WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

MEETING OF THE WMO TASK TEAM ON METEOROLOGICAL ANALYSES FOR FUKUSHIMA DAIICHI NUCLEAR POWER PLANT ACCIDENT

GENEVA, SWITZERLAND, 30 NOVEMBER – 2 DECEMBER 2011

FINAL REPORT

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EXECUTIVE SUMMARY

The first meeting of WMO Technical Task Team (TT) on Meteorological Analyses for Fukushima Daiichi NPP accident took place at the WMO Headquarters, in Geneva, Switzerland, from 30 November to 2 December 2011. The TT's work is to examine how the use of meteorological analyses, and the introduction of additional meteorological observational data, could improve the atmospheric transport, dispersion and deposition calculations as validated against radiological monitoring data, which at a minimum should contribute to the requirements which the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) stated in its request for assistance from WMO. At the same time, this work should contribute to the review and possible enhancements to the nuclear emergency response system, presently in place.

The TT reviewed and adopted its Terms of Reference, and reported on each of its terms, including: (a) meteorological observational data, (b) meteorological NWP analyses data, (c) gaps in the meteorological analyses, (d) meteorological conditions during the nuclear accident, (e) evaluation of the observational data and analyses, (f) uncertainty of the atmospheric dispersion and deposition calculations, (g) liaison with UNSCEAR, (h) proposal fro enhancements of the WMO EER system. Mr Roland Draxler (RSMC Washington, USA) is named as the Chairperson of the TT.

The TT agreed to focus its work on the period 11 March to 20 April 2011. It developed a bibliography of relevant publications and presentations, stated its current point of view regarding arrangements for sharing of information, and agreed a tentative work plan to the planned completion of the final UNSCEAR study in 2013.

GENERAL SUMMARY OF THE WORK OF THE SESSION

1. Opening

1.1 The first meeting of the Technical Task Team (TT) on Meteorological Analyses for Fukushima Daiichi NPP Accident was opened by Dr Geoffrey Love, Director of the WMO Weather and Disaster Risk Reduction Services Department, on behalf of the Secretary-General of WMO. He expressed appreciation to the experts and their respective organizations for agreeing to contribute to this important work. He noted that while the WMO Environmental Emergency Response (EER) system responded well to the NPP accident during the response phase with real-time meteorological systems, including meteorological analyses and forecasts, and atmospheric dispersion predictions, the current task is to examine how the use of meteorological analyses and the introduction of additional meteorological observational data could improve the atmospheric dispersion calculations as validated against radiological monitoring data. The work of the TT should at a minimum contribute to the requirements which the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has stated in its request for assistance from WMO. At the same time, this work should contribute to the review and possible enhancements to the EER system, which was essentially designed following the Chernobyl nuclear accident of 25 years ago.

2. Adopting of agenda and working arrangements

2.1 Mr Peter Chen of the Secretariat, introduced the Expanded Provisional Agenda, and suggested to the meeting to consider who could act as Chairperson for the Task Team. Mr Roland Draxler (USA), with the unanimous agreement of the participants, agreed to chair the TT and this first meeting.

2.2 The meeting revised and adopted the agenda, which is found in Annex I.

2.3 The list of participants is found in Annex II. The meeting was informed that Mr René Servranckx (Canada), Chairperson of the CBS Coordination Group for Nuclear Emergency Response Activities, had notified the Secretariat that he was unable to attend this meeting.

3. Introduction

3.1 The Secretariat provided background information related to the work of the TT, in particular the request of UNSCEAR to participate in its study on the levels and effects of the radiation released from the nuclear accident at the Fukushima Daiichi NPP.

3.2 This report adopted the acronym “ATM” to refer to “atmospheric transport, dispersion and deposition modelling”, including the numerical simulation systems, and their outputs.

4. Terms of Reference

4.1 The meeting reviewed and revised the TT’s draft Terms of Reference, which is found in Annex III.

5. Relevant period of interest

5.1 Although most of the known atmospheric emissions occurred in the last half of March 2011, the meeting noted that it was difficult to predict the future evaluations that will be performed and that the meteorological data requirements should cover a period from the time of the earthquake - tsunami until the situation had stabilized, 11 March through 20 April, 2011.

5.2 Discharges into the ocean may have occurred over a different time period. Therefore meteorological data may be required by the ocean modeling groups (marine dispersion experts) for a longer period. Other UNSCEAR groups, such as those studying land contamination, may also require data for longer periods. Clarification is needed from the relevant groups. At this point no request was made to the Japan Meteorological Agency (JMA) or other meteorological services, regarding data provision for a more extensive period.

6. Response to the Terms of Reference (ToR)

(a) Meteorological observational data

a.1 The meeting reviewed the meteorological observational data, including from surface, upper-air radiosonde, upper-air wind profiler data, collected by JMA as summarized by K. Saito in Annex IV and determined that all of the data are potentially useful in evaluating the meteorological analyses, and any subsequent dispersion and deposition calculations using the analysis data, and possibly for use by other groups involved in the UNSCEAR assessment. It was proposed that the observational data be supplied in their native JMA binary format along with a description of this format. The archive location is to be determined after consultation with UNSCEAR data working group.

a.2 The meeting agreed that perhaps the most critical element in the deposition calculations was getting the precipitation correct. In this aspect, JMA agreed to provide their Radar/Rain Gauge analyzed precipitation fields available every 30 minutes at 1-km resolution (latitude-longitude, LL, grid), in GRIB2, as summarized by K. Saito in Annex IV.

(b) Meteorological NWP Analyses Data

b.1 The meeting reviewed the meteorological NWP analysis data created by JMA as summarized by K. Saito in Annex V and determined that:

- The 4D-VAR mesoscale analysis, including surface, at 3-hour intervals and 5-km 50-hybrid level resolution (Lambert Conformal, LM, projection), would be the most suitable for local and regional scale atmospheric transport, dispersion and deposition modeling (ATM).
- In addition hourly analysis data from the JMA nowcasting model (3D-Var) (LM projection / 5-km resolution / hourly / GRIB2 / U V T, including AWS data) would also be useful for certain studies.

b.2 JMA has agreed to reprocess these data sets from their internal archive format to GRIB2. The data will remain in the native Lambert Conformal horizontal coordinates on the original model levels.

b.3 Initially these data would be provided to Task Team participants for evaluation purposes and subsequently to UNSCEAR after consultation with their data working group. The archive location is to be determined after consultation with UNSCEAR data working group.

b.4 Although other groups are also creating high resolution meteorological analyses, it is uncertain whether these analyses can approach the level of observational data assimilated by the JMA products. However, other mesoscale analyses could possibly be used in the assessment of uncertainty limits to the critical meteorological fields and their inclusion into any future data archive is encouraged.

b.5 With respect to the global analyses fields, i.e. JMA (Japan), Met Office (UK), NOAA (US), CMC (Canada), and ECMWF (to be provided by ZAMG, Austria) agreed to make their model fields available, initially from their respective centers, but potentially at a common repository after consultation with UNSCEAR. See Annex V.

