Evaluation of the Potential Impact to the Prediction of Typhoon of Geostationary Microwave Sounder using the GRAPES 4D-Var

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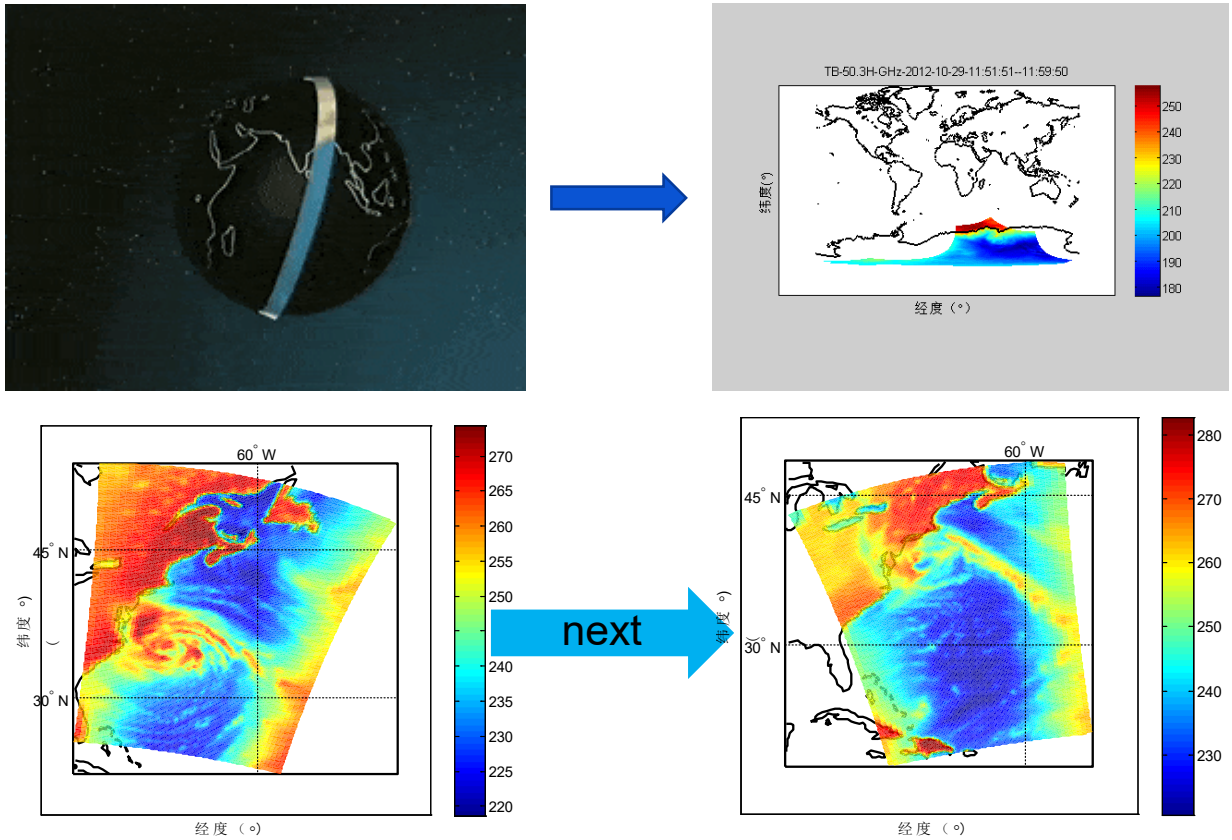
Motivation

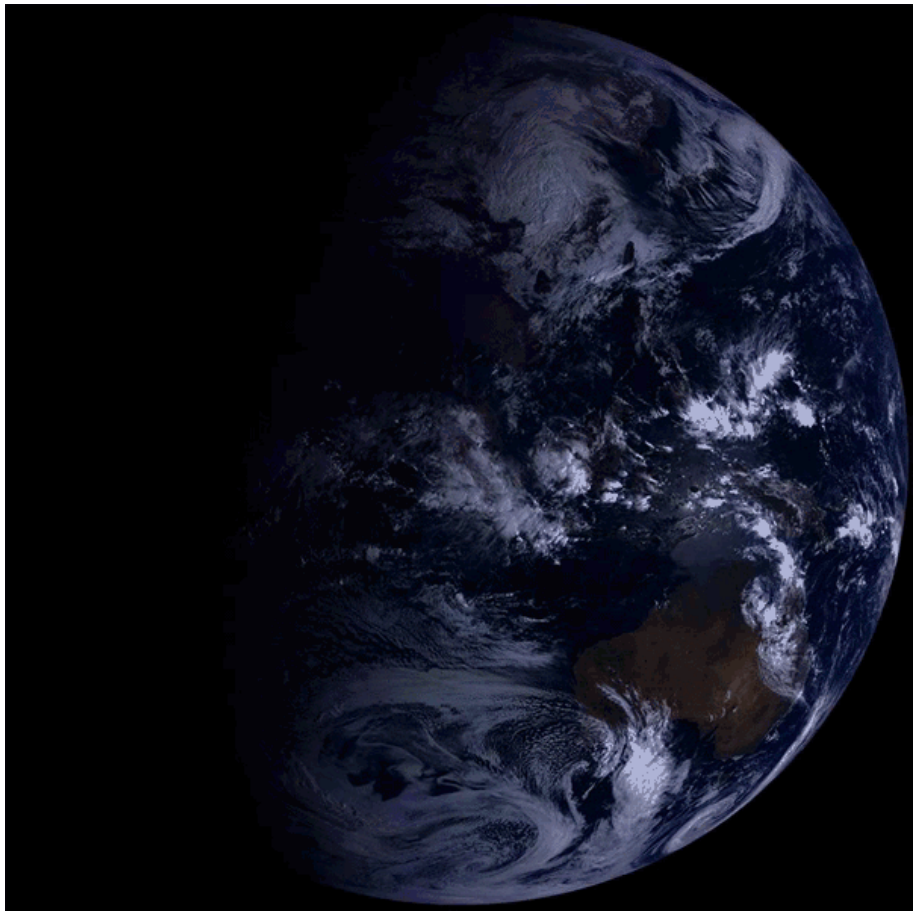
/01

Limitations of polar-orbiting



- observation swaths are limited
- temporal resolution is limited
- the rapidly evolving phenomena, such as typhoons, are poorly sampled

