PROGRESS OF SATELLITE SOUNDING DATA APPLICATIONS IN CHINA

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1. INTRODUCTION

The Qinghai-Xizang (Tibetan) area located in the western part of China is a huge and high plateau. It has the most complex geographical features in the world and its elevation is over 4500 meters on average above sea level and covers a quarter of the continent of China. However, only four radiosonde stations are located in the eastern part of Xizang area. It is extremely difficult for weather forecasting, numerical predicting and climate studying due to the limited radiosonde stations in this area. Rain season (Meiyu), severe rainfall and drought of China are closely associated to the activities of subtropical high at the West Pacific Ocean. However, it is difficult to determine the position of subtropical high and analyze the weather systems over this area for a few radiosonde stations. In recent years scientists from Jiangsu Provincial Meteorological Bureau (JMB), Chinese Academy of Meteorological Sciences (CAMS) and National Satellite Meteorological Center (NSMC) have cooperatively done some sensitive studies on satellite sounding data applications in these areas with sparse radiosonde stations. The study results show that variational processed retrievals from TOVS data can significantly improve the first guess fields and local rainfall prediction in the plateau region. It is favorable for monitoring the movement of subtropical high. Moreover, it is also very useful for predicting the local heavy rainfall, which is usually ignored by normal forecasts with dense data of radiosonde stations only.

2. APPLICATION OF SATELLITE RETRIEVALS IN PREDICTING PRECIPITATION OVER TIBETAN PLATEAU REGION

2.1 Variational correction method

According to variational principle, a functional equation which is related to variables can be written as

$$J[u(x,y)] = \iint_G F(x,y,u,\frac{\partial u}{\partial x},\frac{\partial u}{\partial y})dxdy \quad (1)$$

where, u(x,y) must meet the following Euler equation:

$$Fu - (\frac{\partial Fu_x}{\partial x} + \frac{\partial Fu_y}{\partial y}) = 0 \quad (2)$$

Assuming retrieved parameter field is $\widetilde{T}^*(x,y)$, the corresponding radiosonde data field is $R_a(I,J)$, the difference between the retrieval and radiosonde data for the station location (I,J) is $C\widetilde{R}(I,J)$, and then

$$C\widetilde{R}(I,J) = R_a(I,J) - \widetilde{T}^*(I,J) \quad (3)$$

In fact, since the radiosonde stations are limited, it is necessary to construct a more generalized field function CR(x,y) for correction factor, using variational method to find CR(x,y) and let it meet:

$$J^* = \iint_D (CR - C\widetilde{R})^2 dxdy \rightarrow \min \quad (4)$$

Normally it arrives minimum.

For above variational problem, it may be supposed as follows

$$J^* = \iint_D \{(CR - C\widetilde{R})^2 + \lambda[(\frac{\partial CR}{\partial x})^2 + (\frac{\partial CR}{\partial y})^2]\}dxdy \quad (5)$$

where λ is constraint coefficient. The Eq .(5) can also be written as

$$\delta J^* = \delta\sum\sum\{(CR - C\widetilde{R})^2 + \lambda[(\frac{\partial CR}{\partial x})^2 + (\frac{\partial CR}{\partial y})^2]\} = 0 \quad (6)$$

The corresponding Euler equation can be written as

$$(CR - C\widetilde{R}) - \widetilde{\lambda}(\frac{\partial^2 CR}{\partial x^2} + \frac{\partial^2 CR}{\partial y^2}) = 0 \quad (7)$$

where $\widetilde{\lambda}$ is the modification restrained coefficient. Using iterative method to solve Eq.(7), we can get the variational corrected factor field CR(x,y). After making correction to the retrievals, we can get

$$T(x,y) = \widetilde{T}^*(x,y) + CR(x,y) \quad (8)$$

where T(x,y) is the corrected retrievals (see XU Xiangde et al, 1996).

2.2 Prediction of precipitation with satellite retrievals

Figure 1 shows the distributions of radiosonde stations(a) and satellite retrievals from NOAA-12(b) in Tibetan Plateau. From the figure 1, one can see that only four radiosonde stations in Xizang region, but much more data from the satellite. Figure 2 shows the areas of C_b cloud frequently generating (dark area) every year in China. It is clear that the Tibetan Plateau is involved in that dark area.

The scientists from CAMS and NSMC have studied the use of retrieved temperature, moisture, geopotential height and thermal winds from NOAA-12 satellite in the model MM5, which was developed by BSU/NCAR of the US, for rainfall prediction over the plateau region. The study results indicate that the bias of the retrievals against radiosonde data is existing and has to be removed when the retrievals are used in weather systems. Tables 1 and 2 show the temperature comparisons of retrievals (SR), the retrievals corrected by the variational method (C_SR) and radiosonde data (RAOB) in Naqu(31.29′N,92.04′E)and Lasa(29.40′N,91.08′E) stations of Xizang region.

