Article ID: 1006-8775(2009) 01-073-05

EXPERIMENTS ON ASSIMILATION OF INITIAL VALUES IN NUMERICAL PREDICTION OF A WARM-SECTOR PRECIPITATION IN SOUTH CHINA

ZHANG Cheng-zhong (张诚忠), WAN Qi-lin (万齐林), HUANG Yan-yan (黄燕燕), CHEN Zi-tong (陈子通), DING Wei-yu (丁伟钰)

(Guangzhou Institute of Tropical and Marine Meteorology, CMA, Guangzhou 510080 China)

Abstract: In order to understand the impact of initial conditions upon prediction accuracy of short-term forecast and nowcast of precipitation in South China, four experiments i.e. a control, an assimilation of conventional sounding and surface data, testing with nudging rainwater data and the assimilation of radar-derived radial wind, are respectively conducted to simulate a case of warm-sector heavy rainfall that occurred over South China, by using the GRAPES_MESO model. The results show that (1) assimilating conventional surface and sounding observations helps improve the 24-h rainfall forecast in both the area and order of magnitude; (2) nudging rainwater contributes to a significant improvement of nowcast, and (3) the assimilation of radar-derived radial winds distinctly improves the 24-h rainfall forecast in both the area and order of magnitude. These results serve as significant technical reference for the study on short-term forecast and nowcast of precipitation over South China in the future.

Key words: South China; initial conditions; warm-sector precipitation; numerical simulation experiment

CLC number: P435 **Document code:** A **doi:** 10.3969/j.issn.1006-8775.2009.01.012

1 INTRODUCTION

With the increasing development of numerical weather prediction (NWP) techniques, their products are gradually becoming important reference for routine meteorological weather stations and observatories in making weather forecasts. In spite of it, numerical models are still limited in their ability of handling short-term forecast and nowcast. If the humidity of the initial field and thermodynamic relationships are not properly dealt with, according to Turpeinen et al. [1], the issue of model spin-up will come up to underestimate the amount of rain that is just about to occur. As shown in Kalnay [2], the stability and applicability of NWP products are dependent not only on the design of the model's dynamic framework and the processing of physical processes but also on the initial fields that reflects the true state of the atmosphere. In other words, for the model to simulate the atmospheric evolution, proper initial values must be given for the current state of the atmosphere. Refining initial fields is one of the proved effective means to improve the applicability of model forecast products.

In view of the importance of the initial fields for the forecast accuracy, a series of research has been done in recent years in China to improve them by effectively using and assimilating various datasets and quite a number of informative results have been achieved. To better assimilate surface observations, different assimilation schemes were compared using the 3-dimensional variational assimilation system of PSU-NCAR's MM5 model and informative results were obtained [3]. With the improved Kuo's convection parameterization scheme used as an observational operator, the rainfall data for convective weather systems as recorded by automatic weather stations (AWS) across Guangdong province were assimilated and compared with assimilated sounding data, with the result showing that the AWS rainfall datasets have positive impacts on the short-term forecast of heavy rainfall [4]. Apart from the stations of intensive surface observation, observational Doppler products were also much focused upon for their high spatial and temporal

Received date: 2008-01-18; **revised date:** 2009-02-26

Foundation item: Public Welfare Project (GYHX(QX)2007-6-14); Basic operational fees for highest-level public welfare research institutes

Biography: ZHANG Cheng-zhong, Ph.D., associate professor, mainly undertaking the scientific research on NWP on tropical weather and mesoscale meteorology.

E-mail for correspondence author: cz_zh@grmc.gov.cn

resolutions. Analysis data can be improved by assimilating the radar-derived TREC winds and a case study has shown that forecasts of the typhoon precipitation can be improved using this scheme [5]. The information of radar-derived wind fields are assimilated in simulation experiments on heavy rainfall cases, with the suggestion that the assimilation enable the inclusion of more meso- and fine-scale information about the initial fields, having positive effects on precipitation forecast [6, 7].

Affected by the westerly and tropical systems, the region of South China frequently experiences convective weather (heavy rain, strong wind, etc.) in its raining seasons, which are hard to capture with conventional networks of surface and sounding observation due to their uncertainty in spatial and temporal distribution and smallness in scale and a great challenge for weather forecasters. To have more efficient monitoring and prediction of these disaster-inflicting regimes, several field observational experiments were conducted in the region that concluded with quite a number of useful observations and achievements [8 – 10]. With the development of monitoring techniques, a large number of unconventional observations, such as those from intensive AWS rain gauges, multiple satellite microwaves and Doppler radars, are now available on a daily basis, in addition to conventional surface and sounding data. It is necessary to extract useful meso- and fine-scale information from the existing numerous types of observations and reflect them in the initial value field via the assimilation techniques so as to increase the accuracy of short-term forecast and nowcast of precipitation.

