Flux Correction of the Land Surface Temperature in the UM Model

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climate extremes
ARC centre of excellence

MONASH University

What is Flux Correction?

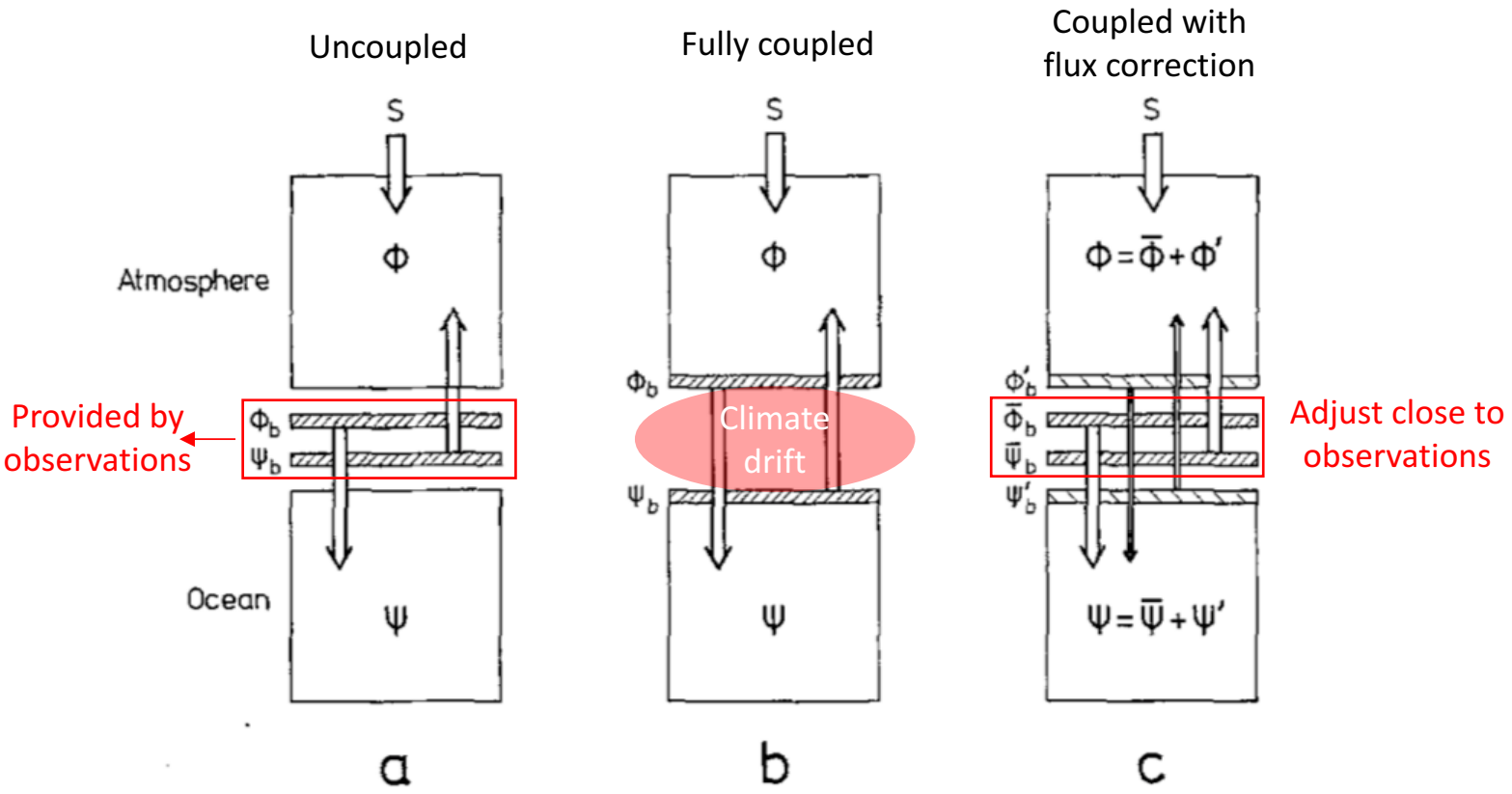


Fig. 1a—c. Boundary or coupling conditions of atmosphere and ocean models in different modes: **a** uncoupled; **b** fully coupled and **c** flux corrected

(Sausen et al. 1988)

