Ground-based network design workshop for validation of CO2M, MicroCarb and related missions

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Contact

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Participants

108 Registered participants of the workshop (see Appendix)

Objectives

The workshop aimed to bring together the satellite community, ground validation data providers and stakeholders from around the world to:

- Receive an update on EUMETSAT's and CNES' initial plans for the CO2M mission and MicroCarb product validation and monitoring;
- Receive an update on results (and tools) from the dedicated CO2M science study supporting this initiative, focussing on ground based network analysis statistics derived to date;
- Discuss the usefulness of such analysis for related satellite missions and studies;
- Discuss current and future ground based network design issues (e.g., improving coverage, defining requirements for products from such measurement networks, etc.).

All presentations are available at https://events.spacepole.be/e/Ground-based-network-design-workshop.

Introductory Presentations

CO2M Cal/Val Planning

R. Lang (EUMETSAT) summarised the approach to CO2M Cal/Val planning and the scope and objectives of the workshop (*EUMETSAT_20230707_CO2M_ParisWorkshop_Lang_v2*). This included the status of work on the CO2M ground-based product requirements, which include:

- the establishment of performance requirements per station, based on overpass statistics and environmental data;
- timely and continuous delivery of data as an operational service;
- description of the traceability to WMO standards (and where it may not exist or not be feasible).

Station survey for XCO2 and XCH4 validation

D. Feist (CO2M Cal/Val Study Team - LMU) presented the database of TCCON, COCCON and NDACC stations for continuous Cal/Val and monitoring of CO2M products

(*LMU_20230707_CO2M_ParisWorkshop_Feist*). The definition of "active" stations was discussed. So far, this is just based on information available on the web, but alternative criteria could be considered. Information can be collected from existing stations via a questionnaire prepared to support filling of the database. New station PIs can also send in their information in this way, to be included in the database. An example file of the questionnaire can be downloaded from the guide page of the website https://co2m.aeronomie.be/guide under section 2 – database information – template.

Availability of NO_2 and aerosol datasets for CO2M product validation

T. Verhoelst (CO2M Cal/Val Study Team – BIRA-IASB) presented the NO_2 validation capacity for CO2M (*BIRA-IASB_20230707_CO2M_ParisWorkshop_Verhoelst*). The current status of the co-located instruments for GHG/NO_2/AOD was presented and highlighted the synergies between monitoring networks and identified gaps. It was mentioned that there are other sources which should be included in the database and synergies study.

Overpass statistics and station footprints quantifying the sensitivity of measurements w.r.t. emissions

T. Kaminski (CO2M Cal/Val Study Team - iLab) presented the computation of overpass statistics and station footprints quantifying the sensitivity of measurements w.r.t. emissions (*iLAB_20230707_CO2M_ParisWorkshop_Kaminski*). It was suggested that an alternative would be to aim for a minimum uncertainty in the final ground-based products, rather than selecting networks and stations for specific missions. It was further noted that this analysis is based on existing networks and has not yet been projected to other areas for gap-filling.

Satellite product uncertainties and their dependencies on influencing parameters at stations

B. Dils (CO2M Cal/Val Study Team – BIRA-IASB) presented the quantification of satellite product uncertainties and their dependencies on influencing parameters at stations (*BIRA-IASB_20230707_CO2M_ParisWorkshop_Dils*), addressing the question: is it possible to use satellite data to inform us on the conditions surrounding a given validation (TCCON/COCCON/NDACC) site as an alternative to model data? This is still work-in-progress but is revealing some useful insights into station surroundings.

Building a science support service dedicated to validation and monitoring of CO2M and extendable to other satellite missions

M. K. Sha (CO2M Cal/Val Study Team – BIRA-IASB) presented the visualization tools for the station database, emissions database, satellite L3 files, overpass statistics and more (*BIRA-IASB_20230707_CO2M_ParisWorkshop_Sha*). It was noted that there are many more sources of emissions inventory data, e.g. GAIA-CLIM, OSCAR, etc. Attendees were encouraged to review the tool (accessible via https://co2m.aeronomie.be/).

MicroCarb XCO2 validation needs

D. Jouglet (CNES) presented the MicroCarb capacities for validation, the current work to prepare validation with TCCON and EM27/SUN, the Cal/Val plan for Level 2 (based on ground networks, in situ measurements and models), and the Cal/Val scientific (including accuracy traceability) and operational needs from the networks (*230706 - IWGGMS side meeting ground based validation - jouglet v2*). The MicroCarb team's requirements on the networks complement those of CO2M, especially concerning the timely availability of data and the need for traceability of intra- and inter - network biases. On the traceability and uncertainty budget (slide 25), it was noted that the WMO

standard is not an absolute value of XCO2. It was also noted that stations in tropical and boreal forests, and other active zones, are required to support biogenic missions. Networks need to be extended and complimented by reaching out to other participants in this area.

