COAST DURING SUMMER-AUTUMN PERIOD ON GROUND-BASED AND SATELLITE MEASUREMENTS

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ABSTRACT

Over the past two and a half centuries, total methane content in the Earth's atmosphere has more than doubled [1]. The global warming potential of methane is 20 times greater than that of carbon dioxide, considering that, monitoring and studying the properties of methane are one of the urgent tasks of modern ecology.

This paper presents a study of methane concentration variations on the Arctic coast of Alaska, according to Barrow station data (1986-2018), and remote sensing data (AIRS radiometer, Aqua satellite). Analysis of the seasonal variation of methane showed that in the off-season (summer-autumn) at station Barrow quite often there are sharp jumps (increases) in methane concentration with amplitudes exceeding the background by ~> 5% and lasting from several / tens of hours to several days. Similar events were mainly observed from June to November. It is logical to assume that this behavior of methane in summer and autumn, when methane content in the atmosphere above the northern seas is on average lower than over land, is due to the dynamics of north and south winds at the observation point (Barrow station). Studies were conducted of the dependence of methane concentration on the direction of wind, that showing significant jumps in methane concentration at the station were recorded with wind blowing from the land. In case of wind from the north, methane values generally corresponded to an unperturbed / background level.

Analysis of monthly averaged distribution maps of methane concentration, based on satellite data, showed that in winter, at high latitudes, methane values above the land surface and northern seas do not differ significantly. However, in summer-autumn period, the concentration of methane over land is much higher than over the seas. Additional calculations of the trajectories of air mass movements in study area also confirmed the assumption that rapid increases in methane concentration in the summer-autumn period at station Barrow, located on the Arctic coast, is caused by the transfer from the landside of the air masses with a high methane content.

1. INTRODUCTION

Effects of global climate change caused by an increase in the content of greenhouse gases (CH4, CO2, etc.) in the atmosphere are most noticeable at high latitudes, in the Arctic zone, where the rate of temperature growth is twice the average for the globe [2].

The rise in temperature has a destructive effect on the permafrost, which contains large quantities (according to rough estimates at least 1400 Gt of methane [3]) greenhouse gases CH4, CO2, and, accordingly, increases the emission of methane from the soil. Compared to the main greenhouse gas - carbon dioxide, level of methane concentration in the atmosphere is much lower, but in terms of global warming potential, methane is more than twenty times [4] higher than the same indicator of CO2. Thus, release of methane into the atmosphere as a result of the degradation of permafrost will increase the rate of heating of the atmosphere. This circumstance determines the relevance of studies of methane in the Arctic zone, the results of which are devoted to a number of publications [5-9].

The aim of this work is to study features of rapid variations in the concentration of atmospheric methane on the Arctic coast based on ground-based and satellite observations.

2. DATA AND METHODS

Data from Barrow station (71 ° 36 'N, 156 ° 6' W) located 500 km north of the Arctic Circle (Fig. 1b) were used. These stations are publicly available on the Internet resource (ds. data. jma. go. JP/gmd/wdcgg). The area near the station is characterized by the absence of large infrastructure facilities, as well as a low population density, which significantly reduces the level of anthropogenic influence on observed results.

Methane measurements at station Barrow has been conducted in continuous mode since 1986. A flame ionization spectrograph is used to measure the concentration of gas components. The data is in an hourly average format with dates and times in UTC.

