RECENT TOVS STUDIES AND APPLICATIONS

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1. INTRODUCTION

At present, the three meteorological satellite ground stations (Beijing, Guangzhou and Urumqi) have been set up. All of them can receive Fy-1 (made in China) and NOAA satellite data and transfer the data to the Satellite Meteorological Center (SMC) located in Beijing. For each day and each satellite, 6 or 8 passes (3 or 4 ascending passes and 3 or 4 descending passes) can be received and transferred to SMC. The maximum data coverage is about 70°N - 10°S, 50° - 160°E. SMC processes TOVS data and AVHRR data routinely in real-time on IBM-4381 computers.

The current TOVS operational processing system of SMC is developed based on the system described in the previous report (Dong, et al., 1988). In the system, calibrated radiances undergo limb correction and other pre-processing using algorithms based on the International TOVS Processing Package (ITTP3, Smith et al., 1983). HIRS data are then cloud-cleared using the well-known N* technique. Temperature and humidity profiles, and total ozone amount are retrieved using the statistical regression methods. The regression coefficients of temperature and humidity retrievals are up-dated about once a week. In order to improve the accuracy of retrievals and to run the system routinely in real-time, a few modifications have been done and some new products have been developed.

Since May of 1988, the 3I package developed by LMD/ARA (Scott, et al., 1988) has been implemented on IBM-4381 computer and tested using TOVS 1B data produced by CMS of Lannion and SMC in Beijing. The preliminary results have been obtained and compared with both radiosonde data and the results from the TOVS operational system, respectively.

McIDAS system of SMC has been implemented. An one step method has been tested using the climate guess, the regression guess and forecast output from B model and analysis fields from NMC as first guess, respectively. Also comparisons are made between the retrievals and radiosondes. The 3I results can be analyzed and displayed using the McIDAS commands.

In recent years, we also have done some studies on inverse theory and methods. Such as, (1) the comparison study of improved fast and accurate transmittance computation methods for TOVS retrievals (Liu et al., 1989). (2) The method of estimating the effect of kernel function error (KFE) on retrieval accuracy (Li et al., 1988). (3) The test of improved high-resolution simultaneous physical retrieval method in the east Asia region including Tibet Plateau. (4) The intercomparison study of inverse methods, and so on.

In addition, TOVS data application are being studied in several fields. The studies on impact of sounding data on some mesoscale analyses are going on and some examples have been done.

2. THE CURRENT TOVS OPERATIONAL PROCESSING SYSTEM

The current TOVS operational processing system is developed based on the system reported at the ITSC-4 and has been processed TOVS data routinely in real-time on IBM-4381 since July of 1988. In order to run the system on IBM-4381 more automatically and try to improve the accuracy of retrievals, the following modifications have been done.

A. Modifications of Input Data

As compared with the old system, the following two kinds of input data modified:

a. TIP Data

For the current system of SMC, the HRPT data are transferred from the three ground stations to the data processing center through the microwave circuit and communication satellite, the TIP data are extracted from the HRPT data stream and stored into disk data files on IBM-4381 as input data of the TOVS operational processing system.

b. Radiosonde Data

The radiosonde data are transferred from the M-160 computer of NMC to the IBM-4381 computer of SMC through the communication line (9600 bps), then the data are pre-processed on IBM-4381 and stored into disk data sets as input data of TOVS support system.

B. Monitoring the Accuracy of Regression Coefficients

Based on the coverage (70°N - 10°S, 50° - 160° E) of data received at Beijing, Guangzhou,and Urumqi stations, three zones are defined: Zone 1 (70° - 60°N), Zone 2 (60° - 30°N), and Zone 3 (30° N - 10°S). So the three sets of coefficients are generated about once a week based on the three zones and used to process TOVS data routinely in real-time. The accuracies of the retrieval coefficients and retrievals are good during the summer time. With the changing of time and weather, we found that the results were getting worse at lower levels, especially in October and November for Zone 1 (see Fig.1).

In this case, we try to improve the accuracies of results. We thought maybe there are two major reason can make the results worse. One is the numbers of statistical samples used to generate retrieval coefficients are too small, the other is the quality of the samples is not good enough. Thus, the boundary of Zone 1 has been changed from (70° - 60°N) to (70° - 50°N) and the samples are more carefully selected since December of 1988. Fig. 1 shows the evaluation of regression coefficient accuracy and monthly trend (using independent samples of the data set). From Fig. 1, it can be seen that the accuracy of regression coefficients is truly improved at the lower levels from December of 1988.

In the Fig. 1, (a) is for upper 10 levels from 10 - 100 mb and (b) for lower 20 levels from 115 - 1000 mb. For upper levels, three kinds of channel combinations are selected: (1) HIRS ch.1 - 3 and MSU ch. 3 - 4, (2) HIRS ch. 1 - 3, and (3) MSU ch. 3 - 4. So the value of each point in Fig. 1a is the mean of 3 channel combinations and 10 levels. For lower levels, there are four kinds of channel combinations selected: (1) HIRS ch. 1 - 17 and MSU ch. 2 - 4, (2) HIRS ch. 1 - 15 and MSU ch. 2 - 4, (3) HIRS ch. 1 - 3 and MSU ch. 2 - 4, and (4) MSU ch. 2 - 4. The value of each point in Fig. 1b, is the mean of 4 channel combinations and 20 levels.

Also, from Fig. 1, we can see the results are consistently better for all of the three zones in the summer and winter, and are pretty good for the lower levels and the low latitude zone(3) in the all seasons. But, in the autumn and spring, the results are poorer for the middle and high latitude zones(1 - 2).

C. The Use of Ground Truth in Retrievals

When calculating geopotential height from sounding data, the major problem is how to get real surface observation data, such as temperature, dewpoint temperature and pressure. The climatological data were used to estimate surface pressure before the communication line between SMC and NMC was available. Now we can obtain either the sea level pressure or the surface pressure of each station. If only the sea level pressure is available, an empirical formula or the hydrostatic formula is used to calculate the surface pressure for getting more accurate geopotential heights for the mandatory levels (see Table 1).

D. Development of TOVS New Products

The TOVS operational processing system produces many kinds of products, such as atmospheric temperature and moisture profiles, total ozone amount, TOVS channel images, ... Now some new products have been tested, for example, cloud top height and temperature, and longwave outgoing radiation. The method for getting cloud parameters is based on the bi-spectral algorithm developed by Smith et al. (1970). In addition, the cloud height can be obtained at two different layers using different HIRS and MSU channel combinations.

As we know, many scientists over the world calculate outgoing longwave radiation using AVHRR data. The advantage of AVHRR is higher resolution in space, but only one channel information from longwave radiation. HIRS instrument has 20 channels scattered in different spectral bands. Although it has lower resolution in space, higher resolution in vertical direction. We take this advantage against the AVHRR and use a quasi-analytic function for getting longwave outgoing radiation with five HIRS channels (ch. 3,7,8,10 and 12). Comparing the results from HIRS different kinds of channel combinations with AVHRR, we found the best one is from HIRS five channel combination, in which the RMS is about 1.68 MW. The reason is that HIRS data contain rich information from the earth-atmosphere such as, effect of water vapour and cirrus.

In addition, the surface (or shelter) temperature can be estimated from TOVS sounding data by using the multiple linear regression method, and the absolute mean bias between the retrieved results and the conventional data is about 2.8 K for the region (20°- 60°N, 75°- 150°E). The mosaics of TOVS water vapour channel (ch. 10,11 and 12) images have been developed for three or four passes (see Fig.2).

3. THE 3I PACKAGE

The 3I (Improved Initialization Inversion) is developed by the Atmospheric Radiation Analysis (ARA) group of the Laboratoire de Meteorologie Dynamique (LMD) in France. During a visit at the Center Meteologic Special (CMS) and LMD, it was glad to have a chance to study the 3I and bring the 3I package back to China and continue to study it in China.

A. Implementation of the 3I Package on the IBM-4381

Since May of 1988, the 3I package has been implemented on the IBM-4381 computer and tested using the NOAA-9 (orbit 3378) and NOAA-10 (orbit 5583) TOVS 1B data produced by CMS at Lannion. The testing results are slightly different with the results made by LMD. The differences may be caused by the different computer systems.

The 3I codes are developed based on the HIRS and MSU 1B data produced by CMS. Both HIRS and MSU 1B data are calibrated and navigated. After the radiances calibrated, the limb correction and the other corrections are done for the MSU 1B data, but not for the HIRS 1B data.

In order to use the 3I codes to process the TOVS data at SMC easier, we decided to start from TOVS 1B data which are calibrated and navigated based on the ITPP3. So an interface module has been developed to perform limb correction and other corrections for MSU based on the ITPP3 and then reformat HIRS 1B and MSU 1B data into standard formats for the 3I codes to use. With the interface module, the 3I codes can be run on the IBM-4381 in batch job using the TOVS 1B data produced by the TOVS operational processing system. For each run, it takes about 24 minutes (CPU) to process about 150 lines and produce over 800 soundings. The computer resources needed for running the 3I package on the IBM-4381 list in Table 2.

B. Application of the 3I Method to NOAA-10 Data Over China

We have applied the 3I procedure to NOAA-10 TOVS data over China for many passes and several different periods. Retrievals are made for each box consisting of 3 scan lines and 4 (small viewing angles) to 2 (large viewing angles) HIRS spots. The resulting spatial resolution for each retrieval is approximately 100 x 100 km^2.

For the input data, HIRS observations are not angle corrected, but MSU does. After determining the air mass for each spot (i.e. polar, middle and tropical), a series of cloud tests are then carried out box by box, and for each box HIRS spot by HIRS spot, in order to declare the box clear or not-clear. In the present 3I package, the test limitations are so tight that it is only about one fifth (1/5) boxes declaring clear for each pass (some pass a little more, some pass much less). Although, most of boxes are declared not-clear, it is only about 4% of the total number of possible retrievals rejected by very heavy clouds and complicated surfaces. So using the 3I procedure, we can get much more retrievals than the current TOVS operational system, especially for the cloud areas in which meteorologists are more interested. Table 3 gives an example about the numbers of retrievals and rejections for several passes. From Table 3, we can see that the number of rejections is very small and the number of clear retrievals also is not too much. Even if there are lots of clouds in the fields of views, a lot of retrievals can be done successfully.

Figs. 3-5 give the examples of the analyses and contours displayed on the McIDAS system. FIg. 3 shows the NOAA-10 TOVS images of HIRS ch. 8 with the latitude and longitude grids, in which (a) is at 12:20 GMT, Apr. 28,1989 and (b) at 00:20 GMT, Apr. 29,1989. Fig. 4 shows the temperature analysis of the 3I retrievals and plots (numbers) of radiosondes at 500 mb over the TOVS images, where,(a) for the pass of 12:20 GMT, and (b) for the pass of 00:20 GMT. The coverages of the above two passes are over the Qinghai-Xizang Plateau and the east of China. From Fig. 4, it can be seen that most of radiosondes have a good agreement with the 3I analysis, but the 3I retrievals are a little colder than radiosondes. A few radiosondes have a little big difference with the 3I analysis due to the effect of the high mountain - Qinghai-Xizang Plateau. Fig. 5 is temperature analysis of the 3I retrievals corresponding to Fig. 4 with the coastline. This kind of map is similar as the synoptic analysis chart. So it is convenient for metrorologists to use.

