Evaluation of hydrometeors of a high-resolution model using a radar simulator

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4th International Verification Methods Workshop, Finnish Meteorological Institute, Helsinki, Finland, 8-10 June 2009.

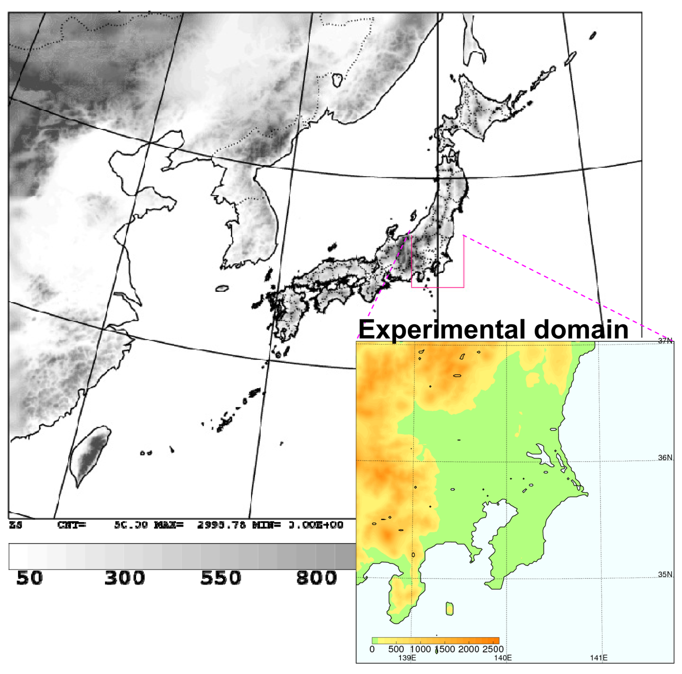
Ⅰ. Introduction

In this work a comparison is made between the simulated reflectivity by a new radar simulator and that of the C-band radar observation, to verify the hydrometeors of high-resolution model. And this verification approach makes use of the Fractions Skill Score (Roberts, 2008) to counter the "double penalty" issue. The new radar simulator is developed in consideration of refractivity distribution (Caumont et al., 2006), which diagnoses the reflectivity from hydrometeors using the bulk microphysics parameterization (BMP) scheme.

This approach makes it possible that the three-dimensional distribution of hydrometeors is verified in more accurate framework. And it contributes to the development of a sophisticated microphysics parameterization scheme which is underway as one of our efforts. This paper presents a new verification approach developed to evaluate the performance of the microphysics parameterization scheme.

Ⅱ. NWP model and experimental design

- Forecast grid spacing: 2 km.
- Experimental domain: 300km X 300km (around the Tokyo).
- Assimilation: an hourly update cycle with 5 km 3DVAR.
- Outer model: an operational meso-scale model at the JMA.
- Cloud microphysical process: 3-ice bulk microphysics process.
- Verification grid spacing: 5km.



Japan Meteorological Agency plans to operate a nonhydrostatic high-resolution local forecast model (LFM) in the future. The main purpose of operating the LFM is the improvement of the disaster prevention information. For this purpose the improvement of short-range precipitation forecasts is an important subject. In the experiment, the number concentration of the rain water is constant, and that of the 3-ice (the cloud ice, the snow and the graupel) is prognostic, and the cumulus parameterization scheme is not designed.

Ⅲ. Radar Simulator

- Horizontal interpolation: BiCubic.
- Vertical interpolation: Cubic spline.
- Measurement of virtual antenna: Gaussian weight to represent main lobes. Neglect the shape of the horizontal beam.
- Back scattering: Rayleigh approximation.
- Effective particle: the rain water, the snow and the graupel.