The aim of this study is, based on previous research, to run a control experiment on a warm-sector heavy rain in South China from 19 to 20 May 2007 and to conduct assimilation tests with different datasets using GRAPES-3Dvar, a 3-dimensional variational and assimilation system developed by Chinese Academy of Meteorological Sciences, and GRAPES_MESO, a model already localized by the Guangzhou Institute of Tropical and Marine Meteorology, for the design and construction of a system for short-term forecast and nowcast of precipitation for the region of South China in the future.

2 DESIGN OF SCHEME

As shown in Table 1, four experiments were designed to compare the effect of different assimilated observational data on the short-term prediction of precipitation. Correspondingly, four types of initial fields were obtained with the application of GRAPES-3Dvar, which were then used to run for 30 hours, respectively. With the system [11], the four schemes are incorporated to generate four initial fields. The 6-hourly model output, with resolution at 12 km, from the Guangzhou Regional Meteorological Center was used as the boundary layer, with the Kain_fristsch scheme used for cumulus parameterization and NCEP's simple ice phase scheme as the microphysics of clouds. For more detail about the GRAPE, see Chen et al.[12]. As for the method for retrieving apparent wind, as well as the assimilation of radial and apparent wind, refer to Wan et al.[13], and the approach for retrieval of radar reflectivity, refer to Brewster [14].

Table 1 Data assimilation for different experiments.

Experiments	Assimilated data
CRTL	None
EXP1	Surface sounding data
EXP2[13]	Surface sounding, nudging of cloud water & rainwater retrieved from radar reflectivity
EXP3 [12]	Surface sounding, radar radial wind and apparent wind

3 RESULTS

3.1 *Analysis of initial condition in temperature and humidity fields for CRTL and EXP1*

The difference in humidity between EXP1 and CTRL at 925 hPa shows that all positive values over the target region, except for values less than -0.5 in a region around 25°N and Pearl River Delta (not shown). The humidity difference (EXP1 minus CTRL) is illustrated in the cross-section, showing that within the spatial zone of the convetive regime, specific humidity is increased by amplitudes ranging from 0.1 to 0.8 (g/kg) from lower to middle troposphere (Fig.1). The temperature difference (not shown) also indicates that the negative center appears to the north of the boundary between Guangdong and Hunan provinces, especially along the coast where rainfall occurred. A positive zone appears in the middle of Guangdong province with a clear sky. These facts imply that humidity increases from the lower to middle troposphere, and that the mesoscale disturbance in temperature fields becomes more distinct after the assimilation of conventional observational data.

3.2 *Comparison of initial wind fields between EXP3 and EXP1*

As the quality of radial wind in the lower level could be affected by rain, the radial wind and apparent wind are assimilated only if the height is higher than 2

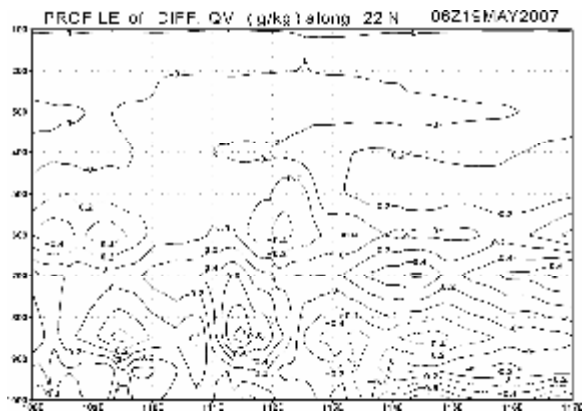

Fig.1 Differences in specific humidity (EXP1 minus CRTL) along the 22°N cross section at 06:00 UTC 19 May 2007; the convective system is at around 111.8°E.

km but lower than 8 km. In the wind vector difference between EXP3 and EXP1, i.e. EXP3 minus EXP1 a wind convergence line appears in the region between the cities of Yangjiang and Jiangmen at 700 hPa (not shown), while the divergence appears in the same place at 400 hPa, indicating the prevalence of updraft over there, which overlaps well with intense radar reflectivity (See Fig.2). These results imply that meso-β and meso-γ scale circulation are well captured in the initial field with the assimilation of radial wind and apparent wind, which is similar to the results from previous studies [5, 6, 12].

