Minutes of the
11th Atmospheric Composition Constellation Workshop (ACC-11)
Frascati, Italy
28-30 April 2015

1.0 Executive Summary

The Committee on Earth Observation Satellites (CEOS) ACC-11 was held at the European Space Agency (ESA) European Space Research Institute (ESRIN) in Frascati, Italy on 28-30 April 2015. The Atmospheric Composition Constellation (ACC) is one of the seven virtual constellations that support the overall goals of the Group on Earth Observations (GEO) and provide prototype systems supporting the implementation of the Global Earth Observing System of Systems (GEOSS). The ACC's key objectives are to collect and deliver data to improve predictive capabilities for coupled changes in the ozone layer, air quality, and climate forecasting and to meet participating agency priorities that are aligned to the GEO societal benefit areas (e.g., health, climate, energy, ecosystems). ACC works to facilitate international collaboration among space agencies and establish a framework for long term coordination of CEOS's goals.

Researchers from participating CEOS agencies, related universities, and supporting organizations were present at the meeting. These organizations included the Aristotle University of Thessaloniki (AUTH), BIRA-IASB, Chinese Academy of Sciences (CAS), CNES, CNRS, DLR, ESA, EUMETSAT, Finnish Meteorological Institute (FMI), Harvard University, JAXA, Karlsruhe Institute of Technology (KIT), KNMI, LATMOS, LuftBlick Earth Observation Technologies, NASA, NCAR, National Institute of Environmental Research (NIER, Korea), Rutherford Appleton Laboratory (RAL), Science Systems and Applications (SSAI), University of Maryland Baltimore County (UMBC), University of Bremen, WMO, and Yonsei University.

The Workshop addressed three principal topics: (1) Long-Term Total Ozone Data Set Harmonization, (2) Greenhouse Gas (GHG) Constellation coordination activities, and (3) Air Quality Constellation coordination activities. The workshop Agenda and participant list are attached to these minutes. The presentations can be found at http://ceos.org/meetings/acc-11/.

2.0 Workshop Highlights and Recommendations

1. Long-Term Total Ozone Data Set Harmonization

   a. The multi-year interagency collaboration facilitated by ACC to harmonize total ozone data sets continued to make progress. Presentations on the creation of a 5°x5° total column monthly mean ozone data set, intercomparisons between European and US data sets, and a new focus on the inclusion of nadir ozone profiles were made.

   b. Participants agreed on next steps for the harmonization work. These include:

1. 5°x5° monthly mean ozone data sets will be created both by US and European groups. New approaches to filling in the missing coverage, using geo-statistical methods or climate models, will be employed. These hybrid results will be delivered in time for the ACC-12 workshop.
2. Gap filling approaches, e.g., using TOMS data, will be tested.
3. The extrapolation of ozone data into the polar night is desired by the community. Approaches using AIRS and IASI will be investigated.
4. Refinement of GODFIT and OMI algorithms will be continued with results to be reported at ACC-12.
5. Intercomparisons of North American and European data sets will use 2008 and 2013 as the years for comparison. The recommended vertical resolution will be based on the lowest resolution instrument.

2. Greenhouse Gas Constellation Activities

a. Presentations were made that described GHG missions in formulation, development, and operation (e.g., OCO-2, GOSAT and GOSAT-2, Merlin, MicroCarb, IASI, IASI-NG, TanSat, CarbonSat, and G3E).

b. In response to the *CEOS Strategy for Carbon Observations from Space*, released in 2014, participants agreed to coordinate the atmospheric composition-relevant actions described in the report. This activity will mirror the successful Air Quality Constellation coordination activities.

c. Following discussions, the following Implementation Plan was agreed:

1. ACC (through its member's space agencies) will support the organization of the annual International Workshop on Greenhouse Gas Measurements from Space (IWGGMS)
2. Agree on an open data policy for GHG data from space and ground-based/in-situ data
3. Share/agree on mission requirements
4. Support the establishment of a common product format (share specifications, metadata definition, etc.)
5. Improve interaction/co-operation among space agencies on GHGs
6. Ensure close interaction between GHG and AQ measurements
7. Support the establishment of common cal/val standards (e.g., pre-calibration procedures, perform algorithm intercomparisons, provide traceability information, use the same spectroscopy, etc.).
8. Undertake best efforts to add future GHG satellites that overlap with existing GHG satellites missions by at least one year (to, e.g., improve spatial resolution and temporal coverage).
9. Support the continuation/possible extension of the TCCON network
10. Link into other related activities, including in-situ measurement coordination (e.g., An Integrated Global Greenhouse Gas Information System)

3. Air Quality Constellation

   a. The significant progress in implementing the recommendations made in the ACC-produced position paper, *A Geostationary Satellite Constellation for Observing Global Air Quality: An International Path Forward*, released in 2011, was reviewed during a 1.5-day session of presentations and discussions. Key outcomes to date include:

      1. Sharing of instrument requirements that influenced instrument specifications, which may facilitate harmonization of data products;
      2. Advocating open data policy with common formats to facilitate broad usage;
      3. Homogenizing L1B and L2 format specifications across AC missions to easily exchange data;
      4. Establishing a new GSICS UV-Vis subgroup

   b. In addition to overviews of the key missions, Europe Sentinel 4, Korea GEMS, NASA TEMPO, and Europe Sentinel 5P (LEO orbit), pre-launch activities, geophysical validation, and specific target activities were reviewed.

   c. The following activities are in progress:

      1. Data harmonization activities are underway: Mission leads have been sharing specifications;
      2. An AQ Constellation Geophysical Validation Document is being prepared with the goal of guiding mission specific requirements being developed by the respective agencies
      3. Past and upcoming airborne field campaigns offer potential for ongoing collaborative GEO mission preparation and possibly early S-5P cal/val;
         1) AROMAT Romania 2015, 2016 (ESA)
         2) KORUS-AQ Korea 2016 (Korea NIER, US NASA)
      4. An AQ Constellation session has been proposed for the Dec. 2015 Fall AGU Meeting, to include all facets of preparation

4. Next Meeting

   a. The National Institute for Environment Research (NIER) offered to host the ACC-12 meeting in Korea. Plans are being made for the meeting to be held adjacent to the GEMS science team meeting, tentatively in the August-September 2016 timeframe. Details will be announced in the near future.

3.0 Summary of Meeting Topics and Discussions

3.1 Introduction

Dr. Maurice Borgeaud, Head of Science, Applications and Futures Technologies Department of the Directorate of Earth Observation Programmes at ESRIN, made the opening presentation. Dr. Borgeaud gave an overview of the ESA Earth Observation programme and its budget. He discussed the Copernicus and Sentinel missions and their timelines. The forthcoming Earth Explorer missions, ADM-Aeolus, EarthCARE, and Biomass were described, as well as the candidate missions for the 8th Earth Explorer: FLEX and CarbonSat. A User Consultation Meeting will be held later this year to discuss these candidate missions. A new Earth Explorer 9 call will be announced by the end of 2015.

3.2 Long-Term Total Ozone Data Set Harmonization

3.2.1 Total Ozone Session Scope (Claus Zehner, ESA)

Claus provided an overview of the ozone session. The following were the key topics to be addressed.

