Short-range numerical forecast system supporting the field experiment of cloud seeding

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1. Introduction

Closely-designed short-range numerical forecast system with a high-resolution model in a particular area targeted in a special field observation provides the information on three dimensional distributions of temperature, humidity, wind speed and direction, and liquid and solid hydrometeors which is useful for the observational director planning the experiment in the following day. Such the information also supports the in-situ operators to foresee the behavior of atmosphere and to correctly recognize the environmental condition. The special forecast system involved into the field observation can yield the interactive communication between the observational operators and model developers so as to further improve the numerical model.

In the Meteorological Research Institute (MRI), Japan Meteorological Agency (JMA), a research project is now on progress to examine the feasibility of cloud seeding technique enhancing the snowfall in Echigo Mountains which is the main water reservoir for the Tokyo metropolitan area. We have established a short-range numerical forecast system to specially support an airborne cloud seeding experiment in the project. In this system, we conduct the successive simulations using a three dimensional cloud seeding model with the horizontal resolution of 1 km (1km-NHM). The design of the system and its efficacy will be reported hereafter.

2. Design of a special forecast system supporting the field experiment

a. Cloud seeding model

We have developed a cloud seeding model based on the Japan Meteorological Agency NonHydrostatic Model (JMA-NHM; Saito *et al.*, 2006). The JMA-NHM has five categories of liquid and solid water substances: cloud water, rain, cloud ice, snow, and graupel, as described in Ikawa and Saito (1991). In this study, a two-moment bulk parameterization scheme, which prognoses both the mixing ratio and number concentration, is applied to the categories of solid hydrometeor, while one-moment scheme, which prognoses only mixing ratio, is applied to those of liquid hydrometeor. In addition to the original model specifications, a new module is implemented so as to simulate the airborne cloud seeding with dry ice pellets, introducing the processes of deposition and fall out of dry ice pellets, and artificial ice nucleation. The module also has the other functions to simulate the cloud seeding using liquid carbon dioxide and silver iodide not only from an aircraft but also from the ground-based generators.

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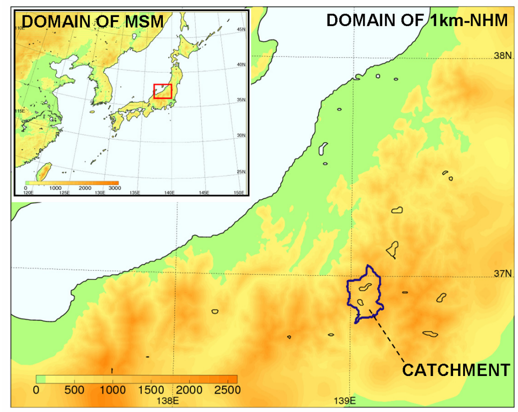

Fig. 1 Domains for the MSM and 1km-NHM.

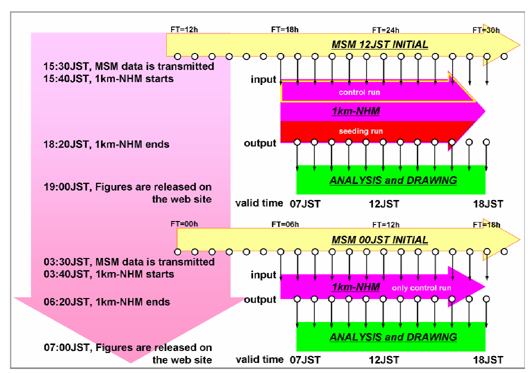

Fig. 2 The sequence of simulation and data handling.

b. Procedure of successive simulations

The numerical forecast data of the JMA mesoscale model with a 5-km horizontal resolution (MSM) is specially forwarded from the JMA headquarter for the project. The 1km-NHM is embedded into the MSM domain, as shown in Fig. 1. Figure 2 shows the sequence of simulation and data handling. The 12-hours control (no seeding) forecast for daytime (06-18 JST, JST = UTC + 9 hours) is performed twice a day using the MSM forecasts with the initial time of 00 JST and 12 JST as the initial and boundary conditions. The simulation for each forecast day finishes around 06 JST at that day and around 18 JST in the previous day, since those simulations are preferentially executed in the super computer system of the MRI. In an hour after then, the final output in the form of figures is presented on the web site for the field experiment.

