China ESM Developments in the past year

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ESM developments in the main land of China

Contributors: IAP, BCC, CAMS, FIO

THU, BNU, NUIST

Model Groups

Group name	Affiliation	Model name
LASG/IAP	Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences (CAS)	FGOALS
IAP/CAS		CAS ESM
CESS/THU	Center for Earth System Science (CESS), Tsinghua University (THU)	CICSM
BNU	Beijing Normal University (BNU)	BNU-ESM
NUIST	Nanjing University of Information Science and Technology (NUIST)	NUIST-CSM
BCC	Beijing Climate Center (BCC) / China Meteorological Administration (CMA)	BCC-ESM/CSM
CAMS	Chinese Academy of Meteorological Science (CAMS) / CMA	CAMS-CSM
FIO	First Institute of Oceanography (FIO) / State Oceanic Administration (SOA)	FIO-ESM

FGOALS: Flexible Global Ocean-Atmosphere-Land System
CICSM / CIESM: Community Integrated CSM / ESM

Model Names

Affiliation	ESM/CSM	AGCM	LSM	OGCM	SIM
CAS	FGOALS-f FGOALS-g	FAMIL GAMIL 3	CLM4.5	LICOM 3 + HAMOCC	CICE4.0
	CAS ESM	IAP AGCM4.0 + AACM	CoLM + IAP DGVM	LICOM2 + IAP OBGCM	CICE4.0
Universities	CICSM	FDAM/FVAM	CLM4.5	POP2	CICE4.0
	BNU-ESM	CAM4	CoLM + improved biogeochem schem	MOM4p1 + Dynamic ecosystem- carbon scheme	Improved CICE4.1
	NUIST-CSM	ECHAM –NUIST	Modified ECHAM5.3 Land Model	NEMO 3.4	CICE 4.1
CMA	BCC-ESM / BCC-CSM	BCC-AGCM3-Ch BCC-AGCM3-MR BCC-AGCM3-HR	BCC-AVIM2	MOM4- HAMOCC	CICE5
	CAMS-CSM	ECHAM5.0	CoLM	LICOM2	CICE4.0
SOA	FIO-ESM	CAM4 / CAM5	CLM4.5 + DGVM	NEMO3.6 + OCMIP-2 + MASNUM	CICE5

Model Resolutions

Affiliation	ESM/CSM	AGCM / LSM	OGCM/SIM
CAS	FGOALS	C96(1^0x1^0), C384(0.25^0x0.25^0); L32 for FAMIL 2^0x2^0, 1^0x1^0; L26 for GAMIL	1^0 x 1^0 (0.5^0 near EQ) L80
	CAS ESM	1^0x1^0 L26	1^0 x 1^0 (0.5^0 near EQ) L30
Universities	CICSM	1^0x1^0 L30	1^0 x 1^0 (0.5^0 near EQ) L30
	BNU-ESM	FV144x96 L30	360x200 L50
	NUIST-CSM	T63 L47 / T31 L31	~1^0 L46 / ~2^0 L31 Sea ice: 1^0 x 0.5^0
CMA	BCC-ESM / BCC-CSM	T42 L26 for ESM1-LR T106 L46 for CSM2-MR T266 L26 for CSM2-HR	1/3 ^{0} in 50S-50N 1/3-1^0 in 50N-60N 1^0 in high latitudes
	CAMS-CSM	T106 L31	1^0 x 1^0 (0.5^0 near EQ) L30
SOA	FIO-ESM	200, 100, 50 km; L26	100, 50, 25 km; L75 WAV: 200, 100, 50 km

16 MIPs are considered by the model groups in China

	Short name of MIP	CAS		Universities			CMA		SOA	Total
		FGOALS	CAS ESM	THU	BNU	NUIST	BCC	CAMS	FIO	
0	DECK	✓	✓	✓	✓	✓	✓	✓	✓	8
1	AerChemMIP	✗	✓	✗	✗	✗	✓	✗	✗	2
2	C^4MIP	✗	✓	✗	✗	✗	✓	✗	✓	3
3	CFMIP	✓	✗	✓	✓	✗	✓	✓	✗	5
4	DAMIP	✗	✗	✗	✗	✓	✓	✗	✗	2
5	DCPP	✗	✗	✗	✗	✓	✓	✗	✓	4
6	GeoMIP	✗	✗	✗	✓	✗	✗	✗	✗	1
7	GMMIP	✓	✓	✓	✓	✓	✓	✓	✓	8
8	HighResMIP	✓	✗	✗	✗	✗	✓	✓	✗	3
9	LS3MIP	✗	✗	✗	✗	✗	✓	✗	✗	1
10	LUMIP	✗	✗	✗	✗	✗	✓	✗	✗	1
11	OMIP	✓	✗	✓	✗	✗	✓	✗	✓	4
12	PMIP	✓	✗	✗	✗	✓	✗	✗	✗	2
13	RFMIP	✗	✗	✗	✗	✗	✓	✗	✗	1
14	ScenarioMIP	✓	✓	✓	✓	✗	✓	✗	✓	6
15	SIMIP	✗	✗	✓	✗	✗	✗	✗	✓	2
16	CORDEX	✗	✗	✓	✗	✗	✗	✗	✗	1

(Key: ✗ = orange cell, ✓ = green cell)

✗ do not plan to contribute simulations

✓ plan to contribute simulations

Progress -1

(on cumulus convective scheme)

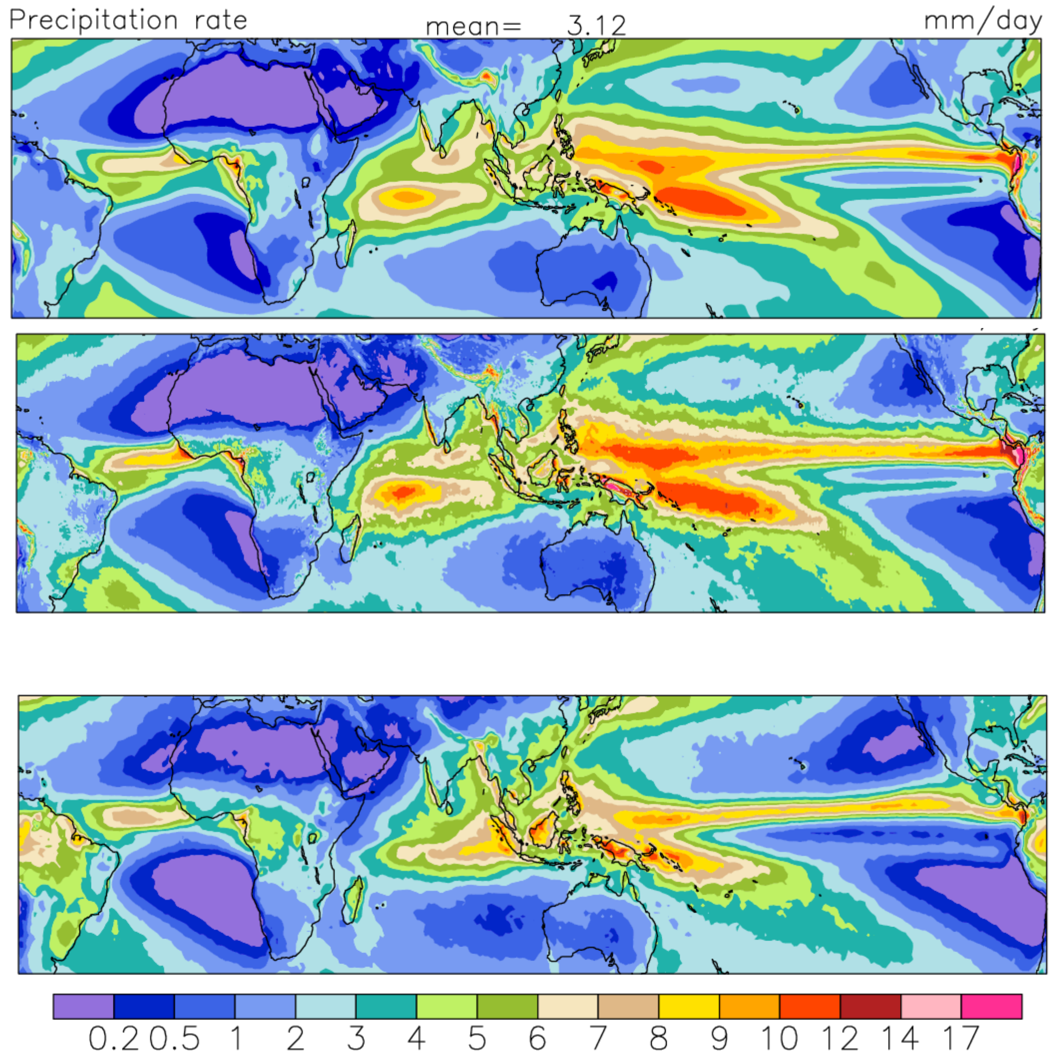
- Improvements of cumulus convective process lead to the reduction of ITCZ bias and improvements of ENSO, MJO, Diurnal cycle of precipitation, and probability distribution of intense daily tropical precipitation ;

ITCZ in FGOALS-f/LASG

C96 （1° ）

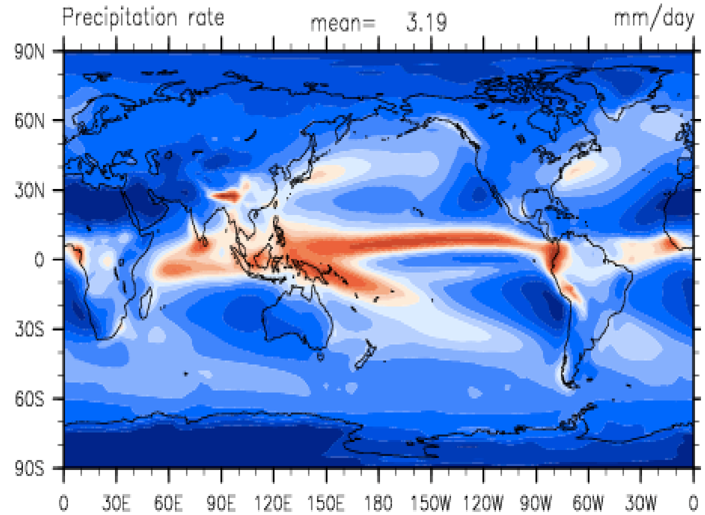
C384 （0.25° ）

TRMM

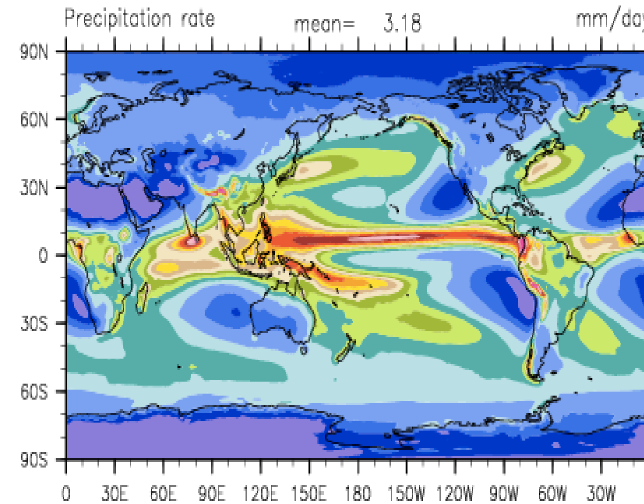


ITCZ in CICSM/THU

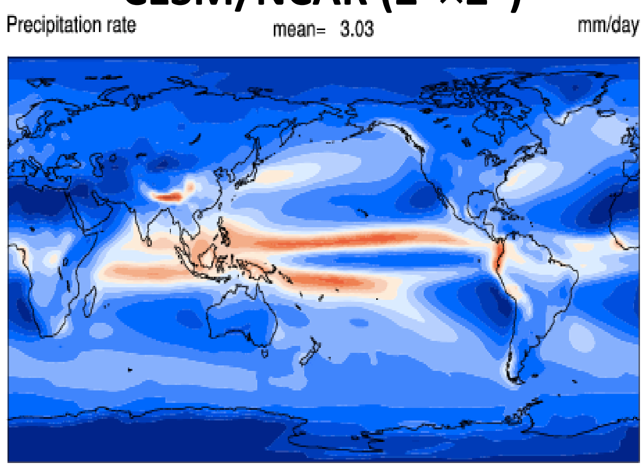
CICSM/THU (2°×2°)

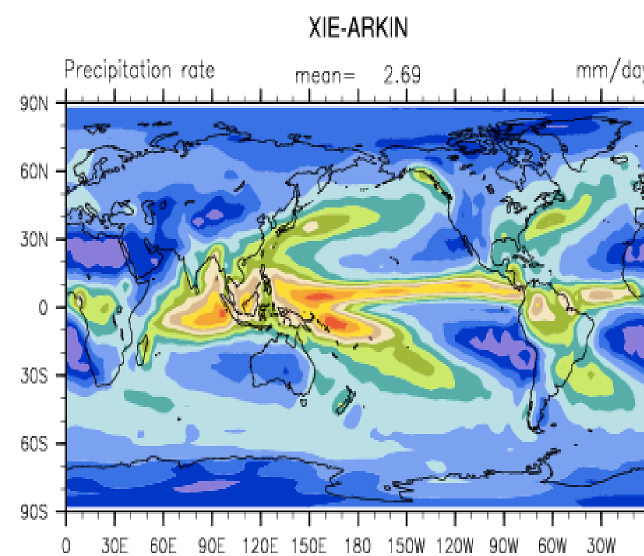


CICSM/THU (1°×1°)

