NDACC capacity and sustainability report

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1. Introduction

According to the NORS description of Work (DoW), this deliverable entitled 'NORS capacity and sustainability' reports about the NORS achievements and experience at meetings of the CEOS Working Group on Calibration/Validation (CEOS WGCV).
It is important to summarize the major achievements of NORS and to make sure that the CEOS WGCV recognizes these achievements, because the needs and requirements for the that the Copernicus Atmospheric Monitoring Service (CAMS) has for its quality assessment using in-situ data are mostly identical to the ones that the CEOS community has for the quality assessment of the satellite L2 (and higher) data. This means that almost all that has been achieved in NORS can be of direct use for the CEOS community. The only required essential adaptations are the collocation algorithms in the NORS Validation Server: colocation with a model output provided on a fixed model grid is different from colocation with a satellite L2 data set, in which the data are geolocated on a satellite ground pixel for a nadir-looking satellite, or along a line-of-sight for a limb viewing satellite. This colocation problem was already addressed in the former ESA GECA project (Generic Environment for Calibration/Validation Analysis), and can be refurbished in an extended NORS Validation Server.

2. Summary of NORS achievements in view of future

The achievements of NORS that will survive the project duration are the following:

- The NDACC UV-Vis community in Europe has made significant advances with the MAXDOAS technique, in particular with a harmonized analysis of the data, e.g., for deriving tropospheric NO_2, for determining aerosol extinction profiles in the lowest troposphere, for detecting and classifying cloud occurrences, etc. One can state that the MAXDOAS techniques is getting mature for becoming a certified NDACC technique.

- Discrepancies between data retrieved from different techniques (e.g., NO_2 and HCHO from FTIR and UV-VIS, CO from mid-infrared and near-infrared FTIR) have been studied and understood. This paves the way for a more appropriate analysis and combined use of the various data sets, in different applications.

- The tropospheric information in the NORS data products has been verified against the information available from in-situ observations and models (see WP5 of NORS, and deliverable D5.3)

- For all ground-based remote sensing techniques involved in NORS (LIDAR, Microwave radiometry (MWR), FTIR and UV-Vis spectrometry), the data have been better characterized in terms of their uncertainties and their representativeness. This information will remain publicly available from the NDACC Webpage. Moreover, this information is included in the datafiles (or it is the intention to include it in a future update of the GEOMS/HDF templates) and as such is directly available for the data users. Also a Data User Guide is available on the NDACC database.

- The NDACC database has made progress towards a more consistent and homogeneous database. Although there are still two data formats co-existing in the archive (NASA Ames and GEOMS/HDF), there is a net progression towards the (correct) use of the GEOMS/HDF format. In this format, the datafiles are self-explaining, easily searchable, and quality-controlled upon submission as to format and variables reporting.

- Moreover, the GEOMS/HDF templates for reporting data acquired with the various NDACC measurement techniques have been optimized in order to contain all the relevant information (uncertainties, averaging kernels, cloud flags, spatial representativeness information …) that is required for correct use of the data, and especially for validation purposes. To avoid updates of the templates too often, some Working Groups preferred to accumulate a few changes before implementation in the near-future.

- The Rapid Delivery (within one month or faster) of the data has been implemented by many groups. The data are submitted to a dedicated section in the NDACC Data Handling Facility which will continue operation after the end of NORS. In general dedicated software tools have been developed for this purpose and as such, there is a good chance that rapid delivery will continue after the end of NORS, provided that there is a minimum of manpower available and that the station infrastructure can be maintained (see section 4 hereafter). This Rapid Delivery is very attractive for all users of the data: better and more use of the data enhances significantly the visibility of the NDACC.

- The NORS Validation Server, a Web-based interactive tool, enables browsing through validation reports for the MACC target products that are generated automatically and on a daily basis. Underlying the server are a set of generic colocation and comparison algorithms that have been developed in Python (Open source code) and that have been published in the MACC Special Issue in Geoscience Model Development (Langerock et al., 2014).These comparison algorithms can be re-used for satellite validation purposes without essential changes; the colocation algorithms have to be adapted according to the work already done in the ESA GECA project.

- The development or improved operation of new stations outside Western Europe, where local people have been trained to operate the instruments, analyse the data and archive the data according to the NDACC standards and NORS procedures, will expand NDACC to reach a better global coverage. It has created new partners and collaborations in the atmospheric community, and possibilities for environmental education. For more detailed information: see Deliverable D10.1 ‘Capacity report’.

