

Earth's radiation budget and energy balance based on CMIP6 historical experiment

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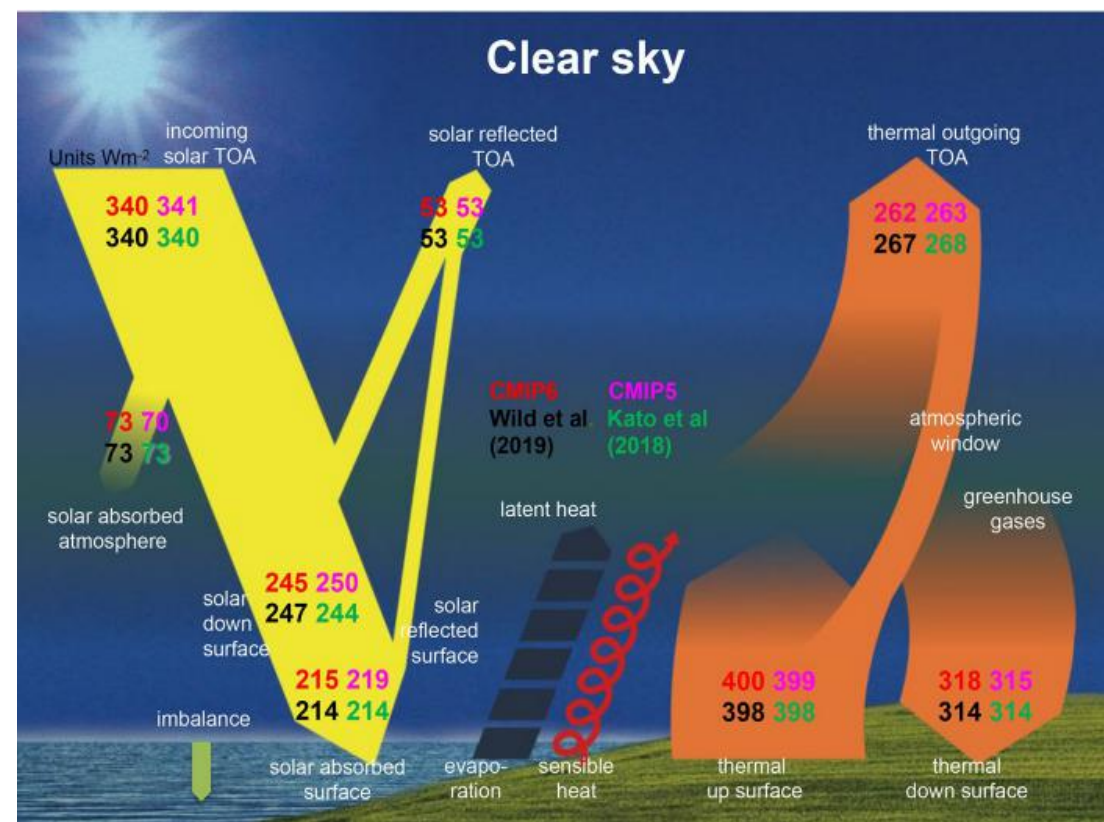
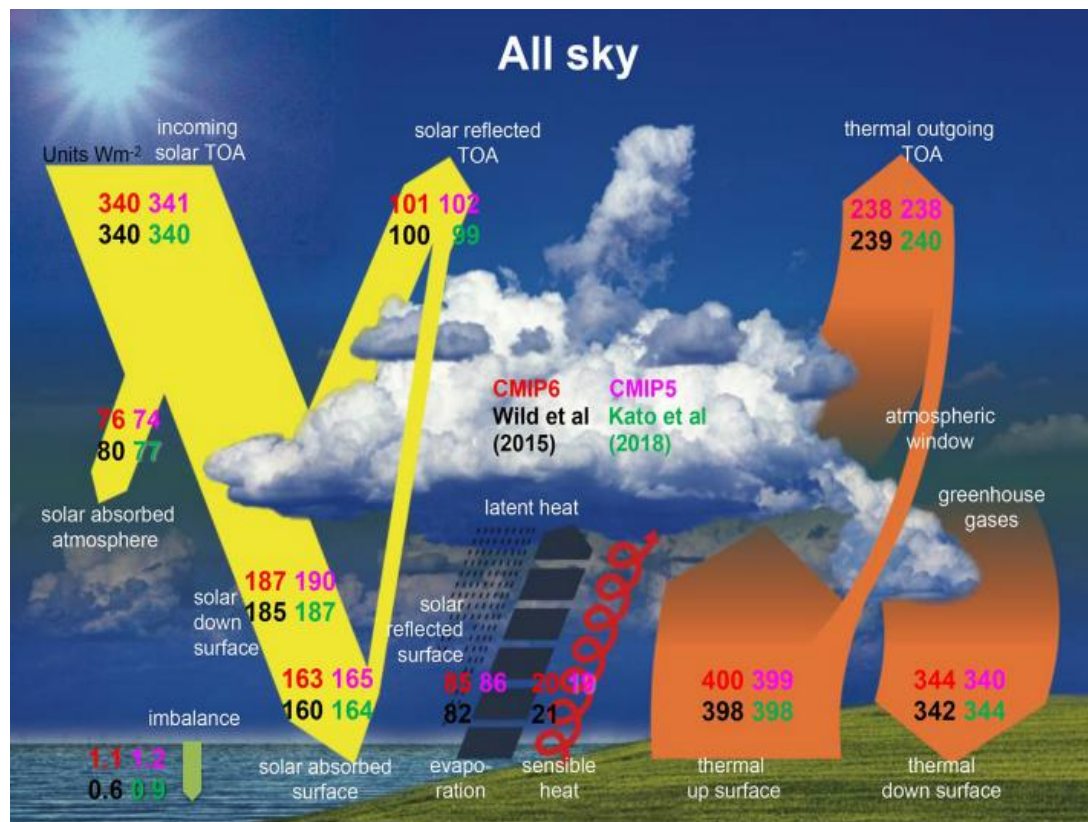
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5. 下一步计划

1. 辐射收支与能量平衡对于研究气候变化的重要性



(Wild et al., 2020)

与地面直接观测的比较表明，气候模型倾向于高估地面向下的短波辐射，而低估了向下的长波辐射，这是一个长期存在的问题，已经存在了数十年，并持续了几代GCM的发展。

2. 数据与方法

2.1 Coupled Model Intercomparison Project phase 6 (CMIP6)

截至2020年05月16日，共有36个模型上传了辐射与能量通量的数据，其历史模拟时间跨度为1850年至2014年。

2.2 Clouds and Earth's Radiant Energy System (CERES)

自2000年3月开始观测至今，大气顶层各变量数据源自直接观测，地表各变量数据由计算得出。

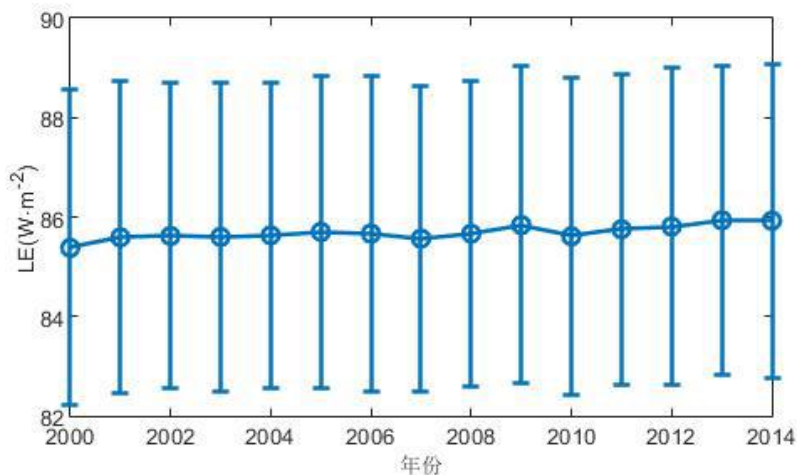
变量	潜热通量	感热通量	地表向下长波	晴空地表向下长波	地表向上长波	地表向下短波	晴空地表向下短波	地表向上短波	晴空地表向上短波	大气顶层入射短波	大气顶层出射短波	晴空大气顶层出射短波	大气顶层出射长波	晴空大气顶层出射长波
缩写	LE Flux	SH Flux	L_{\downarrow} -SFC	L_{\downarrow} -SFC-C	L_{\uparrow} -SFC	K_{\downarrow} -SFC	K_{\downarrow} -SFC-C	K_{\uparrow} -SFC	K_{\uparrow} -SFC-C	K_{\downarrow} -TOA	K_{\uparrow} -TOA	K_{\uparrow} -TOA-C	L_{\uparrow} -TOA	L_{\uparrow} -TOA-C

