Short term Forecast of Total Ozone Content over Bulgaria Based on Autocorrelation Analysis

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INTRODUCTION

The proposed method for short-term (1-5 days ahead) forecast of the values of the Total Ozone Content (TOC) over Bulgaria based on auto-regression dependence on the value of a variable, in the presence of sufficiently long time series of measurements, allows the empirical determination of basic probability characteristics on day-to-day variability (Kutiev et al., 1999). The method is an application of the Wiener-Hopf theorem (Korn and Korn, 1968).

For a stationary random process *x(t)*, for which the mathematical expectation, variance and autocorrelation function are known quantities then an unknown value of the process *x(t)* at future moment t_f can be represented at minimum squares deviation as alinear combination of some sample of known values of the process *x(t)* at the moments: $t_1, t_2, \ldots, t_n$. Then:

(1) $$x(t_f) = \bar{x} + \sum_{i=1}^{n} \beta_i \left(x(t_i) - \bar{x}\right)$$

The coefficients βi from (1) are a solution of the system of equations:

(2) $$\sum_{p=1}^{n} \beta_p \rho(t_k - t_p) = \rho(t_f - t_k) \quad k = 1,2,\ldots,n$$

The normalized (by dispersion) autocorrelation function of the process *x(t)*, denoted by ρ, is present in the system of Eq. (2) and it is a function of time lag. The right part of the system of Eq. (2) contains the autocorrelations at time lags between the moment for prediction and the moments where there are known values. Hence the deviation of the prediction from the observations, based on this method, depends on the values of the autocorrelation coefficients at time lags corresponding to the distances between the moment for prediction and the moments for which the values of the process *x(t)* are known (Mukhtarov et al., 2014).

DATA

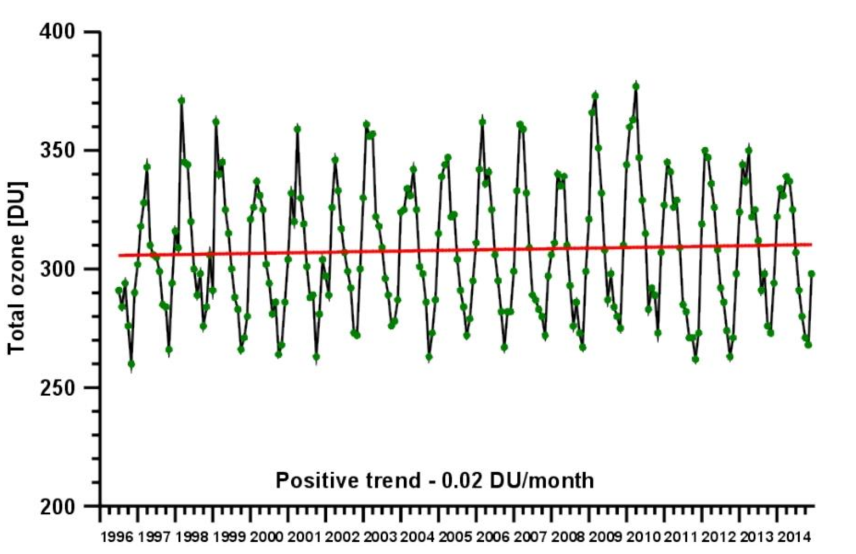

Fig. 1. Mean monthly values of TOC over Bulgaria 1996-2014 (www.geophys.bas.bg/total_ozone/total_ozone_bg.htm)

The measurements of TOC in NIGGG are conducted with the sun photometer Microtops II. The measurements with Microtops II are complemented with data from Ozone Monitoring Instrument (OMI). The data row was extended to 1996 with the data from Total Ozone Mapping Spectrometer (TOMS). The simultaneous data from TOMS and OMI from October 2004 to December 2005 allow to calibrate the data of TOMS to OMI and then to the data of Microtops II (Kaleyna et al., 2014).