BMP scheme for radar simulator

- Intercept parameter

$$N_{0X} = N_X \lambda_X \quad (X = r,s,g)$$

- Slope parameter

$$\lambda_X = \left(\pi \frac{\rho_X N_X}{\rho_a Q_X}\right)^{\frac{1}{3}} \quad (X = r,s,g)$$

- Reflectivity

$$Z_e = Z_r + Z_s + Z_g$$

$$Z_r = 720 \frac{N_{0r}}{\lambda_r^7}$$

$$Z_X = 720 \frac{|K_i|^2 \rho_X^2}{|K_w|^2 \rho_i^2} \frac{N_{0X}}{\lambda_X^7} \quad (X = s,g)$$

$\lvert K_w \rvert^2$	$\lvert K_i \rvert^2$	ρ_a	N_X
Dielectric factor for water	Dielectric factor for ice	Air density	Number concentration

This radar simulator provides more accurate position of beam path, and an equivalent reflectivity factor which was computed from the size-distribution of precipitation particles on beam-path through the geometry of the pointing angle of the virtual antenna in the LFM forecast field.

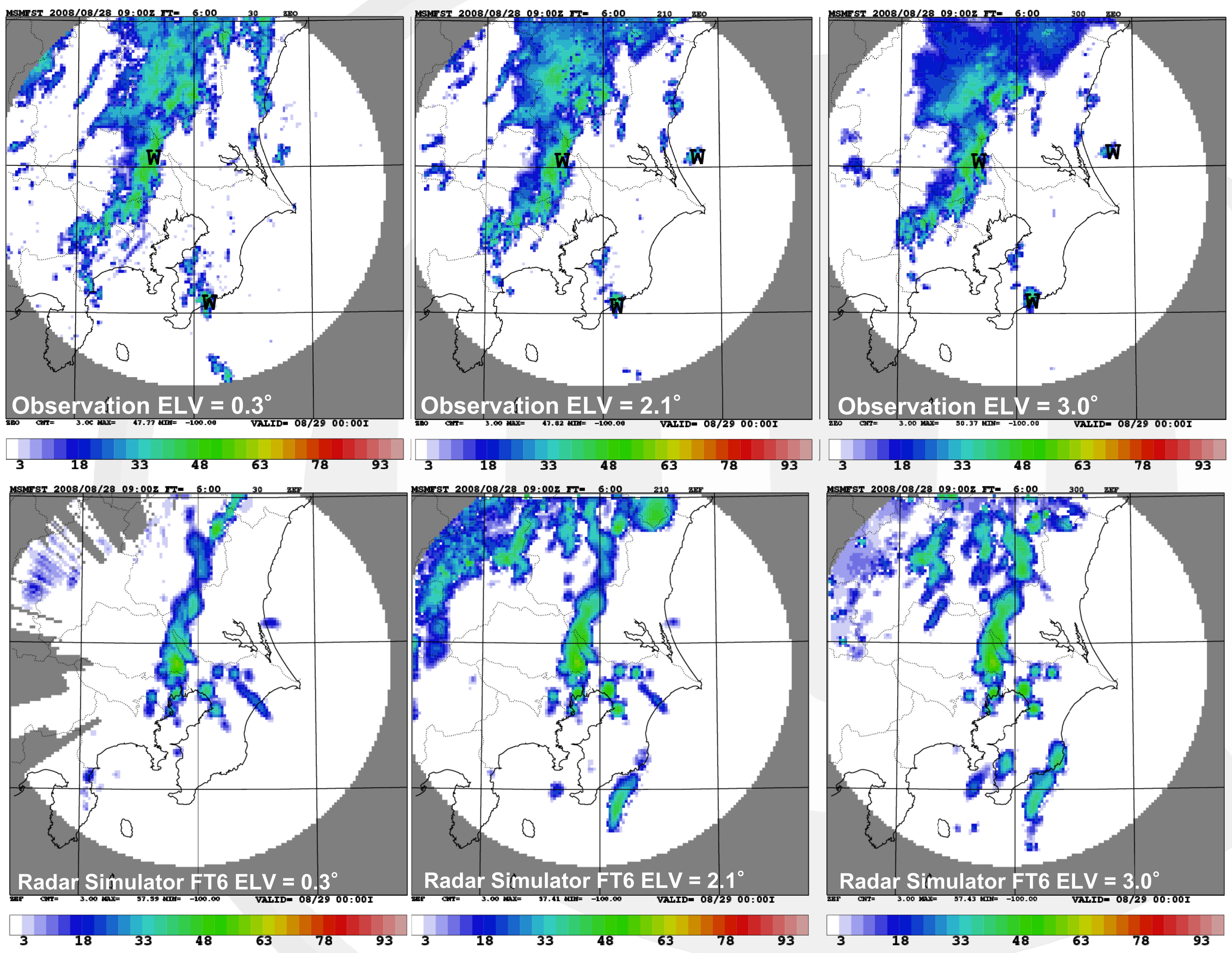
The distribution of the particle is diagnosed by the BMP scheme similar to the forecast model. The cloud particle is disregarded in this simulator, because the diameter of the clouds is smaller more enough than the wavelength of the C-band radar.