The above progress has been disseminated in the whole NDACC community (i.e., beyond the NORS consortium, see Section 2 hereafter) and as such will make the whole NDACC community and all the users of NDACC data benefit from it now and in the future. It is for example evident that this progress will serve the validation of the Sentinel 4 and 5 missions, and in the immediate future the Sentinel 5 precursor TROPOMI mission.

3. Report about NORS presentations at NDACC Working Group (WG) and Steering Committee (SC) meetings

The progress in NORS was presented at all successive NDACC SC meetings and at many WG meetings:

De Mazière, M., NORS – Demonstration Network of Ground-Based Remote-Sensing Observations in Support of the GMES Atmospheric Service, oral presentation at the 2012 NDACC SC meeting.

De Mazière, M., Transition to HDF status, discussion about the format homogenization in the NDACC DHF at the 2012 NDACC SC meeting

De Mazière, M., How NORS Is Enhancing the Value of NDACC, Especially for Validation Purposes, oral presentation at the 2013 NDACC SC meeting.

Langerock, Bavo, and M. De Mazière, Demonstration Network Of ground-based Remote Sensing observations in support of the GMES Atmospheric Service, oral presentation at the NDACC IRWG meeting in June 2012

De Mazière, M. & the GEOMS Board (I. Boyd, (A.F. Vik), A.M. Fjaeraa, T. Krognes, G. Taha, J. Wild, C. Retscher, B. Bojkov, A. Burini, S. Niemeijer), GEOMS templates, oral presentation at the NDACC IRWG meeting in June 2013

Langerock, Bavo, and M. De Mazière, Outline of the use of FTIR measurements in the NORS validation server, oral presentation at the NDACC IRWG meeting in June 2013

Langerock, B. and M. De Mazière, Developments in the NORS Validation Server, oral presentation at the NDACC IRWG meeting in May 2014.

De Mazière, M., NORS: overview and project status, oral presentation at the NDACC UVVIS WG meeting, BIRA-IASB, July 2012.

Gomez, L., NORS WP10: Status of the MAX-DOAS instruments operated by INTA in Antarctica (Marambio, Belgrano, Ushuaia), oral presentation at the NDACC UVVIS WG meeting, MPI-Mainz, July 2013.

Goutail, F., A Bazureau, and the SAOZ team, Status of the rapid data delivery to the NORS/NDACC database, oral presentation at the NDACC UVVIS WG meeting, MPI-Mainz, July 2013.

Hendrick, F., NORS WP3 status: GEOMS data formatting-Rapid delivery service, QA/QC procedures, oral presentation at the NDACC UVVIS WG meeting, BIRA-IASB, July 2012.

Hendrick, F., and M. Van Roozendael, Harmonisation of MAX-DOAS retrievals within NORS, oral presentation at the NDACC UVVIS WG meeting, MPI-Mainz, July 2013.

Hendrick, F., C. Fayt, M. Van Roozendael, and I. Boyd, NORS WP3: rapid data delivery at 4 NDACC stations, oral presentation at the NDACC UVVIS WG meeting, MPI-Mainz, July 2013.

Richter, A., F. Wittrock, E. Peters, and J. P. Burrows, NORS WP4: uncertainties, oral presentation at the NDACC UVVIS WG meeting, MPI-Mainz, July 2013.

Wagner, T., NORS WP4: data reporting of parameterized profile inversions, oral presentation at the NDACC UVVIS WG meeting, MPI-Mainz, July 2013.

Wittrock, F., with contributions from BIRA-IASB, UBremen, INTA, MPI-Mainz, NORS WP4 status, oral presentation at the NDACC UVVIS WG meeting, BIRA-IASB, July 2012.

NORS was also presented to the GRUAN community, during their ICM-6 meeting in Greenbelt, March 10-14, 2014:

De Mazière, M. and M. Kurylo, A view from the Network for the Detection of Atmospheric Composition Change (NDACC)

The final results of the NORS project were presented during the joint NORS/NDACC/GAW workshop (Nov. 5-7, 2014, Brussels, Belgium) to a wide audience. This workshop was preceded by the NDACC SC annual meeting 2014 and many SC members attended the NORS/NDACC/GAW Workshop as well.

4. Report about NORS presentations at CEOS WGCV (Working Group on Cal/Val) and ESA Cal/Val Infrastructure meetings:

The NORS project was introduced to CEOS WGCV during its Plenary of February 2012 (WGCV-34, Brisbane). Progress was reported in October 2014 (WGCV-38, College Park, MD), by J.-C. Lambert, and in larger detail in February 2014 (WGCV-37) by M. De Mazière.

NORS was also presented to the ESA Working Group on Cal/Val Infrastructures, at DLR, Bonn on December 3-4, 2013:

De Mazière, M., The FP7 NORS project and way forward: The evolution of NDACC and perspectives for satellite validation.

