

CO2M preparations for product validation

CO2M Validation



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ROYAL BELGIAN INSTITUTE
FOR SPACE AERONOMY

CO2M Cal/Val requirements science support – Phase 1 (July 2021 – June 2024 (3 years))

<https://www.eumetsat.int/co2m-calval-requirements-science-support-phase-i>

This service provided EUMETSAT with support for the definition of requirements for the routine monitoring and scientific validation of GHG products (CO₂, CH₄, NO₂ and Aerosol) from the CO2M mission, during Phase I of the Cal/Val concept definition.

The study was performed by Ludwig-Maximilians-Universität München (LMU), in partnership with the Royal Belgian Institute for Space Aeronomy, the University of Bremen, and The Inversion Lab, with LMU also providing the service management.

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.

Building up of a database to support validation of CO2M and extendable to related satellite missions

- Creation of a template for collection of parameter inputs for the database
- The information to be collected per station basis is sorted in four categories and stored as csv files

TCCON/NDACC station St. Denis
longitude [°E] : 55.48500061035156
latitude [°N] : -20.900999069213867
network : TCCON;NDACC; NDACC_ZSL-DOAS_StNO2; AERONET_AOD
altitude [km] : 85
SZA [degrees] : 0 - 85
instrument : FTIR Bruker IFS 125HR; ZSL-DOAS; sun-photometer
detectors : InGaAs;Si
resolution [cm-1]: 0.02

Siteinfo

TCCON/NDACC station St. Denis
longitude [°E] : 55.48500061035156
latitude [°N] : -20.900999069213867
network : TCCON;NDACC; NDACC_ZSL-DOAS_StNO2; AERONET_AOD
atmospheric pressure : 1
air_temperature : 1
air_relative_humidity : 1
wind_direction : 0
wind_speed : 1
solar_spectral_irradiance : 1
precipitation : 1
vertical_profile_of_atmospheric_pressure : 0
vertical_profile_of_atmospheric_temperature : 0

Meteoinfo

nitrogen_dioxide_total_column : 0
nitrogen_dioxide_tropospheric_column : 0
nitrogen_dioxide_stratospheric_column : 1
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

Gasesinfo

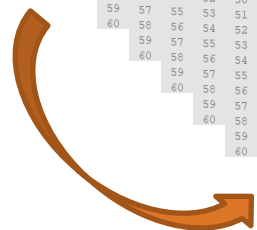
TCCON/NDACC station St. Denis
longitude [°E] : 55.48500061035156
latitude [°N] : -20.900999069213867
network : TCCON;NDACC; NDACC_ZSL-DOAS_StNO2; AERONET_AOD
spectral_emissivity_of_surface : 0
spectral_albedo_of_surface : 0
spectral_brdf_of_surface : 0
snow_ice_flags : 0
cloud_top_height : 0
cloud_optical_thickness : 0
aerosol_optical_depth : 1
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

Ancillaryinfo

Collection of individual csv files for each station with station parameters following the template, created via survey

1	Parameter	CF name	Value	Processor (version)	Units	Min Value	Max Value	Description						
2	Name	Sodankyla						Station long name						
3	1	Parameter	CF name	Value	Processor (version)	Units	Min Value	Max Value	Description					
4	2	Name	Sodankyla					Station long name						
5	3	1	Parameter	CF name	Value	Processor (version)	Units	Min Value	Max Value	Description				
6	4	2	Name	Sodankyla				Station long name						
7	5	3	1	Parameter	CF name	Value	Processor (version)	Units	Min Value	Max Value	Description			
8	6	4	2	Name	Sodankyla				Station long name					
9	7	5	3	1	Parameter	CF name	Value	Processor (version)	Units	Min Value	Max Value	Description		
10	8	6	4	2	Name	Sodankyla				Station long name				
11	9	7	5	3	1	Parameter	CF name	Value	Processor (version)	Units	Min Value	Max Value	Description	
12	10	8	6	4	2	Name	Sodankyla				Station long name			
13	11	9	7	5	3	1	Parameter	CF name	Value	Processor (version)	Units	Min Value	Max Value	Description
14	12	10	8	6	4	2	Name	Sodankyla				Station long name		
15	13	11	9	7	5	3	Identifier	so				Station identifier (if applicable)		
16	14	12	10	8	6	4	Network	TOCON; NDACC; COCCON; ICOS				Station Network: TOCON, COCCON, NDACC		
17	15	13	11	9	7	5	Latitude	Latitude	67,3668	[degrees_north]	0	90	Station latitude [°N]	
18	16	14	12	10	8	6	Longitude	Longitude	26,6310	[degrees_east]	-180	360	Station longitude [°E]	
19	17	15	13	11	9	7	Altitude	Altitude	0,1890	[km]	-420	8900	Station altitude above sea level [km]	
20	18	16	14	12	10	8								
21	19	17	15	13	11	9	Instrument type	FTIR Bruker IFS 125HR; FTIR Bruker EM27/SUN; PICARRO; AirCore					E.g. - FTIR Bruker IFS 125HR	
22	20	18	16	14	12	10	Detectors	InGaAs; Si; InSb; MCT					E.g. - InGaAs & Si, InSb & MCT	
23	21	19	17	15	13	11	Spectral resolution	0,02; 0,005; 0,5			cm-1		E.g. - 0.02 cm-1, 0.5 cm-1	
24	22	20	18	16	14	12								
25	23	21	19	17	15	13	Atmospheric pressure	Pressure	yes	[Pa]			Atmospheric pressure at the site altitude	
26	24	22	20	18	16	14	Vertical profile of atmospheric pressure	Pressure	no	[Pa]				
27	25	23	21	19	17	15	Air temperature	Temperature	yes	[K]			Air temperature at the site altitude	
28	26	24	22	20	18	16	Vertical profile of atmospheric temperature	Temperature	no	[K]				
29	27	25	23	21	19	17	Air relative humidity	relative_humidity	yes	[1]			Air relative humidity at the site altitude	
30	28	26	24	22	20	18	Wind direction	wind_direction	yes	[degree]				
31	29	27	25	23	21	19	Wind speed	wind_speed	yes	[m/s]				
32	30	28	26	24	22	20	Solar spectral irradiance	solar_irradiance	no	[W/m2]				
33	31	29	27	25	23	21	Precipitation	yes						
34	32	30	28	26	24	22	Solar zenith angle	43 - 85	[degree]	43	85			
35	33	31	29	27	25	23								
36	34	32	30	28	26	24	Carbon dioxide total column	dry_atmosphere_mole_fraction_of_carbon_dioxide	yes	GGG2014	[ppv]			
37	35	33	31	29	27	25	Carbon dioxide vertical profile	atmosphere_mole_content_of_carbon_dioxide	yes	AirCore	[ppv]			
38	36	34	32	30	28	26	Carbon dioxide surface concentrations	dry_atmosphere_mole_fraction_of_carbon_dioxide	yes	ICOS	[ppv]			
39	37	35	33	31	29	27	Methane total column	dry_atmosphere_mole_fraction_of_methane	yes	GGG2014; SFTI4	[ppv]			
40	38	36	34	32	30	28	Methane vertical profile	atmosphere_mole_content_of_methane	yes	AirCore	[ppv]			
41	39	37	35	33	31	29	Methane surface concentrations	dry_atmosphere_mole_fraction_of_methane	yes	ICOS	[ppv]			
42	40	38	36	34	32	30	Carbon monoxide total column	mole_fraction_of_carbon_monoxide_in_air	yes	GGG2014; SFTI4	[ppv]			
43	41	39	37	35	33	31	Carbon monoxide vertical profile	atmosphere_mole_content_of_carbon_monoxide	yes	AirCore	[ppv]			
44	42	40	38	36	34	32	Carbon monoxide surface concentrations	mole_fraction_of_carbon_monoxide_in_air	yes	ICOS	[ppv]			
45	43	41	39	37	35	33	Nitrous oxide total column	mole_fraction_of_nitrous_oxide_in_air	yes	GGG2014	[ppv]			
46	44	42	40	38	36	34	Nitrous oxide vertical profile	atmosphere_mole_content_of_nitrous_oxide	yes	AirCore	[ppv]			
47	45	43	41	39	37	35	Nitrous oxide surface concentrations	mole_fraction_of_nitrous_oxide_in_air	no	ICOS	[ppv]			
48	46	44	42	40	38	36	Hydrogen fluoride total column	yes	GGG2014	[ppv]				
49	47	45	43	41	39	37	Hydrogen fluoride vertical profile	no	[ppv]					
50	48	46	44	42	40	38	Water vapour total column	mole_fraction_of_water_vapor_in_air	yes	GGG2014	[ppv]			
51	49	47	45	43	41	39	Water vapour vertical profile	atmosphere_mole_content_of_carbon_monoxide	yes	[ppv]				
52	50	48	46	44	42	40	Water vapour surface concentrations	mole_fraction_of_water_vapor_in_air	no	[ppv]				
53	51	49	47	45	43	41	Nitrogen dioxide total column	atmosphere_mole_content_of_nitrogen_dioxide	yes	SFTI4	[mol/m2]			
54	52	50	48	46	44	42	Nitrogen dioxide tropospheric column	troposphere_mole_content_of_nitrogen_dioxide	no	[mol/m2]				
55	53	51	49	47	45	43	Nitrogen dioxide stratospheric column	stratosphere_mole_content_of_nitrogen_dioxide	no	[mol/m2]				
56	54	52	50	48	46	44	Nitrogen dioxide vertical profile	mole_concentration_of_nitrogen_dioxide_in_air	no	[mol/m3]				
57	55	53	51	49	47	45	Nitrogen dioxide surface concentrations	mole_concentration_of_nitrogen_dioxide_in_air	no	[mol/m3]				
58	56	54	52	50	48	46	Glyoxal total column	no	[ppv]					
59	57	55	53	51	49	47	Solar-Induced Fluorescence	no						
60	58	56	54	52	50	48								
61	59	57	55	53	51	49	Spectral emissivity of surface	no						
62	60	58	56	54	52	50	Spectral albedo of surface	surface_albedo	no	[1]				
63	61	59	57	55	53	51	Spectral BRDF of surface	no						
64	62	60	58	56	54	52	Snow-Ice flags	yes						
65	63	61	59	57	55	53	Cloud top height	cloud_top_height	no	[m]				
66	64	62	60	58	56	54	Cloud optical thickness	cloud_optical_depth	no	[1]				
67	65	63	61	59	57	55	Cloud particles: concentration and effective diameter		no					
68	66	64	62	60	58	56	Aerosol optical depth	aerosol_optical_depth	no	[1]				
69	67	65	63	61	59	57	Aerosol vertical distribution	no						
70	68	66	64	62	60	58	Shape, size, type and number concentration of aerosols		no					
71	69	67	65	63	61	59	Aerosol vertical profile	no						
72	70	68	66	64	62	60	Vertical mixing depth of planetary boundary layer depth		no					

Station files



Run a PyDAP server that reads a list of csv files and creates an "in-memory" netcdf4 file, this file can then be reached using the oPeNDAP interface.

A WSGI (Web Server Gateway Interface) application running on a BIRA-IASB server, provides access to the database via a web browser.

