9.11 AVIATION FORECAST PRODUCTS USING THE JMA 10-KM MESO-SCALE MODEL (MSM)

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1. INTRODUCTION

The Japan Meteorological Agency (JMA) operates various weather observations and forecasts to contribute to the safety and efficiency of flights and flight control. The Numerical Prediction Division of JMA (NPD/JMA) produces many kinds of aviation weather forecast products which are derived from numerical weather prediction (NWP) output data.

In Japan, as well as other countries, the air traffic is increasing significantly, and therefore we are urged to provide more accurate and precise aviation weather forecasts to users such as air traffic controllers, airline companies, and so on. To meet such requests, NPD/JMA members keep on making efforts to develop better products using NWP data.

Recently (Sep. 1, 2004), our meso-scale NWP model (MSM) was upgraded to a non-hydrostatic model with more realistic cloud-microphysics.

In this report, we would introduce JMA's aviation weather forecast products derived from MSM.

2. SPECIFICATIONS OF MSM

The non-hydrostatic MSM which has advanced cloud-microphysics, has been operated since Sep. 1, 2004. The specifications of MSM are shown in Table 1 (Fujita *et al*, 2002).

The introduction of non-hydrostatic dynamics and improved cloud-microphysics can give us more precise forecasts of significant weather which has serious effects on aircraft in flight and during takeoff or landing, for example, turbulence, cumulus convection, heavy precipitation, and so on.

3. AVIATION WEATHER FORECAST PRODUCTS

JMA provides many products for aviation weather forecasting. In this section, we explain grid point values (GPV) of parameters on the significant weather for aviation (Sig-GPV) and the Terminal Area Forecast Guidance (TAF Guidance) as typical products derived from MSM output.

Table 1 specifications of MSM

Dynamical Frame	Eulerian, flux form, nonhydrostatic fully compressible equations
Horizontal Grid	Arakawa C
Projection	Lambert
Vertical Coord.	Z*, Lorenz type
Advection Term	Flux form, second order scheme with flux correction
Dynamical Core	HE-VI
Turbulent Closure	Deardorff level 2.5
Numerical Diffusion	Fourth order linear damping, nonlinear damping
Moist Process	Bulk cloud microphysics (qv, qc, qr, qi, qs, qg) / Moist convective adjustment
Surface Layer	Monin-Obukhov
Upper Boundary	Rigid lid, Rayleigh friction layer
Lower Boundary	4-level prognostic ground temperature

3.1 SIGNIFICANT WEATHER GPV

The Significant Weather GPV (Sig-GPV) is a 3 hourly series of MSM data interpolated into every 2000ft layers vertically, and its horizontal resolution is 80km. The Sig-GPV is an important data which supports forecasters to predict significant weather in the area over Japan and its surroundings. And it is used as the original data for forecast charts such as domestic sig-charts (FBJP112) shown in the Figure 1.

From the results of verification by the data from Apr. to Jun. 2004, it was proved that the accuracy of the Sig-GPV derived from the new MSM was equivalent to or better than that of Sig-GPV calculated from the former MSM. Now we discuss the turbulence index a little in detail, as a typical index in the Sig-GPV.

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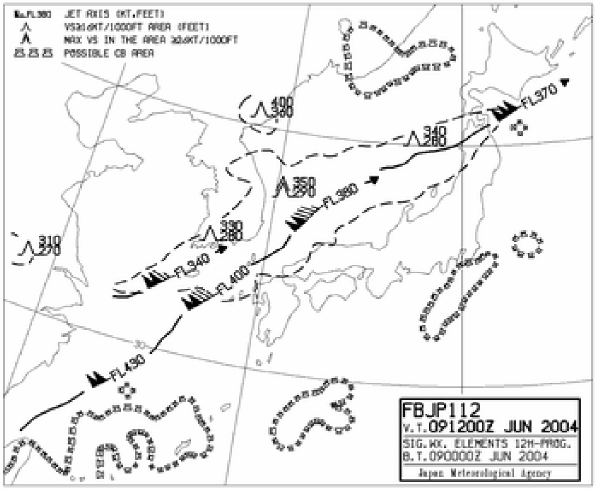

Figure 1　FBJP112

FBJP is one of the domestic sig-charts drawn from Sig-GPV automatically. It shows a 12-hour forecast of areas of turbulence, CBs, and Jet axis.