3. 结果

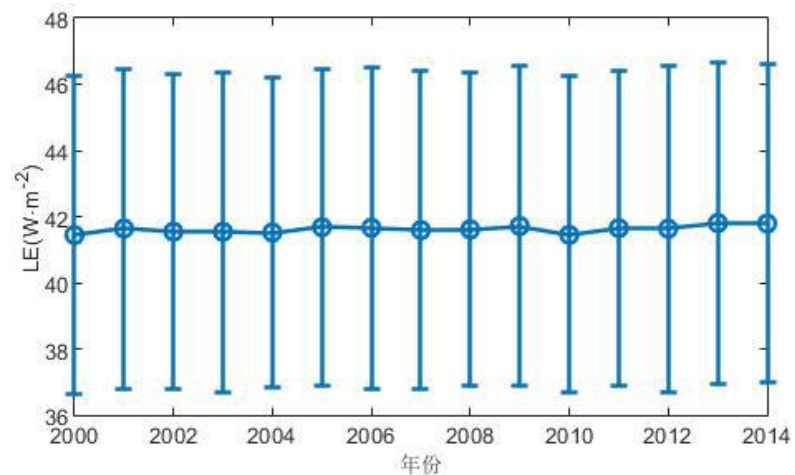
3.1 CMIP6与CERES各变量全球，陆地，海洋年际变化特征

3.1.1 潜热通量

全球



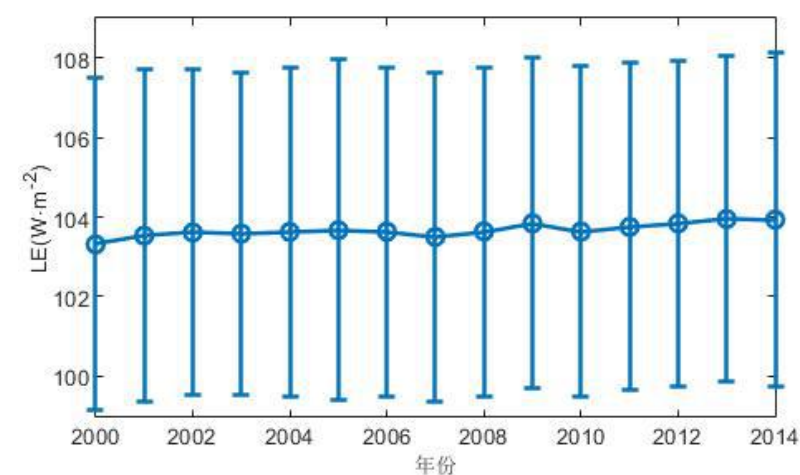
陆地



CMIP6

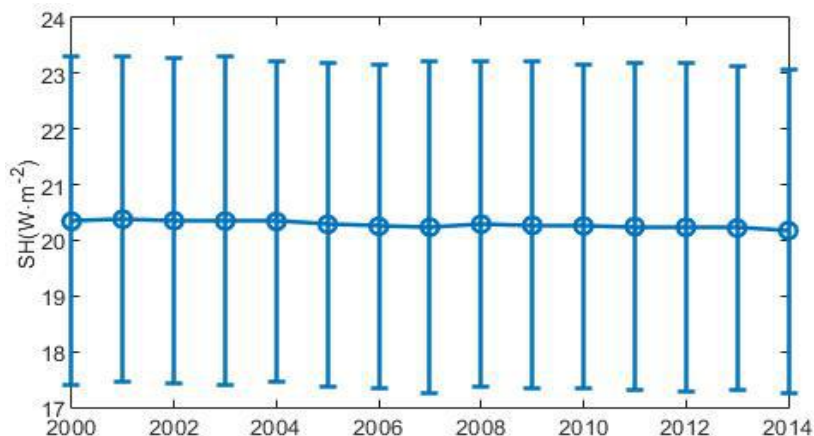
CERES

海洋

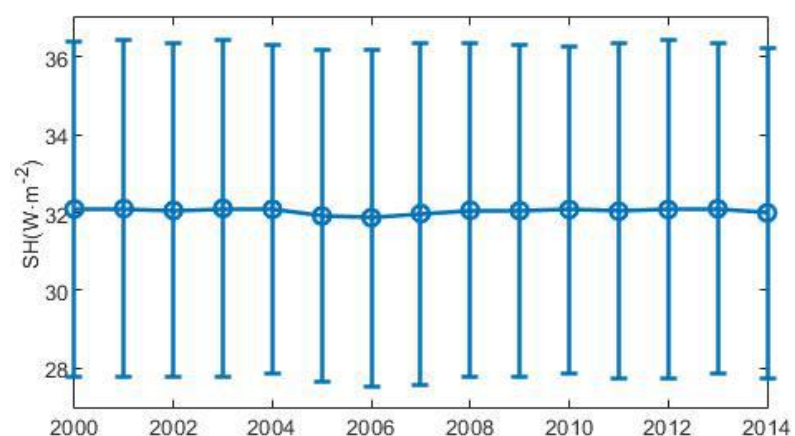


3.1.2 感热通量

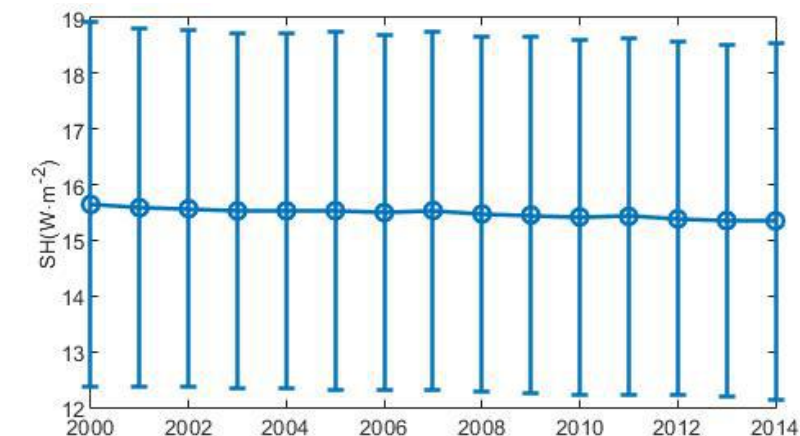
全球



陆地

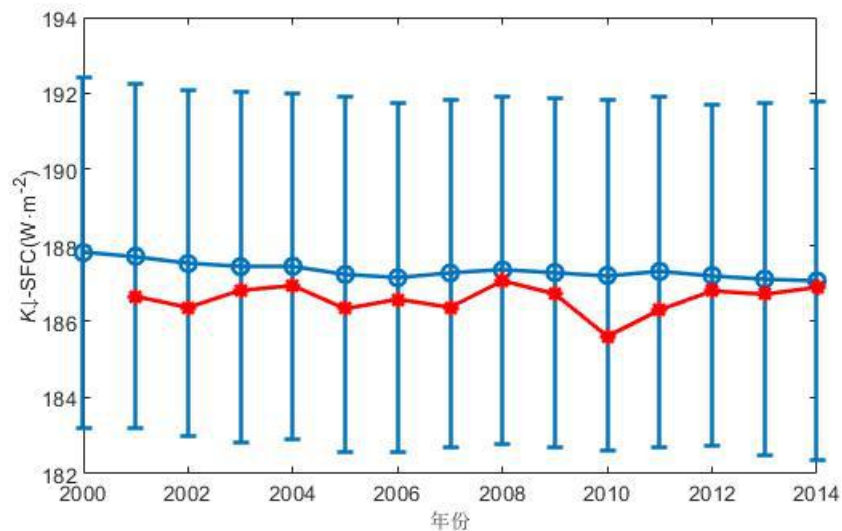


海洋

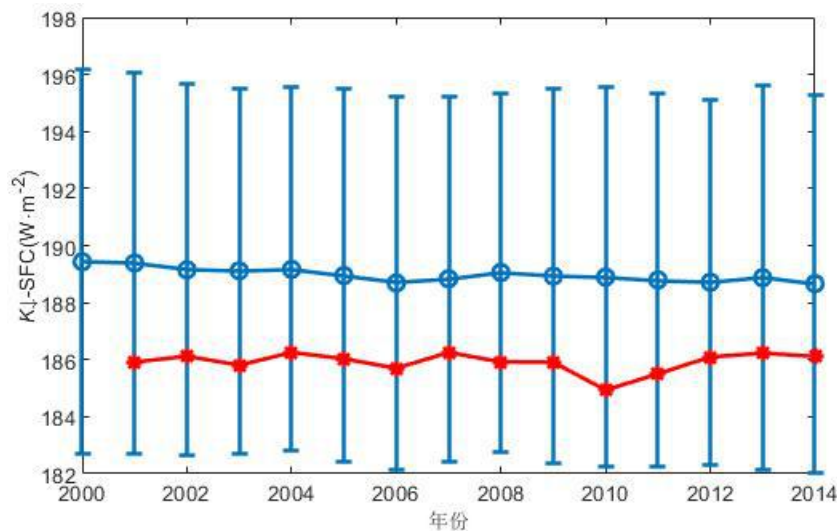


3.1.3 地表向下短波

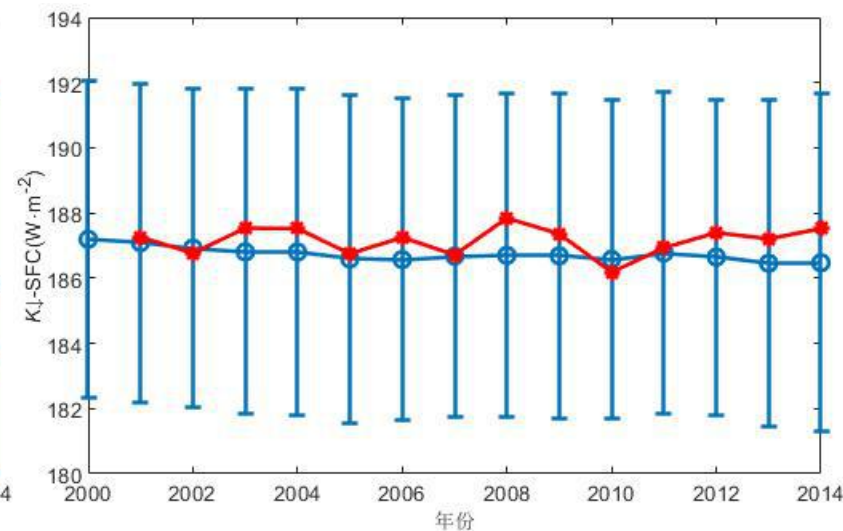
全球



陆地

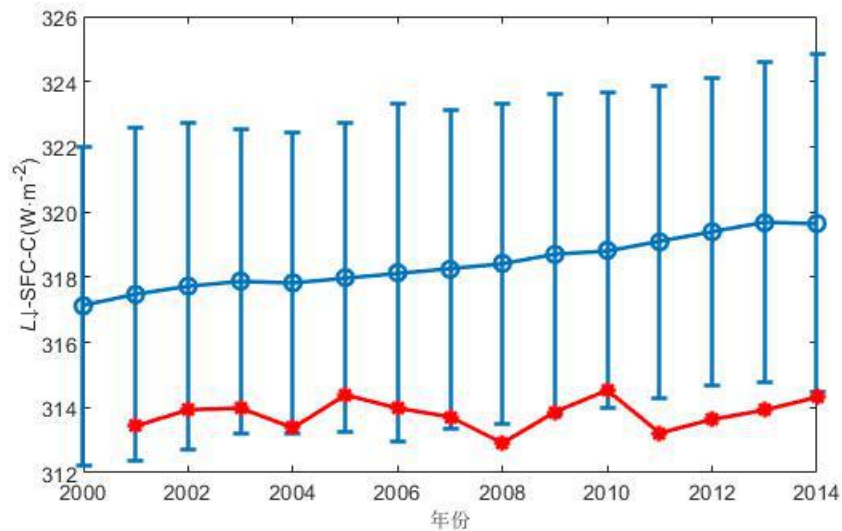


海洋

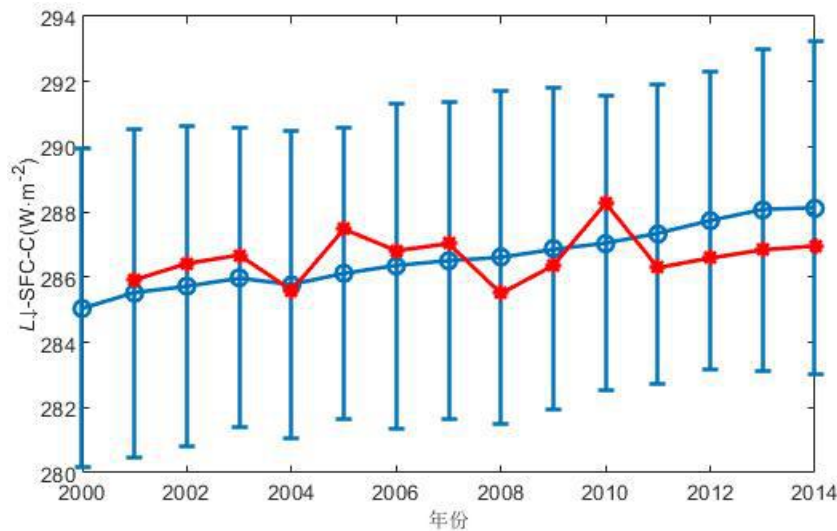


3.1.4 晴空地表向下短波

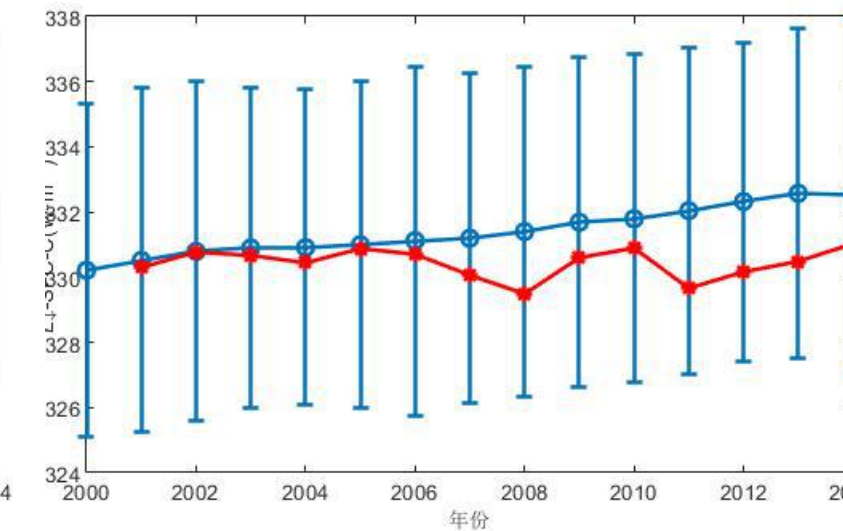
全球



陆地

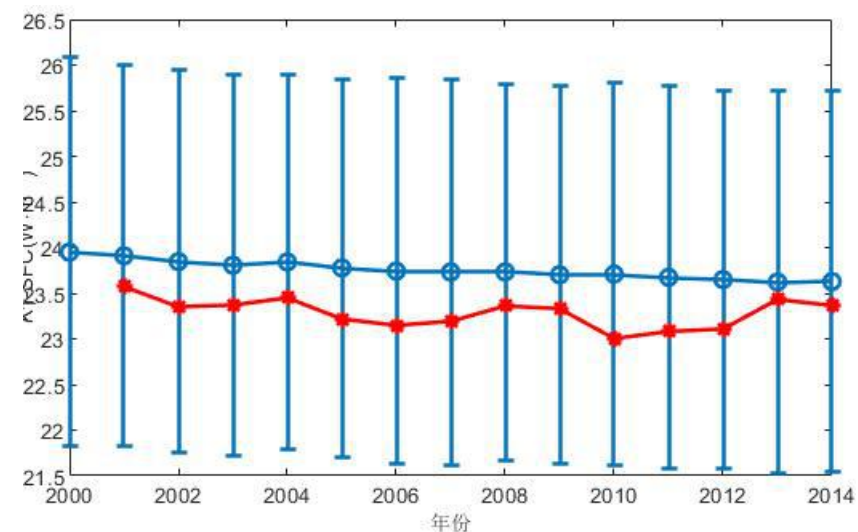


海洋

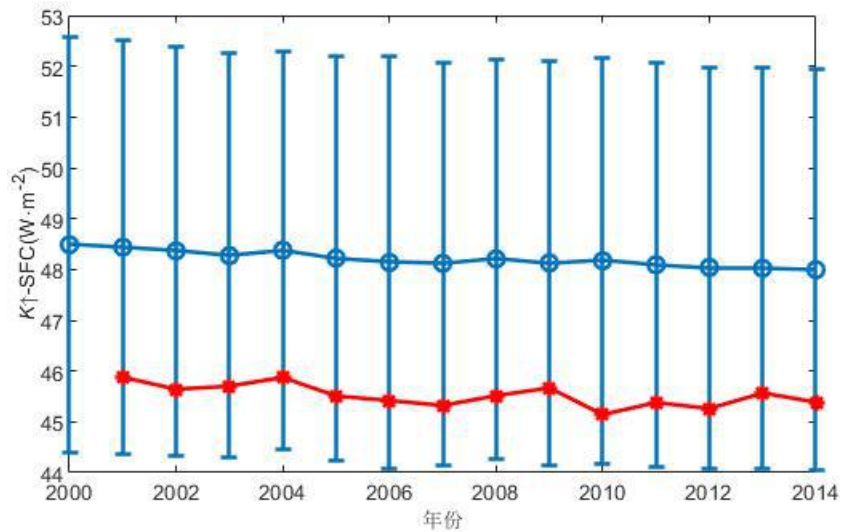


3.1.5 地表向上短波

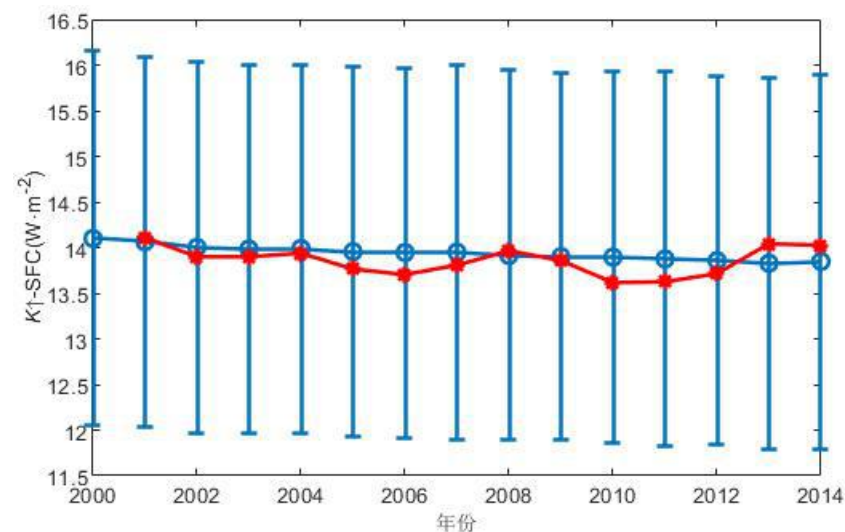
全球



陆地

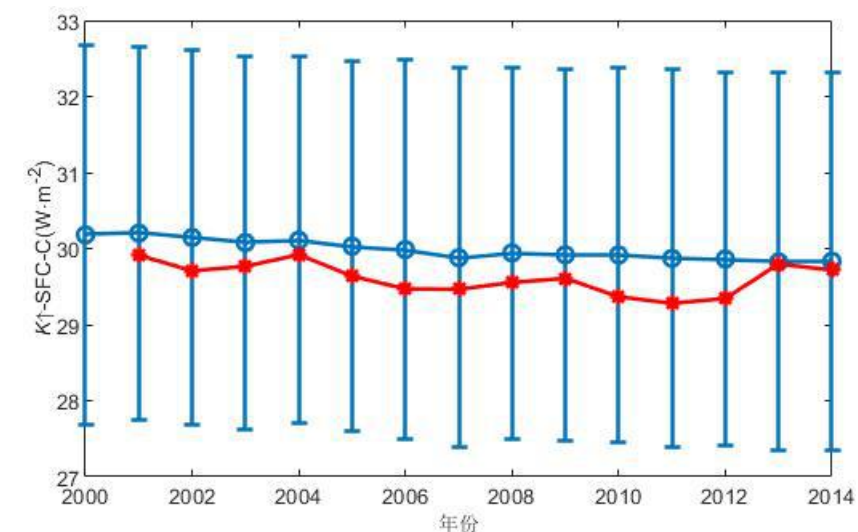


海洋

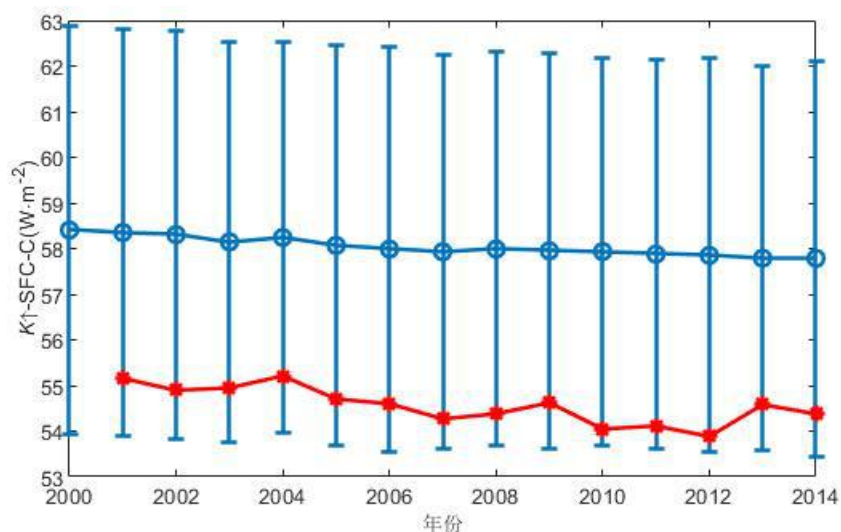


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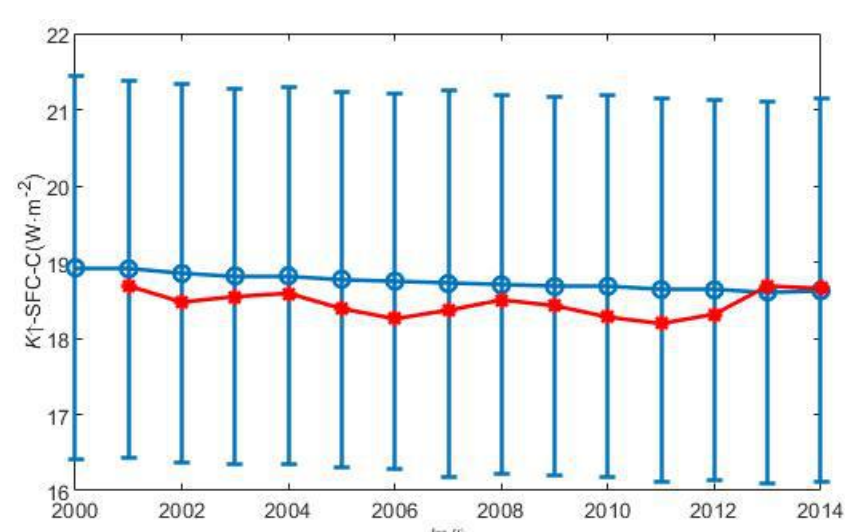
全球



陆地

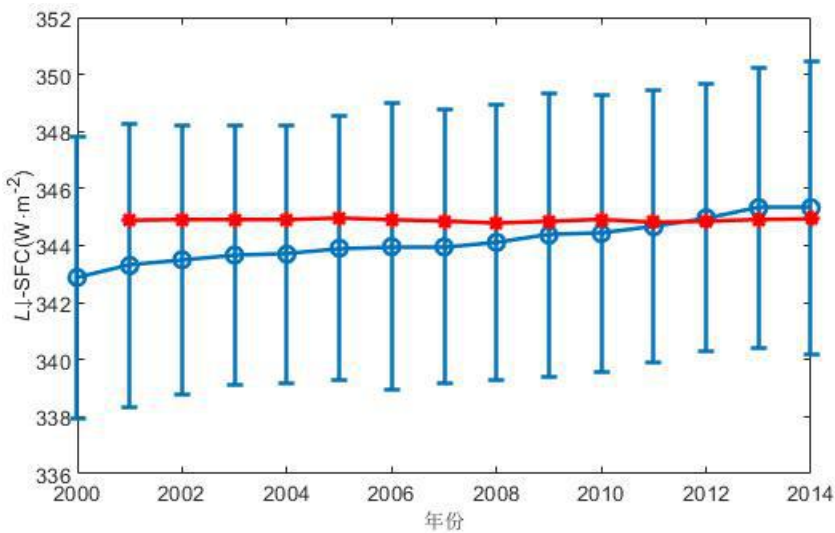


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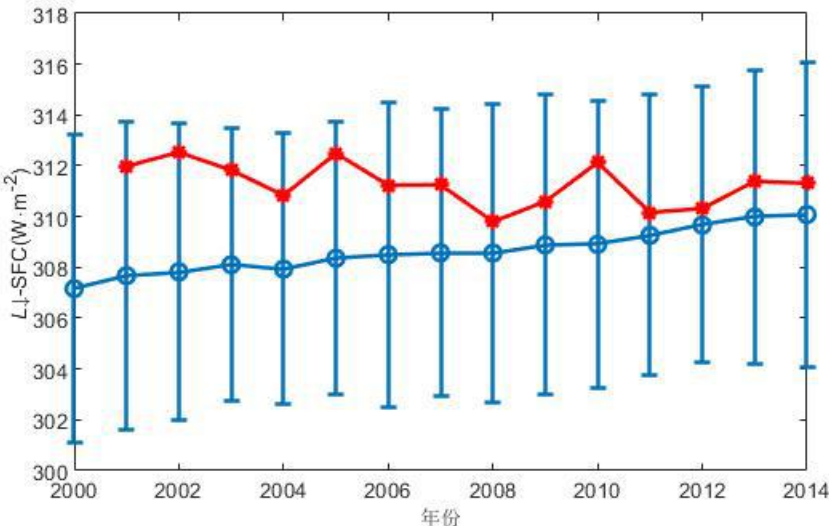


