns	ns	ns	ns	* ↓
VAL1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
VEN1	ns	ns	* ↓	ns	ns	ns	ns	ns	ns	ns
LOM2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
LOM3	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
TOS2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
BOL1 (99-05)	ns	* ↑	ns	ns	ns	ns	ns	ns	ns	ns
BOL1 (90-05)	ns	-	-	-	-	-	-	ns	-	-

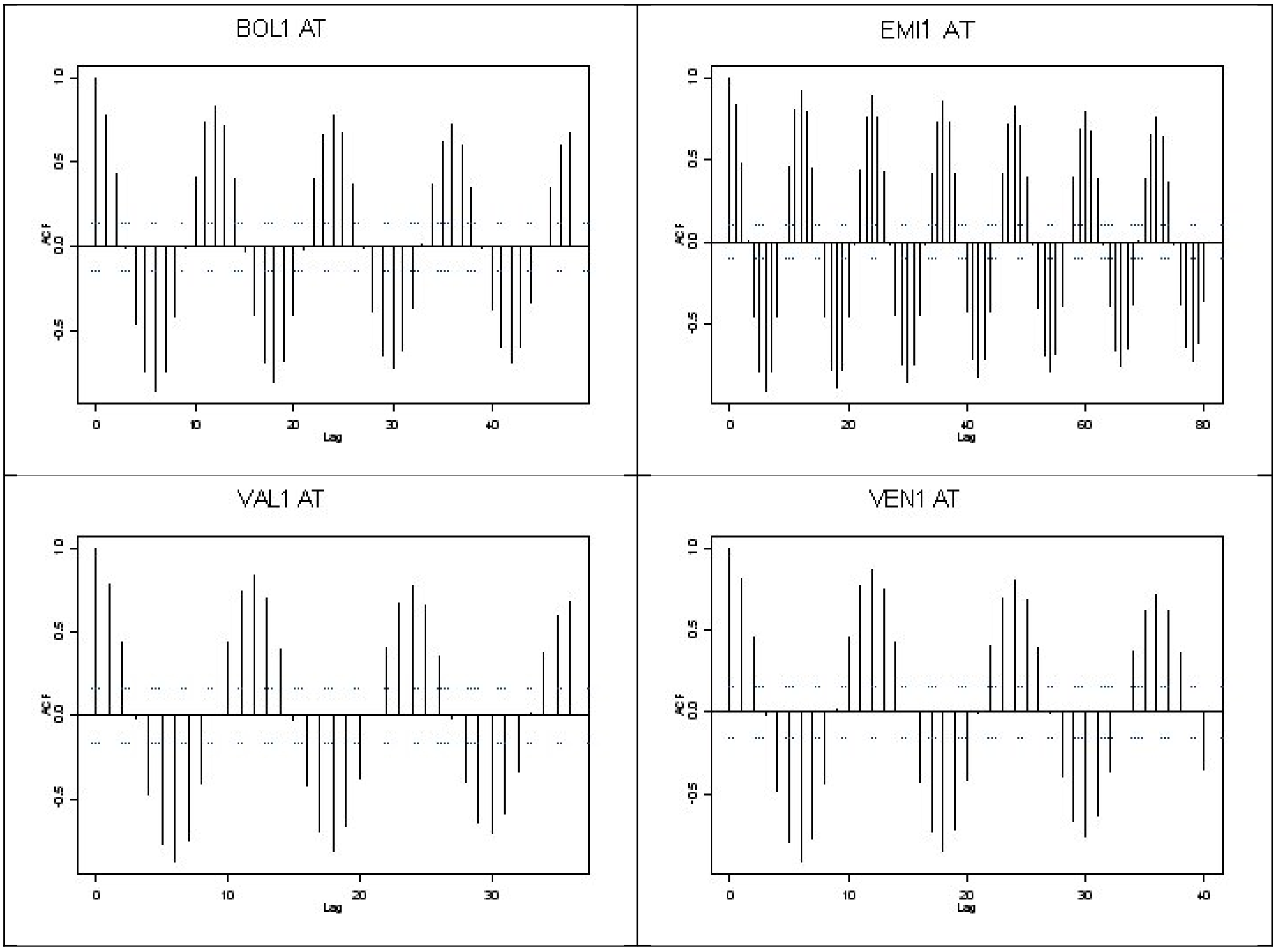

Figure 5 - Air temperature autocorrelation function.
Funzione di autocorrelazione della temperatura dell'aria.

comparison with EMI1 and VEN1. The ACF of VAL quickly reached a null value (clearly a white noise) and it means no seasonal component.

