Minutes of the
12th Atmospheric Composition Virtual Constellation Workshop (AC-VC-12)
Seoul, Korea
13-14 October 2016

1.0 Executive Summary

The Committee on Earth Observation Satellites (CEOS) AC-VC-12 was held at the Yonsei University in Seoul, Korea, on 13-14 October 2016. The Atmospheric Composition Virtual Constellation (AC-VC) 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 AC-VC'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). AC-VC works to facilitate international collaboration among space agencies and establish a framework for long term coordination of CEOS's goals. This was the first AC-VC meeting held outside of North America and Europe.

Researchers from participating CEOS agencies, related universities, and supporting organizations were present at the meeting. These organizations included BIRA-IASB, Chinese Academy of Sciences (CAS), CNES, CNRS, DLR, Deutscher Wetterdienst (DWD), ESA, EUMETSAT, Finnish Meteorological Institute (FMI), Harvard University, JAXA, Karlsruhe Institute of Technology (KIT), KNMI, LATMOS, Nara Women's University, NASA, NCAR, National Institute of Information and Communications Technology (NICT, Japan), National Institute of Environmental Research (NIER, Korea), National Institute of Meteorological Sciences (NIMR, Korea), Rutherford Appleton Laboratory (RAL), Science Systems and Applications (SSAI), United States Environmental Protection Agency (US EPA), University of Maryland Baltimore County (UMBC), University of Bremen, WMO, Yonsei University, and York University.

The Workshop addressed three principal topics: (1) Air Quality Constellation coordination activities, (2) Long-Term Total Ozone Data Set Harmonization, and (3) Greenhouse Gas (GHG) Constellation coordination activities. The workshop Agenda and participant list are attached to these minutes. The presentations can be found at http://ceos.org/meetings/ac-vc-12/.

We deeply appreciate our meeting hosts, the National Institute of Environmental Research (NIER), and Yonsei University. In particular, we are grateful to Professor Jhoon Kim and his wonderful students for showing the meeting attendees the warmth and hospitality of Korea.

2.0 Workshop Highlights and Recommendations

1. Air Quality Constellation

a. Overviews of planned air quality relevant space missions were presented. AC-VC members are eagerly anticipating the near-term launch of Sentinel 5P.

b. AC-VC members welcomed the first participation by colleagues at the Chinese Academy of Sciences who discussed the forthcoming GaoFen-5 mission. It was agreed that this mission would be embraced by members in future discussions of the AQ constellation.

c. Geophysical validation was discussed, both in the context of ground based observing networks and ongoing interagency activities sponsored by groups like Global Space-based Inter-Calibration System (GSICS). A working session on a "validation needs document" was held. Development of this document is proceeding as a near-term CEOS Deliverable for which AC-VC is responsible.

d. It was agreed that there is a need for an ongoing "data content" discussion to support AQ constellation harmonization.

2. Total Ozone Harmonization and Trends

a. Status reports on progress of this multi-year activity, sponsored by AC-VC, were presented on both US and European UV sensors. Work remains on schedule to provide global (pole to pole) total ozone gridded data sets from US and European sensors and to produce a comparison paper.

b. Nadir ozone profiles were discussed by several groups. It was agreed that AC-VC members would interact with the "SI2N (SPARC/IO3C/IGACO-O3/NDACC) follow-up" initiative to assess the need of complementary work by our virtual constellation.

c. It was agreed that comparisons of tropical tropospheric ozone from US and European sensors should be initiated.

3. Greenhouse Gas Constellation Activities

a. Following on from the ACC-11 meeting in Frascati, status updates on GHG missions in formulation, development, and operation were presented. Discussions focused on the utility of ongoing GOSAT/OCO-2 calibration and validation activities, including the development of common standards, and the need for supporting ground-based observations.

b. It was noted that the CEOS Strategy for Carbon Observations from Space, released in 2014 (http://ceos.org/home-2/the-ceos-carbon-strategy-space-satellites/) identified 42 actions. The AC-VC was tasked with leading 6 of these actions, which involve the coordination of detailed planning and preparation for a constellation of low Earth and geostationary orbiting measuring atmospheric CO_2 and CH_4.

In addition, individual CEOS agencies with interests in and/or mandates for providing improved information on natural and anthropogenic emissions of carbon (CO_2, CH_4, etc.) will coordinate their efforts in consultation with relevant CEOS WGs and the AC-VC.

c. Based on discussions at recent CEOS Strategic Implementation Team (SIT) meetings and at AC-VC-12, it was agreed that AC-VC would:

1. Support the organization of yearly International Workshop on Greenhouse Gas Measurements from Space (IWGGMS): next planned at FMI (Helsinki, Finland) on 6-8 June 2017 (see http://iwggms13.fmi.fi/program.html).

2. Prepare a white paper within 2 years on GHG constellation coordination activities, mirroring the multi-year AC-VC activities with its Air Quality constellation coordination activities.

3. Write a Technical Note within 2 years describing planned calibration/validation activities.

4. Other Activities

a. It was noted that a 2nd Atmospheric Composition OSSE Workshop was being held on 9-11 November 2016 at ECMWF. The workshop was sponsored by AC-VC, NASA, ECMWF, and the Copernicus Atmospheric Monitoring Service. Details of this workshop (held after the conclusion of AC-VC-12) may be found at http://atmosphere.copernicus.eu/events/second-workshop-atmospheric-composition-observation-system-simulation-experiments-osses

b. There was discussion at AC-VC-12 about initiating a new Aerosol focus activity within the virtual constellation. Omar Torres (NASA Goddard) agreed to formulate ideas for consideration and to organize a session at AC-VC-13 to explore potential further AC-VC involvement.

c. Both CEOS and CGMS have had a focus on "Non-meteorological applications for Next Generation Geostationary Satellites." CEOS has prepared a study on these activities (http://ceos.org/document_management/Meetings/Plenary/30/Documents/6.1_Schroeder_NMA_Report_2016-09-05_v.2.00.pdf) which was released at the CEOS Plenary subsequent to the AC-VC meeting.

The activity has a focus on next-generation imagers, e.g. AHI (JAXA), AMI (KMA), ABI (NOAA), FY-4 (CMA), FCI (EUMETSAT). It was noted that there may be potential opportunities for AC-VC relating to cloud products, aerosols, and fire hot-spots.

5. Next Meeting

a. The Centre national d'études spatiales (CNES) has offered to host the AC-VC-13 meeting in Paris, France, on 28-30 June 2017 at CNES Salle de l'Espace. We thank the local organizers, Cathy Clerbaux and Carole Deniel.