The presentations raised interest with the space agencies to build further on the achievements of NORS, and in particular the NORS Validation Server concept and the underlying algorithms for comparison between two datasets, to develop generic calibration/validation systems for satellite data. Also the harmonization of the data acquisition, data retrieval, estimation of associated uncertainties, data file format, metadata and faster data delivery in the NDACC Working Groups is of large interest for the space agencies for satellite validation applications, being considered as remarkable progress to meet the general objectives of traceability, harmonization and interoperability.

5. Report about the relationship between MACC and NORS and NORS sustainability:

NORS has been presented at various MACC meetings:

De Mazière, M., Demonstration Network Of ground-based Remote Sensing Observations in support of the GMES Atmospheric Service ", oral presentation at the MACC-II KO meeting, Reading, March 1, 2012.

De Mazière, M., B. Langerock and the NORS consortium, Remote sensing network observations of atmospheric composition for assessing and improving the MACC-II products: status of the NORS project, January 27-30, 2014.

Moreover, M. De Mazière participated regularly to the monthly MACC Project Management Board teleconferences to ensure the link between NORS and MACC.

To enable the sustainability of NORS, a White Paper (see Annex) has been published that was presented to the MACC coordinator and to the EU DG Enterprise on April 28, 2014.
Since then, we succeeded to integrate some basic operational features of NORS, namely the continuation of the NORS Validation Server and its exploitation, in MACC-III: NORS is now considered as an integral part of the MACC-III Validation Subproject. As such, it will most probably be maintained and hopefully further improved and expanded in the Copernicus Atmospheric Monitoring Service.

There is however an important shortcoming:

Although there is good hope that some support for use of the NDACC data in the validation of the Copernicus Atmospheric Monitoring Service will be provided, there is still a problem of sustainability of the Network as such: there is no sustained funding for the maintenance of the stations infrastructure, for the operation and maintenance of the instruments, nor for the analysis and delivery of the data and the required developments for guaranteeing up-to-date reliable data.

6. References

Langerock, B., M. De Mazière, F. Hendrick, C. Vigouroux, F. Desmet, B. Dils, and S. Niemeijer, Description of algorithms for co-locating and comparing gridded model data with remote-sensing observations, Geosci. Model Dev. Discuss., 7, 8151–8178, 2014, doi:10.5194/gmdd-7-8151-2014

White Paper

Why should NORS be sustained on the long-term ?

I. The Copernicus Atmosphere Monitoring Service must include validation activities using independent reference measurements.

It is recognized in Copernicus, and in particular by the former GMES Atmospheric Core Service (GACS) Implementation Group, and all current CAMS scientists and users, that the CAS products are of no value if their quality has not been assessed and characterized [1]. The quality assessment and characterisation must continue throughout the lifetime of the CAMS, knowing that the CAMS products and services evolve continuously. The evolution of the CAMS products is a must as new satellite data become available, new model developments need to be integrated, and as new and/or updated user requirements appear [1].
The validation must be done with independent data. Among the independent data are the in-situ data, and in particular the remote sensing ground-based network data that provide 3D information (i.e., vertically resolved (profiles) or vertically integrated (columns) data, on a quasi-global scale). They are therefore more similar in nature to the CAS products than for example the surface data. For many stratospheric gases, they are the only source of independent in-situ data.

[1] states explicitly that the validation activities are an integral part of the GACS:

"Cal/val activities in relation to Core Service products fall entirely within the GACS" (see also Fig. 1 in chapter 5 of [1]: GAS Functional Architecture).

In the same context, to guarantee the availability of independent data for calibration/validation of the CAS products, [1] argues explicitly for sustainable support to provision of reference data:

"The EU should support the operation and further development of European facilities including…the provision and storage of quality-controlled long-term reference data sets for open access by the GACS and GMES users".

"The implementation of an operational GACS requires the availability of European atmospheric monitoring systems which should be sustainably supported as part of this operational activity through appropriate funding mechanisms."

"The EU funding support should in particular be focused on:

· The gap filling in observation infrastructure, enabling e.g. relocation of observation capacities and development of observation networks in e.g. Eastern part of Europe or outside Europe,

…

· The European contributions, in particular through European capacities, to international observation networks and data management systems,

· Technical (e.g. Cal/Val and data management facilities) and institutional coordination activities."

II. NORS contributes significantly to fulfilling the Copernicus Atmospheric Monitoring Service validation needs.

The timely provision of reference ground-based remote sensing network data from the international Network for the Detection of Atmospheric Changes (NDACC) for quality assessment of the CAMS products, and the implementation of facilities for performing this quality assessment in an operational mode is exactly what has been set up in the EU NORS FP7 project (see annex 1 for a reminder about the NORS project) and needs to be continued.

