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Exploration of Atmospheric Compositions by TROPOMI on Sentinel-5P

NASA/Goddard Earth Sciences Data and Information Services Center (GES DISC)

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Introduction

Since its launch in October 2017, the Sentinel-5 Precursor (Sentinel-5P, S5P) satellite, one of the European Commission's new Copernicus family – Sentinels, has continuously proven to be successful, enhanced, and upgraded compared to its predecessor missions. The sole payload on Sentinel-5P is the TROPOspheric Monitoring Instrument (TROPOMI), a nadir-viewing, 108° field-of-view push-broom grating hyperspectral spectrometer, covering the wavelengths of ultraviolet-visible (270 nm - 495 nm), near infrared (675 nm - 775 nm), and shortwave infrared (2305 nm - 2385 nm). Sentinel-5P is currently providing measurements of total column ozone, tropospheric nitrogen dioxide and formaldehyde, sulfur dioxide, methane, carbon monoxide, aerosol index, and cloud at very high spatial resolutions. Ozone vertical profile products are scheduled to become available in April 2020. In addition, S5P/TROPOMI spectral design provides the possibility of developing other atmospheric composition products such as bromine monoxide (BrO), aerosol optical depth, sun-induced fluorescence, and other products.

The NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) is one of the 12 Distributed Active Archive Centers (DAACs) within NASA's Earth Observing System Data and Information System (EOSDIS). The GES DISC archives and supports over a thousand data collections in the focus areas of Atmospheric Composition, Water & Energy Cycles, and Climate Variability. Under the End User License Agreement between NASA, the European Space Agency (ESA) and the European Commission (Copernicus Programme), GES DISC is curating S5P/TROPOMI Level-1B and Level-2 products, and providing information enhancement through advanced tools and services that offer convenient solutions for complex Earth science data and application needs. This presentation will demonstrate up-to-date TROPOMI products and their applications, as well as various efficient yet straightforward methods to access, visualize and subset TROPOMI data at the GES DISC.

