ENSEMBLE FORECAST DURING THE MEI-YU SEASON

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1. INTRODUCTION

The concept of ensemble forecasting was first initiated by Lorenz (1963), where he examined the initial state uncertainties in the atmosphere and discussed the well-known "butterfly" or chaos effect. Much progress has been made in ensemble forecasts using numerical weather prediction (NWP) models, especially for global NWP application (Krishnamurti et al. 1999). With the increase of computational power, now is the time to attempt the ensemble forecasting on the mesoscale (Kuo 2000).

Wang and Seaman (1997) performed a comparison study of four cumulus parameterization schemes (CPSs), the Anthes-Kuo, Betts-Miller, Grell, and Kain-Fritsch schemes, using the Penn State/NCAR MM5 model. Performance of these CPSs was examined using six precipitation events over the continental United States for both cold and warm seasons. They found that no one CPS always outperformed the others. The general 6-h precipitation forecast skill for these schemes was fairly good in predicting four out of six cases examined in the study, even for higher threshold. The forecast skill was generally higher for cold-season events than for warm-season events. There was an increase in the forecast skill with the increase of horizontal resolution, and the gain was most obvious in predicting heavier rainfall amounts. The model's precipitation skill is better in rainfall volume than in either the area coverage or the peak amount.

Du et al. (1997) examined the uncertainities of initial condition and cumulus parameterization on quantitative precipitation forecasts (QPFs) for a cyclogenesis case in the United States using the Penn State/NCAR MM4 model. Ensemble QPF had large sensitivity to initial condition uncertainities. Ensemble averaging reduced the root-mean-square error for QPF and nearly 90% of QPF improvement was obtained using ensemble sizes as small as 8-10. Further sensitivity experiments showed that the QPF improvement by ensemble forecasting exceeded the improvement by doubling horizontal resolution.

Mullen et al. (1999) investigated the impact of differences in analysis-forecast systems on dispersion of an ensemble forecast for a cyclogenesis case. Error growth by initial condition uncertainities significantly depended on the analysis-forecast system. QPFs and probabilistic QPFs were extremely sensitive to the choice of precipitation parameterization in the model, similar to the findings of Yang et al. (2000) for a Mei-Yu frontal precipitation event. Therefore, the combined effect of uncertainties in precipitation physics and the initial conditions provides a means to increase the dispersion of QPF ensemble forecast system.

2. ENSEMBLE FORECAST IN THE 2000 MEI-YU SEASON

Based on the concept of ensemble forecasting discussed in the introduction, scientists at several universities and operational centers in Taiwan jointed together to conduct the Ensemble Forecast Experiment during the Mei-Yu season (May and June) in Year 2000 and 2001. The participating sites in Taiwan included National Taiwan University (NTU), National Central University (NCU), National Taiwan Normal University (NTNU), Chinese Culture University (CCU), Central Weather Bureau (CWB), and Civil Aeronautics Administration (CAA). Each site used the Penn State/NCAR MM5 (Grell et al. 1994) Version 3.3 as a common model with different precipitation (cumulus and microphysics) parameterizations at different institute. Table 1 lists the physics schemes used in the MM5 ensemble experiment. In Year 2001, Dr. Jim Bresch at NCAR joined the Ensemble Forecast Experiment and conducted additional four MM5 runs (Set B in Table 1) in order to increase the ensemble spread and test new physics schemes.

The model configuration for the MM5 ensemble forecast experiment includes a coarse mesh of 45-km grid size and a fine mesh of 15-km grid size. Domain size is 81× 71 for coarse mesh and 79× 79

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for fine mesh, with 23 σ levels in the vertical. Each MM5 run is 36 hours. The initial condition for MM5 ensemble is provided by the analysis field of the Central Weather Bureau Global Forecast System (CWBGFS; Liou et al. 1997) as the first-guess field and the boundary condition is provided by the CWBGFS forecast field through the "regrid" package. Surface observations and sounding data are included by objective analysis to improve the first-guess field through the "little-r" package.