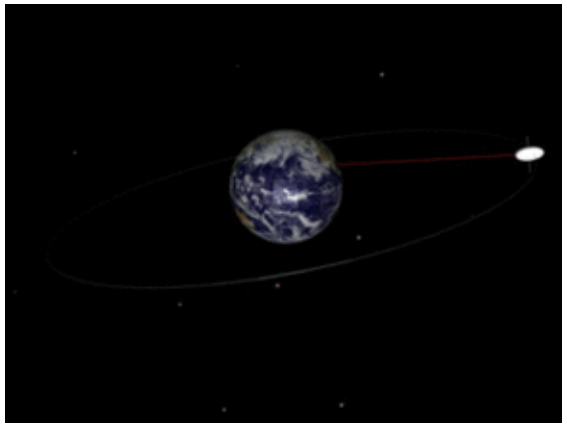
Limitations of optical

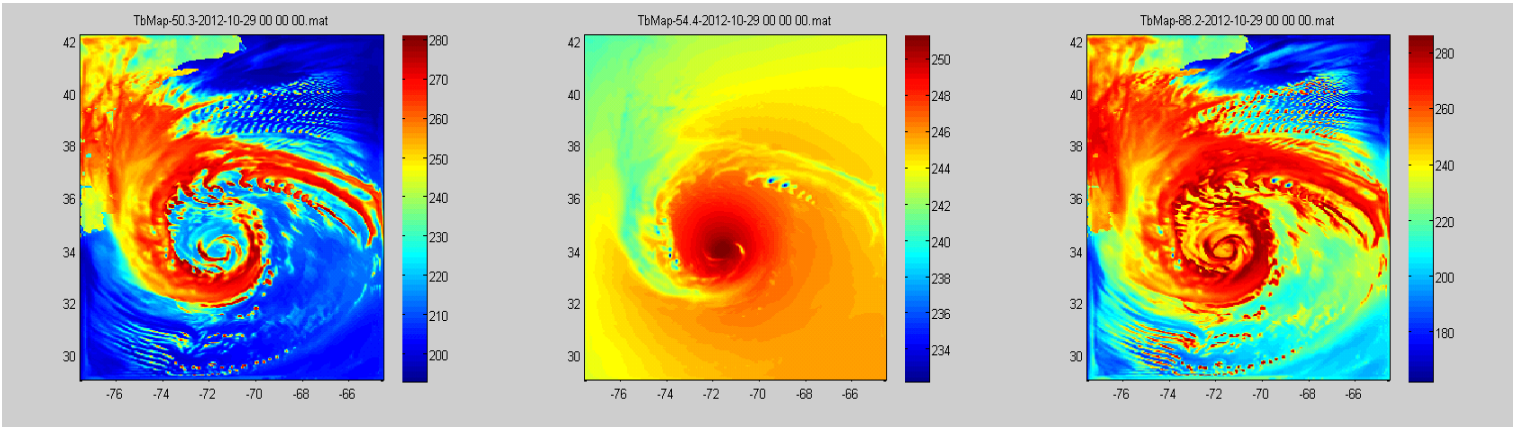


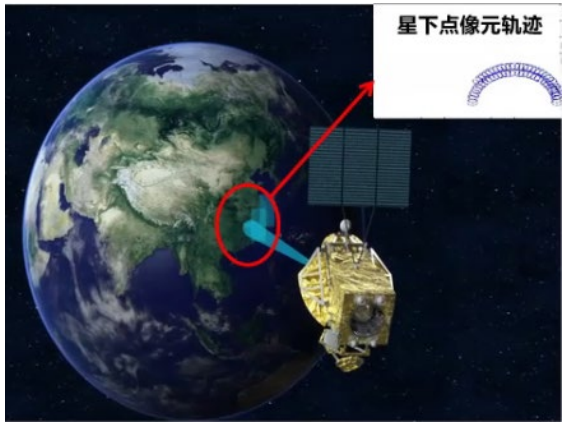
- cannot penetrate clouds which cover 1/3-1/2
- Unable to observe within clouds and rainfall
- Infrared sounding is available in clear sky

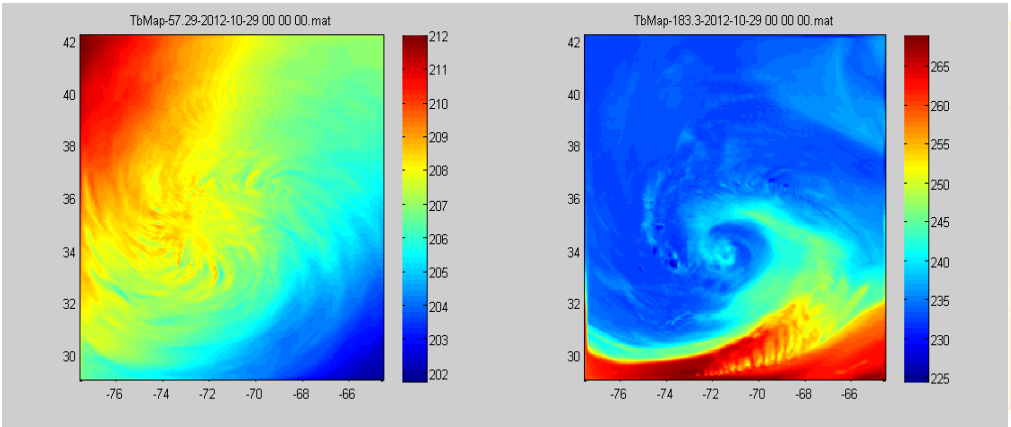
Geostationary Microwave Sounding (GEO-MW)

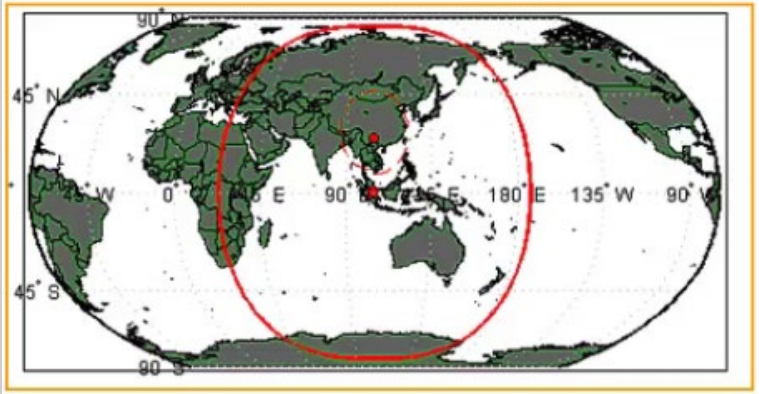
- All-sky temperature and humidity sounding at ~15-30 minute intervals over a large fraction (up to ~25%) of Earth's surface
- Improve mesoscale weather forecasting through data assimilation





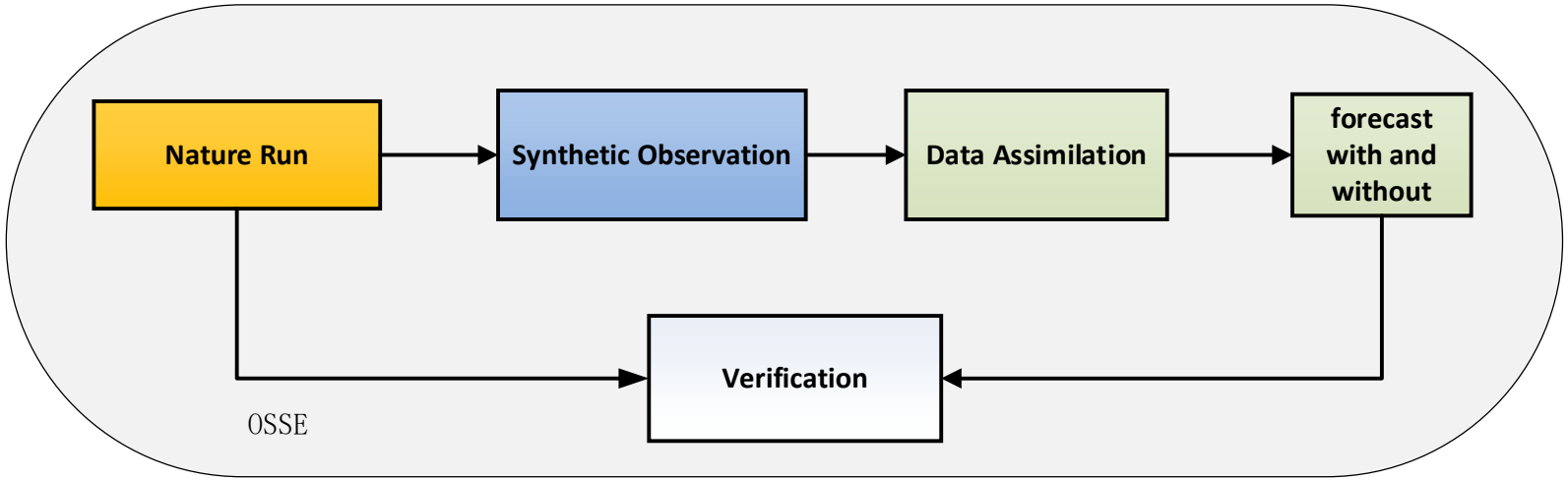






Motivation of GEO-MW OSSEs

- As a new satellite observation, GEO-MW sounding has no practical experience for optimal system design and assimilation applications.
- The observing system simulation experiment (OSSE) is to assimilate synthetic observations derived from an NWP model state assumed to represent the truth and then determine the impact on analyses and forecasts.