Instrument Specification & Products

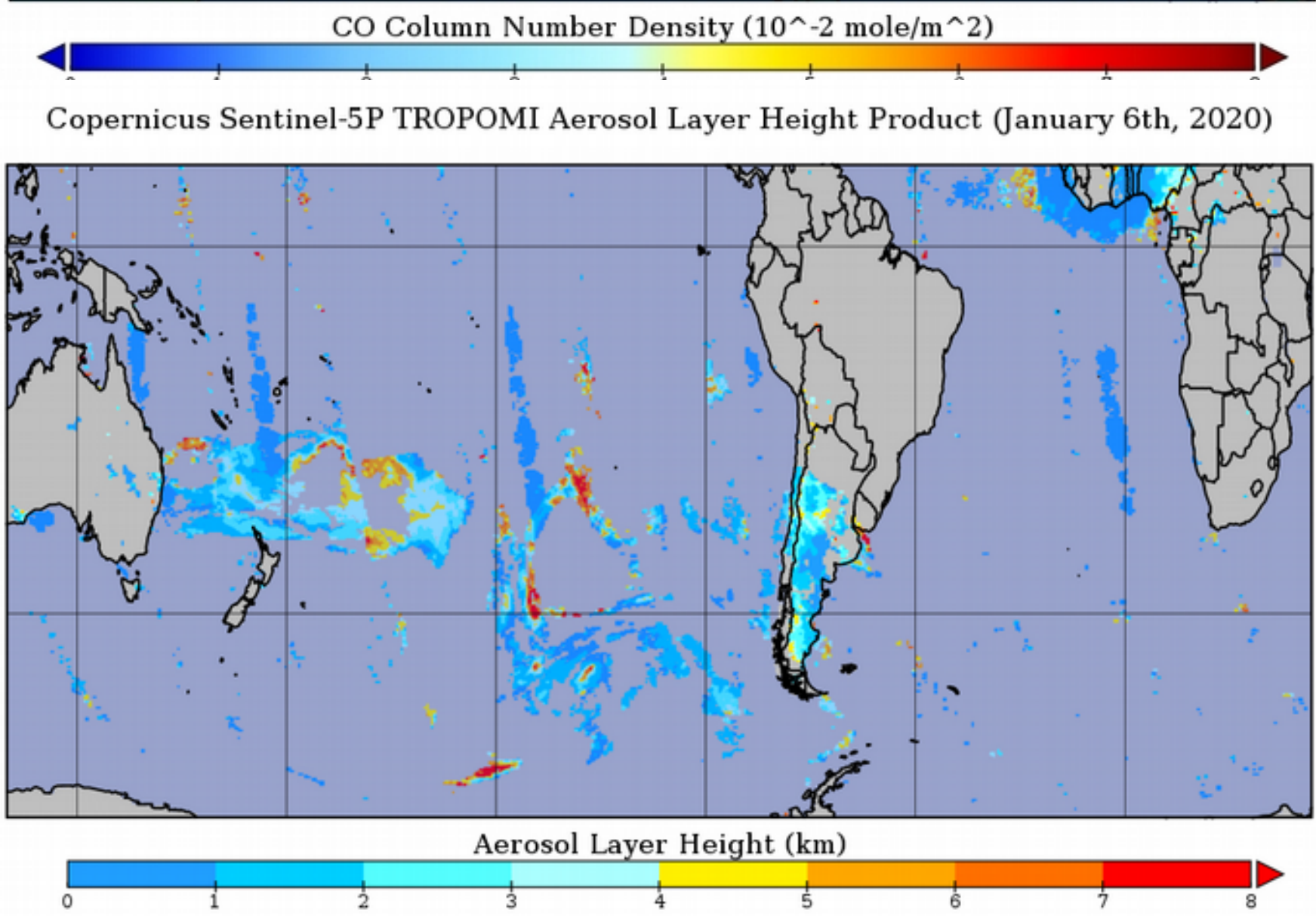