The database is accessible via oPeNDAP interfaces

Data descriptor structure => https://api.aeronomie.be/co2m/co2m_sites_db.dds

Data attribute structure => https://api.aeronomie.be/co2m/co2m_sites_db.das

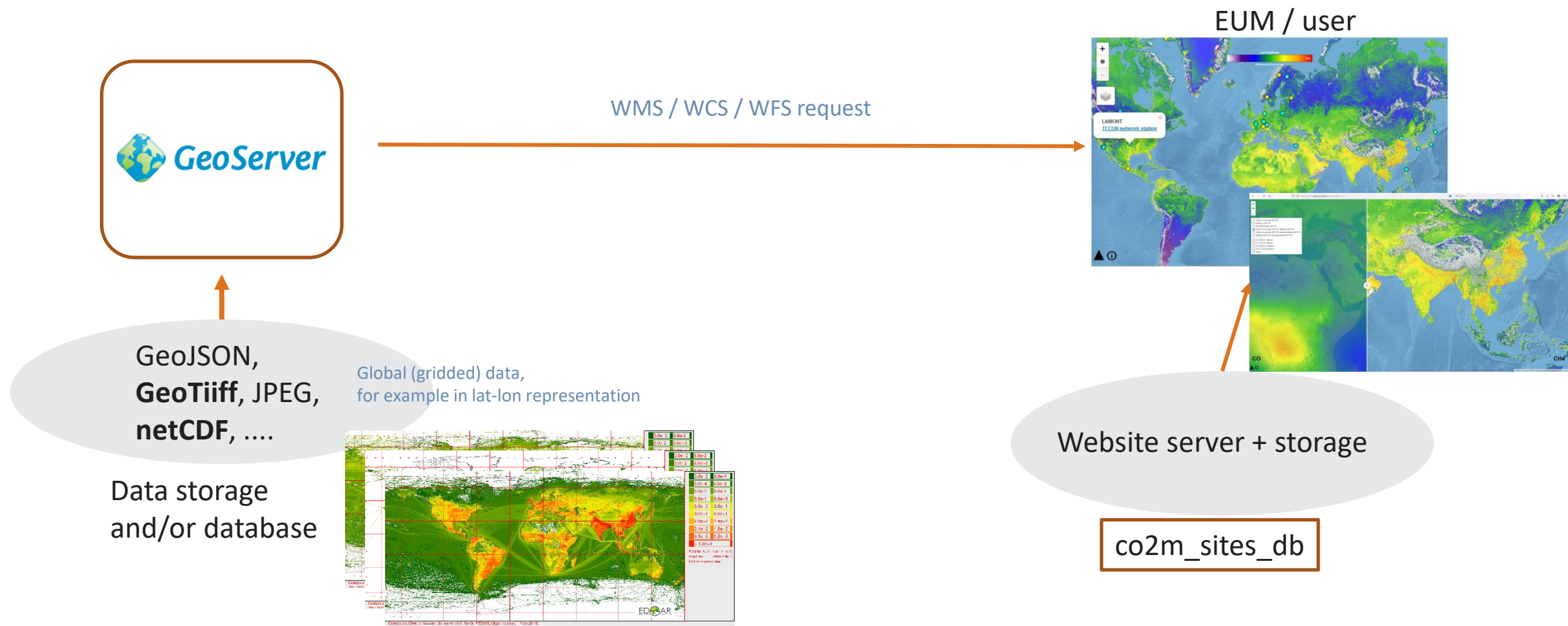
The user can get access to the content either in json or ncojson.

Example to get station name, network they belong to, latitude and longitude =>

https://api.aeronomie.be/co2m/co2m_sites_db.ncojson?name,network,latitude,longitude

https://api.aeronomie.be/co2m/co2m_sites_db.ncojson?name,latitude,longitude,altitude&carbon_dioxide_total_column=1&latitude>-25&latitude<70.0&longitude>0.0&longitude<90.0

Visualization of the co2m.aeronomie.be site



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 (vector data: shapefile, geojson, ...)



Getting access to the Map server

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

Create an account

Login with your **Username** & **Password** and check "Remember Me" box for future easy login

CO2M

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Welcome to the CO2M.aeronomie.be website

Login Form

☐ Remember Me

[Log in](#)

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The content of this website is part of the results from the EUMETSAT project "Science Service Support for CO2M Product Validation and Monitoring". The study is lead by 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 the service management. Please visit <https://www.eumetsat.int/CO2M-cal-val-support> for more information on the project.

This website provides access to the Cal/Val database for continuous Cal/Val and monitoring of operational CO2M products. The key parameters of existing stations can be viewed via a global map. A visualisation of the global plots of satellite level-3 files of trace gases, emission inventory databases and potential other relevant parameters is provided. The database is linked to these maps with the possibility to over plot the parameters from the database in the global plots.

This task is lead by [the Royal Belgian Institute for Space Aeronomy](#) in collaboration with [the Ludwig-Maximilians-Universität](#), [the University of Bremen](#) and [The Inversion Lab](#).

This site is maintained by [Maresh Kumar Sha](#)

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Satellite level-3 files visualisation (individual map or comparator)

+

Emission data visualisation (individual map or comparator)

+

Station database visualisation

+

Satellite overpass statistics

+

Cities

Background: Open Street map / Natural Earth / Grey Earth

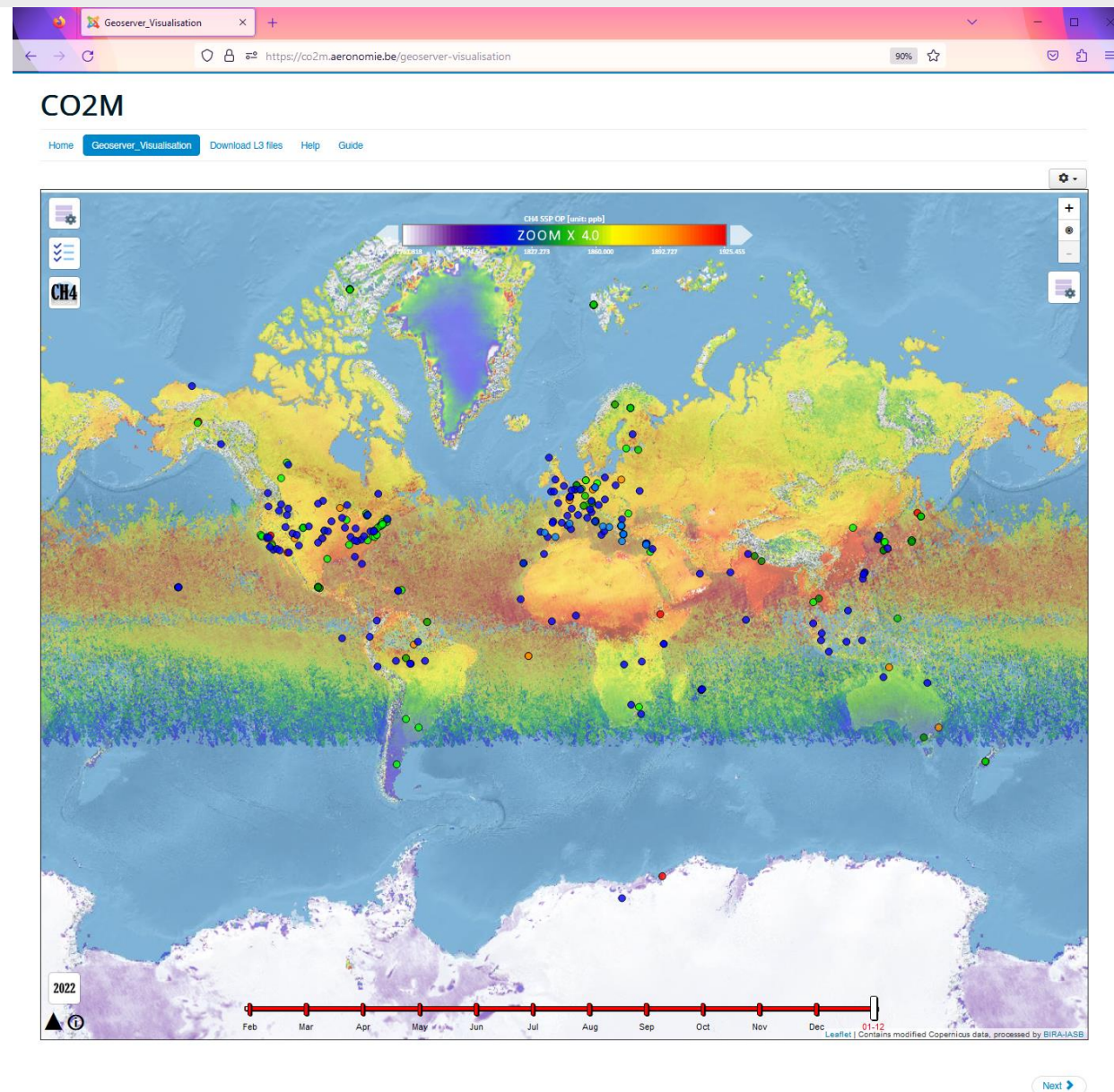
Colour scale: Rainbow / Magma / Grey

Opacity: 0 – 1

Resolution: native resolution / gridded resolution

Download of SAT level-3 files

Help & Guide



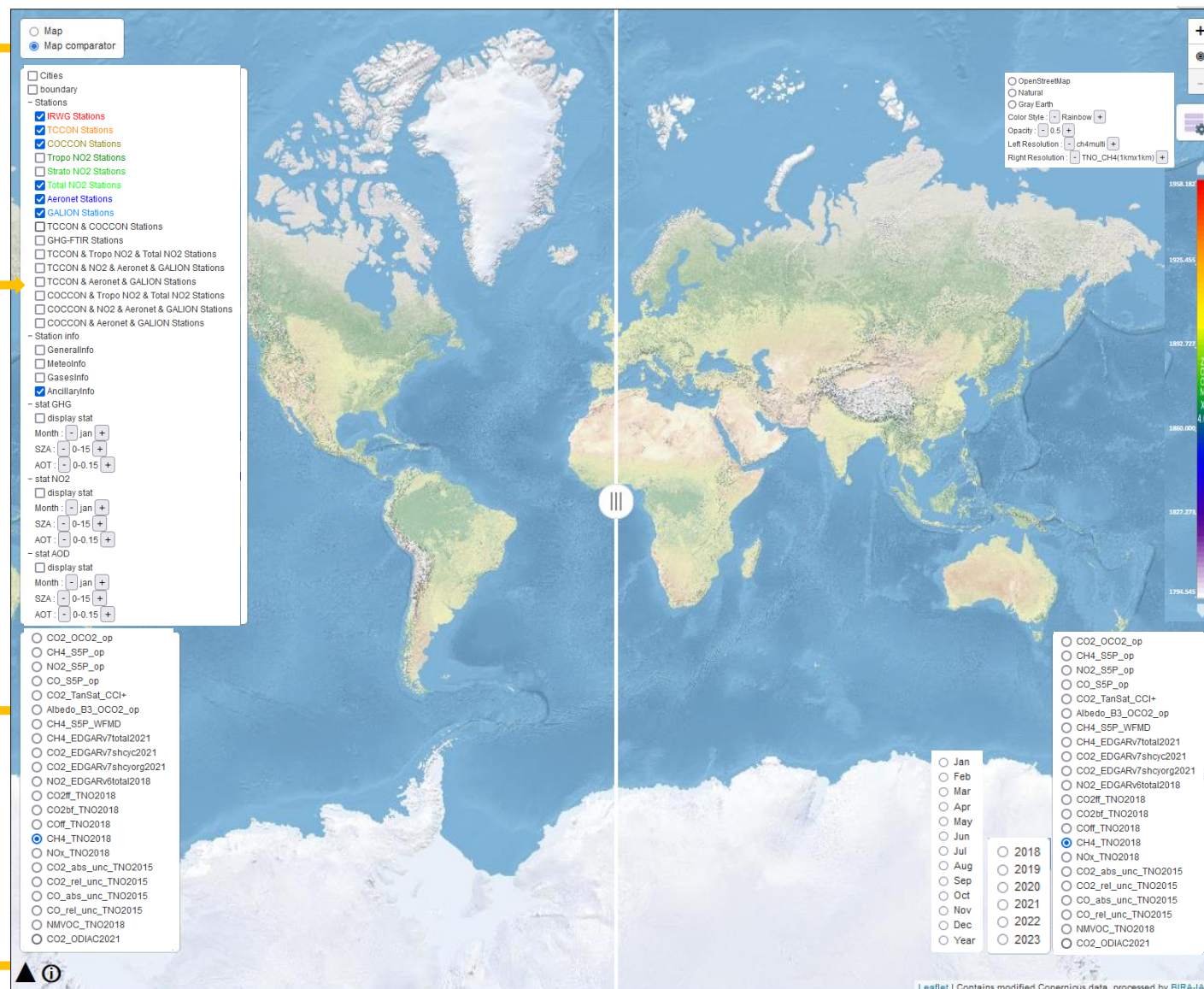
Map server – visualisation options

Select individual maps or comparator view

Select list of stations from database with information on parameters, cities, list of stations based on networks – TCCON, COCCON, NDACC, AERONET, GALION, ...
Overpass statistics for CO2M for the sites – GHG, NO2, AOD

