Continuous, high-spatial-resolution, and high-temporal-resolution measurements for emissions and chemical transformations interacting with weather and sunlight including the rapidly varying PBL and continental-scale transport of pollution.

**Geostationary Environmental Monitoring Satellite (GEMS)**

**Objectives**

1. To provide air chemical species measurements with high temporal resolution over Asia
2. To monitor regional transport events: transboundary transport of pollution and Asian dust
3. To enhance our understanding on interactions between air chemistry and meteorology
4. To improve forecasting air quality:
   - Constraining hourly emissions
   - Data assimilation of chemical observations
1. Monitoring atmospheric chemical environment

Monitoring NO$_2$, SO$_2$, O$_3$, HCHO, Aerosol in East Asia – Emission/Distribution

from Bhartia, Richter from OMI and SCIAMACHY
Both Anthropogenic and Natural Sources throughout the year

**Anthropogenic**
- Pollution
- Industry
- Transportation
- Developing Country

**Geogenic**
- Asian dust
- Land use change
- Monsoon
- Typhoon

**Biomass burning**
- Wild fires
- Drought

**Biogenic**
- Sink change
- Deforestation

Asia is an important source region for global tropospheric chemistry.
Asia is the largest source region of anthropogenic emissions

Large Asian population and its continuous growth
Many developing countries in Asia
Increase in the use of fossil fuels and in air pollution

(http://www.newint.org/features) (http://www.climateark.org)
Satellite OBS. of tropospheric NO$_2$ columns

- Strong NO$_2$ increases over China
- Reductions in Europe and parts of the US
- 7 years of GOME satellite data

A. Richter et al., Increase in tropospheric nitrogen dioxide over China observed from space, Nature, 437 2005
Large discrepancy between simulated and satellite observed HCHO over East Asia

State-of-the-art “bottom-up” Reactive VOC emission inventories

- Anthropogenic 40 Tg Streets et al. [2003]
- Biomass burning 12 Tg Streets et al. [2003]
- Biogenic 80 Tg Guenther et al. [2006]

GOME HCHO column June 1996~2001

Model HCHO column June 2001

[10^{16} molec cm^{-2}]
(Fu et al., 2007)
Asian biofuel uses account for over 50% of global biofuel uses. Biofuel is used mostly for household cooking and heating. Its emissions consequently are difficult to accurately assess.

Data from Yevich and Logan (2007)
2. Accurately monitoring transboundary transport of pollution in East Asia

Long-range transboundary transport of air pollutants in Northeast Asia (source-receptor regions)

Fig. 8. Total emission amounts of SO$_2$ and NOx for each source/receptor region.

[LTP project, 2007]
Monitoring transpacific transport of pollution from Asia to NW pacific

Transport of Mongolian dust to N. America in April 2001.

This image was made by compositing several days of TOMS data. [courtesy, Bhartia]

Terra detected strong sources of CO in Southeast Asia during April and May 2000.
3. Study interaction between air chemistry and meteorology over East Asia

Through environmental (chem.+met.) measurements with high temporal and spatial resolution, the following interactions/feedback can be investigated:

- Aerosol and cloud in short time scale
- Changes in temperature and biogenic VOC emissions (diurnal variation)
- Ozone and meteorological variables such as wind and temperature
- Convection and vertical transport of air pollution from the surface
4. Air Quality forecasting along with weather forecasting

(Chemical Transport Model)

| Table 1. The U.S. EPA Air Quality Index for Particulate Matter. |
| --- | --- | --- | --- |
| Index Values | Category | Cautonary Statements | PM$_{10}$ (µg m$^{-3}$) | PM$_{2.5}$ (µg m$^{-3}$) |
| 0 to 50 | Good | None | 0 to 15 | 0 to 10 |
| 51 to 100 | Moderate | Unusually sensitive people should consider reducing prolonged or heavy exertion | 15.5 to 40.4 | 55 to 154 |
| 101 to 150 | Unhealthy for sensitive groups | Sensitive groups should reduce prolonged or heavy exertion | 40.3 to 65.4 | 155 to 254 |
| 151 to 200 | Unhealthy | Sensitive groups should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion | 65.5 to 150.4 | 255 to 354 |
| 201 to 300 | Very unhealthy | Sensitive groups should avoid all physical activity outdoors; everyone else should avoid prolonged or heavy exertion | 150.5 to 250.4 | 355 to 424 |

Source: US EPA, 1997

Air Quality Index (AQI) Values:
- When the AQI is in this range:...
- ...air quality conditions are:...
- ...as symbolized by this color:
Using 3-D and 4-D VARs to constrain pollutant emissions with sufficient temporal resolutions

Geostationary Satellite + Various Observations
Numerical Models
A priori Knowledge on Atmospheric Flow + Chemistry

Data Assimilation

Most Complete and Accurate Description (Optimal States) of the Atmospheric Environment
OBSERVING SYSTEM FOR ATMOSPHERIC COMPOSITION MUST INTEGRATE SATELLITES, IN SITU MEASUREMENTS, AND MODELS

NEW KNOWLEDGE

- Air quality monitoring & forecasting
- Source quantification, policing of environmental agreements
- Long-range transport
- Biogeochemical cycling
- Climate forcing
- Weather forecasting
1. Reduced uncertainties in East Asian emissions with high spatio-temporal scale observations
2. Quantification of East Asian pollution contribution to global tropospheric chemistry
3. Enhanced understanding of interactions between air chemistry and meteorology
4. Evaluation/validation of chemistry models
5. Continuous monitoring of transboundary and transpacific transport of air pollutants
6. Improve air quality forecasting using data assimilation techniques (3-D/4-D VARs)
7. …
Global and Seasonal Aerosol Distributions from MISR

December-January-February

March-April-May

June-July-August

September-October-November

aerosol optical depth

(http://earthobservatory.nasa.gov)
• The first set of multi-model experiments focuses on the source-receptor relationships between individual continents for ozone and its precursors, PM, and others, and will be concluded by May 2007 and the interim report due in June 2007.

1) Base case simulation for year 2001 with ‘best’ emission inventory and fixed CH$_4$ concentrations globally at 1760 ppbv.

2) CH$_4$ global mixing ratio reduced to 1408 ppbv (−20%).

3) Delta emission experiments with each of NO$_x$, NMVOC and CO reduced by 20% for anthropogenic emissions over each of four source regions (Europe, North America, East Asia, and South Asia).

4) Combined 20% reduction of all anthropogenic emissions for NO$_x$/NMVOC/CO/SO$_2$/NH$_3$/POM/EC over each region (SR6 runs)

5) Passive CO tracer experiment with tagging by sources and regions.

• Currently over 35 institutions from Europe and North America participate including Harvard and with GMI.

• Detailed information is given at [http://aqm.jrc.it/HTAP/](http://aqm.jrc.it/HTAP/).