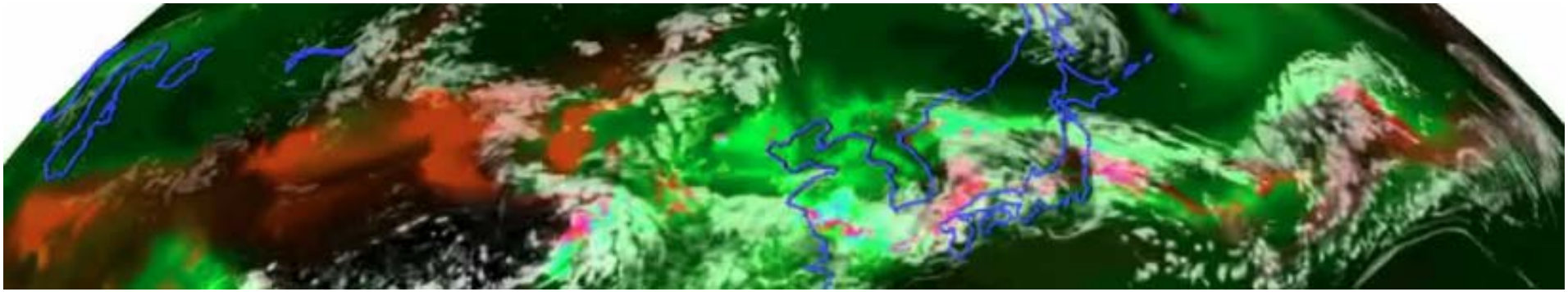
独立行政法人
国立環境研究所
National Institute for Environmental Studies

Simulation of atmospheric air pollutants over Japan and its application to health impacts under MEXT/RECCA/SALSA project in Japan



Daisuke GOTO (NIES/Japan; goto.daisuke@nies.go.jp)

Collaborating with :

Terry Nakajima[#], *T. Dai, J. Uchida, S. Misawa, R. Murata, T.T.N. Trieu, T. Inoue, H. Tsurua,…*
<AORI/SALSA member in University of Tokyo>

M. Satoh, H. Tomita, H. Yashiro, … <NICAM core developers>

K. Ueda, C.F.S. Ng, A. Takami, Y. Morino, T. Ohara, … <NIES/SALSA members>

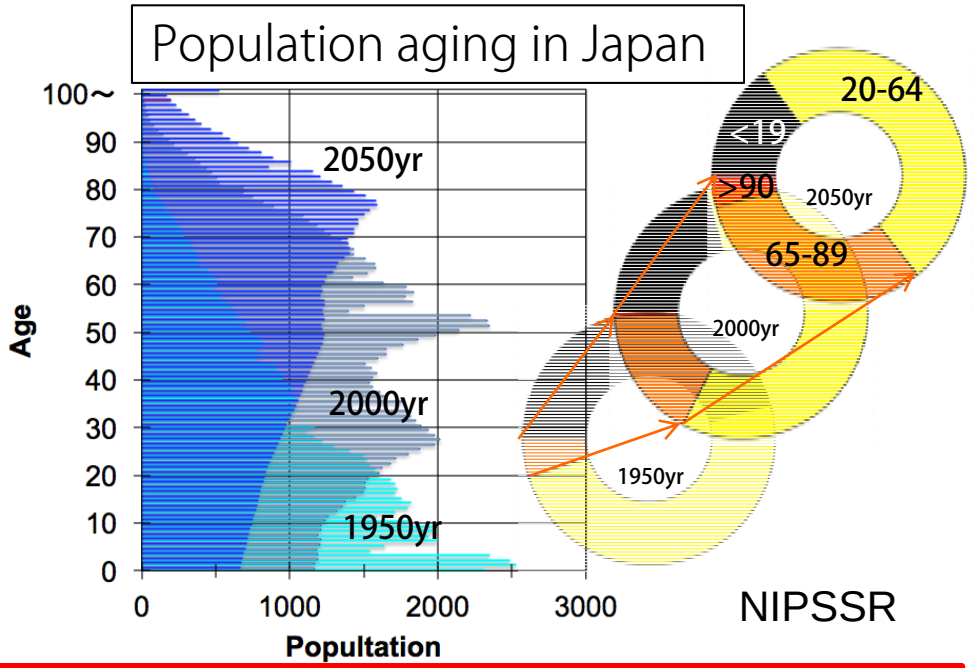
and MEXT/RECCA/SALSA project team

[#] PI of MEXT/RECCA/SALSA project (2010-2014)

Today's my talk

Contents

- Simulation of air pollutants (Aerosols and tropospheric ozone) with 10 km-grids over Japan in August (summer) 2007
- Application of the simulation results to health impacts
- Further application of NICAM



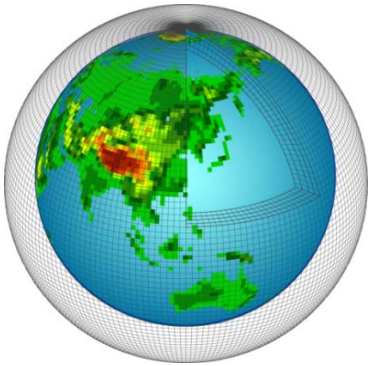
Conclusions

Developing a new aerosol-chemistry model "NICAM-Chem" with high resolution covering global-to-regional scales, as a next generation model, reflecting on high-performance of super-computer.

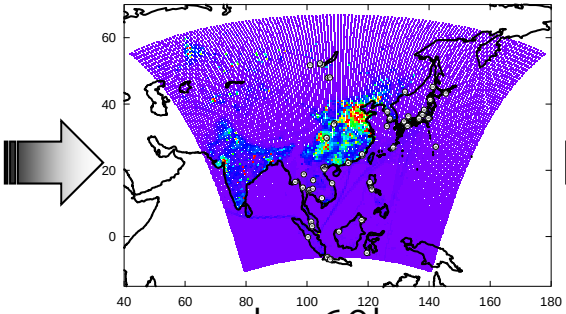
Calculating air pollutions with high resolution

(a) Combination of multi-models by multiple nesting

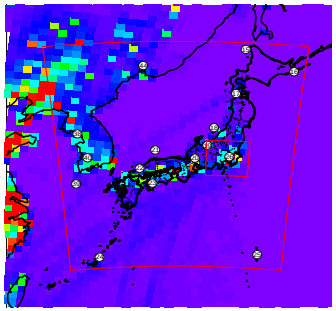
GCM/CTM (Spectral): dx>20km — **Regional CTM**



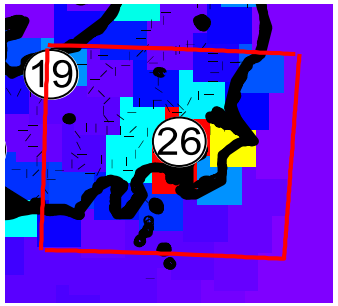
dx=180km (T63)



dx=60km
(Domain 1)



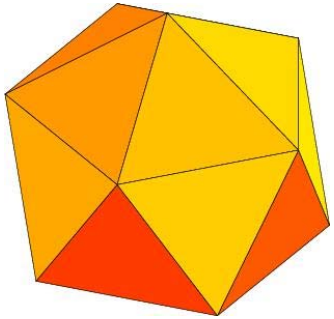
dx=15km
(Domain 2)



dx=5km
(Domain 3)

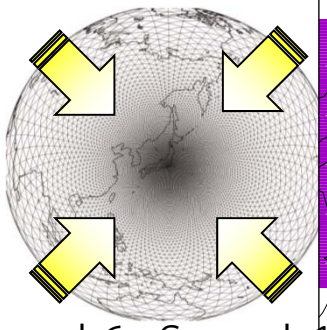
(b) One model without nesting or 1-nesting (New approach by our group!)