Table 1. Temperature Comparison Between SR, C_SR and RAOB(00 UCT 06/07/95)

Station	Data Type	P(hpa)						
		500	400	300	250	200	150	100
Naqu	RAOB	-2.2	-12.3	-25.8	-35.0	-48.7	-60.9	-70.9
	SR	-0.2	-11.8	-28.8	-37.1	-48.5	-58.7	-67.9
	C_SR	-2.9	-12.6	-28.7	-35.8	-47.6	-57.5	-66.5
Lasa	RAOB	-2.9	-13.8	-27.7	-36.0	-49.5	-60.0	-75.6
	SR	1.7	-11.1	-26.9	-36.1	-48.6	-60.0	-72.5
	C_SR	-4.2	-12.1	-27.5	-35.3	-47.3	-57.6	-68.0

Table 2. Same as Table 1 but for Different Time(00UTC 06/07/95)

Station	Data Type	P(hpa)						
		500	400	300	250	200	150	100
Naqu	RAOB	1.6	-10.8	-24.5	-33.5			
	SR	3.6	-11.1	-26.4	-35.4	-45.8	-57.8	-71.4
	C_SR	-1.7	-13.2	-25.1	-33.4	-43.3	-57.1	-70.8
Lasa	RAOB	1.2	-10.1	-23.1	-33.9	-45.9	-60.7	-75.5
	SR	4.0	-10.0	-25.5	-35.7	-47.9	-61.4	-73.0
	C_SR	-0.6	-11.1	-25.2	-31.9	-47.2	-61.9	-73.7

From the two tables, it can be seen that for most of the levels the C-SR is closer to the corresponding RAOB data than SR. In order to make further comparison, three sets of data are used in our study on rainfall prediction model over Tibetan region, respectively. The data sets are: 1)RAOB; 2)SR(SR and RAOB); 3) C_SR (C_SR and RAOB).

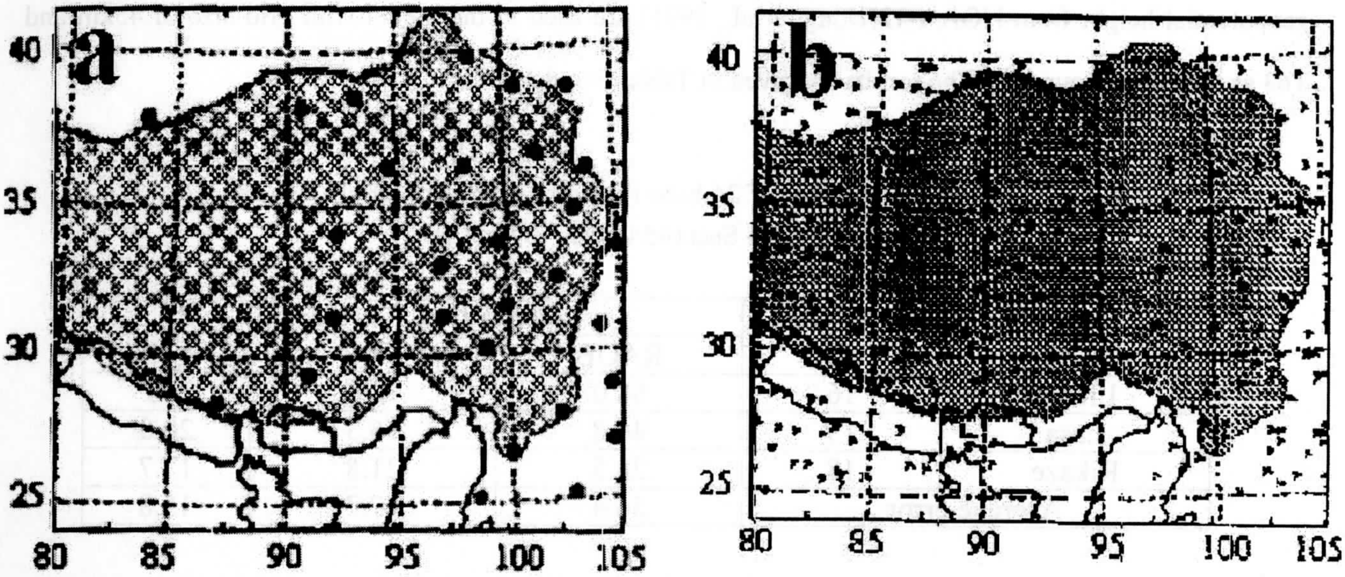

Figure 1. Distributions of radiosond stations and satellite retrievals in the Tibetan plateau area

