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on the Acid Deposition Monitoring Network in East Asia
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Model Inter-Comparison Study in Asia, Phase III (MICS-Asia III)
Progress and on-going work

Network Center for EANET

I. Background

Progress of MICS-Asia Phase I to Phase III

In order to obtain common understanding of model performance and uncertainties in Asia, MICS-Asia Phase I (1998-2000) and Phase II (2004-2009) were carried out as international initiatives of model intercomparison study on long-range transport and deposition initially of sulfur in Phase I and then including nitrogen compounds, ozone and aerosols in Phase II. The findings of the Phase II activities were published in Atmospheric Environment in 2008, and the 10th MICS-Asia Workshop in February 2008 at IIASA started to discuss the prospect of Phase III.

The initiative was succeeded to the First International Workshop on Atmospheric Modeling in East Asia organized by ACAP and IAP in Dalian in March 2010, which aimed to give an opportunity for more Asian scientists to participate in future international collaboration in atmospheric modeling and related atmospheric chemistry studies. At the Second Workshop on Atmospheric Modeling in East Asia in Sanya in December 2010, three topics of MICS-Asia Phase III were accepted and the leader of each topic was identified as follows.

Topic 1: Model Intercomparison (Leader: Zifa Wang, Institute of Atmospheric Physics, China)
Topic 2: Development of reliable emission inventories in Asia (Leader: Jung-Hun Woo, Konkuk University, Republic of Korea)
Topic 3: Air Quality/Climate Change (Leader: Gregory Carmichael, University of Iowa, USA)

At the Third Workshop on Atmospheric Modeling in East Asia in Chengdu in September 2011, all the participants had group discussion to materialize more concrete work plan for each of the three topics. Based on the discussion, the Leaders prepared the draft work plans for MICS-Asia Phase III, and it was further discussed at the International Workshop on MICS-Asia III in Beijing in July 2012 to finalize the Work Plans.

MICS-Asia Phase III is a part of EANET additional research activity as same as Phase II. Phase III activities will be financially and technically supported by IAP and ACAP through Joint International Center on Air Quality Modeling Studies (JICAM) between them.

Prospectus of Phase III

Model intercomparison of Topic 1 is the continuing activity of MICS-Asia series. Based on the experience of Phase I and II, model intercomparison activities in Phase III have been proposed to be carried out using common meteorological fields, emission data, boundary conditions, etc. in order to

allow the discussion of the cause of disagreement among participating models rather than just showing the variability of model output and uncertainties.

As for the preparation of common emission data to be used in Topic 1, development of reliable emission inventories in Asia for 2008-2010 has been planned as Topic 2. In this activity, as compared to existing and widely used global and regional emission inventory database in Asia, more reliable country-specific data has been incorporated particularly for China, Japan and Korea. The database can be used not only in MICS-Asia Phase III activity, but in other atmospheric modeling studies in Asia.

Intercomparison of model performance for air quality and climate change has been adopted as Topic 3 for the first time in MICS-Asia in Phase III. Concerns on air quality and climate interaction have recently been evolved not only in scientific interest but also in mitigation policy defining radiatively active air pollutants as short lived climate forcer or pollutant (SLCF or SLCP). Topic 3 will discuss on this theme giving more focus in Asia.

Objectives of Three Research Topics

- (Topic 1) To evaluate strengths and weaknesses of current multi-scale air quality models and provide techniques to reduce uncertainty in Asia
- (Topic 2) To develop a reliable anthropogenic emission inventories in Asia and understand uncertainty of bottom-up emission inventories in Asia
- (Topic 3) To provide multi-model estimates of radiative forcing and sensitivity analysis of short-lived climate pollutants

II. Topic 1: Model Intercomparison (Leading Scientists: Zifa Wang, Kazuyo Yamaji and Joshua Fu)

II-1. Objective

Aims to evaluate strengths and weaknesses of current air quality models for air quality prediction, and provide techniques to reduce uncertainty and improve performance in Asia. We will seek to answer the following key questions, including:

- ❖ Assessing the ability of models to reproduce pollutants concentrations under highly polluted conditions (e.g. Regional Haze);
- ❖ Quantifying uncertainties of each process (emissions, chemical mechanisms, transportations and depositions) and model resolutions (horizontal and vertical) on air quality modeling. In particular, uncertainties in key boundary layer parameters, which have both direct and indirect impacts on modeling results through transporting meteorological fields and providing parameters in physical-chemical modules, respectively, need to be addressed;
- ❖ Investigating the air quality responses to specific emissions perturbations in a common case.