For these data sequences, the cyclic seasonal component was removed to isolate the trend term. The seasonalized and smoothed trends of temperatures and precipitation for the 4 plots are given in Figure 7 and 8, respectively. Although the eye tends to impute negative trends to precipitation of BOL1 and VAL1, no linear trends are present. The outliers play an important role on trend and they could introduce a bias due to the too small datasets. For instance, the positive trend to temperatures of EMI1 was caused by the exceptionally hot summer 1993. This analysis confirms the result obtained with the Mann-Kendall test.

Conclusions

Although ten years of data are not sufficient to point out any possible climatic trends in Italy, the analysis was useful to a first evaluation of the high interannual and spatial variability at almost all PMPs. This evaluation integrates the results from the other CONECOFOR surveys.

The Mann-Kendall test was used to investigate trends in temperature, precipitation and temperature stress indexes, both annually and monthly. A significant increase was observed in precipitation and in the number of rainy days only for CAL1, with a correspondent decreasing in temperature. A temperature increase happened for TOS1, due especially to the increase of summer temperature (SI) and linked to an increase of maximum temperature. A decrease of winter temperature was measured only at PIE1, as showed by WI and N_WI; it is interesting that this phenomenon is not joined to a corresponding decrease of mean temperature, which on the contrary showed an increase, even if not significant. All these trends could be influenced by the reduced number of available data and short- term fluctuations. On a longer period, no trends in temperatures or precipitation were found for EMI1 (1977-2005) and BOL1 (1990-2005).

Time series analysis for EMI1, BOL1, VAL1, and VEN1 also provided the same results of the Mann-Kendall test. From the autocorrelation, temperatures and, to a lesser extent, precipitation showed a strong dependence from seasonal periodicity. The deseasonalised time series showed no trends in temperatures or precipitation for the 4 PMPs with long datasets.

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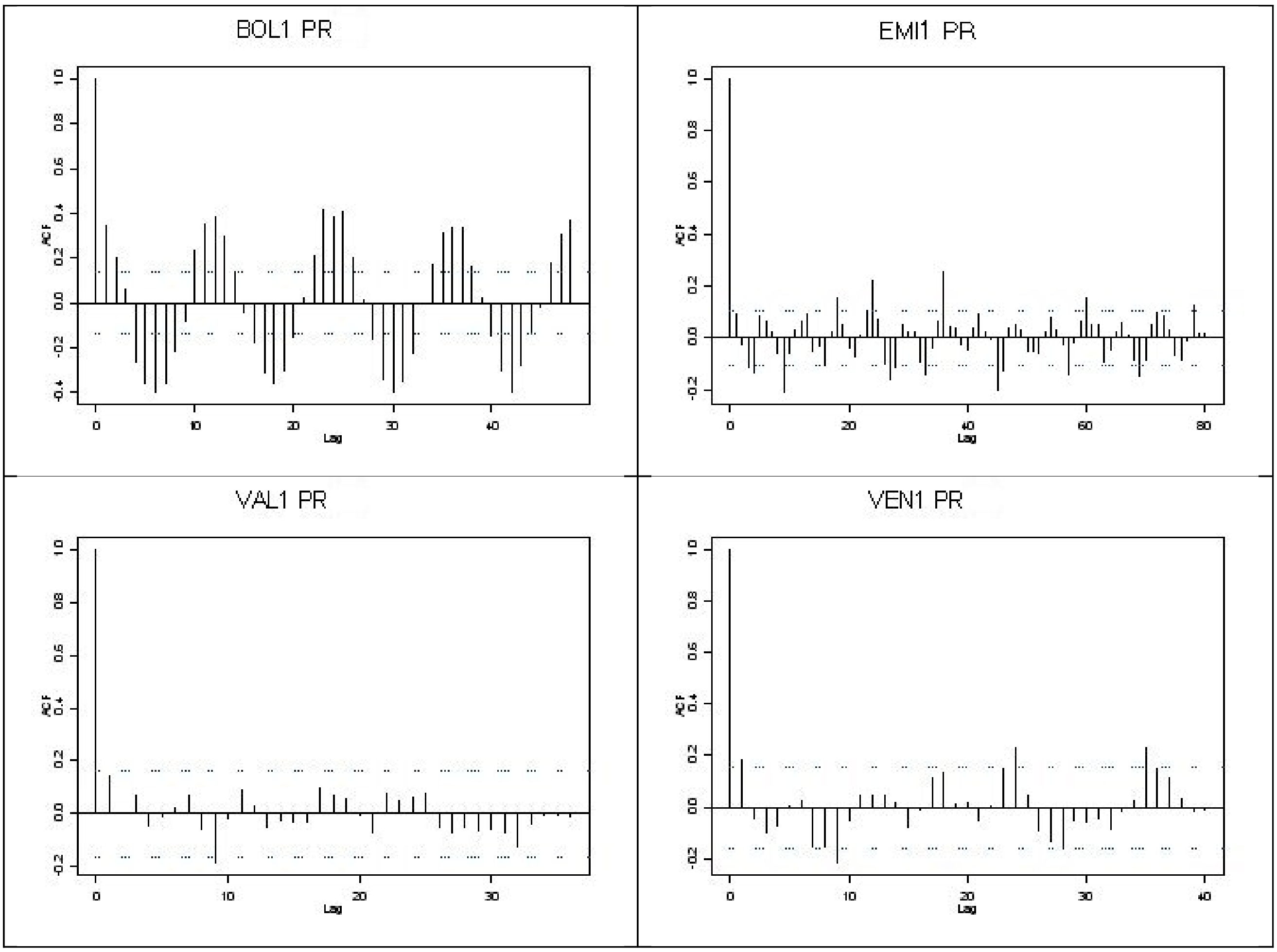

