New Era of Air Quality Monitoring from Space
Geostationary Environment Monitoring Spectrometer (GEMS)

Level-2 Status – Presenting author: Heesung Chong (Yonsei Univ.)


GK-2B launch: 2020.02.19 (Korea Standard Time)
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GEMS E-W scan scenario

2048 N-S x 695 E-W x 8 times/day
= 11,386,880 spectra/day

Morning
Noon
Afternoon
Field of regard

[Kim et al. (BAMS 2020)]

Updated scan profiles

[Courtesy of NIER]
### GEMS baseline products

<table>
<thead>
<tr>
<th>No.</th>
<th>Product</th>
<th>Importance</th>
<th>Min</th>
<th>Max</th>
<th>Nominal</th>
<th>Accuracy</th>
<th>Wavelengths (nm)</th>
<th>Spat. Resol. (km²) @ Seoul</th>
<th>SZA (deg)</th>
<th>Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Trop. O₃</td>
<td>Oxidant</td>
<td>20 DU</td>
<td>50 DU</td>
<td>30 DU</td>
<td>20%</td>
<td>300-340</td>
<td>317.5, 331.2, 340, 380</td>
<td>7 x 8</td>
<td>&lt;70</td>
</tr>
<tr>
<td></td>
<td>Strat. O₃</td>
<td>Pollutant O₃ layer</td>
<td>180 DU</td>
<td>450 DU</td>
<td>270 DU</td>
<td>5%</td>
<td>3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total O₃</td>
<td></td>
<td>200 DU</td>
<td>500 DU</td>
<td>3000 DU</td>
<td>3%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>AOD</td>
<td>Air quality</td>
<td>0</td>
<td>3.6</td>
<td>0.54</td>
<td>20% or 0.1@ 400nm (for AOD)</td>
<td>354, 388, 412, 443, 477, 490</td>
<td>3.5 x 8</td>
<td>&lt;70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AI</td>
<td>Climate</td>
<td>-7</td>
<td>7</td>
<td>0.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SSA</td>
<td>Public health</td>
<td>0.82</td>
<td>0.99</td>
<td>0.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AEH</td>
<td></td>
<td>0 km</td>
<td>6 km</td>
<td>1.19 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>HCHO</td>
<td>VOC proxy</td>
<td>8x10⁴ cm⁻²</td>
<td>6.2x10¹⁶ cm⁻²</td>
<td>5x10¹⁵ cm⁻²</td>
<td>1x10¹⁶ cm⁻²</td>
<td>328.5–356.5</td>
<td>7 x 8 4 pixels</td>
<td>&lt;50</td>
<td>DF</td>
</tr>
<tr>
<td>1</td>
<td>CHOCHO</td>
<td></td>
<td>1x10¹⁴ cm⁻²</td>
<td>1x10¹⁵ cm⁻²</td>
<td>5x10¹⁴ cm⁻²</td>
<td>1x10¹⁵ cm⁻²</td>
<td>435–461</td>
<td>7 x 8 4 pixels</td>
<td>&lt;50</td>
<td>DF</td>
</tr>
<tr>
<td>2</td>
<td>Trop. NO₂</td>
<td>O₃ &amp; aerosol precursor</td>
<td>1x10¹³ cm⁻²</td>
<td>4x10¹⁷ cm⁻²</td>
<td>1x10¹⁴ cm⁻²</td>
<td>1x10¹⁵ cm⁻²</td>
<td>432–450</td>
<td>7 x 8 2 pixels</td>
<td>&lt;70</td>
<td>DOAS</td>
</tr>
<tr>
<td>2</td>
<td>Strat. NO₂</td>
<td></td>
<td>4x10¹³ cm⁻²</td>
<td>1x10¹⁴ cm⁻²</td>
<td>1x10¹⁵ cm⁻²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>SO₂</td>
<td>Aerosol precursor volcano</td>
<td>8x10¹⁵ cm⁻²</td>
<td>4x10¹⁷ cm⁻²</td>
<td>1x10¹⁴ cm⁻²</td>
<td>1x10¹⁶ cm⁻²</td>
<td>310–326</td>
<td>7 x 8 4 pixels</td>
<td>&lt;50</td>
<td>Hybrid (DOAS-PCA)</td>
</tr>
<tr>
<td>4</td>
<td>UVI</td>
<td>Public health</td>
<td>0</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>354</td>
<td>7 x 8</td>
<td>&lt;70</td>
<td>LUT</td>
</tr>
<tr>
<td>4</td>
<td>Vita. D UVI DNA UVI Plant UVI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Surface prop. (LER, BRDF)</td>
<td>Retrieval 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-λ, Min reflectivity</td>
</tr>
<tr>
<td>3</td>
<td>ECF</td>
<td>Retrieval Climate</td>
<td>0</td>
<td>1</td>
<td>-</td>
<td>5%</td>
<td>300–500</td>
<td>477</td>
<td>7 x 8</td>
<td>&lt;70</td>
</tr>
<tr>
<td></td>
<td>CCP</td>
<td></td>
<td>100 hPa</td>
<td>1013 hPa</td>
<td>-</td>
<td>5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CRF</td>
<td></td>
<td>0</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[Kim et al. (BAMS 2020)]
GEMS algorithm flow chart
GEMS baseline products