Select species for visualization – SAT L3 files or emission data

Information on the content of the data plotted



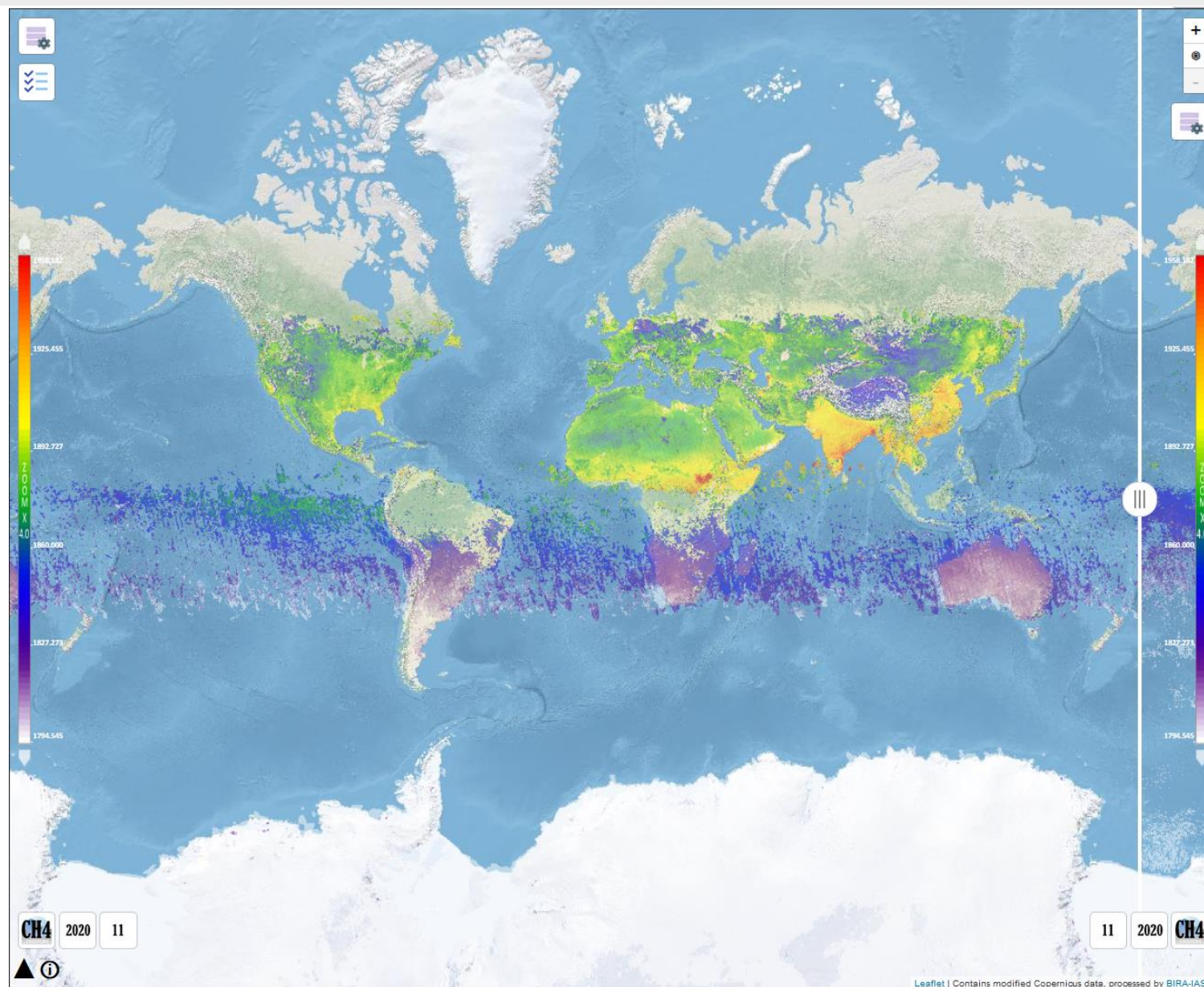
Zooming of the map

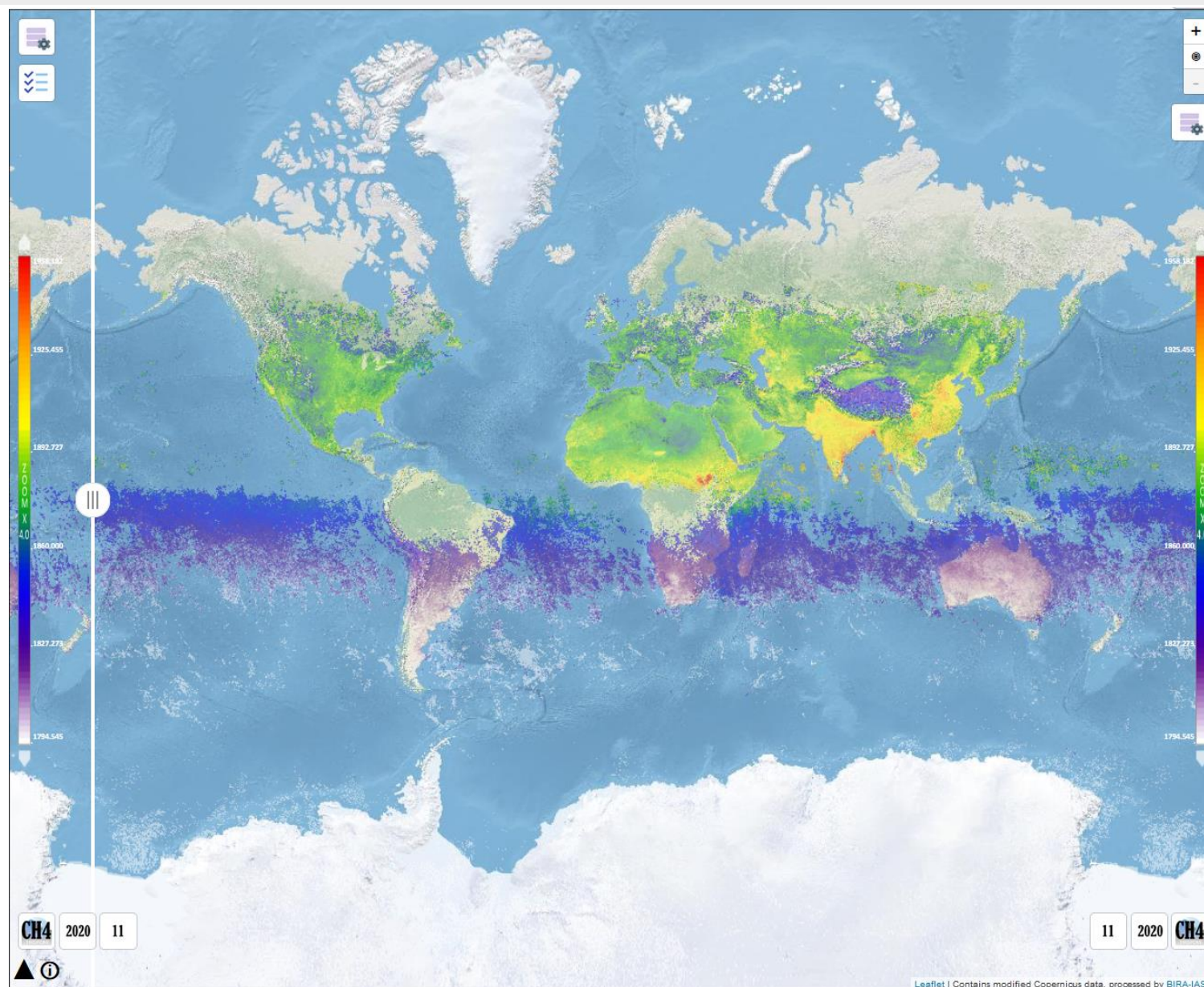
Background map, colour scale, opacity, resolution

Multi level zooming option for the optimised range of the colour scale

Scrolling option for changing range of the colour scale

Select individual monthly or yearly average or option to view different data versions