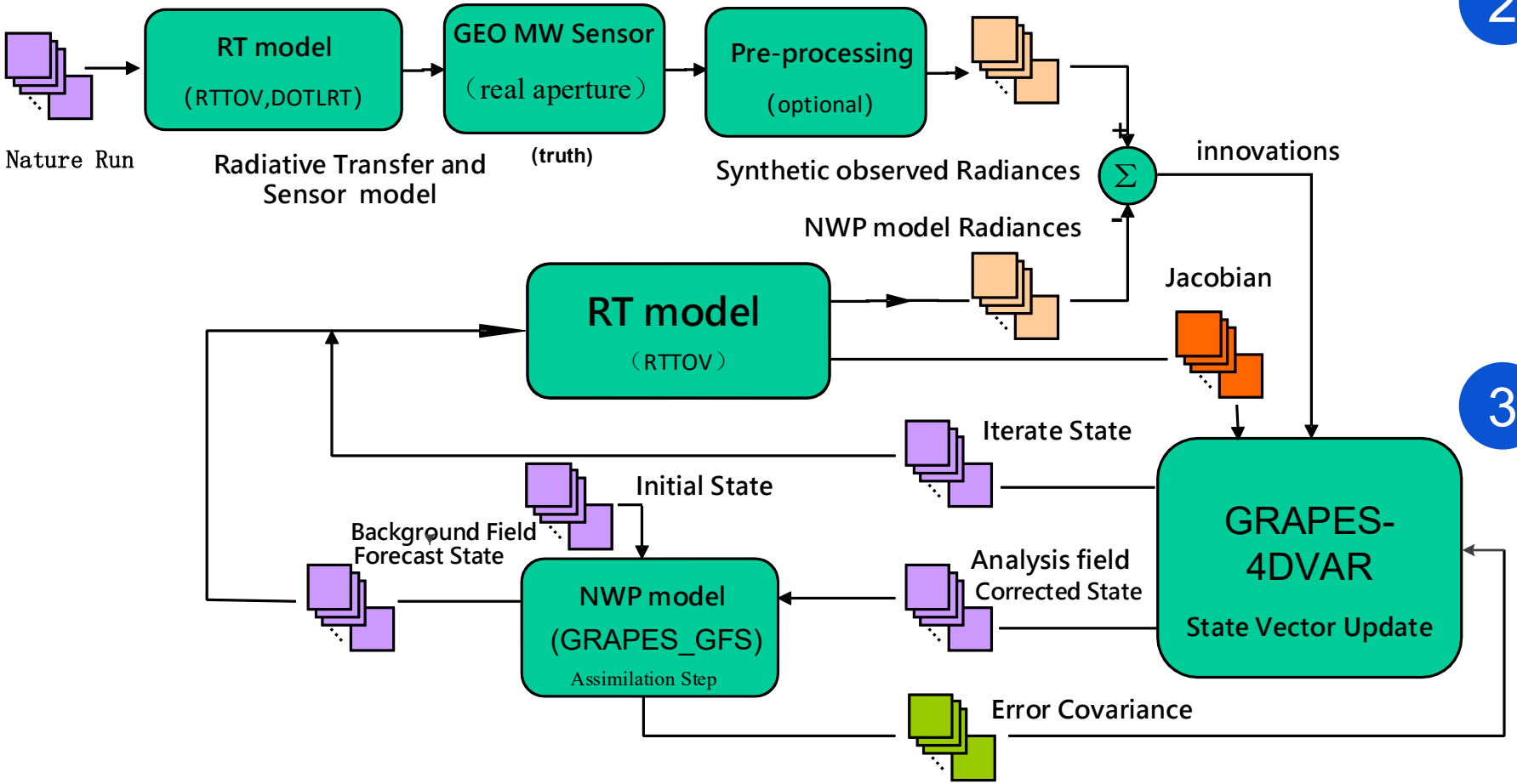


Observation System Simulation Experiment (OSSE)