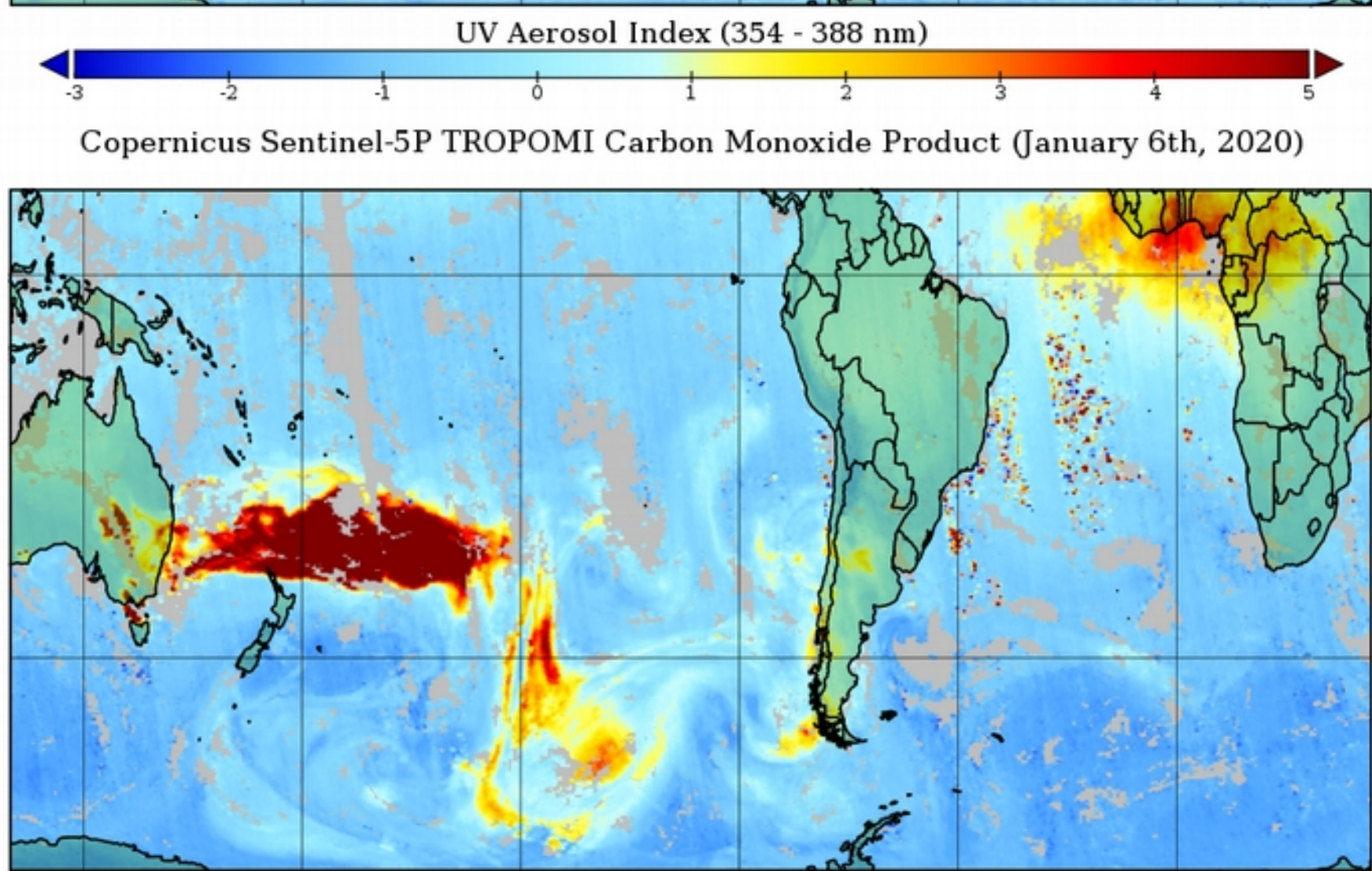
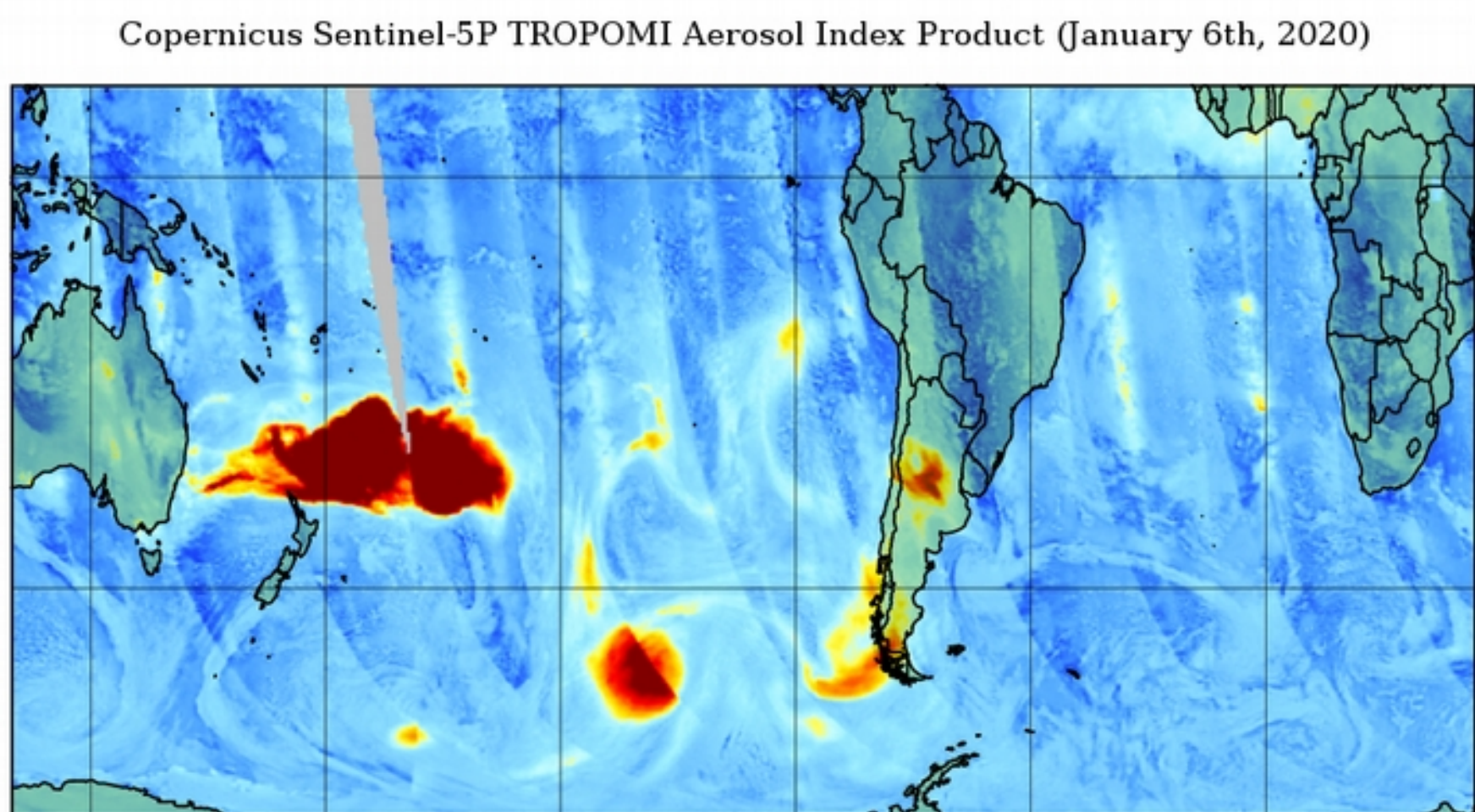
Table 1: Similar Instrument Specification Comparisons between Sentinel-5P TROPOMI, Aura OMI, and S-NPP OMPS