3.0 Summary of Meeting Topics and Discussions

3.1 Introduction

Dr. C. K. Song, on behalf of Dr. J. H. Hong, presented greetings on behalf of the National Institute of Environmental Research (NIER), our meeting hosts. Jay Al-Saadi (NASA, CEOS AC-VC co-chair) presented an overview of CEOS AC-VC activities. He noted that CEOS is standardizing its constellation naming convention, so that our official abbreviation has changed from "ACC" to "AC-VC". Each constellation has deliverables in the CEOS work plan for which it is responsible. The constellation leads report on the group's progress at the organization's Strategic Implementation Team (SIT) meetings twice annually. The current work plan includes the following AC-VC deliverables:

1. Total ozone dataset validation and harmonization
2. Air quality constellation coordination
3. Greenhouse gas constellation coordination.

Each of these topics was discussed at this meeting.

3.2 Air Quality Constellation

3.2.1 Mission Overview: GEMS (Jhoon Kim, Yonsei University)

Jhoon discussed status of the Geostationary Environmental. Monitoring Spectrometer (GEMS) satellite mission. The GEMS Science Team meeting took place immediately preceding the AC-VC meeting. The Advanced Meteorological Imager (AMI) will fly on GEO-KOMPSAT 2A, presently scheduled for a May 2018 launch. The Geostationary Ocean Color Imager-2 (GOCI-2) and GEMS instruments will fly on GEO-KOMPSAT 2B, scheduled for a March 2019 launch by Arianespace.

GEMS will measure aerosol and ozone with their precursors from a geostationary orbit at 102.2°E longitude. Instrument delivery to the Korea Aerospace Research Institute (KARI) is expected in the second quarter of 2017 for spacecraft integration.

Related activities include ongoing operational air quality forecasting by NIER since 2013. Since GEMS will be an operational mission, it is anticipated that the satellite data will be assimilated by models. The KORUS-AQ field mission was successfully conducted earlier in 2016 and included Geostationary Trace gas and Aerosol Sensor Optimization (GeoTASO) and Multi-slit Optimized Spectrometer (MOS) airborne instruments.

Jhoon described the substantial progress in retrieval algorithm development for the various constituents to be measured by GEMS. He noted that synergy with AMI and GOCI-2 will provide more reliable products of aerosol and cloud products, which should improve the accuracy of trace gas column density.

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

Ben noted that former CEOS AC-VC co-chair, Claus Zehner, has been appointed as mission manager for the atmospheric Sentinel missions (Sentinel-4, -5 Precursor mission, and -5).

Sentinel 4, one of the European Copernicus Atmospheric Monitoring Service missions, will measure short-lived species in the troposphere with spatial resolution appropriate for resolving sources and hourly sampling over Europe. Key products will include O_3, NO_2, SO_2, HCHO, CHOCHO, cloud and aerosol.

The Critical Design Review (CDR) was kicked off in November 2016. Instrument construction is well advanced with all lenses fabricated and most coated. Detectors have been built. Delivery is planned for 2019.

AC-VC activities supporting Sentinel-4 include radiometric consistency, sharing of data products, and consistency in retrieval algorithms. Ben noted that participation in reviews of the Algorithm Theoretical Basis Documents (ATBD) from other agencies is welcome.

3.2.3 Mission Overview: TEMPO (Kelly Chance, Harvard-SAO)

Kelly reported on the status of the Tropospheric Emissions: Monitoring Pollution (TEMPO) instrument. He noted that Jhoon Kim will be at Harvard on sabbatical and this will further enhance GEMS-TEMPO interaction.

TEMPO instrument fabrication by Ball Aerospace in Boulder is trailing GEMS by a few months. Since TEMPO will be a hosted launch, its satellite carrier will not be identified until late 2017. At that time, its orbital longitude will be known. Instrument delivery is scheduled for August 2017. Launch is scheduled for no earlier than 2018, although dates in the 2020-21 timeframe are increasingly likely.

Kelly noted that all TEMPO products are low-risk, since all proposed measurements have been validated in low Earth orbit and launch algorithms are implementations of current operational algorithms.

Products will include ozone, aerosols, precursors, and near real time pollution and air quality indices. Nighttime city lights will be among the planned research products.

3.2.4 Mission Overview Sentinel-5 Precursor (Pepijn Veefkind, KNMI)

Pepijn described the Sentinel-5 Precursor (S5P) mission, currently planned for a 2017 launch from Russia. The TROMPOMI instrument payload was developed by the Netherlands and ESA and has a 7-year design life. It has considerable heritage with OMI and SCIAMACHY, but includes additional spectral bands and higher spatial resolution than OMI and will yield more data products.

TROPOMI data will contribute to applications for societal challenges on climate change, air quality and the ozone layer. It will act as the “travelling standard” between the future constellation of geostationary air quality orbiters. S5P will fly in loose formation with Suomi NPP.

Improvements compared with OMI include approximately 6 times higher spatial resolution and 1-5x signal-to-noise per ground pixel. The 11 years of OMI operation has provided valuable lessons learned for TROPOMI operations.

User services is a key focus of the mission with a near real time data stream planned. Data volumes will be large and reliable and rapid data access are key goals. Data formats (netCDF CF) will work with standard tools.

3.2.5 Mission Overview GaoFen-5 (Liangfu Chen, Chinese Academy of Sciences (CAS))

Liangfu discussed the status of the GaoFen-5 (GF-5) mission. He noted several motivations for the mission, which include air quality issues in Chinese urban areas and the importance of controlling pollution. GF-5 is the latest in a series of GaoFen missions and will focus on air quality monitoring. The mission will have 6 instruments:

1. Atmospheric Infrared Ultraspectral (AIUS): an occultation instrument similar to ACE-FTS with a wide range of planned products including temperature, pressure, O_3, H_2O, CO, N_2O, and HCl.

2. Directional Polarization Camera (DPC): similar to the CNES POLDER instrument which will provide measurements of aerosols and clouds with an improved instrument field of view.

3. Environment Monitoring Instrument (EMI): a UV through Near-IR (NIR) instrument that will measure ozone, aerosols, NO_2, SO_2, and other constituents, with design heritage from OMI.

4. Greenhouse-gases Monitoring Instrument (GMI): using spatial heterodyne spectroscopy with spectral ranges similar to those of GOSAT.

