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GSICS
Global Space-based Inter-Calibration System

Spatio-temporal fusion of lunar brightness temperature from multi-source remote sensing data

Lide Zhu[1], Hongchun Zhu[1*], Yong Zhang[2*]

1 College of Geodesy and Geomatics, Shandong University of Science and Technology, Qingdao, China

2 National Satellite Meteorological, China Meteorological Administration, Beijing, China

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Outline

1. Research Background of Lunar Brightness Temperature Data

2. Acquisition of Multi-source Lunar Brightness Temperature Data

3. Lunar Brightness Temperature Model based on Multi-source Remote Sensing Data Considering Spatio-Temporal Characteristics

4. Spatio-temporal Fusion Model to Reconstruct Brightness Temperature data

01

Research Background of Lunar Brightness Temperature Data

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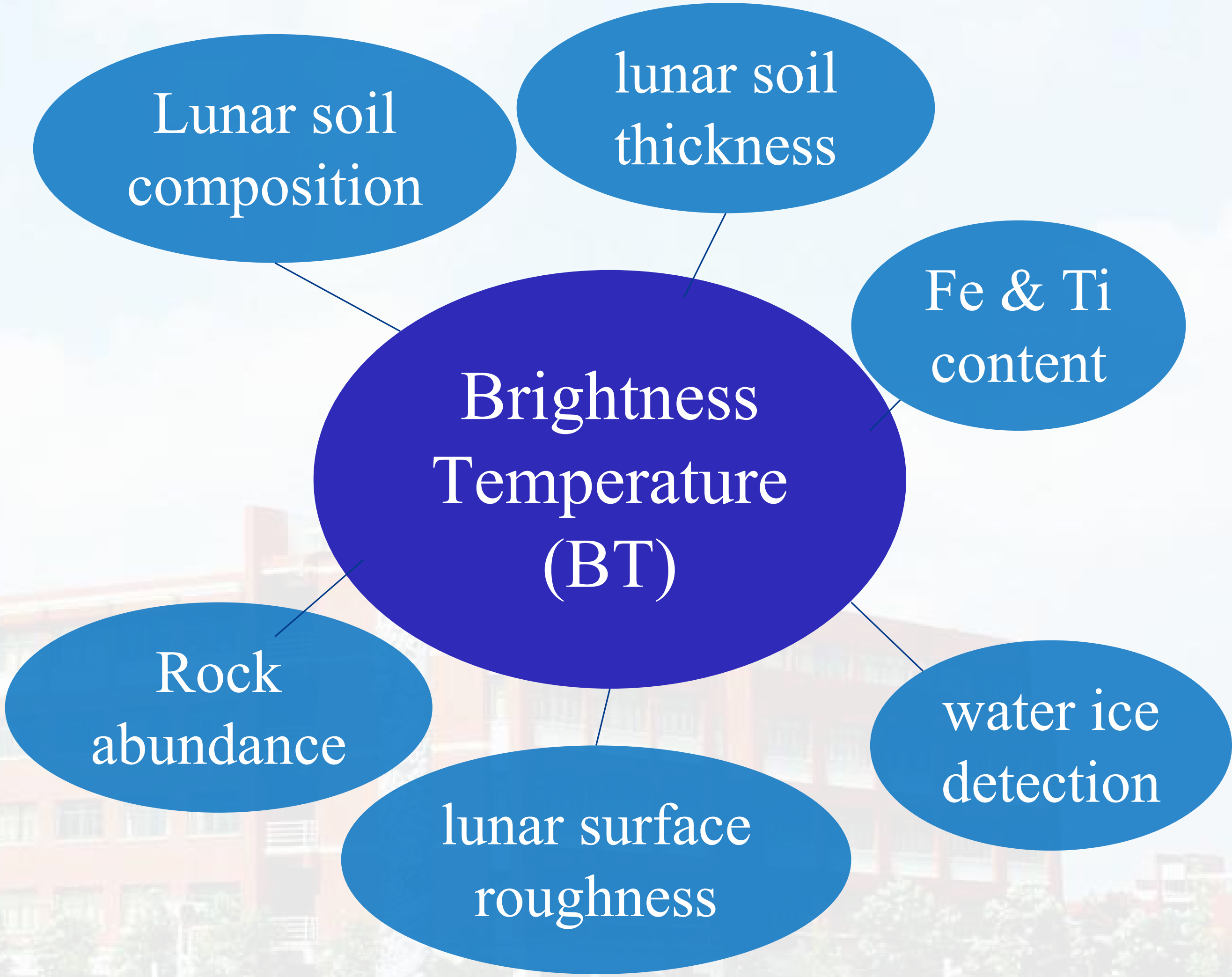
Research Background

As the only natural satellite of the Earth, the lunar has always been one of the objects of human research and exploration. The atmosphere on the lunar surface is very thin, and the internal heat source is slightly hot. The main energy source is solar radiation, which is the main heat source driving the change of the lunar brightness temperature （BT）. Its BT data carries rich geological, geochemical and topographic information, which is of great significance for revealing the lunar internal structure, geological evolution process and potential resources.



Research Background

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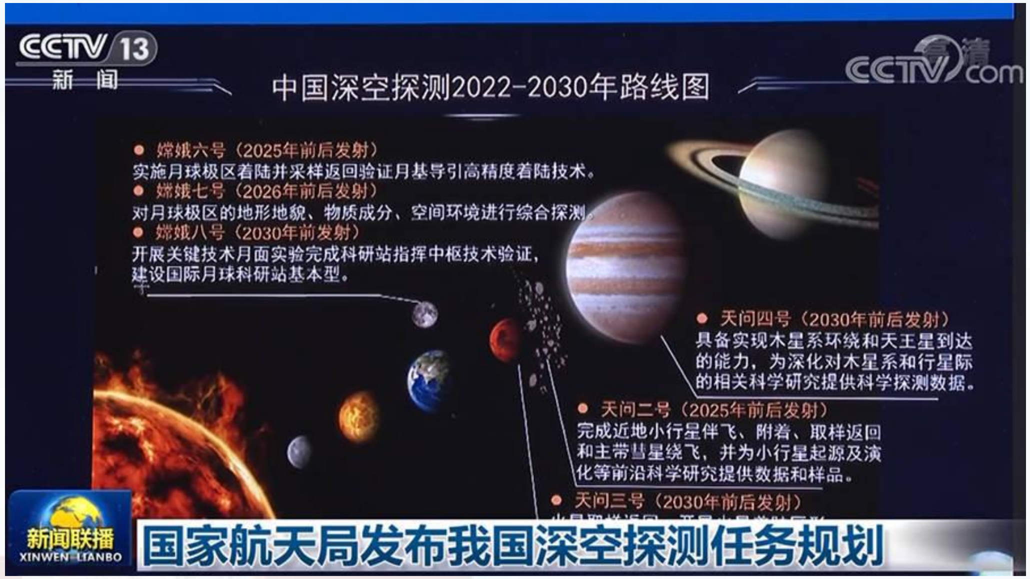
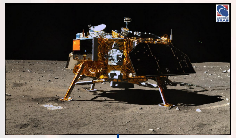
In 2004, China officially launched the lunar exploration project and named it the "Chang'e Project". In October 2007, the "Chang’e-1" was successfully launched into space. The realization of lunar exploration will be a breakthrough in China's deep space exploration. On May 29, 2023, the lunar landing phase of China's manned lunar exploration project has been launched, and it is planned to realize the first landing of Chinese people on the moon before 2030.



CE-1 2007.10.24

CE-3 2013.12.2



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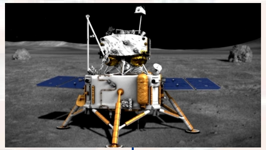

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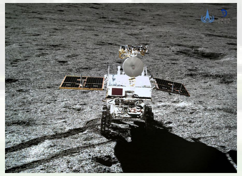
CE-2 2010.10.01

CE-4 2018.12.8



CE-6 2024.5.3

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02

Acquisition of Multi-source Lunar Brightness Temperature Data

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Acquisition of Multi-source Lunar TB Data

