



Measurement of Pollution in the Troposphere (MOPITT) Dataset

02-04 OCT, 2020
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CSA STAFF ARE
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canadienne

Canadian Space
Agency

Canada





NASA's EARTH OBSERVING SYSTEM



The Earth Observing System (EOS)

- A series of coordinated polar-orbiting satellites
- Designed to monitor and understand key components of the climate system and their interactions
- EOS missions focus on the following climate science areas: atmospheric composition; carbon cycle, ecosystems and biochemistry; climate variability and change; water and energy cycles; weather; and Earth surface and interior

TERRA

- Studies the interactions among the Earth's atmosphere, lands, oceans, and radiant energy (heat and light).
- 5 instruments: ASTER, CERES, MISR, MODIS, MOPITT
- Launched: December 1999
- Mission Lifetime: 6 years
- Cost: \$1.3 billion (spacecraft, US instruments, launch vehicle) – does not include ground system, ASTER and MOPITT

AQUA

- Studies the Earth's water cycle (evaporation, water vapour, clouds, precipitation, soil moisture, sea ice, land ice and snow cover).
- 6 instruments: AIRS, AMSU-A, HSB, AMSR-E, MODIS, CERES
- Launched: May 2002
- Mission Lifetime: 6 years
- Cost: \$952 million (development and launch)

AURA

- Studies the Earth's ozone, air quality and climate; conducts research about the composition, chemistry and dynamics of the Earth's atmosphere.
- 4 instruments: HIRDLS, MLS, OMI, TES
- Launched: July 2004
- Mission Lifetime: 6 years
- Cost: \$785 million (development and launch vehicle)





Instruments onboard the Terra Spacecraft



ASTER

- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER);
- Provides high-spatial-resolution multispectral images of Earth's surface and clouds to better understand the physical processes that affect climate change;
- ASTER is the only high spatial resolution instrument on the Terra platform;
- ASTER data is used to help people anticipate and prepare for natural disasters.



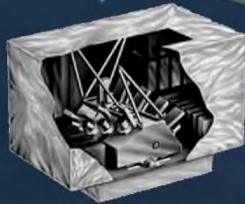
CERES

- Clouds and the Earth's Radiant Energy System (CERES);
- Collects information about Earth's radiative balance and provides cloud property estimates that enable scientists to assess clouds' roles in radiative fluxes from the surface to the top of the atmosphere;
- CERES data is critical for improving climate models to better prepare for future changes in climate.



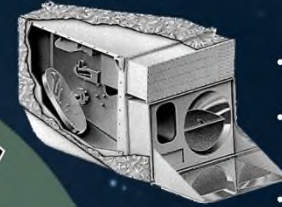
MISR

- Multi-angle Imaging SpectroRadiometer (MISR);
- Provides multiple-angle, continuous-sunlight coverage of Earth with moderately high spatial resolution;
- MISR can distinguish different types of clouds, aerosol particles, and surfaces, and its data helps track volcanic ash and smoke as well as unsafe air quality.



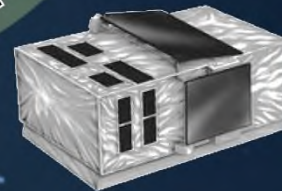
MODIS

- Moderate Resolution Imaging Spectroradiometer (MODIS);
- Provides daily, global observations of biological and physical parameters on and near land and ocean surfaces in the atmosphere;
- Tracks a wider array of Earth's vital signs than any other Terra sensor;
- MODIS monitors large-scale changes in the biosphere such as photosynthetic activity of plants, extent of ice and snow, natural disasters;
- MODIS can detect abnormal hot spots (publishes annual hottest spot on Earth), find active fires and track unsafe air quality so people can take precautions.



MOPITT

- Measurements of Pollution in the Troposphere (MOPITT);
- Collects information of carbon monoxide (CO) distribution, transport, sources and sinks in the atmosphere;
- MOPITT measurements help track unsafe air quality and monitor fires while they are burning as well as their global effects long after they have extinguished;
- MOPITT is the first satellite sensor to use gas correlation spectroscopy.





MOPITT Instrument : Measurements of Pollution in the Troposphere

onboard the NASA Terra satellite



OBJECTIVE : *MONITOR EARTH'S CLIMATE*

To measure the profile and total column concentrations of tropospheric carbon monoxide (CO).

SATELLITE : *705 KM ALTITUDE*

Terra: NASA Earth Observing System Flagship
 Contractor: Lockheed Martin Missiles and Space
 Launch: 18 December 1999
 Location: Vandenberg AFB, California
 Altitude: 705km
 Inclination: 98.21°
 Orbit: Sun-synchronous, near-polar
 Size: 2.7 m x 3.3 m x 6.8 m
 Mass: 5,190 kg
 Power: 2,530 W

INSTRUMENT : *22 KM RESOLUTION*

Contractor: COM DEV
 Dimensions: 115 cm x 105 cm x 71 cm
 Mass: 192 kg
 Power: 250-260 W
 Duty Cycle: 100%
 Data Rate: 28 kbps

