4.3 Ensemble Prediction System

4.3.1 Introduction

JMA launched its operational ensemble prediction systems (EPSs) for one-month forecasting, one-week forecasting, and seasonal forecasting in March of 1996, 2001, and 2003, respectively. At present, the suite of the JMA EPSs covers a wide range of forecast periods from medium-range forecasting to seasonal forecasting. Since March 2006, 51, 50, and 31 initial conditions are integrated by using a low-resolution version of JMA GSM for producing an ensemble of 9-day forecasts in the One-week EPS, 34-day forecasts in the One-month EPS, and 120-day (210-day fifth a year) forecasts in the seasonal EPS, respectively.

4.3.2 Configuration

Specifications of the EPSs are shown in Table 4.3.1. A low-resolution version of the GSM is used at each EPS. Thus, the dynamical framework and physical processes are identical with those of the GSM mentioned at Section 4.2 except for the horizontal resolution. The control analysis is prepared by interpolating the global analysis mentioned at Section 3.5. During the integrations, sea surface temperature (SST) anomalies are fixed, except for the seasonal EPS.

The frequency of operation is different among the EPSs. The One-week EPS runs up to 9 days once a day at 12UTC for medium-range forecasting. The ensemble size is 51 including an unperturbed forecast (control run).

The One-month EPS runs up to 34 days every Wednesday and Thursday,. The model systematic bias is removed from the model results for one-month forecasting. The bias is estimated in advance from the mean forecast error obtained from experimental hindcasts for years of 1984 to 1993.

The seasonal EPS runs up to 120 days around 15th in every month, while it is extended to 210 days in February, March, and April for summer season forecasting, and September and October for winter season forecasting. SST

Table 4.3.1 Specifications of JMA EPSs

	One-week EPS	One-month EPS	Seasonal EPS
Ensemble size	51	50 (25 members x 2 days)	31
Frequency of operation	daily	Wednesday and Thursday	monthly / fifth a year
Forecast range	9 days	34 days	120days / 210days
EPS model	JMA global spectral model		
- Integration domain	Global, surface to 0.4hPa		
- Horizontal resolution	TL159 ; about 1.125-degree Gaussian grid		TL95 ; about 1.875-degree Gaussian grid
- Vertical levels	40 levels		
Perturbation generator	BGM method	Combination of BGM method and LAF method	SV method
Perturbed area	The Northern Hemisphere and the tropics (20S-90N)		The Northern Hemisphere (20N-90N)

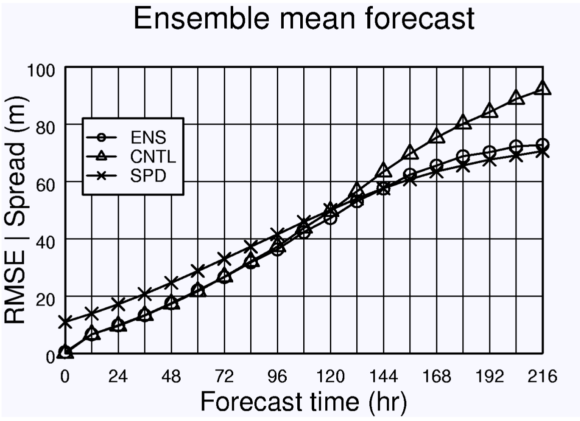

Fig. 4.3.1 RMSEs for the Northern Hemisphere (20N-90N) 500 hPa height forecasts of the ensemble mean (ENS) and the control run (CTL) for September 2006 by JMA One-week EPS. The size of spread in the ensemble is also shown (SPD).