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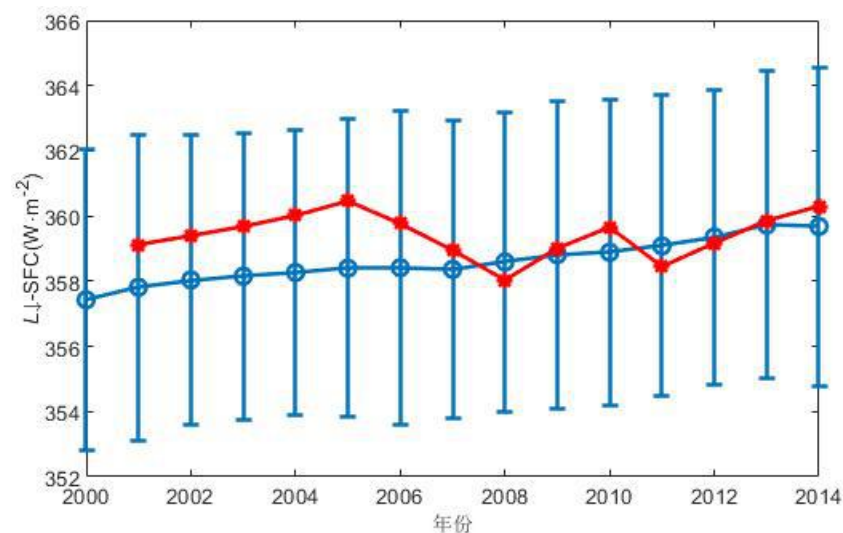
全球



陆地

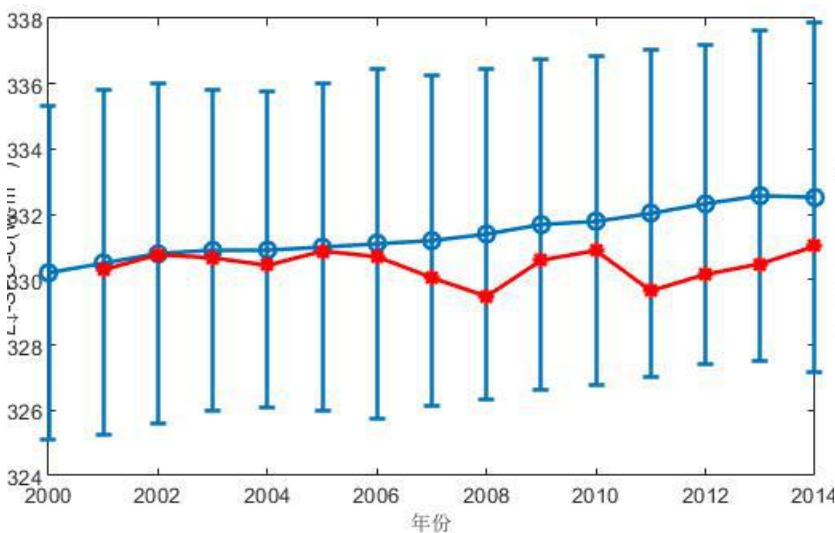


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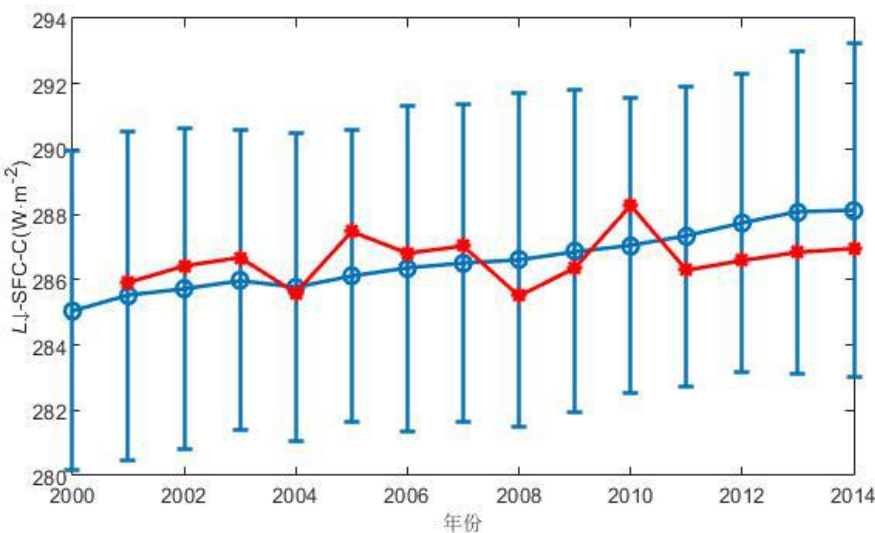


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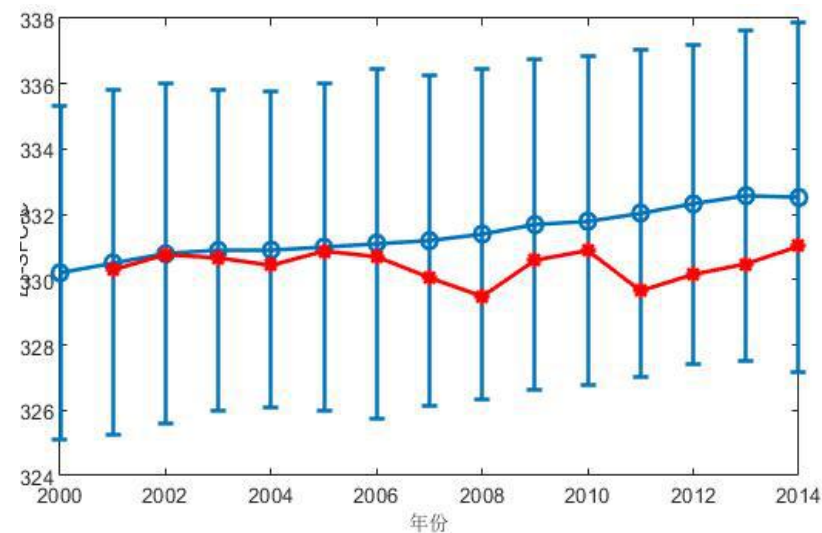
全球



陆地

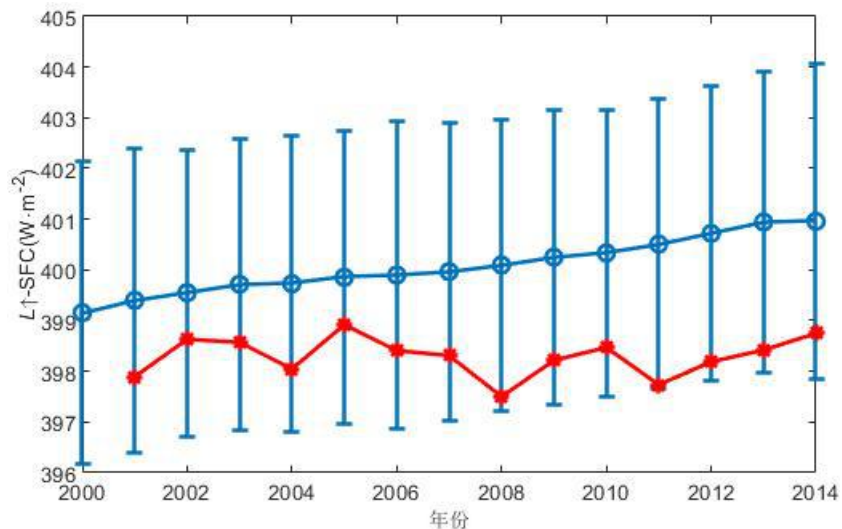


海洋

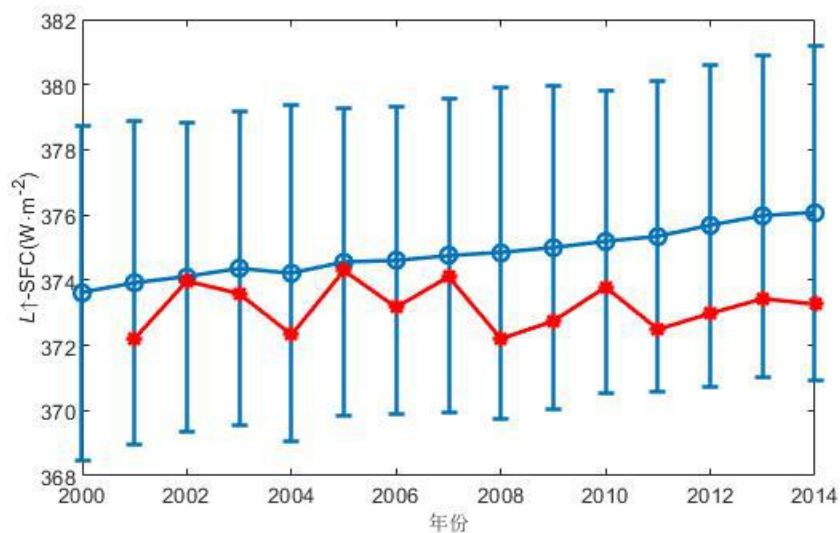


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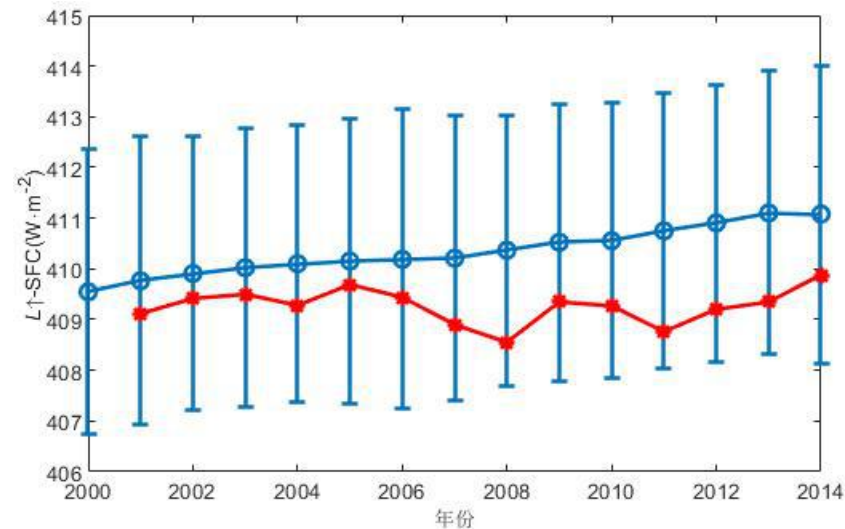
全球



陆地

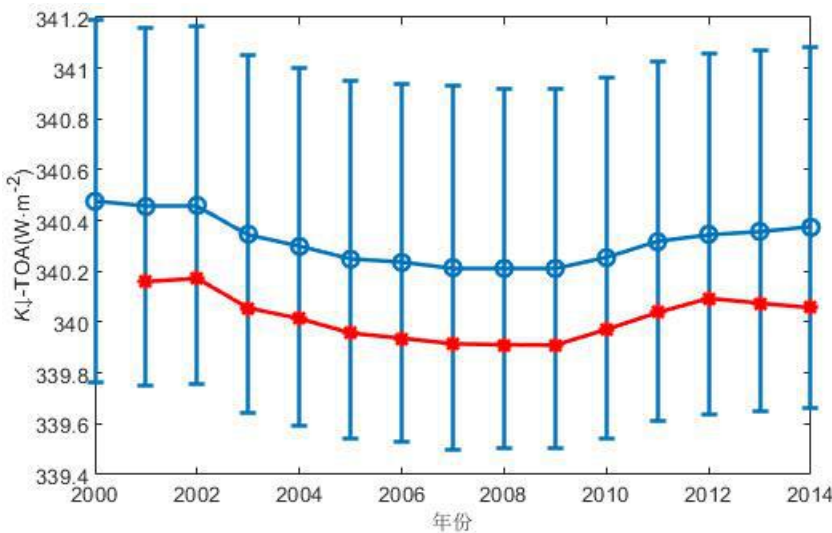


海洋

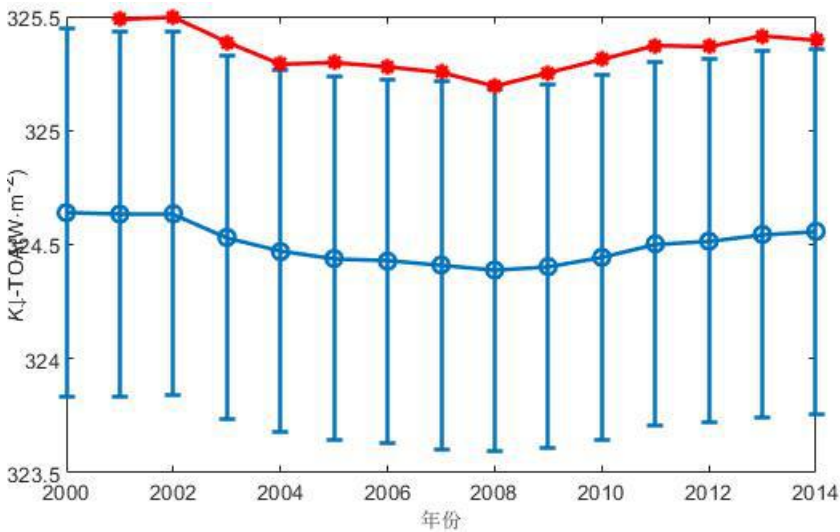


3.1.10 大气顶层入射短波

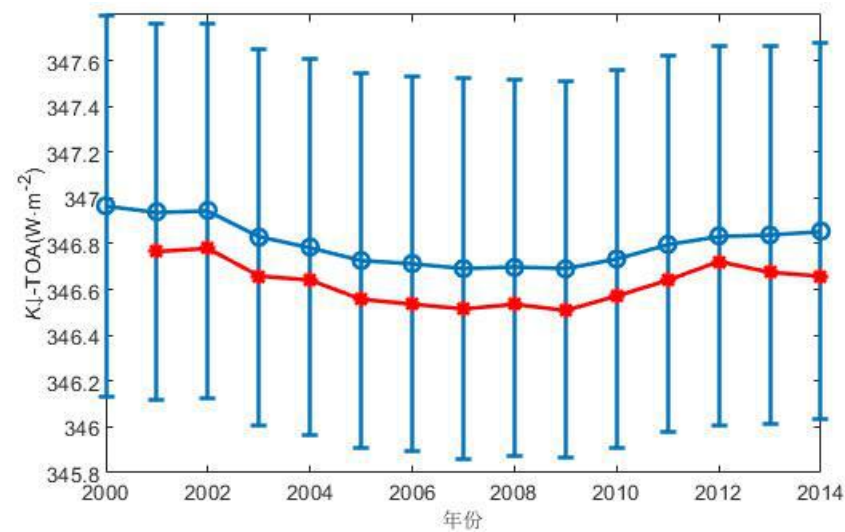
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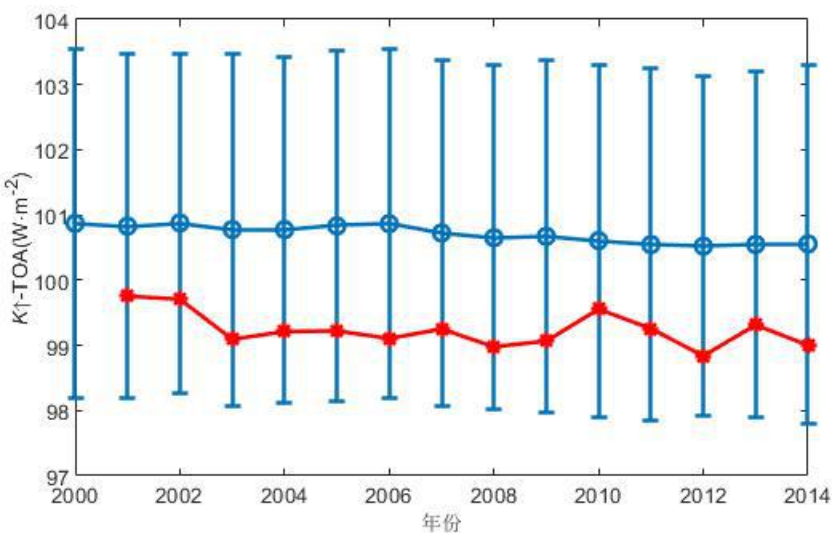


