Modeling Radiation-Active Gases Content Variability in the Arctic and Subarctic

Ali Tao'mah Mekhalif[1*], **Qasim S. Kadhim**[2]

Abstract

In view of the importance of the influence of radiation-active gases on changes in the global and regional climate, a study of their content in the Arctic and Subarctic regions was carried out. The modeling of the concentrations of atmospheric gases was carried out using the continental model of the composition of the lower and middle atmosphere, which describes their space-time distribution. The features of internal and seasonal fluctuations in the content of radiation-active gases (CH_4, CO, O_3, H_2O) and their relationship with temperature variability were studied. The analysis of the obtained results is carried out and an estimate of the concentration variations at the polar and subpolar stations is obtained.

Key Words: Radiation-active Gases, Arctic and Subarctic.

DOI Number: 10.14704/nq.2022.20.3.NQ22040 **NeuroQuantology 2022; 20(3):51-55**

Introduction

The peculiarities of the distribution of radiation-active gases in the Arctic and Subarctic regions are due to the peculiarities of the atmospheric circulation in this region, the presence of large sources of methane hydrates, as well as the amount and duration of insolation. The methane content in the polar and subpolar regions is 10-15% higher than throughout the entire globe (Fung, Inez, et al, 1991). Methane is one of the radiation-significant gases that absorbs long-wave radiation and thus has a direct effect on the radiation balance; indirect influence of methane on the latter (radiation balance) consists in a number of chemical reactions that lead to the formation of other radiation-significant gases (Gershenzon, Yu M., 1990). In particular, through the reaction of methane oxidation, which is initiated by the hydroxyl radical, in the presence of nitrogen oxides and solar radiation, another radiation-significant gas is formed - tropospheric ozone (Fig. 1). Ozone concentrations in the Arctic and Subarctic regions affect the local fluxes of solar radiation, which cannot but affect the temperature regime and the transport of air flows (Saha, S., et al., 2006).

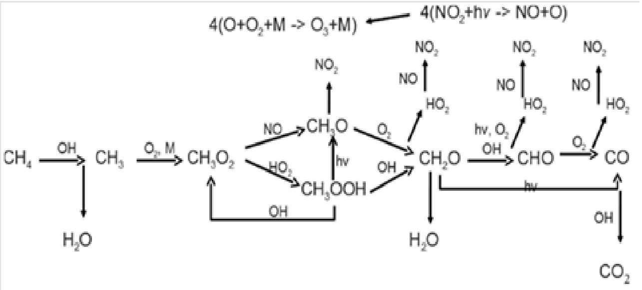


Fig. 1. Methane effluent and ozone formation process

Corresponding author: Ali Tao'mah Mekhalif

Address: [1*]Department of Physics, College of Science, Ali Tao'mah Mekhalif Babylon University, Iraq; [2]College of Basic Education, University of Babylon, Babil, Iraq.

[1*]E-mail: Aliasar62@yahoo.com

[2]E-mail: basic.qasim.shakir@uobabylon.edu.iq

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received: 24 December 2021 **Accepted:** 28 January 2022