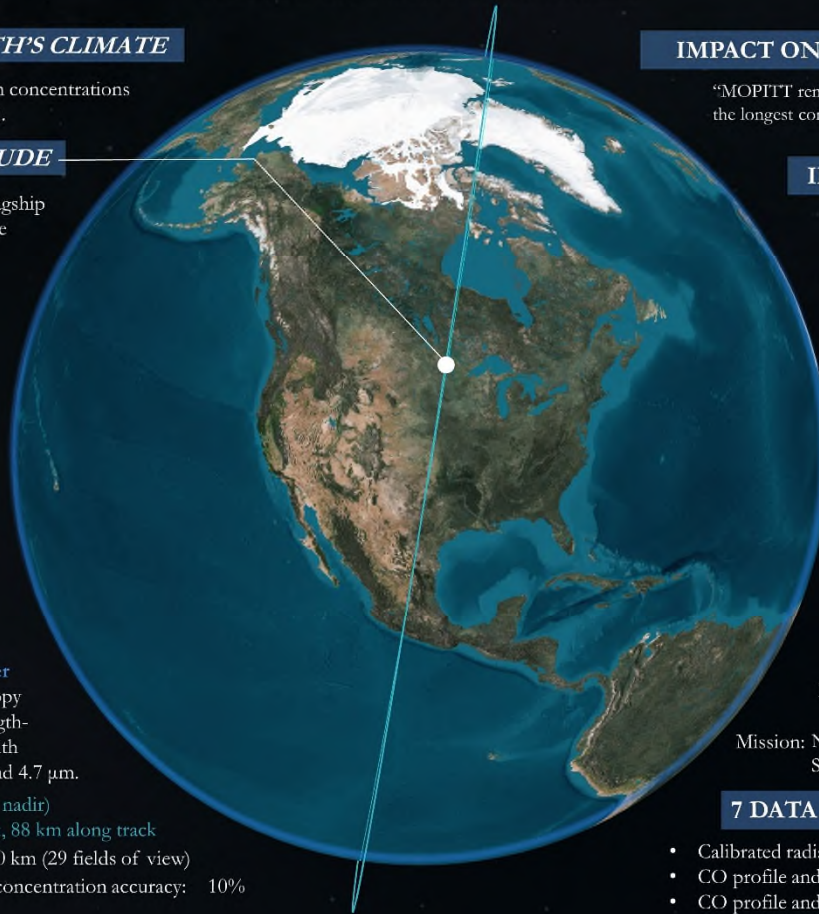
Instrument type: *8-Channel radiometer*

Spectral range: Correlation spectroscopy with pressure- and length-modulated gas cells, with detectors at 2.3, 2.4, and 4.7 μm .

Spatial resolution (each pixel): 22 km x 22 km (at nadir)
 Instantaneous Field of View: 22 km across track, 88 km along track

Swath: 640 km (29 fields of view)

CO concentration accuracy: 10%



IMPACT ON SCIENCE : *LONGEST RUNNING*

"MOPITT remains the longest-running pollution monitor in space today. It is the longest continuously-operating space mission in Canadian history."

- MOPITT Instrument Operations Team

IMPACT ON CANADA : *CLIMATE CHANGE*

"ECCC requires MOPITT observations to inform research that supports the delivery of its mandate to protect and improve Canada's air quality and improve understanding of the climate system."

- ECCC ADM, October 2019

IMPACT ON EARTH OBSERVATION

"MOPITT, the first instrument designed to observe the distribution and transport of tropospheric carbon monoxide, ...help[s] advance our understanding of air quality and biomass burning emissions. The merit of the Terra team goes beyond data acquisition. Terra is arguably one of the most successful Earth sensing satellites ever deployed."

- Jim Bridenstine, NASA Administrator, October 2019

- David Bernhardt, Secretary, US Department of the Interior

OPERATIONS : *20 YEARS*

Spacecraft: National Aeronautics and Space Administration (NASA)

Instrument: University of Toronto

Data production: National Center for Atmospheric Research (NCAR)

Mission: National Aeronautics and Space Administration (NASA), Canadian Space Agency (CSA), Japan Aerospace Exploration Agency (JAXA)

7 DATA PRODUCTS

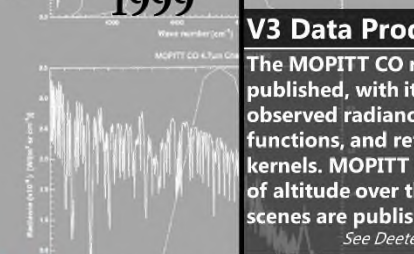
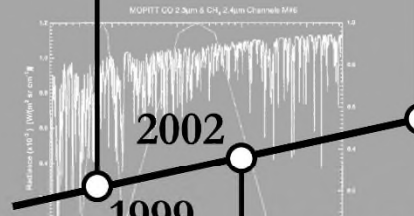
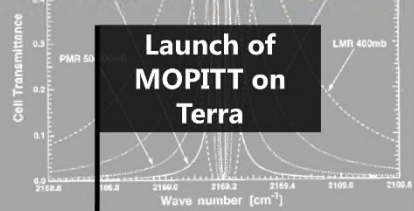
- Calibrated radiances and geolocations
- CO profile and total column (TIR, NIR, TIR/NIR)
- CO profile and total column
 - daily and monthly-mean (TIR, NIR, TIR/NIR)



20 YEARS OF MOPITT DATA PRODUCTS



Launch of MOPITT on Terra



V4 Data Product Release

Performance of the CO product is improved under both clean and polluted atmospheric conditions. Dataset biases are less than 1% at the surface and up to 6% through the atmosphere.

See Deeter et al., JGR, v115, D07306, 2010.

V6 Data Product Release

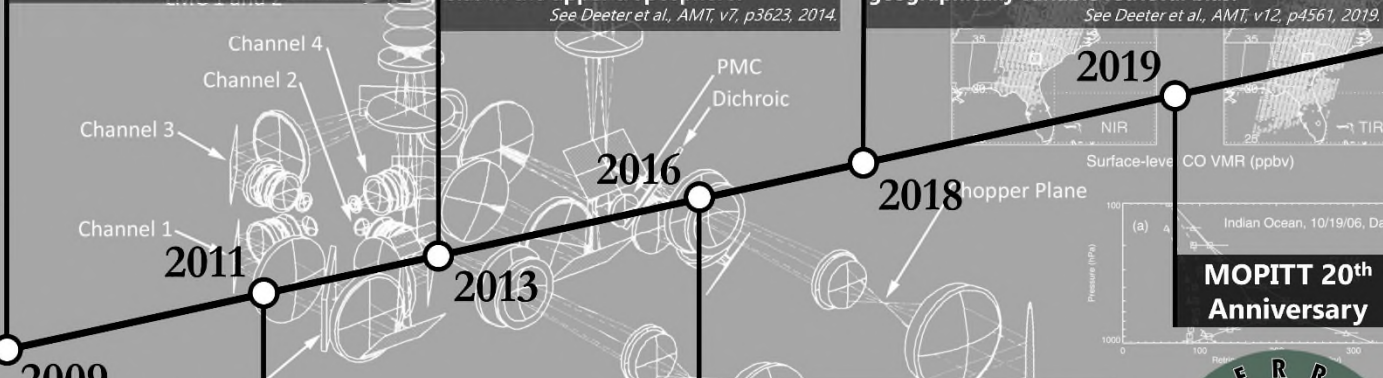
Improvements in this dataset include removing geolocation bias, using CAM-Chem as the source of a priori CO concentrations, using MERRA as the source for meteorological fields, and reducing a latitude-dependent retrieval bias in the upper troposphere.

