Overview of ATOVS Data Processing and Applications at NSMC

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1. Introduction

At the middle of 1999, National Satellite Meteorological Center (NSMC) of China Meteorological Administration (CMA) made the real time HRPT/ATOVS data receiving and processing in operational. The HRPT data obtained from the 3 ground stations of Beijing, Guangzhou and Urumqi as shown in Figure 1 are sent to the NSMC in real time. The HRPT/ATOVS data processing system was built based on the AAPP and ICI/IAPP processing packages in which the AAPP is used for ATOVS data preprocessing and the ICI/IAPP are used for temperature and moisture profiles retrieving. Some adaptations were made for the AAPP and ICI/IAPP according to the situation of NSMC.

In order to more easily check if the ATOVS products are correct, the PC-ATOVS displaying system has been developed, and the collocations and validations of the sounding products have been made as well.
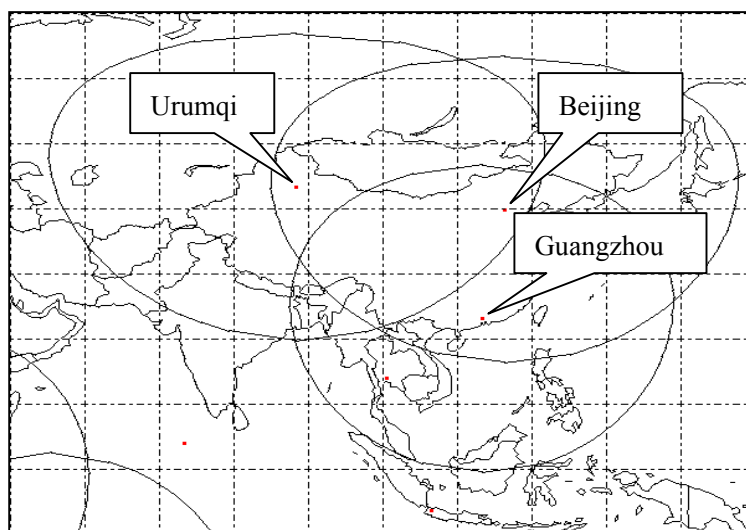

Fig. 1 The receiving coverage for the 3 HRPT stations of NSMC, CMA, China

The progress of ATOVS data applications has been made for recently years, such as, typhoon and rainstorm monitoring, variational assimilating, atmospheric temperature and moisture profiles analyzing and so on. It is obvious that more and more meteorologists in China will take account of ATOVS data into their NWP model and weather analyzing and forecasting.

Section 2 shows the outline of ATOVS operational processing system. Section 3 introduces the validation of ATOVS sounding products. Section 4 gives examples of ATOVS data applications at CMA. The summary will be given at the end of our paper.

2. Outline of ATOVS Processing System

Figure 2 illustrates a flow chart of the ATOVS operational processing system at NSMC. From it we can see that ATOVS operational processing system is comprised of 3 primary subsystems, those are satellite navigating, preprocessing, and retrieval. The processing system is developed on UNIX system. The validation and display subsystems are developed on PC-Windows.

The satellite navigation subsystem is running daily at specified time. The preprocessing and retrieval subsystems are running for each orbit. And distributions of ATOVS products to users have been done immediately after generated. At present, the validation and display of ATOVS products are done on the PC, they are not running every day.

2.1 Satellite Navigation

The satellite navigation subsystem has been built based on a part of AAPP and the situation of NSMC. The major input data is TBUS bulletin issued by NOAA/NESDIS and obtained from the GTS. The major output file is the so-called SATPOS file and used for ATOVS/AVHRR earth location. This subsystem is running daily on the server of HP system.

2.2 Preprocessing

The preprocessing subsystem has been built based on the AAPP. Some adaptations were made according to the situation of NSMC. For the AAPP, it is designed for processing ATOVS /AVHRR data received from a single HRPT station. However, there are 3 HRPT stations at NSMC, and the position and coverage for them are shown in Fig.1. From that, it can be seen that the data received from Beijing and Guangzhou stations are normally in the same orbit. When the two pass files from the two stations are sent to NSMC, and they are jointed into one file. So the modification must be made according to the coverage of two joined stations. This subsystem is running in real time after the new HRPT data file available on the HP server.

2.3 Retrieval

The ATOVS retrieval subsystems have been built based on ICI and IAPP. Some adaptations were made according to the situation of NSMC. Before 2003, the ATOVS sounding products are generated using ICI. After that, they are generated using IAPP.