4. COMPARISON OF THE RETRIEVALS WITH COLLOCATED RADIOSONDES

The 3I temperature profiles (called "3I") have been collocated with the radiosondes to assess the quality of the retrievals, and similar comparisons have been done for the retrievals (called "REG") produced by SMC TOVS operational system. The resolution of the 3I is about 100 km and the REG is about 80 km.

The maximum time difference for comparisons is 3 hours, while the maximum distance is either 70 km (=0.6°) or 110 km (=1.0°). Radiosondes of questionable quality (observation and transmission problems,...) have been eliminated for differences greater than 10 k. And in this way, the bad retrievals have been eliminated too. The comparisons have been done for the following four types.

A. Comparisons Made for the Entire Region and Different Periods

Based on the evaluation of the regression coefficient accuracy, we have found that the accuracy of the REG retrievals is changing with time and space, even if the regression coefficients are updated in regular time (see Fig. 1). During the altering of the seasons, such as October or November, the daily variation of temperature is very large over the land, especially in the west of China (most of places are desert). Since the REG retrievals are more smooth and can not exactly represent real situation with big daily variations of temperature profiles. In order to assess the quality of both the REG and 3I more objectively, the comparisons have been done for the following three different periods: (a) Aug. 26-27 (in summer), (b) Oct. 5-6 (in autumn) and (c) Dec.14-15 (in winter) of 1988. Results are shown in Figs. 6-8 for the three different periods. Fig. 6 is for Aug. 26-27, 1988 in which total 11 orbits data are used. Fig. 7 is for Oct. 5-6,1988 (12 orbits) and Fig. 8 for Dec. 14-15, 1988 (6 orbits). All of the retrievals have been done for NOAA-10 TOVS data.

From the Figs. 6-8, we can see the 3I results are quite similar for the three different periods. The REG results are similar in summer and winter, but more different in autumn. Also, the 3I and the REG results are similar except for the autumn. In particular, the bias is similar, but the 3I results are a little colder at the most of levels. The standard deviations and the RMS are similar except for the lower levels. For the lower levels, the 3I (without using the surface data) is poorer, but for the upper levels, the 3I is better. In autumn, both of them appear quite different, and the 3I are much better than the REG.

B. Comparisons Made for the Different Sections

From Figs. 6-8, we know the 3I and the REG results are similar in the summer and winter time, but the REG results are much poorer in autumn. In order to know which section is poorer, the comparisons have been done for four different sections in the autumn time. Fig. 9 A,B,C and D are corresponding to Section A (0° - 25°N, 60°- 160°E), Section B (25°- 70°N, 120°- 160°E), Section C (25°- 70°N, 105°- 120°E), and Section D (25°- 70°N, 60° - 105° E), respectively. From Fig. 9, we can see that the REG is better than the 3I for the tropical area and over the sea (A), the 3I is much better than the REG for the middle latitude zone and over the land with the very completed surface (D), and for the others (B and C), both are similar.

Since the REG results have been screened strongly, so the numbers of the collocated radiosondes with the 3I are about twice of the ones with the REG.(see Figs. 6-9).

C. Comparisons Made for the Different Stations

In addition to the above comparing the 3I and the REG with radiosondes have been made station by station. Fig. 10 shows the temperature profiles at four stations with the collocated 3I and REG for Dec. 14-15, 1988. Both the REG and the 3I are quite similar, and very close to the radiosonde data, except for the lowest levels near the surface. Since the 3I didn't use the surface data, so the results at the lowest levels are poorer than the REG. Fig. 11 shows the similar results as Fig. 10, but for Oct. 5-6, 1988 at six stations. Similarly, the 3I results are good at all the six stations, the REG are good at Nanning, Chengdu, Hangzhou (in tropical area) and Dalian (near the sea), but not good for Beijing and Hailar (in the midlatitude zone). However, both the 3I and the REG can not represent real situations when inversion layers appear in the atmosphere (see Chengdu and Hangzhou).

In summary, the 3I results are consistently better for any-time and any region. The REG results are better in the tropical region and over the sea for any time, and good for the entire region in summer and winter, but not so good over the land in autumn and spring.

D. Comparisons of the First Guess with the 3I Retrievals

As we know, the 3I is the improved initilization inversion method, so many people more concern about how the first guess of the 3I is. Thus the comparisons of the first guess with the 3I retrievals and the radiosondes have been done (Fig. 12). In Fig. 12, (a) is a comparison of temperature profiles at Beijing station on Oct. 6,1988, and (b) is statistics for the entire region and the period of Dec. 14-15, 1988 corresponding to Fig. 8. From these figures, we can see that the first guess of the 3I are very close to the retrievals, especially at the lowest levels and upper levels, and, sometimes,better than retrievals at some levels.

5. THE STUDIES ON IMPACT OF SOUNDING DATA ON SOME MESOSCALE ANALYSES

In order to investigate the impact of satellite sounding data produced operationally by SMC on some mesoscale analysis, a Limited area Fine mesh Model (LFM) for heavy rain was developed by a group of the Institute of Atmospheric Physics, Acdemia Sinica. The model can be run with satellite sounding data or without sounding data, and there are five vertical levels and the domain of 3000 x 2400 km with 100 km horizontal resolution.

Two 24 h simulations were conducted using the initial data with or without satellite TOVS data. It is found that satellite sounding can only describe the thermal fields of the atmosphere and, therefore, the model was initialized with satellite - derived temperature height fields. Lateral boundary conditions were held constant during the course of the 24 h forecast sequence, and, in addition, large scale condensation and cumulus convective parameterization were included in this model. The resulting simulation contains the combined effects of the satellite sounding errors, numerical modeling errors and errors from simplifications (Zhou et al., 1988). Since this was a data evaluation study, an attempt was made to reduce the effects of the modeling and simplification (fixed boundaries, etc.) by verifying the simulation against a control run. This control run was initialized in the same manner as the satellite - derived forecast, except that no TOVS data is used. A comparison of the simulation with TOVS data to the simulation without TOVS data (the control run) may provide insight into retention of sounding errors in numerical model simulations.

Such a comparison is shown in Fig. 13 which presents the precipitation amount from the control run and data simulation, respectively. From this figure, it can be found that the patterns between precipitation amounts simulated by TOVS data and only radiosonde data are very similar to each other. The difference between them is that the rain band simulated with TOVS data is broader than that with radiosonde data. Nevertheless, this can still provide very useful information for data sparse area, because the position of simulated rain area is very close to the observed.

As mentioned above, it is necessary to examine the relative accuracy of the TOVS and control simulations by comparing them with analyses that have the same valid time as the simulations (verifying analyses). Simulation results give specific information about the location and the magnitude of simulation errors for a given parameter at a given level. We will be concerned primarily with the accuracy of the simulation over land, and we expect the impact upon the simulation to occur mainly over land, because the verifying analyses are more accurate there due to the presence of data. In this report, the tool used to evaluate the forecast is the S1 score. The S1 score is a measure of the gross accuracy of the gradients of a scalar field,

$$S1 = 100 \sum_{i=1}^{N} \frac{e_i}{G}$$

where

e = the error in the gradient between two geographically adjacent points;

G = the largest gradient (either simulated or observed) between the two adjacents; and

N = the number of pairs of points used in the comparison.

It is pointed that this score is a useful measure of simulation accuracy. However, the S1 score has some limitations. First, the score applies to an entire geographic region and, therefore, constitutes a rather blunt instrument for measuring simulation accuracy. The S1 score is also crucially dependent upon the availability and the spacing of upper air stations, because normally the points used to calculate the gradients are radiosonde stations. This latter problem has avoided in this paper by using of objective analyses at grid point rather than at radiosonde stations. The advantage of this technique is that analyses of radiosonde data probably more representative than individual soundings, because measurement errors are random. Show in Fig. 14 are S1 scores of 24 h LFM TOVS and control simulation of 500 mb height for cases. The scatter diagrams indicate that, overall, the TOVS simulation have slight better than the control simulation, even though assimulation system have not been used so for. However, S1 scores at 700 mb (not shown) are slightly poorer, in general,than that at 500 mb, probably because the latter scores were calculated in the lower troposphere near surface ground. Nevertheless, the S1 score in the middle troposphere is helpful.

6. FUTURE PLANS

It is planed to continue running statistical regression model in our operational TOVS processing system. More modifications will be made in the statistical method in order to make that more efficient over China. The improved physical simultaneous retrieval method has been tested to operate in the eastern Asia region. It is planned to continue trials of the 3I and the simultaneous methods in several ways, such as, using TIGR data set employed by the 3I method as first guess of simultaneous approach. We are continuing to work on evaluation of TOVS products and comparison between the operational results with the retrievals from the 3I and one-step methods so that to investigate which method is more suitable in China. The impact studies of sounding data on numerical forecast model just start and will be continued.

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Table 1. Comparison of NOAA-10 geopotential heights for using both climate(C) and real(R) surface data with radiosonde observations on June 20, 1989

Level(mb)		850	700	500	400	300	250	200	150	100	70	50	30	20	10
Samples		40	53	57	57	55	52	51	52	44	44	48	37	32	6
Bias	C	52	40	25	20	19	18	26	37	37	41	18	27	24	-16
	R	-1	4	-4	-10	-9	-9	0	8	10	16	-4	2	4	3
RMS	C	58	56	52	54	55	59	63	70	68	76	66	60	61	51
	R	11	32	42	47	49	51	52	56	53	52	54	46	44	51

Table 2. Computer resources needed for the 3I system running on the IBM-4381

Charged CPU	24 minutes
Elaped Time	38 minutes
Center Memory	6000 K
TIGR Size	35 M
Topography File(gloable)	12 M

Table 3. List of the number of retrievals and rejections (III)

NO. of Passes	Time	NO. of Retrievals	NO. of Rejections	NO. of Clears	NO. of Clouds
1	88/10/5 23Z	823	4	72	751
2	88/10/6 00Z	809	22	197	612
3	88/10/6 02Z	531	63	144	387
4	88/10/6 10Z	525	19	207	318
5	88/10/6 12Z	610	13	83	527
6	88/10/6 14Z	620	45	163	457
7	88/12/14 10Z	260	1	84	176
8	88/12/14 14Z	419	18	122	297
9	88/12/14 22Z	650	4	66	584
10	88/12/15 00Z	674	29	208	466
11	88/12/15 02Z	618	57	114	504
Total		6539	275	1460	5079
Percentage		96%	4%	22%	78%