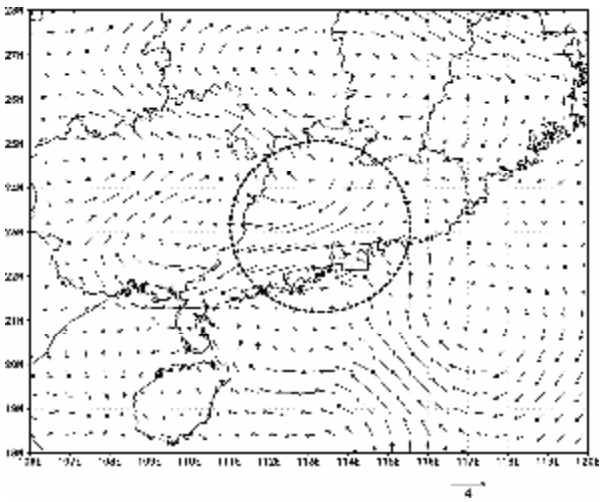

Fig.2 Differences in wind vector (EXP3-EXP1) at 400 hPa at 06:00 UTC 19 May 2007; the dot-dash circle indicates the detection range of Guangzhou radar.

3.3 *Impact of the four schemes on accumulated 24-hour forecast precipitation*

From the results of simulation, CTRL is able to forecast the heavy rainfall along the coast, but fails to forecast the one in the middle of Guangdong (not shown). Compared with CTRL, EXP1 successfully corrects the predicted amount of precipitation that is either lower or higher than the observation in several parts of the region; it positively corrects the rainfall on a 20- to- 30-mm order of magnitude in the western and middle parts of Guangdong and decreases it to make it closer to the observation in the eastern section of the province's coast.

The difference between EXP1 and EXP2 for 24-hour forecast precipitation seems to be very small, except that some positive values of 1-10 mm appear in the region of the Pearl River Delta and the eastern part of the coastal area, implying a small impact of rainwater nudging on the 24-hour forecast. EXP3 (see Fig.3) successfully predicts the heavy rainfall in the region from the coastal to central Guangdong province,

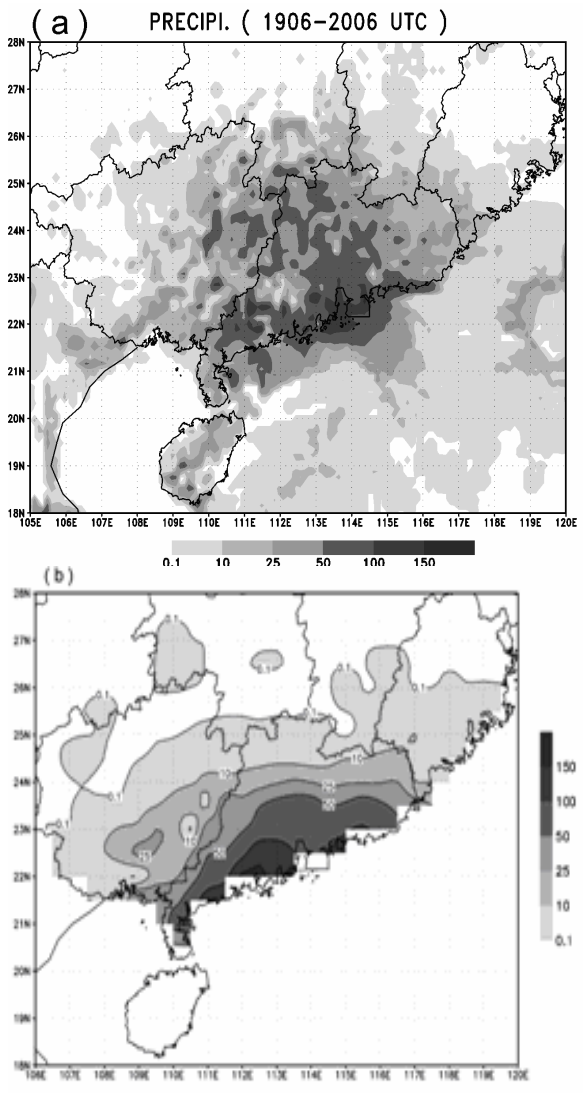

Fig.3 Accumulated 24-hour precipitation from EXP3 (a); accumulated 24-hour observed precipitation (b).