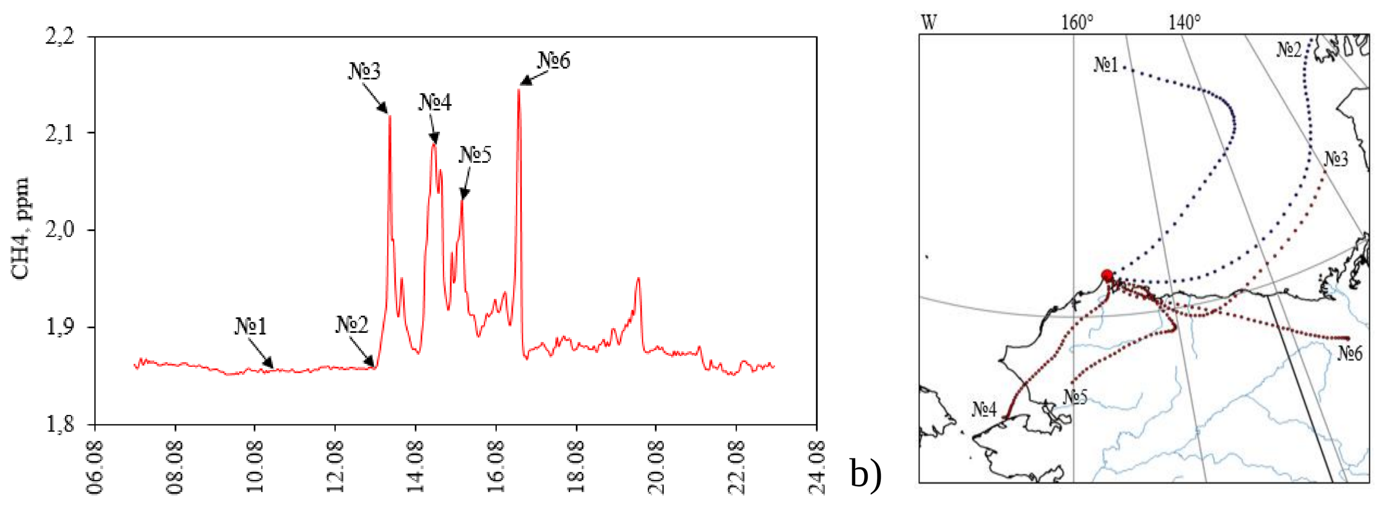

Figure: 1a) variations in methane concentration at st. Barrow August 7-22, 2010; b) trajectories of air mass transfer constructed according to the HYSPLIT model for the dates corresponding to time stamps.

Average hourly meteorological data, such as the wind direction and speed were taken from an Internet resource https://www.esrl.noaa.gov/gmd/dv/data/index.php?parameter_name=Meteorology&site=BRW.

In addition to ground-based measurements, work used data from the AIRS (Atmospheric Infrared Sounder) orbital diffraction spectrometer, which records the atmospheric absorption spectra of the Earth's infrared radiation in the spectral range from 3.75 to 15.4 μm, which is located on board the AQUA satellite. In this article, we used the AIRX3STM product, which is a map of the monthly average distribution of methane with a resolution of 1x1 deg. (ascending trajectories only) available from the URL https://giovanni.gsfc.nasa.gov.

Air mass transport tracing was built using the HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory model) model, which can be freely used via the web interface at the URL https://www.ready.noaa.gov/hypub-bin/ trajtype.pl?runtype=archive.

3. DISCUSSION

As a result of the analysis of a set of ground-based methane measurements from 1986 to 2018. Period June-November was identified, during which sharp jumps (increases) in methane concentration values were more often observed with the following signs:

• sharp increase in CH4 was preceded by a calm, undisturbed period of at least three days;
• the amplitude of the CH4 jump exceeded the unperturbed values by ~> 5%;
• the duration of individual jumps in increasing methane concentration ranged from several / tens of hours to several days;
• after sudden increases in methane, a calm period of at least three days was observed.

An example of one of the many considered events with a sharp increase in methane concentration is shown in Fig. 1a, from which it follows that during August 7-12, 2010, methane concentration remained at the undisturbed background level. From 13 to 17 August, several sharp jumps in concentration with high amplitudes are observed. After August 17, the methane concentration decreases to unperturbed values and remains at this level for several days.

Using the HYSPLIT model, trajectories of air mass transfer were constructed in two days preceding the dates marked with arrows (Fig. 1b). Tracing results are shown in Fig. 1b. The time interval between the trajectory points corresponds to one hour. Blue trajectories (No. 1, No. 2) correspond to unperturbed values of methane concentration - August 10 and 12, and "red" trajectories (No. 3-6) - two sharp jumps in concentration values on August 13-15 and 16, respectively.

As follows from Fig. 1b, the "blue" trajectories (No. 1 and No. 2) are completely in the Beaufort Sea. The trajectory of red color No. 3, although it originates in the Beaufort Sea, passes through the land for the last ~ 1.5 days. The rest of the trajectories (No. 4-6) completely or predominantly lie within the land.