- Creation of a combined TOC record
- Establishment of a validation protocol
- Intercomparisons to be performed
- Creation of a 5°x5° gridded monthly product
- IR data to fill gaps in polar night
- Start work on combined nadir profiles record

3.2.2 Creation of a 5 x 5 Degree Monthly Mean Total Column Ozone Data Set (Gordon Labow, SSAI/NASA Goddard)

Gordon described the TOMS v9 product which is nearing completion. There are issues, including data gaps between Meteor 3 and EP TOMS. Calibration issues with OMI and Suomi NPP were also discussed. As a result, SBUV is the preferred instrument record. Since it's a nadir instrument with a drifting orbit, there are coverage issues and no data in polar night. Coverage is between 80°N and 80°S.

A major issue is how to fill in missing measurements. Gordon explored Delaunay triangulation/interpolation which yielded reasonable results, but it tends to smear out the structure. Missing information also causes huge sampling errors.

An alternative is to use the MERRA-2 assimilation system as a "smart interpolator". These data will be available in summer 2015. Using MERRA-2, yielded a much better interpolated daily picture. But, there were occasionally problems which could be solved by normalizing the model to SBUV. An OMI bias in the northern hemisphere was observed in this process. Validation of this product is necessary with other observations, including TOMS v9, OMI, NPP, GOME, and Sciamachy. Polar night issues could be dealt with using AIRS and IASI, but the AIRS retrieval still has issues at present.

In conclusion, Gordon raised a question whether MERRA assimilate other quantities to improve the results, e.g., radiosondes, aircraft, satellites, but not, at present, ozonesondes. This will be investigated in the near future.

3.2.3 OMI GODFIT/TOMS Total Ozone Intercomparison Results (Christophe Lerot, BIRA/IASB)

Christophe described the GODFIT algorithm used to produce the ozone data sets from GOME, Sciamachy, and GOME-2. It is the baseline algorithm for producing the ESA O3_CCI total ozone data sets.

The algorithm is now adapted for use by OMI. The O2-O2 cloud product was used. A row-dependence remains in the OMI total ozone product. All online RT calculations are replaced by interpolation through precalculated tables of radiances.

The team made initial comparisons, investigating the dependence of solar zenith angle (SZA), row, total ozone, and cloud top pressure. OMI-GODFIT agrees very well with the other CCI data sets and with SBUV V8.6. Despite a small discontinuity in 2012, the time stability of GODFIT-OMI is excellent (<0.5%/decade) and meets the CCI user requirements. In future CCI activities, this product will be used as the long-term reference for soft-calibrating other sensors.

3.2.4 Plans to Combine Long Term European Total Ozone Date Sets With USA Data Sets (Diego Loyola, DLR)

Diego presented a description of the GTO-ECV homogenized total ozone L3 dataset which is based on the GODFIT L2 version 3 algorithm. It uses a merge of the GOME/ERS-2, SCIAMAHCY/ENVISAT, and GOME-2/MetOp-A datasets to produce a monthly 1x1° grid data set in NetCDF CF 1.5 format. The merging algorithm was recently published (Coldewey-Egbers et al., AMTD, 8, 1-46, 2015).

In addition to monthly mean total ozone, the GTO-ECV provides standard deviation and standard error (the latter is estimated using an OSSE). Sampling error can yield errors of 5-10% in the monthly mean. A ground based validation was carried out with good results.

For ozone_cci phase 2, an extended GTO-ECV is available using GODFIT L2 from GOME in 1995 and GOME-2A/MetOp-A data from 2012-2014. The extended data set has been included in the "State of the Climate 2014" submitted to BAMS (M. Weber et al., 2015). Comparisons between GTO-ECV and the old version of SBUV-MOD yielded excellent agreement between the two sets. See AMT paper by E.W. Chiou et al. Intercomparisons between GTO-ECV and the new SBUV-MOD yielded very good results.

Plans for ESA CCI phase II include extending GTO-ECV with OMI and GOME-2/MetOp-B, geo-statistical spatial-temporal interpolation of data satellite data, and further comparison of the new GTO-ECV with new SBUV-MOD in collaboration with the NASA team.

3.2.5 Multi Sensor Reanalysis of Total Ozone from Satellites for the Period 1970-2012 (Ronald van der A. KNMI)

Ronald discussed a multi-sensor reanalysis of total ozone using data assimilation. The underlying assumption is that the ground observations are on average a good approximation for the true values. The procedure used all UV-visible satellite data from 1970-2012 corrected for biases. The measurements were then assimilated by CTM to achieve complete global and temporal coverage. This multi sensor reanalysis is available at www.temis.nl and is published in AMTD (van de A et al., Extended and refined multi sensor reanalysis of total ozone for the period 1970–2012, Atmos. Meas. Tech. Discuss., 2015).

The reference data is from WOUDC 91 ground stations that were selected with a long and reliable record. These are Dobson and Brewer instruments with the Dobson data corrected for temperature dependence. The satellite data are corrected for SZA, viewing zenith angle, effective temperature, time (trend), and offset (calibration). The procedure was to fit all time series to these 5 parameters to construct corrected level 2 data. The data assimilation is used to create an homogenized data record. Outputs are the total ozone field every 6 hours on a 1x1° degree provided (but with an actual resolution of 0.5°). Intercomparisons with AC&C/SPARC data look quite reasonable.

To fill in the gaps of the period 1970-1978, ground observations are used in the data assimilation as a "19th satellite instrument". An open question for future work is whether it is possible to extend the MSR into the past by starting earlier using only Dobson observations.

3.2.6 Updated Validation Protocol To Include As Well Nadir Ozone Profiles (Jean-Christopher Lambert, BIRA/IASB)

Dating back to ACC-9 (2013), the concept of the validation protocol was put forward to define a restricted set of common validation parameters and analyses. In this way, results obtained by different validation groups using different reference data sets can be better compared and discussed. A round robin evaluation from GOME, SCIA, and GOME-2 was discussed at last year's ACC meeting. A paper on these results was just accepted in AMT (the earlier discussions reference is Keppens et al., AMTD, 7, 11481-11546, 2014). A generic QA/Validation suite has been developed which deals with, inter alia, data selection, filtering and post processing, data content study, information content study, selection and characterization of correlative data, derivation of fit for purpose quality indicators.

A common issue to these data is that the South Atlantic anomaly creates significant issues for the calculation of zonal means. Information content studies have employed an analysis of the vertical averaging kernels. An approach to intercomparisons with ground based data (e.g., NDACC, SHADOZ, GAW) has been developed. Issues involving resampling, smoothing, and unit conversions have been considered. The dependency on vertical sensitivity has been found to be important. An approach to validation reporting compliant with user requirements has been employed.

3.2.7 Assessment of SBUV Profile Algorithm Using High Vertical Resolution Sensors (Richard McPeters, NASA Goddard)

Richard talked about the long history of BUV/SBUV observations dating from 1970 to current observations by OMPS aboard Suomi/NPP. Version 8.6 of the ozone data set uses SBUV data from a series of 9 instruments reprocessed with coherent calibration. The SBUV retrieval uses a 20-layer structure which is much finer than its actual resolution. The mixing ratio profile is restricted to where good results are obtained.

Key results from this dataset include comparisons with MLS that are almost always within 5% at all altitudes and seasons. The QBO causes problems with these intercomparisons. There is not enough vertical resolution in the equatorial lower stratosphere which appears to be a smoothing error. In the upper stratosphere, SBUV and MLS yield the same pattern. Comparisons with the NPP-Limb profiler demonstrate its high vertical resolution. NPP-Limb ozone reveals the lower edge of ozone hole, while for SBUV, its smoothing error can get quite larger in lower stratosphere.