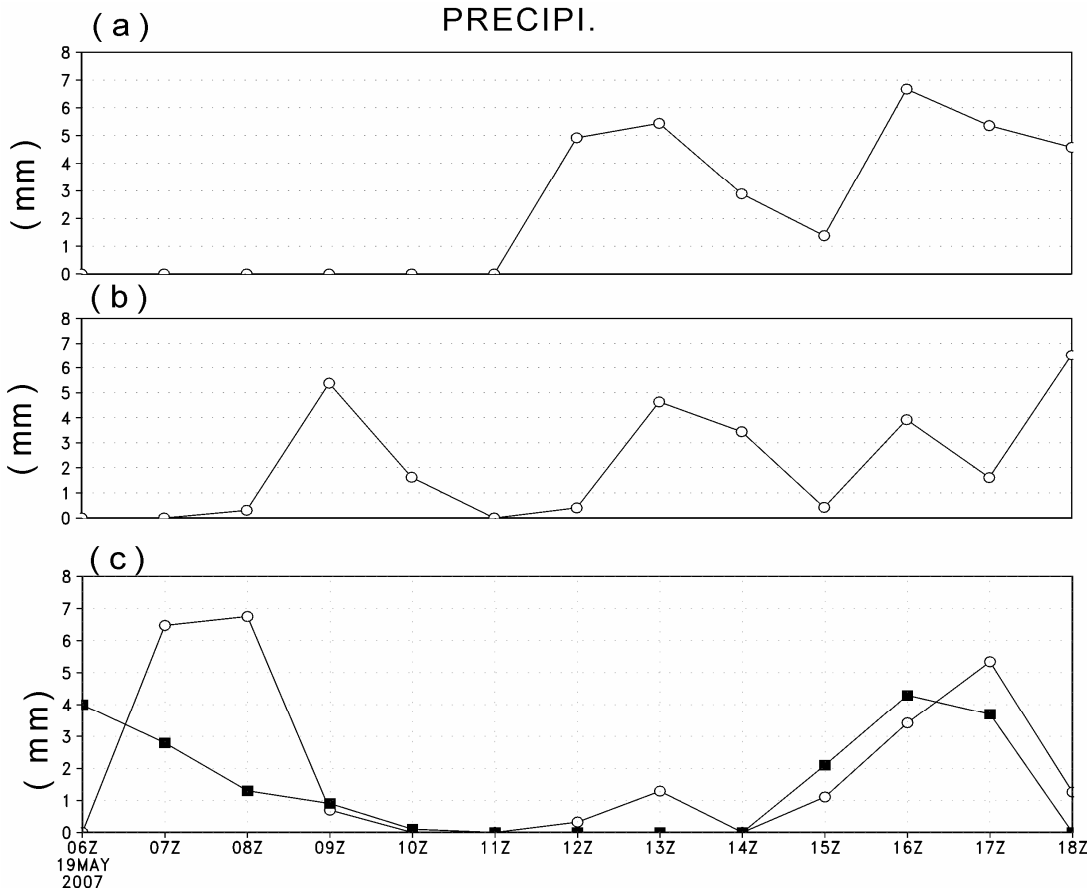

Fig.4 Hourly forecast and observed precipitation for Yangjiang weather station: a) CTRL; b. EXP3; c. EXP2 (dots vs. dashes circle), observation. (solid square vs. dashes line)

and is, compared with observation data, the best of the four schemes in predicting accumulated 24-hour precipitation.

3.4 *Impact of the four schemes on rainfall nowcasting*

In an attempt to clarify the impact of 4 schemes on rainfall nowcasting, one of the observation stations, which is located just leeward of intensive radar reflectivity at the initial time, is selected. Since the predicted rainfall from EXP1 and EXP3 during the first 6 hours are similar to each other, the results of CTRL, EXP2 and EXP3 will be analyzed.

As shown in Fig.4, EXP2 successfully reproduces the rainfall for the first two hours and two precipitation peaks within the first 12 hours, as compared with the observed precipitation (as shown by the dash-square line in the figure). EXP3 is also able to predict the two peaks of precipitation within the first 12 hours, yet it is delayed by 2 hours and the amount is a bit lower as compared with EXP2. CTRL is a complete failure as far as the prediction of the precipitation for the first 6 hours is concerned.

For analyses of other aspects, refer to the Chinese edition of the journal.

4 SUMMARIES

In order to improve the short-term forecast and nowcast of precipitation for South China and to understand how they are affected by initial value fields, four experiments have been designed in this study to run a control, assimilate conventional sounding and surface data, test with nudging rainwater data and radar-derived radial wind, for a warm-sector heavy rain, the largest ever since the beginning of the regional raining season in 2007. The following conclusions have been drawn based on the analysis of the results from a 30-h simulation on the GRAPES_MESO.