Beam path bending

The beam path is calculated from the earth curvature and the refractivity of atmosphere. The refractivity is computed from the temperature, the pressure and the water vapor partial pressure.

$$N = \frac{77.6}{T}\left(p + 4810\frac{e}{T}\right)$$

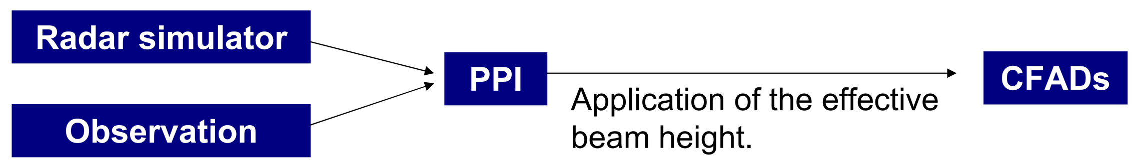
Ⅳ. Reflectivity of the observation and the radar simulator



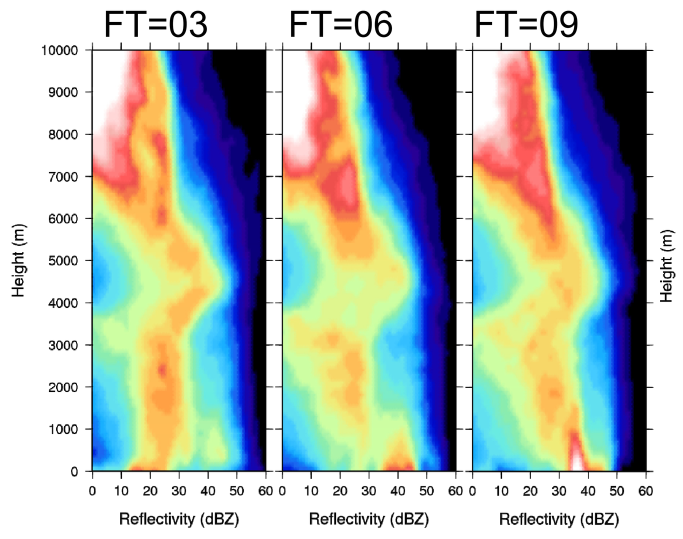
In this case the automatic observation station recorded precipitation of 63 mm h-1 at 0200UTC 29 Aug 2008. The shaded region of the gray represent the missing value, which is treated as 0 dBZ, in the verification process. The missing value of the simulator also provide information on inaccessible region of the realistic beam.

Ⅴ. Contoured frequency with altitude diagrams (CFADs)

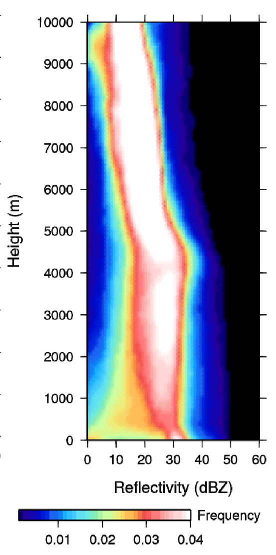
The radar simulator provides the PPI, the elevation of which is equal to that of the observations.

