Bulgarian Academy of Sciences. Space Research and Technology Institute.
Aerospace Research in Bulgaria. 35, 2023, Sofia

DOI: https://doi.org/10.3897/arb.v35.e04

INCREASE OF CARBON DIOXIDE AND METHANE EMISSIONS OVER BULGARIA ON THE BASE OF GOSAT SATELLITE DATA

Plamen Trenchev, Maria Dimitrova, Deyan Gochev

Space Research and Technology Institute – Bulgarian Academy of Sciences
e-mail: ptrenchev@space.bas.bg

Key words: *Ecology, Remote sensing, Greenhouse gases*

Abstract

The paper presents an assessment of the change in carbon dioxide and methane concentrations in the atmosphere over Bulgaria over the last 13 years. GOSAT data for the period April 2009 to the end of 2021 are used for this purpose. The data are presented as monthly averages with a spatial resolution of 2.5×2.5 degrees. The seasonal and spatial behaviour of carbon dioxide and methane emissions in the respective regions of interest has also been investigated.

Introduction

Air pollution is a local, pan-European and intercontinental problem and is now one of the major environmental concerns worldwide. Air pollutants emitted in one country can be transported into the atmosphere and degrade air quality elsewhere [1]. More than 80 % of Europe's urban population is exposed to pollutants at concentrations significantly above the limit values for the pollutant type concerned.

Atmospheric pollution is a volumetric phenomenon. They are most often triggered by a specific source and then spread relatively rapidly (within hours) both in altitude and in different directions in the atmosphere. Each individual type of pollutant has a different lifetime (residence time in the atmosphere). In some cases, pollution is local and mainly affects the region around its source (mainly industrial sites and transport). In others, however, there is long-range atmospheric transport and areas thousands of kilometres away can be affected. Depending on the specificity of the phenomenon under investigation, the choice of methods and data for its recording also becomes important.

The recording of atmospheric pollutants is carried out in two main ways, by direct and by remote measurements.

Direct measurements are carried out at a single point (local), while remote methods provide data on volumetric content. Measurements from satellites obtain

the content for a given pollutant in the whole column of the atmosphere over a given area corresponding to the spatial resolution of the instrument. To obtain a complete picture of the phenomenon, it is best to use both sources of information in conjunction.

Particularly important from an ecological and climatic point of view are so-called greenhouse gases. The generic term 'greenhouse gases' refers to all gases that warm the Earth's surface and the lower atmosphere. Carbon dioxide allows the sun's rays to reach the Earth's surface but prevents the heat from radiating back. Other gases that act in the same way are methane, nitrogen oxides and chlorofluorocarbons (Freons), which are used in aerosol preparations, in old refrigerators and in many air conditioners.

The relative share of major greenhouse gases is:

- About 80 % CO_2
- About 10 % methane
- About 5 % NO_2
- About 2 % hydrofluorocarbons
- About 3 % other.

CO_2 is the most widespread greenhouse gas, which is why it is the biggest problem. But CO_2 emissions have been stable in recent years and concentrations are rising at a predictable rate, as shown by many large-scale studies, including satellite observations. Methane emissions are lower as a percentage of CO_2, but it has a much higher global warming potential and is better at trapping heat than carbon dioxide.

Unfortunately, satellite measurements of these pollutants, especially methane, are still very poor.

In this work, we aim to track the behaviour of carbon dioxide and methane over Bulgaria for the period April 2009 to the end of 2021 based on data from the GOSAT satellites [2–6].

Satellite data and data processing

In this work, we have used averaged monthly CO_2 and CH_4 data from GOSAT [5, 6]. The spatial resolution is equal to 2.5×2.5 degrees. Fig. 1 shows some of the study areas over Bulgaria with their corresponding numbers.