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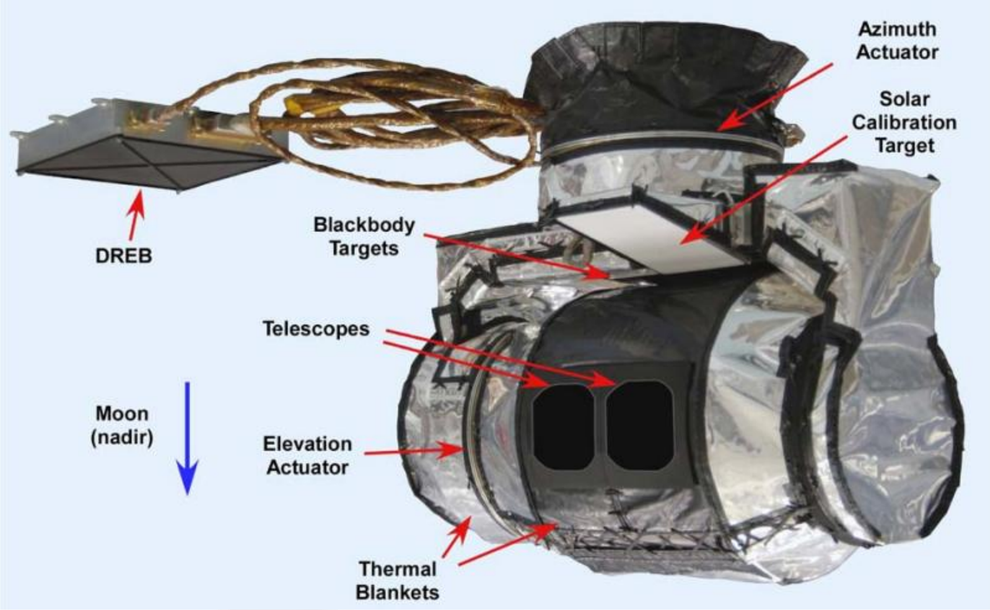
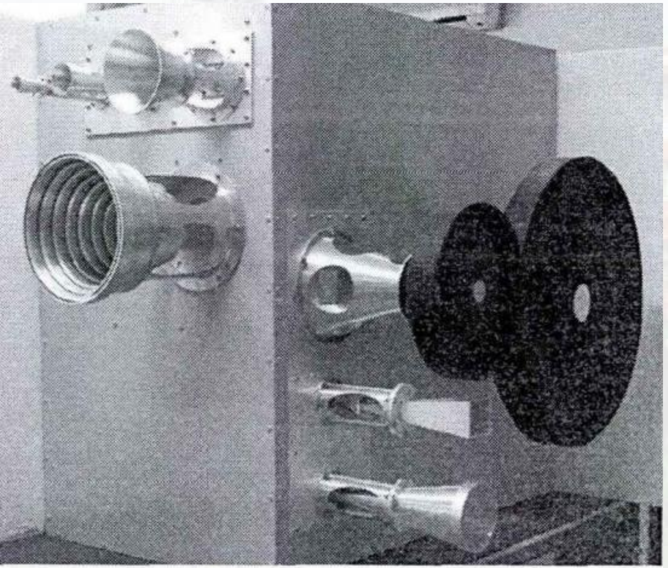
The Diviner probe onboard LRO, is currently the most advanced means of detection, the highest spatial resolution, the best data integrity, and the most complete detection area for lunar infrared research, and has systematically measured the lunar surface, obtaining solar reflection and infrared radiation measurements on a lunar-wide scale .



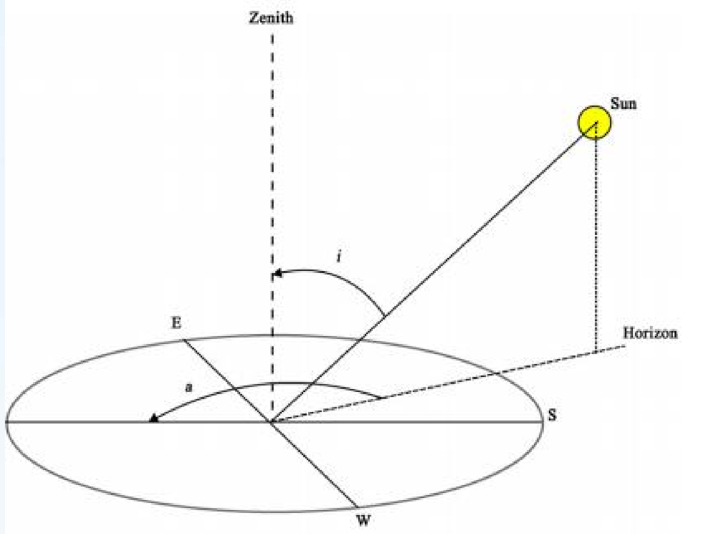
Diviner instrument with major components labeled

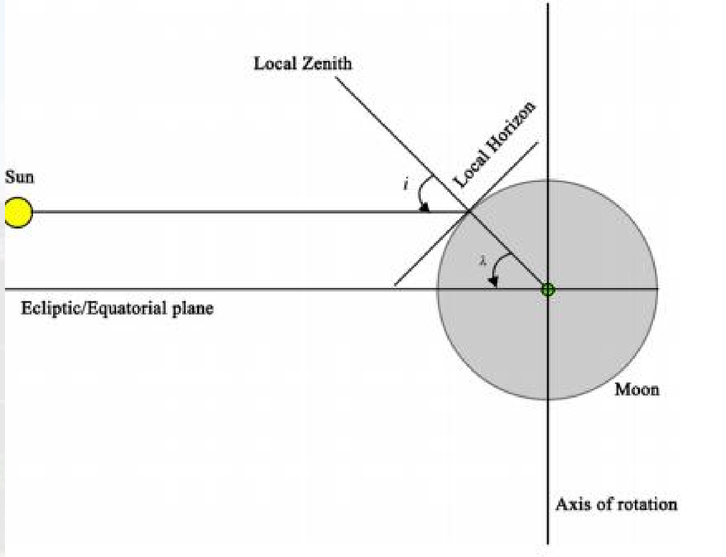
CE-1 Microwave Radiometer



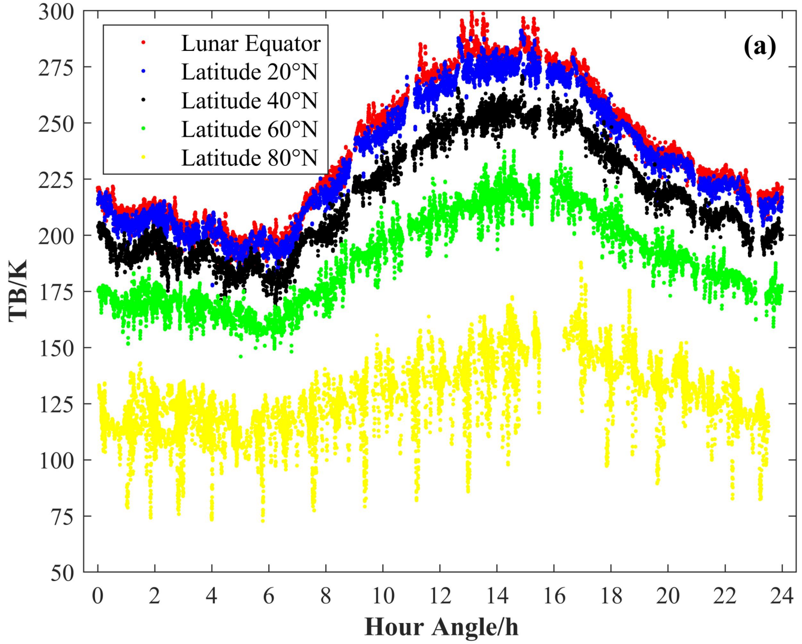
As one of the main payloads, the MRM carried on Chang'e satellite realized the first passive microwave detection around the lunar in the world and obtained the full lunar temperature distribution under four microwave bands [5]. Microwave BT data is very sensitive to the temperature and composition of the shallow lunar surface. The four frequency channels used reflect the temperature and composition information of lunar regolith within different penetration depth ranges.

Acquisition of Multi-source Lunar TB Data



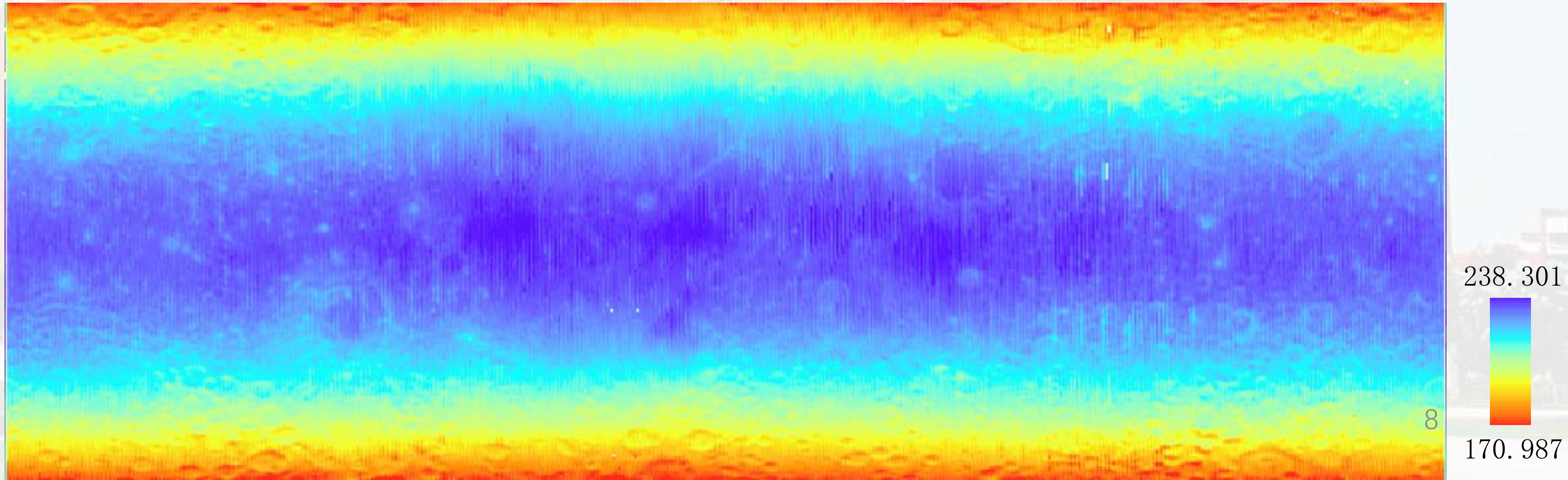


The hour angle correction method



CE-2 37 GHz Microwave BT Data

Based on the Chang'e MRM data, time angle conversion, and simulation of diurnal changes in BT can generate a full lunar TB distribution image.



