GEMS* mission status in ground segment and application (including operation)

*Geostationary Environmental Monitoring Spectrometer

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• Products and validation plan
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• GEMS ground segment
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Current status of GEMS mission
GEMS Space Segment

• GK-2B Satellite
  (Geostationary orbit)
  - Payloads: GEMS, GOCI-II
  - Lifetime > 10 years

• Construction of ground segment
  (Commanding & data downlink)
  - KARI(Daejon, Korea)
    : S-band TM & TC
  - NIER(Incheon, Korea)
    : X-band
    Data processing and service
Roadmap of the GEMS mission

- Calibration program will be delivered to NIER in early 2019
Currently state and plans

• Level2 Algorithms developed for 16 species (~ 2017)
  * Final 24 products will be tested for operation (2018~2019)
• New building and antenna system constructed (~2017)
• GEMS payload delivered to KOREA (Jan, 2018)
• Creating a new department (Environmental Satellite Center) (Apr, 2018)
• Ground systems CDR (Apr, 2018), patch up the issues (May, 2018)

• <Future>
• Installation of operation S/W and H/W (~Dec, 2018)
• S/W development for satellite data analysis (2018~2019)
• Development of algorithms for Level3 and Value added products (2018~2020)
• Launching (Oct., 2019~Mar., 2020)
• Data service for the forecaster (2020~) and for the public (2021~)
Creating a new department for GEMS operation

- Environmental Satellite Center is a department for GEMS operation (Apr, 2018)

- ESC consists of three teams:
  1) Development team
  2) Analysis team
  3) Operation team

- Construction of GEMS ground station was completed for receiving, processing, management, and distribution of data
  - Located in NIER, in Incheon, South Korea
  - Dual Reflector type of 9m Antenna
Role of Environmental Satellite Center

GEMS development team

- Routine Quality Control
- Long-term Monitoring (sensor, ageing, ...)
- Calibration study
- Geophysical validation of products
  - DOAS, Pandora, ...
  - NIER announcement of opportunity call in 2019 to engage experts for the calibration and validation of GEMS
  - select projects and release the validation team, 2019
  - Cal/Val activity and feedback, 2020~
- Maintenance and evolution of Algorithms
  - Manage the updates of: calibration algorithm and tools
  - L1, L2, L3, VAP processor algorithm
  - Quality control tools
  - Validation algorithms
Role of Environmental Satellite Center

Data analysis team

• Analysis of air quality with near real-time satellite data for an air quality forecaster
  – Development of satellite data analysis system
  – Analysis of the distribution of the characteristics of air pollutants from the satellite data, targeting the forecasted materials

• Making a report for the cases of high concentration of air pollutants
  – Study for the contribution rate of air pollutants from overseas
  – Correction of bottom-up emission and analysis of how it was changed compared to the past
Role of Environmental Satellite Center

Operation team

• Operation of GEMS payload
  – Implement observation mission of GEMS
  – Establishment of daily GEMS observation plan
  – Real-time verification to check outlier
  – Products management

• Operation of GEMS ground segment
  – Check any faults of integrated data processing system
  – Management of network and security

• Data service system development
  – Collecting data requirements and feedback to the service system
  – Development and improvement of transmission techniques between GEMS ground segment and the air quality forecasting system
  – Web-site management and data service to the related organization

• International cooperation and sharing data with another country
Products and validation plan
Each level of products

Level1B product

• Definition
  – Calibrated radiance data from 300nm to 500nm with navigation coordinate (not including of resampling)

• Measurement types (TBD)
  – Earth, Working solar diffuser, reference solar diffuser, Dark current, Light Emitting Diode(LED)

• Format : NetCDF

• Data policy(TBD) : service for public in phases
  – First phase: air quality forecaster in NIER (L+8M IOT~)
  – Second phase: public(uploading data after all observation are finished in a day) (L+2Y~)
Each level of products

Level2 product

• Definition
  – Total column density or background products that are retrieved by level2 algorithms

• Products
  – Ozone, Aerosol, NO2, HCHO, SO2, CHOCHO, Cloud, Surface reflection, UVI, ...

• Format : NetCDF

• Data policy(TBD) : service for the public in phases
  - first phase: air quality forecaster in NIER (L+8M IOT~)
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Optimization of Level2 algorithm

- The prototype of level2 algorithm was developed by algorithm science group (PI: Jhoon Kim) since 2012.
- **Optimization** of developed programs will be performed from 2018 to 2019.
Each level of products

Level3 products

• Definition
  – Correcting low-quality pixel in Level2 products to improve retrieval accuracy and support more information to non-specialists with handling satellite data
  – Composing and averaging Level2 products in temporal and spatial with resampling work

• Target: NO2, O3, Aerosol

• Format: Binary(TBD)

• Schedule: Plan to undertake development these algorithms in Mar, 2018
Each level of products

