ESA ATMOS 2015, Heraklion, Greece

Greenhouse Gases (GHG) and Future Missions sessions:

Summary of Discussion and Recommendations to ESA

(11 recommendations, not prioritized)

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Session overview

GHG session:

- 11 talks
  - Very interesting presentations from carbon experts from Europe, USA and Japan presenting results from past and existing missions (SCIAMACHY, GOSAT, OCO-2, IASI, …) incl. ongoing projects (GHG-CCI, CMS, …) and also addressing future needs (CarbonSat, …)
- More than 13 poster …

Future Missions session:

- ESA presentation on S-4, S-5, EarthCARE, ADM-Aeolus
- BIRA presentation on limb missions ALTIUS and PICASSO
- (S-5p: separate session)

Recommendation 1

R1: **Need for a European carbon mission:**

A carbon mission delivering the Essential Climate Variables (ECVs) CO2 and CH4, such as CarbonSat, is of strategic importance for Europe. Europe was an early pioneer in this area, with SCIAMACHY, but now is lagging behind in terms of carbon observation capability from space. Such a mission – combining high spatial resolution with broad coverage - is urgently needed to improve our knowledge on natural and anthropogenic CO2 and CH4 sources and sinks on various spatial and temporal scales and to keep and expand the European expertise in the vital area of carbon observations from space. This is particularly urgent with respect to quantification of national emissions, and the emissions of emission hot spots. Ultimately a constellation of (European and non-European) carbon missions is required in particular for the frequent detection, quantification and monitoring of the emissions of anthropogenic sources such as cities, oil and gas fields, power plants, etc. **We recommend that ESA work with its member states to accelerate the deployment of a European greenhouse gas mission, and collaborate with its international partners to implement a coordinated, space based greenhouse gas constellation to address these needs.**

Recommendation 2

R2: **Essential Climate Variables / ESA Climate Change Initiative (CCI) incl. GHG-CCI:**

High quality, long-term observations are needed for climate applications and several important Essential Climate Variables (ECVs) are generated within the ESA Climate Change Initiative (CCI) program using satellite data. **This CCI program ends early 2017 and there are concerns that the European effort to generate the needed long-term ECV data set will not be continued.** This would be short-sighted for many reasons, e.g., because the operational Copernicus programs CAMS and C3S need satellite-derived CO2 and CH4 data sets as input data but do not provide the resources needed for the generation and improvement of the Level 2 products meeting the GCOS ECV requirements. **It is recommended to continue the CCI program including continuation of the GHG-CCI project which started to build up the needed long-term satellite-derived CO2 and CH4 ECV data sets.**

Recommendation 3

R3: **Sentinel-5 (S-5) instrument issues :**

Serious concerns were expressed on incompliances presented by ESA on critical requirements concerning the S-5 instrument. **It is recommended to build an instrument compliant with the requirements.** It is recommended to ESA to perform an independent review based on the outcome of the next milestone in the project (PDR) to evaluate the causes leading to such serious incompliances so early in the project and take appropriate measures, allowing for reconsideration on hardware choices made. ESA is also recommended to take advantage of the extensive knowledge built up in the community during the last 20-25 years, with instruments such as GOME, SCIAMACHY, OMI, GOME-2 and S-5p/TROPOMI. The series of 3 S-5 instruments form the backbone of atmospheric composition measurements in the next decades to come, and the continuation of the current operational Copernicus services, as well as the long term records needed for climate, heavily depend on the quality of the S-5 instruments built. The non-compliances are such that now already serious concerns exist on the quality of the measurements the S-5 instruments will provide in the next decades.

Recommendation 4

R4: **S-5p processing capability:**

Concerns have been expressed that the computing capability is not adequate for processing of all S-5p data.

It is recommended that adequate processing capability is put in place for the generation of the operational data products.

Recommendation 5

R5: **Data Access Sentinels / Copernicus Satellites :**

To fully exploit the data returned by the Sentinels, **ESA must ensure that users have "good access" to all data products including, Level 1**.

ESA seems to focus mainly on the open data access needed for the Operational Copernicus Services. **ESA is recommended to** take care that open data access for the scientists is also guaranteed within a reasonable time (preferably NRT), not only for Level 2, but also Level 1 data.

The rolling archive setup of the currently proposed ground segment does not provide the open and free access to the satellite data needed by the scientific community.

…

Recommendation 5 - II

R5 (continued): **Data Access Sentinels / Copernicus Satellites :**

…

After a couple of months the data will not be accessible anymore, which means that scientists can not get the data older than a couple of months. This will limit research that needs long(er) data records severely. Also not all researchers will have sufficient computer power to download and keep whole data sets.

A rolling archive is therefore not considered to be appropriate as this is only useful for some “super users” but not for the (expected) majority of (potentially very important) users who need Sentinel data for specific scientific studies (starting often several years after data acquisition).

