A Real-time MM5/WRF Forecasting system in Taiwan

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1. Introduction

Ensemble forecast has been extensively used in operations, since early 1990s, at many forecast centers over the world. In recent years, there have been many studies discussing the performance of an ensemble rainfall forecast (e.g., Du et al. 1997; Ebert 2001; Zhang and Krishnamurti 1997). Most of them showed that the ensemble mean rainfall forecasts can provide more accurate results than a rainfall forecast from a single ensemble member.

In view of the need of mesoscale ensemble of precipitation forecasts, a group of researchers in Taiwan has, since 2000, jointly run an MM5 ensemble system in real time during each Mei-yu season. The system consists of six members, each run by a university or a government institute. The participators include the National Taiwan University (NTU), the National Central University (NCU), the National Taiwan Normal University (NTNU), the CWB, and the CAA. Verification of this ensemble system in terms of precipitation forecasts during the Mei-yu seasons of 2000, 2001, and 2002 was presented in Chien and Jou (2004). The paper shows that the best hydrological physics combination of MM5 suitable for simulations in the Taiwan area during a Mei-yu season is the Grell cumulus scheme and Reisner I microphysics scheme. It also documents that applying appropriate weighting to members helps to create better ensemble rainfall forecasts.

Since the Mei-yu season (15 May to 20 June) of 2004, we have set up a real-time mesoscale ensemble forecasting system that included a WRF model and two MM5 members. Rain and meteorological fields from the forecasts of each single member and the ensemble mean are generated and posted on a website called MEFSEA (Mesoscale Ensemble Forecast for SouthEast Asia; see Fig. 1):

http://pblap.atm.ncu.edu.tw/mefsea

In this paper, forecast comparisons between the WRF member and the two MM5 members in Taiwan are presented.

2. Configuration of WRF and MM5 simulations

The model configuration of the ensemble system includes two domains with 45 and 15 km horizontal grid spacing and 31 vertical levels. The models ran twice a day at 0000 UTC and 1200 UTC, with forecasts extended to 48 hours. Based on the experience in the past, we chose the Grell cumulus parameterization scheme, the Mixed-phase (Reisner I) microphysics scheme, and the MRF PBL scheme for the two MM5 members (MM5N and MM5C). The only difference between these two members is on the initial and boundary conditions. The MM5N used the analyses and forecasts of the NCEP GFS (global forecast system) as input data, while the MM5C used those of the CWB GFS. The WRF model used the Kain-Fritsch (new Eta) cumulus parameterization scheme, the WSM 5-class microphysics scheme, and the YSU PBL scheme. Its initial and boundary conditions were obtained from the NCEP GFS.

3. Case studies

In 2004, there were several typhoons approached Taiwan and produced heavy rainfall, resulting in severe flooding and mudslides. We provide two cases here to make comparisons of forecasts among members with the observations.

Typhoon Mindulle (2004) occurred in late June and early July 2004. It approached southern Taiwan on 1 July and moved northward along the eastern coast. The typhoon itself was not intense, but its associated southwesterly flow brought heavy rainfall on southern and central Taiwan. Daily rainfall on 2-4 July exceeded 300 mm in many local areas, resulting in severe mudslides. A cross-mid-Taiwan roadway meandering over the Central Mountain Range (CMR) was severely damaged. The road is not expected to be rebuilt in the near future. Overall, the typhoon caused 29 people dead and 12 missing. More than 10 thousand people were forced to evacuate their homes. The simulations of the WRF and MM5 show that the WRF model produced a better rainfall pattern and amount than the MM5 models (Fig. 2).

During 23-25 August 2004, typhoon Aere (2004) lashed across northern Taiwan, bringing heavy precipitation and triggering mountain torrents and mudslides over the northwestern slope of the CMR. It left 22 people dead and 6 other accounted for missing. The simulated rainfall of the WRF model was more consistent with the observations than the MM5N (Fig. 3).

4. Sensitivity studies

We also performed sensitivity studies for WRF model, in order to search for the best physics combinations for simulation in the Taiwan area during a Mei-yu season. Two PBL schemes (YSU and MYJ), three cumulus parameterization schemes (Kain-Fritsch, BMJ, and Grell-Devenyi), and two microphysics schemes (WSM 5-class and Ferrier) are chosen for the studies. The above combinations ended up with 12 WRF members. We performed the simulations of each member twice a day from 15 May to 15 June 2004. The overall performance of each member was evaluated by examining the simulations of meteorological fields and 12-h precipitation for the entire month. We compared the simulated geopotential height, temperature, specific humidity, and winds at standard pressure levels with the sounding observations in both domains 1 and 2. Mean bias and root-mean-square error (RMSE) were calculated for evaluation. Precipitation verification was carried out by comparing 12-h rainfall simulation with rain gauge data. The equitable threat score (ETS) and bias score were used to evaluate the performance of each member.