Satellite	Sentinel-5P	S-NPP			Aura
Sensor	TROPOMI	OMPS Nadir Mapper	OMPS Nadir Profiler	OMPS Limb Profiler	OMI
Spectrometer	Push-broom grating spectrometer 2D CCD	Push-broom grating spectrometer 2D CCD	Push-broom grating spectrometer 2D CCD	Prism spectrometer 2D CCD 3 vertical slits	Push-broom grating spectrometer 2D CCD
Spectral coverage	UV-VIS: 270-495 nm NIR: 675-775 nm SWIR: 2305-2385 nm	300 – 380 nm	250 – 310 nm	290 – 1000 nm	UV-1: 270-314 nm UV-2: 306-380 nm VIS: 350-500 nm
Spatial resolution	5.5 X 3.5 km near nadir	50 X 50 km at nadir	250 X 250 km	1 km reporting vertical resolution	13 X 24 km at nadir
Field-of-View	108° (2600 km)	110° (2800 km)	16.6°	1.95°	114° (2600 km)
Spectral resolution	0.23 – 0.5 nm	1.1 nm	1.1 nm	1 - 40 nm (2 pixels/FWHM)	1.0-0.45nm
Ascending node equator local crossing time	~13:30	~13:30	~13:30	~13:30	~13:45