II-2. Activities

1) Candidate model selections and model setting

- ❖ Candidate models:

Global models: CHASER (Dr. Kengo Sudo), GEOS-Chem (Dr. Rokjin Park), CUCTUS (Dr.

Hong Liao), GEATM (Dr. Zifa Wang), GEM-MACH (Dr. Sunling Gong), CAM-chem (Dr. Louisa Emmons), MOZART, etc.

Regional models: CMAQ (Dr. Kazuyo Yamaji 4.7.1, Dr. Joshua S. Fu 5.0.1, Drs. Narisara Thongboonchoo and Ngo Tho Hung [Southeast Asia domain nested 2]), CAMx (Dr. Zifa Wang), NAQPMS (Dr. Zifa Wang), TAQM (Drs. Lin and Genhui), WRF-Chem (Drs. Gregory Carmichael, Chuan-Yao Lin, and Yafang Cheng), RAMS-CMAQ (Dr. Meigen Zhang), GEOS-chem nested, LOTUS-TNO, RAQM2, etc.

❖ Common domain:

Global - Asia - Megacities

First domain (D1:45 km mesh):

Asia, including East, Southeast, South, and Central Asia

Second domain (D2: 15 km mesh):

- Northeast Asia covering Northeast and Southeast China, Korea, and Japan.
- Southeast Asia

Third domain (D3: 5 km mesh)

Megacities

Case study (Mandatory)

Target area: Beijing and surroundings.

Case study (Optional)

Selected cities within D2 (Tokyo, Seoul, PRD, etc.) may be analyzed by each modeler's interest

Vertical resolutions: 40 layers 20-2000m (?)

❖ Simulation period:

First domain (D1)

Through year simulation 2008-2010: simulated by some models

2010 is the initial choice followed by 2008 and 2009 calculation for seasonal variation and inter-annual variability of wet deposition

(S/N ratio, nitrogenious species deposition, etc.) and atmospheric concentrations (O_3, $PM_{2.5}$, BC, etc.)

Severe pollution case in January 2013: all models considering influences of emission variation (e.g. heating period) and meteorological condition.

Second domain (D2)

Periods required for D3 simulation

Third domain (D3)

Case study (Mandatory):

Four episodes in 2010 (high O_3, $PM_{2.5}$, BC, and dust) in Beijing

About 10 days simulation for each episode.

Severe pollution case in January 2013

Case study (Optional):

Should be decided by modeler's interest

2) To prepare inputs for all the participated models

- Gridded emissions

All models should use the same emission fields as following:

Anthropogenic emissions datasets:

Asian emissions from Topic 2 group (MIX inventory)

Global emissions from newest HTAP datasets which include MIX inventory

Natural emissions datasets:

Standard-static emissions database (0.5deg, 2010, D1 only) and emissions modeling inputs (framework) will be provided by Topic 2 group

- Biogenic emissions: MEGAN/Monthly (or maximum temporal resolution)
- Biomass burning emissions: GFED v3.1/Monthly (or maximum temporal resolution)
- Dust emissions: Dust model/Monthly (or maximum temporal resolution)
- Sea salt emissions: SMOKE/Monthly (or maximum temporal resolution)

Volcano emissions (Points, Monthly) will be provided by Topic 2 group.

Other natural emissions such as dust, sea-salt, soil and lightning NO_x should be prepared within each model and their emission numbers should be reported to Topic 2 group.

- Meteorological fields

Participants should use the same meteorological model (WRF) which will be prepared by IAP to drive their air quality models. The participants who have to use other meteorological fields are requested to compare them with the reference meteorological fields.