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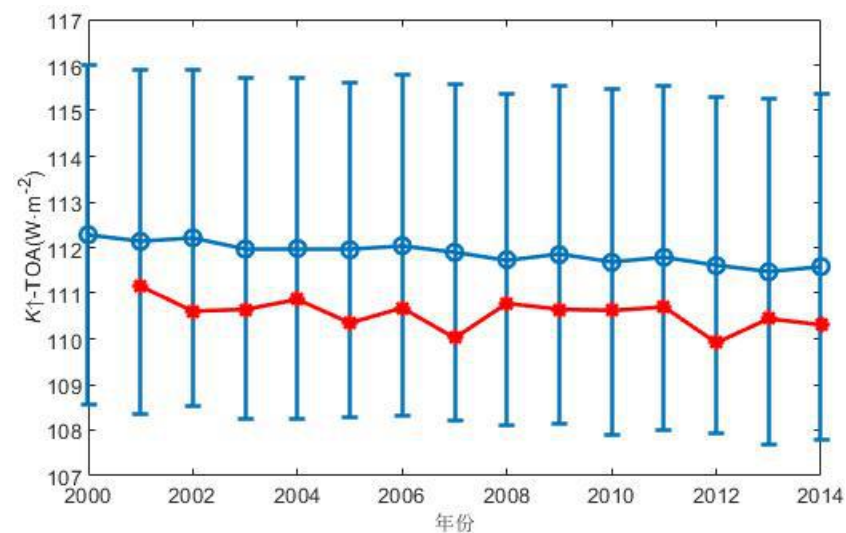


3.1.11 大气顶层出射短波

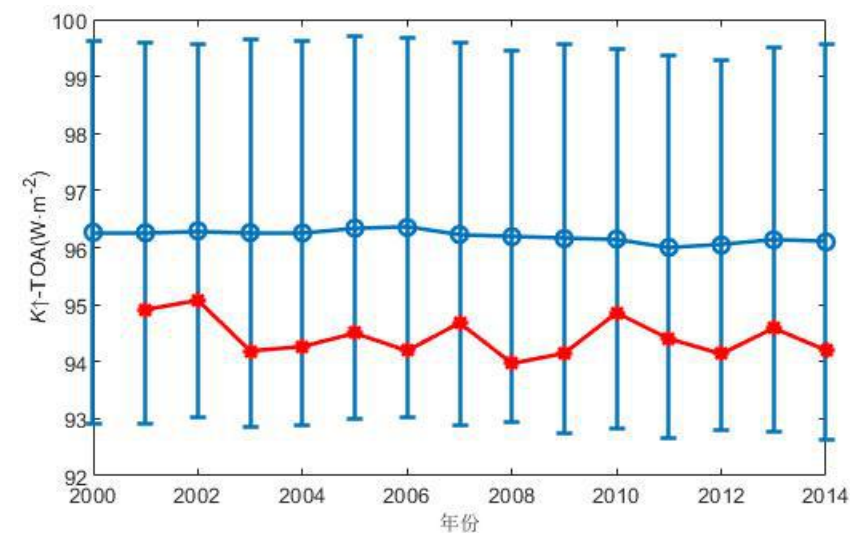
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陆地

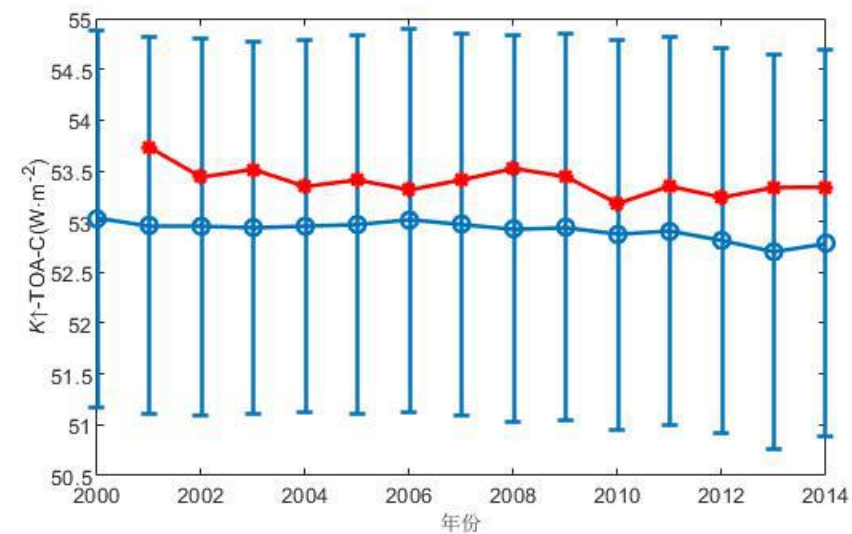


海洋

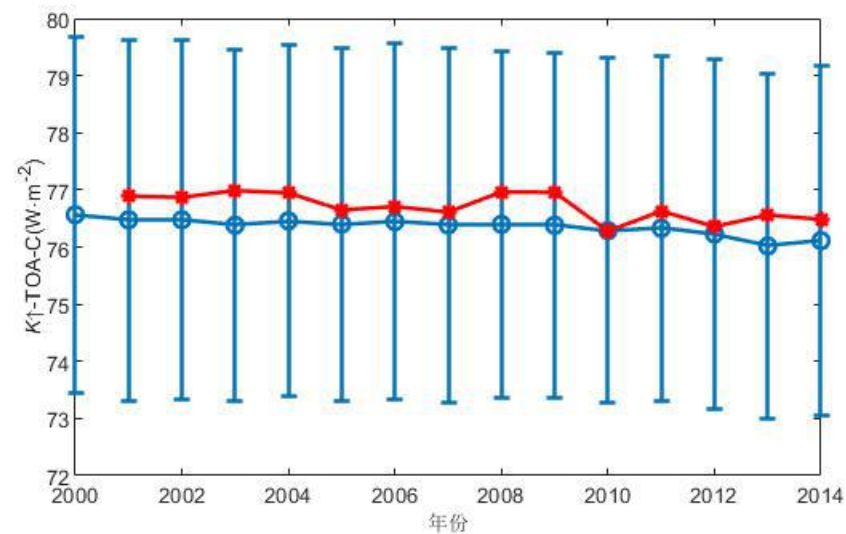


3.1.12 晴空大气顶层出射短波

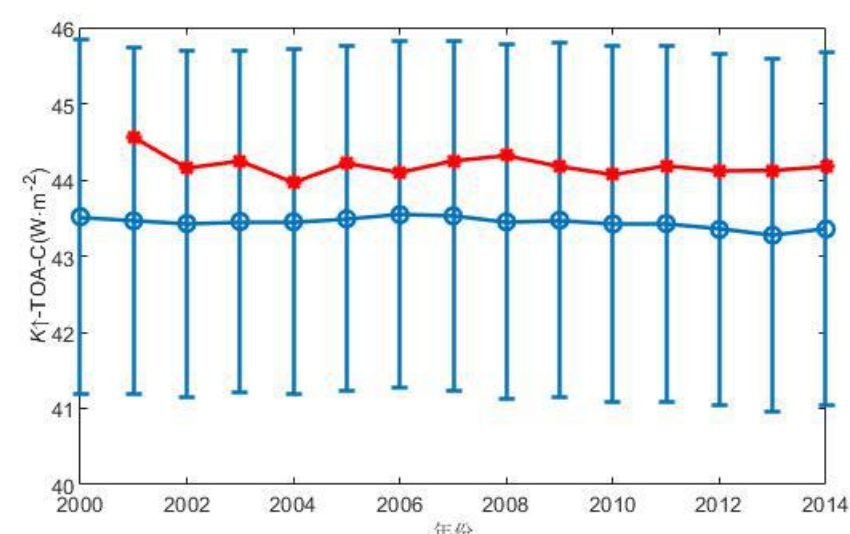
全球



陆地

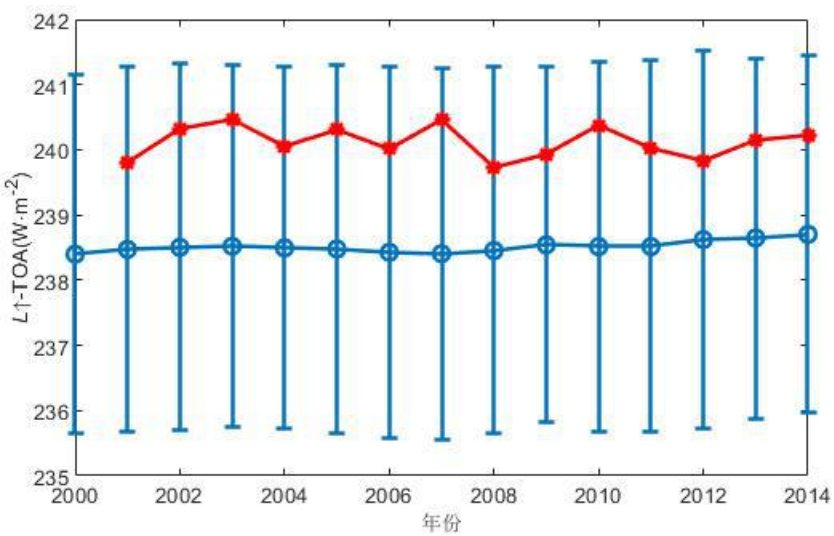


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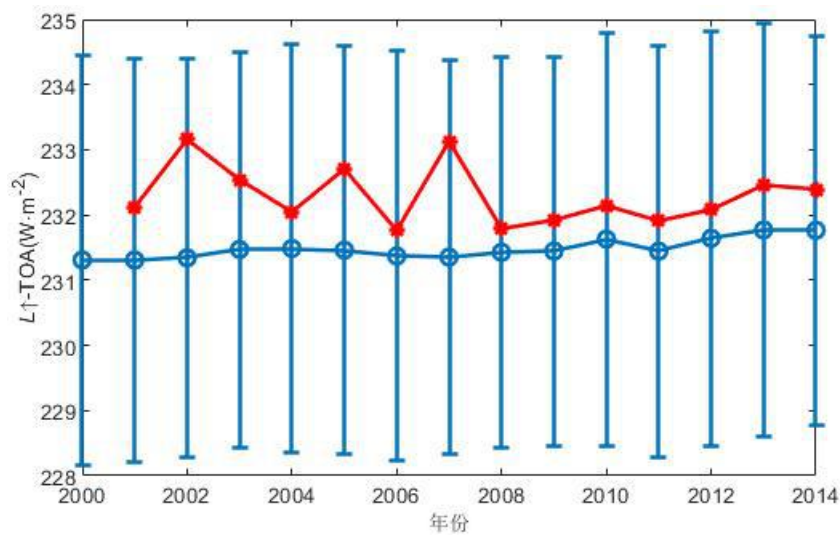


3.1.13 大气顶层出射长波

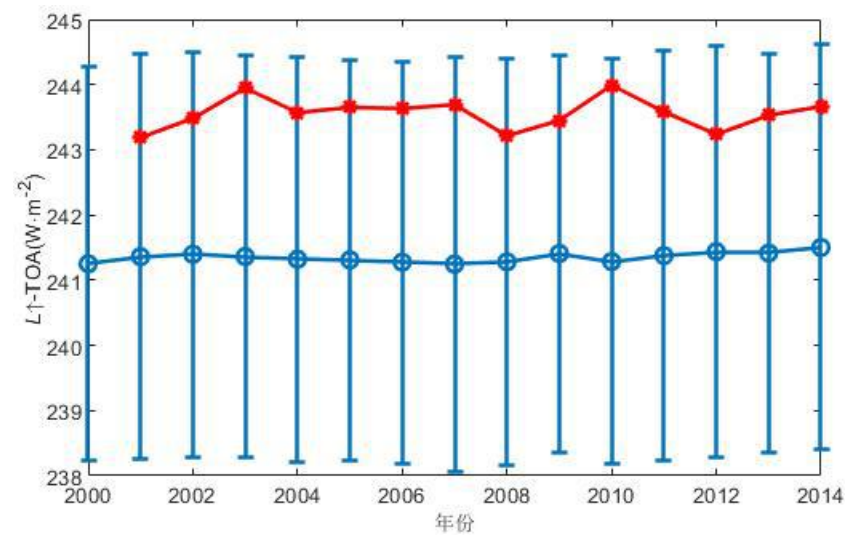
全球



陆地

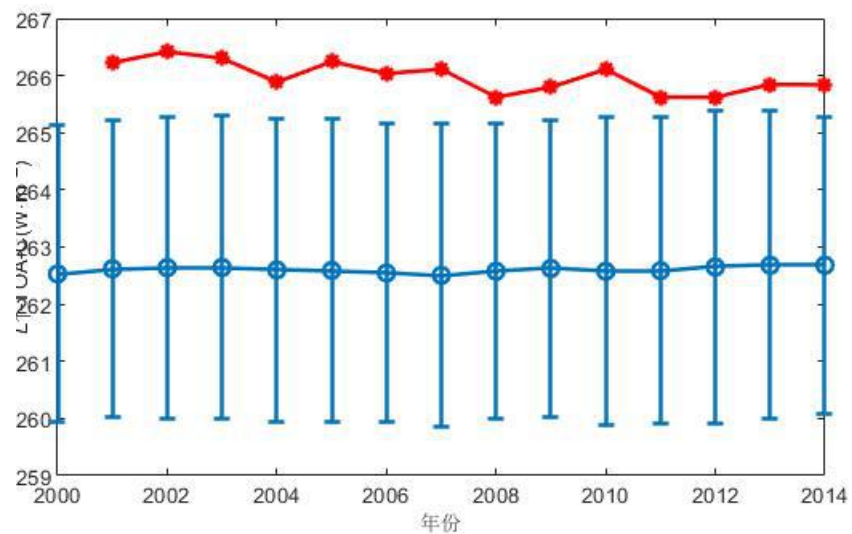


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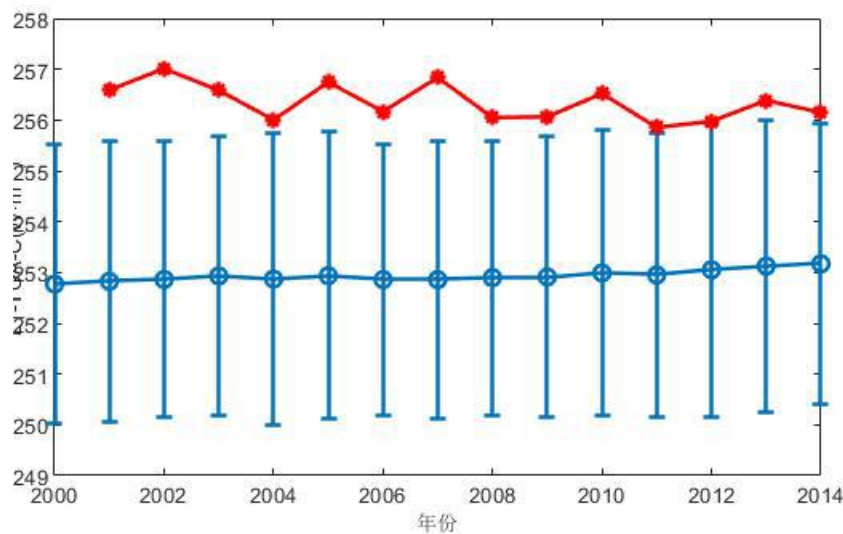