GCRM (Grid-spacing): dx~any scales — **Stretch grid** — **Diamond grid**

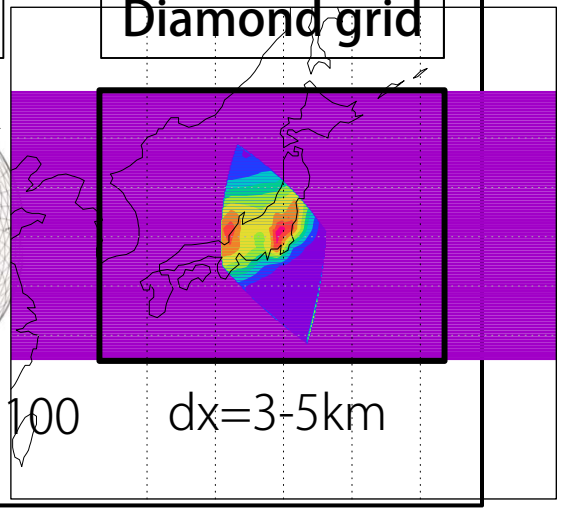


Glevel 0
(dx=7141km)

Glevel 6
(dx=112km)

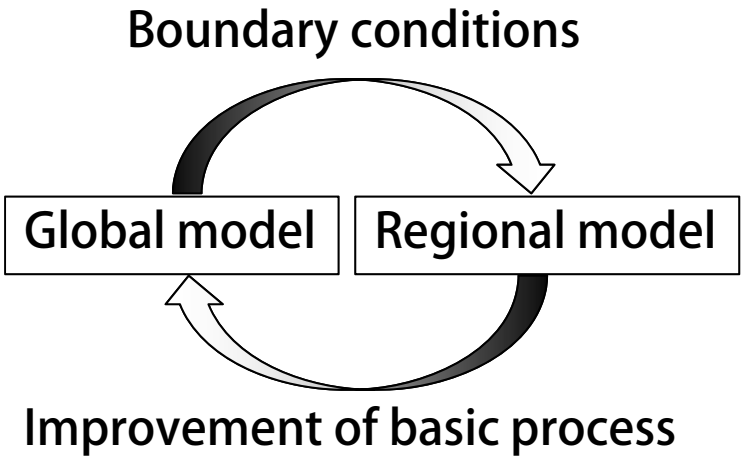


Glevel 6+Stretch100
(dx=11km)



dx=3-5km

Type of aerosol-chemistry unified models



Advantage
- Computer resources: LIGHT
- Effective working among researchers

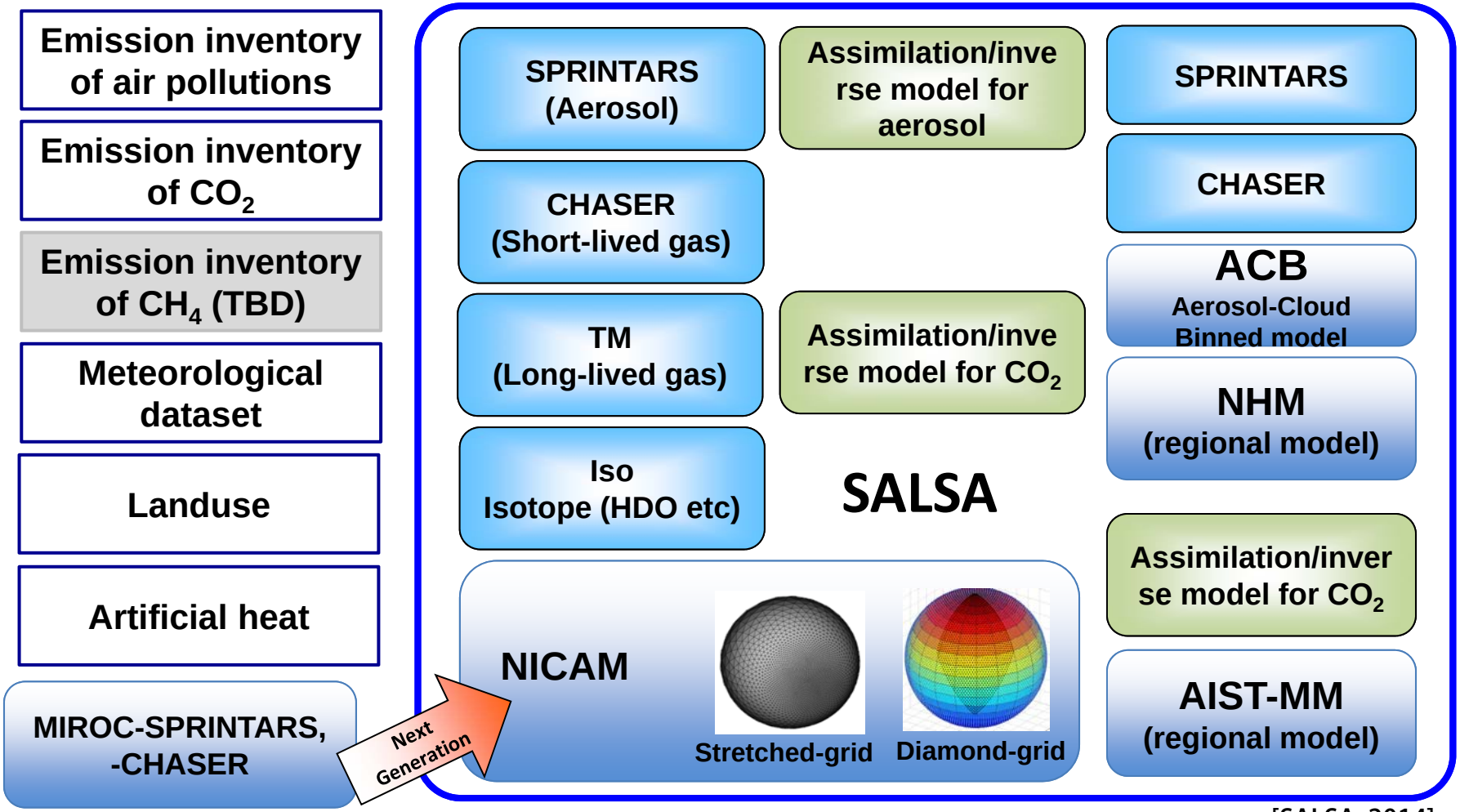
Disadvantage
- Boundary conditions (Potential problem)
- Unbalance b/w global and regional models

	GCM/CTM	Regional CTM	GCRM+Chem
Climate Issue	○	×	△~○
Heterogeneity of air pollutions	×	○	○
Health impacts in prefectures	△	△~○	△~○
Development of basic processes	×	○	○
Number of model	>20	>20	Limited or 0
Example	CHASER, MOZART	CMAQ	NICAM-Chem

Modeling system developed under MEXT/RECCA/SALSA project

H22-H26（PI：Terry Nakajima @Univ. Tokyo)

- Modeling of air pollutions using assimilation system
  - Long-lived gases, Short-lived gases, Aerosols, and Isotope
- NICAM covers global-to-regional scales with one model system.
  - Great advantage for various-scaling modelers (at least for Japanese modeling community)



[SALSA, 2014]

NICAM (Non-hydrostatic Icosahedral Atmospheric Model)

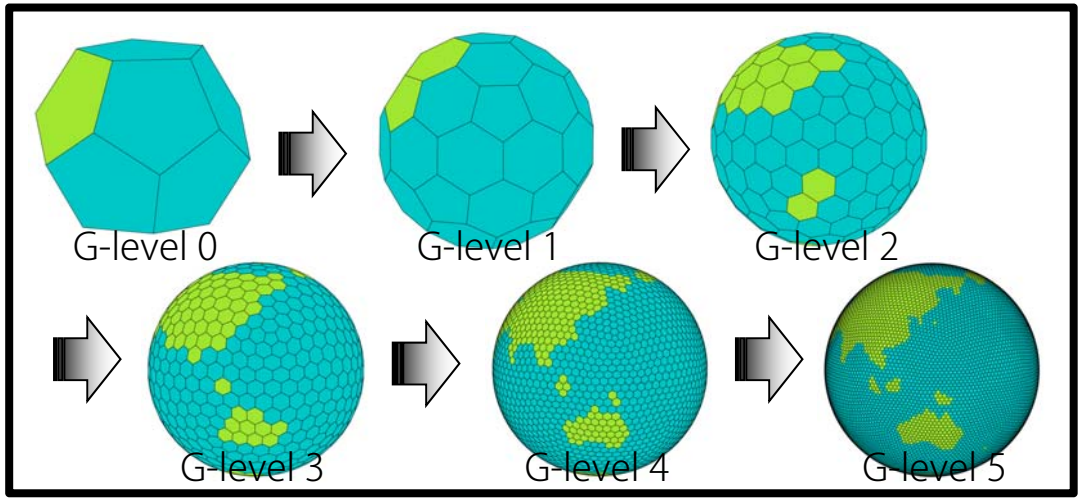
- Developed by Tomita and Satoh (2004) and Satoh et al. (2008) as the next generation atmospheric model
- Successful simulating MJO with global 3.5 km resolution (Miura et al., 2007) and recently simulating cloud structure with global 870 m resolution (Miyamoto et al., 2013).
- Seamlessly covering global-to-regional scales with the same package:

  (1) globally uniform model: Global NICAM

  (2) Stretch model (Tomita, 2008b): Semi-regional model with reducing CPU time even with high-resolution

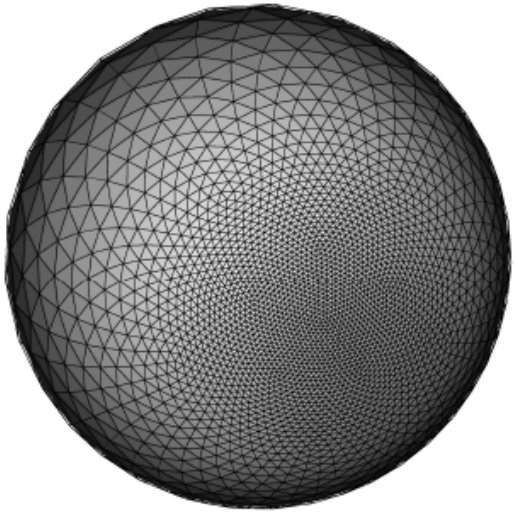
  (3) Diamond model (SALSA, 2013) : Perfect regional model

Global NICAM



NICAM grid system (The number of diamond is "10x4^{g}". "Glevel" means the number of cutting times.

Stretch NICAM

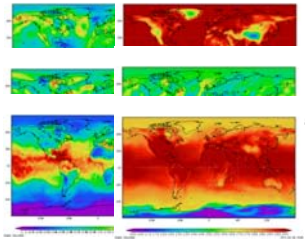


Experimental conditions in this study: "NICAM-Chem"

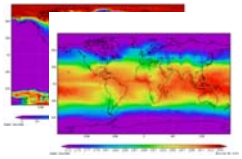
	NICAM-g5	NICAM-g6	NICAM-g6str
Grid configuration	Uniform		Stretch
Horizontal resolution	220 km	110 km	11 km (finest)
Vertical layers	40		
Timestep (s)	1200	600	20
Microphysics	---		NSW6 (Tomita, 2008)
Large-scale cloud	LSC		---
Cumulus	Arakawa-Schubert		---
Aerosol	SPRINTARS (Takemura et al., 2005). PM2.5=EC+OC+sulfate(as $(NH_4)_2SO_4$)		
Short-lived gas	CHASER (Sudo et al., 2002)		
Radiation	K-distribution by MSTRN (Sekiguchi and Nakajima, 2008)		
Turbulence	MY-MOIST2 (Meller & Yamada, 1974; Nakanishi & Niino, 2004; 2009)		
Land	MATSIRO (Takata et al., 2003)		

Flowchart of simulating atmospheric tracers (aerosols and gases)

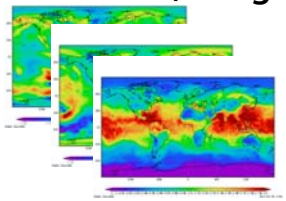
Initial conditions



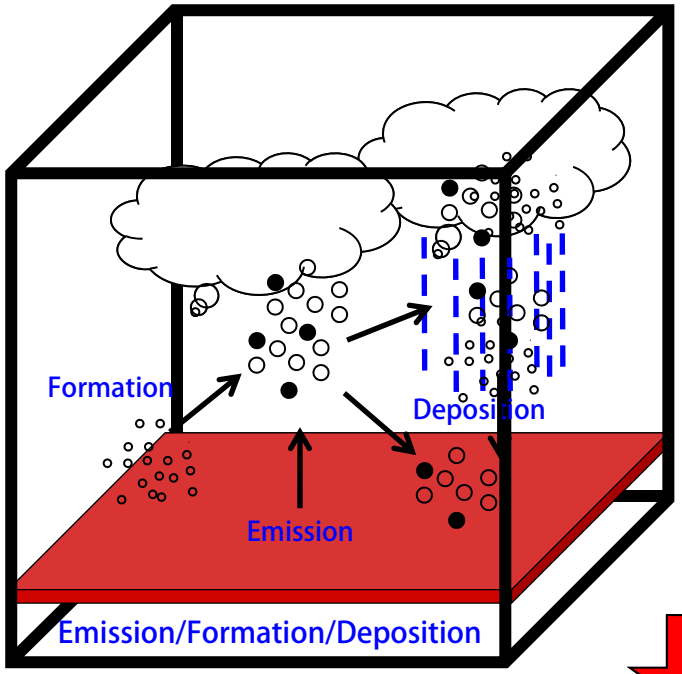
SST and Sea-Ice



NCEP-FNL (Nudging)

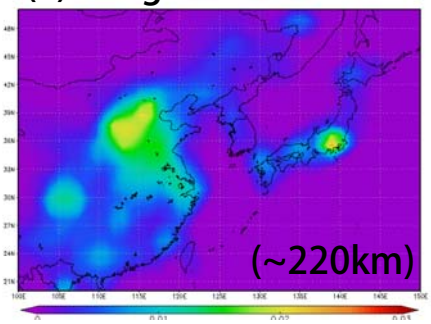


Inside the grid

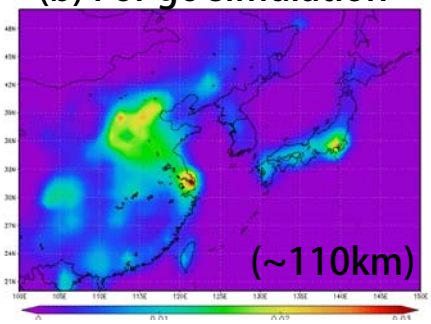


Emission inventory of anthropogenic sources (e.g., Black Carbon)
by Kannari et al. (2007), Kurokawa et al . (2013), Diehl et al. (2012)