Acquisition of Multi-source Lunar TB Data

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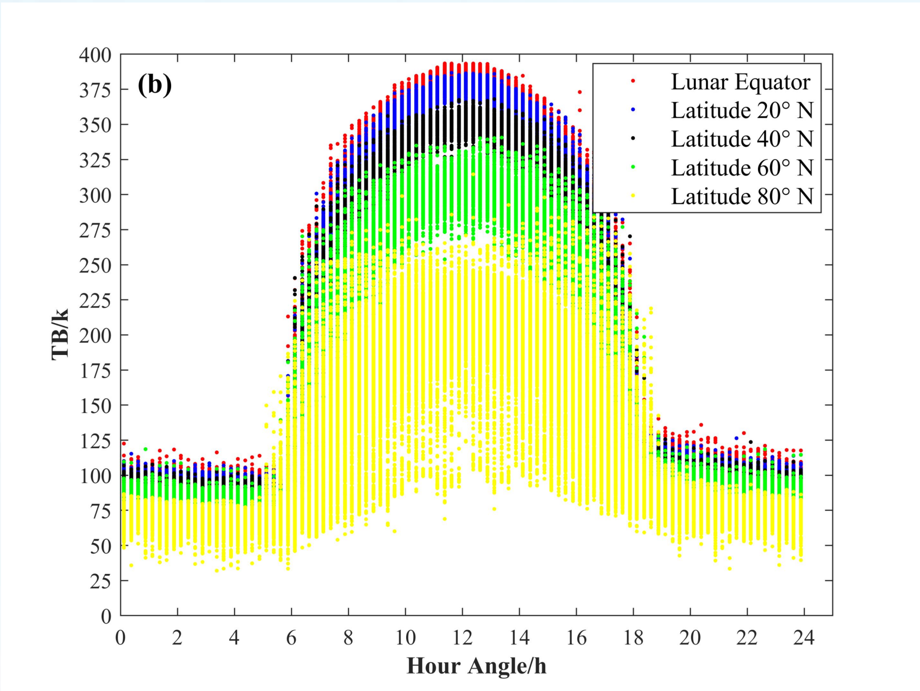
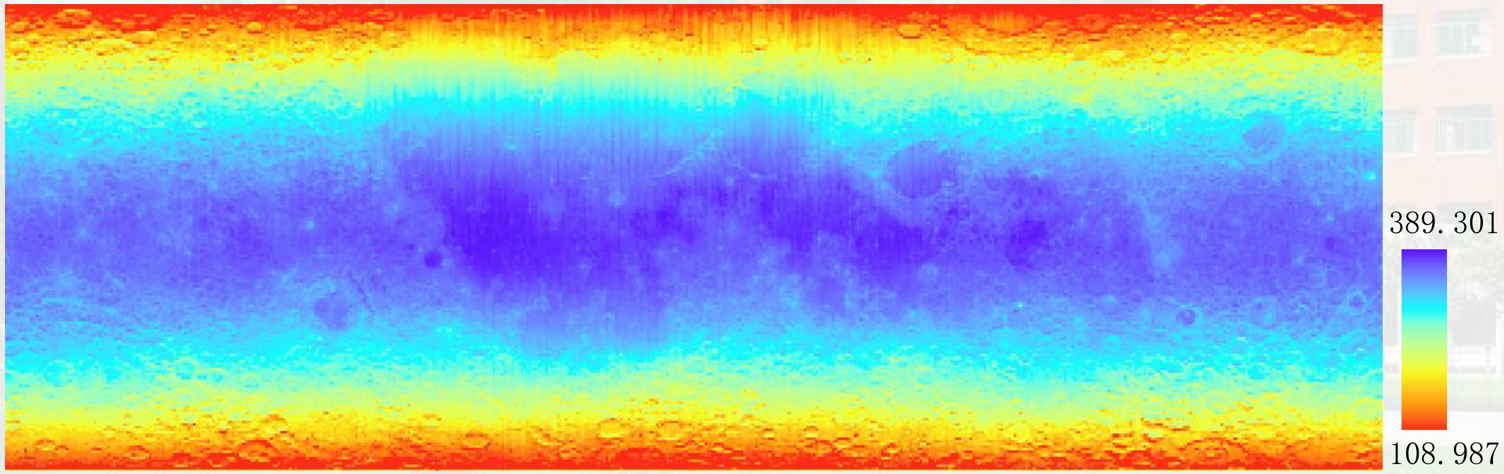
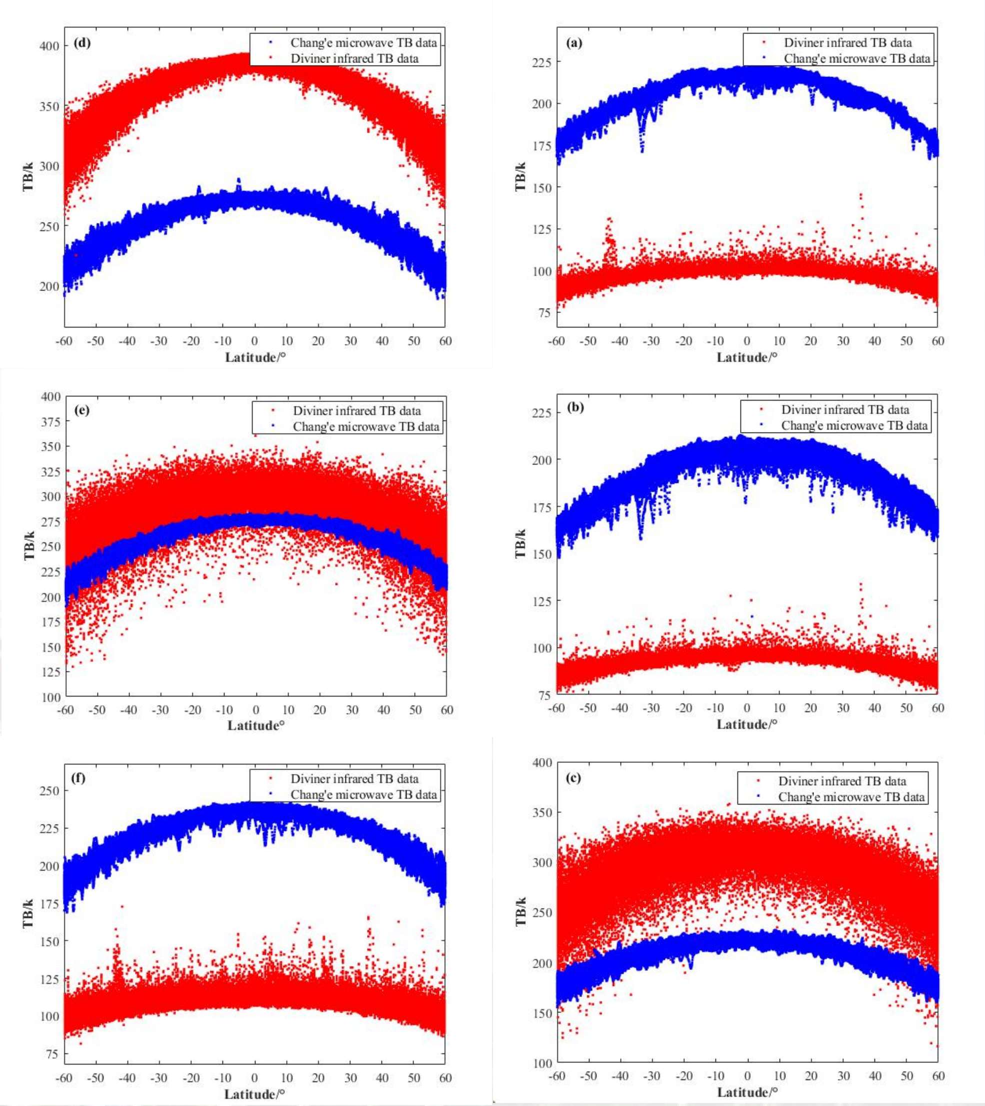


Diviner Channel 7 Infrared BT Data



Infrared BT & microwave BT relationship?

