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2017 DRAGON 4 SYMPOSIUM
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ESA–MOST Dragon Cooperation
2017 DRAGON 4 SYMPOSIUM

A3-ID32426: Calibration and Data Quality

RESEARCH ON CALIBRATION, VALIDATION AND RETRIEVALS ON SATELLITE-BASED MICROWAVE INSTRUMENTS

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Outline

- Motivation
- Project introduction
- Main research
- Case study
- Summary and further plan
- Acknowledgement

Motivation

- Global monitoring of precipitation is important because of its significant human consequences.

- Satellite-based radiometer is a good way to monitor and retrieve global precipitation.

- An obvious challenge is that different levels of bias and calibration accuracy for similar sensors can not be avoided.

Dragon-4 Project

The paper develops a passive sub-millimeter precipitation retrievals algorithm for Microwave Humidity and Temperature Sounder (MWHTS) onboard the Chinese Feng Yun 3C (FY-3C) satellite.

Meanwhile, calibration and validation between similar instruments onboard different satellites are also important to ensure the effectiveness of observations and accuracy of precipitation retrievals.

In the ongoing work, we are going to carry out the calibration and validation among a series of MWHTS on FY-3 satellites.

2nd Generation of LEO: FY-3

FY-3 Constellation (FY-3A:Morning ,FY-3B:Afternoon)

- ✓ *After FY-3A, FY-3B was successfully launched on Nov. 5, 2010*
- ✓ *FY-3C was successfully launched on Sept. 23, 2013*

No.	Launch	Orbit	Status
FY-3A	May 27,2008	M	Off
FY-3B	Nov 5, 2010	A	On
FY-3C	2013	M	On
FY-3D	2017	A	Op.
FY-3E	2020 (plan)	M	Op.
FY-3G	2023 (plan)	A	Op.
FY-3I	2025 (plan)	M	Op.

Microwave instruments on board FY-3A/B/C, including:

