Building a validation support service for CO2M and other GHG satellite missions

CO2M – cal/val

Mahesh Kumar Sha^{*1}, Nicolas Kumps¹, Bavo Langerock¹, Dietrich G. Feist^{2,3}, Tijl Verhoelst¹, Martine De Mazière¹, Jean-Christopher Lambert¹, Michael Buchwitz⁴, Thomas Kaminski⁵, Michael Vossbeck⁵, Hannah Clarke⁶, Ruediger Lang⁶

- 1. Royal Belgian Institute for Space Aeronomy (BIRA-IASB), Belgium
- 2. Ludwig-Maximilians-Universität München, Germany
- 3. Deutsches Zentrum für Luft- und Raumfahrt, Germany
- 4. University of Bremen, Germany
- 5. The Inversion Lab, Germany
- 6. EUMETSAT, Germany



ROYAL BELGIAN INSTITUTE FOR SPACE AERONOMY







*mahesh.sha@aeronomie.be



Overview

The Copernicus Carbon Dioxide Monitoring mission (CO2M) is the space component of the European integrated **monitoring and verification support** capacity (**MVS**) dedicated to the monitoring of anthropogenic CO₂ emissions. EUMETSAT is developing a significant part of the CO2M ground segment to undertake day-to-day operations of CO2M and the processing of CO2M products (see poster 2-PO4 for further details).

We are performing the **CO2M cal/val requirements science support study** – EUMETSAT project – lead by the **Ludwig-Maximilians-Universität** in partnership with the **Royal Belgian Institute for Space Aeronomy**, the **University of Bremen** and **The Inversion Lab**, with LMU also providing service management. <u>https://www.eumetsat.int/CO2M-cal-val-support</u>

Objectives:

- Identification of datasets for continuous cal/val and monitoring of operational GHG products.
- Proposal for improvement of ground-based fiducial reference dataset quality, network architecture and data-provision where needed.
- Definition of scientific methodologies for monitoring and cal/val for all proposed datasets.

Focus of this presentation:

- Database with key station parameter ranges in support of satellite validation
- Creation of gridded satellite level-3 files
- Visualisation of satellite files, emission data and parameters from station database (beta testing official release later)
- Examples of some potential applications

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Station parameter database

Modular dynamic database describing the station characteristics, key instrument parameters, available data products and their quality, and network characteristics.

Information collected per station/location and stored in csv files.

