INVERSION ESTIMATES OF METHANE EMISSION IN THE MIDDLE EAST IN 2010-2017 WITH GOSAT OBSERVATIONS

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ABSTRACT

Ten years of Greenhouse gas Observing SATellite (GOSAT) observation achieves valuable retrievals for top-down methane (CH_4) emissions estimates especially in regions lacking ground-based observations. This paper presents the long-term 2010-2017 trend in CH_4 emissions in the Middle East countries. We use a global 0.1° × 0.1° high-resolution inverse model, NIES-TM-FLEXPART-VAR (NTFVAR) with GOSAT retrievals and surface observations. Prior fluxes contain adjusted EDGAR v4.3.2 scaled to match the country totals by national reports to the United Nations Framework Convention on Climate Change (UNFCCC), augmented by biomass burning emissions from Global Fire Assimilation System (GFASv1.2) and wetlands emissions from Vegetation Integrative Simulator for Trace Gases (VISIT) model. The result shows the total annual CH_4 emission of 23.54 Tg CH_4 yr^{-1} in the Middle East with more than 95% emissions from anthropogenic sources, and there is no statistically significant emissions trend from 2010 to 2017.

Index Terms— GOSAT, methane emissions, Middle East countries

1. INTRODUCTION

GOSAT, in operation since 2009, is the world's first satellite dedicated to greenhouse-gas-monitoring. It retrieves the column-averaged dry air mole fraction of atmospheric carbon dioxide (XCO_2) and methane (XCH_4) globally covering many places where surface observations are sparse. GOSAT retrievals have been widely used for top-down greenhouse estimations by inverse models, proven worthy for emission inventory evaluation (e.g., [1-8]).

There is the growing concern that CH_4 emissions undermine the net climate benefit of using it as fuel, as it is short-lived greenhouse gas and a pollutant having adverse impacts on human health (eg., [9]) and ecosystem productivity [10]. GOSAT retrievals show that XCH_4 are high in Asia, West Africa and the Middle East [11]. A few studies have addressed the CH_4 emission in the Middle East, which accounts for one-third of global oil production, one-sixth of gas production, 48% of proven oil reserves and 38% of proven gas reserves. Oil and gas production systems emit CH_4 both from normal operations and system disruptions. In this paper, we present the long-term 2010-2017 trend in CH_4 emissions in the Middle East derived with a 0.1° × 0.1° high-resolution inverse model at country scale.

2. METHODOLOGY

The global Eulerian–Lagrangian coupled model NIES-TM-FLEXPART-VAR (NTFVAR) consists of the National Institute for Environmental Studies (NIES) model as a Eulerian three-dimensional transport model (TM), and FLEXPART (FLEXible PARTicle dispersion model) as the Lagrangian Particle Dispersion Model (LPDM) [12, 13]. Flux corrections were estimated independently for two categories of emissions (anthropogenic and natural). Variational optimization was applied to obtain flux corrections as two sets of scaling factors to vary prior uncertainty fields on a monthly basis at a 0.1° × 0.1° resolution separately for anthropogenic and natural wetland emissions. More description of model settings is in our previous paper [14]. Prior CH_4 fluxes used in the model included anthropogenic emissions, natural emissions from wetlands, soil sink, emissions from biomass burning and other natural sources from the ocean, geological reservoirs and termites. Annual anthropogenic emissions were taken from the Emissions Database for Global Atmospheric Research (EDGAR v4.3.2) at a spatial resolution of 0.1°×0.1° scaled to match the country reports to the UNFCCC, including monthly variability. Beyond 2012 we used the report from PBL Netherlands Environmental Assessment Agency [15] to extend EDGAR values of 2012 using equation (1), where t is year from 2013 to 2017:

$$E_{UNFCCC}(t) = E_{UNFCCC}(2012) \times \frac{PBL_{CH4}(t)}{PBL_{CH4}(2012)} \qquad (1)$$

In addition to the GOSAT retrievals (NIES, Level 2 retrievals, v. 02.72), we used ground based atmospheric CH_4 observations in the inversions (for more details refer to [13]). The meteorological data used for the transport model were obtained from the Japanese Meteorological Agency (JMA) Climate Data Assimilation System (JCDAS) [16].

3. RESULTS AND DISCUSSION

The anthropogenic and natural CH_4 emissions in 2010-2017 were estimated by the NTFVAR inverse model. The optimized average anthropogenic CH_4 emission for the Middle East for 2010-2017 is 22.44±0.57 Tg CH_4 yr^{-1} (mean ± standard deviation), sharing more than 95% of total CH_4 emissions from the region (23.54±0.62 Tg CH_4 yr^{-1} with an uncertainty of 3.30 Tg CH_4 yr^{-1}) in the Middle East. The estimated anthropogenic emission in the Middle East is similar in magnitude to that in Europe (23.9 Tg CH_4 yr^{-1}) [13].

