Introduction of a New Radiation Scheme to the Operational Global NWP Model at JMA

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1 Introduction

The operational Global Spectral Model (GSM) at JMA has warming bias in the upper stratosphere and cooling bias in the lower stratosphere, and underestimates the downward longwave flux at the ground. It is considered that low accuracy of the radiation scheme causes most of these errors. JMA has developed a new radiation scheme to reduce the errors. As it was confirmed that the forecast skill of GSM improved with the new scheme, it has been in operation since 2 December 2004.

2 Outline of the new scheme

Longwave spectrum is divided into 9 bands and the radiation flux is calculated in each band separately. Considering a tradeoff between accuracy and efficiency, gaseous transmittance is computed using three different approaches, depending on the absorber and the spectral band.

In order to take account of the Doppler absorption effect accurately, a table look-up method (Yabu 2003) is used for spectral bands contributing cooling in the stratosphere. It is accurate enough to calculate transmission functions though it is computationally expensive.

For calculating the other line absorptions, a k-distribution method with linear pressure scaling based on Chou et al. (2001) is used. The scaling parameters are decided to calculate heating rate properly compared with results by a line-by-line method.

A parameterization of water vapor continuum absorption is also revised. The old scheme uses parameterization of Roberts et al. (1976) and takes account of only e-type absorption. The new scheme is based on Zhong and Haigh (1995), which can deal with the effect of P-type absorption. In our parameterization, absorption coefficients are fitted by using the MT-CKD continuum model.

Effects of absorption by trace gases such as CH_4, N_2O and CFCs are newly introduced into the longwave calculation.

In addition to above changes in the longwave scheme, the absorption coefficient parameterization for CO_2, O_2 and O_3 is refined in the new shortwave scheme.

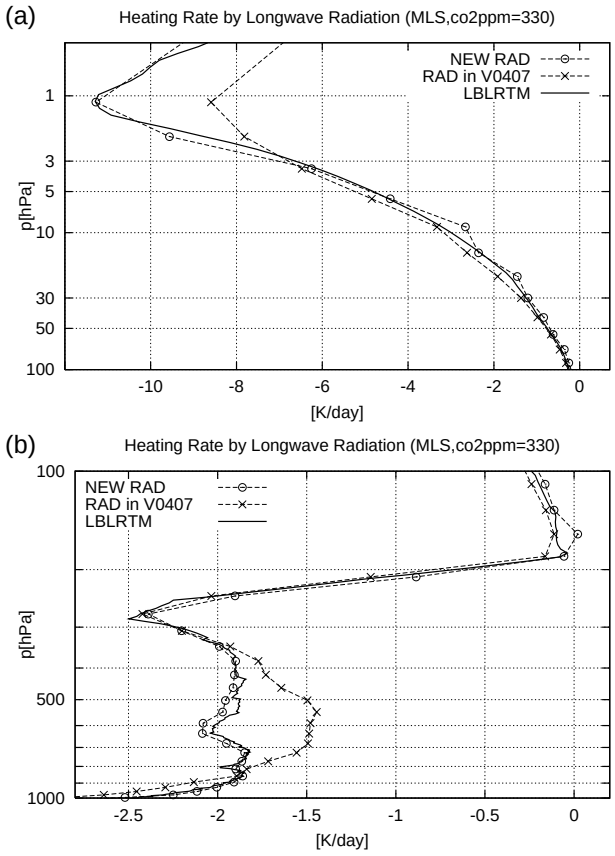

Figure 1. Heating rate by longwave radiation for the midlatitude summer profile by the old scheme (×), the new scheme (○) and the line-by-line method (solid line) (a) above 100hPa, (b) below 100hPa.

3 Characteristic of the scheme

Figure 1 shows the longwave heating rate profiles calculated for the midlatitude summer profile. The old scheme underestimates the cooling around the stratopause (near 1hPa in Figure 1(a)), and the new scheme reduces the error. This change is brought mainly by taking account of the Doppler absorption effect properly. Heating rate profiles for the troposphere are shown in Figure 1(b). The old scheme underestimates the cooling in the middle troposphere and overestimates near the surface. These errors are reduced by the revision of transmittance calculation of line absorptions and the introduction of P-type absorption.