2.3.1 ICI

For ICI, the major modification is about creating initial guess rolling library. The analyses of regional NWP model HLAFS (High-resolution Limited Area Forecasting System) of the National Meteorological Center (NMC) of CMA are utilized to create a rolling library over the last ten days at a zone of 10ºby 10º.The HLAFS covers area of 5--64ºN and 55—145ºE and provides 4 times analyses per day with spatial resolution of 1ºby 1º and vertical resolution of 14 levels up to 50 hPa for

temperature and 8 levels up to 200 hPa for relatively humidity. The HLAFS is running based the T106 NWP model. At the beginning of 2003, the T106 is updated by the T213, since then the HLAFS is not available, therefore the ICI retrieval system is terminated.

The retrieval processing for the ICI is based on a field-of-array (BOX) containing 2 by 2 adjacent HIRS/3 FOVs. So the spatial resolution of sounding products is about 50km. The temperature profiles were derived with the data from the AMSU-A and HIRS instruments, and the moisture profiles were derived with the data from AMSU-B and HIRS instruments.
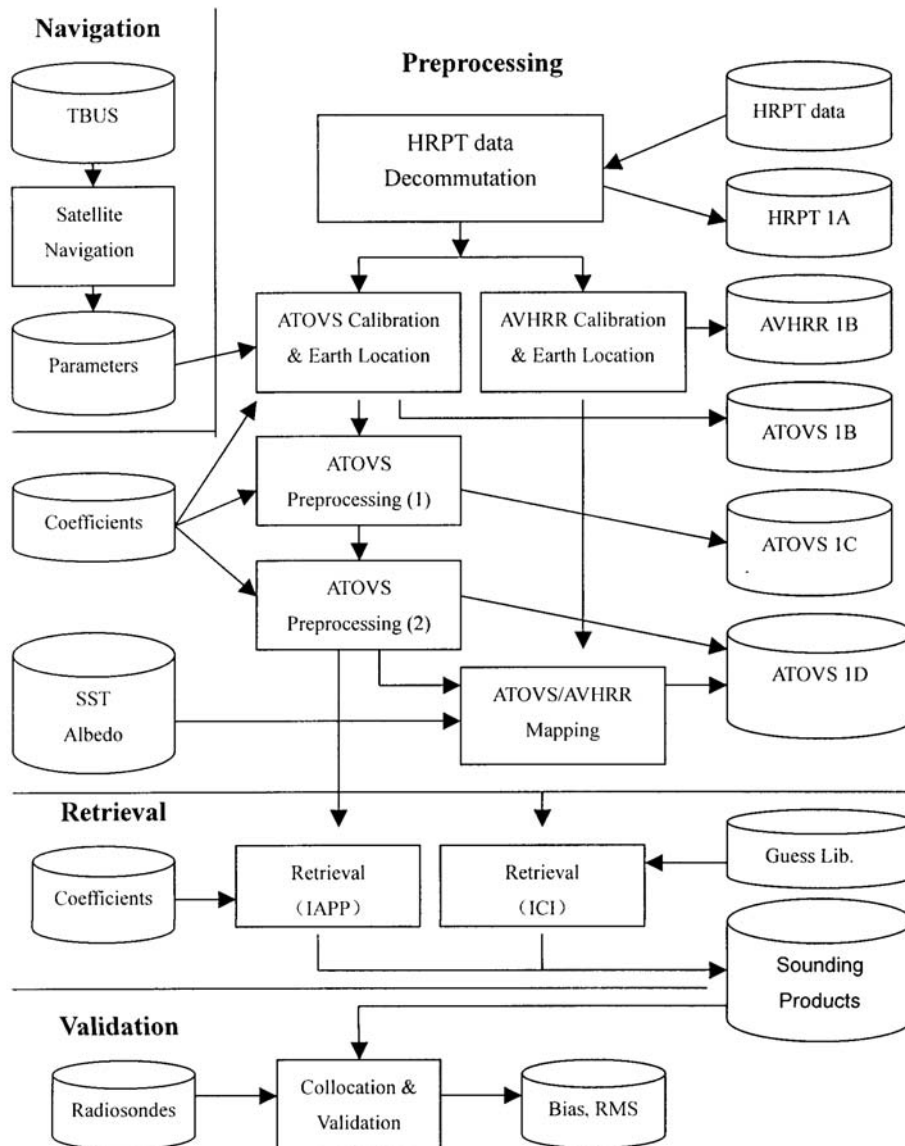

Fig. 2 A flow chart of the HRPT/ATOVS data operational processing system at NSMC

2.3.1 IAPP

Regression retrieval is selected for the first guess profile. The retrieval processing for IAPP is based on a field-of-array (BOX) containing 3 by 3 adjacent HIRS/3 FOVs. In order to make higher resolution of retrievals, a retrieval BOX was selected with 2 by 2 HIRS/3 FOVs instead of 3 by 3. Same as ICI, the

temperature profiles were derived with the data from the AMSU-A and HIRS instruments, and the moisture profiles were derived with the data from AMSU-B and HIRS instruments.