Thus, time dependence of the methane concentration shown in Fig. 1a is most likely explained by the nature of the wind dynamics: winds coming from the land side bring air masses with a high methane content, and then to station Barrow, a sharp increase is recorded, and winds from the north is air with a low concentration of CH4 and, accordingly, the methane content drops to unperturbed values.

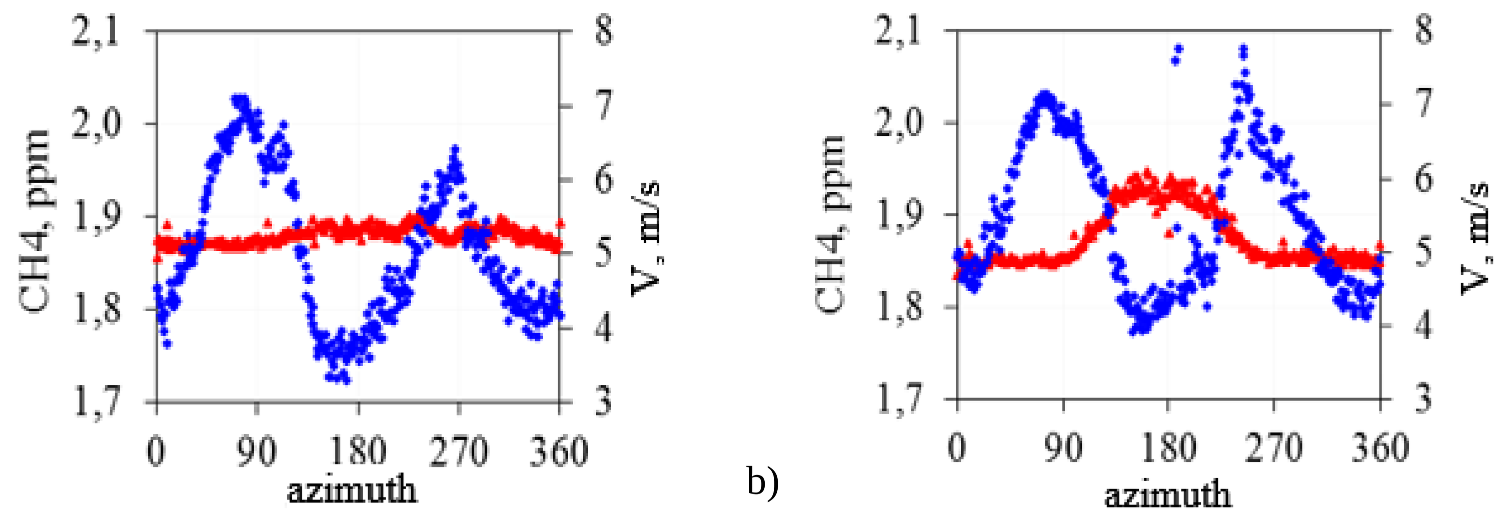

Figure: 2 Dependence of methane concentration (red markers) and wind speed (blue markers) on azimuth: a) December-May, b) June-November 1986 - 2018.

Figure 2 shows the dependences of methane concentration (red markers) and wind speed (blue markers) on azimuth in the periods of December-May and June-November, averaged over the entire observation period (1986-2018). Direction of the wind blowing from the land corresponds to the azimuthal sector of 80-280 degrees, the rest of the directions refers to winds blowing from the water area of the northern seas (Beaufort and Chukchi). It should be noted the wind dynamics characteristic of the Arctic coast - winds from the northern seas, on average, have a noticeably greater amplitude compared to the southern winds.

As can be seen on the graph (Fig. 2a), the level of methane concentration in December-May does not depend on direction (azimuth) of the wind. Whereas graph. 2b shows that in June-November for the azimuthal sector of land, noticeably higher values of methane (~> 5%) are observed, compared with the azimuths of winds blowing from the northern seas. Therefore, it can be assumed that the southerly winds bring air masses with a high concentration of methane to the observation point, and winds from the seas - with a low concentration of methane.