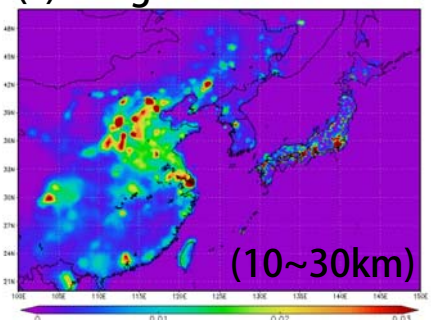
(a) For g5 simulation

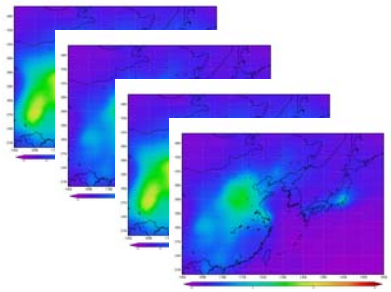


(b) For g6 simulation



(c) For g6str simulation

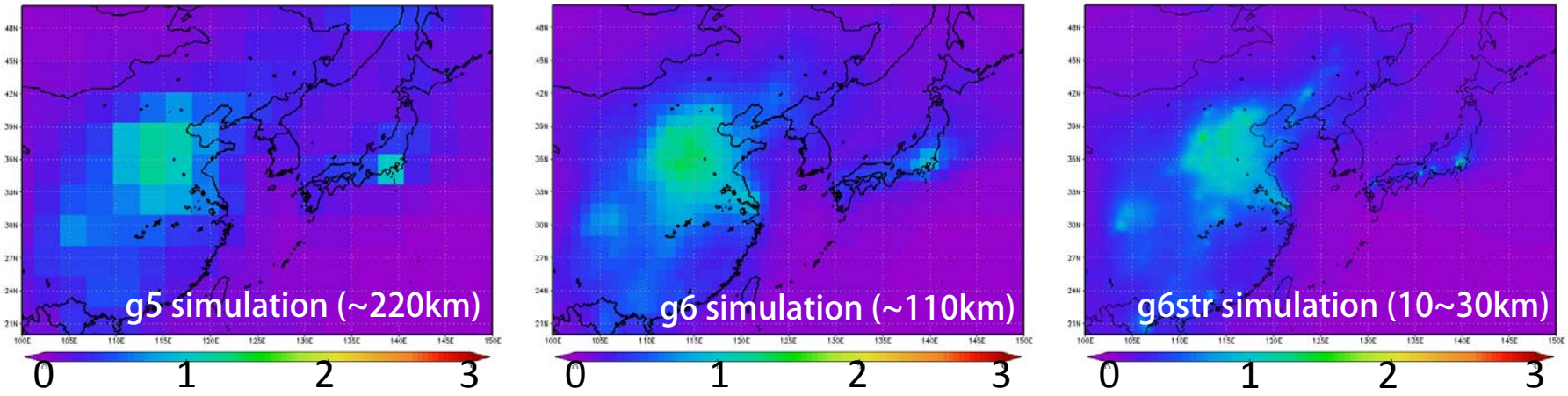




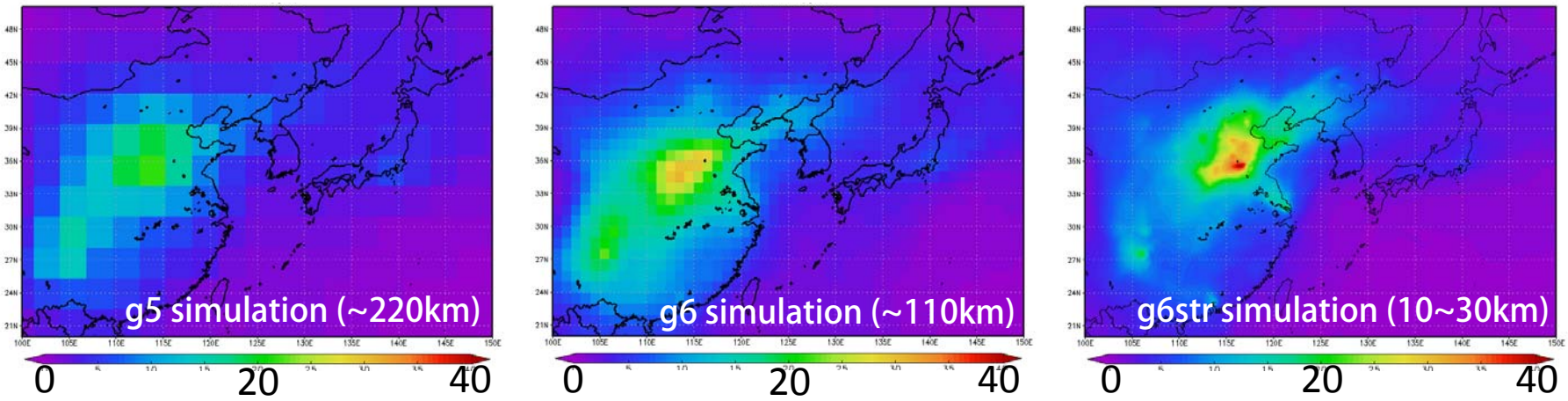
Predicting concentrations of
atmospheric tracers

Aerosols concentrations over east Asia in August 2007

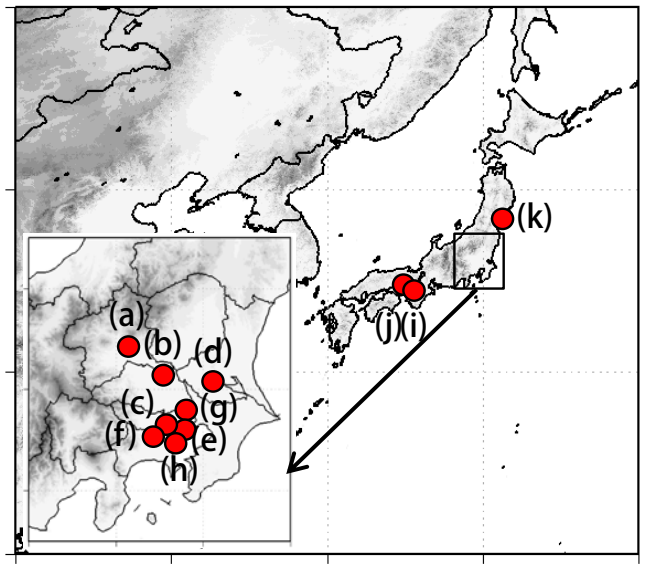
Monthly-mean surface BC [μg/m³]

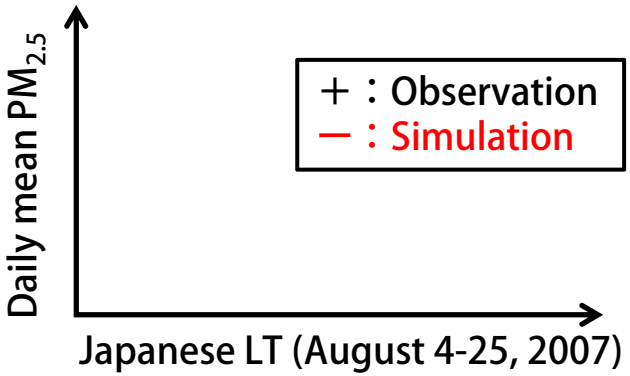


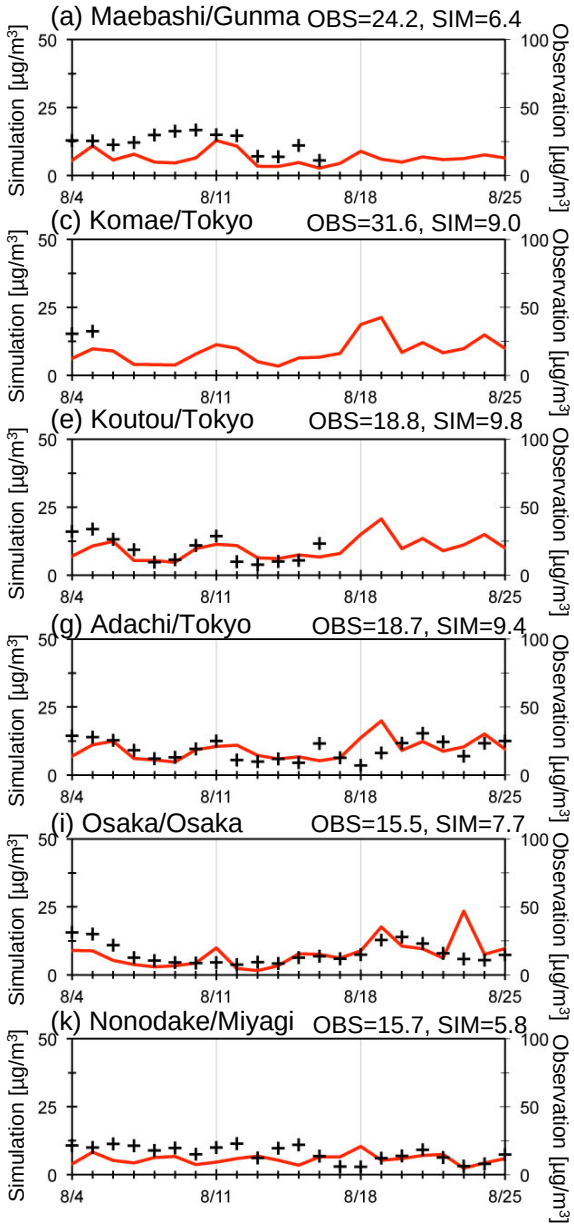
Monthly-mean surface SO_4^{2-} [μg/m³]

