Status of Geostationary Environmental Monitoring Spectrometer, GEMS

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The GEMS system employs a 1032 x 2048 pixel CCD detector that operates from 300 - 500 nm, which at a minimum, enables NO$_2$, SO$_2$, HCHO, O$_3$, and aerosol retrieval. The telescope projects the slit field of view onto the Earth, and the full field of regard is achieved via a 2-axis onboard scan mirror.

Ground processing spatially bins and geo-locates each co-added image.

Images from each scan mirror position are co-added on-board...

...Co-added images are then transmitted to ground.
International collaboration

Constellation of GEO Mission for synergistic products

TEMPO (America)

GMES S4 UVN (Europe)

GEMS + AMI + GOCI2 GEO KOMPSAT (Asia)

Constellation synergy
- Improving spatial and temporal coverage to monitor globalized pollutants & SLCF
- Sharing basic requirements on data products and instrument to maintain data quality
- Consolidating socio-economic benefit analysis
- Supporting QA and CAL/VAL
GEMS Instrument

- Step-and-stare UV-Vis imaging spectrometer scanning at least 8/day in 30 min
- Daily solar and dark calibration
- Images coadded at each position + mirror move back < 30 minutes
- Diffusers for on-orbit solar calibration and onboard LED light source
- Redundant electronics for 10-year lifetime

✓ Preflight tests ongoing, to be delivered in September, 2017

Pre-thermal panel

Thermal panel and CMA Installation
GEMS Status

• Schedule
  - L1-2 Progress Evaluation & Review, June 2017; Grant renewed until 2020
  - PSR, August/September, 2017
  - Delivery September, 2017
  - AIT, 2017-2019
  - Launch, March 2019

• AIT schedules at KARI
  - Bus I&T: ~ November 2017
  - Payload I&T: Dec. 2017 – Feb. 2018
  - Antenna I&T: Mar – Apr. 2018
  - Thermal Vac test: May – Jul 2018
  - SA I&T: Jul – Aug 2018
  - Dynamic Test: Aug – Oct 2018
  - EMC Test: Nov 2018
  - Final Preparation: Dec 2018
  - Launch Campaign: Feb – Mar 2019
L0-L1b Processor

- Under development by BATC & KARI

- Dark correction
  - fitting by temperature changes added

- Smear correction:
  - ratio of frame transfer time to integration time, with previous frame effects considered

- Straylight correction:
  - matrix, Richardson-Lucy deconvolution,

- Spectral correction:
  - Reference solar spectrum convolved with GEMS bandpass functions, polynomial equation

- Onboard LED calibration:
  - for linearity, gain and PRNU(TBD)

- Polarization correction:
  - VLIDORT, Linear polarization sensitivity tests
Building to be completed by Dec. 2017

Receiving and processing system to be installed from Mar. 2018
<table>
<thead>
<tr>
<th>Product</th>
<th>Importance</th>
<th>Min (cm(^{-2}))</th>
<th>Max (cm(^{-2}))</th>
<th>Nominal (cm(^{-2}))</th>
<th>Accuracy</th>
<th>WIndow(nm)</th>
<th>Spat Resol (km(^{2}))@Sel</th>
<th>SZA (deg)</th>
<th>Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO(_2)</td>
<td>O3 precursor</td>
<td>3x10(^{13})</td>
<td>1x10(^{17})</td>
<td>1x10(^{14})</td>
<td>1x10(^{15}) cm(^{-2})</td>
<td>425-450</td>
<td>7 x 8 x 2 pixels</td>
<td>&lt; 70</td>
<td>BOAS DOAS</td>
</tr>
<tr>
<td>SO(_2)</td>
<td>Aerosol precursor</td>
<td>6x10(^{8})</td>
<td>1x10(^{17})</td>
<td>6x10(^{14})</td>
<td>1x10(^{16}) cm(^{-2})</td>
<td>310-330</td>
<td>7 x 8 x 4 pixels x 3 hours</td>
<td>&lt; 50 (60*)</td>
<td></td>
</tr>
<tr>
<td>HCHO</td>
<td>VOC proxy</td>
<td>1x10(^{15})</td>
<td>3x10(^{16})</td>
<td>3x10(^{15})</td>
<td>1x10(^{16}) cm(^{-2})</td>
<td>327-357</td>
<td>7 x 8 x 4 pixels</td>
<td>&lt; 50</td>
<td>OE TOMS</td>
</tr>
<tr>
<td>CHOCHO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TropLO3</td>
<td>Oxidant Pollutant</td>
<td>4x10(^{17})</td>
<td>2x10(^{18})</td>
<td>1x10(^{18})</td>
<td>3%(TOz) 5%(Stra) 20(Trop)</td>
<td>300-340</td>
<td>7 x 8</td>
<td>&lt; 70</td>
<td>Multi- (\lambda) O(_2)O(_2)</td>
</tr>
<tr>
<td>TropUO3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>O(_2)O(_2) RRS</td>
</tr>
<tr>
<td>StratO3 TotalO3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AOD AI SSA AEH</td>
<td>Air quality Climate</td>
<td>0 (AOD)</td>
<td>5 (AOD)</td>
<td>0.2 (AOD)</td>
<td>20% or 0.1@ 400nm</td>
<td>300-500</td>
<td>3.5 x 8</td>
<td>&lt; 70</td>
<td>Multi- (\lambda)</td>
</tr>
<tr>
<td>ECF CCP</td>
<td>Retrieval Climate</td>
<td>0 (COD)</td>
<td>50 (COD)</td>
<td>17 (COD)</td>
<td></td>
<td>300-500</td>
<td>7 x 8</td>
<td>&lt; 70</td>
<td></td>
</tr>
<tr>
<td>Surface Property</td>
<td>Environment</td>
<td>0</td>
<td>1</td>
<td>-</td>
<td></td>
<td>300-500</td>
<td>3.5 x 8</td>
<td>&lt; 70</td>
<td>Multi- (\lambda)</td>
</tr>
<tr>
<td>UVI</td>
<td>Public health</td>
<td>0</td>
<td>12</td>
<td>-</td>
<td></td>
<td>300-350</td>
<td>7 x 8</td>
<td>&lt; 70</td>
<td></td>
</tr>
</tbody>
</table>
Validation tests