(c) Gaps in the meteorological analyses

c.1 The meeting agreed that it was difficult to determine what is required to improve the analyses used for the dispersion calculations prior to actually having evaluated these data in any detail. However, one obvious problem emerged in the discussion that the long-range results were very sensitive to precipitation fields and the dispersion model scavenging coefficients.

c.2 NOAA provides estimated precipitation fields derived from CMORPH, see: (http://www.cpc.ncep.noaa.gov/products/janowiak/cmorph.shtml), and ftp://ftp.cpc.ncep.noaa.gov/precip/global_CMORPH/30min_8km/

CMORPH is a technique for generating global precipitation analyses at very high spatial and temporal resolutions (8-km horizontal resolution at hourly intervals) using precipitation estimates that have been derived from low orbiter satellite microwave observations, but there are known retrieval issues over land, problems with frozen precipitation and limitations in orbital coverage. Mr Draxler agreed to investigate their availability and provide these data to the Task Team and UNSCEAR.

c.3 The CMORPH data as well as similar global datasets could potentially be used by ATMs to better represent the precipitation encountered by the plume for long range studies. However, the value of these data has not been tested for atmospheric deposition applications, considering their known limitations.

(d) Meteorological conditions during the nuclear accident

d.1 The meeting reviewed a summary of the meteorological conditions in East Japan for the March 11-26 (2011) period, provided by K. Saito (see Annex VI for an extended discussion). He noted that the primary contribution to the Japan land areas may have occurred within two periods: March 15-16 and March 20-23. The meeting discussed that a preliminary report to UNSCEAR (May 2012) could incorporate an expanded discussion of these events building upon the material already provided by JMA.

(e) Evaluation of the observational data and analyses

e.1 The meeting discussed how the suitability of the existing meteorological analyses for ATM calculations could be assessed. The meeting assumed that these calculations would primarily rely upon the meteorological analyses produced by major weather centres rather than the meteorological observations. The meeting decided that the best approach would be to compare radiological plume calculations based upon the different analyses with each other and meteorological and radiological observations. This can be achieved through comparison of predicted and measured patterns or correlations which do not rely upon exact knowledge of the radiological source term beyond what is already established.

e.2 The WMO Secretariat will arrange with CTBTO for radiological measurement data availability and sharing under the framework of cooperation with UNSCEAR. In this context, the task team members assume that radiological data obtained by UNSCEAR will be available to the team for the support task as well as any scientific papers that result from these evaluations.

e.3 The meeting agreed that the mesoscale analysis provided by JMA (see b.1) would be used to run their ATM calculations in addition to their existing simulations with global analyses (ECMWF, NCEP, CMC, Met Office UK). Because wet deposition was recognized as a major source of uncertainty, consideration will be given on how to best use the JMA high resolution precipitation analysis (1-km, 30-min).

e.4 The chairperson presented to the meeting a possible framework for conducting the ATM simulations independent of any emission assumptions. The computational scheme was based upon creating multiple ATM runs for specific time intervals using a unit emission rate that can later be multiplied with any time varying emission scenario without having to rerun the ATMs. The meeting agreed to use this framework as a reference and produce output fields in accordance with the scheme. Technical details are provided by the chairperson, included in Annex VII. Mr Draxler also agreed to host a web page (see: http://ready-testbed.arl.noaa.gov/READY_fdnpp.php for a prototype) that will include the modeling results from the other participants.

e.5 The meeting discussed possible ways to evaluate the different ATM results against the measurements. It was agreed that the DATEM framework (http://www.arl.noaa.gov/DATEM.php) created by NOAA would be the most efficient approach to perform this comparison. ZAMG agreed to convert the radiological measurement data to the DATEM format, and NOAA agreed to investigate how these measurement data could be incorporated into the computational framework.

(f) Uncertainty of the atmospheric dispersion and deposition calculations

f.1 The meeting discussed the various uncertainties involved in the calculation of dispersion and deposition. Although suitable meteorological analysis data sets have been identified, there will always be some uncertainty regarding the meteorological parameters at any one point in space and time because the data analysis fields are snapshots in time which are averaged over grid cells with underlying complex terrain. Most of the time, the prevailing flow direction was offshore away from the existing land-based monitoring network. The remaining significant releases with on-shore flow were related to complex meteorological situations (see Section 6 (d)) with rapidly changing wind direction and variable precipitation patterns. Model derived wet deposition calculations carry large uncertainties and therefore observed precipitation fields need to be incorporated into the calculations.

f.2 The meeting proposed the use of the results from the framework discussed in the previous section to address uncertainties described above. The framework allows for the comparison of multiple model results either with different meteorological analyses using the same ATM model or, the same meteorological analysis using different ATMs. This would provide an estimate of the range of possible air concentration and deposition values,

(g) Liaison with UNSCEAR

g.1 The meeting noted that the proposed modeling framework did not require a precise knowledge of the emissions and in fact could be used by UNSCEAR to optimize the emissions to match the measurement data. However for certain model comparisons, it would be desirable to have an estimate of the temporal variation of the emissions. The Task Team would rely upon advice from UNSCEAR source term group to propose a scenario that can be used for meteorological model evaluations.

g.2 As was already discussed in the previous section, the most appropriate way to evaluate meteorological analyses in this case is to compare the ATM outputs based upon these analyses with radiological measurement data. In that aspect, the Task Team would rely upon the UNSCEAR data group to provide access to the appropriate measurement data.

g.3 The group agreed to provide UNSCEAR access to the model comparison framework and/or to the individual ATM calculations.

g.4 The working arrangements between UNSCEAR Expert Group B and the WMO Task Team will initially be coordinated through the chairpersons from each group. However, it is expected that the groups would meet as needed to discuss technical issues, either through Telecon or Webex meetings if possible.