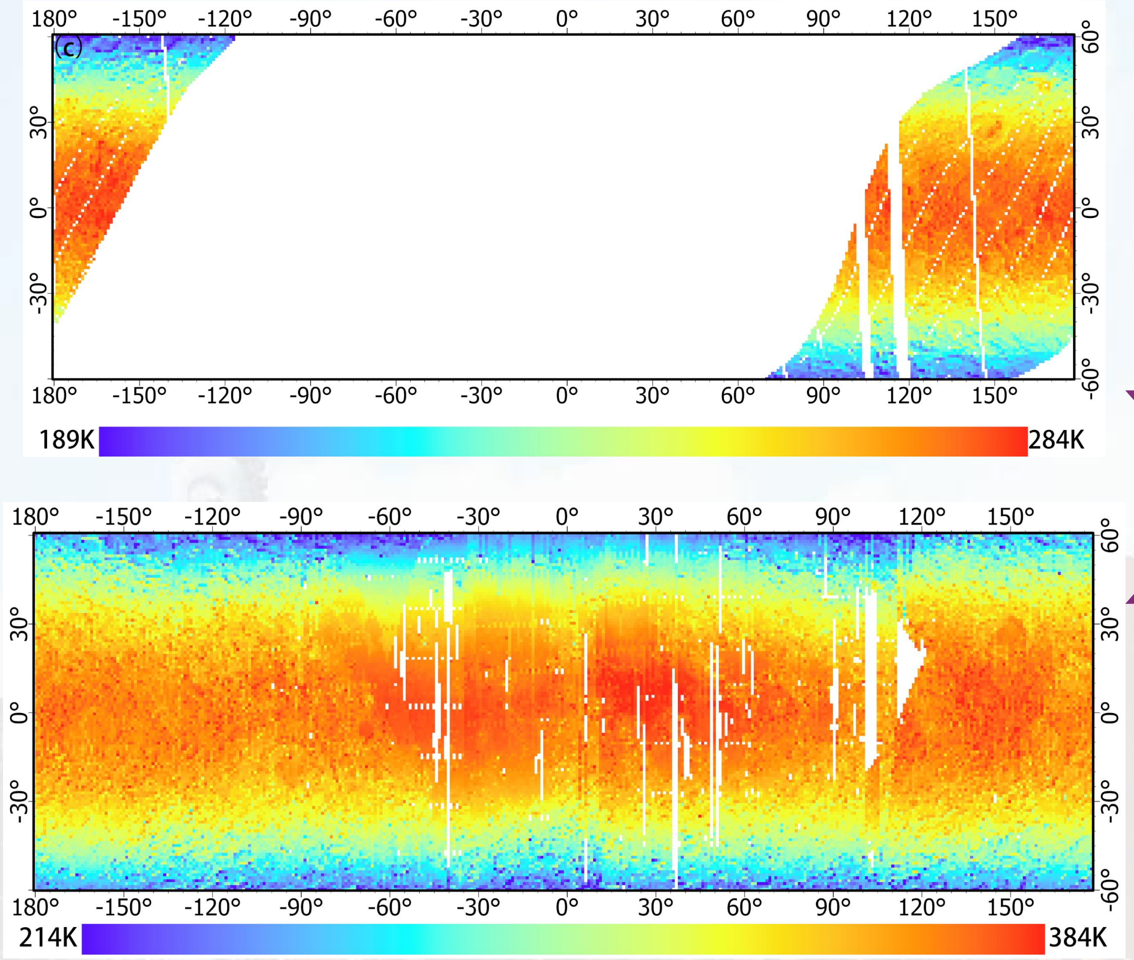


The changes of BT data from different sources in the latitudinal direction at different times.

03

Lunar Brightness Temperature Model based on Multi-source Remote Sensing Data Considering Spatio-Temporal Characteristics