5. Advanced Hyperspectral Imager (AHSI)

6. Visual and Infrared Multispectral Sensor (VIMS)

A haze monitoring system is one of the future applications being developed. A complementary ground-based ozone network is quite extensive. The team is looking forward to cooperation and interaction with the existing air quality constellation activities.

3.2.6 Japanese AQ Missions and Activities (Yasuko Kasai, NICT)

Yasko recounted previous Japanese air quality mission concepts, including GMAP-Asia, APOLLO, and uvSCOPE, which regrettably did not proceed beyond conceptual studies. Himawari-8 is providing outstanding measurements and could be used in synergistic analyses with other atmospheric measurements.

A focus on health and air quality applications has motivated the establishment of a pollution prediction service in Kyushu, where more than 70% of the pollution is estimated to originate from outside of Japan. Using satellite observations together with ground-based measurements, an air quality health index at 1x1 km resolution is being implemented for Fukuoka.

A micro-satellite for NO_2 hot spot detection is the subject of a current feasibility study. The measurement will be limited to only NO_2 to keep the instrument weight below 80 kg with an IFOV of between 1x1 and 2x2 km. The accuracy requirement for the NO_2 observation is about 5%. Initial studies suggest that this is attainable at the 2x2 km resolution.

3.2.7 Role of IR Observations in AQ Constellation (Cathy Clerbaux, LATMOS/IPSL)

Cathy described current and future IR satellite sounders. IASI on MetOp-A and MetOp-B have observed numerous atmospheric constituents including CO, O_3, NH_3, and SO_2. She discussed long-term time series of SO_2 and NH_3 data demonstrating the role of human activities and their contribution to the construction of emission inventories.

The future IASI-New Generation (NG) mission will have increased spectral resolution (~factor of 2 improvement). The Infra-red Sounder (IRS)/Meteosat Third Generation (MTG) geostationary mission will also feature improved resolution and pixel size.

IASI data, together with many related field missions, ground-based data, and spectroscopic information, are available from the AERIS web portal (http://www.pole-ether.fr).

3.2.8 Sentinel-5 Precursor Validation Plan Approach (Thorsten Fehr, ESA)

Ben Veihelmann presented on behalf of Thorsten on a geophysical validation plan for S5P. He emphasized the need for an independent approach that carefully examines the quantification of errors throughout the mission lifetime.

Detailed validation requirements have already been developed for the key parameters to be measured. Ben described the multiple sources of validation measurements, including fiducial reference measurements, a suite of ground-based measurements that provide the required confidence in the data products for users. These employ a QA4EO (http://qa4eo.org/) framework. Risk assessment is also a critical factor in the validation approach and was employed for each parameter considered.

Next steps include additional pre-launch activities, including an update to the science validation implementation plan. Following S5P launch, the first L1b and L2 product validation will take place towards the end of the commissioning phase (approximately 6 months after launch).

3.2.9 KORUS-AQ Campaign: Overview and Status (Limseok Chang, NIER & Jay Al-Saadi, NASA)

Jay described the recently completed KORUS-AQ field mission, which focused on a region of changing emission characteristics to better understand the factors controlling air quality. The field mission also provided a means to enhance collaborations to prepare for the next generation of air quality satellites (TEMPO and GEMS). In the immediate aftermath of the mission, a rapid science synthesis was produced to provide advice to the Korean Ministry of Environment for the improvement of air quality.

The mission utilized 3 aircraft and ~100 ground monitoring sites. During the 6-week campaign, a wide range of air quality conditions was sampled and there was much focus on repetitive sampling in the Seoul region and adjacent rural areas, as well as sampling of point sources from manufacturing and power plants.

A science team meeting took place in late February 2017 and data will be publicly available in the near future.

3.2.10 CINDI-2 Campaign: NO_2 Inter-comparison (Michel Van Roozendael, BIRA)

Michel described the Cabauw Intercomparison of Nitrogen Dioxide Measuring Instruments (CINDI-2) mission that took place in September 2016 in areas that are strongly affected by varying sources. The key objectives were:

1. To assess the consistency of slant column measurements of several key target species (NO_2, O_3, O_4 and HCHO) of relevance for the validation of S5P and the future ESA atmospheric Sentinels,
2. To study the relationship between remote-sensing column and profile measurements of NO_2, HCHO and O_3 and reference in-situ concentration measurements of the same species, and
3. To investigate the horizontal representativeness of MAXDOAS measuring systems in view of their use for the validation of satellite tropospheric measurements featuring ground pixel sizes in the range of 25-50 km^2.

Over 40 systems were operated side-by-side providing simultaneous measurements for 3-4 weeks using a semi-blind intercomparison technique. Data analysis is ongoing. Further information may be found on the campaign website (http://projects.knmi.nl/cindi-2).

3.2.11 Pandonia Ground Based Network (Alexander Cede, Luftblick / Michel Van Roozendael, BIRA)

Michel Van Roozendael presented on behalf of Alex. He described the Pandonia, which is a ground-based remote sensing network for air pollution monitoring and satellite validation using Pandora instruments. The goal is to assemble the infrastructure for long, uninterrupted, well-maintained, homogeneously calibrated time-series of ground-based remote sensing of atmospheric constituents, similar to existing ozone networks.

A detailed calibration plan, in the process of implementation, was described. A new technique for direct moon total column NO_2 and NO_3 shows promise. Pandora instruments participated in KORUS-AQ and in the CINDI-2 field campaigns.

3.2.12 US Federated Approach to Co-locate Ground Based Measurements with Existing EPA Core Sites (Lukas Valin, US EPA)

Luke discussed the US Environmental Protection Agency's (EPA) approach to better understand surface-level pollution from space-based data products, by co-locating measurements of surface and column quantities. A coordinated ground validation network across the US is being implemented. It will leverage existing and expanding state-operated air quality monitoring networks. This network will promote the use of forthcoming geostationary AQ measurements from TEMPO by the air quality community.

Among the improvements planned to this ground-based network are the inclusion of Pandora spectrometers at some sites, with a goal of 20 installations by 2020. These instruments will measure column densities of O_3, NO_2, HCHO, and SO_2.

3.2.13 Ground Based Reference Measurements Covering Asia (Sang-woo Kim, Seoul National University)

Sang-Woo described current Asian ground-based aerosol measurement networks. These include vertical measurements from AD-Net, the Asian dust and aerosol lidar observation network (http://www-lidar.nies.go.jp/AD-Net/) and KALION, the Korea aerosol lidar network.