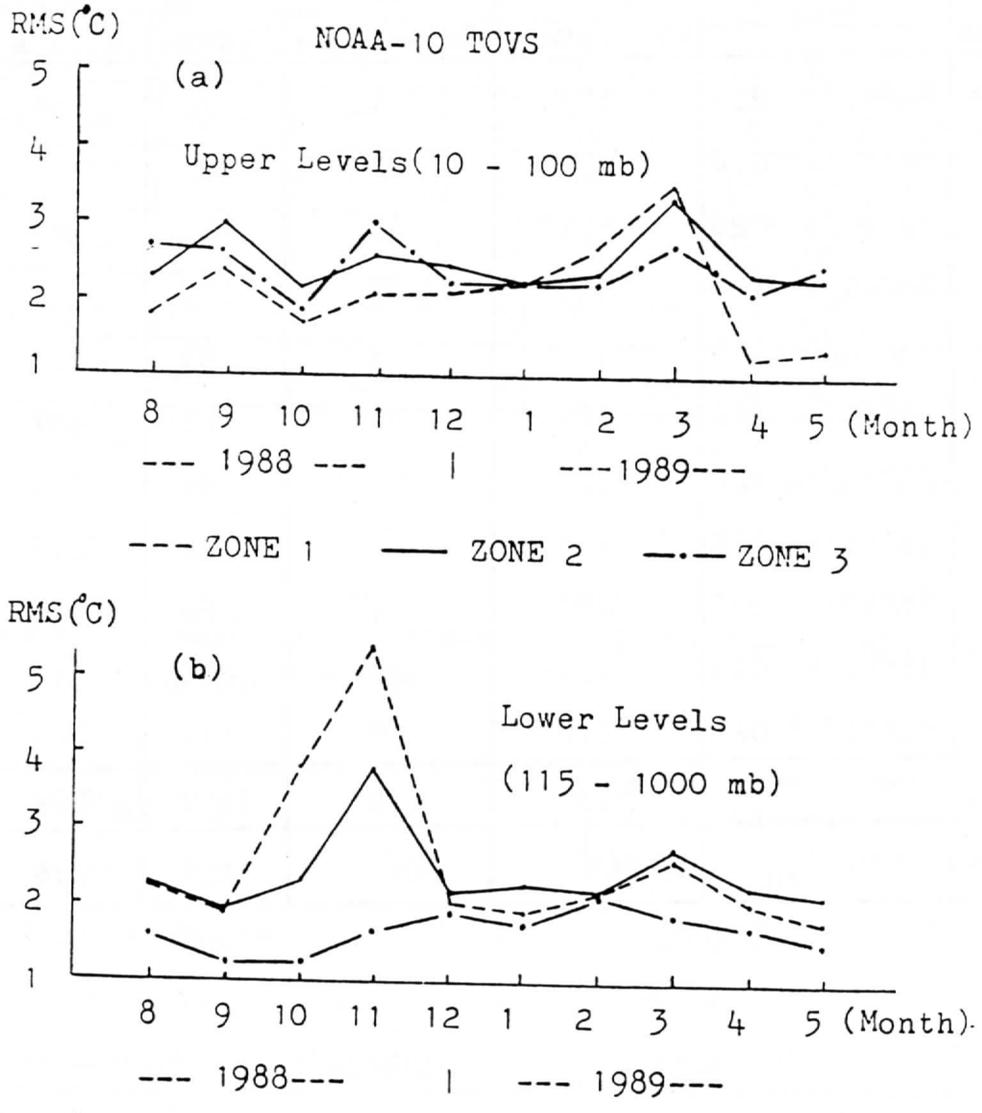
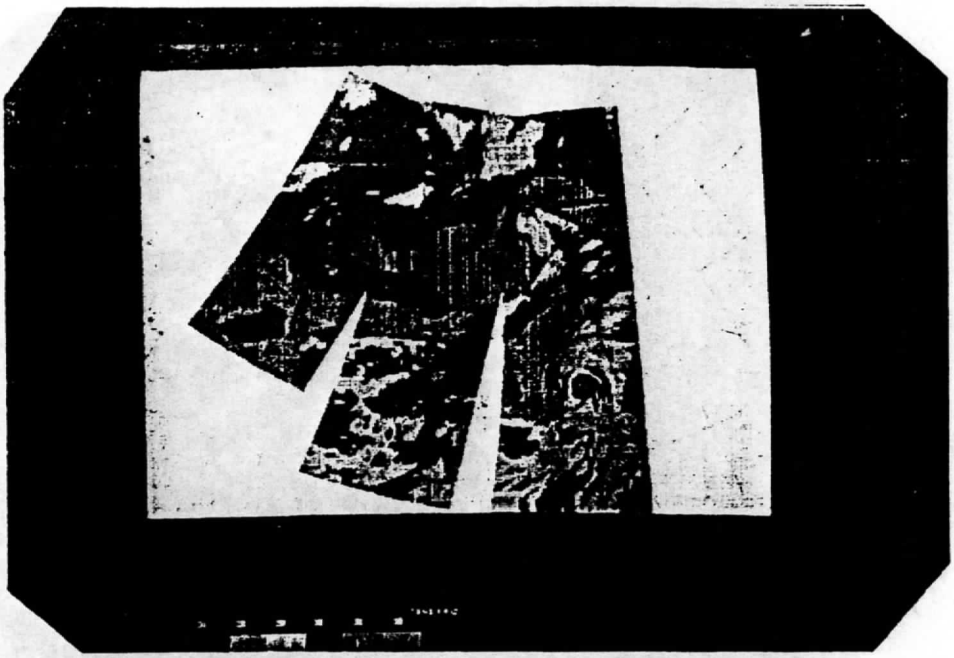


Fig.1 Evaluation of regression coefficient accuracy and monthly trend.

(A)



(B)

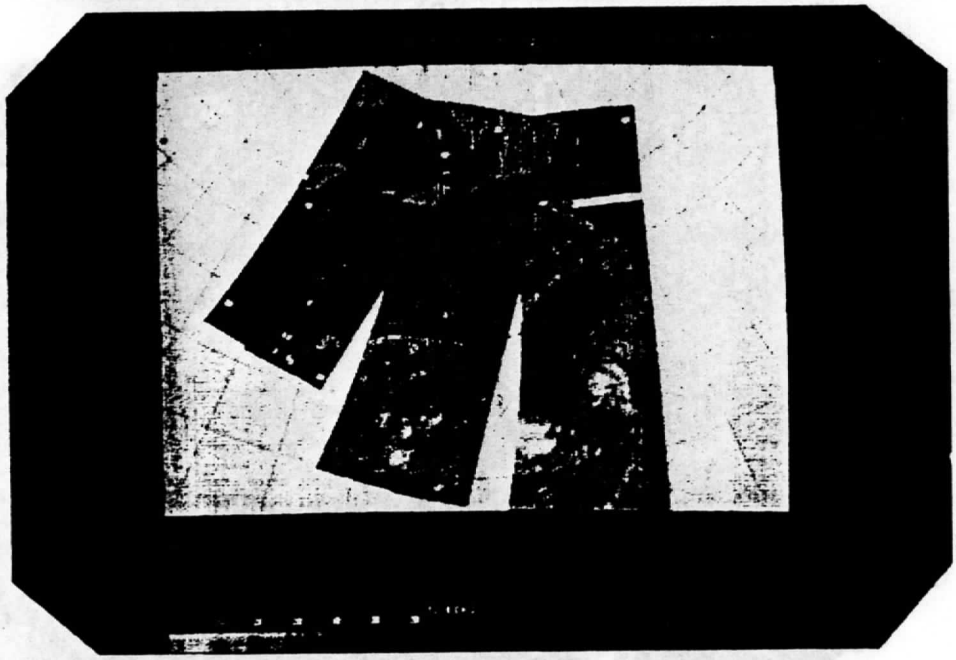
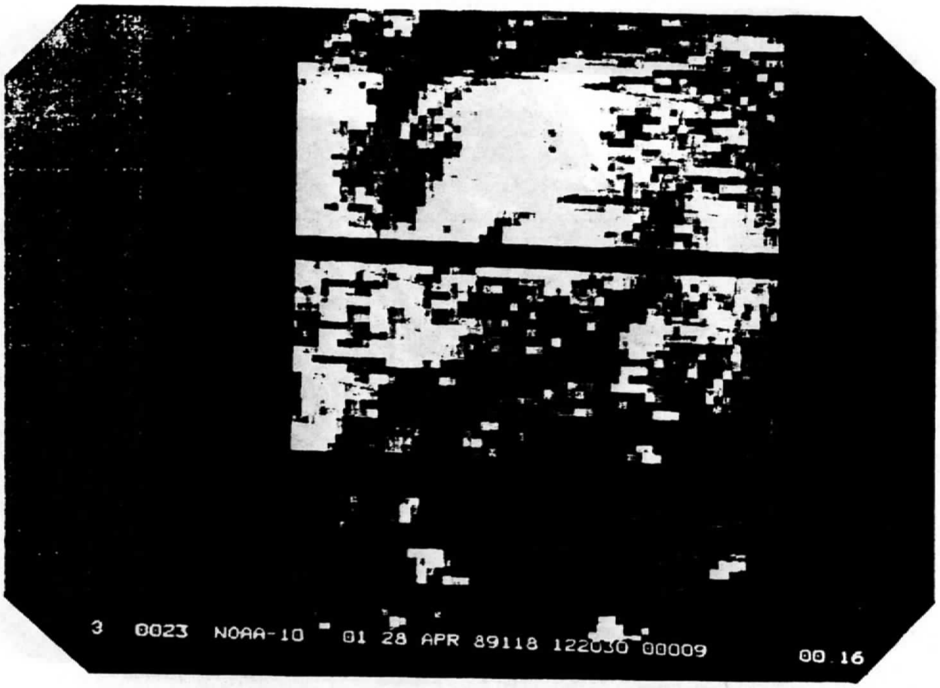


Fig.2 The masaics of NOAA-10 TOVS water vapour channel (ch.12) images for the three passes on the morning of Oct.5,1988. (A: colour, B: black)

(A)



(B)