(1) With the surface and sounding data assimilated, the initial wind, temperature and humidity fields are closer to the observations and the 24-h rainfall forecast is improved in both the area and order of magnitude.

(2) With the inclusion of nudging rainwater data in the initial value fields, significant positive impacts have been achieved in precipitation nowcast while the effect on the 24-h forecast of the area and order of magnitude

is insignificant.

(3) The assimilation of radar-derived radial wind has large positive effect on the 24-h forecast of area and order of magnitude but insignificant effect on the nowcast.

As shown in the simulation experiments above, various types of conventional and unconventional observations are useful not only in improving short-term forecast and nowcast of precipitation and justifying the argument that an improved initial field helps relief the problem of model spin-up, but also in better predicting the rain area and order of magnitude over the next 24 hours. The conclusions above are preliminary; a large amount of case studies need to be done to further understand the role of initial fields in the short-term forecast and nowcast of precipitation.

REFERENCES:

[1] TURPEINEN O M. Diabatic initialization of the Canadian regional finite-element model (RFE), using satellite data Part II: Sensitivity to humidity enhancement, latent heating profile, and rain rates [J]. Mon. Wea. Rev., 1990, 118: 1 396-1 407.

[2] KALNAY E. Atmospheric Modeling, Data Assimilation and Prediction [M]. Cambridge: Cambridge University Press, 2003: 341 pp.

[3] XU Zhi-fang, GONG Jian-dong, WANG Jian-zhe, et al. Preliminary study on surface observational data assimilation [J]. J. Appl. Meteor. Sci., 2006, 17(suppl.): 1-10.

[4] DING Wei-yu, WAN Qi-lin, YAN Jian-hua, et al. Variational assimilation of automatic weather stations rainfall in convective systems and its impact on rain forecast [J]. Chin. J. Atmos. Sci., 2006, 30(2): 317-326.

[5] WAN Qi-lin, XUE Ji-shan, CHEN Ji-tong, et al. The test of applying radar TREC wind in three-dimensional variational assimilation [J]. J. Trop. Meteor., 2005, 21(5): 449-457.

[6] YANG Yi, QIU Chong-jian, GONG Jian-dong, et al. Comparison of two methods of assimilating Doppler radar wind data [J]. Plateau Meteor., 2007, 26(3): 547-555.

[7] LI Bai, ZHOU Yu-shu, ZHANG Pei-yuan. Application of the China new generation weather radar data to the torrential rain simulation over the Yangtze River-Huaihe River basin in 2003: contrast of precipitation and wind [J]. Chin. J. Atmos. Sci., 2007, 31(5): 826-838.

[8] WANG Li-kun, ZHENG Yong-guang, WANG Hong-qing, et al. Preliminary analysis of environment and cloud clusters during Huanan rainstorm experiment [J]. Acta Meteor. Sinica, 2001, 59(1): 115-119.

[9] Collective writing group. Heavy Rain for Yearly First Raining Season for South China [M]. Guangzhou: Science Press of Guangdong, 1986: 244.

[10] XU Bao-xiang. Advances in HUAMEX [R]. Annual Report of Chinese Academy of Meteorological Sciences, 1998: 25-26.

[11] ZHANG Hua, XUE Ji-shan, ZHUANG Shi-yu, et al. Ideal experiments of GRAPeS three-dimensional variational data assimilation system [J]. Acta Meteor. Sinica, 2005, 63(2): 129-145.

[12] CHEN De-hui, SHEN Xue-shun. Recent progress on GRAPES research and application [J]. J. Appl. Meteor. Sci., 2006, 17(6): 773-777.

[13] WAN Qi-lin, XUE Ji-shan, ZHUANG Shi-yu. Study on the variational assimilation technique for the retrieval of wind fields from Doppler radar data [J]. Acta Meteor. Sinica, 2004, 62(1): 31-41.

[14] BREWSTER K. Application of a Bratserth analysis scheme including Doppler radar data[C]// 15th Conference on Weather Analysis and forecasting. Norfolk: Am. Meteor. Soc., 1996: 92-95.

Citation: ZHANG Cheng-zhong, WAN Qi-lin and HUANG Yan-yan et al. Experiments on assimilation of initial values in numerical prediction of a warm-sector precipitation in South China. *J. Trop. Meteor.*, 2009, 15(1): 73-77.