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Greenhouse Gas CCI: Achievements, May 2012

User Requirements: The GHG-CCI user requirements are based on GHG-CCI Climate Research Group (CRG) user expertise, peer-reviewed publications and other documents, which have been generated during the last years primarily in the context of the greenhouse gas (GHG) satellite missions SCIAMACHY (ESA), GOSAT (JAXA), OCO (NASA) and CarbonSat (ESA, DLR). They are based on dedicated Observing System Simulation Experiments (OSSE) and extensive experience with real data (primarily SCIAMACHY). The User Requirements Document (URD) (available on the GHG-CCI website http://www.esa-ghg-cci.org/) was favorably reviewed by the CCI Climate Modeling User Group (CMUG), by the ESA Climate Office and others. CMUG highlighted that the GHG-CCI URD could serve as a template for the other ECV projects. Suggestions have been made to cover additional aspects in future updates such as future satellite missions. Key GHG-CCI user requirements have been presented and discussed at various conferences and workshops (EGU, International Workshop on Greenhouse Gas Measurements from Space (IWGGMS), COSPAR, GOSAT-2, etc.). The GHG-CCI user community is well represented by the inverse modeling experts, which are members of the GHG-CCI CRG. The GHG-CCI CRG chair is also chair of MACC GHG. The GHG-CCI user requirements reflect critical needs of the European atmospheric GMES core service (MACC). Products generated with GHG-CCI algorithms are delivered to MACC. The threshold requirements as formulated in the GHG-CCI URD reflect the minimum the users would like to see achieved (they have to be interpreted as “minimum wanted” rather than “worse is useless”). Several requirements are very demanding, especially the relative accuracy requirement for XCO_2 (the column-averaged mixing ratio of CO_2). In several aspects the requirements are more demanding than the GCOS requirements (as formulated in document GCOS-107 available prior to the start of CCI). For example, the GCOS requirement is 3 ppm for the CO_2 column (more precisely: XCO_2) and 20 ppb for the CH_4 column (XCH_4). The GHG-CCI requirements are 0.5 ppm for XCO_2 and 10 ppb for XCH_4, i.e., six times more demanding for XCO_2 and two times more demanding for XCH_4 compared to GCOS-107. In other aspects the GHG-CCI requirements are less demanding but realistic as they refer to the only existing instruments, which can be used by GHG-CCI. In case where a parameter cannot be changed (e.g., spatial resolution of an existing instrument) the corresponding parameter has been reported in the URD but no new (likely more demanding) requirement has been formulated. A typical parameter in this category is the observing cycle which needs to be 3 hours according to GCOS-107 but will (by far) not be met by any existing or even planned future mission.

Algorithm Selection Criteria and Round Robin (RR) exercise: The GHG-CCI algorithm selection criteria have been formulated in the GHG-CCI “Round Robin Evaluation Protocol” (RREP) also available on the GHG-CCI website. Initially it was suggested to use a single score-based selection procedure. This however was finally rejected because a sound basis for this could not be established. Instead the selection will be based on a series of Figures of Merit (FoM), an analysis of time series and global maps and expert judgement. As described in RREP, the selection procedure depends on the type of the algorithm, i.e., ECV Core Algorithm (ECA) or Additional Constraints Algorithm (ACA). The above description refers to ECAs. The ECAs are algorithms to retrieve the near-surface sensitive ECV core products XCO_2 and XCH_4 (using SCIAMACHY nadir observations and TANSO/GOSAT near-infrared/short-wave-infrared (NIR/SWIR) spectra). Near-surface sensitivity is mandatory in order to deliver the ECV GHG as defined by GCOS (“Product A.9: Distribution of greenhouse gases, such as CO_2 and CH_4, of sufficient quality to estimate regional sources and sinks”). The ACAs are algorithms to retrieve CO_2 and CH_4 information in layers above the planetary boundary layer such as mid/upper tropospheric columns from IASI and stratospheric profiles from MIPAS. For each ECA product several algorithms have been further developed in competition during the RR phase. ACAs are not in competition. For ACAs a number of criteria have to be fulfilled for a given algorithm to be selected (see RREP). The goal of the RR selection is to identify which algorithms to use to generate a data product which will be part of the GHG-CCI Climate Research Data Package (CRDP). The GHG-CCI RR exercise is currently in its final phase and ends end of August 2012. Therefore the final RR decision is not yet available. Nevertheless, major decisions have already been made at the GHG-CCI Progress Meeting in May 2012 based on a detailed assessment of various algorithms and corresponding data products as available in the GHG-CCI Round Robin Data Package (RRDP).

GHG-CCI Products and Data Access: The GHG-CCI CRDP will be ready in March 2013 for project internal evaluation (validation and user assessment). The CRDP will be made publicly available with all relevant documentation end of August 2013. At present the RRDP products are ready and available on request for all interested users via the GHG-CCI website (see ECA and ACA products tables on RR page). The RRDP is currently being analyzed, e.g., by comparison with ground-based observations. The findings will be documented in dedicated documents to be written by the retrieval team in cooperation with the users (AIECAR, due August 2012) and the independent validation team (PVASR, also due in August 2012). The final decision will be reported in a dedicated document (Algorithm Selection Report (ASR), due end of August 2012). For SCIAMACHY XCO_2 and XCH_4 the global RRDP products cover the time period 2003-2010 (or later, depending on algorithm), i.e., cover nearly the entire ENVISAT mission. This is also true for GOSAT XCO_2 and XCH_4 (nominal operations since mid 2009). Also the ACA products cover at least several years (in the time period 2003-2011, depending on algorithm/sensor). Detailed information on coverage etc. is given in the ECA and ACA product tables mentioned above. The GHG-CCI products are Level 2 products. The spatio-temporal sampling and resolution is therefore determined by the sensors (e.g., typically 30x60 km^2 for SCIAMACHY and 10 km diameter for GOSAT).