For each of the study areas, we processed and obtained monthly averages for CO_2 and CH_4 for each month from April 2009 to the end of 2021 inclusive. Based on these values, we have plotted the seasonal distribution of the averaged value, the temporal distribution with the calculated percent change for the entire study period, and the variance of the values for each area. This process was conducted in parallel for both CH_4 and CO_2.

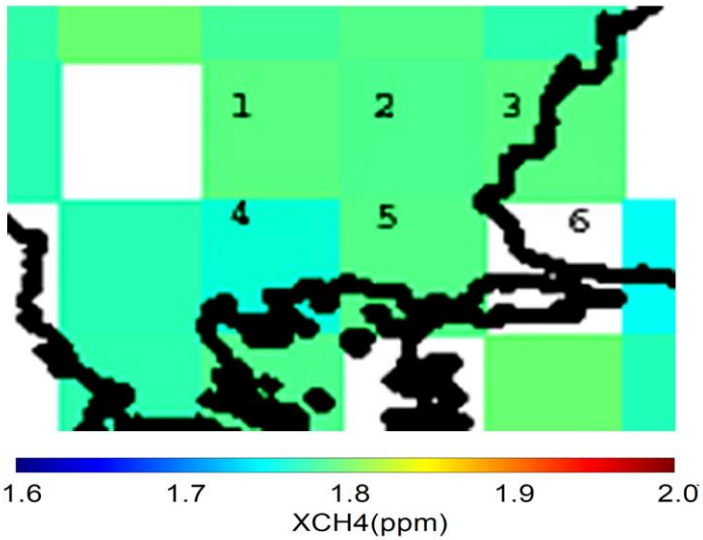

Fig. 1. Areas and an example of monthly average CH4 value

Results and Discussions

Figures 2–4 show the averaged seasonal distribution of CH_4 over Bulgaria (for the 6 regions in Fig. 1), the temporal variation of CH_4 for each of the 6 regions and the averaged temporal variation of CH_4 over Bulgaria.

