B. Overview

B-1. Overview of the WMO Task Team[1]

The World Meteorological Organization (WMO) organized a small Task Team (TT) to respond to a request from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) to assist them with the meteorological aspects of a dose assessment from the radiological releases from the Fukushima Daiichi nuclear power plant accident.

The TT consisted of participants from the Canadian Meteorological Centre (CMC), the U.S. National Oceanic and Atmospheric Administration (NOAA), the Met Office UK (UKMET), the Japan Meteorological Agency (JMA), and the Austrian Zentralanstalt für Meteorologie und Geodynamik (ZAMG) (Table B-1-1). A representative from the European Commission Joint Research Centre's ENSEMBLE project (Ispra, Italy) was later invited to participate in the data analysis phase of the effort.

The TT's primary mission was to examine how the use of enhanced meteorological analyses and the introduction of additional meteorological observational data, could improve atmospheric transport, dispersion and deposition calculations. Although the direct evaluation of meteorological analyses is possible by comparing weather observations with the analyses, the TT members agreed that the best way to evaluate the suitability of the various meteorological analyses for the assessment was to actually use the meteorological data in Atmospheric Transport Dispersion and Deposition Models (ATDM) and compare the model predictions against radiological monitoring data, total accumulated deposition as well as time-varying air concentrations at a few locations.

Naturally the evaluation of the ATDM calculations relies not only upon the meteorological data, but also upon the time varying source term used in the calculation, a preliminary version of which was provided to the TT by the UNSCEAR source reconstruction group.

The methodology for evaluating the meteorological analyses by computing the dispersion and deposition and comparing these calculations with measurement data was designed during the first meeting (WMO, 2011; see I-1) of the TT and then updated during the TT's second meeting (WMO, 2012a; see I-2). The general approach was that each of the TT participants would run their own ATDM using the meteorological data analysis fields already available to them and, if possible, the higher spatial and temporal resolution fields provided by JMA (see C-3). The ATDM calculations were standardized as much as possible in terms of input and output parameters but each ATDM would retain its unique treatment of the meteorological input data, dispersion, and deposition computations, thereby providing a range of possible solutions due to variations in model parameterizations as well as the driving meteorological analysis data (see D-1).

At the conclusion of the TT's efforts, 20 simulations using different ATDM-meteorology combinations were available and 18 of these were used in the final analysis. The meteorological analyses, the individual ATDM air concentration and deposition calculations, and various ensemble

[1] R. Draxler, M. Hort, A. Malo, K. Saito, R. Servranckx, and G. Wotawa

mean calculations were made available to UNSCEAR community as described in the third and final meeting report (WMO, 2012b; see I-3) which also has been published (Draxler et al., 2013).

Because all of the TT ATDM calculations were done using a constant unit-source emission rate during the respective time window (3 hours), varying the source term between the time windows did not require re-running any of the ATDM calculations. The preliminary source term used in the WMO evaluation was not the same as the final source term adopted by UNSCEAR (2013; 2014), and after the completion of the TT efforts under the guidance of WMO, the TT continued its work independently to re-compute all of the statistics and graphics (Draxler et al., 2015) using the source term of Terada et al. (2012) (see D-2). In addition, other WMO ATDM modeling centers were invited to add their computations to the NOAA web page summarizing the TT calculations (see D-4).

Table B-1-1. List of the WMO Task Team members.

Name	Country	Affiliation	Remarks
Roland Draxler	United States of America	National Oceanic and Atmospheric Administration (NOAA)	Air Resources Laboratory (ARL) Chairman of the Task Team
Matthew Hort	United Kingdom	Met Office (UKMET)	Research Scientific Manger RSMC Exeter EER
Gerhard Wotawa	Austria	Zentralanstalt für Meteorologie und Geodynamik (ZAMG)	Data, Methods and Modelling Division EER ATDM
Kazuo Saito	Japan	Japan Meteorological Agency (JMA)	Meteorological Research Institute (MRI)
René Servranckx*	Canada	Canadian Meteorological Center (CMC)	Chairman of CBS EER Group
Peter Chen	--	World Meteorological Organization (WMO)	Chief, Data Processing and Forecasting Systems (DPFS) Division Secretary of the Task Team

* Absent at the 1st meeting. Alain Malo (CMC) participated in the 2nd meeting.

