Catalogue of the supplementary materials	
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Section S1. Supporting tables and figures for the manuscript

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Figure S1	The annual-mean sea surface temperature (SST; units: °C) bias during 1979-2005 of different coupled climate models (CCMs) in CMIP5 (a and c-v) and their ensemble mean (b) over the southern tropical Atlantic. The blue box denotes the Atlantic cold tongue (ACT; 10°S-3°N, 20°W-10°E) region.
Figure S2	The same as Figure S1 but for the annual-mean surface zonal wind (units: m s^{-1}) bias. The blue box denotes the central and western equatorial Atlantic (5°S-5°N, 40°W-5°W).
Figure S3	The same as Figure S1 but for the annual-mean surface meridional wind (units: m s^{-1}) bias. The blue box includes the ACT and the region south of it.
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Figure S5	The same as Figure S1 but for the surface specific humidity (units: g kg^{-1}) bias.
Figure S6	The same as Figure S1 but for the precipitation (units: mm day^{-1}) bias. Note that, the color bar is reversed compared with that of the figures above.
Figure S7	The same as Figure S1 but for the downward shortwave radiation (units: W m^{-2}) bias. The blue box includes the ACT and a part of the SETA region.

Table S1. CMIP5 models used in this study.

Models	Ocean Component	Ocean Resolution (lat×lon, levels)	Atmospheric Component	Atmospheric Resolution (lat×lon, levels)
ACCESS1-0	MOM4p1	0.9º×1.0º, L50	UM	1.25º×1.875º, L38
bcc-csm1-1	MOM4-L40	(0.3-1)º ×1.0º, L40	BCC_AGCM2.1	T42 (2.8º), L26
BNU-ESM	MOM4p1	0.9º×1.0º, L50	CAM3.5	2.81º×2.81º, L26
CanESM2	CanOM4	0.94º×1.4º, L40	AGCM3	T63 (1.8º), L35
CCSM4	POP2	(0.27-0.64)º×1.125º, L60	CAM4	0.9º×1.25º, L26
CESM1-CAM5	POP2	(0.27-0.64)º×1.125º, L60	CAM5	0.9º×1.25º, L30
CMCC-CESM	OPA8.2	~2.0º, L31	ECHAM5	1.8º×1.8º, L31
CNRM-CM5	NEMOv3.2	0.7º, L42	ARPEGE-Climate	1.4º×1.4º, L31
FGOALS-g2	LICOM2	~1º, L30	GAMIL2	2.81º×2.81º, L26
FIO-ESM	POP2	(0.27-0.64)º×1.125º, L40	CAM3	T42 (2.8º), L26
GFDL-CM3	MOM	~1º, L50	AM3	~2º, L48
GFDL-ESM2M	MOM4p1	0.9º×1.0º (tripolar), L50	AM2	2.5º×2º, L24
GISS-E2-H	Hycom	1.0º×1.0º (tripolar), L26	ModelE	2.5º×2º, L40
GISS-E2-R	Russell	1º×1.25º, L32	ModelE	2.5º×2º, L40
HadCM3	HadOM3	1.25º×1.25º, L20	HadAM3	2.75º×2.5º, L19
INM-CM4	Ocean	0.5º×1.0º, L40	Equation	1.5º×2º, L21
IPSL-CM5A-LR	ORCA2	2º×2º, L31	LMDZ5A	1.9º×3.75º, L39
IPSL-CM5A-MR	ORCA2	2º×2º, L31	LMDZ5A	1.3º×2.5º, L39
MPI-ESM-LR	MPIOM	1.5º×1.5º, L40	ECHAM6	T63 (1.8º), L47
MRI-ESM1	MRICOM-3	0.5º×1º, L51	MRI-AGCM3	1.1º×1.1º, L60
NorESM1-M	MICOM	0.5º×1º, L53	CAM4-Oslo	2.9º×2.5º, L26

