# Experiments in Forecasting Mesoscale Convective Weather over Changjiang Delta[①]

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Received May 8, 1991 ; revised September 29, 1991

ABSTRACT

    The real time operational severe convective weather forecast experiment carried out during May to July in 1990 over the Changjiang Delta is briefly described. The heavy rainfall and severe convective weather forecast worksheets for the Changjiang Delta have been proposed and used in the daily forecasting. Results show that the ability of 0–12h convective weather prediction has been improved significantly after the development of the forecast methods and the establishment of a mesoscale forecast base at Shanghai Meteorological Center during 1986 to 1990.

    Three cases of convective weather systems (meso–alpha, meso–beta, meso–gamma) during the experiment period are described and discussed.

## I. INTRODUCTION

    Heavy rainfall, high wind gusts, intense lightning activity and hail occur frequently every year during May to July over the Changjiang Delta and lead to severe disasters since this region is an important economic and densely populated area in this country. Until mid eighties, the development of observation tools (such as satellite, radar, surface mesoscale observation network), communication and computers has provided meteorologists with favourable conditions to study and forecast the mesoscale weather process. A five–year mesoscale meteorology research project sponsored by China Scientific and Technical Committee was carried out during 1986 to 1990, and a mesoscale meteorology research and prediction base has been established at Shanghai Meteorological Center.

    The factors and conditions which lead to the formation and evolution of severe convective storms have been studied, and several forecast methods have been developed during 1986 to 1989. Then, a real time operational forecast experiment was carried out from May to July in 1990 for the Changjiang Delta, an area which covers 29°N–34°N, 118°E–122.5°E, about 245000 Km². The forecast worksheets for heavy rainfall and severe convective weather were used (Tables 1 and 2). Six kinds of diagnostic or forecast methods have been included in the worksheets, i.e., fine–mesh numerical prediction produced by a five level PE model devised by the Institute of Atmospheric Physics, Chinese Academy of Sciences (Zhou et al, 1980; Dang and Jiang, 1990), diagnostic analysis with Barnes' filtering method (Dang and Wang, 1989), heavy rainfall and severe convective weather types, statistical method (Xu and Chen, 1989), the application of satellite imagery (Dang and Fang, 1988; Yao and Yang, 1989), and

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the use of radar mosaics. The forecast worksheets are similar to those of Rodgers et al. (1984). The differences between them are: (1) More forecast methods have been contained in our worksheet; (2) All the methods and experiences are suitable to the Changjiang Delta region.

The purpose of the forecast experiment is to examine the ability of current 0–12 h mesoscale forecasting methods developed by us. Participants in the experiment included scientists from the mesoscale meteorology research group of the department of atmospheric sciences, Nanjing University and from the nowcasting and very short range forecasting group of Shanghai Meteorological Center (SMC).

II. THE FORECAST EXPERIMENT

An experiment for mesoscale convective weather prediction was made in Shanghai Meteorological Center from May to July in 1990. We issued 0–12 h convective weather outlook twice a day at 12 h and 16 h local time. The heavy rainfall is defined as rainfall amount beyond 20 mm / hr or 50 mm / 6hr, and the severe convective weather is defined as wind speed beyond 17 m / s with thunder or squall, or hail occurred during forecast period over an area of 110 Km × 220 Km within the Changjiang Delta.

By summarizing the results of studying the mesoscale forecasting methods over the Changjiang Delta during past four years, the heavy rainfall forecast worksheet and severe convective weather forecast worksheet for this area have been proposed and examined by real time operational forecast from May to July in 1990. Procedures of data processing, weather map analysis, animation of satellite images, radar mosaics, diagnosis and numerical prediction were performed routinely by VAX 3500.

Tables 1 and 2 show the worksheets.

