Numerical Prediction of Typhoon Tracks and Intensity using a Multimodel Superensemble

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Abstract

Using currently available operational forecast data sets on the tracks and intensity of Pacific typhoons of the years 1998, 1999 and 2000 we have constructed a multimodel superensemble following our earlier work on the Atlantic hurricanes. The models included here comprise forecasts from the ECMWF, EMC/NCEP (AVN and MRF), NOGAPS, UKMET and JMA. The superensemble methodology includes a bias estimation training phase where a multiple regression based least square minimization principle is employed. This is quite different from a simple bias correction where a mean value is simply shifted. These bias estimates are described by separate weights for each 12-hour of forecasts for each of the member models; these forecasts are carried out to 144-hours. These past weights are used to construct a superensemble forecast for the future. Some 150 past forecasts of typhoon days are used for the training phase. Our findings show a marked improvement for the tracks and intensity of forecasts from the proposed multimodel superensemble as compared to the forecasts from member models and the ensemble mean. The paper will discuss the detailed statistics for the Pacific typhoon forecasts for the three years 1998, 1999 and 2000

1. Introduction:

In this paper, an attempt has been made to construct the superensemble based track and intensity forecasts for the Pacific typhoons of the years 1998 through 2000. The methodology for the construction of the superensemble forecasts follows a similar procedure that has been used for the Atlantic Hurricanes. Multimodel Superensemble forecasts have shown somewhat higher skill for the Atlantic Hurricane tracks and intensity prediction for the 1998, 1999 and 2000 seasons. Some of our recent publications (Krishnamurti et al., 1999, 2000a, b and 2001) illustrate in detail the superensemble methodology. Multimodel Superensemble technique is a unique approach for collectively removing the models' biases and improving the skill of the forecasts. This approach appears to have great use in NWP, Seasonal Climate, Precipitation Forecasts and hurricane track and intensity forecasts. The present study includes forecasts from currently available operational forecast data sets on the tracks and intensity of Pacific typhoons. The models included here comprise forecasts from the ECMWF, EMC/NCEP (AVN and MRF), NOGAPS, UKMET and JMA. The main results of this study are that the multimodel superensemble has much higher skill than the participating member models and the ensemble mean.

2. Superensemble Method for typhoon track and intensity prediction:

The superensemble methodology includes a bias estimation training phase where a multiple regression based least square minimization principle is employed. This is quite different from a simple bias correction where a mean value is simply shifted. During this phase, model forecasted position (latitude and longitude) and intensity are regressed against the best (observed) position (latitude and longitude) and intensity for each forecast time. A simple multiple linear regression technique is employed (Krishnamurti et al., 2000) to generate weights (coefficients) for each model. These bias estimates are described by separate weights at an interval of every 12-hours of the 144 hour forecasts for each of the member models. These past weights are used to construct a superensemble forecast for the future. Some 100 to 150 past forecasts of typhoon days are used for the training phase for each of the years of 1998, 1999 and 2000. The performance of the superensemble largely depends on the consistency of the member models in their design and is found to be sensitive to changes in the performance of the member models. Any changes in the dynamics/physics/data assimilation procedure or other features of the member models during the training phase can adversely affect the superensemble performance and hence independent training has been carried out for each of these three years and separate statistics are generated. Our findings show a marked improvement for the tracks and intensity of forecasts from the proposed multimodel superensemble as compared to the forecasts from member models and the ensemble mean. This paper will discuss the detailed statistics for the Pacific typhoon track and intensity forecasts for the three years 1998, 1999 and 2000.

3. Data used for this study:

In this study, the model forecast position (latitude and longitude) and intensity, along with best (observed) track and intensity information is collected from different operational models listed in Table 1. A relatively large area comprising East Pacific/ Northeast Pacific, West Pacific/ Northwest Pacific, Central North Pacific and Southwest Pacific/ Central South Pacific regions was chosen for this study. Table 1 gives the details of the number of storms, models used, number of forecast days (time line) during the training and forecast phases of the superensemble respectively. Independent statistics are generated for each year of study from 1998 through 2000.

Table 1. Data used in the study and the time line of the superensemble

Year	No. of storms	Models used	Time line (No. of Forecast days)	
			Training Phase	Forecast Phase
1998	47	ECMWF, MRF, NOGAPS, UKMET, JMA GSM and TYM	100 (23 storms)	113 (24 storms)
1999	56	ECMWF, MRF, NOGAPS, UKMET, JMA GSM and TYM	150 (30 storms)	114 (26 storms)
2000	55	ECMWF, MRF, NOGAPS, AVN and UKMET	148 (30 storms)	116 (25 storms)

