Methane distribution over Greece as derived from Sentinel-5P TROPOMI data

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Abstract.
Global warming, induced mainly by greenhouse gases emitted by human activities, is an environmental issue of crucial importance for society. Greenhouse gases, such as methane (CH_4), need to be monitored and their anthropogenic emissions quantified in order to be reduced. We here present, the first systematic investigation of CH_4 columns over Greece derived from the Sentinel-5 Precursor TROPOMI satellite instrument L-2 high spatial resolution data for the period 2019-2020. We gridded the data in 0.2°x0.2° grids and find an increase in CH_4 columns between 2019 and 2020 and a clear seasonal pattern in CH_4 column with high columns in summer and fall and the lowest in winter. We also identify Athens, Thessaly, Thessaloniki, Thrace and the Crete as areas with high CH_4 columns.

Keywords: methane, remote sensing, variability, TROPOMI

1. Introduction

The Paris Agreement promised to confine global warming to less than 2 °C or preferably, to less than 1.5 °C in comparison with the pre-industrial average temperature (UNFCCC, 2015). For sustainable development of the society, it is necessary to limit anthropogenic climate change through targeted emission reductions. Methane (CH_4), a greenhouse gas of major importance, is the second contributor to radiative forcing caused by anthropogenic activities, after carbon dioxide. Methane has a shorter atmospheric lifetime (~ 9 years) and a global warming potential larger than that of carbon dioxide (Holmes et al., 2013). Methane can thus aid governments to meet global emission goals in the short-term. In the global atmosphere, CH_4 mole fractions, after a plateau between 2000 and 2007 (Cunnold, 2002), started increasing worldwide again (Rigby et al., 2008) and this increase has steepened after 2014 (Nisbet et al., 2019). Methane is emitted from a variety of sources, both anthropogenic and natural, such as wetlands, livestock, rice paddies, fossil fuels, landfills, and waste from agricultural activities (Dimitriou et al., 2021).

In order to mitigate emissions and meet global climate targets, the understanding of CH_4 quantification as well as sources and concentration changes is vital (Ganesan et al., 2019). "Bottom-up" strategies, which are based on inventories derived from activity statistics, together with "top-down" ones, which are using atmospheric concentration measurements to evaluate emissions, can help to assess to which extent we meet these targets (Tunnicliffe et al., 2020). Frequent, region-wide monitoring of emissions is needed, which can be facilitated by methane measurements using space-based sensors of high temporal and spatial resolution.

Remote sensing is the acquisition of information about an object or phenomenon on Earth without making physical contact with the object, using electromagnetic waves. Satellites or aircraft-based sensor technologies are successfully used to capture images and detect Earth's surface. Remote sensing satellites have the capability to observe the Earth for a designated period of time with high frequency and with the desirable spatial coverage, global or regional (Fu et al., 2020). TROPOspheric Monitoring Instrument (TROPOMI) onboard the Sentinel-5 Precursor satellite is a newly launched instrument which enables for high quality, wide-region and great temporal coverage with remarkable accuracy (Veefkind et al., 2012), and can detect sources of considerably large contribution to emissions in a sole overpass (Schneising et al., 2020).

The Eastern Mediterranean Basin is a climate sensitive region, it is warming faster than the globe and is subject to water stress (The World Bank 2012). This is due to the fact that Eastern Mediterranean is at a crossroad of air masses from Asia, N. America, Europe and Africa (Dimitriou et al., 2021). Temperature trends during summer in Greece are greater than those of the northern hemisphere as shown by Mamara et al. (2016). Therefore, continuous and basin-wide monitoring of greenhouse gases is essential in the region of Eastern Mediterranean Basin and particularly in Greece. In this work, we aim to investigate a "quasi – climatology" of CH_4 over Greece using the high spatial resolution Sentinel-5 Precursor TROPOMI CH_4 product that is available for 2019 and 2020.