Turbulence Index (TI) is an index to represent the potential of clear air turbulence (CAT). It is the value of vertical wind shear (VWS, kt/1000ft) spline-interpolated from the adjacent two model layers. VWS is one of the indices to predict CAT caused by Kelvin-Helmholtz waves.

The following is a result from verification of the TI derived from MSM data. We used pilot report (PIREP) data for verification.

Since aircraft-pilots tend to avoid the area where turbulence was forecasted or reported, it is difficult to ascertain the effectivity of the forecast. Therefore, we used two rates – the capture rate (CR) and the volume rate (VR) – for the verification of TI, instead of threat score and bias score, which are commonly used to verify surface weather forecasts.

$$CR = \frac{T_{in}}{T_{in} + T_{out}}$$

$$VR = \frac{T_{in} + N_{in}}{T_{in} + N_{in} + T_{out} + N_{out}}$$

where T_{in}, T_{out}, N_{in}, and N_{out} are the numbers of PIREP reported about TURB shown in contingency table (table 2).

Table 2　T_{in}, T_{out}, N_{in}, N_{out}

	Turblence observed	No Turbulence observed
Turbulence forecasted	T_{in}	N_{in}
No Turbulence forecasted	T_{out}	N_{out}

Figure 2 shows a diagram of VR (abscissa) on CR (ordinate). At the upper right corner, TI threshold is 1kt/1000ft. TI increases by 1kt/1000ft towards the lower left corner. If CR is higher and VR is lower, i.e. nearer to upper left corner, the accuracy of TURB forecast is better.

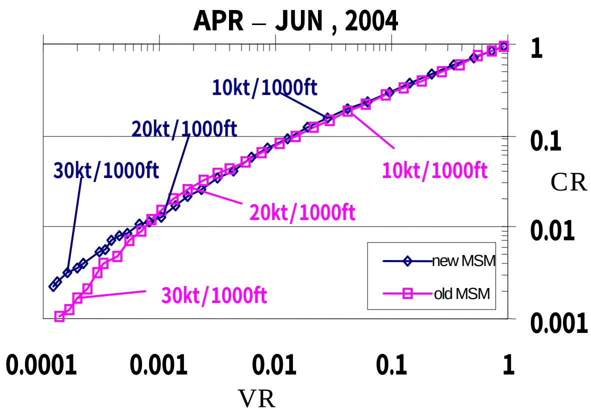

Figure 2　Capture rate (CR) at volume rate(VR) for Turbulence Index thresholds, APR – JUN 2004

In this figure, when the TI threshold is 26kt/1000ft or above, the value of CR in relation to the VR from MSM's Sig-GPV is higher than that from the former MSM's. This means the Sig-GPV from the new MSM provides the better forecasts for turbulence. When the TI threshold is smaller than 26kt/1000ft, there is no significant difference.

Figure 3 shows the encounter probability ratio(EPR) at every TI thresholds. The EPR is defined as

$$EPR = \frac{T_{in}}{T_{in} + N_{in}} \div \frac{T_{in} + T_{out}}{T_{in} + N_{in} + T_{out} + N_{out}}.$$

The EPR represents the ratio of turbulence encounter probability in the area where the TI is greater than the threshold relative to the average state.

In figure 3, the EPR in the case of MSM's Sig-GPV is equal to or greater than that of the former MSM's Sig-GPV, except where the threshold is between 19kt/1000ft and 21kt/1000ft.