MWTS： MicroWave Temperature Sounder

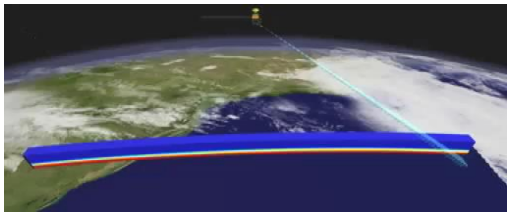
MWHS: MicroWave Humidity Sounder

MWRI: MicroWave Radiation Imager

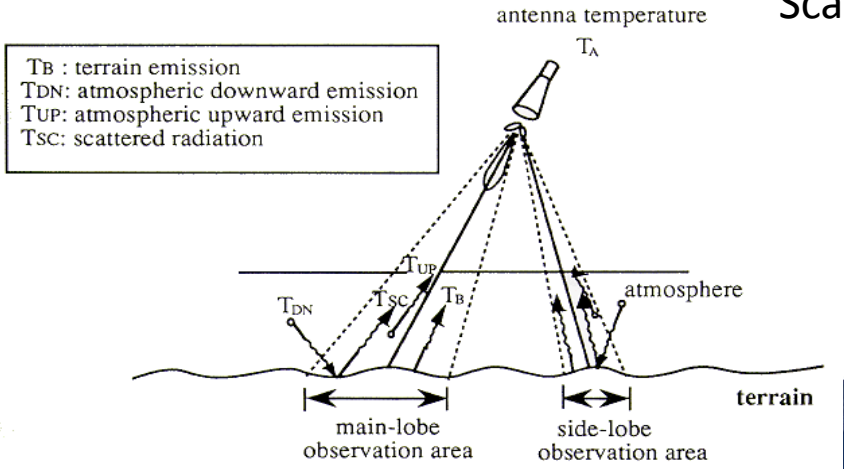
Ongoing progress

1. Instrument: Satellite-based MWHTS/FY-3C

- FY-3C: launched in 23 Sept, 2013.
- MWHTS (mwhs-II): since 2013.9.30

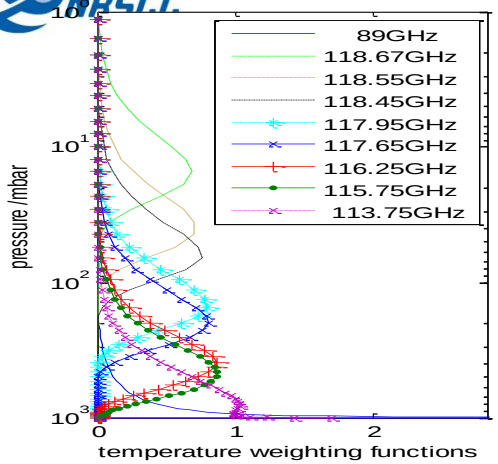


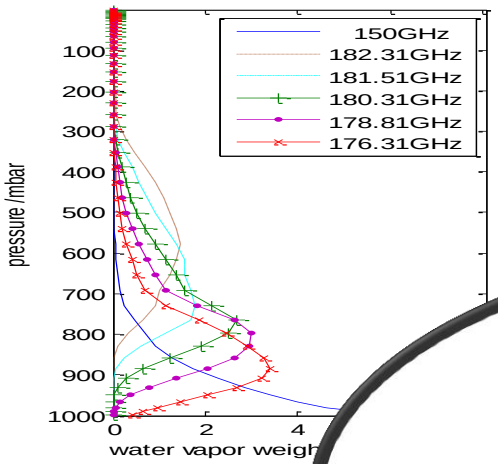
Scanning mode

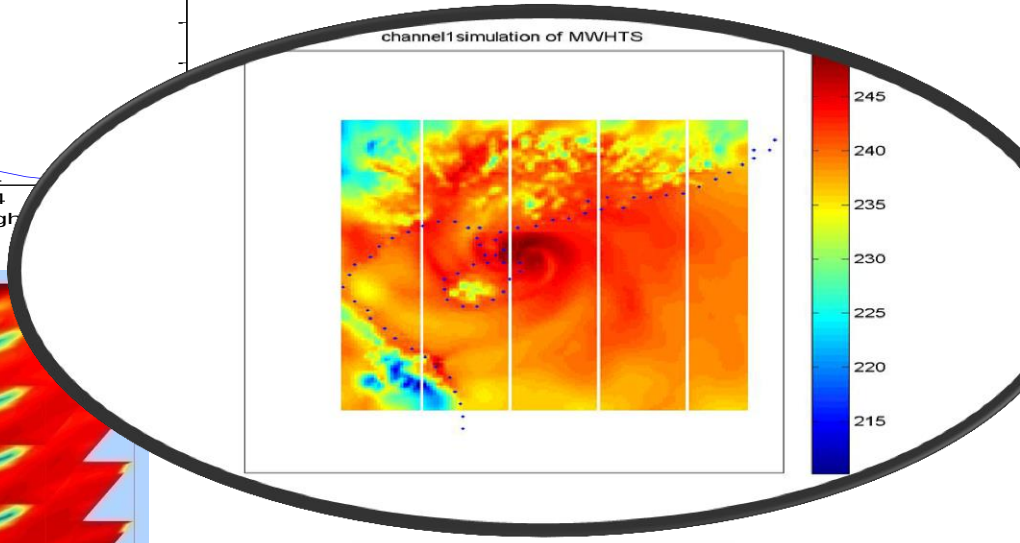


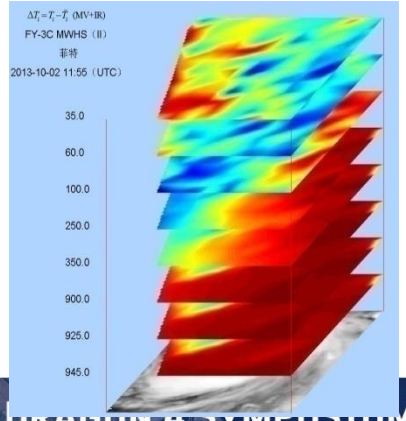
序号	中心频率 (GHz)	极化	带宽 (MHz)	频率稳定度 (MHz)	动态范围(K)	灵敏度 (K)	定标精度 (K)	主波束宽度	主波束效率	交叉极化电平
1	89.0	V	1500	50	3—340	1.0	1.3	2.0° ±0.1°	>92%	≤-17.5dB
2	118.75±0.08	H	20	30	3—340	3.6	2.0	2.0° ±0.1°	>92%	--
3	118.75±0.2	H	100	30	3—340	2.0	2.0	2.0° ±0.1°	>92%	--
4	118.75±0.3	H	165	30	3—340	1.6	2.0	2.0° ±0.1°	>92%	--
5	118.75±0.8	H	200	30	3—340	1.6	2.0	2.0° ±0.1°	>92%	--
6	118.75±1.1	H	200	30	3—340	1.6	2.0	2.0° ±0.1°	>92%	--
7	118.75±2.5	H	200	30	3—340	1.6	2.0	2.0° ±0.1°	>92%	--
8	118.75±3.0	H	1000	30	3—340	1.0	2.0	2.0° ±0.1°	>92%	--
9	118.75±5.0	H	2000	30	3—340	1.0	2.0	2.0° ±0.1°	>92%	--
10	150.0	V	1500	50	3—340	1.0	1.3	1.1° ±0.1°	>95%	≤-17.5dB
11	183.31±1	H	500	30	3—340	1.0	1.3	1.1° ±0.1°	>95%	--
12	183.31±1.8	H	700	30	3—340	1.0	1.3	1.1° ±0.1°	>95%	--
13	183.31±3	H	1000	30	3—340	1.0	1.3	1.1° ±0.1°	>95%	--
14	183.31±4.5	H	2000	30	3—340	1.0	1.3	1.1° ±0.1°	>95%	--
15	183.31±7	H	2000	30	3—340	1.0	1.3	1.1° ±0.1°	>95%	--

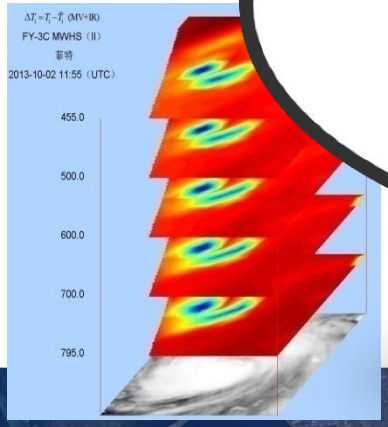
- ✓ polar-orbiting satellites in sun-synchronous orbits
- ✓ approximately 14 orbits
- ✓ MR： either daylight or night mode
- ✓ Polar regions are observed nearly every 100


89GHz
118.67GHz
118.55GHz
118.45GHz
117.95GHz
117.65GHz
116.25GHz
115.75GHz
113.75GHz
pressure /mbar
temperature weighting functions


150GHz
182.31GHz
181.51GHz
180.31GHz
178.81GHz
176.31GHz
pressure /mbar
water vapor weigh

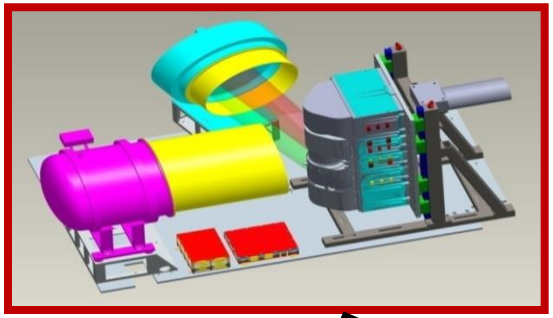

channel1simulation of MWHTS
245
240
235
230
225
220
215

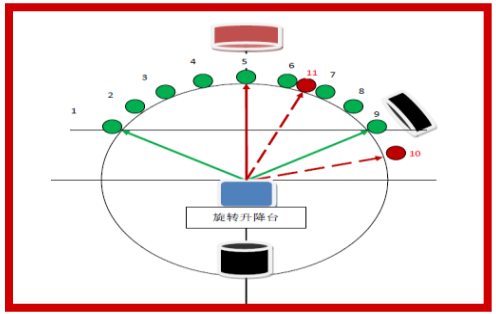

FY-3C MWHS (II)
2013-10-02 11:55 (UTC)
35.0
60.0
100.0
250.0
350.0
900.0
925.0
945.0

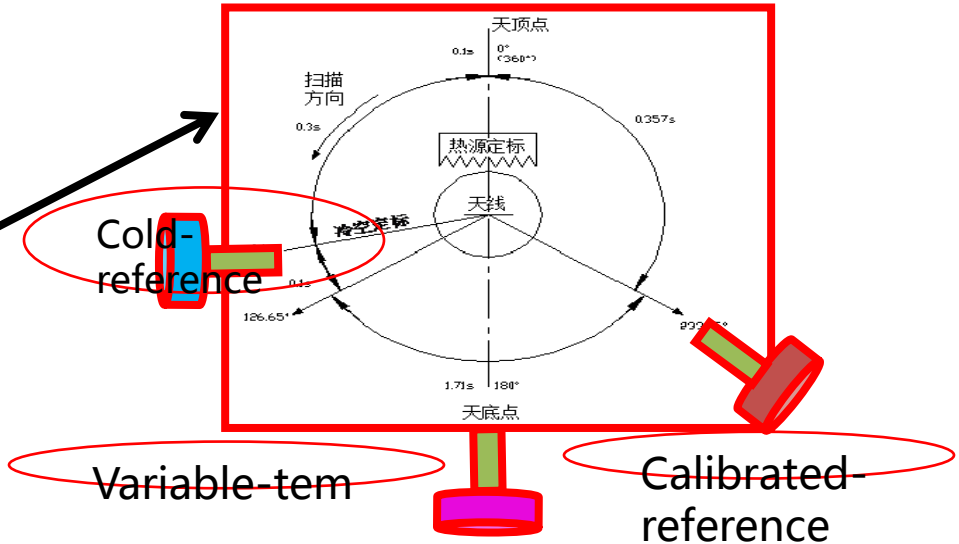

FY-3C MWHS (II)
2013-10-02 11:55 (UTC)
455.0
500.0
600.0
700.0
795.0

2. Calibration and validation

T/V calibration FY-3C----FY-3D------FY-3(05)