See Deeter et al., AMT, v7, p3623, 2014.

V8 Data Product Release

The MOPITT v8 data product benefits from updated spectroscopic data for water vapour and nitrogen, and implements a new method to minimize retrieval biases through radiance bias correction. Validation results illustrate clear improvements in long-term bias drift and geographically variable retrieval bias.

See Deeter et al., AMT, v12, p4561, 2019.



V3 Data Product Release

The MOPITT CO retrieval algorithm is published, with its theoretical basis, observed radiances, weighting functions, and retrieving averaging kernels. MOPITT profiles as a function of altitude over three tropical oceanic scenes are published.

See Deeter et al., JGR, v108, p4399, 2003.

V5 Data Product Release

First satellite data product to use multispectral measurements (NIR and TIR) simultaneously to enhance retrieval sensitivity in the lower troposphere. A new method is implemented to calculate radiance uncertainties. The retrieval biases are on the order of a few percent.

See Deeter et al., JGR, v117, D13306, 2012.

V7 Data Product Release

This version of the MOPITT dataset includes enhancements in N₂O representation, usage of meteorological fields from MERRA-2, usage of the updated MODIS cloud mask, improvements in radiance biases, and a better method to calibrate NIR radiances. Clear improvements are demonstrated in overall retrieval biases, bias variability, and bias drift uncertainty.

See Deeter et al., AMT, v10, p2533, 2017.

2019

Surface-level CO VMR (ppbv)

Chopper Plane

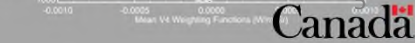
MOPITT 20th Anniversary



NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH



Canadian Space Agency / Agence spatiale canadienne





CSV Files

An example python code to read and visualize the csv data files is provided:

MOPITData_ReaderAndVisualization.py

Downloading the csv Files

- Select desired year/month/day from :

ftp://ftp.asc-csa.gc.ca/users/OpenData_DonneesOuvertes/pub/MOPITT/

Index of /users/OpenData_DonneesOuvertes/pub

[parent directory]

Name	Size	Date Modified
2019/		5/27/20, 11:17:00 AM
2020/		5/27/20, 11:18:00 AM
MOPITData_FileConverter.py	3.6 kB	5/26/20, 7:04:00 AM
MOPITData_ReaderAndVisualization.py	2.4 kB	5/26/20, 7:04:00 AM
readme.txt	6.3 kB	5/26/20, 7:04:00 AM



Index of /users/OpenData_DonneesOuvertes/pub/MOPITTData

[parent directory]

Name	Size	Date Modified
April-April 2020/		5/27/20, 11:05:00 AM
March-Mars 2020/		5/27/20, 11:05:00 AM



Index of /users/OpenData_DonneesOuvertes/pub/MOPITTData/March-Mars 2020/

[parent directory]

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MOP02J-20200305-L2V18.0.3.csv	26.5 MB	5/26/20, 7:13:00 AM
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MOP02J-20200320-L2V18.0.3.csv	27.8 MB	5/26/20, 7:10:00 AM
MOP02J-20200321-L2V18.0.3.csv	27.2 MB	5/26/20, 7:10:00 AM
MOP02J-20200322-L2V18.0.3.csv	26.9 MB	5/26/20, 7:10:00 AM

MOPITT Data in the .csv Files

Latitude	Longitude	COTotalColumn	COMixingRatio	RetrievedSurface Temperature
1 column for the latitude of pixel location in degrees [deg]	1 column for the longitude of pixel location in degrees [deg]	1 column for the measured CO levels on the total atmospheric column in molecules per cm ² [mol/cm ²]	10 columns for the CO Mixing Ratio in parts per billion by volume [ppbv], for 10 pressure profiles: <ul style="list-style-type: none">- 1000 hPa (surface)- 900 hPa- 800 hPa- 700 hPa- 600 hPa- 500 hPa- 400 hPa- 300 hPa- 200 hPa- 100 hPa	1 column for the temperature measurements at the surface in Kelvins [K].

Python Code Provided to Read and Visualize .csv Files

MOPITTDData_ReaderAndVisualization.py

```
37 import os
38 import matplotlib as mpl
39 import matplotlib.pyplot as plt
40 from mpl_toolkits.basemap import Basemap
41 import numpy as np
42
43 #Nom du fichier csv à lire / Name of the csv file to read
44 FILE_NAME = 'MOP02J-20200322-L2V18.0.3.csv'
45
46 #lecture des données / Read data
47 data = np.loadtxt(FILE_NAME,delimiter=',',skiprows=0).T
48
49 lat,long = data[0:2] #Latitude + Longitude
50 COTotalColumn = data[2] #CO total
51 COMR_Surface = data[3] #CO Mixing Ratio Surface
52 COMR_Profile = data[4:-1] #CO Mixing Ratio profile (900hPa-100hPa)
53 RetrievedSurfaceTemperature = data[-1] #Retrieved Surface Temperature
54
55 # VISUALISATION GRAPHIQUE DE LA COLONNE TOTALE DU CO SUR CARTE DU MONDE BASEMAP
56 # DATA VISUALIZATION OF CO TOTAL COLUMN ON WORLD MAP USING BASEMAP
57 m = Basemap(projection='cyl', resolution='L',
58             llcrnrlat=-90, urcrnrlat=90,
59             llcrnrlon=-180, urcrnrlon=180)
60 m.drawcoastlines(linewidth=0.5)
61 m.drawparallels(np.arange(-90, 91, 45))
62 m.drawmeridians(np.arange(-180, 180, 45), labels=[True,False,False,True])
63 sc = m.scatter(long, lat, c=COTotalColumn, s=1, cmap=plt.cm.jet,
64               edgecolors=None, linewidth=0)
65 cb = m.colorbar()
66 cb.set_label('mol/cm^2') #Unités, voir readme.txt / Units, see readme.txt
67
```