Figure 4 indicates the ratio of a volume of areas where the TI is greater than a threshold value between MSM and the old MSM. When the TI threshold is not larger than 18kt/1000ft, the ratio is smaller than 1, the TI from MSM encloses less volume than that from the previous MSM does. The volume ratio is 0.91 with 16kt/1000ft TI (target of MOD TURB forecast in FBJP), and is about 1.4 when the TI is 26kt/1000ft (target of SEV TURB forecast).

From these results, It was proved that MOD TURB expectations areas (where TI is equal to or greater than

16kt/1000ft) became smaller, and SEV TURB expectations areas (where TI is equal to or greater than 26kt/1000ft) conversely enlarged after the introduction of non-hydrostatic MSM.

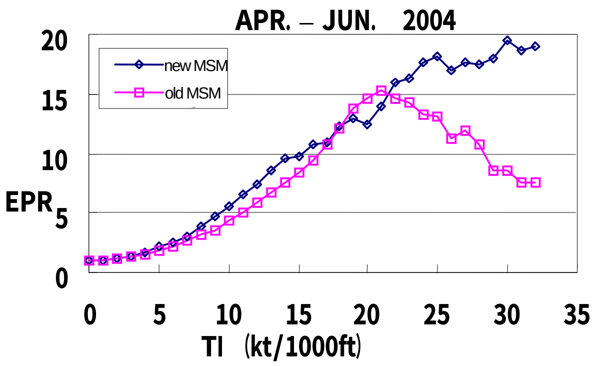

Figure 3 Encounter Probability Ratio (EPR) for APR – JUN 2004

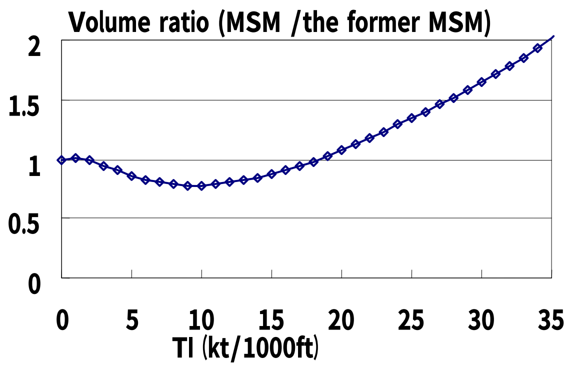

Figure 4 Volume ratio APR – JUN, 2004

3.2 TAF guidance

We are also making guidance products for the terminal area forecast. Short-TAF (TAF-S) guidance is calculated from MSM, and it includes such elements as minimum visibility, cloud base height and cloud amounts for three layers, maximum wind speed and direction, and weather. The specifications of TAF-S guidance are shown in table 3. The elements of TAF-S are calculated with Kalman Filter method except weather, which is derived diagnostically from NWP output.

For reference, the specification of long-TAF (TAF-L) guidance which is calculated from another model (JMA regional spectral model, RSM), are shown in table 4.

Figure 5.a and b show the threat score and the bias score of maximum wind speed of TAF-S guidance, verified against surface observational data at airports from APR to JUN, 2004. The scores were calculated for three thresholds of wind speed (3m/s, 6m/s, 10m/s).

In figure 5.a, the threat score of guidance declines as the threshold of max wind speed becomes large, while the bias scores are still around 1.0. This means it is more difficult to predict max wind speed, if the threshold is larger. The accuracy of guidance from MSM equals or exceeds that from the former MSM, at any thresholds.