(h) Proposal for enhancements of the WMO EER system

h.1 The meeting agreed that the results of the Task Team are important in the consideration of future EER products and services.

7. Bibliography

Source Estimation

- Chino, M. et al., 2011. Preliminary Estimation of Release Amounts of 131 I and 137 Cs Accidentally Discharged from the Fukushima Daiichi Nuclear Power Plant into the Atmosphere. *Journal of NUCLEAR SCIENCE and TECHNOLOGY*, 48(7), pp.1129–1134.
- Stohl, A. et al., 2011. Xenon-133 and caesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion and deposition. *Atmos. Chem. Phys. D.*

Radiological Observations

- Masson, O. et al., 2011. Tracking of Airborne Radionuclides from the Damaged Fukushima Dai-Ichi Nuclear Reactors by European Networks. *Environmental Science & Technology*, 45(18), pp.7670–7677.
- Tagami, K. et al., 2011. Specific activity and activity ratios of radionuclides in soil collected about 20km from the Fukushima Daiichi Nuclear Power Plant: Radionuclide release to the south and southwest. *Science of the Total Environment*, 409(22), pp.4885–4888.
- Kinoshita, N. et al., 2011. Assessment of individual radionuclide distributions from the Fukushima nuclear accident covering central-east Japan. *Proceedings of the National Academy of Sciences*.

Dispersion and Deposition Modeling

- Yasunari, T. et al., 2011. Cesium-137 deposition and contamination of Japanese soils due to the Fukushima nuclear accident. In *Proceedings of the National Academy of Sciences*. Proceedings of the National Academy of Sciences.

Presentations

- *EUROSAFE Forum 2011, Brussels, November 5th to 6th, 2012. http://www.eurosafe-forum.org/eurosafe-forum-2011*
- *Presentations at the special session "Current status and subjects of the radionuclide transport models" at the autumn meeting of the Meteorological Society of Japan (MSJ, http://msj.visitors.jp/notification/pdf/A2011oral_20110909.pdf), including:*

  - Tanaka, T. et al., Global transport model using MASINGAR.
  - Kajino, M. et al., MRI regional chemical transport model using NHM-Chem.
  - Maki, T. et al., Emission flux estimation by inverse model.
  - Tsuruta, H. et al., Regional Deposition of Radioactive Cs and I by the Accident of the Fukushima Daiichi NPP.
  - Takemi, T. and H Ishikawa, High-Resolution modeling analyses of wind and diffusion fields over Fukushima.
  - Kondo, H. et al., Transport and deposition analysis by AIST-MM.
  - Takigawa, M. et al., Deposition estimation using WRF/Chem.
  - Kato, M. et al., Transport and diffusion simulation using CReSS.

8. Arrangements for sharing information

8.1 The meeting noted that the creation of a central data repository for all meteorological and ATM products considered by the Task Team is not currently feasible. The Task Team noted that UNSCEAR would address the data repository issue in their data sharing plan.

8.2 With respect to the data, it is expected that all data collected and generated in this effort will be shared between UNSCEAR and the Task Team.

8.3 The meeting noted that all results generated by the Task Team will become publicly available, either through the web or scientific publications.

9. Work plan and timetable

16 January 2012 - Task Team Meeting Report (Draxler and Secretariat)

30 January – 3 Feb 2012 – UNSCEAR work group meeting

Week of 6 February - TT teleconference (to revise work plan and timetable)

March 2012 – sample mesoscale analysis available from JMA (Saito)

April 2012 – TT to provide preliminary ATM results for the full period (11 March to 20 April 2011) to NOAA (Draxler) in the model evaluation framework format.

23 April 2012 – TT meeting

14 May 2012 - Preliminary TT report to UNSCEAR on meteorological analyses and ATM results

21 May 2012 – 59th session UNSCEAR progress and preliminary report

June 2012 - meteorological data and NWP analyses from TT members will be ready for sharing within TT

July 2012 – ZAMG (Wotawa) to provide available measurement data in DATEM format

October 2012 – TT to complete and provide ATM results using JMA meso-analyses within TT

November 2012 – NOAA (Draxler) to provide DATEM statistical results linked with model evaluation framework

December 2012 – TT meeting

March 2013 – TT to provide draft final report on meteorological analyses and ATM results

April 2013 – Final TT report provided to UNSCEAR on meteorological analyses and ATM results

May 2013 – 60th session UNSCEAR report

10. Closing

10.1 The first meeting of the Technical Task Team (TT) on Meteorological Analyses for Fukushima Daiichi NPP Accident closed at 17:15 on Friday, 2 December 2011.

ANNEX I

Agenda

1. **Opening**
2. **Adopting of agenda and working arrangements**
3. **Introduction**
4. **Terms of Reference**
5. **Relevant period of interest**
6. **Response to the Terms of Reference (ToR)**
7. **Bibliography**
8. **Arrangements for sharing information**
9. **Work plan and timetable**
10. **Closing**

ANNEX II

List of Participants

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ANNEX III

WMO Technical Task Team on Meteorological Analyses – Fukushima Daiichi NPP Accident

Terms of Reference

Membership and Chairperson

- Roland Draxler, Chairperson (RSMC Washington, USA)
- Matthew Hort (RSMC Exeter, UK)
- Gerhard Wotawa (RSMC Vienna, Austria)
- Kazuo Saito (Meteorological Research Institute, Japan Meteorological Agency, Japan)
- René Servranckx (Chairperson of CBS Coordination Group on Nuclear ERA, RSMC Montreal, Canada)

Terms of work

(a) Determine the relevant meteorological observational data sets and related information required to support the meteorological analyses and identify their archive location and availability;

(b) Determine which of the existing meteorological analyses are of sufficient spatial and temporal detail that can be used to estimate the atmospheric transport, dispersion, and surface deposition of radionuclides that were released from the nuclear accident and identify their archive location and availability;

(c) Identify gaps in the existing meteorological analyses that if addressed would make them more suitable for estimating atmospheric transport, dispersion, and deposition and in coordination with the WMO Secretariat, identify which members will provide updated analyses;

(d) Based upon the observational data and analyses, prepare a report on the temporal and spatial variations in atmospheric conditions during the nuclear accident;

(e) Evaluate the suitability and quality of the observational data and meteorological analyses for computing atmospheric transport, dispersion, and surface deposition by comparing the computational results with radiological measurements;

(f) Estimate the uncertainty in the atmospheric transport, dispersion and deposition (ATM) computations by comparing the results from several different ATMs and using different meteorological analyses;

(g) Liaise and assist where possible with the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), in their study on the levels and effects of exposure due to the Fukushima Daiichi nuclear accident.