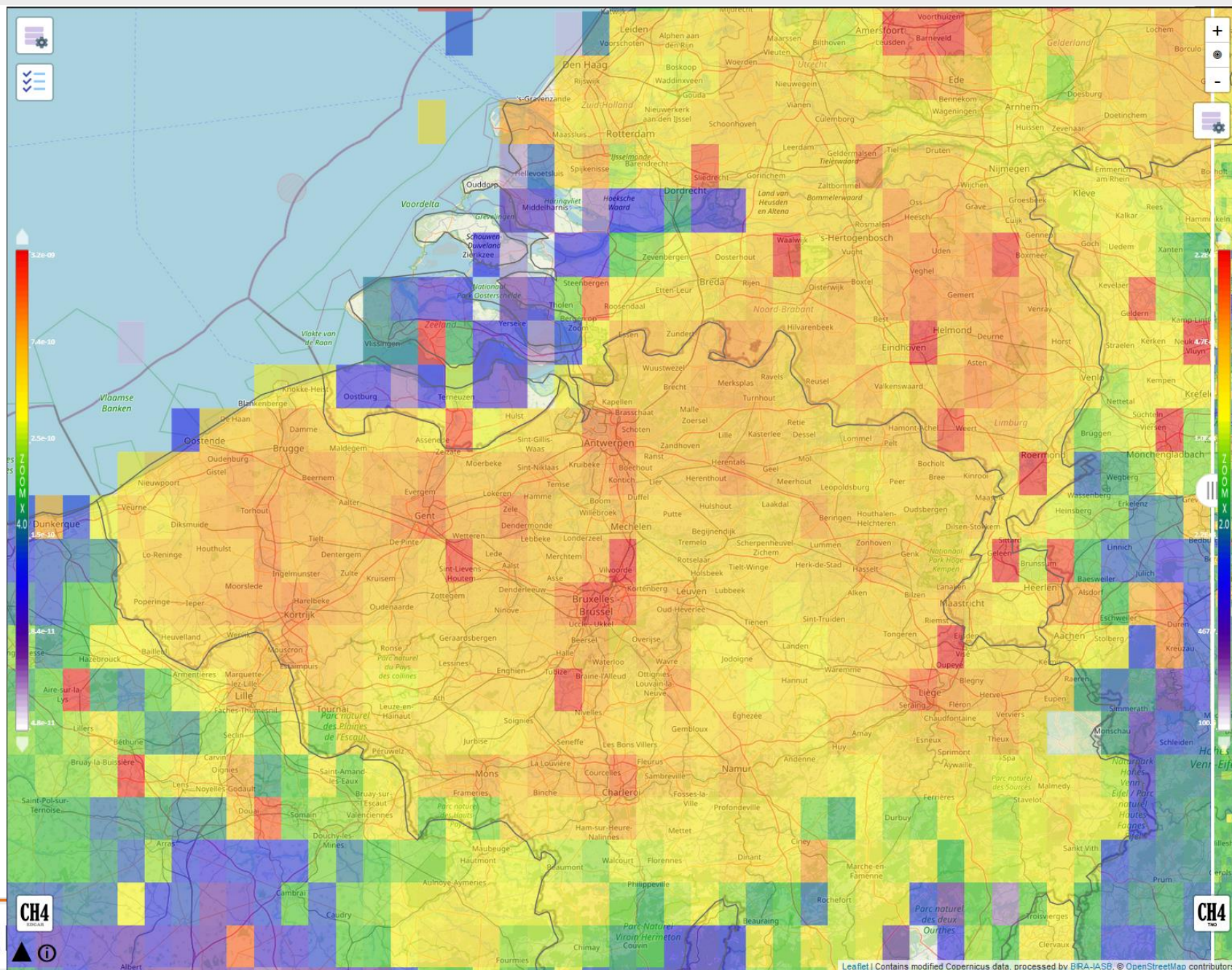




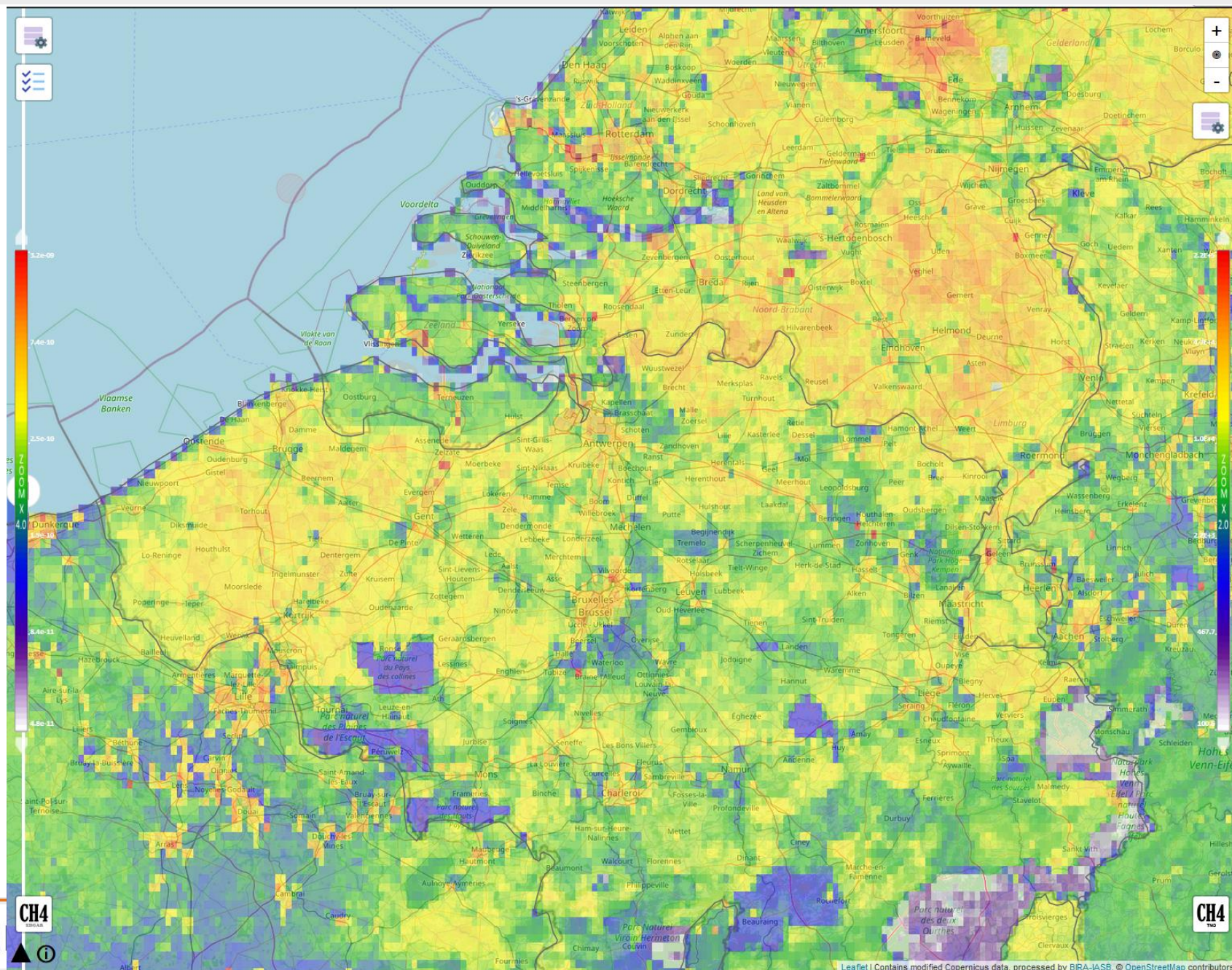
CH4_S5P_OP

CH4_S5P_WFMD

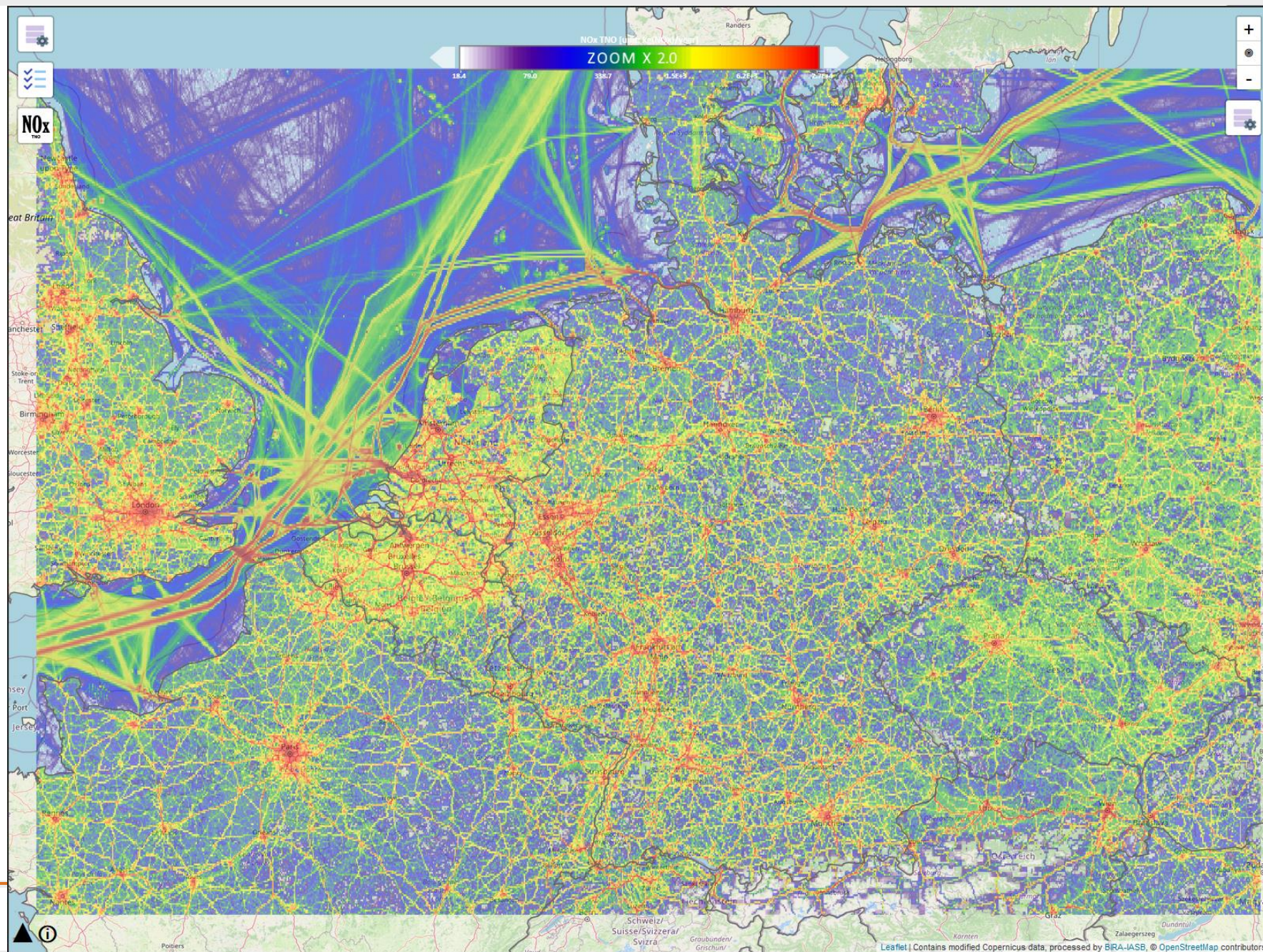
Map server – Global vs regional emission inventories – CH₄ hot spots

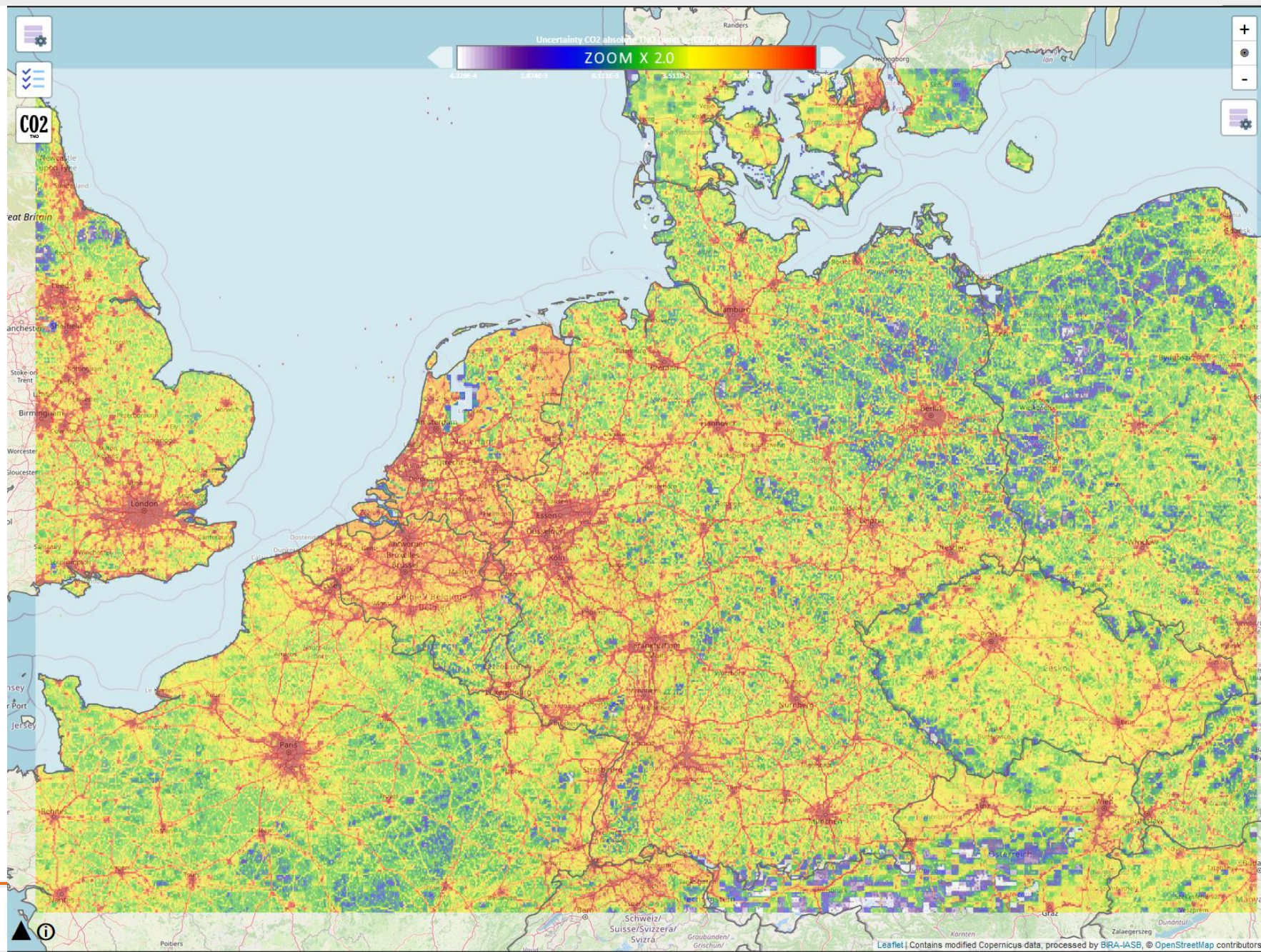


Map server – Global vs regional emission inventories – CH₄ hot spots



Map server – Regional emission inventories – NO_x





Pandonia Global Network:

- Total column of NO₂ (+ for some: O₃, SO₂, HCHO, profiles)
- Central processing (Luftblick, Austria),
- Central database(s) (Luftblick and EVDC),
- Single point(s) of contact, but PIs should be informed
- Network under strong expansion

NDACC MAX-DOAS Network:

- Tropospheric column of NO₂ (+ for some: profile retrieval)
- Multiple directions sometimes facilitated to sample an inhomogeneous field, i.e. 2-D MAX-DOAS
- No harmonized processing or central database yet, but central processing is under development in ESA's FRM4DOAS
- Contacts with station PIs (for S5P: coordination by Gaia Pinardi in AO project NIDFORVAL)

NDACC ZSL-DOAS (incl. SAOZ) network:

- Zenith-sky twilight
- 27 (12) instruments currently operational
- SAOZ: Fully automated
- SAOZ LATMOS_RT processing = <2 days delay
- Fully automated contribution to the S5P-MPC VDAF
- Requires photo-chemical adjustment from twilight to CO₂M overpass time

NDACC FTIR and TCCON:

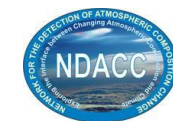
- 10 sites in common, several in Europe.
- IR retrieval (as opposed to satellite and ZSL-DOAS UV-Vis retrievals) -> potential cross section inconsistencies
- For the S5P MPC, data come through the NIDFORVAL AO project.

