Future response of the intertropical convergence zone under global warming

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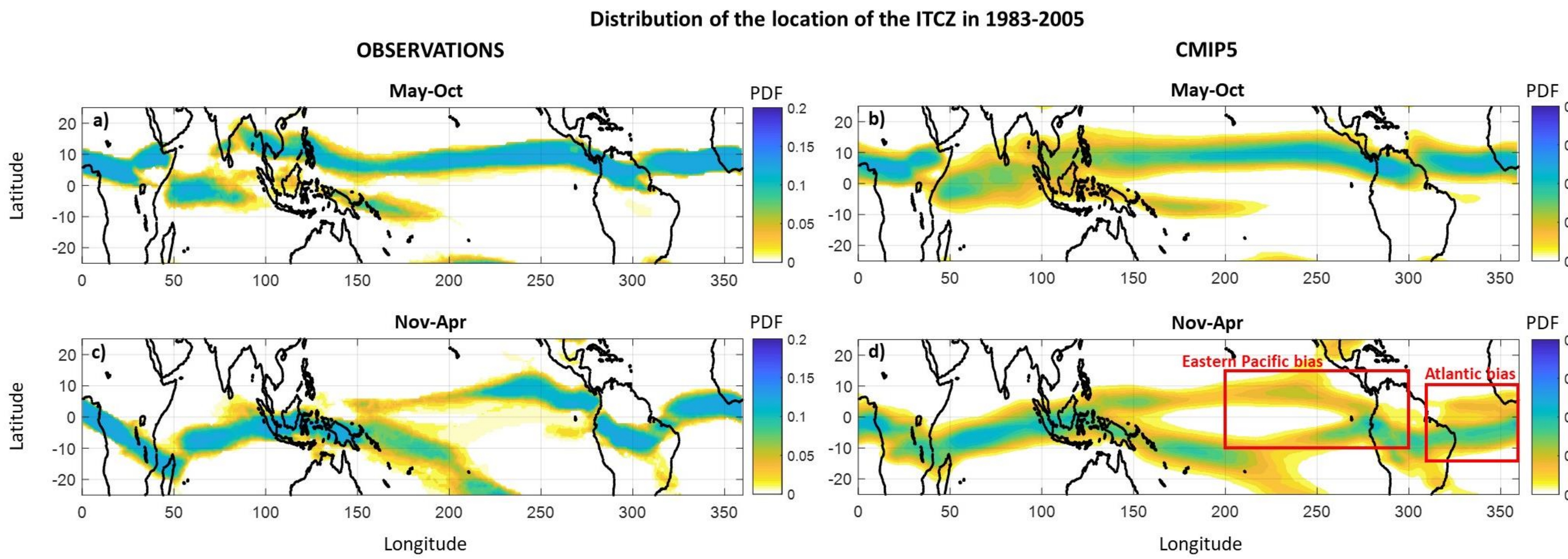
1. Motivation and Summary

Future changes in the location of the intertropical convergence zone (ITCZ) under global warming are of high importance, since they could substantially alter precipitation patterns and water cycle dynamics in the tropics and subtropics, and greatly affect the vulnerability of ecosystems and rainforests. **Although recent studies report a likely average northward shift and contraction of the ITCZ, predictions remain uncertain and highly variable among climate models. Moreover, most studies have focused on the zonal mean changes of the ITCZ, lacking information on regional ITCZ responses, and possibly masking model agreements over particular areas.**