NORS has achieved the following:

1. It has improved the quality and consistency of the NORS/NDACC ground-based remote sensing data and their suitability for validation purposes:

The ground-based remote sensing data have been optimized and harmonized across the network, they have been better documented and their uncertainties have been evaluated, and new products are under development.

2. It has improved the timely delivery of the NORS/NDACC ground-based remote sensing data:

The NORS partners have committed themselves to delivery within 1 month from data acquisition *at latest (some are already doing it faster)*. They have established more automatic data processing and submission procedures, and the standard GEOMS HDF format. Under the impulse of NORS, additional NDACC partners are adopting similar approaches and are achieving rapid data delivery.

3. NORS has developed and implemented a Web-based validation server:

This server collects the data from the CAMS and from NORS/NDACC on a daily basis and generates automatically comparison reports (plots and statistics). All algorithms used in the comparison tool chain are open source; they are documented in a paper to be published in the peer-reviewed literature. They are compliant with the atmospheric community's best practices [2]. Reports generated by the NORS validation server have already been used in the MACC-II Validation Reports [3]. As such, the scientists and users involved with CAMS and with NDACC get automatic feedback concerning their data: they can easily detect deficiencies from which guidance towards the required improvements can be derived.
NORS and MACC-II are discussing how the server can be integrated in the MACC-II system before the end of the project.

In summary:

By the end of the NORS project in November 2014, we have developed a validation activity using NDACC ground-based remote sensing reference data that is an integral part of the Copernicus Atmospheric Monitoring Service, fulfilling an important part of its validation needs. Sustaining this validation support is mandatory for ensuring accurate and continuous quality assessment of the CAMS data and services, and at the end for the sustainment of the CAMS.

III. What is required to sustain NORS ?

A. To guarantee the continuation of the NORS Validation Server supporting the Copernicus Atmospheric Monitoring Service in its Operational Phase, it is ***essential*** that

1) the ground-based remote sensing network (NDACC) gets the necessary support to continue the timely delivery of high-quality and well-characterised products
2) the systematic use of the NDACC data in support of the quality assessment of the satellite and CAMS products is guaranteed – meaning that the validation server must be maintained and kept operational, embedded in the CAMS portal.
3) the evolution of both the ground-based remote sensing products and the validation server follow closely the evolution of the needs for validation of the satellite and the CAMS products (e.g., new products, higher-precision requirements, etc.).

Such can only be guaranteed if NORS-like activities remain supported in the Copernicus Operational Phase as an integral part of the Atmosphere Core Service.

B. It is also ***essential*** for the continuation of NORS in the Operational Phase of the Copernicus Operational Phase ***that the gap between FP7 and the Operational Phase is bridged.***

The NORS FP7 project ended in November 2014. It is not likely that the Copernicus Operational Phase will start before April 2015**.** That means that there is a significant risk that in the gap between the FP7 funding and the Copernicus funding, the activities developed in NORS will die out and the expertise and momentum acquired in NORS will get lost. Also the maintenance of the necessary infrastructure may be endangered. Moreover, stopping or interrupting NORS would imply that the impulse that NORS is giving to the whole NDACC, - which will result in a better spatial coverage and larger product span for the quality assessment of the CAMS products -, vanishes. Also, the contacts that have been established between the MACC-II and the NDACC communities will fade out.
If a NORS-type activity has to continue in the Copernicus Operational Phase, *which we believe is the case*, then it is of utmost importance to keep NORS running - at least the operational part - in the period of the gap, by funding at least the operational activities at a minimum level.
A rough estimation of the cost of NORS-type activities is provided in Annex II.

IV. Additional benefits of sustaining NORS

1. An important additional achievement of NORS is the enhanced value (timeliness, consistency, characterization, ..) of the NDACC data, not only for validation purposes but also for environmental monitoring purposes. Moreover, at some points in time, when a satellite dies, NDACC data may be the only ones that provide essential information about certain atmospheric constituents – e.g., for comparison with model data-, and are the ones that guarantee continuity between the lost satellite and the follow-up one. This is a supplementary argument for sustaining the Network as an essential component in the Copernicus Atmosphere Core Service.

2. It should be noticed that the Validation Server has been built in such a way that non-standard comparisons can also be accommodated. With 'non-standard' we refer to different reference data (not coming from NDACC) and/or different models (not coming from the present CAS prototype).
3. It should be noticed that the Web-based validation server can easily be expanded to also accommodate comparisons between the ground-based remote sensing data of NORS/NDACC and upstream satellite data, in particular the ones that are used in the MACC-II assimilation models. All

comparison algorithms remain valid to a large extent. Tools for collocation between satellite data and NORS/NDACC data do exist from a former ESA GECA project.

