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Sentinel-5P products in Terrascope

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Terrascope

The system

The Terrascope system constitutes the so-called Belgian Copernicus Collaborative Ground Segment that provides value-added satellite data products in response to the needs from local user communities. Hosted at VITO, it comprises the Terrascope website, the Terrascope Viewer, as well as a Virtual Environment that provides analysis and (parallel) processing capacity to users. Terrascope provides open source high-quality data from the Sentinel missions, which are not disseminated through the official ESA/EU Copernicus channels.

The viewer

The Terrascope Viewer is the web interface for consulting satellite data products (**viewer.terrascope.be**). The user can currently choose from data collections from the Sentinel 1, Sentinel 2, Sentinel 5-P, and PROBA-V platforms, as well as several additional data layers, such as from the Copernicus Global Land Service and the recently launched ESA Worldcover. The viewer offers a wide range of options, like the comparison of two different data sets (see **Figure 1**), the search for imagery over a certain location, filtering for imagery with low cloud cover, the download of data, and the export of images.

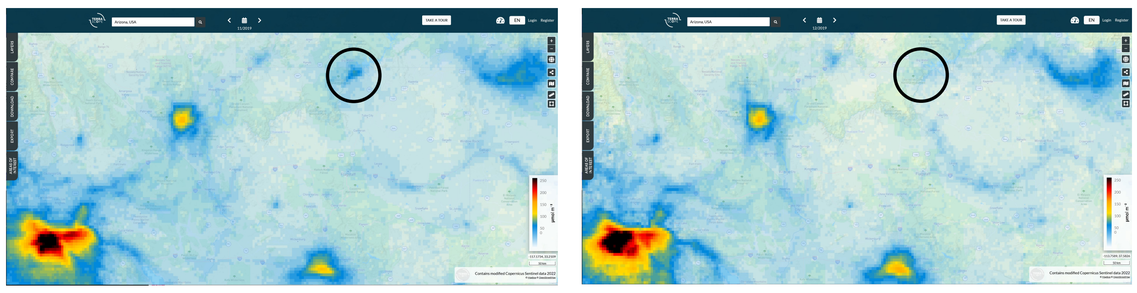

Figure 1 In this comparison of monthly-averaged S5P NO_2 vertical column signal over Arizona of November 2019 (left) and December 2019 (right), one source is clearly missing in the right panel (black circle): the Navajo coal plant at this location was decommissioned on 18 November 2019 (https://mobile.twitter.com/DGoldbergAQ/status/1339978187401547778).

The Terrascope-S5P project

The main goal of Terrascope is to provide satellite products that are of added value to the user community in comparison with the operational product. For example, some Terrascope products are averaged over longer time-periods, offering reduced noise and removing data gaps caused by cloud cover. In 2021, BIRA-IASB and VITO released global daily, monthly, and yearly averaged Sentinel 5P/TROPOMI (S5P) Level 3 data (L3, gridded at 0.05° × 0.05°) of nitrogen dioxide (NO_2) and carbon monoxide (CO) in Terrascope, derived from the official S5P Level-2 (L2) data products.

The ESA PRODEX-sponsored project Terrascope-S5P aims at adding additional products, derived from S5P measurements, to Terrascope. For some of these products the derivation is relatively straightforward, whereas others require more effort or depend on the outcome of scientific research. Within Terrascope-S5P, a total of 5 new data products are foreseen to gradually be implemented in the Terrascope system until early 2024.
An overview of these products can be found below.

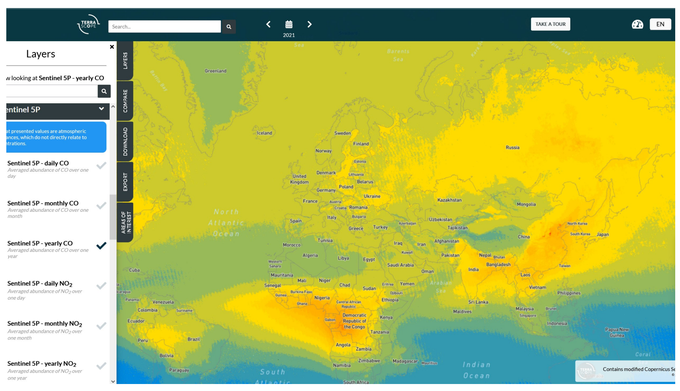

Figure 2 The Terrascope viewer, showing Sentinel 5P global carbon monoxide (CO)vertical column density, averaged over the year 2021.