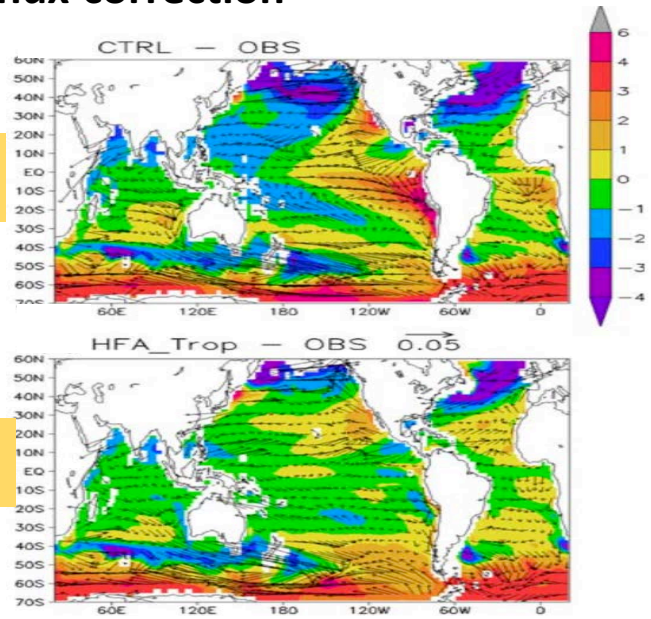
Pros: Fast, cheap and easy to apply; Mean state bias can be significant improved

Cons: may have unexpected effects on both mean state and variability.

Studies with flux-correction

Uncorrected

Flux-correction



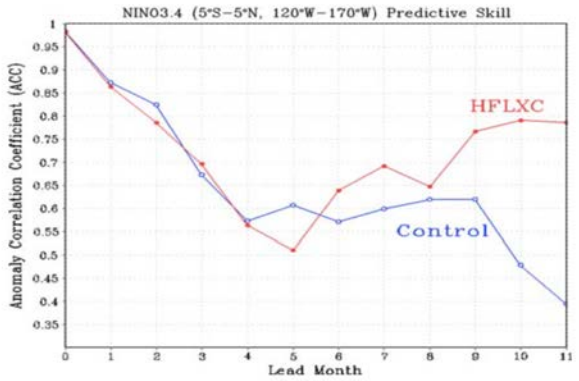
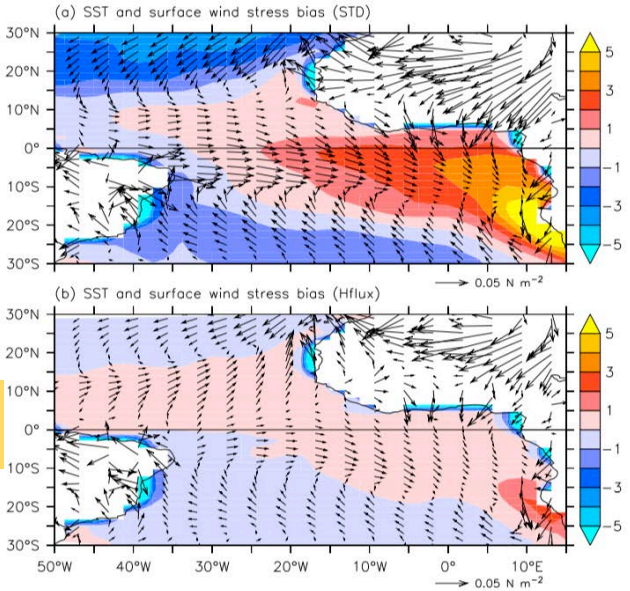


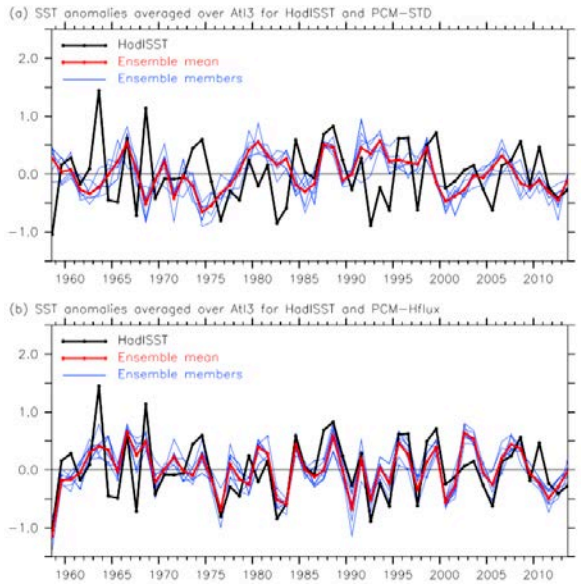
Fig. 13 Anomaly correlation of the monthly mean Niño-3.4 SST over the period 1982–1997 as a function of lead month for the Control (*blue line*) and HFLXC (*red line*) ensemble-mean forecasts. Observational estimate of SST is from COLA ODA