Disagreement in the lower stratosphere/troposphere is a result of the low SBUV vertical resolution. The averaging kernel brings agreement and additional wavelengths may give a bit more profile information in troposphere. The total column ozone shape error is significant at SZA>80°.

3.2.8 Assessment of the RAL Nadir Profiling Ozone Algorithm (GOME2) (Georgina Miles, Rutherford Appleton Laboratory)

Georgina presented progress on the RAL UV ozone scheme. Tropospheric info is obtained from the Huggins and Hartley bands. The nadir profile scheme uses GOME, Sciamachy, OMI, and GOME-2 A&B. RAL currently produces NRT profiles for GOME-2 which are part of trial assimilation into ECMWF analysis.

Comparisons of profiles from MetOp GOME-2 with ozonesondes in the tropospheric yield good results. Regional seasonal cycles in lower tropospheric ozone reveal biomass burning transport across the southern Atlantic. A recebt AMT paper by Miles AMT paper evaluated comparisons with CTMs (e.g., TOMCAT) since ozonesonde coverage is geographically sparse.

RAL UV+IR ozone profiles are being produced by combining GOME-2A and IASI-A observations. The joint scheme yields improved results in the upper stratosphere and in the UT/LS region. Near-surface ozone can be obtained using the Chappuis band. But, it's a very challenging fitting problem Current work is assessing whether these data are accurate enough to be useful. The initial results are very promising. The NO_2 fit is very good over Eastern Asia. For ozone, the UV and visible slant columns agree very well in many regions, but not everywhere. This approach could have utility for TEMPO. The team is working towards a publication this year.

3.2.9 Assessment of the IASI Nadir Profiling Ozone Algorithm (Cathy Clerbaux, LATMOS)

Cathy described recent results of IASI profile ozone produced in near real time with a 12 km footprint. These profiles are available both during day and night and have global coverage from the two IASI instruments (A & B).

Initial results show tropospheric seasonal ozone variation over cities. Stratospheric intrusions can be seen, combined with high photochemical summer production. The monsoon effects and its seasonality is also evident. Seasonal increases in the Mediterranean in summer are from various sources (e.g., city inputs, stratospheric intrusions).

Validation is ongoing with balloons, satellites, and ground based measurements. Temperature profile differences cause differences in retrieved profiles. Some positive biases are seen in total column ozone (3-5%) and in the UT/LS (~15%). Changes in HITRAN database yields some improvements.

IASI-C will be launched around 2018 (as part of MetOp-C). IASI-NG is scheduled for ~2021 and will feature improved spectral resolution and reduced noise, yielding better sensitivity in the troposphere.

3.3 Greenhouse Gas Constellation Activities

3.3.1 OCO-2 Results (David Crisp, NASA JPL)

David described the key factors that control atmospheric carbon dioxide (CO_2). 40 GT of carbon dioxide is emitted by human activities, which is enough to increase atmospheric abundance by ~1% year. The land biosphere and ocean are absorbing over half of the emitted CO_2 limiting the rate of buildup and its impact on Earth's climate. The processes responsible for maintaining this absorption are critical to understand.

OCO-2 was launched on 2 July 2014, it joined A-train on 3 August, and started taking routine measurements on 6 September. There are several challenges in obtaining an accurate calibration of its measurements. The O_2 A-band sensitivity is changing over time. At present, the cause is unknown. Cosmic rays are also an issue, particularly when the satellite passes through the South Atlantic Anomaly. An algorithm to screen out these issues has been implemented.

Nadir and glint are the standard operating modes. There's also a target mode for validation. There are 21 target stations. TCCON has been extremely useful for this validation.

In summary, OCO-2 operations are nominal. Level 1B product are being delivered to GES-DISC for distribution to the science community. A preliminary level 2 has been released, but validation is still ongoing.

3.3.2 GOSAT results and status of the GOSAT2 mission (Kei Shiomi for Masakatsu Nakajima, JAXA)

Kei discussed the status of GOSAT. There are two instruments: TANSO-FTS (Fourier Transform Spectrometer) and TANSO–CAI (Clouds and Aerosol Imager). GOSAT was launched in 2009 and is currently in extended operations phase. Calibration/validation activities are in progress. The TCCON network is used for validation. In addition to global CO_2 measurements, TANSO-FTS has observed polar ozone, Tropospheric ozone can also be measured, revealing long-range transport of human impacts that affect ozone. Sun-induced chlorophyll fluorescence has been obtained from highly-resolved O_2 A-band spectra.

GOSAT-2 was also described. It will have improved measurement precision for CO_2 and CH_4 yielding an improvement of the estimation of fluxes and the ability to monitor aerosols in the atmosphere. It will also measure the CO column. The instrument will use intelligent pointing to avoid clouds and increased SNR for the acquisition of high latitude data. GOSAT-2 development is currently in phase C study will the launch planned for early 2018. GOSAT-2 will collaborate with other GHG satellites on orbit.

3.3.3 GHG measurements from space: MERLIN, MICROCARB, IASI and IASI NG for CH_4 and CO_2 observations in the troposphere (Carole Deniel, CNES)

Carole discussed CNES greenhouse gas activities and projects. IASI-1 and IASI-2 are both flying and measuring CH_4, CO_2, and CO. More than 20 species can be detected and are used for a variety of applications including weather prediction, atmospheric composition, and the creation of essential climate variables (ECVs).

IASI measures mid-tropospheric columns of CO_2, CH_4 and CO over both land and sea, during both day and night. Over Asia, strong emission of CH_4 by rice paddies can be seen.

IASI-NG, the first planned for 2021, will assure the continuity of IASI for NWP, atmospheric chemistry and climate applications. These measurements will improve the characterization of the lower part of the troposphere, the UT/LS region and, more generally, of the full atmospheric column. Improvements will be made to the precision of the retrievals to allow for the detection of new species. Mid-tropospheric CO_2 and CH_4 should see 30-45% improvements in measurement precision.

MERLIN is a CNES-DLR cooperative project begun in 2009 to measure CH_4. It is currently in phase B. Phase C/D should start in 2016 with launch planned for 2019. Its objective is to improve the understanding of the CH_4 exchanges at the surface, identify and monitor the global carbon sources and sinks, and assess how these exchanges may be impacted by the climate change.

It will employ an Integrated Path Differential Absorption (IPDA) LIDAR in the near IR using pulsed laser transmitter and range-gated receiver in nadir-viewing mode. Precision is expected to be 18 ppb (1%) with < 2 ppb systematic error.

MicroCarb will measure CO_2 column with precision less than 1 ppm. The mission is currently in Phase A. It objective is to improve the understanding of the CO_2 exchanges at the surface, facilitate the quantification of CO_2 surface fluxes at regional scales (500 km), and identify and monitor global carbon sources and sinks and assess how these exchanges may be impacted by the climate change.

A grating spectrometer using 3 bands (O_2 and CO_2, similar to OCO-2) will be employed. It will be a very compact instrument (less than 60 kg). Launch could be as early as 2020.

3.3.4 The TanSat Mission status (Yi Liu, CAS)

Yi discussed the TanSat mission. Funding was initially provided by the Ministry of Science and Technology of China (MOST). The Chinese Academy of Sciences is now responsible.