**Table 1**

Heavy–Rainfall Forecast Worksheet

DATE / TIME (Forecast valid 04–16Z)

Using the analyzed weather maps, numerical forecast products and experiences, will there be the following?

| | (YES)(NO)(RANKING) |
|---|---|
| 1) One of four weather systems at 500 / 700 hPa over region | (  )(  )(      ) |
|   A. at the north border of subtropical high    B. trough | |
|   C. shear line                   D. cyclonic vortex | |
| 2) Surface data analyzed by filtering method | (  )(  )(      ) |
|   A. CVG 6 l0 s      B. a couple of CVG and DIV center at / less a distance of 100 Km | |
| 3) Fine–mesh numerical prediction | (  )(  )(      ) |
|   A. heavy rainfall area | |
|   B. strong upward motion, $W_{700} < -10 \times 10^{-3}$ hPa $s^{-1}$ | |
|   C. moist area at surface $> 14g$ / Kg, or at 850 hPa $> 12g$ / Kg | |
| 4) Diagnostic analysis | (  )(  )(      ) |
|   DIV (200 hPa)–DIV(850)$> 10 \times 10^{-5} s^{-1}$ | |
| 5) Satellite Imagery | (  )(  )(      ) |
|   A. occurrence of convective cloud cluster | |
|   B. overlapping of $W_{700} < -10 \times 10^{-3}$ hPa $s^{-1}$ isoline with the | |
|     continuous cold ($< -53°C$) cloud shield | |
| 6) Precipitation echoes appear in radar composite map | (  )(  )(      ) |
| 7) Heavy rainfall expected by statistical method | (  )(  )(      ) |

**Table 2**

Severe Convection Forecast Worksheet

DATE / TIME (Forecast Valid 04–16Z)

Using the analyzed weather maps, numerical forecast products and experiences, will there be the following?

| | (YES) | (NO) | (RANKING) |
|---|---|---|---|
| 1) Cold and dry airflow at 500 hPa, while warm and moist airflow at 850 hPa | ( ) | ( ) | ( ) |
| 2) Strong upward motion at 700 hPa, $W_{700} < 10^{-3}$ hPa s$^{-1}$ | ( ) | ( ) | ( ) |
| 3) K index $> 35$ | ( ) | ( ) | ( ) |
| 4) Satellite imagery | ( ) | ( ) | ( ) |
|   A. formation or approaching of convective cloud cluster | | | |
|   B. a front or outflow boundary approaching as a trigger | | | |
| 5) Severe convection expected by statistical methed | ( ) | ( ) | ( ) |
| 6) In area C of Kessler's conceptual model | ( ) | ( ) | ( ) |
| 7) One of the following six weather types is occurring: | ( ) | ( ) | ( ) |
|   A. north China cut–off low type | | | |
|   (a) A cut–off low with cold center exsits in (38–48°N,113–123°E) at 500 hPa | ( ) | ( ) | ( ) |
|   (b) to the west of the cut–off low, a 500 hPa short wave trough is approaching the forecast area | ( ) | ( ) | ( ) |
|   (c) a cold front located in area (42°N, 116°E), (36°N, 107°E), (32°N, 112°E),(39°N,122°E) | ( ) | ( ) | ( ) |
|   B. Coastal long wave trough type | | | |
|   (a) a 500 hPa longwave trough exists in (37°N, 123°E), (28°N, 113°E), (25°N, 119°E), (35°N, 129°E) | ( ) | ( ) | ( ) |
|   (b) to the west of the longwave trough, a shortwave trough is approaching | ( ) | ( ) | ( ) |
|   (c) a cold front located in area (43°N, 122°E), (36°N, 110°E), (33°N, 114°E), (39°N, 126°E) | ( ) | ( ) | ( ) |
|   C. North and South trough types | | | |
|   (a) a 500 hPa trough exists in area (37°N–50°N), (100–120°E) | ( ) | ( ) | ( ) |
|   (b) another 500 hPa trough (the south trough) exists in area (37°N, 105°E), (28°N, 101°E), (28°N, 115°E), (37°N, 119°E) | ( ) | ( ) | ( ) |
|   (c) a cold front located in area (44°N, 116°E), (36°N,108°E), (30°N, 115°E), (38°N, 123°E) | ( ) | ( ) | ( ) |
|   D. Warm shearline type | | | |
|   (a) a 500 hPa trough exists in area (28–37°N), (104–120°E) while a 700 hPa shear line exists in the same area | ( ) | ( ) | ( ) |
|   (b) the 5800 meter contourline reaches 30°N along 115°E | ( ) | ( ) | ( ) |
|   (c) a warm front located in area (30–35°N) | ( ) | ( ) | ( ) |
|   E. In front of a 500 hPa trough type | | | |
|   (a) a 500 hPa dry area, specific humidity $< 4$g / Kg | ( ) | ( ) | ( ) |
|   (b) a 850 hPa moist area, specific humidity $> 12$g / Kg | ( ) | ( ) | ( ) |
|   (c) $\theta_{se}$ (500 hPa)$-\theta_{se}$ (850 hPa)$< -2$K | ( ) | ( ) | ( ) |
|   F. In the rear of a 500 hPa trough type | | | |
|   (a) a moist area at surface, specific humidity $> 14$g / Kg | ( ) | ( ) | ( ) |
|   (b) cold advection at 500 hPa | ( ) | ( ) | ( ) |
|   (c) strong moisture convergence at surface, while divergence at 700 hPa | ( ) | ( ) | ( ) |
|   (d) a convergence line at surface | ( ) | ( ) | ( ) |
|   (e) raining when the trough passed yesterday, a dry and warm lid formed afterwards and a cold front is approaching | ( ) | ( ) | ( ) |
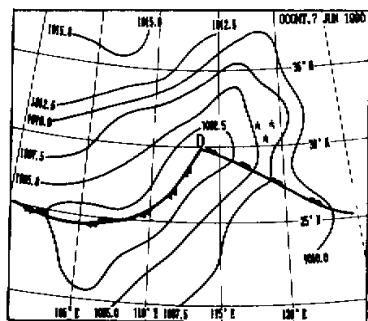
Fig.1. Surface analysis valid 00GMT 7 June 1990. Symbol $\dot{R}$ stands for thunderstorm observed during 04 to 16 GMT on the same day.
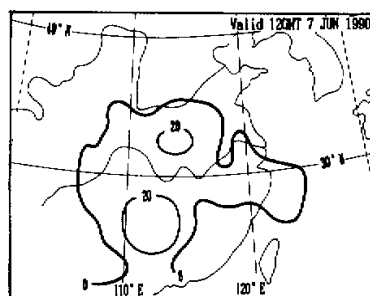