AOD at 443 nm
2020.05.12.
00:45 UTC

Total O$_3$
2020.08.06.
00:45 UTC

Tropospheric O$_3$
2020.08.06.
00:45 UTC

UV Index
2020.08.06.
00:45 UTC

NO$_2$ (total VCD)
2020.06.16.
00:45 UTC

SO$_2$ (total VCD)
2020.08.03.
00:45 UTC

HCHO (total VCD)
2020.08.03.
00:45 UTC

CHOCHO (total VCD)
2020.08.03.
00:45 UTC

Total O$_3$
2020.08.06.
00:45 UTC

UV Index
2020.08.06.
00:45 UTC

Tropospheric O$_3$
2020.08.06.
00:45 UTC

UV Index
2020.08.06.
00:45 UTC

Cloud centroid pressure
2020.09.06.
00:45 UTC

Effective cloud fraction
2020.09.06.
00:45 UTC

Surface albedo at 477 nm
2020.08.02.
00:45 UTC
Algorithm tests during IOT

<Adjusting spectral fit setting>

- The suitability of fitting windows was examined considering noise, bias, and capability of source detection.

- Changed fitting window: 308–324 nm → 310–324 nm
- The number of principal components (PCs) are adjusted.
- Modified clean sector selection method
Early results: $\text{O}_3$

**GEMS**

$\text{O}_3$ total VCD
2020/08/06 00:45 UTC

**TROPOMI**

$\text{O}_3$ total VCD
2020/08/06
Early results: Aerosols

GEMS AOD at 443 nm

AHI AOD at 550 nm

GEMS SSA at 443 nm

(AOD>0.4)

Consistent features
Retrieval over bright surface

Lim et al. (RS 2018, AMT 2021)
Early results: NO$_2$

GEMS SCD

NO$_2$ total SCD
2020/08/20 00:45 UTC

GEMS VCD

NO$_2$ total VCD (cloud fraction < 0.3)
2020/08/20 00:45 UTC

TROPOMI VCD

NO$_2$ total VCD (cloud fraction < 0.3)
2020/08/20
Early results: $\text{SO}_2$

**GEMS SO$_2$**

SO$_2$, total VCD
2020/07/29 01:45 UTC

**GEMS UV aerosol index**

UV aerosol index
2020/07/29 01:45 UTC

**TROPOMI SO$_2$**

SO$_2$, total VCD
2020/07/29

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Volcanic eruption at Nishinoshima Island, Japan
Early results: HCHO

GEMS HCHO

TROPOMI HCHO
Early results: UV index

GEMS UV index

TROPOMI UV index
GEMS validation results

Period: August–October 2020

**AOD**
- **GEMS domain**
  - Validation Results (GEMS Domain)
  - $R = 0.75$
- **East Asia domain**
  - Validation Results (East Asia Domain)
  - $R = 0.80$