Figure 6 - Precipitation autocorrelation function.
Funzione di autocorrelazione delle precipitazioni.

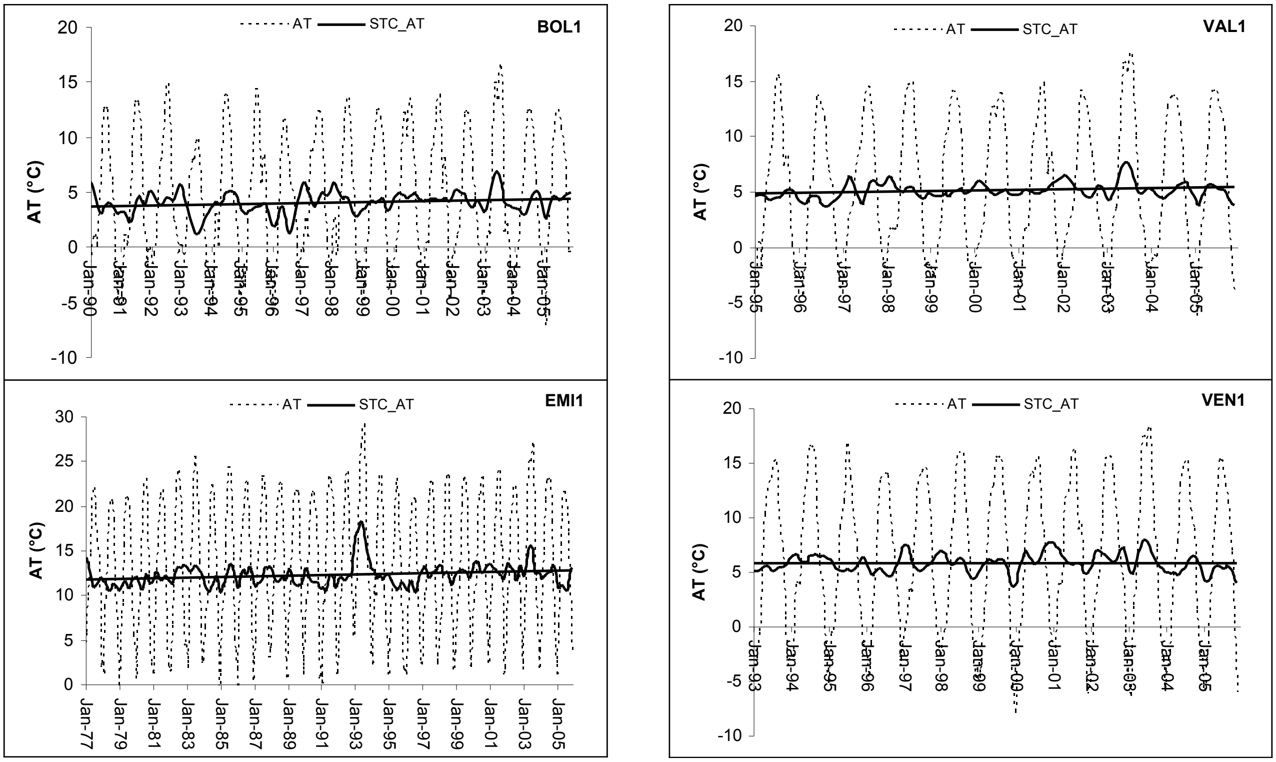

Figure 7 - Monthly mean air temperature AT (dotted line), deseasonalised and smoothed monthly mean air temperature STC_AT (undotted line) and trend at 4 PMPs.
Temperatura media mensile dell'aria AT (linea tratteggiata), temperatura mensile media dell'aria destagionalizzata e lisciata STC_AT (linea continua) e trend per 4 aree permanenti.