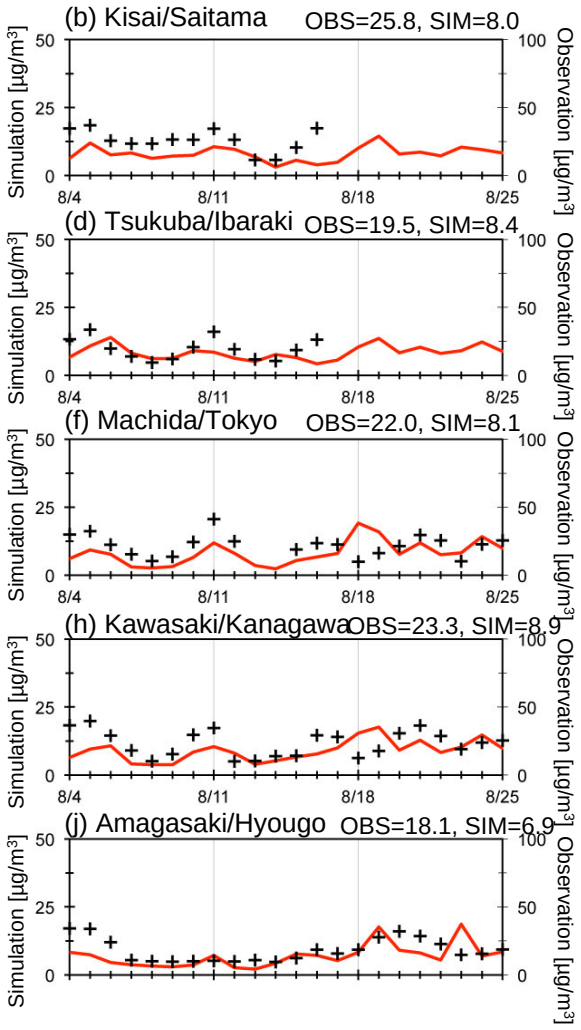


Stretch-NICAM-Chem simulated $PM_{2.5}$ over Japan



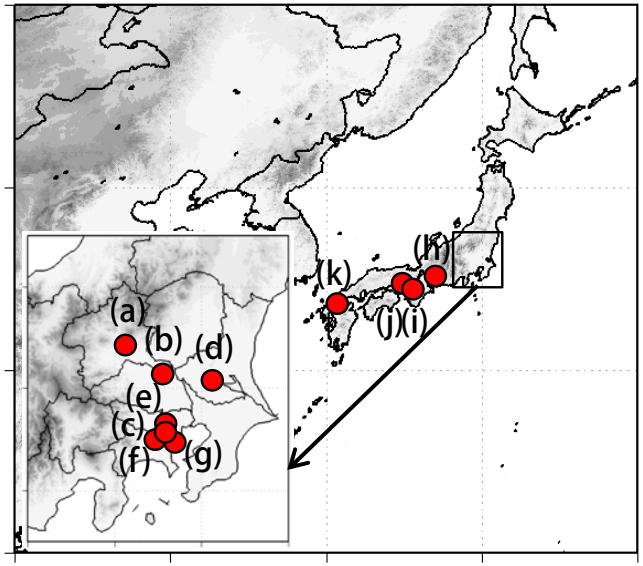


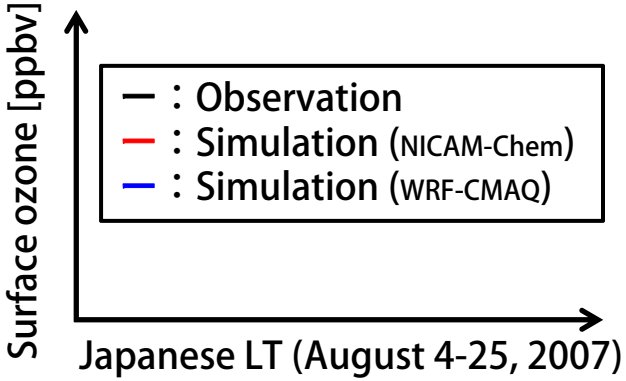


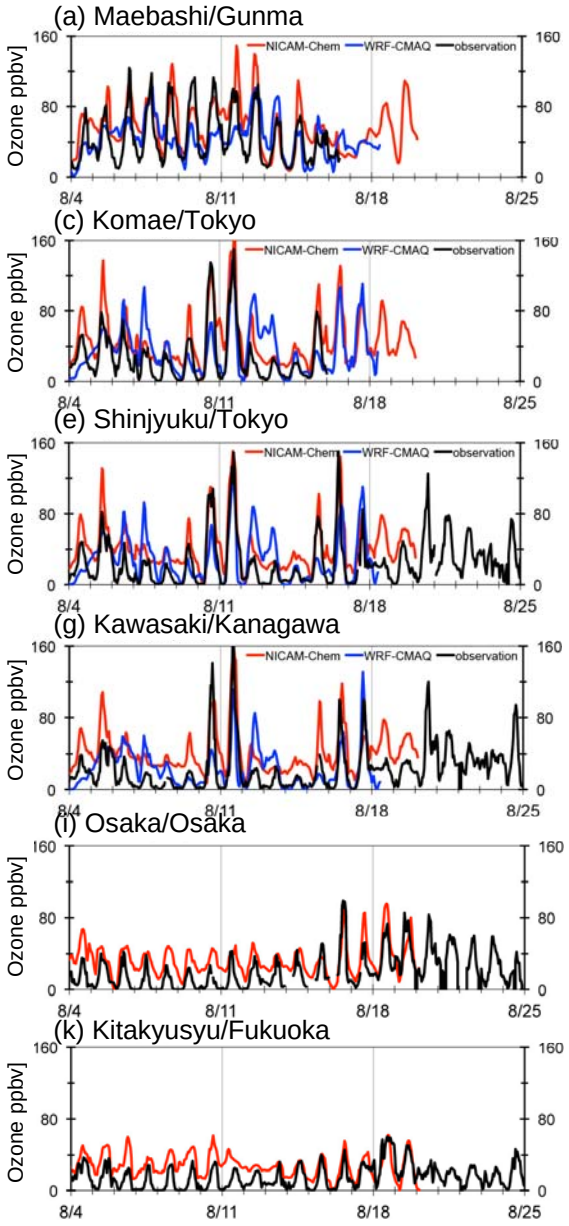


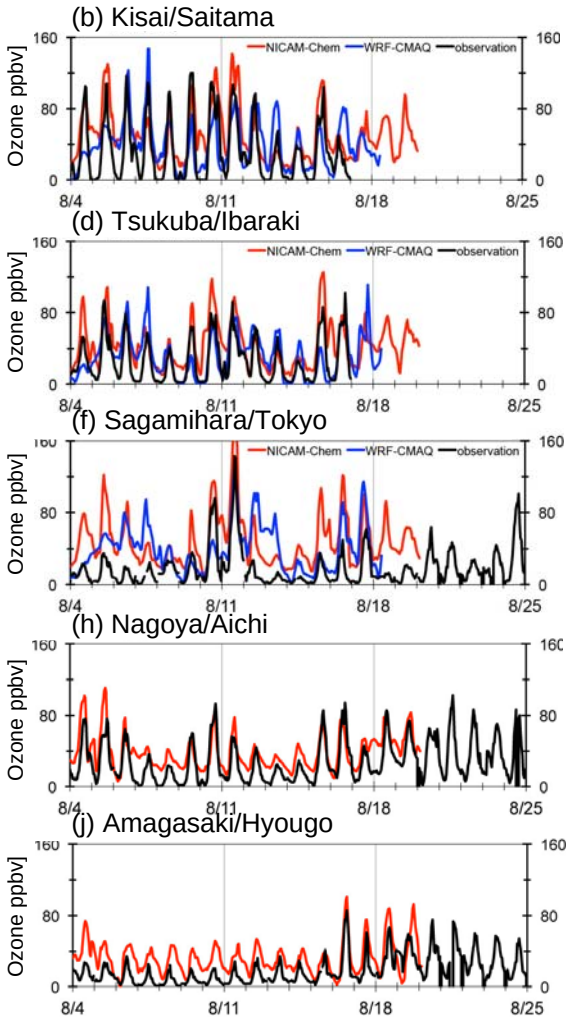
[Goto et al., 2014]