(h) Propose possible enhancements to the WMO EER system, including additional products and/or additional modes of operation with the relevant international organizations.

Duration and working arrangements

It is anticipated that the work of the Task Team would commence immediately, and span a period of 12 -18 months. The Team will work mainly by e-correspondence, and meet face-to-face, as needed. WMO Secretariat will facilitate the work of the team.

ANNEX IV

Table A4.1 - Meteorological observational data collected by JMA

Data name	Number of point	Duration	Data amount	levels	Elements
AWS (Fig. A4.1)	1300	10-minute: hourly, daily	Total amount of data 10-minute: 18GB (2003-2011) hourly & daily: 22GB (1976-2011) Shorter time periods are available	1	Precipitation amount (10-minute, hourly, daily), daily maximum precipitation (10-minute, hourly)
	800			1	temperature, wind speed/direction, sunshine duration (10-minute),
	300			1	Snow depth (hourly), snowfall depth (hourly, daily), maximum snow depth (daily)
Note of precipitation	150		16MB/month	1	Kinds of precipitation phenomenon, start/end time of the phenomenon, etc. (written in Japanese)
Radiosonde (Fig. A4.2)	16	twice a day	2MB/month	25	altitude, temperature, relative humidity, wind direction, wind speed and passing time at 25 standard level
			temperature/relative humidity: 8MB/month wind direction/speed: 5MB/month	variable	temperature/relative humidity, wind direction/speed at significant level
Wind profiler (Fig. A4.2)	31	every 10 minutes	50KB/day	variable	Wind direction, Wind speed, Vertical speed Signal to noise ratio

Table A4.2 - Precipitation analysis of radar and raingauge observations

Data name	Domain size	Map projection	Resolution	Duration	Data amount (Daily)	levels	Elements
Radar /Rain gauge-Analyzed Precipitation	2560x3360 (SW:20N 118E, NE:48N 150E)	LL	1km (0.0125x0.008333)	Twice an hour	0.375MB (18MB)	SURF	RAIN

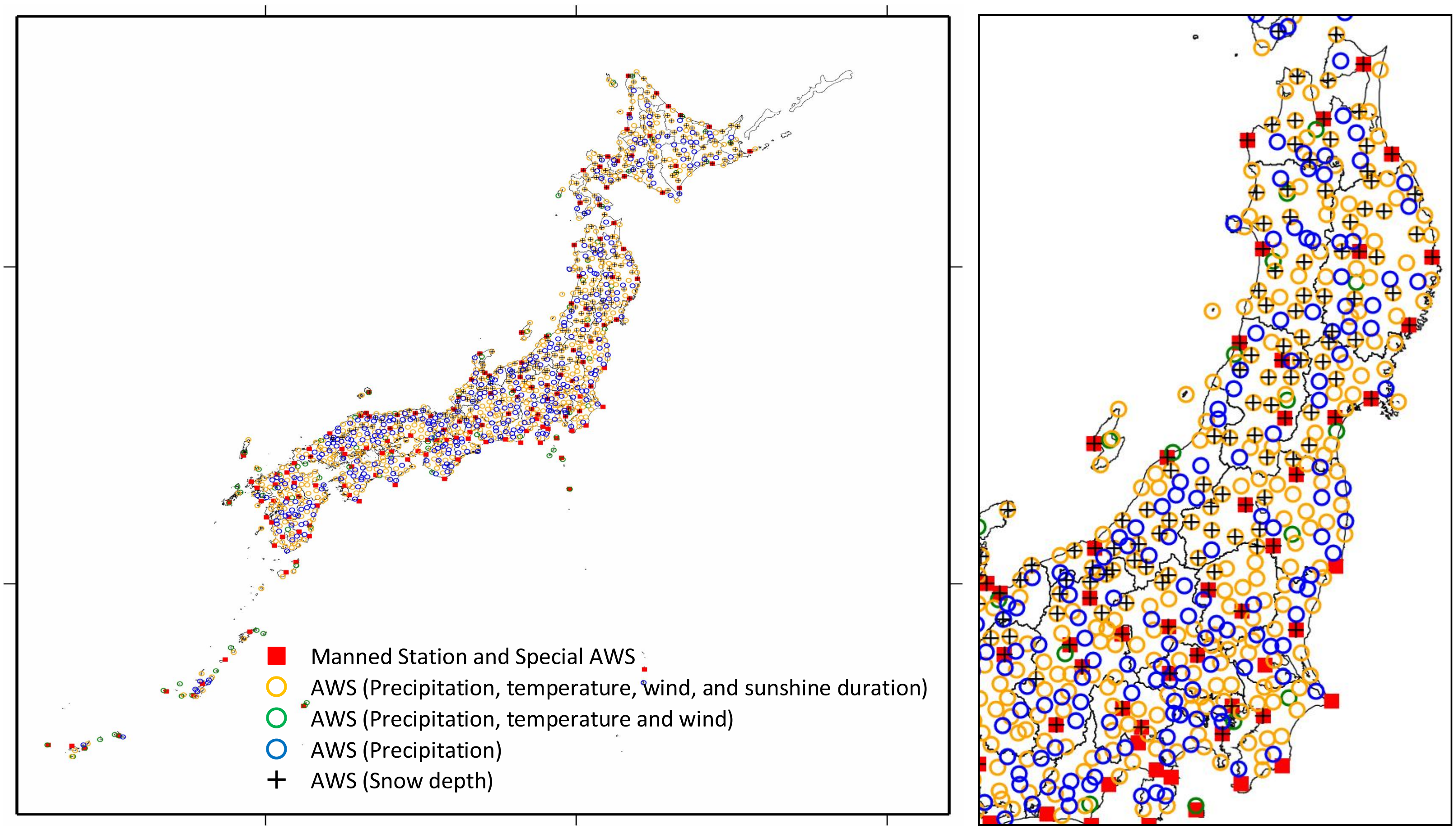

Fig. A4.1 - Left: Distribution of surface stations in Japan. Right: Enlarged view in East Japan.