AUTOCORRELATION FUNCTION OF TOC

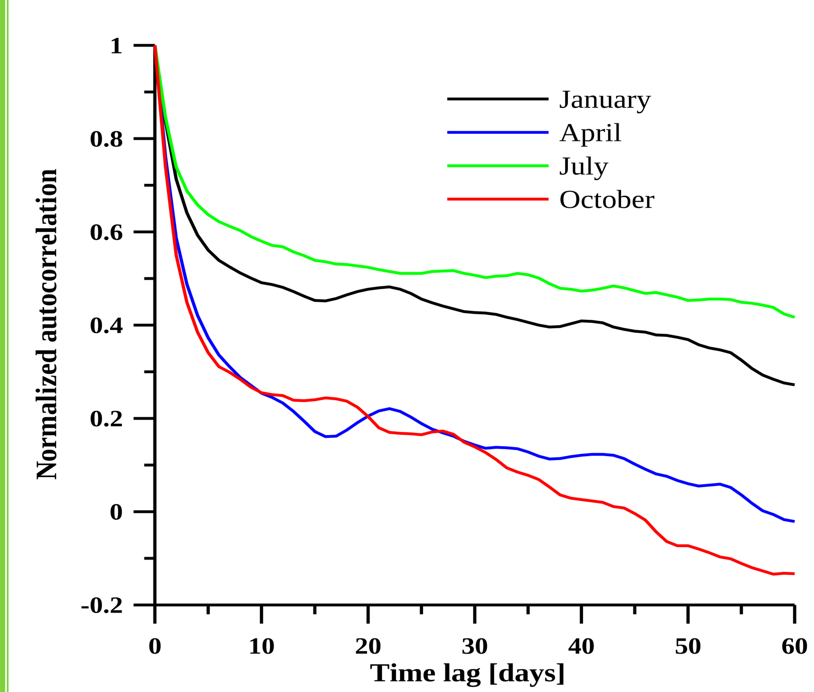

Fig. 2. Autocorrelation functions

The time series of TOC values does not respond the requirement of stationarity because of seasonal move and the increased variability in winter compared to summer. Autocorrelation functions are calculated separately for each calendar month for improvement of the quality of forecasting autocorrelation. It has been used sliding segment centered on a given month of the year with length 6 months. Fig. 2 presents the empirical autocorrelation functions for the months of January, April, July and October for period from 1997 to 2012.

The simulated further short term forecast for the years 2013-2014 represents a test of how autocorrelation dependencies used for forecasting are valid for years in which the data were not used.

SIMULATION OF SHORT TERM FORECAST OF TOC

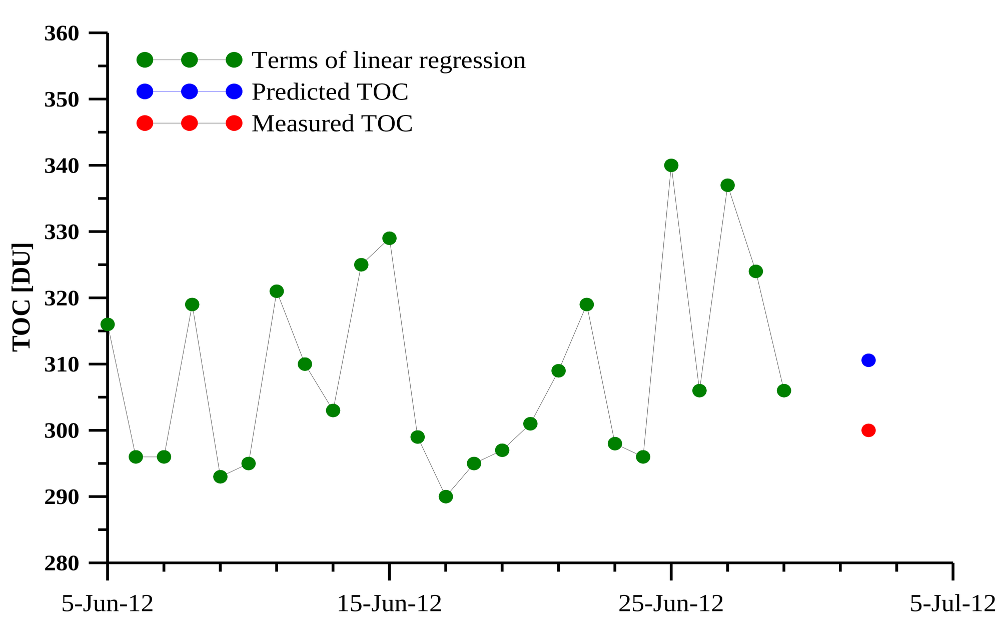

Fig. 3 Sample forecast procedure at 02.07.2012, offset 3 days.

Simulation of short-term forecasting is carried out on the base of data from 2013 to 2014 and determinate for the autocorrelation functions for the period 1997-2012. The forecast is simulated with distance in time from 1 to 11 days ahead. Distance during the forecast is referred as offset and it is a time lag between the date for predicted TOC and the last day for which there are measured values. For each day for which a prediction is calculated by the autocorrelation method, there are selected 25 measured values from previous days that are offset in time of no less days of the set distance (offset).

