Inter-comparison of data characteristics and impact on NWP

of FY-3B NPP and NOAA18 Microwave observation

Peiming Dong   Wei Han   Zeshuai Cai   Jiangping Huang

Numerical Prediction Center, Chinese Meteorology Administration, Beijing 100081, China

1 Introduction

Microwave satellite observation plays a very important role in the improvement of NWP. The typical microwave sensors are AMSUA/MHS, ATMS and MWTS/MWTS. AMSUA/MHS is flown on NOAA KLM and METOP. ATMS is launched onboard NPP and following JPSS. Chinese FY-3A/B have the microwave sensor MWTS/MWHS and the later polar orbiting meteorological satellites have the updated MWTS/MWHS.

The assimilation modules of FY-3A/B MWTS/MWHS and NPP ATMS were implemented in WRFDA and released in the version 3.5.0. FY-3A/B MWTS/MWHS assimilation module had also been extended in GSI. WRFDA and GSI are two current popular data assimilation systems. It promotes the use of these microwave satellite observation in NWP and also provides with a platform to investigate and inter-compare the data characteristics and impact on numerical weather forecast.

This presentation reports on the study of inter-comparison of data characteristics and impact on regional numerical weather forecast of FY-3B, NPP and NOAA18 microwave observation by using the data assimilation system WRFDA and the numerical forecast model WRF. Section 2 gives a brief description of the data and experiment design. The inter-comparison of data characteristics is described in Section 3. Details of data impact on analysis and forecast are presented in Section 4. Finally, summary and discussion are provided in the last Section 5.

2 Data and Experiment design

2.1 Data

The data used are FY-3B MWTS/MWHS, NPP ATMS and NOAA18 AMSUA/MHS, the microwave observation onboard three satellites with almost similar equator crossing time. The channel setup and other parameters of microwave satellite sensor MWTS/MWHS and ATMS, against that of AMSUA/MHS are listed in table 1 and 2, respectively. Compared to AMSUA/MHS, it could be seen that MWTS/MWHS and ATMS are two new sensors in the Microwave Sounding Unit. Besides the channel setup, there also exist significant differences between these three microwave sensors in the number of scan position, Field Of View (FOV) size and swatch width.

2.2 Experiment design

The experiment configuration takes 161×151 horizontal grid points with 30-km resolution. There are 28 vertical levels with model top at 10 hPa. The radiative transfer model CRTM version 2.05 is used as the satellite observation operator. The experiment is performed from 29 July, 2012 to 6 August, 2012 with two times at 0600 UTC and 1800 UTC every day. Totally there are 18 times analysis and forecast during this period.

Table 1　The list of channel setup

Channel			Centre Frenquency（GHz）			Polarization		
ATMS	MWTS/MWHS	AMSU	ATMS	MWTS/MWHS	AMSU	ATMS	MWTS/MWHS	AMSU
1		1	23.8		23.8	V		V
2		2	31.4		31.4	V		V
3	1	3	50.3	50.3	50.3	H	V	V
4			51.76			H		
5		4	52.8		52.8	H		V
6	2	5	53.596+/-0.115	53.596+/-0.115	53.596+/-0.115	H	H	H
7		6	54.4		54.4	H		H
8	3	7	54.94	54.94	54.94	H	V	V
9		8	55.5		55.5	H		H
10	4	9	f_0=57.290344	57.290344	f_0=57.290344	H	H	H
11		10	f_0+/-0.3222+/-0.217		f_0+/-0.217	H		H
12		11	f_0+/-0.3222+/-0.048		f_0+/-0.3222+/-0.048	H		H
13		12	f_0+/-0.3222+/-0.022		f_0+/-0.3222+/-0.022	H		H
14		13	f_0+/-0.3222+/-0.010		f_0+/-0.3222+/-0.010	H		H
15		14	f_0+/-0.3222+/-0.0045		f_0+/-0.3222+/-0.0045	H		H
16	1	1	88.2	150.0	89.0	V	V	V
17	2	2	165.5	150.0	157.0	H	H	V
18	5	5	183.31+/-7.0	183.31+/-7.0	190.311	H	H	V
19			183.31+/-4.5			H		
20	4	4	183.31+/-3.0	183.31+/-3.0	183.31+/-3.0	H	H	H
21			183.31+/-1.8			H		
22	3	3	183.31+/-1.0	183.31+/-1.0	183.31+/-1.0	H	H	H

