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Readiness of User Communities: Air Quality

(Submitted by Richard Eckman, NASA)

Summary and Purpose of Document

A new generation of geostationary satellites to measure tropospheric ozone, aerosols, and their precursors to is under development and will be launched by multiple space agencies in the next 5 years. The geostationary vantage point provides the ability to measure these constituents at high spatial and temporal resolution. Researchers are cooperating through the Committee on Earth Observation Satellites (CEOS) Atmospheric Composition Virtual Constellation (AC-VC) to enhance the value of the individual satellite observations through an integrated observing strategy. Together with future low Earth orbit (LEO) missions like Sentinel 5-P, these multiple space-based assets will provide unprecedented observations and products for end-users in the air quality community.

ACTION PROPOSED

The third session is invited to take note of the CEOS AC-VC activities relating to these space-based air quality observation coordination and harmonization activities and to consider potential actions supporting these tasks.

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DISCUSSION

Introduction

Three geostationary satellite missions are under development to observe and characterize natural and anthropogenic activities in the troposphere by measuring tropospheric ozone, aerosols, and their precursors. The vantage point of a geostationary orbit affords the ability to observe the Earth at high spatial and temporal resolution, albeit for only a portion of the globe. Through an integrated observing strategy, these multiple geostationary sensors, together with low Earth orbiting satellite platforms, can provide unprecedented information for researchers and policy makers. An ongoing activity of the Committee on Earth Observation Satellites (CEOS) Atmospheric Composition Virtual Constellation (AC-VC) is working towards the harmonization and coordination of activities on these upcoming missions to enhance their utility. Its annual meeting was held in October 2016 in Seoul, South Korea (http://ceos.org/ourwork/virtual-constellations/acc/) and the meeting minutes will be posted in the near future. The status of these activities is reported in this paper.

Air Quality Constellation Status

GEMS

The Korean Geostationary Environmental. Monitoring Spectrometer (GEMS) satellite mission 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.

Related to GEMS, the joint Korean-US KORUS-AQ field mission was successfully conducted during mid-2016 and focused on the Korean peninsula, 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. The Geostationary Trace gas and Aerosol Sensor Optimization (GeoTASO) and Multi-slit Optimized Spectrometer (MOS) airborne instrument was flown during the KORUS-AQ mission.

GEMS investigators are making substantial progress in retrieval algorithm development for the various constituents to be measured by GEMS. There is ongoing collaboration with the Advanced Meteorological Imager (AMI) and Geostationary Ocean Color Imager-2 (GOCI-2) that will provide more reliable products of aerosol and cloud products, which should improve the accuracy of trace gas column density measurements.

TEMPO

The NASA Tropospheric Emissions: Monitoring Pollution (TEMPO) instrument is under development. 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, but it will cover much of the United States and adjacent areas. 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.
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.

Sentinel 4

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.

Sentinel 5P

Two low Earth orbit missions will provide observations in regions not covered by the three geostationary sensors, allowing for cross comparisons and additional science products. The Copernicus Sentinel-5 Precursor (S5P) mission, currently planned for a 2017 launch from Russia employs the Tropospheric Monitoring Instrument (TROPOMI) instrument payload, developed by the Netherlands and ESA, which 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.

GaoFen-5

The Chinese GaoFen-5 (GF-5) is a related LEO mission, with multiple motivations including air quality issues in Chinese urban areas and the recognition of 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, including an Atmospheric Infrared Ultraspectral (AIUS), an occultation instrument similar to ACE-FTS, with a wide range of planned products including temperature, pressure, O3, H2O, CO, N2O, and HCl; a 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; an Environment Monitoring Instrument (EMI), a UV through Near-IR (NIR) instrument, that will measure ozone, aerosols, NO2, SO2, and other constituents, with design heritage from OMI; a Greenhouse-gases Monitoring Instrument (GMI), using spatial heterodyne spectroscopy with spectral ranges similar to those of GOSAT, an Advanced Hyperspectral Imager (AHSI) and a Visual and Infrared Multispectral Sensor (VIMS).

Constellation Coordination Activities

A white paper was written by an AC-VC team and released in 2011 and subsequently endorsed by the CEOS Strategic Implementation Team (http://ceos.org/document_management/Virtual_Constellations/ACC/Documents/ACC_White-Paper-A-Geostationary-Satellite-Cx-for-Observing-Global-AQ-v4_Apr2011.pdf). The white paper described an integrated observing approach to address science and societal benefits from these geostationary observations. A variety of activities were proposed to exploit these observations, including collaboration on retrieval algorithms and approaches, observation system simulation experiments (OSSEs), quantification of societal benefits, improvements to data quality, content, access, and

utilization, and improvements to air quality models and data assimilation techniques.

The white paper made recommendations of concrete actions to be undertaken to support these collaborative activities. Since 2011, the CEOS AC-VC has implemented many of these recommendations. These have included collaboration on retrieval algorithm development and the organization of multiple OSSE workshops. The 2nd Atmospheric Composition OSSE Workshop was 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 may be found at http://atmosphere.copernicus.eu/events/second-workshop-atmospheric-composition-observation-system-simulation-experiments-osses.

During the past two years, many of these recommended activities have been implemented. For example, the sharing of instrument requirements has influenced instrument specifications, which may facilitate harmonization of data products; team members have advocating open data policy with common formats to facilitate broad usage; and the harmonization of L1B and L2 format specifications across AC missions to easily exchange data has been accomplished.

More recently, geophysical validation issues were discussed at the October 2016 AC-VC meeting, both in the context of ground based observing networks and ongoing interagency activities sponsored by groups like the 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. It was also agreed that there is a need for an ongoing “data content” discussion to support air quality constellation harmonization.

A recently-funded NASA project is providing support to the GEMS mission in the implementation of state-of-the-art retrieval algorithms for SO_2, tropospheric O_3, as well as aerosol optical depth and single scattering albedo. The team is using the Advanced Himawari Imager (AHI) on the Japanese Himawari-8 geostationary platform to provide additional information for aerosol remote sensing. The automatic GEMS-AHI collocation will be used to enhance the accuracy of GEMS aerosol products by addressing cloud contamination and aerosol optical depth over land retrieval issues. The effort has significant relevance to related TEMPO retrieval development using GOES-16 and highlights an activity relevant to the joint CEOS-Coordinating Group for Meteorological Satellites (CGMS) report on non-meteorological applications for next-generation geostationary satellites to be discussed during this meeting.