B-2. Task Team meetings[1]

B-2-1. The first task team meeting

The Task Team's first meeting was conducted at WMO Headquarters in Geneva from November 30th to December 2nd, 2011.

The following eight items were confirmed as the terms of reference (ToR) for the Task Team:

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 so 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.

Although the period of interest was from 11 March through 20 April, 2011, the Task Team focused their study from 11 – 31 March 2011 because the largest emissions occurred during this early period. The Task Team regarded the JMA 4D-VAR mesoscale analysis meteorological data as the most suitable for local and regional scale simulations.

---

[1] K. Saito, P. Chen and R. Draxler

In the first meeting, JMA presented its observation network, available meteorological fields during the accident period, its numerical weather prediction (NWP) system and mesoscale 4D-VAR, the JMA regional ATM, and other relevant studies in Japan (Section B-3-1).

As one of the main decisions of meeting, JMA decided to prepare its meso-ground surface analysis and meso-analysis data in the original model coordinate system by the end of June 2012 and to be distributed in the GRIB2 format to the other Task Team members.

It was decided that the domain of the regional atmospheric transport dispersion and deposition model (ATDM) experiment should target an area of 30 degrees east-west and 20 degrees north-south (Fig. B-2-1), with horizontal resolution of 0.05 degree (about 5 km). The first meeting report has been uploaded on the WMO website (WMO, 2011; Appendix I-1).

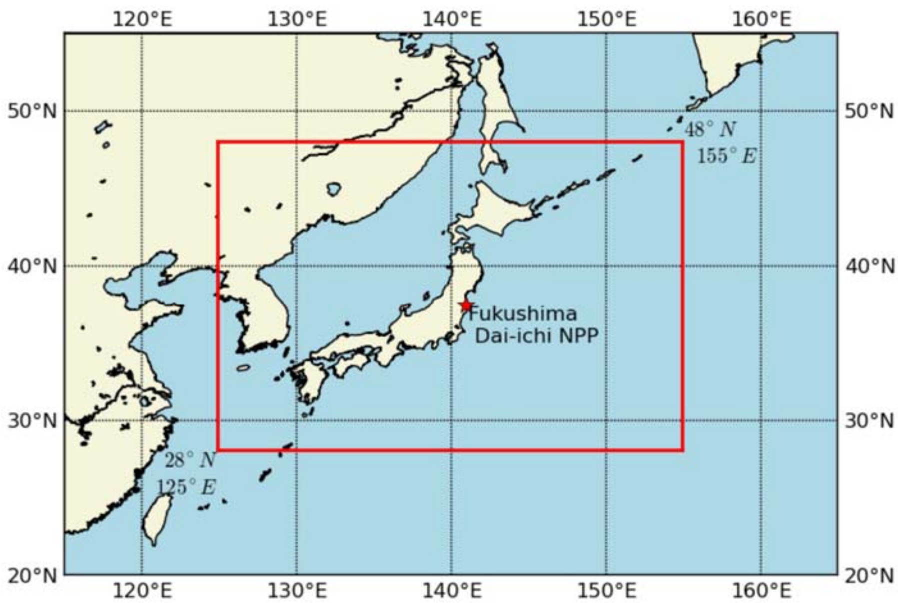

Fig. B-2-1. Domain of regional ATDM experiment of the Task Team. After Draxler et al. (2013a).

B-2-2. The first telephone meeting

A telephone meeting of the Task Team members was held on February 13, 2012. Because some ATDM simulations were already carried out in Group B of UNSCEAR using global analysis data of ECMWF (originally 0.125 degrees), the Task Team decided not to perform global ATDM simulations, but to focus on regional ATDM experiments. It was decided that the period of the experiment would cover 11-31 March 2011 and each simulation would be for a 3 hour emission period followed for up to 72 hours for each radionuclide release. Table B-2-1 shows the basic specifications of ATDM experiment. For further detail of the experiments, see Section D-1.

