

The Forecast Skill of DMO Surface Weather Element Forecasts
from ECMWF for Beijing for the 11th Asian Games 1990

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The 11th Asian Games were held in Beijing in Autumn 1990. For offering better weather service to the Asian Games, NMC Beijing asked for help from ECMWF. ECMWF did give us scientific support by making and transmitting 10 days DMO(Direct Model Output) surface weather element forecasts to Beijing once a day from Sep. 10 through Oct. 9 1990. The DMO element forecasts for Beijing were used as guidance to make final weather forecast for the 11th Asian Games.

It has been well known that the ECMWF operational model wins great reputation in the world for many years. But what about the weather element forecasts for locations in the Far East ?

In order to know the forecast skill of the DMO element forecasts for Beijing, it is necessary to verify them.

1. Data

1.1 The Elements to Be Verified

The weather element forecasts offered by ECMWF covered 8 weather elements as follows :

cloud amount (%),
relative humidity (%) at 850 hpa,
precipitation (mm / 6 hr),
pressure (hpa) at sea level,
wind direction & speed (kt), 10 m above ground,
temperature (C), 2 m above ground,
temperature (C), at 850 hpa.

All weather elements of the above except the two at 850 hpa were verified.

1.2 The Sample Involved in the Verification

The dates from which the forecasts made at the data time, 12 GMT, are from September 10 through October 9 1990, except Sep. 18 (not received).

1.3 The Observation Used for Verifying

The synoptic reports from Beijing are taken 4 times a day at 00, 06, 12, and 18 GMT from September 11 to October 15 1990.

The observation site for Beijing is located at 39 56' N , 116 17' E and 54 m above sea, instead of 40 N, 116 E and 949 m above sea, onto which model fields were interpolated from grids.

2. Four Scores were Used for Verifying

The first one is Threat Score (TS):

$$\text{Threat Score} = \frac{H}{OB+FO-H} \quad (1)$$

where

H is for the number of cases hit by forecasts,
OB is for the total number of the observations for the event,
FO is for the total number of the forecasts for the event.
Threat Score has the values between 0 and 1; the best is 1, the worst is 0 .

The Threat Score can also be written as

$$\text{Threat Score} = \frac{H}{M+FA+H} \quad (2)$$

where

M is for the number of missing cases by the forecasts,
FA is for the number of false alarm cases by the forecasts.

The others are Mean Error(ME), Mean Absolute Error(MAE) and Correlation Coefficient(CORR)

$$ME = \frac{1}{N} \sum_{i=1}^N (F_i - O_i) \quad (3)$$

$$MAE = \frac{1}{N} \sum_{i=1}^N |F_i - O_i| \quad (4)$$

$$CORR = \frac{\sum_{i=1}^N (F_i - \bar{F}) \cdot (O_i - \bar{O})}{\sqrt{\sum_{i=1}^N (F_i - \bar{F})^2} \cdot \sqrt{\sum_{i=1}^N (O_i - \bar{O})^2}} \quad (5)$$

where

F_i is the forecast made on the i th day,
 O_i is the i th observation to verify the forecast made on the i th day,
 N is the sample size,

$$\bar{F} = \frac{1}{N} \sum_{i=1}^N F_i$$

$$\bar{O} = \frac{1}{N} \sum_{i=1}^N O_i$$

3. Verification

3.1 Verification of Precipitation Forecasts

It is encouraged that by examining the whole period from Sep. 11 to Oct. 10 1990, the ECMWF D+1 and D+2 precipitation forecasts (Yes or No) were as good as the local final forecast for D+1. The Threat Scores were 0.46, and 0.40 for ECMWF D+1, and D+2 forecasts, respectively, 0.45 for the local final forecast for D+1.

But for the day of Sep. 22, on which the opening ceremony of the 11th Asian Games was held, the local final forecast successfully predicted no rain issued to the public on TV 24 hr ahead, while the ECMWF model forecast made a false alarm of rain, 2, 1, and 2 mm rainfall for the day, Sep. 22, by D+1, D+2 and D+3 precipitation forecast, respectively. The satellite pictures showed on the screen that a thick cloud band was over northern China, Beijing was also covered by the cloud band. But the rainfall observation chart for Sep. 22 shows that Beijing was just off the edge of the rain area.

The precipitation forecasts for Beijing by ECMWF had wet bias, the cases of false alarm for rain were much more than the cases of missing and precipitation amounts were forecast too much by the model (see Fig. 3.1.1).