2.4 ATOVS Data Distribution

ATOVS operational products are distributed to users at the conclusion of orbital processing, which takes about 10 minutes, with a complete orbit spanning about 15-20 minutes. The operational products that are routinely distributed to users include:

- ATOVS L1C data (AMSU-A, AMSU-B, HIRS)
- ATOVS L1D data (AMSU-A, AMSU-B, HIRS)
- ATOVS sounding products

There are two dedicated links to distribute these data to users out of NSMC:

- NSMC → NMC / CAMS users
- NSMC → CMA users (9210 net work)

For the NSMC users, the AMSU-A and AMSU-B L1C data are available in real time, which are directly used for monitoring the typhoon, rainstorms, etc. For NMC and CAMS (Chinese Academy of Meteorological Sciences) users, the AMSU-A, AMSU-B and HIRS L1D data are available on time for applying to the variation assimilation system in NWP models. For CMA users, the temperature and moisture soundings are available in near real time for analyzing.

3. Validation of ATOVS Sounding Products

The sounding products produced by ICI and IAPP are validated with the radiosonde data, respectively. The collocations are made between the radiosonde and ATOVS soundings. A matched radiosonde and satellite sounding sample is compiled if the candidate radiosonde and satellite sounding data:

- are within specified time (6 hours) and distance (1º) windows
- differ by less then 10K for each temperature level (1000 --10 hPa)
- have similar surface

The primary validation strategies consist of

- vertical profile comparison
- vertical accuracy statistics
- horizontal field analysis

3.1 Vertical Profile Comparison

The vertical Profile comparisons were made among the radiosonde, ATOVS retrievals and corresponding first guess. The two typical stations were selected for Beijing (in the median region) and Guangzhou (in the tropic region). Figure 3.1 shows the comparisons of the IAPP retrievals and radiosondes for Beijing and Guangzhou. In the comparisons, the retrievals were made from NOAA-16 data around 18UTC of July 23 of 2002, the radiosonde data at the 12/24 UTC of July 23 of 2002. In the figures, the right side is temperature profile, the left side is the dew point temperature profile.

IAPP温度反演、初始和RAOB廓线
气压(hPa)
温度(K)

IAPP湿度反演、初始和RAOB廓线
气压(hPa)
露点温度(K)

IAPP温度反演、初始和RAOB廓线
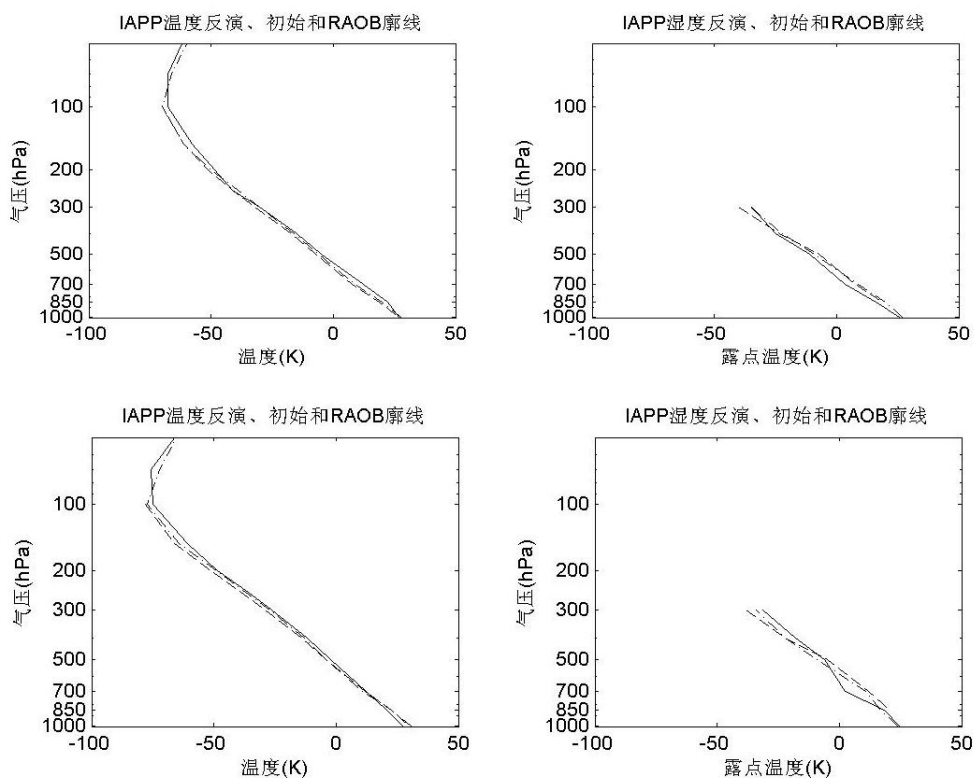气压(hPa)
温度(K)