Recommendation 6

R6: **Science and operational services:**

Scientific expertise and appropriate financial science-related resources are mandatory in order to generate and use satellite-derived data products with a quality as needed for climate, greenhouse gas fluxes, air quality and other atmospheric chemistry and physics applications. **Concerns have been expressed that in the future the focus will be primarily on operational services (e.g., Copernicus) with no or only a marginal role for basic scientific research.** This is NOT recommended as this will lead to services which will not reflect the state of the art, precluding critical advances needed to address evolving needs. **We recommend that ESA ensures the availability of resources for the continued scientific activities needed to further improve the state of the art (e.g., retrieval algorithms) and to support continuing improvements in quality of the operational products and services.**

Recommendation 7

R7: **Validation data:**

Because space based measurements of CO2 and CH4 require unprecedented accuracy (~0.25%) **surface observations networks and other important reference data sources (e.g., TCCON, HIPPO, and AIRCORE for GHGs) are of vital importance for the assessment of the quality of the satellite data.** Internationally established and accepted reference standards are also needed for integrating the satellite data records collected over long time periods from multiple satellites (SCIAMACHY, GOSAT, OCO-2, GOSAT-2, Sentinel 4, 5p, 5, MERLIN, CarbonSat, etc.) to produce continuous records of Essential Climate Variables (ECVs). **Fast delivery of the reference data is needed to assess the quality and implement product improvements, especially in the first years of a new mission (e.g., Sentinel-5p).** Because of their critical role, it is essential to ensure that these reference/validation networks and activities receive adequate funding to maintain and expand observational capabilities for the generation and timely delivery of reference data. For some of these activities (e.g., TCCON, NDACC), this requires a coordinated action by several space agencies. **We recommend that ESA work proactively with its partner space agencies and validation data partners to ensure the continued and fast enough availability of these critical ground-based / non-satellite data sources.** …

Recommendation 7 - II

R7 (cont.): **Validation data:**

…

This does not only account for the greenhouse gas validation needs, but is in fact a wider issue covering also trace gases related to air quality, ozone layer and climate, as well as for aerosols. Also for those measurements insufficient validation measurements are available and existing ground based networks are diminished.

Recommendation 8

R8: **Limb gap:**

Again, as at many occasions in the past (e.g. ATMOS-2012, Brugge), concerns about the “limb gap” have been highlighted.

It is again recommended to perform altitude-resolved atmospheric composition observations (≥ UTLS), i.e., actions need to be taken to close the limb gap.

Specific recommendations / proposed solutions:

(i) Use existing aircraft instruments which have demonstrated the needed capabilities and determine which of these concepts can be used for a satellite mission,
(ii) use new technology aiming at small instruments,
(iii) make use of the ISS.

ESA is advised to

- take note of the existing nationally available instruments and
- take into account the findings and recommendations of the recent ESA Limb study

Recommendation 9

R9: **GEO missions / tropics:**

The tropics are an important region and could be well observed by GEO missions but the tropics are not covered by the planned GEO missions S-4 , TEMPO and GEMS .

It is recommended to also aim at GEO observations of the tropics.

Recommendation 10

R10: **High latitudes:**

Observations at high latitudes are urgent, because this region is evolving rapidly in response to climate change.

S-4 will not observe high latitudes and S-5 is not optimized for high quality high latitude observations.

It is recommended to implement a satellite mission optimized for performing atmospheric composition measurements at high latitudes (see, e.g., activities of the Canadian Space Agency).

Recommendation 11

R11: **Small Satellite Program:**

ESA is recommended to consider a program for small satellites as add-on's to the Copernicus backbone in order to, e.g.,

a. be more flexible / fill observational gaps / ensure faster response compared to the current long term program,
b. test new instrumentation in order to be able to improve on existing technologies.

Recommendation 12

R12: **Complementary missions:**

In addition to the continuation of long-term climate data sets (based on simple instrumentation), **Europe needs to implement complementary missions with sophisticated innovative instrumentation, in order to fill the current gap of knowledge regarding climate-relevant processes** (dynamics, transport, chemistry). Three-dimensional (limb) observations in the whole atmospheric altitude range (troposphere to mesosphere) appear to be best suited for this purpose. Such missions should be designed according to current scientific needs, but also provide the potential of new discoveries.

Recommendation 13

R13: **Coupling lower / upper atmosphere:**

It is recommended that ESA spends more efforts on studying coupling processes between Earth's lower atmosphere and the upper atmosphere/ionosphere. The ionosphere is essential for the performance of many systems that use radar, communications and geo-positioning signals. The prediction of ionospheric variability and the improvement of forecasts of extreme "space weather" is one of the key challenges with respect to the use of these techniques. In this context, the dynamical and chemical forcing of the ionosphere from the troposphere to the mesosphere gained increasing awareness in recent years. However, this forcing is poorly understood compared to our knowledge of the solar driven inputs. Therefore we propose to foster satellite measurements with high temporal and spatial resolution to study wave propagation as well as chemical forcing covering the whole atmosphere, in view of our scientific understanding as well as the operational prediction of "space weather".

Recommendation 14

R14: **Constellations:**

The recommendation is for ESA to develop the S4/S5/S5P as one constellation. Therefore, a consistent approach shall be developed regarding:

- instrument development (i.e. by ensuring overlap in the ESA project teams for S5P, S4 and S5
- on-ground and in-flight calibration (i.e. by using the same calibration standards)
- algorithms for Level 0-1B processing
- algorithms for Level 1-2 processing
- L1B and L2 data formats
- quality assurance
- geophysical validation approach

In addition, also consistency should be aimed for in the ESA/NASA/KARI air quality constellation. ESA should actively work towards consistency on the following aspects for the S4/TEMPO/GEMS + S5 constellation:

- exchange of calibration standards
- data formatting
- comparison of algorithms by applying them to the same dataset
- geophysical validation approach