Supporting Information for "How tropical convection couples high moist static energy over land and ocean"

Yi Zhang[1], Stephan Fueglistaler[1,2]

[1]Program in Atmospheric and Oceanic Sciences, Princeton University, Sayre Hall, Princeton NJ 08544, USA.

[2]Dept. of Geosciences, Princeton University, Guyot Hall, Princeton NJ 08544, USA.

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Text S1. Land mask

Coastal regions and islands are known to have substantial amounts of rainfall. The horizontal resolution of data used in this work implies ambiguity regarding the separation into land and ocean which could damp the differences between the calculated convective MSE over land and ocean. We therefore employ a strict criterion to eliminate the grid boxes that are not overwhelmingly land or ocean. A grid box is classified as ocean if the land area fraction is less than 5%, and is classified as land if the land area fraction is more than 95%. The remaining "coastal" grid cells taking up about 5% of area of the entire tropics are discarded in this analysis. For ERA-Interim, the land cover type data (MCD12C1) on $0.05° \times 0.05°$ grid from Moderate Resolution Imaging Spectroradiometer data (Friedl & Sulla-Menashe, 2015) is used to calculate the fraction of land in each box of the reanalysis grid. For CMIP5 models, the land area fraction provided by the modeling centers is used.

Text S2. Convective subcloud moist static energy (MSE) in CMIP5 models.

A simplified procedure for the calculation of the subcloud MSE is used for the CMIP5 model output where less detailed boundary layer information is available. The reduced vertical resolution of the CMIP5 model output to the standard pressure levels (1000, 925, 850 hPa ...) precludes the same accuracy as with the reanalysis data in the determination of the lifting condensation level (LCL). In addition, most models do not extrapolate data over land to the 1000 hPa level. We thus use a simplified procedure to estimate the subcloud MSE in the CMIP5 models: We use the 925 hPa as the generic upper boundary of the subcloud layer following Williams, Pierrehumbert, and Huber (2009); Williams and Pierrehumbert (2017). For models that report all the required data on the near-surface level (temperature, specific humidity, orography) and the 925 hPa pressure level (temperature, specific humidity, geopotential height), subcloud MSE is the average of the near-surface MSE and the 925-hPa MSE; For models that do not report all the required data on the near-surface level but report extrapolated information on the 1000 hPa over land, subcloud MSE is the average of the MSE on 1000 and 925 hPa pressure levels. This calculation is based on monthly mean data. To estimate the error introduced by the simplification, we apply this simplified procedure to the monthly mean ERA-Interim and TRMM data and find that the convective MSE is still similar over land and ocean on monthly timescale.

Fig. S3 shows the convective MSE over land vs. over ocean calculated with the simplified calculation for the CMIP5 models. Most models produce very similar convective subcloud MSE over land and ocean, but there are a few strong outliers. The multi-model mean values shown in Figs. 3 and 4 only include those models (SI Appendix, Table S1) that reasonably reproduce the observation in the Historical experiment and have a difference in the convective subcloud MSE between land and ocean of less than 2 J/g. For the multi-model mean, all the zonal-mean quantities are first calculated on the models' native grids and then interpolated onto a common 1° meridional grid.

References

Friedl, M., & Sulla-Menashe, D. (2015). *Mcd12c1 modis/terra+ aqua land cover type yearly l3 global 0.05deg cmg v006 [data set]* (Vol. 10). doi: https://doi.org/10.5067/MODIS/MCD12C1.006

Williams, I. N., & Pierrehumbert, R. T. (2017). Observational evidence against strongly stabilizing tropical cloud feedbacks. *Geophysical Research Letters*, *44*(3), 1503–1510.

Williams, I. N., Pierrehumbert, R. T., & Huber, M. (2009). Global warming, convective threshold and false thermostats. *Geophysical Research Letters*, *36*(21).

