Suggestions on TAP

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National Institute of Environmental Research, Korea

TAP, 9~ 10 July, Russia
1. Background
2. Suggestions
3. Discussion
1. Background and Objectives
### No Comprehensive mechanism in NE Asia

<table>
<thead>
<tr>
<th>Targets</th>
<th>NE Asia</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Acid deposition, Eeutrophication</td>
<td>○(EANET, LTP)</td>
<td>EMEP</td>
</tr>
<tr>
<td>2. Photochemical Oxidnats</td>
<td>○(LTP, TEMM Project)</td>
<td>EMEP</td>
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<td>3. Heavy metals</td>
<td>○(LTP)</td>
<td>EMEP</td>
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<td>4. POPs</td>
<td>△(East Asia POPs Monitoring)</td>
<td>EMEP</td>
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<td>5. PM</td>
<td>○(LTP)</td>
<td>EMEP</td>
</tr>
<tr>
<td>6. Integrated Modeling</td>
<td>×</td>
<td>EMEP</td>
</tr>
<tr>
<td>7. Emission Inventory</td>
<td>△(LTP, MICS-ASIA)</td>
<td>EMEP</td>
</tr>
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<td>8. Emission Process Model</td>
<td>○(LTP)</td>
<td>EMEP</td>
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<tr>
<td>9. Openness</td>
<td>×</td>
<td>EMEP</td>
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<tr>
<td>10. Collaboration with HF-TAP</td>
<td>×</td>
<td>EMEP (HTAP)</td>
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</tbody>
</table>
LTP Background

- LTP was started in year 2000 as a government-based air pollution research framework among China, Japan, and Korea.

- LTP’s activities have been mostly focusing on understanding transboundary air pollution and S-R relationship among three countries, using modeling and monitoring techniques.

- Now LTP members are planning the 4th year of the 3rd Stage (2012).
Similarities and uniqueness of LTP Framework to other activities

• Similarity
  - Air Quality Monitoring for Asia (to EANET)
  - Air Quality S-R Modeling for Asia (to MICS-Asia)
  - Target pollutants – Sulfur, Nitrogen, and others (EANET and MICS-Asia)
  - RAINS-Asia, GAINS-Asia, ABC, Global-Chem Modeling, and others...

• Uniqueness
  - Government-initiated scientific research collaboration framework in support of regional air quality issues
  - Both modeling and monitoring
  - Both pure science and policy supporting science
  - Strictly focus on East Asia (three countries)
  - Long lasting geo-scientific collaboration in East Asia
Model weakness (Model domain and locations of measurement)