- Boundary conditions

Information on global model output for boundary conditions of D1 during 2008 and 2010 will be provided by CHASER, GEOS-chem, and other global models using the newest HTAP emission inventory.

- Observational data

Beijing Olympic Games monitoring data in 2008;

Rudong Campaign monitoring data in 2010;

Lidar monitoring data in IAP and other sites;

Pollution concentration observed data in Beijing and surrounding area (24 sites) in 2010 (By Prof. Yuesi Wang);

EANET data for 2008-2010; CMA, etc.

Severe pollution case in January 2013 in Beijing and surrounding area?

3) To perform base year model simulation by all the participants and compare models to the best available observational data

- Monthly mean 3-D concentrations of pollutants and radicals, and meteorology in base year simulations by all participating models with the same emission inventory and meteorological fields.
- Hourly mean 3-D concentrations of pollutants and radicals, and meteorology in pollution

case simulations

- ❖ Comparing concentrations and meteorological parameters modeling results between all participating models with available observations.
- ❖ Evaluating abilities of each participating models in Asia air quality modeling.

4) To perform model simulation for air quality responses in various areas to specific emission perturbations by all the participants: Source-receptor relationship and future projection

- ❖ Comparison of source-receptor relationships based on model calculation with specified emission reduction
  - Emission perturbation: 20% reduction of all anthropogenic emissions
  - Source area: Northeast and southeast China (divided by 32N), Korea, Japan, other area within D1.
  - Four seasons: January, April, July, and October in 2010
- ❖ Comparison of future projection based on a common future emission scenario
- ❖ Comparison of chemical mechanism, transportation and deposition.
- ❖ Comparison of boundary layer process, horizontal and vertical model resolutions.
- ❖ Evaluating the impact of uncertainties of the key process on model results by sensitivity analysis.

II-3. Deliverables

Under a common case submitted data includes:

- ❖ Hourly mean 3-D concentrations of SO_2, NO_x, O_3, NO_y (or HNO_3), $PM_{2.5}$, PM_{10} (Compositions? If could be provided) and aerosol extinction (Time, lev, lat, lon);
- ❖ Hourly mean vertical profile of aerosols at Lidar observation sites (NIES lidar network? If could be provided). (It is key to lifetime of pollutants);
- ❖ Hourly mean budget analysis (transport, chemical production and loss, dry and wet depositions) at observation sites;
- ❖ Hourly mean PBL height and vertical exchange coefficients at observation sites.

Under monthly simulations, submitted data includes:

- ❖ Monthly mean 3-D concentrations of SO_2, NO_2, O_3, $PM_{2.5}$, and PM_{10}.
- ❖ Monthly mean 3-D concentrations of radicals (OH, HO_2,)
- ❖ Monthly mean chemical production and loss of pollutants, dry and wet depositions (dry deposition rates).

Details of deliverables should be further discussed and summarized by leaders of Topic 1.

III. Topic 2: Development of reliable emission inventories in Asia (Leading Scientists: Jung-Hun Woo, Toshimasa Ohara, and Qiang Zhang)

III-1. Objective

To evaluate strengths and weaknesses of current emission inventory and provide techniques to reduce uncertainty and improve performance in Asia.

III-2. Activities

1) To develop anthropogenic emission datasets for emissions inter-comparison study

❖ Mosaic national emission inventories

- China (Q. Zhang and K. He): MEIC inventory
- Beijing (Z. Wang): For D3 simulation. Comparison between the total amount of Beijing 3km gridded data (Z. Wang) and MEIC inventory data (Q. Zhang) is necessary.
- Japan (T. Ohara and J. Kurokawa): JEI-DB (JATOP) (2005 JEI-DB with REAS growth factor to 2010. Only 2010 JEI-DB for road transport sector is available) and ship emissions from OPRF.
- Korea (J. Woo): CAPSS inventory for 2009 (mole-based speciation fraction), no monthly profile available
- India: SO_2, BC, and OC from Z. Lu and D. Streets, other species from REAS
- All other regions (T. Ohara and J. Kurokawa): REAS

❖ Future emissions (IIASA, Zig Klimont)

- Use growth factors from GAINS for 2030, which include projections from Chinese (Tsinghua and ERI) and Indian (TERI) groups. Baseline and control scenario need to be provided.
- Discussion will be made at the HTAP Meeting in October how to harmonize GAINS and MICS-Asia inventories.