IAPP湿度反演、初始和RAOB廓线
气压(hPa)
露点温度(K)

Fig. 3.1 Comparisons of the IAPP retrieval and corresponding first guess with radiosonde data for Beijing (top) and Guangzhou (bottom) from NOAA-16 ATOVS data at around 18UTC of July 23 of 2002 (right side is temperature, left side is dew point temperature, sold line is radiosonde, dash line is first guess, dot and dash line is retrieval)

Same as Figure 3.1, Figure 3.2 shows the comparisons of the ICI retrievals and corresponding first guess with radiosonde for Beijing and Guangzhou.

From the comparisons, we can see that the temperature retrievals from both of IAPP and ICI are quite close to the rediosonde, but for dew point temperature, the IAPP is better than the ICI, especially for Beijing.

3.2 Vertical Accuracy Statistics

The vertical accuracy statistics based on satellite minus radiosonde differences were computed from the collocations for NOAA-16 at the period of July in 2002. The statistics were made from total collocations which include the types of land and sea, and clear and cloudy and the coverage of collocated data shown in the Fig.1.

Figure 3.3 shows the statistics of temperature (top) and relatively humidity (bottom) for the IAPP retrieval and first guesses from NOAA-16 at the period of July in 2002. The total collocations are about 10000 samples.
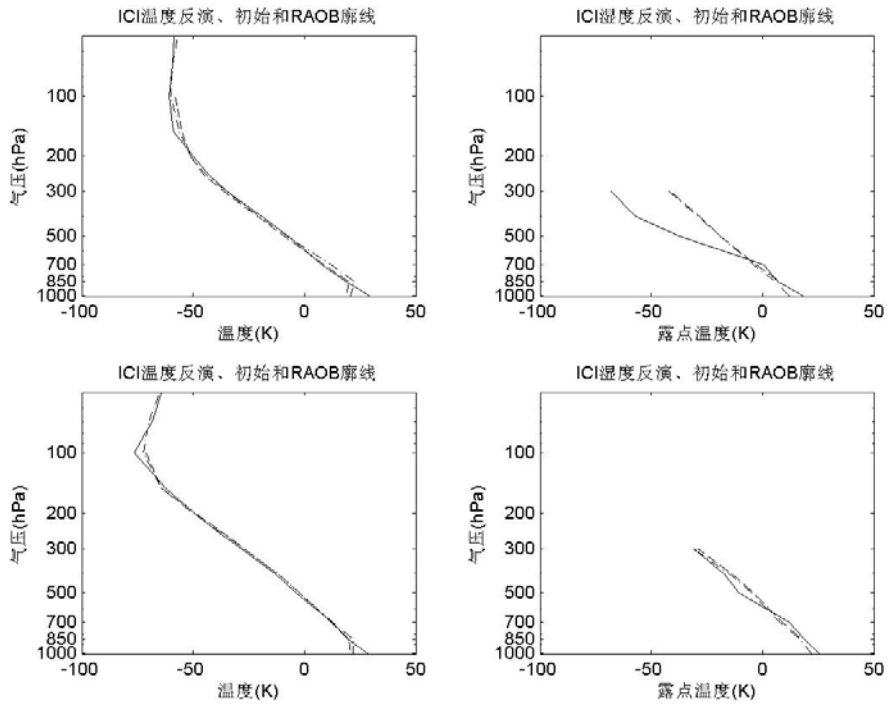
Fig. 3.2   Same as Fig.3.1, but for ICI retrieval and corresponding first guess (right side is temperature, left side is dew point temperature, sold line is radiosonde, dash line is first guess, dot and dash line is retrieval)
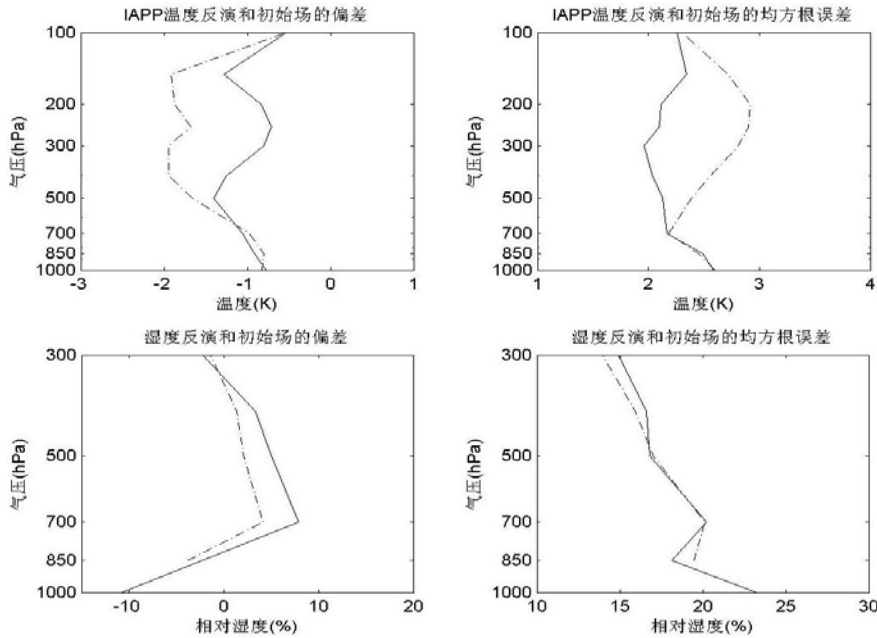