AERONET Cimel sun photometers:

- AOD
- Harmonized processing
- Centralized database (GSFC)

GALION aerosol lidar networks

- Backscatter measurements (probing aerosol layer height)
- Network of networks
- Harmonized metadata and variable naming



Network overlap – colocated measurements

Decreasing NO2 levels

GHG FTIR						NO2 @ FTIR	Closest PGN site with properties	Closest MAX-DOAS site with properties	Closest AERONET site with properties			
	C	D	E	F	H	I	J	K	M	N	P	Q
1	site	latitude	longitude	altitude	dataSource	field_estimated	closest_PGN_site	closest_F	closest_MAXDOAS_site	closest_MA	closest_AERONET_site	closest_AER
6	Pasadena	34,14	-118,13	0,23	TCCON(a)	1,041E+18	WrightwoodCA	49,2187	Cuautitlan	2460,3055	Santa_Monica_Colg	34,2724951
7	Xianghe	39,75	116,96	0,05	NDACC*(p),TCCON(a)	9,463E+15	Beijing-RADI	56,7671	Xianghe	0	Anmyon	893,255659
8	JPL	34,2	-118,18	0,39	TCCON(ai)	7,837E+15	WrightwoodCA	50,1056	Cuautitlan	2467,941	Santa_Monica_Colg	33,6626443
9	Paris	48,85	2,36	0,06	TCCON(a)	7,011E+15	Brussels-Uccle	259,976	Uccle	257,74265	Paris	0,48464998
10	Hefei	31,91	117,17	0,03	TCCON(a)	6,5E+15	Beijing-RADI	902,362	Gucheng	815,495	EPA-NCU	865,862017
11	Karlsruhe	49,1	8,44	0,12	NDACC*(n),TCCON(a),COCCON(n)	4,226E+15	Cologne	229,643	Heidelberg	39,302546	HohenpeissenbergDWD	238,333459
12	Toronto	43,6	-79,36	0,17	NDACC(a)	4,202E+15	StGeorge	7,40783	Cuautitlan	3233,6793	Toronto	22,9033474
13	Tsukuba	36,05	140,12	0,03	TCCON(a),COCCON(a)	4,082E+15	Tsukuba-NIES	0	Chiba	46,736719	Fukuoka	924,01316
14	Bremen	53,1	8,85	0,03	NDACC(a),TCCON(a)	3,532E+15	Bremen	0	Bremen	0	FZJ-JOYCE	295,28835
15	Thessaloniki	40,63	22,97	0,06	COCCON(n)	3,312E+15	Athens-NOA	301,512	Thessaloniki (lap)	0,8438934	Thessaloniki	0,84389336
16	Anmyeondo	36,54	126,33	0,03	TCCON(a)	3,165E+15	Seosan	30,2634	Seoul	116,17425	Anmyon	0,16359908
17	Harwell	51,57	-1,31	0,12	TCCON(a)	3,107E+15	Brussels-Uccle	404,244	Uccle	404,12379	Bayfordbury	86,7836403
18	Boulder	40,04	-105,24	1,61	NDACC(a)	3,085E+15	BoulderCO-NCAR	0	Cuautitlan	2331,7783	NEON_Sterling	193,385129
19	St. Petersburg	59,88	29,83	0,02	NDACC(a)	2,551E+15	Helsinki	272,699	Bremen	1482,9474	Kuopio	354,747502
20	Wollongong	-34,41	150,88	0,03	NDACC(a),TCCON(a)	2,489E+15	Canberra	187,914	Lauder	1987,4295	Lucinda	1822,03793
21	Saga	33,24	130,29	0,01	TCCON(a)	2,397E+15	Fukuoka	35,2615	Kasuga	35,785492	Fukuoka	35,9488037
22	Orleans	47,97	2,11	0,13	TCCON(a)	2,205E+15	Brussels-Uccle	354,289	Uccle	351,99755	Palaiseau	82,8266305
23	Nicosia	35,14	33,38	0,19	TCCON(a)	2,145E+15	Tel-Aviv	361,99	Athens	908,86066	Nicosia	0,14146378
24	Edward	34,96	-117,88	0,7	TCCON(a)	1,794E+15	WrightwoodCA	67,0365	Cuautitlan	2496,6675	Santa_Monica_Colg	118,040515
25	Bialystok	53,23	23,05	0,18	TCCON(ai)	1,776E+15	Berlin	659,18	Bremen	945,16724	Belsk	217,551298
26	Garmisch	47,48	11,06	0,74	NDACC*(a),TCCON(a)	1,513E+15	Innsbruck	34,8717	Munich	82,049372	HohenpeissenbergDWD	35,9746448
27	Lamont	36,6	-97,49	0,32	TCCON(a)	1,501E+15	ManhattankS	288,521	Cuautitlan	1884,3433	ARM_SGP	0,69574803
28	Zugspitze	47,42	10,98	2,96	NDACC(a), TCCON(a)	1,372E+15	Innsbruck	35,6505	Munich	90,791378	HohenpeissenbergDWD	42,532679
29	Harestua	60,2	10,8	0,6	NDACC(a)	1,091E+15	Helsinki	780,996	Bremen	798,34254	Debrzyna_PULS	794,483172
30	Jungfraujoch	46,55	7,98	3,58	NDACC(a)	1,052E+15	Davos	144,807	Munich	323,1346	Sirmione_Museo_GC	233,916572
31	Fairbanks	64,86	-147,85	0,21	COCCON(n)	1,01E+15	FairbanksAK	0	Ily-Alesund	3972,9159	ARM_Oliktok_AK	632,828587
32	Altzomoni	19,12	-98,66	3,98	NDACC(a)	9,568E+14	Altzomoni	0	INAM	59,380828	NEON_OAES	1811,85711
33	Darwin	-12,46	130,93	0,04	TCCON(a)	9,238E+14	AliceSprings	1294,45	Phimai	4381,4421	Lake_Argyle	468,816686
34	Izafia	28,3	-16,5	2,37	NDACC(a),TCCON(a),COCCON(n)	9,202E+14	Izana	1,11195	Uccle	3050,3329	Izana	1,04041612

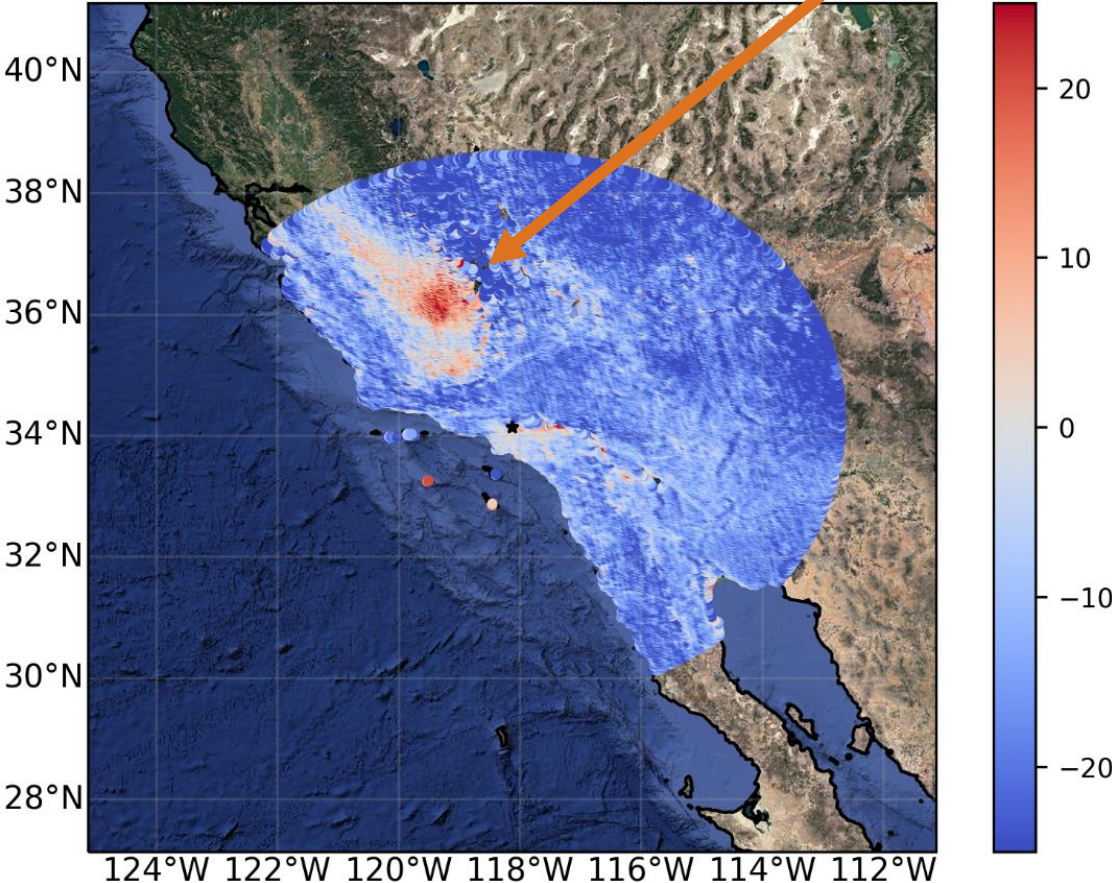
Overpass Statistics (<1% cloud cover) Karlsruhe July-December

Supports the estimation of the duration of commissioning phase of the satellite

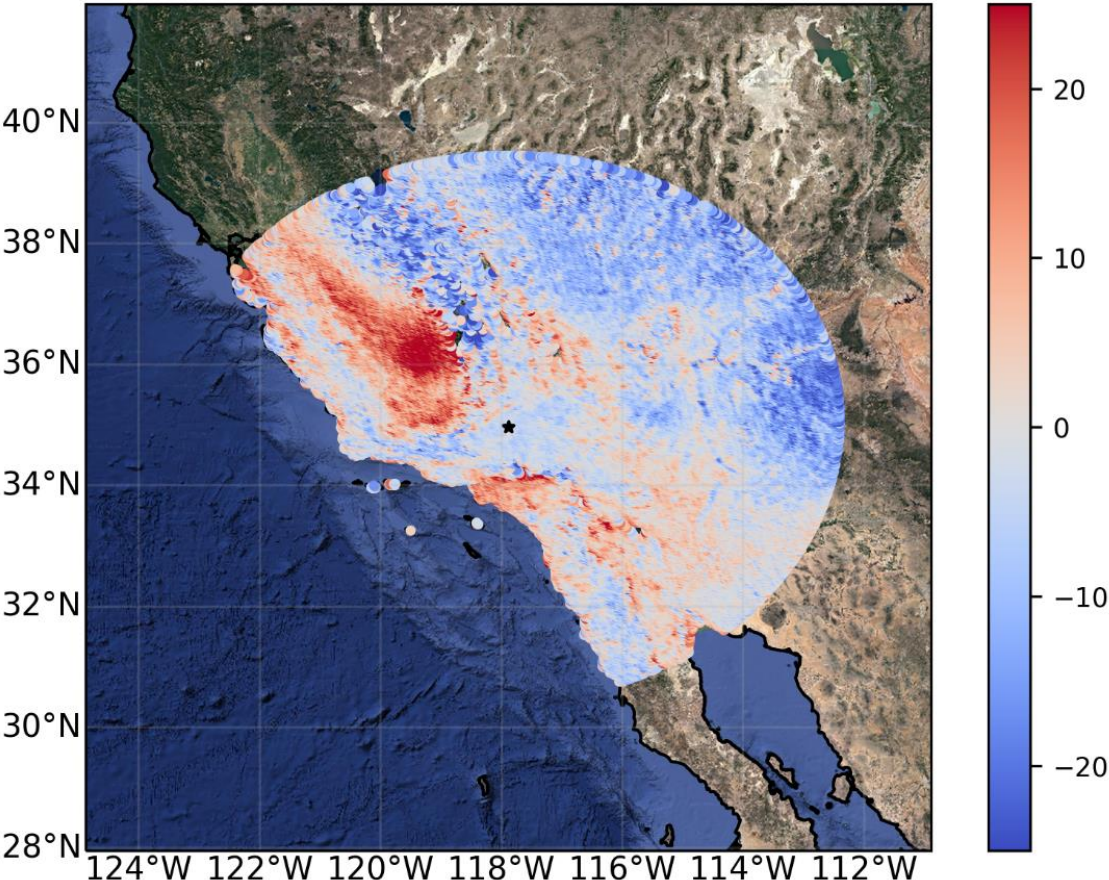
platform	AOT	0-15 deg	15-30 deg	30-45 deg	45-60 deg	60-80 deg	Total
CO2Mcent	0.00-0.15	0	11537	1179	28555	32122	73393
CO2Mwest		0	15699	8221	42972	17967	84859
CO2Mcent	0.15-0.30	0	0	3	1009	0	1012
CO2Mwest		0	0	187	2117	0	2304
CO2Mcent	0.30-0.50	0	0	0	0	0	0
CO2Mwest		0	0	0	0	0	0
CO2Mcent	0.50-1.00	0	0	0	0	0	0
CO2Mwest		0	0	0	0	0	0
CO2Mcent	Total	0	11537	1182	29564	32122	74405
CO2Mwest		0	15699	8408	45089	17967	87163

