DOCUMENT

Geostationary Environmental Monitoring Spectrometer (GEMS) Mission Announcement of Opportunity Validation Team

GEMS Development Team of Environmental Satellite Center

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Table of Contents

Environmental Satellite Center
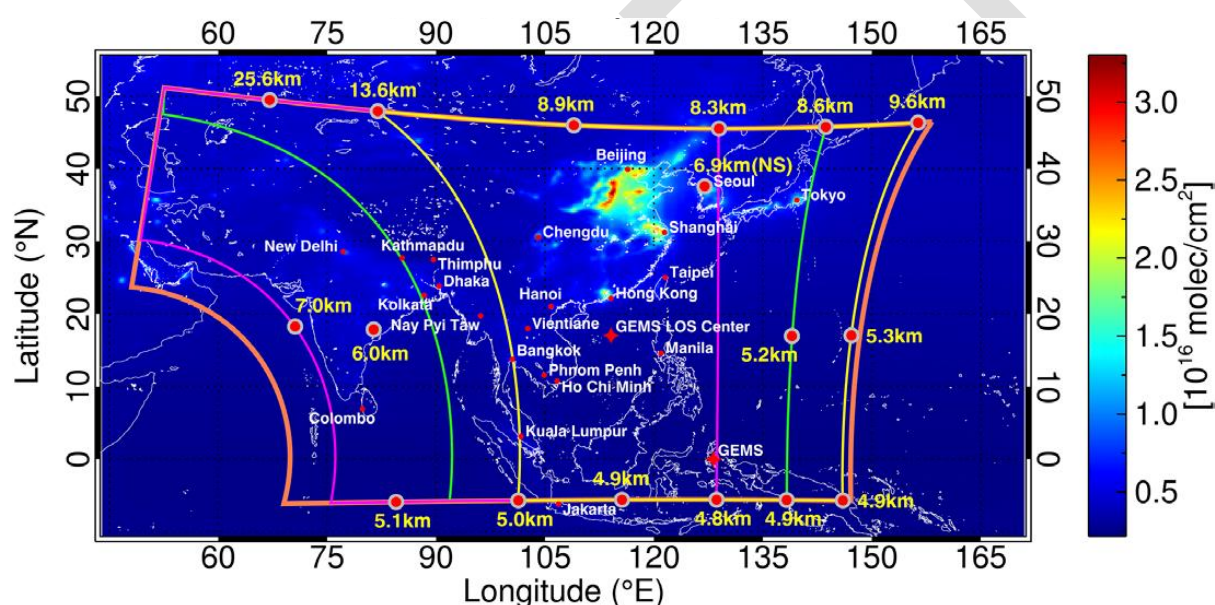National Institute of Environmental Research

1. Description of the opportunity

The main purpose of the Announcement of Opportunity Call is to harness professional knowledge and expertise of experienced scientists to perform objective validation and accuracy assessment of data and products of the Geostationary Environmental Monitoring Spectrometer (GEMS) through independent data analysis.

GEMS will monitor atmospheric composition over East Asia and part of Southeast Asia. Although there have been several polar-orbit satellites including GOME (ERS-2), SCIAMACHY (Envisat), OMI (Aura), and GOME-2 (MetOP), TROPOMI (Sentinel-5P) that provide global atmospheric chemistry measurements, they are inherently not suitable for observing diurnal variation in specific areas of interest. On the other hand, GEMS with the capability of UV-Vis spectrum (300 – 500 nm) measurements, like other heritage low earth orbit sensors, scans East Asia (see Fig. 1) hourly during the daylight at 128.2°E longitude and 36,000 km altitude over the equator, providing high temporal resolution (up to 12 scans per day depending on seasonal conditions). This superior temporal resolution allows estimation of concentrations, transport, and extinction of air pollutants in targeted areas.

