## 7. Predictability of a SSW in the winter of 2001

Mukougawa *et al.* (2005) found, by using the operational one-month ensemble forecasting data of the JMA, that the SSW that occurred in December 2001 was predictable about two weeks prior to the date corresponding to the warming peak at 80°N of the zonal-mean temperature at 10 hPa. The predictable period was assessed from the spread of ensemble members (Figures 13a–d); the spread of forecasts starting on 12 and 13 December (Figure 13c) becomes much smaller than the spread of forecasts from 5 and 6 December (Figure 13b). The polar stratospheric temperature attains its maximum around 28 December. However, because the operational one-month forecast was conducted only twice a week (Wednesday and Thursday), a detailed examination of daily variations of the spread was not possible.

In this section, we examine the predictability of the SSW by using the newly developed MRI-EPS. We also investigate the dependence of the predictability on the NWP model that represents the temporal evolution of bred modes and also on the analysis dataset that provides the initial conditions of the forecast. Figure 13 shows the results of ensemble forecasts for the 10-hPa zonal-mean temperature at 80°N made by using the GSM0103 (Figures 13a–d), which was also used by Mukougawa *et al.* (2005); made by using the GSM (Figures 13e–h), which was used in the calculation of the BGM cycle for the MRI-EPS; and by using the MRI-AGCM3.2 (Figure 13i–l). Here, the red lines show the observations (NCEP/NCAR reanalysis). Each ensemble forecast was conducted with 26 ensemble members and was started every Wednesday and Thursday, as was the case in the operational 1-month forecast of the JMA in 2001. Note that the initial conditions for the GSM0103 were provided by the operational analysis of the JMA (GANAL), whereas those of the other models were provided by the JRA-25/JCDAS analysis. Thus, differences between the NWP model and the analysis dataset might affect the forecast. For the forecast that started on 28 and 29 November, no member of the GSM0103 predicted the occurrence of the SSW (Figure 13a), whereas several members predicted the SSW in the cases of the GSM and MRI-AGCM3.2 (Figures 13e and 13i). However, the forecasts that started on 5 and 6 December were very similar to each other (Figure 13b, f, and j). For the forecasts that started on 12 and 13 December, although all ensemble members of the forecasts predicted the occurrence of the SSW (Figures 13c, g, and k), the spread for the MRI-AGCM3.2 was relatively large (Figure 13k). For the forecast that started on 19 and 20 December, all the forecasts captured the occurrence of the SSW well, and the spreads were very small (Figures 13d, h, and l). Hence, the overall performances of the ensemble forecasts for the prediction of the SSW were very similar to each other.

We also conducted ensemble forecasts by using the GSM and the MRI-AGCM3.2 initialized every day. Figure 14 shows the ensemble mean (contour) and the standard deviation (shading) among the ensemble means for 10-hPa zonal-mean temperature at 80°N. Even in this

figure, there is no apparent difference between the two NWP models for the prediction of stratospheric polar temperatures: both ensemble mean values tend to increase after 20 December for the forecasts that started after 10 December; the forecasts that started after 13 December have the same peak value of 245 K around 27 December. Thus, both models predict the occurrence of the SSW almost two weeks in advance. However, when we closely examined both forecasts, we found that the performance of the GSM was slightly better than that of the MRI-AGCM3.2: the forecast of the GSM that started on 12 December predicts the peak temperature of the SSW well (Figure 14a). The performance of that model is almost the same as that of the MRI-AGCM3.2 that started on 13 December (Figure 14b).