Fig.3.3 The statistics for temperature (top) and relatively humidity (bottom) for IAPP retrievals and corresponding first guess from NOAA-16 at the period of July in 2002 (sold line for IAPP retrievals, dash line for first guess, the left side is bias, the right is RMS (total samples are about 10000))
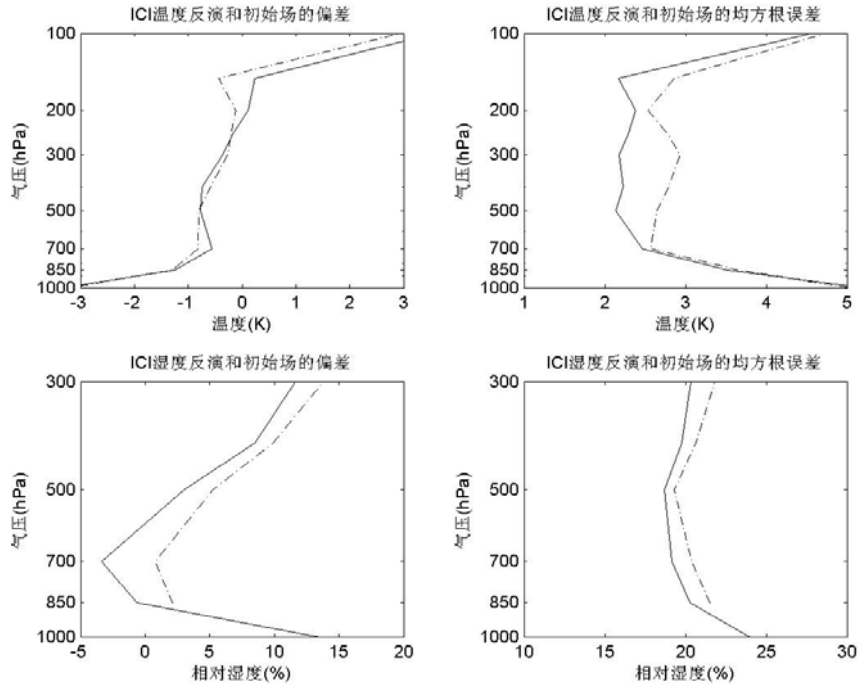
Fig.3.4   Same as Fig.3.3, but for ICI retrievals and corresponding first guess (total
samples are about 8000)

Similarly, Figure 3.4 shows the statistics of temperature (top) and relatively humidity (bottom) from
the ICI retrievals and corresponding first guesses for the same situations as in Figure 3.3. But the total
collocations are about 8000 samples.

From these figures, it can be seen that the root mean square (RMS) accuracies of temperature retrievals
for both IAPP and ICI are about 2-2.5K. But for relatively humidity, the IAPP is better than the ICI, the
IAPP is about 15-20%, while the ICI is about 20%.

3.3 Horizontal Fields

Horizontal field analysis provides better meteorological context concerning the characteristics of the
derived satellite products than the vertical accuracy statistics, and is an important component of the
product validation function.

Figure 3.5 illustrates examples of temperature (ºC) and water vapor mixing ratio (g/kg) analysis over
the region around China for the level of 500 hPa from NOAA-16 ATOVS retrievals produced by IAPP
at time 18-22UTC of July 23 in 2002. The background image is made from HIRS/3 channel 8
brightness temperature. The corresponding water vapor image made from AMSU-B channel 3
brightness temperature is shown in Figure 3.6.