During the Mei-Yu seasn (May and June), Miss Hui-Chuan Lin at CAA put the initial-condition and boundary-condition files for the MM5 ensemble runs at a common ftp site (provided by CWB) twice a day (00 UTC and 12 UTC). Each participating site came to this ftp site to obtain files for the MM5 ensemble run. Because of the narrow bandwidth of Taiwan's educational network, each participating site only ftped the digital 6-hourly rainfall forecast of 15-km MM5 run back to CWB. Dr. Jen-Hsin Teng at CWB then produced ensemble rainfall forecasts to be used by forecasters to assist CWB's issuing of heavy rainfall warnings in the Mei-Yu season.

3. PRELIMINARY RESULTS

In order to verify the precipitation forecast, we first utilized the objective analysis technique of Cressman (1969) to interpolate the observed rainfall data recorded by islandwide 343 raingauge stations in Taiwan to the 155 grid points on the 15-km MM5 grid (Fig. 1). The influence radius of 10 km around a grid point was taken to perform interpolation, based on the small-scale nature of precipitation phenomenon and the grid size (15 km) of the MM5 fine mesh. Then the threat score was calculated for the 155 grid points in Taiwan on the 15-km MM5 grid by comparing the forecasted rainfall by each MM5 ensemble member with the "observed" rainfall after objective analysis.

Figure 2a shows the threat score for the 12-24 h forecast for all 6 members of MM5 ensemble runs during the 2000 Mei-Yu season (15 May to 20 June 2000). It included the MM5 runs with both the 00 UTC initializations and 12 UTC initializations. In the figure, the "ensemble-mean forecast" ("Average" curve) was done by simply averaging the rainfall forecasts of 6 MM5 ensemble members. The threat score decreased with the increase of precipitation threshold, consistent with Olson et al. (1995), Chien et al. (2001) and others. It is very clear from Fig. 2a that the ensemble-mean forecast always out-performed individual forecast in all precipitation thresholds. For the lowest threshold (0.25 mm), the threat score of ensemble-mean forecast (Average) had the highest score of 0.39 and the lowest score of ensemble member (NTNU) was 0.32. In other words, the ensemble forecast technique improved the rainfall forecast for lowest threshold (i.e., the possibility for rainfall occurrence) as much as 30%! Figure 2b is the threat score for the 24-36 h forecast for all 6 MM5 ensemble members during the 2000 Mei-Yu season. Similarly, the ensemble-mean forecast apparently out-performed individual forecast and this improvement persisted in all precipitation thresholds.

Finally, the forecasts of NWP models have inherent limitation due to the uncertainties of initial condition and physical parameterization. Taiwan's steep mountain and rich weather phenomena (Mei-Yu front, typhoon, winter-time cold front, summer-time afternoon thunderstorm and local circulation) make the NWP limitation more severe. In order to reduce the impact of uncertainties of initial condition and physical parameterization on NWP performance, ensemble forecasting is one way to enhance the NWP value and extend its predictability.

ACKNOWLEDGEMENTS

The authors would like to express appreciation to the Central Weather Bureau and the Civil Aeronautics Administration for their supports of the Ensemble Forecast Experiment. The study is supported by National Science Council in Taiwan under Grant NSC 89-2111-M-034-007.

REFERENCES

Chien, F, -C., M. -J. Yang, and Y. -H. Kuo, 2001: Precipitation forecast of the MM5 in Taiwan area during the 1998 Mei-Yu season. *Wea. Forecasting*, submitted.

Cressman, G. P., 1959: An operational objective analysis system. *Mon. Wea. Rev.*, **87**, 367-374.

Du, J., S. L. Mullen, and F. Sanders, 1997: Short-range ensemble forecasting of quantitative precipitation. *Mon. Wea. Rev.,* **125**, 2427-2459.

Grell, G. A., J. Dudhia, and D. R. Stauffer, 1994: A description of the fifth generation Penn State/NCAR mesoscale model (MM5). NCAR Tech Note NCAR/TN-398+STR, 138 pp.