SKYNET, a Global Atmosphere Watch (GAW)-contributing network, provides column-integrated measurements. Near the surface, the UNEP Atmospheric Brown Cloud – Asia network and the GAW and NOAA/ESRL federal aerosol networks also make contributions.

Sang-Woo presented ongoing correlation and intercomparison results among these networks.

3.2.14 GSICS UV-Vis: GEO-GEO, GEO-LEO (Rose Munro, EUMETSAT)

Rose presented a report on the Global Space-based Inter-Calibration System (GSICS) UV Sub-Group activities. Several baseline projects are in progress, including:

- Reference solar spectrum: evaluating available spectra and making recommendation for a reference spectrum for community use
- White paper on ground-based characterization of UV/Vis/NIR/SWIR spectrometers
- Match-ups and target sites: produce overpass comparisons of UV sensors for specific target sites for community use
- Cross-calibration below 300 nm: devising new methods for comparison of wavelength pairs for different viewing geometries

The GSICS UV sub-group is working closely with the CEOS Working Group on Calibration & Validation. The calibration of radiance and irradiance data remains a primary focus.

Rose noted that the sub-group welcomes additional topics from the community. Volunteers to lead the Match-ups and Target sites work are also needed.

3.3 Total Ozone Harmonization and Trends

3.3.1 Satellite Ozone Needs for Climate Applications (Wolfgang Steinbrecht, DWD)

Wolfgang, participating via WebEx, discussed the importance of ozone to climate and anthropogenic impacts on the ozone layer. He described global ozone measurements and trends, noting that the detection of stratospheric ozone recovery will be difficult. Latitudinal trends in total ozone are not consistent and not as expected by models. Fingerprints of ozone recovery were discussed. The importance of future satellite measurements of ozone was emphasized, but anticipated gaps, particularly for limb sounding observations, remain a concern to the community.

3.3.2 Total Ozone: Harmonization of Gridded Satellite Data Sets (Diego Loyola, DLR)

Diego recounted progress in total ozone harmonization, an activity that the AC-VC has supported for many years. He described current progress with the GOME-type Total Ozone Essential Climate Variable (GTO-ECV) merging and validation activities. The US MERRA reanalysis effort was also described, noting issues with SBUV inputs and intercomparisons with TOMS and ground-based observations. Plans for future activities include the finalization of the comparison of GTO-ECV and MERRA-2 gridded data and the extension of GTO-ECV with TROPOMI/S5P and GOME-2/MetOp-C measurements and updates to regional trends.

3.3.3 Total Ozone: Gridded Assimilation Including Ground-based Observations (Ronald Van der A, KNMI)

Ronald described a multi-sensor reanalysis of total ozone and ozone profiles. The overall assumption is that ground observations are on average a good approximation for the true values. The procedure involves correcting satellite data to remove biases and then assimilating satellite data into a chemical-transport model to achieve full spatial and temporal coverage. These Multi Sensor Re-analysis (MSR) data are available at www.temis.nl.

He described the corrections that are applied to the satellite data including solar zenith angle, effective temperature, trend (due to instrument degradation), and offset. This results in a bias corrected level 2 ozone data set. Ronald discussed intercomparisons with a wide range of other data sets. A similar method has been applied to nadir ozone profiles and the first results are now available. Operational MSR updates will be provided via the Copernicus Climate Change Service (C3S).

3.3.4 Gridding Ozone Profiles from Nadir Measurements from AIRS + OMI (UV+IR) (Dejian Fu, NASA)

Dejian described a joint retrieval approach to provide tropospheric profiles of ozone, CO, and methane. These retrievals are significantly different than other methods as they are merged at the radiance level, rather than at the product level. AIRS/OMI and SNPP CrIS/OMPS can support this constellation by distinguishing lower and upper tropospheric ozone signals. In the future, LEO sounders will be a crucial link between GEO sounders over America, Europe and Asia as well as the providing satellite observations in the southern hemisphere.

Joint AIRS/OMI ozone retrievals were presented during the TexAQS Aircraft Flight Campaign. These retrievals distinguish the amount of ozone between lower and upper trop, similar to TES, with broader spatial coverage, which helps to distinguish between stratospheric influences and biomass burning. He noted that multiple spectral observations enable the continuation of key EOS observations including TES and MOPITT which do not have follow on missions.

Joint CrIS/TROPOMI retrieved CO profiles show a similar vertical resolution as MOPITT TIR/NIR, but with a factor of two finer footprint size and daily global coverage, while the retrieved CH_4 profiles will provide similar vertical resolution as joint TES/GOSAT, but with a factor of ~100 times daily spatial coverage.

3.3.5 Gridding Ozone Profiles from TES/IASI (John Worden, NASA)

Continuing with the theme of using multiple LEO and GEO sensors to characterize tropospheric ozone, John noted that shifts in ozone precursors are changing the distribution and trends in ozone. He asserted that continued measurements of ozone profiles in the stratosphere and troposphere as well as spatially resolved measurements of its pre-cursors requires a constellation of GEO and LEO orbits. We will have dedicated composition sounders from TEMPO, GEMS, TROPOMI, and Sentinel 5p, 4, and 5 to obtain TCO, NO_2, and formaldehyde, a tracer of VOC's. We could get ozone profile and ozone pre-cursor measurements (methanol, PAN, NH_3, and CO) from CRIS and the IASI series, but there is at present no dedicated program to retrieve these measurements. He noted concern that we may not have measurements in the future from MLS which provide a critical constraint on stratospheric-tropospheric exchange.

John concluded that there is a need to resolve different measurement approaches (e.g. MLS/OMI relative to TES/IASI) to ensure that observed trends are real and not due to data artifacts. Continued, consistent calibration and validation measurements are critical for creating a robust set of measurements.

3.3.6 Gridding Ozone Profiles from Nadir Measurements from GOME-2/SCIA (Richard Siddans, RAL)

Richard, participating via WebEx, reported on a retrieval scheme developed at the Rutherford Appleton Laboratory (RAL) to infer ozone profiles, with tropospheric sensitivity, from nadir-uv spectrometers. The scheme was selected to provide the nadir-uv-profile data for ESA's Climate Change Initiative (CCI) to generate multi-year data sets from GOME-1, GOME-2, SCIAMACHY and OMI. Re-processed versions of this data also to feed into Copernicus Climate Change service (C3S).

He showed tropospheric ozone results derived from GOME-2 in a quantitative study of the Mediterranean summer ozone maximum compared with TOMCAT model results. Research is in progress to combine IR with UV observations to improve the vertical resolution in UTLS. Plans to exploit the ozone visible band to increase near-surface sensitivity are also underway. The scheme is being adapted to be used as the basis for development of the operational processors for Sentinel 4 & 5.