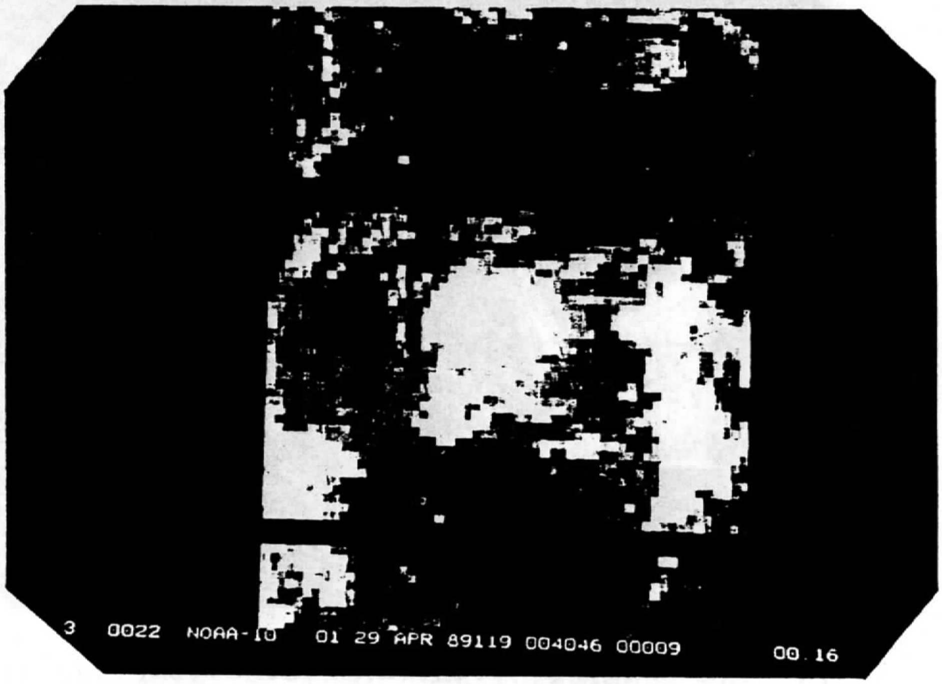
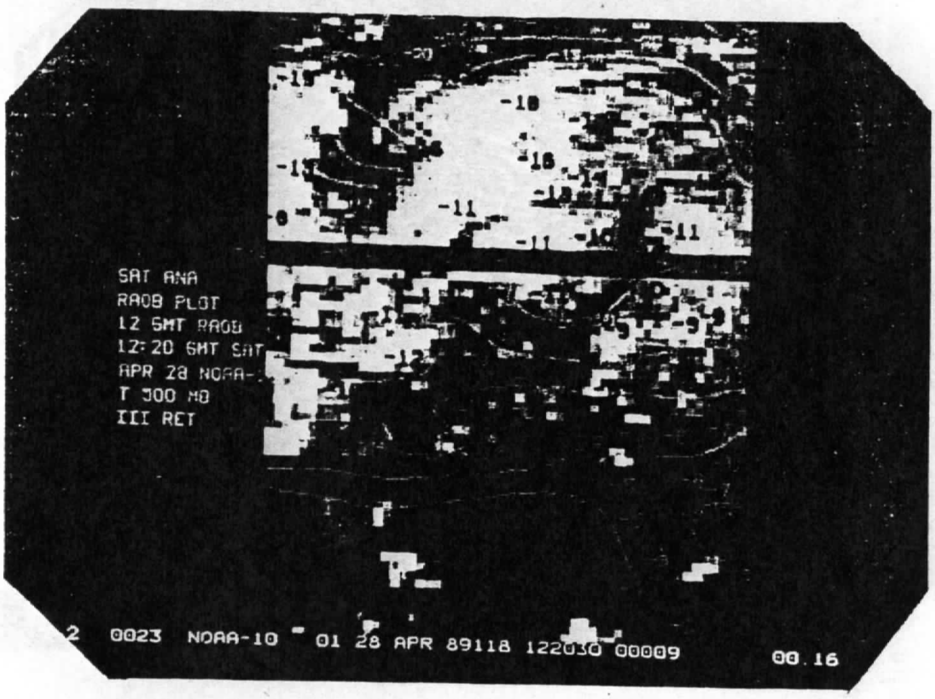


Fig.3 NOAA-10 TOVS HIRS ch.8 images with the latitude and longitude grids.
(a) at 12:20 GMT, Apr.28,1989.
(b) at 00:20 GMT, Apr.29,1989.

(A)



(B)

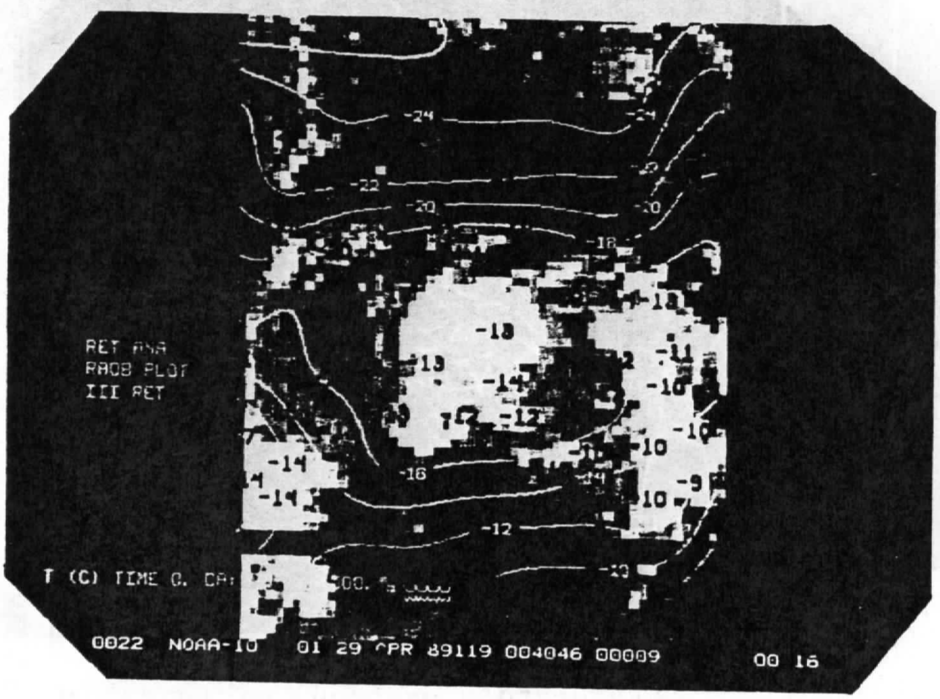
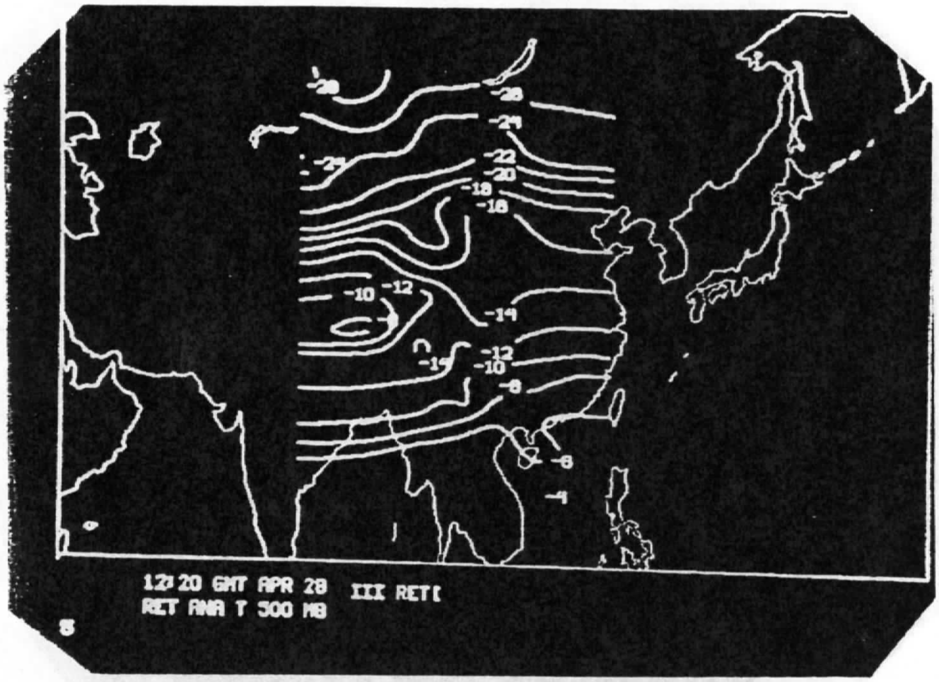
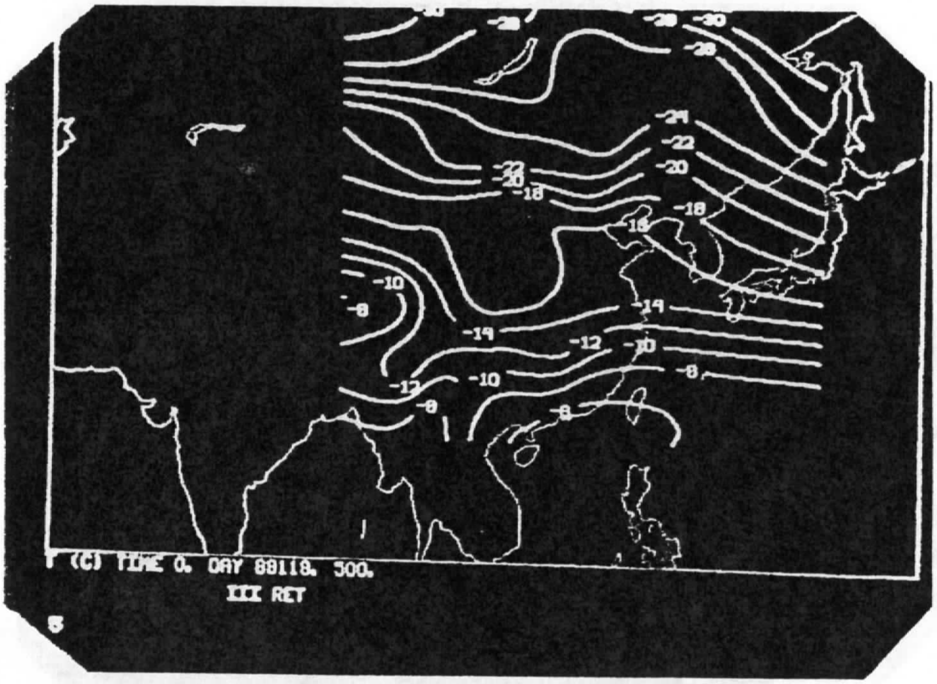


Fig.4 The temperature analysis of the 3I retrievals (contours) and plots of radiosondes (numbers) at 500 mb over the TOVS images.
(a) at 12:20/12 GMT, Apr.28,1989.
(b) at 00:20/00 GMT, Apr.29,1989