It is found that in general the YSU PBL scheme performed better than the MYJ PBL scheme. The WSM 5-class microphysics scheme outperformed the Ferrier scheme. As for the cumulus schemes, the Kain-Fritsch scheme appeared to be the best choice among the three schemes. The Grell-Devenyi scheme usually over-predicted rainfall.

References:

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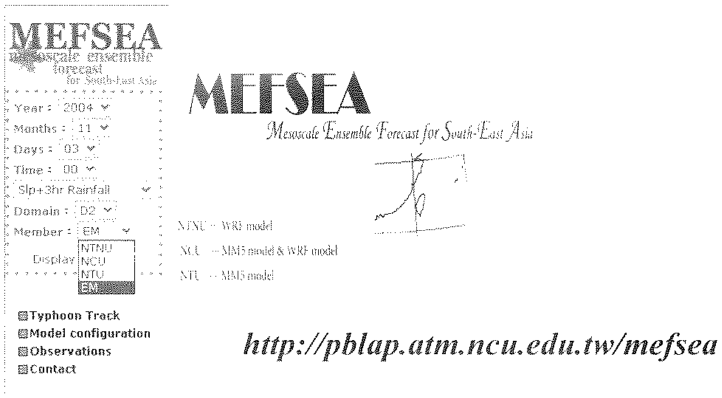

Fig. 1: Home page of the MEFSEA website.

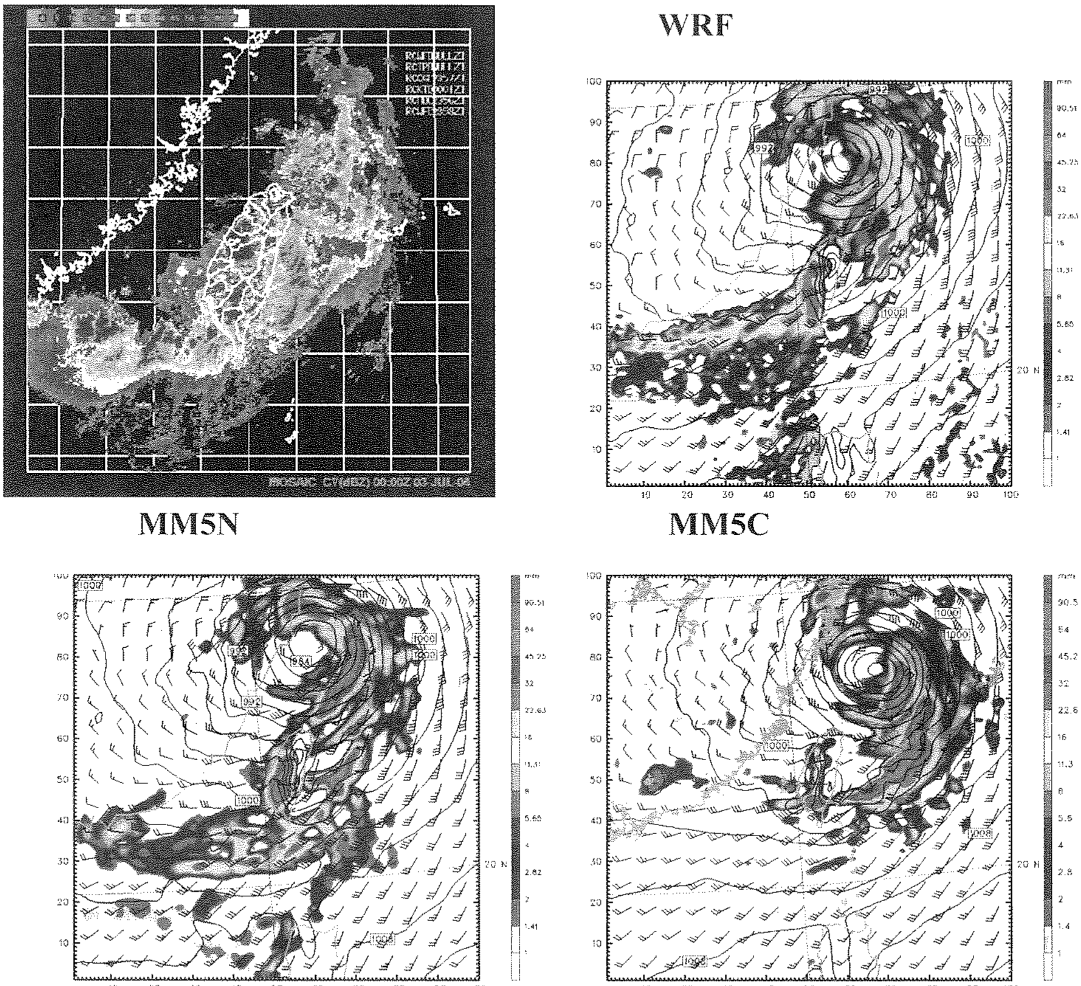

Fig. 2: (top left) Radar reflectivity at 0000 UTC 3 July 2004; (others) Simulated SLP, wind, and 3-h accumulated rainfall of domain 2 at 24 h of the WRF, MM5N, and MM5C initialized at 0000 UTC 2 July 2004.