3.3.7 Ozone Profiles from Limb and Occultation: MLS (Nathaniel Livesey, NASA)

Nathaniel described the measurement approach of the Aura Microwave Limb Sounder (MLS), noting that it yields very good vertical resolution and good signal to noise. While the long path length does reduce horizontal resolution, the MLS retrieval approach does mitigate its impact. New technology developments since the construction of MLS can reduce its size and power consumption. He showed recent ozone profile measurements from MLS and comparisons with many other sensors (as published by Hubert et al., AMT, 2016). MLS maintains excellent stability 12 years after its launch.

Applications of MLS ozone observations for climate and related research include the identification of signs of recovery in upper stratospheric ozone, the ongoing characterization of polar processing and ozone loss, notably for the 2010/2011 northern hemisphere winter, and the quantification (in conjunction with TES) of the impact of variability in stratospheric circulation on tropospheric ozone. More information can be found on the MLS web site http://mls.jpl.nasa.gov/.

3.3.8 Merging O_3 Limb Data (Viktoria Sofieva, FMI)

Viktoria presented the construction of a harmonized record of limb profile ozone observations conducted for the ozone CCI. This level 2 HARMOZ dataset has these profile data on the same vertical grid. Level 3 products being produced include monthly zonal means from individual sensors, merged monthly zonal means, mesospheric datasets, and tropospheric column ozone. These data are available at http://www.esa-ozone-cci.org.

Near-term plans include adding Suomi-NPP OMPS data. In future, SAGE III/ISS and ALTIUS will be included. An advantage of this approach is that all limb-scattered data are processed using the same approach. These data will contribute to Obs4MIPs and the next WMO ozone assessment and related SPARC activities.

3.3.9 Tropospheric Ozone Derived from OMI/MLS (Gordon Labow, NASA)

Gordon discussed the use of OMI and MLS to measure tropospheric ozone. The approach is to use the OMI total column ozone and subtract the MLS stratospheric column ozone to yield a tropospheric residual. He showed global results which have good qualitative appearance. There are areas of high mid-latitude tropospheric ozone, likely due to stratosphere-troposphere exchange, lightning, pollution, and biomass burning. Comparisons with the OMPS nadir mapper reveal the same geographical patterns, giving additional confidence in the product.

Work to assess Owen Cooper's significant trends in tropospheric ozone (~8% per decade), suggest that these trends are predominantly real. Gordon has made available a variety of tropospheric ozone products to the climate community. In the future, OMPS will replace Aura for the stratospheric column component.

3.3.10 Tropospheric Ozone Derived from TropOMI (Pepijn Veefkind, KNMI)

Pepijn reported on planned tropospheric ozone observations from TropOMI. The TropOMI requirements are based on ozone CCI requirements guidance (precision and accuracy of 15%).

One approach being developed at DLR is to use a cloud convective differential (CCD) algorithm. He showed results of this algorithm applied to GOME-2 demonstrated good results. An ozone profile algorithm being developed at KNMI was also discussed. This employs optimal estimation with on-line radiative transfer yielding 21 vertical levels and 4 sub-columns, two of which are in the troposphere. The UV spectrometer is optimized for ozone profile retrieval.

There are research opportunities for a combined UV-TIR retrieval (with NPP/CrIS) and for higher spatial resolution products. Pepijn noted that algorithms should be optimized for tropospheric ozone with respect to a-priori ozone profile and a-priori errors. The UV ozone profile products are complex to use because of the tropospheric ozone averaging kernels and dependence on the a priori.

3.4 Greenhouse Gas Constellation

3.4.1 GOSAT Results (Kei Shiomi, JAXA)

Kei discussed GOSAT activities, highlighting results of monthly mean CO_2 and CH_4 from GOSAT, which has been orbit since 2009. The typical accuracy of retrieved column-averaged dry air mole fractions of CO_2 and CH_4 are 2ppm (0.5%) and 13ppb (0.7%), respectively. He described ongoing calibration and validation activities, showing comparisons with TCCON and with OCO-2. GOSAT CH_4 observations reveal regions of significant anthropogenic emissions. Kei also described current level 1 and 2 products and their status. He noted that level 2 products are also being produced by algorithms from other organizations (e.g., NASA, Bremen and Yonsei Universities).

He stressed that improvements in accuracy are important for follow-on GHG mission progress and continuous GHG observations. GHG cal/val activities should be promoted by CEOS AC-VC and WGCV in a collaborative framework.

3.4.2 OCO-2 Results (John Worden, NASA)

John described the current status of OCO-2. Approaching the end of its 2-year prime mission, the spacecraft is healthy and extended mission activities are being planned. Comparisons with TCCON have resulted in reduction in global bias to under 1 ppm in XCO_2. He discussed several recent events and findings, including impacts from the Chilean Calbuco volcano eruption and research findings such as distinguishing small-scale CO_2 emission structures and solar induced chlorophyll fluorescence.

Over 18 months of data have been delivered to the Goddard Earth Sciences Data and Information Services Center (GES-DISC) for distribution to the science community (http://disc.sci.gsfc.nasa.gov/OCO-2). OCO-2 v8 product testing is underway. Updates include improvements to the gas absorption coefficients and solar fluxes, CO_2, cirrus and aerosol priors and the surface reflection model.

3.4.3 Discussion: Implementing a GHG Constellation – Lessons Learned from the OCO-2 / GOSAT Collaboration (Pre-launch and On-orbit Calibration, L2 Comparisons, Validation, Flux Inversions) (John Worden, NASA)

John discussed the need for a GHG observation constellation, noting that the growth rate and future distribution of both CO_2 and CH_4 have large uncertainties and depends on a number of natural and anthropogenic factors. He asserted that a constellation (LEO + GEO) of satellites is needed to globally sample XCO_2 and XCH_4 with the accuracy and sampling needed to relate observed concentrations to fluxes. The constellation needs to be augmented with other measurements (e.g. CO, SIF, biomass, ET, inundation, rainfall, etc.) in order to relate fluxes to their anthropogenic and natural emissions and processes. One example of such a constellation is OCO-3, GEDI, and ECOSTRESS onboard the ISS.