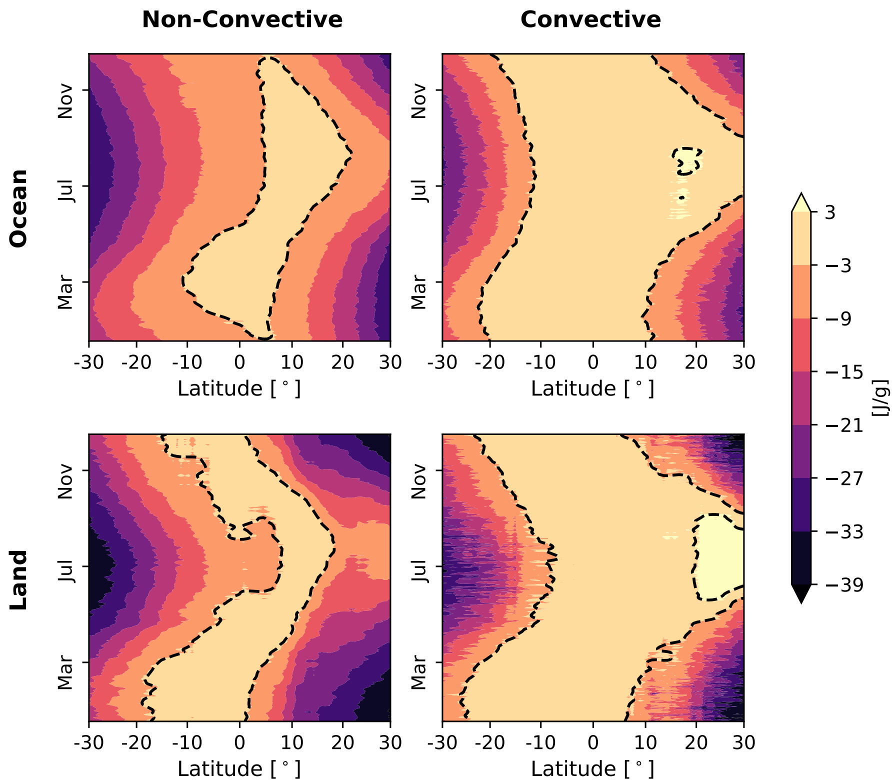

Figure S1. The mean subcloud moist static energy (MSE) as a function of latitude and day of year in the non-convective and convective regions over land and ocean. Convective and non-convective regions are identified with a rainfall threshold of 2 mm/day.

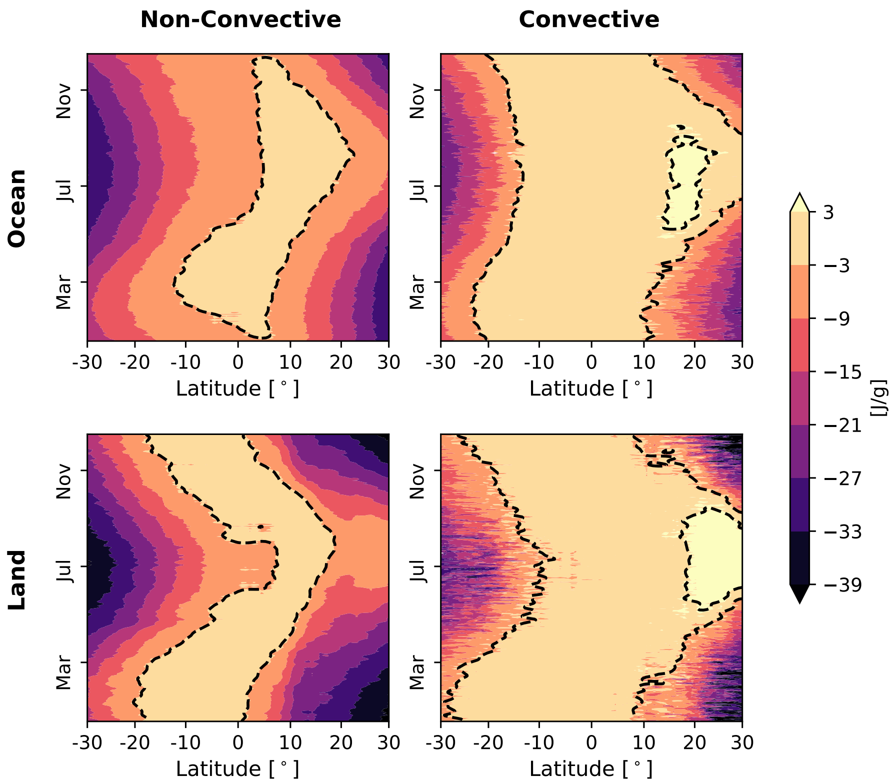

Figure S2. The mean subcloud moist static energy (MSE) as a function of latitude and day of year in the non-convective and convective regions over land and ocean. Convective and non-convective regions are identified with a rainfall threshold of 20 mm/day.