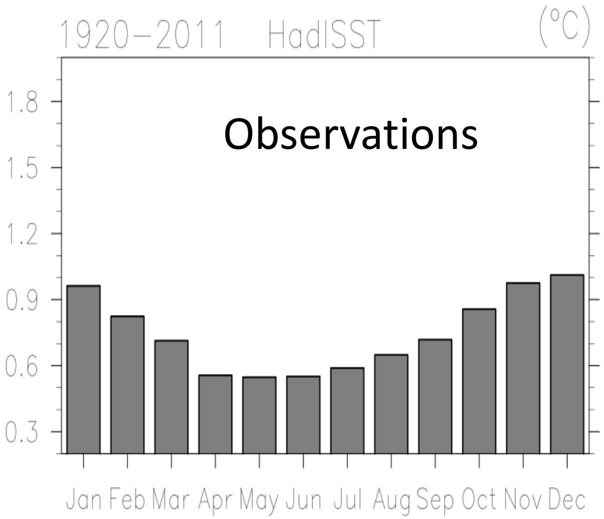


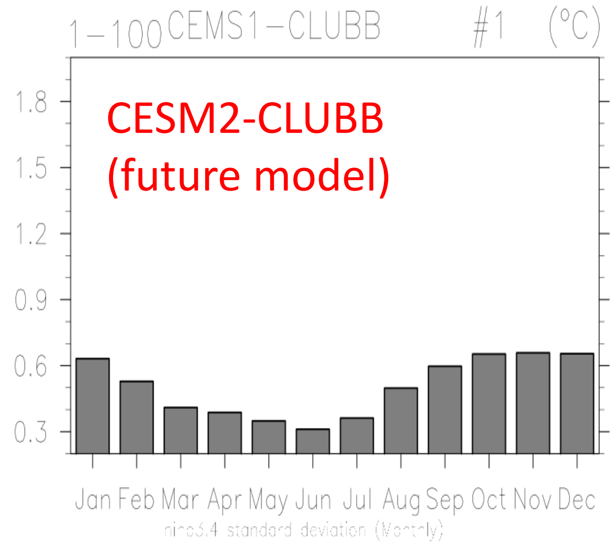
CESM/NCAR (2°×2°)

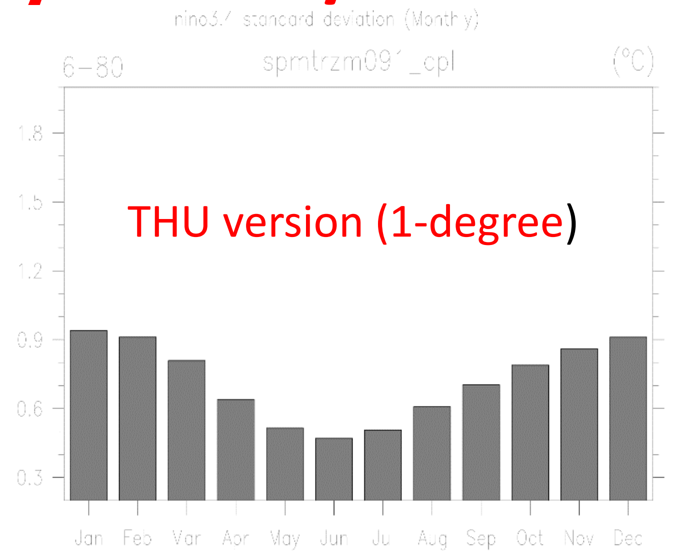


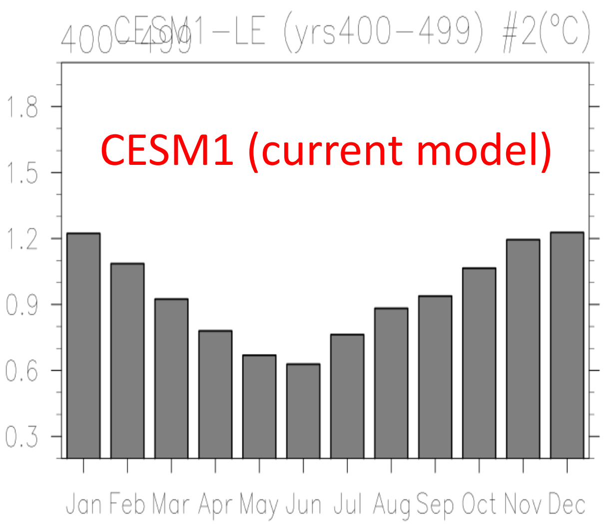


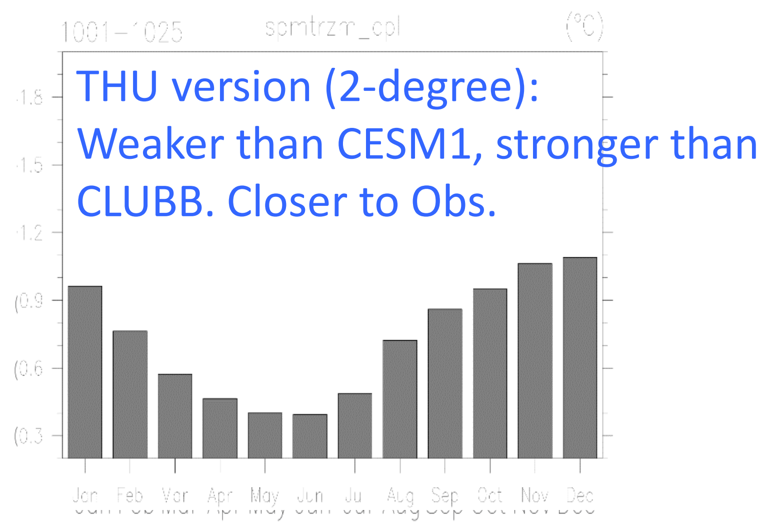
Seasonality of ENSO intensity by CICSM / THU



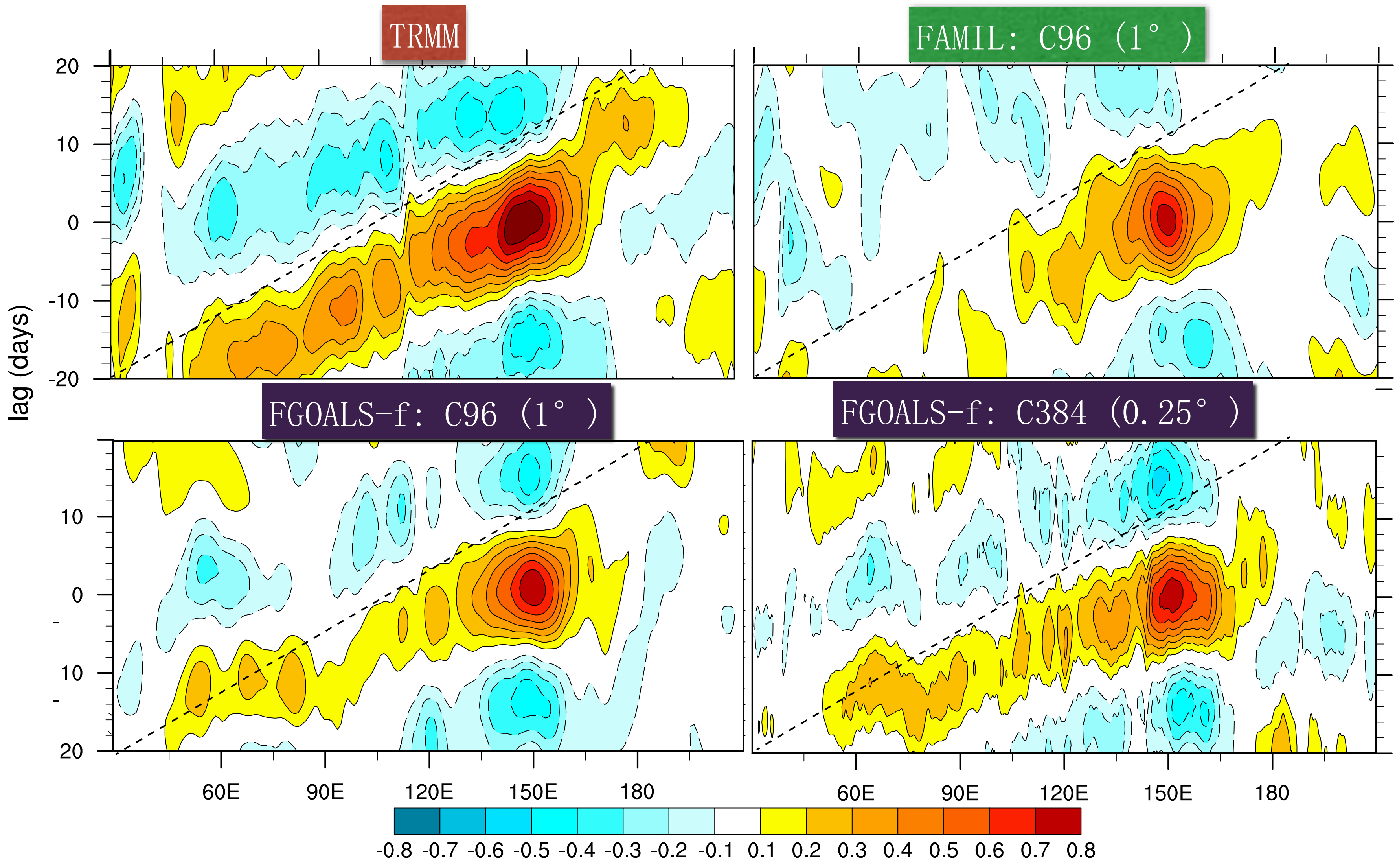






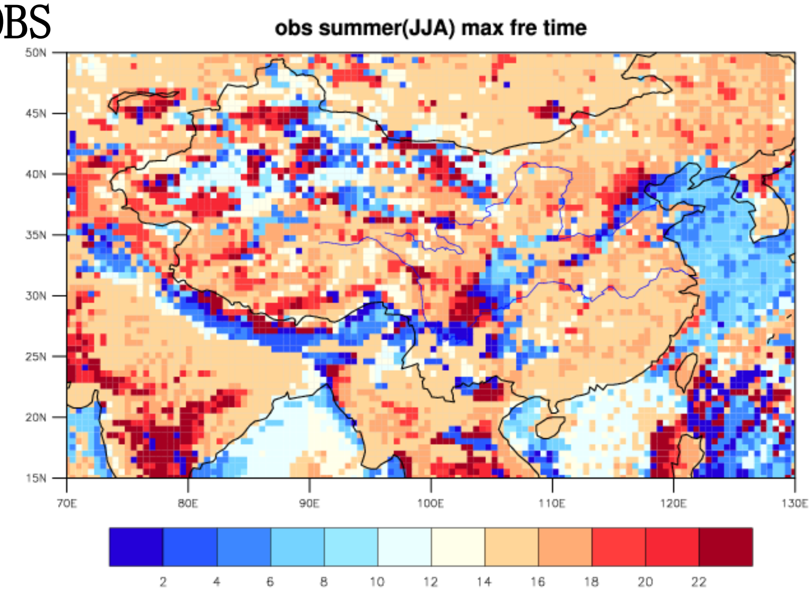


MJO in FGOALS-f/LASG

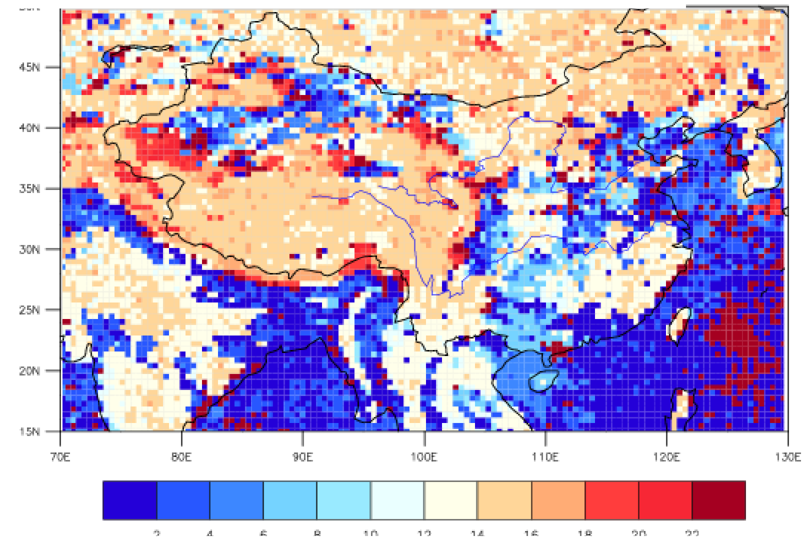


The local time of maximum frequency of diurnal rainfall

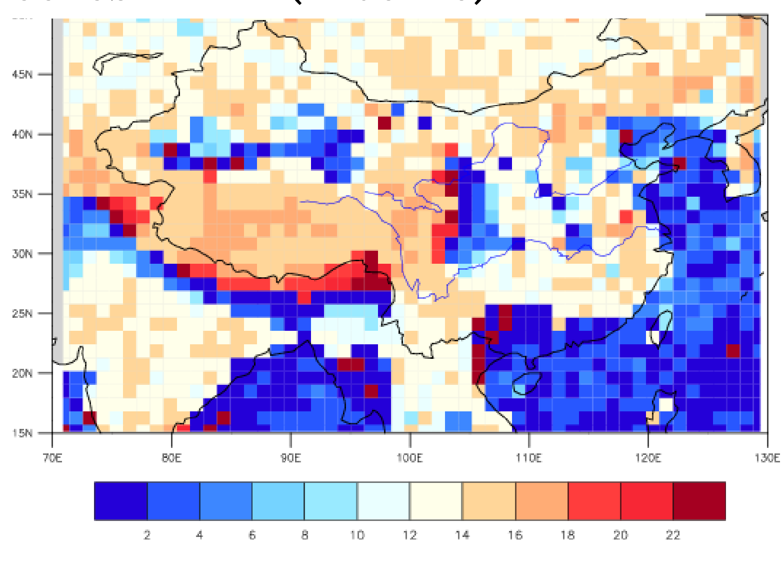
OBS



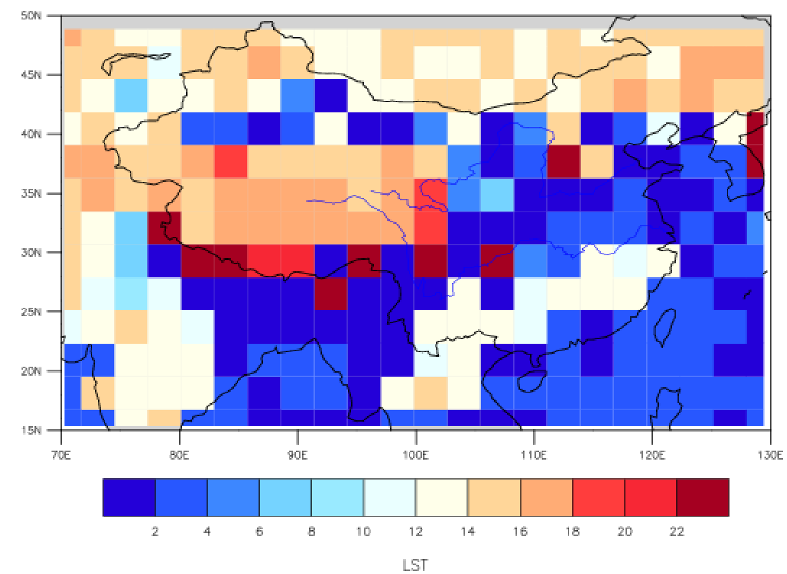
BCC-CSM2-HR (T266L26)