Matching results for validation

FY-3A

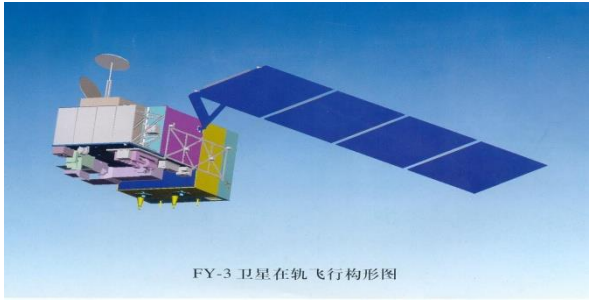
time	satellite	Pass time	Raob
2008/9/9	FY3A	11：22	10：50
2008/9/9	AQUA	14：38	14：00
2008/9/10	N18	14：45	14：15
2008/9/11	N18	14：34	14：00
2008/9/12	FY3A	12：06	11：30
2008/9/12	N18	3：07	2：30

FY-3B

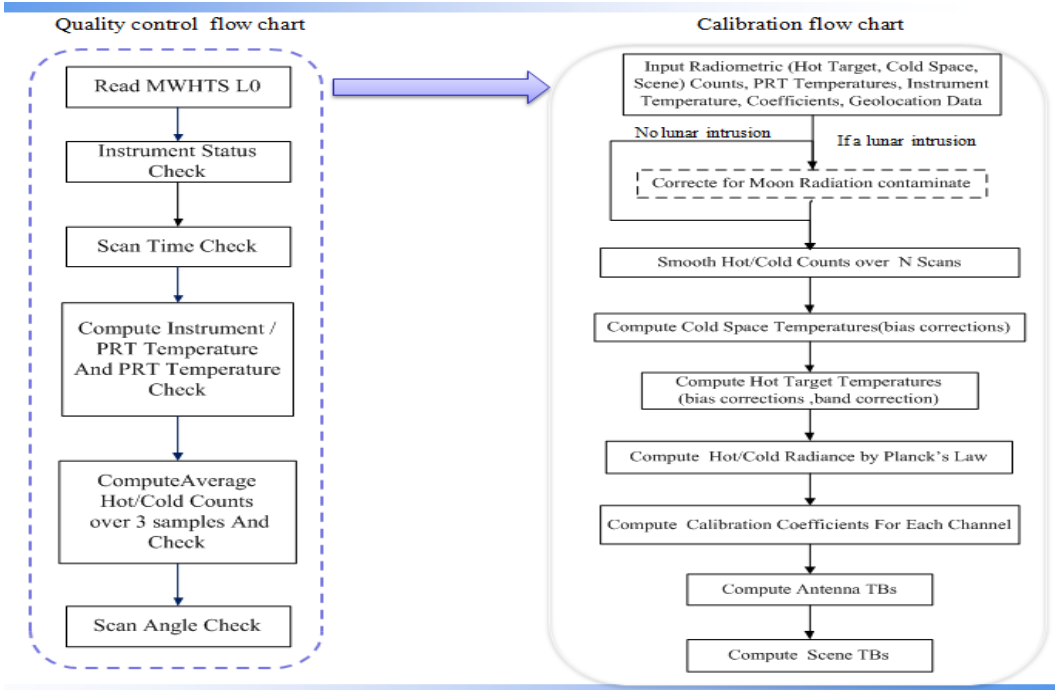
time	satellite	Pass time	Raob	Observing time
2010/11/11	AQUA	3:01	2:30	2:01-4:01
2010/11/12	AQUA	14:39	14:09	12:39-15:39
2010/11/14	NA19	14:28	14:00	12:28-15:28
2010/11/14	NA18	15:27	15:00	13:27-16:27
2010/11/15	NA19	3:01	2：31	1:01-4:01
2010/11/15	NA18	4:00	3：30	2:00-5:00
2010/11/15	FY	23:12	22：42	21:12-00:12

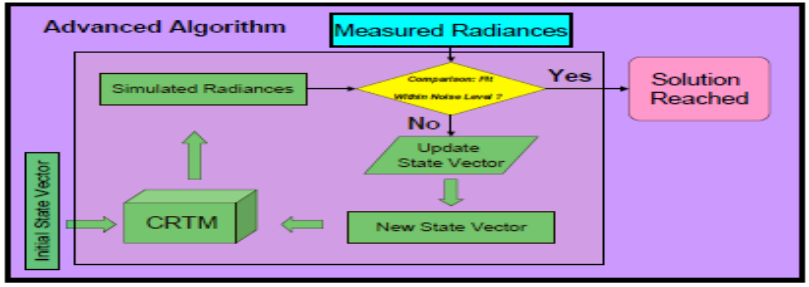
FY-3C

DATE	Sensors	Pass time	Incident angle	Raob
2015-12-01	FY-3C/MWHTS	**11:55:10**	9.06	**11:30**
	NPP/ATMS	**14:33:40**	10.31	**15:00**
	FY-3B/MWHS	**15:29:00**	2.29	
2015-12-02	NPP/ATMS	**03:02:00**	9.05	**03:30**
	FY-3B/MWHS	**03:59:20**	3.54	
	Metop-A/MHS	**11:13:23**	27.71	**11:10**
	FY-3C/MWHTS	**11:36:30**	26.83	
	NPP/ATMS	**14:15:00**	25.38	**14:40**
	FY-3B/MWHS	**15:14:00**	26.24	
	Metop-A/MHS	**22:25:23**	7.89	**22:00**



3. Quality control

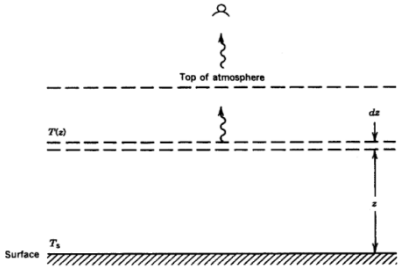




4. Atmospheric retrievals

- RT Solutions

$$B(\nu, T) = \frac{2kT\nu^2}{c^2}$$



$$B_a(\nu) = \int_0^\infty \alpha(\nu, z) B[\nu, T(z)] e^{-\tau(\nu,z)} dz$$

$$\tau(\nu, z) = \int_z^\infty \alpha(\nu, \zeta) d\zeta$$

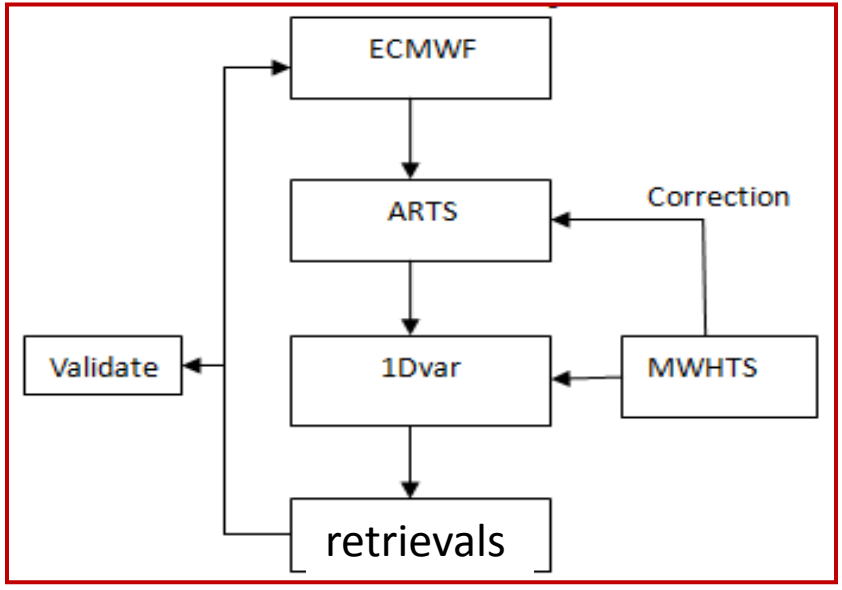
$$T_a(\nu) = \int_0^\infty \alpha(\nu, z) T(z) \exp\left[-\int_z^\infty \alpha(\nu, \zeta)\, d\zeta\right] dz$$

$$T_a(\nu) = \int^\infty W(\nu, z) T(z) dz \qquad W(\nu, z) = \alpha(\nu, z) \exp\left[-\int_z^\infty \alpha(\nu, \zeta)\, d\zeta\right]$$