[illegible] temperature analyses of the [illegible] retrieved [illegible]
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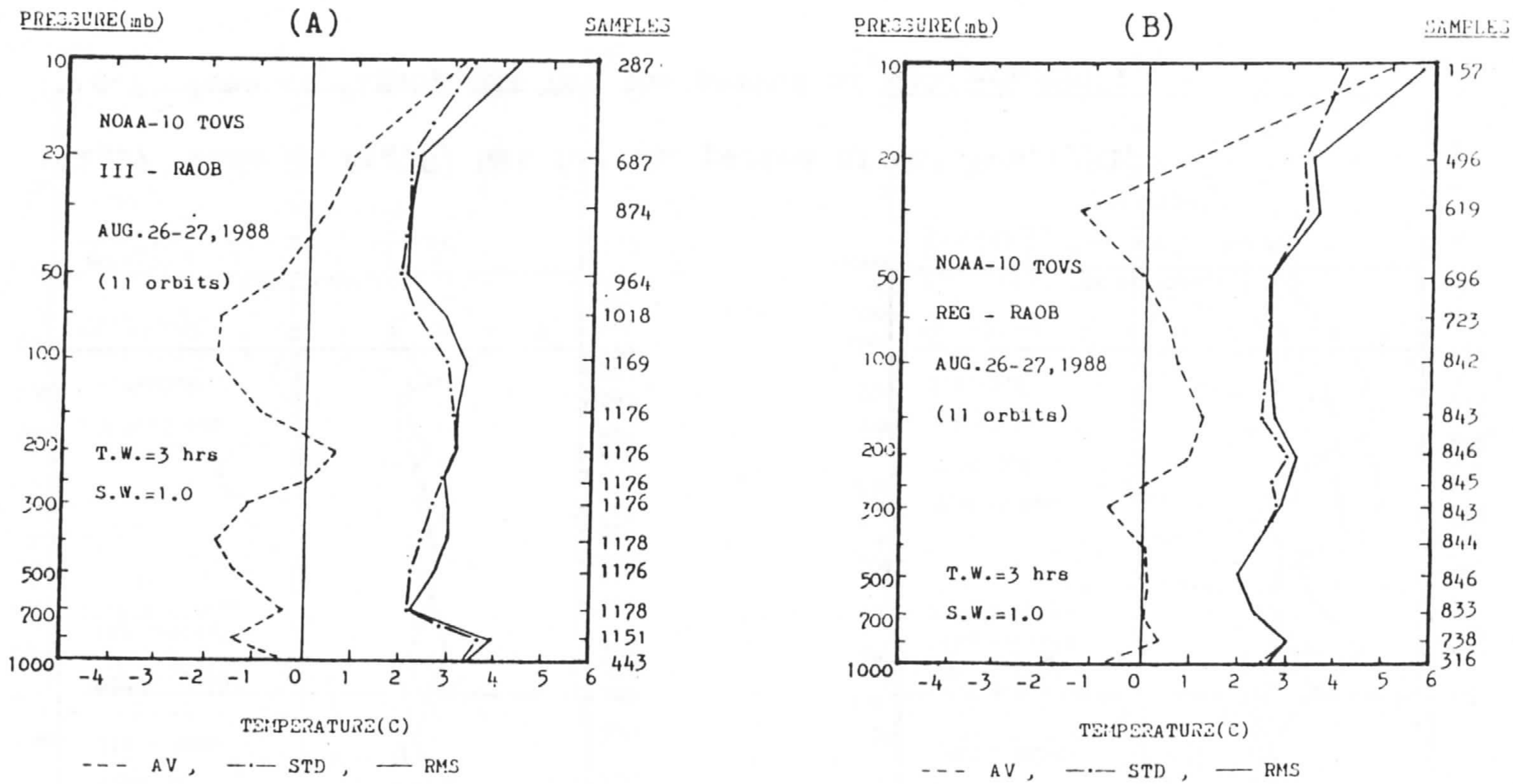


Fig.6 Comparisons of NOAA -10 TOVS retrieved temperature profiles with the collocated radiosondes for the period of Aug.26-27,1988.(AV: Bias) (T.W. = the match-up time window, S.W. = the match-up space window)

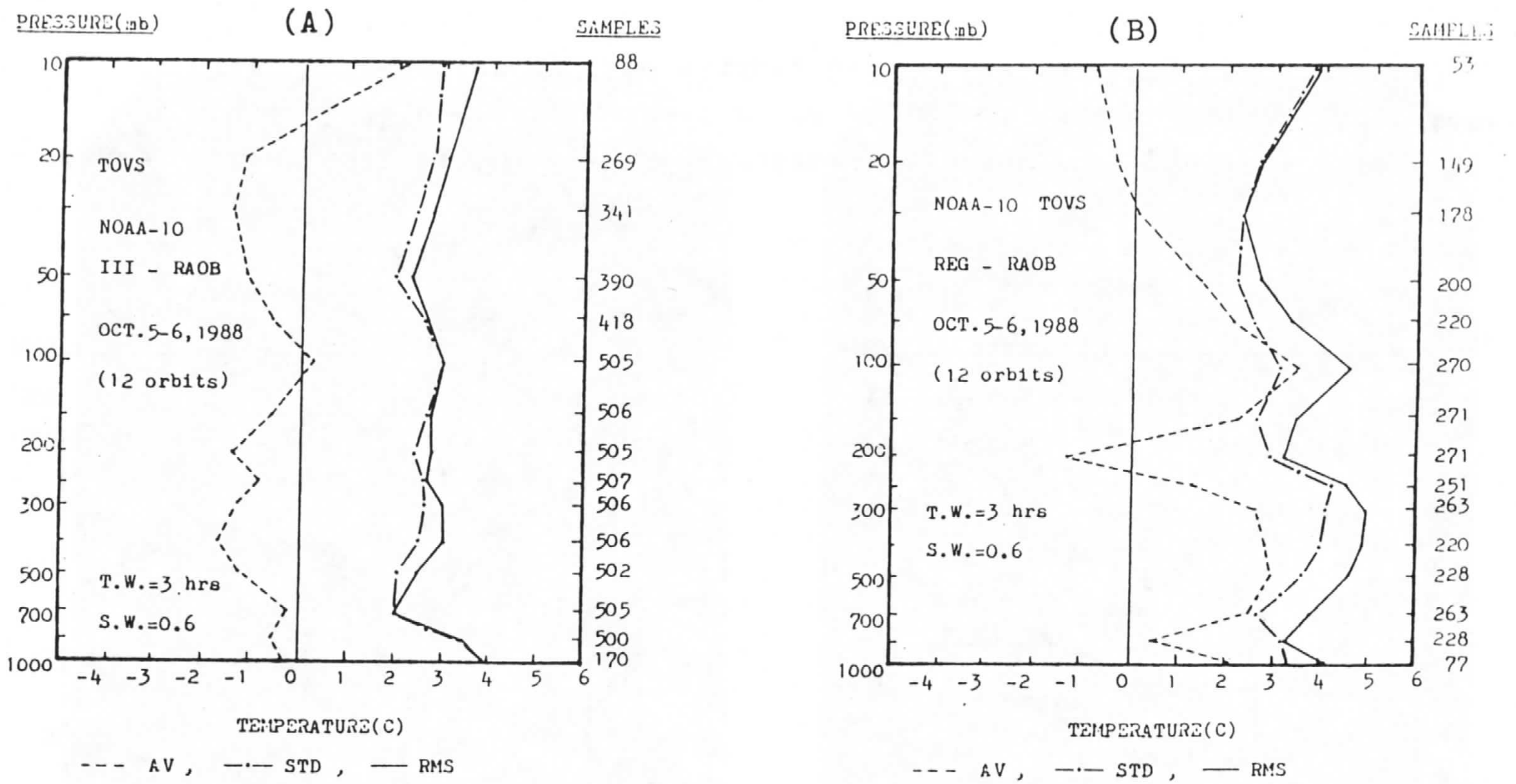


Fig.7 Same as Fig.6, but for the period of Oct.5-6,1988.

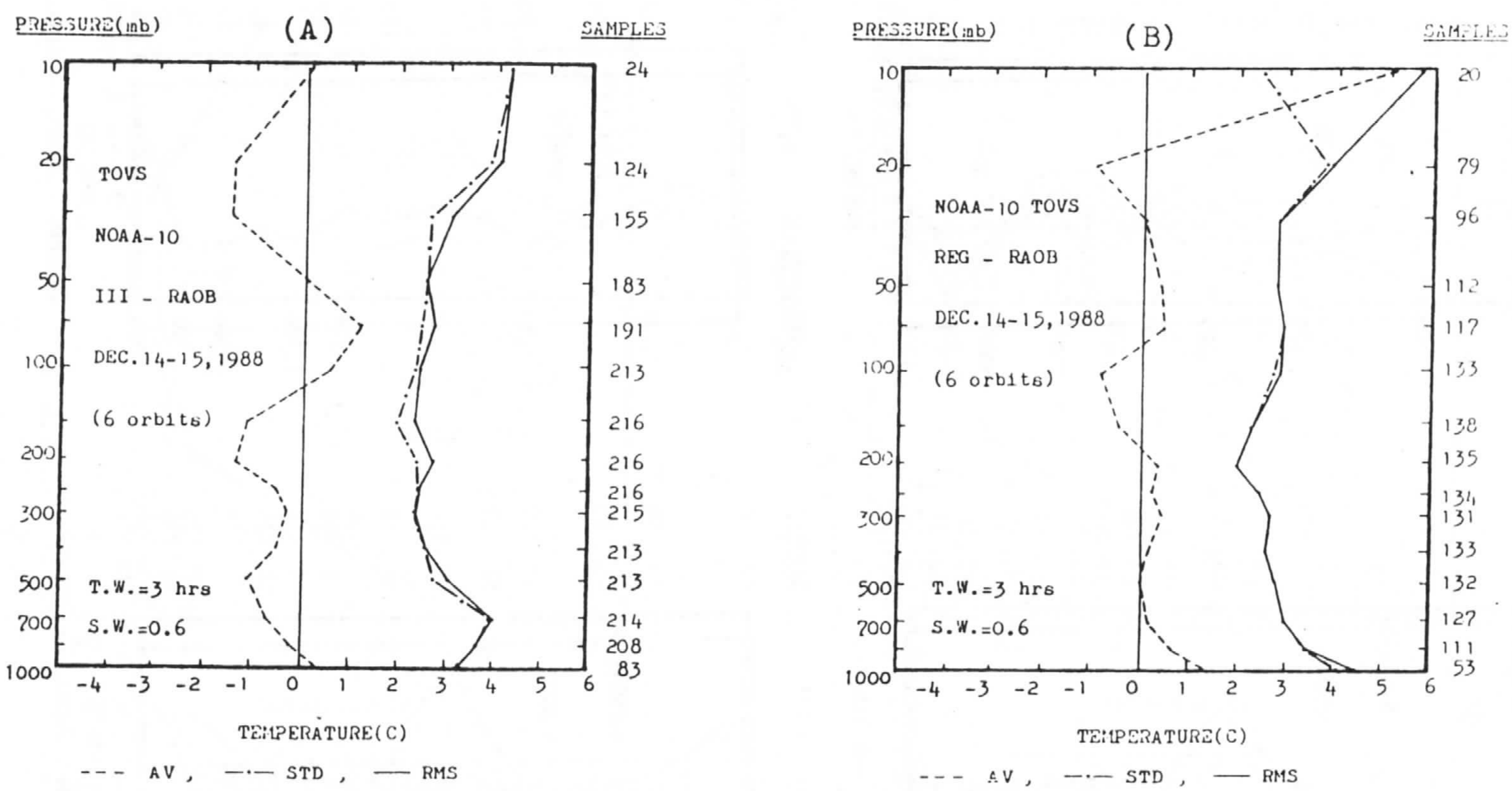


Fig.8 Same as Fig.6, but for the period of Dec.14-15,1988.