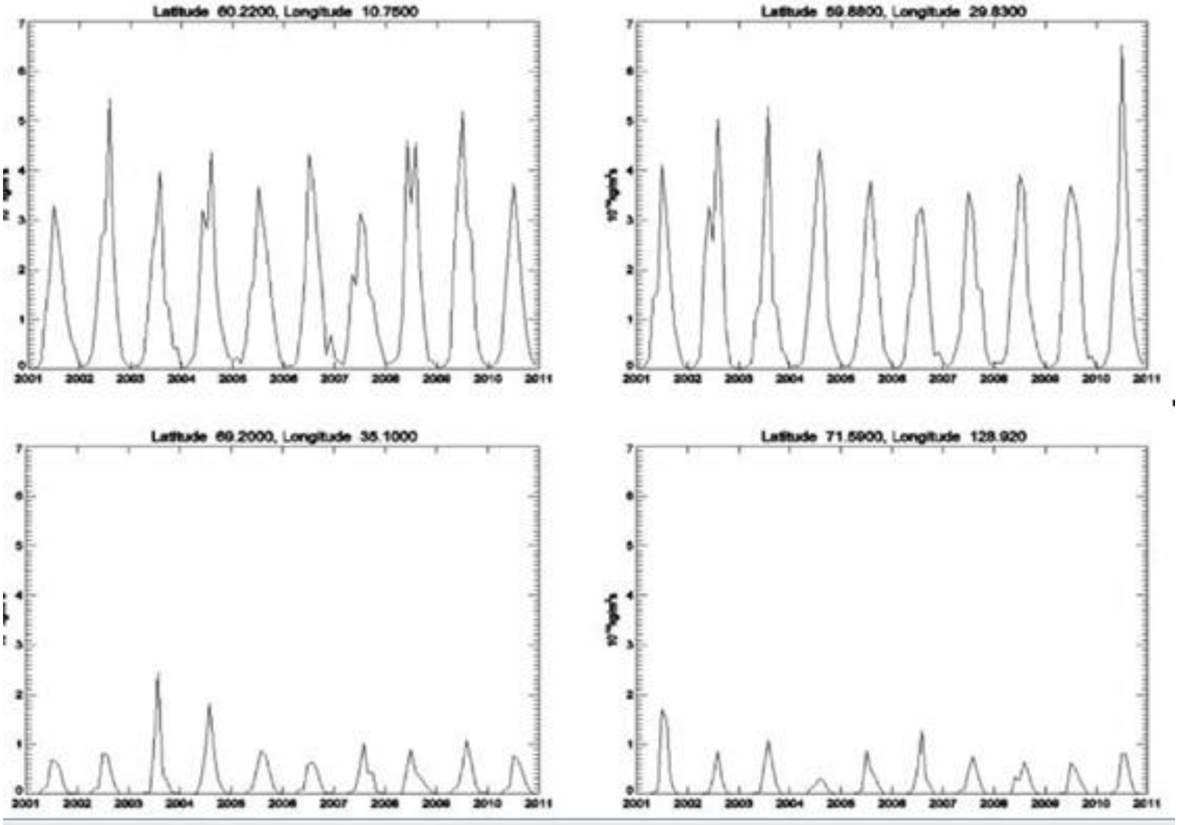
Water vapor is also one of the most important long-wave radiation absorbers; its accounting and assessment of concentrations is especially important in view of climatic changes, as well as from the point of view of the influence of water vapor content on weather and climate (Wuebbles, Donald J., and Katharine Hayhoe, 2002). In view of the physical and geographical location of the Arctic and Subarctic regions, the influence of the weather and climatic features of the studied region on the content of carbon monoxide and the effect of the latter on the climate is no less important. Assessment and forecast of radiation-active gases are directly related, both by direct and feedback, with the climate of the polar and circumpolar regions. Currently, there is an increasing interest in the polar and circumpolar regions, circulation features and climatic changes (Janssens-Maenhout, Greet, et al, 2012). In this study, a number of numerical experiments were performed using a continental model of the composition of the lower and middle atmosphere, which makes it possible to estimate the content of radioactive gases under given climatic features, as well as to trace their seasonal variability .The aim of this work is to study the variability of the content of radiation-active gases in the Arctic and Subarctic - both seasonal and internal (Kadhim, Qasim S., Iqbal H. Abdulkareem, and Nagham T. Ibraheem, 2021).