Fig.2. Fine–mesh model 24 h forecast of precipitation (mm) valid 12 GMT 7 June 1990.

Forecaster's remarks:

During the period from May to July in 1990, ten significant convective weather systems occurred in the forecast area , we got eight successful forecasts among them. The scores for the whole period are as follows:

Verification by Brier's method (see Panofsky and Brier, 1968)

B = 0.12;

POD = 0.61, FAR = 0.15, CSI = 0.55.

Where POD and FAR represent the probability of detection and the false alarm rate respectively, and CSI is the critical success index. These verification indexes have also been used by Program for Regional Observing and Forecasting Services (PROFS), ERL, NOAA.

### III. THREE CASES OF SEVERE CONVECTIVE WEATHER SYSTEMS

Several meso–alpha, meso–beta and meso–gamma convective weather systems appeared during the experiment period. Three cases of them will be described here.

7 June 1990

By 0000 GMT 7 June 1990, a cyclone developed near 30°N–114°E with 1000 hPa at its center, Fig.1 shows the sketched surface map. The cyclone moved northeastward and reached its mature stage by 0000 GMT 8 June.

Severe convective weather occurred during the forecast period (04 GMT to 16 GMT 7 June) over southern part of the Changjiang Delta, symbol $\dot{R}$ in Fig.1 indicates the severe convective weather observed during the same period. For this case, forecast methods included in the forecast worksheet indicated that severe convection will be formed in the area. For example, fine–mesh model 24 h forecast of precipitation (mm) valid 12 GMT 7 June 1990 (Fig.2) showed that the rainfall maximum accompanied with the initiating cyclone was approaching the forecast area, while from satellite images we found that the actual speed would be much quicker than the numerical forecast. For the forecast area, the K index indicated that it was very unstable, and the filtered surface wind field revealed strong convergence there. All of these helped us to forecast that severe convection will occur. This is one of the successful forecasts of the experiments.

26 June 1990

The Meiyu period began on 24 June 1990, Fig.3a shows the sketched surface map valid 0000 GMT 26 June 1990, where $\dot{R}$ indicates the severe convection observed during the forecast period (04 GMT to 16 GMT 26 June 1990). By 00 GMT 26 June, the Meiyu stationary front located from 20°N, 113°E through 33"N, 121°E. Meanwhile, a 700 hPa shearline corresponded to the surface front.