(Manganello et al. 2009)

Uncorrected

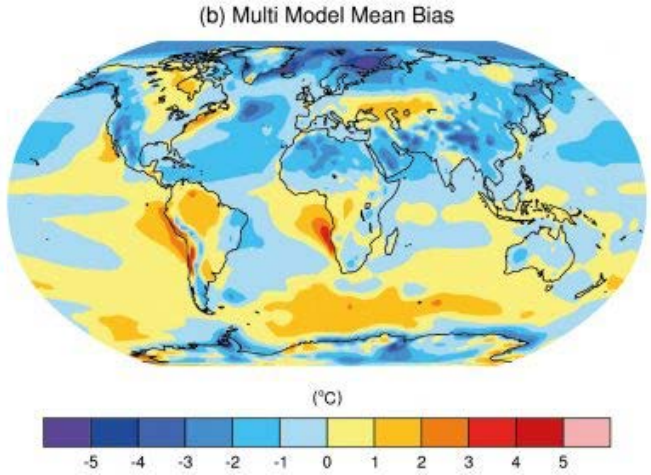
Flux-correction





(Ding et al. 2015)

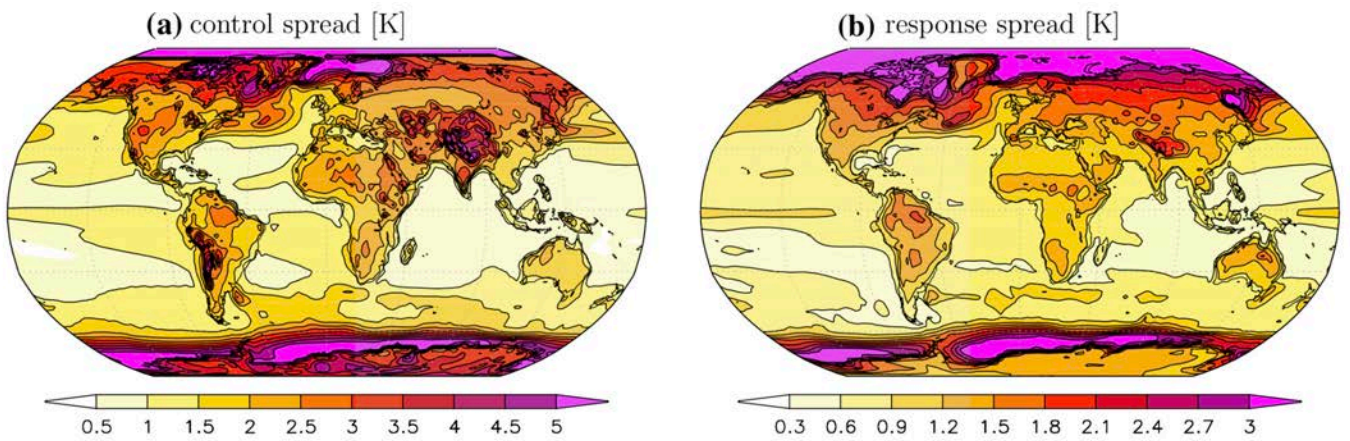
Importance of Land surface temperature



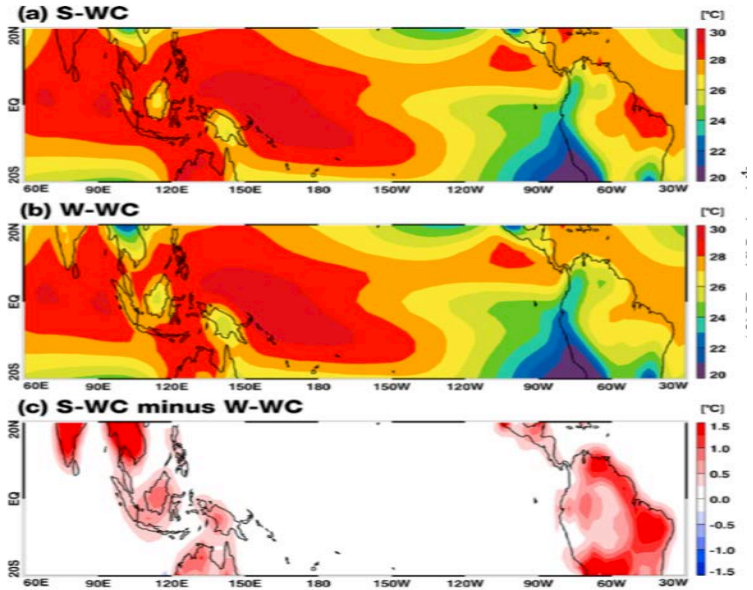
(IPCC fifth assessment report)