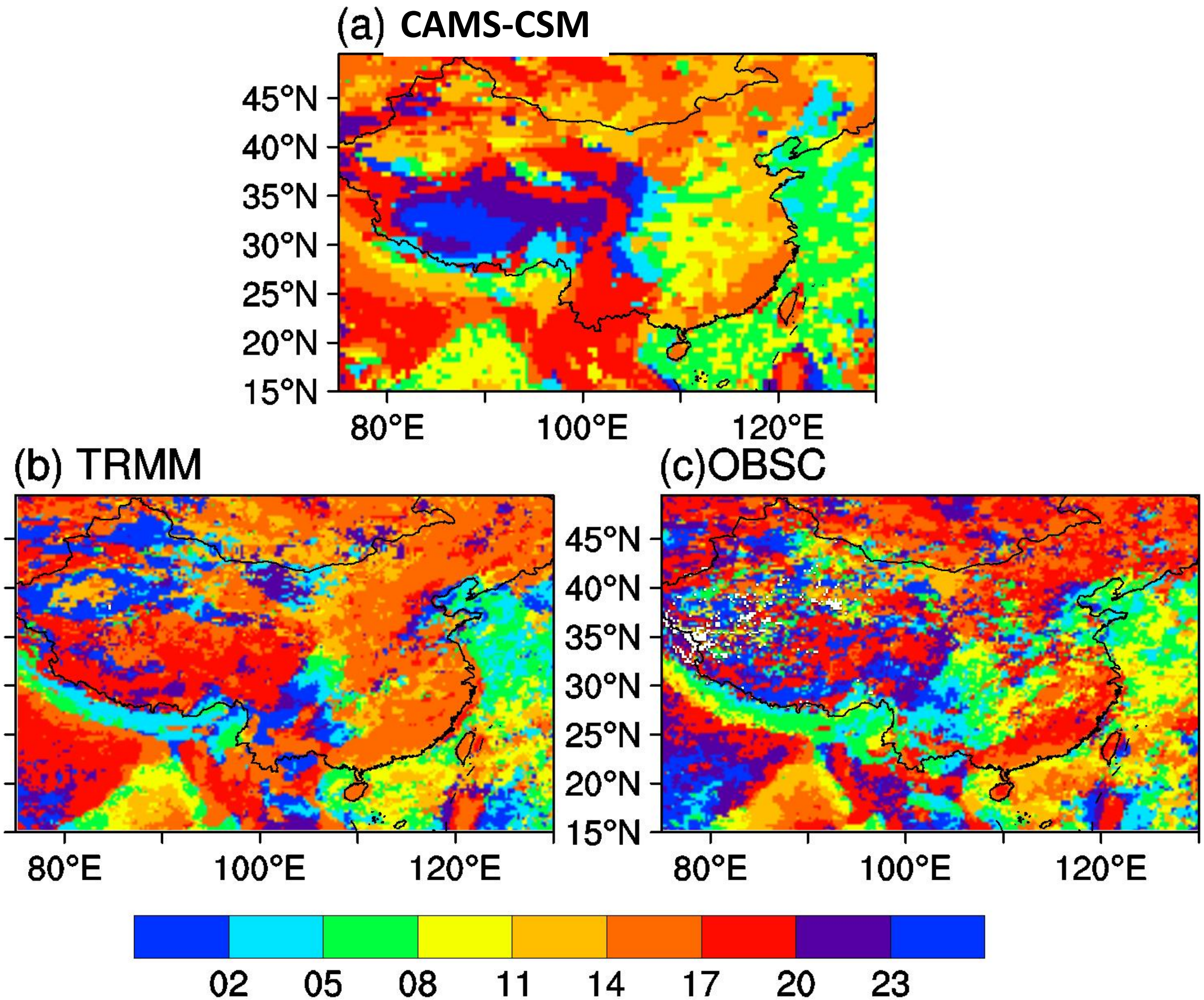
BCC-CSM2-MR (T106L46)



BCC-CSM2-LR (T42L26)



High resolution simulation of the diurnal precipitation peak time in summer. The peak time over eastern China are well captured.

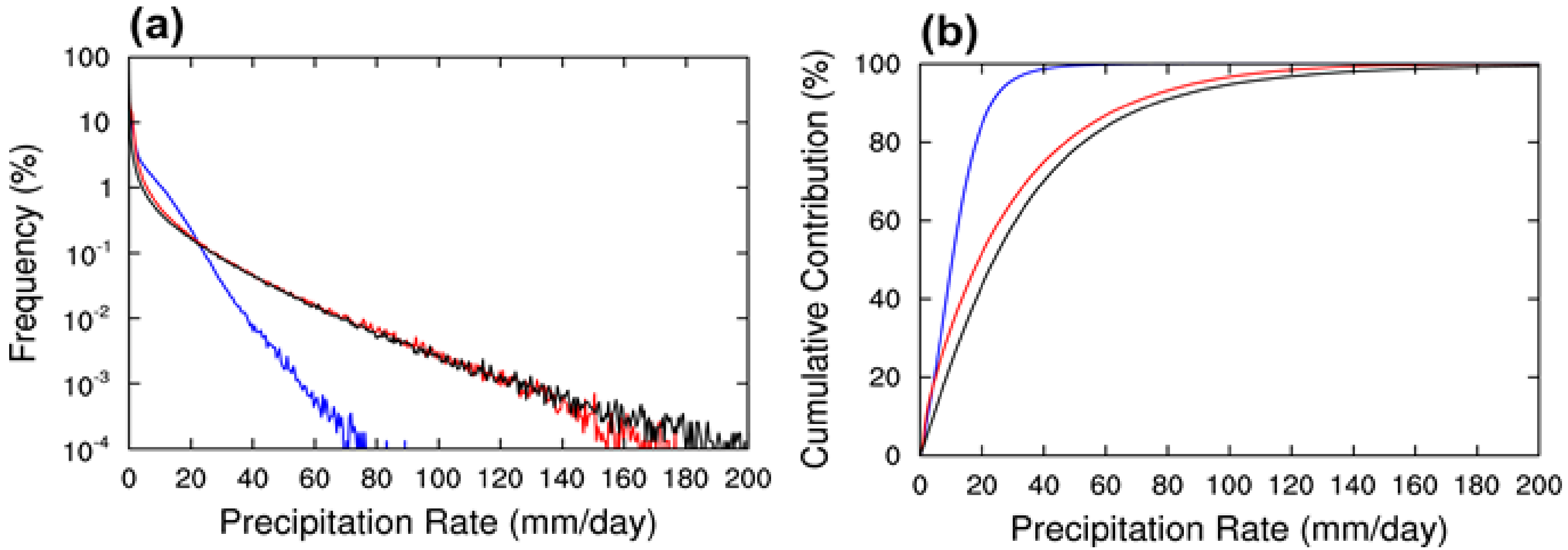


The probability distribution of intense daily tropical precipitation

Black: TRMM;

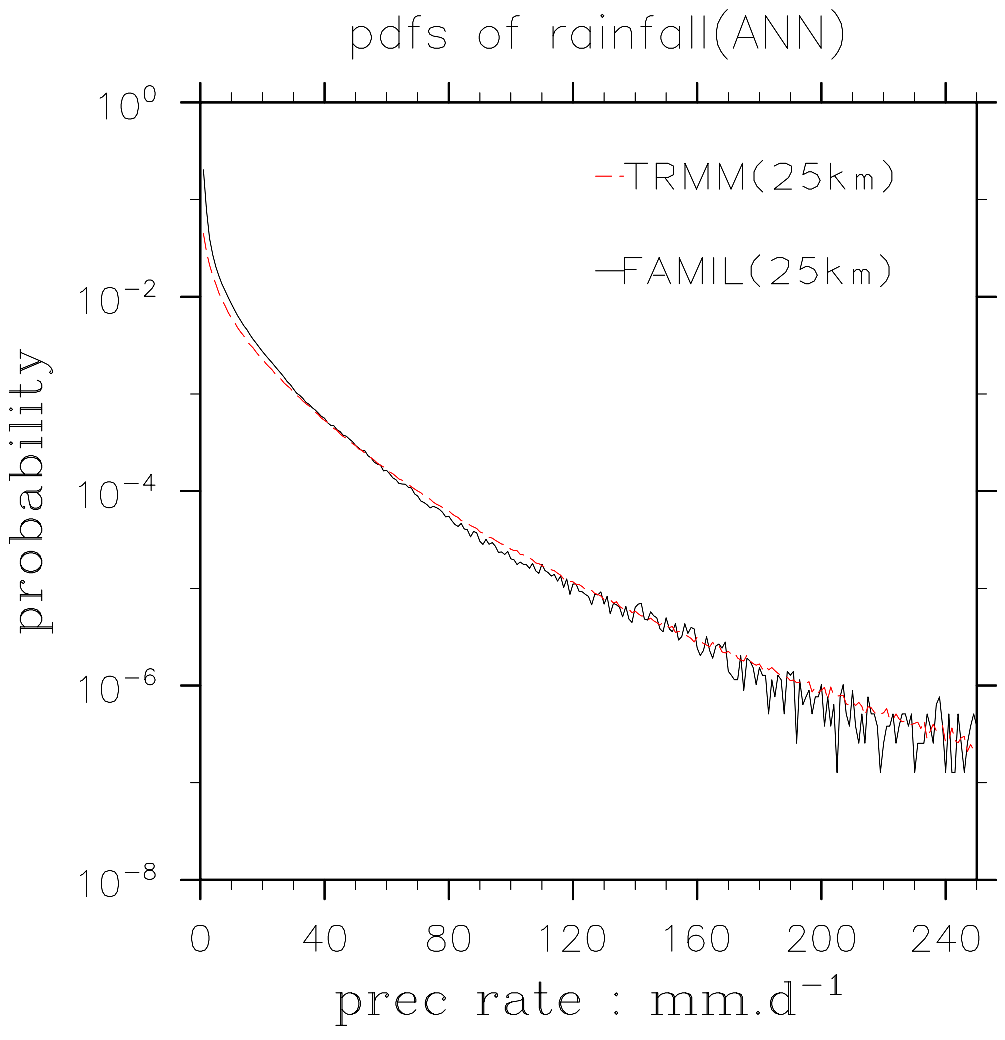
Blue: CAM5.3 without stochastic process;

Red: CICSM-AGCM/THU with stochastic process



Wang et al. (2016, GRL)

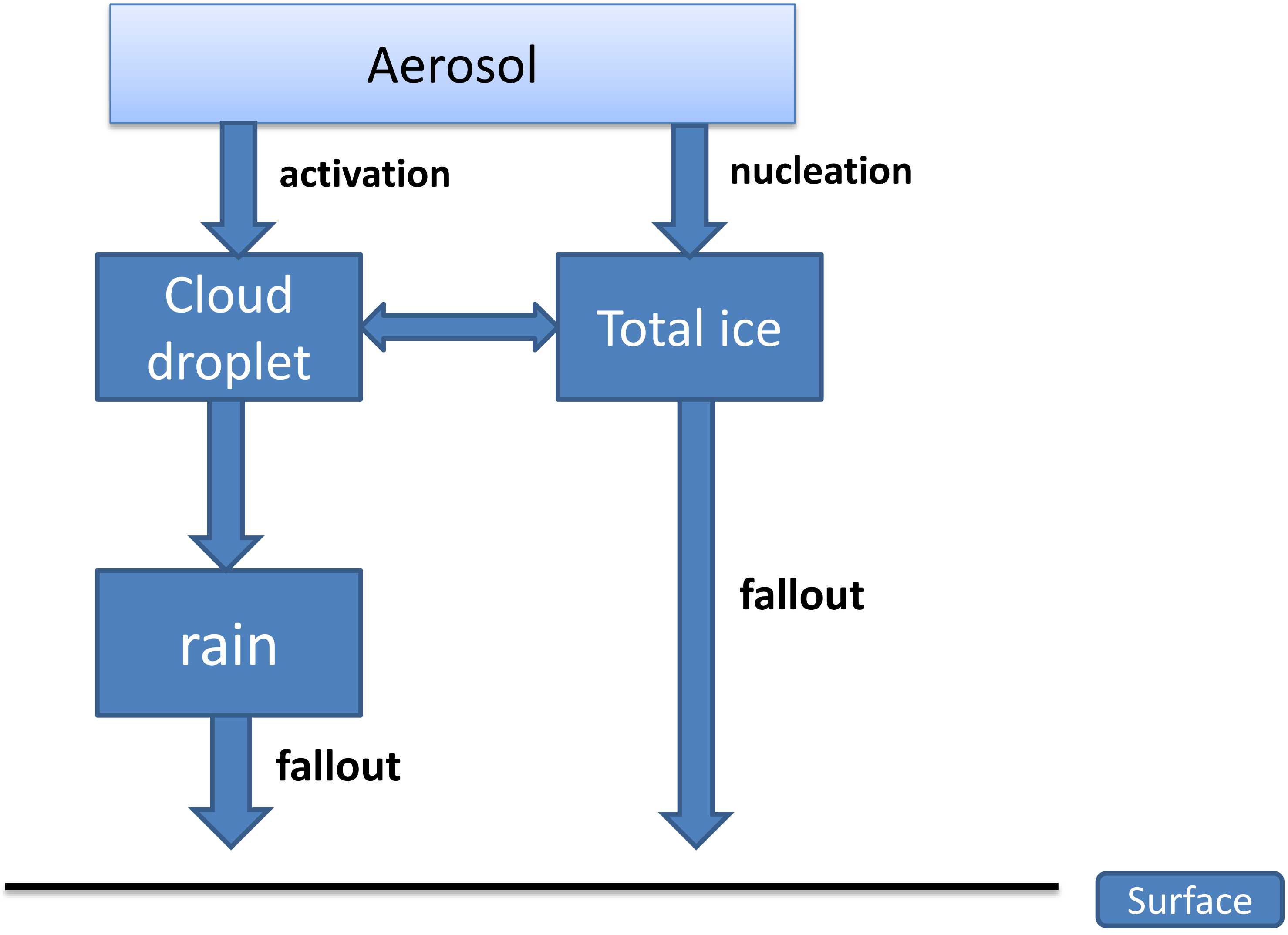
The probability distribution of intense daily tropical precipitation