3.1.14 晴空大气顶层出射长波

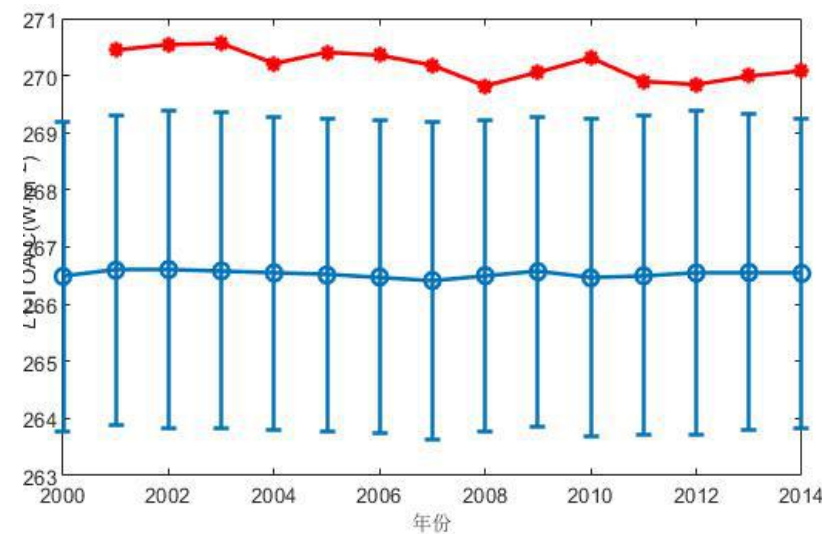
全球



陆地

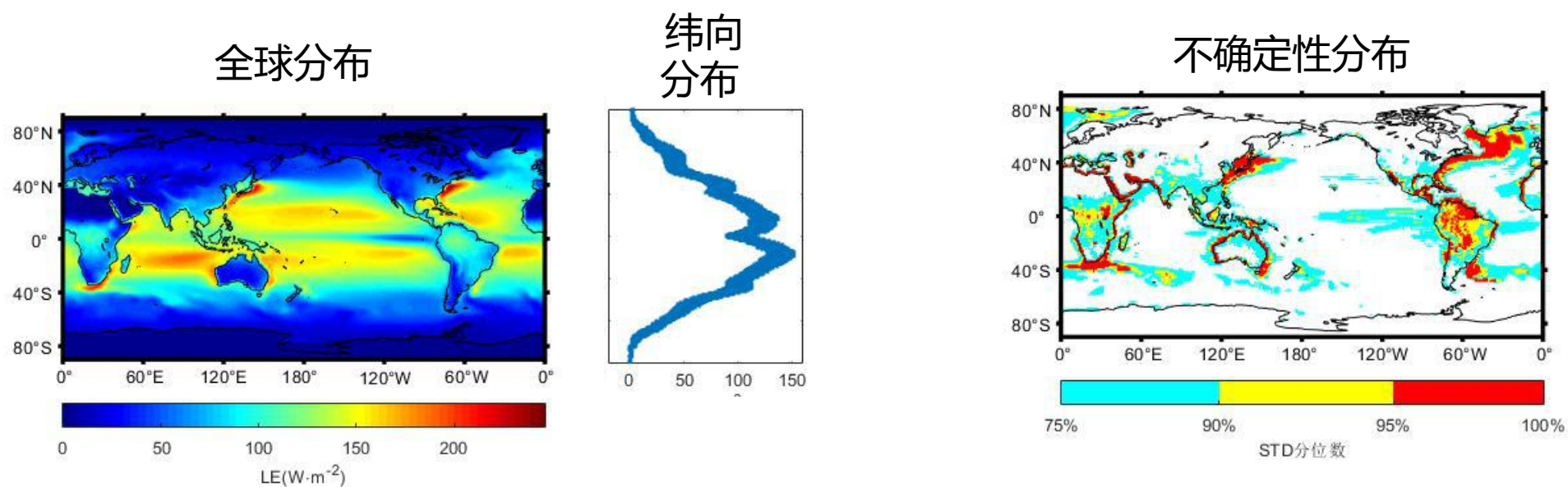


海洋

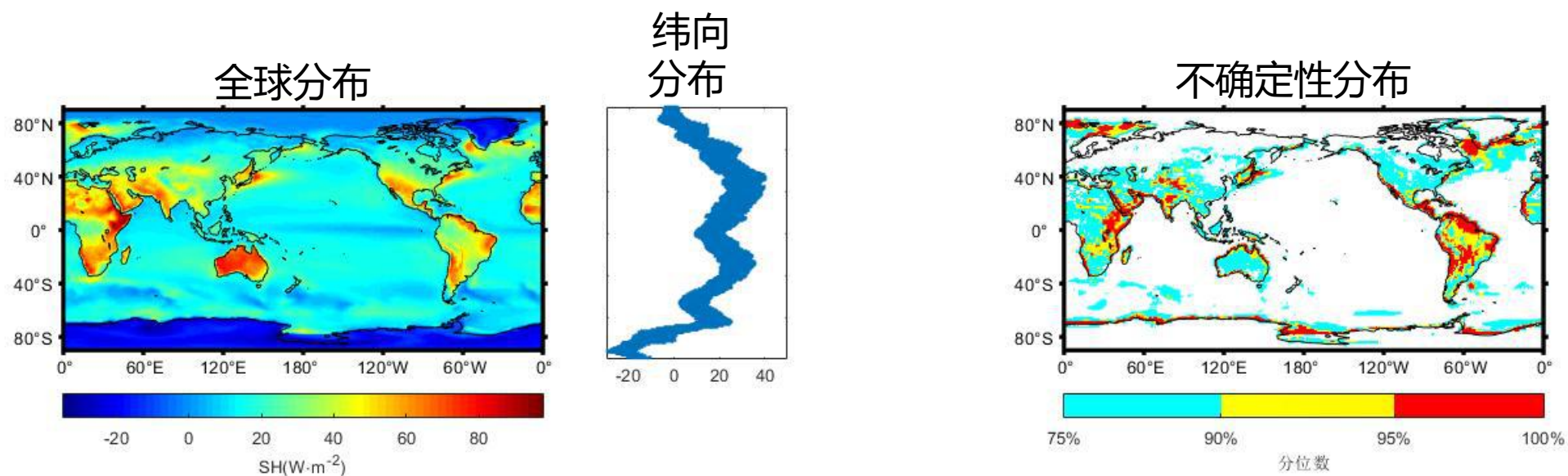


3.2 CMIP6与CERES各变量空间变化特征

3.2.1 潜热通量



3.2.2 感热通量

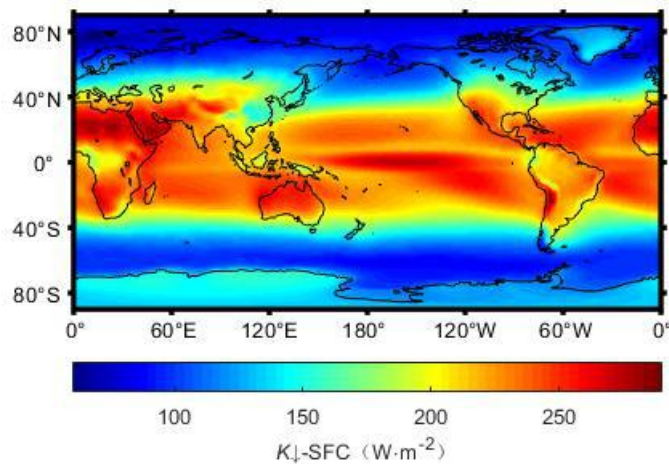


3.2.3 地表向下短波

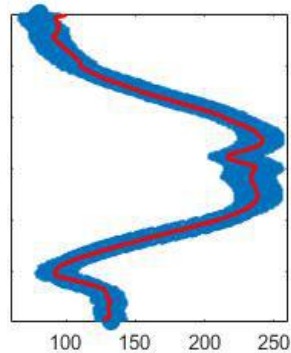
CMIP6

CERES

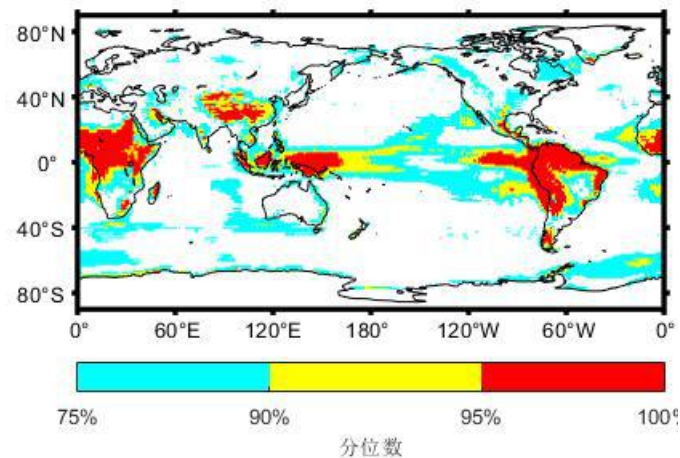
全球分布



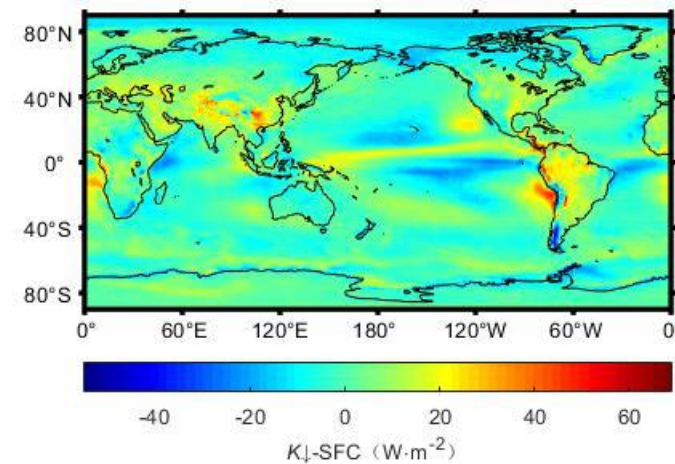
纬向分布



不确定性分布

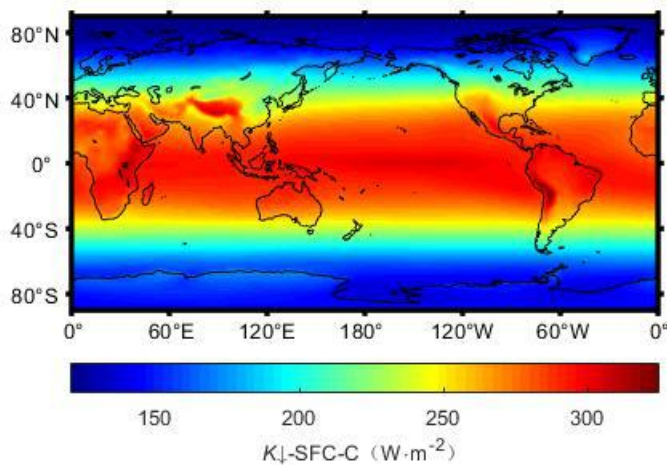


CMIP6与CERES差值

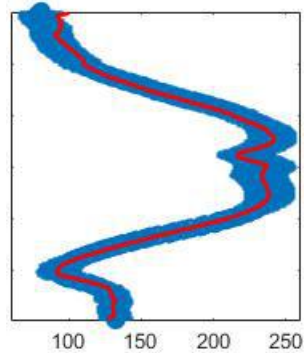


3.2.4 晴空地表向下短波

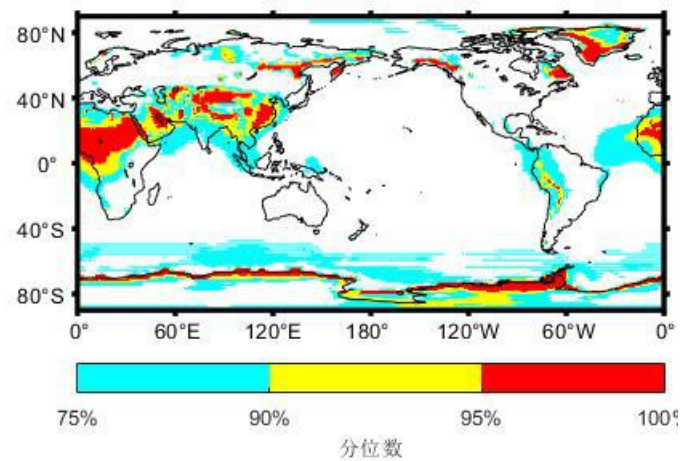
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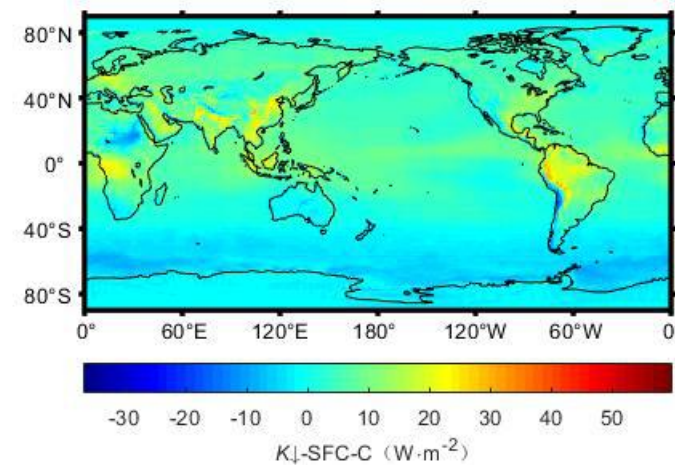
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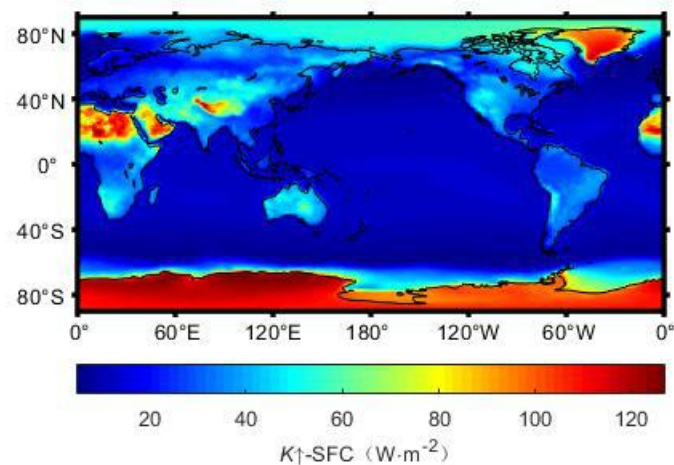


CMIP6与CERES差值

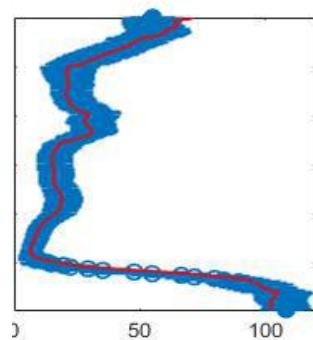


3.2.5 地表向上短波

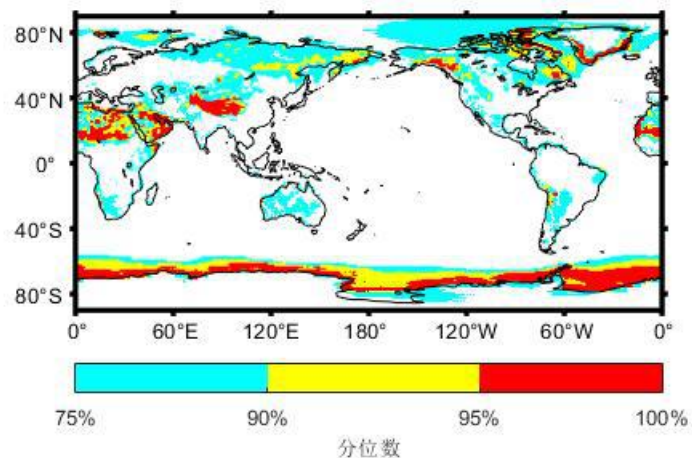
全球分布



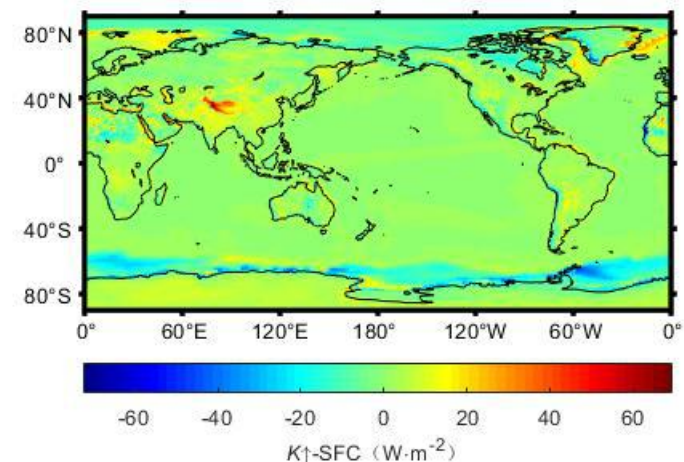
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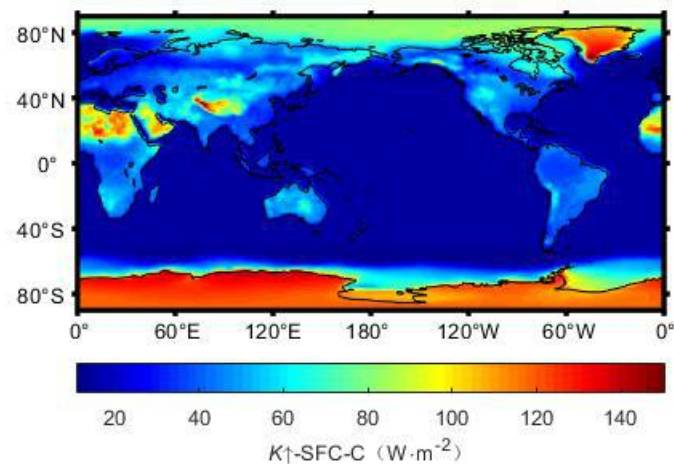