OCO-2 and GOSAT and the ground-based TCCON network demonstrates that ~1 ppm and ~8 ppb accuracy is achievable for XCO_2 and XCH_4 measurements respectively. This accuracy is sufficient for quantifying regional-scale fluxes and to relate them to climatic and hydrological variations as well as isolated anthropogenic emissions (e.g. Los Angeles, Four-Corners).

Improvements in radiative transfer algorithms coupled with ancillary measurements could greatly improve this accuracy and enable finer scale emissions estimates. John noted the need to continue to improve on model capabilities in order to fully utilize these data.

Most importantly from a CEOS perspective, continued multi-national calibration and validation of XCO_2, XCH_4, and ancillary measurements are a critical element of the observing strategy needed to characterize the global carbon cycle and the future distribution of XCO_2 and XCH_4.

3.4.4 Sentinel 5P TROPOMI (Ben Veihelmann, ESA)

Ben discussed CO and CH_4 from TROPOMI aboard Sentinel 5P. TROPOMI has a planned 7-year lifetime with a launch in 2017. Total column CO will have an expected accuracy of less than 15%, while total column CH_4 accuracy should be 1.5%. He described the operational algorithms for both constituents developed by Landgraf et al (SRON). Simulated measurements, which demonstrate the capability of detecting regional biomass burning events.

TROPOMI will act as a “travelling standard” between the future constellation of geostationary air quality satellites. It will fly in “loose formation” with Suomi NPP to use VIIRS for cloud clearing.

3.4.5 TanSat Mission Status (Yi Liu, CAS)

Yi gave an update of the status of the TanSat mission. He noted that the carbon budget is a strategic priority research program of the Chinese Academy of Sciences. Emission inventories are becoming more uncertain with continuing global growth of CO_2 emissions. The Chinese carbon cycle is not well constrained.

TanSat measurement goals include X_{CO2} accuracies of 1-4 ppmv and relative CO_2 flux errors of 20% on monthly time scales. TanSat will be a sun-synchronous mission, flying at 700 km at 98° inclination with a 13:30 local time.

Yi described algorithm development status and ground-based calibration plans. Subsequent to the CEOS AC-VC meeting, TanSat was successfully launched on December 22, 2016.

3.4.6 GOSAT-2 Mission Status (Kei Shiomi, JAXA)

Kei gave a brief overview of GOSAT-2, contrasting its capabilities with GOSAT. Key upgrades include intelligent pointing and CO detection for the FTS-2 and forward/backward looking capability for CAI-2. Significant improvements in the concentration measurement precision for CO_2 (0.5 ppm) and CH_4 (5 ppb) are planned. Also, improvements in the estimation of monthly net fluxes are envisaged. GOSAT-2 will also calculate the optical thickness of the aerosols at 550nm and 1.6mm. Planned launch is expected in 2018.

3.4.7 OCO-3 Mission Status (John Worden, NASA)

John described differences between OCO-2 and OCO-3, noting some of the planned changes needed to deploy OCO-3 on ISS. The OCO-2 and OCO-3 missions in series provide an extended time series of XCO_2. Since OCO-3 has different sampling characteristics and therefore different error characteristics, these will need to be accounted for when using the datasets together. The existing retrieval algorithm does not need to be modified for use with OCO-3 data.

OCO-3 can also contribute to focused study of how space based measurements can constrain rapidly changing anthropogenic emissions from compact sources, such as cities. Anthropogenic emissions could be the largest source of uncertainty in the global carbon budget as OCO-2 measurements reduce uncertainty of natural fluxes. OCO-3 has differences including measuring at all local times of day between dawn and dusk, while OCO-2 collects measurements only near 1:30 PM. Other aspects of the OCO-3 data, such as its precision, accuracy, and resolution should be similar to that from OCO-2

3.4.8 MICROCARB, IASI and IASI NG for CH_4 and CO_2 Observations in the Troposphere (Carole Deniel, CNES / Cathy Clerbaux, LATMOS/IPSL)

Cathy described the French contribution to the GHG observation constellation, including IASI and IASI-NG, Merlin, and MICROCARB. The objective of IASI CO_2 and CH_4 measurements is to better understand surface sources and sinks of greenhouse gases and the related processes (transport, flux). IASI provides mid-tropospheric columns of CO_2, CH_4 over both land and sea, day and night. She showed multi-year time series of IASI CH_4 measurements.

The IASI-NG series on MetOp-SG has a planned first launch in 2021. In addition to ensuring continuity with IASI observations, improvements in precision are expected due to improved spectral resolution and radiometric noise.

MICROCARB will have three operating modes: nadir over land, glint over ocean, and target for calibration purposes (e.g., TCCON), similar to OCO-2, but it will be smaller so that it can be deployed on a microsat.

3.4.9 MERLIN Mission Status (Gerhard Ehret, DLR)

Gerhard described the MERLIN mission, which will use lidar to measure XCH_4. MERLIN is a collaboration between the French and German space agencies. Mission requirements are random error less than 22 ppb, a systematic error of less than 3 ppb, and a horizontal sampling accumulation of 50 km. Plans are for CH_4 seasonal and annual budgets on a country scale and the resolution of country scale gradients. The very low level of systematic error aims at avoiding geographical biases in the XCH_4 fields that could lead to uncertainties in fluxes.

The expected launch is in the 2020/2021 timeframe with a ~3 years of mission duration.

3.4.10 ESA/EC GHG Mission Plans (Ben Veihelmann / Yasjka Meijer, ESA)

Ben discussed European GHG missions, the desire to monitor fossil CO_2 emissions from space, and the relationship to European Community programs and goals. He noted that EU member states have ambitious goals to reduce emissions as a result of COP-21. There is a desire to support countries in evaluating their Nationally Determined Contributions in the CO_2 budget and the effectiveness of their CO_2 emission reduction strategies. ESA has proposed a generic roadmap towards an operational CO_2 monitoring system.

Key takeaways are that the EU intends to establish an operational CO_2 emission monitoring system by 2030. This system should support countries in monitoring their efforts to reduce CO_2 emissions down to the scale of major cities and power plants.

This system will require bottom-up emission maps, an operational Fossil Fuel Data Assimilation System and adequate space-based and in-situ CO_2 observations. A pre-operational system is being designed with a first satellite CO_2 imagery mission launched around 2025.

This system should be part of the Copernicus program, and will be complementing similar efforts of third parties and be the European contribution to an international CO_2 monitoring framework ("virtual constellation") at global level.