Original HDF-EOS files

A python code to read and convert the HDF-EOS data files is provided:

MOPITData_FileConverter.py



3 Levels of data !

- **Levels 0 and 1:** Engineering, science, and table data, as well as calibrated radiances (no scientific usefulness as it is used to process into level 2 data).
- **Level 2:** Derived Carbon Monoxide profiles at original MOPITT pixel resolution (22km by 22km)
- **Level 3:** Carbon Monoxide gridded data, averaged by days or months, with spatial resolution of 1deg by 1deg



3 types of data available

- **TIR** : Thermal Infrared Radiances
 - Better measurement quality for Tropospheric studies.
- **NIR** : Near Infrared Radiances
 - Better measurement quality for surface data.
- **J** : Joint products (TIR + NIR) *
 - Used to study the entire atmospheric profile (including the surface)

*The csv files contains Joint products (J) data.

Downloading original HDF-EOS files

- Select desired dataset from : https://eosweb.larc.nasa.gov/project/mopitt/mopitt_table

MOPITT Data and Information



Measurements Of Pollution In The Troposphere ([MOPITT](#)) was successfully launched into sun-synchronous polar orbit aboard Terra, NASA's first Earth Observing System spacecraft on December 18, 1999. The MOPITT instrument was constructed by a consortium of Canadian companies and funded by the Space Science Division of the Canadian Space Agency.

MOPITT measurements yield atmospheric profiles of CO volume mixing ratio and CO total column values using near-infrared radiation at 2.3 μm and thermal-infrared radiation at 4.7 μm . There are no current plans to release a MOPITT methane product.

MOP02, MOP03 & MOP03M Version 3, 4, 5, 6 and 7 / 107 products are available by request only. Please contact [User Services](#).

[Level 3](#) [Level 2](#) [Level 1](#) [Level 0](#) [Documentation](#)

Level Description: Derived Carbon Monoxide profiles

1 2

next » last »

Products	Temporal Resolution	Spatial Resolution	Temporal Coverage
MOP02J.007 MOPITT Derived CO (Near and Thermal Infrared Radiances) ⓘ	Observations every 0.4 seconds.	Swath 22km pixels	03/03/2000 - 02/17/2016
MOP02J.008 MOPITT Derived CO (Near and Thermal Infrared Radiances) V008 ⓘ	Observations every 0.4 seconds.	Swath 22km pixels	03/03/2000 - 03/11/2018
MOP02J.107 MOPITT Beta Derived CO (Near and Thermal Infrared Radiances) V107 ⓘ	Observations every 0.4 seconds.	Swath 22km pixels	03/06/2016 - 11/29/2018

Downloading original HDF-EOS files

- Select FTP Access : https://eosweb.larc.nasa.gov/project/mopitt/mop02j_v008

Home » MOPITT » MOPITT Level 2 » MOP02J.008

MOP02J_V008

MOPITT Derived CO (Near and Thermal Infrared Radiances) V008

Project Title:	MOPITT	Earthdata Search:	Order Data
Discipline:	Tropospheric Composition	Subset Data:	MOPITT Order Tool
Version:	V8	Quality Summary:	MOPITT V8 L2 DQS
Level:	L2	DOI:	10.5067/TERRA/MOPITT/MOP02J_L2.008
Platform:	Terra Satellite		Click here for more information on citing ASDC data.
Instrument:	MOPITT		
Spatial Coverage:	(-65, 65)(-180,180)		
Spatial Resolution:	Swath 22km pixels		
Temporal Coverage:	03/03/2000 - 03/11/2018		
Temporal Resolution:	Observations every 0.4 seconds.		
File Format:	HDF-EOS5		

[Parameters](#) [Order Data](#) [Documentation](#)

Search and Order: [Earthdata Search](#)

OPeNDAP Access: [OPeNDAP](#)

FTP Access: [Data Pool](#) ←

Subset Data: [MOPITT Order Tool](#)




Near Real Time: [Worldview](#)

Downloading original HDF-EOS files

- Select desired day and download .he5 file
<ftp://l5ftl01.larc.nasa.gov/MOPITT/MOP02J.008>

Index de /MOPITT/MOP02J.008

 [répertoire parent][i.e. parent directory]

	Nom	Taille	Date de modification	i.e. Name / Size / Modification date
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	2000.03.04/		14/11/2018 19:00:00	
	2000.03.06/		14/11/2018 19:00:00	
	2000.03.24/		14/11/2018 19:00:00	
	2000.03.25/		14/11/2018 19:00:00	
	2000.03.26/		14/11/2018 19:00:00	
	2000.03.27/		14/11/2018 19:00:00	
	2000.03.28/		14/11/2018 19:00:00	
	2000.03.29/		14/11/2018 19:00:00	
	2000.03.30/		14/11/2018 19:00:00	
	2000.03.31/		14/11/2018 19:00:00	
	2000.04.01/		14/11/2018 19:00:00	

Python Code Provided to Read and Convert HDF-EOS to .csv

MOPITTDData_FileConverter.py

```
30 import os
31 import re
32 import h5py
33 import numpy as np
34
35 #Nom du fichier HDF à lire / Name of the HDF file to read
36 FILE_NAME = 'MOP02J-20200322-L2V18.0.3.he5'
37
38 ▼ with h5py.File(FILE_NAME, mode='r') as f:
39     #Lecture des données hdf / reading hdf data
40     #Pour voir toutes les variables disponibles / to see all available data :
41     # print(f['/HDFEOS/SWATHS/MOP02/Data Fields'].keys())
42     group = f['/HDFEOS/SWATHS/MOP02/Data Fields'] #location of data
43
44     #RetrievedCOTotalColumn
45     dsname1 = 'RetrievedCOTotalColumn'
46     data1 = group[dsname1][:].T
47     units1 = group[dsname1].attrs['units'].decode() #Units
48     fillvalue1 = group[dsname1].attrs['_FillValue']
49     data1[data1 == fillvalue1] = np.nan
50
51     #RetrievedCOMixingRatioProfile
52     dsname2 = 'RetrievedCOSurfaceMixingRatio'
53     data2 = group[dsname2][:].T
54     units2 = group[dsname2].attrs['units'].decode() #Units
55     fillvalue2 = group[dsname2].attrs['_FillValue']
56     data2[data2 == fillvalue2] = np.nan
57
58     #RetrievedCOSurfaceMixingRatio
```