2. Data and Method

Methane concentrations are acquired from TROPOMI observations in the shortwave infrared (SWIR) solar radiation spectrum (Schneising et al., 2020). TROPOMI is an imaging spectrometer on board of the Copernicus Sentinel-5 Precursor (S5P), a European satellite for atmosphere monitoring, launched on 13 October 2017 and planned for a mission of seven years. S5P is a sun-synchronous orbit satellite at 817 km altitude, with an Equator overpass time at13:30 and a 17-days cycle. The swath of TROPOMI is about 2600 km and it operates with a horizontal resolution of 7×7 km^2 (5.6×7 km^2 from 6 August 2019) (Cersosimo et al., 2020; Schneising et al., 2020).

We here use Level 2-CH_4 TROPOMI data available from ESA's website (https://s5phub.copernicus.eu/dhus/#/home, access date: 5/2021), which correspond to the period from 1/1/2019 to 31/12/2020. The data points were then gridded within a 0.2° × 0.2° grid in order to produce average distributions of the CH_4 abundances over Greece. Seasonal mean CH_4 concentrations were calculated for the selected period as well as the annual means for each one of the studied years and for the whole period. The derived distributions are presented in Section 3.

3. Results

3.1 Annual mean distribution of CH_4 columns over Greece in 2019 and 2020

Average methane columns over the region of Greece for each year and for the whole time period are shown in Figs. 1-3. High columns of methane are shown over Athens, Thessaly, Thessaloniki, Thrace and Crete, especially in the northwest of the island, during 2019. The TROPOMI CH_4 columns show a clear hotspot over Athens, the capital of Greece, which can be attributed to the anthropogenic activities in the area. During 2020, in comparison to 2019, an overall rise in CH_4 concentrations is observed, following the global trends in CH_4. This rise is as high as 12 ppb over Athens and 22 ppb over Thessaloniki to be compared with the 15.85 ppb incremental annual increase in globally-averaged atmospheric CH_4 reported by NOAA in 2020 for marine sites (Ed Dlugokencky, NOAA/GML (gml.noaa.gov/ccgg/trends_ch4/ access date 5/2021). Furthermore, the uncertainty in CH_4 abundances examined for the studied period and depicted in Fig. 4, is extremely low (less than 3 ppb) for the majority of Greece. It is also far less than half the observed annual increase in globally-averaged atmospheric methane reported by NOAA for the studied years demonstrating that TROPOMI measurements are of sufficient accuracy for trend analysis. Further investigation on the data quality of TROPOMI over Greece can be found on Topaloglou et al. (EGU 2020).