Method

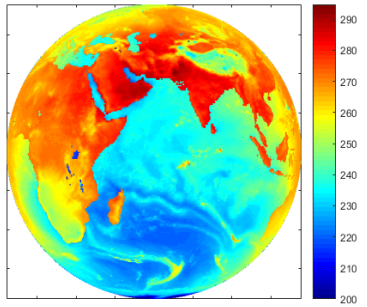
/02

Framework of the GEO-MW OSSE



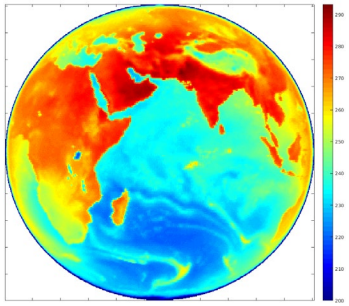
1 Forward upwelling TB

Reanalysis data，NWP model，RT model



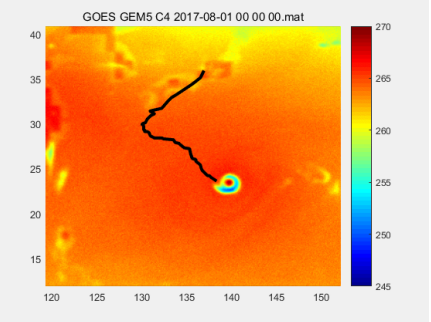
2 simulate the observed TA

Sensor model，GEO orbit parameters，geometry

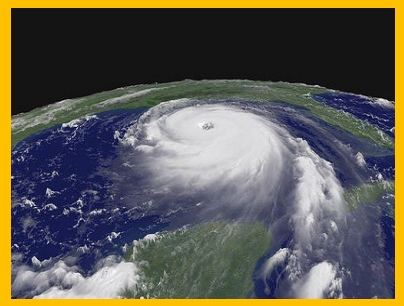


3 DA and NWP forecasting

4D-Var assimilation, NWP forecasting, verification

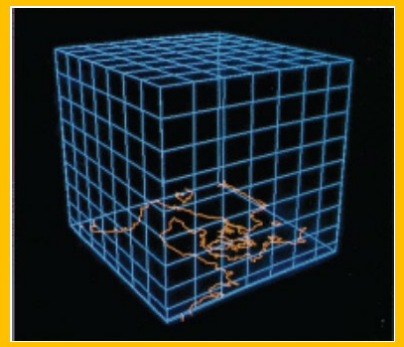


Satellite-based Microwave Observation Simulation and Verification

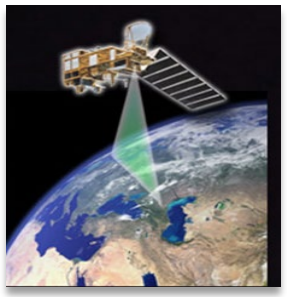


Meteorological event

STATE SPACE

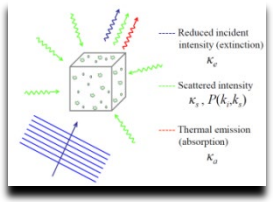


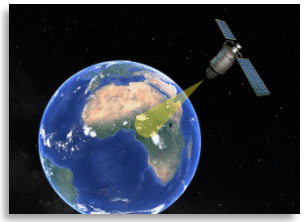
State vector x



A satellite based Microwave Sounder

Real Satellite observation process

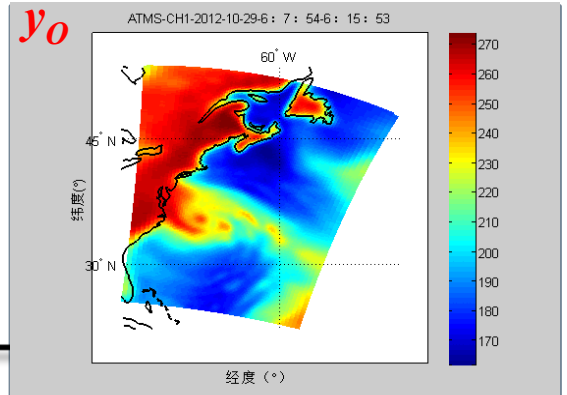




RT Model + Sensor Response

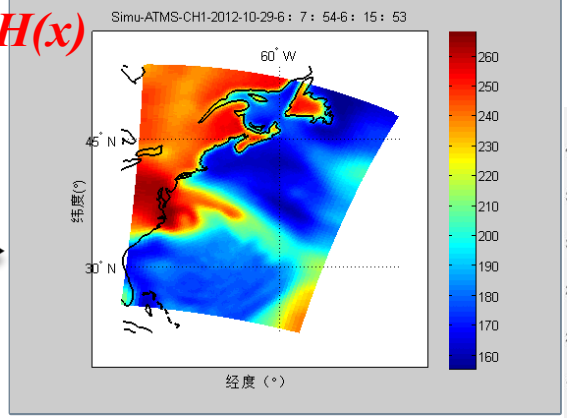
Brightness Temperature forward process

y_o

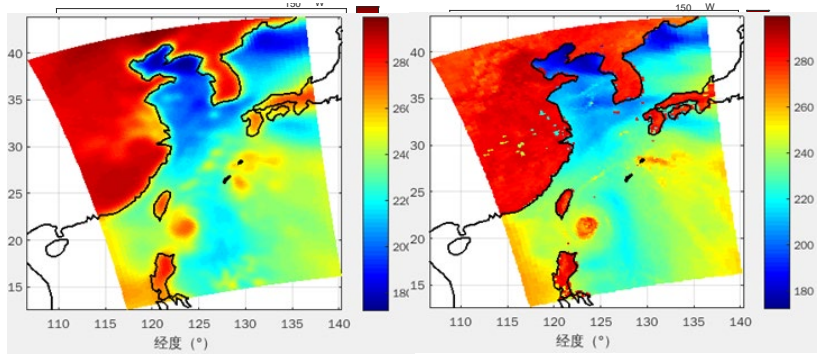


OBSERVATION SPACE

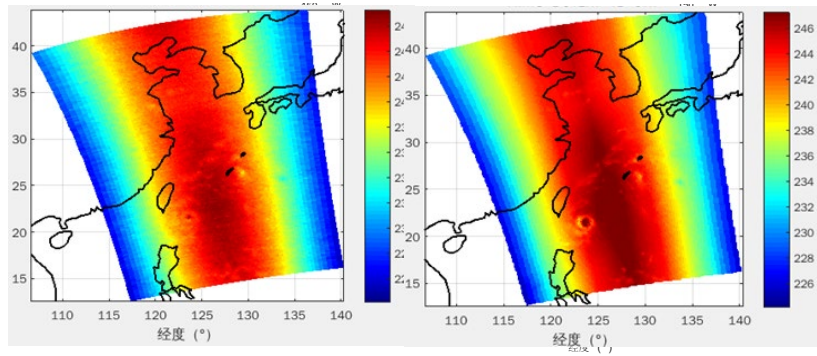
$H(x)$



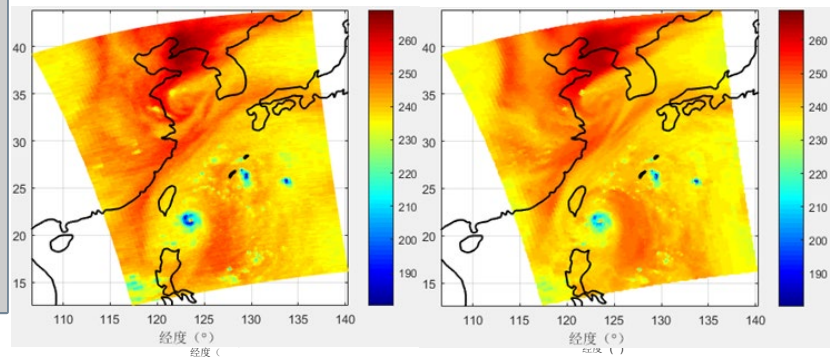
ATMS observation ATMS simulation



23.8GHz



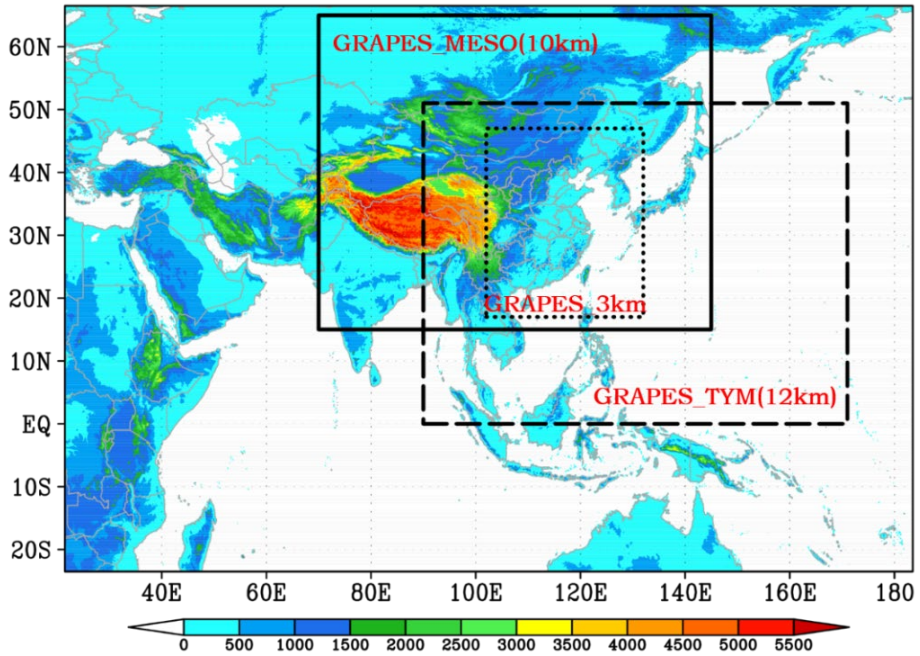
54.4GHz

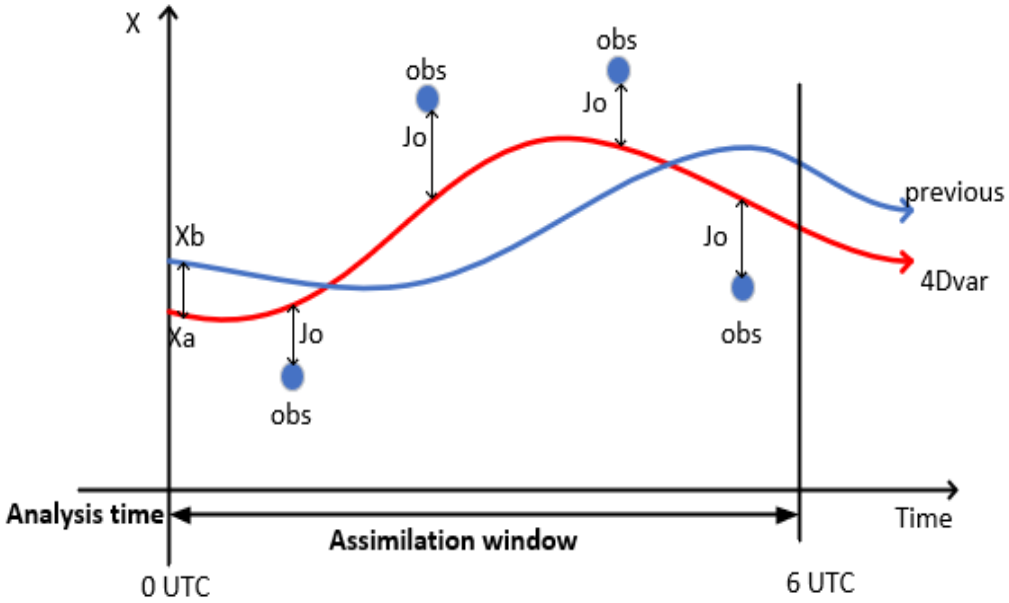


183.31±1GHz

GRAPES and 4D-Var assimilation

- GRAPES (Global/ Regional Assimilation and PrEdiction System) is a global/regional numerical weather prediction system constructed by CMA Earth System Modeling and Prediction centre(CEMC) since 2007.
- Since July 1, 2018, the GRAPES global 4-dimensional variational (4D-Var) data assimilation system has been in operation at CEMC.





