TREND AND VARIABILITY IN TOTAL OZONE CONTENT AT THREE MEASURING STATIONS IN ITALY

Religi A.[1], **Siani A.M.** [1], **Casale G.R.** [1,2], **Diémoz H.**,[2] **Petkov B.**[3]

[1] Sapienza Università di Roma; [2] Arpa Valle d'Aosta; [3] Institute of Atmospheric Sciences and Climate (ISAC-CNR)

INTRODUCTION

This study intends to analyze and to compare variability and trends of total ozone content (TOC) at three Italian stations. TOC data were derived both from ground-based (GB) and satellite-borne (SAT) instruments and from a reconstructed database (COST). The long term variability was analyzed using data sets for longer time than previously done in Italy.

STATIONS

Aosta (45.7°N, 7.4°E, 570 m asl)

Bologna (44.5°N, 11.2°E, 60 m asl)

Rome (41.9°N, 12.5°E, 75 m asl)

GROUND-BASED DATA (GB)

Aosta (Brewer #066): 29/01/2007-31/12/2012

Bologna (UV RAD)[1]: 27/04/2005-31/12/2012

Rome (Brewer #067): 01/01/1992-31/12/2012

Brewer DS data were reprocessed with Brewer Processing Software with std_max = 2.5 D.U:; mu_max = 4.0

SATELLITE DATA (SAT)

Nimbus-7 TOMS (*N7*): 01/01/1992-06/05/1993

Meteor-3 TOMS (*M3*): 09/02/1992-05/07/1994

ERS-GOME (*GOME*): 28/06/1995-26/10/2010

Earth Probe TOMS (*EPT*): 22/07/1996-14/12/2005

AURA-OMI TOMS (*OMI*): 01/10/2004-31/12/2012

THE RECONSTRUCTED COST-726 OZONE DATA [2]

COST ozone data: 01/01/1950-20/03/2009

The COST series for all stations were supplemented by using OMI data valid untill 31/12/2012.

STATISTICAL METHODOLOGY

Non–parametric statistical methods (Wilcoxon's [3] test and Spearman's [4] coefficient) were used to evaluate differences among GB-SAT-COST data series; Mann-Kendall's [5] and Pettitt's [6] tests were applied for detecting linear trends and change points within the series; the flexible trend analysis was applied to study trend evolution [7] .