Value added products

• Definition
  – Surface information of air pollutants and so on

• Target: NO2, O3, Aerosol(PM2.5, PM10)

• Schedule
  – Developed the draft algorithm for PM2.5 retrieval in 2017 and will improve it
  – Plan to undertake development the other algorithms in 2018
Development of surface concentration

- A draft of PM2.5 retrieval algorithm was developed for extracting fine dust information on the ground, that has significant effect on human body
  - Adopting the MLR (Multi Linear Regression) method
  - Consideration of the relationship between AOD and ground PM, weather conditions, and geographical conditions

Figure: Scatter plots between estimated PM2.5 and observed PM2.5 in South Korea (left) and the spatial distribution in winter over East Asia
Validation plan

• Pre-launch
  – Development and optimization of near real-time validation tools such as comparison with other satellite data (2018~2019)
  – Non real-time validation such as comparison with surface observation data (2018~2019)
  – Installation and test in ground segment system (2019)
  – Confirmation of validation data (2019)
  – Project call to construct validation network in GEMS observation area (2019)

• Post-launch
  – Validation activities after every major re-processing expected to affect the data, in order to verify expected algorithm and data improvement
  – Determination of the quality of new data products
  – Evaluation of mission data against user requirements that may has evolved
Validation plan

• Validation data (surface monitoring, MAX-DOAS, LEO...)

Before Launch

- ME. Korea Supersites
- KOR LIDAR Network (KALION)
- KOR PANDORA Network
- KOR GEO (COMS MI, GOCI)
- Int. Campaign (KORUS-AQ, LTP)

After Launch

- Asian EANET Network
- Asian LIDAR Network (AD–NET)
- Asian MAX–DOAS Network
- LEO (TROPOMI 🌑)
- Modeling (OSSE)

Networking

Consistency & Public Service

Level–2 and –3 Products
- O3 COL. Tropo. O3 Profile
- NO2, SO2, HCHO, CHOCHO
- Aerosol AOD, AI, SSA, AEH
- UVI Solar IRA

Validation

Assessment of Accuracy
GEMS ground segment
Data flow and Structure

Receiving System
- Receiving RAW data

Pre-Processing System
- RAW → L0 → L1A (Correction: Smear, Dark current, Temperature..)
  L1A → L1B (INR)

Scientific Data Processing System
- L1B → L2 (16 products)

Data Analysis System
- L2 → L3, VAP

Data Validation System
- Compare L2 with LEO, surface observation

Mission Request System
- Generating observation schedule

Data Management System
- Tier1 SSD (storage for real-time process)
- Tier2 SAS (basic storage)
- Tier3 LTO (storage for backup)

E-portal
  (Data Collection and Distribution System)

KARI
- Generating control information
- GEMS L1B Backup

Related Organization (NMSC, KIOST)
- Sharing data
- GEMS RAW Backup (KIOST)

NIER (Air Quality Forecasting center)
- Offering GEMS L2, L3, VAP

Web site
- GEMS data service
<table>
<thead>
<tr>
<th>Operational Concept</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-stop Operation</td>
<td><strong>Non-stop Operating ground station for 24 hours and 365 days</strong>&lt;br&gt;Securing stability and non-stop automation through active-active high stability multiplexing&lt;br&gt;Constructing an operation system in emergencies and at all times&lt;br&gt;Establishment of back-up system for each sub system</td>
</tr>
<tr>
<td>Real-time Service</td>
<td><strong>Acquisition in real-time and distribution in near-real-time</strong>&lt;br&gt;Distribution within 1 hour after receiving RAW data&lt;br&gt;Improvement of processing efficiency through algorithm parallelization</td>
</tr>
<tr>
<td>Operation for 10 years</td>
<td><strong>Operating 10 years according to designed duration of GK2B operation</strong>&lt;br&gt;Considering expansion possibilities of hardware, software, network, and new facilities</td>
</tr>
<tr>
<td>Data archive</td>
<td><strong>Archiving all data in main storage, that is received and produced</strong>&lt;br&gt;Building storage system that can expand and meet storage requirements</td>
</tr>
<tr>
<td>Back-up system</td>
<td><strong>Constructing back-up system for data reliability</strong>&lt;br&gt;Non-stop Operating with rapid substitution in case of failure&lt;br&gt;Establishment of back-up system to meet system operation concept and requirements</td>
</tr>
<tr>
<td>High Availability</td>
<td><strong>Achieving 99% or more operational availability for high-speed processing and customized services with Hot backup system</strong></td>
</tr>
</tbody>
</table>
Test Operation Plan

Test operation for ground station system before launch

- Tasks
  - Organically interworking between system modules in ground segments
  - Reviewing functionality and appropriateness between operating systems
  - Evaluating retrieval algorithms accuracy

- Detail schedule
  - (1st) Evaluating performance of data retrieval algorithms and validation modules (2018.3 ~ 2018.12)
  - (2nd) Review of operational plan appropriateness, checking functionality of the integrated operating system and operational process (2018.12 ~ launch)