Measurement goals for XCO_2 are 1~4 ppmv, monthly at 500 x 500 km^2 resolution. The goal for CO_2 flux is with a relative error of < 20%, monthly, at 500 x 500 km^2. The nominal plan is to fly TanSat in the A-Train. The orbit will be sun-synchronous at an altitude of 700 km and a local time of 13:30. There will be 3 measurement modes: nadir, sun-glint, and target.

Construction of the CO_2 instrument is in progress and the development of the CO_2 algorithm is also in progress at the Institute of Atmospheric Physics, Chinese Academy of Sciences (IAPCAS). The algorithm is being tested using GOSAT data. Aerosol retrievals are being tested and compared to MODIS and Aeronet. A ground-based network is currently being augmented across China which will be used for calibration, validation, and a priori data.

A formal prototype of the CO_2 spectrometer will be completed by October 2015 with SRR to take place by the end of the year. Launch is planned for June 2016.

3.3.4 The proposed CarbonSat mission (Heinrich Bovensmann, University Bremen)

Heinrich described the Earth Explorer 8 candidate mission, CarbonSat which aims to disentangling natural and anthropogenic GHG fluxes from space using imaging and global mapping of CO_2 and CH_4. Despite the progress to date in measuring atmospheric CO_2 and CH_4 distributions from space-based sensors, these measurements still do not provide the coverage and resolution needed to map CO_2 and CH_4 fluxes at the sub-continental scale down to the city scale - where the majority of the anthropogenic emissions take place. The research objectives of CarbonSat can be characterized at three spatial scales:

1. Regional to global scales: To provide a breakthrough in the quantification and attribution of regional-scale surface-to-atmosphere fluxes of CO_2 and CH_4 and climate impact on it (droughts etc.);
2. Country scale (or equally sized ecosystems): To increase the flux resolving power of greenhouse gas observing satellites to the scale of medium-sized countries; and
3. Local scale (city and below): To pioneer the spaceborne detection, characterization, and quantification of strong local sources of CO_2 and CH_4.

CarbonSat aims to support quantification of natural and anthropogenic CO_2 and CH_4 sources and sinks (“fluxes”) and their changes via global atmospheric XCO_2 and XCH_4 observations including “imaging” of strong localised CO_2 and CH_4 emission areas. In addition, several secondary products will be delivered such as high-quality Solar Induced Fluorescence (SIF).

It will employ an imaging grating spectrometer, based on lessons learned from SCIAMACHY, GOSAT, and OCO-2. High spatial resolution ($2x3\ km^2 = 6\ km^2$) and good coverage (~200 km continuous swath) will be necessary. Nadir and sun-glint modes will be employed. This will be the first satellite mission optimized for detection and quantification of CO_2 and CH_4 emission hot spots via greenhouse gas imaging. A user consultation meeting is scheduled for September 2015.

3.3.5 The project G3E (Andre Butz, KIT)

Andre described a study for measuring greenhouse gases from geostationary orbit. The Geostationary Emission Explorer for Europe (G3E) will measure CO_2 and CH_4 at high accuracy over Europe with $2x3\ km^2$ ground pixels. Source/transport attribution for CO. There will also be support for aerosols and fluorescence observations.

The benefits of a geostationary imager include contiguous spatial and temporal observations providing spatiotemporal context to disentangle transport, boundary conditions and sources/sinks; local horizontal contrast to understand emissions of localized sources; and local temporal contrast for diurnal cycle and source specification.

A 4-channel grating spectrometer would be employed with planned synergies with MTG through its FCI Imager (cloud & aerosols), IR Sounder (mid-tropospheric CO, O_3), and Sentinel 4 UVN.

G3E would complement meteorological and air quality sounders (e.g., MTG and TEMPO), as well as complementing the global view from LEO with regional spatio-temporally dense zoom from GEO. It could feature in a constellation with other agencies.

3.3.6 Results of the ESA GHG Climate Change Initiative project (Claus Zehner, ESA)

Claus described results from the ESA Climate Change Initiative project. The ESA program is led by Mark Doherty (ESA/ESRIN) and leverages SCIAMACY and GOSAT results, with preparations to employ OCO-2 in the near future. IASI, MIPAS, SCIAMACHY/occultation, AIRS, and ACE-FTS could be of value for upper layer CO_2 and CH_4.

The Climate Modeling User Group (CMUG) consists of end-users of the ECVs that provide feedback on quality of these variables. GCOS requirements drive the project goals and objectives. Data available from ESA GHG CCI web page. The number of users and peer-reviewed publications are increasing.

Recent results include the calculation of European terrestrial carbon fluxes from SCIAMACHY and GOSAT, the elucidation of anthropogenic CO_2 emission signal from localized sources isolated via simultaneous SCIAMACHY XCO_2 and NO_2 observations & new spatial filtering method, and the use of SCIAMACHY to measure fugitive CH_4 emissions from fracking.

3.3.7 Ongoing NASA/JAXA/NIES co-operation (David Crisp, NASA)

David noted that a range of greenhouse gas measurement missions will be operating in the coming years. Greater benefits could be realized if these missions were coordinated. For example, products could be cross-calibrated and cross-validated, yielding self-consistent, continuous CDRs. The NASA, JAXA, and NIES, teams on the GOSAT/OCO-2 teams have been pioneers in the implementation of this approach through the OCO/GOSAT collaboration that has been very productive since 2004. Vicarious calibration activities were pursued for GOSAT using multiple algorithms. TCCON has been a major player in this validation effort.

In March 2015, NASA and the GOSAT/GOSAT-2 partners (JAXA, NIES, MoE) signed a new Memorandum of Understanding (MOU) for the GOSAT, OCO-2, and GOSAT-2 missions. The extension of this collaboration to the GOSAT-2 and OCO-3 missions provides opportunities to extend this valuable climate data record beyond the lifetimes of GOSAT and OCO-2 missions.

This closely coordinated ad hoc constellation of greenhouse gas satellites also paves the way for future space-based greenhouse monitoring systems.

3.3.8 Supporting GHG Management Strategies with Observations and Analysis (Oksana Tarasova, WMO)

Oksana described the Role of an Integrated, Global Greenhouse Gas Information System (IG3IS). The proposed system would use existing surface based networks, coordinated through GAW (e.g., AGAGE, TCCON, NDACC) and bring "new" players into the system, including airborne measurements (e.g., MOSAIC, CARIBIC), commercial networks (e.g., Earth Networks), and existing and forthcoming satellites.

A draft Implementation plan is available on the GAW GHG web page (http://www.wmo.int/pages/prog/arep/gaw/ghg/ghgbull06_en.html). The drafting team is led by Phil DeCola (Sigma Space). Among the program's goals are direct improvements resulting in more observations and improved data management, higher resolution transport models, and advanced data assimilation capabilities. Its planned outcomes include a better understanding of the distributions and trends of GHGs, separation of human and natural influences, and ultimately successful policy implementation.

3.3.8 Discussions on the recommendations of the CEOS Carbon Strategy Report on Atmosphere/Implementation Plan of the GHG-Constellation (All, led by Claus Zehner)

Claus discussed the CEOS Carbon Strategy Report, released in 2014, and its proposed actions that are relevant to the ACC. These actions include sponsoring workshops on GHG measurement missions, the detailed planning, preparation, and coordination of both LEO and GEO constellations of GHG measuring satellite missions, and interaction with the CEOS Working Group on Calibration and Validation (WGCV) to facilitate the cross calibration and validation of these sensors against accepted international standards.