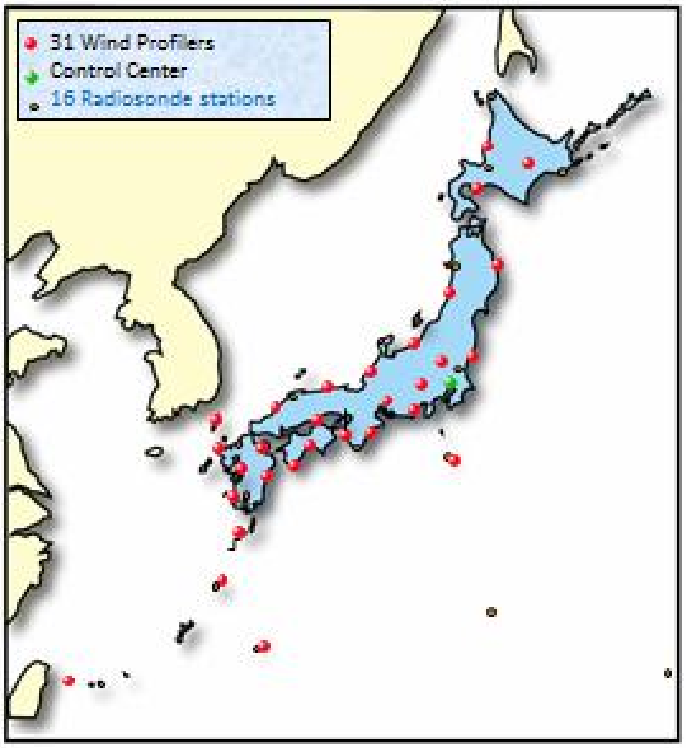

Fig. A4.2 - Left: Upper observations in Japan. Right: Radar observations by JMA.

ANNEX V

Meteorological NWP Analysis Data

Table A5.1 - Regional Meteorological NWP analysis data created by JMA

Data name	Plane	Num of layers	Method	Domain size	Map projection	Resolution	Output interval	Data amount (Daily)	Levels	Elements
Meso analysis	Model	50	4DVAR	721x577 (SW:19.66N 117.74E, NE:47.71N 156.16E)	LM (Lambert conformal)	5km	3 hourly	600MB (4800MB)	z*-z hybrid coordinate (lowest level: 20m, model top: 21.8km)	ZS SL FLAT FLON PAIRF DNSG2 RU RV RW PT TIN(4 layers) QV QC QR QCI QS QG ETURB PRS PSEA
Meso surface analysis	Surface	1		721x577 (SW:19.66N 117.74E, NE:47.71N 156.16E)	LM	5km	3 hourly	15MB (120MB)	SURF	TUGDG(4 layers) KINDG SST KIND TUGD(4 layers) JFLG HRAIN CLD TBB CVT ETOP PARM
Hourly analysis	P	17	3DVAR	721x577 (SW:19.66N 117.74E, NE:47.71N 156.16E)	LM	5km	hourly	43MB (1032MB)	SURF 1000 975 950 925 900 850 800 700 600 500 400 300 250 200 150 100	U V T

Table A5.2 - Global Meteorological NWP analysis data

Centre + Data name	Plane	Num of layers	Method	Domain size	Map projection	Resolution (Long-Lat degrees)	Output interval	Data amount (Daily)	Lowest 10 levels	Elements
JMA, Global analysis (Global)	Hybrid sigma-pressure	60 up to 0.1 hPa (16 input for ATM)	4DVAR	T_L959 (TL319 input for ATM)	LL	0.1875 (0.5625 input for ATM)	6 hourly	132MB (input for ATM)	SURF, 1000, 925, 850, 700, 600, 500, 400, 300, 250 hPa (input for ATM)	U V T Z RH OMG P(surface) PHI(surface)
ECMWF, Global analysis	Hybrid pressure	91 up to 0.01 hPa	4DVAR	T1279	LL (for standard products)	0.125 (for standard products). Fields can be requested at lower res	3 hourly	Depends on area, res and field set	1012, 1009, 1005, 1000, 993, 986, 977, 966, 954, 940 hPa (w.r.t. reference surface pressure of 1013.25 hPa)	All standard 3-d and 2-d fields required by a dispersion model + wide variety of other fields.
UK Met Office, Global UM analysis	Hybrid height above ground	70 up to 80km	4DVAR	1024 x 769	LL	0.3515625, 0.234375	3 hourly	354 Mb (12 Gb un compres sed)	SURF, 10.0, 36.7, 76.7, 130.0, 196.7, 276.7, 370.0, 476.7, 596.7 m agl	3d: U, V, W, T, Q, QCL, QCF, P + variety of 2d fields
NOAA, Global analysis	Hybrid sigma-pressure	56	3DVAR	720x361	LL	0.5	3 hourly	500 MB	Delta hPa: 4, 5, 7, 8, 9,10,11,12,14,16,18	U V T Z Q + variety of 2-d surface fields
CMC, Global analysis	Eta	58	4DVAR	801 x600	LL	0.3	6 hourly	1.0 GB (for 4 cycles)	1.0 .995 .985 .9733 .9606 .9477 .9316 .9151 .8973 .8780	U V T GZ P0 HU HR ES WE + variety of surface fields
	Hybrid	80	4DVAR	801 x600	LL	0.3	6 hourly	1.6 GB (for 4 cycles)	1.0 .995 .985 .974 .961 .947 .932 .916 .898 .879	U V T GZ P0 HU HR ES WE + variety of surface fields

ANNEX VI

Meteorological conditions in East Japan for the March 11-26, 2011

1) Synoptic weather pattern:

After the passage of a weak pressure trough over East Japan from 9th to 11th a high pressure system moved eastward along the south coast of the main island of Japan from 11th to 13th. A weak low pressure system moved eastward off the south coast of the main island from 13th to 15th, and moved toward the northeast while developing rapidly after 15th. A low pressure system passed from 20th to 22nd over main island. (Fig. A6.1)