The numerical forecast didn't predict well in this case because dispathe process was of meso—beta scale. It's difficult to predict by using the conventional analysis. However, the forecast was made mainly by using satellite images. We found that the movement of small cloud clusters and an arc cloud line displayed clearly by the animation of satellite images, it revealed that the arc cloud line will move to an unstable area and trigger new convection. The IR satellite image for 26 June 1990 at 00 GMT (Fig.3b) shows the 700 hPa shearline cloud band, no convective weather occurred over the Changjiang Delta at that time. Six hours later,
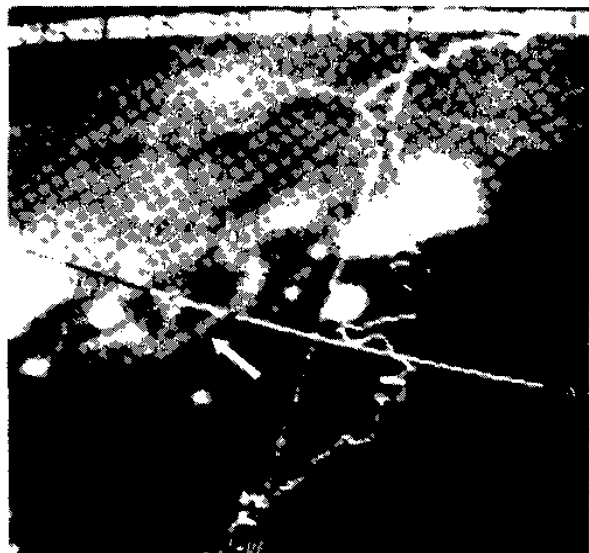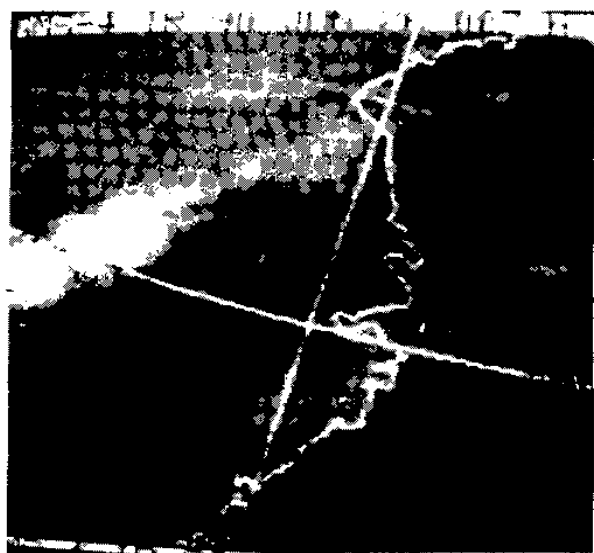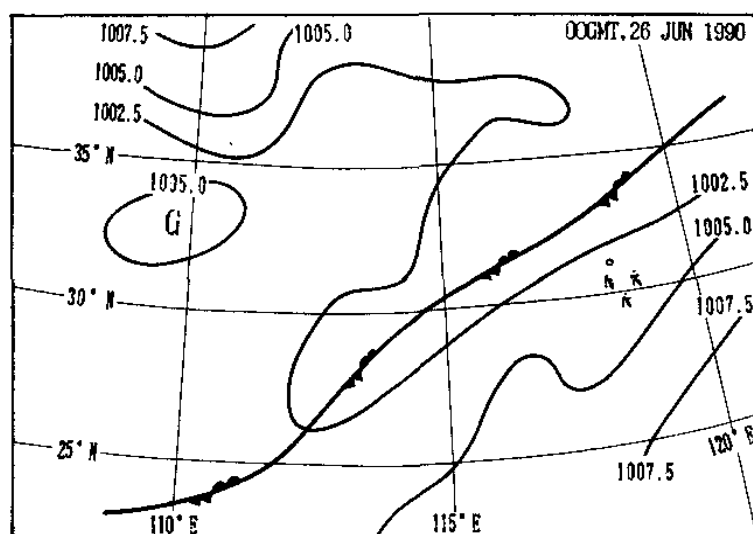