**Trop. O$_3$**
- Validation Results
  - $R = 0.81$

**Total O$_3$**
- Validation Results
  - $R = 0.97$

**NO$_2$**
- Validation Results
  - $R = 0.81$

**SO$_2$**
- Validation Results
  - $R = 0.88$

**UVI**
- Validation Results
  - $R = 0.87$

**HCHO**
- Validation Results
  - $R = 0.87$

**Surface albedo**
- Validation Results
  - $R = 0.99$

**Cloud**
- Validation Results
  - $R = 0.90$
  - $R = 0.84$
## GEMS validation results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Goal correlation (R)</th>
<th>Achieved correlation (R)</th>
<th>Slope (a)</th>
<th>Intercept (b)</th>
<th>RMSE</th>
<th>Reference</th>
<th>Region</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₃ (Trop.)</td>
<td>0.5–0.8</td>
<td>0.81</td>
<td>0.71</td>
<td>-3.17 DU</td>
<td>15.21 DU</td>
<td>OMI</td>
<td>East Asia</td>
<td>2020.08–2020.10</td>
</tr>
<tr>
<td>O₃ (Total)</td>
<td>0.82–0.97</td>
<td>0.89</td>
<td>0.94</td>
<td>24 DU</td>
<td>1.83 DU</td>
<td>Pandora</td>
<td>Busan &amp; Ulsan</td>
<td>2020.08–2020.10</td>
</tr>
<tr>
<td>NO₂</td>
<td>0.80</td>
<td>0.81</td>
<td>1.69</td>
<td>-2.49×10¹⁵ molec. cm⁻²</td>
<td>1.87×10¹⁵ molec.cm⁻²</td>
<td>TROPOMI</td>
<td>GEMS domain</td>
<td>2020.08–2020.10</td>
</tr>
<tr>
<td>SO₂</td>
<td>0.70</td>
<td>0.88</td>
<td>1.05</td>
<td>-0.03 DU</td>
<td>1.14 DU</td>
<td>TROPOMI</td>
<td>GEMS domain</td>
<td>2020.08–2020.10</td>
</tr>
<tr>
<td>HCHO</td>
<td>0.81</td>
<td>0.87</td>
<td>0.90</td>
<td>-2.0×10¹⁵ molec. cm⁻²</td>
<td>3.08×10¹⁵ molec.cm⁻²</td>
<td>TROPOMI</td>
<td>East Asia</td>
<td>2020.08–2020.10</td>
</tr>
<tr>
<td>AOD</td>
<td>0.70</td>
<td>0.75</td>
<td>0.63</td>
<td>0.12</td>
<td>1.29</td>
<td>AERONET</td>
<td>GEMS domain</td>
<td>2020.08–2020.10</td>
</tr>
<tr>
<td>UVI</td>
<td>0.86–0.96</td>
<td>0.87</td>
<td>1.03</td>
<td>-0.30</td>
<td>0.25</td>
<td>TROPOMI</td>
<td>GEMS domain</td>
<td>2020.08–2020.10</td>
</tr>
<tr>
<td>ECF</td>
<td>0.90</td>
<td>0.90</td>
<td>0.86</td>
<td>0.03</td>
<td>0.15</td>
<td>TROPOMI</td>
<td>GEMS domain</td>
<td>2020.08–2020.10</td>
</tr>
<tr>
<td>CCP</td>
<td>0.80</td>
<td>0.84</td>
<td>0.68</td>
<td>282.24 hPa</td>
<td>152 hPa</td>
<td>TROPOMI</td>
<td>GEMS domain</td>
<td>2020.08–2020.10</td>
</tr>
<tr>
<td>SFC</td>
<td>0.70–0.91</td>
<td>0.99</td>
<td>0.97</td>
<td>0.0001</td>
<td>0.0036</td>
<td>MODIS</td>
<td>GEMS domain</td>
<td>2020.08–2020.10</td>
</tr>
</tbody>
</table>
GEMS validation network

[Kim et al. (BAMS 2020)]
GEMS images open to the public

NIER website: https://nesc.nier.go.kr/product/view

[Courtesy of NIER]
GEMS images open to the public

Hourly observations are presented in near real time (in a figure form but NOT in a data form).

AOD 443 nm

Figures are downloadable

[Courtesy of NIER]
GEMS images open to the public

28 Mar 2020

Examples of downloaded maps covering the GEMS field of regards (FOR)

<Source>
https://nesc.nier.go.kr/product/view

[Courtesy of NIER]
GEMS images open to the public

28 Mar 2020

Examples of downloaded maps covering regions around the Korean Peninsula

<Source>
https://nesc.nier.go.kr/product/view

[Courtesy of NIER]
Summary

- GEMS has been successfully operating after its launch in Feb 2020.
- Early retrieval results of trace gases and aerosols from GEMS are presented.
- GEMS retrievals are in good agreement with other satellite and ground-based observations.
- Images of some L2 products (AOD, total $O_3$, cloud, $NO_2$, and UVI) are now open to the public.
Thank you!