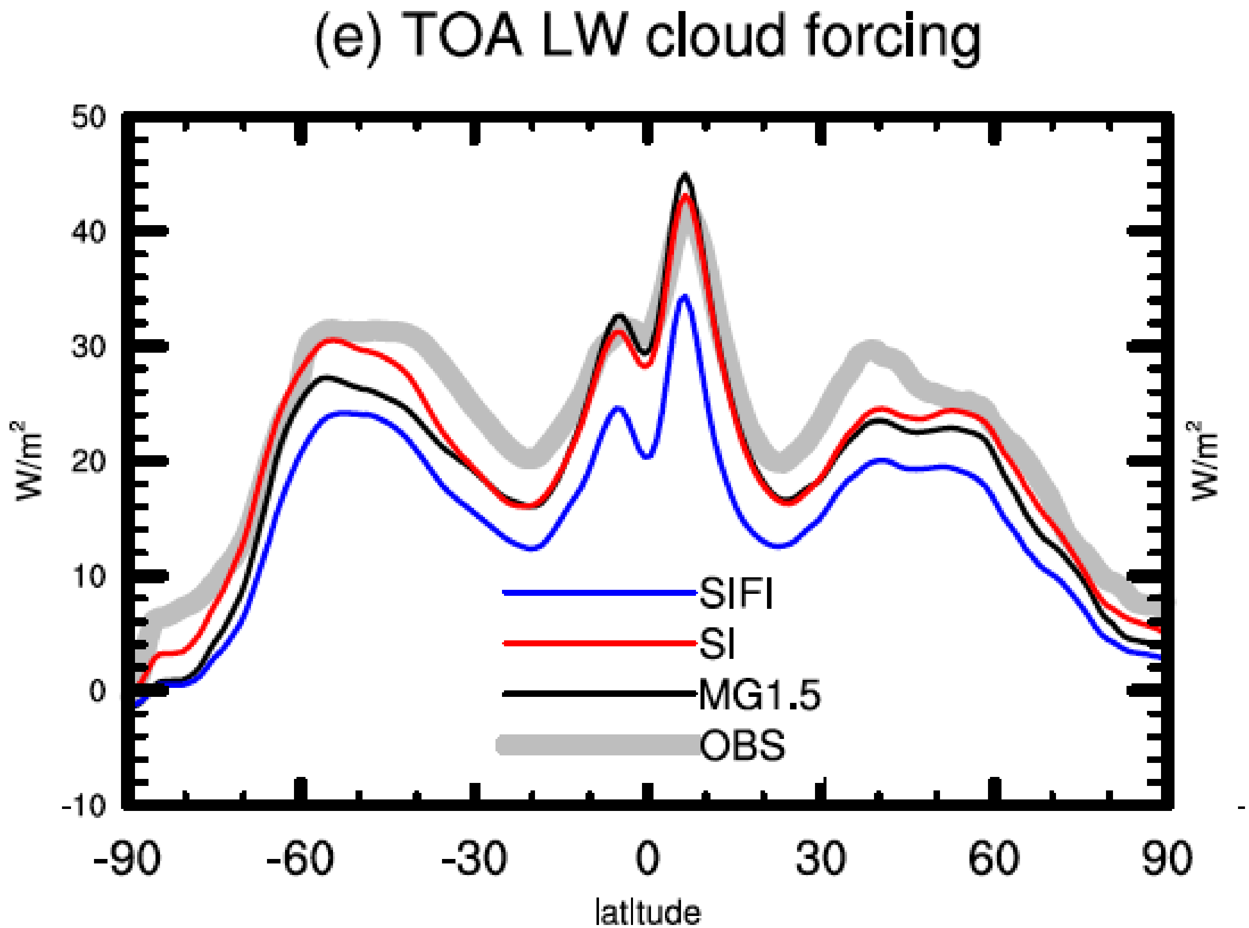
Progress -2
(on other schemes)

- Improvements of cloud (micro- or macro-) physics lead to the reductions of errors in LWCF and Low cloud;
- Update of boundary layer leads to better eastward propagation of MJO;
- Introduction of gravity wave drag caused by convection leads to reasonable presentation of QBO;
- Update of subgrid-scale orographic form drag leads to better simulation of 10-m wind speed;

A single ice cloud microphysics (by THU)



Single-ice improves the LWCF simulation



A new PDF method for cloud macrophysics (by THU)

Default Scheme

- Diagnostic RH cloud fraction scheme

Inconsistency

- Prognostic condensate scheme (Zhang et al., 2003)
  - Equilibrium state (complex)

- Need adjustment

New Scheme

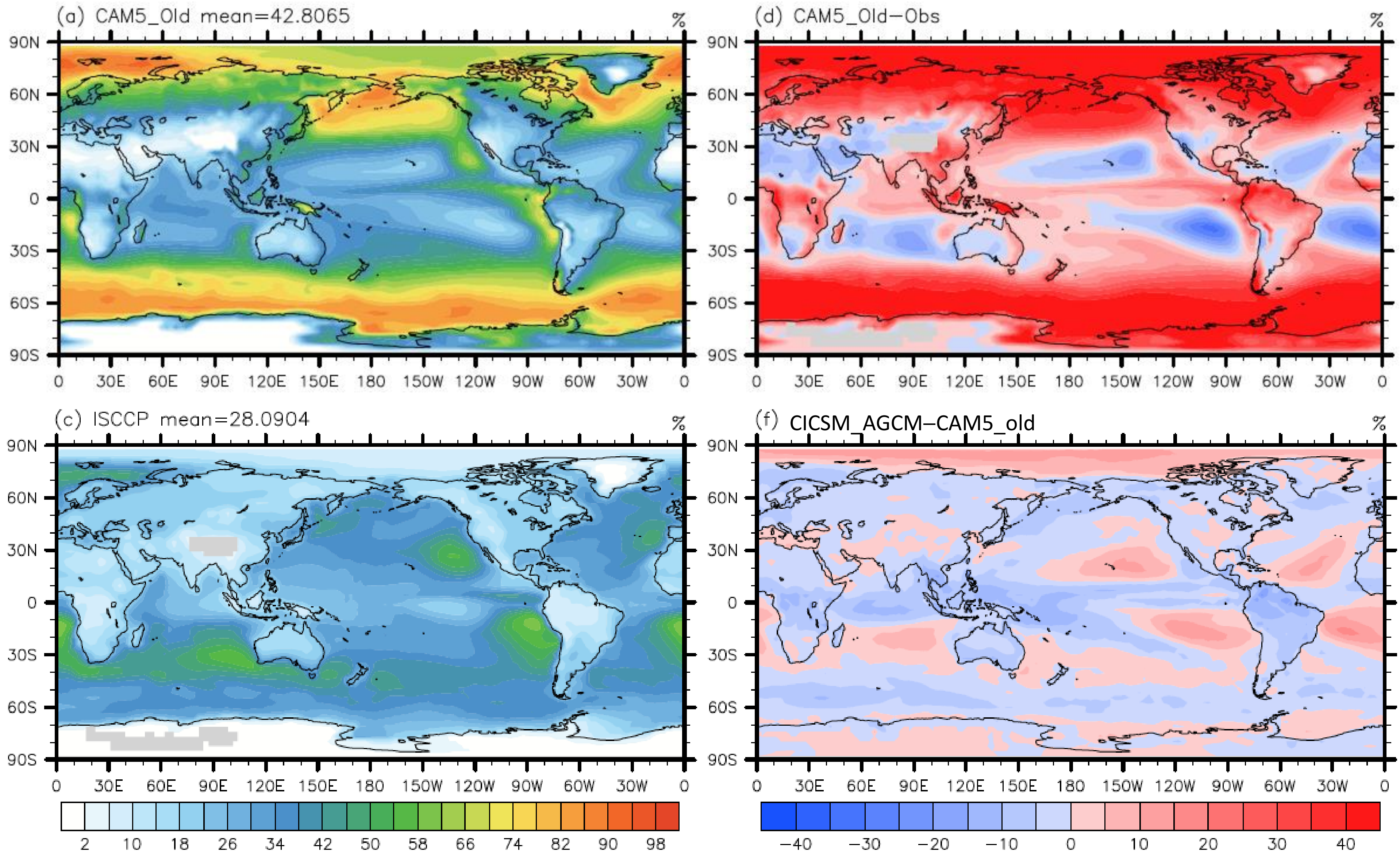
- Diagnostic Gaussian cloud fraction scheme

consistency

- Diagnostic Gaussian condensate scheme
  - none

- No adjustment needed
- Consider sub-grid variability

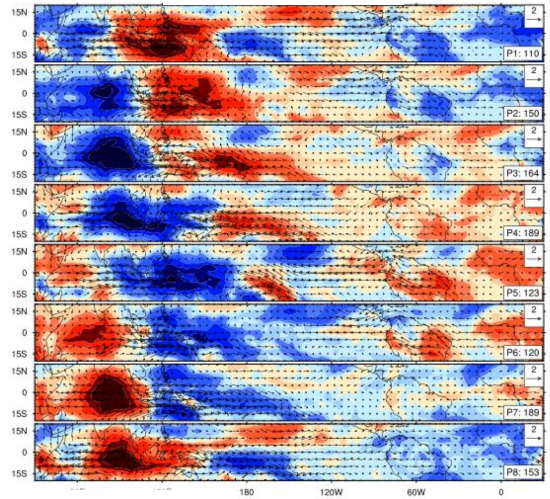
Improvement of low cloud



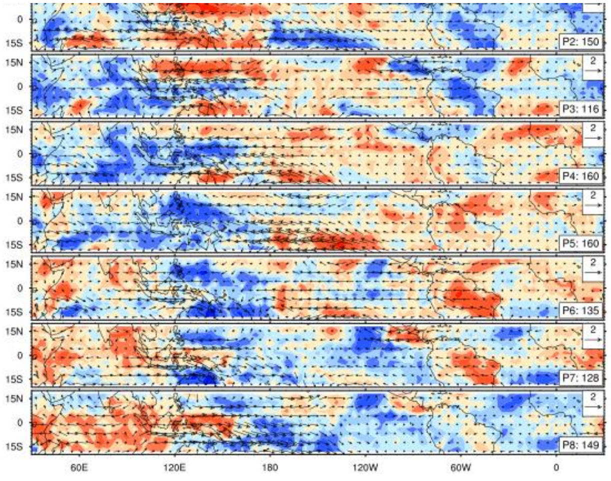
The new scheme improve marine low cloud simulations.

MJO in GAMIL / LASG (Nov to Apr)

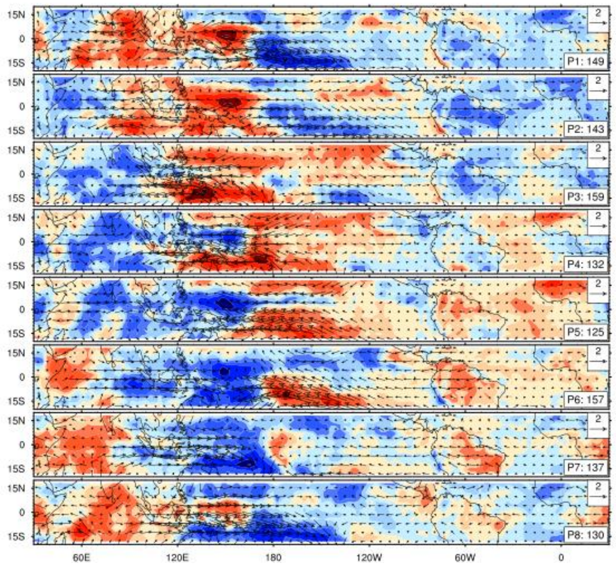
OBS



GAMIL2(K-profile)

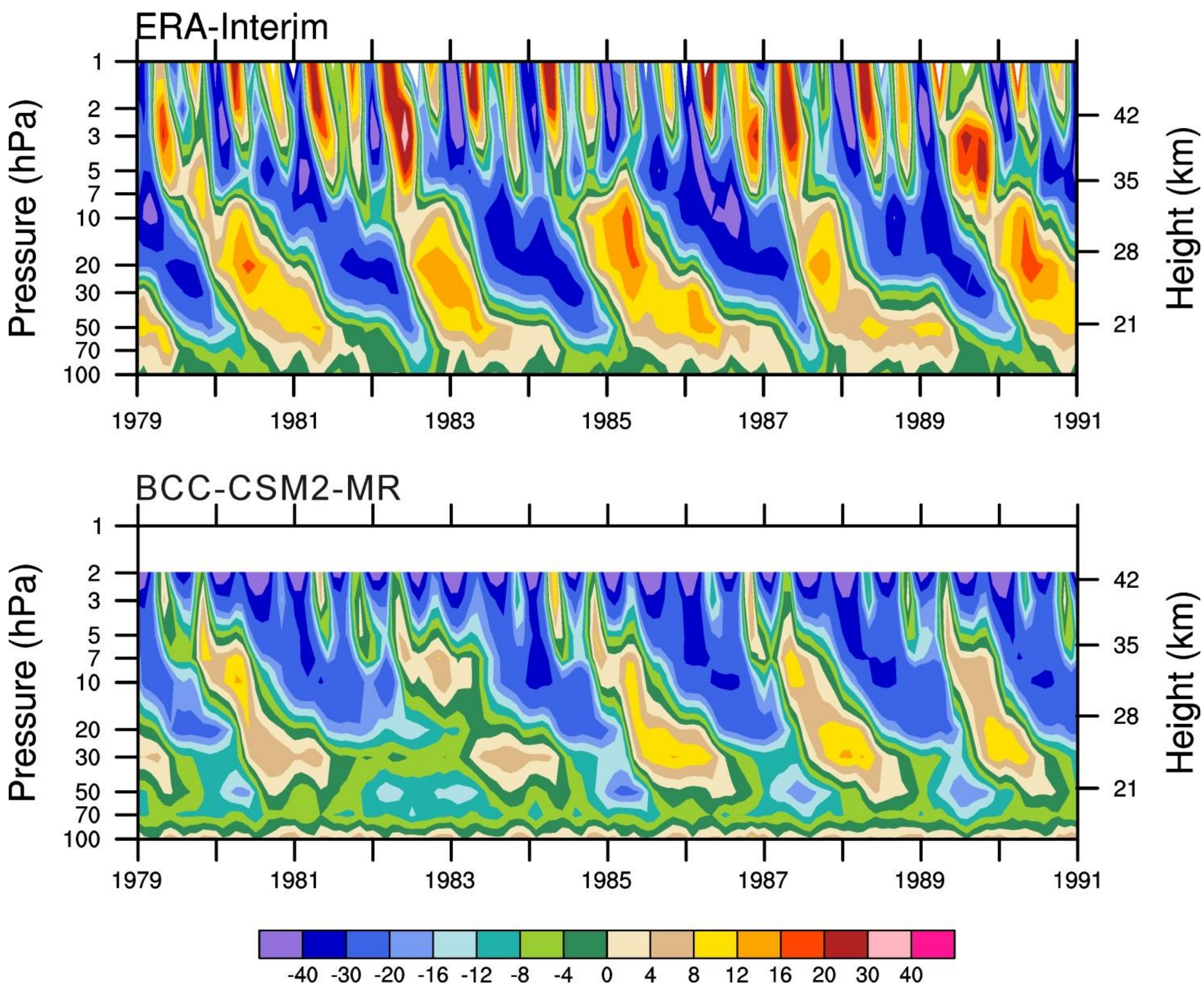


GAMIL3(TKE)