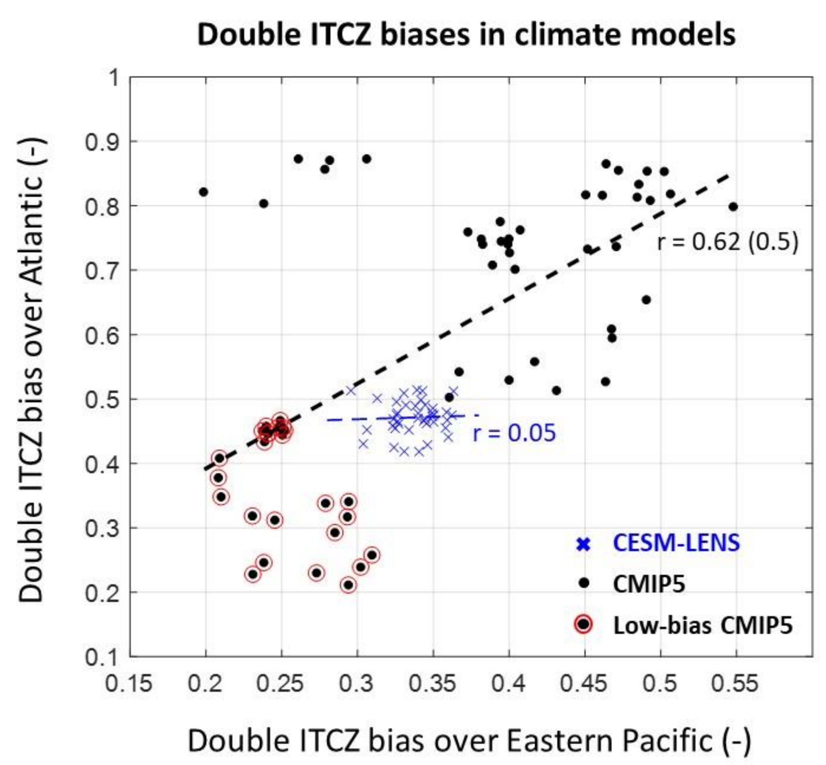
Based on climate model simulations, here we use a longitudinally explicit probabilistic method to track the ITCZ and explore future ITCZ trends in all seasons and longitudes of the globe, under increased CO_2 emissions (scenario RCP8.5). After accounting for double-ITCZ biases in the models, **we reveal a robust dipole response of the ITCZ:**
A northward shift of the ITCZ over Africa and Asia, and a Southward shift in the eastern Pacific and Atlantic basins. We provide evidence that this large-scale ITCZ dipole can be explained by accelerated atmospheric energy imbalances due to global warming.

2. Model Simulation of Contemporary ITCZ Position in 1983-2005

Probabilistic tracking of the ITCZ. We seasonally and longitudinally track the ITCZ by simultaneously considering the fields of multiple variables e.g. precipitation, outgoing longwave radiation (OLR), etc., and thus decreasing the likelihood of detecting spurious ITCZ features which might be picked up using only a single variable (Mamalakis and Foufoula-Georgiou, 2018).