Based on the analysis fields and corresponding images, it can be seen that the analysis fields and the
patterns of clouds and water vapor have a good consistent, thus, it indicates that the ATOVS sounding
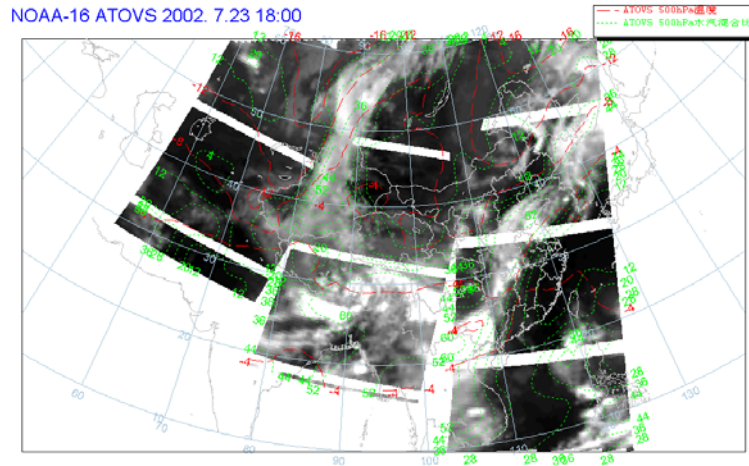products are reasonable.

Fig. 3.5 Example of temperature (ºC) and water vapor analysis over the region around China for the level of 500 hPa from NOAA-16 ATOVS retrievals produced by IAPP at time 18-22UTC of July 23 in 2002 (red line is temperature, green line is water vapor mixing ratio (g/kg*10)
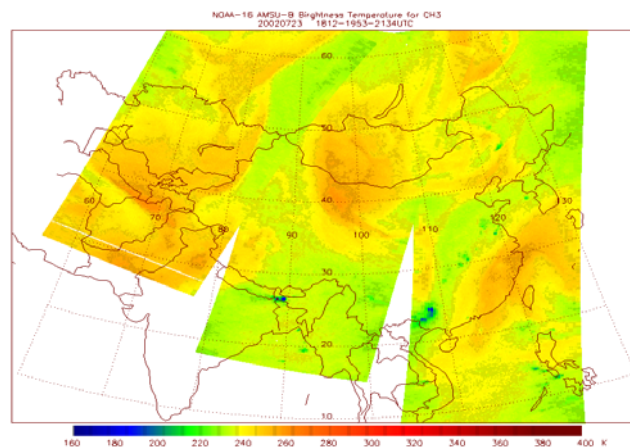

Fig. 3.6 Example of water vapor image over the regional around China from NOAA-16 AMSU-B channel 3 183±1GHz brightness temperature at time 18-22UTC of July 23 in 2002.(dry air in yellow /dark yellow, wet air in green)

4. Examples for ATOVS Data Applications

The progress of ATOVS data applications has been made for recently years, such as, the AMSU-B L1C data are directly applied to monitor routinely the typhoon, rainstorm at NSMC, the ATOVS L1D data are applied to the variation assimilation system of NWP models at the several centers of CMA, the ATOVS the atmospheric temperature and moisture profiles are used in the case study of weather analyses and so on. Here we just show the two examples of ATOVS data applications at CMA.

4.1 Applications of ATOVS Radiances in NWP System

During the past several years, NSMC made cooperation with the Research Center for Numerical Meteorological Prediction (RCNMP) of Chinese Academy of Meteorological Sciences (CAMS) to

study a direct assimilation of ATOVS radiances in GRAPES/3DVAR system. The ATOVS radiances are processed at NSMC using AAPP. It is very clear that there is improvement on forecast by the impact of these data. The following example shows the trace of WeiMaXun typhoon developing and landing to Korea during July 4-6 of 2002. The experiments of the model configuration are as follows:

- assimilation model: GRAPES/ 3DVAR
- forecast model: WRF Weather Region Forecast
- Background: T213

The experiments include two tests:

Test 1: radiosonde data only

Test 2: radiosonde data + ATOVS/AMSU-A radiances

Figure 4.1 shows the geopotential height fields for 850 hPa at 15UTC of July 4 in 2002, which are generated from Test 1(left) and Test 2 (right), respectively. From these analysis fields, we can see that there are some differences.

Figure 4.2 is the analysis geopotential height field for 850 hPa at 00Z of July 6 in 2002 produced by the T213 operational system.