- six SO₂ monitoring sites, and aircraft pathways
# LTP Modeling framework

<table>
<thead>
<tr>
<th>China</th>
<th>Japan</th>
<th>Korea</th>
</tr>
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<tbody>
<tr>
<td><strong>Model system</strong></td>
<td><strong>Model system</strong></td>
<td><strong>Model system</strong></td>
</tr>
<tr>
<td>Models-3 / CMAQ, (\sigma) coordinate</td>
<td>RAQM (Regional Air quality Model)</td>
<td>CADM (Comprehensive Acid Deposition Model)</td>
</tr>
<tr>
<td>14 layers, 70×66 grids, 60km resolution</td>
<td>terrain following coordinate</td>
<td>terrain following coordinates</td>
</tr>
<tr>
<td>(Byun and Ching, 1999)</td>
<td>12 layers, 110×80 grids, 60km resolution</td>
<td>12 layers, 110×80 grids, 60km resolution</td>
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<tr>
<td></td>
<td>(An et al., 2002)</td>
<td>(Lee et al., 1998)</td>
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<tr>
<td><strong>Domain</strong></td>
<td><strong>Domain</strong></td>
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<tr>
<td>20～50N, 100～150E</td>
<td>20～50N, 100～150E</td>
<td>20～50N, 100～150E</td>
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<tr>
<td><strong>Meteorological Model</strong></td>
<td><strong>Meteorological Model</strong></td>
<td><strong>Meteorological Model</strong></td>
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<tr>
<td>MM5</td>
<td>MM5</td>
<td>CSU-RAMS</td>
</tr>
<tr>
<td>34 layers with FDDA using NCEP reanalysis</td>
<td>125×95 (45km), 23 layers, FDDA using NCEP FNL reanalysis</td>
<td>110×80, 29 vertical layer FDDA using NCEP FNL reanalysis</td>
</tr>
<tr>
<td><strong>Chemical Mechanism</strong></td>
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<td><strong>Chemical Mechanism</strong></td>
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<td>RADM Chemistry</td>
<td>CBM-IV mechanism</td>
<td>RADM Chemistry</td>
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<tr>
<td><strong>Cloud Model Physical option</strong></td>
<td><strong>Cloud Model Physical option</strong></td>
<td><strong>Cloud Model Physical option</strong></td>
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<tr>
<td>Diagnostic cloud model in RADM</td>
<td>Cloud model in MM5</td>
<td>Cloud model in CSU-RAMS</td>
</tr>
<tr>
<td>Simple explicit moisture scheme</td>
<td>Betts-Miller cumulus scheme, MRF RRTM</td>
<td>Anthes-Kuo cumulus scheme, MRF</td>
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<tr>
<td>Grell cumulus schemes, MRF</td>
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<tr>
<td><strong>Emission</strong></td>
<td><strong>Emission</strong></td>
<td><strong>Emission</strong></td>
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<tr>
<td>(\text{SO}_2, \text{NOx, VOC, NH}<em>3, \text{CO, PM}</em>{10}) biogenic VOC provided by LTP for the base year of 1998 (1°×1° resolution)</td>
<td>Same as China</td>
<td>Same as China</td>
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<tr>
<td><strong>Dry deposition</strong></td>
<td><strong>Dry deposition</strong></td>
<td><strong>Dry deposition</strong></td>
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<tr>
<td><strong>Wet deposition</strong></td>
<td><strong>Wet deposition</strong></td>
<td><strong>Wet deposition</strong></td>
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<td><strong>Land use type</strong></td>
<td><strong>Land use type</strong></td>
<td><strong>Land use type</strong></td>
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<td>EPA/NOAA global ecosystem (11 categories)</td>
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<tr>
<td></td>
<td>Obs</td>
<td>China</td>
</tr>
<tr>
<td>------------------------</td>
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<td>-----------</td>
</tr>
<tr>
<td>Sample size</td>
<td>57</td>
<td>57</td>
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<tr>
<td>Range(ppb)</td>
<td>0.0042-35.43</td>
<td>0.0-11.387</td>
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<tr>
<td>Mean(ppb)</td>
<td>4.59</td>
<td>2.35</td>
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<tr>
<td>Standard deviation (ppb)</td>
<td>7.13</td>
<td>2.66</td>
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<tr>
<td>Mean of ratio model/obs (S/O)</td>
<td>0.91</td>
<td>1.99</td>
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<tr>
<td>Standard deviation of ratio model/obs (S/O)</td>
<td>1.37</td>
<td>6.81</td>
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<tr>
<td>Absolute gross error</td>
<td>3.11</td>
<td>3.61</td>
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<tr>
<td>Correlation coefficient</td>
<td>0.54</td>
<td>0.19</td>
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<tr>
<td>Mean difference</td>
<td>2.24</td>
<td>1.68</td>
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<tr>
<td>Difference standard deviation</td>
<td>6.13</td>
<td>7.24</td>
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<tr>
<td>Root-mean square error</td>
<td>6.48</td>
<td>7.37</td>
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<td>Mean square error. MSEN</td>
<td>5.06</td>
<td>10.21</td>
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<td>Mean square error. MSES</td>
<td>37.54</td>
<td>45.05</td>
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<tr>
<td>Index of agreement</td>
<td>0.53</td>
<td>0.37</td>
</tr>
<tr>
<td>Mean fractional error</td>
<td>0.59</td>
<td>0.22</td>
</tr>
</tbody>
</table>
Model performance comparison

Dalian

Xiamen

Ganghwa

Gosan

Oki

Rishiri
Model performance comparison

Aircraft Height

SO2 (ppb)

MODEL

Altitude (m)

Concentration (ppb)

CHINA
JAPAN
KOREA

0307 0308 0309 0311
Spatial distribution of the simulated [SO2] from (a) China, (b) Japan, and (c) Korea on 5-13 March.