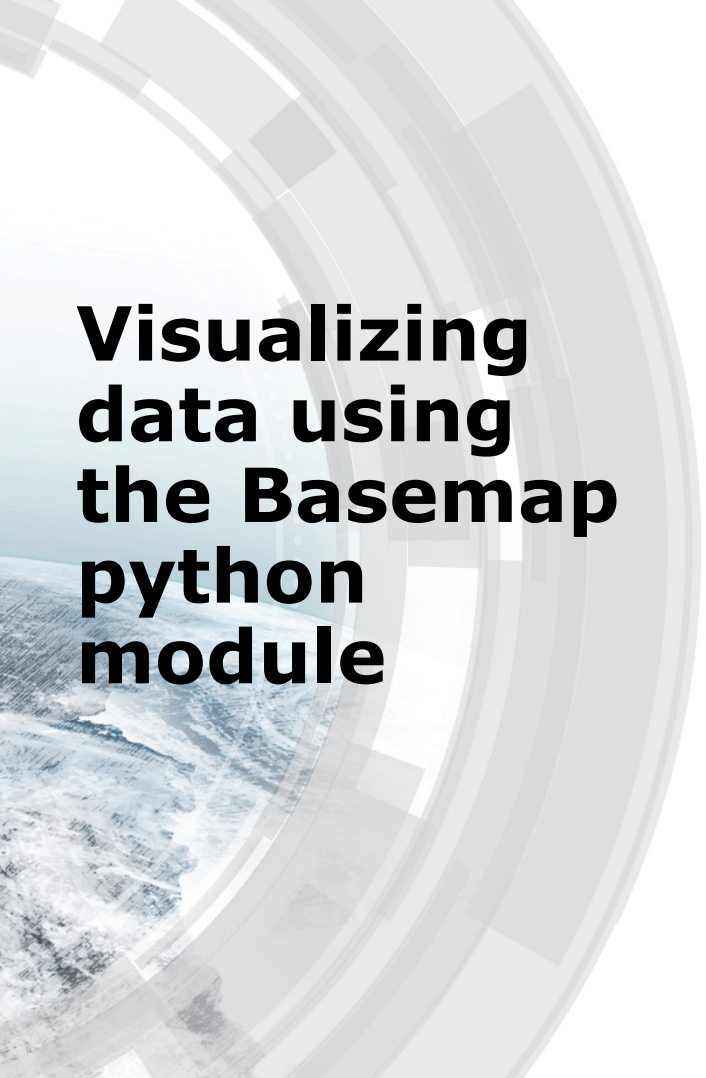


Data Visualization

An example python code to read and visualize the csv data files is provided:*


MOPITData_ReaderAndVisualization.py

* See earlier slide



Visualizing data using the Basemap python module

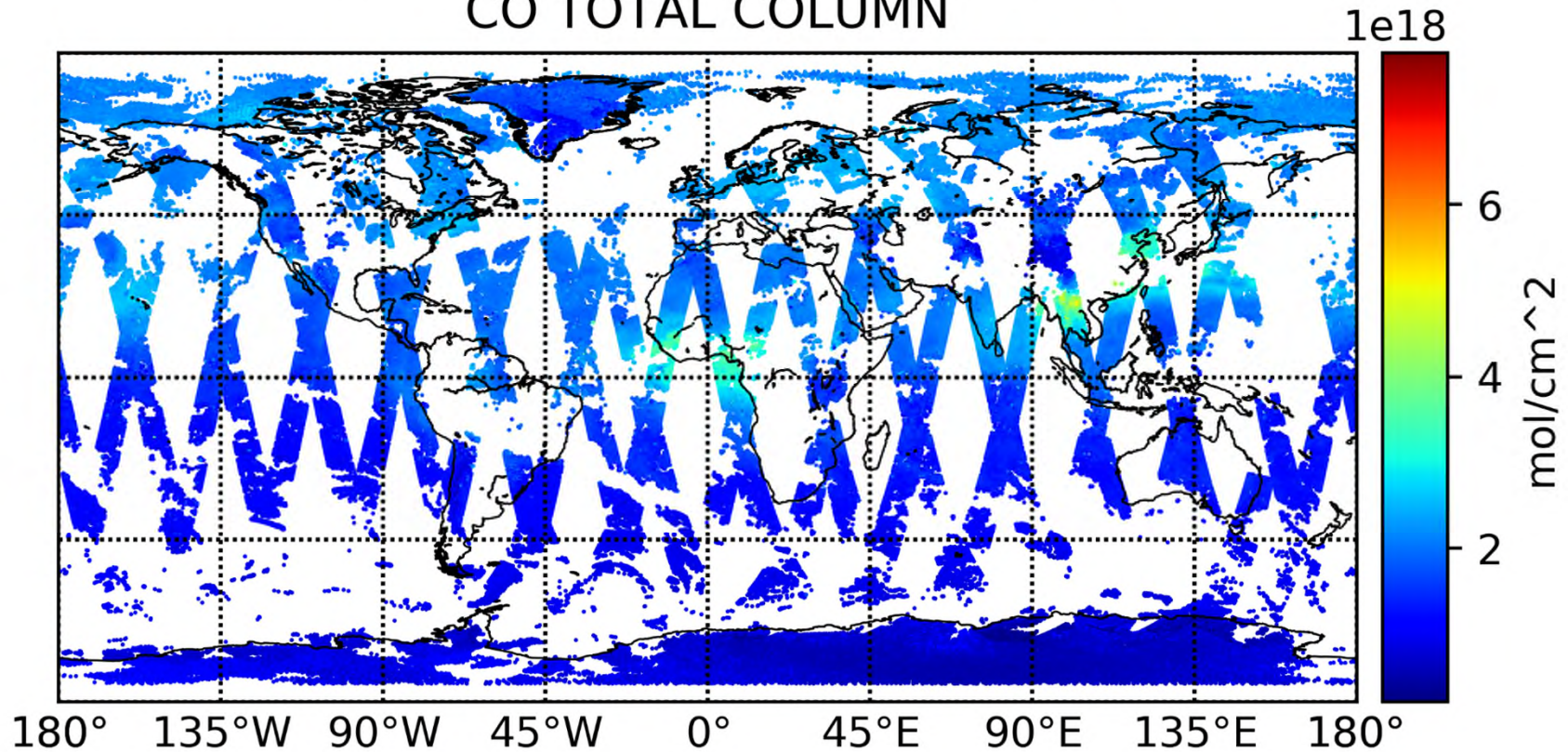
- Basemap is a module from the Matplotlib python library :
<https://matplotlib.org/basemap/>
- Basemap creates a basic world map for you
- You can use satellite images to enhance your visualization if you want !