Figure 4.3 shows the 45 hour forecast geopotential height fields for 850 hPa at 00Z of July 6 in 2002 produced according to Test 1 and Test 2, respectively. Comparing the 45 hour forecasts with T213 analysis, it is clear that the forecast of center position is improved about 200-300 km for the 45 hour forecast produced according toTest2.
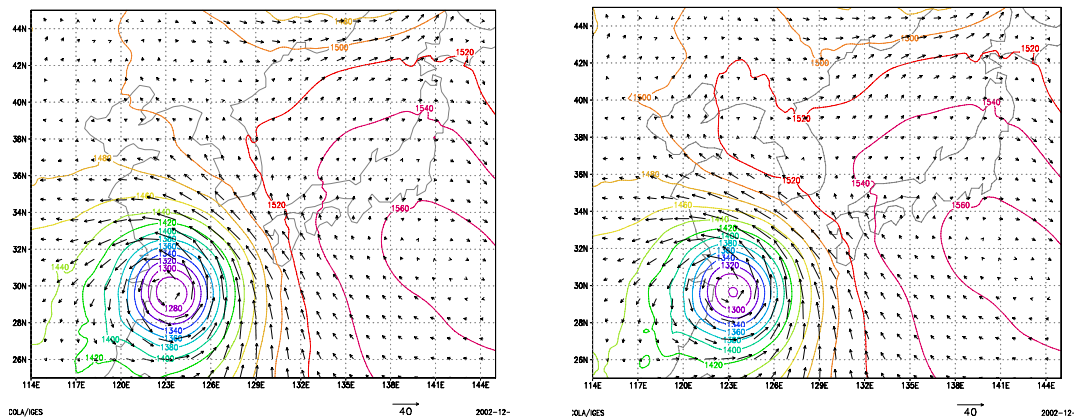

Fig. 4.1 The analysis geopotential height fields for 850 hPa at 15UTC of July 4, 2002 which are generated from Test 1(left) and Test 2 (right) and used for 45 hour forecast, respectively
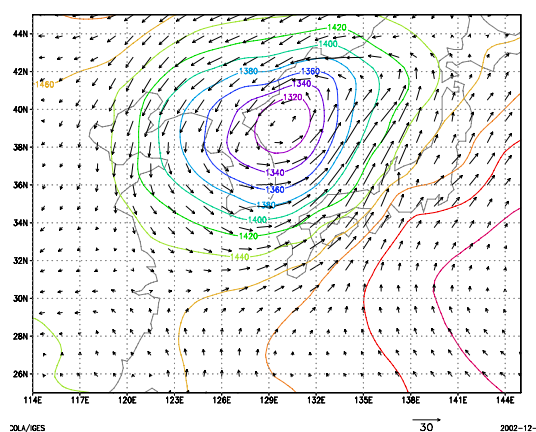
Fig. 4.2 The analysis geopotential height field for 850 hPa at 00Z of July 6 in 2002 produced by the T213 operational system (the center position at 39N,130E)
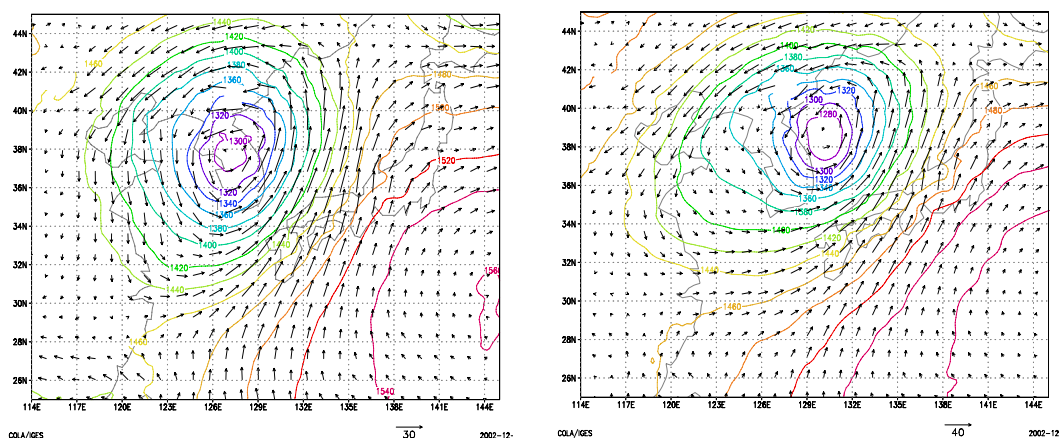

Fig. 4.3 The 45 hour forecast geopotential height fields for850 hPa at 00Z of July 6 in 2002 which are produced based on Test 1 (left: the center position at 37.5N,127.3E) and Test 2 (right: the center position at 38.7N,130.2), respectively .

4.2 Applications of ATOVS Sounding Products in Synoptic Analysis

During Jun 20-24 of 2002, a heavy rainstorm was occurred in the region of Changjiang valley. It was reported that the rainstorm was caused by sequence 3 middle α convective scale (MαCS) air mass based on the analysis from several kinds of data. Figure 4.4 shows the total precipitation for 20-24 of Jun 2002 (left top).