Stretch-NICAM-Chem simulated surface ozone over Japan









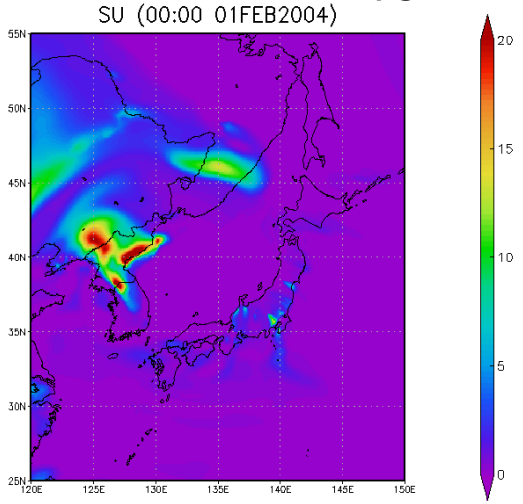
Application of NICAM products to health impacts

Collaborating with Prof. K. Ueda @Kyoto Univ., Dr. C.F.S. Ng @Tokyo Univ., and Dr. A.Takami @NIES

1. NICAM-simulated PM2.5 & O_3

- Stretch-NICAM: dx~10km
- Short-term exposure (1 month)
- Bias correction is required for PM2.5
- Under various scenarios of
  - (1) NCEP-FNL in 2007
  - (2) MIROC-AOGCM in 1970, 2000, 2030 of RCP4.5 and/or SRES-A1B

NICAM-simulated sulfate [μg/m³]

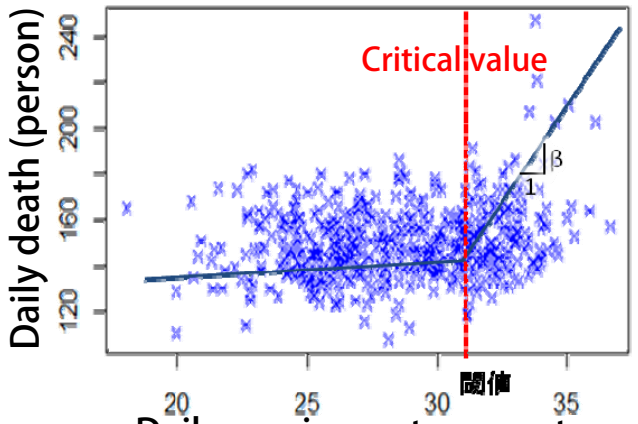


2. Estimate excess mortality

$$\Delta y = y_0 \times P \times (\exp(\beta \Delta X)-1)$$

ΔX : Change in the concentrations of air pollution
β : Impact depending on factors
P : Population density (each scenario)
y0 : Prevalence and/or incidence rate

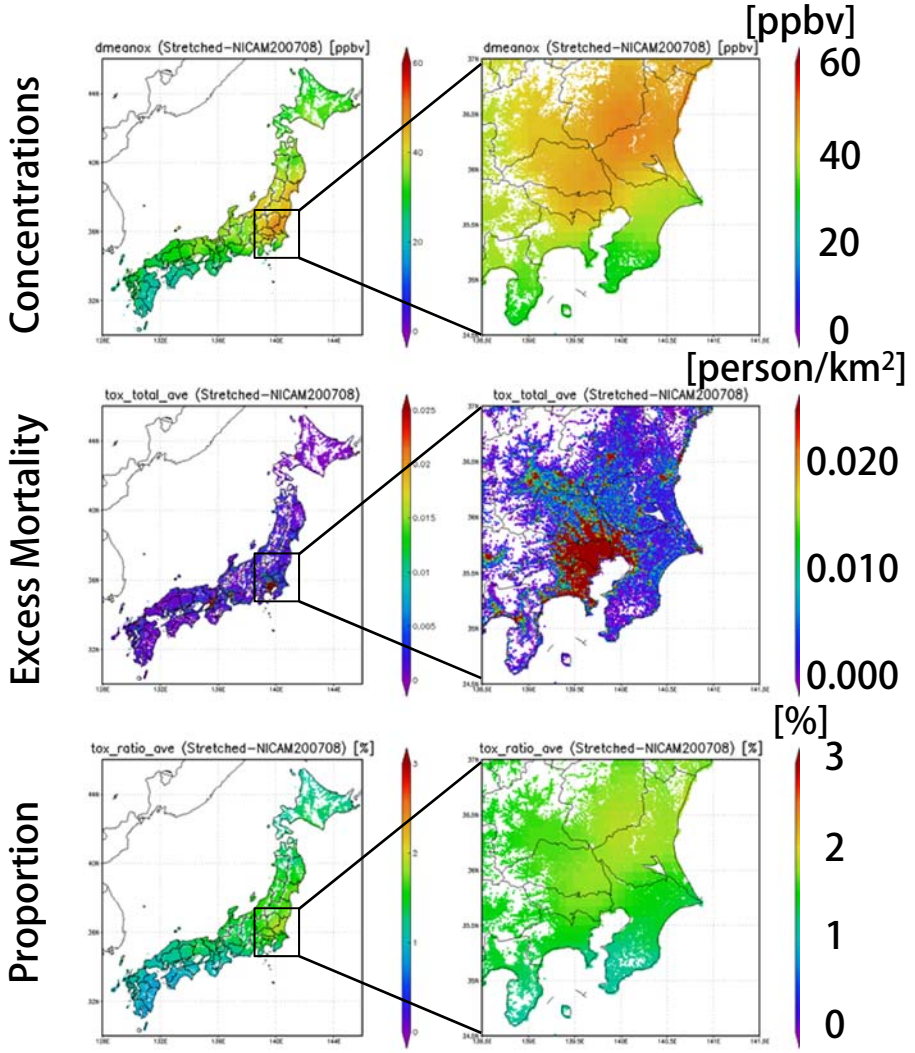
Daily maximum temperature vs. daily death (Tokyo, 2002-2007)



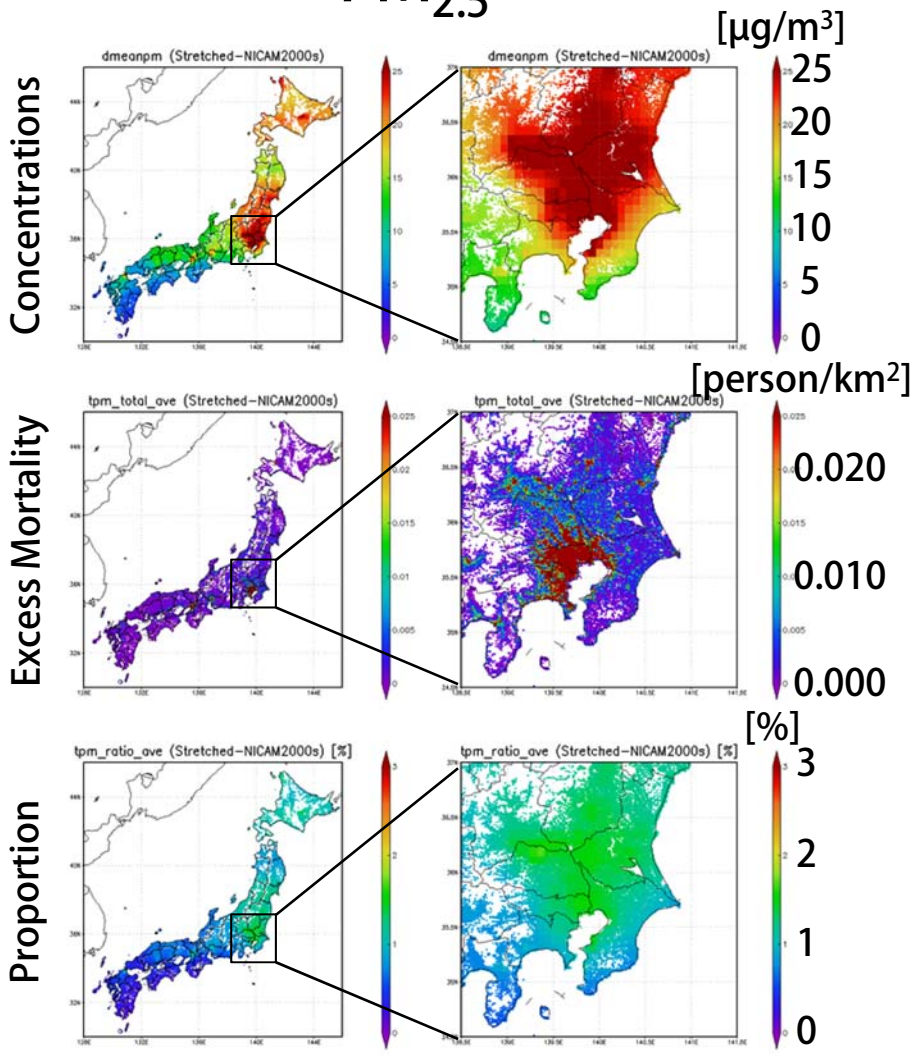
[SALSA-G3, 2012; 2013; 2014]