Simulated surface SO₂ concentrations from (a) China, (b) Japan, and (c) Korea on 5-13 March.
Conversion ratio of SO2 to sulfate

Time variations of longitudinal cross-section of simulated conversion ratio of sulfur ($F_s = \frac{SO_4^{2-}}{(SO_2 + SO_4^{2-})}$) from (a) China, (b) Japan, and (c) Korea on 5-13, March.
Spatial distribution of the simulated [SO2 ]

Seasonally averaged surface SO$_2$ and SO$_4^{2-}$ concentrations simulated by (a) China, (b) Japan, and (c) Korea for the year of 2002.
Model validation by observations

Comparison between monthly variation of simulated versus observed SO$_2$ concentrations at 6 LTP sites in 2002
New Challenges

- The LTP research framework has been working out, but the data and methodology for research are outdated from scientific viewpoint and research components are not complete in policy supporting viewpoint

- Climate change
  - Climate influence on air quality
  - Future scenario
  - Co-benefits

- Local and regional air pollution
  - Inter- vs. intra-national S-R
  - Megacity impacts

- Category Integration
  - CAPs + GHGs + HAPs
  - Impact study

- Understand pollution events
  - Dust storm, wildfire, storms, heat
  - Air quality forecasting
Trend

Night light during last 10 years

1992년  
2002년  
2010년  

Rapid economic growth ➔ Transboundary Air Pollution Problem ➔ Collaboration among stakeholders
Population and Urbanization

Target year?

ROK

DPRK

China

Japan

Urbanization
Time and Emissions

Source: NIER, 2011
New Objectives

- Two major and one supplemental objectives

  : Understand **air quality issues** in East Asia in consideration of **new challenges**, such as **secondary pollutants**, HAPs, **climate change**, and etc. Decide what we want to pursue and what we won’t (**State-of-art science**)

  : Use our understanding to prioritize our actions to **mitigate** adverse AQ effects for another decade. Health/environmental **impact** and **mitigation policy** study need to be initiated (**Policy supporting science**)

  : How can we **improve our collaborative research framework** to accomplish these objectives effectively?
2. Suggested Topics

- Air Quality Forecast for Northeast Asia
- Implementation of Advanced S-R Methodologies
- Assessment of O₃ and PM
- Scenario-based Collaboration Simulation Approach
2.1 Chemical Air Quality Forecast for Northeast Asia
Air Quality Forecast - Existing Efforts (examples)

- **Modeling Frameworks**
  - Meteorological Models: MM5, RAMS, WRF
  - Chemical Models: CMAQ, CFORS, CAMx
  - Domain, Grid, and Emissions

- **China**
  - Horizontal Grid Spacing:
    - Asia: 36km, China and Korea: 12km, Beijing Metropolitan Area: 4km
  - Vertical Layer: 14 layers
  - Emissions: Trace-P 2000 + Statistical Books

- **Japan**
  - Horizontal Grid Spacing:
    - Asia: 80km, 15 km (in preparation)
  - Vertical Layer: 23 layers to 20km
  - Emissions: Trace-P 2000 + dust, sea salt, lightening, volcano, radon, Biomass burning

- **Korea**
  - Horizontal Grid Spacing:
    - East Asia: 27km, Korea: 9km, SMA: 3 km
  - Vertical Layer: 11 layers to 14.7km
  - Emissions: INTEX-B 2006+ CAPSS 2007+ fugitive dust, biogenic, biomass burning
Air Quality Forecast – a Framework (Draft)

- Three countries generate the common meteorological/emissions data for the simulation
- Each country uses its own chemical model(s)
- Cooperation with other fields (ground and airborne monitoring, satellite data retrieval, LIDAR networks)

- Integrated performance testing during Intensive Monitoring Period (e.g., forecast for 72 hours for the entire month of IMP)
  - National Air Quality Index (API)
  - Concentration of air pollutants: O₃, PM₁₀, PM₂.₅, SO₂, NO₂, sulfate, nitrate, ammonia, mercury, etc.

