

Flat steps models for the analysis of temperature and precipitation italian time series from 1961 to 2007¹

Sara Giavante, Edmondo Di Giuseppe, Stanislao Esposito

CRA-CMA Unità di ricerca per la climatologia e la meteorologia applicate all'agricoltura,
via del Caravita 7/A 00186 Roma Italy, e-mail: sara.giavante@entecra.it

Abstract: recently international literature has turned attention to climate change effects on temperature and precipitation. Flat steps models allow to identify breakpoints among stationary phases in time series analysis. We propose flat steps models for detecting structural changes in annual and seasonal italian time series (period 1961-2007) of minimum and maximum temperature and precipitation. The analysis reveals that a temperature and precipitation's regime shift has occurred in last 1980s suggesting a further investigation on connections with other indicators of climatic system.

Keywords: Environmental Statistics, Time Series, Breakpoints, Structural Changes, Climate Changes

1. Introduction

Recently several works have shown how to apply standard linear regression models is often inadequate when analysing time series of climatological data. A linear regression model assumes that there is just one change which structure is explained by regression coefficients whereas different methods allow for several shifts and stationary phases. We apply flat steps models in order to find out structural changes in temperature and precipitation time series data and to determine related indicators (breakpoints, levels of subperiods) which are used in climatic change's assessment.

2. Methods and data

This study employs a dataset which consists of daily maximum and minimum temperature and precipitation for 83 Italian locations over the 47 years period 1961-2007. Data have been homogenized according to temporal and spatial criteria whereas locations have been selected having a lower than 800 meters altitude.

Besides, data have been grouped by mean into seasonal and annual time series and, successively, the dataset has been reduced to four dimensions by constructing an average

(¹) This paper has been funded by TEMPIO Project "Previsioni mensili di temperatura e precipitazioni a supporto della pianificazione dell'attività agricola" financed by Mipaaf.

value of all location's data series in Italy, Northern Area (NA), Central Area (CA) and Southern Area (SA).

Following Bai and Perron (2003) we analyze structural changes for 12 annual time series (maximum and minimum temperature and precipitation for Italy, NA, CA and SA) and for 36 seasonal time series (maximum and minimum temperature and precipitation for Italy, NA, CA and SA for the seasons Winter, Spring, Summer and Autumn) by means of R's library "Strucchange" (Zeileis et al., 2003).

If we consider a standard linear regression model

$$y_i = x_i' \beta_i + u_i \quad (i = 1, \dots, n)$$

where y_i is the observed dependent variable at time i , x_i is a $k \times 1$ vector of regressors and β_i is the $k \times 1$ vector of regression coefficients, which may vary over time, it is possible to set m breakpoints for which regression coefficients are constant in $m+1$ segments.

We allow up to 5 breaks and use a trimming $\xi = 0.15$. For each m -partition we obtain least squares estimates of β and we determine breakpoints estimators of $(i_1, \dots, i_m)$ as global minimizers over all partitions of the objective function

$$RSS(i_1, \dots, i_m) = \sum_{j=1}^{m+1} rss(i_{j-1}+1, i_j)$$

where $rss(i_{j-1}+1, i_j)$ is the minimal residual sum of squares in the j th segment.

Thus we have OLS estimates of breakdates for each m and we select the dimension of the model, i.e. the number of change points using the Bayesian Information Criterion (BIC):

$$BIC = k \ln(n) - 2 \ln(L_{max})$$

where n is the number of observations, k is the number of estimated regressors coefficients and L_{max} is the maximum likelihood function. As suggested by Perron (2003) the BIC performs reasonably well in the absence of serial correlation in the errors.

3. Results and perspectives

We briefly discuss relation between climatic regimes and breakdates detected in temperature and precipitation time series data by applying procedures presented in this paper. Firstly we present results for annual data and subsequently for seasonal data.

For annual data of minimum temperature (Tab. 1), the BIC selects a model with a breakpoint in 1986 for Italy and CA, a breakpoint in 1987 for NA and a breakpoint in 1985 for SA. The second subperiod account for an increasing mean level between 0.7 and 1.1 °C in all areas. For annual data of maximum temperature, the selection of breakdates is 1985 and 1996 for Italy, 1987 and 1996 for NA, 1984 and 1998 for SA and 1991 for CA. Comparison of the last and first subperiod reveals a significant mean levels' increase with a maximum of 1.4 °C. Finally for annual data of precipitation, the selection of breakdates is

1987 with a decreasing annual total amount of 90 mm for Italy and CA whereas no change points have been found for NA and SA.