Test operation for LEOP and IOT after launch (Launch + 8 months)

- Tasks
  - System functionality test using actual satellite observation data
  - Fine-tuning algorithms for changes after launch
Application and service plan
The roadmap of GEMS application

2016~2017

Forums with experts
→ Creating fusion application fields

Forums with non-experts
→ Exploring users and requirements

2016

Planning application

2017~2018

Development of surface concentration

2018~2019

Development of analysis technique

2016

Discovery of fusion application

2017

Design and planning of fusion products

2018~

Development of fusion products

2018~

Joining CEOS AC-VC

Formulating data policy

Data service

Data format

Data type
GEMS data service plan (TBD)

• Via Landline (web-based service)

• Web-based service system will be constructed for 3 years (2018~2020)

• For public, GEMS data will be available in a ESC website every day (TBD)

• For air quality forecaster, data will be serviced every hour

• Target products to service
  – GEMS Level1B (300~500nm, 0.6nm interval, TBD)
  – GEMS Level2 (16 products + more)
  – Scan every hour when sun is rising
SUMMARY

• The Ministry of Environment (National Institute of Environmental Research) is developing a geostationary environment satellite for monitoring air pollutants over East Asia and climate change causing substances at all times.

• Expected products are column density such as O3, NO2, SO4, HCHO, AOD, periodic averaged and gridded data (Level3), and valued added products.

• The Environmental Satellite Center for GEMS is created and construction of data processing system is on-schedule, that will be stable and process data rapidly.

• In the future, GEMS will be launched in 2019 and perform in orbit test for 8 months. GEMS data will be serviced for public after 2021.

• The GEMS will be used to monitor air pollutants such as long range transport and it will contribute to improvement accuracy of air quality forecasting and emission data with top-down approach.
Thank you
Development plan of LEO GHG satellite

• Organized user requirement of LEO GHG Satellite  2016
• Preparing a report for the feasibility test  2017~2018
• Feasibility test for LEO GHG satellite  2019~2020 (TBD)
• Development of the LEO GHG satellite  2021~ (TBD)
• Launch .... (TBD)
Nominal daily operations and calibration

- 33 co-adds per mirror position meet SNR and 30 minute scan duration requirements
- 8-12 scans acquired per day, seasonally varying
- 2 Dark calibrations/day
- 1 Solar calibration opportunity per day at all times over the year
## Nominal Daily operations and calibration

### In-flight calibration observation plan

<table>
<thead>
<tr>
<th>Activity</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark Imaging</td>
<td>Twice/day</td>
</tr>
<tr>
<td>Working Solar Diffuser Observation</td>
<td>Once/day</td>
</tr>
<tr>
<td>Reference Solar Diffuser Observation</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>LED Light Source Linearity Sweep</td>
<td>Once/week</td>
</tr>
</tbody>
</table>
Examples of Level 2 products using OMI

Troposp. O$_3$

O$_3$ profile

NO$_2$

HCHO

Credit:
Mijin Kim (Yonsei U) – Aerosol
Y.S. Choi (EWU) – Cloud
Jae H. Kim (Busan NU) – O$_3$
Hanlim Lee (Pukyung NU) – NO$_2$
Rokjin Park (SNU) – HCHO, CHOCHO
Y.J. Kim (GIST) – SO$_2$
J.M. Yoo (EWU), M.J. Jeong (GWNU) – Sfc prod
M.H. Ahn (EWU) – calibration
GEMS Ground segment in ESC

Currently state and plans

- System Design review Jan, 2017
- Preliminary Design Review Mar, 2017
- Critical Design Review Apr. 2018
- Delta-Critical Design Review May. 2018
- Construction of data processing room with servers Jun. 2018
- Realization of operation software Aug. 2018
- First stage of optimization of level2 algorithms Aug. 2018
- Integration test Sep.2018~Dec.2018
- Launch Oct.2019~ 2020
Plans for LEO GHG satellite
Initiative of LEO GHG Satellite

Summary
• To monitor quantity and emission of greenhouse gas in global scale
  • Two sensors will be developed
    - Near infrared hyper-spectrometer
    - Imager for aerosol and cloud correction (optional)
• In a part of the third phase mission of compact advanced satellite in KARI, Korea

Specification(TBD)

<table>
<thead>
<tr>
<th>classification</th>
<th>specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight / Size</td>
<td>150kg(payload) / 1.6x0.4x0.6(m)</td>
</tr>
<tr>
<td>Resolution</td>
<td>2km</td>
</tr>
<tr>
<td>Orbit height</td>
<td>705km</td>
</tr>
<tr>
<td>Channel</td>
<td>Three bands (0.76, 1.61, 2.06μm)</td>
</tr>
<tr>
<td>Target</td>
<td>CO2, O2</td>
</tr>
</tbody>
</table>