Air Quality perspectives from Japan and Response/impact of the recent Earthquake/Tsunami

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Part 1. Air quality forecast in Japan
Part 2. Response/impact of the Earthquake/Tsunami/Nuclear accident this Mar.
The background of the air quality forecast in Japan

photochemical oxidant:
  • rise of concentration (particularly in western Japan) in decades and extension of high concentration area recently
  • possible cause = long-range transport

PM$_{2.5}$:
  • air quality standard for PM$_{2.5}$ was enacted in 2009 — 35μg/day 15μg/year
    (only SPM standard before that since 1973)

public concern about environment (including non-atmosphere):
  • 1st priority now = radioactive materials in life, possibly food etc. already negligible in the atmosphere, though
  • except for that, public concern about air quality has been increasing

Also, local governmental officers need information to issue warnings (due to difficulty with increasing influence of long-range transport)
Abstract of air quality forecast in Japan

Active research institutions:
Kyushu University
JAMSTEC (Japan Agency for Marine-earth Science and Technology)
NIES (National Institute for Environmental Studies)
MRI (Meteorological Research Institute)

Government offices:
Ministry of education, culture, sports, science and technology
Ministry of the Environment
JMA (Japan Meteorological Agency)

Brief history of operational AQ forecast in Japan
2000 CFORS by I. UNO = pioneer in Japan
2002 Chemical weather forecast by Frontier Research Center of Global Change
2008 collaboration started between Ministry of the Environment and JMA (Japan Meteorological Agency) about AQ forecast etc.

Headline of this topic
In transition from individual researches to officially projects
Active institute 1. Kyushu University (1/2)
Prof. Itsushi Uno

CFORS (Chemical weather FORecast System)

Public release: 2000
Core: RAMS online tracer transport
Species: dust & sulfate aerosols
resolution: 40km
Emission:
period: 4 day
SPRINTARS (Spectral Radiation-Transport Model for Aerosol Species)

Originally developed: 2000
Public release: 2008
Core: SPRINTARS (GCM based aerosol transport model)
Species: dust, BC, OC, sulfate
Resolution: T213 \(\approx 0.5\)degree mesh
Period: 7 day
Global Chemical Weather Forecast System

Public release (global ver.): 2002
Public release (regional v.): 2008
Core: CHASER (GCM based chemistry climate model) + WRF/Chem
Species: 56 species, 142 reactions
O$_3$ and NO$_x$ for public
Resolution: 5km (greater Tokyo) 15km (other Japan areas)
T42 ≒ 2.8 degree mesh
Emission: JCAP & EAGRID2000
Period: 1 day
Active institute 3. Meteorological Research Institute

Photochemical smog–weather forecast & Dust forecast

Public release: 2008
Core: MOZART (global chemistry climate model)
Species: surface O₃ for public
Resolution: about 100km
Emission: REAS
Period: 3 day

Public release: 2004
Core: MASINGAR (global model)
Species: dust and other aerosols
Resolution: about 100km
Period: 4 day

becoming deeper in regional modelers
Active institute 4. NIES (National Institute for Environmental Studies)

Dr. Toshimasa Ohara, Dr. Seiji Sugata and colleagues

VENUS (Visual atmospheric Environmental Utility System)

Public release: 2008
Core: RAMS + CMAQ
Species: O$_3$ and NO$_2$ for public
Resolution: 5km (areas), 25km (Japan), 100km (E Asia)
Emission: EAGRID (Japan) & REAS (other)
Period: 2 day
Species for public is now photochemical Ox and NO2. Sulfate aerosol after next spring.

Can choose hourly on the day and the next animation display simultaneously for one day.

Download
Features and Specification

- Core: Combination of **RAMS** + **CMAQ**

- Nudging: simply with GPV weather forecast data by JMA

- Emissions: **EAGRID** (in Japan) and **REAS** (others in Asia)

- Domain: 3 level nesting to cover East Asia to urban areas in Japan
  East Asia 100km ⇔ Japan 25km ⇔ each local area 5km

- Species: hourly **Ox** and **NO2** on the day and the next day

- Schedule: update every 9 o’clock in the morning (local time)

- Computer: NIES supercomputer system (scalar system)
Core: Coupling of **RAMS + CMAQ**

development history

Idea: Prof. Itsushi UNO and Dr. Daewon Byun in mid 1990s

first release of the interface (MCIP for RAMS) : in 1999

when I stayed EPA/NERL for 1 year (1998-99) to develop it

with supervised by Dr. Byun

MCIP for RAMS has been developed:

up to RAMS 4.4 and CMAQ 4.4

but no update recently → VENUS

VENUS development: since 2004

internal use/test

Public open 2008
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VENUS
Emission

**REAS (Regional Emission inventory in ASia)**
By JAMSTEC, NIES etc.
resolution: 0.5 degree
Species: NO\textsubscript{x}, SO\textsubscript{2}, CO, CO\textsubscript{2}, N\textsubscript{2}O, NH\textsubscript{3}, BC, OC, CH\textsubscript{4}, NMVOC

**EAGrid2000 (East Asian air pollutant emission GRID database)**
By Drs. Kannari, Tonooka, Murano etc.
base year: 2000
resolution: 1km (Japan), 0.5 degree (others)
Species: NO\textsubscript{x}, SO\textsubscript{2}, CO, NH\textsubscript{3}, PM\textsubscript{10}, Hg, NMVOC
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VENUS

3 level nested domain: Asia (100km)–Japan (25km)–Each area (5km)

Colors in maps=NOx emission
VENUS

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- Schedule: update every 9 o’clock in the morning (local time)

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Evaluation of VENUS by comparing Ox in May and Aug. 2009 between the result of VENUS and the observation data at air pollution monitoring stations.