Model Description

For this study, a continental three-dimensional chemical-prognostic model of the gas and aerosol composition of the atmosphere was used, which allows one to analyze (diagnose) the observed concentrations, and also allows the calculation of predicted concentrations. Thus, the configuration of the continental model provides operation in two modes, which is possible thanks to meteorological data, which will be described below. In this study, the model was run in diagnostic mode (Atkin, O.K., B. Botman, and H. Lambers, 1996). The model used has a resolution of 0.50 latitude-longitude grid; vertically, the model is limited to a level of 10 hPa, covering the troposphere and the lower part of the stratosphere. The modeling area covers the region north of 400 N. The mesh step of the model makes it possible to describe in sufficient detail the concentration of the gas composition of the atmosphere, taking into account the mesoscale features of the distribution of small gas components, and a smaller modeling area in comparison with the global one makes it possible to speed up the computation processes (Griffis, Timothy John, W.R. Rouse, and J.M. Waddington, 2000). The chemical scheme of the model describes 74 gaseous constituents (ozone, hydrogen compounds, nitrogen compounds, carbon oxides, some hydrocarbons, oxidized organic compounds) participating in 174 chemical reactions. The model takes into account surface emissions, chemical transformation, dry and wet deposition, heterogeneous reactions on the aerosol surface, and also takes into account thunderstorm activity. The meteorological data of the Global Forecast System (GFS) (Wuebbles, Donald J., and Katharine Hayhoe, 2002), used in the model, allow it to be run in two modes (diagnostic and forecast), since they contain not only analysis data, but also forecast data. The GFS data has the same resolution as the continental model - 0.50 × 0.50. The vertical structure of the model contains 64 σ-levels, which are located from the surface to a height of 10 hPa with a variable step. Meteorological data are updated four times a day (00, 06, 12, 18 hours UTC) with a time step of 3 hours with a forecast of up to 180 hours. Surface fluxes of chemical components were taken from the EDGAR, NASA, AEROCOM, GEIA databases, which describe both anthropogenic and biogenic emissions (Kadhim, Qasim S., and Alaa H. Kamil, 2020). The boundary conditions were taken from the global model (Kamil, Alaa H., Iqbal H. Abdulkareem, and Qasim S. Kadhim, 2020).

Results of Model Experiments

The study of the variability of radiation-active gases was carried out seasonally, thus making it possible to assess their inter-seasonal variability. This article presents the results of studies of the variability of radioactive gases near the surface using methane as an example - both seasonal and internal - in polar and subpolar regions. Variations in methane concentrations were studied, including at the stations of Peterhof (59.880 N, 29.830 E, H = 20 m), Kharestua (60.220 N, 10.750 E, H = 569 m), Teriberka (69.200 N, 35.100 E, H = 40 m), Tiksi (71.590 N, 128.920 E, H = 8 m). The data on the fluxes of biogenic emissions at the stations are shown in Fig. 2. The results of modeling methane concentrations are shown in Fig. 3, 4, 5, 6 (a), respectively. In fig. 6 (b) shows the results of modeling the surface concentrations of the hydroxyl radical.



Rice 2. Fluxes of biogenic methane emissions at stations Kharestua, Peterhof, Teriberka, Tiksi

As can be seen from the graphs shown in Fig. 2, the seasonal variation of methane emissions from the surface is well traced at all stations under study. The maximum fluxes from the surface are observed in the summer, the minimum - in the winter. At stations located to the north, fluxes from the surface are significantly less than at stations Kharestua and Petergof. Thus, in more northern regions, biogenic emissions are lower and have a less distinct structure of long-term variability.