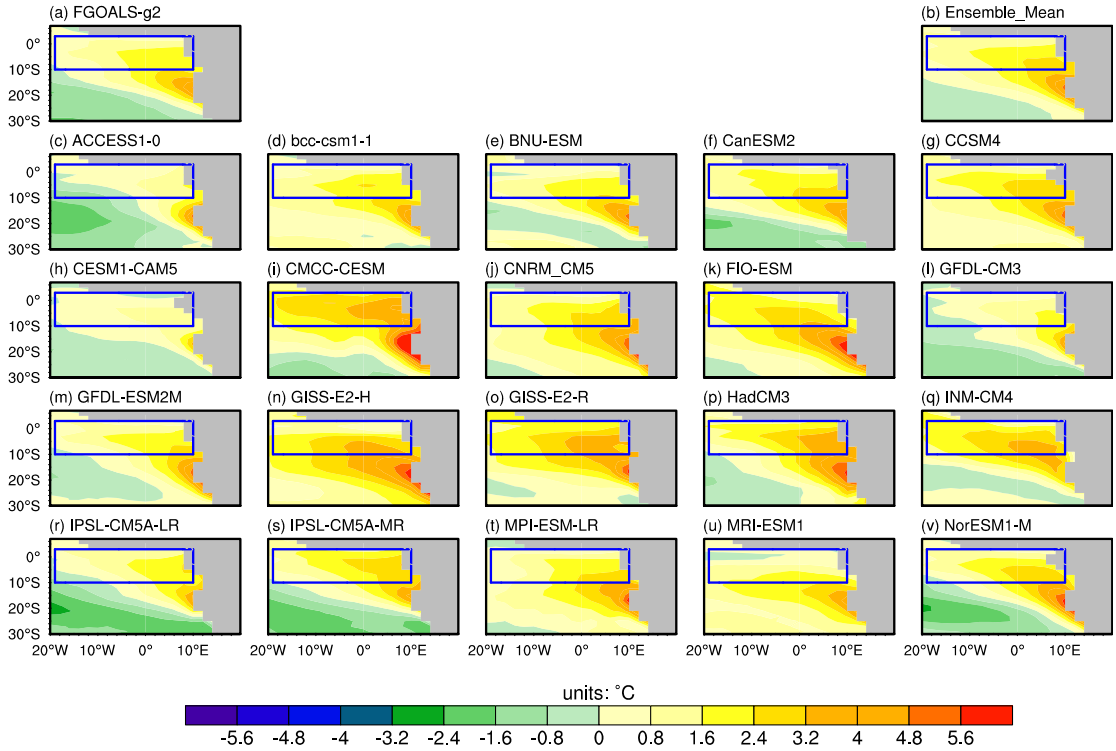

Figure S1. The annual-mean sea surface temperature (SST; units: °C) bias during 1979-2005 of different coupled climate models (CCMs) in CMIP5 (a and c-v) and their ensemble mean (b) over the southern tropical Atlantic. The blue box denotes the Atlantic cold tongue (ACT; 10°S-3°N, 20°W-10°E) region.