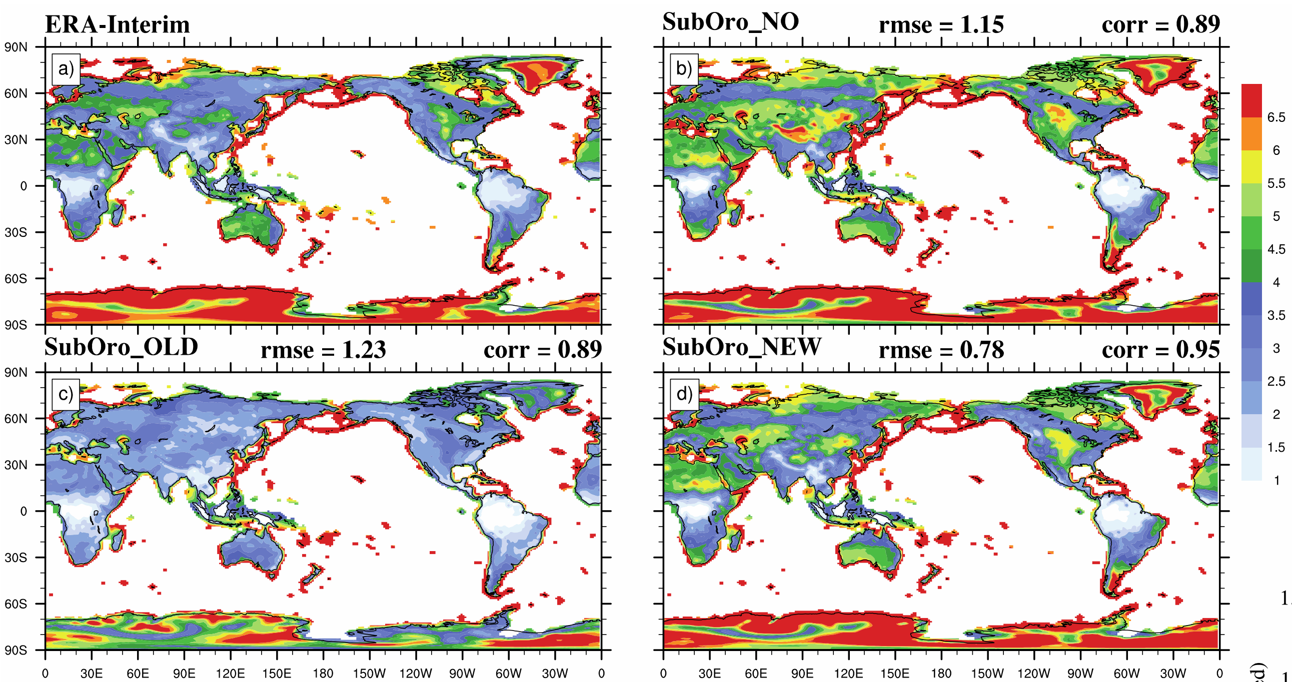
QBO in BCC-CSM2-MR

U at 5°N-5°S in m/s



Parameterizations of Subgrid-scale Orographic Form Drag (by BNU)

10-m wind speed

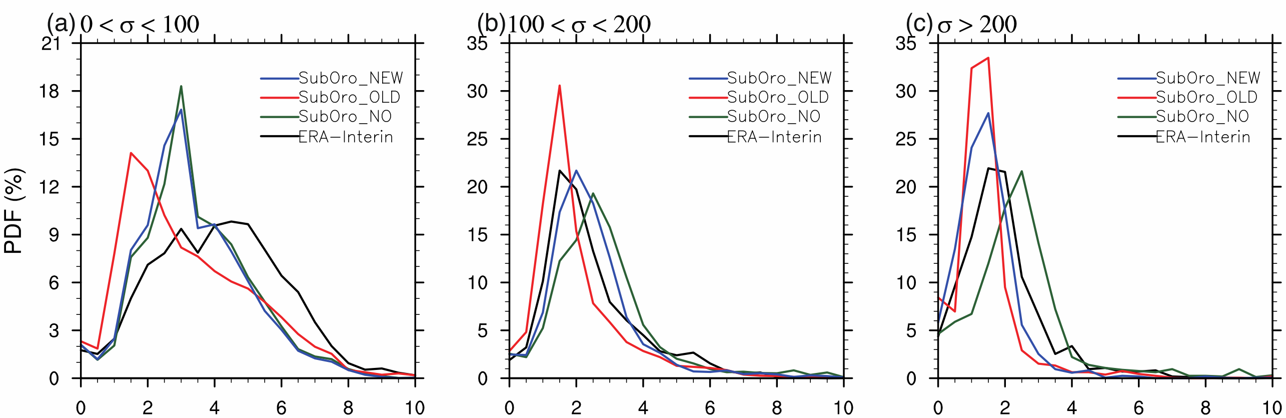


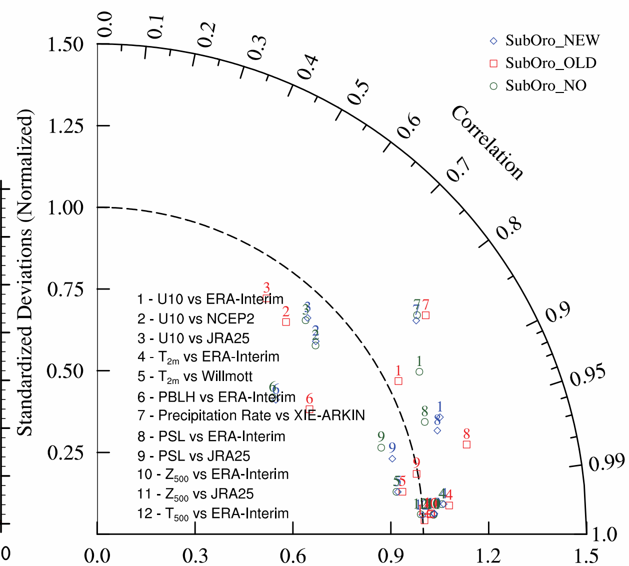
ERA-Interim

SubOro_NO: Control run

SubOro_OLD: TMS scheme

SubOro_NEW: BBW04 scheme



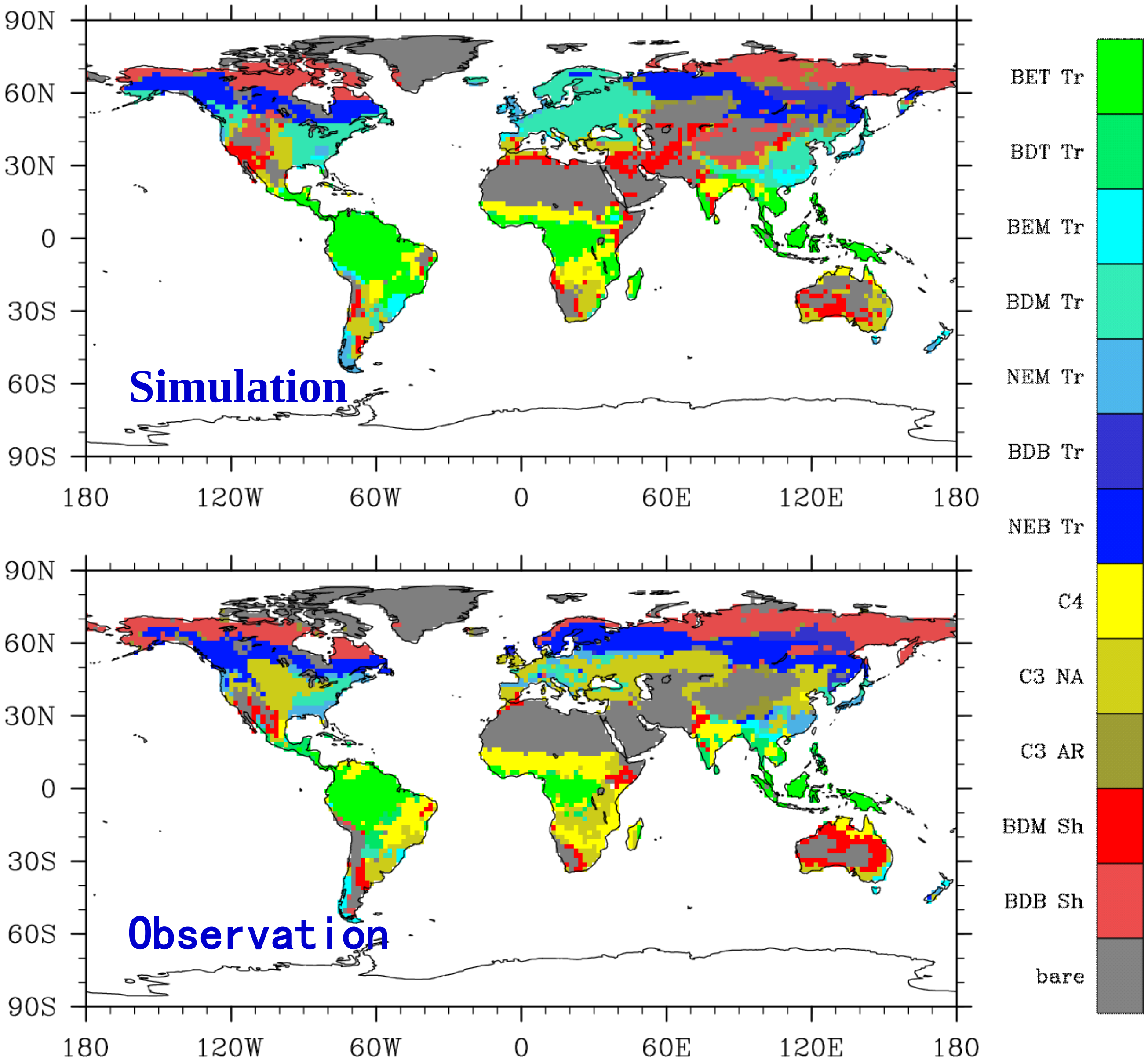


Progress-3

(on other components)

- Terrestrial and marine ecosystem components are developed or improved, and perform reasonably;

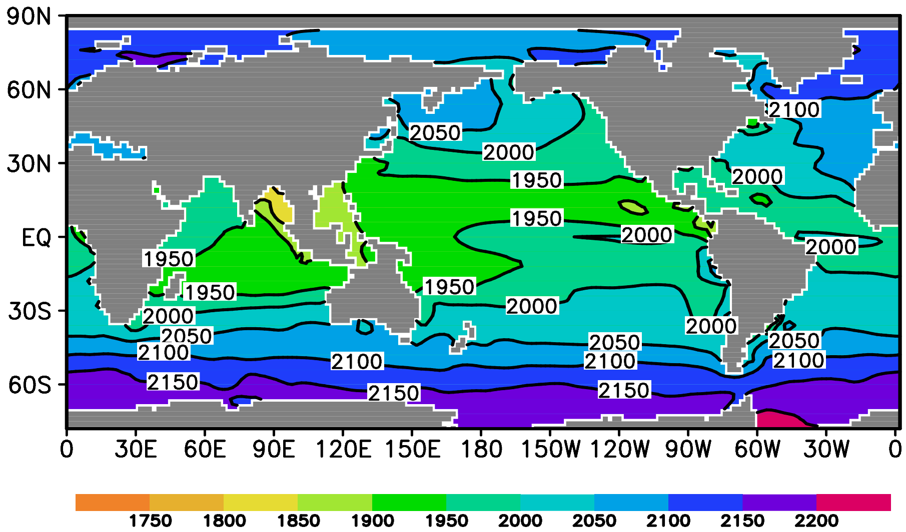
IAP-DGVM1



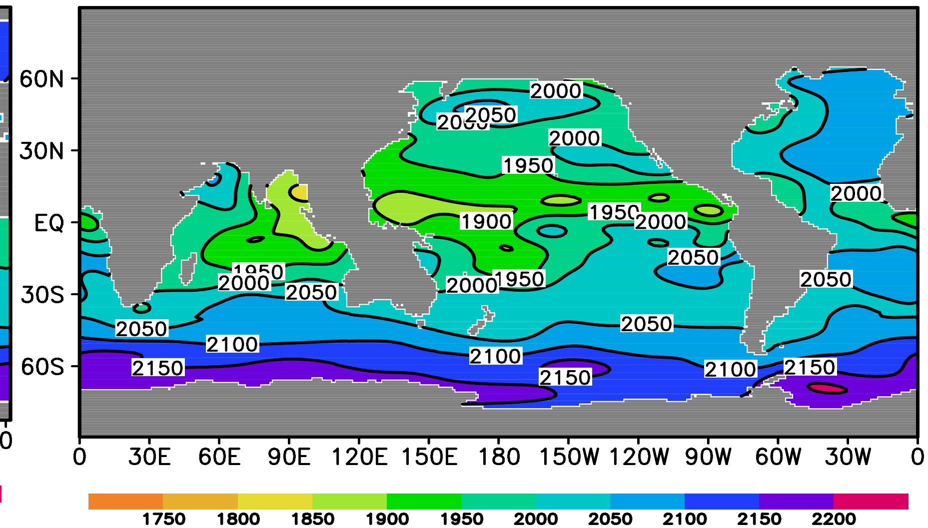
Horizontal distribution of Dominant vegetation types