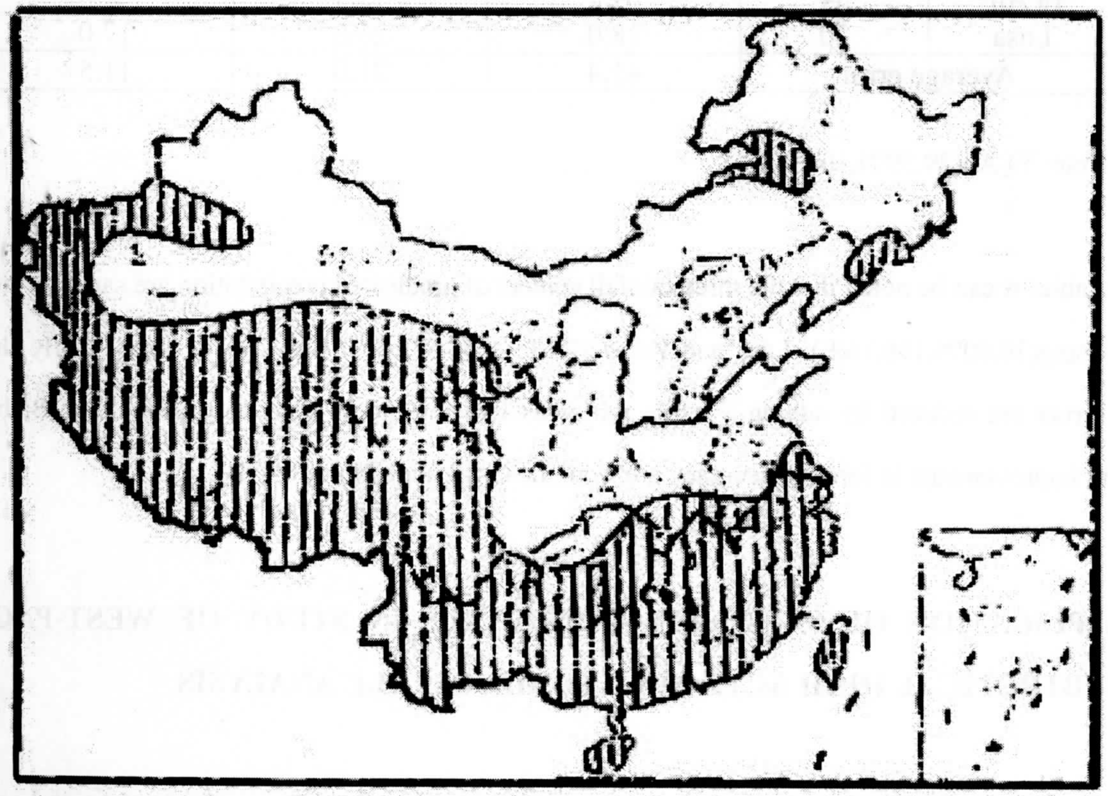

Figure 2. Cb clouds frequently occurring every year in China (dark)

The model MM5 is used for 24-hour precipitation prediction in the study. The temperature, moisture and geopotential height from NOAA-12(Dong, et al., 1991) are used in the model with grid size of 45km and T63 as the lateral boundary. The results are given in Tables 3 and 4.

Table 3 Comparison of 24-hour Precipitation Errors for Using Different Data Sets (05/07/95 00UTC)

Station Name	Truth Data (mm)	Precipitation error (mm)		
		RAOB	SR	C_SR
Litang	16	98.0	15.1	9.8
Lasa	19	46.8	16.3	20.0
Rikaze	18	24.5	21.8	17.7
Average error		56.4	17.7	15.8

Table 4 Comparison of 24 hr Precipitation Errors(06/07/95 00UTC)

Station name	Truth Data (mm)	Precipitation error (mm)		
		RAOB	SR	C_SR
Ya An*	34	64.7	15.4	5.9
Lasa	20	18.0	26.6	17.0
Average error		41.4	21.0	11.5

*Note: Ya An(29.59′N,103.00′E)

From the tables it can be noted that the three rainfall centers of predicated precipitation are same as the truth data in Litang(30.00′N,100.16′E), Lasa and Rikaze(29.15′N,88.53′E). It also can be seen clearly that the forecast errors are reduced by adding satellite retrievals into the model than only using RAOB, but the significant improvements in forecast accuracy are from the C-SR added into RAOB.

3. APPLICATION OF SATELLITE RETRIEVALS IN STUDY OF WEST-PACIFIC SUBTROPICAL HIGH ACTIVITY AND MESOSCALE ANALYSIS

The east part of China, which is the ecomomically developed areas, is always influenced by the synoptic system, such as westerlies, subtropical belt, and tropical belt, and rain storm. Jiangsu province is closer to the coastal areas in east China and often suffers from floods by Jianghuai cyclone, which is closely related to the position and intensity of the subtropical high in West Pacific, southwest cyclones and tropical storms.