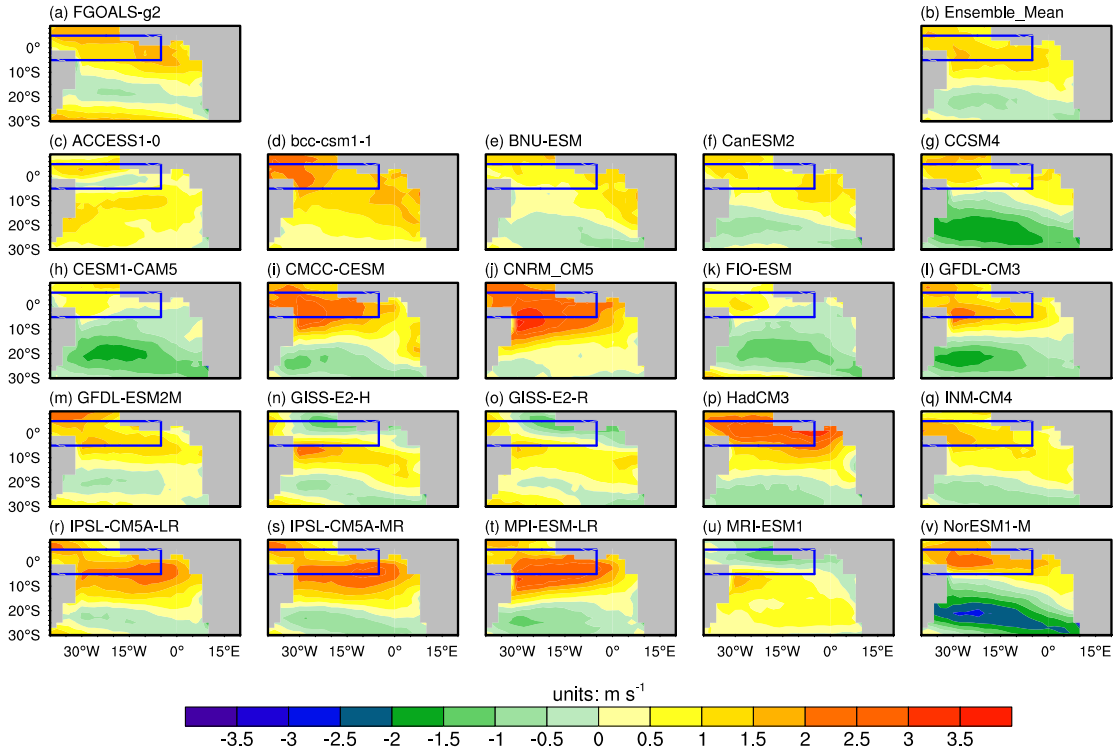

Figure S2. The same as Figure S1 but for the annual-mean surface zonal wind (units: m s^{-1}) bias. The blue box denotes the central and western equatorial Atlantic (5°S-5°N, 40°W-5°W).

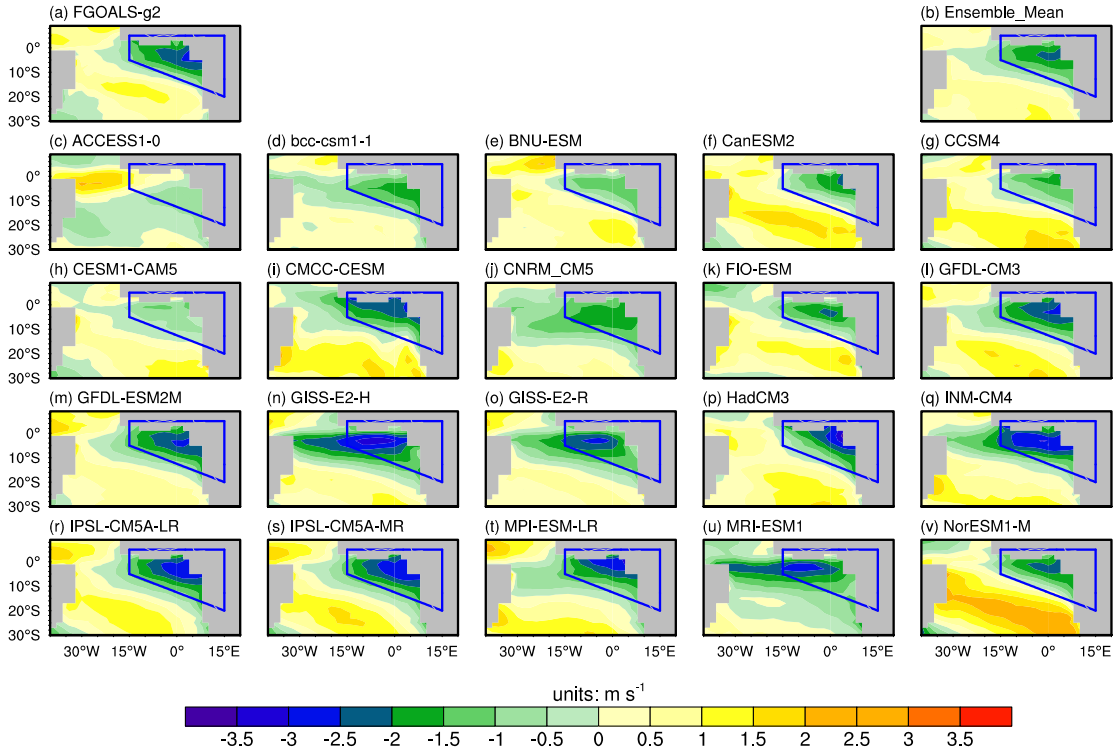

Figure S3. The same as Figure S1 but for the annual-mean surface meridional wind (units: m s^{-1}) bias. The blue box includes the ACT and the region south of it.

