Background and aims

(1) The rapid growth in many Asian countries in recent years led to the significant increase of urban, regional, and trans-boundary air pollution.

(2) An understanding of long-term and future changes for Asian emissions is an area of increasing scientific interest and political concern.

(3) To understand the current status, recent trend, and future change of anthropogenic emissions in Asia,

(a) update of the REAS v.1 to the REAS 2.1.

(b) verification and improvement of the REAS 2.1
Limitation of REAS v.1
Ohara et al. (2007) ACP

- Latest year of historical emissions and the base year of projected emissions become older.
  → Energy consumption in Asia is growing continuously.
- Recent changes of EFs due to emission control were not taken into account.
  → Ex. FGD for coal-fired power plants.
- Request from recent simulation models:
  - Fine spatial resolution
  - Seasonal variation
  - Expansion of model domain and species

Outline of REAS 2.1

Spatial distribution: $SO_2$, $NO_x$, NMVOC, and $NH_3$

Spatial distribution: BC/OC and LLGHG ($N_2O$, $CH_4$)

Eastern China, Chongqing and Sichuan province, the Indo-Gangetic Plain, Southern India, and Indonesia:
→ These area have large population and significant economic and industrial activities
Temporal variation of annual emissions in Asia

- Asian NOx emissions were increased by 50%.
- China's NOx was more than doubled, but the increase rate becomes smaller recently.
- NOx in SE Asia and India also increased rapidly (65% and 40%, respectively) due to the increase of energy consumption in power plants and road transport.

- Asian SO2 emissions were increased by 35%.
- However, they were decreased after 2006.
- The contribution of power plants was decreased after 2004.
- India's SO2 were still increasing rapidly (50%).

Fuel/sector matrix of NOx emissions in Asia

- Each colored area is proportional to the NOx emissions by sector and fuel.
- The proportion of sectoral and fuel-typed emissions varies with region.

Fuel/sector matrix of NMVOC emissions in Asia

- Emission structure in each region is quite different.
- (East Asia) Combustion < non-comb.
- (Southeast Asia) Combustion >> non-comb.
Fractions and trends of monthly emissions in China

Monthly fractions are average of all values between 2000 and 2008.

Emissions from PPs and IND sectors are lower during summer and higher in winter based on the monthly generated power and production of industrial products obtained from statistics of India.

Seasonality of BC is similar to that in China (winter maximum and summer minimum).

But, the amplitude of seasonality is smaller than that in China due to smaller seasonality of temperature.

Comparison with other inventories

ReAS 2.1 is consistent with Chinese inventories. Global inventory, EDGAR 4.2, shows a different situation.
Comparison with other inventories (South and Southeast Asia)

There are large differences among inventories. Much efforts for evaluation and improvement of emission inventory for SE and S Asian regions are required.

Trends of NO2 VCD in CEC
– CMAQ (based on REAS 2.1) and satellite -

Irie et al. (2013) ACPD

Trop. NO2 VCD from satellite and CMAQ/REAS2.1 are consistent well though CMAQ is lower than satellite due to the course resolution of CMAQ. (Sensitivity analysis shows ~20% higher in fine resolution case)

Temporal variation of NO2 VCD
– CMAQ (based on REAS 2.1) and OMI -

Itahashi et al. (2013) ACPD

Top-down and bottom-up NOx emissions

Stavrakou et al. (2013) ACPD

Number: NOx emissions in China (10^{10}molec.cm^{-2} s^{-1})
Top-down and bottom-up NOx emissions

Ongoing works
(Harmonization and future projection)

MICS-Asia (Model Inter-Comparison Study - Asia) III

Best MIX anthropogenic emission inventory in Asia
- China, from MEIC (Multi-resolution Emission Inventory for China) database developed by Q. Zhang and K. B. He at Tsinghua University
- India (SO\textsubscript{2}, BC, and OC), from D. G. Streets at Argonne National Lab
- South Korea, from J.-H. Woo at Konkuk University
- Other Asia and India (other than SO\textsubscript{2}, BC, and OC), from REAS version 2.1
- New emission inventories of Thailand, Malaysia, and Vietnam are now under development by researchers in each country.

Outline of emission scenario

<table>
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<th>Baseline scenario</th>
<th>Air pollution control</th>
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<td>BAU</td>
<td>BC-1</td>
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<tr>
<td>CO2 half reduction</td>
<td>GC-1</td>
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- Base year: 2005
- Projected year: 2010-2050
- Activity data: AIM (Asia-Pacific Integrated Model; model for RCP6.0) output
- Air pollution control reinforcement scenario for 2030:
  (Developed countries) Reasonably Available Control Technologies/Measures
  (Developing countries) Control technol./Meas. level for 2005 in Japan
Future projection of emissions in Northeast Asia

- CO2 reduction is effective for reduction for SO2 and NOx, but is ineffective for BC and NMVOC.
- However, only CO2 reduction is insufficient for air pollution reduction. Reinforcement of air pollution control is needed.
- Air quality in NE Asia can be improved by the introduction of current emission control in Japan.

Summary

- We have updated the regional emission inventory in Asia (REAS v1) to the REAS 2.1 and verified it by top-down approach. The REAS 2.1 covers the anthropogenic emission sources in Asia during 2000-2008.
- Asian emissions for all species (except SO2) show increasing trend during 2000 and 2008.
- The contributions from China are the largest in Asian emissions. However, the growth of China’s emissions are slowing down due to a series of reinforcement of emission control.
- Relative importance of emissions from Southeast, India, Russian and Central Asia is increasing.
- Information for developing accurate emission inventory is not enough, especially in Southeast and South Asia.
  → Continuous surveys of activity data and parameters
  → Verification using model simulation and monitoring data

Data download site of REAS 2.1

http://web.nies.go.jp/REAS/

(Ref.) Kurokawa et al., ACPD, 2013

Monthly gridded emission data sets at 0.25 degree by 0.25 degree resolution for each major sector for all species

Country and regional emission tables that present annual emissions for detailed sub-sectors and fuel types

Please use REAS and give us critical feedbacks!