Health impacts due to Ozone and $PM_{2.5}$ over Japan (*Present*)

Ozone



$PM_{2.5}$



Details are shown below ↓

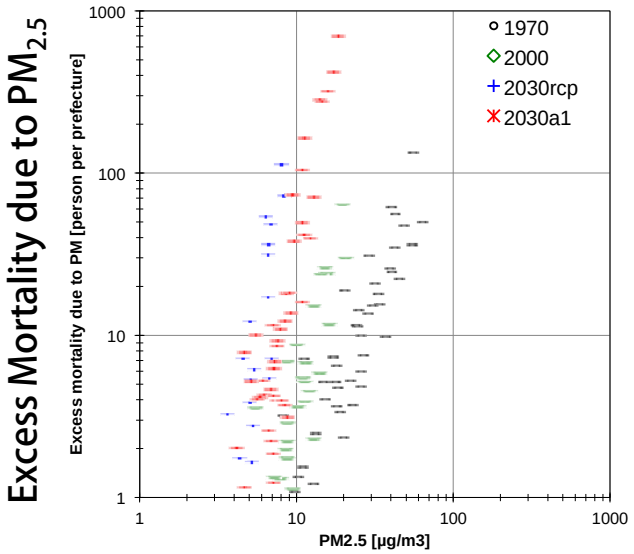
[SALSA-G3, 2014]

http://cesdweb.aori.u-tokyo.ac.jp/~database/salsa/SALSA_NICAM/data_health.html

Health impacts due to $PM_{2.5}$ over Japan (*Past-Present-Future*)

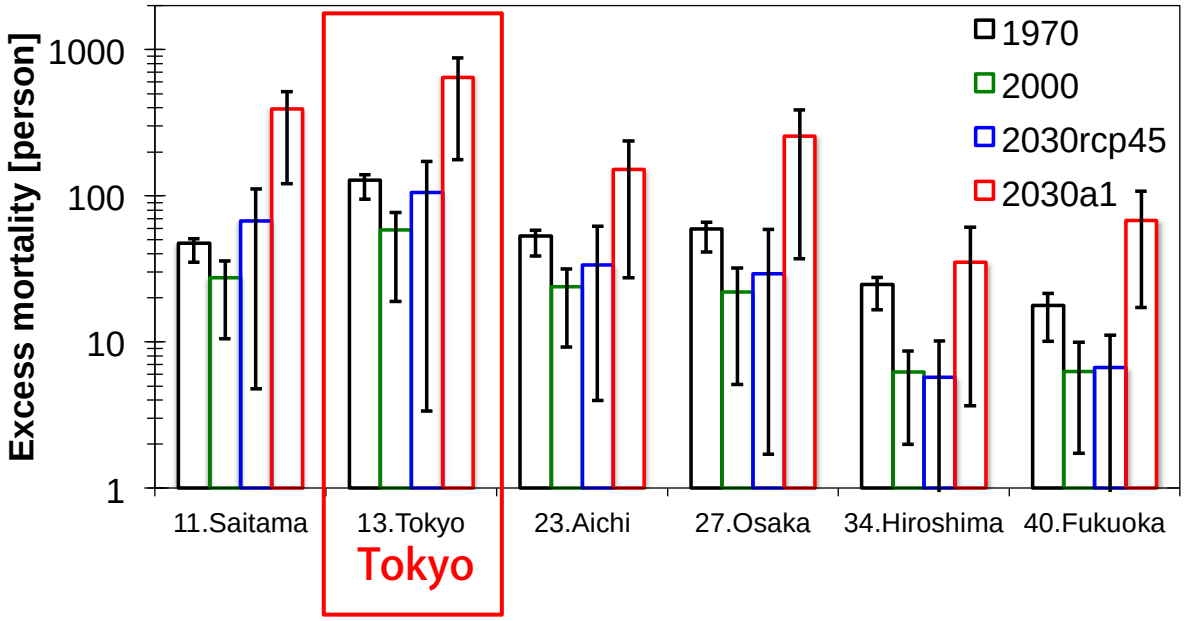
- Past: 1970s (Heavy air pollution in Japan under the rapid economic growth)
- Present: 2000s (Moderate clean air)
- Future1: 2030s of RCP4.5 (very clean air)
- Future2: 2030s of SRES-A1B (cleaner but more dirty than RCP4.5 scenario)

Mortality due to $PM_{2.5}$



$PM_{2.5}$ concentrations

Annual mean excess mortality of 6 prefectures



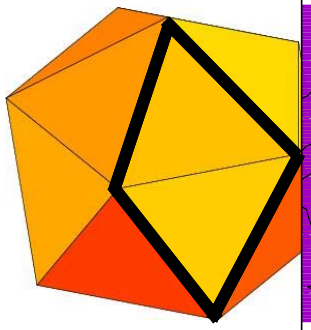
Future morality depends on the scenario!
(because of aging in Japan)

[SALSA-G3, 2014]