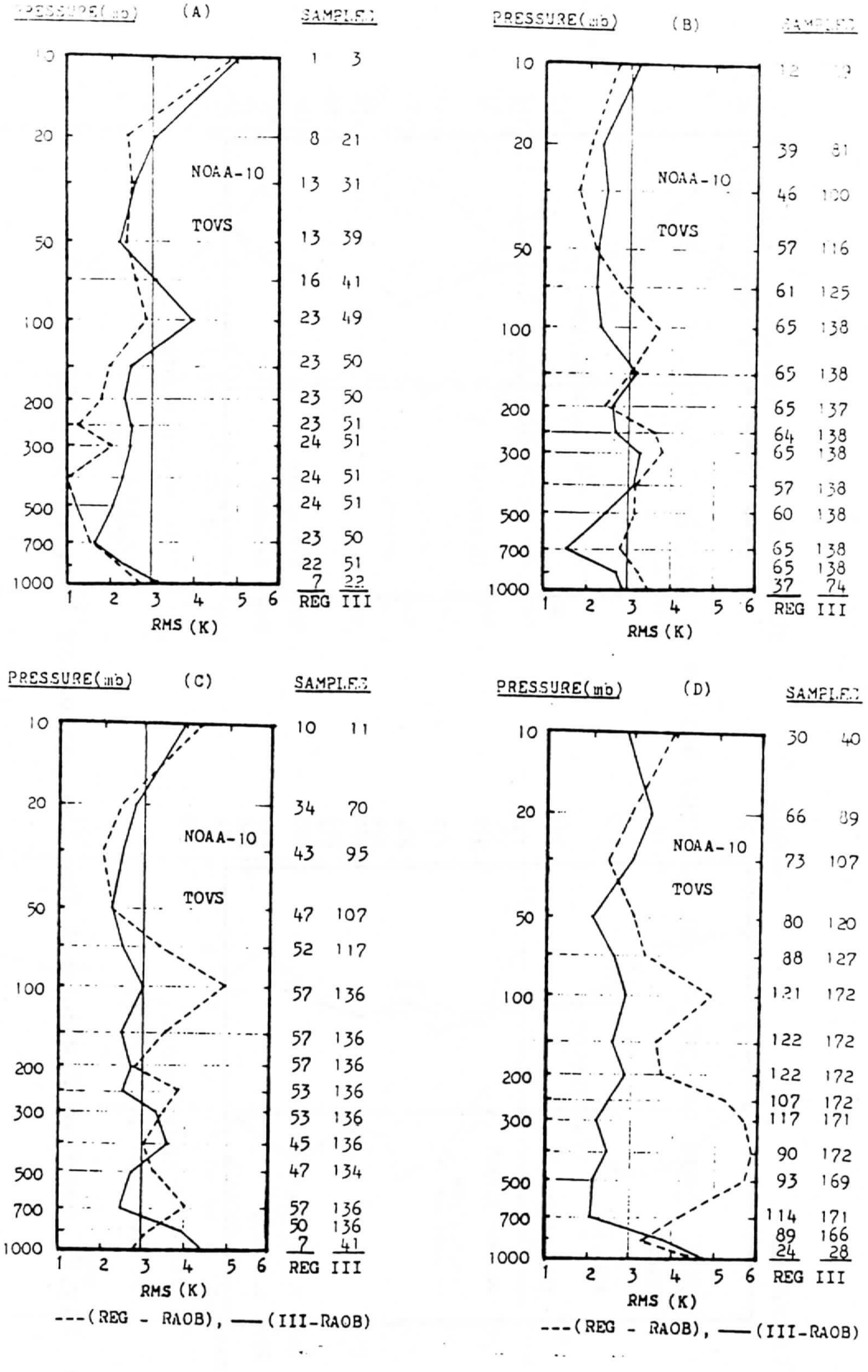


Fig.9 Comparisons of the 3I and REG temperature profiles with the collocated radiosondes for four different sections at the period of Oct.5-6, 1988. (Section A (0°-25°N, 60°-160°E), Section B (25°-70°N, 120°-160°E), Section C (25-70°N, 105°-120°E), and Section D (25°-70°N, 60°-105°E))

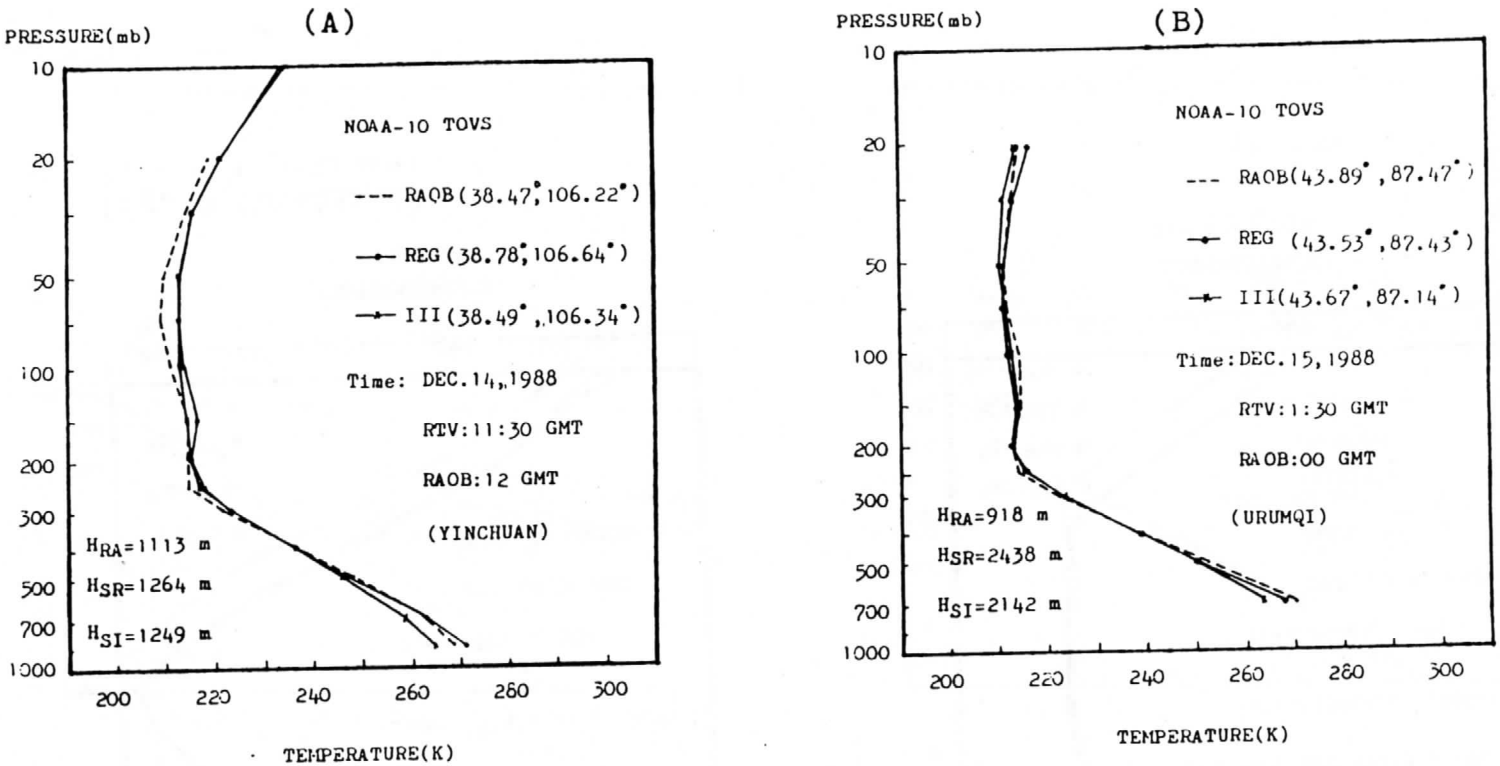


Fig.10 Temperature profiles for: (1) the radiosonde (RAOB), (2) the statistic regression retrievals (REG) from the TOVS operational system, and (3) the 3I retrievals (III) for Dec.14-15,1988. (H_{RA} = the elevation of RAOB station, H_{SR} = the elevation of REG point, and H_{SI} = the elevation of 3I point.)

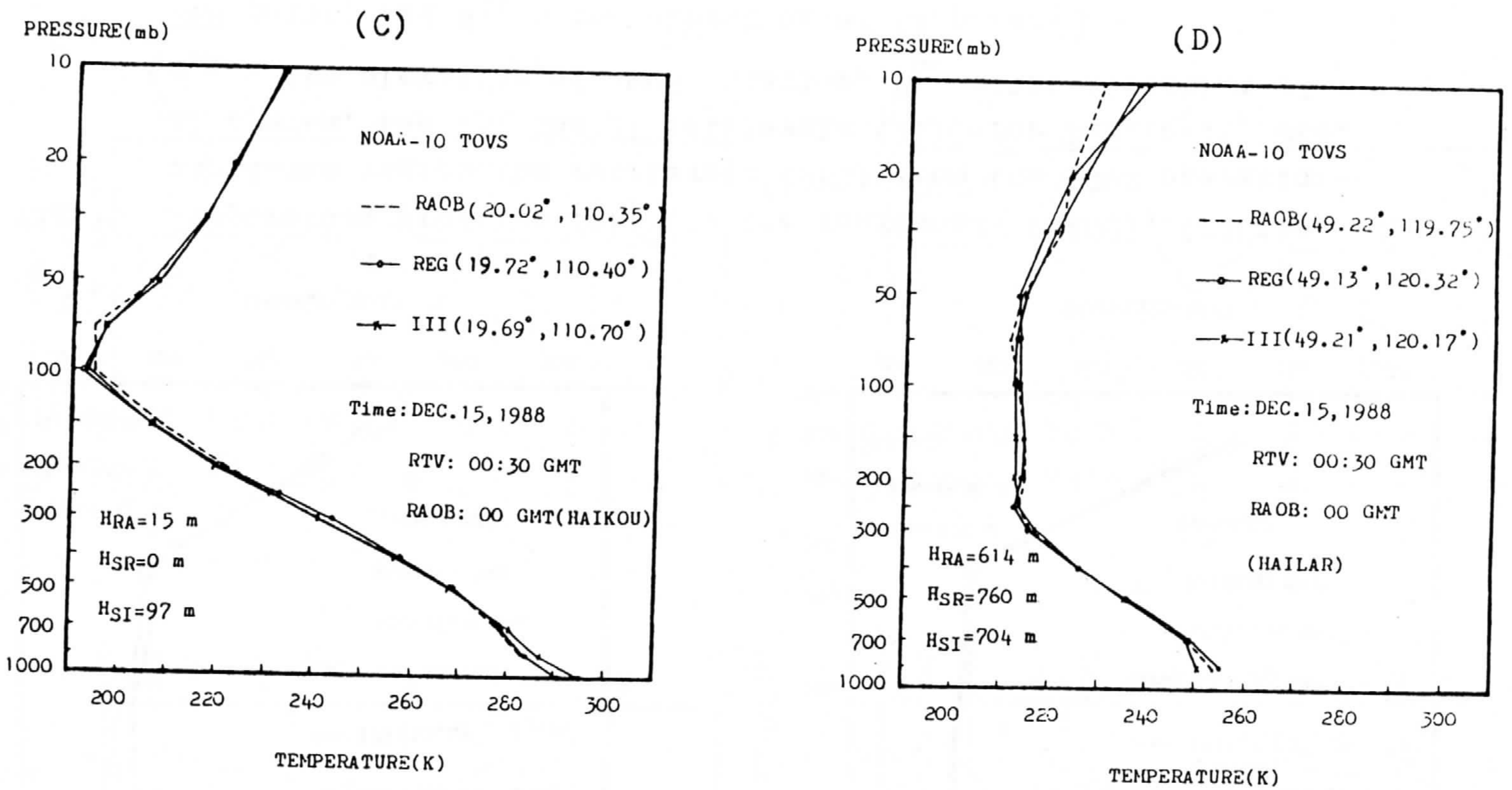


Fig.10 (continue)