As part of the GK2(A/B) Project initiated from the need for monitoring air pollution and climate change in East Asia, GEMS started being developed in 2012 [RD-01, RD-02]. After its system design in 2013, critical design in 2015, and environmental

Page 2 / 16
Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

testing in 2017, GEMS was launched onboard GEO-KOMPSAT-2B (GK-2B) from the Guiana Space Center in Kourou, French Guiana in February 2020. The GK-2B spacecraft was built by the Korea Aerospace Research Institute (KARI) based upon its experience of developing the Communication, Ocean and Meteorological Satellite (COMS), and GEMS was jointly developed by KARI and Ball Aerospace & Technologies Corp. (Boulder, Colorado, USA).

Figure 1. The E-W scan scenarios of GEMS, nominal daily scan (yellow), full central scan (green), and full west scan (magenta), within the field of regard (FOR; orange). (RD-02)

GEMS is a UV-Vis (300 – 500 nm) hyperspectral sensor and the first of its kind to observe atmospheric composition (e.g., aerosols, NO_2, SO_2, O_3, and HCHO) from geostationary orbit. Some of the GEMS data products are listed in Table 1. More detailed description on the GEMS products and their applications can be found in [RD-01]. Although several polar-orbiting sensors including GOME, SCIAMACHY,

Page 3 / 16
Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

OMI, and TROPOMI have long provided global coverage for air quality measurements, unexpected problems might be caused during GEMS operation since its geometric properties are different from those of the sun-synchronous instruments. This is why a systematic and sophisticated approach to performance assessment of GEMS products in terms of e.g., accuracy, error budget, and uncertainty is needed, and diurnal variations of atmospheric chemistry that are unobservable from polar orbit satellites should be analyzed as well.

Page 4 / 16
Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

Table 1. Baseline products of GEMS.

Product		Importance	Window (nm)	Spatial resolution (km × km) at Seoul	Algorithm	Remark
NO$_2$	Trop	O3/aerosol precursor	432-450	7×8	DOAS	RD-04
	Strat					
SO$_2$		Aerosol precursor	310-326	7×8	DOAS-PCA	RD-05
		volcano	310-340			
HCHO		VOC proxy	328.5-356.5	7×8	DF	RD-06
CHOCHO			435-461	7×8	DF	RD-07
O$_3$	Trop	Oxidant, pollutant, Ozone layer	300-340	7×8	OE	RD-08
	Strat		300-340		OE	
	Total		317.5, 331.2, 331.2, 340, 380		TOMS	RD-09
Aerosol	AOD	Air quality, climate	354, 388, 412, 443, 477, 490	3.5×8	LUT, OE	RD-10
	UVAI				LUT	
	SSA				LUT, OE	
	AEH		477		O$_2$-O$_2$	RD-11
Cloud	ECF	Retrieval, climate	300-500	7×8	O$_2$-O$_2$	RD-12
	CCP		477			
	CRF					
Surface reflectivity		Retrieval, environment	300-500	3.5×8	Multi-channel, BRDF	RD-13
UVI	UVI	Public health	354	7×8	LUT	RD-14
	VitaD					
	DNA					
	Plant					

Page 5 / 16
Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

2. Objectives of the opportunity

The National Institute of Environmental Research (NIER) is announcing this opportunity to form validation teams of GEMS data, whose main focus should be on obtaining data reliability and availability through quantification/qualification of uncertainty and error budget regarding the end-to-end retrieval performance of GEMS by comparing GEMS level-2 products (acquired during daytime and nighttime normal processing) with independent data (from airborne, ground-based, and other satellite measurements, and simulation models). Keeping this in mind, interested scientists or groups of scientists may select some of the following activities, or propose other research areas based on them.

- Evaluation of Level-2 retrieval algorithms (in terms of e.g., stability and accuracy)
- Assessment of regional errors and their sources
- Comparison with other space-borne instruments (e.g., TROPOMI, GOME-2, etc.)
- Comparison with ground-based and/or airborne measurements (including effects caused by differences in resolution)
- Comparison of diurnal variations of each atmospheric species between GEMS measurements and modelling results

Page 6 / 16
Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

- Assessment of the impact of auxiliary data used in product retrieval (e.g., temperature, humidity, altitude, cross-section data, etc.)