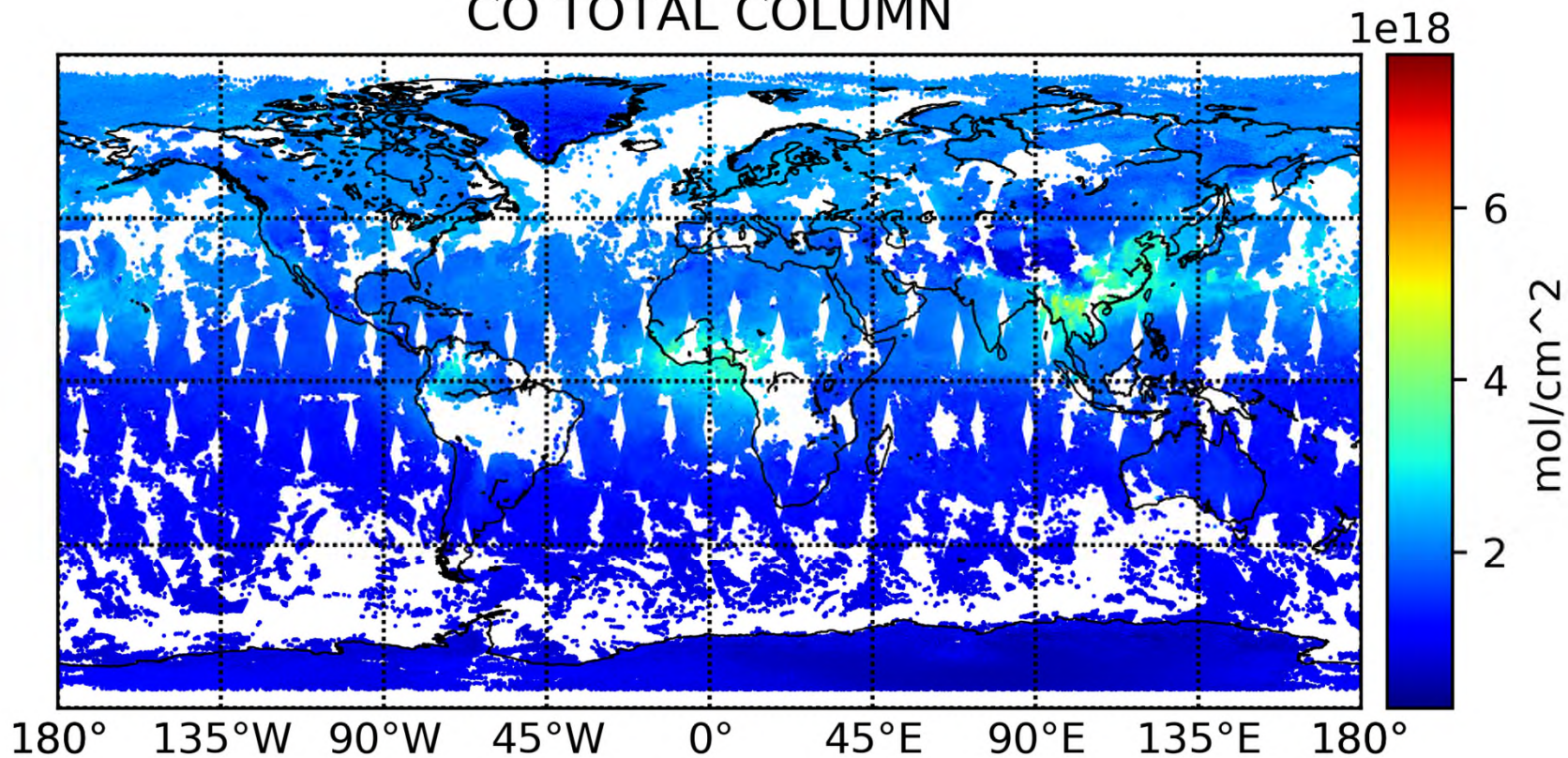
Data visualization examples

- The NASA Terra satellite takes about 3-4 days to acquire data for the whole globe.
- What follows are 4 examples of the measured CO total column levels over 1, 3, 5 and 8 days. A profile measurement is also provided.
- Data is taken from the period between March 15th, 2020 and March 22nd, 2020.