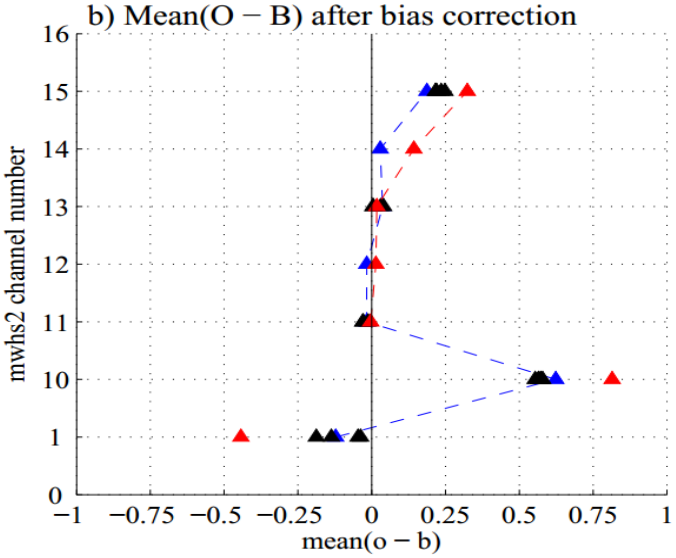
$$T_a(\nu) = \sum_{n=1}^{N} W(\nu, z_n) T_n \Delta z \qquad T_{am} = \sum_{n=1}^{N} W_{nm} T_n$$

$$\mathbf{T_a} = \mathbf{WT} \qquad \mathbf{T} = (\tilde{\mathbf{W}}\mathbf{W})^{-1}\tilde{\mathbf{W}}\mathbf{T_a}$$

Algorithm and operation steps

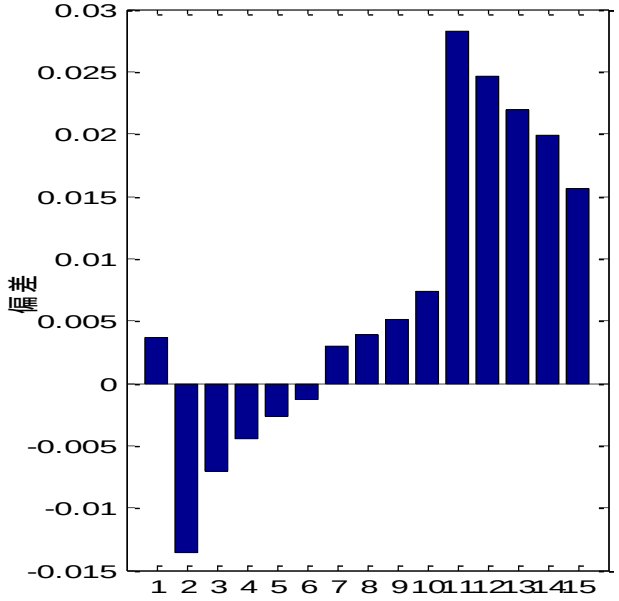


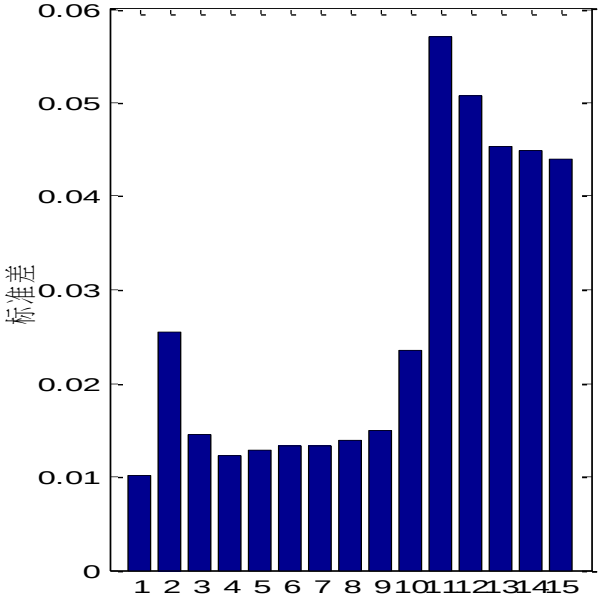
Simulation, retrieval and validation of TPW using MWHTS onboard FY-3C satellite



Comparison between ARTS and mwhs-II data using radiosondes (assessment form ECMWF also)

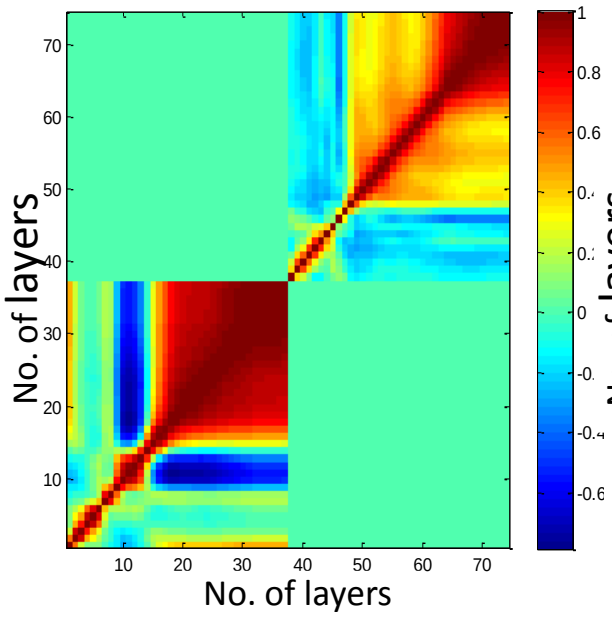
Bias and standard deviation between model and observations



