A HIGH-RESOLUTION WIDE-RANGE NUMERICAL SIMULATION OF CLOUD BANDS ASSOCIATED WITH THE JAPAN SEA POLAR-AIR MASS CONVERGENCE ZONE IN WINTER USING A NON-HYDROSTATIC MODEL ON THE EARTH SIMULATOR

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1. INTRODUCTION

During winter monsoon season, broad cloud bands extending southeastward from the base of the Korean Peninsula sometimes bring heavy snowfalls to the Sea of Japan-side coastal regions of Japan Islands. These cloud bands form over the low-level convergence zone (Japan Sea Polar-air mass Convergence Zone; JPCZ) between two cold airflows with different property. In this study, a high-resolution wide-range simulation of cloud bands associated with the JPCZ is performed using a non-hydrostatic model (NHM) with 1-km horizontal resolution and 2000 x 2000 km calculation domain on the Earth Simulator (ES). The case studied is a typical broad cloud bands that developed over the Sea of Japan on 14 January 2001.

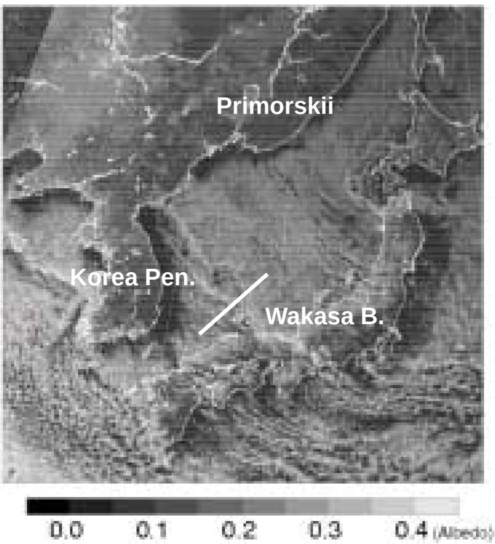

Fig. 1: GMS-5 visible imagery at 14 JST on 14 January 2001. A white solid line shows the flight path of an instrumental aircraft.

2. OBSERVATIONS

Figure 1 shows the GMS-5 visible imagery at 14 JST on 14 January 2001. Several clouds were found over the Sea of Japan, as a consequence of heat and moisture supply to continental cold air mass. The remarkable cloud bands, where cumulus convections developed, were distributed over the Sea of Japan from the base of the Korean Peninsula to Wakasa Bay. These cloud bands were also observed with an instrumental aircraft (Murakami et al., 2002). The conceptual model of the cloud bands, which is derived on a basis of the aircraft observation, is shown in Fig. 2. Air-mass on the SW side of JPCZ was warmer. Longitudinal mode (L-mode) cloud streets with top height of ~3 km observed in the SW side of JPCZ were taller than those in the NE side (~2 km). Deepest (~4 km) convective clouds formed on the southwestern edge of the JPCZ. Transverse mode (T-mode) clouds were mainly produced by anvil clouds (ice and snow particles) blowing from the deepest convective clouds.

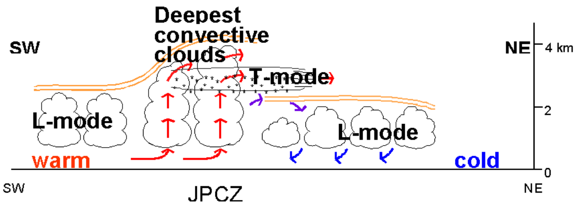

Fig. 2: Schematic structures of cloud bands associated with JPCZ observed on 14 January 2001 (from Murakami et al., 2002).

3. NUMERICAL MODELS

The NHM developed by Japan Meteorological Agency (JMA) is used in this study (Saito et al., 2001, JMA-NHM). The fully compressible equations with the conformal mapping are employed as the basic equations of JMA-NHM. Primary physical processes such as cloud physics, atmospheric radiation and mixing in the planetary boundary layer are also included in JMA-NHM. The JMA-NHM has been transferred to the ES, which is the fastest supercomputer in the world. In the present study, the JMA-NHM has a horizontal grid size of 1km with 2000 x 2000 grid points (1km-NHM). The vertical grid with a terrain-following coordinate contains 38 levels with a variable grid interval of 40 m near the surface and 1090 m at the top of the domain. The model top is 20.36 km. The time step interval is 5 seconds. The 1km-NHM is one-way nested within the JMA-NHM with a 5-km grid forecast (5km-NHM). The initial and boundary conditions for the 5km-NHM are provided from output produced by Regional Spectral Model (RSM). The RSM with a horizontal grid size of about 20km is a hydrostatic model used operationally in JMA.

4. RESULTS

The 1km-NHM successfully reproduced cloud bands associated with the JPCZ extending southeastward from the base of the Korean Peninsula to the San-in and Hokuriku district over the Sea of Japan (Fig. 3). Several cloud streets were also calculated around cloud bands. The 5km-NHM also well reproduced the features of cloud bands and other clouds (Fig. 4). However, more detailed features were not reproduced by the 5km-NHM. Figure 5 shows the structures of cloud bands in a vertical cross section on the white line in Fig. 3. The JPCZ formed between warmer west-northwesterly and colder north-northwesterly flows in the lower level. A strong horizontal convergence line was situated at the southwestern edge of the JPCZ. Deep convective clouds with the height of ~4 km formed along the line. L-mode cloud streets with top height of ~3 km were calculated on the SW side of the JPCZ. The top height of L-mode cloud streets calculated on the NE side of the JPCZ was lower (~2 km). These features almost agreed with those of the aircraft observation. However, effects of anvil-like snow and ice particles were small in the model-simulated T-mode clouds. Model-simulated T-mode clouds looked like developed convective clouds. Satellite and radar observations indicate that both convective and anvil-like clouds were responsible for the origin of T-mode clouds.