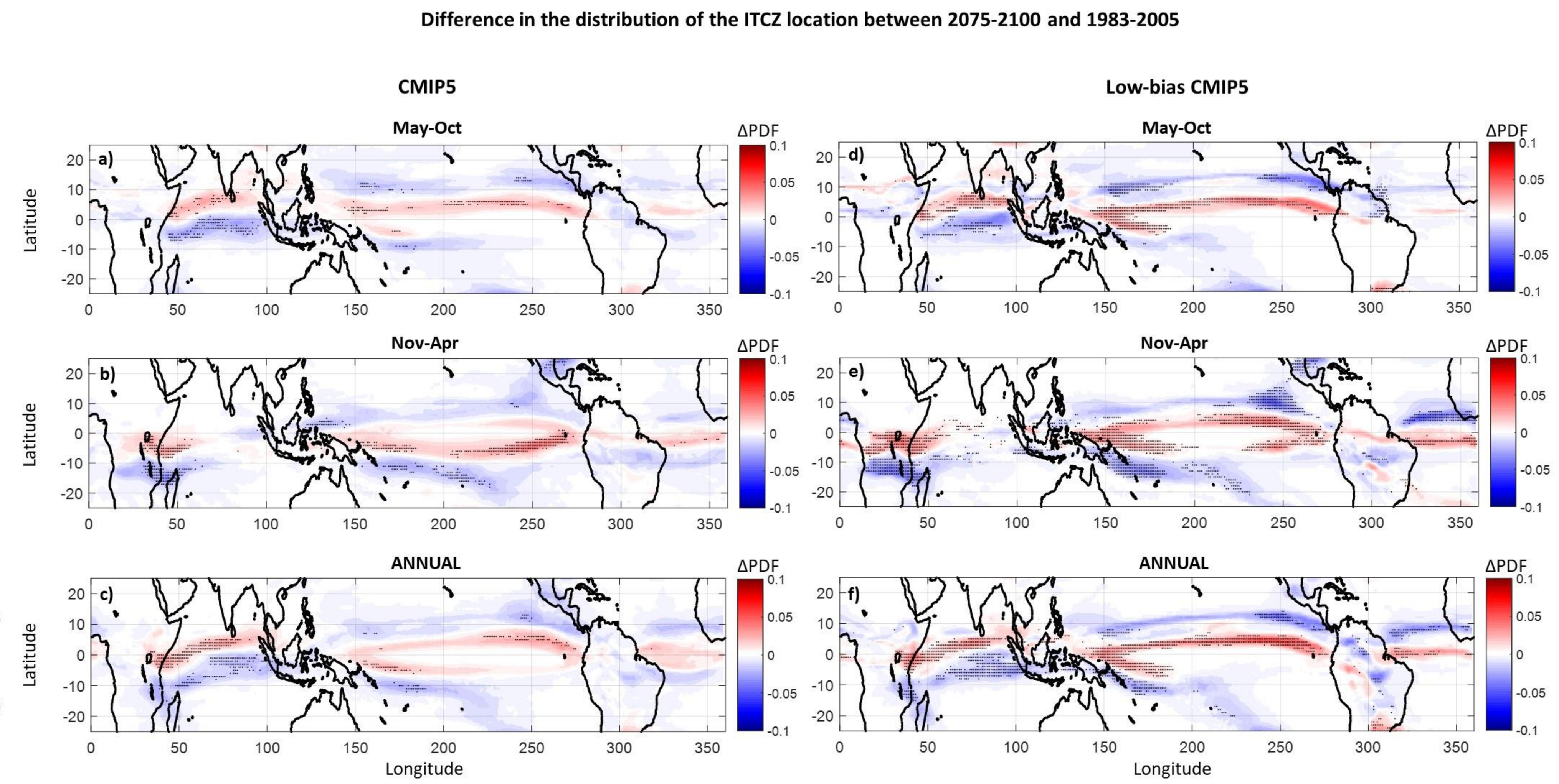


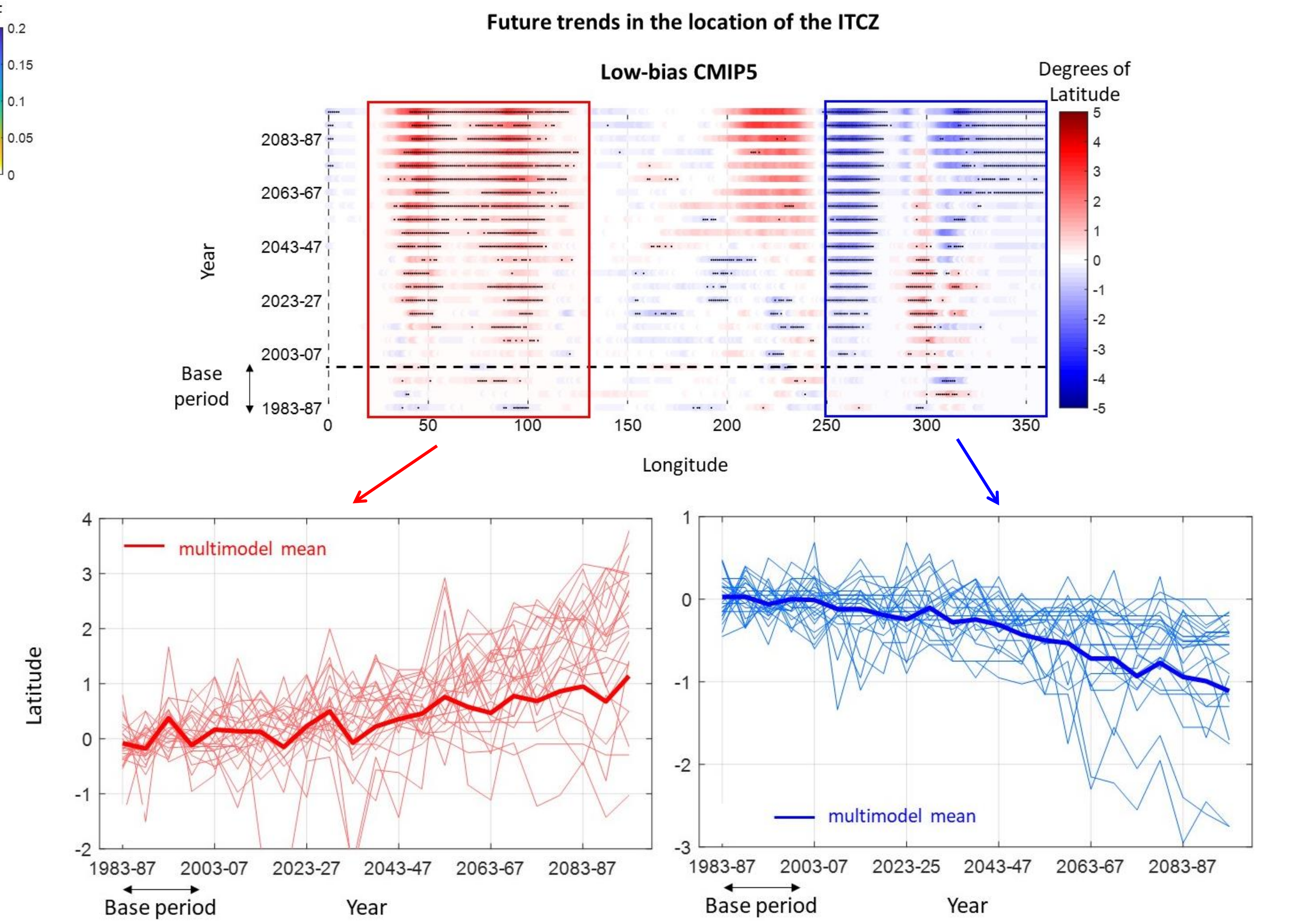
Project	Model	Number of ensembles	Eastern Pacific double ITCZ bias	Atlantic double ITCZ bias	Average bias
CMIP5	***ACCESS1.0***	**1**	**0.27**	**0.23**	**0.26**
	ACCESS1.3	**1**	**0.29**	**0.21**	**0.27**
	CanESM2	5	0.40	0.53	0.44
	CMCC-CESM	1	0.37	0.76	0.50
	CMCC-CM	1	0.24	0.80	0.43
	CMCC-CMS	1	0.20	0.82	0.41
	CNRM-CM5	5	0.40	0.73	0.51
	CSIRO Mk3.6.0	**10**	**0.25**	**0.45**	**0.31**
	FGOALS-s2	**2**	**0.29**	**0.34**	**0.30**
	GFDL-CM3	1	0.55	0.80	0.63
	GFDL-ESM2G	1	0.47	0.59	0.51
	GFDL-ESM2M	1	0.49	0.65	0.54
	GISS-E2-H	5	0.49	0.83	0.61