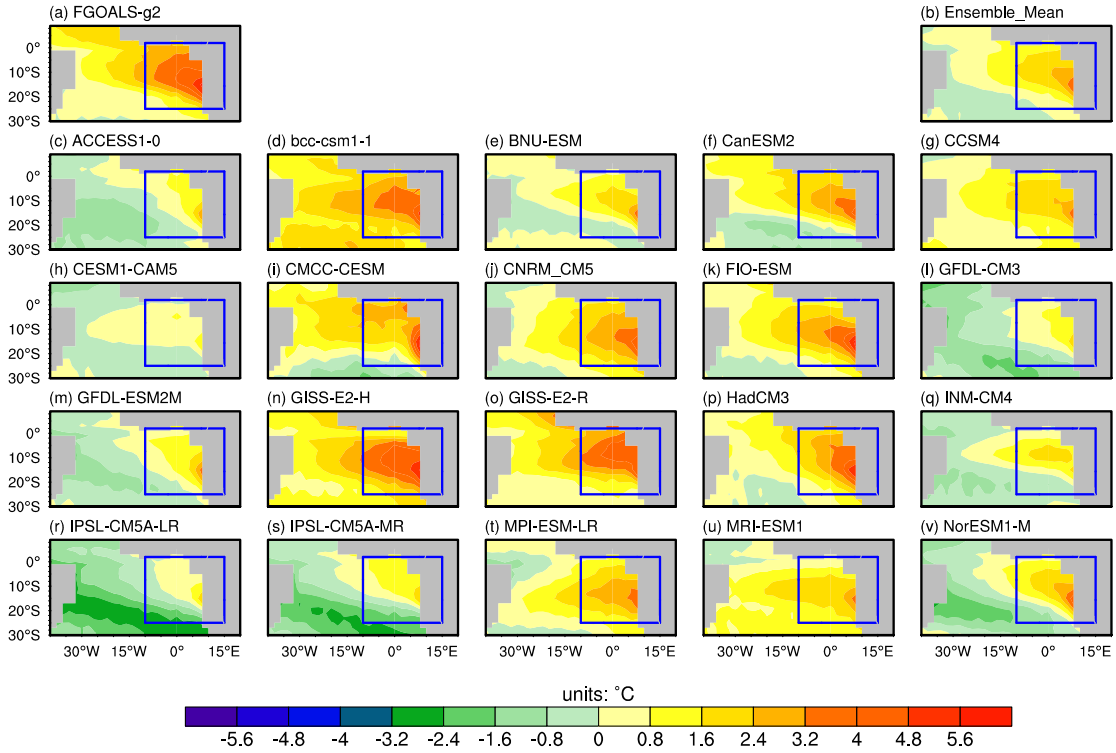

Figure S4. The same as Figure S1 but for the surface air temperature (units: °C) bias. The blue box includes the ACT region and the southeastern tropical Atlantic (SETA; 25°S-10°S, 10°W-15°E).