Historical

RCP8.5 - Historical



(Dommenget 2016)



(Yim et al. 2017)

The Walker Circulation trends in AGCMs with identical SST forcing can be linked to differences in the land surface temperature

AGCM simulations with prescribed land surface temperature

Met Office Unified Model (UM 7.3): UM-fixed SST

Horizontal grid spacing of 3.75 longitude by 2.5 latitude, 38 vertical levels (N48L38)

Met Office surface Exchange Scheme (MOSES)

Soil temperature

Sensible and latent heat flux

$$T_* = T_s + \frac{1}{A_*}\left[R_s - H - \lambda E + \frac{C_c}{\Delta t}\left(T_*^{prev} - T_s\right)\right]$$

(UM original code)

Net radiation

Ground heat flux

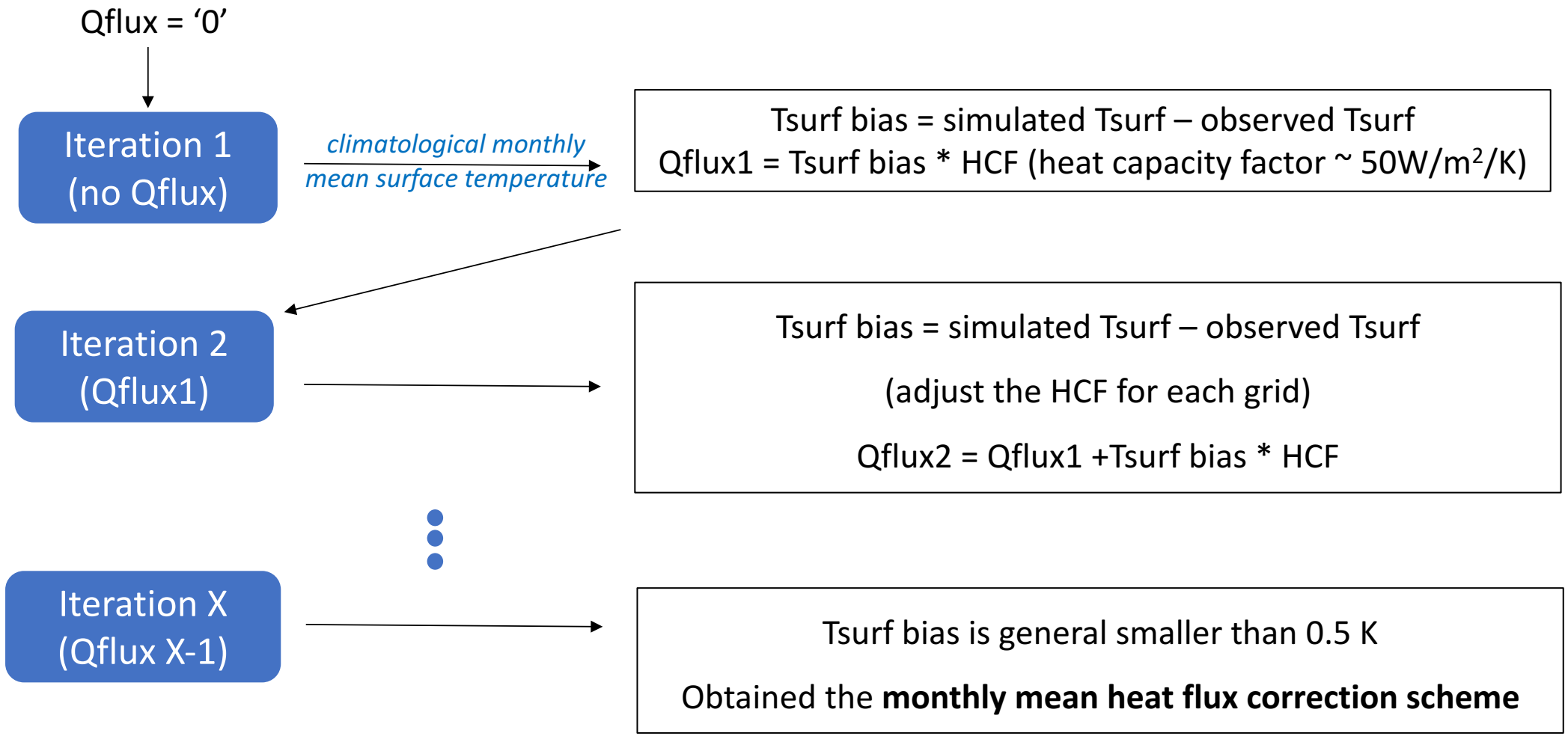
$T_* = T_{PRES}$ (3-hourly data) *(Ackerley and Dommenget 2016)*