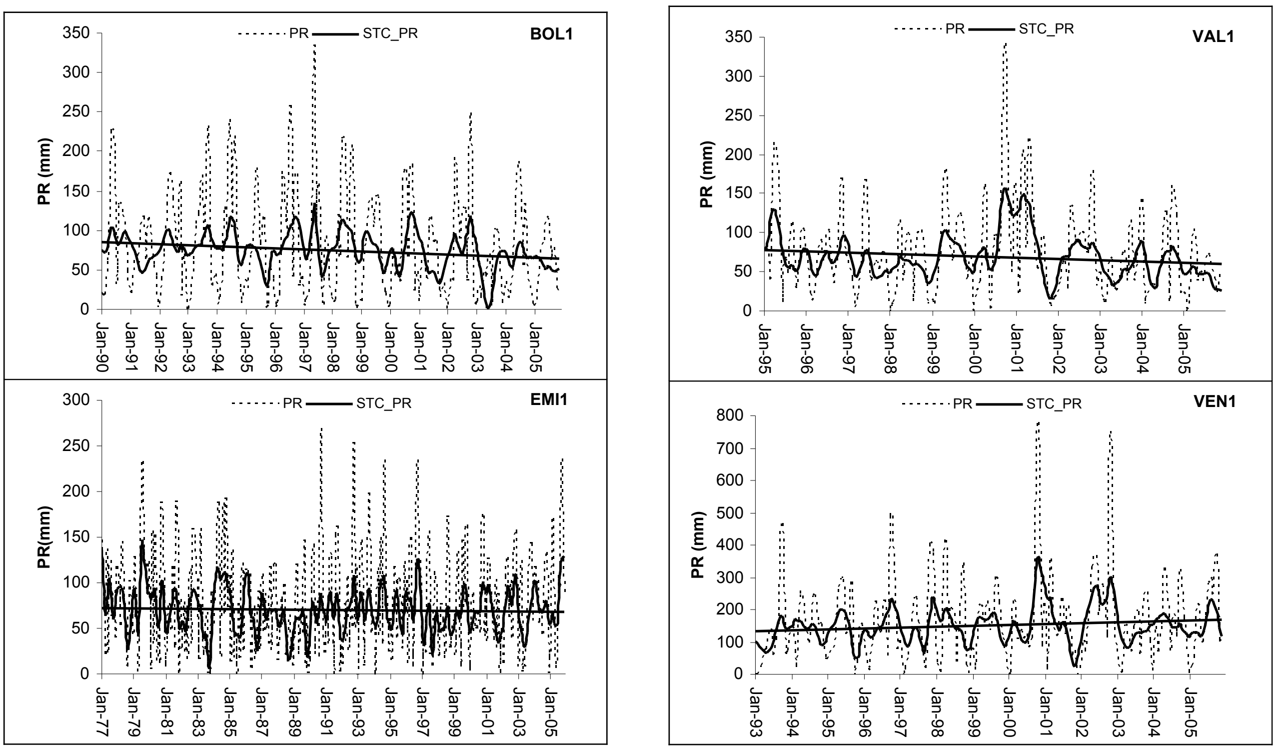

Figure 8 - Monthly precipitation PR (dotted line), deseasonalised and smoothed monthly precipitation STC_PR (undotted line) and trend at 4 PMPs.
Precipitazioni mensili PR (linea tratteggiata), precipitazioni destagionalizzate STC_PR (linea continua) e trend per 4 aree permanenti.

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