The studies on using satellite soundings to improve the prediction of the subtropical high have started since 1995. First, analyzing the bias of satellite retrievals from radiosonde data is performed, and then variational corrections to the retrieval parameters are made. The study examples show that the application of retrievals tied to the data variational assimilation technique has significant benefit in the analysis and prediction. Figure 3 shows the average bias distribution of 500hPa high from retrievals subtracting T106 as the truth here. Figure 4 shows the average bias distribution of 500hPa height from the variational corrected retrievals. By analyzing these two figures, the following conclusions can be given:

A. Bias between TOVS retrieval data and T106 data is smaller to what we have analyzed to the discrete stations (Note: basically negative), increasing gradually from low latitude to high latitude.
B. Bias has been greatly reduced after correction to retrievals by using variational analysis. The maximum value is less than 45 meters over the high latitude, but below 10 meters for the most areas.
C. Higher resolution and more detailed description of weather system can be remained by using the combined data set than only by using RAOB data.

3.1 Analysis and prediction of subtropical high

In order to use satellite soundings for determining the parameters of West Pacific subtropical high, a PC-based system with C Language is developed by JMB. The system can automatically draw the typical line with 588 height values, encircling the area by line 588 and ridge point of subtropical high, such as latitude nodes of 120°E, 130°E and 140°E.

This system can also be used to predict the shift of subtropical high by a large margin, i.e, rise in the north or fall in the south beyond 5-degree longitude (120° E ridge line) on the basis of years of experience in analysis and prediction with the derived retrievals at high spatial and temporal resolution in real time, and by using the learning and deducing capability of artificial neural network. There are 35 cases in the process of shifting by a margin up to or more than 5-degree latitude within 24 to 48 hours during June to August of 1996 and 1997, if 120° E subtropical high ridge line is taken as a standard. Through operation, learning and iterative steps up to 1500, the convergence is got and the fitness rate is up to 95% for the prediction of the subtropical high activities as

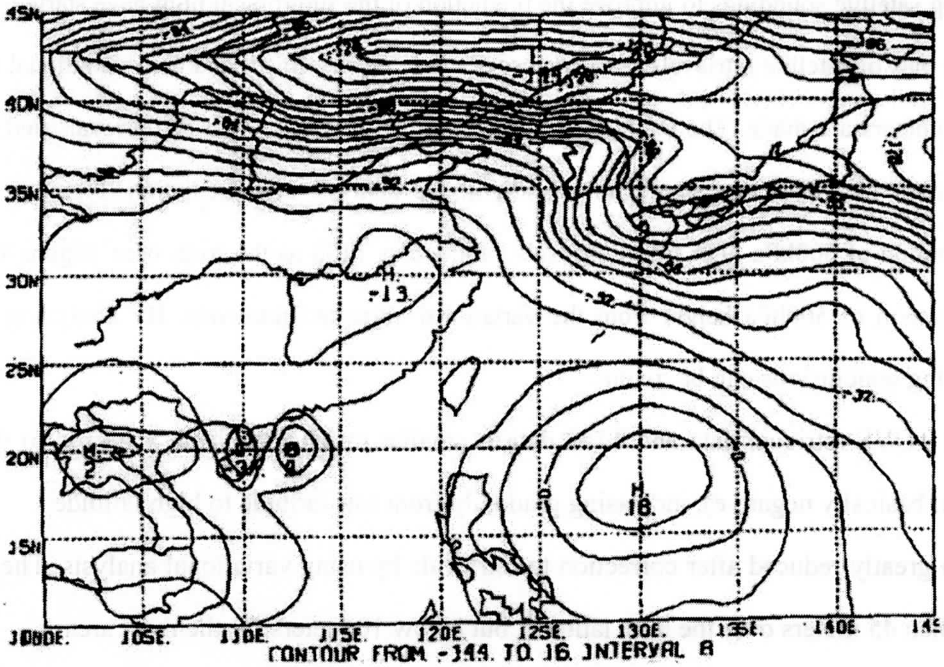

Figure 3. The difference between retrieved geopotential height and T106 data at 500 hPa