3.4.11 Geostationary CH_4 Concepts (David Edwards, NCAR)

David discussed the advantages of geostationary observations of CH_4, including high-density, hourly observations, the ability to stare to obtain sufficient signal, and increasing the probability of cloud-free observations. Continuous, near real-time data delivery will increase the uptake of the observations for regional air quality applications, like chemical weather forecasting and wildfire monitoring.

CHRONOS is a candidate mission proposed to the NASA EVI-4 solicitation. Its science goal is to characterize and understand changing emissions of methane and other pollutants in North America from urban sources, wetlands, fires and fossil fuel extraction and their complex consequences for air quality, climate and energy policy decisions. CHRONOS observations will resolve large uncertainties in current CH4 and CO emissions inventories and track rapidly changing vertical and horizontal atmospheric pollution transport to determine near-surface air quality on urban to continental, diurnal to seasonal scales. The proposed mission is complementary with TEMPO and supports CEOS air quality constellation activities.

After the CEOS AC-VC meeting, in early December 2016, NASA announced the selection of the GeoCarb mission as the second space-based investigation in the Earth Venture Mission series. GeoCarb is currently scheduled for launch as early as 2021 and will measure X_{CO2}, X_{CH4}, and X_{CO} as well solar induced chlorophyll fluorescence (SIF) from a geostationary orbit above 85° W longitude.

3.4.12 Common Calibration and Validation Standards for AC and GHG Constellations, The Total Carbon Column Observing Network (TCCON) (Tae-Young Goo, NIMR)

Tae-Young described the Total Carbon Column Observing Network (TCCON). He noted that total column measurements are less influenced by local sources and sinks than in situ and are less influenced by vertical transport. TCCON is useful both as a standalone network for model comparisons and for satellite validation (e.g., SCIAMACHY, GOSAT, OCO-2, TanSat). In order to be useful, TCCON must be accurate and precise and traceable to WMO mole fraction scales.

TCCON includes over 20 stations covering a range of latitudes spanning Eureka Canada (80.5° N) to Lauder, New Zealand (45°S). Its data continue to be heavily used in validation and science. Data delivery to archive has been timely. The network continues to expand, but there are still gaps in parts of China, India, Siberia, and in the tropics. TCCON is mission-critical to a number of current and future GHG satellite missions. TCCON data are freely available from the Oak Ridge archive at tccon.ornl.gov. While TCCON data are free, operation of TCCON is not. Setting up and running a TCCON station anywhere in the world for 10 years costs around €1.5M.

3.4.13 Integrated Global Greenhouse Gas (GHG) Information System (IG3IS) (Oksana Tarasova, WMO)

Oksana described the Integrated Global Greenhouse Gas (GHG) Information System (IG3IS). Its goal is to support the success of post-COP-21 actions of nations, sub-national governments, and the private sector to reduce climate-disrupting GHG emissions. IG3IS uses sound, scientific, measurement-based approach to reduce uncertainty in national emission inventory reporting, identify large and additional emission reduction opportunities, and provide nations with timely and quantified guidance on progress towards their emission reduction strategies and pledges (e.g., NDCs).

IG3IS will serve as an international coordinating mechanism to establish and propagate consistent methods and standards. Diverse measurement and analysis approaches will fit within a common framework. Stakeholders will be entrained from the beginning to ensure that information products meet user priorities and deliver on the foreseen value proposition. Success-criteria are that the information guides additional and valuable emission-reduction actions. IG3IS must mature in concert with evolution of technology and user-needs/policy.

Improved national inventory reporting will make use of atmospheric measurements for all countries. Satellite observations can help to "close the budget" by contributing measurements over ocean and over land areas with poor data coverage. Satellites can also identify and quantify "hot spots." A comprehensive carbon observing system requires 24/7 observations of very high spatial resolution over fixed areas, multi-parameter observations are needed for attribution.

3.4.14 Opportunities for Community Interactions: IWGGMS Summary and Organization of Next Meeting (Viktoria Sofieva, FMI)

Viktoria briefly spoke about the upcoming 13th International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-13), which will take place at the University of Helsinki from June 6-8, 2017. The goal of the workshop is to review the state of the art in remote sensing of CO_2, CH_4, and other greenhouse gases from space. Further information is available at iwggms13.fmi.fi.

3.4.15 Geostationary CO_2 Concepts (Andre Butz, KIT/DLR)

Andre reported on the Geostationary Emission Explorer for Europe (G3E) mission concept. This is a joint effort of several German and European universities and institutes. From geostationary orbit, contiguous spatial and temporal imaging is possible, enabling the disentanglement of transport, boundary conditions and sources/sinks.

The current mission concept deploys a 4-channel grating spectrometer in GEO (leveraging extensive LEO/GEO heritage: S5, S4, CarbonSat). An alternative instrument concept exists: an imaging FTS, but there are some issues, including the need for high pointing stability over its 900s exposure, high detector readout rates (> 1 kHz) and large data rates (1 Gbyte/sec) that required on-board processing.

3.4.16 Update on Canadian AQ-GHG Activities (Ray Nassar, ECCC)

Tom McElroy reported on the Canadian highly elliptical orbit (HEO) mission concept. Two or more satellites in a Highly Elliptical Orbit (HEO) configuration can be used for quasi-geostationary coverage of the high latitudes. Tom talked about previous HEO concepts like PHEOS and the Weather, Climate and Air quality (WCA) mission concept.

A new CSA and Environment and Climate Change Canada (ECCC) mission concept study entitled “Air Quality and GHG mission focused on Northern Regions” builds off the past Canadian concepts. An industry team led by ABB has been enlisted to re-examine the concepts. HEO remains the leading option for quasi-geostationary high latitude coverage, giving some mid-latitude overlap with GEO missions. Partnerships with other countries/agencies may be needed to make a quasi-geostationary northern AQ and GHG mission a reality.

3.4.17 GHG Constellation Action Items (Discussion)

See the “Workshop Highlights and Recommendations” (section 3) for the near-term GHG constellation action items.

3.4.18 Geostationary Satellite Constellation for Observing Global Air Quality: Geophysical Validation Needs (Side meeting)

The “Geophysical Validation Needs” document will be available on the CEOS AC-VC website in the near future.