Lunar Brightness Temperature Model

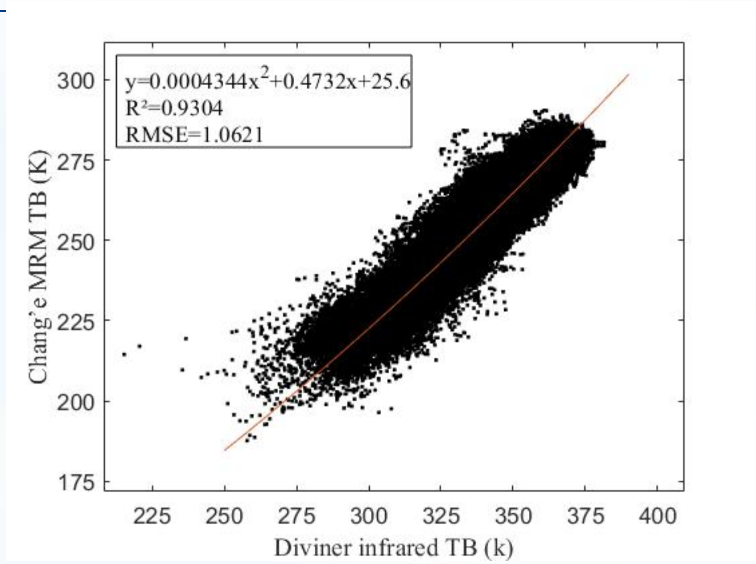


Distribution of microwave and infrared brightness temperature at the same time

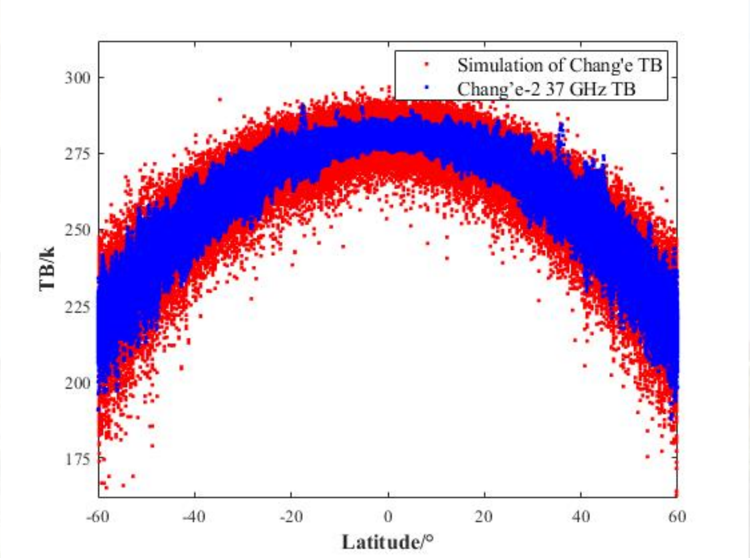
Numerical Modeling Methods

$$TB_{CE} = F(TB_{Diviner})$$

$$y = (A_T)x^2 + (B_T)x + (C_T)$$

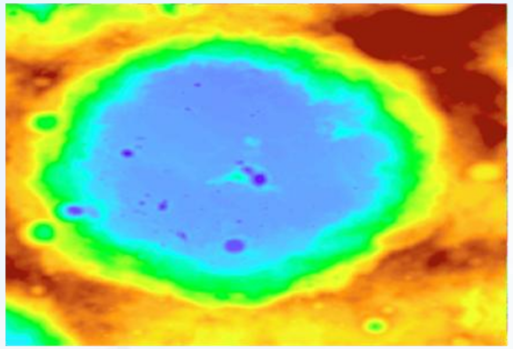


Scatter fitting of multi-source BT data

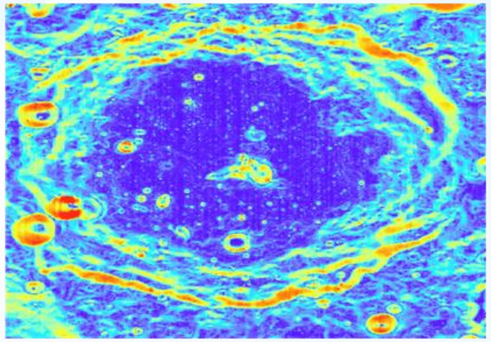


Model effects considering only numerical relationship

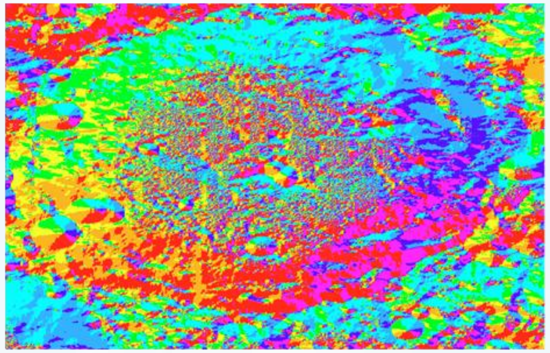
Lunar Brightness Temperature Model



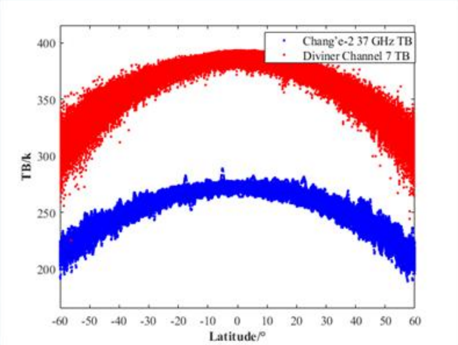
Elevation



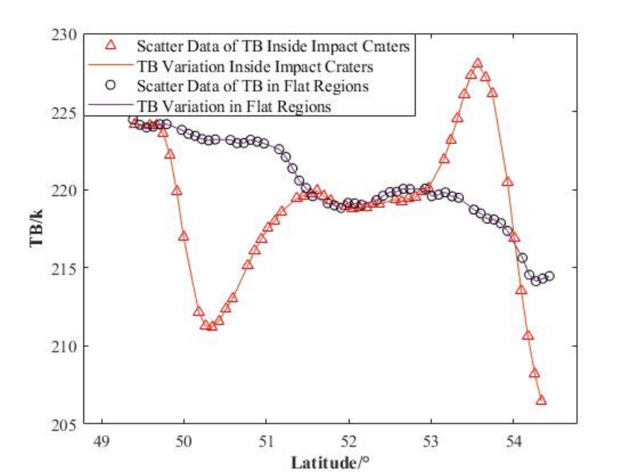
Slope

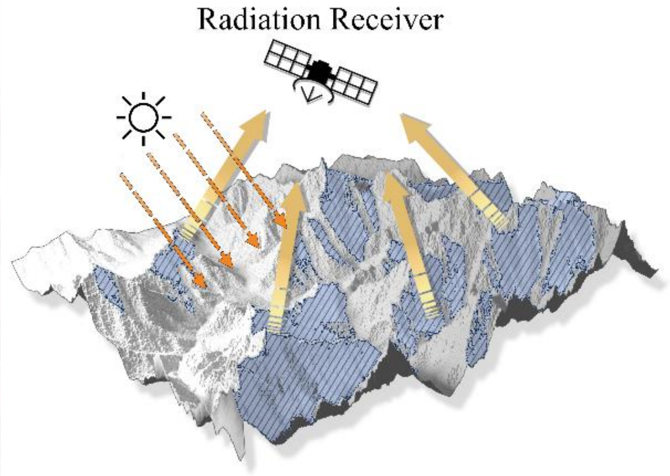


Aspect



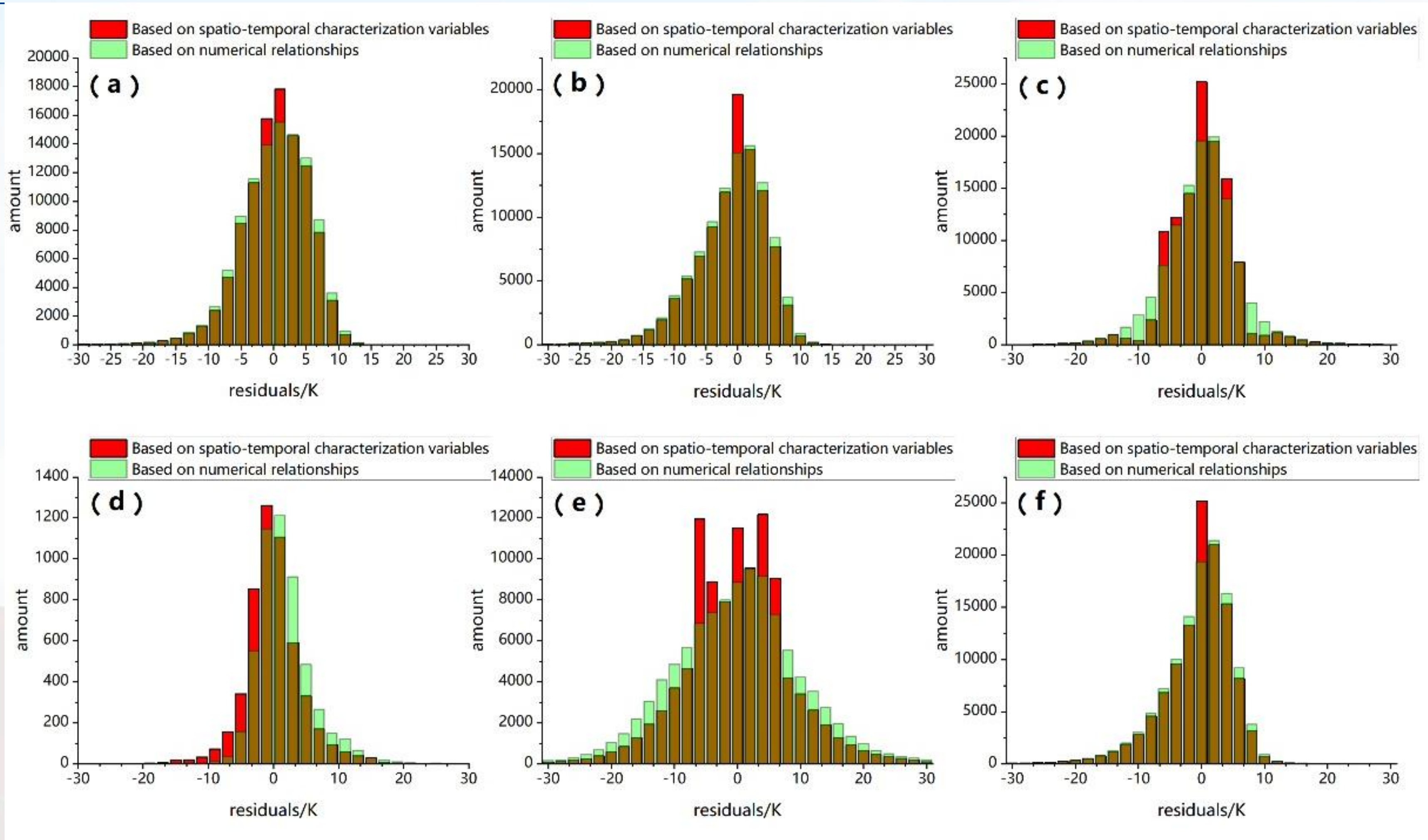
Latitude





$$y=(A_T)x^2+(B_T)x+(C_T) \longrightarrow y=(A_T+A_S)x^2+(B_T+B_S)x+(C_T+C_S)$$

Lunar Brightness Temperature Model



Residual distribution of the multi-source TB relationship model before and after adding spatio-temporal characteristic variables.
(a) 0:00 am. (b) 4:00 am. (c) 8:00 am. (d) 12:00 am. (e) 4:00 pm. (f) 8:00 pm.

Lunar Brightness Temperature Model

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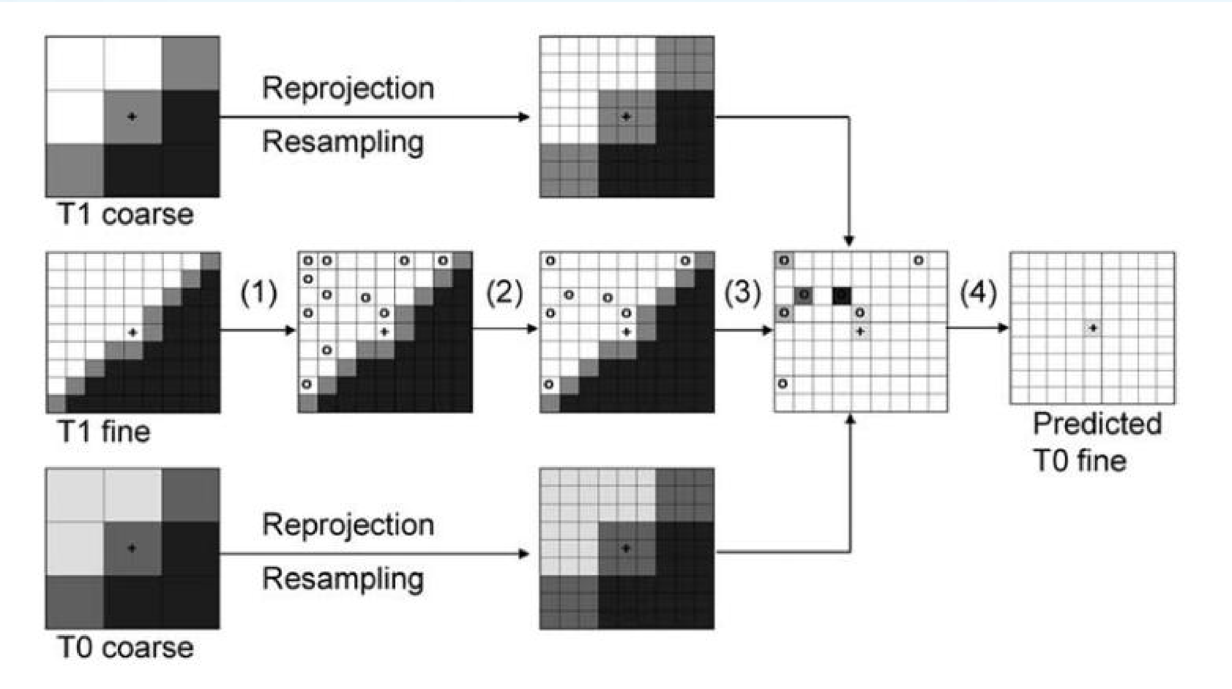
Statistics of residuals generated by the multi-source BT relation model before and after adding spatio-temporal characteristic variables

Parameters	numerical statistics			spatio-temporal characteristic variables		
Time	mean	standard deviation	± within 5k	mean	standard deviation	± within 5k
0： 00	0.0532	6.2353	65.49%	0.0233	6.0288	68.74%
4： 00	-0.9981	5.9062	64.87%	-0.9931	5.6823	67.68%
8： 00	-0.1121	5.8106	68.57%	-0.0280	4.5924	81.08%
12： 00	0. 0116	3.0879	91.35%	0.0215	2.8692	92.76%
16： 00	0.0816	10.0781	41.17%	0.0066	8.5257	57.96%
20： 00	-0.5217	5.6239	69.82%	-0.5438	5.4041	72.53%