Is that possible to use a flux correction (Qflux) to adjust the surface temperature instead of holding it to a fixed value?

$$T_* = T_S + \frac{1}{A}\left[R_{LW+SW} - H - \lambda E + \frac{C_c}{\Delta t}\left(T_{*pre} - T_S\right) + Qflux\right]$$

Estimate the Qflux through Iteration process

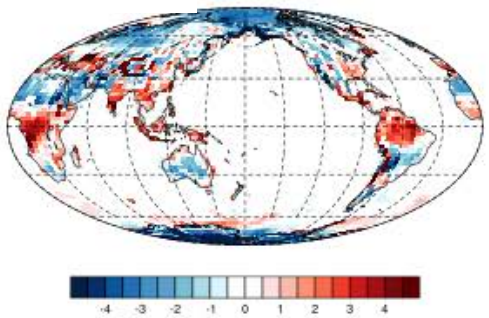
Reference data: ERA-interim skin temperature (climatological 1979-2017)



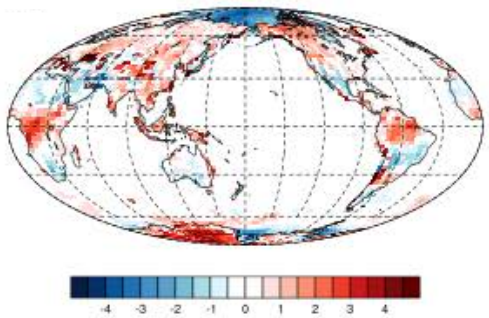
Run length	Climatology
5 years	Last 3 years
10 years	Last 5 years
20 years	Last 10 years

Annual mean surface temperature bias: Model - ERAint

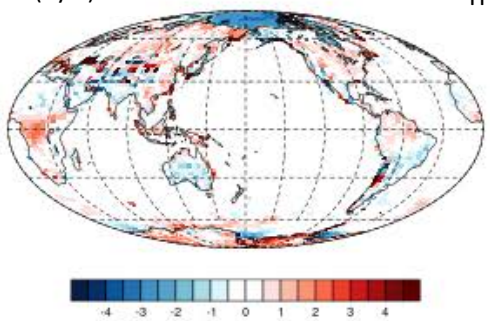
ITER1 (5yrs)



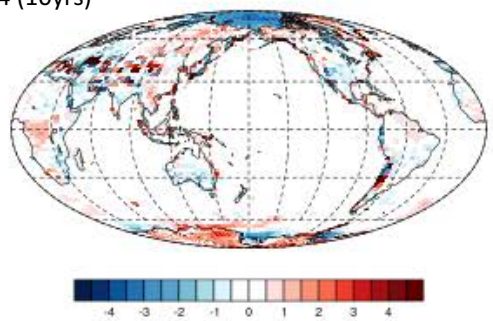
ITER2 (5yrs)



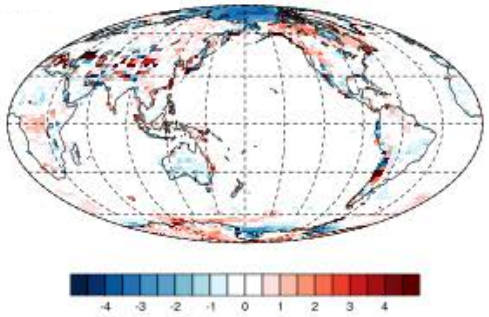
ITER3 (5yrs)