Table B-2-1. Specifications of the regional ATDM experiment of the Task Team.

		Remarks
Horizontal resolution	0.05 degree (about 5 km)	
Domain	125E-155E, 28N-48N	Fig. B-2-1
Initial time	2011 March 11-31, 3-hourly	Totally 168 times
Forecast time	72 hours	
Emission rate	Unit release (1 Bq/hr)	Linear sum based on estimated release rate is computed
Release height	From ground to 100 m	
Computation	Concentration average from the ground to 100 m AGL and surface deposition for Noble gases (Ngas), Depositional gases (Dgas), Light particles (Lpar)	half - life period is considered for Iodine-131 (^{131}I)

B-2-3. The second Task Team meeting

The Task Team's second meeting was held in the United Kingdom Met Office London Branch on May 1-3, 2012. In addition to the six members of the Task Team, Dr. Florian Gering (Federal Office for Radiation Protection of Germany), Dr. Oliver Isnard (Radiation Protection Nuclear Safety Institute of France), and Mr. Peter Bedwell (UK Health Protection Agency) participated, as experts from the UNSCEAR working groups.

Preliminary runs of the regional ATDMs targeting on March 11 to 31 were presented by the four centers (ATDM NOAA-HYSPLIT, UKMET-NAME, the CMC-MLDP0, and JMA-RATM; see Appendix I-2). From JMA, rainfall analysis data (Section C-4) and mesoscale analysis data (Section C-2) for the whole period were distributed to the meeting attendees. In addition, JMA offered to provide a software tool to convert these files to a latitude-longitude grid, while retaining the vertical hybrid terrain-following grid and also with an option to convert these data to pressure-level surfaces by the end of June 2012 (see Section C-6).

The TT members reviewed and made one modification to its ToR (in paragraph (f)), which is found in Annex III of the meeting report (see Appendix I-2).

B-2-4. The 2nd-4th telephone meetings

On June 7, 2012, the second telephone meeting was held. The regional ATDM simulation results of each team member and assessment methods based on the sampling data were discussed. JMA commented that a file conversion tool proposed in the second meeting would be prepared by the end of June.

On July 23, the third telephone meeting was held. The chairman of the Task Team (Draxler) reported on the meeting of the Expert Group B of UNSCEAR that took place in the previous week. The Task Team confirmed the necessity to finish all ATDM calculations of the Task Team by the end of September.

On October 4, the fourth telephone meeting was held. In addition to the successful NOAA, CMC and UKMET ATDM calculations using the JMA Meso analysis, ZAMG reported that they would use the JMA rainfall analysis in the calculation of wet deposition.

Discussions were held about the Fukushima special Symposium carried out in the 93rd annual meeting of the American Meteorological Society and ATDM intercomparison by Science Council of Japan (SCJ) to target the Fukushima nuclear accident (see Section G-1).

B-2-5. The third task team meeting

The Task Team third meeting was carried out on 3-5 December 2012 at the Austrian Meteorology and Geodynamic Central Research Institute (ZAMG).

Almost all the proposed ATDM calculations were completed, and verification results were shown. As an additional topic, the ensemble analyses of the Task Team's ATDM experiments were prepared and presented by Dr. Stefano Galmarini (EC Joint Research Center). The final report of the third meeting of the Task team (WMO, 2012b) has been uploaded on WMO website (http://www.wmo.int/pages/prog/www/CBS-Reports/documents/FINAL-REPORT-Vienna-Dec2012.pdf, with a detailed description of verification results presented in Annex III. Based on Annex III, a final report of the Task Team activity has been published as the WMO technical publication No. 1120 (Draxler et al., 2013). A summary of the scientific findings obtained in the Task Team activities has been published in a special issue of the Journal of the Environmental Radioactivity (Draxler et al., 2015).