(Zeng et al, 2014)

Surface water concentration of Disolved Inorganic Carbon (DIC) (μmol/kg) averaged in 1990s



Simulation by IAP OBGCM



GLODAP Observational estimates

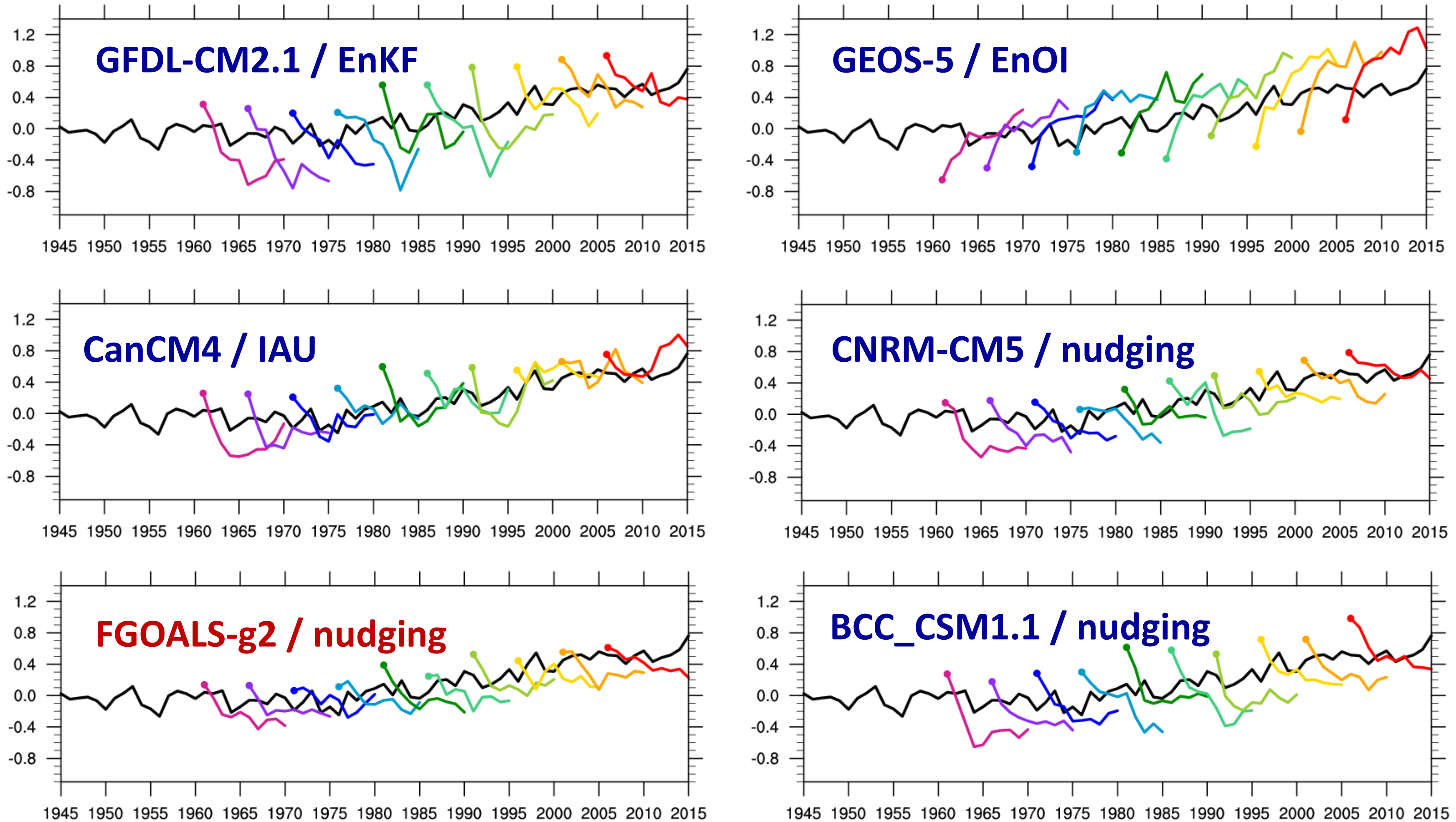
Progress-4

(on decadal prediction)

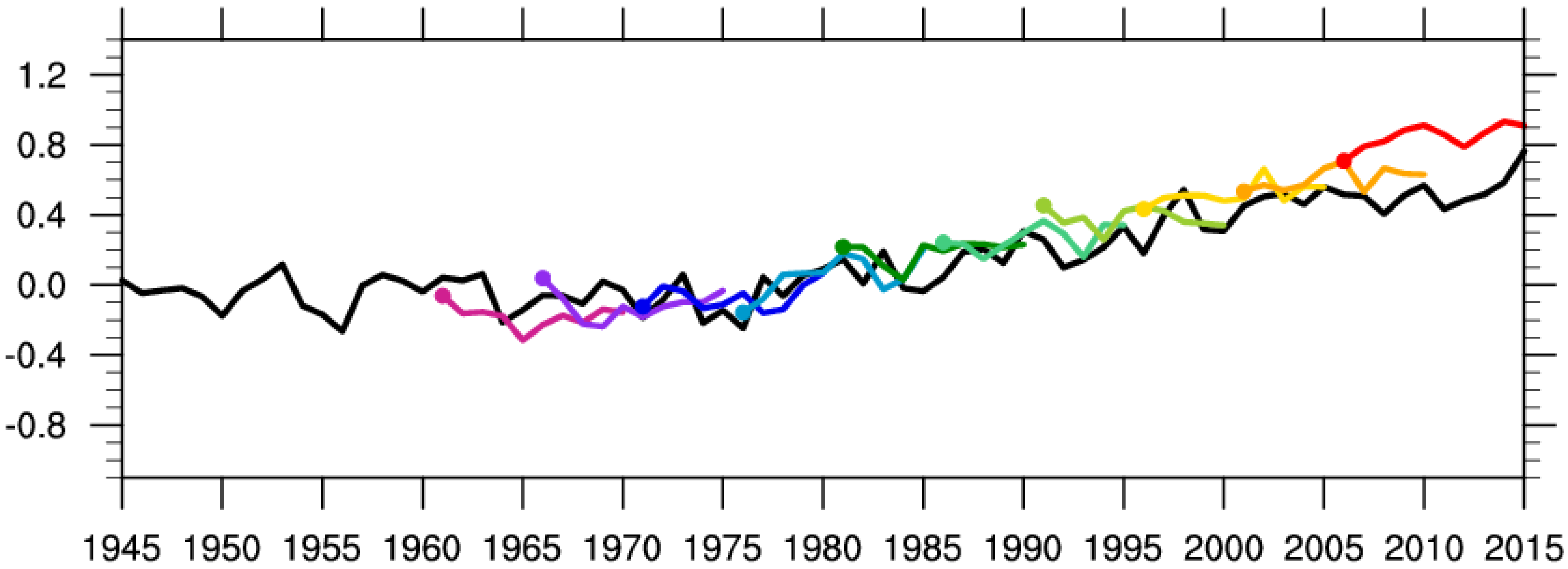
- Initial shock in decadal prediction caused by assimilations of full-field observation is reduced due to the use of DRP-4DVar, a kind of 4DEnVar.

Initial shock in CMIP5 models

(coupled, full observation)



FGOALS-g2 with DRP-4DVar
(coupled, full OBS)



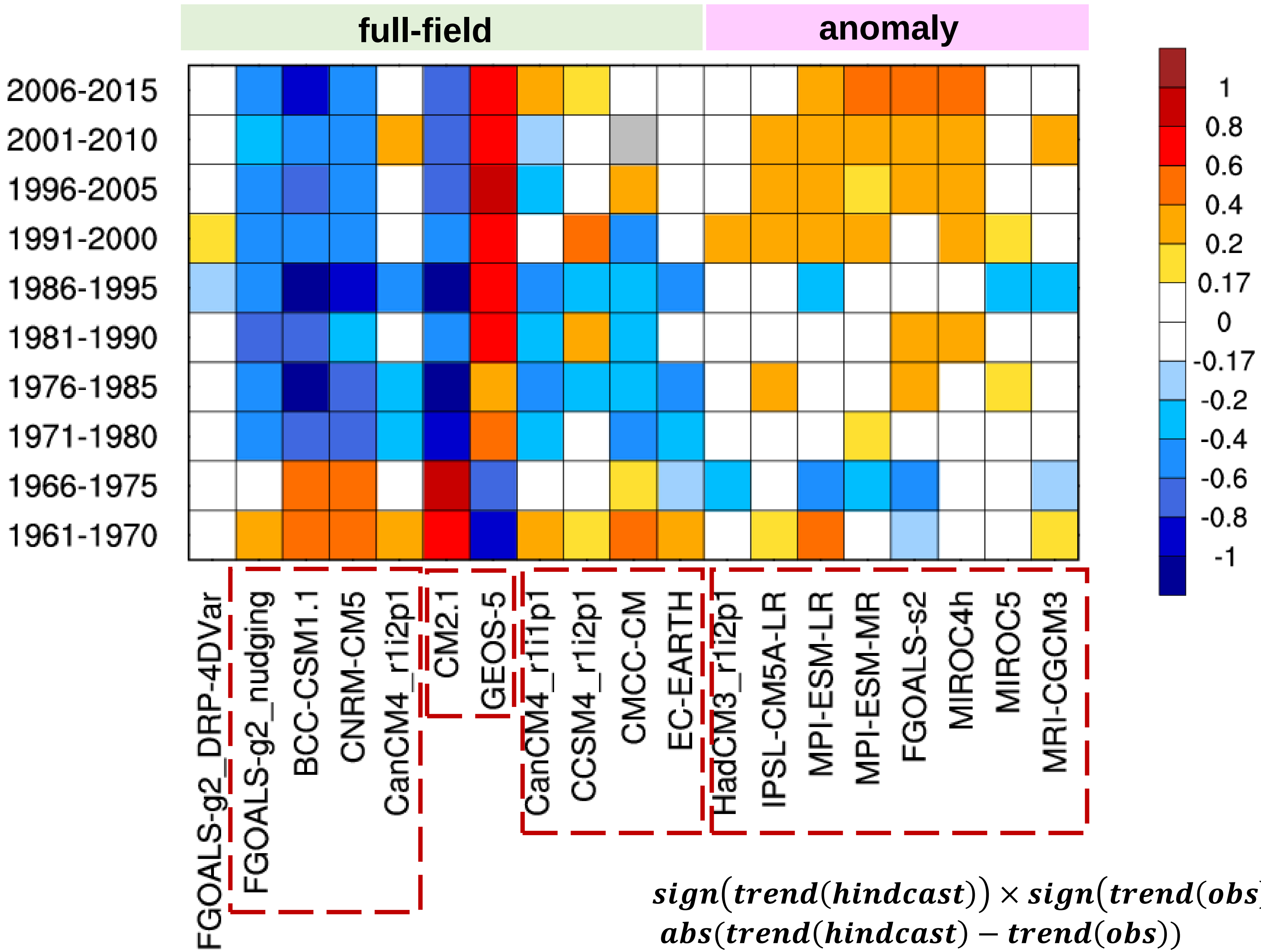
Three indices to measure initial shock

- $Trend_{index} = sign(trend(hindcast)) \times sign(trend(obs)) \times abs(trend(hindcast) - trend(obs))$
- **Standard deviation:** $STD_{index} = \frac{std(obs)}{std(hindcast)}$

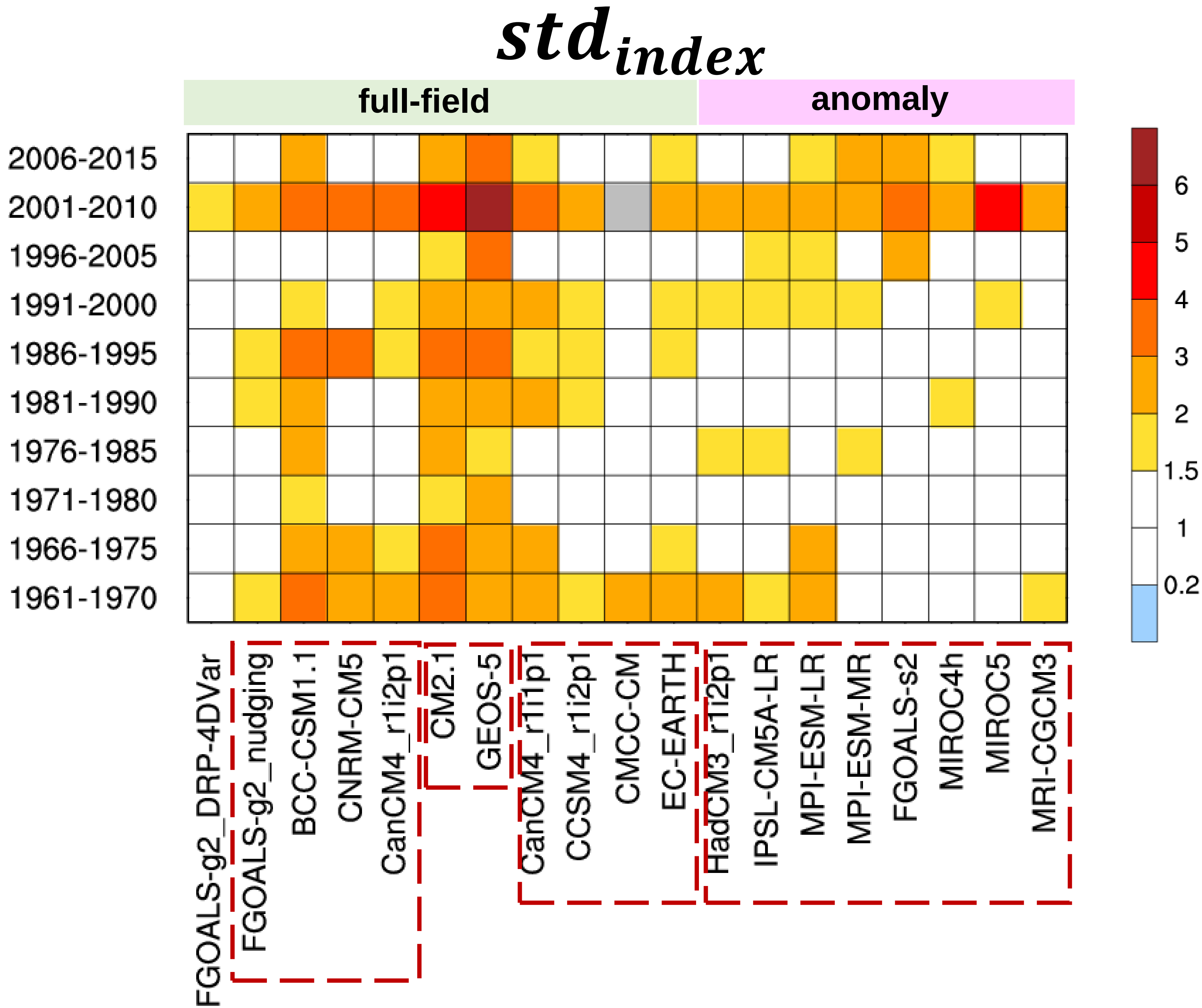
  where $STD = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2}$
- **Root mean square error:**

  $$RMSE_{index} = std(obs - hincast)$$
- All based on the 10-year hindcasts;
- **The closer to 0, the better (for Trend and RMSE);**
- **The closer to 1, the better (for STD).**