GEO-MW OSSE Results /03

GEO-MW sounding frequency and channels

Absorption coefficient β_a [1/km]

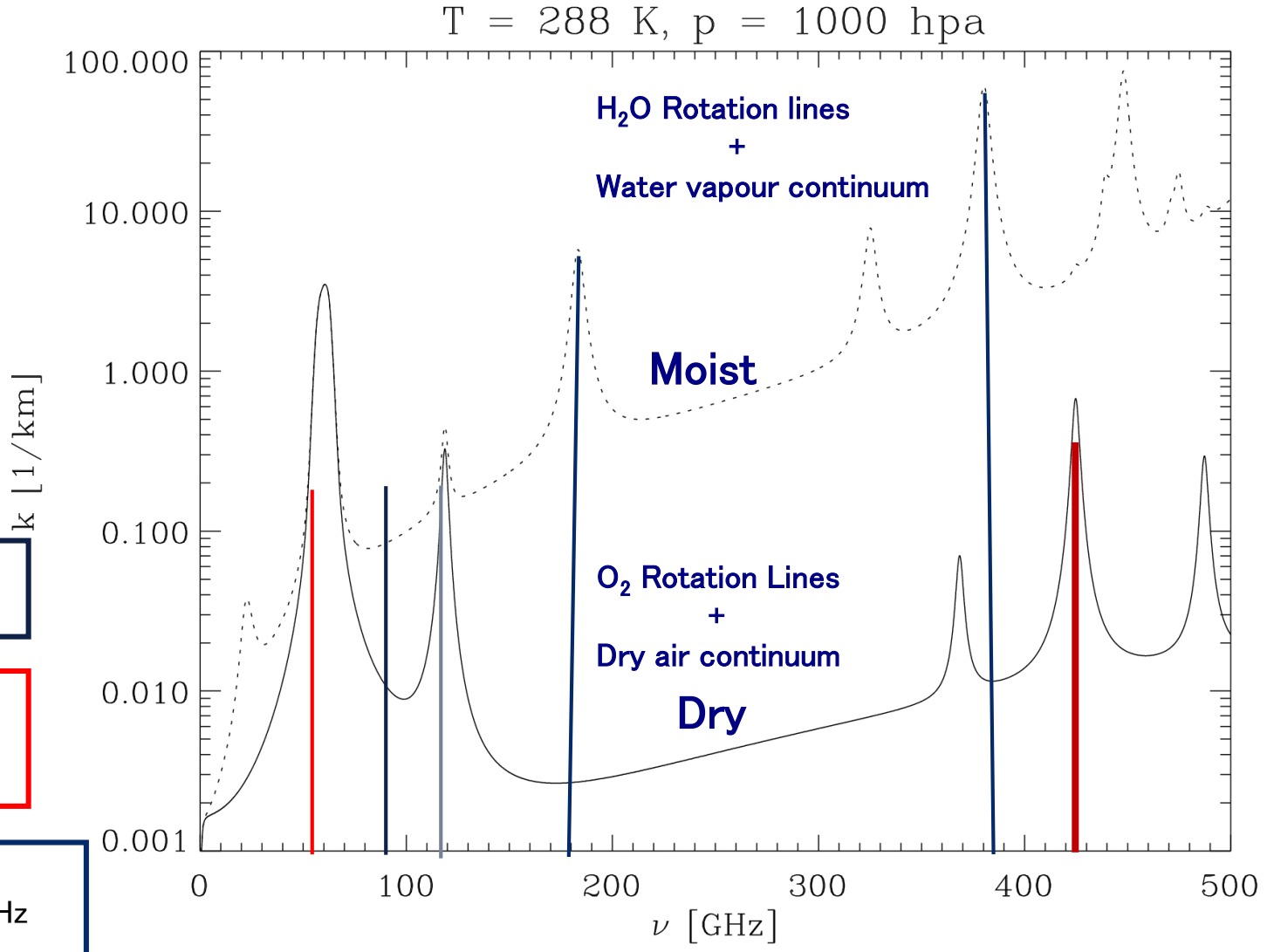
425GHz,FY4A

118GHz,FY3C MWHS

"Imaging channels" in the windows

Temperature sounding:
60 GHz oxygen line

Moisture sounding:
183 GHz and 380 GHz water vapour lines



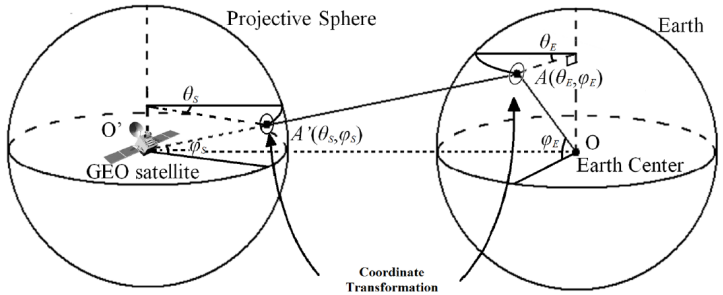
Ch.	frequencies (GHz)	height of IWF
1	50.3	surface
2	51.76	1 km
3	52.8	2 km
4	53.596	4 km
5	54.4	8 km
6	54.94	10 km
7	55.5	12.5 km
8	88.2	surface
9	118.75±0.8	12 km
10	118.75±1.1	9 km
11	118.75±3.0	3 km
12	118.75±5.0	surface
13	165.5	surface
14	183.31±7.0	1.8 km
15	183.31±4.5	3 km
16	183.31±3.0	4 km
17	183.31±1.0	6 km
18	380.197 ± 18	3 km
19	380.197 ± 9.0	4.5 km
20	380.197 ± 4.0	6.5 km
21	380.197 ± 1.5	8.5 km
22	424.763±4.0	4 km
23	424.763±1.5	7.5 km
24	424.763±1.0	11.5 km

GEO-MW observation simulation

A filled aperture radiometer with a deployable antenna

- **5m** antenna diameter for 50-60GHz
- **2.4m** antenna diameter for 88-425GHz

$$T_A(\theta_0,\varphi_0)=\int TB(\theta,\varphi)G_n(\theta_0,\varphi_0;\theta,\varphi)d\Omega+\Delta T_{rms}$$

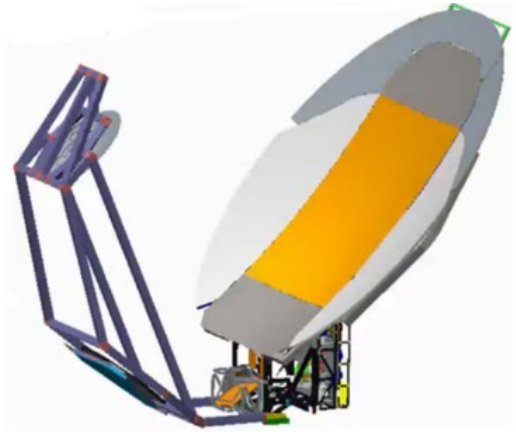


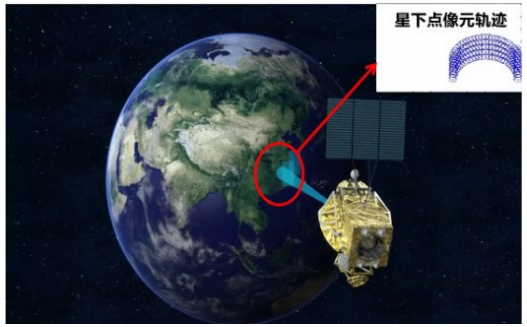
① sensor antenna response function

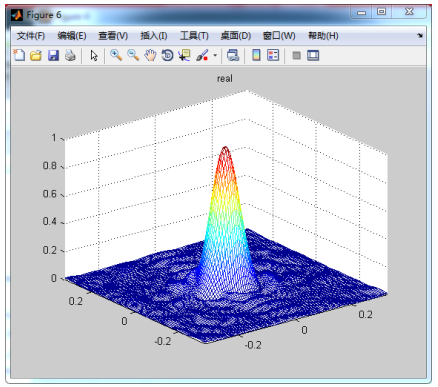
② project earth grid to antenna coordinate