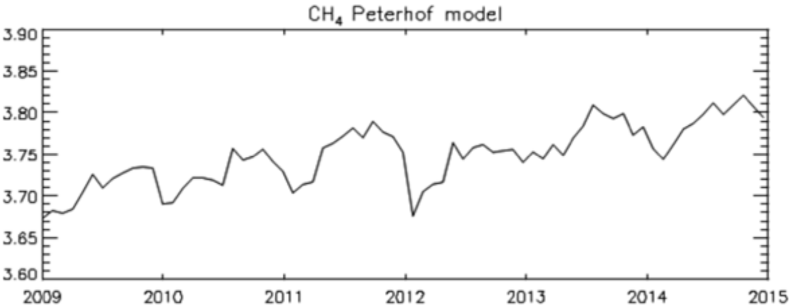


Fig. 3. Results of modeling methane concentrations at st. Peterhof

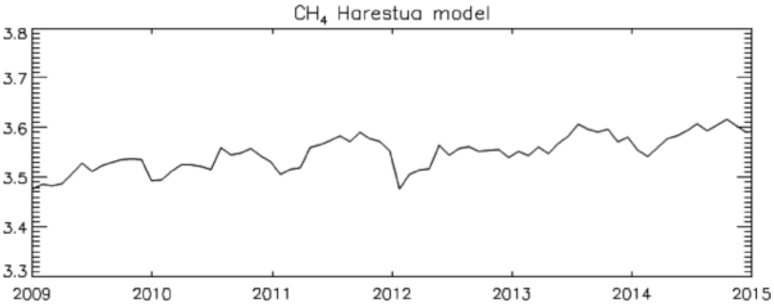


Fig. 4. Results of modeling methane concentrations at st. Harestua

According to the simulation results at Peterhof and Kharestua stations, the seasonal variation of methane concentrations is weakly expressed. Kharestua station is high-altitude, and the weakly pronounced course of concentrations can be explained, among other things, by this factor. Peterhof station is located in the immediate vicinity of the megalopolis, this factor has a direct impact on the interannual variability of concentrations. In general, at Peterhof and Kharestua stations, there is a tendency to an increase in surface methane concentrations from year to year.

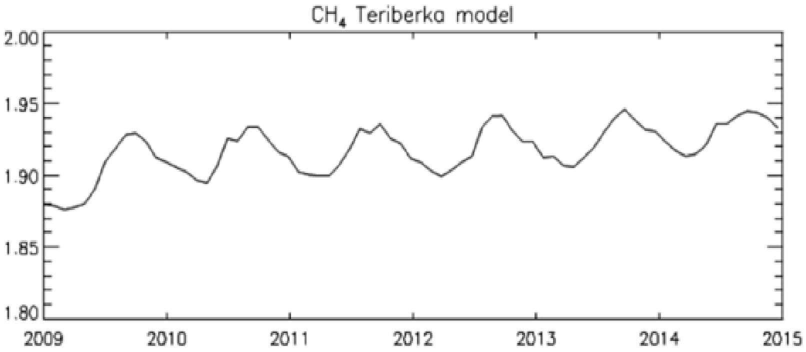


Fig. 5. Results of modeling methane concentrations at st. Teriberka

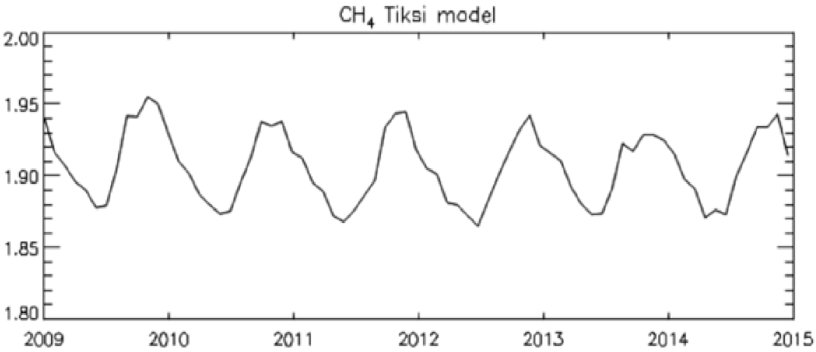


Fig. 6 (a). Results of modeling methane concentrations at st. Tiksi

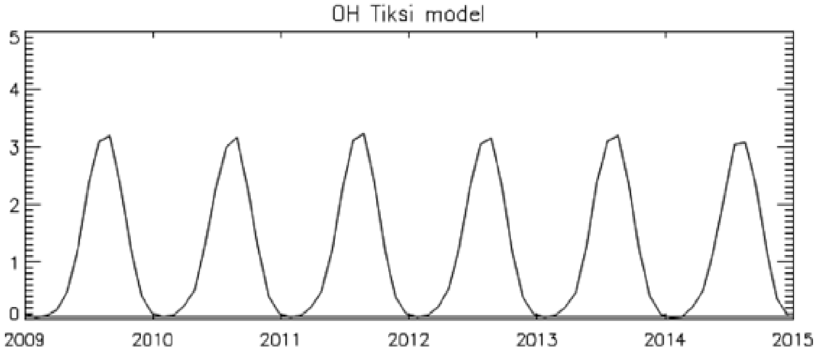


Fig. 6 (b). The results of modeling the concentrations of the hydroxyl radical at st. Tiksi