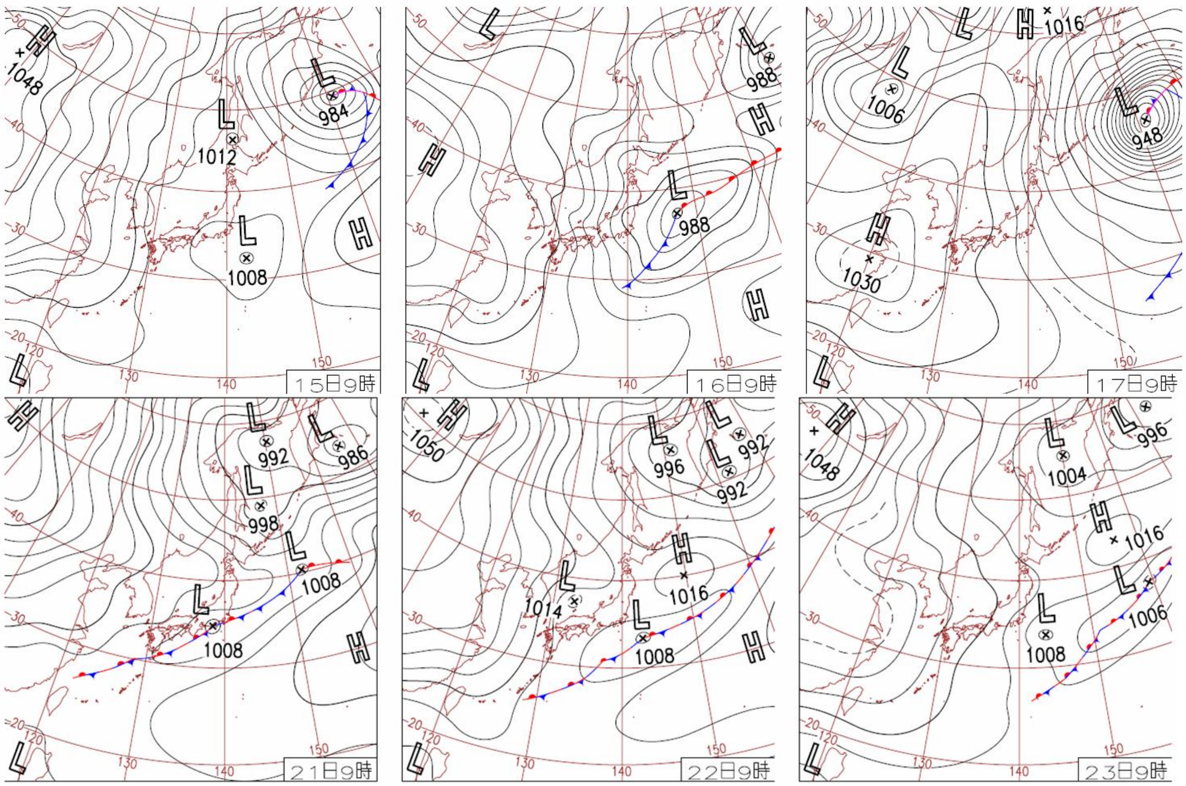

Fig. A6.1 - Surface weather chart at 0000 UTC (0900 JST) from 15 to 17 (upper) and from 21 to 23 (lower), March 2011.

2) Precipitation over east Japan:

Light rains were observed from 9th to 12th morning due to passage of a weak pressure trough over East Japan. Light rains were also observed from 15th to 17th morning due to a weak low pressure system which moved eastward off the south coast of the main. Moderate rains were given in the Kanto area from 20th to 23rd by a low pressure system which passed over the main island of Japan. (Fig. A6.2)

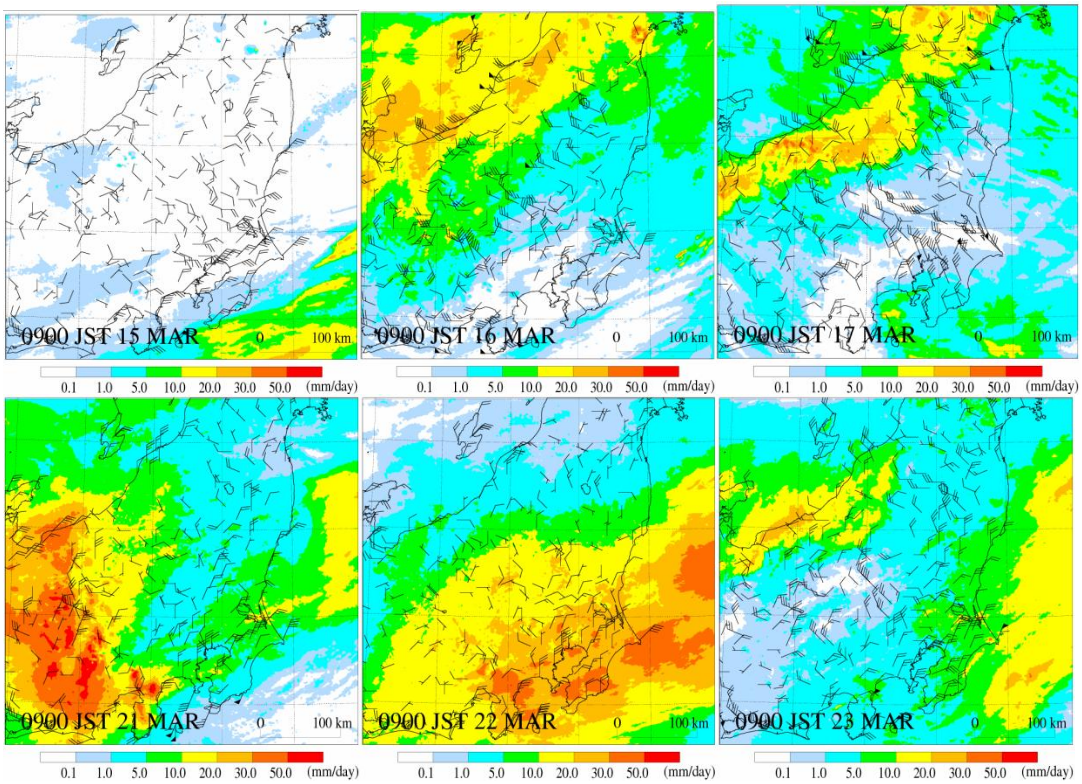

Fig. A6.2 – 24-hour accumulated precipitation amount and observed surface winds at 0000 UTC (0900 JST) for 15-17 (upper) and for 21-23 (lower), March 2011.

3) 950 hPa winds on March 15 by the mesoscale analysis of JMA:

The 950 hPa winds were westerly until the morning of 15^{th}, but changed to NN-Easterly during the daytime of the 15^{th}. After 1500 JST, the winds turned ES-Easterly, and then changed to Northerly after 0000 JST on the 16^{th} (Fig. A6.3).