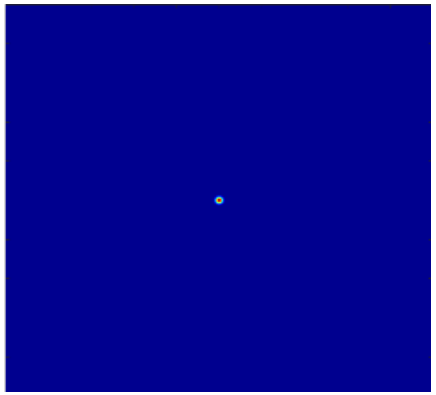
③ observation convolution operation

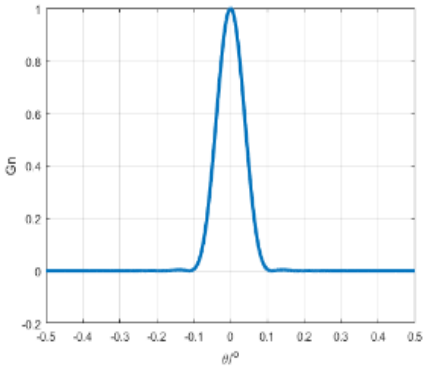
④ add instrument system noise





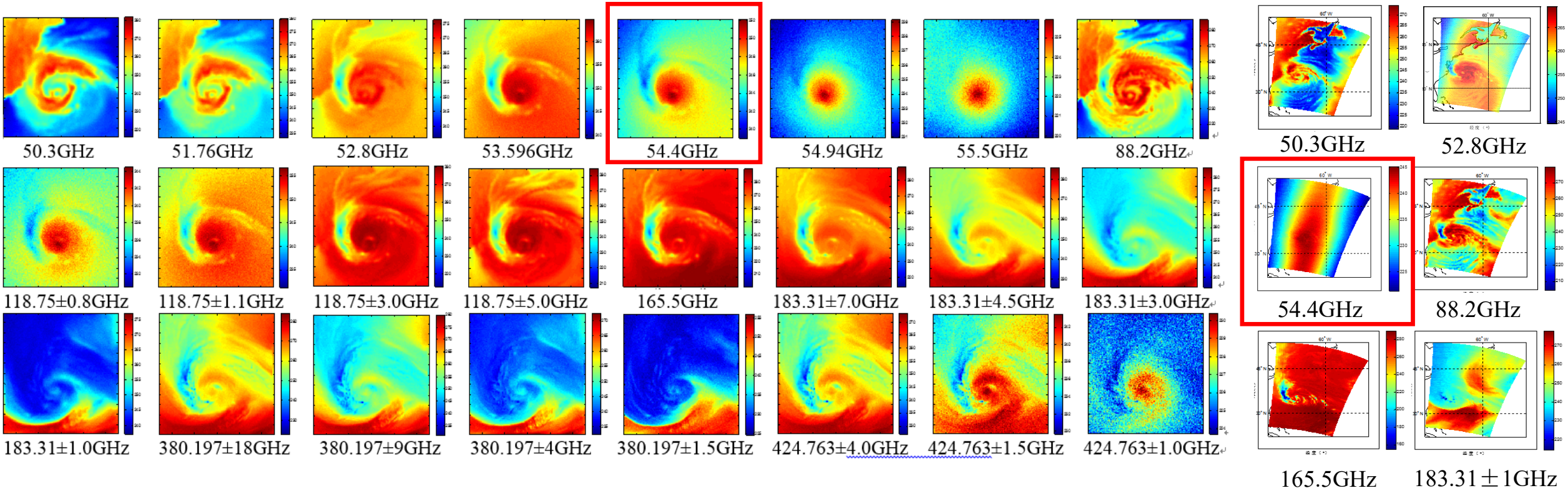






Simulated GEO-MW TB and TA of Hurricane “sandy”

- The simulated GEO brightness temperature in 50GHz-183GHz are consistent with the ATMS observation of polar-orbiting satellites.
- Compared with polar-orbit, due to the higher orbit altitude, GEO brightness temperature is less affected by the incident angle, which can show the thermal structure more clearly.