CMIP6与CERES差值

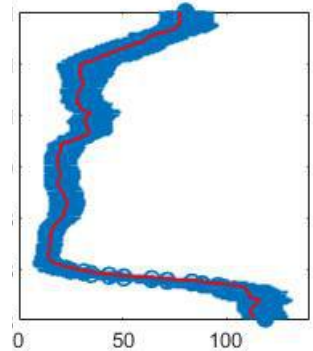


3.2.6 晴空地表向上短波

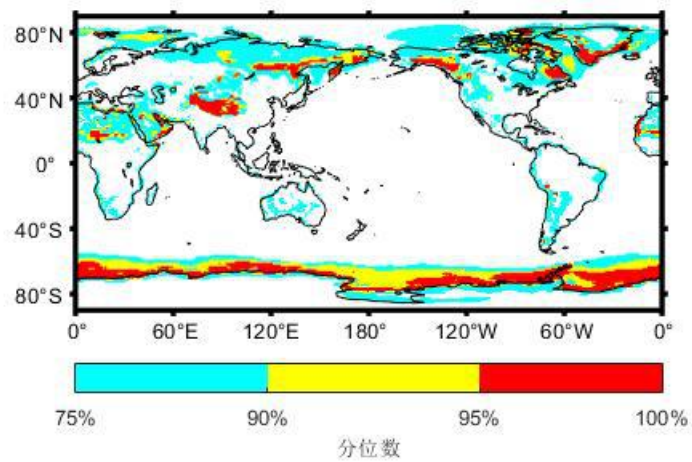
全球分布



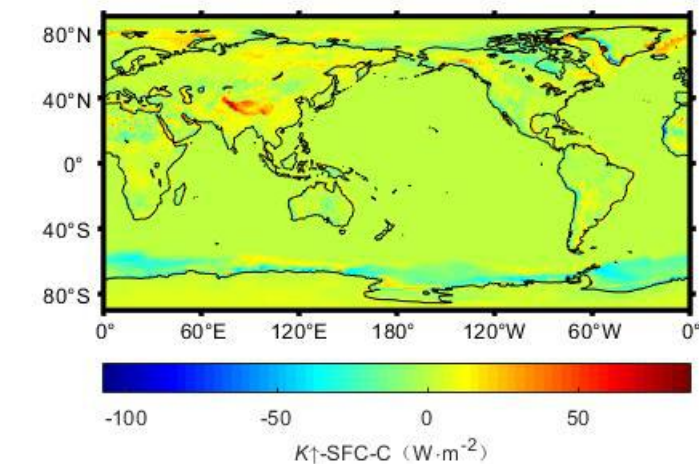
纬向分布



不确定性分布

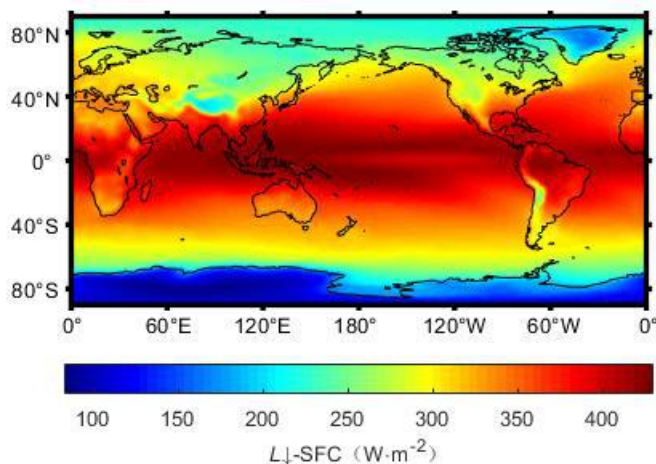


CMIP6与CERES差值

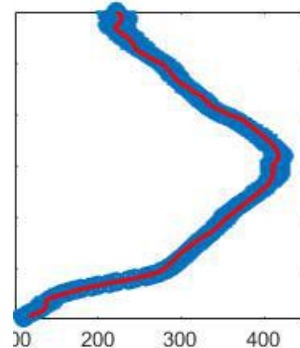


3.2.7 地表向下长波

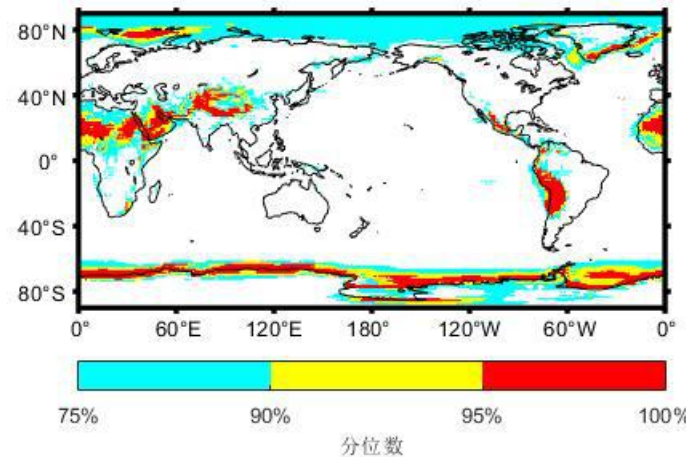
全球分布



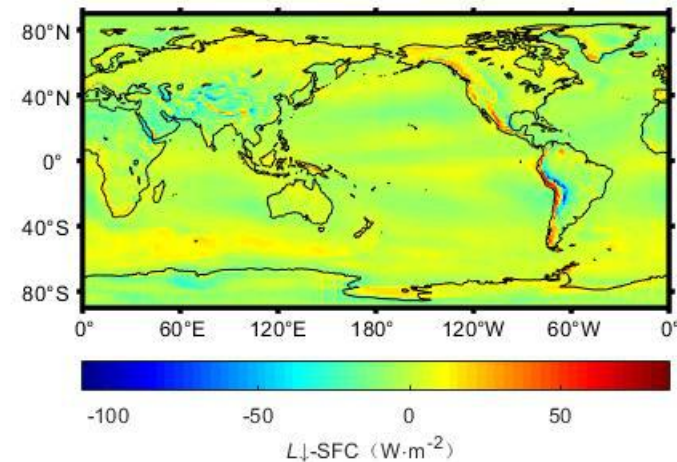
纬向分布



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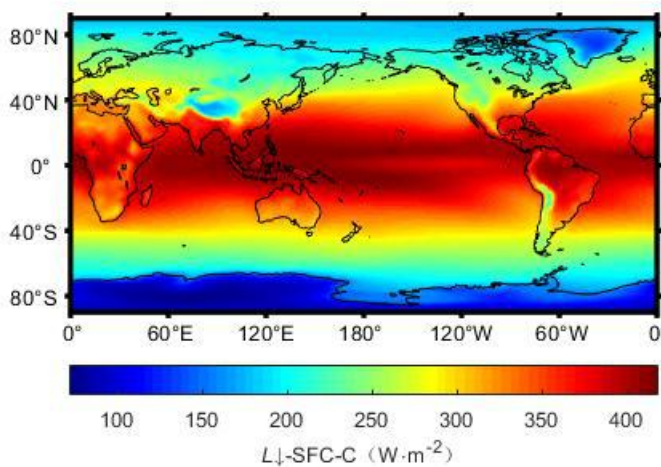


CMIP6与CERES差值

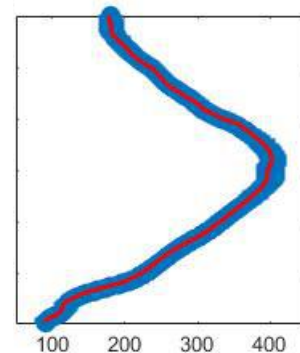


3.2.8 晴空地表向下长波

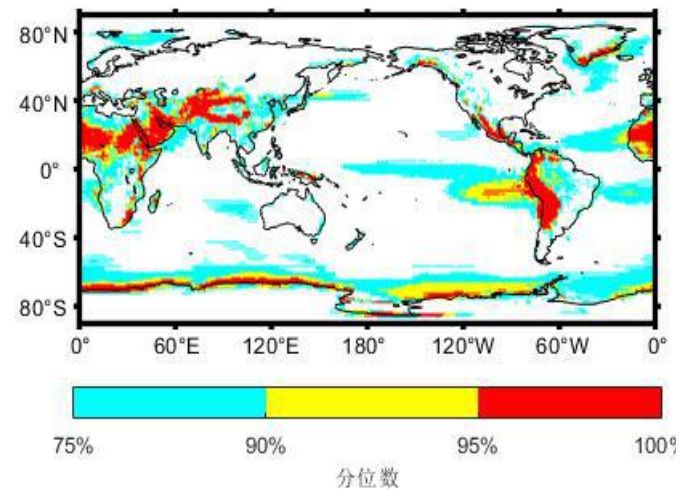
全球分布



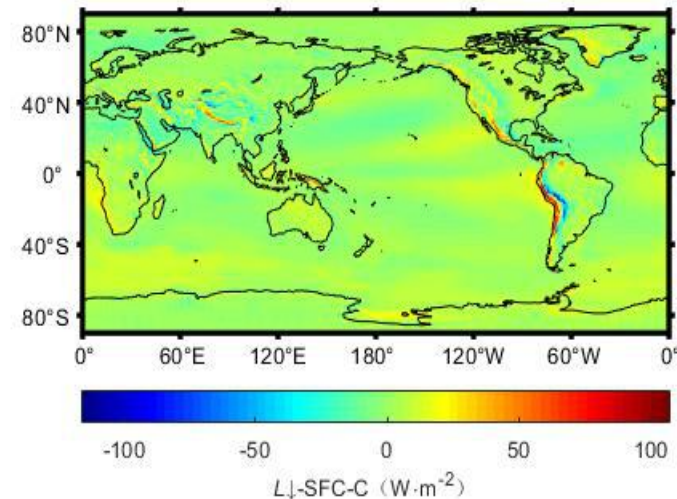
纬向分布



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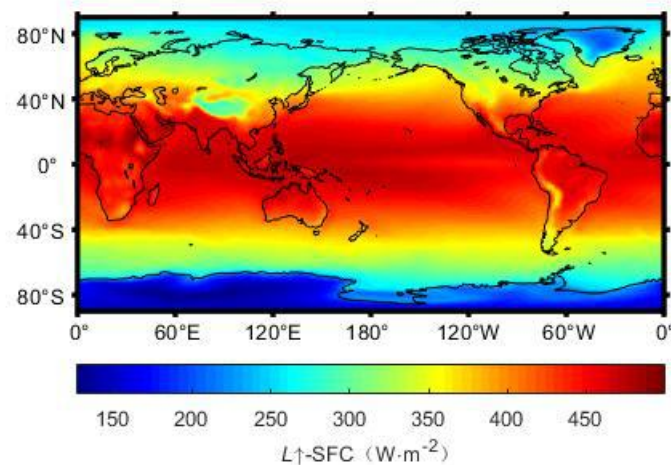


