The Committee on Earth Observation Satellites (CEOS) Atmospheric Composition Virtual Constellation (AC-VC) is one of seven virtual constellations that assemble a set of space and ground segment capabilities operating together in a coordinated manner to produce a virtual system that overlaps in coverage in order to meet a combined and common set of Earth observation requirements.

The goal of the AC-VC is to collect and deliver data to develop and improve predictive capabilities for changes in the ozone layer, air quality, and climate forcing associated with changes in atmospheric composition.

Within the GEOSS framework, AC-VC supports multiple societal benefit areas, including health, disasters, energy, climate, and ecosystems.
New generation of geostationary satellites to measure tropospheric ozone, aerosols, and their precursors is under development and will be launched by multiple space agencies in the next 5 years.

Geostationary vantage point provides the ability to measure these constituents at high spatial and temporal resolution, but only viewing part of the globe.

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.

Missions will provide unprecedented observations and products for end-users in the air quality community.
Air Quality Missions

• GEO Missions
  • NASA TEMPO
  • KARI/ME GEMS
  • Copernicus Sentinel-4

• Complementary LEO Missions
  • Copernicus Sentinel-5P
  • CAS Gaofeng-5
Geostationary Air Quality Constellation Coordination

- Geostationary orbit provides “continuous” observations (many times per day) but a single geostationary satellite can view only a portion of the globe.

- Several countries and space agencies are planning to launch geostationary satellites in the 2018-2022 time frame to obtain air quality measurements.

- NASA TEMPO
- NOAA GOES-16/S
- Copernicus Sentinel-4
- EUMETSAT MTG
- KARI, ME GEMS
- JMA Himawari-8/9

- These missions share common objectives yet, individually, are restricted to regional relevance. Harmonization through a constellation framework will provide a global perspective otherwise impossible to achieve.

- Such an integrated global observing system for atmospheric composition is key to abatement strategies for air quality as laid down in various international protocols and conventions (IGACO, GEO, WMO GAW).

(Constellation white paper (2011) available at http://ceos.org/acc)
Policy-relevant science and environmental services enabled by common observations

- Improved emissions, at common confidence levels, over industrialized Northern Hemisphere
- Improved air quality forecasts and assimilation systems
- Improved assessment, e.g., observations to support United Nations Convention on Long Range Transboundary Air Pollution

From: Kelly Chance, CEOS AC-VC-12 Meeting, October 2016
Baseline and threshold data products

<table>
<thead>
<tr>
<th>Species/Products</th>
<th>Required Precision</th>
<th>Temporal Revisit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2 km O₃ (Selected Scenes)</td>
<td>10 ppbv</td>
<td>2 hour</td>
</tr>
<tr>
<td><strong>Baseline only</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropospheric O₃</td>
<td>10 ppbv</td>
<td>1 hour</td>
</tr>
<tr>
<td>Total O₃</td>
<td>3%</td>
<td>1 hour</td>
</tr>
<tr>
<td>Tropospheric NO₂</td>
<td>1.0 × 10¹⁵ molecules cm⁻²</td>
<td>1 hour</td>
</tr>
<tr>
<td>Tropospheric H₂CO</td>
<td>1.0 × 10¹⁶ molecules cm⁻²</td>
<td>3 hour</td>
</tr>
<tr>
<td>Tropospheric SO₂</td>
<td>1.0 × 10¹⁶ molecules cm⁻²</td>
<td>3 hour</td>
</tr>
<tr>
<td>Tropospheric C₂H₂O₂</td>
<td>4.0 × 10¹⁴ molecules cm⁻²</td>
<td>3 hour</td>
</tr>
<tr>
<td>Aerosol Optical Depth</td>
<td>0.10</td>
<td>1 hour</td>
</tr>
</tbody>
</table>