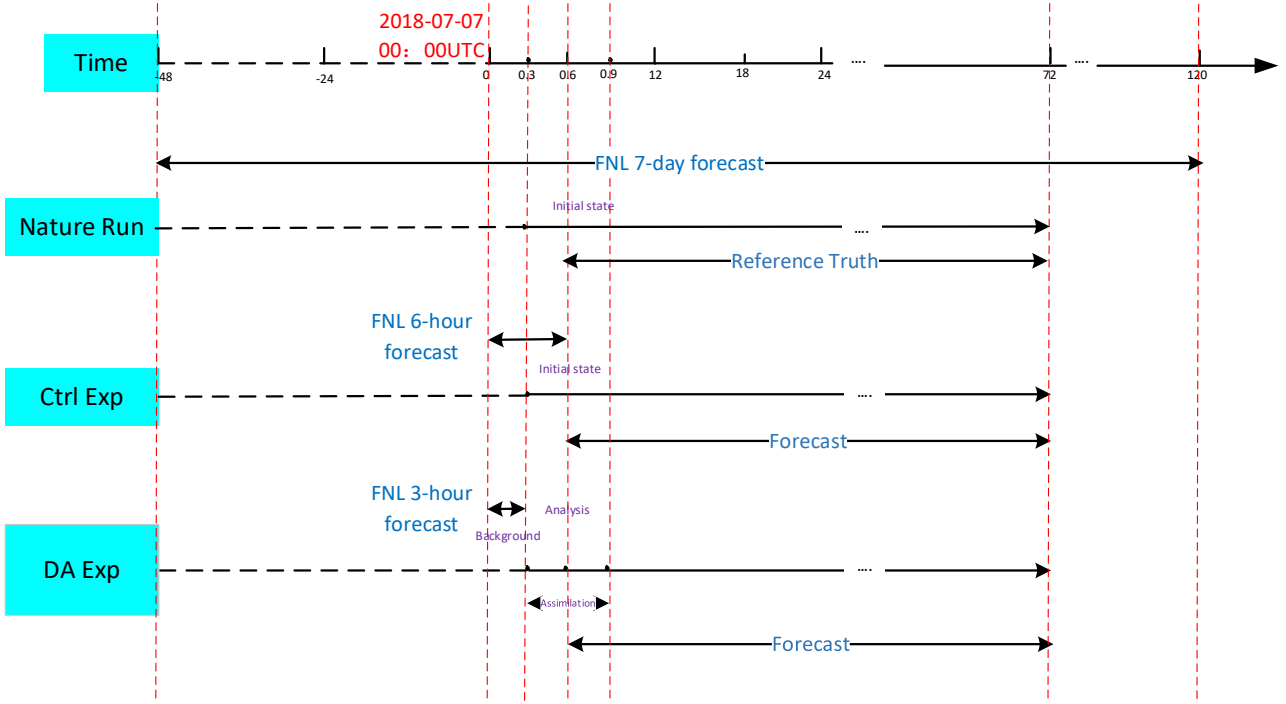
GEO-MW simulation

ATMS observation

GEO-MW OSSEs configurations

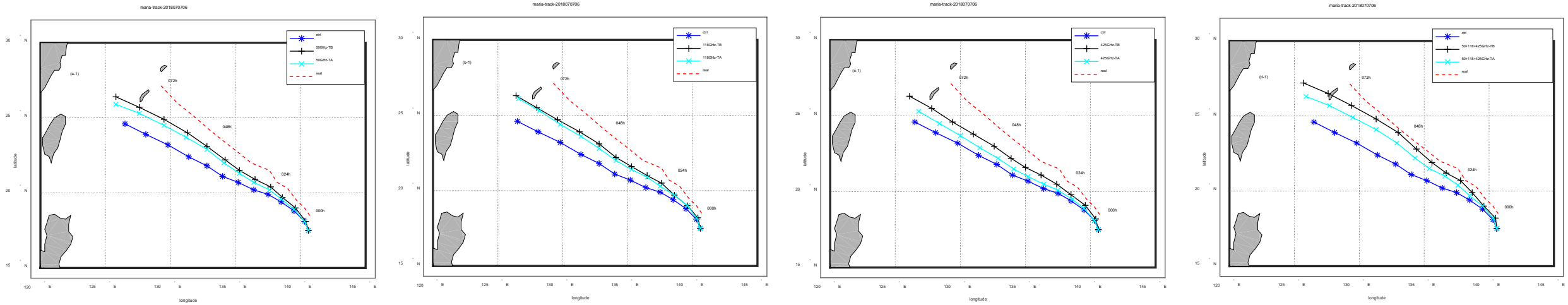
case	Typhoon Maria	Typhoon Mangkhut
time	July 7, 2018, 6:00 - July 10, 6:00	Sept. 11, 2018, 6:00 - Sept. 14, 6:00
center	(27.5°N，132.5°E)	(17.5°N，132.5°E)
longitude	(120°—145°E)	(120°—145°E)
latitude	(15°—40°N)	(5°—30°N)
grid size	28 km×28 km	28 km×28 km

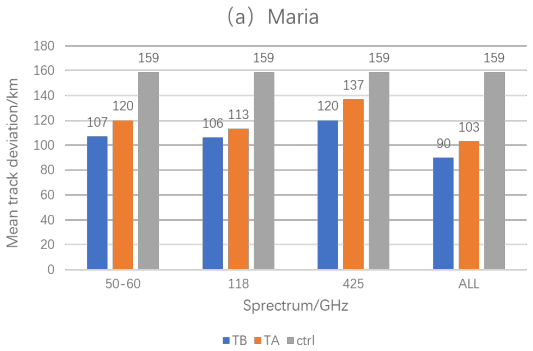
case	Maria	Mangkhut
Forecast time	July 7，06:00 - July 10, 06:00	Sept. 11, 6:00—Sept. 14, 6:00
grid size	0.25°，28 km	
grid number	1440*720	
layer number	17	
Top pressure	10 hpa	
Initial	FNL reanalysis	
time window	6 h	
RT model	RTTOV _DIRECT	
time interval	1 h	

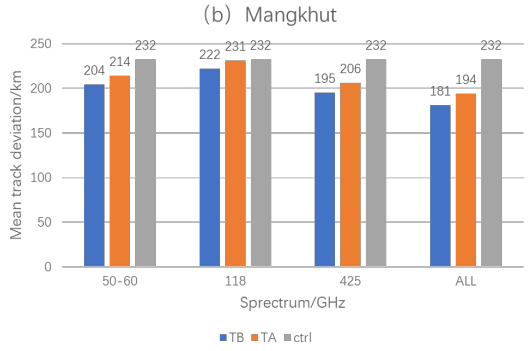


GEO-MW OSSE——Frequency bands analysis

- Simulated GEO-MW brightness temperature data in atmospheric temperature sounding bands of 50-60 GHz, 118 GHZ and 425 GHz were assimilated into GRAPES by 4D-Var, respectively.
- Verification against the CTRL showed that the experiment with the assimilated GEO-MW data gave a consistently more accurate prediction of the track for Typhoons Maria and Mangkhut.



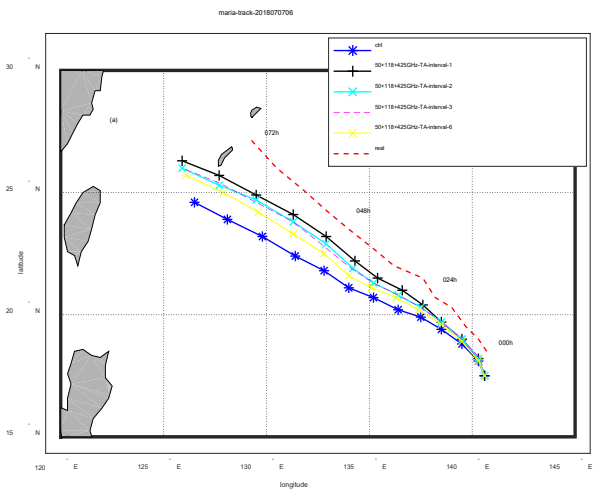


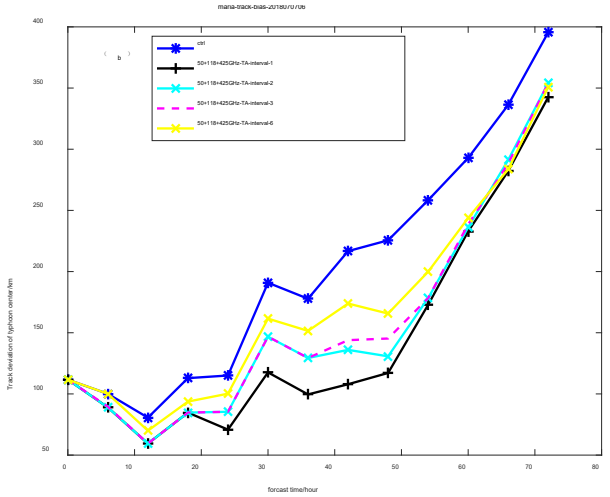


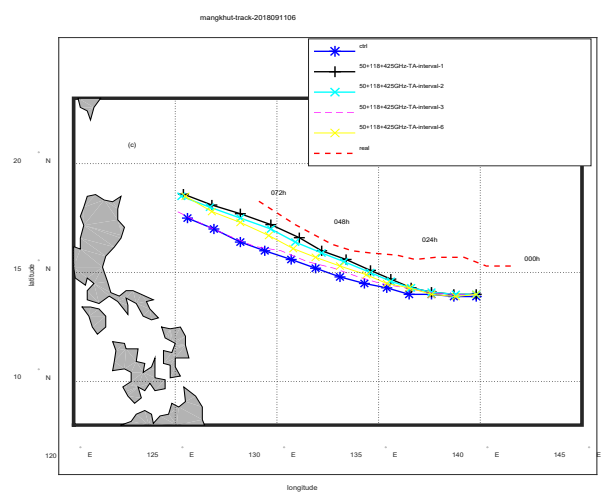
Compared with CTRL, for Maria and Mangkhut, DA all-bands improved the average 72-h typhoon track forecast accuracy by 32.5% and 25.5%, respectively, which is better than DA any single frequency band.