	GISS-E2-H-CC	1	0.49	0.81	0.60
	GISS-E2-R	1	0.45	0.73	0.55
	GISS-E2-R-CC	1	0.47	0.74	0.56
	HadGEM2-CC	**2**	**0.29**	**0.26**	**0.28**
	HadGEM2-ES	**4**	**0.24**	**0.27**	**0.25**
	INM-CM4	1	0.46	0.82	0.58
	IPSL-CM5A-LR	4	0.39	0.74	0.51
	IPSL-CM5A-MR	1	0.39	0.77	0.52
	IPSL-CM5B-LR	1	0.45	0.82	0.57
	MIROC5	**3**	**0.21**	**0.38**	**0.27**
	MIROC-ESM	**1**	**0.31**	**0.26**	**0.29**
	MIROC-ESM-CHEM	**1**	**0.29**	**0.32**	**0.30**
	MPI-ESM-LR	3	0.27	0.87	0.47
	MPI-ESM-MR	1	0.31	0.87	0.49
	MRI-CGCM3	1	0.46	0.86	0.60
	MRI-ESM1	1	0.47	0.85	0.60
	NorESM1-M	1	0.47	0.61	0.51
	NorESM1-ME	1	0.46	0.53	0.48
CESM-LENS	CESM1(CAM5)	40	0.34	0.47	0.38