Fig.3. (a) Surface analysis valid 00GMT 26 June 1990. Symbol $\dot{R}$ indicates thunder storm observed during 04 to 16 GMT on the same day.(b) and (c) are IR satellite images for 26 June 1990 at 00 GMT and 06 GMT respectively.
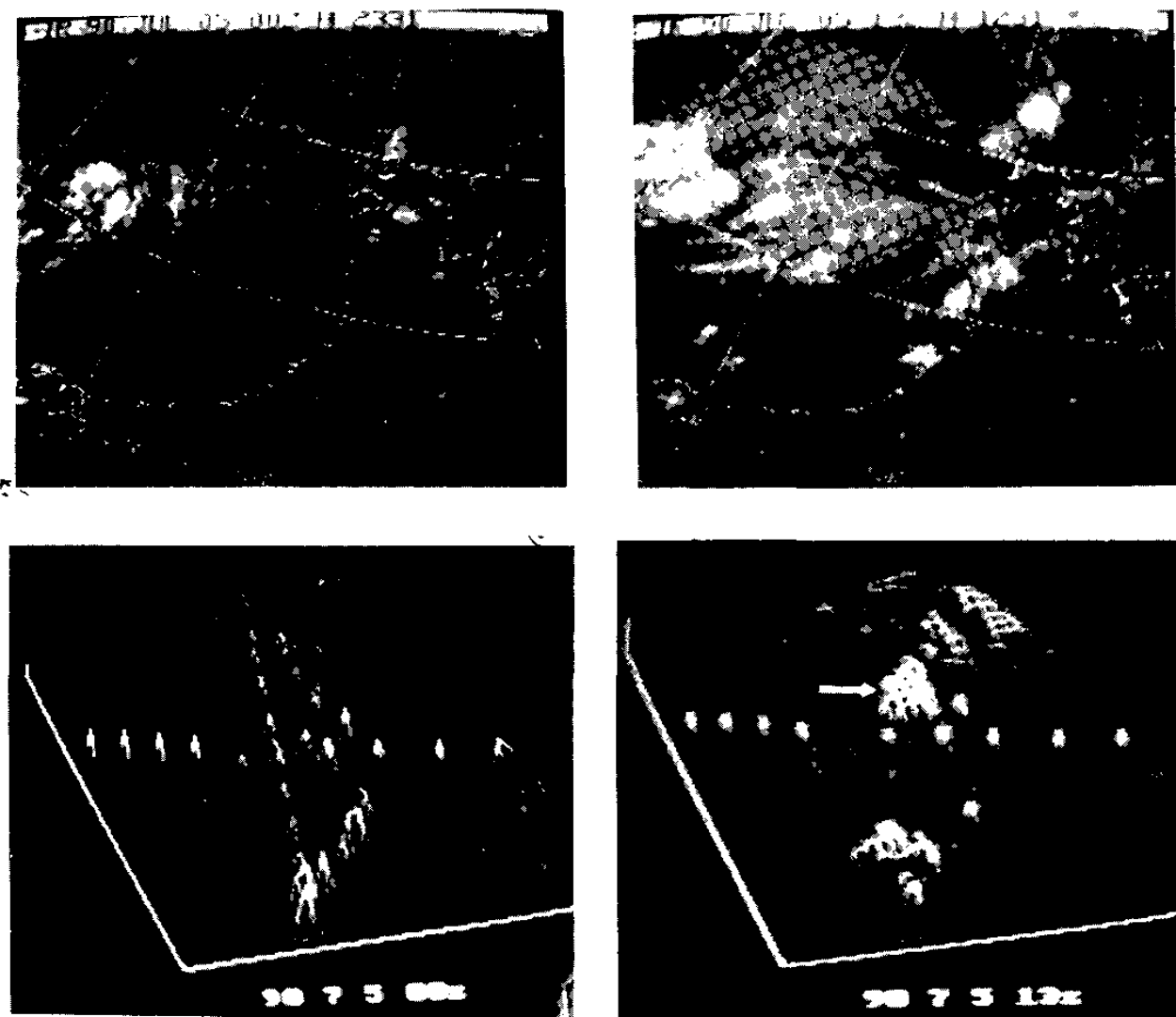
Fig.4. (a) and (b) are IR satellite images for 5 July 1990 at 00 GMT and 13 GMT respectively. (c) and (d) are stereo displays for 5 July 1990 at 00 GMT and 13 GMT respectively, covering less area than those of figures 4a and 4b.

cumulo−nimbus developed near 32°N, 121°E, and the arc cloud line as indicated by an arrow in Fig.3c was moving eastward and much stronger convective weather initiated over the area.