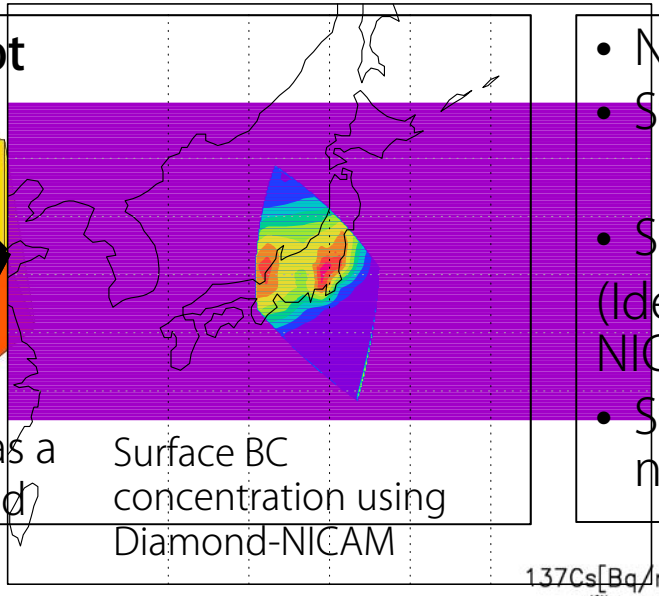
Application (1): Diamond-NICAM

Mainly working by Dr. J. Uchida and Mr. Misawa @AORI and Dr. M. Hara @JAMSTEC

Model concept



Use one panel as a form of diamond



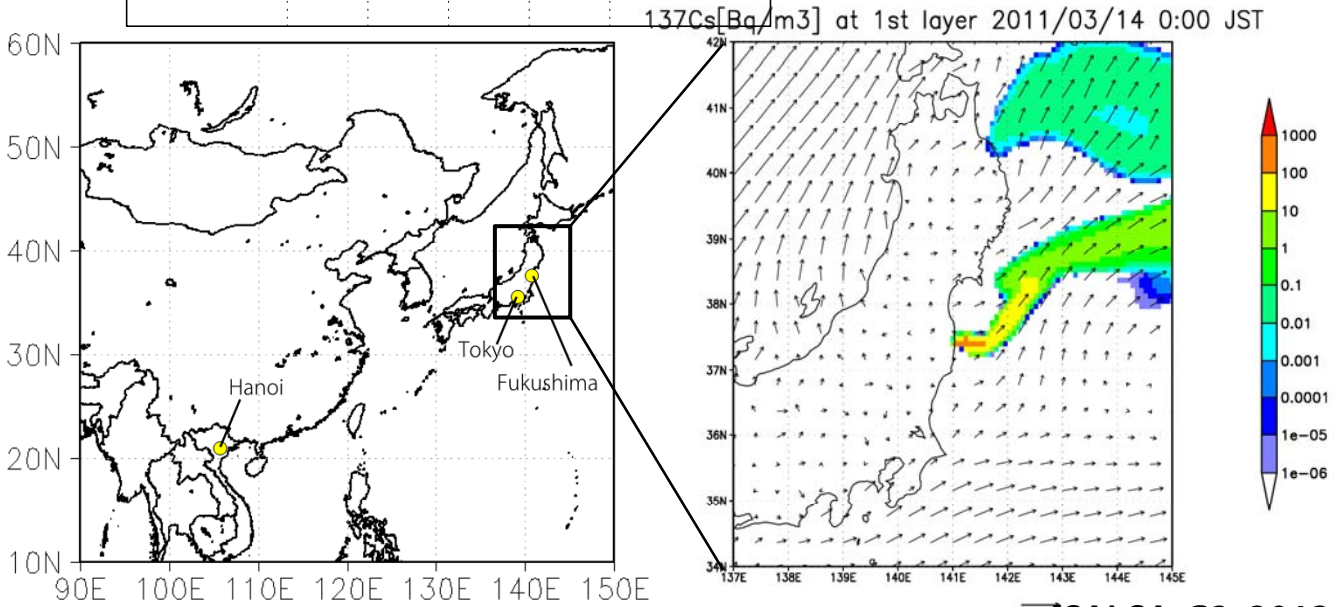
Surface BC concentration using Diamond-NICAM

- NICAM setting: G-level 7, R-level 3
- Stretch ratio (for stretching): 100

- Spatial resolution: 3.5~5 km

(Ideal CPU time is smaller than global NICAM by 10 times)

- Start from March 11, 2011 (Fukushima nuclear accident; cesium137)



[SALSA-G2, 2013; Misawa, 2014]

Application (2): Assimilation (Local Ensemble Transform Kalman Filtering; LETKF)

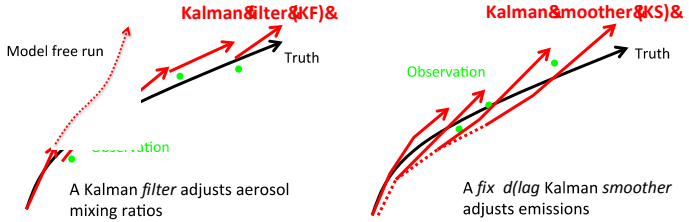
Mainly working by Dr. T. Dai @IAP/CAS, Dr. N. Schutgens @Oxford, Mr. S. Misawa@ AORI

LETKF system (by Dr. T. Miyoshi)

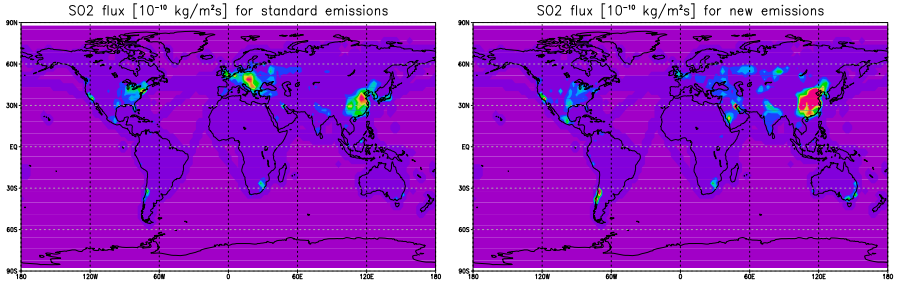
$$\mathbf{x}^a = \mathbf{x}^f + \mathbf{P}^a\mathbf{H}^T\mathbf{R}^{-1}\left(\mathbf{y} - \mathbf{H}\mathbf{x}_f\right)$$

$$\mathbf{P}^a = \left(\mathbf{I} + \mathbf{P}^f\mathbf{H}^T\mathbf{R}^{-1}\mathbf{H}\right)^{-1}\mathbf{P}^f$$

[Rodgers, 2000]
a: analyzed state
f: forecast state
y: actual values
Hx_f: simulated values

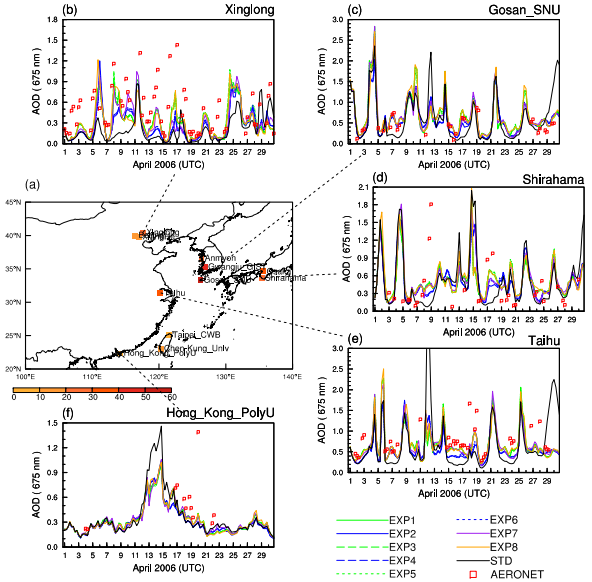


MIROC + Smoother (by N. Schutgens)



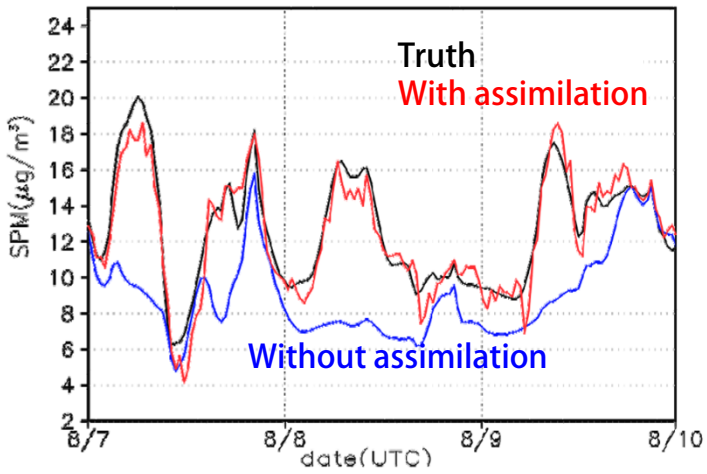
→ Estimate emission inventories

Global-NICAM + LETKF (by T. Dai)



Stretch-NICAM + LETKF (by S. Misawa)

Kasawaki (near Tokyo)



Conclusions

1. Developing a new aerosol-chemistry model "NICAM-Chem"

2. High resolution covering global-to-regional scales (Global-NICAM, Stretch-NICAM, and Diamond-NICAM)

3. Next generation model reflecting on high-performance of super-computer.

4. Under MEXT/RECCA/SALSA and related projects, estimate of human health impacts under various scenarios starts.

5. Please contact me (Daisuke Goto; goto.daisuke@nies.go.jp), if you are interested.