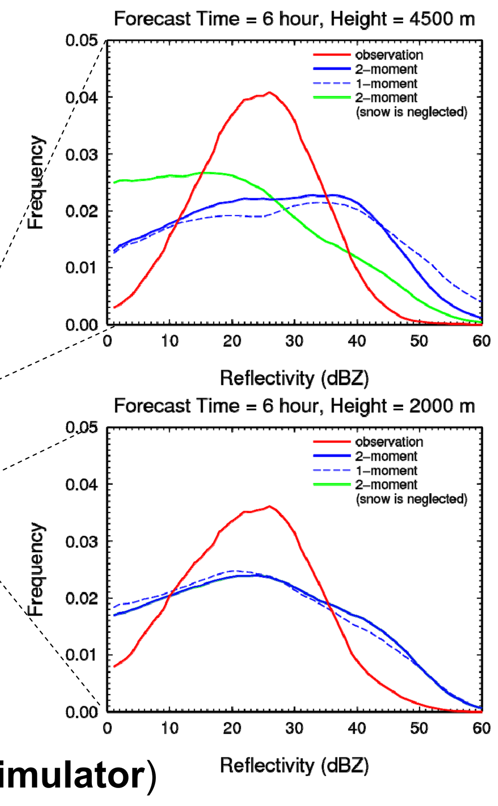


Simulated reflectivity CFADs
3-ice 2-moment Ze=Zr+Zs+Zg

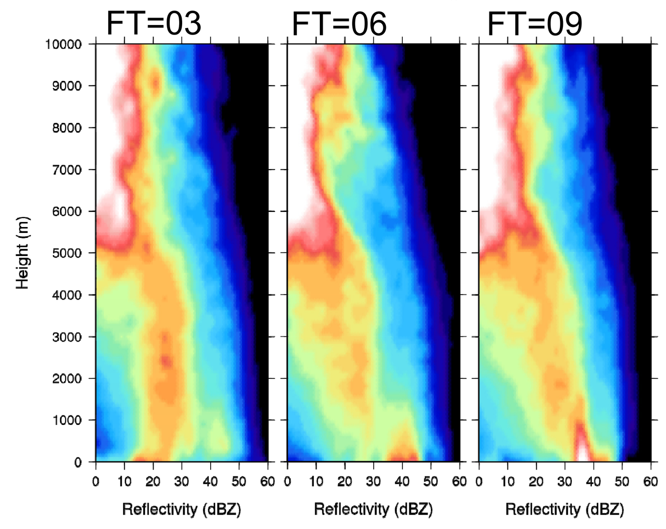


Observed reflectivity CFADs





Simulated reflectivity CFADs
3-ice 2-moment Ze=Zr+Zg (Snow is neglected **in the radar simulator**)



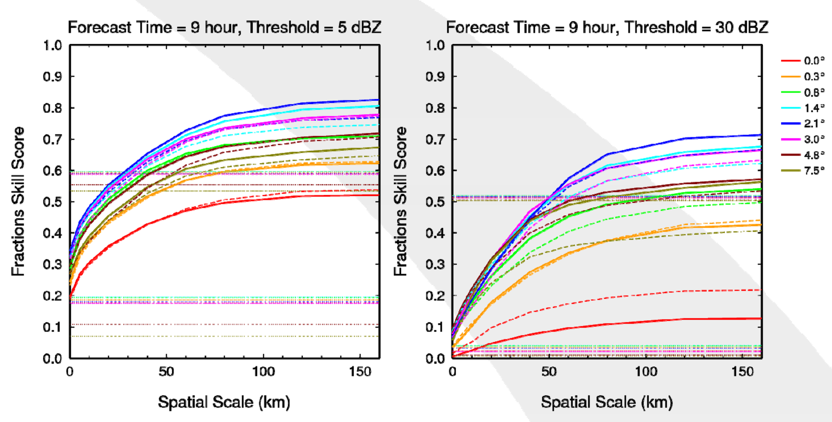
The statistics period is 3 days (28 - 30 Aug 2008) with convective activity. The frequency distribution of the simulated reflectivity is larger, and more widely spread than that of the observation in all level. Especially, the snow contributes to the bias of the frequency in the upper levels. Such a large number of the snow particles are confirmed in the verification using the simulated P18 and PCT89 (Eito and Aonashi 2008).