It's interesting that the clouds separated from the cloud band of the 700 hPa shearline moved southeastwards and triggered severe convection, while the shearline itself remained stationary.

5 July 1990

In the late afternoon on 5 July 1990 there was a strong convective weather in the forecast area. The 700 hPa analysis shows that the forecast area lies within the subtropical high region (not shown). We found that radar echoes covered an area of 25 Km × 40 Km occurred at 1100 GMT 5 July 1990. The height of the cloud top was 18 Km.

It's very difficult to forecast such a local severe convection, because all the forecast

methods failed.

We analyzed a series of satellite images of this process afterwards by stereo display. It's interesting that there were cloud cells moving southeastwards, and one of them finely developed to form severe convection. Fig.4a shows the cloud band located well north to the Changjiang Delta. Thirteen hours later (Fig.4b), strong convection of meso—gamma scale occurred nearby $31^{\circ}$N, $121^{\circ}$E. The stereo display (Fig.4c) shows a portion of Fig.4a, it was cloudless over the Changjiang Delta for 5 July 1990 at 00 GMT, while strong convection is shown nearby $31^{\circ}$N, $121^{\circ}$E with an arrow indicated in Fig.4d.

IV. SUMMARY

(1) Encouraging results have been obtained for predicting meso—alpha and part of meso—beta weather systems after the establishment of mesoscale forecast base at Shanghai Meteorological Center. At present it is very difficult to forecast meso—gamma scale weather systems.

(2) Numerical models, mesoscale synoptic methods and other forecast methods are required for predicting meso—beta scale weather systems.

(3) In some cases, the clouds originated from the main cloud band of the 700 hPa shearline moved southeastwards and triggered severe convection, although the shearline itself didn't move. Further study is needed for such cases.

The author Dang Renqing is grateful to Dr. Thomas Schlatter for his valuable comments when Dang visited PROFS and to Prof. Tao Shiyan for his encouragement and suggestions concerning this work.

REFERENCES

Dang, R. Q. and Fang Z. Y. (1988),   The applications of meteorological satellite imagery to weather analysis and forecasting in China, International Journal of Remote sensing, **9**: 151—158.

Dang, R.Q. and Wan Z. Q (1989),   A bandpass filtering method and its preliminary application, *J.Aca. Meteor. Sci.*, SMA, China, **4**: 29—34.

Dang, R.Q. and Jiang D. C. (1990),   Numerical simulation of raim storm during pre—Meiyu period, Joint US—PRC Workshop on mesoscale meteorology. Abstracts, 19—21 September 1990. NCAR, Boulder, Colorado, pp.44—45.

Panofsky, H.A. and G.W.Brier (1968),   Some applications of statistics to meteorology. Chap, IX, § 4. The Pennsylvania state University Press.

Research group of Jiangsu Provincial Meteorological Bureau, ed. (1988),   Analysis and forecasting of significant weather for Jiangsu Province, China Meteorological Press, China.

Rodgers, D.M. et al. (1984),   Experiments in forecasting mesoscale convective weather systems, 10th Conference on Weather Forecasting and Analysis, June 25—29, 1984, Fla. Published by A.M.S., pp. 486—491.

Tang, X.Z. (1990),   A review of nowcasting over the world *Q. J. App. Meteor.*, **1**: 93—99, (in Chinese).

Xu Y. M. and Chen Z. (1989),   A synthetic objective method for 0—12 hour convective weather forecasting, *J. Nanjing Inst. Meteor.*, **12**: 93—98, supplement, (in Chinese).

Yang, G.X., cd (1989), ' Analysis and forecasting of convective weather over East China, China Meteorological Press (in Chinese).

Yao, Z.Q. and Yang L.H. (1989),   An analysis on the evolution of two summer mesoscale cases with animated quan-

titative satellite images, *J.Nanjing Inst. Meteor.*, **12:** 87–92, supplement, (in Chinese).

Zhou, X.P. et al. (1980),    A fine–mesh numerical model, separate print, Institute of Atmospheric Physics, Chinese
    Academy of Sciences.