3.2 Verification of Temperature Forecasts

The day to day change of the temperature(max. and min.) was well forecast by ECMWF model (see figures in 3.2). The D+1 temperature forecasts both max. and min. won a little bit higher correlation coefficient between forecast and observation than the local final forecast on TV . But the mean error and mean absolute error of the temperature forecasts (max. and min.) was much worse than the local.

Besides the temperature forecasts had cold bias, their mean errors ranged between -1.2 C and -8.1 C.

3.3 Verification of Forecasts for Sea Level Pressure, Wind, and Cloud Amount

The DMO sea level pressure forecast from ECMWF was excellent, the 36 hr and 60 hr pressure forecast curves fit the observed very well(see Fig. 3.3.3). The correlation coefficient between pressure forecast and observation reached 0.94 up to day+4. It proves that the ECMWF numerical model is really the one of the best in the world.

The wind speed forecast up to D+9 were very good, whose mean absolute errors all were under 1.9 s/m. But the 10 m wind direction forecast for 00 GMT from day+1 to day+9 for Beijing could not be taken into consideration, the mean absolute errors were all above 74 degrees. The possible reason might be the local orography and weather features. For example in the morning hours, around 00 GMT, in Beijing the observed wind is usually weak, say 2 m/s , and from north, that means the wind direction does not coincide with the pressure system unless the city is covered by a strong pressure system.

4. Comments

4.1 The DMO surface element forecasts offered by ECMWF were very helpful for us to make weather forecasts 1 to 5 days ahead for the 11th Asian Games(Sep.22 through Oct.7, 1990) in Beijing.

4.2 The conclusion can not be made based on the verification above, which was done on the short sample size. But the useful forecasts shown in Table 4.2.1 could be thought as a kind of reference.

4.3 Interpolation from grids onto individual locations must be done as accurate in position (latitude and longitude) as possible for the observation site for the location. For example, the temperature forecasts for Beijing had cold bias, some of possible reasons for that could be:

- 1) the forecast model had the cold bias, and
- 2) the position and elevation for Beijing put into interpolation was not exactly as it is. Beijing is located at 39 56' N and 116 17' E, 54 m above sea instead of 40 N 116 E, 949 m above sea. The much higher elevation put into interpolation for Beijing might be caused by the inaccurate position which was further west and further north than observation site for Beijing. As the matter of fact there are mountains located at west and north of Beijing.

4.4 Adding MOS techniques into the DMO element forecasts could improve their forecast skills. For example the cold bias of maximum temperature forecasts for day+2 up to day+5 was around 3 degree C. If MOS techniques had been used on such a good model base, most of the cold biases would have been removed already. The operational MOS temperature forecasts for day+1 up to day+3 in NMC Beijing were based on its 5-level PE model in horizontal resolution, 381.0 km. The model is much worse than the ECMWF operational model, T106L19. But the mean absolute errors of the MOS maximum temperature forecasts during 11th Asian Games were 1.65 C, and 2.31 C for day+1 and day+2, respectively. The mean absolute errors of the MOS minimum temperature forecasts were 2.00 C, and 2.84 C for day+2 and day+3, respectively. It was better than the DMO temperature forecasts for Beijing.

4.5 Resolution increasing, especially in horizontal, could improve the forecast skill of the DMO element forecasts for almost all locations in the world. Many experiments for testing different resolutions have been done, and given the positive answer, higher DMO forecast skill partly resulted from higher resolution. As mentioned above, on the opening day of the 11th Asian Games, Beijing was just off the edge of raining area. It would be possible that a higher resolution model might successfully forecast the weather for Beijing for the day as it was. It is believed that DMO surface element forecast could be made as accurate as experienced weather forecasters did, and ECMWF would be one of the candidates to win the first place.