CMIP6与CERES差值

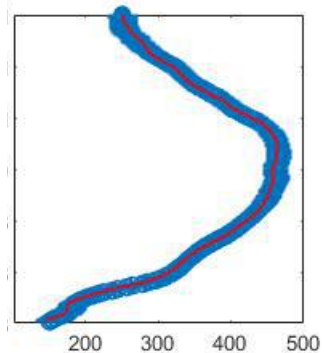


3.2.9 地表向上长波

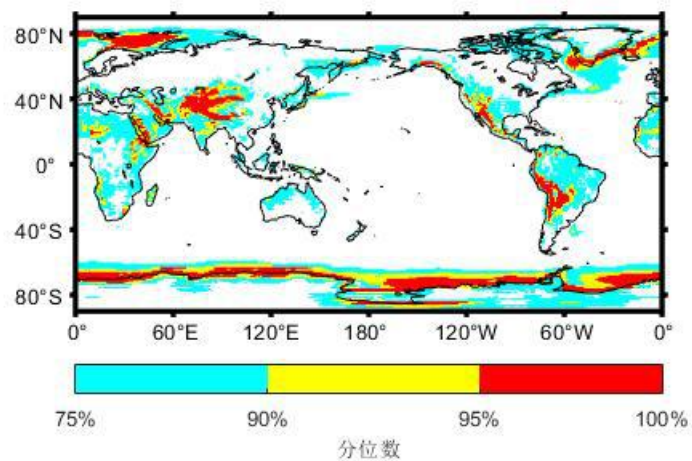
全球分布



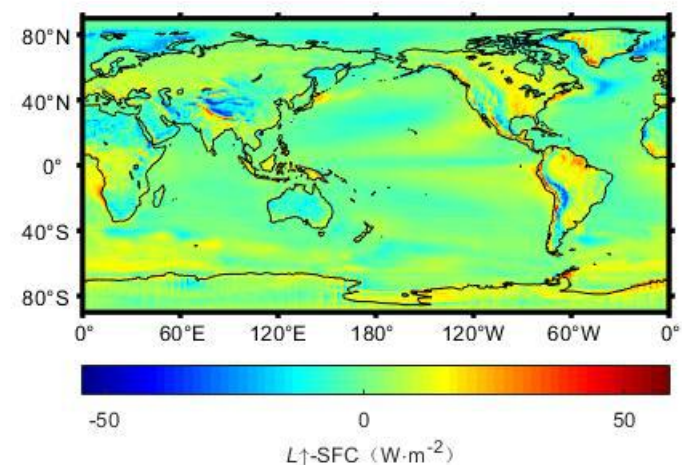
纬向分布



不确定性分布

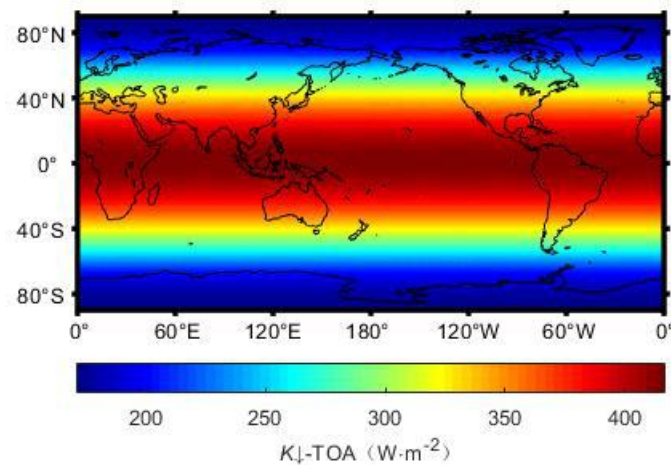


CMIP6与CERES差值

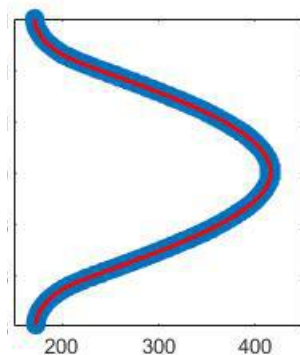


3.2.10 大气顶层入射短波

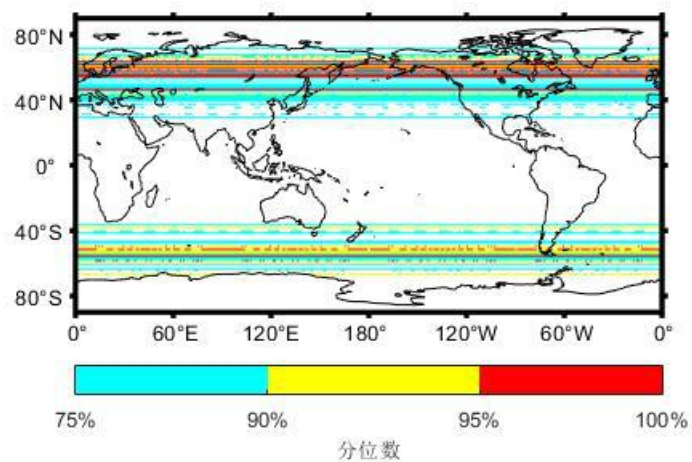
全球分布



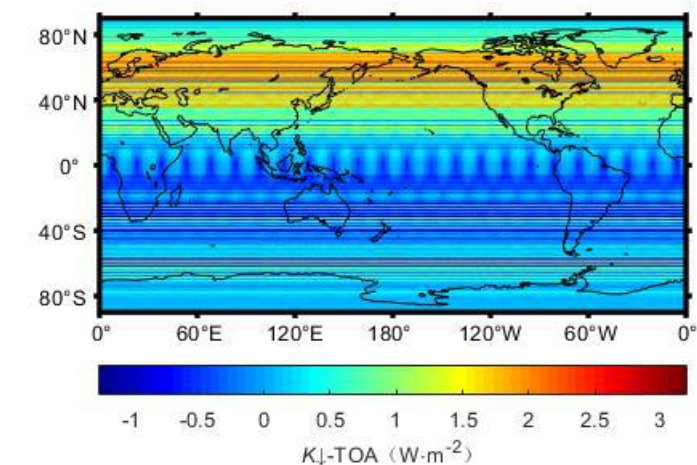
纬向分布



不确定性分布

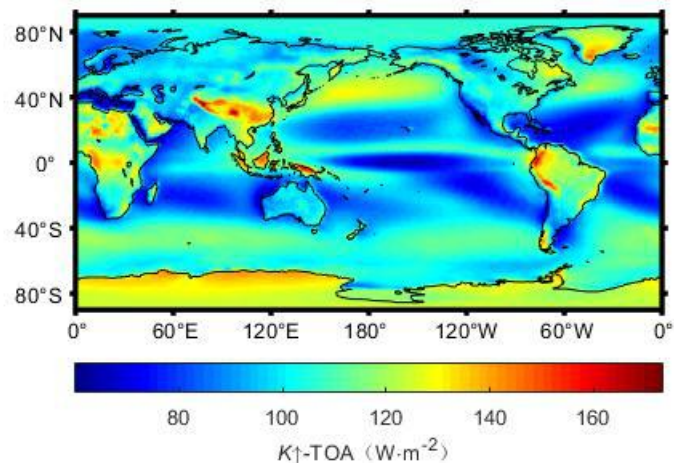


CMIP6与CERES差值

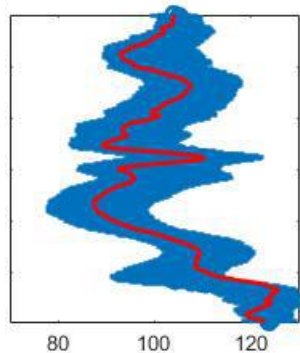


3.2.11 大气顶层出射短波

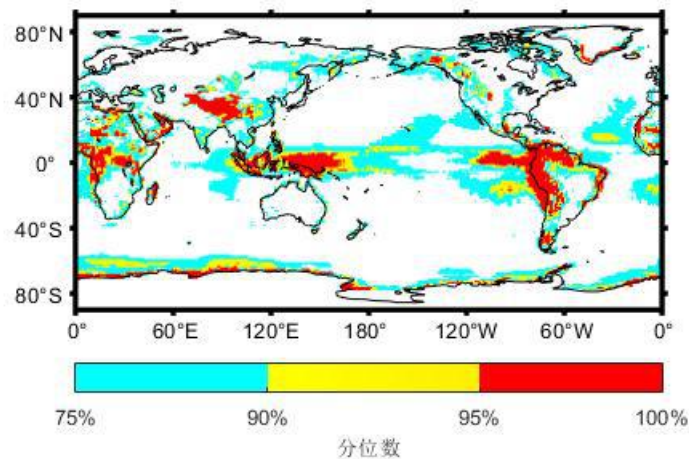
全球分布



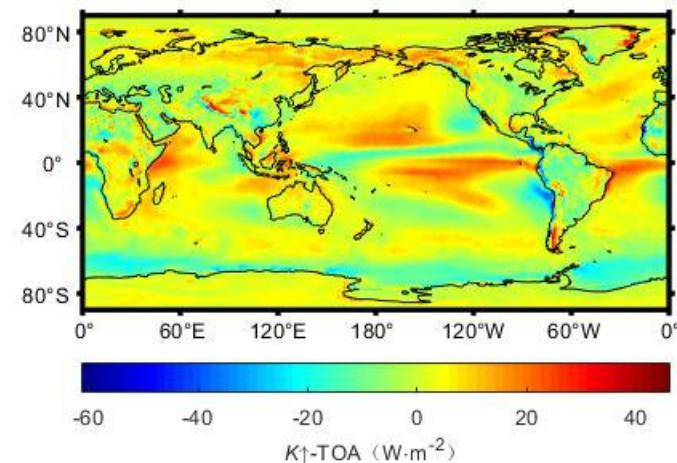
纬向分布



不确定性分布

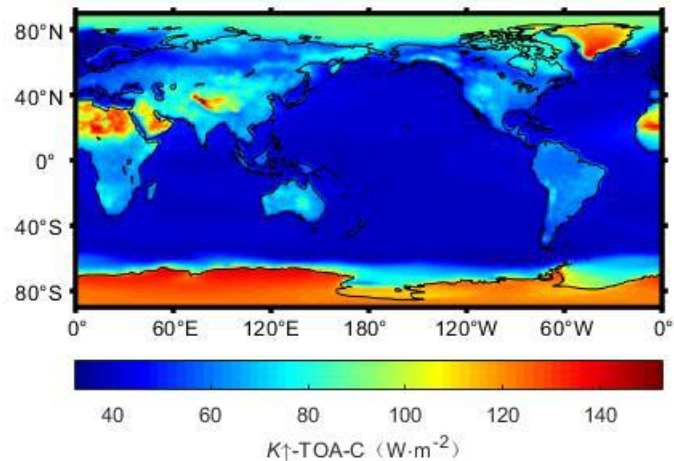


CMIP6与CERES差值

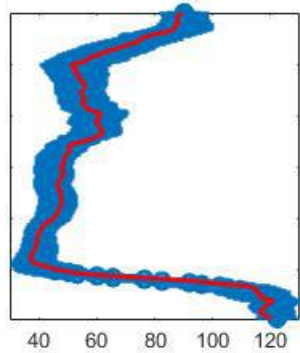


3.2.12 晴空大气顶层出射短波

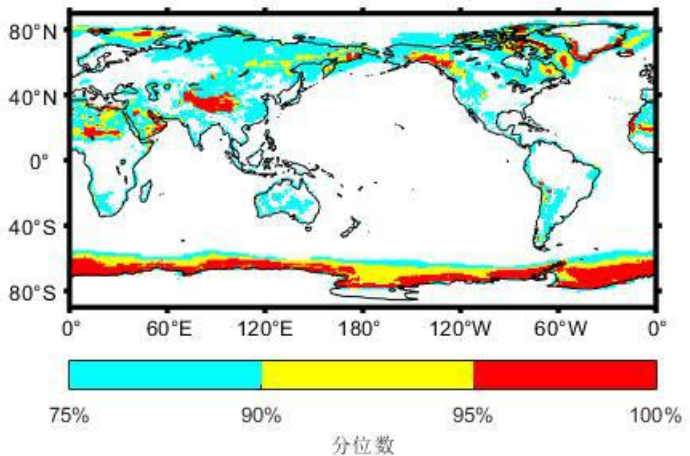
全球分布



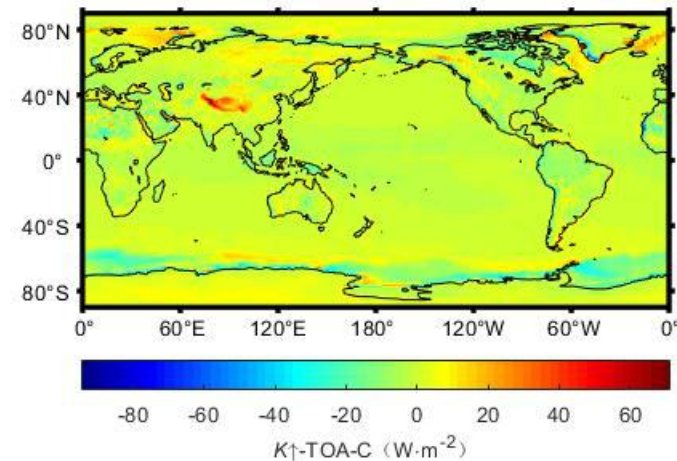
纬向分布



不确定性分布

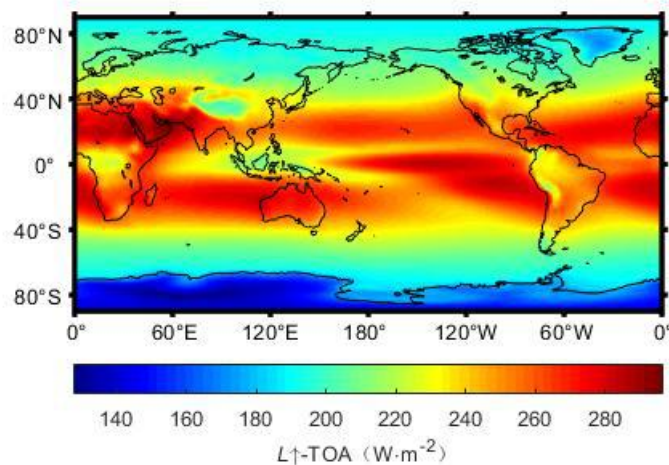


CMIP6与CERES差值

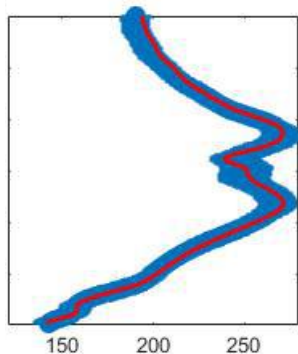


3.2.13 大气顶层向上长波

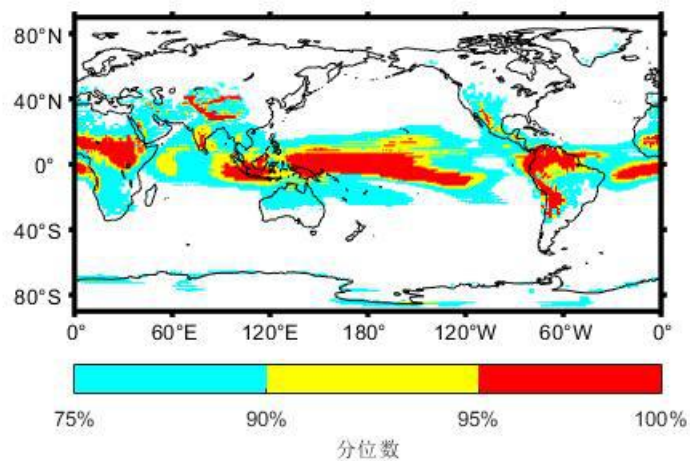
全球分布



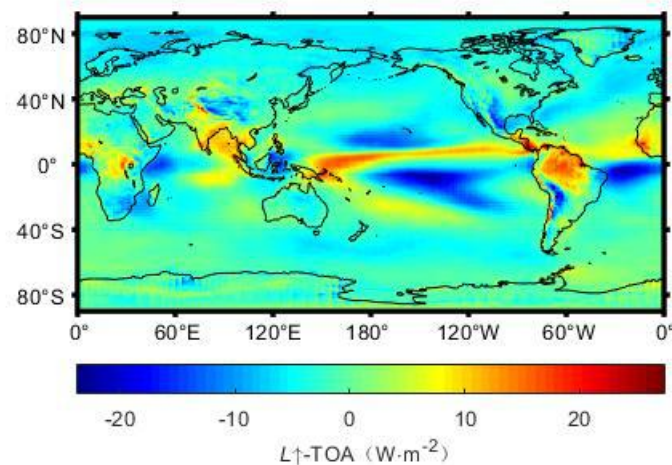
纬向分布



不确定性分布

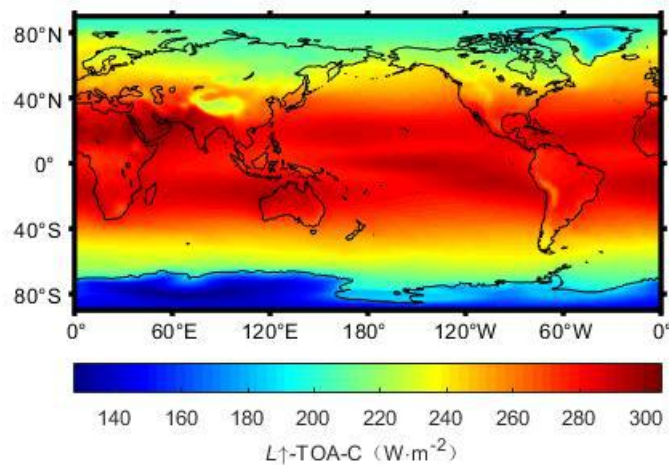


CMIP6与CERES差值

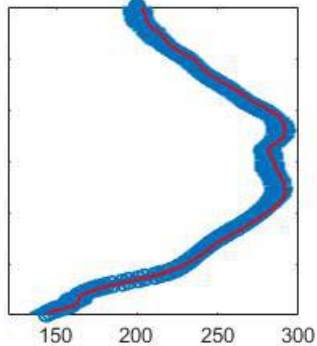


3.2.14 晴空大气顶层向上长波

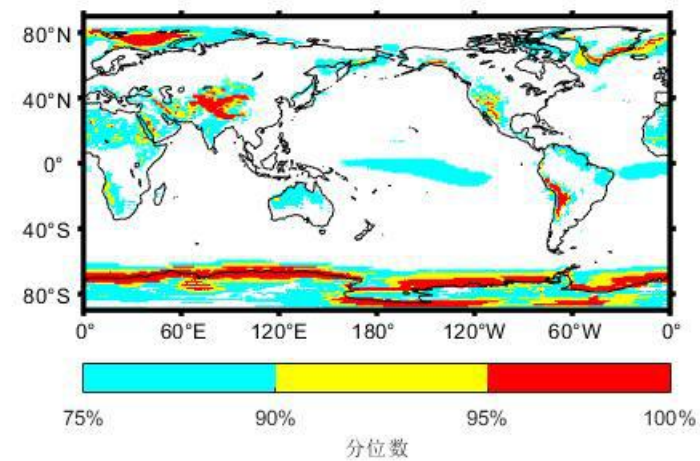
全球分布



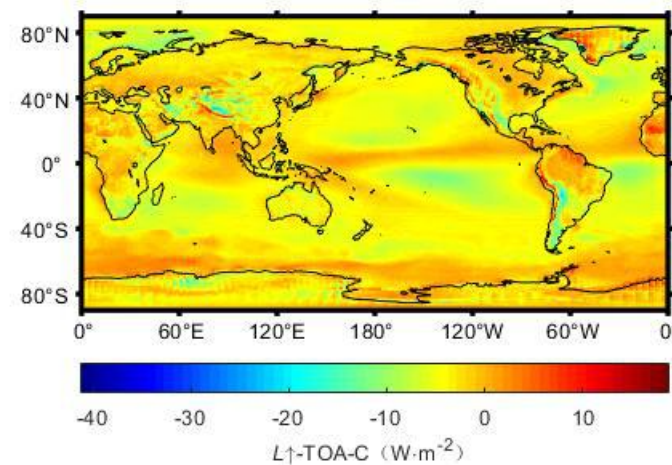
纬向分布



不确定性分布



CMIP6与CERES差值



3.3 CMIP6 2000-2014年平均的辐射和能量通量的统计数值

	W/m ⁻²	LE Flux	SH Flux	L _↓ -SFC	L _↓ -SFC-C	L _↑ -SFC	K _↓ -SFC	K _↓ -SFC-C	K _↑ -SFC	K _↑ -SFC-C	K _↓ -TOA	K _↑ -TOA	K _↑ -TOA-C	L _↑ -TOA	L _↑ -TOA-C
Global	Mean	85.7	20.3	344.1	318.4	400.1	187.4	244.8	23.8	30.0	340.3	100.7	52.9	238.5	262.6
	STD	3.1	2.9	4.7	4.8	2.9	4.6	2.8	2.1	2.5	0.7	2.7	1.9	2.8	2.6
	Max	93.3	25.3	353.8	330.8	405.1	199.8	251.1	29.5	36.2	341.8	109.7	56.9	244.6	270.3
	Min	79.4	12.1	333.5	308.3	393.4	179.1	235.3	20.0	23.7	337.5	96.6	49.1	229.0	257.8
	FOS	1.2	2.1	1.1	1.1	1.0	1.1	1.1	1.5	1.5	1.0	1.1	1.2	1.1	1.1
	Dispersion	3.63%	14.38%	1.38%	1.51%	0.72%	2.44%	1.15%	8.77%	8.18%	0.21%	2.63%	3.55%	1.17%	1.00%
Land	Mean	41.6	32.0	308.6	286.6	374.8	189.0	236.5	48.2	58.0	324.5	111.9	76.4	231.5	252.9
	STD	4.8	4.3	5.6	4.7	4.8	6.5	3.6	4.0	4.3	0.8	3.7	3.1	3.1	2.8
	Max	49.3	40.2	322.4	298.0	389.1	200.7	243.5	59.5	70.1	326.3	122.1	84.1	239.7	261.5
	Min	24.3	23.3	297.8	277.1	367.3	176.8	225.2	39.0	48.7	321.7	104.1	71.2	225.5	247.2
	FOS	2.0	1.7	1.1	1.1	1.1	1.1	1.1	1.5	1.4	1.0	1.2	1.2	1.1	1.1
	Dispersion	11.48%	13.31%	1.82%	1.64%	1.28%	3.44%	1.53%	8.23%	7.46%	0.25%	3.31%	4.00%	1.32%	1.09%
Ocean	Mean	103.7	15.5	358.6	331.4	410.4	186.7	248.2	13.9	18.7	346.8	96.2	43.4	241.4	266.5
	STD	4.1	3.2	4.6	5.0	2.7	4.9	3.0	2.0	2.5	0.8	3.3	2.3	3.1	2.7
	Max	111.5	21.8	365.8	344.2	415.3	199.4	254.5	20.6	26.2	348.7	107.9	49.7	246.7	273.9
	Min	95.1	6.8	347.9	320.8	403.8	175.8	239.4	11.6	13.4	344.0	90.4	40.0	230.5	261.0
	FOS	1.2	3.2	1.1	1.1	1.0	1.1	1.1	1.8	2.0	1.0	1.2	1.2	1.1	1.1
	Dispersion	3.96%	20.62%	1.27%	1.51%	0.66%	2.63%	1.20%	14.52%	13.25%	0.24%	3.44%	5.27%	1.28%	1.03%

注：包括均值、标准差、上下限 (W m⁻²)、离散系数以及离差。FOS为离散系数 (Factor of spread) 是最大值和最小值的比值，离差 (Dispersion) 是多模式之间的标准差与多模式集合均值的比值。