- Minimal set of products sufficient for constraining air quality
- Across Greater North America (GNA): 18°N to 58°N near 100°W, 67°W to 125°W near 42°N
- Data products at urban-regional spatial scales
  - Baseline ≤ 60 km² at center of Field Of Regard (FOR)
  - Threshold ≤ 300 km² at center of FOR
- Temporal scales to resolve diurnal changes in pollutant distributions
- Collected in cloud-free scenes
- Geolocation uncertainty of less than 4 km
- Mission duration, subject to instrument availability
  - Baseline 20 months
  - Threshold 12 months

From: Kelly Chance, CEOS AC-VC-12 Meeting, October 2016
### GEO-KOMPSAT 2

**2A Sat.**: AMI  
**Launch**: 5/2018

**2B Sat.**: GEMS, GOCI-2  
**Launch**: 3/2019

#### Specification

<table>
<thead>
<tr>
<th>Payload</th>
<th>2A</th>
<th>2B</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMI</td>
<td>GOCI-2</td>
<td>GEMS</td>
</tr>
<tr>
<td>Lifetime</td>
<td>10 years</td>
<td></td>
</tr>
<tr>
<td>Channels</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>Wavelength range</td>
<td>0.4 - 13 (\mu)m</td>
<td>375 - 860 nm</td>
</tr>
<tr>
<td></td>
<td>300-500 nm</td>
<td></td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>0.5 / 1 km (Vis)</td>
<td>250 m@ eq 1 km (FD)</td>
</tr>
<tr>
<td></td>
<td>2 km (IR)</td>
<td></td>
</tr>
<tr>
<td>Temporal resolution</td>
<td>10 min (FD)</td>
<td>1 hour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 hour</td>
</tr>
<tr>
<td>Major Products</td>
<td>CTP, CTT, CF, AOD, FMF, OLR, SI, CSR, SST, LST, AMV, … (56)</td>
<td>Ocn. current, chlorophyl, DOM, Phytoplankton, …</td>
</tr>
</tbody>
</table>

From: Jhoon Kim, CEOS AC-VC-12 Meeting, October 2016
GEMS Objective: Measurements of O₃ & aerosol with precursors

- NO
- O₃
- RO₂
- NO₂
- HCHO
- hν (λ<345 nm)
- O₃
- hv (<420 nm)
- NO
- NO₂

AOD, type, Height

Oxidation (OH, O₃, NO₃)

From: Jhoon Kim, CEOS AC-VC-12 Meeting, October 2016
Synergistic products

AMI

GOCI-2

Cloud center height
AMV
AOD over desert
Aerosol type
Sfc. ref.
Cloud mask
Cloud top pressure
...

Ocean current,
AOD, Aerosol type
Green tide, Red tide

SST, AMV, Fog

AOD
Aerosol type
Sfc. ref.

NO2
UV spectrum

✓ 24 hr Asian dust monitoring over dark and bright surface
✓ Cloud morphology (thickness, fraction, type ...)

From: Jhoon Kim, CEOS AC-VC-12 Meeting, October 2016
Copernicus Missions for Atmospheric Composition

**Sentinel-4**
- **Focus**: short lived species in troposphere
- **Orbit**: Geostationary
- **Sampling**: Hourly over Europe
- **Air Quality**: NO₂, O₃, aerosol, SO₂
- **Climate**: aerosol, O₃
- **Ozone & UV**: O₃, cloud, aerosol
- **Emissions**: NO₂, SO₂, aerosol, HCHO, CHOCHO

**Sentinel-5 & 5 Precursor**
- **Focus**: Short and long lived species in troposphere and stratosphere
- **Orbit**: Low Earth Orbit
- **Sampling**: Daily global
- **Air Quality**: NO₂, O₃, aerosol, SO₂, CO
- **Climate**: CH₄, CO, aerosol, O₃
- **Ozone & UV**: O₃, cloud, aerosol
- **Emissions**: NO₂, SO₂, aerosol, HCHO, CO, CH₄

From: Ben Viehlmann, CEOS AC-VC-12 Meeting, October 2016
The ESA Sentinel-5 Precursor (S-5P) is a pre-operational mission focusing on global observations of the atmospheric composition for air quality and climate.