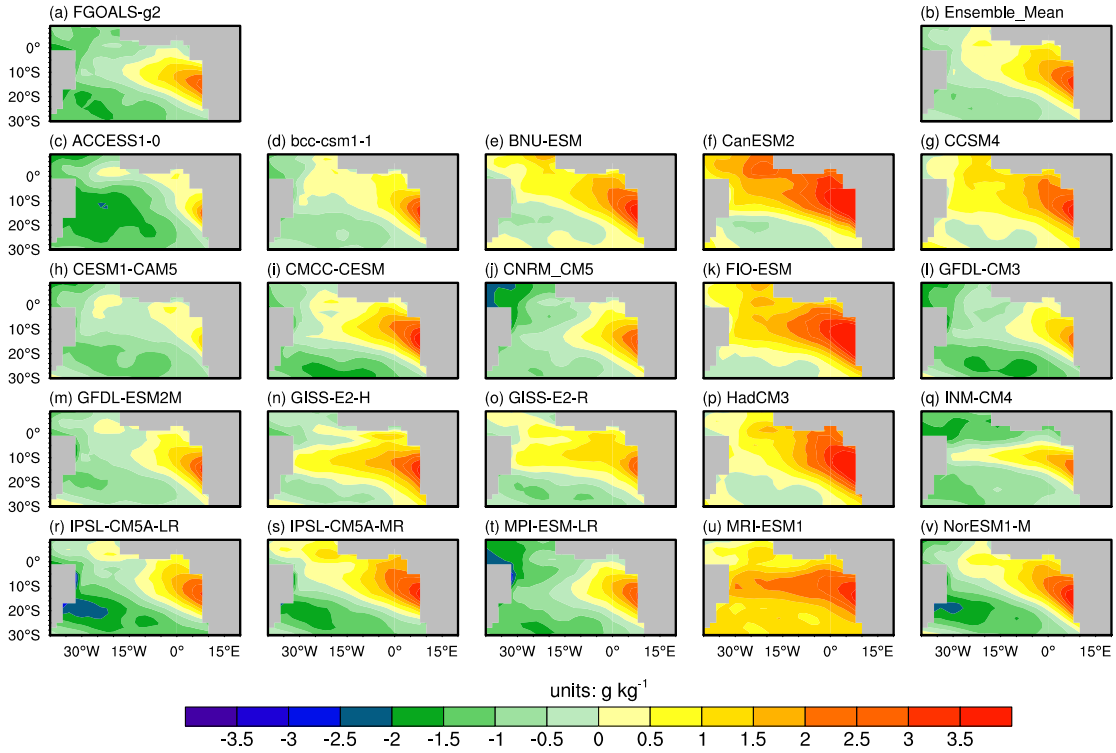

Figure S5. The same as Figure S1 but for the surface specific humidity (units: g kg^{-1}) bias.

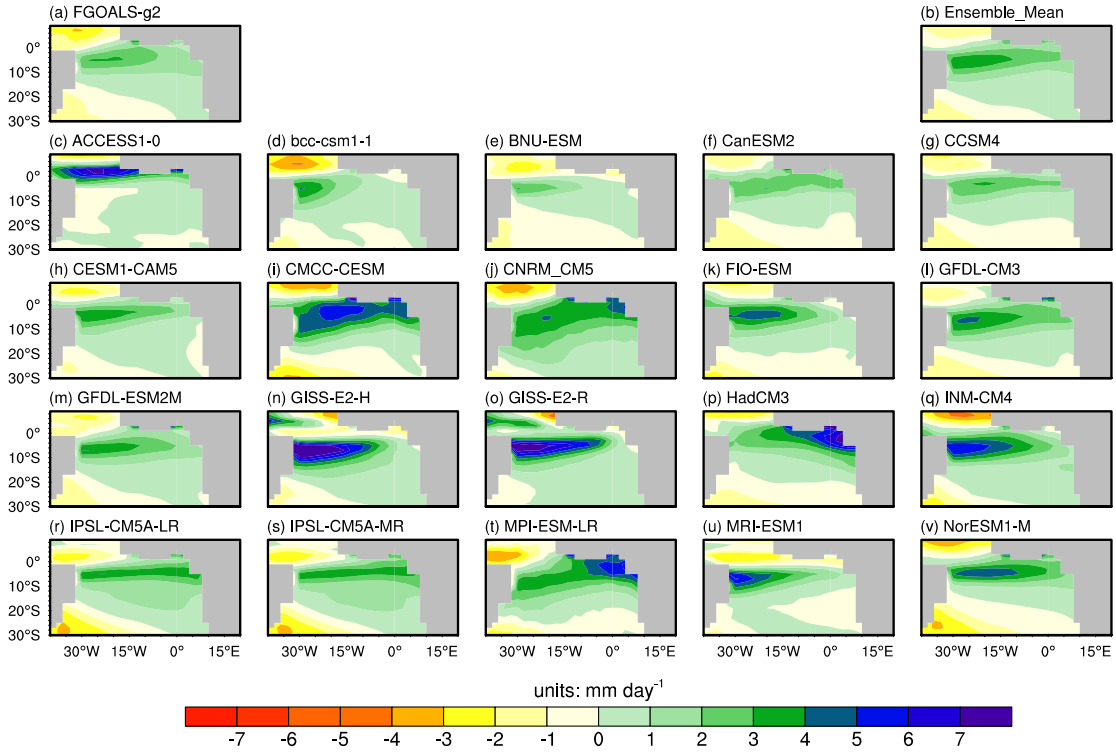

Figure S6. The same as Figure S1 but for the precipitation (units: mm day^{-1}) bias. Note that, the color bar is reversed compared with that of the figures above.