❖ Other anthropogenic emission categories

- Aircraft and international shipping emissions will be provided by Dr. J.-H. Woo based on RCP. Dr. Z. Klimont will give suggestion for which RCP should be chosen.
- Domestic shipping (port, etc.) is included in REAS but gridded using population. Domestic shipping is not included in MEIC & CAPSS.

❖ Develop a "preferred" emission data for air quality model inter-comparison study. Some alternative emission dataset can be examined for emission "scale up/down" type experiments (on request basis)

❖ Alternative emission inventories

- More local emissions for anthropogenic and biomass burning (Southeast Asia, especially).
- Taiwan emissions (detailed sectors and 1 km resolution): Prof. Neng-Huei (George) Lin.
- Thailand anthropogenic emissions: Dr. Narisara Thongboonchoo
- Malaysia anthropogenic emissions: Dr. Justin Sentian
- Vietnam anthropogenic emissions: Dr. Ngo Tho Hung
- Thailand (Southeast Asia) biomass burning emissions: Dr. Savitri Garivait

2) To develop natural emissions datasets for emissions inter-comparison study

❖ Standard-static emissions database (0.5deg, 2010, D1 only) and emissions modeling inputs (framework) will be provided. If AQ model can calculate natural emissions in each model, the informed framework will be used. Otherwise, standard-static emissions will be used as input data.

❖ Biomass burning emissions:

- Data Source/Resolution/Format: GFED V3.1/Monthly (or maximum temporal

resolution possible)/0.5deg/ASCII, Year 2010 available
- Categories/sectors: deforestation, savanna, forest, agricultural, and peat fires.
- Pollutants: carbon (C), dry matter (DM), CO_2, CO, CH_4, H_2, N_2O, NO_x, non-methane hydrocarbons (NMHC), OC, BC, $PM_{2.5}$, total particulate matter (TPM), and SO_2.

❖ Biogenic emissions:
- Data Source/Resolution/Format: MEGAN (Model of Emissions of Gases and Aerosols from Nature)/Monthly (or maximum temporal resolution possible)/0.5deg/ASCII

❖ Dust emissions:
- Data Source/Resolution/Format: Dust model (?)/Monthly (or maximum temporal resolution possible)/0.5deg/ASCII

❖ Sea salt:
- Data Source/Resolution/Format: SMOKE (?)/Monthly (or maximum temporal resolution possible)/0.5deg/ASCII

❖ Volcano emissions:
- Data will be prepared by Dr. Ohara.

3) To provide modeling emission inventories to the air quality modelers

❖ For anthropogenic emissions, gridded data with monthly variation will be provided by MEIC emission processing system (Prof. Zhang).

❖ Model-ready emissions (ASCII Text) for biogenic and open biomass burning (Prof. Woo)

4) To investigate discrepancies between bottom-up and top-down emission inventories

There is no specific plan at this time, but the following participants will join:
Prof. Gakuji Kurata, Kyoto University, Japan
Prof. Yunsoo Choi, University of Houston, U.S.
Dr. Changsub Shim, Korea Environment Institute, Korea

III-3. Deliverables

- **Spatial domain:**
  Asia (INTEX-B EI + Asian region of Russia + Central Asia (Kaz etc.))
- **Year:**
  2008, 2010, and 2030
- **Spatial and temporal aspects:**
  1) 1st level admin units and annual/monthly emissions for inventory researchers
  2) Gridded, model-ready emissions for modeling working group
     Spatial resolution:
       0.25 x 0.25 degree for anthropogenic emissions
       0.5 x 0.5 degree for biomass burning emissions
       0.5 x 0.5 degree for biogenic emissions
     Temporal resolution:
       Monthly
  3) Projections: Lat/lon (Conversion to model map projections should be done by each

modeler.)