	1	Para	imete	r (F nam	e Val	ue Processor (version) Units Min Value Max Value Description					
	2 3 -	Name	Par	amete	r C	yia F nam	Station long name					
	4	2	Name	2	s	odank	Via Station long name					
	5	3 1 Parameter CF name Value Processor (version) Units Min Value Max Value Description										
	6 7	4	2	Nam	e	So	Sodankyla Station long name					
	8	6	3	1	Para	ameter	CF name Value Processor (version) Units Min Value Max Value Description					
	9	7	5	3		Para	JOURNEYIA JESTON FOR HAME STOREN AND A STORE					
1		8	6	4	2	Name	Sodankyla Station long name					
1	2	9	7	5	3	1	Parameter CF name Value Processor (version) Units Min Value Max Value Description					
1	3	11	9	6 7	4	2.	Name Sodankyla Station long name					
1	4	12	10	8	6	3	1 Parameter CF name Value Processor (version) Units Min Value Max Value Description					
1	5	13	11	9	7	5	3 Identifier so Station identifier (if applicable)					
1	7	15	12	10	8	6	4 Network TCCON; NDACC; COCCON; ICOS Station Network: TCCON, COCCON, NDACC					
1	8	16	14	12	10	7	5 Latitude Latitude 67,3668 [degrees_north] 0 90 Station latitude [*N]					
1	9	17	15	13	11	9	 Longitude Longitude 20,0310 [degrees_east] -180 300 Station longitude ["E] Lititude Altitude 0.1880 [km] -420 9000 Station altitude abute sea level [km] 					
2		18	16	14	12	10	8					
2	2	20	17	15	13	11	9 Instrument type FTIR Bruker IFS 125HR; FTIR Bruker EM27/SUN; PICARRO; AirCore E.g FTIR Bruker IFS 125H					
2	3	21	19	17	14	12	10 Detectors InGaAs; Si; InSb; MCT E.g InGaAs & Si, InSb & MCT					
2	4	22	20	18	16	14	1 Spectral resolution 0,02; 0,005; 0,5 cm-1 E.g 0.02 cm-1, 0.5 cm-1					
2	5 c	23	21	19	17	15	13 Atmospheric pressure Pressure yes [Pa] Atmospheric pressure at the site altitude					
2	7	24	22	20	18	16	14 Vertical profile of atmospheric pressure Pressure no [Pa]					
2	8	26	24	21	20	17	15 Air temperature Temperature yes [K] Air temperature at the site altitude					
2	9	27	25	23	21	19	10 Vertical profile of atmospheric temperature lemperature no [K] 12 bir relative humidity relative humidity uss [1] bir relative humidity at the site altitude					
3		28	26	24	22	20	18 Wind direction wind direction yes [degree]					
3	1 2	29	27	25	23	21	19 Wind speed wind_speed yes [m/s]					
3	3	31	20	26	24	22	20 Solar spectral irradiance solar_irradiance no [W/m2]					
3	4	32	30	28	25	23	21 Precipitation yes					
3	5	33	31	29	27	25	22 Solar zenith angle 43 - 65 [degree] 43 65					
3	6 7	34	32	30	28	26	24 Carbon dioxide total column dry_atmosphere_mole_fraction_of_carbon_dioxide yes GGG2014 [ppv]					
3	8	36	33	31	29	27	25 Carbon dioxide vertical profile atmosphere_mole_content_of_carbon_dioxide yes AirCore [ppv]					
3	9	37	35	33	30	28	26 Carbon dioxide surface concentrations dry_atmosphere_mole_fraction_of_carbon_dioxide yes ICOS [ppv]					