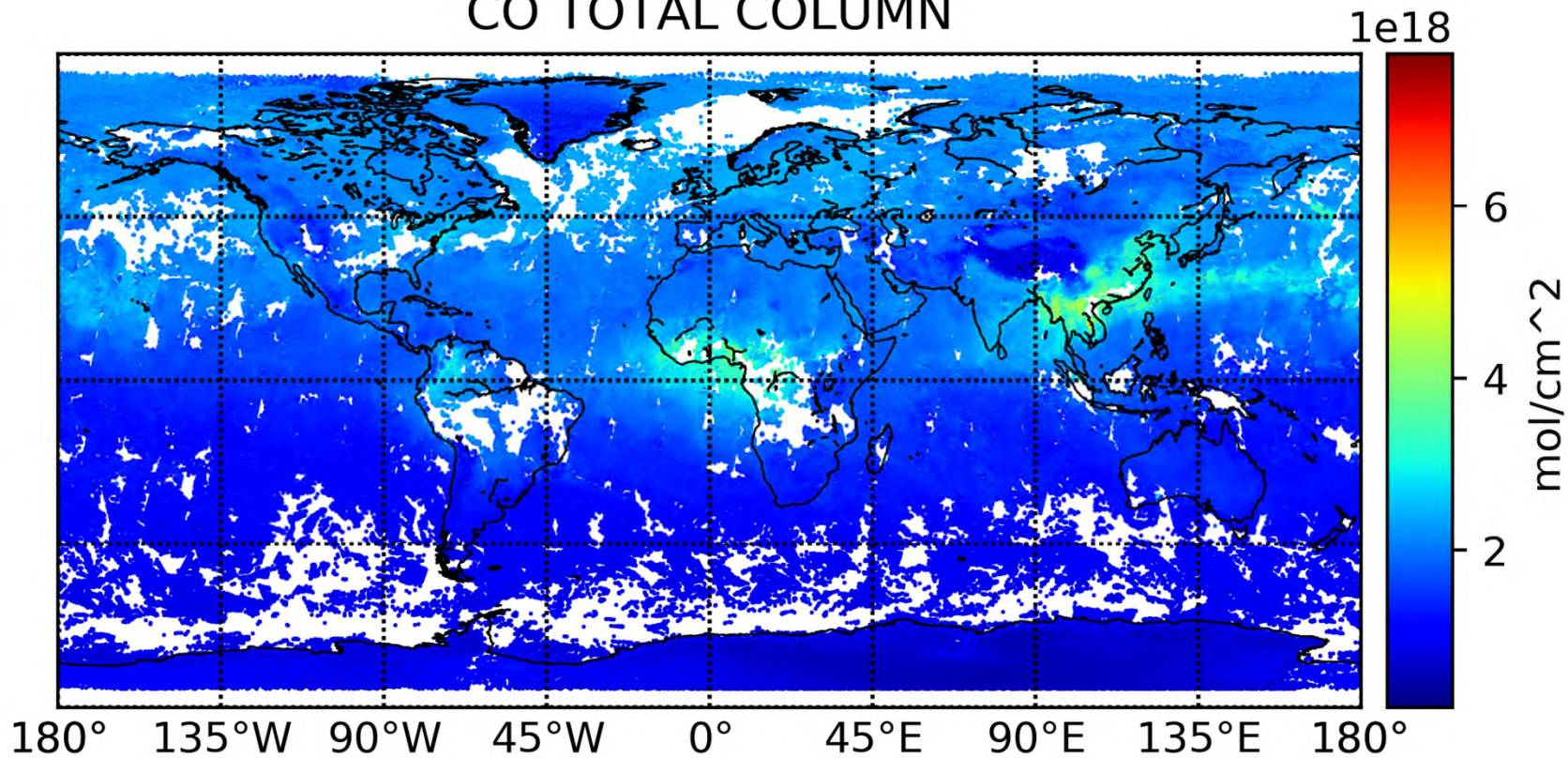
MOP02J-20200322-L2V18.0.3.csv
CO TOTAL COLUMN