04

Spatio-temporal Fusion Model to Reconstruct Brightness Temperature data

Spatio-temporal Fusion Model



In the fusion model, we chose the spatio-temporal adaptive reflectivity fusion model (STARFM) algorithm proposed by Gao ,et al to fuse microwave BT and simulated microwave BT. Using this method, we can mix the high-frequency temporal information from Chang'e microwave BT and the high-resolution spatial information from Diviner infrared BT.

$$TB_{\text{simulate}}\left(x,y,t_p\right)=a\left(x,y,\Delta t\right)\times TB_{\text{simulate}}\left(x,y,t_0\right)+b\left(x,y,\Delta t\right)$$

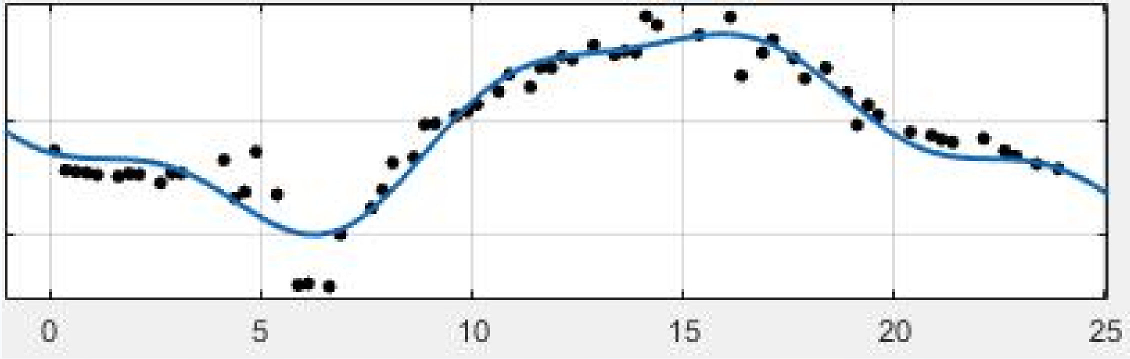
Predicted time | acquisition date | Predicted time | acquisition date

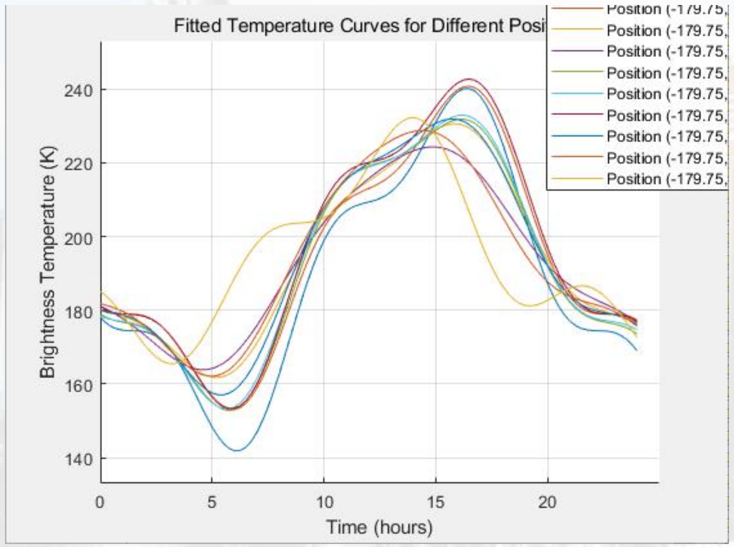
$$TB\left(x,y,t_p\right)=TB\left(x,y,t_0\right)-STB\left(x,y,t_p\right)+STB\left(x,y,t_0\right)$$

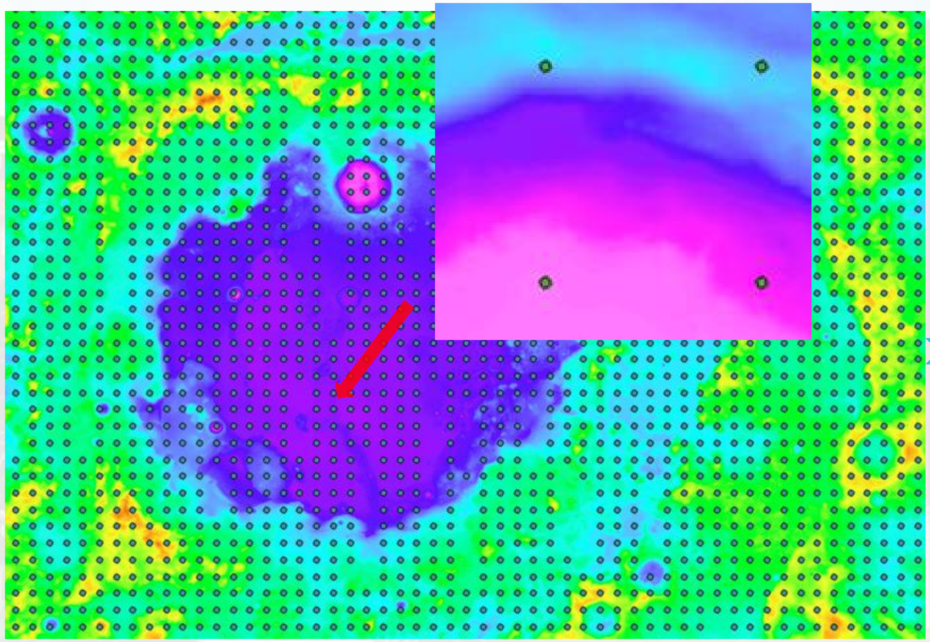
[1] Gao F , Masek J G , Schwaller M R ,et al.On the Blending of the Landsat and MODIS Surface Reflectance: Predicting Daily Landsat Surface Reflectance[J].IEEE Transactions on Geoscience and Remote Sensing, 2006

Spatio-temporal Fusion Model

Based on the time-space fusion (STARFM) algorithm, we simulate the complete time series information of microwave TB.