Table 2: Current Ongoing Air Quality Products from Sentinel-5P TROPOMI, Aura OMI, and S-NPP OMPS

	S5P TROPOMI	S-NPP OMPS	Aura OMI
UV Aerosol Index	June 2018	November 2011	October 2004
Ozone Total Column	April 2018	November 2011	October 2004
Sulfur Dioxide	May 2018	January 2012	October 2004
Nitrogen Dioxide	April 2018	January 2012	October 2004
Formaldehyde	May 2018		October 2004
Cloud	April 2018	January 2012	October 2004
Carbon Monoxide	April 2018		
Methane	April 2018		
Tropospheric Ozone Column	April 2018		
Ozone Vertical Profile	Coming in 2020	November 2011 (NP) February 2012 (LP)	October 2004
UV Aerosol layer Height	April 2018		
Aerosol Extinction Vertical Profile		February 2012	
Aerosol Optical Depth			October 2004
Bromine Monoxide Total Column			October 2004
Chlorine Dioxide			October 2004
Surface UV Irradiance			October 2004
Merged cloud product	S-NPP VIIRS Cloud at TROPOMI band 3, 6, and 7		Aura OMI and Aqua MODIS merged cloud

Air Quality Applications



Smoke/Fire Applications:

The 2019-20 Australia biomass burning event was triggered by bushfires in Victoria and New South Wales in June 2019. The crisis peaked in December 2019 and January 2020, after these fires transformed into out-of-control forest fires, augmented by unusually hot weather and strong winds.

The left three figures demonstrate S5P TROPOMI UV Aerosol Index (top), carbon monoxide column number density (middle), and Aerosol Layer Height (bottom) on January 6, 2020, a few days after the most explosive fire activity injected smoke plumes into stratosphere.

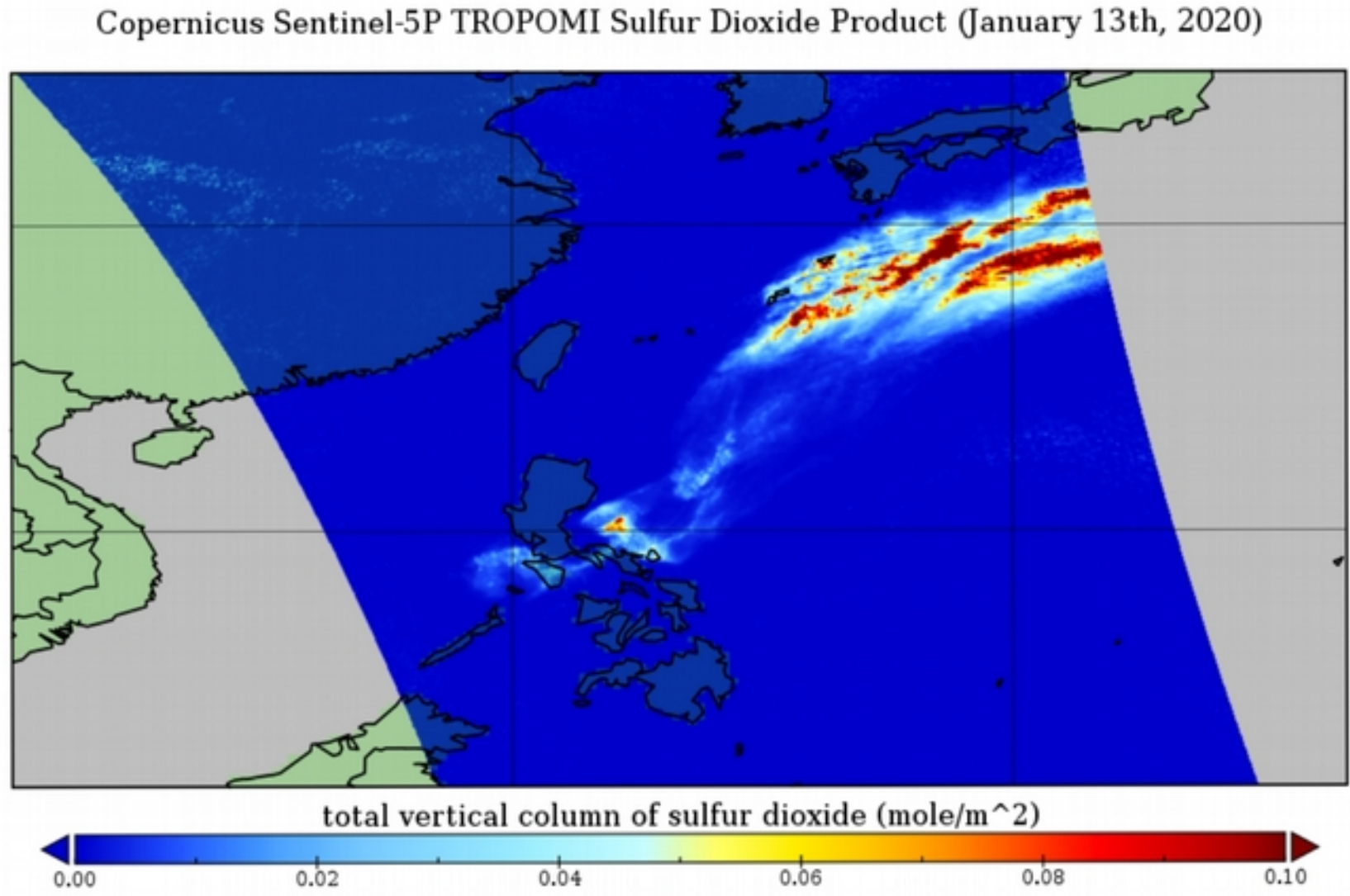
The amount of carbon monoxide released by the 2019-20 Australian fires could be three times more than the 2017 British Columbia fire and 2009 Australian fire, according to preliminary data from the Microwave Limb Sounder (MLS) on NASA's Aura satellite.