The result of the radar simulator to neglect the snow confirms that the snow is the cause of the bias of the altitude about 4500 m. As for the forecast experiment of 2-moment, the peak of simulated reflectivity becomes a sharp compared with 1-moment experiment, and the frequency of strong reflectivity has decreased.

Ⅵ. Fractions Skill Score

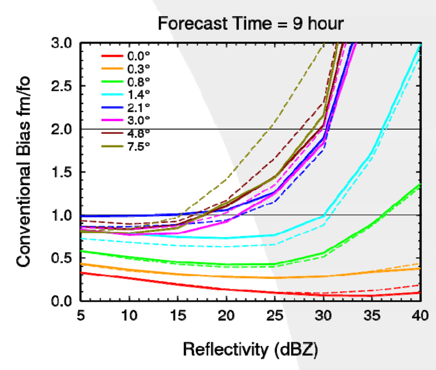
FSS figure compares the experiment of the 1-moment (dashed line) and the experiment of 3-ice 2-moment (solid line), when the threshold is 5dBZ and 30dBZ in each elevation. The statistics period of the FSS is the same period of the CFADs analysis. The FSS of the simulated low elevations PPI are small in this case study. And, the FSS of those elevations doesn't reach the target skill score in threshold 30dBZ. Moreover The FSS of 1-moment larger than that of 3-ice 2-moment in the low elevation.

These result implies that the BMP scheme, especially 3-ice 2moment, needs to be improved to simulate the precipitation process in the case of deep convection activity.

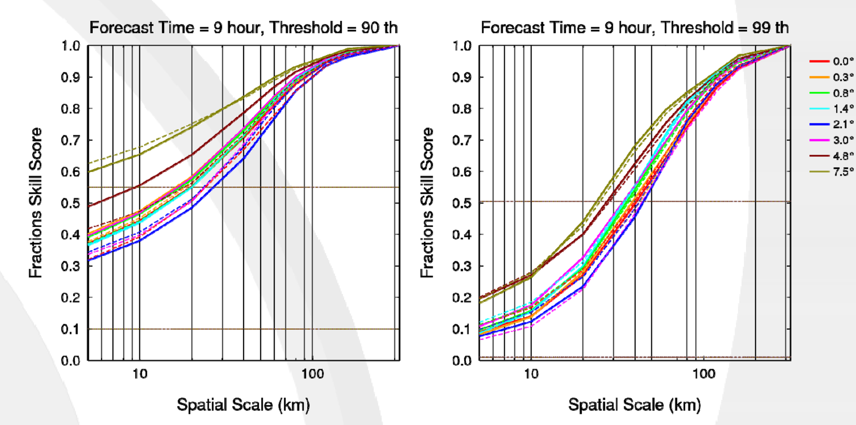


Conventional bias

The frequency bias is the ratio of the simulation frequency fm to the observation frequency fo. The reflectivity frequency of the low elevation is simulated to small.