Based on the discussion of ACC participants, a set of initial GHG coordination activities was developed. Its key elements are summarized in the Workshop Highlights section.

3.4 Air Quality Constellation

3.4.1 Missions Overview

3.4.1.1 Mission Overview: GEMS (Ji-Hyung Hong, NIER and Jhoon Kim, Yonsei University)

Ji-Hyung noted that NIER is very excited about the forthcoming GEMS mission and the constellation activities being coordinated by ACC. In addition to GEMS, Korea has activities with airborne and surface-based measurements of PM, ozone, and precursors, as well as air quality modeling capabilities.

GEMS passed its CDR in February 2015. The program is in its main phase with an anticipated launch in March 2019. It is being built by Ball Aerospace and shall be delivered to KARI in 2017.

GEMS will use a step-and-stare UV-Visible imaging spectrometer scanning at least 8 times per day in 30 minutes. GEMS will be an operational satellite. The field of view covers much of Eastern Asia from 75°E to 145°E longitude with a target center of 120°E and 17°N. Baseline products include NO_2, SO_2, HCHO, O_3, AOD, clouds, and surface property. A unified data retrieval algorithm is being developed and is being tested using OMI and other measurements. The predicted performance of trace gases from the initial design of GEMS satisfies the product accuracy requirements of NO_2, HCHO, O_3. Collaboration with the teamsof TROPOMI, Sentinel-4 & TEMPO is proving valuable in calibration, algorithm development and application.

3.4.1.2 Mission Overview: Sentinel-4 (Ben Veihelmann, ESA)

Ben gave an overview of the Sentinel-4 mission's objectives and implementation status. Sentinel-4 is designed to provide tropospheric composition measurements with fast revisit time at high spatial resolution over Europe. Planned operation is for over 15 years and it will support the Copernicus Atmosphere Monitoring Services. Copernicus is to provide operational information to policy makers and citizens. Among its near-real-time services are local air quality, health warning, and aviation routing. Assessments to improve understanding of processes, validate chemical transport models, and ground measurement networks will be undertaken. Focus on tropospheric composition with fast revisit time at high spatial resolution over Europe. Sentinel-4 level 2 products include O_3, NO_2, SO_2, CHOCHO (TBC), CH_2O, aerosol, cloud, and surface reflectance.

The S4/UVN instrument has passed its PDR. CDR is planned for 2016, with flight acceptance in 2021. EUMETSAT will operate the instrument and process the mission data up to Level-2.

3.4.1.3 Mission Overview: TEMPO (Kelly Chance, SAO)

Kelly talked about the TEMPO mission status. It was selected in November 2012 as NASA's first Earth Venture Instrument. NASA will arrange hosting on commercial geostationary communications satellite with launch expected not earlier than November 2018. TEMPO will provide hourly daylight observations to capture rapidly varying emissions & chemistry important for air quality. The UV/visible grating spectrometer will measure key elements in tropospheric ozone and aerosol pollution. It exploits extensive measurement heritage from LEO missions. TEMPO will distinguish the boundary layer from free tropospheric & stratospheric ozone.

TEMPO's field of regard (FOR) spans from Mexico City/Yucatan Peninsula to the Canadian tar/oil sands and from the Atlantic to the Pacific. The instrument slit aligned N/S and will sweep across the FOR in the E/W direction, producing a radiance map of Greater North America in one hour. Most constituents will be sampled hourly, including eXceL O3 (troposphere, PBL) for selected areas. H_2CO, $C_2H_2O_2$, SO will be sampled hourly. Algorithm testing is in progress using OMPS H_2CO and NO_2

It was noted that TEMPO passed KDP-C and is now in the implementation phase. The instrument CDR is scheduled for summer 2015 and it is expected that a satellite host will be selected in the 2017 timeframe.

3.4.1.4 GEO-specific retrieval challenges (Chance, Kim, & Veihelmann)

It was noted that instruments will be changing with time Especially temperature variations can lead to changes in the slit function and in the wavelength grid, which needs to be accounted for in the data processing.

Spatial and temporal heterogeneity must be considered. More resolved source regions and source variation will lead to a greater challenge for a priori. New challenges arise from the sun-satellite geometry, as compared to the LEO heritage; the wide diurnal SZA range poses a challenge for the treatment of a priori and of surface reflectance. High VZA in combination with partially cloudy conditions are expected to limit the retrieval accuracy. The exploitation of visible Chappuis band (TEMPO) for ozone raises tricky questions such as: Will EOFs be enough to characterize the surface? If so, how many are needed? 3?

3.4.1.5 Mission Overview: Sentinel-5 Precursor (Thorsten Fehr, ESA)

Thorsten presented on the Sentinel-5 Precursor mission (S5P). This is a pre-operational mission focussing on global observations of the atmospheric composition for air quality and climate. The TROPOspheric Monitoring Instrument (TROPOMI) is the payload of the S5P mission and is jointly developed by The Netherlands and ESA. The planned launch date for S5P is Q2/2016 with a 7-year design lifetime.

S5P and Suomi-NPP are planned to be in a loose formation flight with separation of ~5 min. There will be tailored VIIRS cloud products for S5P and the synergistic use of S-NPP & S5P products to improve the S5P-only cloud information. Level 2 products include O_3, NO_2, SO_2, CH_2O, CH_4, clouds, and aerosols. All ATBDs (L1 and L2) will be made available to the science community.

Validation is based on existing experience gained on heritage or operational missions. There is excellent experience and existing infrastructure for stratospheric products, in particular ozone and GHGs. S5P requires a focus on the validation of air quality parameters. Several airborne campaign opportunities have been identified in the Validation Call and are discussed later in the session.
TROPOMI instrument environmental testing was completed in 2014. Instrument calibration has been ongoing since December 2014. Delivery is foreseen in May 2015.

3.4.1.6 Distinguishing Local from Non-local Sources of Pollution: The Role of LEO Sounders in the CEOS Air-quality Constellation (John Worden, NASA)

John discussed the role of remote sources on local air quality in the context of changing global emissions. He noted that ozone pre-cursor emissions have dramatically changed over the last decade with substantial consequences for background ozone levels and their role on air quality. The change in global ozone (as measured from TES) in response to changes in NO_2 is less clear. NO_2 is down in US and Europe, but up in the Middle East and E. Asia. It's also unclear why CO is decreasing. Air quality in the western US should be impacted by ozone precursors in Asia, according to models. But, observations are not definitive.

Combining UV and thermal IR can increase the vertical resolution of ozone profile soundings (OMI/AIRS, CRIS/OMPS). GEO-Sounders will enable the quantification of ozone pre-cursor emissions and their perturbation to column ozone with unprecedented spatio-temporal resolution. Multi-spectral/multi-instrument LEO measurements of ozone profiles and its precursors (e.g. CO and PAN) can connect GEO-based measurements for quantifying the role of remote sources and background ozone on local air quality. Ideally, a programmatic framework needs to be put in place to systematically process the LEO based data such as from AIRS/OMI, CRIS/OMPS, and IASI.

3.4.1.7 Latest Results on NH_3 and CO from IASI (Cathy Clerbaux, LATMOS)

Cathy discussed recent measurements from IASI. CO "profiles" are obtained in near real time with a 12 km footprint during day/night with global coverage. NH_3 total columns are being obtained in research mode, along with SO_2.