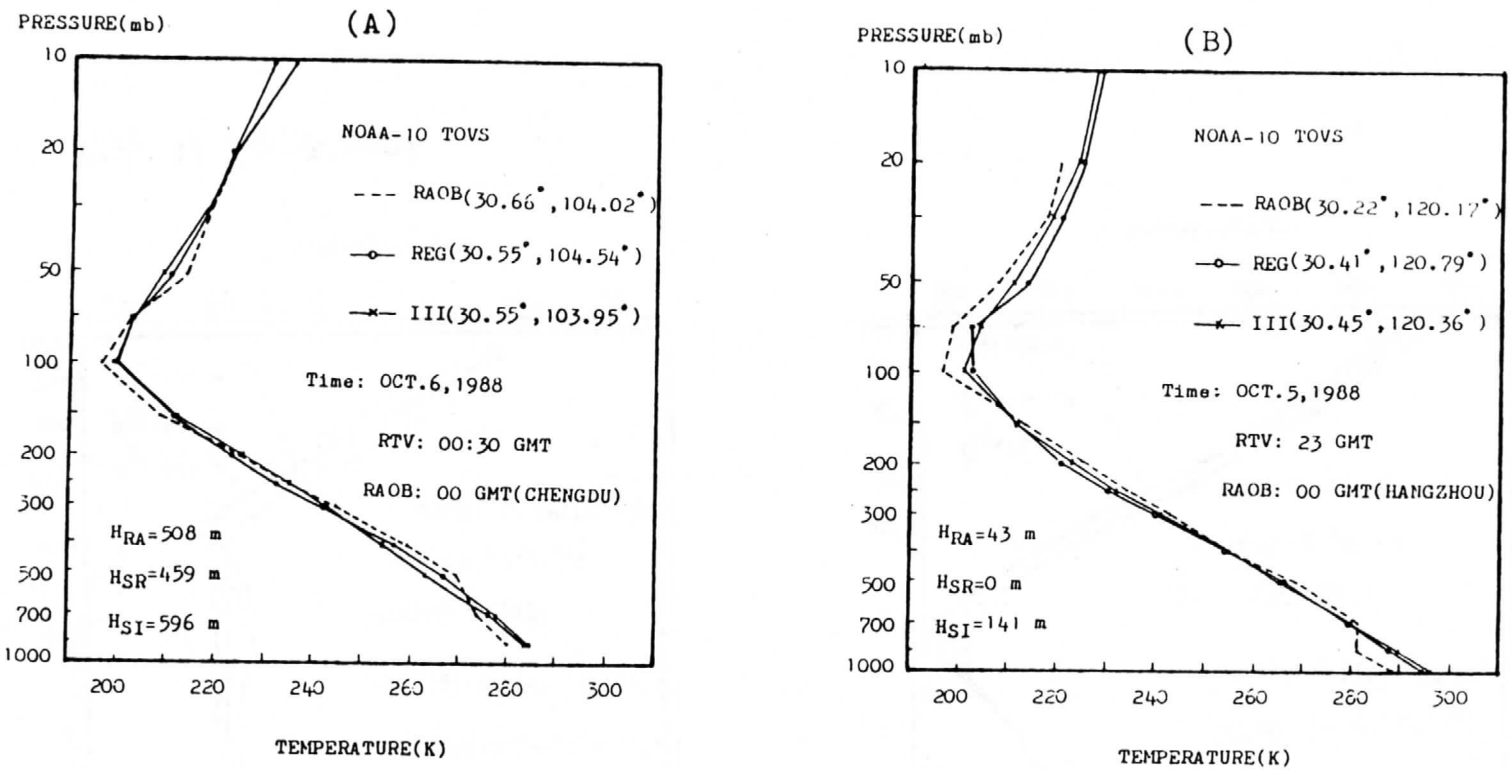
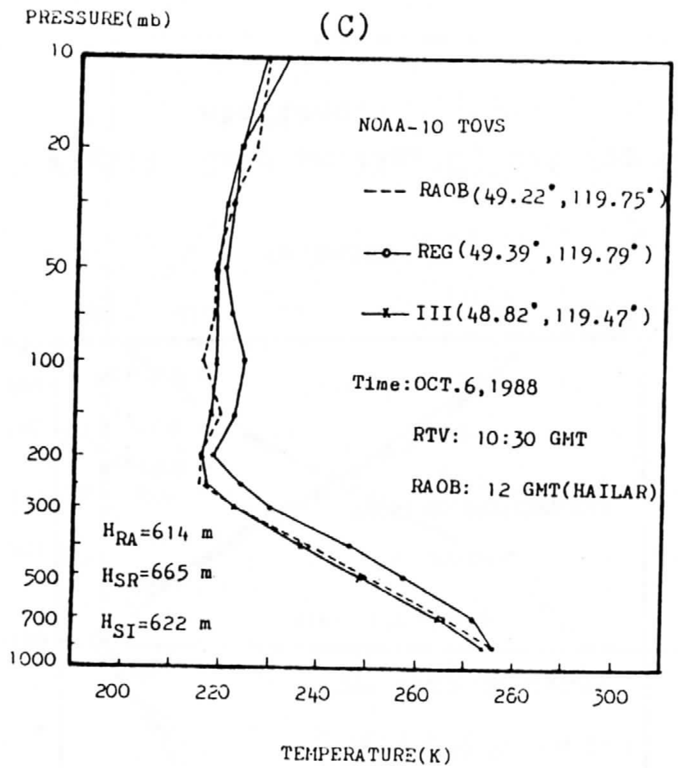


Fig.11 Same as Fig.10, but for Oct.5-6,1988 and the six different stations.



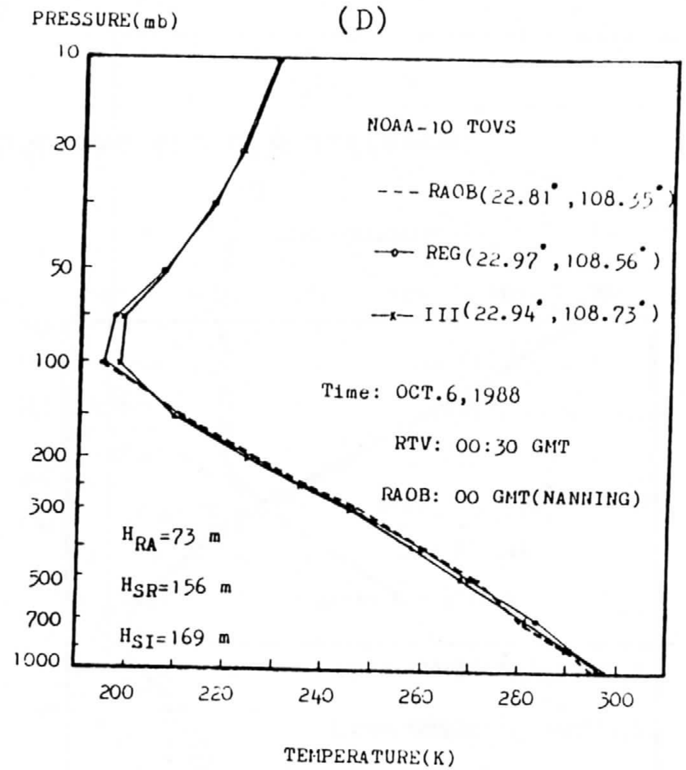


Fig. 11 (continue)

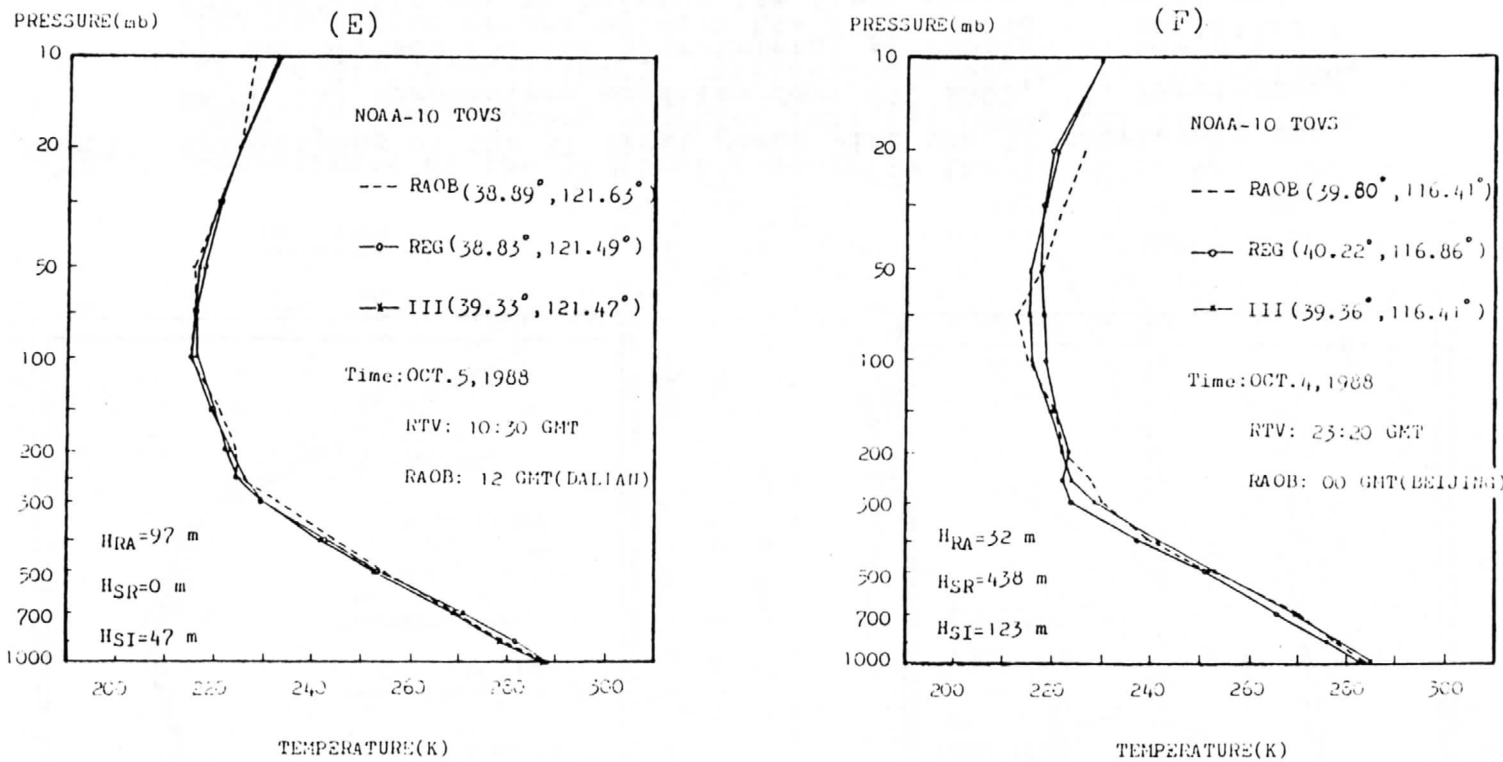


Fig. 11 (continue)