4. Results:

The track errors (distance in km) from multimodels, ensemble mean and the superensemble for the years 1998, 1999 and 2000 are shown in Figures 1, 2 and 3 respectively. It can be seen here that the skill from the superensemble is consistently high as compared to the member models and also the ensemble mean. The histograms showing the intensity errors (knots) from multimodels, ensemble mean and superensemble are shown in Figures 4 and 5 for the years 1998 and 1999. Here also we can find that the skill from the superensemble is relatively high compared to the member models and ensemble mean. These are some of the important results from our study over the whole of the Pacific region. Independent basin statistics have also been generated and the results (not shown here) for each of the basins confirm the superior performance of the superensemble methodology as revealed by less track and intensity errors compared to member models and the ensemble mean. Certain examples of track forecasts from the superensemble are shown in Figures 6, 7 and 8. These correspond to 108 hr forecasts for a) Typhoon Faith that hit the central Vietnam in the west Pacific on December 14, 1998; b) Typhoon Olga that hit the South Korean coast in the west Pacific on August 3, 1999 and c) Hurricane Daniel that passed the Hawaii islands over the eastern Pacific during July 30-31, 2000. It is evident from these figures that the superensemble has more accurate track forecasts compared to member models and the ensemble mean. Particularly the landfall positions predicted by the superensemble are more close to the observation (typhoon Faith and typhoon Olga) and this is one of the important and useful results obtained using the superensemble methodology. Such improvement in track errors, particularly after 96 hours of forecast, is very much useful in disaster mitigation planning and can have a huge impact on economy and loss of life and property.

One of the main constraints for the success of Superensemble technique is that the member models should be consistent throughout the training phase. Any changes applied to model physics/data assimilation techniques/storm bogussing techniques contaminate the superensemble performance due to the change in the characteristics of the model biases. Since there are constant improvements of the member models over the period of this study, the superensemble forecasts using the coefficients generated from earlier versions of the models may not yield better results. This was shown in Figure 9 in the case of Atlantic Hurricane track forecasts for the year 2000. Since many models have undergone improvements in the year 2000, when the model coefficients for the year 1999 were used to predict the tracks of hurricanes during 2000, the errors of the superensemble are large (green bars) compared to other member models and also the ensemble mean. When the exercise was repeated using the model bias history of year 2000, the skill of superensemble went up again (red bars).

5. Summary and conclusions:

The multimodel forecasts for Pacific Typhoon tracks and intensity during 1998, 1999 and 2000 for forecast periods at 12 hr interval through 144 hrs of forecast are examined. It appears that the superensemble approach for

Pacific typhoon track and intensity forecasts show somewhat improved skill. The landfall positions are better estimated by the superensemble as seen through reduced errors in the position at the time of landfall. This can have a great economic impact on management and disaster mitigation planning. Approach of superensemble is particularly more useful for track and intensity forecasts beyond 72 hours, where the superensemble errors are relatively small while all member model errors are quite large. Consistency in the member models is important for this method to be successful. Independent statistics for separate basins over the Pacific Ocean also give a score for a better understanding of the model biases. The overall results are quite encouraging and we are planning to implement this method of superensemble forecasts of tracks and intensity on a near-real time basis.

References:

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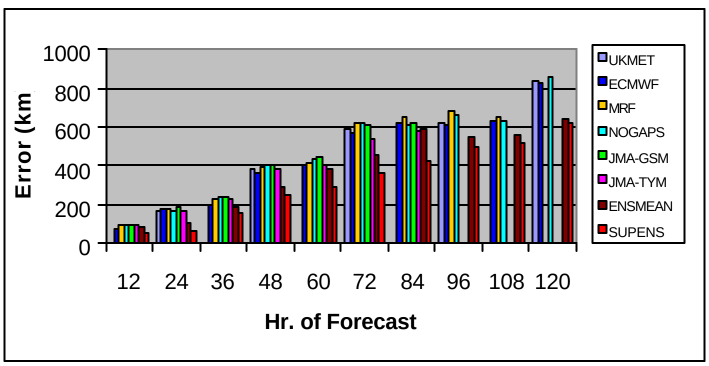