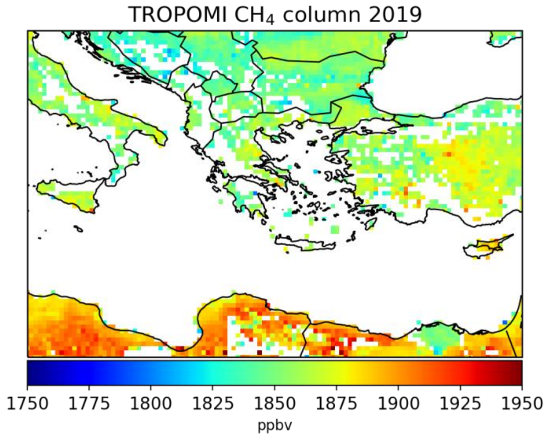

Figure 1. Annual mean TROPOMI CH_4 column distribution for 2019

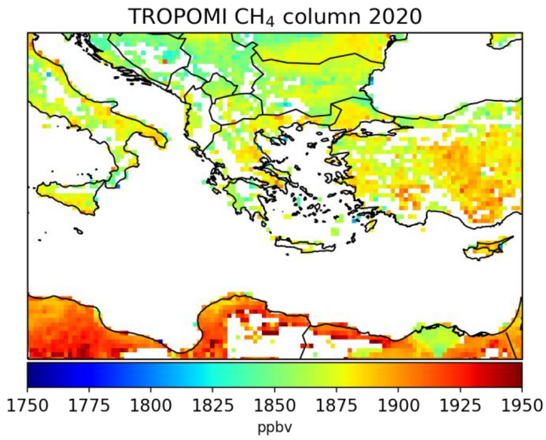

Figure 2. Annual mean TROPOMI CH_4 column distribution for 2020

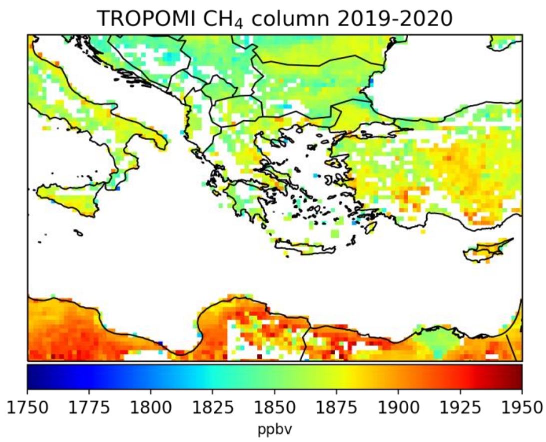

Figure 3. TROPOMI Average CH_4 column distribution for the 2-years period (2019-2020)

3.2 Seasonal variation of CH_4 columns over Greece

Mean distributions of CH_4 columns for each season for the time period 2019-2020 are shown in Figs. 5-8. Higher

CH_4 columns are observed during summer and autumn months and lower during spring and winter, reflecting seasonality in sources and sinks of CH_4 as well as transport patterns.

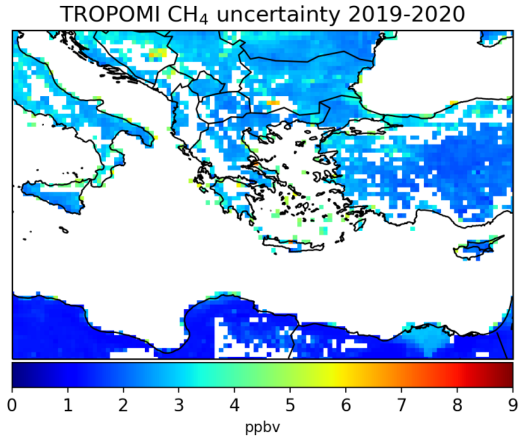

Figure 4. TROPOMI Methane column uncertainty for the two years period (2019-2020).

These findings agree with the earlier study by Georgoulias et al. (2011) for the period 2003-2004, who investigated CH_4 column distribution over the Greater Area of the Eastern Mediterranean using the SCIAMACHY satellite, which had a lower spatial resolution than TROPOMI. They found CH_4 columns of 1761±27 ppb for 2003, consistent with TROPOMI observations when accounting for CH_4 global trends, and shown a summer and autumn maximum and a winter minimum, which agree with our results. In support of our findings Javadinejad et al. (2019) showed an increase in CH_4 concentration with low vegetation cover and high temperature and Tian et al. (2015) related high CH_4 levels with biomass burning episodes.

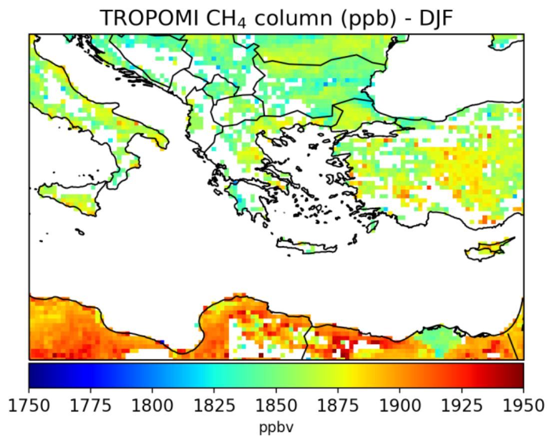

Figure 5. TROPOMI Average CH_4 column distribution for winter for the 2-years period (2019 - 2020).