B-3. Overview of JMA's contribution to the WMO Task Team[1]

B-3-1. JMA's presentation at the first Task Team meeting

In the first Task Team meeting (Section B-2-1), JMA presented the following information on its observation, analysis, and prediction systems and summary of the meteorology during the accident period as potential contributions to the Task Team activity:

1) Observation network of JMA (Section C-1-1) and the example of the JMA precipitation analysis rainfall (Section C-4)
2) Characteristic features of the meteorological field in the accident period (Surface weather charts, surface wind field observed by the JMA's AWS network (AMeDAS) with 24-hour accumulated rainfall based on precipitation analysis, and 950hPa wind field from JMA Meso-scale (MESO) analysis (Section C-9)
3) Specifications of the numerical weather prediction products and operational analysis systems of JMA (global and mesoscale forecast-analysis systems) (Section C-7), MESO 4DVAR analysis (Section C-8) and hourly MESO atmospheric analysis, and the list of the data assimilated in the operational analysis systems (Section C-1-2)
4) Introduction of JMA's ATDMs (global ATM for EER; Section G-2) and regional ATM (Section E).
5) Relevant studies at MRI and JMA (Section B-2 and Section G)

As for 5), based on the special session at the autumn meeting of the Meteorological Society of Japan (Kondo et al., 2012), the following nine topics were introduced:

・Global transport model using MASINGAR (Tanaka)
・Regional passive tracer model using WRF (Kajino)
・MRI regional chemical transport model using NHM-Chem (Kajino; Section G-3)
・Emission flux estimation by inverse model (Maki; Section G-5)
・Regional Deposition of Radioactive cesium (Cs) and iodine (I) by the Accident of the Fukushima Daiichi NPP (Tsuruta et al., Univ Tokyo)
・High-Resolution modeling and analyses of wind and diffusion fields over Fukushima (Takemi and Ishikawa, Kyoto Univ.)
・Transport and deposition analysis by AIST-MM (Kondo et al., AIST)
・Deposition estimation using WRF/Chem (Takigawa et al., JAMSTEC)
・Transport and diffusion simulation using CReSS (Kato et al., Nagoya Univ.)

B-3-2. MESO Analysis of JMA

To assist in the regional ATDM calculations, JMA provided their MESO analysis fields to the WMO Task Team and UNSCEAR for the period of 11 to 31 March 2011, at three-hourly intervals and at a 5-km horizontal resolution. The MESO analyses are produced by the operational JMA regional

---

[1] K. Saito, T. Fujita, T. Kato, T. Hara, K. Nagata, Y. Honda and E. Toyoda

non-hydrostatic 4D-VAR system, which assimilates a variety of local meteorological observations, including 16 radio sondes and 31 wind profilers, Doppler radial winds from 16 JMA C-band radars and 9 Doppler radars for airport weather, total precipitable water vapor derived from about 1,200 GPS stations of the Geospatial Information Authority of Japan and satellite data (Section C-1).

One of the unique features of JMA MESO analysis is that the JMA Radar/Rain Gauge-Analyzed Precipitation (RAP) data, based on the JMA radar network and rain gauge observations (see B-3-3 and C-4), is also assimilated in the 4D-VAR. These data are assimilated in hourly time slots in the 3-hour data assimilation windows by the inner loop (simplified nonlinear/adjoint) model with a horizontal resolution of 15 km, and all analysis fields including liquid and solid precipitation are produced by a 3-hour forecast of the non-linear outer-loop model (JMA nonhydrostatic model (JMA-NHM); Saito et al., 2006; 2007; 2012) of the incremental 4D-VAR with a horizontal resolution of 5 km. The JMA-MESO analysis covers Japan and its surrounding area by 719 (x-direction) x 575 (y-direction) grid points on a Lambert Conformal projection (see Fig. 1 of Draxler et al. (2015)) up to about 21 km above ground level (AGL). It has 50 vertical levels, including 11 levels below 1 km AGL. Although the original horizontal and vertical grid configurations of the JMA Mesoscale model and 4D-VAR analysis (JNoVA; C-8) are Arakawa-C and Lorentz types, respectively, for handling simplicity all data on the staggered points (horizontal and vertical wind speeds) are interpolated to the scalar points (position of pressures and potential temperatures) in the data provided to the Task Team.