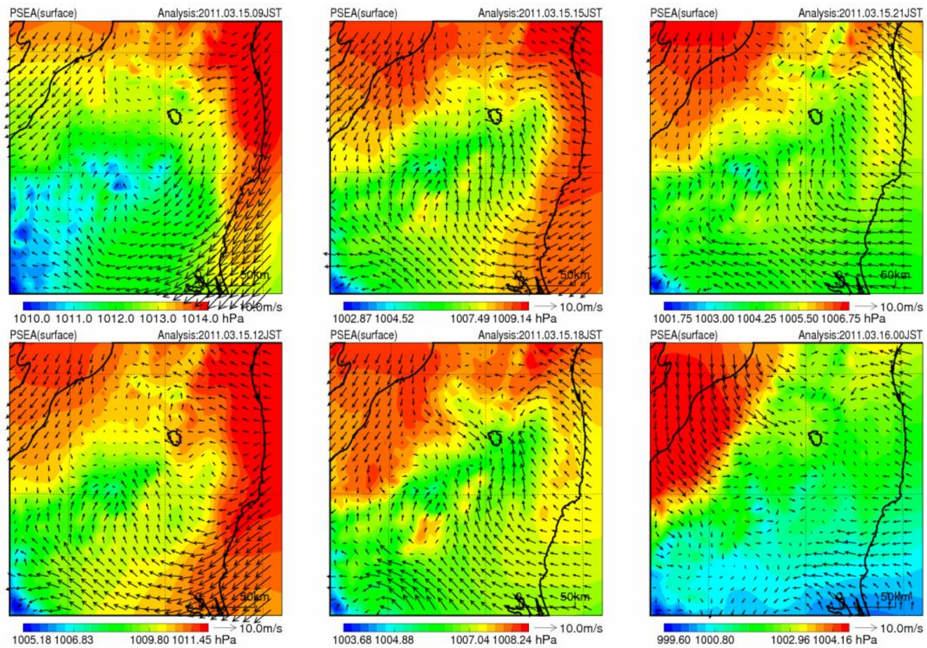

Fig. A6.3 – 950hPa winds (arrows) and mean sea level pressure (colour shade) by mesoscale analysis of JMA for 0000 UTC (0900 JST) – 1500 UTC (0000 JST), 15 March 2011.

4) Winds below 7 km observed at the wind profiler (Mito) nearest to the NPP during the period March 12-20:

The wind direction was southerly below 1 km while westerly above 1 km in the afternoon of March 12 when the hydrogen explosion occurred at the No. 1 reactor. Low level wind was southwesterly during the morning of the 14th when the hydrogen explosion occurred at the No. 3 reactor. Winds below 1 km were N-Easterly during the morning of the 15th when the reactor container burst occurred at the No. 2 reactor (Fig. A6.4).

a)

b)

c)

Fig. A6.4 – Time series of winds below 7 km observed by a JMA wind profiler at the nearest point (Mito). a) From 1200 JST to 2400 JST, March 14. b): From 0000 JST to 2400 JST, March 14. C) From 0000 JST to 2400

JST, 15 March. Horizontal wind direction (barbs) and vertical speed of precipitation or air (colour shade).

5) Summary

The radionuclides were dispersed due to winds and other conditions, and this has been monitored (Fig. A6.5) and confirmed by Ministry of Education and Science and Technology (MEXT). The following two periods may have been the primary contributors to the observed deposition pattern:

- Southwestward transport by northeasterly low level winds from midnight of the 14th to early morning of the 15th and northwestward transport that resulted in the high density deposition pattern during the afternoon of the 15th

- Northward transport in the afternoon of the 20th and southward transport from midnight of the 21st to the early morning of the 22nd.

Modeling results by researchers in Japan generally support the above speculation *(e.g., Yasunari et al., 2011; Kajino et al., 2011; Kondo et al., 2011; Takigawa et al., 2011; Kato et al., 2011)*, but a high deposition area over the middle of the Fukushima prefecture has not yet been well simulated.