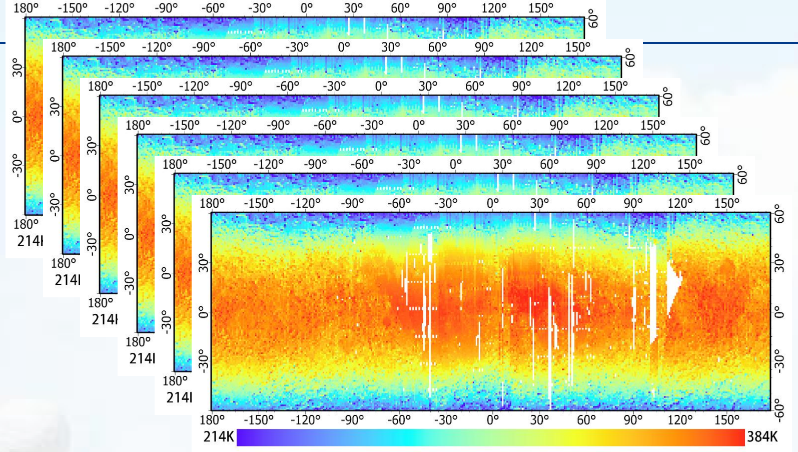




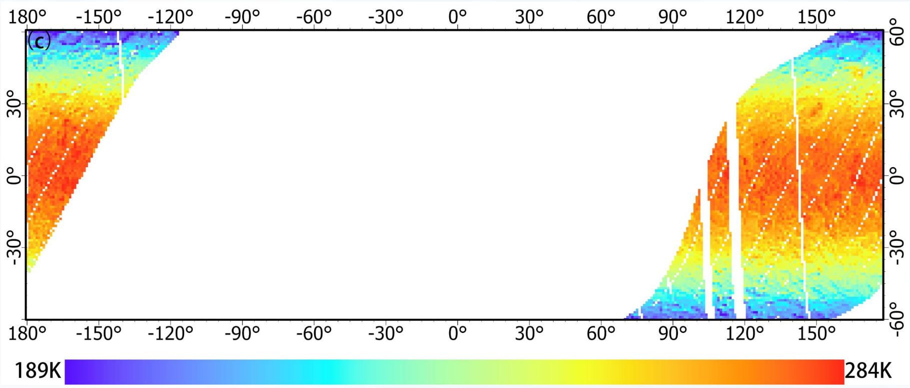


179.7500	59.7500	0.3800	87.1155	171.7702
179.7500	59.7500	0.6200	89.3683	175.8103
179.7500	59.7500	0.8800	89.2985	175.6526
179.7500	59.7500	1.1200	88.2756	172.8200
179.7500	59.7500	1.3800	86.9061	167.8822
179.7500	59.7500	1.6200	86.8596	169.0736
179.7500	59.7500	2.1200	86.3311	171.3606
179.7500	59.7500	2.3800	87.4609	171.2028
179.7500	59.7500	2.6200	86.8500	171.0043
179.7500	59.7500	2.8800	86.0840	170.5112
179.7500	59.7500	3.1200	85.0157	165.5171
179.7500	59.7500	3.3800	85.8185	169.0497
179.7500	59.7500	4.3800	83.4815	163.5399
179.7500	59.7500	4.6200	84.4451	162.4585
179.7500	59.7500	4.8800	83.4846	159.1706
179.7500	59.7500	5.1200	84.6795	164.6863
179.7500	59.7500	5.3800	82.1595	156.3964
179.7500	59.7500	5.6200	84.1637	161.1620
179.7500	59.7500	5.8800	81.8797	100.4348
179.7500	59.7500	6.3800	146.4560	170.2309
179.7500	59.7500	6.6200	145.8993	149.1112
179.7500	59.7500	6.8800	147.8056	129.3876
179.7500	59.7500	7.8800	233.9668	174.4489
179.7500	59.7500	8.3800	242.7470	173.2798
179.7500	59.7500	8.6200	234.9671	164.7808
179.7500	59.7500	9.1200	266.1190	182.8988
179.7500	59.7500	10.1200	291.0636	194.8322
179.7500	59.7500	10.3800	296.5572	198.5599
179.7500	59.7500	11.3800	301.8971	206.1981
179.7500	59.7500	11.6200	298.4543	200.5612
179.7500	59.7500	11.8800	299.9127	205.6167
179.7500	59.7500	12.1200	304.4324	209.8131
179.7500	59.7500	12.3800	311.3023	214.5492
179.7500	59.7500	12.8800	305.7257	215.6820
179.7500	59.7500	13.3800	299.6021	214.5309
179.7500	59.7500	13.6200	295.0743	216.6921
179.7500	59.7500	13.8800	290.7098	214.4230
179.7500	59.7500	14.1200	304.1732	227.3032
179.7500	59.7500	14.6200	286.6587	221.3071
179.7500	59.7500	15.1200	267.8364	212.7053
179.7500	59.7500	15.8800	272.9645	237.3891

Spatio-temporal Fusion Model

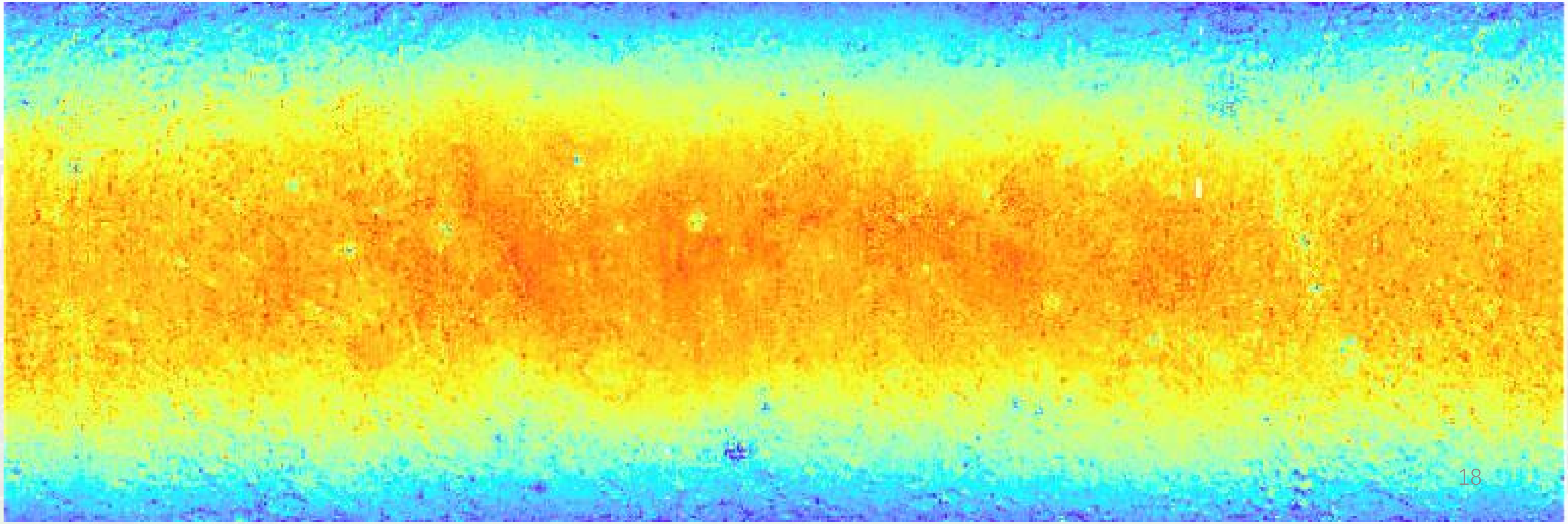


Simulate microwave BT time series information



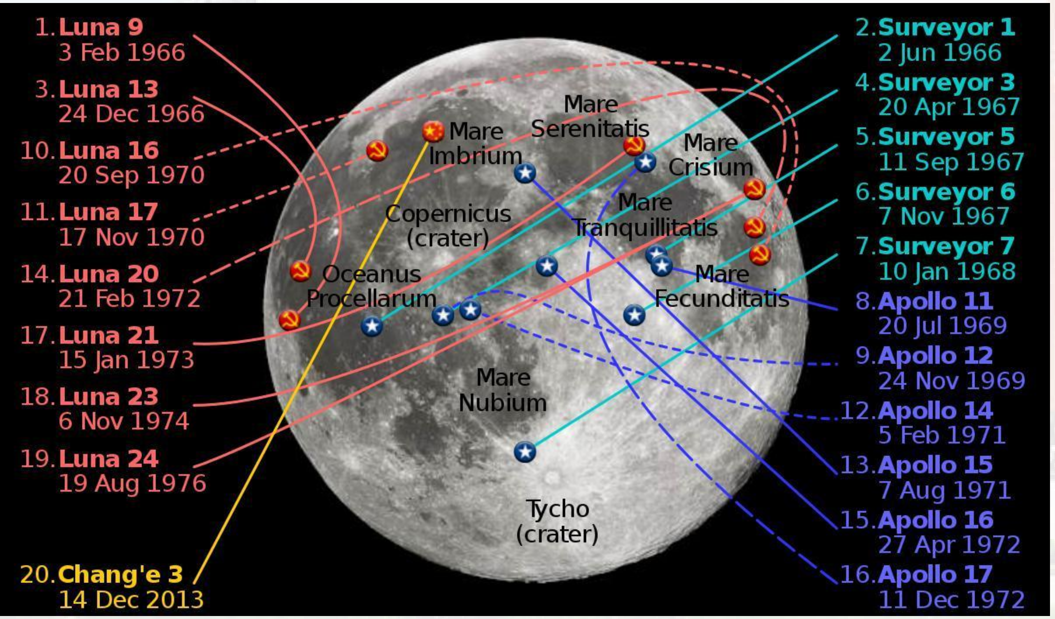
Chang'e microwave BT measured data

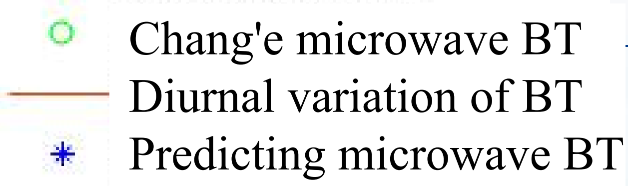
12：00
fusion
microwave
BT

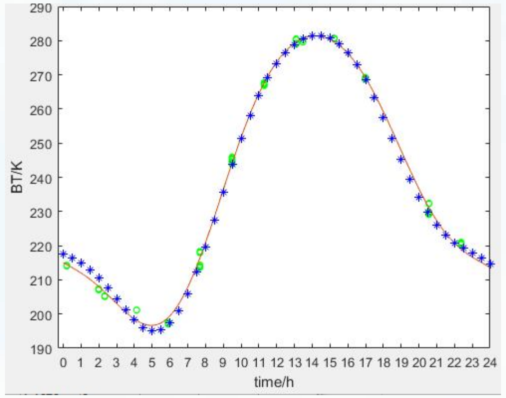


Spatio-temporal Fusion Model

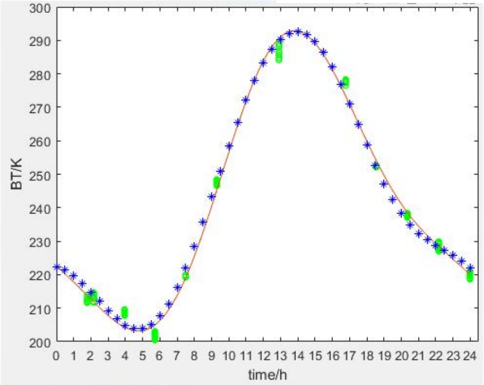
Area	Lat	Lot
Mare Serenitatis	31.5°W	44.1°N
Apollo 12	23.2°W	3.0°S
Apollo 15	3.4°E	26.1°N
Apollo 16	15.3°E	9.0°S
Lunar 20	56.4°E	3.5°N
CE 5	51.5°W	43.0°N