- NRT operation tests using OMI l1b data
- Blind test using proxy data from RTM and CTM
Examples of retrieved products using OMI

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 pro
- M H. Ahn (EWU) - calibration
Ozone

- **O3 Profile**

  O3 Profile Retrievals

  ![Ozone Profile Retrievals](image)

  Validation with ozonesonde (2004-2008)

  ![Ozone Profile Retrievals](image)

- **Total O3**

  ![Total Column Ozone (2005m0921)](image)

  Validation with Brewer (2005-2006)

  ![Ozone Profile Retrievals](image)

  ![Ozone Profile Retrievals](image)

<table>
<thead>
<tr>
<th>O3 (Trop.)</th>
<th>Target</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>0.5-0.8</td>
<td>0.79</td>
</tr>
<tr>
<td>Slope</td>
<td>0.5-0.9</td>
<td>0.89</td>
</tr>
<tr>
<td>Intercept</td>
<td>0-15 DU</td>
<td>1.91 DU</td>
</tr>
<tr>
<td>RMSE</td>
<td>5-10 DU (10-20%)</td>
<td>6.48 DU</td>
</tr>
<tr>
<td>Error (%)</td>
<td>3-6 DU (10-20%)</td>
<td>2 DU (7.29%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>O3 (Total)</th>
<th>Target</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>0.82-0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>Slope</td>
<td>0.83-0.97</td>
<td>0.955</td>
</tr>
<tr>
<td>Intercept</td>
<td>35.5 DU</td>
<td>5.4 DU</td>
</tr>
<tr>
<td>RMSE</td>
<td>7 %</td>
<td>2.35 %</td>
</tr>
</tbody>
</table>

(Juseon Bak, Gang Hyun Paik, Jae H. Kim)
NO2

- Validation with OMI L1b
  NO2 SCD (OMI L2)
  NO2 SCD (GEMS algorithm)

March, 2015

R 0.8 0.98
Slope 0.5 1.2
Intercept 3.0 [10^{15} \text{ mole/cm}^2] 1.2 [10^{15} \text{ mole/cm}^2]

(Hyunkee Hong, Hanlim Lee)
SO2

**Anthropogenic**

\[ y = 0.40x + 0.06 \]

\[ R = 0.88 \]

**Volcanic**

\[ y = 1.17x + 2.35 \]

\[ R = 0.98 \]

(J.H. Jeong, Y.J. Kim)
HCHO

OMI

March

June

GEMS

R=0.84
Slope=1.03

R=0.84
Slope=1.15

(Hyeongahn Kwon, Rokjin Park)
AOD, SSA, and HGT

Retrieved AOD [443 nm]
Retrieved SSA [443 nm]
Fitted HGT [km]

OMI AOD [388 nm]
OMI SSA [388 nm]
HGT : Peak level height
CALIOP Lv2 : Top layer height
MODIS RGB : 2012/04/27

(Mijin Kim, Sujung Go)
Summary

• L0-1 and L1-2 algorithms are under the development to be ready for the launch of GEMS in March 2019.

• L1-2 algorithm for gases and aerosols show reasonable performances, but requires further improvement, hourly retrieval in AMF, S/T separation in particular.

• Careful consideration of aerosol is required to retrieve trace gas concentration from geostationary satellite remote sensing, especially for absorbing aerosols in particular.

• Preflight test results to characterize stray light, polarization, spectral accuracy, diffuser BTDF, dark current etc. can provide more accurate analysis on the GEMS performance and L2 algorithm.

• Synergy with AMI and GOCI-2 will provide more reliable products of aerosol and cloud, which eventually improve the accuracy of trace gas column density.
GEMS will be launched in 2019!

French launcher Ariane 5 lifts off Arabsat-5A and South Korea's COMS satellites in French Guiana one minute after the launch window opened at 6:41 p.m. Saturday local time (GMT 0941).
(Xinhua/AFP Photo)
THANK YOU