Fig.3.1.1 Precipitation Forecast

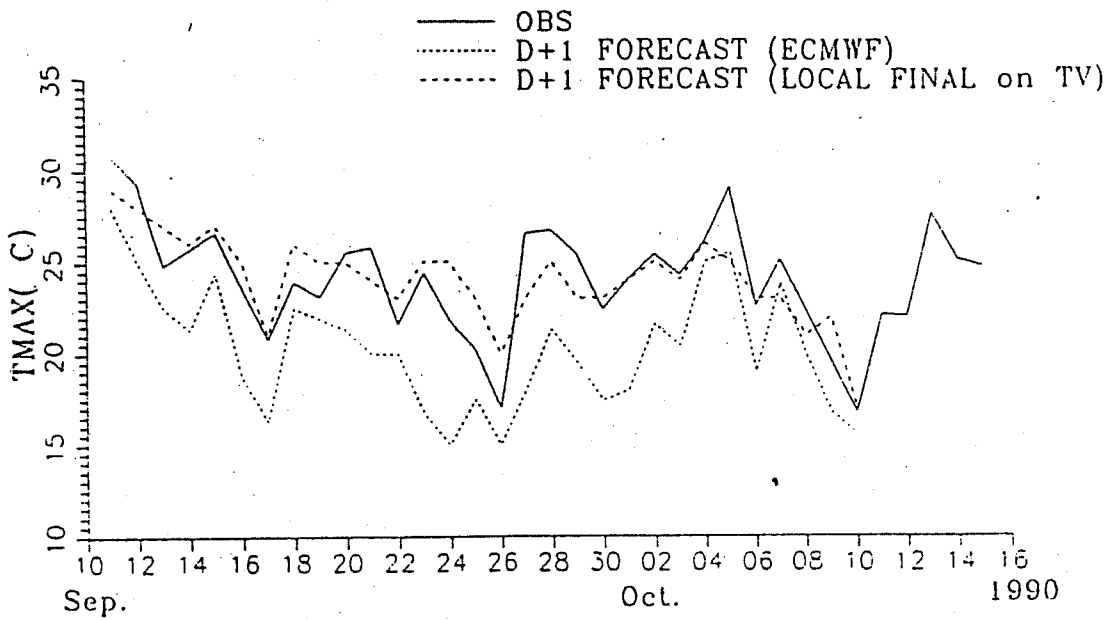
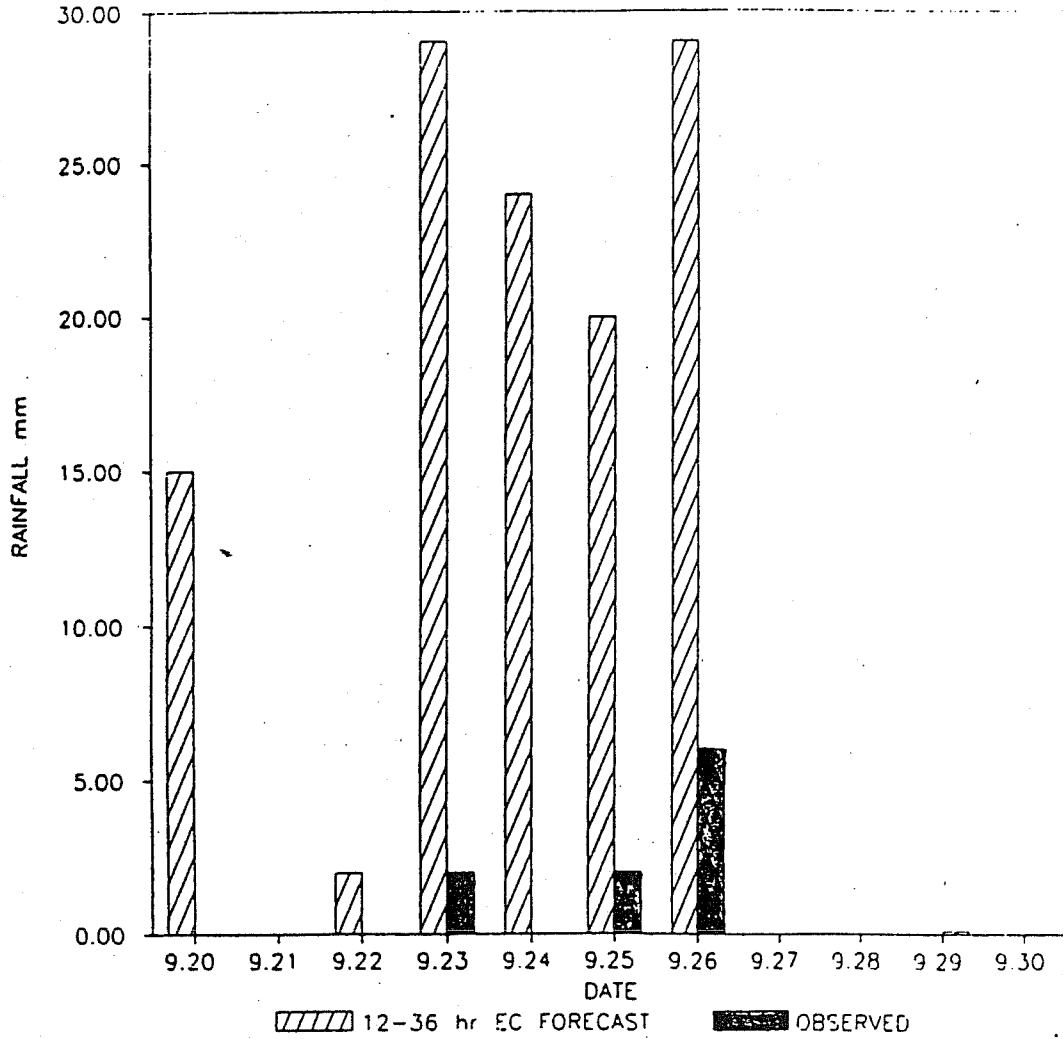