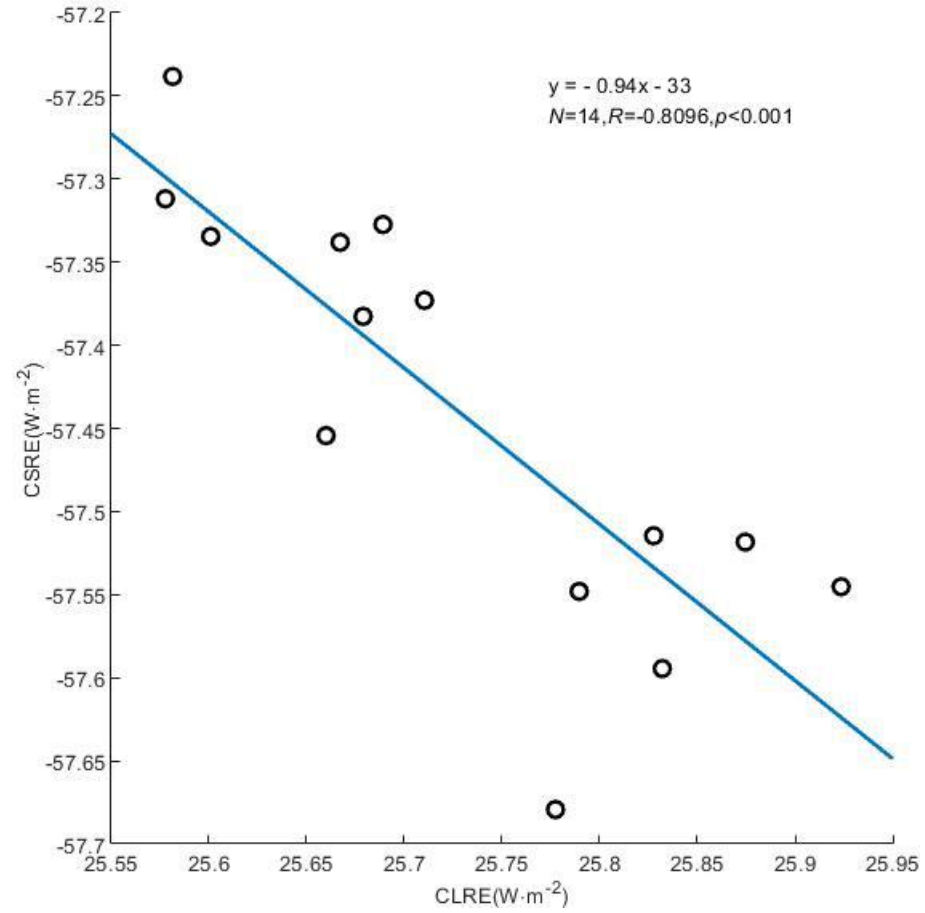
3.4 云的影响

$$CLRE = L_{\downarrow} - SFC - \text{all sky} - L_{\downarrow} - SFC - \text{clear sky}$$

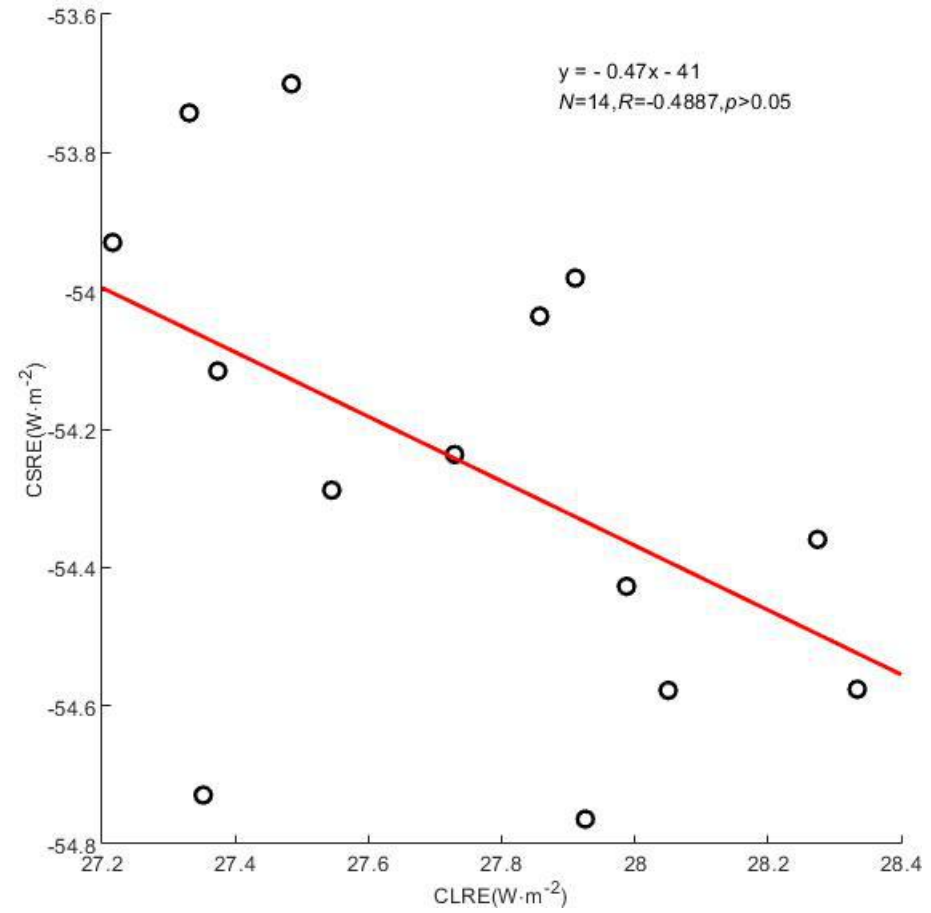
$$CSRE = K_{\downarrow} - SFC - \text{all sky} - K_{\downarrow} - SFC - \text{clear sky}$$

3.4.1 全球

CMIP6

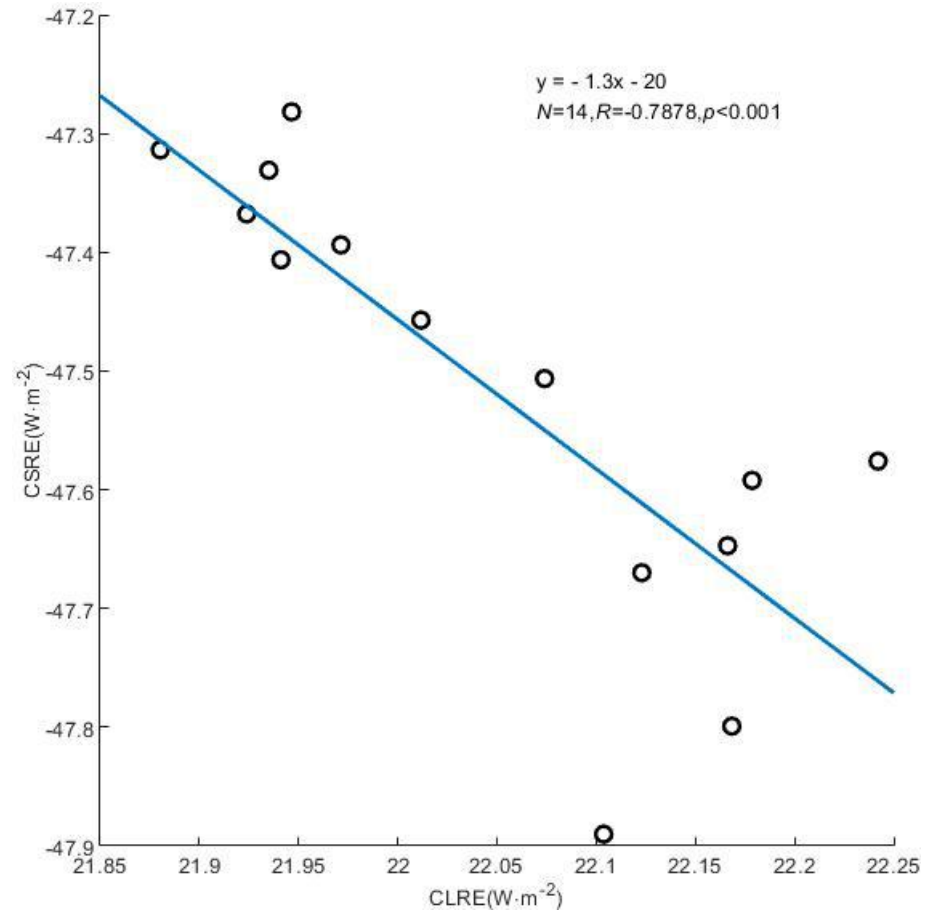


CERES

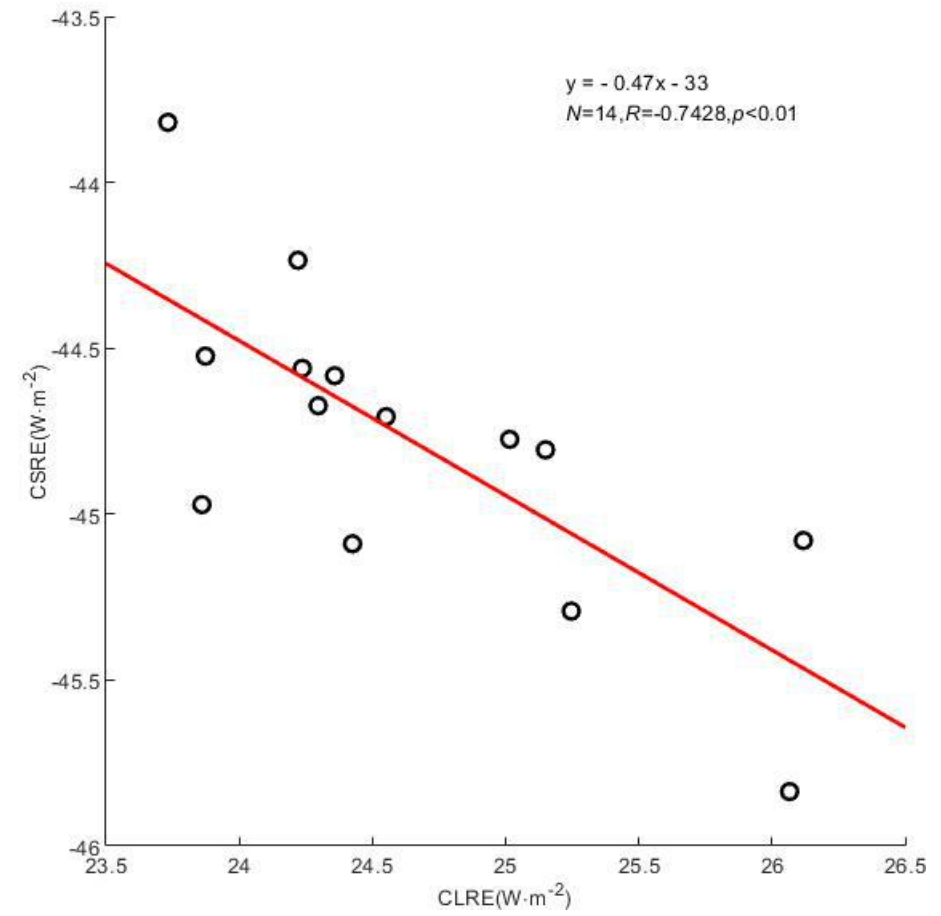


3.4.2 陆地

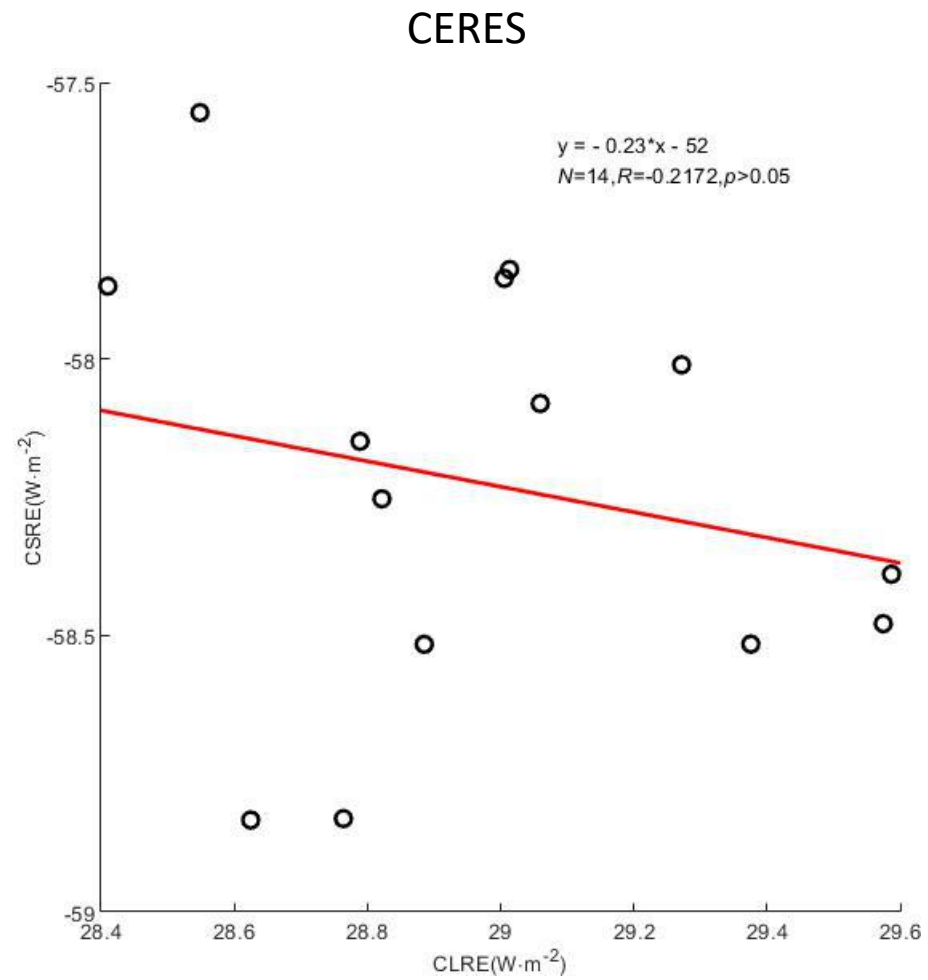
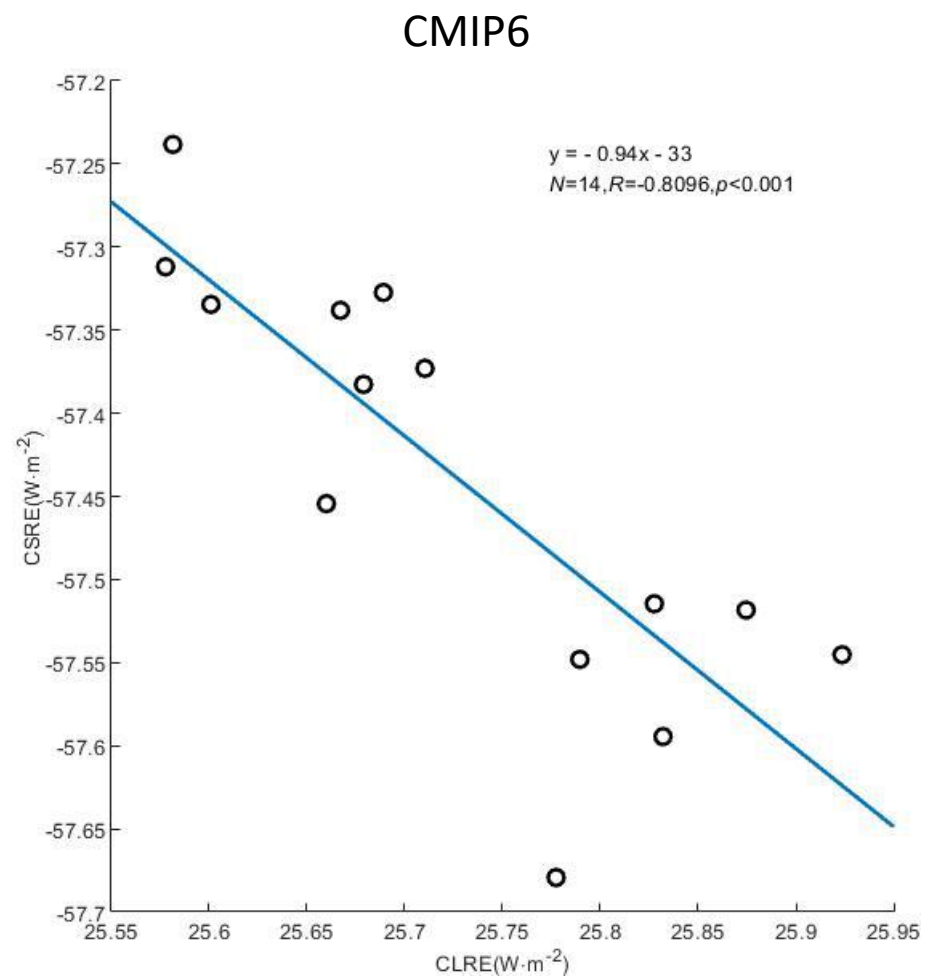
CMIP6



CERES



3.4.3 海洋



4. 存在的问题

4.1 停留在数据分析和绘图，对于物理过程认识和理解不够。

4.2 没有提炼出更多的新意。

5. 下一步计划

5.1 计算各模型的云对地表向下短波和地表向下长波的效应。

5.2 对比分析本研究计算结果与前人的结果。