Table 2　The list of the number of scan position, Field Of View (FOV) size and swatch width

| Satellite	Sensor	Number of scan	FOV size (Km)	Swatch width (Km)
FY-3A/B	MWTS	15	62	2,250
	MWHS	98	15	2,700
NPP	ATMS	96	75(channel 1-2) 32(channel 3-16) 16(channel 17-22)	2,300
NOAA KLM and METOP	AMSUA	30	48	2,340
	MHS	90	17	2,250

3 Inter-comparison of data characteristics

Fig. 1 gives an overview of the departure statistics of observation against clear-sky simulated over sea. Generally speaking, ATMS is of good quality. MWTS is comparable to ATMS and AMSUA. The bias of MWHS is the largest. The statistics presented also illustrates that there are large bias of observed and simulated brightness temperature in the lower level and higher level channel. The former is attributed to the inaccurate surface emissivity and the ignorance of radiative effect of hydrometeor. The latter is because of the model top. Currently the fundamental channel selection assimilated is to use the middle level channel.
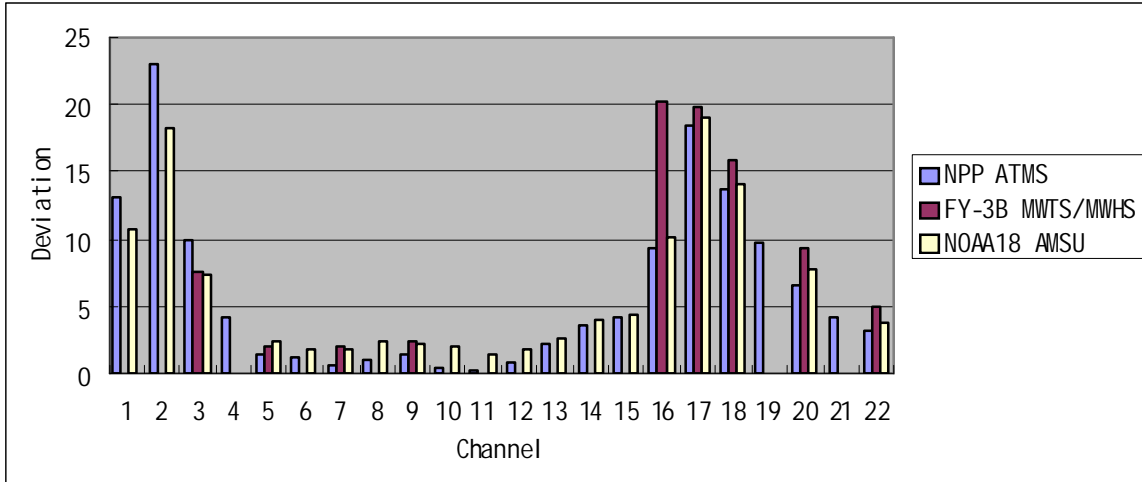
Fig. 1 RMS of observed and simulated brightness temperature over sea

The Bias and RMS of temperature and humidity sounding channels are shown in Fig. 2. It presents that in temperature unit, the RMS of ATMS is the smallest and the RMS of MWTS is comparable to AMSUA. The characteristics of ATMS and AMSUA agree with each other well. ATMS channel 9, corresponding AMSUA channel 8 has the largest RMS. MWTS channel 4 has significant positive bias average. In humidity unit, The RMS of ATMS is also the smallest. The RMS of MWHS is a little larger than that of MHS. Again the characteristics of ATMS match that of MHS well. MWHS both channel 4 and 3 have obvious negative bias average.
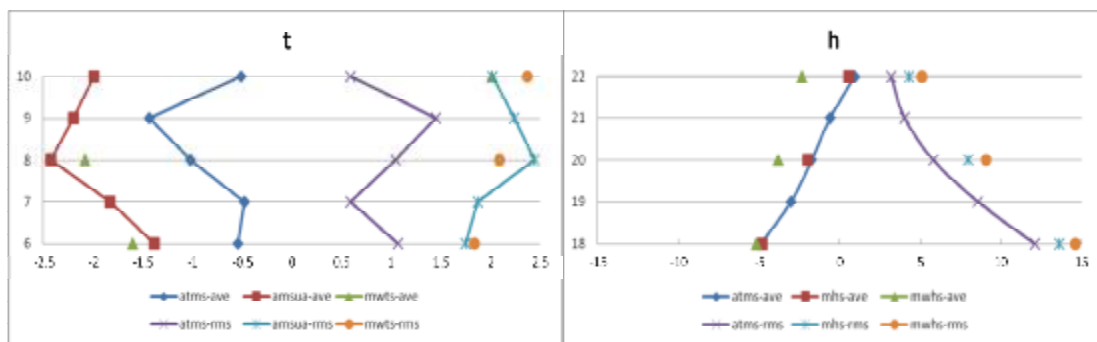
Fig. 2 Bias and RMS of temperature (left) and humidity (right) sounding channels over sea