4		38	36	34	32	30	2/ Methane total column ary atmosphere_mole_iraction_or_methane yes GuGZU1; Sri14 [ppv] 28 Methane vertical profile_ atmosphere mole content of methane yes birCore [nov]					
4	2	39	37	35	33	31	29 Methane surface concentrations of my atmosphere mole fraction of methane yes ICOS [ppv]					
4	3	40	38	36	34	32	30 Carbon monoxide total column mole_fraction_of_carbon_monoxide_in_air yes GGG2014; SFIT4 [ppv]					
4	4	42	40	38	36	33	31 Carbon monoxide vertical profile atmosphere mole content of carbon monoxide yes AirCore [ppv]					
4	5	43	41	39	37	35	32 Nitrois oxide total column mole fraction of nitrois oxide in air ves GG2014 [Drv]					
4	6 7	44	42	40	38	36	34 Nitrous oxide vertical profile atmosphere mole content of nitrous oxide yes AirCore [ppv]					
4	8	45	43	41	39	37	35 Nitrous oxide surface concentrations mole_fraction_of_nitrous_oxide_in_air no ICOS [ppv]					
4	9	47	45	43	40	38	36 Hydrogen fluoride total column yes GGG2014 [ppv]					
5	0	48	46	44	42	40	37 myorogen Huboride Vertical profile no [ppv] 38 Water vanour total column mole fraction of water vanor in air ves GGG2014 [ppv]					
5	2	49	47	45	43	41	39 Water vapour vertical profile a timosphere_mole_content of carbon monoxide yes [ppv]					
5	3	50	48	46	44	42	40 Water vapour surface concentrations mole_fraction_of_water_vapor_in_air no [ppv]					
5	4	52	50	48	45	43	41 Nitrogen dioxide total column atmosphere_mole_content_of_nitrogen_dioxide yes SFIT4 [mol/m2]					
5	5	53	51	49	47	45	autrogen dioxide tropospheric column troposphere mole content of nitrogen_dioxide no [mol/m2] 43. Nitrogen dioxide stratospheric column stratosphere mole content of nitrogen dioxide no [mol/m2]					
5	6	54	52	50	48	46	44 Nitrogen dioxide vertical profile mole concentration of nitrogen dioxide in air no [mol/ma]					
5	8	56	53	51	49	47	45 Nitrogen dioxide surface concentrations mole_concentration_of_nitrogen_dioxide_in_air no [mol/m3]					
5	9	57	55	52	50	48	46 Glyokal total column no [ppv]					
6	0	58	56	54	52	50	47 Solar-Induced Fluorescence no					
		59	57	55	53	51	49 Spectral emissivity of surface no					
		80	58	56	54	52	50 Spectral albedo of surface_albedo no [1]					
			60	58	55	53	51 Spectral BRDF of surface no					
				59	57	55	oz onow-retingy yes 53 Cloud top height cloud top height no. [m]					
				60	58	56	54 Cloud optical thickness cloud optical_depth no [1]					
					59	57	55 Cloud particles: concentration and effective diameter no					
					60	58	56 Aerosol optical depth aerosol_optical_depth no [1]					
						60	or Arrosolverical discribution no 58 Shape, size, two and number concentration of aerosols no					
							59 Aerosol vertical profile no					
							60 Vertical mixing depth of planetary boundary layer depth no					