The MAGIC Initiative

C. Crevoisier (LMD) presented the MAGIC initiative – description, tools and future plans (*LMD_20230707_IWGGMS_sideevent_magic_Crevoisier*). MAGIC involves the simultaneous measurements of the atmosphere with balloon and airborne in situ instruments, as well as ground remote instruments. The objectives are to better characterize the atmospheric composition, inter-compare instruments and validate space missions. Additional information is available at MAGIC – Monitoring Atmospheric composition and Greenhouse gases through multi-Instrument Campaigns (aeris-data.fr).

Discussions

Picking up on the issues raised during the presentations, a list of questions was compiled for further discussion.

Can we use in-situ measurements for Level-2 product validation/evaluation?

S. Pandey (NASA) presented recent work on using surface observations to evaluate errors in total column satellite retrievals (*Pandey_230710_CO2M_MC_meeting*). This is a new approach for assessing errors in total column satellite retrievals of long-lived GHGs by using NOAA marine boundary layer observations and global transport models. The growth rate estimates from satellite observations (GRESO) method is employed to compare the global means and growth rates from both satellite and NOAA's global time series. The differing sampling of the satellite and NOAA observations is accounted for by using an ensemble of global atmospheric transport model runs. This approach offers a valuable tool for comparing satellite retrievals with NOAA surface observations, which serve as the primary reference for global atmospheric greenhouse gas concentrations.

Y. Meijer asked about the error on the suggested bias correction and if use of such a correction could be avoided. The presenter felt that there is justification for the bias correction, especially over ocean. The fact that there are fewer validation points over ocean regions could be contributing to the problems over oceans.

A. Eldering noted the need to balance effort between land vs TCCON, ocean vs TCCON and the difference between land and ocean. There was some agreement that focus should be directed towards land vs. ocean biases.

Should we not better optimise the tools and the networks for all missions (add more information)?

There was some concern that the discussion should not be limited to just specific missions, as ground-based networks cannot continually change to target specific satellites. On the other hand, forthcoming missions require a pragmatic approach. In general, the meeting was not in favour of optimising networks for all missions as funding/support for one mission can also bring benefits for other missions. CO2M has very specific requirements. Working towards these would automatically benefit other missions.

The possible role of a tiered network approach (in terms of timeliness, data coverage and quality) was discussed, as an intermediate step towards optimisation. The WMO Global Greenhouse Gas Watch (GGGW) initiative is already considering this, with a workshop planned for 3 – 5 October 2023 (https://community.wmo.int/en/meetings/observations-within-global-greenhouse-gas-watch). The

concept will include continuous flow of CAMS data for QC. Liaison with WMO can also support information on/access to other types of global GHG data, e.g. from China if/when bi-lateral talks take place.

The networks we want to rely on are not operational (TCCON, COCCON). What needs to be done about it?

The question of what "operational" means was discussed. A service-based component with a single interface, addressing the needs of space-based and modelling-based operational system infrastructure is required, providing continuous data flow, high availability and good timeliness.

TCCON is currently releasing its data within 1 year at worst, most stations providing them within 3 to 6 months. GGGW are aiming for 3 weeks. For CO2M, EUMETSAT's requirement for routine monitoring is 2-3 days. This is in line with how EUMETSAT already function for their other operational missions. This will be especially crucial during the Commissioning Phase. It was noted that OCO had a special arrangement with a subset of TCCON stations for Commissioning. A EUMETSAT local processing system could help to overcome delays with the quality monitoring of the incoming data.

MicroCarb have a slightly lower requirement for timeliness, at 2 to 4 weeks (especially during Cal/Val). D. Jouglet noted that quality monitoring and bias correction have different requirements. Bias characterisation does not need to be done in NRT but cannot wait several months during commissioning phase.