In this example, S5P TROPOMI demonstrates its capability to monitor widespread smoke pollution outbreaks in 3-D.

Volcanic Eruption Application:

Taal volcano is the second-most active volcano in the Philippines. On January 12, 2020, it started to erupt fine ash and volcanic gases. The strong eruption was accompanied by earthquakes, thunder, and lightning in the ash cloud.

The right figure displays S5P TROPOMI sulfur dioxide total column amount on January 13, 2020.



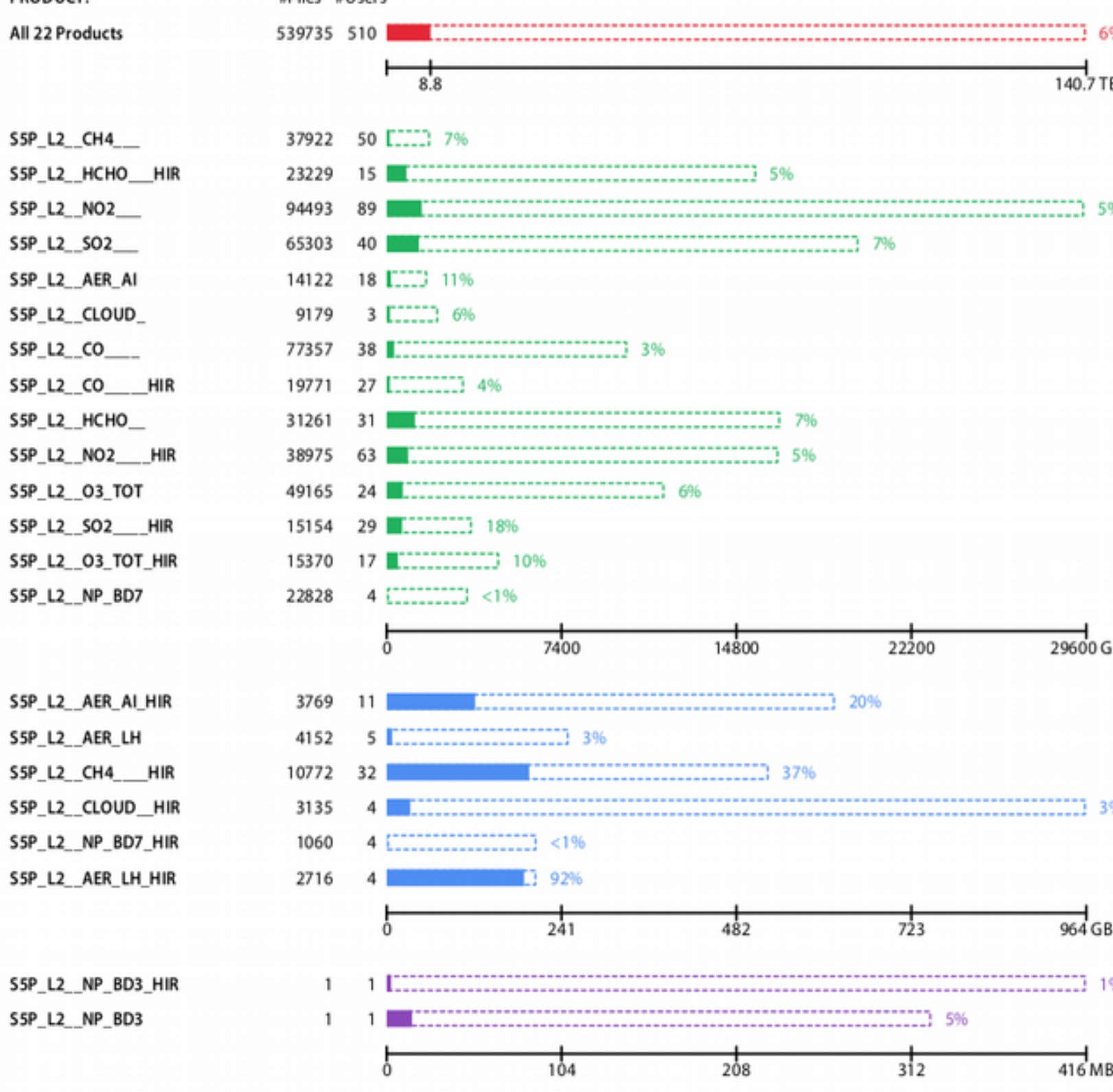
Summary and Future Work

- Copernicus Sentinel-5P TROPOMI is continuously showing excellent capabilities in space-based remote sensing of air quality with its exceptionally fine spatial resolution and data quality. Along with OMI on Aura and OMPS on both S-NPP and the JPSS series, more air quality applications may be explored.
- TROPOMI is likely to continue the legacy of Aura OMI trace gas measurements, such as bromine monoxide, chlorine dioxide, and SIF.

Acknowledgment: The authors acknowledge ESA Copernicus Programme for the S5P/TROPOMI products. Acknowledgment also goes to S-NPP/OMPS and Aura OMI L1B calibration/validation and L2 science teams for the science algorithms.