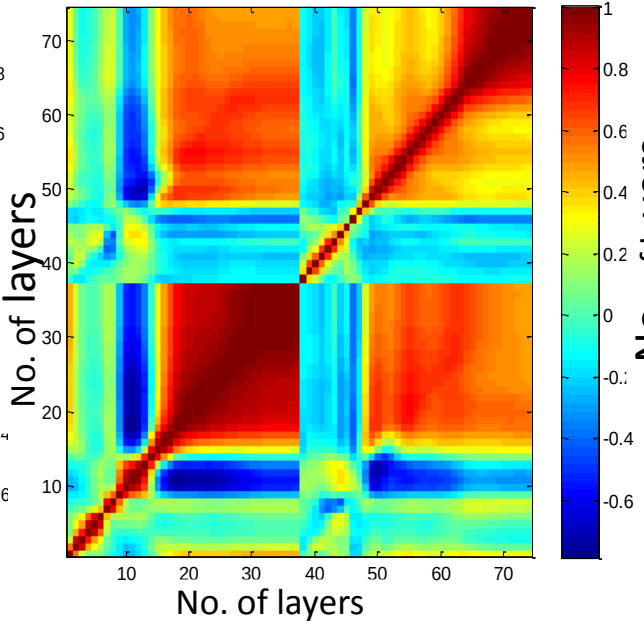


MWHS-II

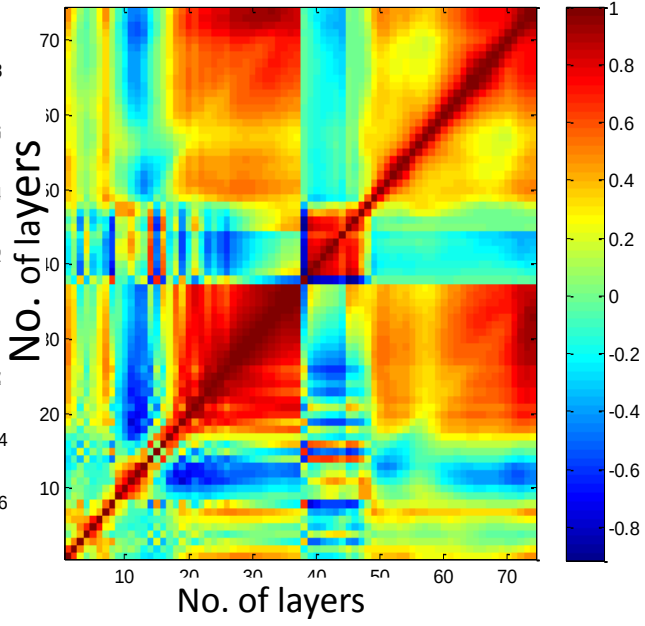
Correlation coefficient matrix



Single Correlation matrix

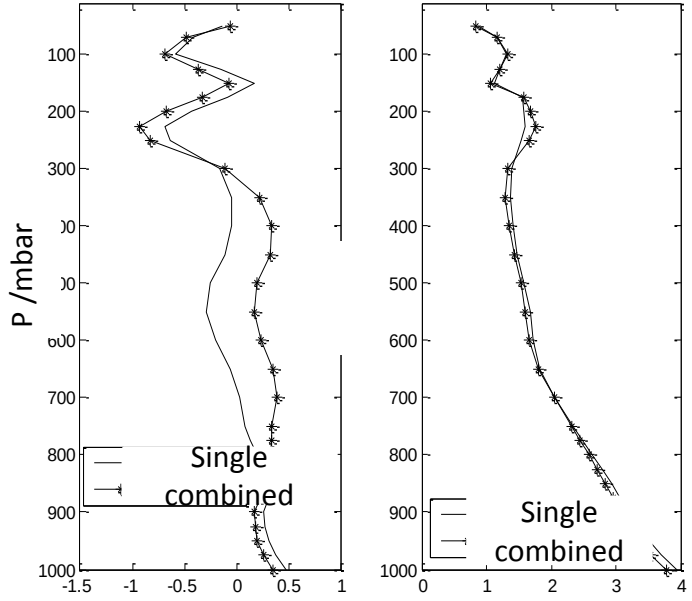


Combined Correlation matrix

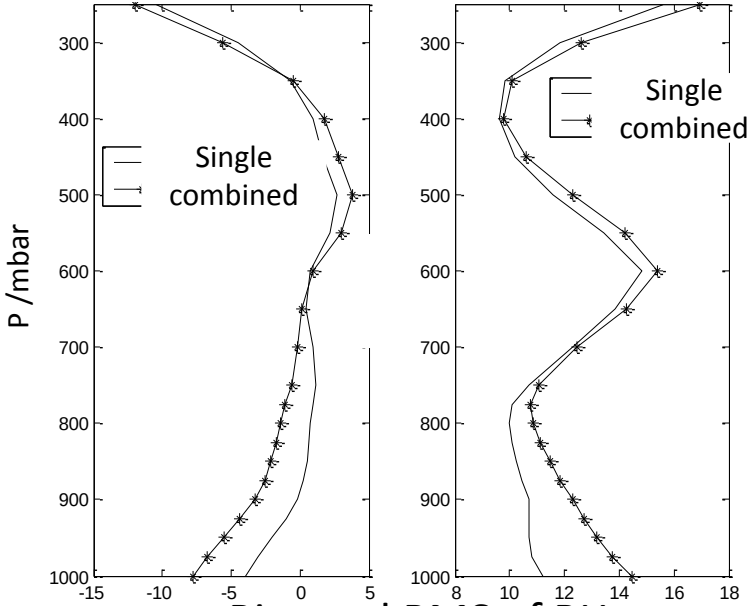


Combined Correlation matrix mixing ratio partial density

Role of background error covariance

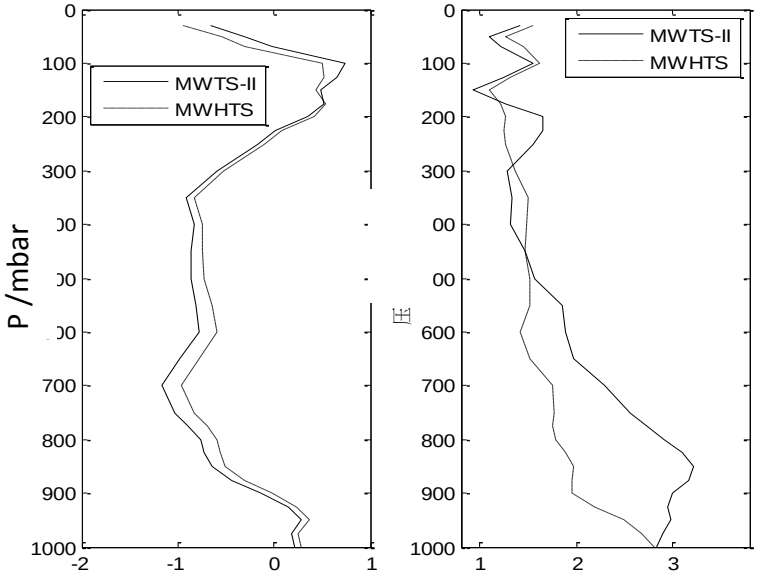


Bias and RMS of temperature retrievals

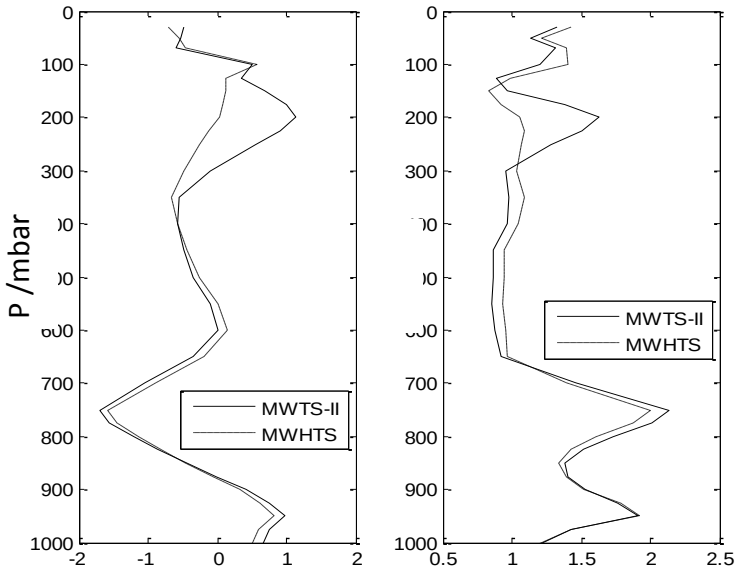


Bias and RMS of RH retrievals

5. Results of retrievals



（a）land surface

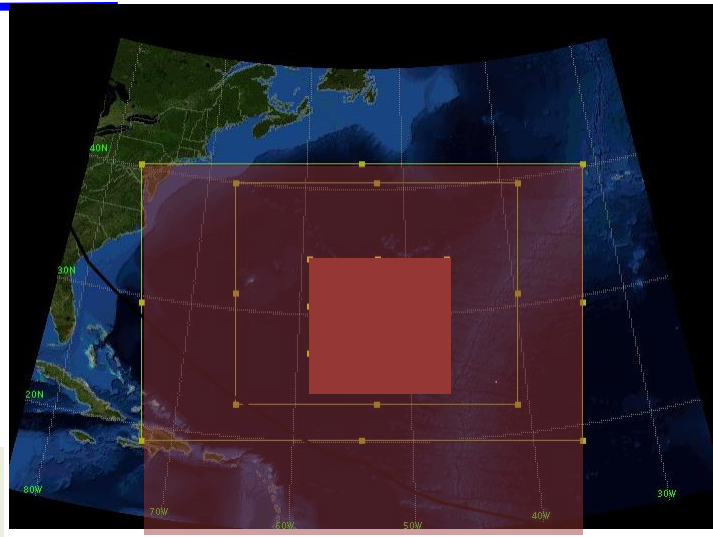


（b）ocean surface

6. Focus on extreme situations (urgent)

Case study for hurricane Hermine(2016)