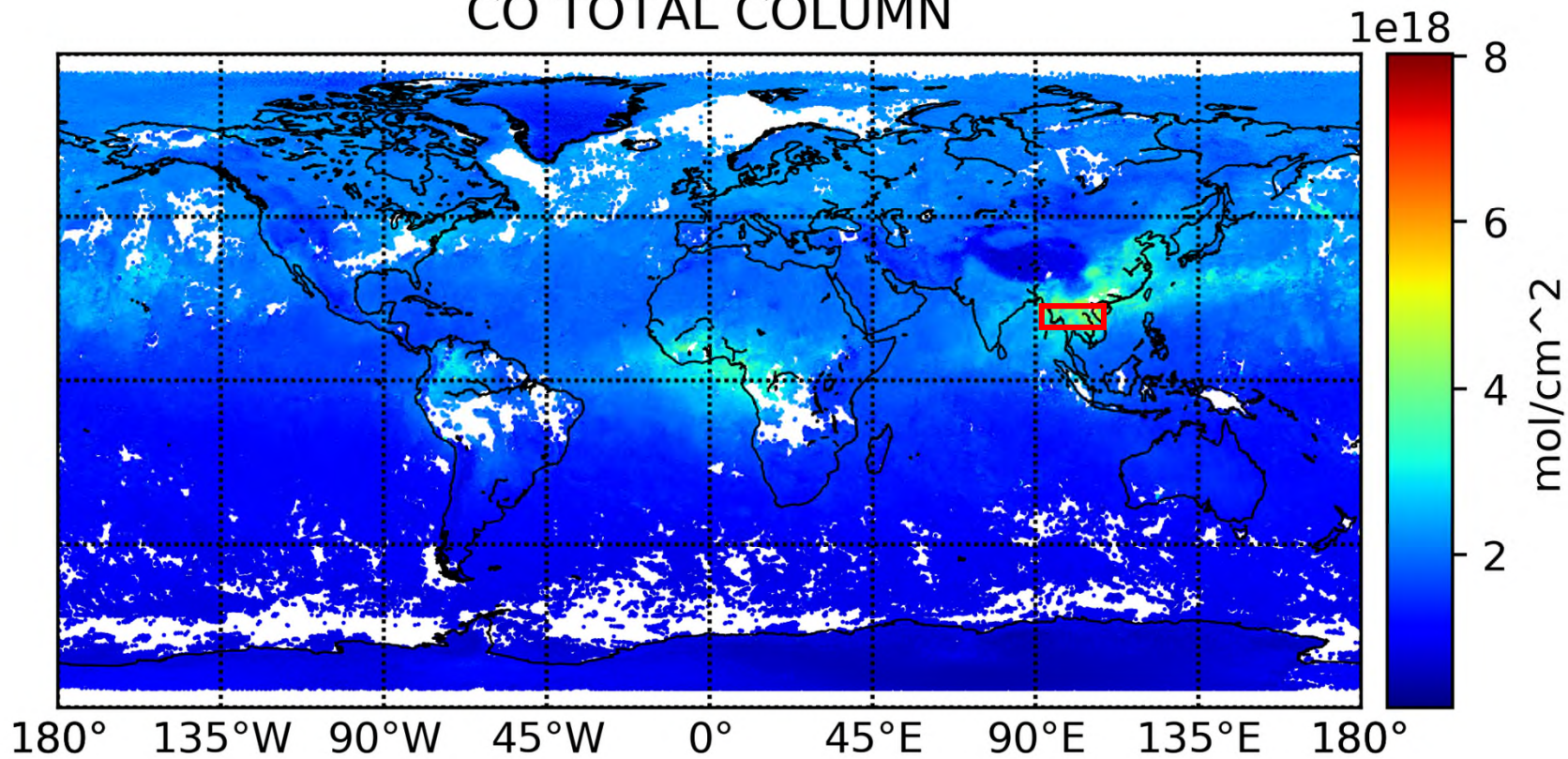
20200320 - 20200322
CO TOTAL COLUMN



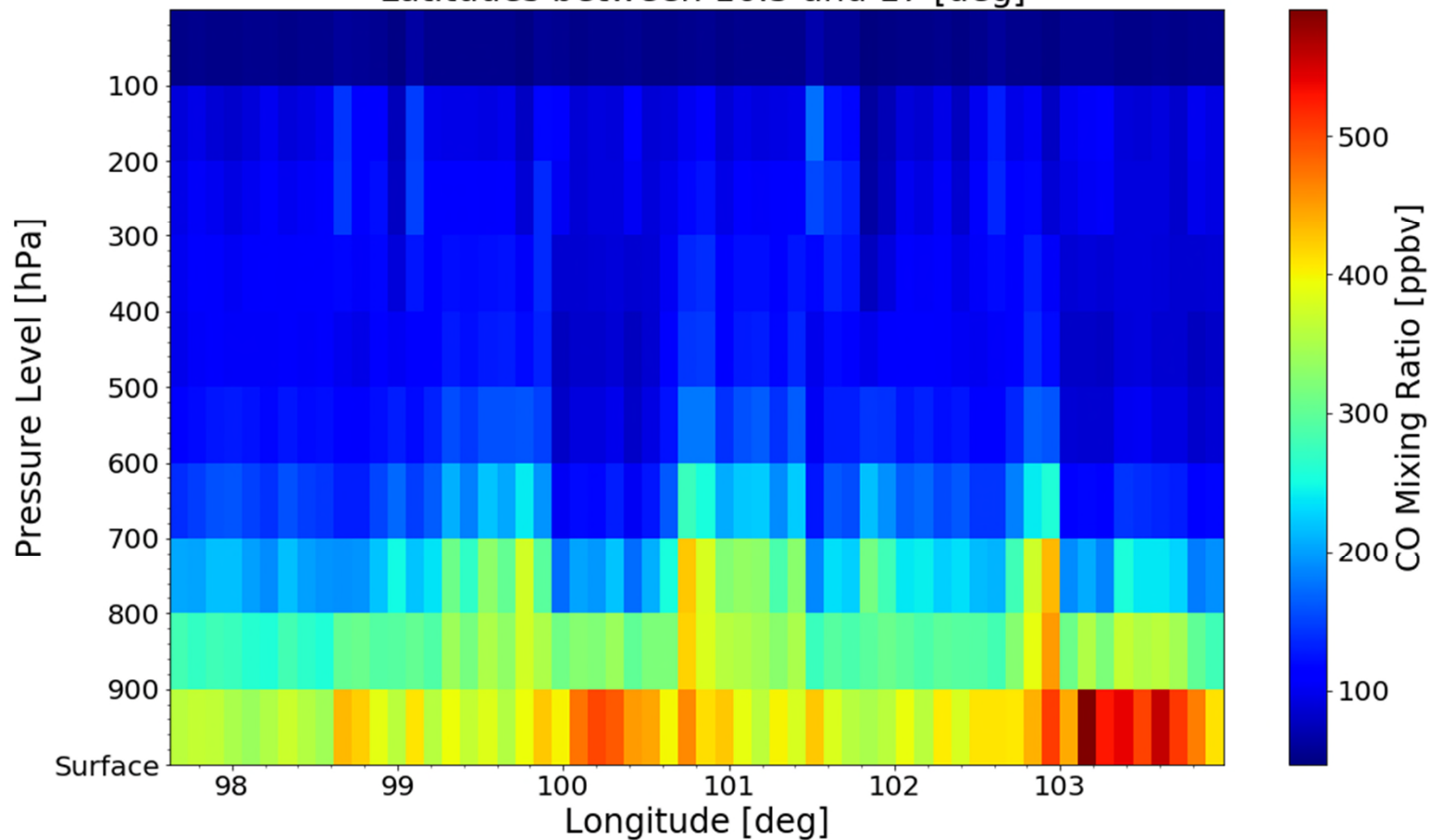
20200318 - 20200322
CO TOTAL COLUMN



20200315 - 20200322
CO TOTAL COLUMN



22/03/2020 CO Mixing Ratios
Latitudes between 16.5 and 17 [deg]



Thank You and Have Fun!

- We hope you're inspired and excited to use Canada's datasets developed specifically for the Oct. 2020 Space App Challenge!
- Have fun with different colour palettes:
https://eos.org/features/visualizing-science-how-color-determines-what-we-see?utm_source=eos&utm_medium=email&utm_campaign=EosBuzz052920
- Many Canadian Space Agency personnel are available on Discord to answer your questions.
- We look forward to seeing your results at the end of the weekend. Good luck!
- @CSA-Nathalie, @CSA-Marcus, @CSA-Nadine, @CSA-Pierre, @CSA-Viqar, @CSA-Julie, and many others!

Agence spatiale canadienne



Canadian Space Agency