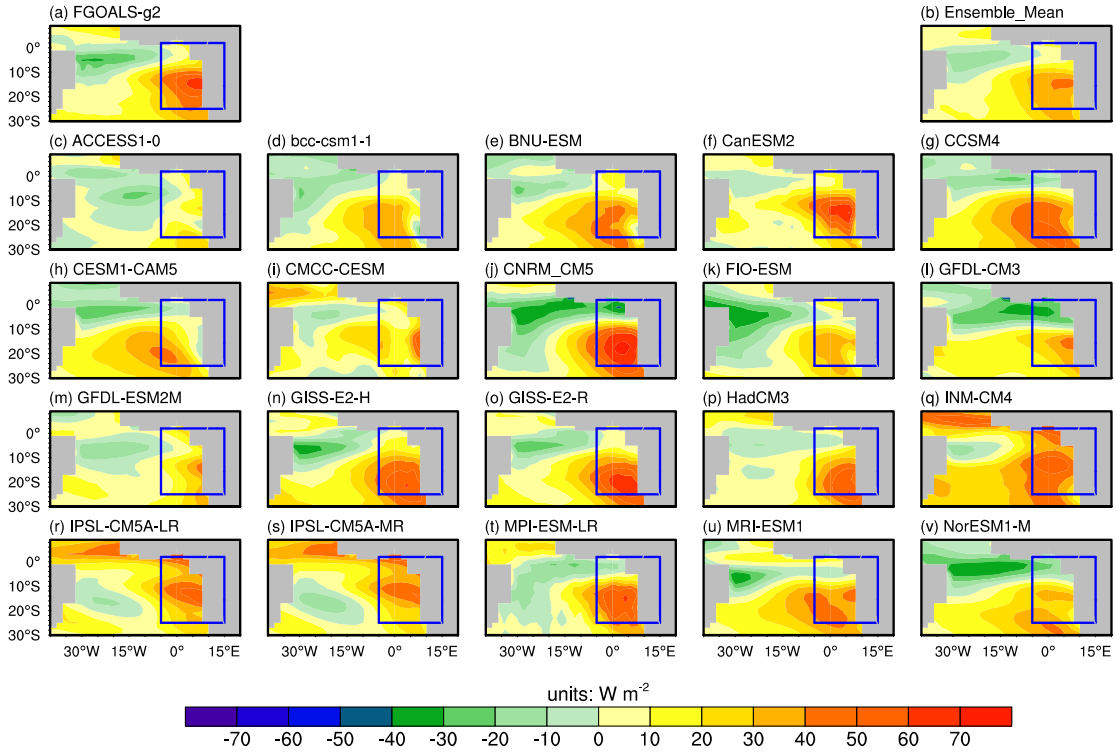

Figure S7. The same as Figure S1 but for the downward shortwave radiation (units: W m^{-2}) bias. The blue box includes the ACT and a part of the SETA region.

Section S2. Results of the nudging type of experiments

Section S2.1 Role of surface wind bias in FGOALS-g2 model

This type of experiments contains three nudging experiments U_MAM_nudg, V_MAM_JJA_nudg and U_V_nudg. These three runs apply a nudging method in the FGOALS-g2 model to validate the role of winds in reducing the ACT SST bias in a coupled climate model. The nudging has been conducted on the sigma levels between 1000 hPa and 10 hPa. We have tried to only nudge the wind on the sigma level closest to the sea surface, however, the model cannot integrate for a longer period (e.g. 10 years). In addition, we have also conducted the nudging experiment by nudging the five bottom sigma levels, however, the model still cannot integrate for a longer period. Numerous experiments revealed that the in-consistence of the values on different sigma levels after nudging only the values on one or several sigma levels may lead to numerical instability. Therefore, we conduct the experiments by nudging the winds up to 10 hPa. Table S2 gives the detailed information of this type of experiments.

In order to quantify the impact of the zonal wind bias during MAM along the equator (5°S-5°N) in a coupled climate model (CCM), we perform the U_MAM_nudg experiment in which the NCEP-NCAR zonal wind during MAM along the equator (5°S-5°N) is nudged from 1000 hPa to 10 hPa in the atmospheric component of FGOALS-g2. In U_MAM_nudg , the seasonal cycle of the SST over the Atlantic cold tongue (ACT) region (10°S-3°N, 20°W-10°E) is improved significantly and the warm bias over this region is alleviated (Table S3). The warm SST bias during JJA is reduced by 1.69 °C over the ACT region in U_MAM_nudg compared with that in H_CCM, and the reduction of this warm bias is approximately 45.6% of the origin warm bias in H_CCM (Figure S8). It should be noted that the contribution ratio of the zonal wind bias during MAM along the equator to the warm SST bias during JJA over the ACT region in the coupled model (45.6%) is larger than that in the ocean-ice model (32.6%; Table S3).

