Temporal variability of the atmospheric methane content under the effect of North Atlantic Oscillation

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The influence of a large-scale atmospheric circulation on the methane content in Mace Head (Ireland) from March 1994 to December 2000 has been studied. One of the most prominent teleconnections of all seasons, the North Atlantic Oscillation (NAO), was taken into account. The within-year variability of the methane is characterized by its minimum in July and two maxima, namely, winter (main) and spring (secondary). However, in some years the winter maximum was lower than the spring one. It is shown that just these years, either a strong positive phase of NAO (western transfer) or its insignificant indices (meridional transfer) were observed. In winters with a strong negative phase of NAO, the winter maximum exceeded the spring one.

Methane is a chemically and radiatively active gas in the Earth's atmosphere. Regular measurements of its concentration have been started in 1978 (see, for example, Ref. 1). Besides, data on its concentration in the atmosphere for the past 420 thousand years are available, which were obtained based on the analyses conducted by the Soviet Antarctic expedition at the Vostok station.[2] Up to now, the inland and glacier ice is the only "archive" directly keeping components of the atmospheric air.

Prior to the industrial time, the CH_4 concentration, with insignificant exclusions, varied in accordance with the principal peculiarities of climate, i.e., its least concentrations (about 350 ppbv) refer to the glacial epochs, and the largest (about 700 ppbv) ones were observed in warm periods. Natural changes, most probably, can be attributed to the length and intensity of sources in the swamp areas. An anthropogenic increase of the methane concentration from 700 to more than 1700 ppbv for the past 200 years is caused by emissions connected with growth of population on our planet, followed by an increase of population of ruminant animals, rice plantations, man-made fires, and use of fossil fuel.[3]

In addition, the urban contribution to the CH_4 global content increase should be taken into account, which was shown through the climate simulation using the model developed at Massachusetts Institute of Technologies.[4]

This increase of the atmospheric methane concentration is responsible for roughly 20% of the estimated change in the direct radiation impact due to anthropogenic emissions of all long-lived greenhouse gases. For the past 150 years, the methane contribution to the impact on the climate was 0.57 W/m^2, that makes about 35% of the estimated contribution of CO_2 (Ref. 5). Although the global methane content is increasing, the total rate of the increase slows down.[6] It should be noted that the decrease of anthropogenic emissions of CH_4 in 1992 has resulted in a sharp fall of the rate of the methane increase. This was shown with a two-dimensional model of global chemistry including 34 components and 104 chemical and photochemical reactions.[7] Since the total productivity of the methane anthropogenic source is about 410 tons per year and the mean increase is 20 tons per year, then only 5% decrease of productivity of the anthropogenic source would allow stabilizing the methane level in the atmosphere.

In this paper, we analyze the influence of large-scale atmospheric circulation on the methane mixing ratios in Mace Head (Ireland) from March 1994 to December 2000. Similar analysis we have earlier conducted for CO_2 (Ref. 8). The main difference of this work is in the choice of the site. Mace Head is situated on the west extremity of Ireland, where concentration of any atmospheric gas strongly depends on the direction of air flows above it: west winds bring fresh air from the Atlantic and east ones are characterized by the influence of industrially polluted air from Western Europe. Moreover, in the chosen site, only the flows of east quarter bring the highest concentrations of the anthropogenic aerosol. We used in this analysis the monthly mean data on the methane mixing ratios compiled at the CO_2 Information and Analysis Center (CDIAC, USA), which are available at http://cdiac.ornl.gov/home.html.

To estimate quantitatively the intensity and direction of the large-scale circulation over the geographic range under study, we used one of the most prominent teleconnections schemes of all seasons, i.e., the North Atlantic Oscillation (NAO), described by Barnston and Livezey.[9] The NAO consists of the pressure anomaly dipole, one center of which is located above Iceland (Iceland minimum), and the second one, of the opposite sign, in the region of the Canary Islands (Canary maximum). Within the positive phase of NAO, in high latitudes of the North Atlantic, the pressure is lower than the standard, and the pressure recorded over the central part of the North Atlantic, East USA, and Western Europe, is somewhat higher than the standard. Within the negative phase of NAO,

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anomalies of opposite signs are observed above these regions. Both of the phases are connected with variations of the intensity and location of the North Atlantic air mass flow above the whole basin, as well as the large-scale transfer of heat and moisture.[10] Obviously, at positive monthly mean indices of NAO, predominantly west transfer is observed over Ireland, and at the indices of opposite sign – the east one. Values of the indices close to zero evidence either of a long meridionality of the streams or of a frequent change of the geographic location of centers of the above-mentioned baric formations. The data on the NAO monthly mean indices, shown in Fig. 1, were obtained from http://cgd.ucar.edu/~jhurrell/nao.html.

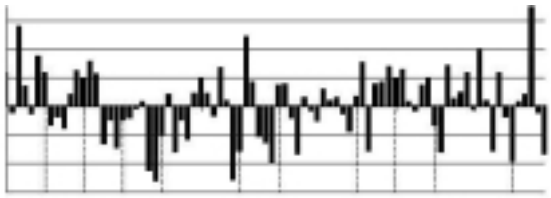

Fig. 1. NAO indices for 1994–2000.

The NAO phases reflect significant inter-seasonal and interannual variability; therewith the long (for several months) positive and negative phases are usual. The winter NAO is also subject to significant interannual and secular oscillations.[10] Fifteen years prior to the winter 1994/95 were characterized by the predominantly positive NAO phase, and only the winter 1995/96 was marked by a strong negative phase (Fig. 1).

Figure 2 shows the variation of the atmospheric methane concentration in Mace Head from March 1994 to December 2000. Note that the yearly mean CH_4 concentration increased by 1% in this period and reached 1842 ppbv. The within-year CH_4 variability is characterized by minimum in July and two maxima: in winter (main) and spring (secondary). The fall of the atmospheric methane in summer months is determined by a decrease of anthropogenic impacts in this period and increasing photochemical decomposition of methane at its weak transfer.[11]

Analysis of Fig. 2 shows that in some years the standard annual behavior of the methane content significantly changes. Thus, the winter maximum in 1997/98 and 1999/2000 was lower than the spring one, and in 1994/95 it shifted to October. Simultaneous analysis of both figures shows that just these years, either an intense positive NAO phase (western transfer) or low NAO indices (meridional transfer) were marked. In winters within significantly negative phase (1995/96 and 1996/97) the winter maximum exceeded the spring one. Similar dependence can be shown for the summer minimum of the methane mixing ratio as well.

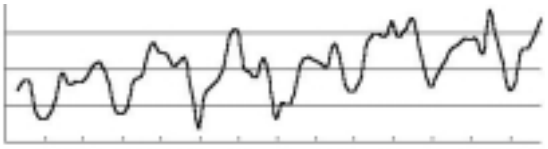

Fig. 2. The mixing ratio of methane (ppbv) in Mace Head for 1994–2000 period.

Thus, the obtained results confirm the fact that the variability of the methane concentration, being the gas of the anthropogenic origin, is affected by the large-scale atmospheric circulation. Note that the same dependence was also found for other greenhouse gases (F-11, F-12, N_2O, CH_3CCl_3, CCl_4, and so on), although we do not present here the corresponding results. Moreover, a quantitative characteristic (NAO indices) is pointed, which allows revealing this dependence and, if necessary, finding correlations between the atmospheric aerosol content and the large-scale atmospheric circulation.

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