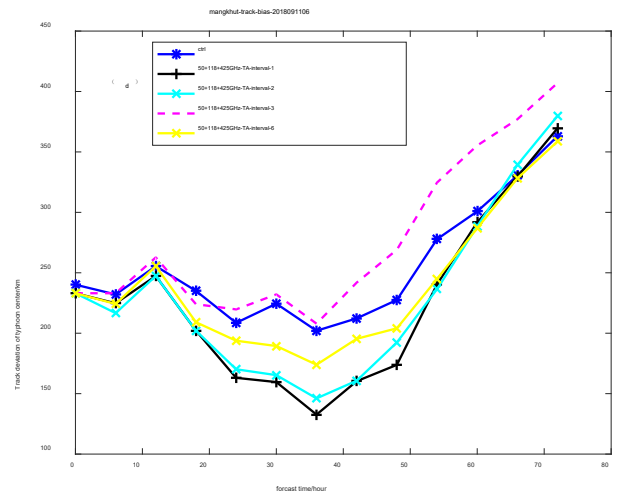
GEO-MW OSSE——Time interval analysis

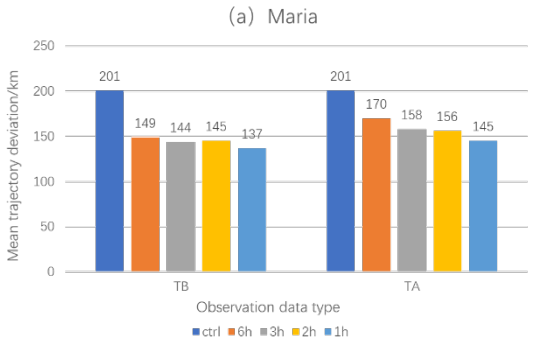
- Simulated GEO-MW brightness temperature data with time interval of 1h, 2h, 3h and 6h were assimilated into GRAPES by 4D-Var, respectively.
- Verification against the CTRL showed that the reduction of time interval of GEO-MW data can improve the prediction accuracy of the track for Typhoons Maria and Mangkhut.

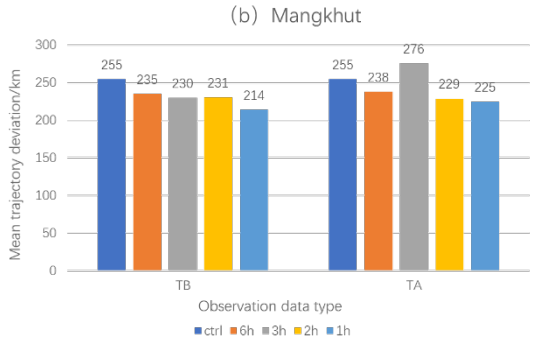








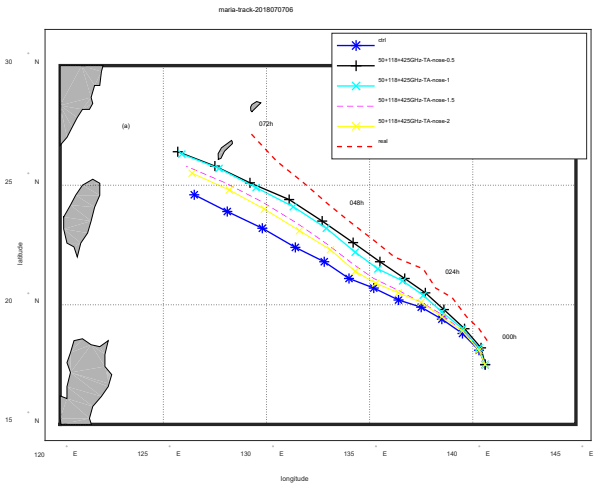


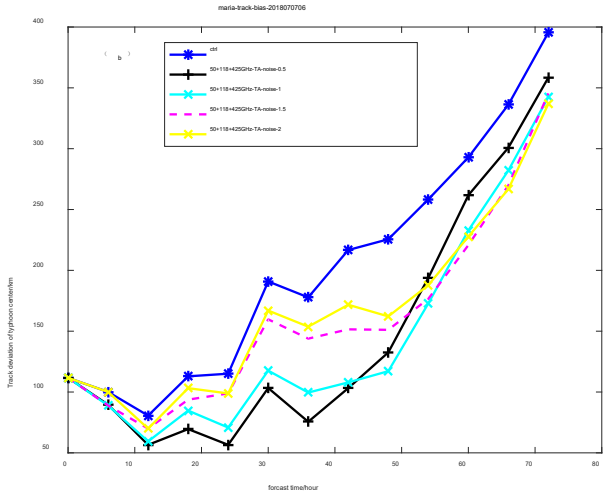


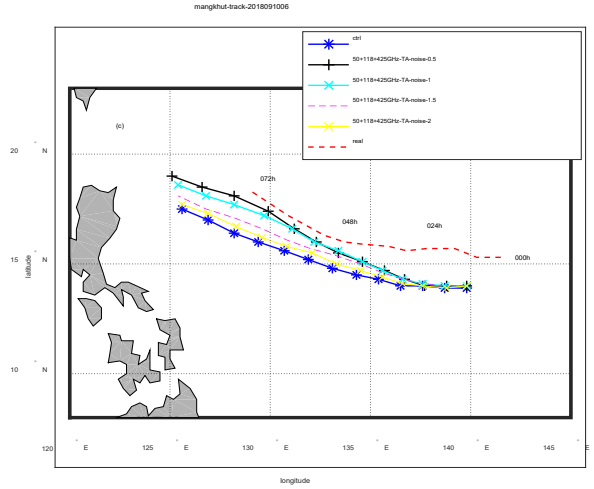
Compared with CTRL, DA with time interval of 1h, 2h, 3h and 6h can improved the average 72-h typhoon track forecast accuracy by 19.7%, 18.5%, 6.5% and 11.0%, respectively.

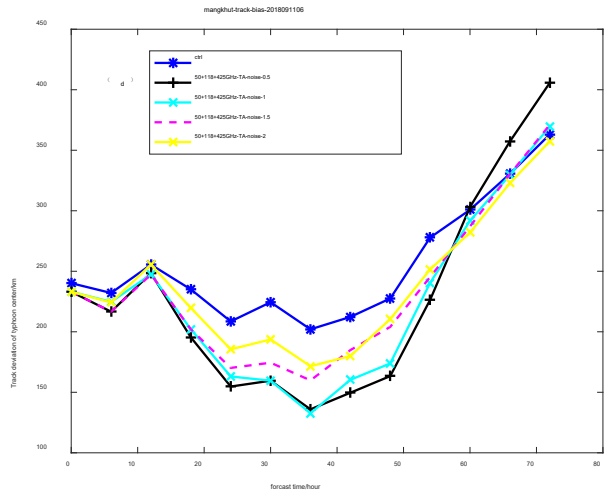
GEO-MW OSSE——Radiometer noise analysis

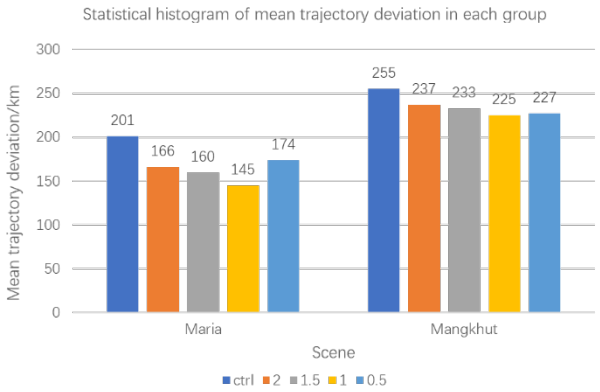
- Simulated GEO-MW brightness temperature data with 0.5, 1.0, 1.5 and 2.0 times the standard noise level were assimilated into GRAPES by 4D-Var, respectively.
- Verification against the CTRL showed that the reduction of noise level of GEO-MW radiometer can improve the prediction accuracy of the track for Typhoons Maria and Mangkhut.











Compared with CTRL, DA with 1.0, 1.5 and 2.0 times the standard noise level can improved the average 72-h typhoon track forecast accuracy by 19.7%, 14.5%, and 12.1%, respectively.

Summary

/04

Summary

- Verification against the control experiment showed that the experiment with the assimilated GEO-MW data gave a consistently more accurate prediction of the track for Typhoons *Maria* and *Mangkhut*.
- GEO-MW OSSEs analysis showed more frequency channels, reducing the time interval and noise level can improve the prediction accuracy of the typhoon track.
- To further consolidate the conclusions, more experiments concerning different cases are needed.

Thanks