Comparison is made for the following three cases for four local domains in Japan:

<table>
<thead>
<tr>
<th></th>
<th>Japan 25km mesh</th>
<th>Local 5km mesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2009</td>
<td>○</td>
<td>×</td>
</tr>
<tr>
<td>Aug. 2009</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Colors in map = NOx emission
Dots = air pollution monitoring stations
Monitoring time for NO, NO2, OX > 90%

NO/NOx ≤ 0.2

Four domains evaluated this time
VENUS Evaluation
Skill scores for prefecture daily 95 percentile Ox between obs. and VENUS

Japan domain (25km) May 2009

Japan domain (25km) Aug. 2009

Local domain (5km) Aug. 2009

Black: Correlation coefficient
Red: NMB (obs. - cal.)
Blue: NME
Summary of VENUS

• VENUS: air pollution forecast system
developed by NIES and colleagues

Jointly developed by
• Ministry of the Environment
• Central Res. Inst. of Electric Power Industry
• local government environ. institutes

Assisted by
• Fujitsu FIP corporation
• Japan Weather Association

• Evaluation about Ox:
good for daytime high concentration
poor for low concentration at night

• Next step:
  Fully update or change to WRF+CMAQ
  before evaluation
Lessons learned about AQ forecast in Japan,

- Original emission inventories, original GCM and CTM
  But no original regional models
- Small (or no) official support for the AQ forecast so far
  with no or small funded ($\sim$100,000?)
- Not by team but by individual researcher
  like handicraft industry
  $\Rightarrow$ these are problems.

One good news is collaboration of MOE and JMA since 2008

Before that, bureaucratic sectionalism like “forecast” is under JMA, “environment” is under MOE…
Examples of collaboration of MOE and JMA

Information homepage for oxidant

Information homepage for Asian dust

Kyushu University
For the next fiscal national budget:
MOE submitted about three million dollar

to develop a national AQ modeling system,
which is actual detail are not decided,
based on VENUS for regional scale?
and on JMA models for larger scale?

I don’t know whether it works
but their positions are positive

AQ forecast in Japan
will hopefully go to the next stage soon!?
Part 2.
Response/Impact to
The Tohoku earthquake and tsunami
(March 11, 2011)
Part 2. The Tohoku earthquake and tsunami (March 11, 2011)

photos from NY times, USA today, etc.

# of deaths=15840
missing=3611
(official data on Nov.24)
My personal affairs related to the earthquake

Mar. 11 2:46 p.m.: The largest quake I ever experience, hard to stand a little
      Cell phone didn’t work at all (mobile e-mail worked, I realized later)
About 30 mins later: Went home. No one home.
      Went to the elementary school to pick up my kids. Met my family
Damages: just many plates in the kitchen. No human injured including friends
At the night: electricity outage. Went to bed on 8 p.m. without knowing tsunami
For a few days: no water supply
With the news of the plant accident (about 100 mile apart):
      let my kids go to school with flu mask. Some of classmates evacuated.
About a week: almost no food and bottle water at stores
About two weeks: gasoline shortage=over 1 mile line of cars for gas stands
About 2 months: polluted tap-water
For several months, even now: hundreds of aftershocks
Newest publication says meltdown at the plant occurred after 5 hours from the earthquake.

Total emitted radioactive material is

\( \sim \) several hundreds of thousands tera-becquerel

Bad materials in the larger emission order

<table>
<thead>
<tr>
<th>Species</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-131</td>
<td>8 day</td>
</tr>
<tr>
<td>Cs-134</td>
<td>2.1 year</td>
</tr>
<tr>
<td>Cs-137</td>
<td>30 year</td>
</tr>
</tbody>
</table>

hourly radiation dose in Tsukuba (including natural)

observed radiation dose

10 day for half

almost no decrease

March  November
How much bad is radiation dose in Japan?

natural radiation exposure  
(from space, earth, food, atmosphere)  
\(~2400 \mu \text{Sv/year}\) (world average)

US-EPA yearly limit on radiation exposure to a single member of the public  
\(= 1000 \mu \text{Sv}\)

yellow area  
\(~300-1200 \mu \text{Sv}\)

is almost no problem. Just need to pay attention to internal exposure

\[\text{observed radiation dose (near surface, including natural dose)}\]

yellow area  
\(= 0.1-0.2 \mu \text{Sv/h}\)

Tokyo

Tsukuba
Present state and damage after the earthquake

From earthquake and tsunami damage: reestablishing

Fukushima power plant: manage to control
  no longer large leakage toward atmosphere and ocean

Air and tap-water: Free of radioactive materials now

Soil: polluted by Cesium-134&137
  only surface to 5cm depth (cesium tends to unite with clay)

  →  food (animals and plants)
    dry grass & pruned branch ⇒ garbage incinerators

Problems:

  for public= Food safe
  for regional government = Management of accumulated radioactive materials
    Decontamination of soil etc.
  for Japan = money for recovery, reconsideration of energy policy
  for travelers = no problem at all unless you go to Fukushima
How was the distribution of the radiation dose in eastern Japan determined?