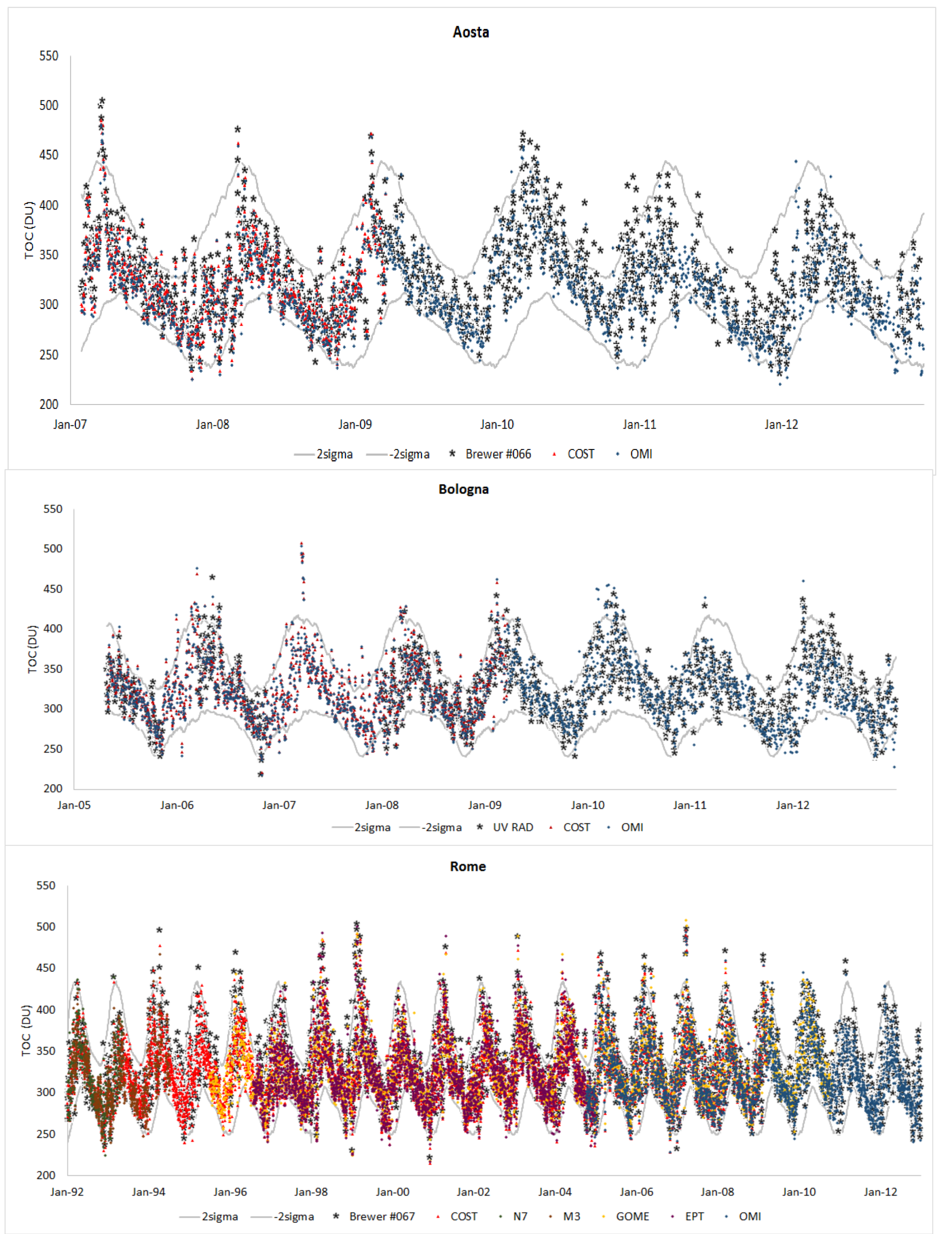

Fig. 1: Daily TOC time series for the three selected stations. For each panel GB, SAT and COST data are shown together with +/- 2 standard deviations (sigma) with respect to the climatological moving average (60-day window).

Aosta

	days	*R*	*Bias%*	*MD(DU)*	*months*	*R*	*Bias%*	*MD(DU)*
OMI vs GB	1488	0.97	-3.21±2.89	-9.3	72	0.96	-2.91±2.69	-4.6
COST vs GB	626	0.99	-2.17±1.65	-6.1	27	0.98	-1.66±2.18	-0.5
OMI vs COST	1521	0.99	-0.93±1.33	-3.0	54	0.99	-0.85±0.83	-3.0

Bologna

	days	R	Bias%	MD(DU)	months	R	Bias%	MD(DU)
OMI vs GB	1245	0.93	-0.10±4.32	-2.6*	75	0.94	0.11±3.71	-1.0*
COST vs GB	569	0.92	-0.23±4.86	-4.6	32	0.92	0.98±4.41	-4.6*
OMI vs COST	1450	0.99	-0.36±1.06	-1.1.	51	0.99	-0.33±0.31	-0.7

Rome

	days	*R*	*Bias%*	*MD(DU)*	*months*	*R*	*Bias%*	*MD(DU)*
N7 vs GB	280	0.93	0.86±3.86	6.2	15	0.89	1.00±4.18	5.7*
M3 vs GB	379	0.93	-1.38±3.60	-1.5	24	0.90	-0.69±3.16	1.1*
EPT vs GB	2607	0.96	-1.90±2.92	-6.3	110	0.96	-1.96±2.22	-4.3
GOME vs GB	2311	0.96	-1.13±3.04	-5.3	176	0.96	-1.11±2.53	-4.9
OMI vs GB	2186	0.98	-1.70±2.08	-5.9	298	0.98	-1.58±1.44	-5.3
COST vs GB	4703	0.95	-1.73±3.08	-6.0	197	0.96	-1.74±2.40	-6.1
OMI vs COST	1531	0.99	-0.05±1.25	0.35	54	0.99	-0.02±0.74	-0.1

Table 1: summary of the differences among GB-SAT-COST daily and monthly data series (days: number of days included in the comparison; months: number of months included in the comparison).