The statistics after cloud detection is presented in Fig.3. The departure is less decreased by cloud detection in temperature unit. The pattern remains the same as that of before. In humidity unit, the departure is decreased significantly by cloud detection. There is still the obvious negative bias average for MWHS channel 4 and 3.

The FY-2E VISSR image, together with FG-departure for MWTS channel 1 and ATMS channel 3, the scattering index combined AMSUA channel 1 and 15 are shown in Fig. 4. They are utilized as cloud

detection for temperature sounding channels. Fig. 5 is the same as Fig. 4 except that it is the cloud detection for humidity sounding channels that is shown. They are FG-departure for MWHS channel 1 and the scattering index combined ATMS channel 16 and 17, along with that of MHS channel 1 and 2. ATMS FG-departure for channel 3 is also proposed as cloud detection for humility unit in ECMWF. It could be found that all these criterions are potential index to detect the presentation of radiative effect due to clouds. The crucial item is to get the threshold in preference. It should be noticed that the use of the absolute value of the FG-departure for channel 3 leads to the exclusion of some ATMS data with large negative value of the FG-departure. For example, the satellite observation over Japanese Sea where there seems no cloud. This may have to be revisited in the future study.
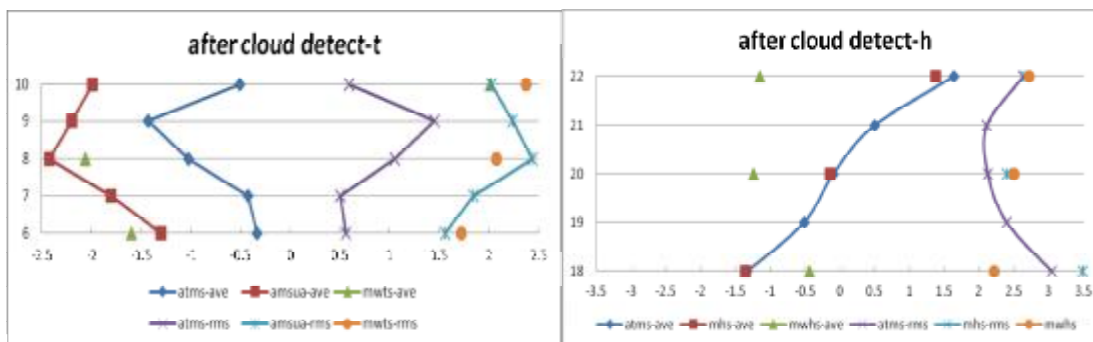