According to the results of model studies, at Tiksi and Teriberka stations, the seasonal variation of methane concentrations at the surface is clearly pronounced. The observed maxima at the stations are in October and November, respectively. The presented results of model calculations at st. Tiksi, show co-phasing in variations in the concentrations of methane and hydroxyl radical. The simulation results show that the observation of concentration maxima at the surface has a phase shift at different stations, which is explained by dynamic processes. Considering the variability of methane and other radiation-active gases (CO, O_3, H_2O), the following results were obtained:

1. Trace the seasonal course of concentrations at the surface
2. The observation period of minima and maxima of surface concentrations depends on local

features, including dynamics, as well as on solar radiation.

3. Methane fluxes from the surface are maximum in August
4. Surface concentrations of methane and hydroxyl radical for a number of stations are co-phase (OH radical is short-lived, depends on solar radiation, maximum concentrations are observed in summer; hydroxyl radical is the main (destroyer of methane).
5. With an increase in methane concentrations, which does not depend on solar radiation, the concentrations of the hydroxyl radical decrease.
6. There is an indirect dependence of the concentrations of methane and ozone (taking into account the presence / absence of solar radiation).
7. In some polar regions, an increase in methane concentrations is observed.
8. Concentrations of carbon monoxide vary slightly.
9. Trends of growth of methane and ozone concentrations are observed.

Conclusion

In this work, an assessment was made of the variability of radiation-active gases in polar and circumpolar regions using the continental model of the gas composition of the atmosphere. A seasonal variation of concentrations is observed near the surface; their distribution is explained both by dynamic factors (as, for example, in methane) and by local features and the amount of solar radiation. Small year-to-year variations are also observed.

References

Atkin OK, Botman B, Lambers H. The causes of inherently slow growth in alpine plants: an analysis based on the underlying carbon economies of alpine and lowland Poa species. *Functional Ecology* 1996; 10: 698-707.

Fung I, John J, Lerner J, Matthews E, Prather M, Steele LP, Fraser PJ. Three-dimensional model synthesis of the global methane cycle. *Journal of Geophysical Research: Atmospheres* 1991; 96(D7): 13033-13065.

Gershenzon YM. Heterogeneous processes in the Earth's atmosphere and their ecological consequences. *Russian Chemical Reviews* 1990; 59(11).

Griffis TJ, Rouse WR, Waddington JM. Interannual variability of net ecosystem CO2 exchange at a subarctic fen. *Global Biogeochemical Cycles* 2000; 14(4): 1109-1121.

Janssens-Maenhout G, Dentener F, Van Aardenne J, Monni S, Pagliari V, Orlandini L, Keating T. *EDGAR-HTAP: a harmonized gridded air pollution emission dataset based on national inventories.* European Commission Publications Office, Ispra, Italy, EUR report No EUR, 25229, 40, 2012.

Kadhim QS, Abdulkareem IH, Ibraheem NT. Study of Distribution Ice-Forming reagent in the Boundary layer of the atmosphere When Exposed by Ground Aerosol Generators NAG-07M. *In IOP Conference Series: Materials Science and Engineering* 2021: 1058(1).

Kadhim QS, Kamil AH. Simulation of Feedbacks between Threated Activity, Atmosphere Composition, and Regional Climate. *Simulation* 2020; 29(5): 5249-5254.

Kamil AH, Abdulkareem IH, Kadhim QS. Physical Mechanism of Sediment Education in Heatclouds. *Solid State Technology* 2020; 63(1s): 1466-1472.

Saha S, Nadiga S, Thiaw C, Wang J, Wang W, Zhang Q, Xie P. The NCEP climate forecast system. *Journal of Climate* 2006; 19(15): 3483-3517.

Wuebbles DJ, Hayhoe K. Atmospheric methane and global change. *Earth-Science Reviews* 2002; 57(3-4): 177-210.

Aziz SA, Ali RS, Abd AN. Characterization studies of nickel oxide nanostructure films prepared by electrolysis method for photo detectors applications. *NeuroQuantology* 2020; 18(2): 45-49.