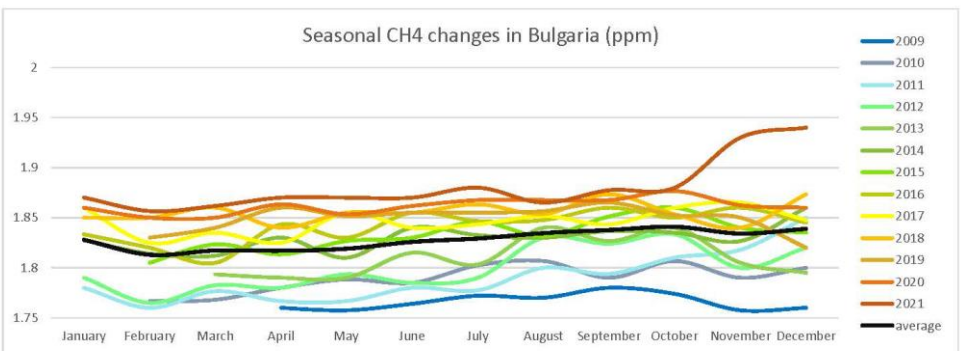

Fig. 2. Seasonal behavior of CH4 over Bulgaria

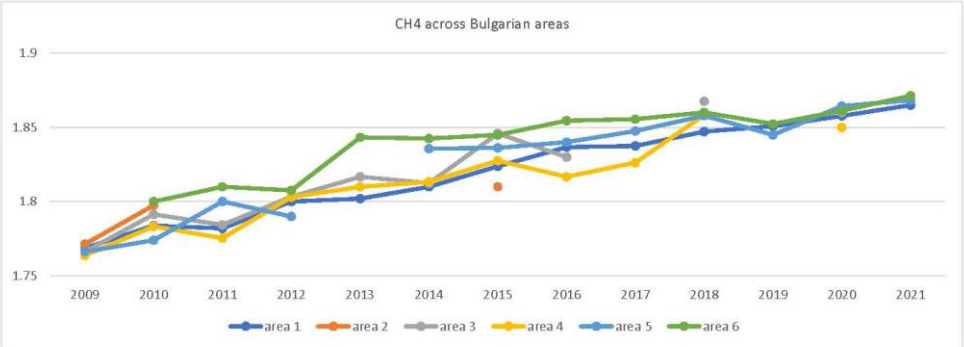

Fig. 3. Temporal behavior of CH4 over different Bulgarian regions

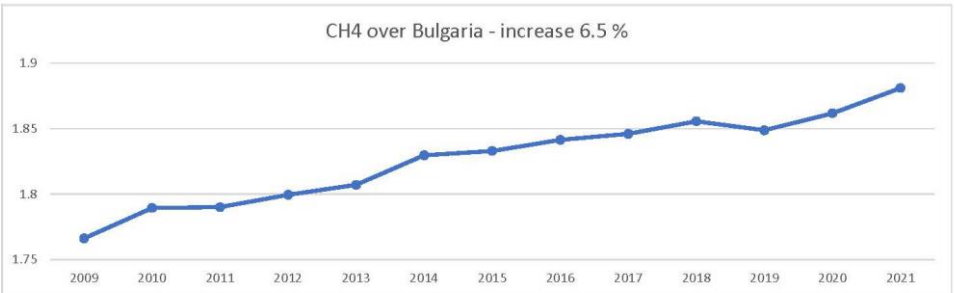

Fig. 4. CH4 increase over Bulgaria

As can be seen in Fig. 4, CH_4 emissions over Bulgaria have been increasing by nearly 6% for about 12 years. This result is in line with the observed trend for Europe and globally.

Figures 5–7 show the CO_2 values for the respective studies.