4) AQ modelers need to decide 3D structure of emissions (i.e. injection height of some emissions, such as LPSs and/or biomass burning) by themselves. Some guidelines or suggestions will be provided from emissions group to decide emission injection heights.

- **Categories/sectors:**

  Anthropogenic (Industry, Power generation, Domestic, Transportation, and etc), Biogenic, Biomass, Volcano

- **Pollutants:**

  1) SO_2, NO_x, CO, NMVOC, NH_3, BC, OC, $PM_{2.5}$, PM_{10}, CO_2

  2) CH_4 and N_2O from REAS can be used only for 2008. Otherwise will use EDGAR.

- **Speciation:** CB05 and SAPRC99 for NVMOC

IV. Topic 3: Air Quality/Climate Change (Leading Scientists: Greg Carmichael, Zhiwei Han, and Yafang Cheng)

IV-1. Objective

- ❖ Sharing of best practices in AQ/CC modeling in Asia (leads to improved capacities and predictions).
- ❖ Evaluation of strengths and weaknesses of current AQ/CC models (leads to improvements in AQ models and predictions).
- ❖ Ensemble estimates of AQ/CC quantities (concentrations, deposition, AOD) (leads to improved (reduced uncertainty) estimates of impacts)
- ❖ Carry out interesting science
- ❖ Policy relevant analysis (scenarios)

IV-2. Activities

Candidate models:

- Online-coupled models (global/regional): WRF-Chem, WRF-CMAQ, RegCCMS, RIEMS-Chem, ECHAM, AM2, NCAR and other models participating in this topic. (Eumetchem www.eumetchem.info)
- Offline models (global/regional): CHASER, GEOS-Chem, CACUTS, GEATM, MOZART, CMAQ, CAMx, NAQPMS, RAQM2, and other models participation in Topic 1.

Domain settings (coordinate with Topic 1):

- Common domain settings as in Topic 1
- Even higher resolution for cloud resolving simulation, down to 1-2km?

1) To provide multi-model estimates of SLCF distributions & deposition for use in health, ecosystem & climate studies for base case and selected emission scenarios

Specific tasks –

- Multi-model estimates for MICS framework of aerosols (BC, sulfate, OC, dust, nitrate) and ozone by sector
- For base periods in 2008, 2010 + scenarios focused on SLCF agents & AQ+CC policy
- With and without data assimilation (OI, GSI, EnKF, etc.) using AOD
- Online-coupled models can provide on-line calculation of aerosol optical properties and radiative forcing, as well as coupled feedbacks to the climate/weather system.
- Offline models can provide simulation of aerosol and ozone fields and then be used to calculate aerosol optical properties and radiative forcing by common radiative transfer model.
- Also, they may participate in studying how the changing meteorology fields feedback to the air quality. (Do we need future scenario /projection of climate and weather?)

2) To provide multi-model estimates of radiative forcing (direct + other elements) and regional responses for base case and selected emission scenarios.

Specific tasks –

- Multi-model estimates of DRF at surface, atmosphere and top of atmosphere due to anthropogenic SLCFAs by sector
- Multi-model estimates of meteorological feedbacks caused by SLCFAs, including changes in 2 m temperature, winds, mixing layer heights, and precipitation
- Base + scenarios focused on SLCF agents & AQ+CC policy
- The selected emission scenarios might be different from air quality perspective. We will also exam emission reduction scenario regarding the climate change perspective. For example, the best reduction ratio between SO2 and BC, to reduce which emission sector or specific emission source will benefit the global / regional climate / weather the most. Combined with air quality emission reduction scenario to explore the two-wind strategy for Asia region (adjoin model/method to support this study?).

3) To provide analysis of the sensitivity of estimates to key processes/inputs.

Specific tasks –

- Conduct sensitivity analysis of the impacts of model resolution, emissions, optical properties on the results in tasks a & b.
- Conduct sensitivity analysis of the impacts of model chemical or physical mechanism on the results in task 1) & 2), for example, deposition, convection, cumulus scheme, aerosol microphysics?