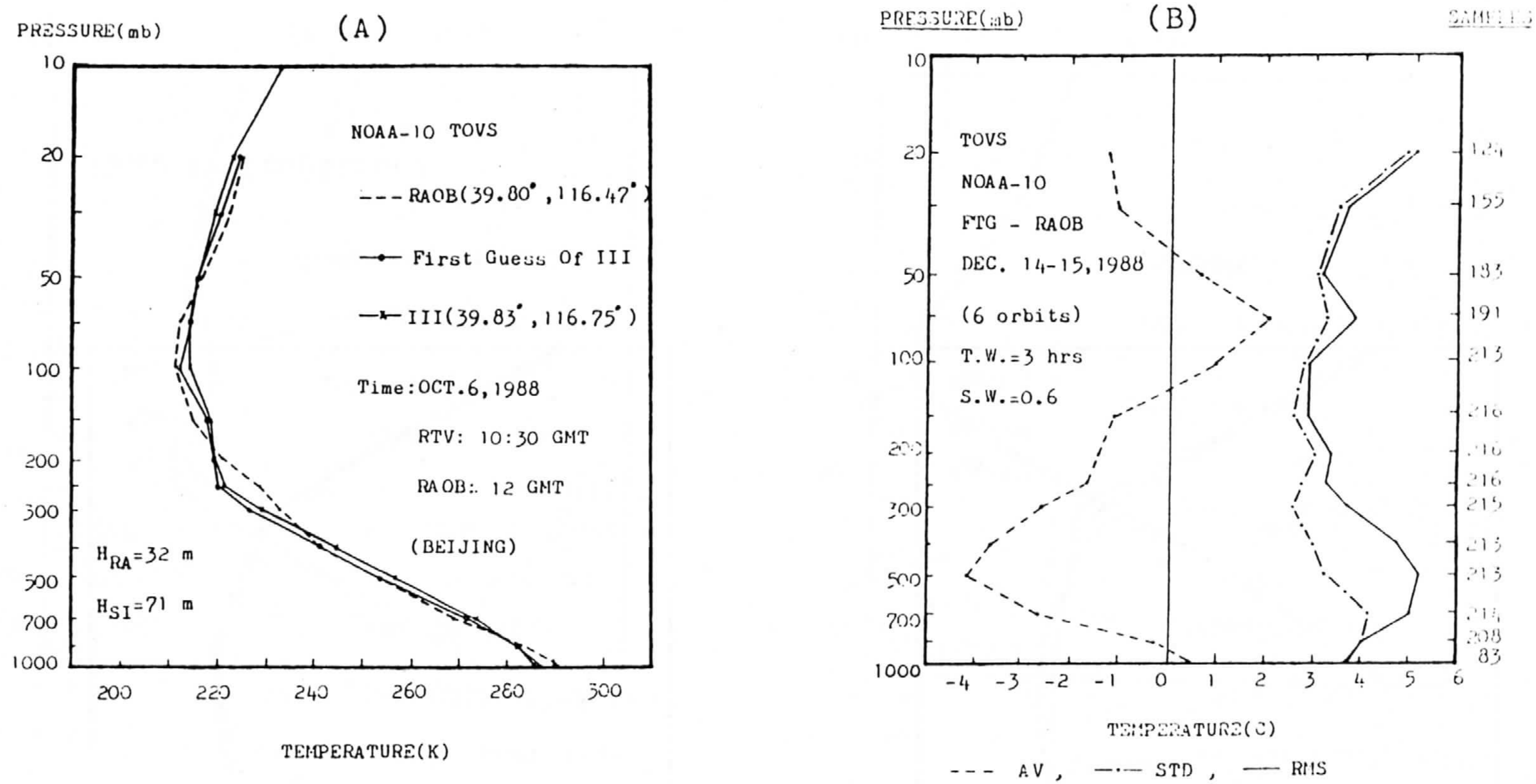


Fig.12 Comparisons of the 3I first guess with the 3I retrievals and RAOB. (a) temperature profiles for: (1) RAOB, (2) First guess of the 3I, and (3) the 3I retrieval at Beijing on Dec.6,1988; (b) statistic errors between **the** first guess of the 3I and the RAOB for Dec.14-15,1988. **(AV: Bias)**

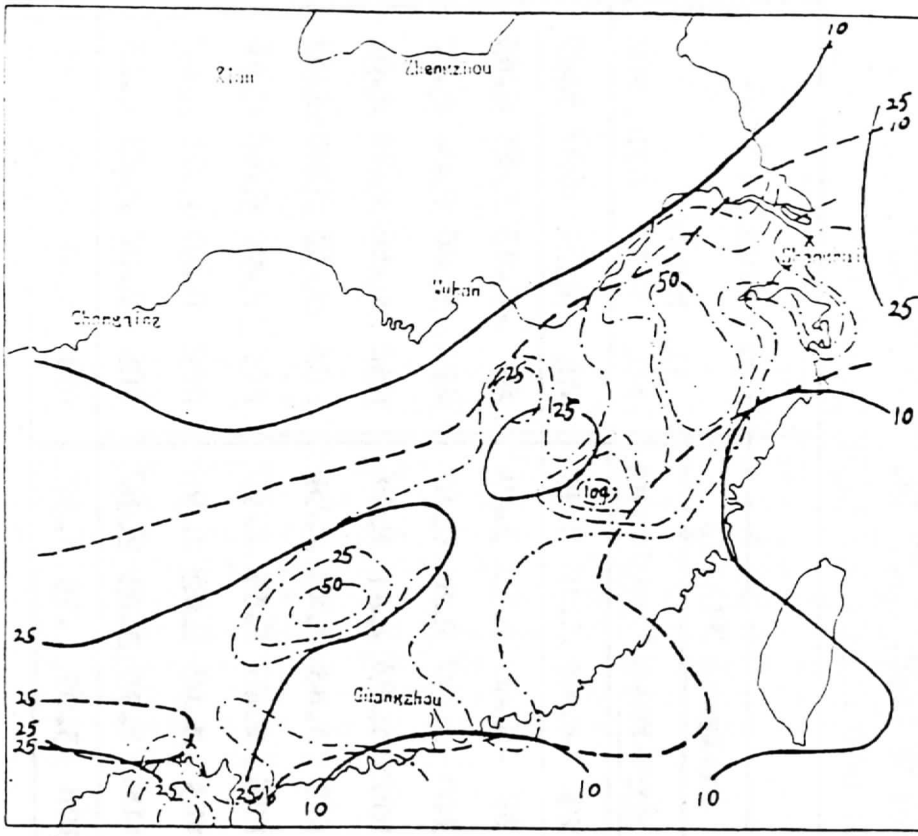


Fig.13 24 hour forecast precipitation amount valid at 0000 GMT 24 July,1987 (unit: mm). Solid - forecast with TOVS and radiosonde data, dashed - forecast with radiosonde data, dashed and dot - observation.

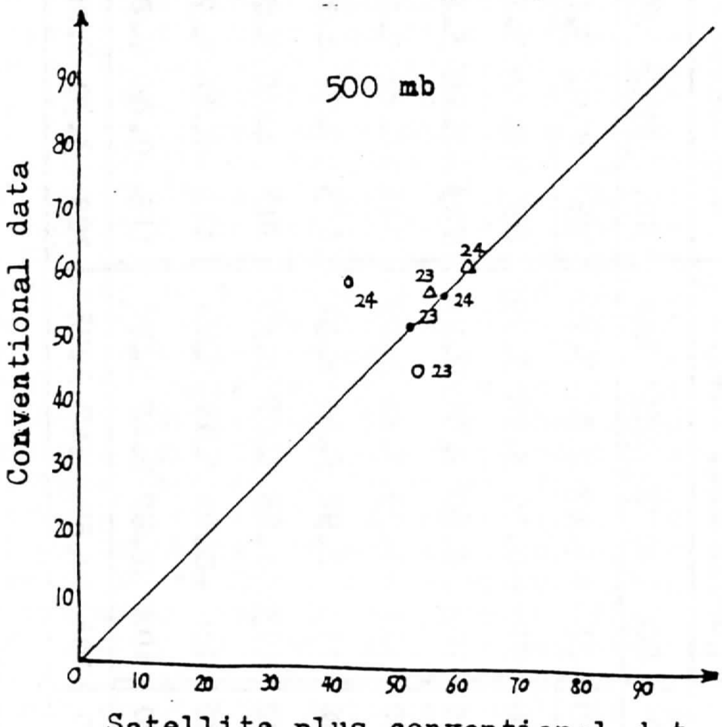


Fig.14 S1 scores of 24 hour LFM - TOVS and control simulation of 500 mb height for two cases of 00 GMT 23 and 00 GMT 24 July,1987. • - whole domain, ▲ - subregion centered

Table 4 Comparisons of Retrieval Accuracies (Apr. 29, 1989, SAT: 00:40Z
RAOB: 00Z (20 - 60 N, 80 - 120 E))

	ONE STEP MODEL												3I MODEL			
	Local Reg. Coef.				B - Model				Analysis Fields							
P	NO.	BIAS	STD	RMS	NO.	BIAS	STD	RMS	NO.	BIAS	STD	RMS	NO.	BIAS	STD	RMS
1000	21	-1.47	2.84	3.20	26	-1.22	3.05	3.29	26	-0.60	3.18	3.27	25	-2.51	2.97	3.89
850	91	-0.30	3.98	3.99	89	-2.15	3.22	3.87	89	0.21	3.73	3.74	89	-0.13	3.83	3.83
700	104	0.60	2.91	2.97	103	-2.40	3.26	4.05	100	0.57	2.61	2.67	104	0.70	2.70	2.97
500	111	1.93	3.26	3.79	112	0.86	2.97	3.09	112	0.83	2.43	2.56	112	0.56	2.78	2.84
400	113	2.92	3.44	4.51	113	2.97	2.83	4.10	113	1.46	1.85	2.36	113	1.53	3.03	3.39
300	113	1.86	3.08	3.60	113	4.59	3.39	5.70	113	2.17	1.92	2.90	113	1.01	2.68	2.86
200	110	-0.60	5.11	5.14	112	-0.84	4.77	4.84	111	1.95	2.23	2.96	112	0.40	4.05	4.07
100	108	2.87	2.47	3.78	109	3.30	3.06	4.50	108	3.09	1.79	3.57	109	0.02	2.23	2.23

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