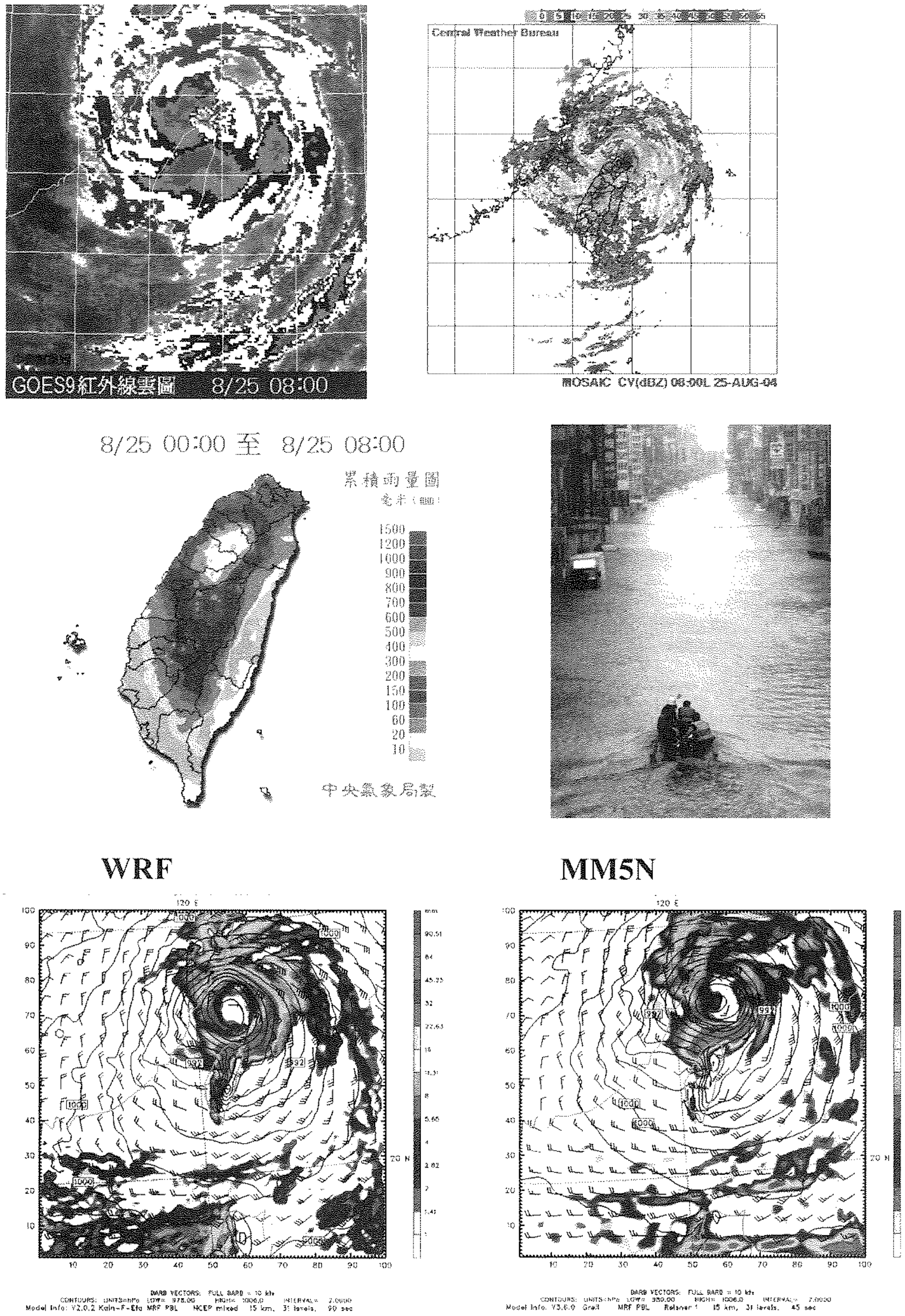

Fig. 3: (top) Satellite picture and radar reflectivity at 0000 UTC 25 August 2004, (middle left) accumulated rainfall from 1600 UTC 24 to 0000 UTC 25 August 2004. (middle right) Flooding in Taipei County, (bottom) SLP, wind, and 3-h accumulated rainfall forecasts of domain 2 at 24 h of the WRF and MM5N. Models are initialized at 0000 UTC 24 August 2004.