Figure B-3-1 shows averaged surface precipitation (mm per hour) by JMA-MESO for 15 March 1200-1500 UTC for rain (left), snow (center) and total precipitation (right). The time evolution of 950 hPa winds and mean sea level pressure by JMA-MESO for 15 March 2011 is shown in Fig. C-9-7. One-hour average surface precipitation by JMA precipitation analysis for 15 March 1200-1500 UTC is shown in Fig. B-3-2.

For more scientific details of JMA nonhydrostatic 4D-VAR, see Section C-8.

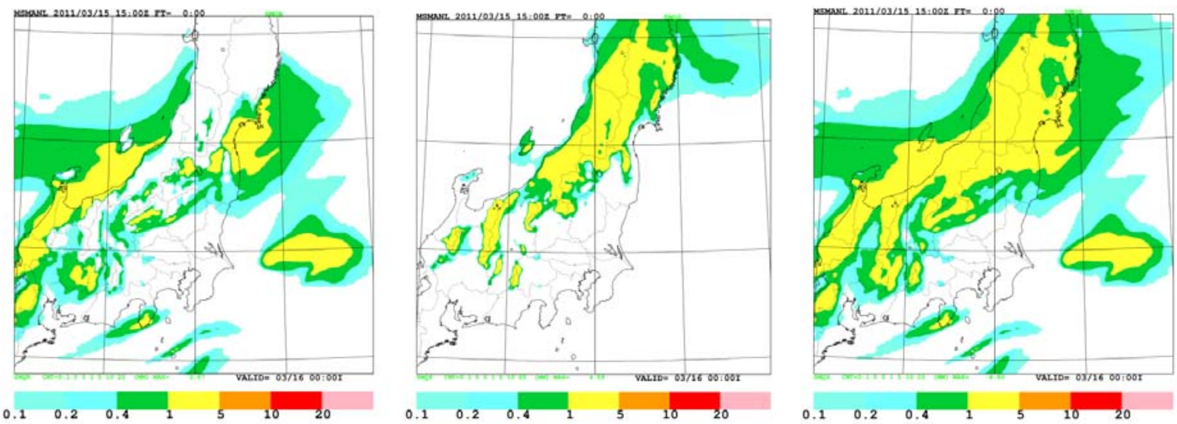

Fig. B-3-1. Averaged surface precipitation (mm per hour) by JMA-MESO for 15 March 1200-1500 UTC. Rain (left), snow (center) and total precipitation (right). After Saito et al. (2015).

B-3-3. Radar/Rain Gauge-Analyzed Precipitation (RAP)

JMA provided the RAP dataset at 30-minute intervals, with a horizontal resolution of 45 seconds (about 1.11 km at 37°N) in longitude and 30 seconds (about 0.93 km) in latitude covering a region from 118-150°E and from 20-48°N (2560 by 3360 grid points). RAP is produced from calibrating radar reflectivity data with one-hour accumulated rain gauge precipitation data. In addition to the JMA network of 20 C-band radars and 1,300 surface observations (Section C-1-1), echo data from additional 26 C-band radars operated by the Ministry of Land, Infrastructure, Transport and Tourism and precipitation data from additional 8,700 rain gauges in Japan are collected in the real-time operation. A more detailed description of the RAP processing is found in section C-4.

JMA-RAP intensities at one-hour intervals for 15 March 1200-1500 UTC are shown in Fig. B-3-2. This illustrates a good agreement between RAP and the JMA-MESO total precipitation (Fig. B-3-1). A circle-shaped very small intense precipitation area is seen around the radar site at Sendai (38.3N, 140.9E) for 1200-1300 UTC (left), which is due to a bright-band observed by the Sendai radar.

For more details of the JMA precipitation analysis, see Section C-4. A documentation of GRIB-2 format of RAP data is given in Section C-5.