A measure of the agreement was provided by using the Spearman correlation coefficient (R) at the 99% confidence level, the percentage bias (Bias%) and the median difference (MD) determined with the Wilcoxon matched pairs test (the symbol * indicates there is no statistical difference between the two medians, p>0.05).

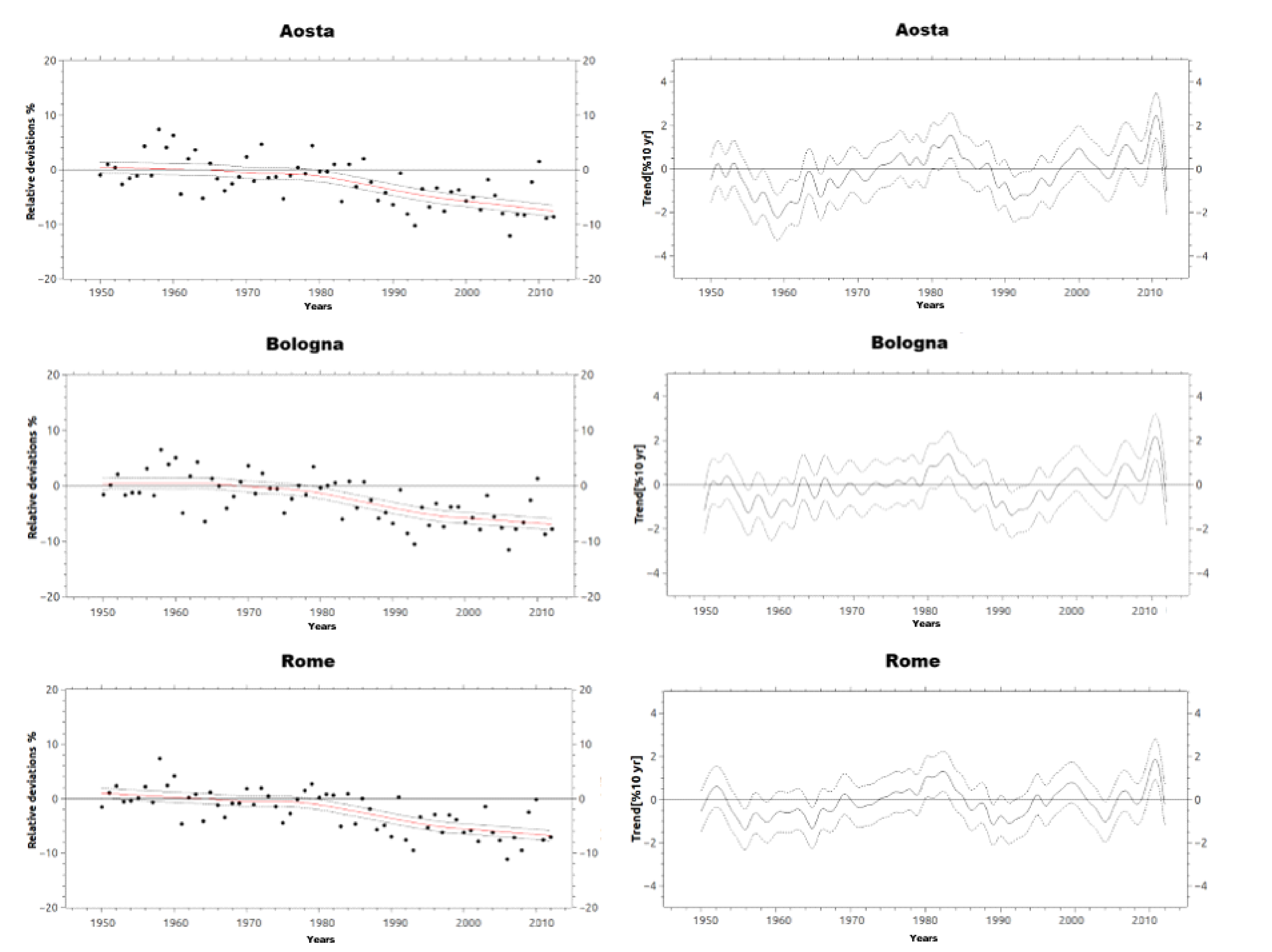

Fig. 2: Left panel: relative deviations (%, dots), with respect to the reference period 1950-1978 with their smoothing (red line) and 95% confidence interval (grey). Right panel: flexible trend (% over 10 years) for the three stations during the cold season, from October to April of the following year (COST data series). The trend value is obtained as the difference between the trend curve values (derived by smoothing of data) and a 5-year moving average divided by the length of the time interval. Grey light curves show 95% confidence interval. Warm seasons did not present any statistically significant trend.

DISCUSSION

TOC values ranged for all stations between about 210 DU and 500 DU (Fig.1). Several values were beyond the 2 sigma upper and lower bounds, with respect to the climatological moving average. The R Spearman coefficients on daily basis were above 0.90 for all GB-SAT-COST data series. The Bias% variability was lower for OMI vs Brewer than OMI vs UV RAD data. Moreover, the agreement between COST and OMI data in the overlapping period (01/10/2004-20/03/2009) was within 1% and this justified to extend the COST series till 31/12/2012 using OMI data. The analysis of linear trends on the long COST series (Table 2) allowed to detect the existence of significant negative slopes for all stations when the entire period was considered (1950-2012) and significant change points in the decade 1981-1991. In the sub-series no trend was evident and this result needs further investigation since it could be due to the introduction of satellite series in the COST reconstruction. The flexible trend analysis (Fig.2) showed a complex but consistent behaviour among the three stations, with significant decreasing trend periods during the 50s and 90s decades of last century.