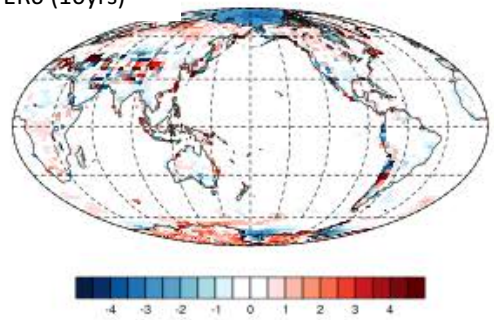
ITER4 (10yrs)



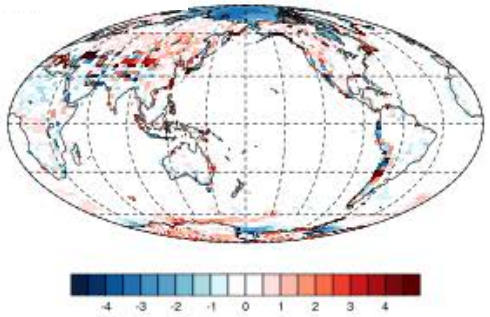
ITER5 (10yrs)



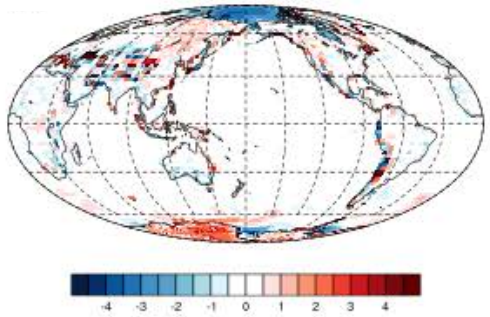
ITER6 (10yrs)



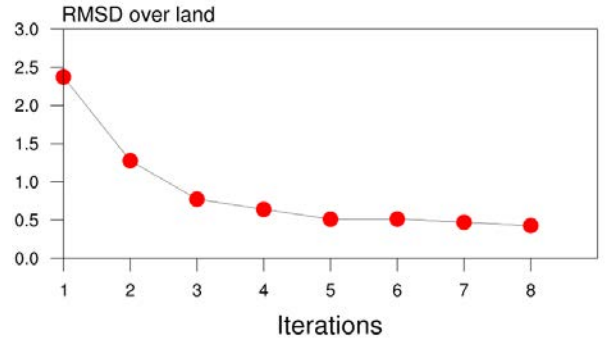
ITER7 (20yrs)



ITER8 (20yrs)

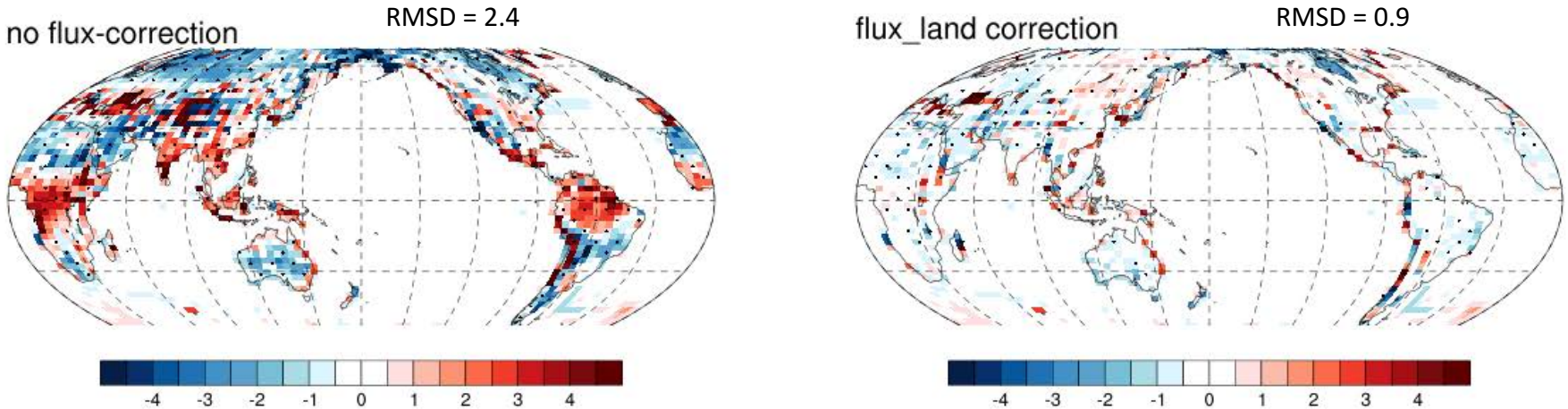


Two long-term runs: with/without heat flux correction
Running 50years, analysis the last 30 years