Station parameter database

Database stored as netCDF file and accessible using a oPeNDAP interface.

Possibility to request the parameters, filter and select variables via web-based interface in json, ascii or netCDF.

Raw data from the database showing output of selected parameters for the 62 stations included in the database so far.

Examples: (future implementation) https://co2m.aeronomie.be/co2m_sites_db.json?&netwo rk>>"TCCON" #list of stations which are part of TCCON

https://co2m.aeronomie.be/co2m_sites_db.json?name,la titude,longitude,altitude&carbon_dioxide_total_column= 1&latitude>-

25&latitude<70.0&longitude>0.0&longitude<90.0

Save Copy Pretty Print

{ "name": ["Addis Ababa, Ethopia", "Altzomoni, Mexico", "Arrival Heights, Antarctica", "Mt. Barcroft, CA, USA", "Boulder, CO, USA", "Bratts Lake, SK, Canada", "Cabauw, Netherlands", "Egbert, ON, Canada", "Fort McMurray, AB, Canada", "Halifax, NS, Canada", "Harestua, Norway", "Jungfraujoch, Switzerland", "Kiruna, Sweden", "Kitt Peak, AZ, USA", "Mauna Loa, Hawaii", "Mexico City, Mexico", "Paramaribo, Suriname", "Poker Flat, AK, USA", "Porto Velho, Brazil", "Maido, Reunion Island", "St. Petersburg, Russia", "Syowa Station, Antarctica", "Table Mountain, CA, USA", "Thule, Greenland", "Timmins, ON, Canada", "Tomsk, Russia", "Toronto, ON, Canada", "Yekaterinburg, Russia", "Zugspitze, Germany", "Anmyeondo, Korea", "MPI-BGC FTIR on Ascension Island", "Ascension Island", "Bialystok, Poland", "Bremen, Germany", "Darwin, Australia", "Armstrong Flight Research Center, Edwards, CA, USA", "Eureka, Canada", "Four Corners, NM, USA", "Garmisch, Germany", "Izana, Tenerife", "MPI-BGC Jena, Germany", "KIT, Karlsruhe, Germany", "Lamont, OK (USA)", "ISF120HR at Lauder, New Zealand", "ISF125HR at Lauder, New Zealand", "Manaus, Brazil", "Moshiri, Japan", "Ny Alesund, Spitsbergen", "Orleans, France", "Paris, France", "Park Falls, WI (USA)", "Caltech, Pasadena, CA, USA", "St. Denis, Reunion Island", "Reunion Island", "Rikubetsu, Hokkaido, Japan", "STEL IFS120M at Rikubetsu, Hokkaido, Japan", "Saga, Japan", "Sodankyla, Finland", "Sodankyla", "IFS120HR at Tsukuba, Japan", "IFS125HR at Tsukuba, Japan", "MPI-BGC FTIR at UOW, Campus East, Fairy Meadows, Australia"], "latitude": [8.982999801635742, 19.1200008392334, -77.83000183105469, 37.58000183105469, 40.03799819946289, 50.20000076293945, 51.970001220703125, 44.21699905395508, 56.650001525878906, 44.63999938964844, 60.20000076293945, 46.54999923706055, 67.83999633789062, 31.959999084472656, 19.540000915527344, 19.329999923706055, 5.809999942779541, 65.12000274658203, -8.699999809265137, -21.07900047302246, 59.880001068115234, -69.0, 34.400001525878906, 76.52999877929688, 48.56999969482422, 56.474998474121094, 43.65999984741211, 57.03799819946289, 47.41999816894531, 36.53820037841797, -7.916500091552734, -7.916500091552734, 53.22999954223633, 53.099998474121094, -12.455900192260742, 34.95838928222656, 80.05000305175781, 36.797489166259766, 47.47600173950195, 28.299999237060547, 50.91033172607422, 49.099998474121094, 36.604000091552734, -45.03799819946289, -45.03799819946289, -3.2132999897003174, 44.400001525878906, 78.9000015258789, 47.970001220703125, 48.970001220703125, 45.94499969482422, 34.13600158691406, -20.900999069213867, -20.901500701904297, 43.459999084472656, 43.459999084472656, 33.24095916748047, 67.3667984008789, 67.3667984008789, 36.051300048828125, 36.051300048828125, -34.39781188964844], "longitude": [38.79999923706055, -98.6500015258789, 166.64999389648438, -118.23999786376953, -105.23999786376953, -104.19999694824219, 4.929999828338623, -79.76699829101562, -111.22000122070312, -63.59000015258789, 10.800000190734863, 7.980000019073486, 20.40999984741211, -111.58999633789062, -155.57000732421875, -99.18000030517578, -55.209999084472656, -147.42999267578125, -63.900001525878906, 55.38399887084961, 29.829999923706055, 39.59000015258789, -117.69999694824219, -68.73999786376953, -81.37999725341797, 85.0459976196289, -79.4000015258789, 59.54499816894531, 10.979999542236328, 126.33110046386719, -14.332500457763672, -14.332500457763672, 23.024999618530273, 8.850000381469727, 130.92660522460938, -117.88215637207031, -86.41999816894531, -108.48008728027344, 11.062999725341797, -16.5, 11.568710327148438, 8.437999725341797, -97.48600006103516, 169.6840057373047, 169.6840057373047, -60.59830093383789, 142.3000030517578, 11.899999618530273, 2.11299991607666, 2.369999885559082, -90.27300262451172, -118.12699890136719, 55.48500061035156, 55.48500061035156, 143.77000427246094, 143.77000427246094, 130.28823852539062, 26.631000518798828, 26.631000518798828, 140.1215057373047, 140.1215057373047, 150.89979553222656], "altitude": [2444.0, 4010.0, 220.0, 3793.0, 1612.0, 587.0, -2.0, 251.0, 369.0, 65.0, 596.0, 3580.0, 420.0, 2060.0, 3396.0, 2260.0, 7.0, 610.0, 80.0, 2155.0, 20.0, 10.0, 2300.0, 225.0, 295.0, 106.0, 174.0, 300.0, 2964.0, 30.0, 30.799999237060547, 30.799999237060547, 180.0, 27.0, 32.0, 699.0, 610.0, 1643.0, 740.0, 2370.0, 211.6999969482422, 110.0, 320.0, 370.0, 370.0, 50.0, 295.0, 20.0, 130.0, 60.0, 440.0, 230.0, 85.0, 87.0, 380.0, 380.0, 7.0, 188.0, 188.0, 30.0, 30.0, 8.0] }





Map server



WMS = Web Mapping Service: provides requested map (png, jpeg, geotiff, pdf, kml, ...) WCS = Web Coverage Service: provides requested data (GeoTiff, arcGrid, jpeg, ...) WFS = Web Feature Service: provides requested features (vestor data: shapefile, geojson, ...)