Domain 1: -75 to -35 lon, 20 to 42 lat
Domain 2: -65 to -43 lon ; 22 to 40 lat
time_step=90
interal time： 60， 15mins
frames per outfile: 1000
mp_physics=6 (includes 6 water particles)
mp_physics=3 (old version)



Atmospheric state:
Vars: H, P, T, ROv, ROcloud, ROrain, ROice, ROsnow, ROgraup)
Level: 33 with surface
Time interval: 15mins,
Spation:5km
Frame: 48

Case study for hurricane Hermine(2016)

Domain 1: -75 to -35 lon, 20 to 42 lat
Domain 2: -65 to -43 lon ; 22 to 40 lat
time_step=90
interal time： 60， 15mins
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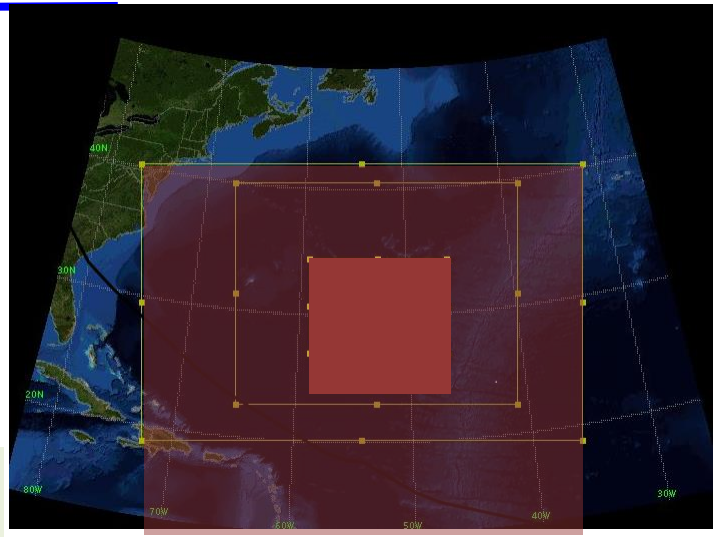
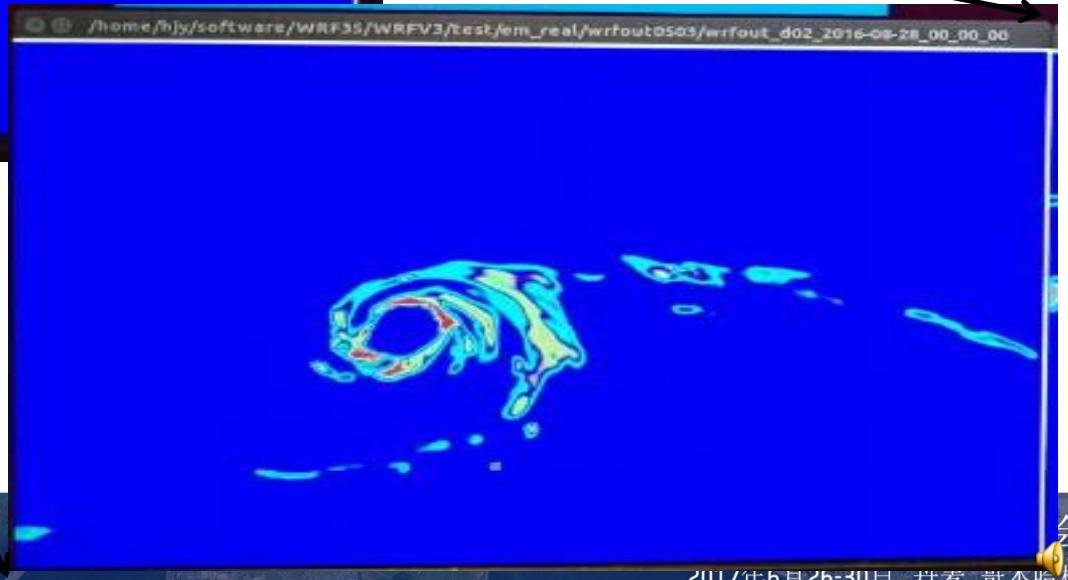
mp_physics=6 (includes 6 water particles)
mp_physics=3 (old version)