GHG-CCI Processing: The GHG-CCI data products have been generated using the scientific data processing systems of the participating institutions. Using these systems global multi-year data sets from various sensors have been generated as described above.

Merging: The GHG-CCI users (e.g., MACC) typically prefer individual well characterized Level 2 products. Merging is therefore not mandatory for GHG-CCI. Nevertheless, for XCO_2 significant efforts have already been undertaken which may be classified as merging of the SCIAMACHY and GOSAT XCO_2 data products. A careful analysis of the existing GHG-CCI European data products and several state-of-the-art non-European products (the GOSAT products generated at NIES and NASA) has revealed that typically the GCOS XCO_2 accuracy requirement (< 3 ppm) has been met with the latest versions of most of the algorithms, not however the much more demanding GHG-CCI requirement (< 0.5 ppm). It has therefore been identified that all satellite XCO_2 algorithms need significant further attention but this requires time. In order to have a short/mid-term solution a new method is under development (“EMMA”) to make optimum use of the existing multiple data products, which all have their pros and cons. Currently EMMA is used to generate a Level 2 XCO_2 product based on 2 SCIAMACHY and 5 GOSAT XCO_2 algorithms. Initial results indicate that EMMA outperforms each of the individual products. In contrast to the individual products the EMMA product does not suffer from a significant fraction of apparent outliers. Another important strength of EMMA is that it provides very realistic error estimates taking into account the inter-algorithm scatter. EMMA therefore addresses critical user needs. Initial goal is to publish this new and highly innovative method and to encourage use of the EMMA product.

International Participation: The GHG-CCI team members are closely cooperating with many international institutions (e.g., NASA, NOAA, JRC, ECMWF, WMO), programmes/projects (e.g., ICOS, TRANSCOM, MACC, GCP, IGAC, iCACGP), networks (e.g., TCCON, GAW, AGAGE) and committees (e.g., COSPAR and various ESA Mission Advisory Groups such as Sentinel 5/5-P and CarbonSat). GHG-CCI team members are participating as session chairs and co-organizer in various international conferences (e.g., EGU, IWGGMS, COSPAR).

Comparison with Precursor Products: The only existing precursor products corresponding to the GHG-CCI ECV core products are the scientific products generated using SCIAMACHY prior to the start of CCI. However, these products only covered the first few years of the ENVISAT mission. Within CCI these time series have been significantly extended (by several years) and also the data quality has been dramatically improved (by about a factor of two or more especially after October 2005, where SCIAMACHY shows significant degradation in the methane channel). Also the error characterization has been much improved. Prior to the start of CCI only very first preliminary GOSAT XCO_2 and XCH_4 retrievals were available and the quality was rather poor, e.g., due to initial calibration issues. Thanks to JAXA and various GOSAT data users providing feedback (including those participating in GHG-CCI), also this situation has been much improved. This is also true for the GHG-CCI GOSAT (Level 1 to 2) retrieval algorithms (see Publications).

Scientific Outputs: The significantly extended time series of SCIAMACHY methane retrievals as generated within GHG-CCI permitted to study the recent unexpected rise of atmospheric methane (Schneising et al., 2011, Frankenberg et al., 2011). In these publications it has been found that methane has increased by about 7-8 ppb/year mostly in the tropics (~8 ppb/year) and in northern mid-latitudes (~7 ppb/year). A local “hot spot” causing the emissions has not been identified. The analysis was complicated by the increasing degradation of the SCIAMACHY detector elements in the spectral region relevant for methane retrievals. How to optimally deal with this is an ongoing research effort of GHG-CCI. In Schneising et al., 2011, it has also been investigated to what extent CO_2 spatial gradients caused by boreal forest carbon uptake agree or disagree with models. It has been found that overall the agreement is excellent. However the SCIAMACHY data suggest on average a stronger CO_2 uptake of Canadian forests during the vegetation growing season compared to NOAA’s CarbonTracker model and a weaker CO_2 uptake of the Siberian forests. However, it was not possible to draw strong conclusions due to the quite large error bars of the SCIAMACHY WFM-DOAS product used for that publication. In order to improve the quality of the SCIAMACHY XCO_2 retrievals a more accurate but also computationally much more demanding algorithm has been developed (“BESD”) and promising first results have been obtained using this new algorithm (Reuter et al., 2011). The SCIAMACHY XCO_2 and XCH_4 data products generated with the algorithms described in Reuter et al., 2011, and Frankenberg et al., 2011, are those delivered to MACC for assimilation. First peer-reviewed publications discussing GOSAT XCO_2 and XCO_2 retrievals have been published during GHG-CCI (Butz et al., 2011; Parker et al., 2011) and also a first publication on CH_4 stratospheric profiles from SCIAMACHY (Noël et al., 2011). These profiles have the potential to improve the regional methane surface fluxes obtained via inverse modeling because these models are poorly constraint in the stratosphere. The GOSAT publications demonstrate that huge progress has been made towards the generation of accurate GOSAT products during CCI.

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