The old scheme underestimates the downward long-

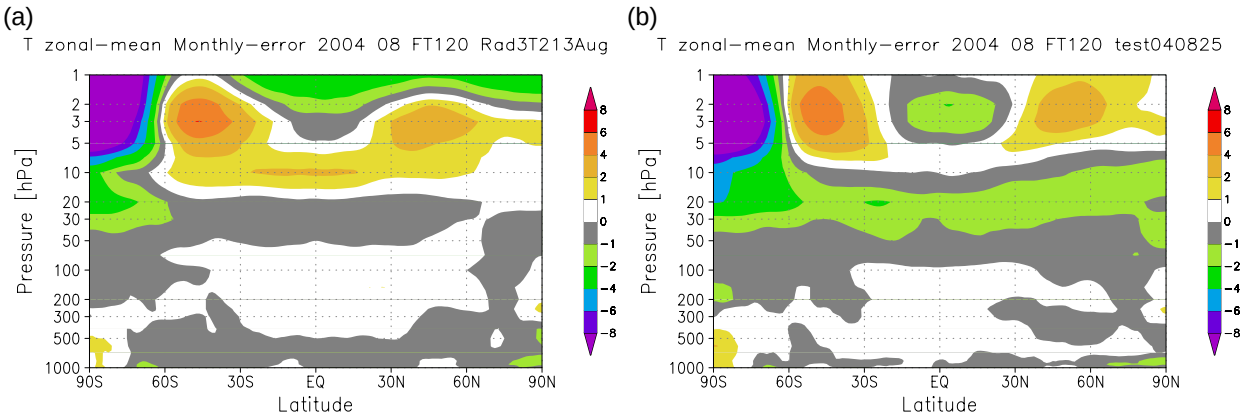

Figure 2. (a) Zonal mean temperature bias for 5-day forecasts by the new scheme. (b) Same as (a) but by the old scheme. Unit is K.

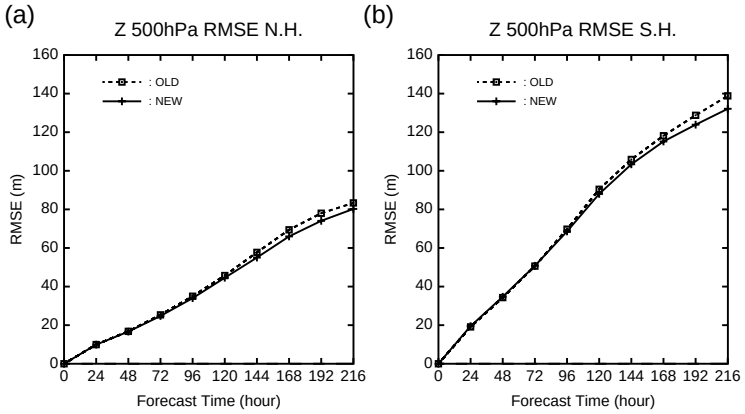

Figure 3. RMSE of the 500hPa geopotential height for August 2004 (a) over the northern hemisphere, (b) over the southern hemisphere.

wave flux at the surface over the nearly whole globe. Flux expressed by the new scheme increases especially over the tropical region and over land. A difference between forecasts and the Surface Radiation Budget (SRB; WCRP-96 1992) is smaller than 10 W/m^2 over the wide area. Overestimation of outgoing longwave radiation (OLR) is also reduced (not shown).

4 Forecast performance of the model

To confirm the impact of the scheme on forecasts, data assimilation and forecast experiments were carried out for January and August 2004.

Figure 2 shows the zonal mean temperature bias for 5-day forecasts. The old scheme has cooling bias over 2K near 20hPa level while the forecasts by the new scheme reduces the bias to 1K or less.

Figure 3 compares the root mean square error (RMSE) of the geopotential height at 500hPa over the northern and southern hemispheres for the experiment of August 2004. The new scheme (solid) improves the objective scores compared with the old scheme (dashed) over both hemispheres.

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