It was noted that there would be uncertainties associated with NRT delivery, which would need to be provided with the data. Data need not necessarily be removed during quality filtering, but the uncertainty could be used to trigger quality warnings. Of course in order to achieve high timeliness, quality cannot be rigorously checked on a short timescale, so a balance is required. Agency support could really help here. Incentives can also help with operational provision (including recognition as well as funding, to highlight provider's contributions to the global system). The AERONET network is given as an example. The FTIR data from the Network for the Detection of Atmospheric Composition Change (NDACC) is also a good example of a journey towards operationalisation (timeliness now at 1 month). Data are sent to the NDACC native database, from which CAMS harvests them. PIs then receive funding on a pro rata basis, depending on the amount of data fed in with the compliant timeliness. NDACC interact with all the global PIs. This system seems to be well received. It was noted that greater investment was needed for setup than routine operations. The NDACC model would be worth exploring further, in terms of funding as well as centralized point of contact.

If EUMETSAT could provide the infrastructure ready to receive ground-based data at the necessary timeliness, the networks could use this as justification to go to their national agencies to request funding to make and supply the necessary measurements.

F. Hase commented that timeliness has always been difficult issue and perhaps model predictions would better serve the timeliness required, using the networks to check the trajectory of the models.

Conclusions: The fact that TCCON and COCCON (as well as NDACC-FTIR) are not operational in terms of timeliness and availability yet for CO2M has been confirmed by the workshop. The potential for EUMETSAT to establish an operational interface for centrally receiving and processing ground-based network data was also highlighted and acknowledged. EUMETSAT proposes direct negotiations with the networks as a whole (through a single interface) for provision of data and discussing the required

resource needed for such a data service (modelled on existing contracts that exist between CAMS and networks like NDACC). Common NRT definitions also need to be established (e.g. with MicroCarb) in order to support the operational timeliness needs towards the GB networks.

Where do we need a traveling standard and where do we need reference measurements? XCO2 traceability to WMO standard. Do we need it?

This was acknowledged as a difficult but key question for ground-based remote sensing as station locations vary so much. It was felt that both have a role to play. AirCore samples would be particularly valuable in the tropics where there is less experience to draw on.

Traceability is perhaps more of an issue for the networks as a whole than for individual stations.

COCCON instruments have already been checked at KIT with a TCCON station before deployment, and a travelling standard is also available. This could be used to connect TCCON and COCCON more closely. Use of a travelling standard is particularly important for stations where AirCore measurements cannot be taken. Further extension of instruments as traveling standards is desired, as a single travelling standard instrument will take a long time to visit the full list of stations in the networks.

The end-to-end metrology (e.g. availability and accuracy of accepted line lists) is currently limiting the traceability of performances (and their requirements). Additional work to close the gaps is for lab spectroscopists, not network operators. A. Eldering pointed out the need meanwhile to document the employed empirical factors, until the availability of fully traceable and accepted spectroscopy. The aim to achieve full traceability to WMO is considered nevertheless important by the participants.

Beyond providing new stations, D. Jouglet indicated a preference for a travelling standard (one or several EM27/SUN instruments) as a regular link between stations (TCCON and COCCON), since the inter-station relative bias has to be monitored and corrected. The EM27/SUN gives the additional advantage that it does not always have to be sent with a large team of people (TCCON PIs are often aware of the use of an EM27/SUN).

An NO_2 travelling standard is already being implemented with support from ACTRIS.

Regardless of traceability to WMO, travelling standards can ensure that stations are consistent with network specifications.

Where do we need to put the stations?

For bias characterisation, MicroCarb would prefer measurements to be away from anthropogenic sources. For anthropogenic emission validation (secondary objective of the mission), MicroCarb would use measurements close to anthropogenic emissions. MicroCarb could target gaps in biogenic measurements and CO2M gaps in anthropogenic measurements.

Generally, there is a need to better characterise the surface (surface albedo, altimetry etc.). The environment for new stations must be well characterised generally, and assessed for favourability towards specific missions. The CO2M visualisation tool can help in this respect. It already includes the ability to write scripts to also query the database directly and this feature will be released externally in due course. EUMETSAT would welcome feedback on the tool and the database.

Instruments on ships should also be considered, especially in support of MicroCarb and analysis of data in glint.

How can we get more co-located XCO2/XCH4/NO_2/Aerosols measurements at the sources?

There was general agreement that more NO_2 and aerosol measurements close to sources are needed, ideally with collocated instrumentation for CO_2 and CH_4. Current collocations are very rare. There are not many barriers to improve this, other than investment.

It would also be useful to demonstrate how the performance of coastal stations could be improved with the addition of NO_2 measurements.

What about Aerosol measurement in the SWIR?

There was support for EUMETSAT's proposal to add AERONET stations to their database and CO2M Cal/Val Plan. MicroCarb will use the AERONET data. Other aerosol networks (EARLINET LIDAR, WMO Global Atmospheric Watch (GAW) Aerosol Lidar Observation Network (GALION) and GAW PFR, plus AIRCORE) should also be considered.