San Joaquin valley (dairy farms)

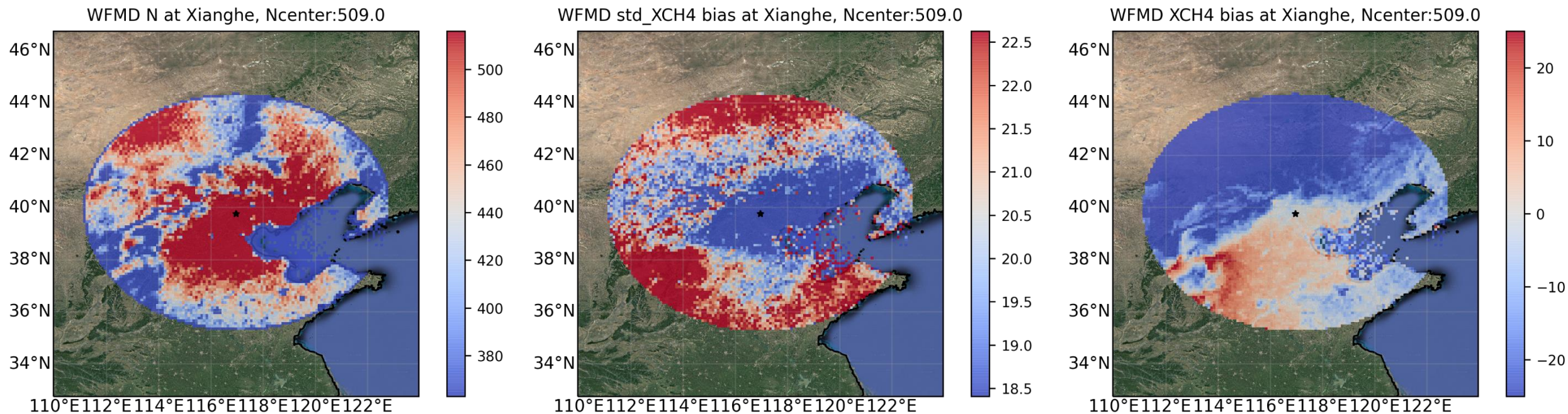
XCH4 at Caltech



XCH4 at Dryden



Xianghe:



High measurement density. Strong positive biases to the South, negative biases towards the North.



Quality Parameters

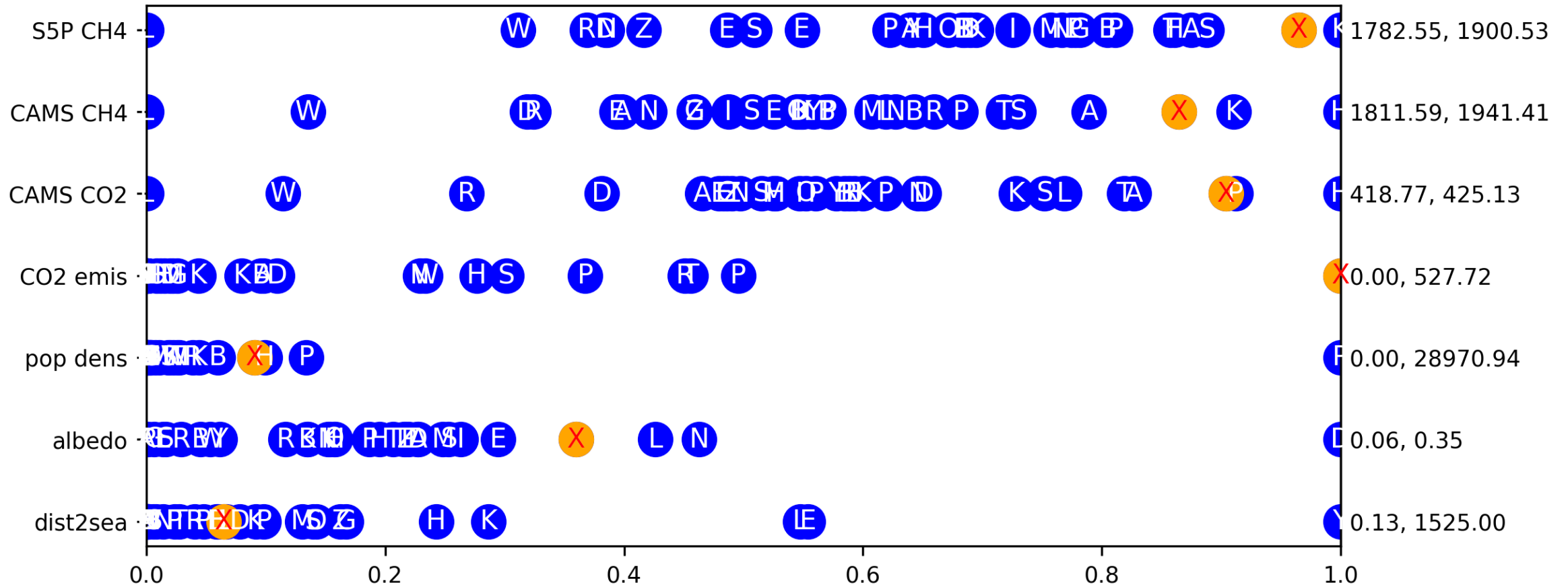
parameter	Anmyeond	Ascension	Bremen	Burgos	Darwin	Dryden	East_Troul	Eureka	Garmisch	Harwell	Hefei	Izana	Karlsruhe	Lamont	Lauder	Nicosia	Ny_Alesun	Orleans	Paris	Park_Falls	Pasadena	Reunion	Rikubetsu	Saga	Sodankyla	Tsukuba	Wollongor	Xianghe
Dist (km)	514	4030	446	1530	3160	94.3	1400	1770	9.11	400	872	2710	265	1200	1990	2300	1360	99	99	1200	94.3	6650	880	514	1360	880	1990	872
nr Cont	7	3	9	7	3	7	7	7	9	9	7	3	9	7	3	9	9	9	9	7	7	3	7	7	7	7	3	7
nr 2000km	5	0	7	2	0	2	1	1	6	6	4	0	6	3	1	0	2	6	6	2	2	0	3	6	2	3	1	3
nr 30lat	16	2	11	3	2	16	11	2	17	11	12	10	16	17	1	16	2	17	16	18	16	3	18	15	4	16	2	19
dist2sea	0.3	0.13	91.5	0.7	3	120	845	2.66	255	90	370	12	437	835	102	21.5	0.42	217	150	73	36	1.66	62	9.45	213	42	2.24	99
Altitude (m)	30	17	30	35	37	699	502	610	743	142	30	2367	119	320	370	185	129	130	60	442	569	87	380	7	188	31	30	36
parameter	Anmyeond	Ascension	Bremen	Burgos	Darwin	Dryden	East_Troul	Eureka	Garmisch	Harwell	Hefei	Izana	Karlsruhe	Lamont	Lauder	Nicosia	Ny_Alesun	Orleans	Paris	Park_Falls	Pasadena	Reunion	Rikubetsu	Saga	Sodankyla	Tsukuba	Wollongor	Xianghe
S5P CH4 (ppb)	1885.8	1858	1863.2	1877.5	1827.9	1864	1839.9	1847.3	1874.8	1859.3	1884.1	1868.2	1864.5	1873.9	1782.5	1873	1828.1	1861.8	1874.3	1856	1878.3	1826	1863.4	1887.3	1842.6	1883.7	1819.3	1896.4
CAMS CH4 (ppb)	1914.5	1861.8	1884.6	1891.6	1852.8	1882.9	1879.4	1862.3	1872.3	1883.6	1941.2	1871.3	1883	1888.8	1812	1891.8	1866.1	1882.6	1885.5	1885.5	1901.4	1851.1	1890.8	1908	1878.5	1905.3	1826.9	1924.6
CAMS CO2 (ppm)	424.6	421.5	422.6	422.6	420.2	423.3	422.1	422.1	422.1	422.2	425.5	422.5	422.7	423.8	418.5	423.3	422.5	422.3	422.6	423	424.9	419.7	422.7	424.2	422.4	424.5	419.2	424.8
CO2 emis (tn/km2)	51.7	0	50.6	0	57.6	10.4	0	0	13.7	7.8	146	0.875	23	0	0	121	0	4.58	261	0	194	238	6.15	159	0.343	241	123	528
pop dens (nr/km2)	80.7	0	1730	0	25.4	0	0.0917	2.22E-05	118	53.1	2870	218	583	0	1.23	789	0	103	29000	0	3870	1130	4.16	537	0.771	751	660	2620
albedo	0.0608	0.127	0.1	0.0741	0.127	0.353	0.0649	0.147	0.0627	0.118	0.107	0.138	0.1	0.185	0.124	0.196	0.105	0.107	0.115	0.0611	0.125	0.0948	0.0692	0.135	0.0654	0.121	0.0764	0.166
nr S5P<5km	18	13	155	46	97	827	38	162	25	149	122	358	202	453	285	591	10	226	212	56	633	6	77	218	70	246	47	509
nr S5P<100km	3372	1141	62480	2782	22461	322801	12695	153107	5500	60850	55579	11342	74557	188878	52126	51124	2003	97912	95649	16641	204435	658	13203	22757	29806	52790	8402	206064
nr S5P<200km	14268	3563	192220	6976	76685	1029945	45256	390637	22951	148997	193195	25404	265923	681592	91909	127872	5425	354681	324054	58340	694687	2282	22331	45932	95663	82032	32965	665040
nr S5P<500km	44627	18573	695119	27674	425947	4485236	214633	1688368	153083	482503	853680	451570	1140254	3377931	127262	2398727	53190	1252640	1234180	246760	3365679	9563	30573	219052	274801	135566	181865	3297840
parameter	Anmyeond	Ascension	Bremen	Burgos	Darwin	Dryden	East_Troul	Eureka	Garmisch	Harwell	Hefei	Izana	Karlsruhe	Lamont	Lauder	Nicosia	Ny_Alesun	Orleans	Paris	Park_Falls	Pasadena	Reunion	Rikubetsu	Saga	Sodankyla	Tsukuba	Wollongor	Xianghe
med S5P CH4 (100 km,ppb)	-5.54	-3.83	0.621	-4.43	-1.77	-0.678	0.13	-9.06	-16.9	-0.87	14.6	-15	-0.26	-2.98	0.908	-0.161	5.97	-0.0933	-8.22	4.83	-13.2	4.39	4.74	-1.52	-4.22	-1.91	-12	-0.886
med CAMS CH4 (100 km,ppb)	-0.644	-0.0245	-0.702	0.407	-0.473	-2.32	0.453	0.625	2.31	0.576	-2.64	11.1	-2.78	-0.447	-1.43	0.825	0	-0.08	-2.13	0.556	-10.8	-0.805	1.5	0.0482	-0.28	-0.966	-1.37	-0.94
med CAMS CO2 (100 km,ppm)	-0.294	-0.00067	-0.069	0.0387	-0.0396	-0.0573	0.0142	0.0205	0.0544	0.0101	-0.511	0.254	-0.208	-0.0161	0.032	-0.0379	0.00119	-0.0142	-0.185	0.0218	-1.13	-0.047	0.0343	0.0551	0.00127	-0.157	-0.0387	-0.125
med CO2 emis (100 km,tn/km2)	-51.6	0	-44.3	0	-57.6	-9.51	0	0	-8.64	-2.34	-135	-0.875	-11	0	0	-121	0	-0.681	-253	0	-191	-238	-2.39	-155	-0.343	-216	-123	-465
med Population (100 km,nr/km2)	-80.7	0	-1640	0	-25.4	0	-0.0917	0	-62.6	4.31	-2550	-218	-372	0.935	-1.07	-789	0	-63.1	-28900	0.961	-3870	-1130	7.31	-432	0	-436	-660	-2090
med Albedo (100 km)	0.0413	-0.00265	0.00771	-0.00759	-0.00856	-0.103	0.00482	-0.00215	0.0101	-0.0162	0.0195	-0.0167	0.00118	-0.00943	-0.0134	-0.106	0.027	0.00807	0.0099	0.0122	0.0249	-0.00087	0.00389	-0.0505	0.000912	-0.0188	-0.00941	-0.0135
med Altitude (100 km,m a.s.l.)	19.3	-8.51	22.7	-65.8	-2.9	193	-28.8	-90.4	-292	-31.4	2.56	-1890	185	32.6	263	-150	242	4.93	63.3	-21.3	238	-33.5	-84.6	45	25.1	5.26	-30.3	9.14
parameter	Anmyeond	Ascension	Bremen	Burgos	Darwin	Dryden	East_Troul	Eureka	Garmisch	Harwell	Hefei	Izana	Karlsruhe	Lamont	Lauder	Nicosia	Ny_Alesun	Orleans	Paris	Park_Falls	Pasadena	Reunion	Rikubetsu	Saga	Sodankyla	Tsukuba	Wollongor	Xianghe
var S5P CH4 (100km,ppb)	24.4	21	9.95	28.4	17	20.4	20.7	19.2	29	8.47	12.3	38.1	13.5	10.3	14.3	13.7	37.7	9.65	8.81	17.6	20.1	18.4	29	22.3	12.7	21.2	29	28.1
var CAMS CH4 (100km,ppb)	4.05	0.793	2.21	5.48	0.743	16.9	3.53	3.98	23.9	3.71	7.35	4.74	7.35	1.89	6.83	6.44	11.4	1.94	2.72	3.67	20.6	2.22	13.2	7.3	3.24	7.91	10.7	20.3
var CAMS CO2 (100km,ppm)	0.732	0.106	0.105	0.384	0.116	0.94	0.136	0.0963	0.666	0.193	0.572	0.152	0.375	0.165	0.171	0.24	0.283	0.121	0.153	0.153	1.36	0.0982	0.455	0.641	0.068	1.07	0.258	1.57
var CO2 emis (100km,tn/km2)	124	0	23.1	0	0.153	60.5	0	0	16.8	45.8	80.2	2.22	32.1	3.18	0	20.1	0	31.7	76.9	3.4	207	6.52	13.9	69.9	0.31	391	50	960
var Population (100km, nr/km2)	1720	0	752	216	1.65	580	0.174	2.22E-05	570	4270	1130	242	1130	22.8	2.97	114	0.122	742	1990	23.3	3690	216	129	1450	8.04	8810	867	5460
var Albedo (100km)	0.0665	0.042	0.0389	0.0705	0.129	0.225	0.0473	0.0334	0.0562	0.0281	0.0526	0.0833	0.0797	0.062	0.0644	0.134	0.0582	0.0662	0.0471	0.0333	0.221	0.0365	0.0645	0.0849	0.0211	0.0832	0.081	0.084
var Altitude (100km, m a.s.l.)	190	96.8	87.2	730	92.8	1090	254	1100	901	129	107	993	520	135	1130	540	746	140	105	279	1330	104	831	690	141	467	733	604