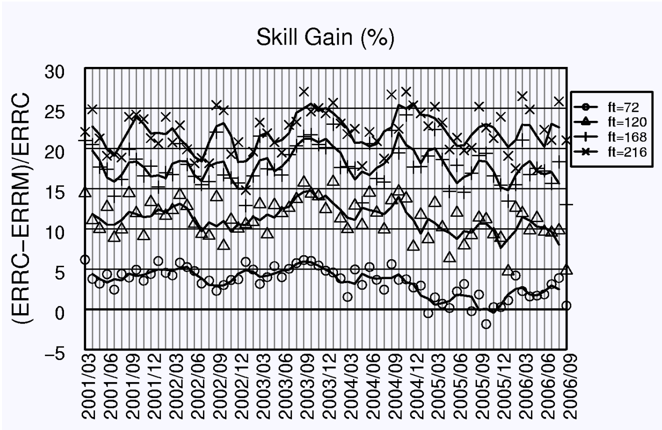

Fig. 4.3.2 Time series of ensemble mean skill score (ERRC-ERRM)/ERRC by JMA One-week EPS, where ERRC is the monthly-averaged RMSE of the control run and ERRM is that of the ensemble mean, for the Northern Hemisphere 500 hPa height forecast with lead time of 72, 120, 168, 216 hours from March 2001 to September 2006. Symbol separates the lead time. Lines indicate the three-month running means.

anomalies used as the ocean boundary condition of the atmospheric model are provided from combination of persisted anomalies, climatology and prediction with an atmosphere-ocean coupled model operated for El-Nino prediction mentioned at Section 6.4.

4.3.3 Generation of initial perturbation in the One-week EPS

Perturbed initial fields are obtained using the Breeding of Growing Modes (BGM) method (Toth and Kalnay 1993; Toth and Kalnay 1997). The processes of a BGM method are as follows. First, short-range forecast errors are added to a control analysis as an initial perturbation. Second, both perturbed analysis and control analysis are integrated up to 12 hours. Third, the difference of the two fields at 12 hours is scaled down to normalize. The normalized perturbation is added again to the analysis at that time. The second and third processes, known as a breeding cycle, are integrated every 12 hours.

In the EPS, 50 perturbed initial fields are generated from 25 independent breeding cycles by adding each perturbation positively and negatively. The amplitudes of the initial perturbation, which are confined in the Northern Hemisphere and the tropics, are adjusted so that the variance of 500 hPa height over the extra-tropical Northern Hemisphere is equal to 14.5% of the climatological variance, and also reflect analysis errors according to a geographical distribution. The normalized perturbations are also orthogonalized to each other before adding to the analysis.

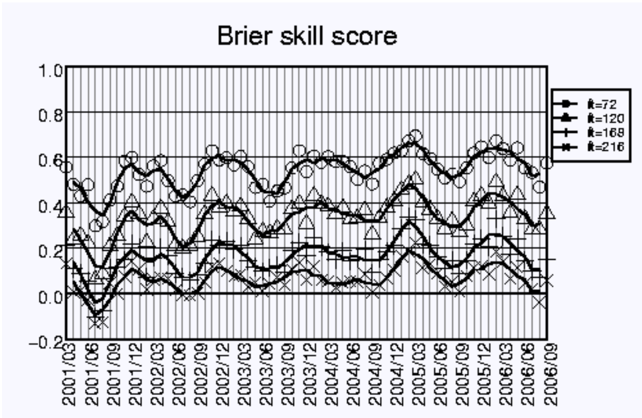

Fig. 4.3.3 Time series of Brier skill score for the probabilistic forecast of negative anomaly in 500 hPa height with magnitude less than one climatological standard deviation over the Northern Hemisphere for lead times of 72, 120, 168, 216 hours from March 2001 to September 2006 by JMA One-week EPS. Symbol separates the lead time. Lines indicate the three-month running means.

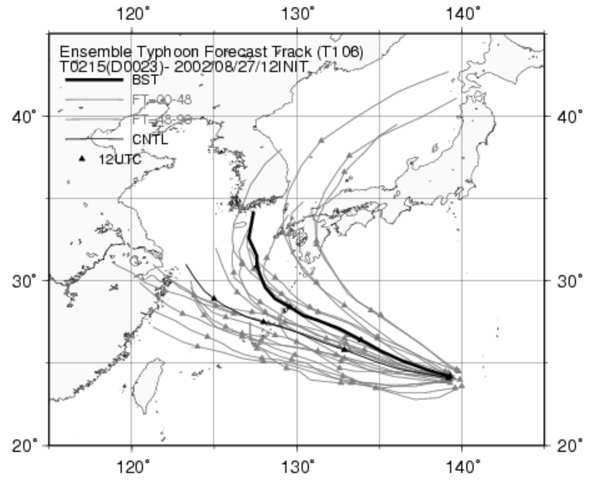

Fig. 4.3.4 A tropical cyclone track ensemble for T0215 up to 90 hours derived from JMA One-week EPS. Initial time is 12 UTC on 27th August 2002. The black thin line, gray thin lines, and the black thick line indicate the control track, all perturbed tracks, and the observed track, respectively.