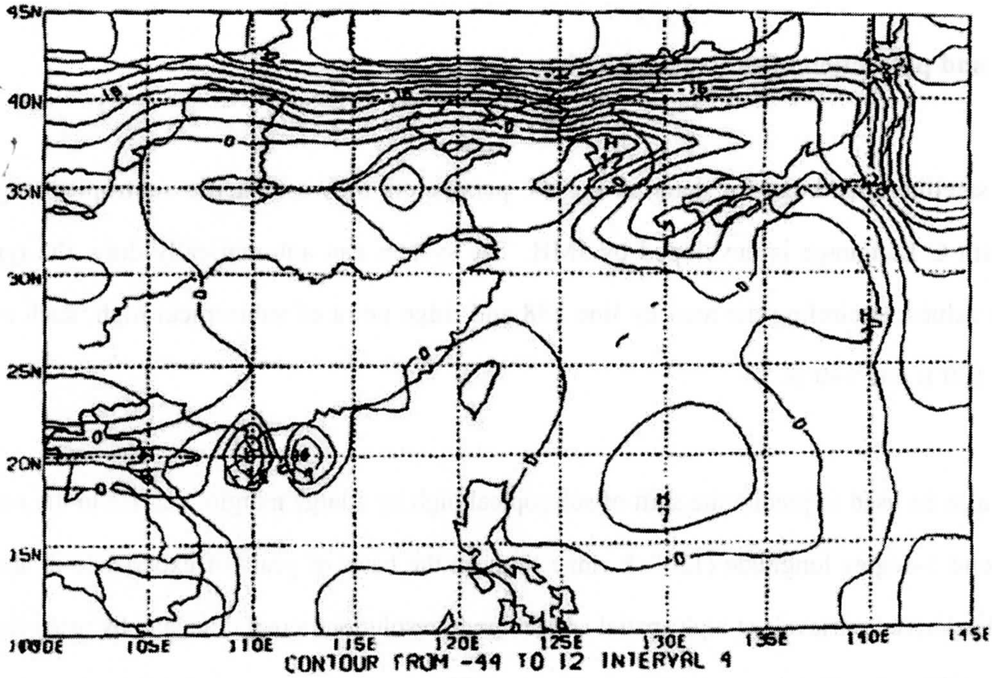

Figure 4. Same as Figure 3 except for the difference between variational analysis of the retrievals and T106 data

mentioned above. Being lack of RAOB, it is quite random in analyzing 588 line in the past. Whereas, this system is relatively accurate by using TOVS retrievals with high resolution to describe the shape of subtropical high and predict its activities.

3.2 Application in initial discernment of typhoon

Since most typhoon activities occur over the ocean, TOVS retrieval data has great advantages in discerning initially tropical cyclone system. Here is an example. The GMS satellite cloud photograph (ignored) showed tropical storm activity in 14.5° N 149.7° E, which had already been numbered as 9704 On 12 UTC 8 July ,1997. Figures 5, 6, 7 show the height analysis from T106, SR and C_SR at 500 hPa on 12 UTC 8 July 1997, respectively. Comparing these three Figures, it can be seen that more lines cover the area of tropic storm in Figure 6. and the macro-scale weather annulus can be distinguished completely in Figure 7.

3.3 More precise recognition of weather system with satellite data

The application of TOVS retrieval data can not only solve the problem of data scarcity in areas like over the ocean with few RAOB stations, but also be helpful to the recognition of weather system over land with comparatively dense RAOB stations. One example is the big and catastrophic rainstorm occurred in Huaibei region of Jingsu province on July 17, 1997. The real situation of rainfall that day is shown in Figure 8 (ignored), with the maximum value of 332.5mm in Xuzhou(34.17′N,117.09′E) area. Figures 9, 10 and 11 are the T106, SR and variation analysis field of geopotential height at 500hPa on 12UTC 17 of July, 1997 respectively. Attention should be paid to the fact that in areas of Yanhuai and Huaibei, Jiangsu province corresponding to the real situation, there is a depression to the left of the storm region under the pressure ridge. In empirical prediction, depression in the mid-pressure ridge is usually ignored. There is a trough in westerlies in TOVS retrieval analysis field and a low value curvature in isobaric line in rainstorm areas, which give full expression to the sensitivity of TOVS data. In variational analysis field, the depression on the Figure 11 under the former pressure ridge shifts to 117.5° E, 35° N with a trough in westerlies to its left. It is in complete agreement with the big rain storm areas (at 34.2° N, 117.1° E, the location of Xuzhou). This depicts the fact that TOVS retrieval data are helpful not only to areas like over the ocean where data is hard to obtain, but also to land areas with dense RAOB stations. Especially, retrieval field of meso-scale can be