I’d like to introduce one study by my colleagues.

Atmospheric behavior, deposition, and budget of radioactive materials from the Fukushima Daiichi nuclear power plant in March 2011

Yu Morino, Toshimasa Ohara, and Masato Nishizawa

Received 27 June 2011; revised 2 August 2011; accepted 11 August 2011; published 15 September 2011.

[1] To understand the atmospheric behavior of radioactive materials emitted from the Fukushima Daiichi nuclear power plant after the nuclear accident that accompanied the great Tohoku earthquake and tsunami on 11 March 2011, we conducted numerical simulations with the Monte Carlo code SAITEKI. Many numerical simulations were conducted after the Chernobyl nuclear accident in 1986 [Albergel et al., 1988; Hass et al., 1990; Wheeler, 1988], and these simulations helped to clarify the atmospheric behavior of the radioactive materials.
Methodology

Meteorological model (WRF)

Emission of I-131, Cs-137 (hourly, by JAEA)

Chemical transport model (CMAQ)
emission, transport, deposition calculation

simulation domain

Results I-131, Cs-137 concentration, deposition
**Model settings (1/2)**

<table>
<thead>
<tr>
<th><strong>Meteorological model</strong></th>
<th>WRF v3.1 (JMA, MSM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemical transport model</strong></td>
<td>CMAQ v4.6</td>
</tr>
<tr>
<td><strong>Domain settings</strong></td>
<td>237 x 237 x 34 grids ⇒</td>
</tr>
<tr>
<td><strong>horizontal resolution</strong></td>
<td>3 km</td>
</tr>
<tr>
<td><strong>Target species</strong></td>
<td>I-131 and Cs-137 (parameters are given in the next slide)</td>
</tr>
<tr>
<td><strong>Emissions</strong></td>
<td>Updated version of Chino et al. (2011): (Nagai, personal communication, 2011, Figure ⇒)</td>
</tr>
<tr>
<td><strong>Period</strong></td>
<td>10-30 March 2011</td>
</tr>
<tr>
<td><strong>Configuration in CMAQ</strong></td>
<td>✓Tracer calculation (TRC).</td>
</tr>
<tr>
<td></td>
<td>✓No chemical/aerosol processes</td>
</tr>
<tr>
<td></td>
<td>✓Programs in Table 2 are changed:</td>
</tr>
<tr>
<td></td>
<td>✓Process Analysis was used for the budget analysis.</td>
</tr>
</tbody>
</table>

*Emission data and Horizontal resolution are updated from Morino et al. (GRL, 2011).*
Model settings (2/2)

<table>
<thead>
<tr>
<th></th>
<th>I-131</th>
<th>Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radioactive decay</td>
<td>8.02 days</td>
<td>—</td>
</tr>
<tr>
<td>Gas-particle ratio</td>
<td>0.8:0.2</td>
<td>All particles</td>
</tr>
<tr>
<td>Particulate diameters</td>
<td>1 μm</td>
<td></td>
</tr>
<tr>
<td>Dry deposition</td>
<td>Same as “SO₂” for gas</td>
<td>—</td>
</tr>
</tbody>
</table>
Evaluation by comparing with observation

1. **MEXT aircraft monitoring**
   (May-Oct. 2011 in eastern Japan)
   → evaluation of Cs-137 deposition distribution

2. **MEXT scheduled deposition monitoring**
   (since Mar. 18, one place in each prefecture, every 24 hour sampling)
   → evaluation of I-131 & Cs-137 deposition temporal variation

MEXT = Ministry of Education, Culture, Sports, Science and Technology
Aircraft monitoring — evaluation of horizontal distribution

**Observed deposition of Cs-137 (May-Oct. 2011)**

**Simulated deposition of Cs-137 (-Mar. 30, 2011)**
Evaluation of reproducibility of deposition

MEXT scheduled deposition monitoring

For Mar. 18-29 numbers are prefecture names (1, Iwate; 2, Akita; 3, Yamagata; 5, Miyagi; 6, Ibaraki; 7, Tochigi; 8, Gunma; 9, Chiba; 10, Saitama; 11, Tokyo; 12, Kanagawa; 13, Shizuoka; 14, Yamanashi; 15, Nagano; 16, Niigata)
Event analysis① — March 15-16

Cs-137 Deposition (all domain)

Wind direction (Fukushima)

Cs-137 deposition
Event analysis

Mar. 15
9 a.m. (LT)

Mar. 15
6 p.m. (LT)

Mar. 15
12 p.m. (LT)
I brought their poster presentation here, so you can see it in the poster session.
Thank you for your attention