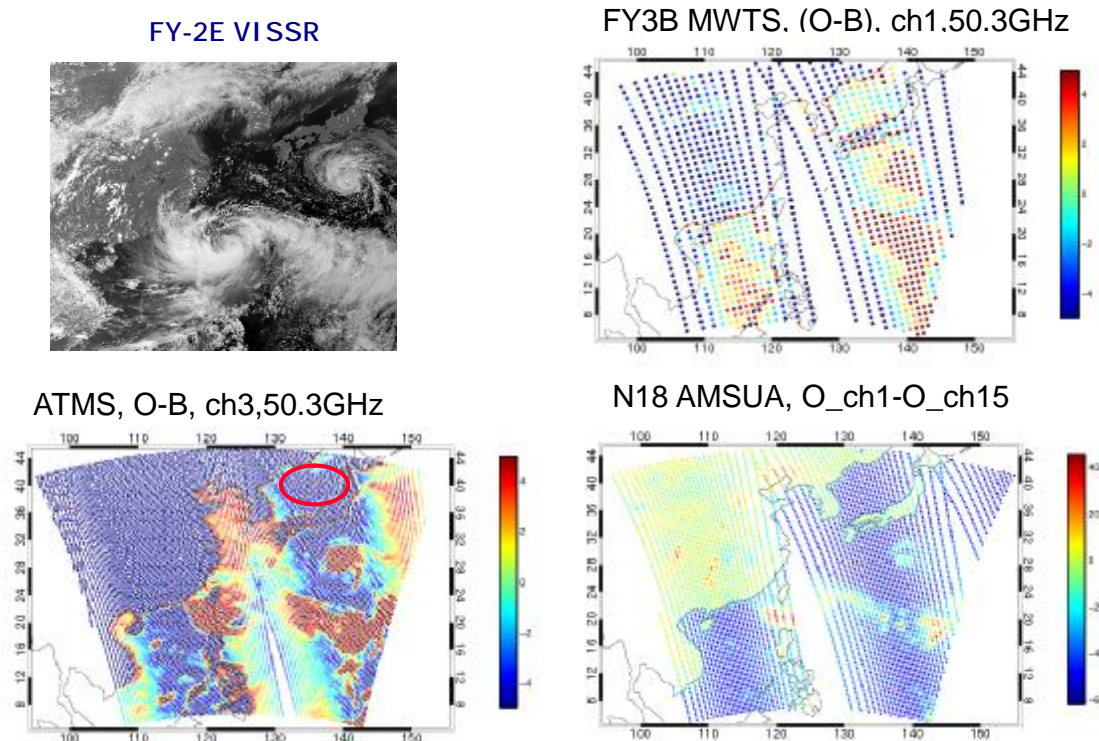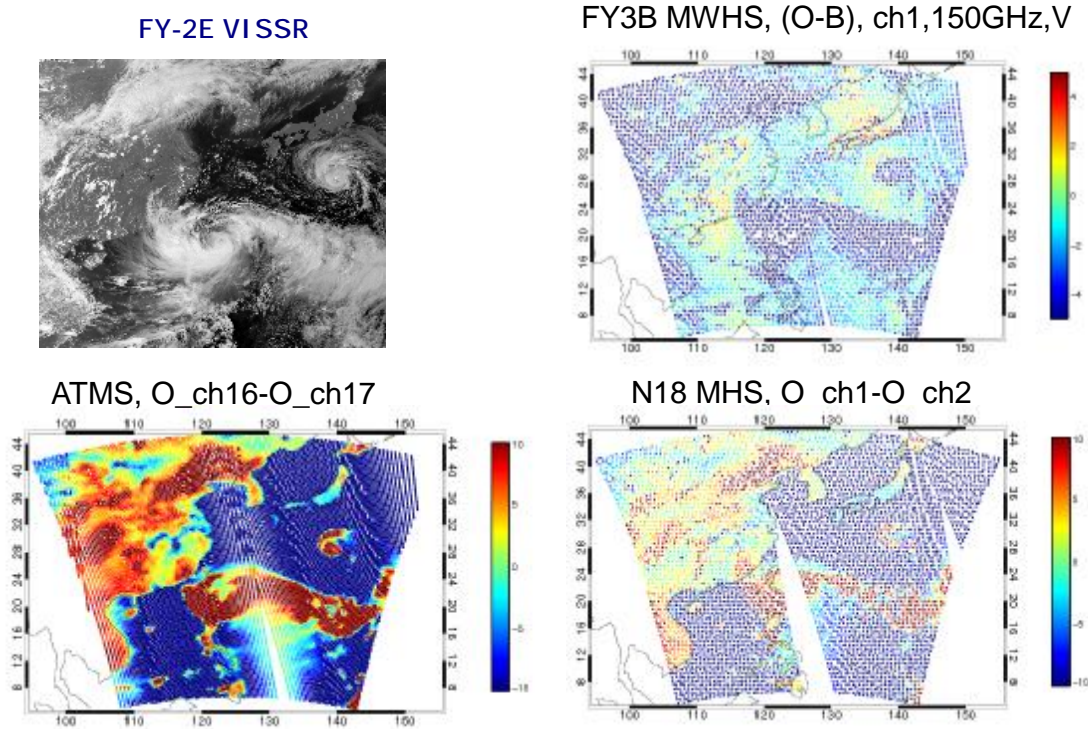
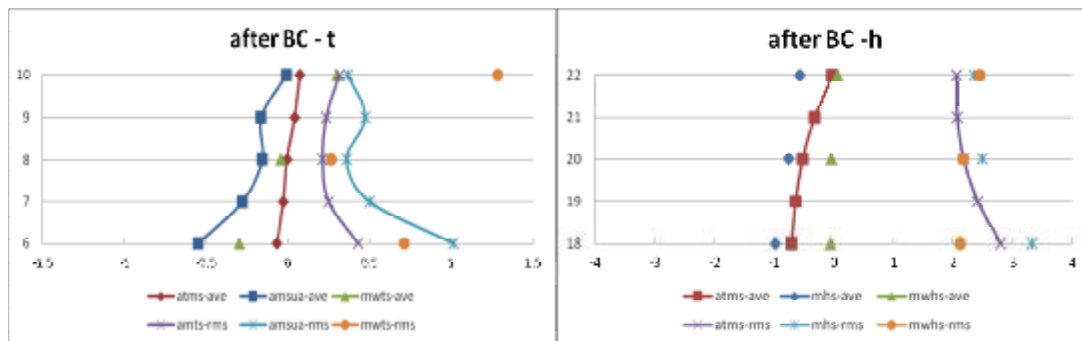**Fig. 3**   The same as Fig.2, but after cloud detection