During high pollution events, Cathy noted that IASI can see impacts of CO and SO2 in areas like China. SO2 from volcanoes and anthropogenic activities are obtained on a global scale. IASI also has good success in retrieving NH3 under high pollution. A consistent set of over 15 years of CO observations is being provided by IASI-A and IASI-B and, soon, IASI-C. IASI-NG will provide a better assessment of the lower troposphere due to its higher spectral resolution and lower noise.

3.4.2 Prelaunch Activities

3.4.2.1 Pre-launch plans for GEMS (Michelle Stevens, BATC; Myoung Hwan Ahn, Ewha Womans University; and Jhoon Kim, Yonsei University)

Jhoon gave an overview of planned GEMS operation procedures, including dark frame calibration and plans for normal operations. A NIST traceable calibration source will be employed for pre-launch activities. Pandora instruments are currently being installed in Korea, along with AERONET/Skynet. The KORUS-AQ airborne campaign will take place next year (see later presentation for details).

3.4.2.2 Pre-launch plans for Sentinel-4/UVN (Berit Ahlers, ESA)

Berit described S4/UVN data processing plans up to L1B. The goal is to maintain attention for balance between L0 performance verification, calibration, and level 0 to 1b data processing to deliver L1b data products within the required specification at end of life.

The S4/UVN instrument is well equipped with on-board calibration hardware (e.g., LEDs, diffusers). For L0 performance verification, it is necessary to verify that S4/UVN is built as designed. So, amongst others polarization and sensitivity must be verified. No spectral features should interfere with atmospheric gas absorptions and straylight should be in compliance. The radiometric calibration parameters were also described. Decontamination measures to prevent optical degradation have also been defined.

3.4.2.3 Pre-launch plans for TEMPO (Kelly Chance, SAO)

Kelly described TEMPO instrument specifications as they pertain to spatial and spectral performance, radiometry, and alignment. The ground system, data, and processing flows were also described. TEMPO L0-L1 processing will be similar to the TROPOMI and OMI L0-L1 processing. Based on the development timeline, the completion of the version 1 algorithms is planned for the middle of 2016. Testing with instrument first look data is expected by the end of 2016.

3.4.2.4 Pre-launch Activities Sentinel-5 Precursor (Pepijn Veefkind, KNMI)

Pepijn discussed the TROPOMI pre-launch activities. The planned launch date for S-5P is 2016 with a 7-year design lifetime. It is expected that S-5P will act as a "travelling standard" between the various geostationary AQ sensors and will cover spatial regions not viewed by the geostationary sensors. The on-ground calibration is in progress right now. Pepijn provided details of its progress and noted that the work is in its final stages.

3.4.3 Geophysical Validation

3.4.3.1 Geo-AQ Geophysical Validation Needs (Jean-Christopher Lambert, BIRA/IASB)

Jean-Christopher discussed lessons learnt from heritage missions. He noted the need for common objectives (identification of users of validation results and the sustained interaction with them), the need for a common set of quality indicators, the need for exhaustive validation over at least one complete annual cycle of important parameters, and the need for common terms and definitions. In addition, it is necessary to carefully identify reference measurements, harmonize these measurements (e.g., common measurement and QA protocols), and to adopt harmonized data formats and dissemination policies.

Calibration and validation procedures require the use of best practices, including traceability of all steps, the need for common guidelines for all data manipulations and the need for appropriate handling of data representativeness. Exhaustive cal/val is necessary for the first year, with ongoing monitoring thereafter. The need for sustained a cal/val infrastructure was noted, but it is difficult to fund campaigns in the long term.

Many specific challenges were described. These include:

- Troposphere: significant gradients and temporal variability, diurnal cycles, local emissions sources and longer-range transport
- Remote sensing: sensitivity to tropospheric targets can be poor due to low concentration, variety of retrieval approaches, complex retrieval chains with dependence on a-prior assumptions, variety of data products
- GEO-AQ: unprecedented horizontal resolution, hourly sampling, moderate to large solar zenith angles, LEO bias of data retrieval and validation experience

3.4.3.2 <u>DISCOVER-AQ campaign (2011-2014)</u> – (Jay Al-Saadi for Jim Crawford & Ken Pickering NASA)

Jay described the recently completed DISCOVER-AQ campaign. Its objectives included:

1. Relate column observations to surface conditions for aerosols and key trace gases O_3, NO_2, and CH_2O
2. Characterize differences in diurnal variation of surface and column observations for key trace gases and aerosols
3. Examine horizontal scales of variability affecting satellites and model calculations.

There were four deployment locations: Maryland, California, Houston, and Colorado. In conclusion, Jay noted that:

1. DISCOVER-AQ has collected a dataset of unprecedented detail on the diurnal trends in air quality as it is discerned from in situ and remote sensing methods.

2. NO_2 columns exhibit both unexpected and diverse diurnal trends that are consistent with vertically resolved profiles.

3. NO_2 tropospheric column retrievals are highly sensitive to diurnal variation in a-priori profile shapes.

3.4.3.3 <u>AROMAT campaign (2014)</u> (Michel van Roozendael, BIRA/IASB)

Michel described the Airborne Romanian Measurements of Aerosols and Trace gases (AROMAT) campaign. The motivation for the campaign was to test newly developed airborne instruments for air quality research in preparation of future Sentinel-5P (4/5) cal/val campaigns and to involve Romania in such activities. Numerous instruments and platforms were used: airborne, mobile, and static/moveable from a variety of universities and agencies. The first week of the campaign concentrated on Bucharest, while the week 2 deployment was in Turceni, a small village near large power plant known to be a major source of NOx, SO_2, and aerosols. Michel showed initial results of measurements and preliminary analyses.

A follow-on mission, AROMAT-2, is being planned for late summer 2015 with an extended focus and more resources to be committed (more ground-based and flight measurements).

3.4.3.4 KORUS-AQ campaign (2016) (Jay Al Saadi, NASA & Ji-Hyung Hong, NIER/ME)

Ji-Hyung described the importance of the GEMS mission noting the high concentration of pollutants in E. Asia which provides a high signal to observe and should provide a chance to verify our understanding of air quality. But, there are challenges. For example, complex terrain may challenge satellite retrievals. Land use in Korea is complicated, which provides for a good region to test measurements for AQ.

The KORUS-AQ campaign is a collaborative field mission between NIER and NASA. The serious air pollution observed at times in Korea and the complex atmospheric chemistry provide an excellent location for coordinated, focused observations.

It will strengthen our understanding in Korean air quality, as well as providing important data sets for GEMS retrievals. KORUS-AQ will integrate the efforts from many platforms to reduce the uncertainties in source attribution through closer integration.

Jay described some additional KORUS-AQ deployment specifics. GEO-TASO (which is nearly identical to the GEMS/TEMPO instruments) may fly during campaign. Currently, the campaign is planned for a 6-week period in April-June 2016. The NASA DC-8, Korean B-200, and ground sites from the Korean AQ network will take part. Each group has already developed white papers (https://espo.nasa.gov/home/korus-aq/content/KORUS-AQ_Science_Overview_0) and core funding has been approved by both agencies. The campaign may provide a possible S5P early validation activity (depending on the S5P launch date). Six AERONET and Pandora instruments are being installed in Korea to support the campaign.

3.4.3.5 Pandonia ground based network (Alexander Cede, LuftBlick e.U.)

Alexander described Pandonia, which is a planned ground-based remote sensing network for air pollution monitoring and satellite validation. The motivation for the network is the need for a long, uninterrupted, well-maintained, homogeneously calibrated time-series of ground-based remote sensing atmospheric ozone measurements. These have been and still are the backbone for the validation of ozone columns measured from satellite (e.g. TOMS, OMI). Alexander noted that there is no comparable network for other satellite-derived trace gas measurements (e.g. NO_2).