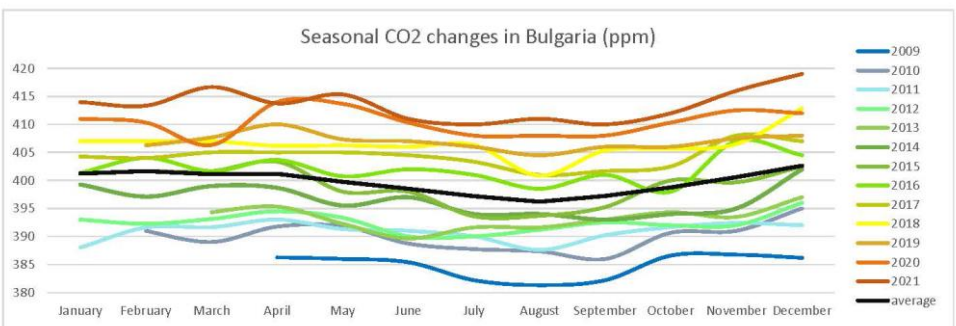

Fig. 5. Seasonal behavior of CO2 over Bulgaria

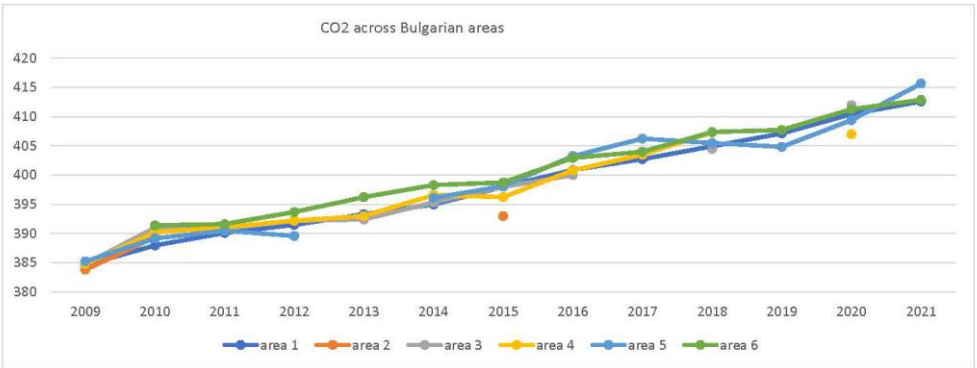

Fig. 6. Temporal behavior of CO2 over different Bulgarian regions

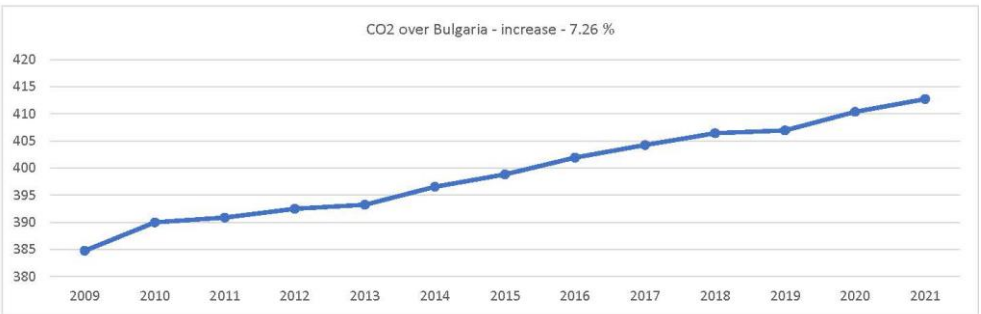

Fig. 7. CO2 increase over Bulgaria

As can be seen from Fig. 7, CO2 emissions in Bulgaria have been increasing by more than 7 % for about 12 years.

Another result of our study is that both pollutants show an increase in winter values. But while CH_4 has a maximum in October, for CO_2 the maximum is in February.

Moreover, the increase of CO_2 is almost the same in all 6 regions, while CH4 shows higher values in the 6th region. The interesting thing about the 6th region is that it covers the southeastern part of Bulgaria (around Burgas) up to the Black Sea where there are no major industrial sources of methane, except the Neftohim-Burgas oil refinery. Therefore, we can conclude that this is also one of the main sources of CH_4 in Bulgaria. More research in this regard is needed to determine the magnitude, intensity of these emissions as well as the level of transport from adjacent areas that affect the pollutant totals for the regions studied.

It should be borne in mind that the results shown here are very global. For a more detailed picture of the spatial distribution of the pollutants considered, satellite data with higher spatial resolution are needed. Such data can be obtained from the Tropomi instrument on the Sentinel-5P satellite, which have a pixel

resolution of 3.5×7 km and a daily acquisition. Several comparisons have been made between the results from GOSAT data and the results obtained from Tropomi data processing [7–9]. These comparisons show good agreement of the results from these two independent sources about CH_4 emissions. Tropomi instrument does not measure CO_2.

Conclusion

Based on the GOSAT data we can say that there has been a significant increase in CH_4 and CO_2 over the last 12 years or so. This increase is about 6.5 % for CH4 and about 7.3 % for CO_2. CO_2 pollution over Bulgaria is almost evenly distributed. CH4 shows slightly higher values in the south-eastern region.