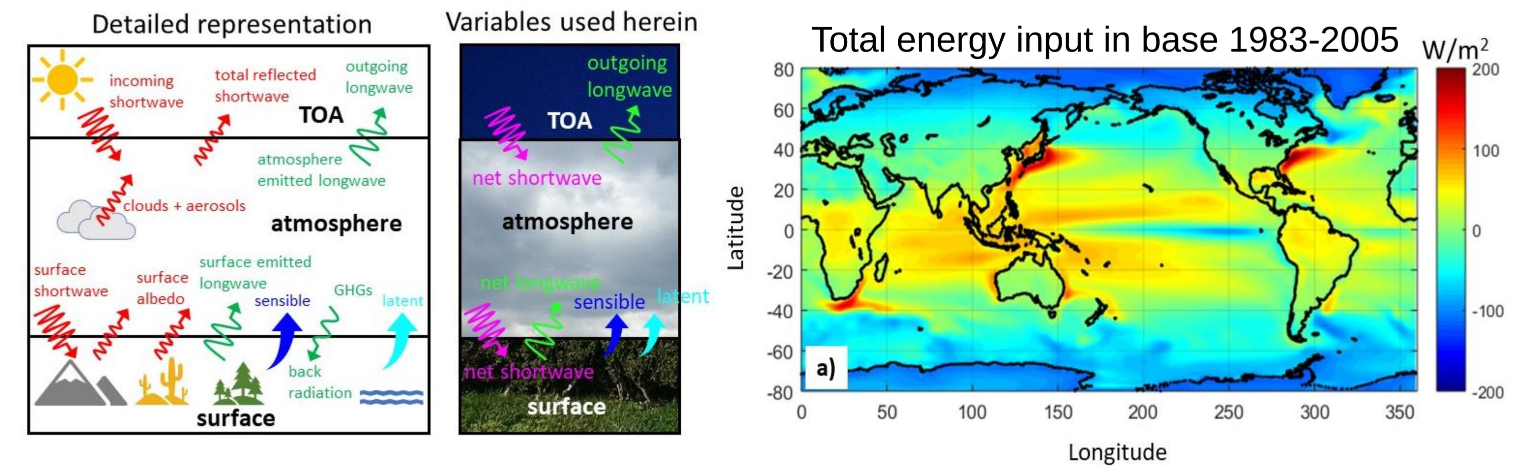
Reference
Mamalakis, A., & Foufoula-Georgiou, E. (2018). A multivariate probabilistic framework for tracking the intertropical convergence zone: Analysis of recent climatology and past trends. *Geophysical Research Letters*, **45**.