The goal is to start building such a self-standing calibrated network for satellite validation using Pandora-2S and Pandora as core instruments for the measurement of O_3 and NO_2, total and tropospheric columns and profiles, spectral AOD from 340 to 900nm, SO_2, HCHO, H_2O, and BrO total columns, and effective O_3 and NO_2 temperature. ESA is funding the Pandonia network since it sees the network as a key element in the validation of the existing and upcoming satellite missions.

Pandora is a spectrometer system for direct sun, sky radiance and direct moon measurements with standard wavelength range: 270-530nm, 0.6nm resolution. Alexander also described the use of Pandora during DISCOVER-AQ.

He noted that NASA has supported the Pandora network since 2006, while ESA funding for Pandonia started in 2013. Alexander included an extensive list of recent peer-reviewed publications involving the use of the Pandora network (see presentation slides).

3.4.3.6 ACSO - Absorption cross sections of ozone – (Johanna Tamminen, FMI)

Johanna described the ACSO effort which has the goals of

- Evaluating the ozone cross sections and their temperature dependence (Huggins band)
- Understanding the differences in instruments which are caused by the absorption cross sections, and to
- Recommend, if possible, a set of cross sections.

A number of groups have participated in this process: laboratory-based, ground-based instruments, and satellite instruments. After four workshops, several reports and new cross sections, this is not the end of the story of ozone cross sections in Huggins band. A teport of the work so far done has been written and formatting is being done at WMO after which it will put out for comments at the end of May, with one month for comments to be provided.

Some initial recommendations are that the Bass & Parr (1985) cross sections should no longer be used for the retrieval of atmospheric ozone measurements. For retrieval of ground-based instruments of total ozone and ozone profile measurements by the Umkehr method performed by Brewer and Dobson instruments data of SER (2014) are recommended to be used. When SER (2014) is used, the difference between total ozone measurements of Brewer and Dobson instruments are very small and the difference between Dobson AD and CD measurements are diminished. For ground-based LIDAR measurements, no recommendation is made whether to use BDM (1995) or SER (2014). For satellite retrieval the presently widely used data of BDM (1995) should be used because SER (2014) seems less suitable for retrievals that use wavelengths close to 300 nm due to a reduction in signal-to-noise in the SER (2014) data set.

Johanna noted the need for to continue laboratory cross section measurements of ozone of highest quality, the careful characterization of their uncertainties, the need to extend the scope of such studies to other wavelength ranges, and the need for regular cooperation of experts in spectral laboratory measurements and specialists in atmospheric (ozone) measurements.

3.4.4 Constellation Targets

3.4.4.1 GEO AQ Constellation Targets (Jay Al Saadi, NASA)

Jay discussed the process that took place within ACC during 2013 which led to the development of recommendations for harmonization to mutually improve data quality and facilitate widespread use of the data products from the forthcoming geostationary AQ missions.

ACC has made considerable progress to date. Among the accomplishments are the sharing of instrument requirements that have influenced instrument specifications, which may facilitate harmonization of data products; advocating for an open data policy (including L1B) with common formats to facilitate broad usage; sharing L1B and L2 format specifications to easily exchange data; the establishment of a new GSICS UV-Vis subgroup; and an AQ Constellation "Geophysical Validation Needs" document is currently in preparation.

This document will include the identification of common parameters in L1b and L2 products, lessons learned from LEO heritage missions, common geophysical validation needs (by mission phase), inter-mission geophysical validation needs (by mission phase), and the development needs for a new validation infrastructure or approach.

Jay also discussed the level 2 potential constellation products that could be developed and their quality assurance challenges. He noted that an AQ Constellation session has been proposed for the Dec 2015 Fall AGU meeting to include all facets of these preparation activities.

3.4.4.2 Product format and units – (Pepijn Veefkind, KNMI)

Pepijn described the S5P/TROPOMI level 2 file format and units. His recommendations are to

- Select a file format that users are already familiar with
- Use a base format that is already well supported in data analysis packages
- Use a self-describing file format
- Build on experience with supporting previous missions.

He noted that S5P/TROPOMI L1B and L2 formats are based on NetCDF-4 with CF metadata. The file format documents are available on request. And, it is recommended that SI units will be used.

3.4.4.3 WGCV ACSG Activities (Thorsten Fehr, ESA for Bojan Bojkov, ESA)

Thorsten discussed recent CEOS Working Group on Calibration and Validation (WGCV) Atmospheric Composition Subgroup (ACSG) activities. The mission of the ACSG is to ensure the accurate and traceable calibration of remotely-sensed atmospheric composition radiance data and validation of higher level products for application to atmospheric composition and in conjunction to climate research.

Recent activities include the support and development of Fiducial Reference Measurements (FRMs) for atmospheric composition in cooperation with WMO/GAW, principally relating to Brewer instruments, support for the intercomparison of ground-based instruments, the development ground-based O_3 and NO_2 profiles from spectrometers, the standardization of the mini-spectrometer retrievals, and cooperation on merging ground-based measurements such as lidar, sun-photometers and spectrometers, to enhance aerosol classification databases.

Thorsten noted that there are clear areas of mutual interest between ACSG and ACC, e.g., the calibration work and the Fiducial Reference Measurement (FRM) activities and welcomed further collaboration between the two groups.

3.4.4.4 GSICS UV sub-group (Ruediger Lang, EUMETSAT)

Ruediger described activities of the recently formed GSICS UV sub-group. Among the initial thoughts for working targets were the reflectivity and aerosol index comparisons (340 nm - 390 nm) by using vicarious methods for ocean, desert and ice sheet targets, a solar measurement comparison by using high resolution reference data sets along with instrument band-passes and Mg II scale factors, comparisons of radiance/irradiance measurements (240 nm – 290/340nm) by using initial measurement residuals with respect to a priori ozone profiles, and the identification of calibration requirements and capabilities.

Details of GOME-2 inter-calibration activities with other sensors (e.g., OMPS NPP, AVHRR, MetOp Seviri MSG) were described in detail.

3.4.4.5 Overview of GEO-CAPE OSSE activities supporting the CEOS AQ constellation (David Edwards, NCAR)

David noted that ACC had identified joint OSSEs as a way to promote collaboration between the planned and proposed geostationary Earth orbit (GEO) missions from NASA GEO-CAPE/TEMPO, ESA Sentinel 4 & KARI GEMS. OSSEs are extensively used by the NWP community to develop and optimize contemporary meteorological satellite instruments; they are now increasingly used in other fields of earth observation.

He described the chemical OSSE framework, details of which may be found in the presentation slides. Initial results reveal that the assimilation of the GEO constellation provides a strong constrain over anthropogenic source locations. The global constraint of CO is also strong in remote regions due to long range transport of assimilation increments. Impacts are reduced over Asia due to increased cloud coverage limiting the number of clear observations. It was also noted that experiments are being extended with a winter case study when the CO lifetime is longer, and emissions and cloud coverage also change.

Next steps include expanding the experiments to consider AOD, tropospheric ozone, and chemical correlations.