Fig.3.2.7 Day+1 Temperature Forecasts (max) for Beijing against Observation

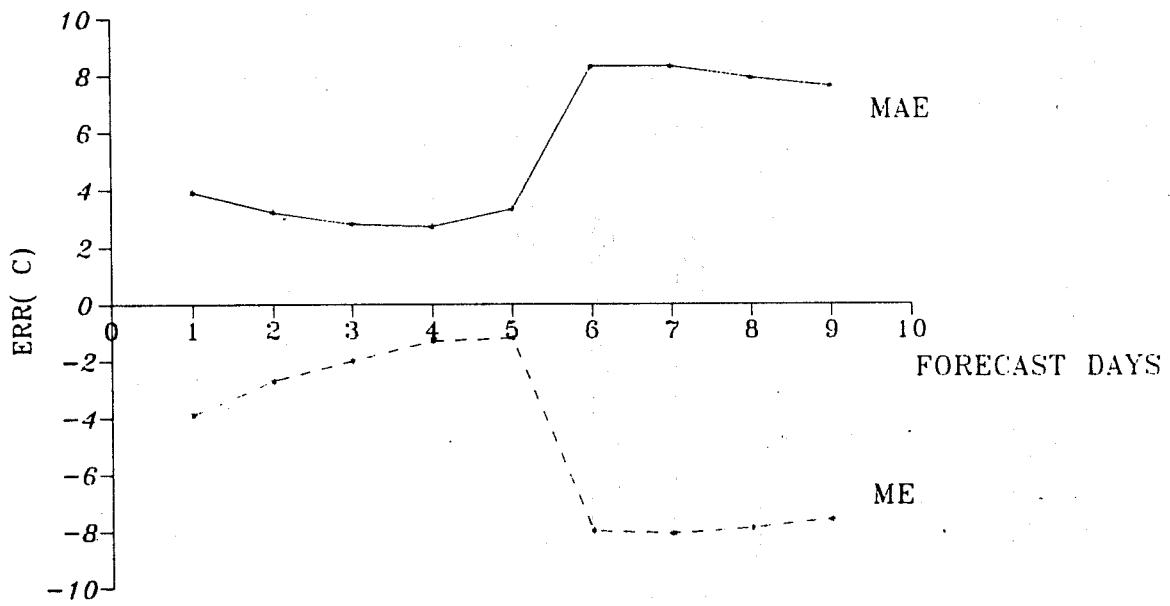


Fig.3.2.a ME & MAE OF T MAX FORECAST

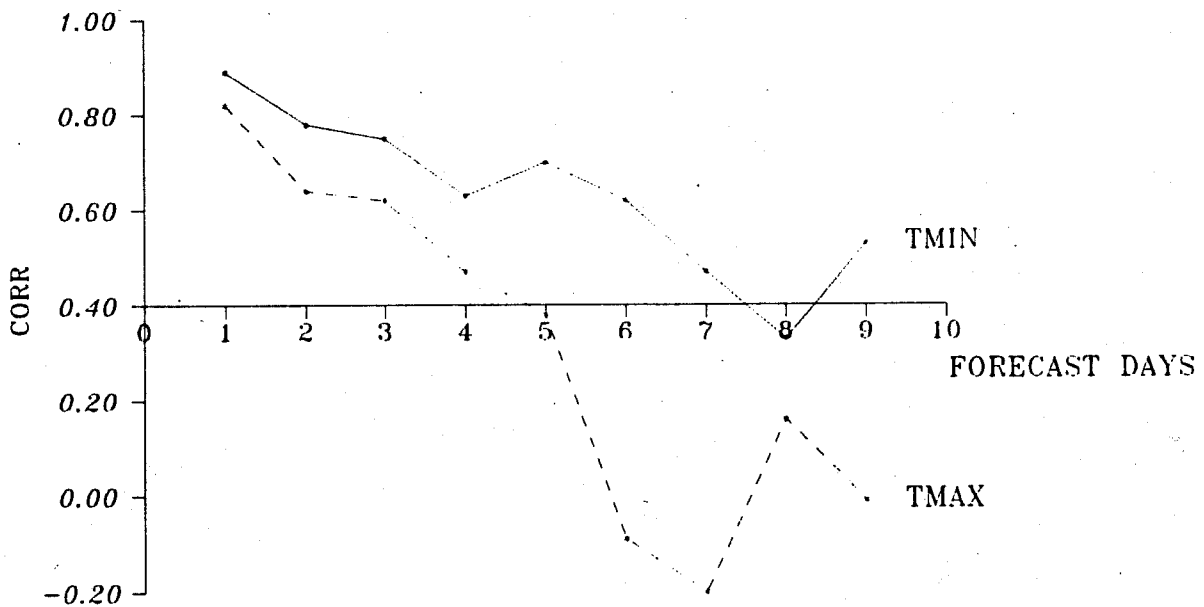


Fig.3.2.c CORR OF TMAX & TMIN FORECASTS

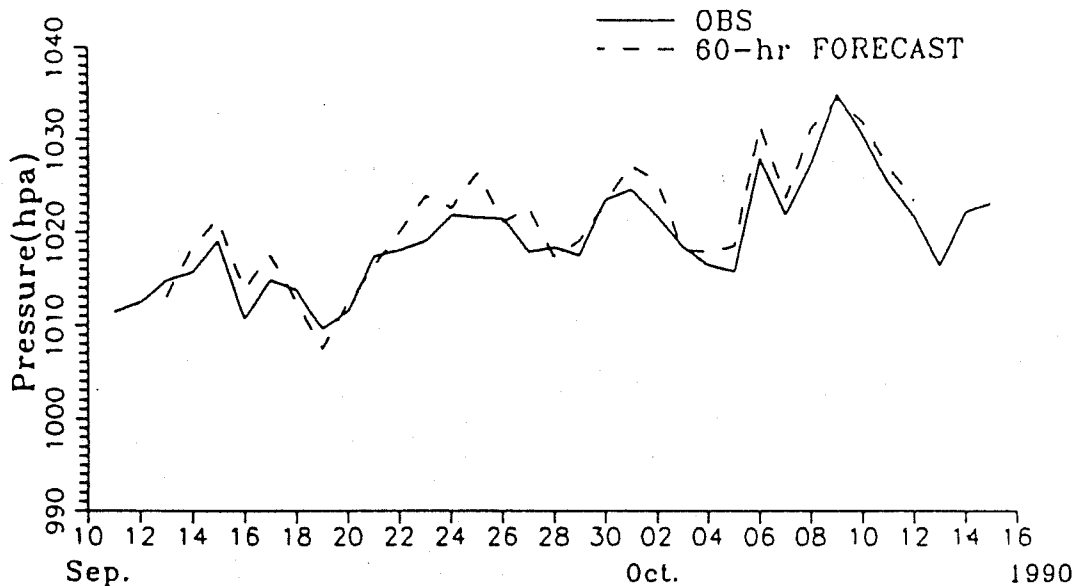


Fig.3.3.3 60-hr Pressure (Sea Level) Forecast for Beijing by ECMWF against Observation

Table 4.2.1 Threshold for Useful Element Forecasts

Element	Forecast Time	Threshold
Precipitation (Yes/No)	Up To D+5	TS about 0.3
Temperature (Min.)	Up To D+6	CORR over 0.6
Temperature (Max.)	Up To D+3	CORR over 0.6
Pressure Sea Level 00 GMT	Up To D+7 Except D+6	CORR over 0.6
Wind Speed 00 and 12 GMT	Up To D+9	MAE below 2 m/s
Wind Direction 00 GMT	Only D+8	MAE below 60 deg.
Wind Direction 12 GMT	Up To D+5 And D+7, D+9	MAE below 60 deg.
Cloud Amount Averaged over 24 hrs	Up To D+9 Except D+7	MAE below 30 %