For the forecast involving cloud seeding, we have made up an optimally positioning scheme that empirically estimates the seeding position maximizing the seeding effect on the surface snowfall in a targeted dam catchment for a given atmospheric condition. The scheme is established based on the sensitivity experiments in which cloud seeding simulations are conducted changing the distance from the dam site to the seeding position along the environmental wind direction for each of 14 different cases to find the optimal seeding position (Hashimoto *et al.*, 2008a). After the control forecst for the next day finished around 18 JST, the seeding forecast is conducted with the same initial and boundary conditions. The seeding rate of dry ice pellets is set to 3 kg min^{-1}. The flight speed of seeding airplane is assumed to be 100 ms^{-1} in the model. The cloud seeding starts one-hour after the launch of simulation and continues until the end (07-18 JST).

3. Available information

a. Basic information

The information on the patterns of pressure, temperature, water vapor, wind and surface precipitation is presented twice a day on the web site. The information in the evening is useful to make a plan for the experiment in the following day, and that in the morning will be a help for a decision on the operation at that day.

For the cloud seeding, it is the most important to know whether the super-cooled cloud appears upstream the targeted area. In addition, it is a clue for the evaluation of seedability (how preferable the atmospheric situation is for the cloud seeding) to know how much glaciated the clouds to be seeded are in the natural. For those purposes, the hourly distributions of liquid and solid hydrometeors, temperature, and humidity in the vicinity of the seeding area are provided, based on the control forecast.

b. Special information for cloud seeding operation

Hashimoto *et al.* (2008b) found the relationship between the seedability and meteorological parameters from the results of the hindcast experiment through the winter seasons of 2005/06 and 2006/07. This relationship enables us to provide the guidance on the seedability for the cloud seeding operators, based on the control forecast. In addition to the seedability, the optimal seeding position which is determined with the optimally positioning scheme is included in the guidance, as shown in Fig. 3.

The predicted seeding effect on the surface precipitation is also presented on the web site by subtracting the result of the control forecast from that of the seeding one, as shown in Fig. 4.

4. Discussions and summary

The short-range numerical forecast system with a three dimensional cloud seeding model is able to provide the useful information for the cloud seeding experiment. The optimally positioning scheme applied in the present study still has a room open to discussion in terms of the accuracy of determined position, as pointed out in Hashimoto *et al.* (2008a). The authors plan to further improve the system so as to apply into the future operational project.

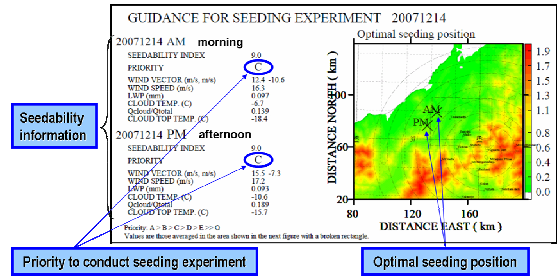

Fig. 3 Guidance on seedability, provided on 14th December, 2007 in the IOP.

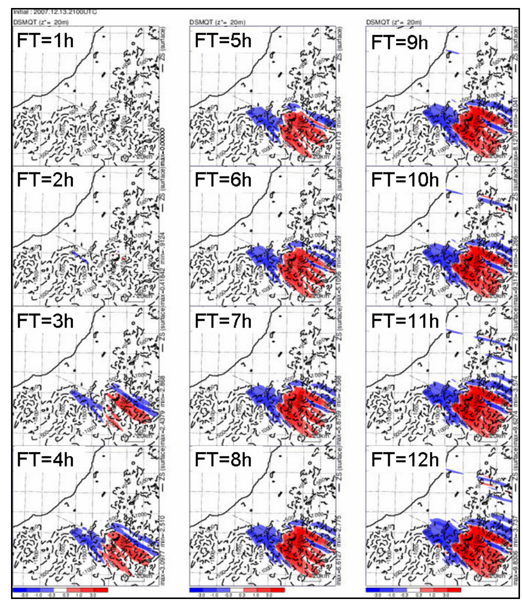

Fig. 4 Accumulated effect of seeding on the surface precipitation.

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