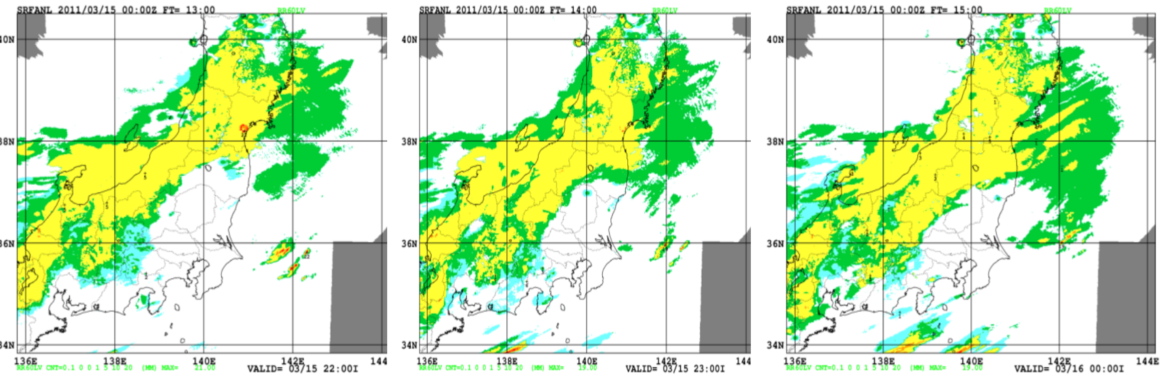

Fig. B-3-2. Rainfall intensity (mm) by JMA-RAP for 15 March. 1200-1300 UTC (left), 1300-1400 UTC (center) and 1400-1500 UTC (right). Colour shade corresponds to Fig. B-3-1. After Saito et al. (2015).

B-3-4. File converter kit and WMO FTP site

JMA provided the MESO and RAP data in GRIB2 format to members of the Task Team and UNSCEAR group B. The MESO data is produced on a Lambert conformal projection in the horizontal coordinate and a terrain-following hybrid vertical coordinate. Furthermore, while the GRIB2 format is officially regulated by WMO as a common format to exchange meteorological data, for some users it is not an easy task to decode and process GRIB2. Considering the situation, JMA also prepared a software tool to read and process the MESO and RAP data. This file converter tool is prepared as a UNIX software kit (C-6) and provides the following three functions;

i) conversion of the GRIB2 format data to the FORTRAN sequential binary format data (GrADS),

ii) re-projection of the data from the Lambert conformal projection to a regular latitude-longitude projection,

iii) conversion of the data from terrain-following hybrid vertical coordinates to an isobaric coordinate at user-specified pressure surfaces.

Figure B-3-3 illustrates the conceptual diagram of the file conversion kit. Both the JMA-MESO and RAP data, detailed instructions, and the above mentioned file converter kit were made available to the UNSCEAR community through a password protected FTP site hosted by WMO. The data were once uploaded on the WMO web server to the scientific community for research purposes, and are still available on the understanding that JMA is acknowledged as the data source.

For more details of the converter kit, see Section C-7.