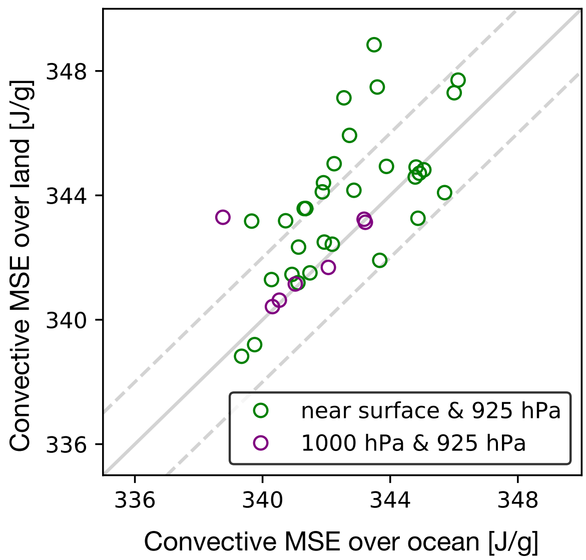

Figure S3. Convective subcloud MSE over land and ocean for CMIP5 models during the period from year 1979 to 2005 in the Historical experiment. Green circles are models where atmospheric near-surface data are available and subcloud MSE is calculated with the near-surface and the 925hPa level data. Purple circles are models that do not report complete near-surface data but report data over land at 1000 hPa and subcloud MSE is calculated with the 1000 hPa level and 925 hPa level data. The multi-model means shown includes only models that approximately reproduce the observation and have less than 2 J/g difference (dashed lines) between land and ocean (Table S1).

Table S1. Table of CMIP5 models used. ✓and ✗indicates whether a model is shown or not, while blank indicates a model that does not report complete information (See Text S2). "S" or "L" indicates the subcloud MSE is calculated with near-surface data or 1000 hPa data (See Text S2).

Model Name	Method	Historical	RCP 8.5	LGM	Institute ID
ACCESS1-0	S	✗	✗		CSIRO-BOM
ACCESS1-3	S	✗	✗		CSIRO-BOM
BCC-CSM1.1	S	✓	✓		BCC
CCSM4	S	✓	✓	✓	NCAR
CESM1-BGC	S	✓	✓		NSF-DOE-NCAR
CESM1-CAM5	S	✓	✓		NSF-DOE-NCAR
CESM1-FASTCHEM	S	✓			NSF-DOE-NCAR
CESM1-WACCM	S	✓			NSF-DOE-NCAR
CMCC-CESM	L	✓	✓		CMCC
CMCC-CM	L	✓	✓		CMCC
CMCC-CMS	L	✓	✓		CMCC
CNRM-CM5	S	✓	✓	✓	CNRM-CERFACS
CNRM-CM5-2	S	✓			CNRM-CERFACS
CSIRO-Mk3-6-0	S	✓	✓		CSIRO-QCCCE
CanESM2	S	✓	✓		CCCMA
GFDL-CM3	S	✓	✓		NOAA GFDL
GFDL-ESM2G	S	✗	✗		NOAA GFDL
GFDL-ESM2M	S	✗	✗		NOAA GFDL
GISS-E2-H	S	✗	✗		NASA GISS
GISS-E2-R	S	✗	✗		NASA GISS
HadGEM2-AO	S	✓	✓		NIMR/KMA
HadGEM2-CC	S	✓	✓		MOHC
HadGEM2-ES	S	✓	✓		MOHC
INM-CM4	L	✗			INM
IPSL-CM5A-LR	S	✗	✗	✓	IPSL
IPSL-CM5A-MR	S	✗	✗		IPSL
IPSL-CM5B-LR	S	✓	✓		IPSL
MIROC-ESM	S	✗	✗	✓	MIROC
MIROC-ESM-CHEM	S	✗	✗		MIROC
MIROC4h	S	✓			MIROC
MIROC5	S	✗	✗		MIROC
MPI-ESM-LR	L	✓	✓		MPI-M
MPI-ESM-MR	L	✓	✓		MPI-M
MPI-ESM-P	L	✓		✓	MPI-M
MRI-CGCM3	S	✓	✓	✓	MRI
MRI-ESM1	S	✓	✓		MRI
NorESM1-M	S	✓	✓		NCC
NorESM1-ME	S	✓			NCC