We also examined the dependence of the ensemble forecast on the analysis dataset that provided the initial conditions by using the MRI-AGCM3.2. Figure 15 shows the ensemble forecasts for the polar stratospheric temperature based on the JRA-25/JCDAS reanalysis (Figure 15a) and the ERA-interim reanalysis (Figure 15b). Each forecast started from the period between 10 and 13 December, when the spread among the ensemble members rapidly decreased (Figure 14). It should be noted that the initial temporal evolution of the bred modes was almost independent of the reanalysis dataset, as shown in Section 6.3. It is apparent that the forecasts based on the ERA-interim reanalysis outperform those based on the JRA-25/JCDAS dataset; all ensemble members for the ERA-interim (JRA-25/JCDAS) reanalysis predict the occurrence of the SSW well for the forecasts that started after 11 December (13 December). This skillful performance may reflect the fact that the ERA-interim reanalysis produced a better representation of the stratospheric circulation compared with the JRA-25/JCDAS reanalysis. This fact is easily recognized by examination of the peak temperature of the 2001 SSW (not shown).

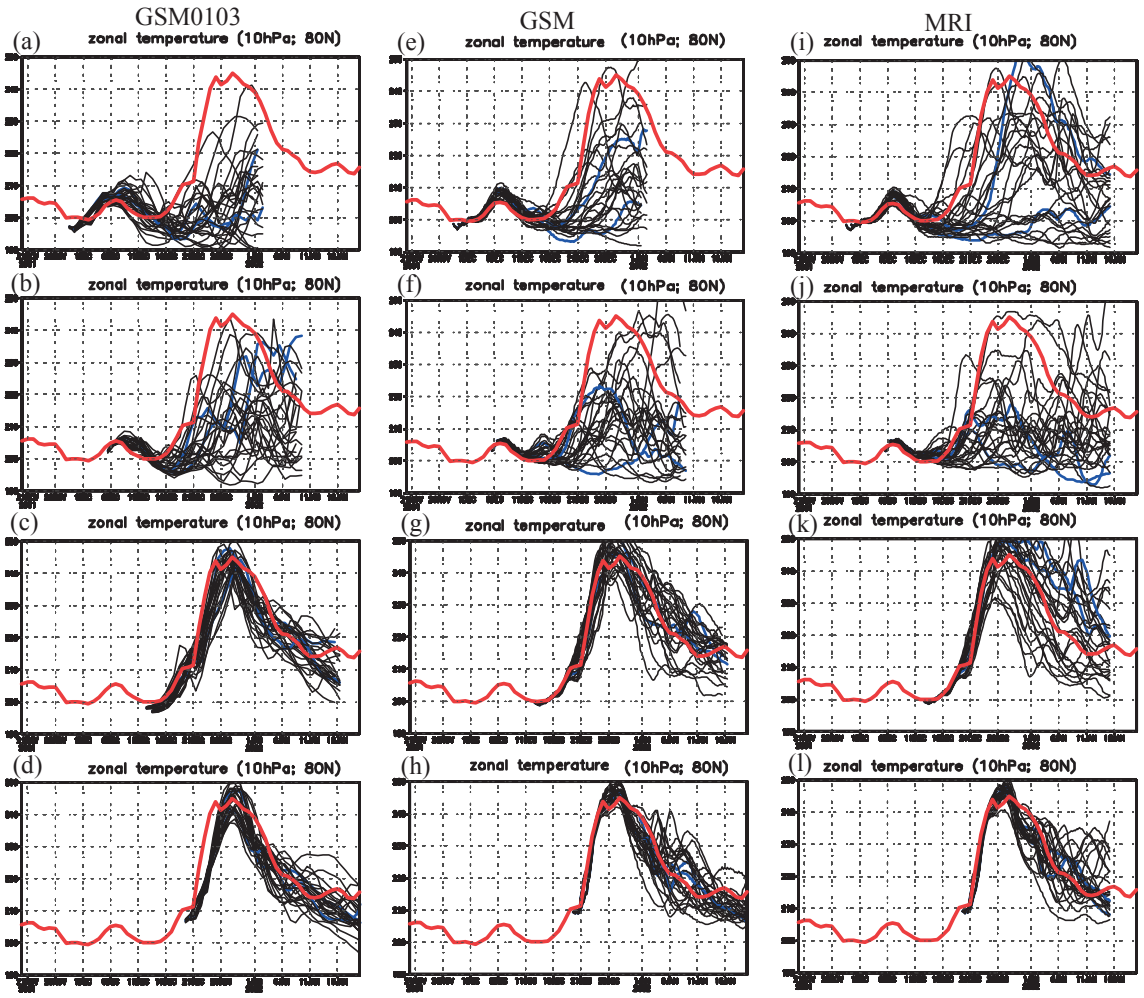


Figure 13: Temporal variation of 10-hPa zonal-mean temperature at 80°N from 20 Nov. 2001 through 20 Jan. 2002 for the analysis (red line) and ensemble forecasts (black lines). The forecasts started from (1st row) 28 and 29 Nov., (2nd row) 5 and 6 Dec., (3rd row) 12 and 13 Dec., and (4th row) 19 and 20 Dec. 2001. Blue lines indicate control runs. Panels (a–d) are forecasts made with the GSM0103, which were also used by Mukougawa *et al.* (2005). Panels (e–h) are forecasts made with the GSM, and panels (i–l) are those made with the MRI-AGCM3.2.