13 Oct 2016, Yonsei University, The Lounge, Grand Ballroom

WebEx Connection: https://meetings.webex.com/collabs/meetings/join?uuid=M0UT6T3Z30ZXBNBJXUI1G1CFM8-3FZX Meeting Number 191 797 743

Topic	Presentation	Speaker	Duration	Start
ACC-12 Opening	0. Welcome and Opening remarks	Dr. J.H. Hong, NIER & Jay Al-Saadi, NASA	10 min	9:00
AQ-Constellation, chair J. Al-Saadi, B. Veihelmann	1. Mission Overview GEMS	Jhoon Kim, Yonsei University	15 min	9:10
	2. Mission Overview Sentinel-4	Ben Veihelmann, ESA	15 min	
	3. Mission Overview TEMPO	Kelly Chance, SAO	15 min	
	4. Mission Overview Sentinel-5 Precursor	Pepijn Veefkind, KNMI	15 min	
	5. Mission Overview GaoFen-5	Liangfu Chen, CAS	15 min	
	6. Japanese AQ missions and activities	Yasko Kasai, NICT	15 min	
	7. Role of IR observations in AQ constellation	Cathy Clerbaux, LATMOS/IPSL	15 min	
Coffee break			30 min	10:55
AQ-Constellation, chair J. Al Saadi, B. Veihelmann	8. Sentinel-5 Precursor Validation Plan Approach	Thorsten Fehr, ESA	15 min	11:25
	9. KORUS-AQ campaign: Overview and Status	Limseok Chang, NIER & Jay Al-Saadi, NASA	15 min	
	10. CINDI-2 campaign: NO_2 inter-comparison	Michel Van Roozendael, BIRA	15 min	
	11. Pandonia ground based network	Alexander Cede, Luftblick / Michel Van Roozendael, BIRA	15 min	
	12. US federated approach to co-locate ground based measurements with existing EPA core sites	Lukas Valin, US EPA	15 min	
	13. Ground based reference measurements covering Asia	Sangwoo Kim, Seoul National University	15 min	
	14. GSICS UV-Vis: GEO-GEO, GEO-LEO	Rose Munro, EUMETSAT	15 min	
	Round-up Discussion	all	10 min	13:10
Lunch			70 min	13:20
Ozone Trends, chair G. Labow, NASA	15. Satellite Ozone needs for Climate Applications	Wolfgang Steinbrecht, DWD, via WebEx	15 min	14:30
	16. Total Ozone: Harmonization of gridded satellite data sets	Diego Loyola, DLR	15 min	
	17. Total Ozone: Gridded assimilation including ground-based observations	Ronald Van der A, KNMI	15 min	
	18. Gridding Ozone Profiles from Nadir measurements from AIRS + OMI (UV+IR)	Dejian Fu, NASA	15 min	
	19. Gridding Ozone Profiles from TES/IASI	John Worden, NASA	15 min	
Coffee break			30 min	15:45
Ozone Trends, chair D. Loyola, DLR	20. Gridding Ozone Profiles from Nadir measurements from GOME-2/SCIA	Richard Siddans, RAL (via webex)	15 min	16:15
	21. Ozone Profiles from Limb and Occultation: MLS	Nathaniel Livesey, NASA	15 min	
	22. Merging O3 Limb Data	Viktoria.Sofieva, FMI	15 min	
	23. Tropospheric ozone derived from OMI/MLS	Gordon Labow, NASA	15 min	
	24. Tropospheric ozone derived from TropOMI	Pepijn Veefkind, KNMI	15 min	
	Round-up Discussion	all	10 min	17:30
Adjourn				17:40

14 Oct 2016, Yonsei University, The Lounge, Grand Ballroom

WebEx Connection: https://meetings.webex.com/collabs/meetings/join?uuid=M6R74IDG0E4M5ZFWH5CUOHE2C9-3FZX Meeting Number 190 201 570

Topic	Presentation	Speaker	Duration	Start
GHG Mission Results, and Implications for a GHG Constellation, chair Dejian Fu, NASA	1. GOSAT Results	Kei Shiomi, JAXA	15 min	9:00
	2. OCO-2 Results	John Worden, NASA	15 min	
	3. Discussion: Implementing a GHG Constellation - Lessons learned from the OCO-2 / GOSAT collaboration (Pre-launch and on-orbit calibration, L2 comparisons, validation, flux inversions)	John Worden, NASA	20 min	
Status of Near-term GHG Missions, chair Jhoon Kim, Yonsei	4. Sentinel 5P TROPOMI	Ben Veihelmann or Paul Ingmann, ESA	15 min	9:50
	5. TanSat Mission status	Yi Liu, CAS	15 min	
	6. GOSAT-2 Mission status	Kei Shiomi, JAXA	15 min	
	7. OCO-3 Mission status	John Worden, NASA	15 min	
Coffee Break			30 min	10:50
Status of Near-term GHG Missions (continued), chair Jhoon Kim, Yonsei	8. MICROCARB, IASI and IASI NG for CH4 and CO2 obs. in the troposphere	Carole Deniel, CNES Presented by Cathy Clerbaux, LATMOS/IPSL	15 min	11:20
	9. MERLIN Mission status	Gerhard Ehret, DLR	15 min	
	Round-up Discussion	all	10 min	11:50
Planned and Proposed GHG Missions, chair Kei Shiomi, JAXA	10. ESA/EC GHG Mission Plans	B. Veihelmann / Yasjka Meijer, ESA	15 min	12:00
	11. Geostationary CH4 concepts	David Edwards, NCAR	15 min	
Lunch			60 min	12:30
Discussion Topics, chair John Worden, NASA	12. Common calibration and validation standards for AC and GHG constellations, The Total Carbon Column Observing Network (TCCON)	Tae-Young Goo, NIMR	15 min	13:30
	13. Integrated Global Greenhouse Gas (GHG) Information System (IG3IS)	Oksana Tarasova, WMO	15 min	
	14. Opportunities for community interactions: IWGGMS summary and organization of next meeting	Johanna Tamminen or Viktoria Sofieva, FMI	15 min	
	15. Geostationary CO2 concepts (moved from planned/proposed session to accommodate schedule)	A. Butz, KIT/DLR, via webex	15 min	
	Opportunities for community interactions: 10th International Carbon Dioxide Conference (ICDC10)	all	15 min	
	16. Update on Canadian AQ-GHG Activities	R. Nassar, ECCC	15 min	
	17. GHG Constellation Action Items	discussion	20 min	15:00
	18. ACC-12 Wrap up, AOB, next meeting		10 min	15:20
	Adjourn Main Meeting, transition to Side Meeting			15:30

Side Meetings, 14 Oct 2016

Room	Time	Topic
Grand Ballroom	16:00-18:00	19. Geostationary Satellite Constellation for Observing Global Air Quality: Geophysical Validation Needs
tbd	16:00-18:00	Space available, contact Ben and Jay to propose additional side meeting topics

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