Table 1: *Change points for Italy, NA, CA and SA annual time series (1961-2007)*

VARIABLE			BREAKPOINT	BREAKDATE	TOTAL MEAN	SUBPERIOD MEAN		SUBPERIOD VARIATION	
ITALY									
Minimum Temperature (°C)	1		1986		10,6	10,3	11,1	0,8	
Maximum Temperature (°C)	2		1985	1996	19,3	18,8	19,4	20,0	1,2
Precipitation (mm)	1		1987		746,9	782,5	698,9		-83,7
NA									
Minimum Temperature (°C)	1		1987		9,0	8,5	9,6		1,1
Maximum Temperature (°C)	2		1987	1996	17,6	17,2	17,8	18,6	1,4
Precipitation (mm)	0				884,6				
CA									
Minimum Temperature (°C)	1		1986		10,3	10,0	10,7		0,7
Maximum Temperature (°C)	1		1991		19,8	19,4	20,3		0,9
Precipitation (mm)	1		1987		712,7	751,7	659,9		-91,8
SA									
Minimum Temperature (°C)	1		1985		12,9	12,6	13,3		0,7
Maximum Temperature (°C)	2		1984	1998	20,6	20,1	20,8	21,4	1,3
Precipitation (mm)	0				619,8				

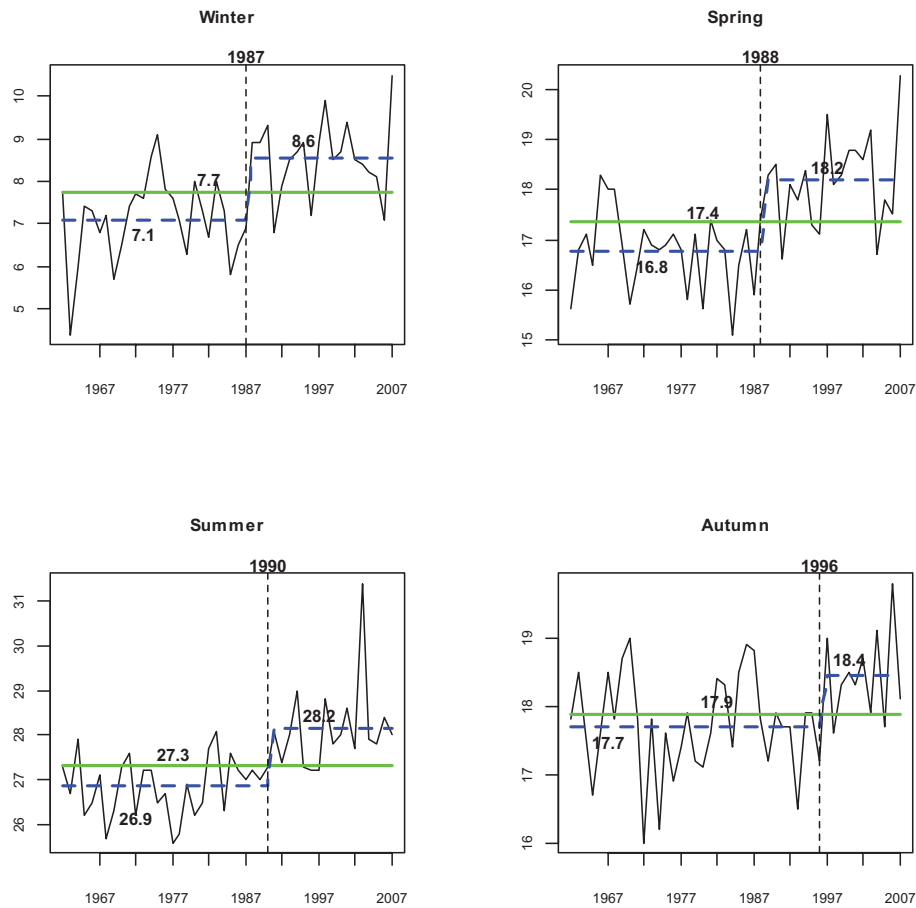
The second part of the analysis allows to distinguish between four climatic seasons by a regime's shifts point of view. A relevant structural change in climate variables is present since 1987 in winter and in spring (up to +1.5 °C for temperature and up to -63 mm for seasonal total amount of precipitation) although in the latter a second change point for temperature is detected in latest 1990s. Summer is characterised by a significant temperature increase (up to +2.2 °C) and two breakdates: one at the beginning of 1980s, another at the beginning of 1990s. For autumn results are not as clear as for other season. Finally we focus the attention on differences between areas, pointing at NA for which the analysis reveals highest mean levels, especially in maximum temperature (Fig. 1).

Information on structural changes of temperature and precipitation time series might aid in determining climatic regime shifts. Thus, for instance breakdates identified in this study for last 1980s and first 1990s agree with either temperature's regime shift or dimension of increase of European climate. They also agree with decrease in precipitation amount which have been observed since last 1980s in many parts of Northern and Central Europe (IPCC, 2007).

In most cases these alternative statistical models incorporating abrupt changes can be useful in climate change detection.

The relationship between structural changes in climatic time series data and structural changes in atmospheric circulation regimes will be the subject of future study.

Figure 1: Breakdates and subperiods mean levels for NA maximum temperature seasonal time series (1961-2007)



References

- Bai J., Perron P. (2003) Computation and Analysis of Multiple Structural Change Models, *Journal of Applied Econometrics*, 18, 1-22.
- IPCC (2007) *Climate Change 2007: The Physical Science Basis, Contribution of WG I to the Fourth Assessment Report of the IPCC*, Cambridge University Press.
- Seidel J., Lanzante R., (2004) An assessment of three alternative to linear trends for characterizing global atmospheric temperature changes, *Journal of Geophysical Research*, 109, 1-10.
- Zeileis A., Kleiber C., Krämer W. and Hornik K. (2003) Testing and dating of structural changes in practice, *Computational Statistics and Data Analysis*, 44, 109-123.