Kuo, Y.-H., 2000: Mesoscale numerical weather prediction. Preprint, International Conf. on Mesoscale Convective Systems and Heavy Rain in East Asia, Seoul, Korea, 1-7.

Krishnamurti and coauthors, 1999: Multi-model superensemble forecasts for weather and seasonal climate. Florida State University, Technical Report, 99-8.

Lorenz, E. N., 1963: Deterministic non-periodic flow. *J. Atmos. Sci.*, **20**, 130-141.

Liou, C.-S, J.-H. Chen, C.-T. Terng, F.-J. Wang, C.-T. Fong, T. E. Rosmond, H.-C. Kuo, C.-H. Shiao, and M.-D. Cheng, 1997: The second generation global forecast system at the Central Weather Bureau in Taiwan. *Wea. Forecasting*, **12**, 653-663.

Mullen, S. L., J. Du, and F. Sanders, 1999: The dependence of ensemble dispersion on analysis-forecast systems: Implications to short-range ensemble forecasting of precipitation. *Mon. Wea. Rev.*, **127**, 1674-1686.

Oslon, D. A, N. W. Junker, and B. Korty, 1995: Evaluation of 33 years of quantitative precipitation forecasting at NMC. *Wea. Forecasting*, **10**, 498-511.

Wang, Wei, and N. L. Seaman, 1997: A comparison study of convective parameterization schemes in a mesoscale model. *Mon. Wea. Rev.*, **125**, 252-278.

Yang, M.-J., F.-C. Chien, and M.-D. Cheng, 2000: Precipitation parameterizations in a simulated Mei-Yu front. *Terr., Atmos. and Oceanic Sci.*, **11**, 393-422.

Table 1: Physics schems of MM5 Ensemble members on the 45-km/15-km nested grid.

Site	Cumulus scheme	Microphysics scheme	PBL scheme
	Set A with the first guess from the CWB Global Model		
NTU	Grell	Resiner 1	MRF
NCU	Betts-Miller	Resiner 1	MRF
NTNU	Kain-Fritsch	Simple Ice	MRF
CCU	Kain-Fritsch	Goddard	MRF
CWB	Anthes-Kuo	Simple Ice	MRF
CAA	Kain-Fritsch	Reisner 1	MRF
	Set B with the first guess from the NCEP AVN Global Model*		
NCAR1	new Kain-Fritsch	Schultz	MRF
NCAR2	Grell	Schultz	MRF
NCAR3	new Kain-Fritsch	Schultz	Eta
NCAR4	new Kain-Fritsch	Reisner 1	MRF

*Note that the MM5 runs in Set B are performed by Dr. Jim Bresch at NCAR.