The number of measured values used to calculate the estimated value with formula (1) is defined experimentally. Selected time lags for measured values define the values of the autocorrelation functions that make up the system of equations (2). For each particular day they are different, as a rule, because the order data gaps. Following the decision of the system of equations (2) calculate the estimated value of the formula (1) contained therein arithmetic average of the 25 selected measured values. Thus effectively take account of seasonal average of TOC.

On Fig. 3 is shown illustration of forecasting TOC for 02.07.2012, assuming that the last date for which there is measured values is 29.06.2012. There are shown the (green color) 25 measured values involved in formula (1), the estimated value (in blue) and the measured value (in red).

RESULTS

On Fig. 4 is shown a comparison between measured and predicted values for TOC for 2014 at offsets 1, 3, 5 and 7 days. Projected value follow satisfactory well seasonal changes of TOC. An increase of offset of forecast short-period variations of TOC in the forecasts are smoothed and there is a delay toward the data due to the decrease in the correlation of the process in time-lag more than 5 days (Fig. 2).

On Fig. 5 is shown root mean square error of the forecasts for the period 2013-2015. Systematic error (mean value of deviations) is practically zero (less than 0.5 DU). The standard deviation of the data is 37 DU, significantly higher than obtained the highest values of root mean square error.

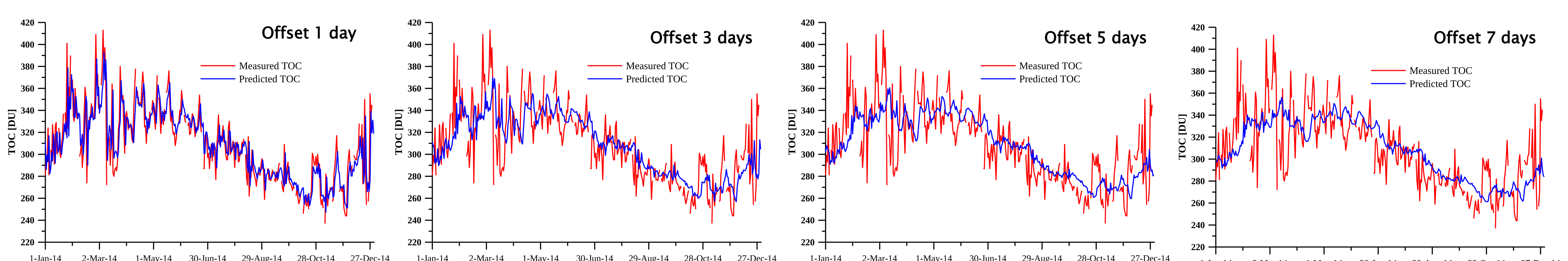

Fig. 4. Measured and predicted values for yeare 2014 by offsets 1, 3, 5 and 7 days.

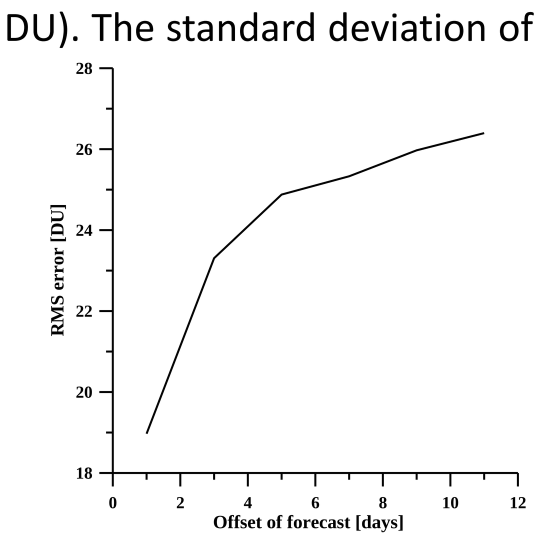

Fig. 5. Root mean square error of forecast by 2013-2014.

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CONCLUSION

The proposed method for short term forecast of TOC over Bulgaria is applicable to 5-7 days forecast ahead. The forecasts up to three days ahead satisfactorily demonstrate short-period variations of TOC, which have, as a rule, random nature. In offsets more than 3 days seasonal changes are satisfactorily predicted. The resulting root mean square errors (maximum of about 26 DU), compared with the accuracy of measurements (for device Microtops II it was about 5 DU) and total dispersion values of TOC (about 37 DU) may be considered satisfactory too.

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