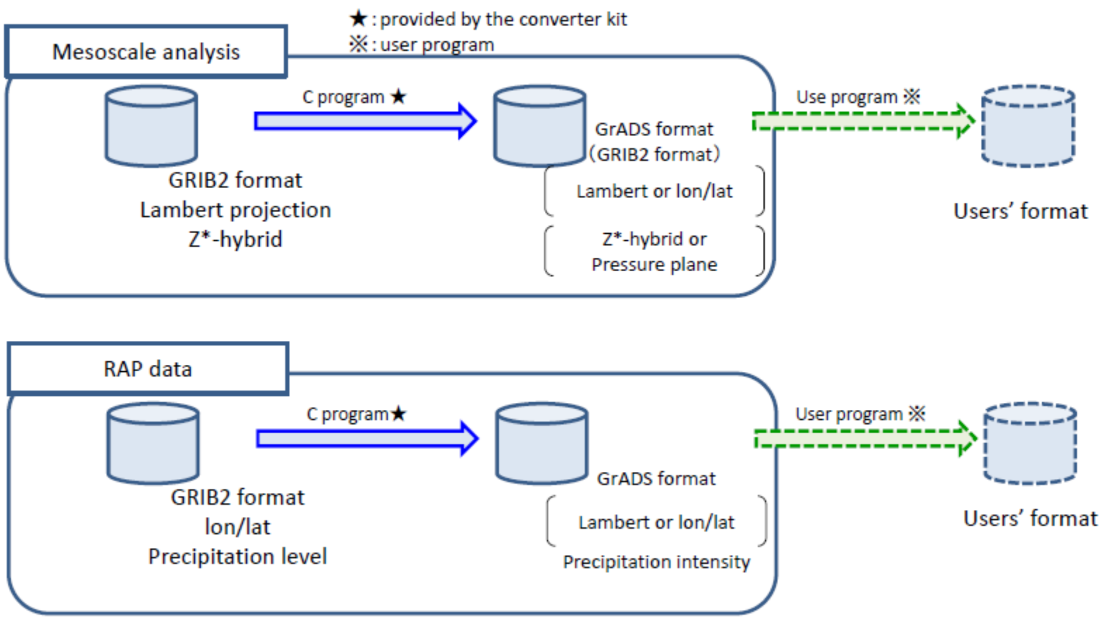

Fig. B-3-3. Conceptual diagram of the file conversion kit provided by JMA. Reproduced from Saito et al. (2015). For more detail, see C-7.

B-4. Offer of Data[1]

The WMO Task Team at its first meeting in Geneva, Switzerland, 30 November - 2 December 2011 (B-2-1 and I-1), determined that all of the observational data collected by JMA are potentially useful in evaluating the meteorological analyses and any subsequent dispersion and deposition calculations using the analysis data, and also, possibly serviceable for use by other groups involved in the UNSCEAR assessment.

Among the observational data, correct precipitation is presumed to be the most critical element in the deposition calculations. In this aspect, JMA agreed to provide its Radar/Rain Gauge analyzed precipitation fields (C-4). Also, the meteorological NWP analysis data created by JMA, namely, the 4D-Var mesoscale analysis (C-2) into which very dense observational data are operationally assimilated, was determined as the most suitable for local and regional scale atmospheric transport, dispersion and deposition modeling (ATDM), while other mesoscale analyses provided by other meteorological centers 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. Thus JMA agreed to provide these dataset along with analyzed precipitation data after reprocessing them from their internal archive format to GRIB2 (C-3 and C-5). The mesoscale analysis data was first encoded in the native Lambert Conformal horizontal coordinates on the original model levels (C-7）.

At the meeting the possibility of improvement of the 4D-Var analysis fields by reanalysis with more observational data was discussed, but finally it was agreed that there is not much room for improvement in the 4D-VAR analysis fields. These data were supposed to be provided to Task Team participants for evaluation purposes and subsequently to UNSCEAR after consultation with their data working group.

At the second Task Team meeting, held in London, United Kingdom, 1 - 3 May 2012 (B-2-3 and I-2), it turned out that the JMA high resolution precipitation analyses (derived from radar and rain gauge data) was not yet applied in the computations by members other than NOAA and JMA due to a technical reason related to its coordinates, and JMA suggested offering data conversion software to promote its usage (C-6).

After preliminary provision of the dataset in May 2012, JMA finally provided its Radar/Rain Gauge analyzed precipitation fields and the 4D-Var mesoscale analysis fields, both in GRIB2 format for the period of 11 – 31 March 2011, along with data conversion software in July 2012. The data set was successfully used by most of the members in their ATDM computations.

The JMA data mentioned above were made available to the UNSCEAR community through a WMO-hosted password protected web site with instructions and a file converter kit for different coordinate systems. The data are available to the scientific community for research purposes with acknowledgement (WMO, 2013).

[1] T. Fujita and Y. Honda