parameter	Anmyeond	Ascension	Bremen	Burgos	Darwin	Dryden	East_Trou	Eureka	Garmisch	Harwell	Hefei	Izana	Karlsruhe	Lamont	Lauder	Nicosia	Ny_Alesun	Orleans	Paris	Park_Falls	Pasadena	Reunion	Rikubetsu	Saga	Sodankyla	Tsukuba	Wollongong	Xianghe
Dist (km)	514	4030	446	1530	3160	94.3	1400	1770	9.11	400	872	2710	265	1200	1990	2300	1360	99	99	1200	94.3	6650	880	514	1360	880	1990	872
nr Cont	7	3	9	7	3	7	7	7	9	9	7	3	9	7	3	9	9	9	9	7	7	3	7	7	7	3	7	
nr 2000km	5	0	7	2	0	2	1	1	6	6	4	0	6	3	1	0	2	6	6	2	2	0	3	6	2	3	1	3
nr 30lat	16	2	11	3	2	16	11	2	17	11	12	10	16	17	1	16	2	17	16	18	16	3	18	15	4	16	2	19
dist2sea	0.3	0.13	91.5	0.7	3	120	845	2.66	255	90	370	12	437	835	102	21.5	0.42	217	150	73	36	1.66	62	9.45	213	42	2.24	99
Altitude (m)	30	17	30	35	37	699	502	610	743	142	30	2367	119	320	370	185	129	130	60	442	569	87	380	7	188	31	30	36
parameter	Anmyeond	Ascension	Bremen	Burgos	Darwin	Dryden	East_Trou	Eureka	Garmisch	Harwell	Hefei	Izana	Karlsruhe	Lamont	Lauder	Nicosia	Ny_Alesun	Orleans	Paris	Park_Falls	Pasadena	Reunion	Rikubetsu	Saga	Sodankyla	Tsukuba	Wollongong	Xianghe
S5P CH4 (ppb)	1885.8	1858	1863.2	1877.5	1827.9	1864	1839.9	1847.3	1874.8	1859.3	1884.1	1868.2	1864.5	1873.9	1782.5	1873	1828.1	1861.8	1874.3	1856	1878.3	1824	1863.4	1887.3	1842.6	1883.7	1819.3	1896.4
CAMS CH4 (ppb)	1914.5	1861.8	1884.6	1891.6	1852.8	1882.9	1879.4	1862.3	1872.3	1883.3	1941.2	1871.3	1883	1888.8	1812	1891.8	1866.1	1882.6	1885.5	1885.5	1901.4	1851.1	1890.8	1908	1878.5	1905.3	1826.5	1924.6
CAMS CO2 (ppm)	424.6	421.5	422.6	422.6	420.2	423.3	422.1	422.1	422.1	422.2	425.5	422.5	422.7	423.8	418.5	423.3	422.5	422.3	422.6	423	424.9	419.7	422.7	424.2	422.4	424.5	419.2	424.8
CO2 emis (tn/km2)	51.7	0	50.6	0	57.6	10.4	0	0	13.7	7.8	146	0.875	23	0	0	121	0	4.58	261	0	194	238	6.15	159	0.343	241	123	528
pop dens (nr/km2)	80.7	0	1730	0	25.4	0	0.0917	2.22E-05	118	53.1	2870	218	583	0	1.23	789	0	103	29000	0	3870	1130	4.16	537	0.771	751	660	2620
albedo	0.0608	0.127	0.1	0.0741	0.127	0.353	0.0649	0.147	0.0627	0.118	0.107	0.138	0.1	0.185	0.124	0.196	0.105	0.107	0.115	0.0611	0.125	0.0948	0.0692	0.135	0.0654	0.121	0.0764	0.186
nr S5P<5km	18	13	155	46	97	827	38	162	25	149	122	358	202	453	285	591	10	226	212	56	633	6	77	218	70	246	47	509
nr S5P<100km	3372	1141	62480	2782	22461	322801	12695	153107	5500	60850	55579	11342	74557	188878	52126	51124	2003	97912	95649	16641	204435	658	13203	22757	29806	32790	8402	206064
nr S5P<200km	14268	3563	192220	6976	76685	1029945	45256	390637	22951	148997	193195	25404	265923	681592	91909	127872	5425	354681	324054	58340	694687	2282	22331	45932	95663	82032	32965	665040
nr S5P<500km	44627	18573	695119	27674	425947	4485236	214633	1688368	153083	482503	853680	451570	1140254	3377931	127262	2398727	53190	1252640	1234180	246760	3365679	9563	30573	219052	274801	135566	181865	3297840
parameter	Anmyeond	Ascension	Bremen	Burgos	Darwin	Dryden	East_Trou	Eureka	Garmisch	Harwell	Hefei	Izana	Karlsruhe	Lamont	Lauder	Nicosia	Ny_Alesun	Orleans	Paris	Park_Falls	Pasadena	Reunion	Rikubetsu	Saga	Sodankyla	Tsukuba	Wollongong	Xianghe
med S5P CH4 (100 km,ppb)	-5.54	-3.83	0.621	-4.43	-1.77	-0.678	0.13	-9.06	-16.5	-0.87	14.6	-15	-0.26	-2.98	0.908	-0.161	5.97	-0.0933	-8.22	4.83	-13.3	4.39	4.74	-1.52	-4.22	-1.91	-12	-0.886
med CAMS CH4 (100 km,ppb)	-0.644	-0.0245	-0.702	0.407	-0.473	-0.232	0.453	0.625	2.31	0.576	-2.64	11.1	-2.78	-0.447	-1.43	0.825	0	-0.08	-2.13	0.556	-10.8	-0.805	1.5	0.0482	-0.28	-0.966	-1.37	-0.94
med CAMS CO2 (100 km,ppm)	-0.294	-0.00067	-0.069	0.0387	-0.0396	-0.0573	0.0142	0.0205	0.0544	0.0101	-0.511	0.254	-0.208	-0.0161	0.032	-0.0379	0.00119	-0.0142	-0.185	0.0218	-1.13	-0.047	0.0343	0.0551	0.00127	-0.157	-0.0387	-0.125
med CO2 emis (100 km,tn/km2)	-51.6	0	-44.3	0	-57.6	-9.51	0	0	-8.64	-2.34	-13	-0.875	-11	0	0	-121	0	-0.681	-253	0	-191	-238	-2.39	-155	-0.343	-216	-123	-465
med Population (100 km,nr/km2)	-80.7	0	-1640	0	-25.4	0	-0.0917	0	-62.6	4.31	-250	-218	-372	0.935	-1.07	-789	0	-63.1	-28900	0.961	-3870	-1130	7.31	-432	0	-436	-660	-2090
med Albedo (100 km)	0.0413	-0.00265	0.00771	-0.00759	-0.00856	-0.103	0.00482	-0.0025	0.0101	-0.0162	0.0155	-0.0167	0.00118	-0.00943	-0.0134	-0.106	0.027	0.00807	0.0099	0.0122	0.0245	-0.00087	0.00389	-0.0505	0.000912	-0.0188	-0.00941	-0.0135
med Altitude (100 km,m a.s.l.)	19.3	-8.51	22.7	-65.8	-2.9	193	-28.8	-90.4	-292	-31.4	2.6	-1890	185	32.6	263	-150	242	4.93	63.3	-21.3	238	-33.5	-84.6	45	25.1	5.26	-30.3	9.14
parameter	Anmyeond	Ascension	Bremen	Burgos	Darwin	Dryden	East_Trou	Eureka	Garmisch	Harwell	Hefei	Izana	Karlsruhe	Lamont	Lauder	Nicosia	Ny_Alesun	Orleans	Paris	Park_Falls	Pasadena	Reunion	Rikubetsu	Saga	Sodankyla	Tsukuba	Wollongong	Xianghe
var S5P CH4 (100km,ppb)	24.4	21	9.95	28.4	17	20.4	20.7	19.2	29	8.47	12.3	38.1	13.5	10.3	14.3	13.7	37.7	9.65	8.81	17.4	20.1	18.4	29	22.3	12.7	21.2	29	28.1
var CAMS CH4 (100km,ppb)	4.05	0.793	2.21	5.48	0.743	16.9	3.53	3.93	23.9	3.71	7.35	4.74	7.35	1.89	6.83	6.44	11.4	1.94	2.72	3.67	20.6	2.22	13.2	7.3	3.24	7.91	10.7	20.3
var CAMS CO2 (100km,ppm)	0.732	0.106	0.105	0.384	0.116	0.94	0.136	0.0961	0.666	0.193	0.572	0.152	0.375	0.165	0.171	0.24	0.283	0.121	0.153	0.153	1.36	0.0982	0.455	0.641	0.068	1.07	0.258	1.57
var CO2 emis (100km,tn/km2)	124	0	23.1	0	0.153	60.5	0	0	16.8	45.8	80.2	2.22	32.1	3.18	0	20.1	0	31.7	76.9	3.4	207	6.52	13.9	69.9	0.31	391	50	960
var Population (100km,nr/km2)	1720	0	752	216	1.65	580	0.174	2.22E-05	570	4270	1130	242	1130	22.8	2.97	114	0.122	742	1990	23.3	3690	216	129	1450	8.04	8810	867	5460
var Albedo (100km)	0.0665	0.042	0.0389	0.0705	0.129	0.225	0.0473	0.0334	0.0562	0.0281	0.0526	0.0833	0.0797	0.062	0.0644	0.134	0.0582	0.0662	0.0471	0.0333	0.221	0.0365	0.0645	0.0849	0.0211	0.0832	0.081	0.084
var Altitude (100km, m a.s.l.)	190	96.8	87.2	730	92.8	1090	254	1100	901	129	107	993	520	135	1130	540	746	140	105	279	1330	104	831	690	141	467	733	604