4. It is stated in [1] that "Monitoring the observations quality and availability is part of the (Copernicus Atmosphere) Core Service", and, "Space agencies should be responsible for cal/val activities with regard to (single-instrument) space observations." The latter has been confirmed by the European Space Agency (ESA) and the Committee on Earth Observation Satellites (CEOS) [B. Bojkov[1], presentation during NORS Second Progress Meeting, Oct. 18, 2013]. A NORS-type activity can provide this important asset without much additional development effort, and as such, contribute to the so-called 'observation acquisition and pre-processing' element of the Atmosphere Core Service [1].

M. *De Mazière and the NORS consortium, Nov. 15, 2013*

References

[1] Global Monitoring for Environment and Security Atmosphere Core Service (GACS) Implementation Group – Final Report, April 2009.

[2] EC FP7 MACC Validation Protocol, 2010, and references therein, in particular
GUM: Joint Committee for Guides in Metrology (JCGM/WG 1) 100:2008, Evaluation of
measurement data – Guide to the expression of uncertainty in a measurement (GUM), http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf
QA4EO – A Quality Assurance framework for Earth Observation, established by the CEOS – see http://qa4eo.org/documentation.html

[3] September issue of the MACC-II Deliverable D_82.9 'Validation report of the MACC near-real time global atmospheric composition service. System evolution and performance statistics - Status up to May 2013' which is available on the MACC-II Webpages at http://www.gmes-atmosphere.eu/services/aqac/global_verification/validation_reports/..

[1] B. Bojkov is Head of Sensor Performance, Products and Algorithms, at ESA, and Chair of Committee on Earth Observation Satellites (CEOS) Working Group on Calibration/Validation (WGCV) Atmospheric Composition SubGroup (ACSG).

Annex I: What is NORS about? Reminder about the NORS project.

NORS is an FP7 R&D project (grant agreement 284421) that is funded in support of the pre-operational Copernicus Atmosphere Service (CAS), with the aim of improving the Service.
NORS focuses on **improving the quality** of the CAS products, currently delivered by the MACC-II project, by improving and enhancing the use of ground-based remote sensing data for independent validation of the CAS products, in the following three ways:

1) by improving the quality and consistency of the ground-based remote sensing data and their suitability for validation purposes,
2) by improving the timeliness of the ground-based remote sensing data
3) by developing a Web-based validation server that performs comparisons between CAS products and NORS reference data in an automatic way, according to the atmospheric community's best practices [2 and references therein] .

The ground-based remote sensing network underlying NORS is the Network for Detection of Atmospheric Composition Change (NDACC, formerly the NDSC), which is a research network, operated in a coordinated manner since 1991, with more than 70 observatories distributed worldwide (www.ndacc.org). NORS demonstrates its goals starting from 4 pilot NDACC stations and a selection of target products, but it is preparing the extension to more/all NDACC sites and data products.

Annex II: What is the minimum cost of continuing a NORS-type activity ?

Cost in the operational phase:

1) Minimum cost for acquiring, processing, verifying and submitting the data, according to best practices :

   Per data product, per station, per year, this cost is estimated as 0.20 FTE of a postdoc researcher.
   This estimate supposes that no specific research is done, and that all station and instrument upgrades are funded through other means.
2) Minimum cost for maintaining the validation server for CAS products validation:

   The yearly cost is estimated at 0.15 FTE of a postdoc researcher.
   This estimate supposes that the server doesn't need any improvements in software nor hardware, nor any new functionalities, but only updates (compliance with updated CAS and NORS/NDACC products).

3) Additional cost for evolution of the independent data products for validation, according to the evolution of the validation requirements:

   Per data product, per station, per year, this cost is estimated as 0.2 FTE of a postdoc researcher.
4) Additional cost for evolution of the validation server for CAS products validation:

   Estimated at 0.20 FTE/year

Cost to bridge the gap between FP7 and the Operational Phase:
Assuming that the bridge lasts 8 months, that there is no further evolution required, neither of the reference products nor of the validation server and taking into account that NORS currently provides 32 products, the minimum cost would be 420 kEuro.

Notes:

- R&D related to the evolution of the ground-based remote sensing products and of the corresponding evolution of the validation server (the 3rd and 4th points in the above list) should also be covered in the EU H2020 programme.
- The additional cost for evolution and maintenance of the server for validation of the *satellite observations themselves* (not included in the above list) should be covered by ESA