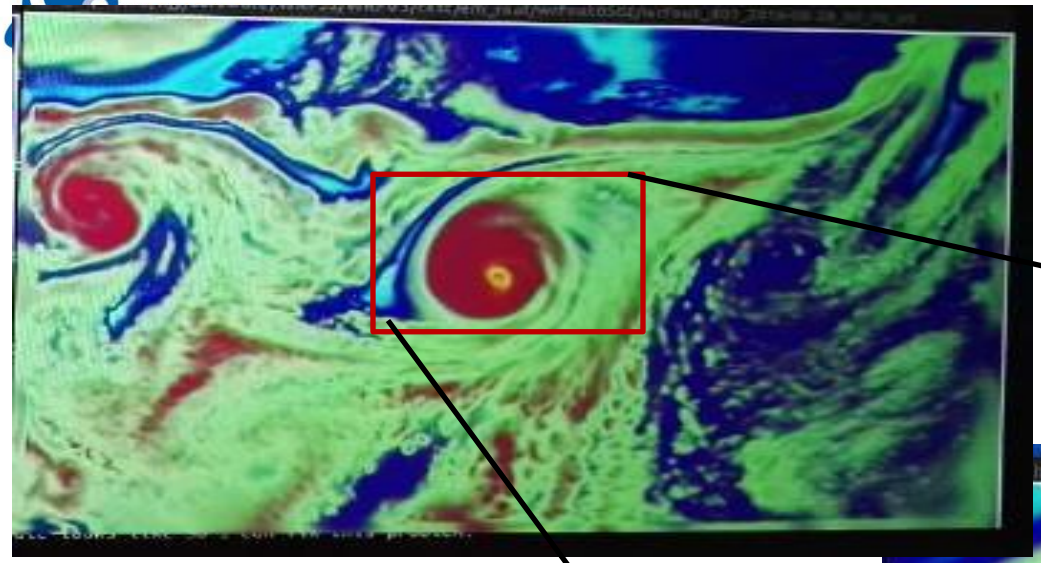


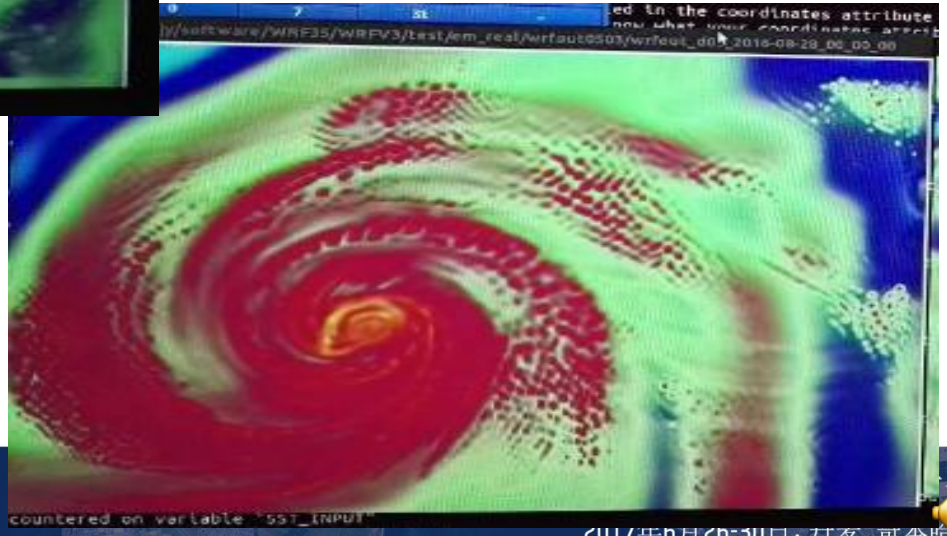
Atmospheric state:
Vars: H, P, T, ROv, ROcloud, ROrain, ROice, ROsnow, ROgraup)
Level: 33 with surface
Time interval: 15mins,
Spation:5km
Frame: 48


/home/hjy/software/WRF35/WRFV3/test/em_real/wrfout0502/wrfout_d01_2016-08-28_00_00_00

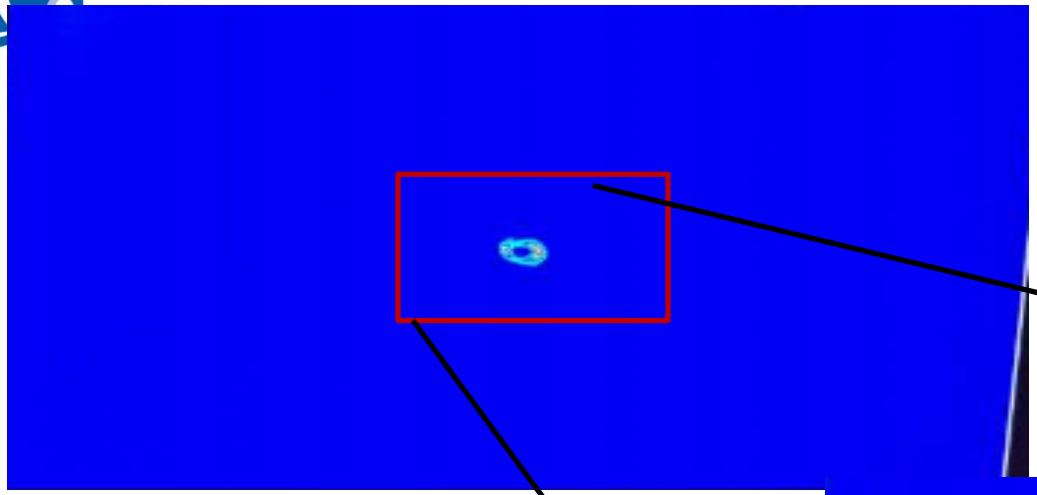

/home/hjy/software/WRF35/WRFV3/test/em_real/wrfout0503/wrfout_d02_2016-08-28_00_00_00