High altitude sites

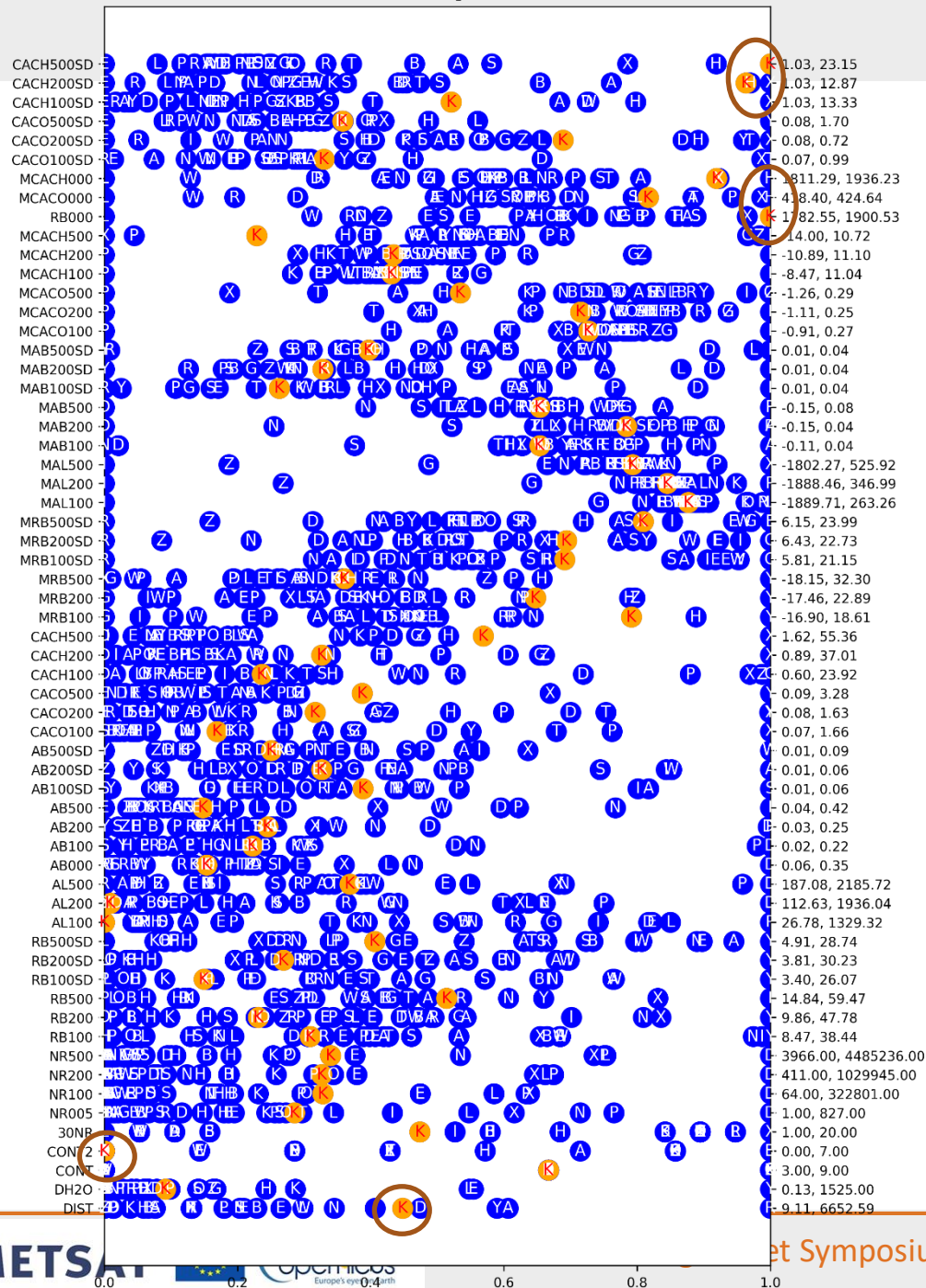
Parameters concerning the reference site (<5km)

At site parameters for Xianghe



One of the highest XCH4 and XCO2 concentrations (together with Kolkata and Hefei) with even more outspoken emissions

Kolkata



- High values for WFMD relative bias and variability (higher than current network)
- Very isolated (see DIST,CONT2 etc)
- Highest observed CH₄ concentrations in the network

Phase II - EUMETSAT Scientific service for the support of CO2M product validation methods, reference data provision and processing

June 2025 – May 2028, with optional +1 and +1 years

The new consortium is led by Royal Belgian Institute for Space Aeronomy (BIRA-IASB) with collaborators from Matthias Buschmann Environmental Research (MBER), S&T Netherlands B.V. (S[&]T), and The Inversion Lab (iLab) with BIRA-IASB also providing the service management.

Activity 1: Expand on the existing definition of requirements, methods and tools to support the validation and monitoring of the main CO2M user products (XCO_2 , XCH_4 , NO_2 , and SIF), as well as aerosol abundance and optical properties.

Activity 2: Maintain the CO2M reference-data resource database.

Activity 3: Design the operational collection and the provision of (ground-based) reference data to the EUMETSAT CO2M Cal/Val facilities.

Activity 4: Develop and provide an operational CO2M GBP data processing system supported by EUMETSAT specifications and establish the operational provision of original as well as pre-processed GBP data.

Activity 5: Prepare for and support the CO2M Cal/Val team during the commissioning of CO2M products and their transition into operations in applying the resources developed under activity 1 to 4.

Ground-based studies led by KIT

Ground-based Product (GBP) processing definition

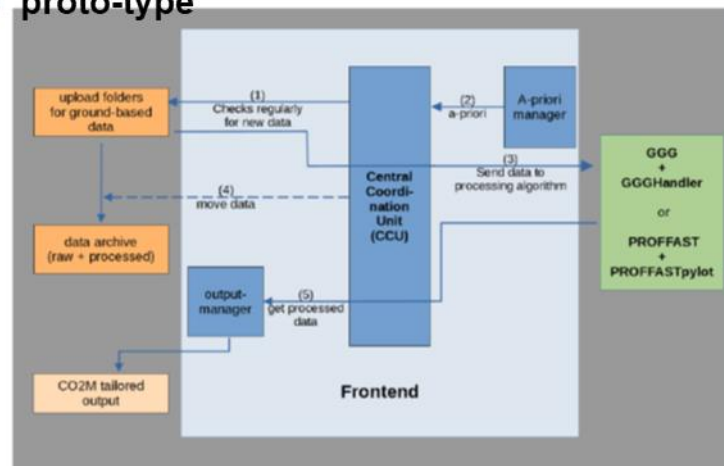
- Data will come from TCCON and COCCON stations
 - Rapid delivery – required due to strict time constraints for commissioning timeline
 - This is NOT standard processing
 - Level 0 or Level 1 data from the stations, processed to produce a Level 2 product created for explicitly CO2M's needs (overpass times, etc)

“SCENE for GDP” CO2M AUX product

CO2M a-priori and auxiliary data products



The EUMETSAT Ground-based Data Processing Facility GDPF proto-type



Level-1

CO2M-GDP Level-2
aim: timeliness < 1 week

TCCON/COCCON Level-2 fiducial reference data (aim: timeliness < 2 month)

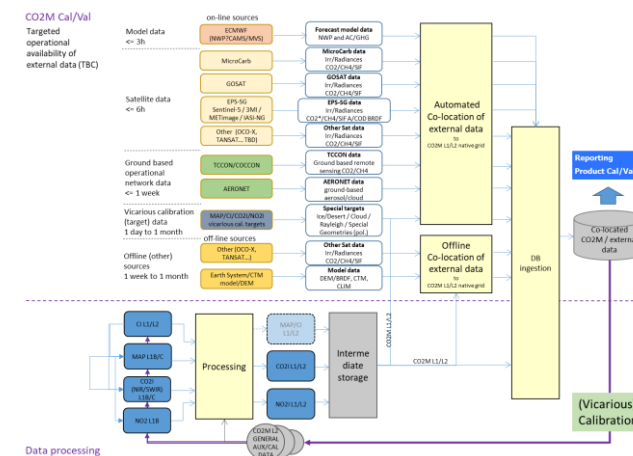


TCCON
0.001 nm (@1.6 μm)



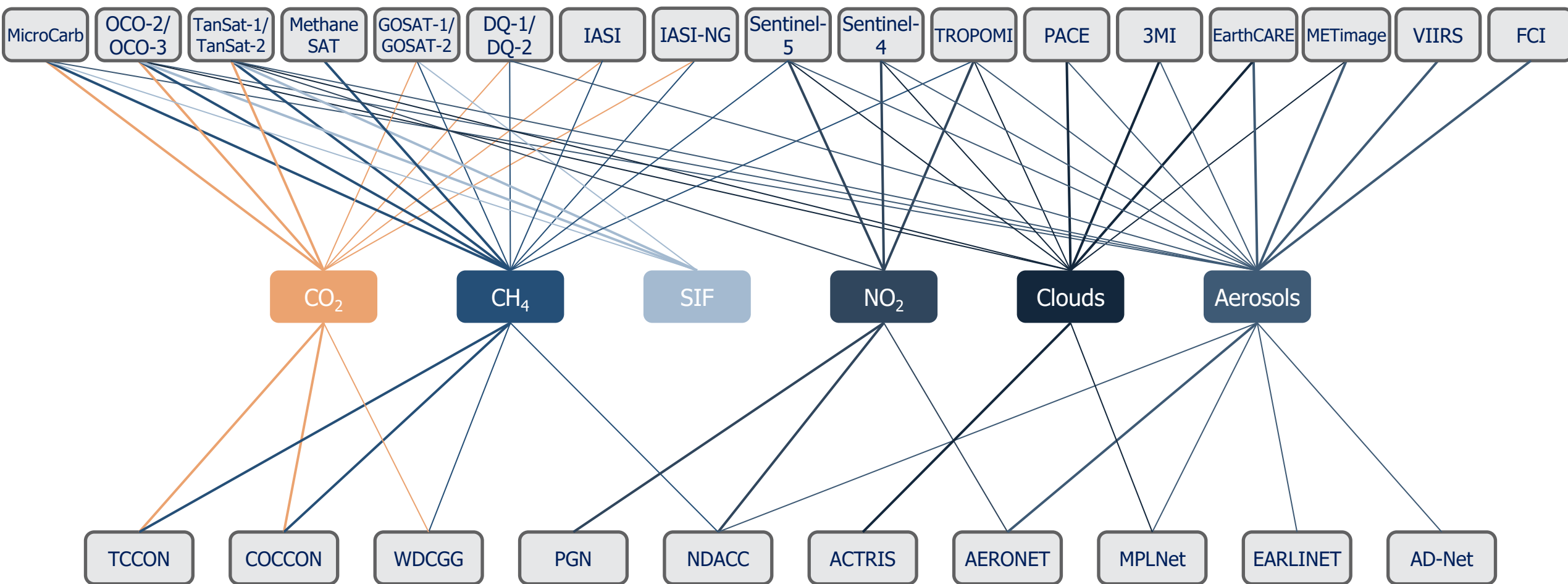
COCCON
0.14 nm (@1.6 μm)

EUMETSAT Cal/Val Facility



Courtesy – Ruediger Lang

Data sets from satellite instruments



Data sets from Fiducial Reference Measurements (FRM)

Courtesy – Catherine Hayer

Thank you for your attention!