- Analysis of major error sources and error budget

- Assessment of heterogeneous geographic effects (e.g., coastlines, mixed environment of lakes and rivers, mountainous areas, etc.)

Furthermore, close cooperation among GEMS algorithm developers and the international GEMS validation teams selected through this AO is expected to facilitate comprehensive evaluation of the accuracy of GEMS L2 products along with quick error detection and correction.

Each GEMS validation team may be requested to participate in some, or all, of the activities as below:

- Sharing of their research findings through kick-off, interim, and final meetings of the GEMS validation teams

- Presentation of their research findings at workshops and/or conferences upon NIER's request

- Support for other validation activities defined by NIER

- Support for algorithm evaluation during GEMS in-orbit test conducted by NIER

Page 7 / 16
Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

Level 1C and Level 2 products obtained during GEMS in-orbit test will be available to the GEMS Validation teams according to an appropriate method. Such products must be strictly limited to the proposed purposes.

Page 8 / 16
Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

3. Main activities

The validation projects selected through this call will be completed in 2021. Depending on the opinions and intentions of NIER and the participating teams, there might be subsequent AO calls, where new teams could be added or some of the current members can be changed in response to new validation requirements and/or alterations or modifications in GEMS operation. Each Opportunity will basically last for about two years but the period can be flexible according to circumstances. The validation teams should perform their activities based on [RD-03].

3.1. Commissioning phase

For approximately nine months after launch, GEMS is undergoing in-orbit testing to ensure the required performance and operation of the sensor and its ground segment. Functional testing is being led by the Korea Aerospace Research Institute (KARI), after which normal retrieval of L1b products will begin. Afterwards, NIER will carry out test operation of the L2 algorithms for about one year, during which the GEMS validation teams will be given the relevant data products for their proposed activities and the results should be submitted to NIER. Detailed timetable of data provision will be announced depending on the test operation schedule of the

ground segment by KARI and the submitted results will be provided to the GEMS Steering Committee and used as evidence to elaborate data distribution and other operation practices.

3.2. Exploitation phase

After completion of the algorithm testing, GEMS data will be normally serviced until the end of the mission lifetime (2029). The validation teams will continue to support retrieval algorithm evaluation and accuracy monitoring during the mission period. In particular, they will be encouraged to present their research progress and outcomes at the annual International GEMS Workshop.

3.3. Reprocessing phase

Once the products retrieved from GEMS are archived enough to estimate annual variations of atmospheric composition, additional research on data reprocessing to improve the overall quality of GEMS products will be conducted through analysis of the archived data, where the validation teams will contribute by providing data trend analysis.

Page 10 / 16
Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

Table 2 illustrates an overview of the timelines of GEMS cal/val activities**.**

Step	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
GEMS Mission life													
Commissioning phase													
Exploitation phase													
Archive													
On-orbit VAL													
Reprocessing													
Validation (post mortem)													
Remark	1st project		2nd project		3rd project		4th project		5th project		6th project		

4. Guidelines for Proposal

The predefined proposal format can be downloaded from the GEMS website (https://nesc.nier.go.kr) and the proposal should be submitted in electronic form (MS-word or PDF) via email. GEMS data products for the validation activities and further information will be provided on the website as well.

Page 11 / 16
Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

5. Evaluation of Proposals

5.1. Evaluation procedure

The submitted proposals will be reviewed by an evaluation panel that consists of:

- GEMS Algorithm Development Team

- Development and Operation Teams of the Environmental Satellite Center (ESC) of NIER

- Other satellite algorithm developers and analyzers

The experts specialized in atmospheric application of satellite data, ground-based and airborne remote sensing, and/or atmospheric chemistry modelling.