Average total CH_4 emissions for each country in the Middle East are shown in Figure 1. The five countries emitting more than 1 Tg CH_4 yr^{-1} are Iran, Turkey, Saudi Arabia, Iraq and Egypt, with average total CH_4 emissions of 6.45 Tg CH_4 yr^{-1}, 3.64 Tg CH_4 yr^{-1}, 2.90 Tg CH_4 yr^{-1}, 2.87 Tg CH_4 yr^{-1} and 2.06 Tg CH_4 yr^{-1}, respectively.

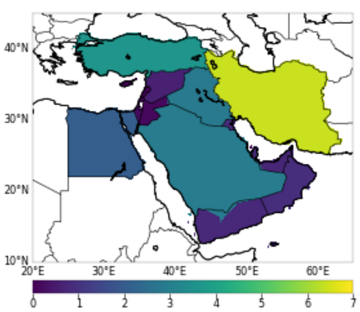

Figure 1. The average (2010-2017) optimized annual total CH_4 emissions for each country in the Middle East (unit Tg CH_4 yr^{-1}).

The interannual variation of total CH_4 emissions in the five top-emitting countries and the Middle East is shown in Figure 2. There is no significant statistic trend in the total emission from 2010 to 2017, with a maximum in 2014 (24.76 Tg CH_4 yr^{-1}) and minimum in 2015 (22.85 Tg CH_4 yr^{-1}). We detected statistically significant decreasing trends in Iran, Yemen and Syria, for the eight years period by using the Mann-Kendall trend test.

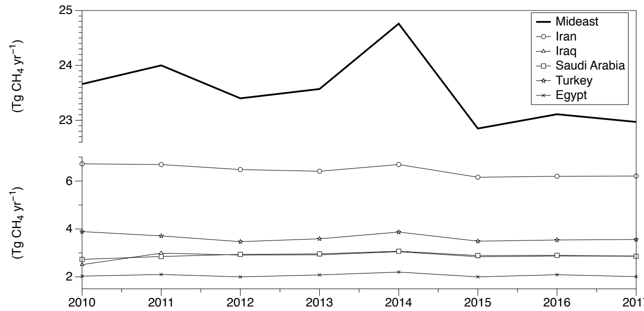

Figure 2. The interannual variation of optimized total CH_4 emissions in the whole Middle East area and the five top-emitting countries.

Anthropogenic fluxes in the Middle East and surroundings are shown in Figure 3. Hot spots are located around the Persian Gulf and its coast areas, where locate the world's largest single source of petroleum, concentrated oil and gas fields. Anthropogenic emissions are the dominant methane emission in the Middle East, as the Middle East is highlighted as the region of oil and natural gas producers in the world. The flaring, venting and combustion processes produce large amounts of CH_4, which induce severe air pollution and climate warming. In recent years, the air quality in this region has worsened dramatically and concurrently global warming is especially strong [17]. Reduction of CH_4 emissions from oil or gas production to final consumer will bring benefits in a short term to reduce the vulnerability of climate warming regarding extreme heat, scarce water resources, potentially increasing migration and risk of conflict in the region.

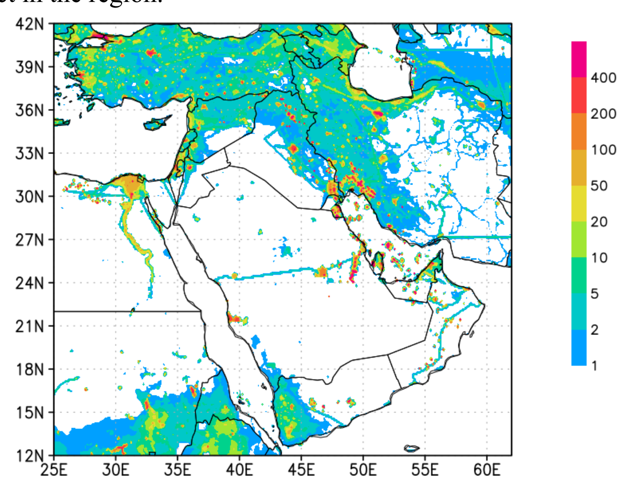

Figure 3. The average (2010-2017) posterior fluxes for anthropogenic CH_4 emissions in the Middle East (mg CH_4 m^{-2} day^{-1}).

4. SUMMARY

Long-term retrievals of column-averaged CH_4 from GOSAT observations are used to estimate the top-down CH_4 emissions in the Middle East with the 0.1° × 0.1° high-resolution inverse model NTFVAR. Although there is no statistically significant trend in regional total CH_4 emissions from 2010 to 2017, a significant decreasing trend is detected in the biggest emitting country Iran. It is found that anthropogenic sources are dominant over total CH_4 emission in the study area.

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