EUMETSAT are currently working with the GRASP team to assess how reliable the SWIR information is in AERONET. It is also currently TBD if aerosol height is provided.

Conclusions

EUMETSAT and CNES thanked the participants for their contributions and invited additional feedback off-line.

EUMETSAT will continue to work on the CO2M ground-based product requirements document, including populating the appendix with collocation criteria per station, adding the status on aspects of traceability, and coordinating the requirements with MicroCarb. This will be further presented and shared at the end of the year.

Following the meeting, EUMETSAT noted the following:

- There is a growing awareness of the need for the networks to **move towards a service-based component with a single interface**, addressing the needs of space-based and modelling-based operational system infrastructure.
- With the current developments for inter- and intra-network(s) "travelling standard", the missing link to WMO traceability remains the spectroscopy (after full implementation of travelling standards).
- EUMETSAT preference for the CO2M mission is **the reception of level-1 data using the GGG (TCCON) and ProFast (COCCON) processors** to produce **CO2M mission dedicated level-2 data** in a EUMETSAT ground-based product processing central facility and **for internal mission use only (and no redistribution of data)!**
- The CO2M mission dedicated level-2 data processing will be done with auxiliary information consistent with what is used in the CO2M operational product processing system. In parallel**, the networks would be provided with all (auxiliary) input data required for their own processing (in case of interest)** - so the PIs can make their own products from such data.
- To ensure the continuous monitoring and validation of operational CO2M products EUMETSAT plans establish **a service agreement with the TCCON and COCCON global networks for the provision of data.**

Appendix: Participants list and statistics

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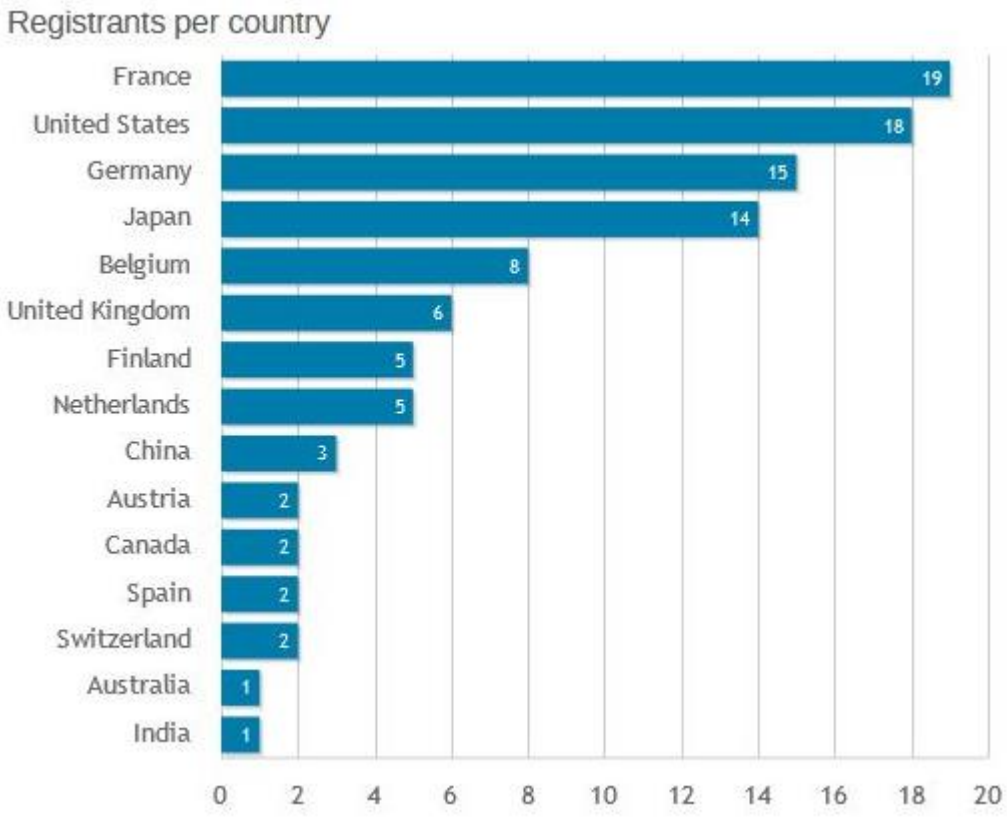
Registrants per country
France
United States
Germany
Japan
Belgium
United Kingdom
Finland
Netherlands
China
Austria
Canada
Spain
Switzerland
Australia
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