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Atmospheric methane variability at the Peterhof station (Russia): ground-based observations and modeling

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The Peterhof station (59.88 N, 29.83 E, 20 m asl) for atmospheric monitoring was founded by Saint - Petersburg State University, Russia. FTIR (Fourier transform IR) observations of methane total column are being carried out by Bruker IFS125 HR since 2009. The study presents a joint analysis of experimental data and EMAC (ECHAM/MESSy Atmospheric Chemistry model) model simulations for Peterhof over the period of 2009-2012.
It was shown that CH4 total columns (TC) and column-averaged dry-air mole fractions (MF) obtained from observations are higher than model results with the difference of 1.3% and 0.3 % respectively. The correlation coefficients between FTIR and EMAC data are statistically significant (with 95% confidence) and equal to 0.82 $\pm$ 0.08 and 0.4 $\pm$ 0.1 for TC and MF of CH4 respectively. The high correlation for TCs shows that EMAC adequately reproduces CH4 variability due to meteorological processes in the atmosphere. On the other hand, the relatively low correlation coefficient for CH4 MF probably indicates an insufficiently precise knowledge of sources and sinks of the atmospheric methane.
Amplitudes of the mean annual cycle of CH4 TC for experimental and model datasets (2009-2012) are of 2.1 % and 1.5 % respectively. The same amplitudes calculated for MF are less than for TC: 1.1% for FTIR and 0.6% for EMAC. Difference between FTIR and EMAC annual variations has pronounced seasonality with a maximum in September – November. It could be attributed to the underestimation of methane natural sources in the emission inventory used for EMAC simulations or by relatively coarse horizontal grid of the model (2.8°x2.8°).
The analysis of modeling results allowed us to estimate the influence of the limited number of sunny days with FTIR measurement (i.e. specific meteorological conditions which usually take place during FTIR observations) on obtained FTIR estimates of the mean levels of TC and MF over 2009-2012. The systematic shifts of FTIR mean levels of TC and MF from the true ones were detected for the Peterhof station (0.4% for TC and -0.2% for MF). It should be also noted that the limited number of sunny days may distort the annual cycle estimated from FTIR data (comparing to true). This fact have to take into account when mean levels of CH4 TC and MF obtained from FTIR compare against climatological or averaged model data.
Ground-based in situ (local) observations of CH4 mole fraction (LMF) are being performed by LGR GGA-24r-EP gas analyzer since 2013 (at the Peterhof station). The monthly averaged amplitude of LMF diurnal cycle shows variations which are similar to the temporal behavior of MF CH4 retrieved from FTIR for 2013. It is suggested that the value of the amplitude of CH4 LMF diurnal variation characterizes the intensity of methane sources for the North-western region of Russia and can be used to explain the observed features of the annual variation of FTIR MF CH4. However, to prove this statement further simultaneous FTIR and in situ measurements of CH4 should be continued.
Both, FTIR observations and EMAC simulations, revealed the positive trend of CH4 over 2009-2012 of about 0.2% per year (statistically significant). FTIR data for 2013 that were taken into account led to a decrease in trend value from 0.2%/yr (2009-2012) to 0.13%/yr (2009-2013). It may indicate the end of the period of extremely high growth rates of methane in the atmosphere that have been registered by different observational systems since 2006.
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