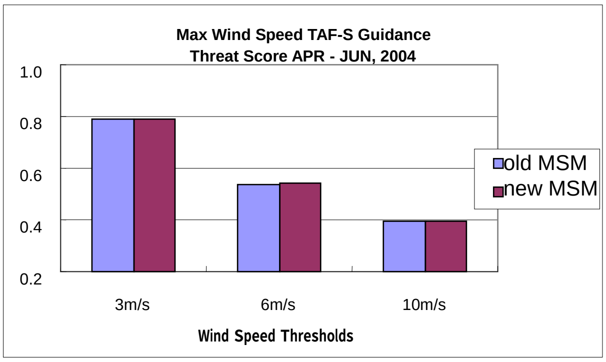

Figure 5.a Max Wind Speed TAF-S Guidance Threat Score

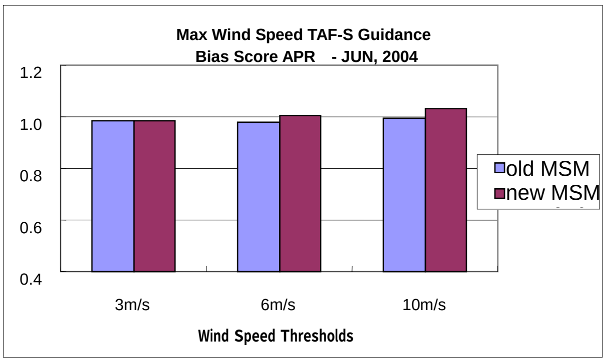

Figure 5.b Max Wind Speed TAF-S Guidance Bias Score

Table 3 The specifications of TAF-S guidance

Methods : KLM - Kalman's filter, NWP - NWP output

Elements	Forecast time (hr)	Methods
Minimum visibility	T=02 ~ 15, 1 hourly	KLM
Cloud base height and amount (in 3 layers)	T=02 ~ 15, 1 hourly	KLM
Maximum wind speed and Its direction	T=02 ~ 15, 1 hourly	KLM
Weather	T=02 ~ 15, 1 hourly	NWP

Table 4 The elements of TAF-L guidance

Methods : KLM - Kalman's filter, NRN - neural network

Elements	Forecast time (hr)	Methods
Minimum visibility	T=03 ~ 45, 3 hourly	KLM
Probability of visibility (less than 5km)	T=03 ~ 45, 3 hourly	KLM
Cloud base height and amount (in 3 layers)	T=03 ~ 45, 3 hourly	KLM
Maximum wind speed and Its direction	T=03 ~ 42, 3 hourly	KLM
Maximum temperature	00UTC : T=00-09, 24-33 12UTC : T=12-21, 36-45	KLM
Minimum temperature	00UTC : T=15-24, 39-48 12UTC : T=03-12, 27-36	KLM
Weather	T=03-06, 06-09, …48-51	NRN

4. FUTURE PLANS

JMA plans to upgrade its computer system for NWP in MAR. 2006. After that, the horizontal resolution of MSM will be improved to 5km (from 10km at the present). And also a more precise 2km resolution model will be introduced in 2008, in order to predict smaller scale severe weather around airports. This 2km model for airport areas is tentatively called the "Airport Model." We will develop many application products from these precise models in few years.

As for TAF guidance, MSM directly predicts the amounts of cloud and water droplets. We are currently developing a technique to calculate cloudiness and visibility using those data.

Besides that, we have a lot of issues : to increase resolution and output frequencies of the Sig-GPV (80km to 40km, 3 hourly to hourly), to upgrade the turbulence indices, and to improve TAF guidance, among others.

5. SUMMARY AND CONCLUSION

So far, we introduced the aviation weather forecast products of JMA which are derived from the new MSM, and their accuracy. It was found that the aviation weather forecast products calculated from the MSM had the effectiveness and accuracy equal to or better than those of the previous MSM. The turbulence prediction became sharper than before. The accuracy of TAF-S Guidance from MSM was almost the same as that from the old MSM.

As for future plans, in aviation weather field where small-scale phenomena, such as turbulence and icing, must be concerned, improvement of the model resolution will give significant effects. The advance of resolution which is scheduled in few years will lead to more accurate forecasts. In addition to that, new application methods have to be developed to make full use of NWP model output.

REFERENCES

T. Fujita, K. Saito, Y. Yamada, J. Ishida, M. Narita, S. Goto, C. Muroi, T. Kato, and H. Eito, 2002 : Development of a nonhydrostatic model for very short-range forecasting at JMA. *15th Conf. on Numerical Weather Prediction,* San Antonio, TX, American Meteorological Society, 13.3