New Sentinel-5P products in Terrascope (2022-2024)

Methane

Large, undetected methane leaks from (petro-chemical) industry can contribute significantly to the total atmospheric methane load and satellites such as S5P can play an important role in their detection (Pandey et al., 2019).
The operational S5P L2 methane product has a rather sparse coverage of quality-approved CH4 pixel values. Looking at aggregated L3 data (monthly or yearly) files makes it much easier to obtain a global picture of the distribution and emission sources of methane (see **Figure 3**). The S5P L3 Methane product is expected to be released in Terrascope by summer 2022.

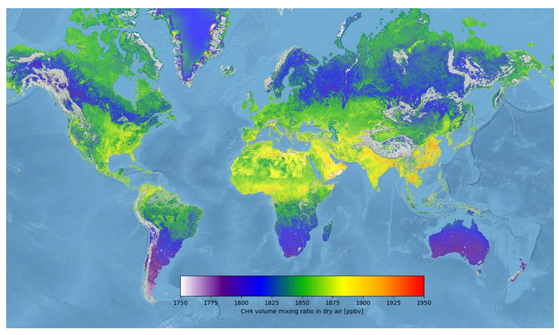

Figure 3 Gridded TROPOMI methane vertical column data, averaged over a 3-year period (2018-2020). By using time-aggregation, the distribution and sources of this important greenhouse gas are easier to recognize than for individual measurements.

NO_2 surface concentration over Belgium

For many users, the primary indicator when it comes to air-pollution is the near-surface concentration. Satellite retrieval products offer vertically integrated columns and complex steps are necessary for the interpretation of their implications at ground level. A surface concentration product derived from satellite data is therefore of high relevance, as it combines the quantity of interest with the large-scale daily coverage from satellite measurements. The development of such a product for Belgium is currently the subject of a PhD study at BIRA-IASB and is based on the development and use of a Machine Learning model. Once mature, it will be integrated in Terrascope.

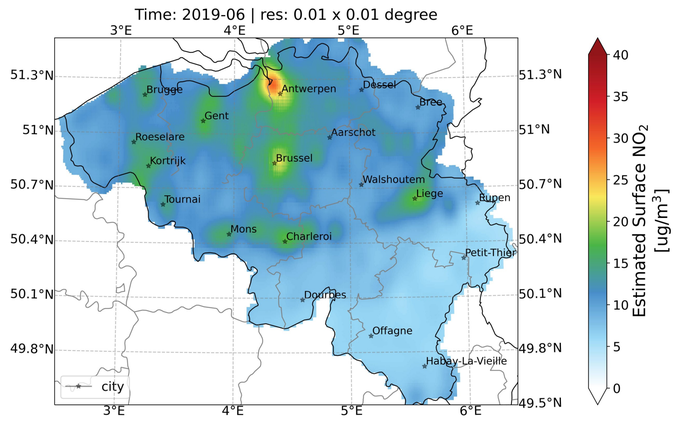

Figure 6 Average surface NO_2 concentrations (0.01° x 0.01°) during June 2019 in Belgium as predicted by a Machine Learning model. The result is the average of 720 time predictions (24 hours for 30 days). The model is composed of an Artificial Neural Networks (ANN) and Convolutional Neural Network (CNN). The model train and prediction are based on the datasets of Irceline ground NO_2 measurements, TROPOMI NO_2 observations, ERA-5 meteorological datasets, Belgian gridded emissions from European Environment Agency, JRC-GEOSTAT 2018 population, Shuttle Radar Topography Mission (SRTM) digital elevation, and CORINE Land Cover (CLC) inventory.

References

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Theys, N., Fioletov, V., Li, C., De Smedt, I., Lerot, C., McLinden, C., Krotkov, N., Griffin, D., Clarisse, L., Hedelt, P., Loyola, D., Wagner, T., Kumar, V., Innes, A., Ribas, R., Hendrick, F., Vlietinck, J., Brenot, H., and Van Roozendael, M.: A sulfur dioxide Covariance-Based Retrieval Algorithm (COBRA): application to TROPOMI reveals new emission sources, Atmos. Chem. Phys., 21, 16727–16744, https://doi.org/10.5194/acp-21-16727-2021, 2021.