4. Conclusions

We here presented the CH_4 column distribution for the years 2019 and 2020 and its seasonality as derived from the TROPOMI L-2 CH_4 data that we have gridded in a $0.2^o \times 0.2^o$ grid in order to calculate average CH_4 abundances over Greece. Hotspots of methane are seen over the largest cities of Greece during 2019-2020 and rising concentrations are observed from 2019 to 2020. A clear seasonality is found with high columns in summer and fall and the lowest in winter.

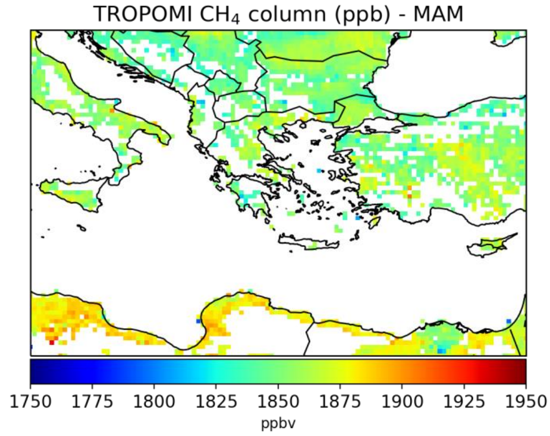

Figure 6. TROPOMI Average CH_4 column distribution for spring for the 2-years period (2019 - 2020).

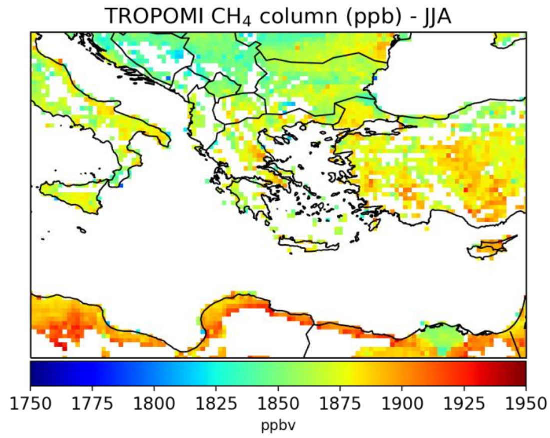

Figure 7. TROPOMI Average CH_4 column distribution for summer for the 2-years period (2019 - 2020).

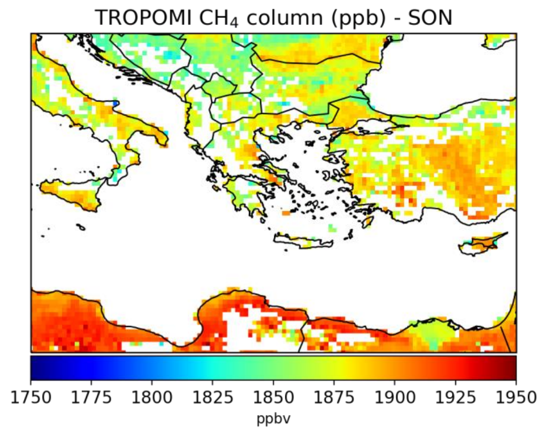

Figure 8. TROPOMI Average CH_4 column distribution for autumn for the 2-years period (2019 - 2020).

This study depicts the situation prevailing in the region during the last two years, and could be considered representative of a quasi-climatology of methane concentration over the Eastern Mediterranean Basin. Further analysis is needed to attribute the seasonal variability of CH_4 columns to specific sources and sinks that will be evaluated using data assimilation modeling.

Acknowledgments. This work is funded by the Action "National Network on Climate Change and its Impacts (CLIMPACT)" implemented under the project "Infrastructure of national research networks in the fields of Precision Medicine, Quantum Technology and Climate Change", funded by the Public Investment Program of Greece, General Secretary of Research and Technology/Ministry of Development and Investments; and by the Deutsche Forschungs-gemeinschaft (DFG, German Research Foundation) under Germany´s Excellence Strategy (University Allowance, EXC 2077, University of Bremen).

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