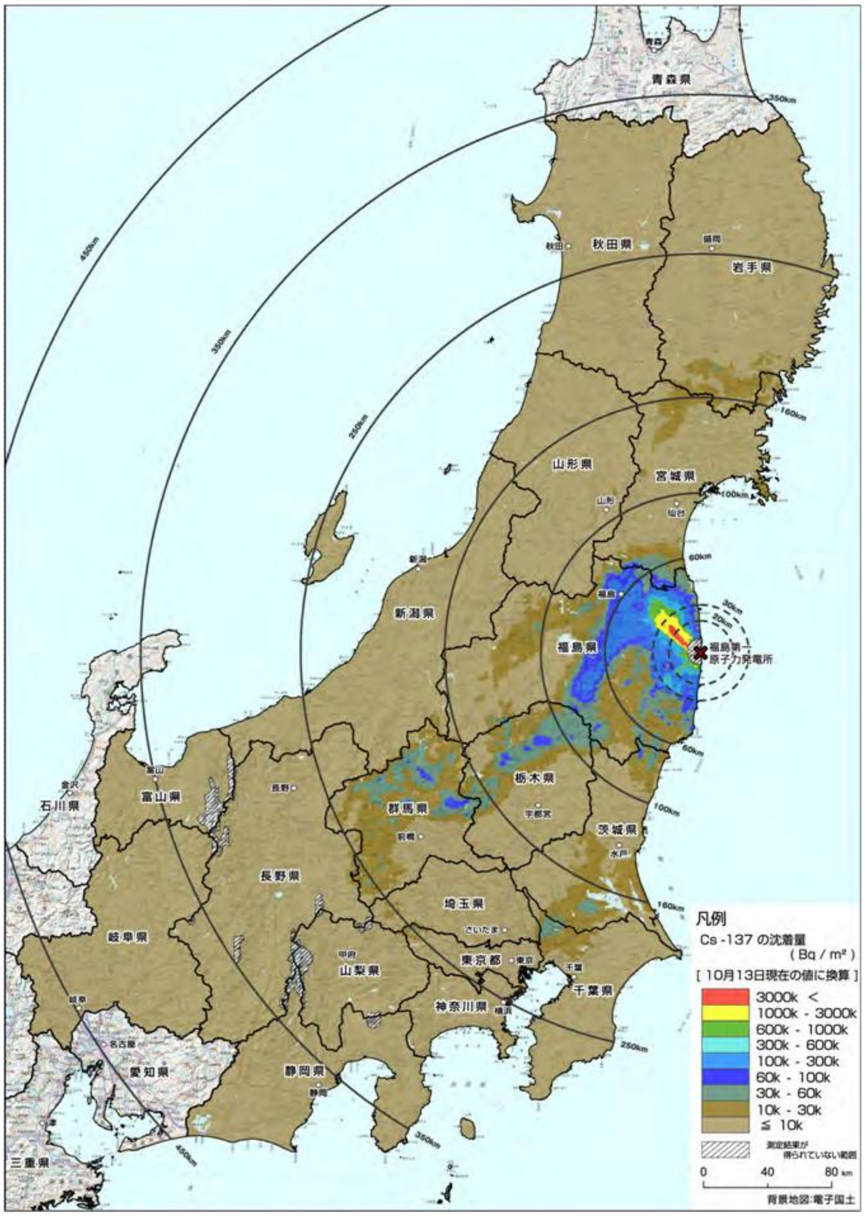

Fig. A6.5 – Regional deposition map of ^{137}Cs in surface soils observed by aircraft monitoring by MEXT (from home page of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan).
(http://radioactivity.mext.go.jp/ja/1910/2011/11/1910_111112.pdf).

ANNEX VII

Computational Framework for the Fukushima Daiichi NPP Accident Simulations

The basic approach to the dispersion-deposition calculations to create an ATM calculation using a unit source rate (1/hr) for discreet emission time segments from the beginning to the end of the computational period. The concentration or deposition at any grid cell in the domain will be the sum of the contribution from each ATM emission segment after multiplying the resulting unit concentrations by the actual emission rate for each segment. Radioactive decay is also applied during this processing step.

- Computational period: 0000Z 11 March 2011 through 0000Z 21 April 2011
- Emission periods: 3-hour segments, 0000-0300; 0300-0600; ...
- Concentration & Deposition: 3-hour average & total, 0000-0300; 0300-0600; ...

The computational period consists of 41 days, each day has 8 emission periods, and therefore 328 independent simulations are required:

- Simulation #1: Emissions 0000Z-0300Z 11 March; Output 0000Z 11 March through 0000Z 21 April (328 output periods)
- Simulation #2: Emissions 0300Z-0600Z 11 March; Output 0300Z 11 March through 0000Z 21 April (327 output periods)
- Simulation # ...
- Simulation #328: Emissions 2100Z-0000Z 21 April; Output 2100Z 20 April through 0000Z 21 April (1 output period)

Three generic species should be tracked as surrogates for the radionuclides: a gas with no wet or dry scavenging, a gas with a relatively large dry deposition velocity and wet removal, and a particle with a small dry deposition velocity and wet removal.

Table A7.1 Summary the computational species

Type	Name	Wet Removal	Dry Deposition	Surrogate for
Gas	Ngas	No	No	Noble gases
Gas, depositing	Dgas	Yes	Yes	I-131
Particle, light	Lpar	Yes	Yes	Cs-137; I-131

The output concentration grid should be a regular spaced latitude-longitude grid where the latitude and longitude grid spacing may be different if desired. Although multiple output levels are possible, to limit the size of the output files, it is proposed that only the data from two levels and three computational species be submitted for evaluation: a level at height "0" m AGL defines the deposition, and a level at "100" represents the average concentration from the ground to 100 m AGL. Two concentration grids are suggested, one for regional simulations and one for global simulations:

Domain	Center Latitude	Center Longitude	Latitude Span	Longitude Span	Spacing Deg Lat	Spacing Deg Lon
Regional	38N	140E	20	30	0.05	0.05
Global	0	0	181	360	0.50	0.50

The file size issues can be significant. For example, a coarser resolution global calculation using a 6-hour emission frequency and a one-degree concentration grid with only one output data level resulted in a space requirement for all files of about 2 GB. For the global grid defined above, one could expect a much larger (4x horizontal, 2x vertical, 2x temporal) space requirement of about 32 GB. The regional grid is expected to require about 10 GB. Output files should be named according to the start of the release time: {Base_Name}_${MM}${DD}${HH}.

The proposed concentration file format follows the convention used by the NOAA ATM (HYSPLIT) and the resulting files would be compatible with all the current web based post-processing routines as well as numerous graphics and other output file manipulation programs available for Windows PC or Mac applications. Concentration files may be written in either packed or unpacked format. Concentration file packing does not write the same information in fewer bytes, but rather writes the same information using twice as many bytes. The packed files are generally smaller because only concentration values at the non-zero grid points are written to the output file by the model. However this requires the grid point location to be written with the concentration, hence the additional bytes. If most of the grid is expected to have non-zero concentrations, then the unpacked format will save space. The output files should be written as unformatted big-endian binary according to the following specification (a sample program will be provided):

Record #1

- CHAR*4 Meteorological *MODEL* Identification
- INT*4 Meteorological file start (*YEAR, MONTH, DAY, HOUR, FORECAST-HR*)
- INT*4 *NUMBER* of starting locations
- INT*4 Concentration packing flag (0=no 1=yes)

Record #2 Loop to record: Number of starting locations

- INT*4 Release starting time (*YEAR, MONTH, DAY, HOUR*)
- REAL*4 Starting location and height (*LATITUDE, LONGITUDE, METERS*)
- INT*4 Release starting time (*MINUTES*)

Record #3

- INT*4 Number of (*LATITUDE-POINTS, LONGITUDE-POINTS*)
- REAL*4 Grid spacing (*DELTA-LATITUDE,DELTA-LONGITUDE*)
- REAL*4 Grid lower left corner (*LATITUDE, LONGITUDE*)

Record #4

- INT*4 *NUMBER* of vertical levels in concentration grid
- INT*4 *HEIGHT* of each level (meters above ground)

Record #5

- INT*4 *NUMBER* of different pollutants in grid
- CHAR*4 Identification *STRING* for each pollutant

Record #6 Loop to record: Number of output times

- INT*4 Sample start (*YEAR MONTH DAY HOUR MINUTE FORECAST*)

Record #7 Loop to record: Number of output times

- INT*4 Sample stop (*YEAR MONTH DAY HOUR MINUTE FORECAST*)

Record #8 Loop to record: Number levels, Number of pollutant types

- CHAR*4 Pollutant type identification *STRING*
- INT*4 Output *LEVEL* (meters) of this record

  No Packing (all elements)

- REAL*4 Concentration output *ARRAY*

  Packing (only non-zero elements)

  INT*4 Number of non-zero elements

- INT*2 First (I) index value
- INT*2 - Second (J) index value
- REAL*4 - Concentration at (I,J)
- ... repeat the above three values: times the number of non-zero elements