5.2. Evaluation criteria

The proposals will be reviewed based on the following criteria:

- Significance of content

- Suitability of the validation purpose

- Rationality (Feasibility) of the proposed method(s)

- Feasibility of the project funding (for long-term maintenance of the monitoring site)

- Balance among countries within the GEMS domain

- Contribution to validation and improvement of GEMS products

Page 12 / 16
Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

6. Reporting and Sharing Findings

The selected validation teams will be required to report and share the progress and achievements of their projects. Each team should prepare a final report before its project is completed and will be encouraged to present their outcomes at workshops or conferences upon requests from NIER.

Confidentiality of not only the proposals but also the processes and outcomes of the selected projects will be required. Publication or dissemination of any of the data and products related to the AO projects shall not be allowed without prior approval from NIER. Project results and related data shall be provided to NIER in computer readable formats. NIER will retain the right to use, apply, and reprocess all, or part, of the submitted data and/or outcomes produced during the course of the projects.

Important dates of AO

- Release of the call (submission opening): 1 April 2020

- Close of the call (submission closing): 31 May 2020

- Notification the evaluation results and activation of the selected validation teams: 1 Jul 2020

- Start of GEMS data delivery to the validation teams: TBD (expected about 4 month after activation)

Page 13 / 16
Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

- Completion of the projects: autumn 2021

7. Help Desk

Further information regarding this AO can be provided from the Help Desk:

Dr. Chang Suk Lee (Researcher)

Hwangyeong-ro 42, Seo-gu, Incheon, Korea, 22689

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If you have any requests or inquiries, please send email at the address above with a title starting with "**[GEMS AO]**". Any information related to the Call will be distributed via email until the official GEMS website is open. Once the website is available, relevant data and documents will be provided on it.

Page 14 / 16

Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

8. Acronyms

AO	**Announcement of Opportunity**
ESC	**Environment Satellite Center**
DF	**Direct Fitting**
DOAS	**Difference Optical Absorption Spectroscopy**
GEMS	**Geostationary Environmental Monitoring Spectrometer**
GK-2	**Geostationary Korea Multi-Purpose Satellite-2**
GOCI2	**Geostationary Ocean Color Imager 2**
KARI	**Korean Aerospace Research Institute**
LUT	**Look-Up Table**
NIER	**National Institute of Environmental Research**
TBD	**To be defined**
IOT	**In-Orbit Test**
OE	**Optimal Estimation**
PCA	**Principal Component Analysis**
VAL	**Validation**

Page 15 / 16

Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research

9. Reference Documents

[RD-01] Choi et al. 2019: Introducing the geostationary environment monitoring spectrometer. J. Appl. Remote Sens. 12(4), 044005.

[RD-02] Kim et al. 2020: New Era of Air Quality from Space: Geostationary Environment Monitoring Spectrometer (GEMS). BAMS

[RD-03] Geophysical Validation of the Geostationary Environmental Monitoring Spectrometer (GEMS), GEMS-WP-NIER-001

[RD-04] GEMS ATBD NO_2 Retrieval Algorithm

[RD-05] GEMS ATBD SO_2 Retrieval Algorithm

[RD-06] GEMS ATBD HCHO Retrieval Algorithm

[RD-07] GEMS ATBD CHOCHO Retrieval Algorithm

[RD-08] GEMS ATBD O_3 Profile Algorithm

[RD-09] GEMS ATBD Total Column O_3 Retrieval Algorithm

[RD-10] GEMS ATBD Aerosol Retrieval Algorithm

[RD-11] GEMS ATBD Cloud Retrieval Algorithm

[RD-12] GEMS ATBD Surface Reflectance Retrieval Algorithm

[RD-13] GEMS ATBD UV-Index Retrieval Algorithm

Page 16 / 16
Doc Name
Date
Issue

Environmental Satellite Center
National Institute of Environmental Research