Map server

CO2M project map server: https://co2m.aeronomie.be/

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	CO2M						
	Home						
	Login Form Username		Welcome to the CO2M.aeronomie.be website				
√e"	Password Remember Me Log in Create an account >	The content of this website is part of the results from the EUMETSAT project "Science Service Support for CO2M Product Valid The study is lead by by the Ludwig-Maximilians-Universität in partnership with the Royal Belgian Institute for Space Aeronomy, the and The Inversion Lab, with LMU also providing the service management. Please visit https://www.eumetsat.int/CO2M-cal information on the project.					
	Forgot your username? Forgot your password?	This website provides access to the Cal/ existing stations can be viewed via a glob and potential other relevant parameters i database in the global plots.	Val database for continuous Cal/Va al map. A visualisation of the global is provided. The database is linked	al and monitoring of operational CO2N plots of satellite level-3 files of trace ga I to these maps with the possibility to	I products. The key parameters of ases, emission inventory databases over plot the parameters from the		
		This task is lead by the Royal Belgian Ins and The Inversion Lab.	stitute for Space Aeronomy in collat	poration with the Ludwig-Maximilians-U	niversität, the University of Bremen		

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Map server – database visualisation

Database information sorted in four categories Siteinfo Meteoinfo

Reunion Island longitude [°E] : 55.48500061035156 latitude [°N] : -20.901500701904297 altitude [km] : 87 SZA [degrees] : 0 - 85 instrument : FTIR Bruker IFS 125HR; PICARRO detectors : InGaAs; Si; InSb; MCT resolution [cm-1]: 0,02 Reunion Island atmospheric pressure : 1 air_temperature : 1 air_relative_humidity : 1 wind_direction : 1 wind_speed : 1 solar_spectral_irradiance : 1 precipitation : 1 vertical_profile_of_atmospheric_pressure : 0 vertical_profile_of_atmospheric_temperature : 0

Gasesinfo

×

Reunion Island

carbon_dioxide_total_column:1 carbon_dioxide_vertical_profile:0 carbon_dioxide_surface_concentrations:1 methane total column:1 methane vertical profile:0 methane_surface_concentrations:1 nitrogen_dioxide_total_column:0 nitrogen_dioxide_tropospheric_column:0 nitrogen_dioxide_stratospheric_column:0 nitrogen dioxide vertical profile:0 nitrogen_dioxide_surface_concentrations:0 carbon_monoxide_total_column:1 carbon monoxide vertical profile:0 carbon monoxide surface concentrations:0 water_vapour_total_column:1 water_vapour_vertical_profile:0 water_vapour_surface_concentrations:0 nitrous oxide total column:1 nitrous_oxide_total_column : undefined nitrous_oxide_surface_concentrations:0 hydrogen_fluoride_total_column:1 hydrogen_fluoride_vertical_profile:0 glyoxal total column:0 solar_induced_fluorescence:0

Ancillaryinfo

Maido, Reunion Island spectral_emissivity_of_surface : 0 spectral_albedo_of_surface : 0 spectral_brdf_of_surface : 0 snow_ice_flags : 0 cloud_top_height : 0 cloud_optical_thickness : 0 aerosol_optical_depth : 0 aerosol_vertical_distribution : 0 shape__size_type_and_number_concentration_of_aerosols : 0 aerosol_vertical_profile : 0 vertical_mixing_depth_of_planetary_boundary_layer_depth : 0



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Map server – visualisation options



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Map server – Satellite & database visualisation





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Map server – Satellite data comparator & database visualisation



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Map server – Satellite data comparator & database visualisation



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Map server – Satellite & Emission data comparator visualisation



Map server – Satellite & Emission data comparator visualisation



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Summary and outlook

Our study supports the development at EUMETSAT of an end-to-end system including operational calibration and validation.

Current features include visualisation of monthly/yearly averaged satellite files, emission data from EDGAR, station database build for CO2M cal/val study – beta testing – official release will be later

Comparator option to compare different level-3 files of different gases from satellites or to compare them against emission data

Quick overview of the availability of ancillary data at the site locations from station database. These include, amongst others, information on albedo, aerosol, snow/ice flags, cloud information, ...

Possibility to view daily/monthly/yearly evolution of satellite data and their comparisons to other products (satellites, emissions, models), handling of data processed with different processor versions

Assists detection of emission hot-spots, suitability of adding additional measurements at certain locations considering the criticality of emissions, co-emitted species and pollution levels

Assists identifying locations with missing fiducial reference measurements for satellite cal/val

Collect user feedback on current status or requests for addition of other products to the map server Thank you for your attention!