$trend_{index}$

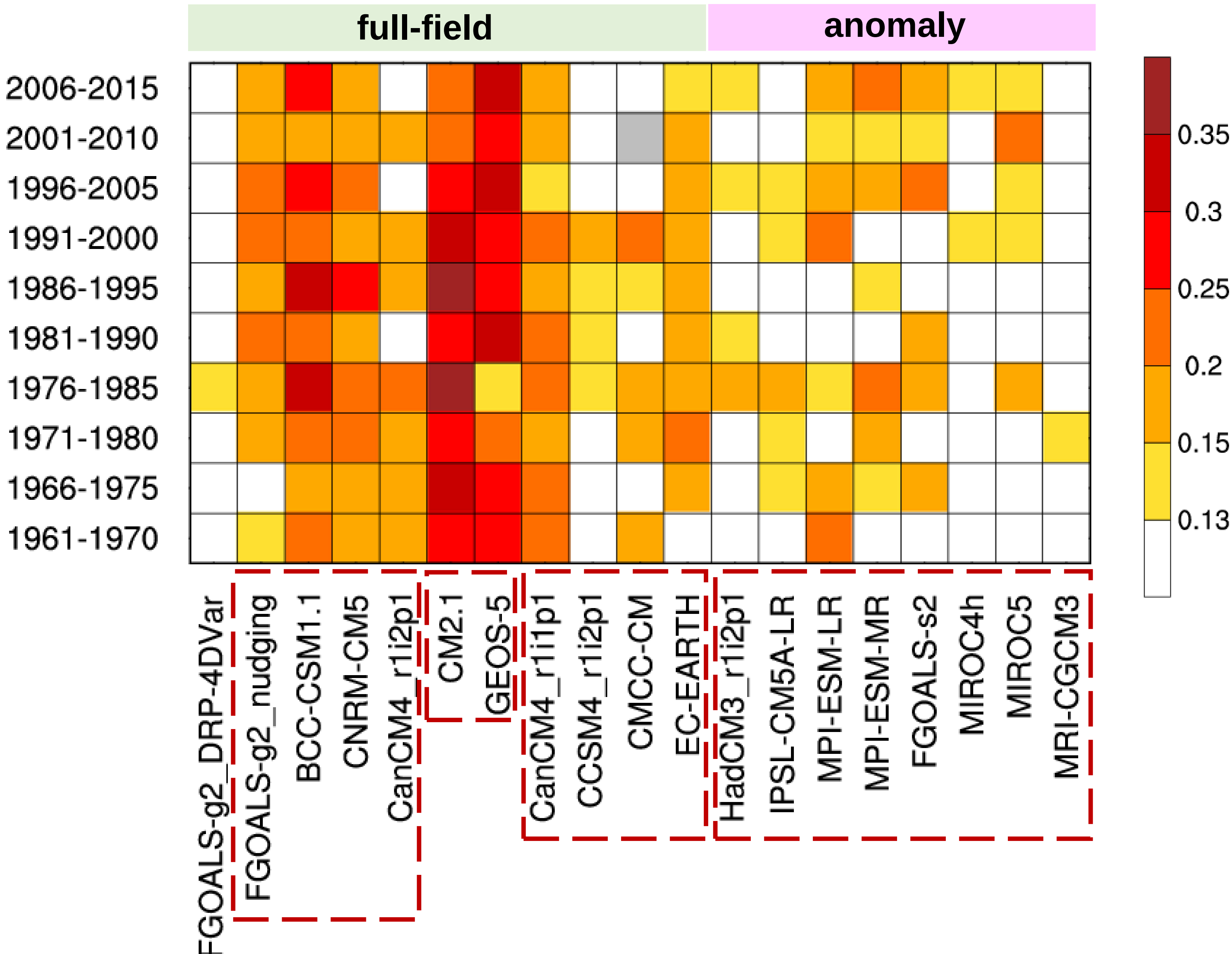


$$sign(trend(hindcast)) \times sign(trend(obs)) \times abs(trend(hindcast) - trend(obs))$$



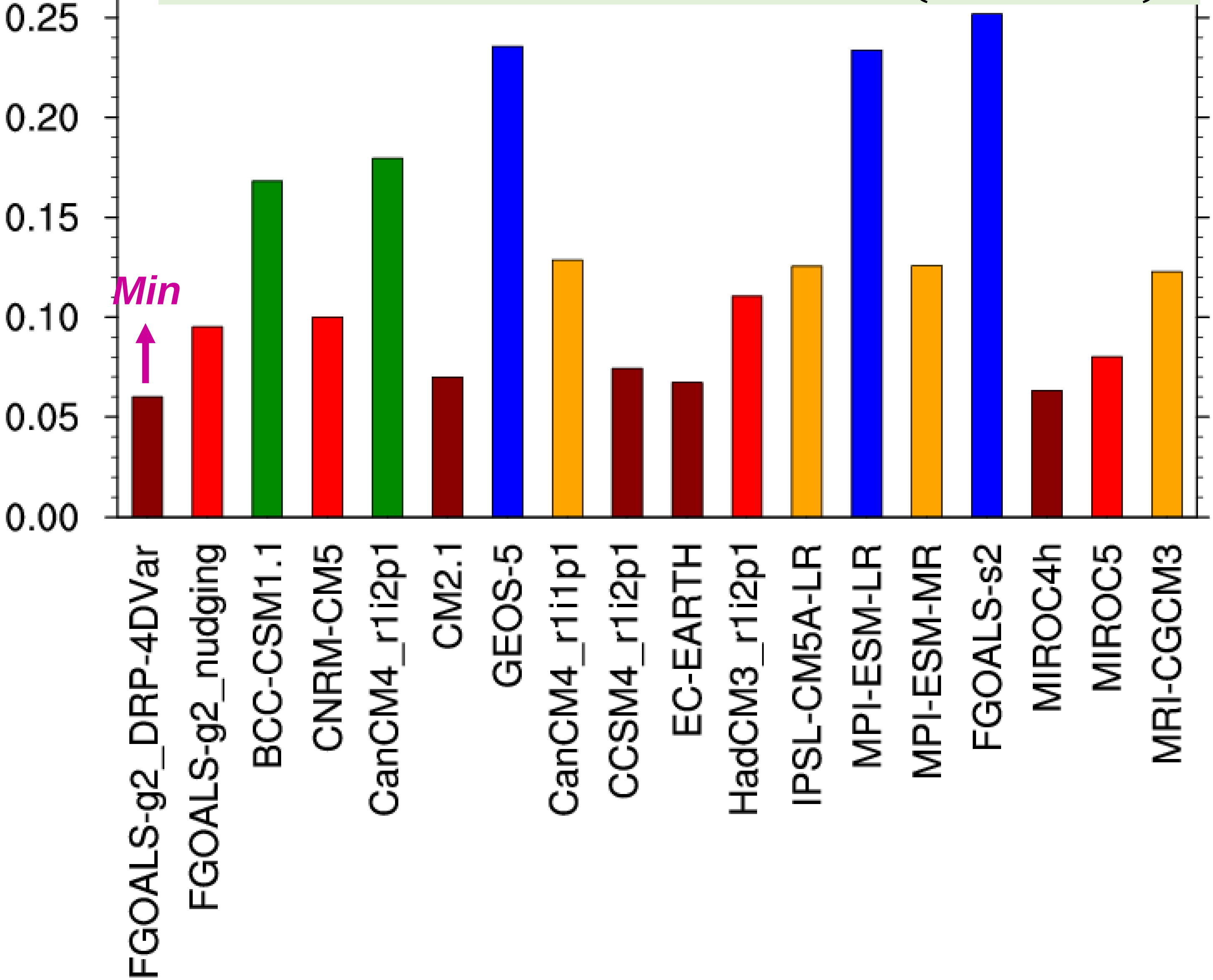
std_{index}
full-field
anomaly
2006-2015
2001-2010
1996-2005
1991-2000
1986-1995
1981-1990
1976-1985
1971-1980
1966-1975
1961-1970
FGOALS-g2_DRP-4DVar
FGOALS-g2_nudging
BCC-CSM1.1
CNRM-CM5
CanCM4_r1i2p1
CM2.1
GEOS-5
CanCM4_r1i1p1
CCSM4_r1i2p1
CMCC-CM
EC-EARTH
HadCM3_r1i2p1
IPSL-CM5A-LR
MPI-ESM-LR
MPI-ESM-MR
FGOALS-s2
MIROC4h
MIROC5
MRI-CGCM3
6
5
4
3
2
1.5
1
0.2

RMSE


full-field
anomaly
2006-2015
2001-2010
1996-2005
1991-2000
1986-1995
1981-1990
1976-1985
1971-1980
1966-1975
1961-1970
FGOALS-g2_DRP-4DVar
FGOALS-g2_nudging
BCC-CSM1.1
CNRM-CM5
CanCM4_r1i2p1
CM2.1
GEOS-5
CanCM4_r1i1p1
CCSM4_r1i2p1
CMCC-CM
EC-EARTH
HadCM3_r1i2p1
IPSL-CM5A-LR
MPI-ESM-LR
MPI-ESM-MR
FGOALS-s2
MIROC4h
MIROC5
MRI-CGCM3
0.35
0.3
0.25
0.2
0.15
0.13

Decadal variation of annual mean SATA

$$GRMSE(detrend) = \frac{RMSE(detrend) \times 2}{1 + CoR(detrend)}$$



Brief Introduction to TaiESM

Contributor: Academia Sinica in Taiwan

Taiwan Earth System Model (TaiESM)

- TaiESM is developed by Academia Sinica in Taiwan.
- TaiESM is based on CESM with components of atmosphere, ocean, land, sea ice, river, and land ice, in which several physical parameterizations in the atmosphere and land are modified.
- TaiESM is able to run at horizontal resolutions of $0.9^{\circ} \times 1.25^{\circ}$ and $1.9^{\circ} \times 2.5^{\circ}$ with 30 vertical layers for the atmosphere, and about 1° with 70 layers for the ocean.
- Contact: Dr. Wei-Liang Lee, Research Center for Environmental Changes, Academia Sinica, Taiwan (leelupin@gate.sinica.edu.tw)

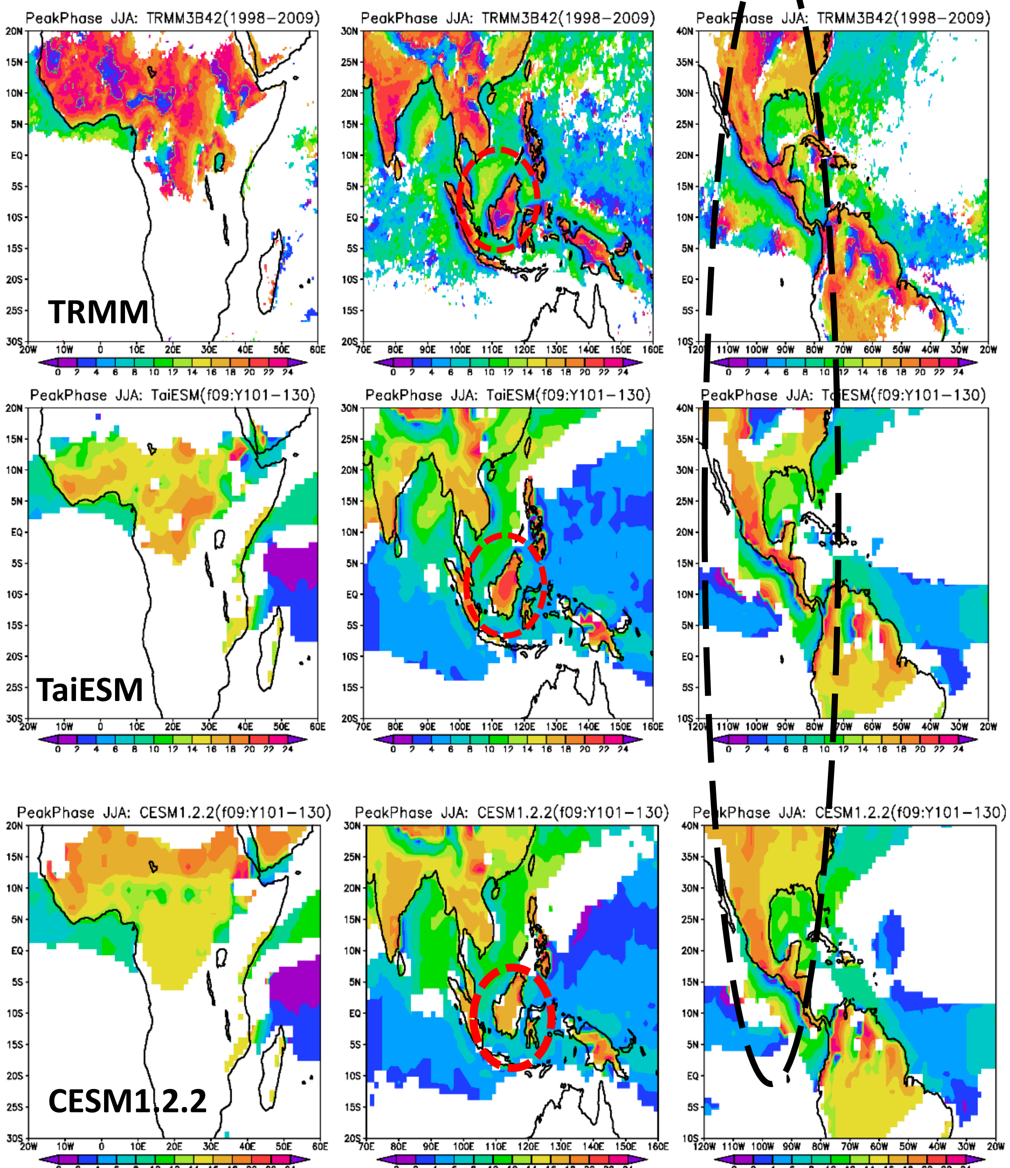
Modified Components in TaiESM

	CESM 1.2.2	TaiESM 1.0
Atmosphere Model	**CAM 5.3**	
Deep Convection	Zhang-McFarlane (1995) Neale et al. (2008)	ZM + trigger function of SAS (Wang et al., 2015)
Shallow Convection & Planetary Boundary layer	Park and Bretherton	NCEP/GFS Physics (Han and Pan 2011)
Cloud Macrophysics	Park et al. (2011)	Wang et al. Shiu et al. (in preparation)
Aerosol	MAM3 (Liu et al., 2012)	SNAP (Chen et al., 2013)
Land Model	**CLM 4**	
Irrigation	(None)	Lo et al. (2010)
Topography Effect on Surface Solar Radiation	(None)	Lee et al. (2011, 2013)
Ocean Model	**POP2**	
Very-high Vertical Resolution Mixed Layer Model	(None)	SIT (Tsuang et al., optionally coupled to CAM)