Fig. 4   FY-2E VISSR image and cloud detection for temperature sounding channels

FY-2E VISSR

FY3B MWHS, (O-B), ch1,150GHz,V

ATMS, O_ch16-O_ch17

N18 MHS, O ch1-O ch2

Fig. 5   The same as Fig.4, but for humidity sounding channels

The statistics of departure after bias correction for both temperature and humidity sounding channels is shown in Fig. 6. The RMS, especially ATMS channel 9 and AMSUA channel 8, is decreased greatly by bias correction. The RMS of MWTS channel 4, however is still large. For humidity sounding channels, the RMS is less affected by bias correction. Bias correction makes the bias average approach to zero, in particular for MWHS channel 4 and 3.


Fig. 6   The same as Fig.3, but after bias correction

4 Data impact on analysis and forecast

It is those satellite data after cloud detection and bias correction in Fig. 6 that are assimilated if they could pass other quality control. Fig. 7 gives the means and RMS of observed and simulated brightness temperature before and after data assimilation. There is a difference between this picture and figures above. The statistics in Fig. 7 is made for all used satellite data in whole domain, not just over sea. The labels oi and ao stand for observed minus background and observed minus analysis, respectively. It could be found that the mean and RMS all decrease after the assimilation of satellite data in both temperature and humility unit. It implies that the simulated fit to the observation more or less after the satellite data is assimilated.

Generally speaking, ATMS has the smallest bias both before and after data assimilation. MWTS has the similar performance except for channel 5 has a little large bias. Compared to ATMS and MHS, the bias of MWHS is the largest before data assimilation. It decreases to the same level as MHS after data assimilation.
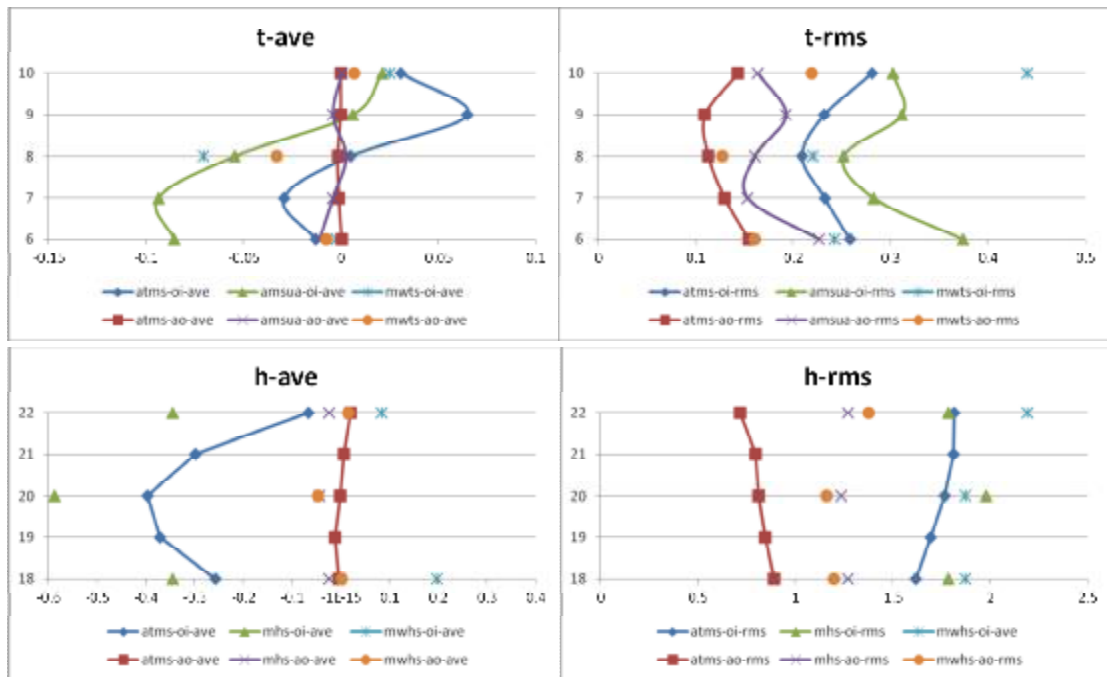
Fig. 7   The statistics of departure before (oi) and after (ao) data assimilation for whole domain