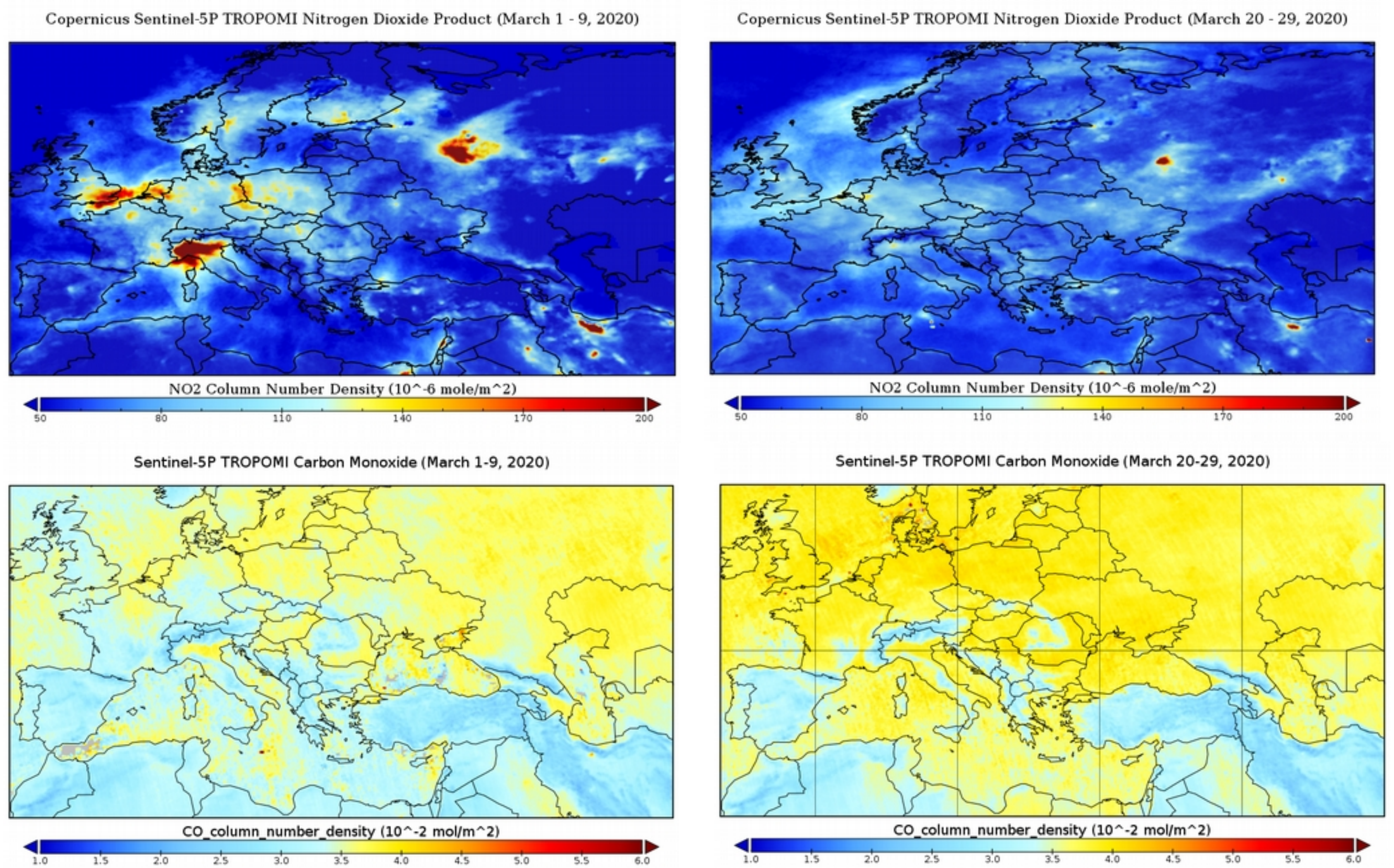
Tools & Services

- Search for the data via the NASA GES DISC home page (<https://disc.gsfc.nasa.gov>) using keywords “**s5p**” or “**tropomi**” to browse all the available products. This is the most direct and convenient way to find data.
- For each specific data collection, users are able to:
 - 1) See and download all the data files on GES DISC public data servers via HTTPS;
 - 2) Use Earthdata Search across multiple data centers;
 - 3) Search for specific regions and/or time periods by using the GES DISC search engine; and
 - 4) Utilize the options of the OPeNDAP protocol.
OPeNDAP is a Web-based data access tool for online data in Data Pools. Using OPeNDAP, users are able to view data field structures defined in the metadata. Users can also choose to download specific variable(s) in either netCDF-4 or ASCII format.
 - 5) Use the GES DISC Level-2 subsetter (L2S) which has the following capabilities:
 - ◆ Spatial subsetting in a lat/lon box, at a designated geographical point, or within a point-plus- radius circular region.
 - ◆ Dimensional and temporal subsetting
 - ◆ Variable selection



GES DISC L2S Efficiency:

- The L2S Service now supports S5P products, including 18 TROPOMI atmospheric composition measurements and 6 TROPOMI S-NPP VIIRS merged cloud products.
- This left figure shows data volumes that users have downloaded via the L2S vehicle (solid bar) compared to the estimated HTTPS volumes (dashed bar). The average efficiency of the L2S tool is approximately 94% in data volume reduction.



Human Activity Application:

Human activities are one of the key factors influencing Earth's environment and atmospheric air quality. Starting early this year, Sentinel-5P TROPOMI measurements have been utilized by researchers to monitor the effects of varying degrees of “lockdown” currently happening in many countries worldwide. The top figures are TROPOMI tropospheric NO₂ vertical column amount in March 1-9 and March 20-29, 2020. The bottom two figures are corresponding carbon monoxide (CO) vertical total column amount. While tropospheric NO₂ amount dropped markedly from early March to late March, the CO in the atmosphere actually increased slightly.