Percentile threshold

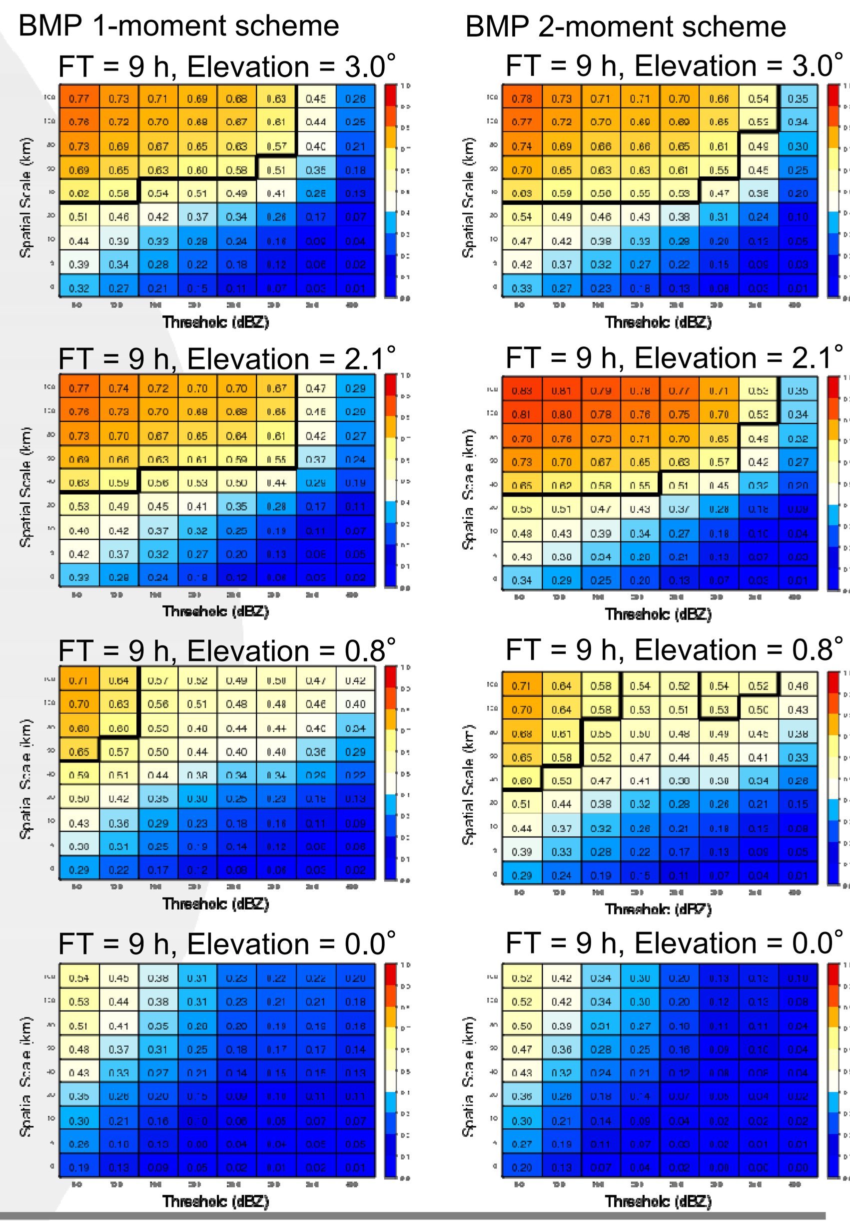


The percentile threshold of the FSS represents the difference of forecast quality between the localized and the widely spread precipitation system. The FSS of the high elevation is larger than the low elevation when the number of observation is large, because the radar detectable area is so limited.

Sensitivity of the BMP scheme

These diagrams represent the accuracy of the simulated reflectivity by the difference of the scheme, the scale dependency and the target skill in each elevation.

The FSS of exceeding the target skill shows that the experiment of 2-moment becomes good forecast, when the threshold is large in the widely spatial scale. But in the low angle elevation the experiment of 2-moment is poor forecast no matter what the spatial scale is.



Ⅶ. Conclusion

- The frequency of the hydrometeors is provided by the more accurate CFADs which is calculated from the simulated PPI. Comparisons between the CFADs with and without snow show that the LFM forecasts the large number of the snow particle in the middle troposphere.
- In the comparison between the experiment of 1-moment scheme and that of 2-moment scheme, the FSS diagrams show the improvement of the reflectivity representation of the experiment of 2-moment scheme except the low elevation. The FSS of the 2-moment experiment exceeds target skill in the high threshold by expanding the space scale to consider the displacement error.
- The verification approach in this study makes it possible to quantitatively discuss the reproducibility of the structure of precipitation system using the explicitly evaluated three-dimensional distribution of hydrometeors.

Ⅷ. References

Roberts, N. M. and H. W. Lean, 2008: Scale-selective verification of rainfall accumulations from high resolution forecasts of convective events. Mon. Wea. Rev., 136, 78–97.
Caumont, O., and Coauthors, 2006: A radar simulator for highresolution nonhydrostatic models. J. Atmos. Oceanic Technol., 23, 1049–1067.
H. Eito and K. Aonashi, 2008: Verification of hydrometeor properties simulated by a cloud resolving model using passive microwave satellite and ground-based radar observations for a rainfall system associated with the Baiu front. 4th Workshop of the International Precipitation Working Group (IPWG), October 13-17, 2008, Beijing, China