The data impact on numerical weather forecast is illustrated by the typhoon "SAOLA" (2012) case. The trace forecast is presented in Fig. 8. Two 54 hours forecasts of initial time at 1800 UTC 30 July 2012 and 0600 UTC 31 July 2012, respectively are shown. The typhoon "SAOLA" is landing Taiwan Island at the verification time. The real position is marked by typhoon label in the figure. It could be seen that the control forecast without satellite data misses the landing obviously, while all the other runs with satellite data are close to the landing. Comparatively, the forecast with ATMS data repeats the landing of the true track almost perfectly.
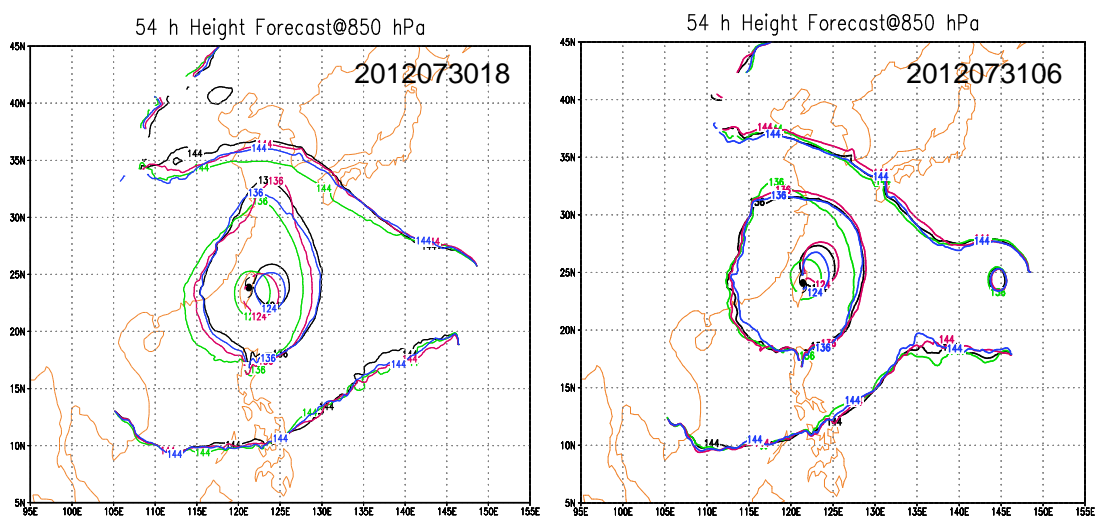
Fig. 8   The impact of microwave satellite data on the typhoon "SAOLA" (2012) trace forecast with initial time at 1800 UTC 30 July 2012 (left) and initial time at 0600 UTC 31 July 2012 (right)

(black: Control; green: ATMS; red: FY-3B MWTS/MWHS; blue: NOAA18 AMSUA/MHS)

5 Summary and discussion

In this presentation, inter-comparison of data characteristics and impact on NWP of FY-3B, NPP and NOAA18 microwave observation is performed. The summary and discussion are:

1) The data characteristics of NPP ATMS agree with that of NOAA AMSUA/MHS well. ATMS data is of good quality.

2) FY-3B MWTS/MWHS has some unique features. MWTS has equivalent RMS between observed with simulated as NOAA AMSUA. It has significant positive bias average in channel 4. The RMS of MWHS is a little large and the negative bias average for both channel 4 and 3 is obvious. The assimilation of FY3 microwave observation shows promising effect on the improvement of NWP. It is expected to be enhanced by using the updated MWTS/MWHS flown on FY-3C.

3) Specially, there is a need to revisit and investigate the cloud detection scheme in the use of FY-3 and NPP microwave satellite data.

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