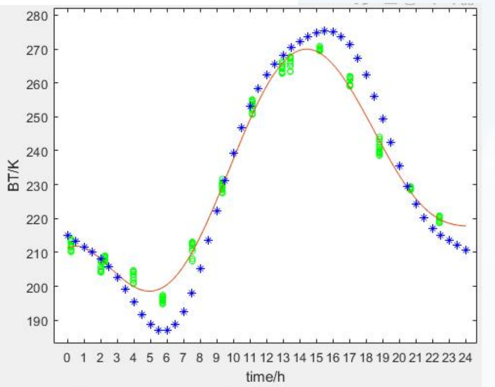




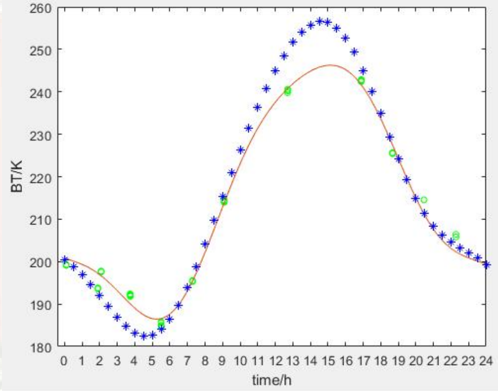
Mare Serenitatis



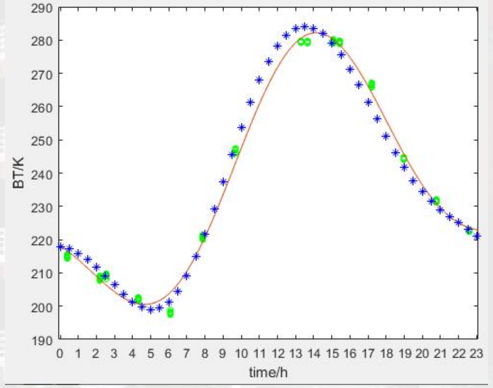
Apollo 12



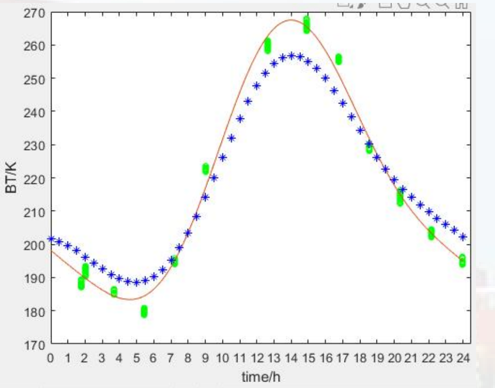
Apollo 15



Apollo 16



Lunar 20



CE 5

Spatio-temporal Fusion Model

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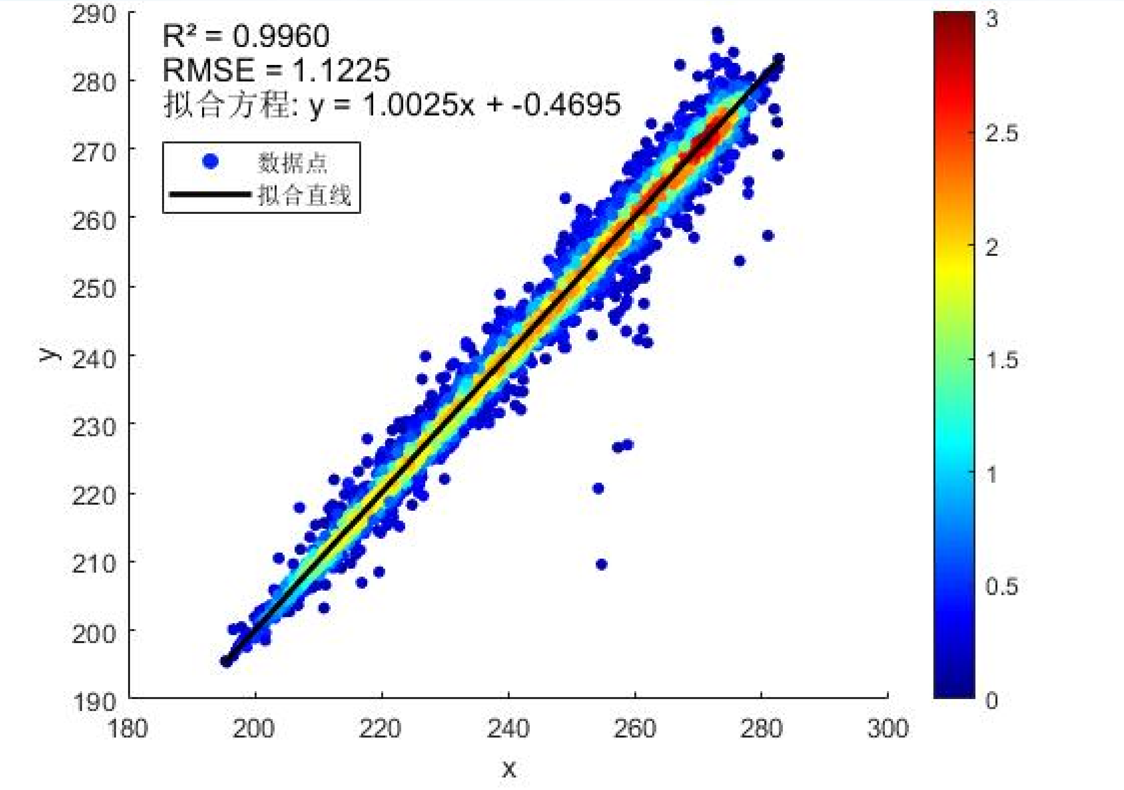
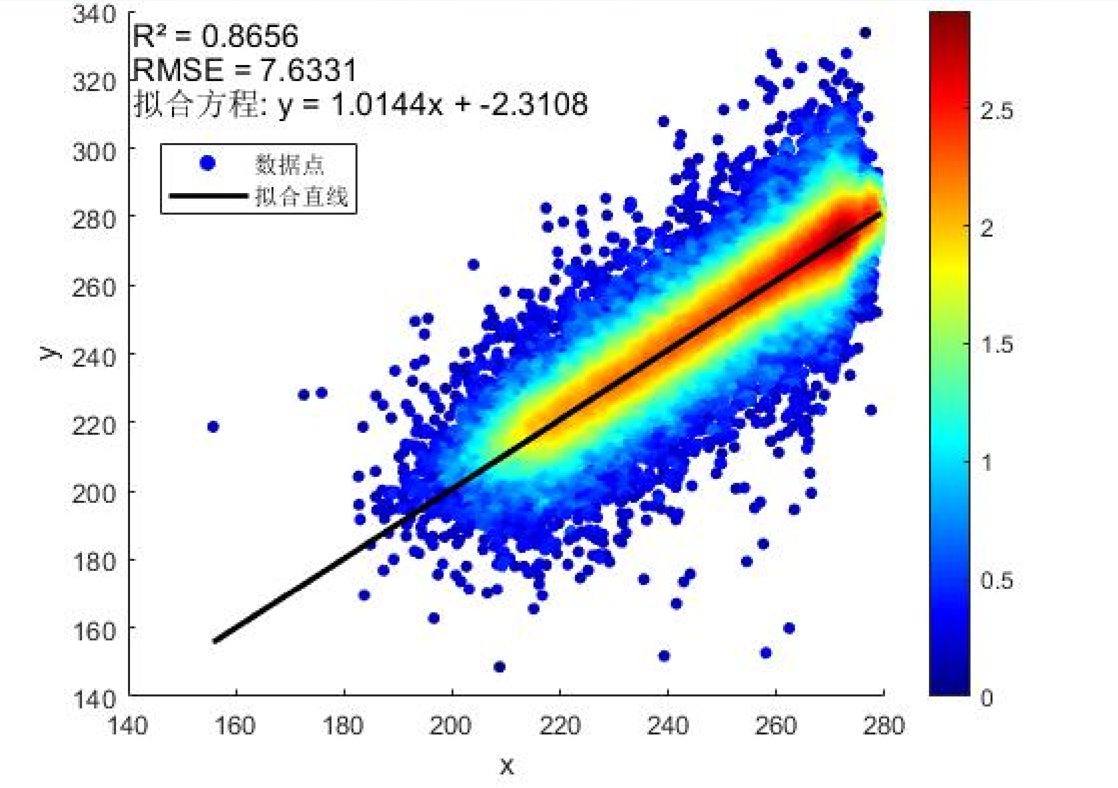
The obtained 12:00 fused microwave BT dataset was verified with the measured microwave BT data (11.875-12.125) and the simulated microwave BT data (12.12) to prove the accuracy and reliability of the fused microwave BT dataset.



Predicting microwave BT & Chang'e microwave BT



Predicting microwave BT & Simulate microwave BT

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Conclusions and Discussions

1.We conduct a comprehensive analysis of the effects of time, latitude, and geomorphic factors on solar radiation received at the lunar surface. The angle and distance of solar radiation incident on the lunar surface, governed by spatio-temporal characteristics, are found to collectively determine the complex pattern of BT distribution.

2.Based on the Diviner infrared BT data, we applied the multi-source BT relation model considering spatio-temporal characteristics to establish high-quality simulated microwave BT data, thereby improving the coverage and spatio-temporal resolution of microwave BT data.

3.Based on the method concept of spatio-temporal fusion model, combined with the high spatial resolution of simulated microwave BT and the high temporal resolution of Chang'e microwave BT, the seamless BT distribution of the moon throughout the day at 0.5° spatial resolution was obtained.

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THE END

Thanks for your attention!

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Reporter：Lide Zhu

Correspondence: zld0122@sdust.edu.cn