4.3.4 Performance of the One-week EPS

Fig. 4.3.1 compares the monthly-averaged root-mean-square errors (RMSEs) of the ensemble mean and the control run. Fig. 4.3.2 shows the percentage of the RMSE reduction of the ensemble mean compared with the control run. The ensemble means have more skill than the deterministic forecasts, especially in longer lead time.

The skills of probabilistic forecasts of the EPS are verified by using the Brier Skill Score (BSS). Fig. 4.3.3 shows the BSS for the Northern Hemisphere 500 hPa height fields. Climatological probabilities are given by the frequency derived from analysis fields of each month. The BSS for the latest four year period shows positive up to 216 hours, indicating that the EPS is capable of providing daily skillful probabilistic forecasts over the whole forecast range.

4.3.5 Application of the One-week EPS to typhoon track forecasts

According to the verification of tropical cyclone (TC) strike probability defined as the fraction of the ensemble members passing within 65 nm (about 120km) of a given location in a 5-day period (Lalaurette and van der Grijn 2002), the One-week EPS is also capable of providing typhoon track forecasts in the medium-range. Fig. 4.3.4 shows an example of a TC track ensemble, indicating that two scenarios could be considered the TC moves towards the southern part of China or the TC recurves and moves into the Sea of Japan. The typhoon actually recurved and hit the Korean peninsula as the second scenario said, although the control run had suggested the first scenario.

4.3.6 Performance of the EPS for one-month forecasting

The skill of ensemble average forecasts is routinely evaluated by the Anomaly Correlation Coefficient (ACC) and RMSE for selected areas with respect to several physical variables. Fig. 4.3.5 shows an example of one-month forecasts for the 500 hPa height and anomaly fields together with the verifying analyses. The anomaly distribution of ensemble forecast resembles that of the analysis, although the amplitude of the ensemble average forecast is smaller than that of the analysis due to the spatial smoothing of anomaly through the averaging of all ensemble members. ACC between these two fields is 0.68 for the Northern Hemisphere (20-90N). Fig. 4.3.6 shows the time sequences of the Northern Hemisphere (20-90N) 500 hPa height anomaly correlations of the ensemble average forecasts from 2 March to 26 October 2006. The one-month forecast is issued once a week on every Friday. Although the skill of an ensemble average is sensitive to an initial condition, it is almost consistently higher than that of a persistence forecast.

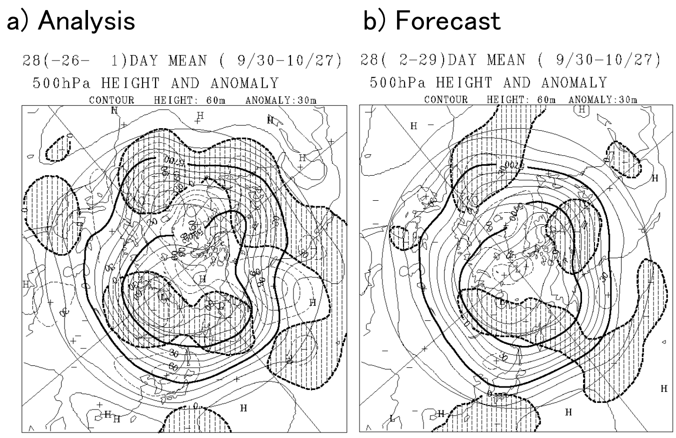

Fig. 4.3.5 500 hPa height (contour interval 60 m) and anomaly (contour interval 30m with negative areas shaded) averaged over the 28-day period from 30 September to 27 October 2006. (a) Verifying objective analysis of JMA. (b) Ensemble average of one-month forecast starting from 12UTC 28 September 2006.