Formaldehyde

The emissions of formaldehyde are less localised than those of NO_2, the sources are more diverse, and the satellite observations show a larger level of noise on individual pixels. Careful averaging is therefore needed to obtain meaningful information about emissions (**Figure 5**). BIRA-IASB experience in improving HCHO maps (through spatial oversampling, use of different spatial resolution for days/months, use of 3-day averages, seasonal averages, etc.) will be exploited for Terrascope. For example, in the special case of fire events, HCHO observations without cloud filtering are very useful to monitor the plumes and the intensity of the fires.
HCHO implementation in Terrascope is foreseen for fall 2022.

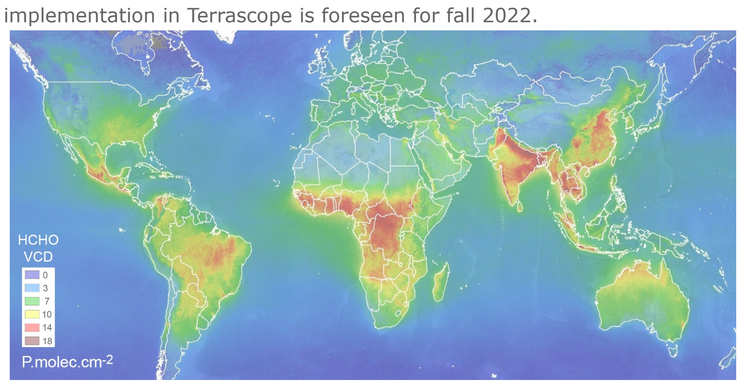

Figure 5 Gridded S5P/TROPOMI formaldehyde vertical column data, averaged over one year. The image shows a wide range of sources from natural origin (vegetation, fires) and from anthropogenic activity (traffic, industry).

COBRA SO_2

The official S5P total SO_2 product is derived with a DOAS retrieval scheme. This method suffers from biases and noise in regions with low SO_2 amounts. The covariance -based SO_2 retrieval scheme COBRA (Theys et al., 2021) has overcome these issues and allows for the detection of emission SO_2 sources as weak as 8 kt yr^{-1} (Theys et al., 2021). This makes the product highly relevant for source inventories and emission monitoring. The implementation of COBRA SO_2 in Terrascope is foreseen for end 2022.

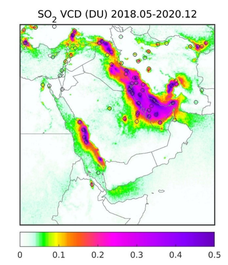

Figure 4 Example of COBRA SO_2 vertical column retrieval from S5P data. The black circles indicate point sources as detected by OMI. As can be seen in the figure, the S5P COBRA product reveals many additional point and area sources in the SO_2 signal.

Regional tropospheric NO_2 columns for the European domain

KNMI has developed an improved tropospheric NO_2 product for the European domain. In this approach, more reliable NO_2 columns are obtained using regional Copernicus Atmosphere Monitoring Service (CAMS) a priori data on a 0.1° × 0.1° spatial grid, as opposed to the 1° × 1° of the TM5-MP atmospheric model used in the operational NO_2 product. The final S5P L2 product is provided at the same spatial resolution as the operational products, but with enhanced accuracy over source regions (in particular urban areas). As such, the product is highly relevant for source detection and emission monitoring to serve, among others, policy makers.
Integration of L3 data, derived from this product, in Terrascope is likely to take place in the first half of 2023.

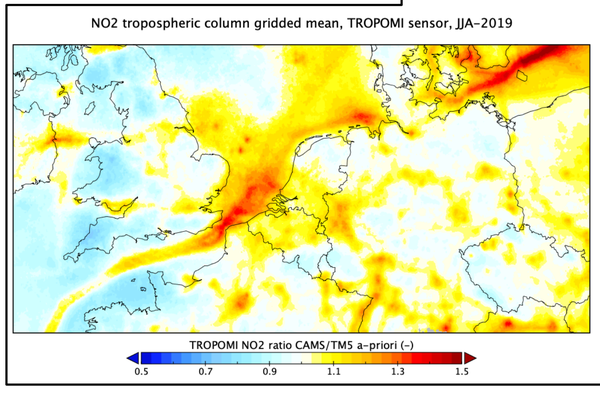

Figure 7 S5P/TROPOMI NO_2 tropospheric column ratio indicating the impact of using a-priori information from the CAMS regional model instead of the TM5 data as used in the operational S5P NO_2 retrieval.

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