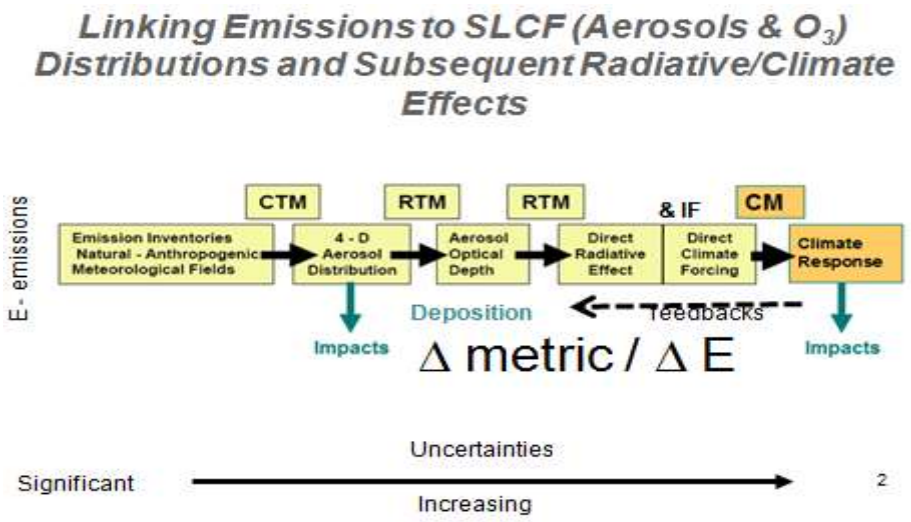
IV-2. Deliverables

1) Multimodel estimates of surface concentration, column amounts and deposition of SLCFAs Hourly 3-D concentrations of SO_2, NO_x, O_3, CO, $PM_{2.5}$, PM_{10}, SO_4, NO_3, BC, OC, dust and aerosol extinction, aerosol number concentration, and size distribution, cloud droplet number

size distributions and the interacted meteorology fields (for comparing with base WRF simulation in Topic 1)

2) Multimodel estimates of AOD and AAOD and BC surface deposition
3) Multimodel estimates of DRF (surface, atmosphere and top of atmosphere (and by sector is possible)) of SLCFAs
4) Multimodel estimates of meteorological responses (changes of 2m T, PBL height, and precipitation amount) due to SLCFAs
5) For base and future emission scenarios
6) Analysis of sensitivities of these model settings and inputs
7) Estimates of health and agricultural impacts of SLCFAs based on these multimodel estimates
8) Examination of the monsoon and ice/glacial changes due to SLFSAs?
9) Seeking other possible missing links and feedbacks in the current set ups towards a more comprehensive earth system modeling?

Details of deliverables should be further discussed and summarized by leaders of Topic 3.



V. Progress, on-going work and schedules for activities in the rest of 2016

- Simulated results using common input data were submitted by 11 groups for model inter-comparison.
- Preliminary results of model inter-comparison for such as ozone and its precursors, wet and dry deposition, aerosols, and relations between air pollution and climates were reported.
- Topics and persons in charge for leading analysis were assigned for wet and dry deposition, ozone, source-receptor relationship, $PM_{2.5}$ and secondary organic aerosols, emission inventories, and inter-actions between air pollution and climate change.
- It is decided that special issues for MICS-Asia III will be established in Atmospheric Chemistry and Physics.

- Discussion workshop by participants who submitted simulated results will be held in November 2016 to promote preparing the scientific papers.
- At the workshop, the current results of analysis, required works and data for further analysis, figures and tables of papers will be discussed.
- Additional simulations for source-receptor analysis and those for fine resolutions will be performed.
- The 8th International Workshop on Atmospheric Modeling Research in East Asia will be held in early next year. At the workshop, results of further analysis after the discussion workshop will be reported and detailed contents of scientific papers will be discussed. Also, work plans for 2017 will be discussed.