Need common/integrated modeling/monitoring framework and may need a modeling center.
Air Quality Forecast – Necessary collaborations

For performance enhancement

- Input data update (Emission Inventory, Land Use, Terrain)
- More detailed emission Inventory (Fugitive dust, Sand storm, Forest fire, Biomass burning, Volcano, Biogenic emission)
- Emission inventory for North Korea
- Background, Boundary Conditions

For implementation - Arrangements

- Each country secures its’ financial support from Government and/or International Organizations.
- Each country reports to the Environmental Minister and endeavors to bring this matter to the Tripartite Environment Ministers Meeting Among China, Japan, and Korea (TEMM)
2.2 Implementation of Advanced S-R Methodologies
Why Do We Need Advanced S-R Methodologies?

- To conduct more sophisticated S-R research
  - Simultaneous analysis for regions-sectors, ICs, BCs
  - Finer S-R (e.g. megacity impact study)
  - Control measure testing …

- To understand various sensitivities
  - Precursor to product sensitivity
  - Region to region sensitivities …

- Benefits
  - Save time, effort, and space (faster and simpler)
  - Avoid non-linearity

What’s available?

- Source tagging (REMSAD, CAMx-PSAT, CMAQ-PPTM)
- Forward Sensitivity (CMAQ-DDM)
- and more…
Source Tagging (CMAQ-PPTM)

- PPTM: Particle and Precursor Tagging Methodology
- Assessment of the source contribution by source tagging method
- Emissions from selected sources, source categories, or source regions are (numerically) tagged and then tracked throughout a simulation
Forward Sensitivity (CMAQ-DDM)

- Calculates sensitivity of concentrations to input parameters along with the concentrations themselves.
- Can provide sensitivity to:
  - species
  - regions or individual sources
  - other model parameters (e.g. reaction rates)

Simulation:

\[ \Delta \text{I.C. Emissions} \rightarrow \Delta \text{B.C. Emissions} \rightarrow \Delta \text{CMAQ} \]
Source Tagging (REMSAD-tagging)

Woo et al. (2006)

Assessment of megacity impacts
2.3 Assessment of \( \text{O}_3 \) and PM for the future LTP Project
Key Findings of O3 Impacts (from TF-HTAP 2010)
(TF-HTAP : Task Force on Hemispheric Transport of Air Pollution)

**O3 Impacts on Health Impacts**
- One study based on the HTAP multi-model comparison estimated that O3 resulting from emissions from foreign regions contributes 20% to >50% of O3 mortalities, subject to large uncertainty.
- Three studies estimate that reductions in O3 precursor emissions may avoid more premature mortalities outside of some source regions than within, mainly because of larger populations outside of the source regions.

**O3 Impacts on Climate Change**
- O3 contributes significantly to climate forcing,
  - Directly as a greenhouse gas that causes warming
  - And indirectly by damaging plants inhibiting their natural uptake of CO2.
- Among ozone precursors, widespread reductions in emissions of CH4, CO, and VOCs better reduce net climate forcing than reducing NOX, which may increase forcing over decadal time scales.
Key Findings of PM Impacts (from HTAP 2010)

PM Impacts on Health

- Contributions to PM from emissions within a region are much more important for health than emissions from foreign continents.
- Intercontinental transport of PM can cause more mortalities than intercontinental transport of O3, due to the stronger PM-mortality relationship.
- Emissions from North America and Europe have much greater impacts on foreign regions than do emissions from East Asia and South Asia.