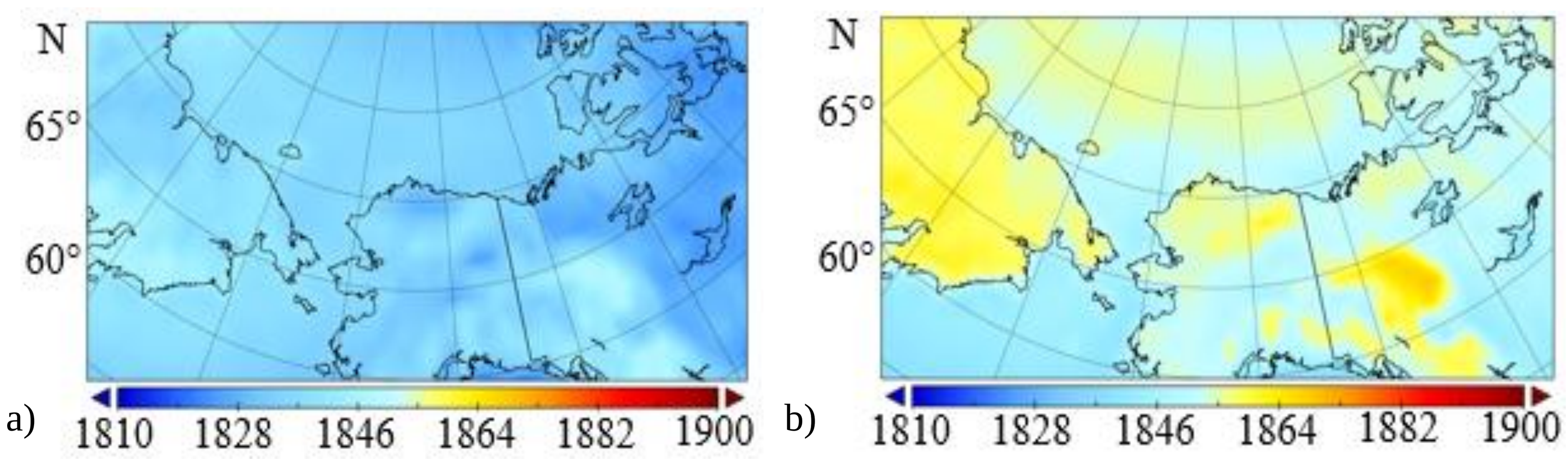

Figure: 3 Average for 2003-2018 distribution maps of methane concentration (units, ppbv) at an altitude of 400 hPa: a) December-May and b) June-November.

Figure 3 shows averaged over 2003-2018 maps of distribution of methane concentration at an altitude of 400 hPa, where, respectively, a) distribution in December-May, and b) - in June-November, constructed according to the data of the AIRS radiometer installed on the AQUA satellite.

The AIRX3STM product provides the ability to build maps at different pressure heights. Choice of the 400 hPa altitude used in this work is due to the recommendations presented in [10, 11], where methane measurements at a level of 400-500 hPa (~ 6-7 km) seem to be the most reliable for the Arctic zone.

In winter and spring, as follows from Fig. 3a, no noticeable difference in the methane content over land and water surface is observed. Otherwise, in the period June-November (Fig. 3b), the methane content over land noticeably exceeds its content over the water surface; boundary between areas with high and low methane content is clearly observed, passing along the coastline.

Peculiarities of the methane distribution pattern are explained by the balance of the mechanisms of the source (biogenic sources) and sink (oxidation of CH4 by free OH radicals) in the above seasons.

4. CONCLUSIONS

As a result of the analysis features of methane concentration on the Arctic coast, according to the data of st. Barrow (1986-2018) made the following conclusions:

- Against the background of seasonal variation in summer-autumn period (most often June-November), there are often sharp increases in methane concentration significantly (~> 5%), exceeding the background level, and lasting from several / tens of hours to several days;
- Similar variations of methane in summer-autumn period at Barrow station, located on the Arctic coast, are explained by the wind regime in vicinity of the observation station: southerly winds from land bring air masses with an increased methane content (a sharp increase in methane concentration is recorded at the observation station), while winds from the water area of e northern seas are lower, and methane level at the station decreases to undisturbed values.

Satellite observations are in good agreement with the results obtained from ground based data and confirm the conclusion about the wind regime.

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