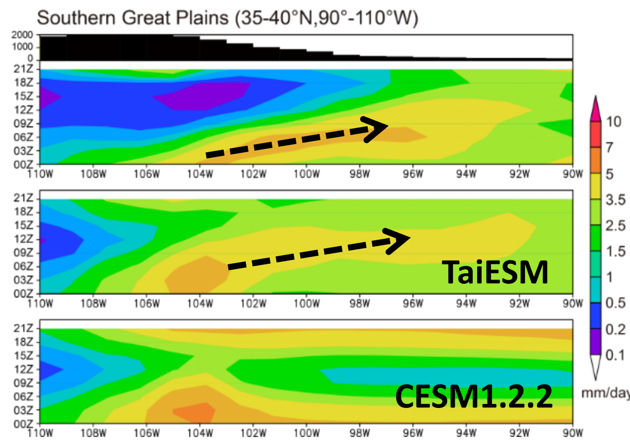
Global-mean Quantities

	Observation		Mean		RMSE	
			CESM1.2.2	TaiESM1.0	CESM1.2.2	TaiESM1.0
Residual Energy Flux at Top of Model			0.057	0.060		
Residual Energy Flux at Surface			0.053	0.056		
Residual Energy Flux at TOA	CERES-EBAF	0.81	2.31	2.31	10.57	8.72
Total Cloud Fraction	CloudSAT	66.82	63.14	70.58	9.63	10.58
OLR	CERES-EBAF	239.67	239.13	240.81	6.07	5.78
Clear-sky OLR	CERES-EBAF	265.73	261.80	262.38	5.55	5.35
Net Shortwave Flux at TOA	CERES-EBAF	240.48	241.43	243.12	11.45	9.99
Clear-sky Net Shortwave Flux at TOA	CERES-EBAF	287.62	289.02	288.85	8.26	8.44
Precipitation	GPCP	2.67	3.05	3.07	1.15	1.10
SST	HadSST	20.38	19.95	19.84	1.00	1.05
Surface Air Temperature at 2m	JRA25	287.61	286.33	286.16	2.49	2.68
Longwave Cloud Forcing	CERES-EBAF	26.06	22.68	21.58	6.18	6.35
Shortwave Cloud Forcing	CERES-EBAF	-47.15	-47.59	-45.73	13.45	11.45

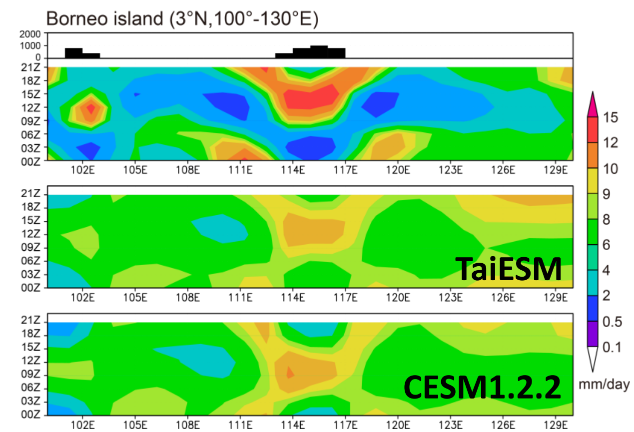
Highlight: Better Diurnal Cycle



SGP: More realistic propagation



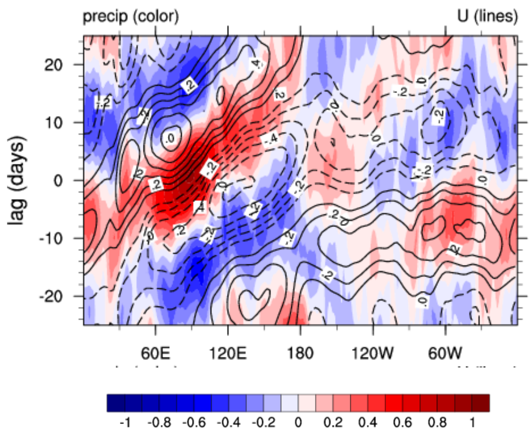
Borneo: Better timing



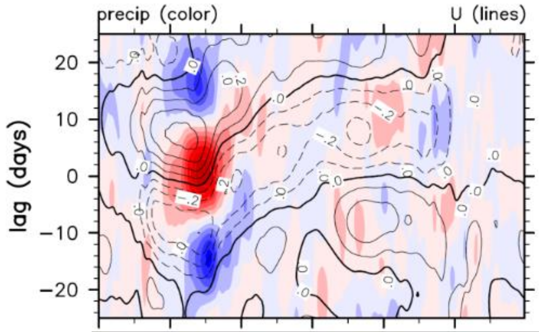
Highlight: Better Madden-Julian Oscillation

Precipitation
U850

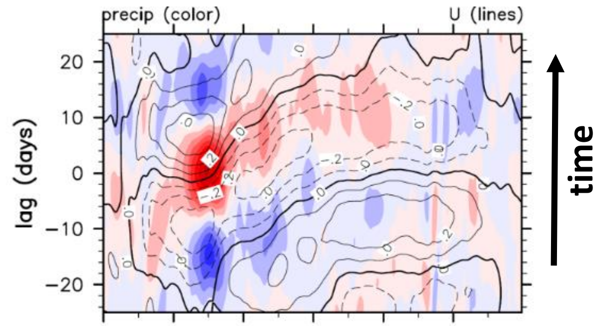
OBS



CESM1.2.2

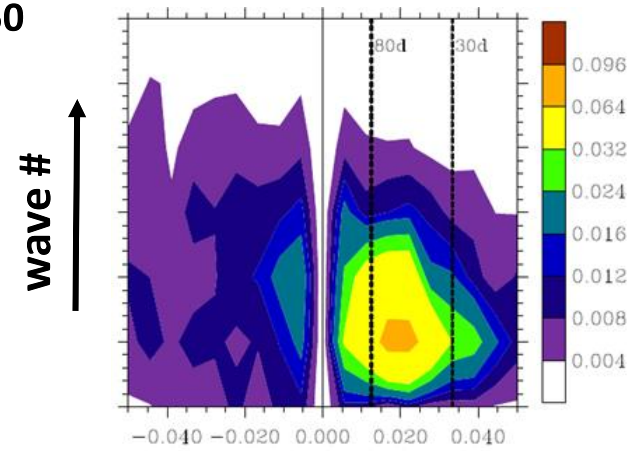


TaiESM



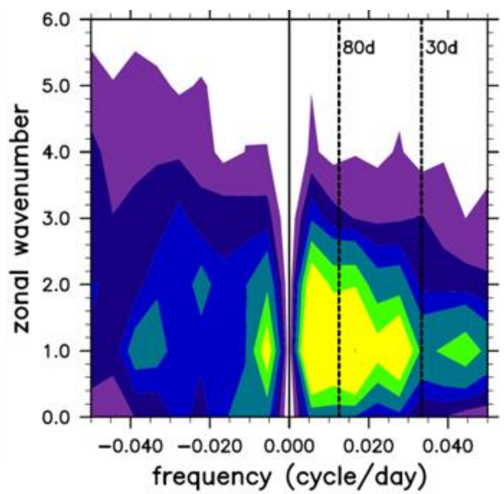
Stronger eastward propagation, although lower frequency bias remains

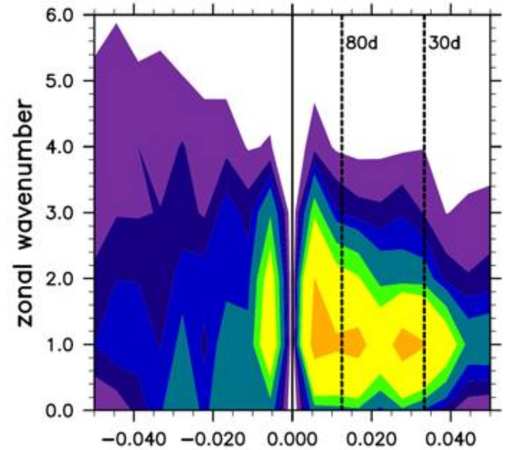
Spectrum:
U850



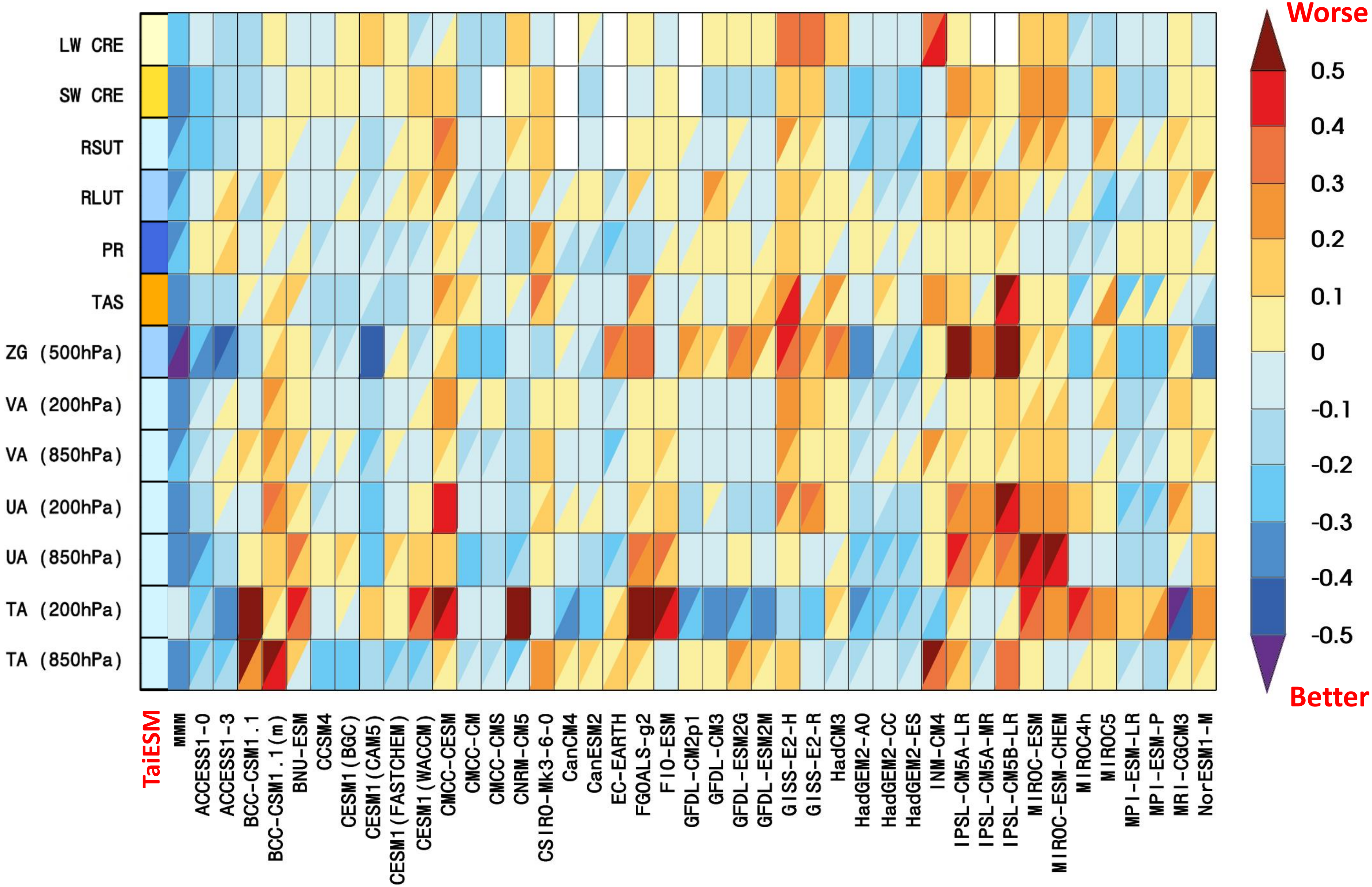
westward (freq.)

eastward (freq.)





Overall Performance: TaiESM vs. CMIP5



MIPs to participate in

MIPs Name	Tier
AerChemMIP	Tier 1
CFMIP	
GMMIP	
LUMIP	
PMIP	Tier 1
ScenarioMIP	Tier 1

Thank you

for your attention.