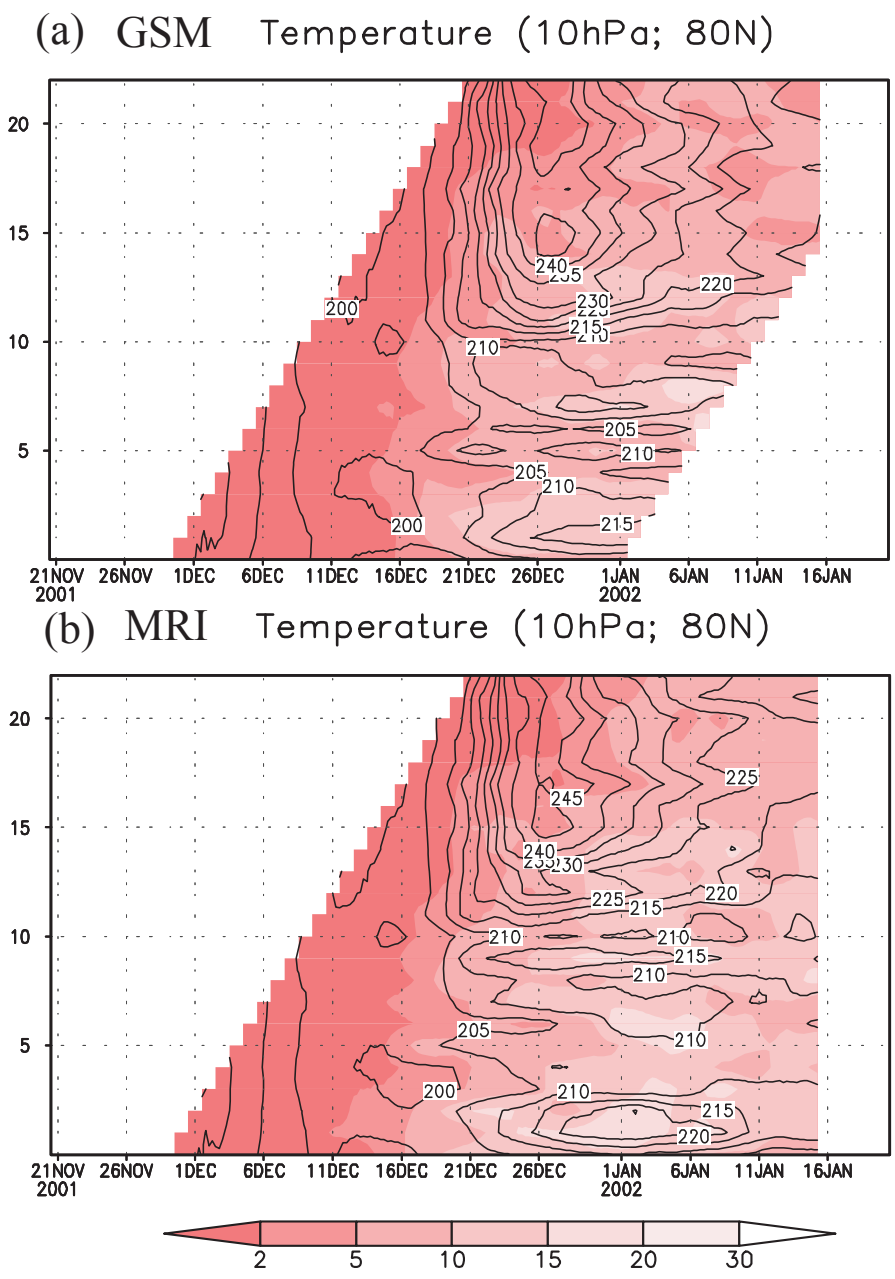


Figure 14: Ensemble mean (contour) and standard deviation (shading) of predicted 10-hPa zonal-mean temperature at 80°N made with (a) the GSM and (b) the MRI-AGCM3.2, initialized every day starting from 28 Nov. 2001.

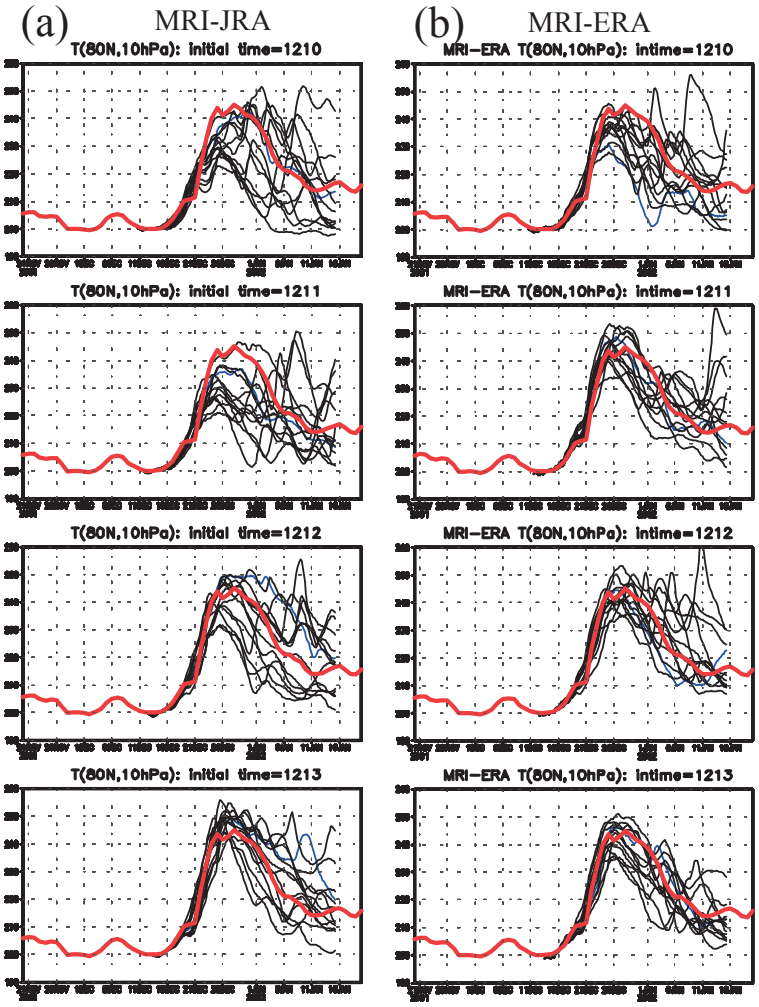


Figure 15: Same as in Figure 13, except that (a) the forecasts were made with the MRI-AGCM3.2 based on the JRA-25/JCDAS reanalysis and (b) the forecasts were made with the MRI-AGCM3.2 based on the ERA-interim reanalysis. Forecasts were initialized every day from 10 (the first row) to 13 (the fourth row) Dec. 2001.