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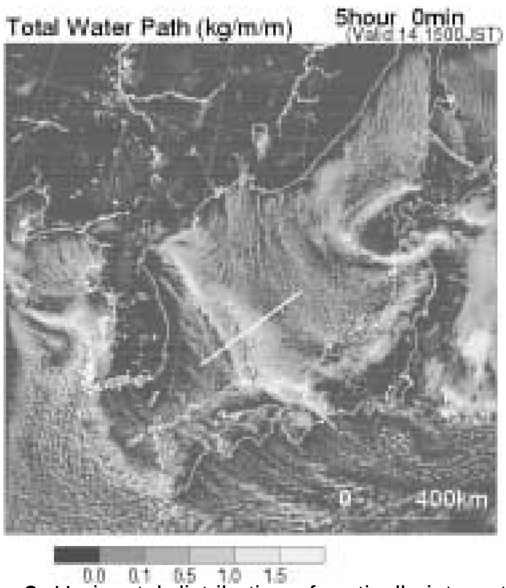

Fig. 3: Horizontal distribution of vertically integrated condensed water simulated by the 1km-NHM.

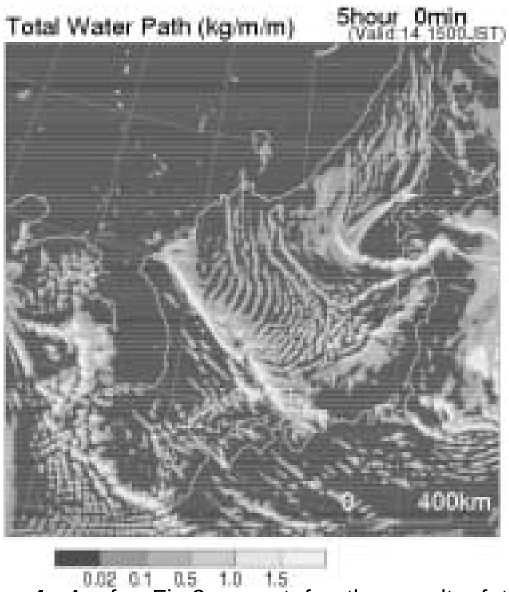

Fig. 4: As for Fig.3 except for the result of the 5km-NHM.

5. SUMMARY

A high-resolution wide-range numerical simulation of cloud bands associated with the JPCZ was performed using a NHM on the ES with 1-km horizontal resolution and 2000 x 2000 km calculation domain. Cloud features observed by a meteorological satellite were well reproduced in the model. Detailed structures of the cloud bands associated with the JPCZ were almost corresponded with those by in-situ airplane observations except for the aspect of T-mode clouds. It is necessary to examine the process of cloud microphysics in the model and also to carry out the comparison with the other cases.

Acknowledgements

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References

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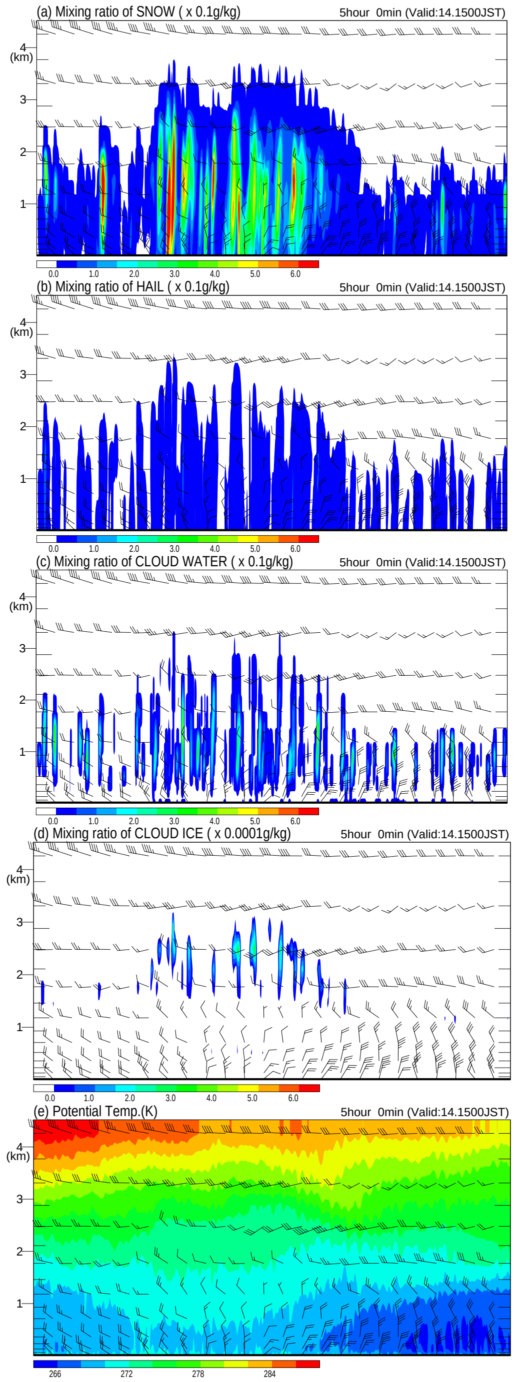

Fig. 5: Structures of cloud bands in a vertical cross section on the white solid line in Fig. 3. (a) Mixing ratio of snow. (b) Mixing ratio of graupel. (c) Mixing ratio of cloud water. (d) Mixing ratio of cloud ice. (e) Potential temperature. Barbs denote horizontal wind velocity at each level.