Next, to quantify the impact of the meridional wind bias during MAM and JJA, we perform the V_MAM_JJA_nudg experiment in which the NCEP-NCAR meridional wind during MAM and JJA over the Southern tropical Atlantic (25°S-3°N, 40°W-20°E) is nudged from 1000 hPa to 10 hPa in the atmospheric component of FGOALS-g2. In V_MAM_JJA_nudg, the nudging of the meridional winds during the MAM and JJA over the southern tropical Atlantic reduces the SST bias during JJA by 1.20 °C (Table S3) about 32.3%. This contribution ratio is larger in the coupled climate model than that in the ocean-ice model (21.4%), which indicates that the bias in meridional winds during MAM and JJA play a more important role in setting the ACT SST bias during JJA in the coupled model.

Furthermore, we perform the experiment U_V_nudg to quantify the combined effect of the zonal wind bias and meridional wind bias mentioned above. In U_V_nudg the NCEP-NCAR zonal wind during MAM along the equator (5°S-5°N) and meridional wind during MAM and JJA over the southern tropical Atlantic is nudged form 1000hPa to 10 hPa in the atmospheric component of FGOALS-g2. In U_V_nudg the SST bias in JJA can be reduced by 2.65 °C (approximately 71.4% of the SST bias in H_CCM) over the ACT region. This combined contribution ratio of the two biases is smaller than the summation of the contribution ratio of each of them.

List of Table and Figure Captions in section S2	
Table S2	Nudging experiments based on the coupled model FGOALS-g2.
Table S3	The mean area-averaged SST bias of MAM and JJA over the Atlantic cold tongue (ACT) region (10°S-3°N, 20°W-10°E) during 1979-2005 for the three nudging experiments based on the FGOALS-g2 model.
Figure S8	Seasonal cycle of the SST (units: °C) over the ACT region during 1979-2005 for HadISST (black dashes line), H_CCM (black solid line), U_MAM_nudg (green solid line), V_MAM_JJA_nudg (blue solid line), and U_V_nudg (red solid line).

Table S2. Nudging experiments based on the coupled model FGOALS-g2.

Experiments	Type	Modifications with respect to the H_CCM run	Modification area
U_MAM_nudg	Sensitivity	Zonal wind during MAM	Along the equator (5°S-5°N)
V_MAM_JJA_nudg	Sensitivity	Meridional wind during MAM and JJA	Southern tropical Atlantic (25°S-3°N, 40°W-20°E)
U_V_nudg	Sensitivity	Zonal wind nudged in U_MAM_nudg and meridional wind nudged in V_MAM_JJA_nudg	Southern tropical Atlantic (25°S-3°N, 40°W-20°E)

Table S3. The area-averaged SST bias of MAM and JJA over the Atlantic cold tongue (ACT) region (10°S-3°N, 20°W-10°E) during 1979-2005 for the three nudging experiments based on the FGOALS-g2 model.

Experiments	**ACT SST bias during MAM (units: °C)**	**ACT SST bias during JJA (units: °C)**
H_CCM	1.05	3.71
U_ MAM_ nudg	0.67	2.02
V_ MAM_JJA_nudg	0.60	2.51
U_V_nudg	0.40	1.06

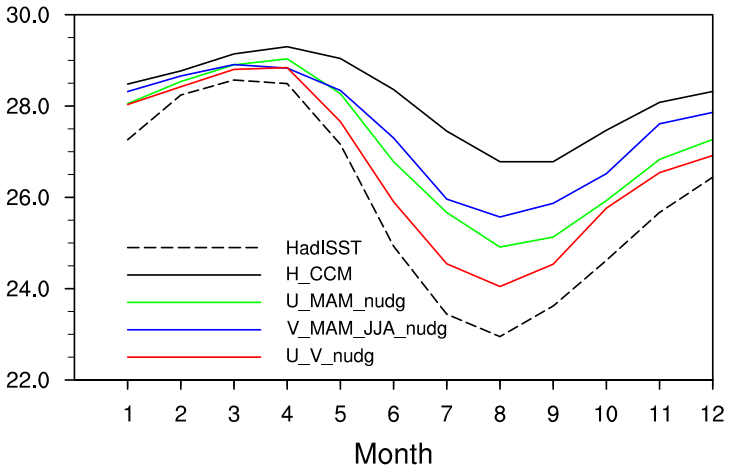

Figure S8. Seasonal cycle of the SST (units: °C) over the ACT region during 1979-2005 for HadISST (black dashes line), H_CCM (black solid line), U_MAM_nudg (green solid line), V_MAM_JJA_nudg (blue solid line), and U_V_nudg (red solid line).