Fig. 1 Mean Pacific Typhoon Track Errors for 1998

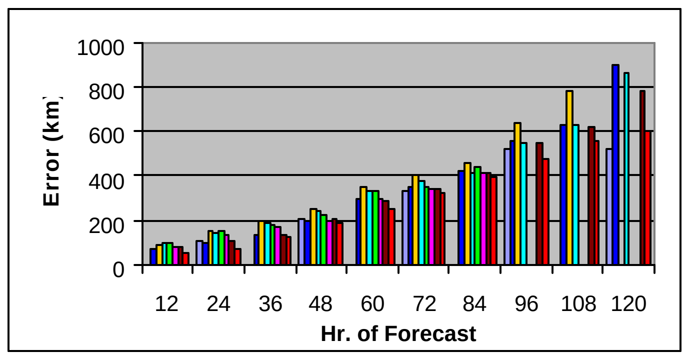

Fig. 2. Mean Pacific Typhoon Track Errors for 1999

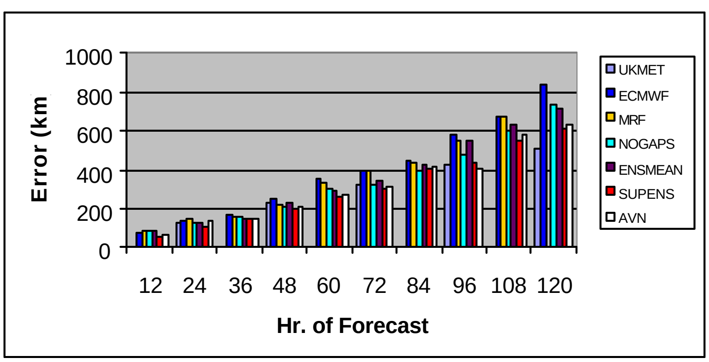

Fig. 3 Mean Pacific Typhoon Track Errors for 2000

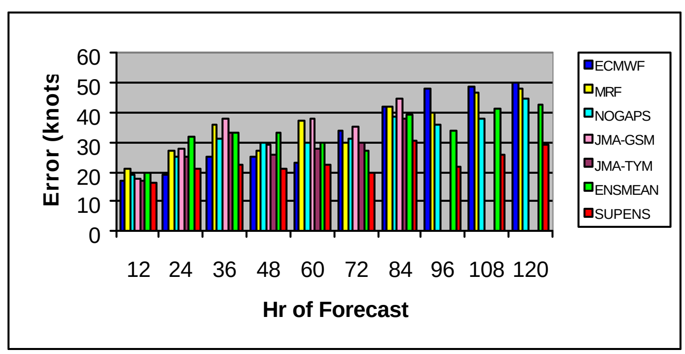

Fig. 4. Mean Pacific Typhoon Intensity Errors for 1998

Fig. 5 Mean Pacific Typhoon Intensity Errors for 1999

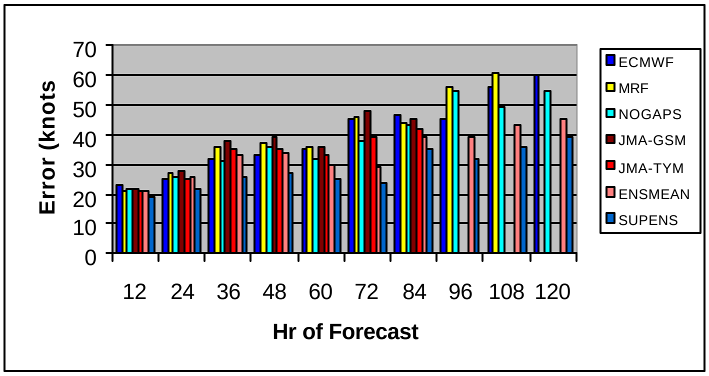

Fig. 6 108 hr Superensemble Track Forecast for Typhoon Faith, 1998120912

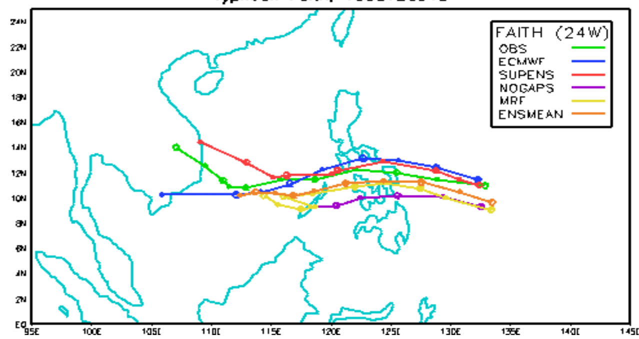

Fig. 7 108 hr Superensemble Track Forecast for Typhoon Olga, 1999073000

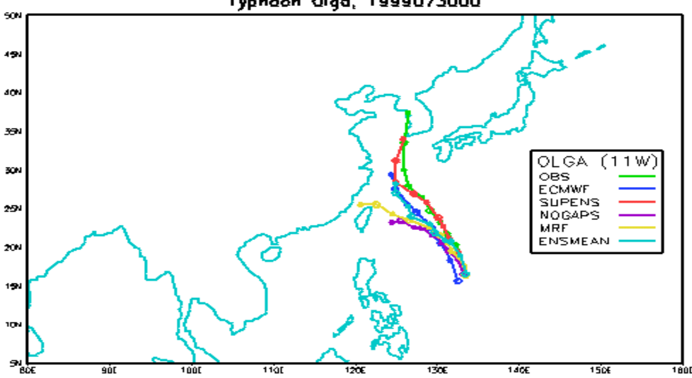

Fig. 8 108 hr Superensemble Track Forecast for Hurricane Daniel 2000072612

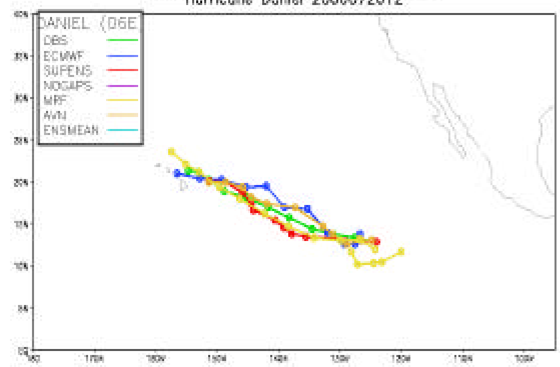

Fig. 9 Track Forecast Errors for Atlantic Hurricanes - Year 2000