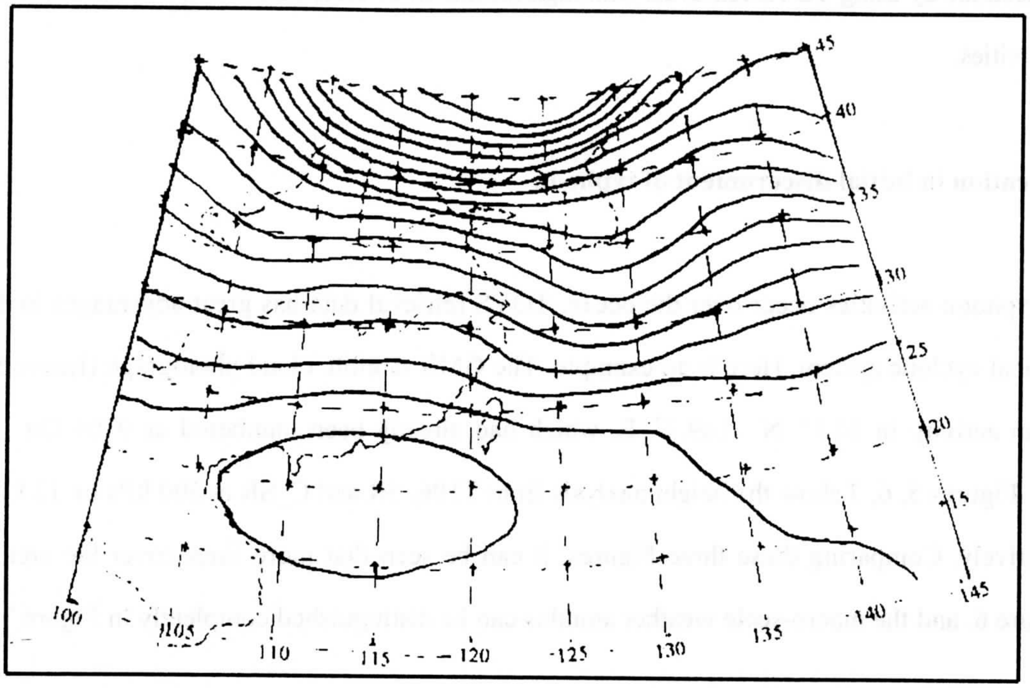

Figure 5. T106 500 hPa geopotential height field on 08/06/97 at 12 GMT

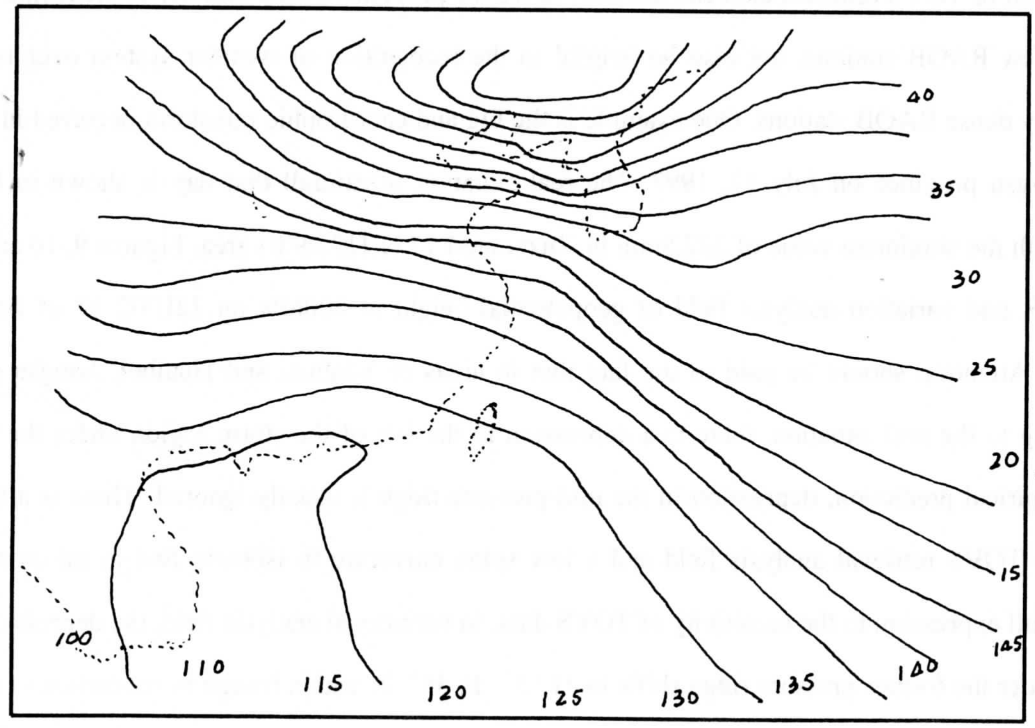

Figure 6. Same as Figure 5 except for TOVS retrievals

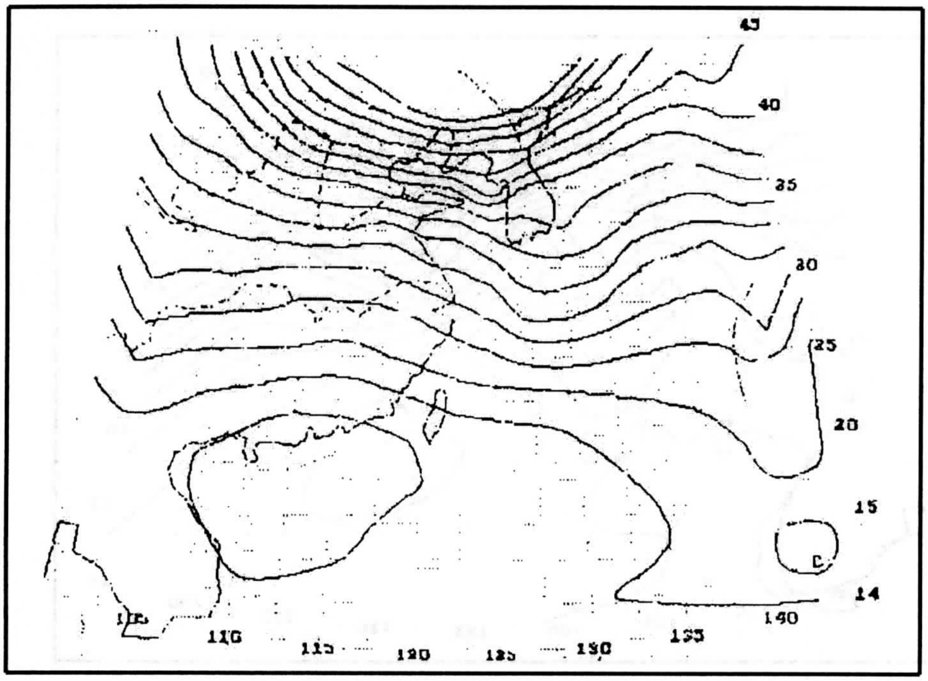

Figure 7. Same as Figure 6 except for TOVS variational analysis field

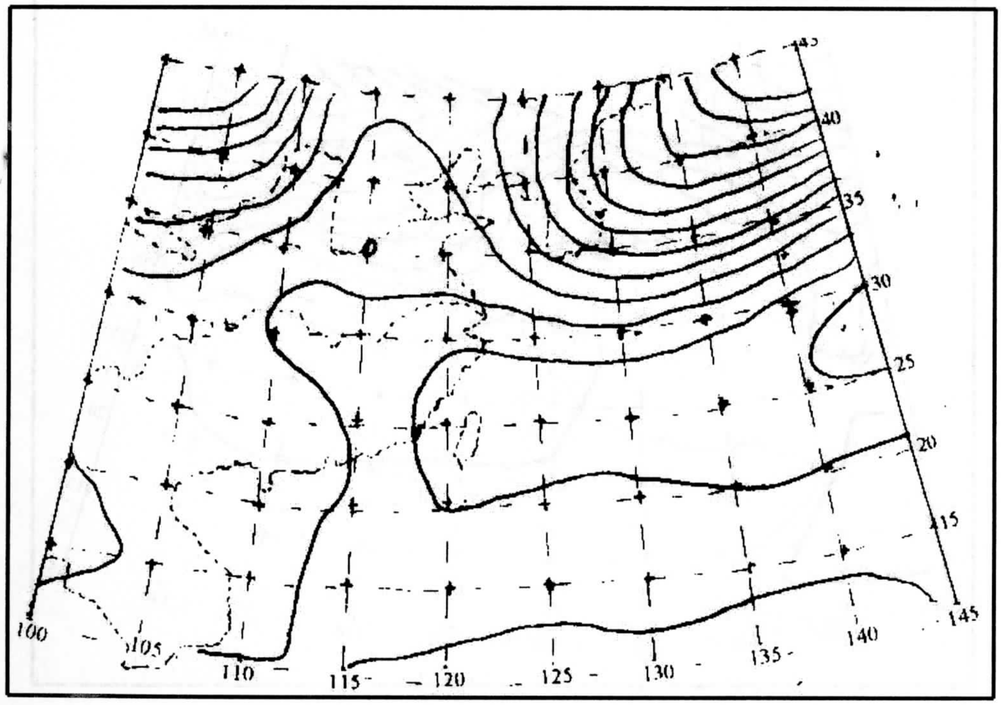

Figure 9. T106 500 hPa geopotential height field on 17/07/97 at 12 GMT

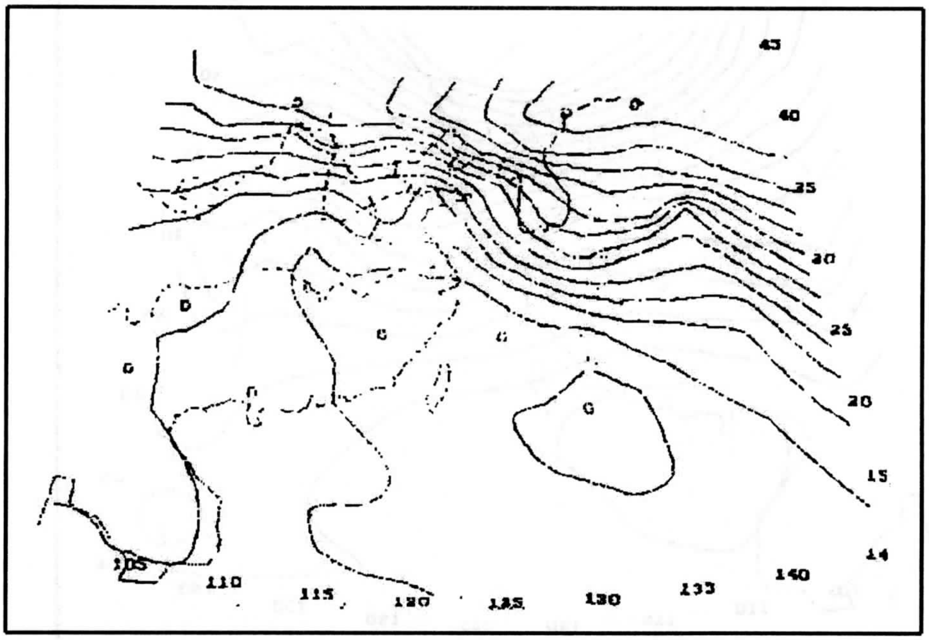

Figure 10. Same as Figure 9 except for TOVS retrievals