When the third MαCS is grown up mature phase at 18UTC of June 22, it is fairly from the ATOVS temperature and moisture fields that there were a cold air core at low level, a wet air belt at middle level, and a warm air core at upper level in the MαCS air mass (see Fig 4.4) These results are consistent with the characteristics of middle convective scale (MCC) described by Maddox in 1983.
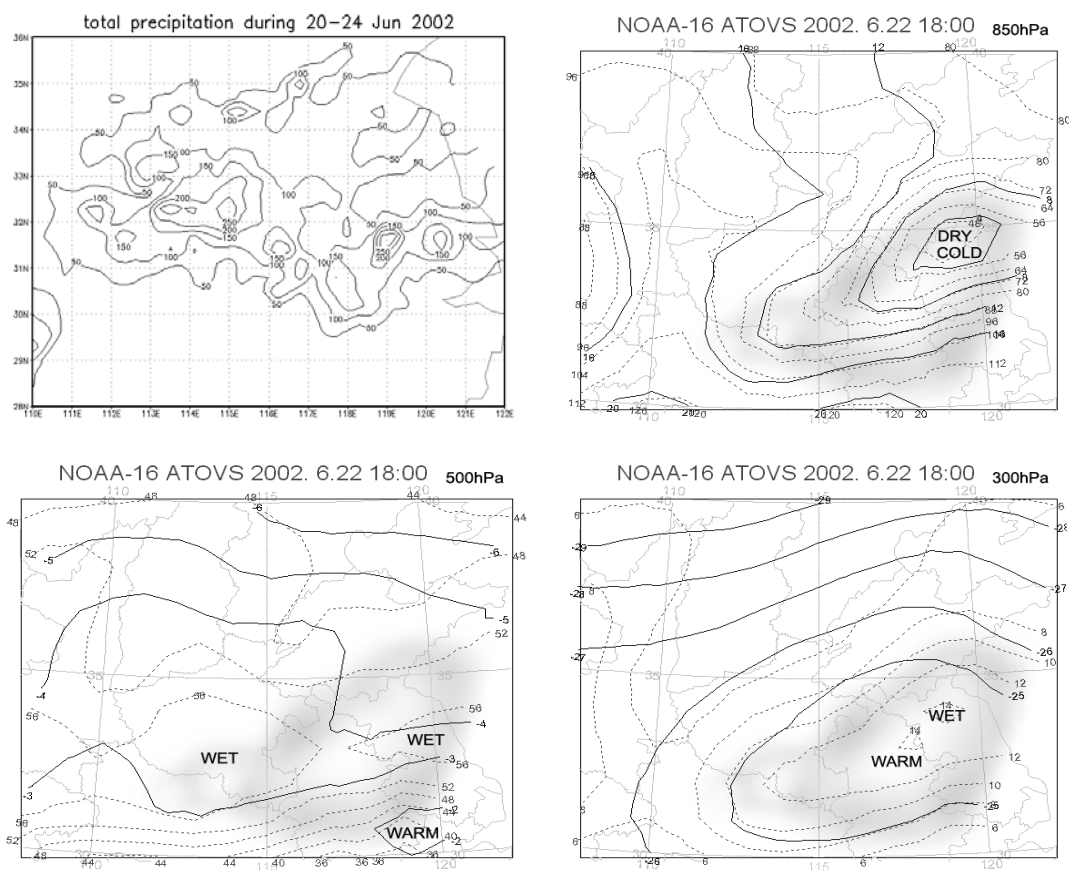
Fig. 4.4 Total precipitation during 20-24 Jun 2002 (left top) and temperature and water vapor analysis fields at 850hPa(right top), 500hPa(left bottom), and 300hPa (right bottom) from the IAPP ATOVS sounding products. In the Figures, the sold line is Temperature (ºC), the dot line is water vapor mixing ratio (g/kg),the shadow area is MαCS. (provided by QinDanyu)

5. Summary

Since the middle of 1999, the National Satellite Meteorological Center (NSMC) of China Meteorological Administration (CMA) has been receiving and processing the HRPT/ATOVS data in operational. The ATOVS data processing system has been built based on the AAPP and ICI/IAPP. The PC-ATOVS display systems were developed by using IDL and C++ languages for checking the ATOVS radiance and sounding products, respectively. The validations of the sounding products generated by the ICI and IAPP were made, respectively. The accuracy of temperature for both ICI and IAPP are similar as about 2-2.5K(RMS), the accuracy of moisture is about 15-20%, and the IAPP is better than ICI. The progress of ATOVS data applications has been made for recent years, especially for the application of the ATOVS radiance data in NWP variational assimilation model.

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