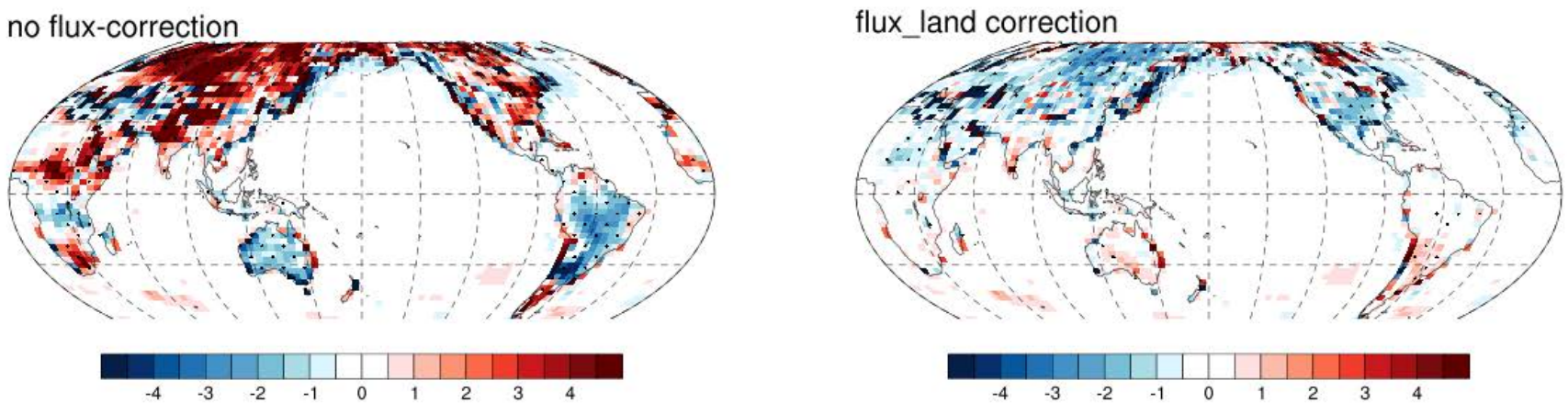


Surface temperature mean state

Annual mean surface temperature bias: Model - ERAint



‘JJA – DJF’ surface temperature bias

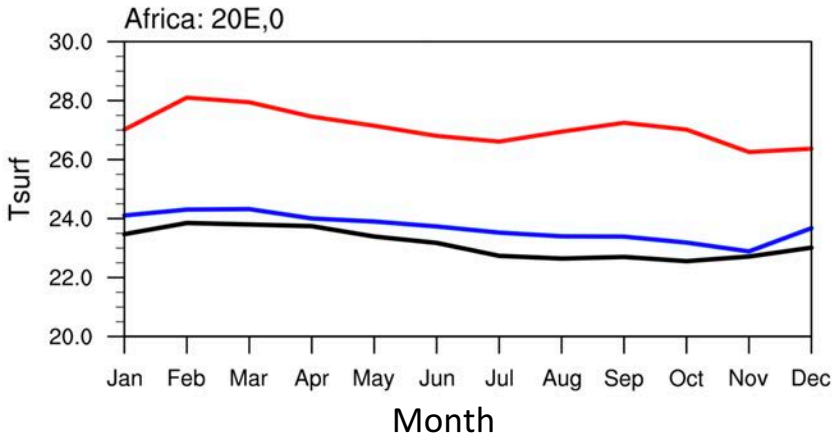


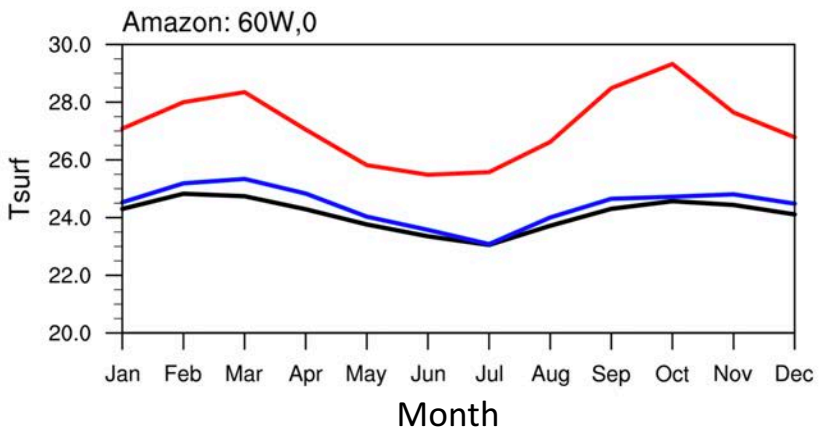
