Periodic Variability of Surface Ozone Concentration over Western and Central Europe from Observational Data

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Abstract—Characteristics of periodic variability of surface ozone concentration at 98 western and central European stations participating in the EMEP program for at least 7 (up to 14) years are determined. Daily and hourly model concentrations of surface ozone for each station are given in an analytical form that presents a sum of a constant constituent and basic harmonics that determine ozone concentration variability throughout a year and a day. A 12-month harmonic, whose maximum is observed in the spring period (in Northern Europe it is observed 1 to 2 months earlier than in Southern Europe) dominates in the energy spectrum of seasonal variability of daily mean ozone concentration at most stations. The energy part of higher (6- and 4-month) harmonics is the largest at the stations close to the sea and ocean coasts. Higher harmonics largely influence the time of the ozone extremum formation, shifting it towards the summer, or even forming a second (summer) maximum, whose magnitude at a number of stations (in Italy, Hungary, in the south of Germany, and in some others) exceeds the spring maximum. A 24-hour harmonic dominates in the energy spectrum of daily ozone variability. The maps of a “normal” distribution of surface ozone fields and their standard deviations for different seasons and time of the day have been compiled based on the model characteristics. The “norms” derived can be used to detect anomalies in the temporal trend of the surface ozone and to validate its climate changes.

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INTRODUCTION

Ozone (O\textsubscript{3}) is one of the strongest atmospheric oxidants that participates in the most important chemical and photochemical reactions in the troposphere, is rather easy and precisely measured, and can pose a threat to health during frequent episodes with its enhanced concentration. Therefore, in Europe and America, a wide network of stations is used for measuring surface ozone concentration (further on simply ozone) [4, 6, 7]. Their observations are used both for operational evaluation of the atmospheric air quality (the maximum number of unsatisfactory air quality is attributed to the exceeded ozone norms) and studying the dynamics of changes and long-range pollution transport. In particular, for Europe, reviews with the maps are yearly published, where it is said how many times at each observational station ozone concentrations were dangerous for the health and vegetation [4, 7]. Many different transport-photochemical models have been developed, which make it possible to compile the maps of ozone fields on a global scale [5, 9, 14]. However, the published maps have a low resolution and contain, as a rule, annual mean or, in the best case, mean summer and mean winter values. It is not said how accurately they describe the observed ozone distribution in space and time (in particular, abroad, the nature of two ozone maximums in a seasonal cycle is debatable till now [3, 10]; transport-photochemical models do not clarify this event). In spite of the available data, which are used to compile the maps on ozone concentrations accumulated in a warm season and the frequency of dangerous ozone levels at different stations [4, 7, 11], no “norms” for the ozone concentration distribution over Europe have been suggested. It is, first of all, connected with a great variability of ozone both in time (seasonal, inter-, and intradurnal variability) and in space, and with difficulties to control observation errors. Presently, based on multiyear observations at the EMEP (Cooperative Program for Monitoring and Evaluation of Long-Range Transboundary Transmission of Air...
Pollution in Europe, http://www.emep.int) stations, basic characteristics of periodic variability of the surface ozone over Western and Central Europe are determined (compared with [1], the number of stations considered was approximately 2.5 times larger); for the first time, the maps of “norms” for surface ozone distribution in different seasons and hours of the day were compiled.

DATA AND MODEL

Hourly averaged results of ozone observations with the help of optical UV-gas-analyzers at the EMEP stations in 1990–2004 were used (http://www.nilu.no) [7]. The purpose of this network is to obtain reliable data on ozone concentrations in rural western European areas, which are used to check the efficiency of available and to develop new international agreements in the field of the environment protection. Therefore, the quality of these data is the highest compared with all available data (their error is not higher than 4 μg m⁻³). Data from 98 stations (their geographical distribution is shown in Fig. 1) were used. The stations are located