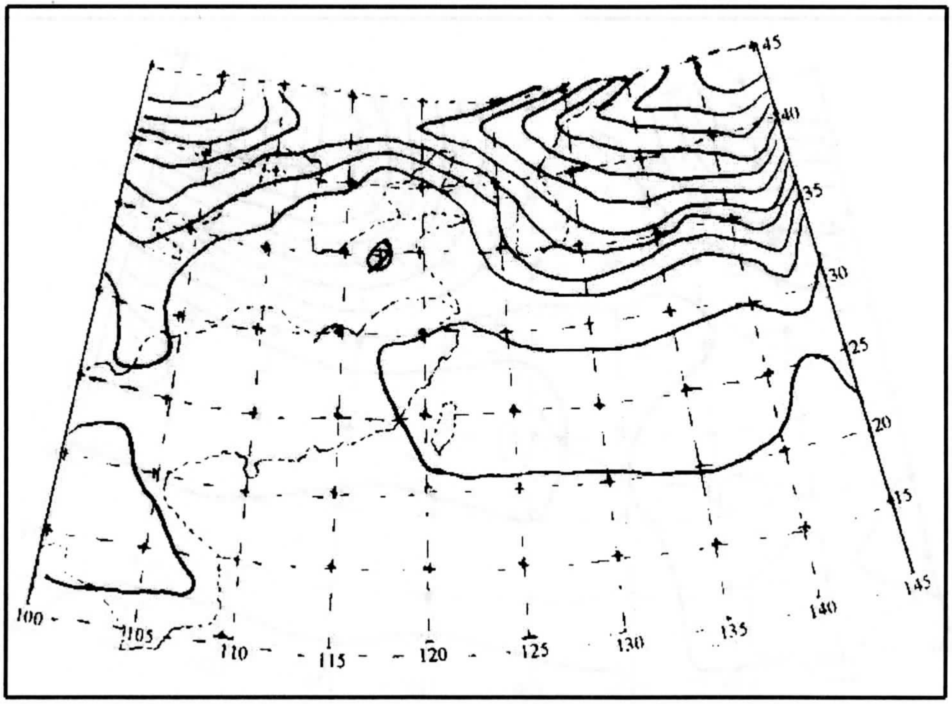

Figure 11. Same as Figure 10 except for variational analysis field of TOVS retrievals

more precisely shown weather system after variation analysis.

4. CONCLUSION

From these application studies, some suggestions can be given as:

- The retrievals from local HRPT receiving and processing system has the capability of analyzing and predicting precipitation, West Pacific subtropical activities, and meso-scale weather system.
- It is necessary to make correction to the retrievals by variational method before the retrievals are used in weather systems.
- The AAPP(ATOVS and AVHRR Processing Package) which is developed by EUMETSAT has been installed on HP workstation in NSMC of CMA. It is successfully to process the real NOAA-15 HRPT data from the three acquisition stations in China. The accuracy of soundings from NOAA-15 is expected to be improved. Applications of the retrievals from this new generation satellite must improve the weather analysis and prediction.

5. REFERENCE

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