3.4.4.6 Status of NASA GMAO atmospheric composition OSSE nature runs (Arlindo da Silva, NASA)

Arlindo gave a status report of the NASA GEOS-5 nature runs for atmospheric composition studies. He described the OSSE experiment construction, noting that the key requirements for a nature run state that it must produce realistic weather and variability and that the climatology must be representative of nature.

Free running simulations have no constraints on meteorology or atmospheric composition. These can be used to investigate impact of meteorological errors on transport. Constrained meteorology, but with free running atmospheric composition simulations can be validated by field campaigns or satellite data.

A GEOS-5 based global, non-hydrostatic 7 km (free running) nature run including aerosols, CO, CO_2 and SO_2 is now available. A full gas chemistry nature run based on GEOS-Chem mechanisms is in the works. Applications of these runs include radiance simulation ataerosol channels for TEMPO/GOES-R synergisms, for the MODIS cloud & aerosol retrieval simulator, and for the PACE simulator.

3.4.4.7 ISOTROP project: OSSE studies on the Impact of S4/5 Spaceborne Observations on Air Quality Data Assimilation Systems (Henk Eskes, KNMI)

Henk discussed OSSE studies carried out by the Impact of Spaceborne Observations on Tropospheric Composition Analysis and Forecast (ISOTROP) team. These are being conducted to study the impact of Sentinel 4 and 5 data on AQ forecasts. O_3, CO, NO_2, HCHO are the focus of these studies. Objectives include a gain in model + forecast skill, improvement of boundary layer (BL) concentrations, improvement of impact long-range transport on BL, improvement of continuous and episodal sources, and optimization of surface emission rates.

Results from these OSSE studies include realistic observations with a full description of kernels and covariances and model differences describing present-day model uncertainty. S4-S5 synthetic observations and lookup-tables are available for future OSSE studies.

Atmospheric Composition Constellation Meeting (ACC-11) – Agenda - ESA/ESRIN

April 28	09:00-09:15	Welcome – M. Borgeaud - ESA
	09:15-09:30	Logistics-Scope/Overview of this Meeting - C. Zehner – ESA
	09:30-09.45	Creation of a 5 x 5 Degree Total Column Monthly Mean Ozone Data Set G. Labow - NASA
	09:45-10:00	OMI GODFIT/TOMS total ozone intercomparison results C. Lerot – BIRA/IASB
	10:00-10:15	Plans to combine long term European total ozone date sets with USA data sets - D. Loyola - DLR
	10:15-10:30	Multi Sensor Reanalysis of Total Ozone from satellites for the period 1970-2012 – R. van der A - KNMI
	10:30-11:00	Coffee Break
	11:00-11:20	Updated validation protocol to include as well nadir ozone profiles JC. Lambert – BIRA/IASB
	11:20-11:40	Assessment of SBUV profile algorithm using high vertical resolution sensors – R. McPeters - NASA
	11.40-12:00	Assessment of the RAL nadir profiling ozone algorithm (GOME2) – G. Miles – RAL
	12:00-12:20	Assessment of the IASI nadir profiling ozone algorithm – C. Clerbaux – LATMOS
	12:20-13:00	Discussion
	13.00-14:00	Lunch Break
	14:00-14:20	OCO-2 Results – D. Crisp – NASA
	14:20-14:40	GOSAT1 results and status of the GOSAT2 mission - M. Nakajima – JAXA
	14:40-15:00	GHG measurements from space (MERLIN, MICROCARB, IASI and IASI NG for CH4 and CO2 obs. in the troposphere) - C. Deniel - CNES
	15:00-15:15	The TansSat Mission status – Y. Liu - CAS
	15:15-15:30	The proposed CarbonSat mission – H. Bovensmann – University Bremen
	15.30-16:00	Coffee Break
	16.00-16:15	The project G3E - A. Butz – KIT
	16.15-16:30	Results of the ESA GHG Climate Change Initiative project C. Zehner - ESA
	16:30-16:45	Ongoing NASA/JAXA/NIES co-operation - D. Crisp – NASA
	16:45-17:00	Supporting GHG Management Strategies with Observations and Analysis O. Tarasova - WMO
	17:00-17:30	Discussions on the recommendations of the CEOS Carbon Strategy Report on Atmosphere/Implementation Plan of the GHG-Constellation
	17:30- 18:30	Icebreaker at ESRIN

April 29	09:00-09:15 Mission Overview GEMS – Ji-Hyung Hong - NIER and J. Kim – Yonsei University 09:15-09:30 Mission Overview Sentinel-4 – B. Veihelmann – ESA 09:30-09.45 Mission Overview TEMPO – K. Chance - SAO 09:45-10.00 GEO-specific retrieval challenges - Chance, Kim, Veihelmann 10.00-10.15 Mission Overview Sentinel-5 Precursor – T. Fehr - ESA 10:15-10:30 The role of LEO sounders in the air-quality constellation: CrIS+OMPS - John Worden – NASA 10:30-10:45 Latest Results on NH3 and CO from IASI – C. Clerbaux - LATMOS 10:45-11:00 Discussion 11:00-11:30 Coffee Break 11:30-11:50 Pre-launch plans for GEMS – Michelle Stevens, BATC, M.H. Ahn – Ewha, Womans University and J. Kim - Yonsei University 11:50-12:10 Pre-launch plans for S4 – B. Ahlers – ESA 12:10-12:30 Pre-launch plans for TEMPO – K. Chance - SAO 12:30-12:50 Pre-launch Activities Sentinel-5 Precursor - P. Veefkind - KNMI 12:50-13:00 Discussion 13.00-14:00 Lunch Break 14:00-14:20 Geo-AQ Geophysical Validation Needs – JC. Lambert – BIRA/IASB 14:20-14:40 DISCOVER-AQ campaign (2011-2014) – Jim Crawford/Ken Pickering NASA 14:40-15:00 AROMAT campaign (2014) – M. v Roozendael – BIRA/IASB 15.00-15:20 KORUS-AQ campaign (2016) – J. Al Saadi – NASA & Ji-Hyung Hong - NIER/ME 15.20-15:40 Pandonia ground based network – A. Cede – LuftBlick e.U. 15:40-15:50 ACSO - Absorption cross sections of ozone – J. Tamminen - FMI 15:50-16:00 Discussion 16:00-16:30 Coffee Break 16.30-16:50 GEO AQ Constellation Targets - J. Al Saadi – NASA 16.50-17:10 Product format and units - P. Veefkind - KNMI 17:10-17:30 ACSG Activities – T. Fehr - ESA 17:30-17:50 GSICS UV/VIS: GEO-GEO, GEO-LEO - R. Lang - Eumetsat 17:50-18:00 Discussion 18:00–21:00 Winetasting/Dinner at Frascati

April 30	09:00-09:20	Overview of GEO-CAPE OSSE activities supporting the CEOS AQ constellation - David Edwards - NCAR
	09:20-09:40	Status of NASA GMAO atmospheric composition OSSE nature runs – Arlindo da Silva - NASA
	09:40–10:00	ISOTROP project: OSSE studies on the Impact of S4/5 Spaceborne Observations on Air Quality Data Assimilation Systems – H. Eskes – KNMI
	10:00-10:30	Discussion/AIs on the AQ Constellation
	10:30-11:00	Coffee Break
	11:00-12:00	Discussions on total ozone and nadir ozone profile intercomparison and generation of combined data sets/AIs
	12:00 -13:00	Discussion on an ACC GHG Constellation Implementation Plan
	13:00-13:20	AOB/next meeting

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