The TROPOspheric Monitoring Instrument (TROPOMI) is the payload of the S-5P mission and is jointly developed by The Netherlands and ESA.

The planned launch date for S-5P is 2017 with a 7 year design lifetime.

TROPOMI

- UV-VIS-NIR-SWIR nadir view grating spectrometer.
- Spectral range: 270-500, 675-775, 2305-2385 nm
- Spectral Resolution: 0.25-0.5 nm
- Spatial Resolution: 7x7km²
- Global daily coverage at 13:30 local solar time.

Contribution to Copernicus

- Total column $O_3$, $NO_2$, CO, $SO_2$, CH₄, HCHO
- Tropospheric column $O_3$, $NO_2$
- $O_3$ profile
- UV Aerosol Index & Aerosol layer height
- Clouds
International Co-operation

- TROPOMI/S5P is part of the CEOS AQ Constellation
  - TROPOMI provides the global coverage
  - Act as a “travelling standard” between the GEOs

- S5P will fly in loose formation with Suomi NPP
  - Primary objective is to use the VIIRS data for cloud clearing

From: Ben Viehlmann, CEOS AC-VC-12 Meeting, October 2016
Sentinel-4 Footprint Size

Similar to Sentinel-5, -5P

→ Big step toward resolving sources

From: Ben Viehlmann, CEOS AC-VC-12 Meeting, October 2016
GF-5 satellite specification and major orbit parameters

<table>
<thead>
<tr>
<th>Orbital Type</th>
<th>Sun synchronous orbit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal orbital altitude</td>
<td>708.45km</td>
</tr>
<tr>
<td>Dip angle</td>
<td>98.218</td>
</tr>
<tr>
<td>Orbital flat period</td>
<td>98.805min</td>
</tr>
<tr>
<td>Eccentricity ratio</td>
<td>E&lt;0.0001</td>
</tr>
<tr>
<td>Flight cylinder number every day</td>
<td>14.57</td>
</tr>
<tr>
<td>Orbital intercept</td>
<td>24.731</td>
</tr>
<tr>
<td>Local time of descending node</td>
<td>13:30</td>
</tr>
</tbody>
</table>

Sensors onboard GF-5

- Advanced Hyperspectral Imager (AHSI)
- Visual and Infrared Multispectral Sensor (VIMS)
- Greenhouse-gases Monitoring Instrument (GMI)
- Atmospheric Infrared Ultraspectral (AIUS)
- Environment Monitoring Instrument (EMI)
- Directional Polarization Camera (DPC)

From: Liangfu Chen, CEOS AC-VC-12 Meeting, October 2016
Activities to enhance user readiness

Recent AC-VC AQ Constellation Activities

- Collaboration on retrieval algorithm development
- Organization of multiple OSSE workshops. The 2nd Atmospheric Composition OSSE Workshop was held on 9-11 November 2016 at ECMWF.
- Sharing of instrument requirements has influenced instrument specifications, which should facilitate harmonization of data products
- Team members have advocated open data policy with common formats to facilitate broad usage
- Harmonization of L1B and L2 format specifications across AC missions to easily exchange data has been accomplished
Recent AC-VC AQ Constellation Activities (cont’d.)

• 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.

• There is a need for an ongoing “data content” discussion to support air quality constellation harmonization.
Future AC-VC AQ Constellation Activities

- Quantification of societal benefits
- Improvements to data quality, content, access, and utilization
- Improvements to air quality models and data assimilation techniques

Synergies with Operational Geostationary Satellites

- NASA project for GEMS mission implementation of state-of-the-art retrieval algorithms for SO₂, tropospheric O₃, as well as aerosol optical depth and single scattering albedo.
- Uses 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.
- Project has relevance to related TEMPO algorithm retrieval development using GOES-16.