Station	Years	Sign	Slope (DU/yr)	Slope (%/10 yrs)	Pettitt	Sub-series	Sign	Sub-series	Sign
Warm Months									
Aosta	1950-2012	–	-0.25	-0.21	1991	1950-1990	0	1991-2012	0
Bologna	1950-2012	–	-0.29	-0.22	1991	1950-1990	0	1991-2012	0
Rome	1950-2012	–	-0.27	-0.14	1982	1950-1981	0	1982-2012	0
Cold Months									
Aosta	1950-2012	–	-0.36	-0.17	1986	1950-1985	0	1986-2012	0
Bologna	1950-2012	–	-0.43	-0.21	1986	1950-1985	0	1986-2012	0
Roma	1950-2012	–	-0.35	-0.34	1981	1950-1980	0	1981-2012	0

Table 2: Summary of linear trend analysis. For each station, the reference period of the analysis (Years) and the negative sign of the trend is given (Sign, column 3) as derived from Mann-Kendall test. Pettitt column reports the detection of a change point year at the significance level of 0.05. The change point divides the series into two partial sub-series with or without trend. Sign=0 indicates no trend.

CONCLUSIONS

This study showed that the analysis of trends and variability in the TOC series is not an easy task even in the case of geographically near stations. Many factors can play a role and mask the real behaviour of ozone in the atmosphere. We conclude that, although a careful statistical analysis was carried out on long time series, uncertainties in the results could derive both from 1) the different instruments/reconstruction techniques on which the database relies, and 2) the adopted statistical methodology, since different approaches can produce different results. Future studies will be devoted to the interpretation of short and long term TOC anomalies in terms of atmospheric and meteorological factors.

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