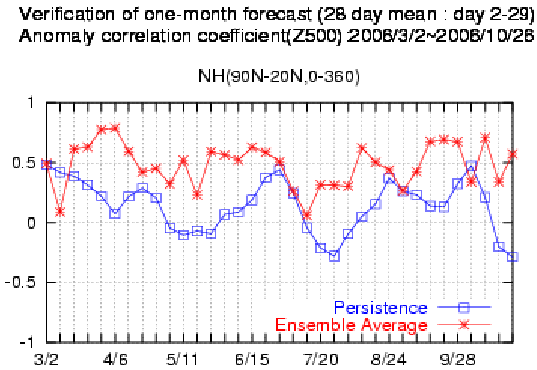

Fig. 4.3.6 The time sequences of the Northern Hemisphere (20-90N) 500 hPa height anomaly correlation coefficient for 28-day mean forecast. Abscissa is the date of initial conditions of one-month forecast from 2 March through 26 October 2006. Line with crosses indicates ensemble average forecast. Line with open squares indicates persistence forecast, which is defined by the sum of the preceding one-month's averaged anomaly and the climatology over target period.

The skill of probabilistic forecasts is also routinely evaluated by the Brier Skill Score (BSS), Reliability skill score (Brel), Resolution skill score (Bres) and Relative Operating Characteristics (ROC) (Palmer et al. 2000). For example, Brel of the Northern Hemisphere (20-90N) 500 hPa height is shown in Fig. 4.3.7. Brel, 100% when forecasts are perfect, is a skill measure relative to the climatological forecast. The skill seems to be relatively higher in spring and autumn than in summer.

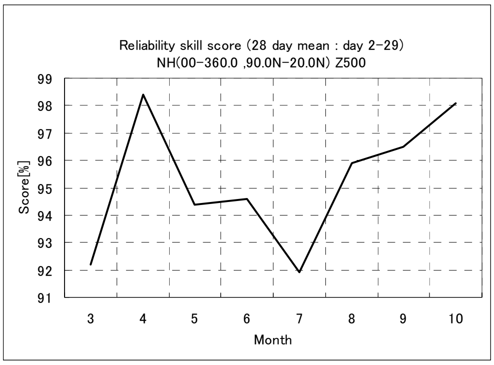

Fig. 4.3.7 Reliability skill score (Brel, in %) of the Northern Hemisphere (20-90N) 500 hPa height for 28-day mean forecast for positive anomaly events. Abscissa is the target month in 2006. All the forecasts whose 28-day forecast period overlaps with the target period of month are used for the statistics.

4.3.7 Performance of the EPS for seasonal forecasting

JMA conducted 21-year (1983-2003) seasonal hindcast experiments in order to evaluate prediction skills. The hindcast was conducted under the same conditions as the operational system except for an ensemble size (5 instead of 31). The prediction skills have been evaluated under the WMO Standard Verification System (SVS) for long-range forecasts, and released at the Tokyo Climate Center Web site. As an example, ROC areas of 2m-temperature (T2m) anomalies and precipitation anomalies are shown in table 4.3.2. Skills of T2m are better than that of precipitation in all regions, and skills in the tropics are better than those in the Northern Hemisphere and the Southern Hemisphere. These results are consistent with those of studies on predictability of seasonal mean fields, such as Sugi et al. (1997).

Table 4.3.2 ROC areas of three-month mean (JJA and DJF) 2m-temperature (T2m) and precipitation anomalies prediction for the Northern Hemisphere (N.H.; 20-90N), the Tropics (20S-20N), and the Southern Hemisphere (S.H.; 20-90S). The event is positive anomaly. Initial date is 10 May for JJA and 10 November for DJF.

T2m	N.H.	Tropics	S.H.
JJA(Initial: 5/10)	66.4	74.4	68.2
DJF(Initial:11/10)	66	73.3	60.4

Precipitation	N.H.	Tropics	S.H.
JJA(Initial: 5/10)	53.5	62.2	53.9
DJF(Initial:11/10)	55.6	61.6	53.9

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