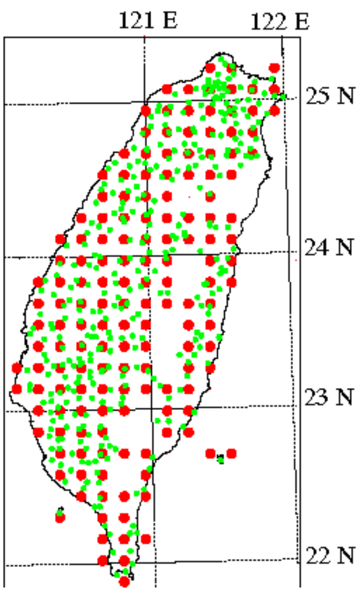
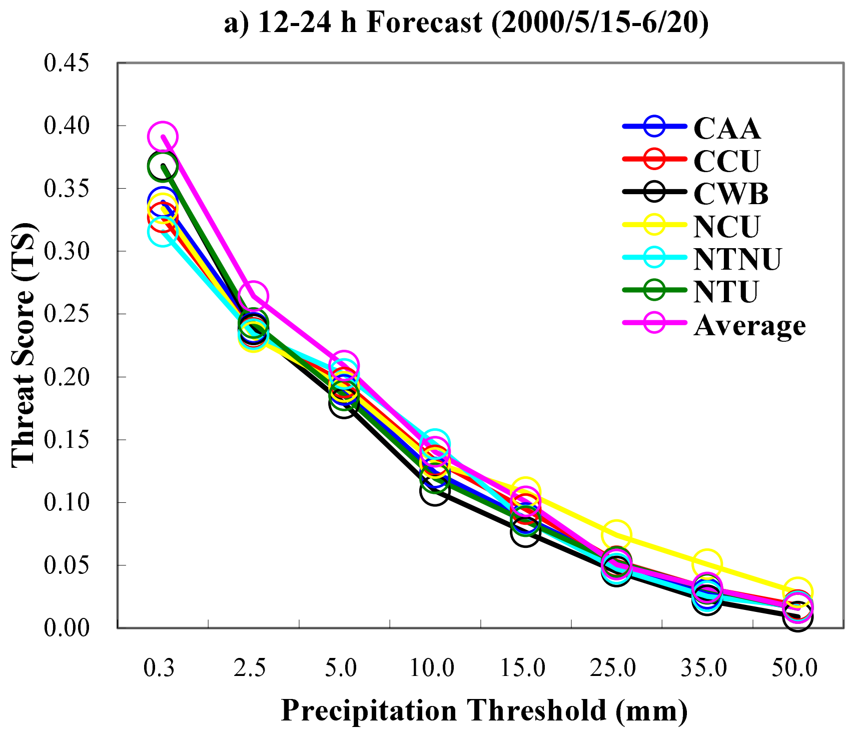


Figure 1: Rain gauge stations (small dots) and the 15-km MM5 grid points (big dots) over the Taiwan area.



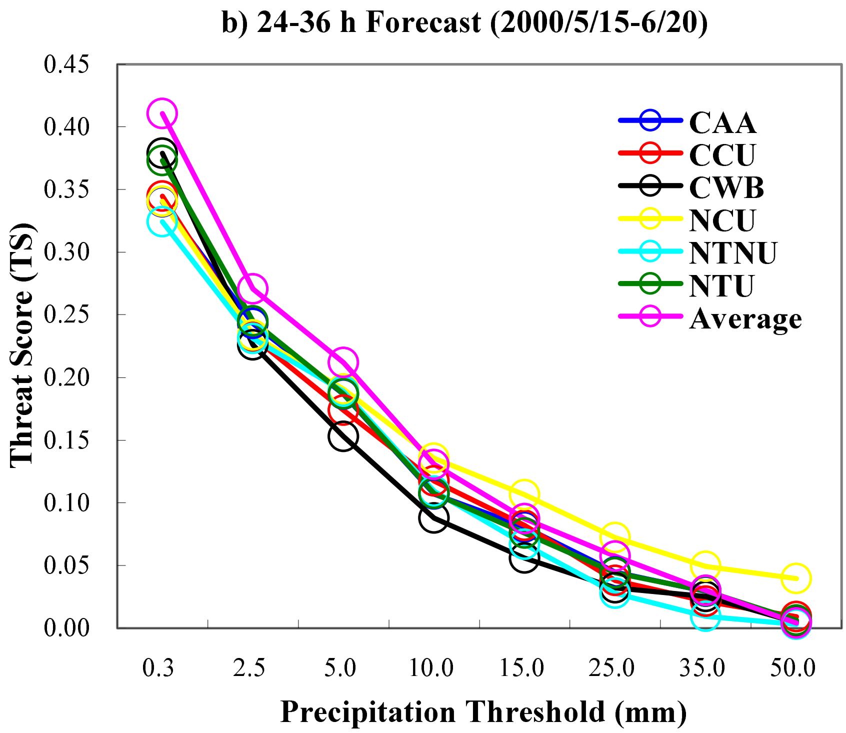


Figure 2: Threat scores of the MM5 Ensemble Forecast during the 2000 Mei-Yu Season: (a) 12-24 h forecast, and (b) 24-36 h forecast.