References

1. Manisalidis, I., E. Staropopoulou, A. Stavropoulos, E. Bezirtzoglou, Environmental and Health Impacts of Air Pollution: A Review, Front. Public Health, 20 February 2020 https://doi.org/10.3389/fpubh.2020.00014
2. Butz, A., S. Guerlet, O. Hasekamp, D. Schepers, A. Galli, I. Aben, C. Frankenberg, J.-M. Hartmann, H. Tran, A. Kuze, G. Keppel-Aleks, G. Toon, D. Wunch, P. Wennberg, N. Deutscher, D. Griffith, R. Macatangay, J. Messerschmidt, J. Notholt, and T. Warneke, Toward accurate CO2 and CH4 observations from GOSAT, GEOPHYSICAL RESEARCH LETTERS, 2011, VOL. 38, L14812, doi:10.1029/2011GL047888, https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1029/2011GL047888
3. Morino, I., O. Uchino, M. Inoue, Y. Yoshida, T. Yokota, P. O. Wennberg, G. C. Toon, D. Wunch, C. M. Roehl, J. Notholt, T. Warneke, J. Messerschmidt, D. W. T. Griffith, N. M. Deutscher, V. Sherlock, B. Connor , J. Robinson, R. Sussmann, and M. Rettinger, Preliminary validation of column-averaged volume mixing ratios of carbon dioxide and methane retrieved from GOSAT short-wavelength infrared spectra, Atmos. Meas. Tech, 2011., 4, 1061–1076, doi:10.5194/amt-4-1061-2011, www.atmos-meas-tech.net/4/1061/2011
4. Turner, A. J., D. J. Jacob, K. J. Wecht, J. D. Maasakkers, E. Lundgren, A. E. Andrews, S. C. Biraud, H. Boesch, K. W. Bowman, N. M. Deutscher, M. K. Dubey, D. W. T. Griffith, F. Hase, A. Kuze, J. Notholt, H. Ohyama, R. Parker, V. H. Payne, R. Sussmann, C. Sweeney, V. A. Velazco, T. Warneke, P. O. Wennberg, and D. WunchPrice, Estimating global and North American methane emissions with high spatial resolution using GOSAT satellite data, Atmos. Chem. Phys. , 2015, 15, 7049–7069, doi:10.5194/acp-15-7049-2015, www.atmos-chem-phys.net/15/7049/2015/
5. GOSAT project - http://www.gosat.nies.go.jp/en/
6. GOSAT instrument and data - https://earth.esa.int/eogateway/missions/gosat

7. Haili Hu, Jochen Landgraf, Rob Detmers, Tobias Borsdorff, Joost Aan de Brugh, Ilse Aben, André Butz, and Otto Hasekamp, Toward Global Mapping of Methane With TROPOMI: First Results and Intersatellite Comparison to GOSAT, Geophysical Research Letters 10.1002/2018GL077259, https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1002/2018GL077259
8. Wecht, K. J., D. J. Jacob, M. P. Sulprizio, G. W. Santoni, S. C. Wofsy, R. Parker, H. Bösch, and J. Worden, Spatially resolving methane emissions in California: constraints from the CalNex aircraft campaign and from present (GOSAT, TES) and future (TROPOMI, geostationary) satellite observations, Atmos. Chem. Phys, 2014., 14, 8173–8184, doi:10.5194/acp-14-8173-2014, www.atmos-chem-phys.net/14/81732014
9. H. Lindqvist1,2 , C. W. O'Dell1 , S. Basu3,4 , H. Boesch5 , F. Chevallier6 , N. Deutscher7,8 , L. Feng9 , B. Fisher10, F. Hase11 , M. Inoue12,13, R. Kivi14, I. Morino12, P. I. Palmer9 , R. Parker5 , M. Schneider11, R. Sussmann15, and Y. Yoshida, Does GOSAT capture the true seasonal cycle of carbon dioxide?, Atmos. Chem. Phys, 2015., 15, 13023–13040, doi:10.5194/acp-15-13023-2015, www.atmos-chem-phys.net/15/13023/2015

УВЕЛИЧЕНИЕ НА ЕМИСИИТЕ ОТ ВЪГЛЕРОДЕН ДИОКСИД И МЕТАН НАД БЪЛГАРИЯ ПО СПЪТНИКОВИ ДАННИ ОТ GOSAT

Пл. Тренчев, М. Димитрова, Д. Гочев

Резюме

В статията е представена оценка на изменението на концентрациите на въглероден диоксид и метан в атмосферата над България през последните 13 години. За тази цел са използвани данни от GOSAT за периода от април 2009 г. до края на 2021 г. Данните са представени като средномесечни стойности с пространствена разделителна способност 2,5×2,5 градуса. Изследвано е също така сезонното и пространственото поведение на емисиите на въглероден диоксид и метан в съответните области на интерес.