qice



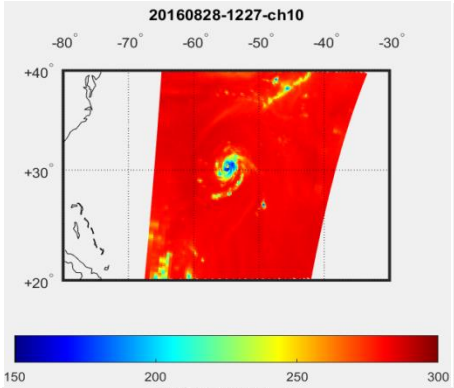


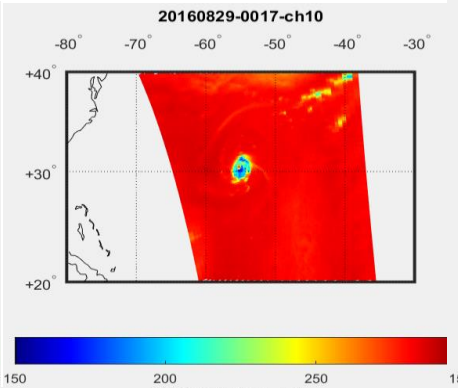
qvapor

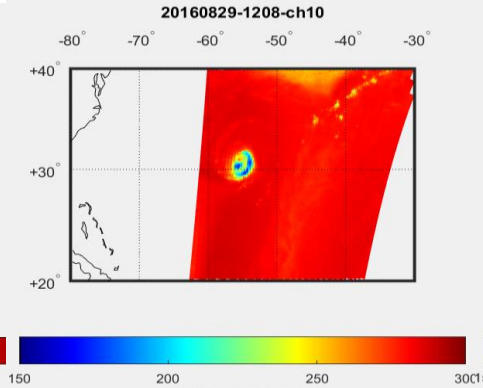


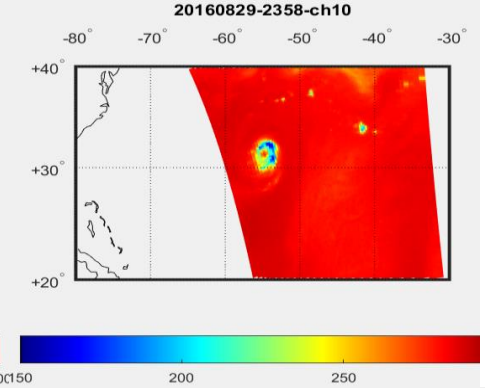
qrain

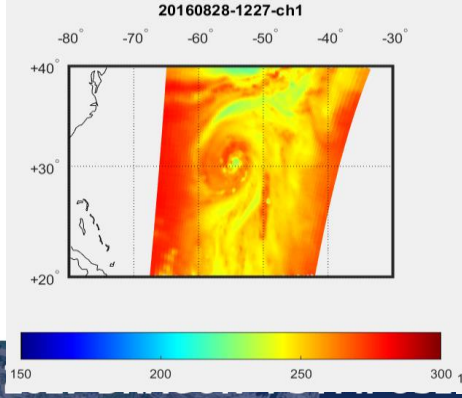
FY-3 mwhs-II observations

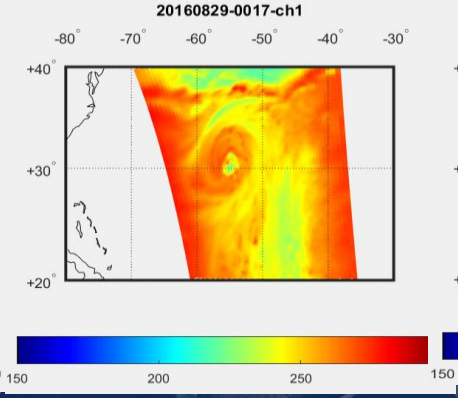


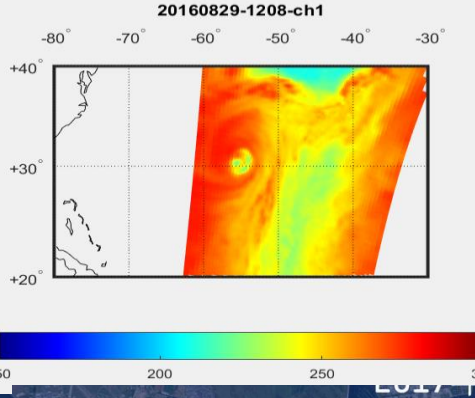


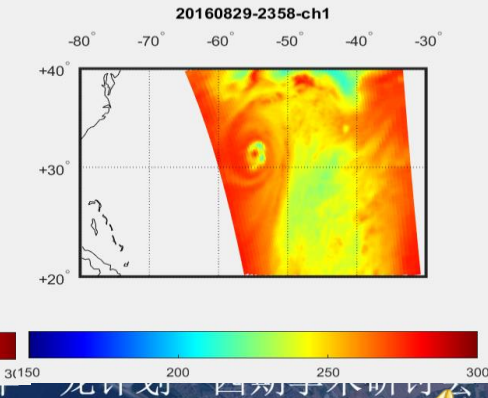








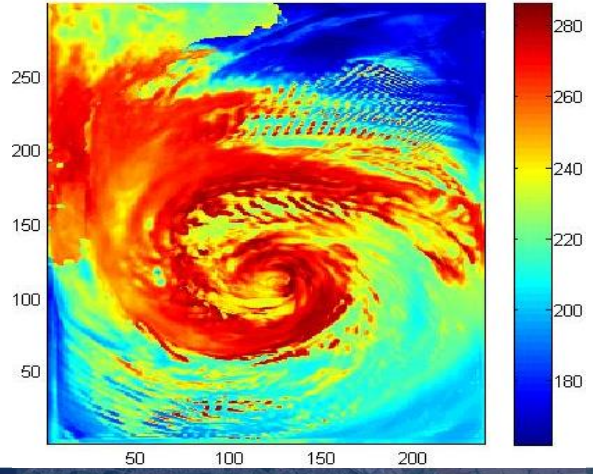




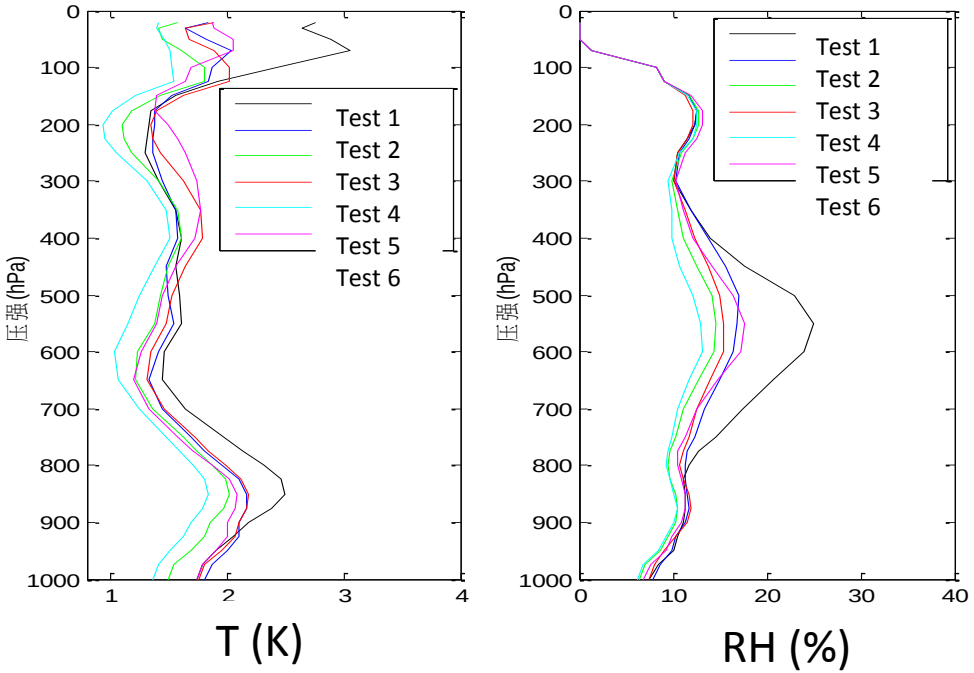
Classification of hurricane area

1. Clear-air in hurricane-eye
2. **Convection in rain band (multi-state)**

   threshold: according to the precipitation
3. Stratiform (ice, cloud, rain)



Results of retrievals



Hurricane area

Precipitation retrievals between Jan,1 to Oct,31, 2016

Location	rain Rate(mm/h)	Land rms/K	sea rms/K	mean
|Lat|<30	0.1-1	1.02	1.84	1.43
	1-10	8.23	5.54	6.88
	10-30	20.31	21.23	21.77
30≤|Lat|≤60	0.1-1	1.11	1.35	1.23
	1-10	8.83	5.77	7.30
	10-30	20.81	22.26	21.72
|Lat|>60	0-1	0.72	0.54	0.63
	1-2	0.53	0.21	0.37
	2-5	1.31	1.03	1.17

Correlation coefficient:

Over ocean: R=0.6931

Over land: 0.6245

Location	rain Rate(mm/h)	Land rms/K	sea rms/K
Typhoon/hurricane domain	0.1-1	/	0.84
	1-5	/	3.54
	5-10	/	6.78
	10-30	/	17.21
	30-50	/	21.23
	50-65	/	32.4

Summary and further plan

- Focus on calibration, validation and Quality control of observations
- Temperature and humidity retrievals based on observations and simulation.
- Study case on hurricane.

Acknowledgement

Collaborators:

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- Space Science and Engineering Center, University of Wisconsin – Madison, US;
- Informus GmbH, Berlin, Germany

Thanks!

Any advice or comments?

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