<table>
<thead>
<tr>
<th>Source Region</th>
<th>NA</th>
<th>EA</th>
<th>SA</th>
<th>EU</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>502</td>
<td>20</td>
<td>9</td>
<td>49</td>
<td>590</td>
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<td>125</td>
<td>19</td>
<td>8</td>
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<tr>
<td>EA</td>
<td>10</td>
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<td>1</td>
<td>39</td>
<td>1099</td>
<td>3</td>
<td>1142</td>
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<tr>
<td>EU</td>
<td>8</td>
<td>82</td>
<td>70</td>
<td>1769</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>78</td>
<td>57</td>
<td>573</td>
<td>71600</td>
</tr>
</tbody>
</table>

Impact on foreign receptor regions:
- NA: 14.9%
- EA: 1.9%
- SA: 2.9%
- EU: 12.0%
Key Findings of PM Impacts (from HTAP 2010)

PM Impacts on Climate Change

- Change of global annual average TOA all-sky aerosol direct RF in response to the 20% reduction of anthropogenic emissions
- BC activity under EMEP/CLRTAP: Focus country specific contribution to direct radiative forcing by BC aerosols

<table>
<thead>
<tr>
<th>Source Region</th>
<th>Sulfate  ±5.6</th>
<th>POM  ±1.0</th>
<th>BC  ±1.9</th>
<th>Sulfate+POM+BC  ±5.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>16.1</td>
<td>1.6</td>
<td>-4.5</td>
<td>13.2 ±5.2</td>
</tr>
<tr>
<td>EU</td>
<td>26.7 ±9.5</td>
<td>1.9 ±1.2</td>
<td>-7.4 ±2.3</td>
<td>21.2 ±9.5</td>
</tr>
<tr>
<td>EA</td>
<td>19.6 ±7.2</td>
<td>3.2 ±1.8</td>
<td>-14.5 ±8.0</td>
<td>8.4 ±10.2</td>
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<tr>
<td>SA</td>
<td>6.1 ±1.9</td>
<td>2.5 ±1.3</td>
<td>-5.5 ±2.4</td>
<td>3.1 ±3.2</td>
</tr>
<tr>
<td>NA+EU+EA+SA</td>
<td>68.4 ±22.9</td>
<td>9.1 ±5.0</td>
<td>-31.9 ±13.7</td>
<td>45.9 ±24.6</td>
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</tbody>
</table>
2.4 Scenario-based Collaboration Simulation Approach
Roadblocks for international environmental cooperation

- **Among countries**
  - Lack of trust, data sharing
  - Different (political and economic) interests
  - Lack of legitimacy of independent modeling

- **Among decisionmakers and scientists**
  - Lack of understanding
  - Different assumption, languages and interests

**Conditions for effective collaboration**

- **Existence of on-going (effective and flexible) communication channels**
  for domestic and international decisionmakers, key stakeholders, and scientists

- **Joint Fact-finding mechanism**
  - Shared assumptions in modelling
  - Shared data and research methods

- **Shared roadmap** from the beginning
Alternative approach to conventional ways

- **Conventional channels**
  - Government-initiated (established) meetings
  - Scientists-oriented meetings

- **Alternative channels**
  - Workshop environment where decisionmakers, key stakeholders, and scientists get together
  - More flexible and creative environment
  - For learning about the relationships between science and policies and politics

**Scenario-based simulation method**

- Construction of potential scenarios regarding transboundary air pollution (and/or) climate change with scenario development team among three countries (China, Japan, and Korea)

- Integration of Scenario with Modeling

- Utilization of scenario-based modeling with collaboration simulation exercise
Potential benefits of alternative approach

- Lower the tension among participants
- Promote comprehensive understanding about complex relationships on the issue
- Focus on future rather than the past
- Facilitate understanding of non-scientists on the model and its outcome
- Improve model design with inputs from other stakeholders and decisionmakers
- Maintain the communication among various actors
- Bridge the flexible communications with formal ones

Pre-requisite

- Acknowledgement of the potential benefits by key decision makers in three countries
- Identification of neutral convener or facilitators, experts on scenario-based planning in each country
- Knowledge on scientific, economic, political, policy factors
“Building an integrated and comprehensive regional air quality research collaboration framework that can produce state-of-art science results (papers) and useful policy supporting information, under the consensus of members from all three member countries”
Thank you for Attention!