IMPALA TROPOMI-based methane emissions over Africa

(Version 1.0)

Introduction

This top-down methane emission estimates are derived from TROPOMI by using the divergence method that is specifically designed for long-lived spices like methane (Liu et al., 2021, 2023; Veefkind et al., 2022). This dataset is the beta version (v1.0) of 0.2° × 0.2° gridded annual emission inventory from 2018 to 2021 over North Africa. The retrieval algorithms have rigorous control of clouds, and the data is available only under clear-sky scenes. It is impossible to derive the annual emissions for locations where are always cloudy during a year. Therefore, this version provides the emissions over North Africa (2°N−40°N, 17°W-45°E).

The accuracy and representativeness of the derived emissions based on the divergence method can be improved by increasing the number of observations. In order to have as much data as possible, we use the latest version of TROPOMI/WFMD (v1.8) from the University of Bremen as a benchmark to estimate methane emissions. In order to assess uncertainties of retrievals and evaluate the reliability of the emissions we derived, we assigned each source (grid cell) an index of its confidence level by using (1) the detection threshold, (2) two filters we built and (3) whether it can be identified by both retrievals. The confidence level starts from 0 (no emissions or not enough sampling) to 5, with which is a virtually certain source. More details can be found in Table 2 and 3.

Combining two retrievals or the use of a strict temporal filter can help to exclude the artefacts caused by retrievals to a certain degree. However, it is hard to validate the final sources in such a big area. The sources with confidence level 3 and 4 can possibly still contain artefacts from retrievals.

In practice, we recommend users to use level 3-5 in their analysis.

File format and content

Four annual gridded TROPOMI-based methane emissions (unit: $kg/km^2/hour$) are provided in NetCDF data format for 2018-2021. Each file is named as NAF_TROPOMI_methane_emission_02x02_v1.0_YYYY.nc, where YYYY represents the year. Specific information is as follows:

General information:

Spatial resolution: 0.2° latitude × 0.2° longitude
Temporal resolution: Annual
Spatial domain: 2°N−40°N, 17°W-45°E

1. Variables of the data file.

Variables	Explanation
lat	Latitude of a grid center (dimension: 190)
lon	Longitude of a grid center (dimension: 310)
div	The averaged divergence of the year.
div_back	Corresponding divergence of the background.
emiss	Annual emissions based on the divergence. −999 represents the grid cell with less than 10 observation days (num < 10) per year.
confidence_category	There are six categories. 5 stands for the highest confidence while 1 stands for the lowest confidence. 0 means there are no emissions detected or there not enough samplings for this grid cell.
num	The total number of days with valid observations in a year.

2. Confidence category.

Category index	0	1	2	3	4	5
[1]Spatial filter passed	−	×	×	×	×	×
[2]Emissions above detection threshold	−	−	×	×	×	×
[3]Identified by two retrieval products	−	−	−	×	−	×
[4]Temporal filter passed	−	−	−	−	×	×

"×"and "−" indicate if a criterion is applied or not applied, respectively.

3. Explanation of the categories

	Explanation
1	The *spatial filter* is built to filter false sources caused by incorrect winds from ERA5 reanalysis data or orography. More information can be found at Liu et al., (2023)
2	The *threshold* ($3kg/km^2/h$) is calculated based on the detection limit of the XCH_4 enhancement of TROPOMI
3	The sources that are identified by both the TROPOMI/WMFD and the official S5P reprocessing product.
4	The *temporal filter* is built to exclude false sources due to surface albedo. A grid cell passing the temporal filter means it is very likely a constant source.

Appendix - filtering and corrections

A.1 Spatial filter and corresponding correction

The 2-order central difference is used to derive the divergence. For each cell, its neighboring cells along south-north (V component) and west-east (U component) directions are firstly used to calculate the divergence. Only when these four cells all have valid observations, the daily divergence, D_d^{xy}, for the cell will be calculated. To use observations as much as possible, we rotate the wind framework clockwise by 45 degrees to use the observations of four cells at the corners. The D_d^{diag}, which represents the divergence of the four cells at the corners, is derived under the same criteria as D_d^{xy}. The final divergence, $\overline{D_d^S}$, is obtained as follows:

$$\overline{D_d^S} = \overline{\frac{1}{2}(D_d^{xy} + D_d^{diag})} \qquad (1)$$

Based on mass balance, $\overline{D_d^{xy}}$ should be very close to $\overline{D_d^{diag}}$ for the average of a certain period. In practice, we set the criteria that the difference between $\overline{D_d^{xy}}$ and $\overline{D_d^{diag}}$ should not be greater than the smaller of the two. Otherwise, it implies the divergence in vertical direction also plays a vital role in transport. It can occur over mountains where the vertical transport is dominant, and the re-analysis data of the wind field from ERA5 may resolve this process poorly. The methane emission E' is set to zero for these grid cells.

A.2 Spatial correction

In addition, we find that areas with negative E' together with negative $\overline{D_d^B}$ and divergence of winds ($\overline{D_d^W}$), implying no significant sources exist. The final estimated emissions at cells with negative E' are also set to zero (Liu et al., 2021). For cells with positive E', a one-order linear regression is applied to its surrounding ±3 cells:

$$y_i = k \cdot x_i + b \qquad (2)$$

where y_i stands for $\overline{D_d^S}$ and x_i stands for $\overline{D_d^B}$ of grid *i*. *k* and *b* are the slope and intercept of the linear regression, respectively. If Eq. (2) is applicable to the center grid, it implies the residue of the background still contributes to E' and should be subtracted. This linear correlation can be quite strong over locations with large variations in orography (e.g., mountains, coastal areas). If more than 68% of the grid cells and the grid cell itself fall within the prediction lines of Eq. (2), it will be filtered (estimated emissions set to zero) because the positive E' of this cell is very likely caused by the remaining background divergence and $\overline{D_d^S}$ can be predicted by $\overline{D_d^B}$ according to Eq. (2). Only "outliners" are considered to be reliable to be further corrected by the spatial correction:

$$E^{corr} = E' - (k \cdot \overline{D_d^B} + b) \qquad (3)$$

in which $(k \cdot \overline{D_d^B} + b)$ is regarded as the contribution from the remaining background, which should be subtracted from the preliminary estimated emissions, E'.

A.3 Temporal filter

A cell with a large E' but no significant linear correlation between $\overline{D_d^S}$ and $\overline{D_d^B}$, contains either a source located in a relatively flat area or caused by artifacts in the retrieval. Therefore, we compare the normalized time series of D_d^S and D_d^B to check if the positive $\overline{D_d^S}$ is related to a real source. If the enhancement is a kind of artifact; for example, caused by a bright surface, it behaves more like a constant and has smaller temporal variations than D_d^B. Then temporal variations of D_d^S will be mainly dominated by variations of the background. The temporal filter is based on their normalized time series and built as follows. Firstly, we remove the cells that have less than 10-day records. Next, if more than half of the days of the time series of a cell have larger normalized positive D_d^S than D_d^B, we keep the grid cell; otherwise, it will be filtered. In this way, the emissions from an artifact or random noise from the retrieval can be effectively filtered.

References

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