3. Future ITCZ trends – Large Scale ITCZ Dipole





4. Future Energy Imbalances Linked with ITCZ Response

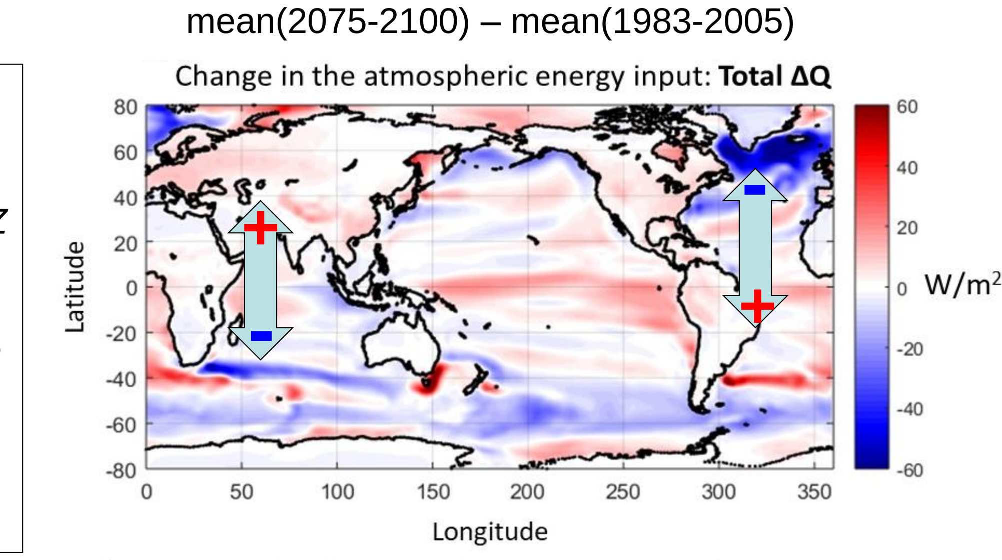


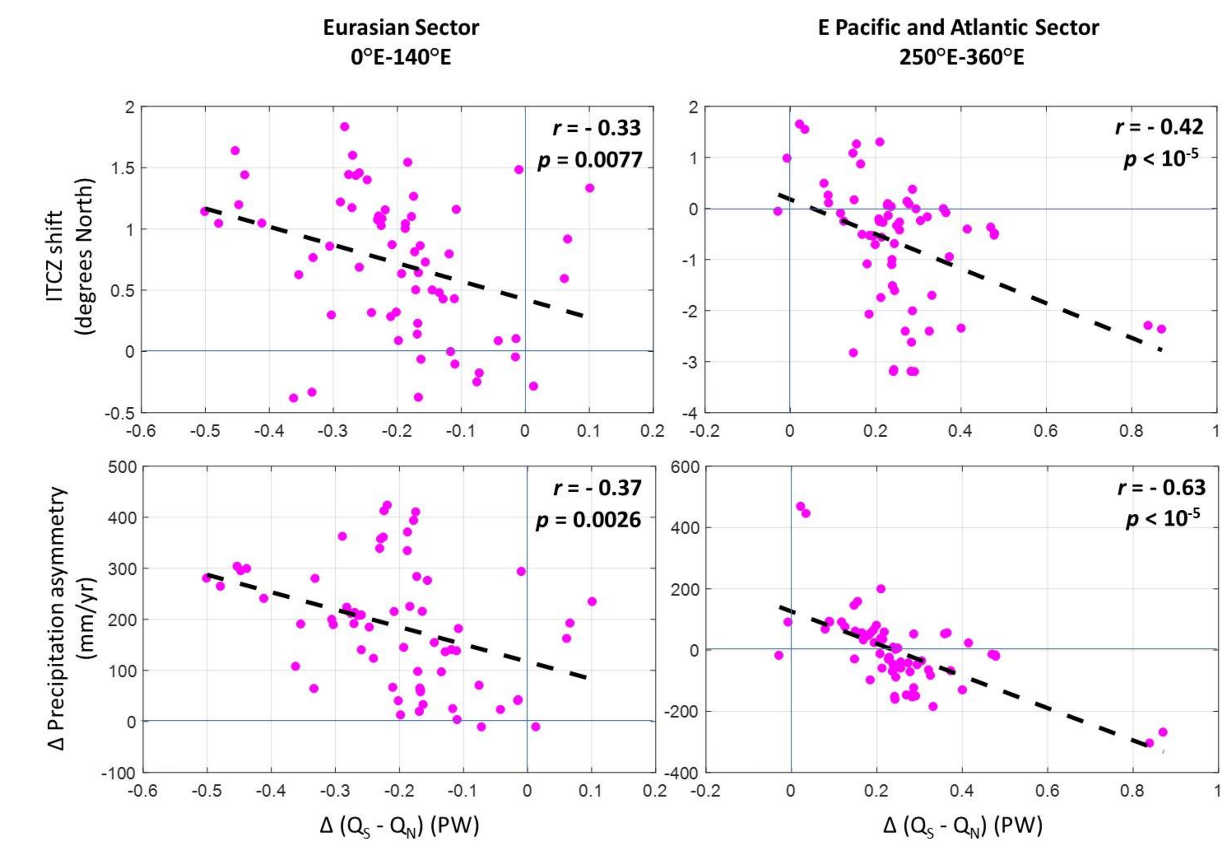
Atmospheric Energy Balance: $\nabla \cdot \mathbf{F_A} = R_A + LH + SH = Q$

Divergence of energy flux

Total energy input

Increased atmospheric heating over Eurasia and cooling over the Southern Ocean is linked with the ITCZ moving northward over the Eurasian sector.
Atmospheric cooling over the north Atlantic Ocean forces the ITCZ move southward over the eastern Pacific and Atlantic basins.





5. Key Points

1) The ITCZ is tracked in a longitudinally and seasonally explicit way and the effect of the models' double ITCZ biases on future changes is explored.
2) **A large-scale dipole response of the ITCZ to climate change is revealed**, which appears in different seasons, over land and over the oceans, and covers almost 2/3 of the globe.
3) We look at the ITCZ dipole from an energetic perspective and **report a similar zonally asymmetric interhemispheric heating pattern as a result of climate change**, which is physically consistent with the revealed ITCZ change.

Acknowledgements

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