Surface temperature seasonal cycle

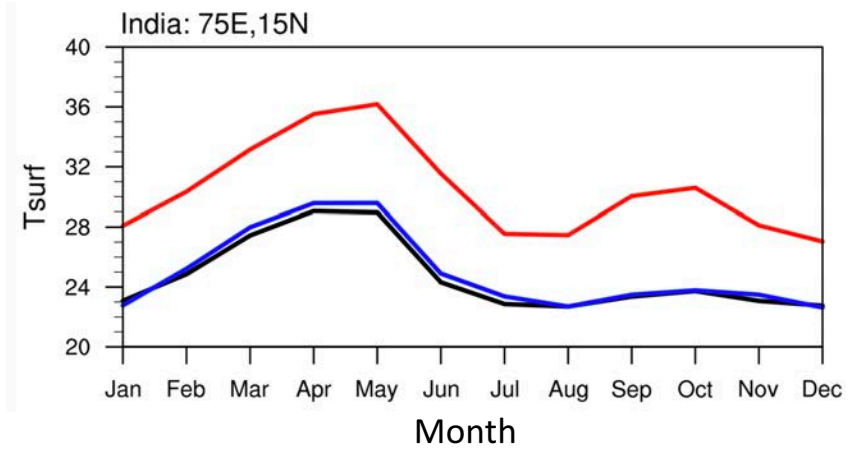
ERAint

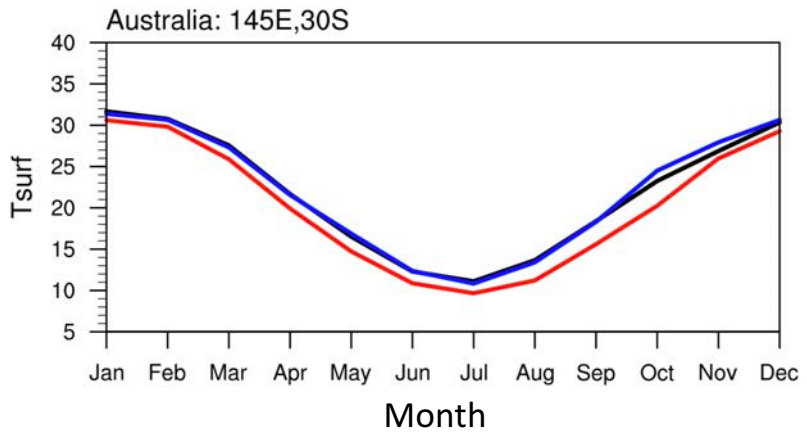
No flux-correction

flux-correction









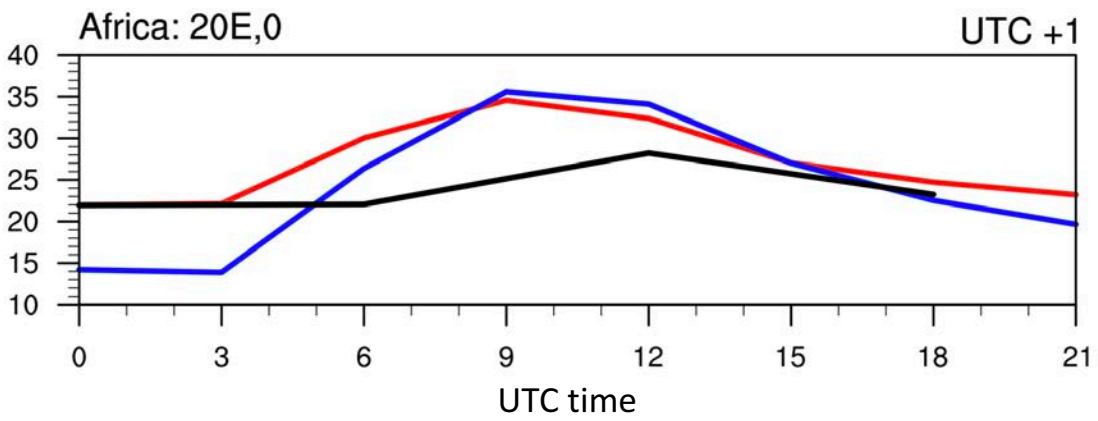
Surface temperature daily cycle

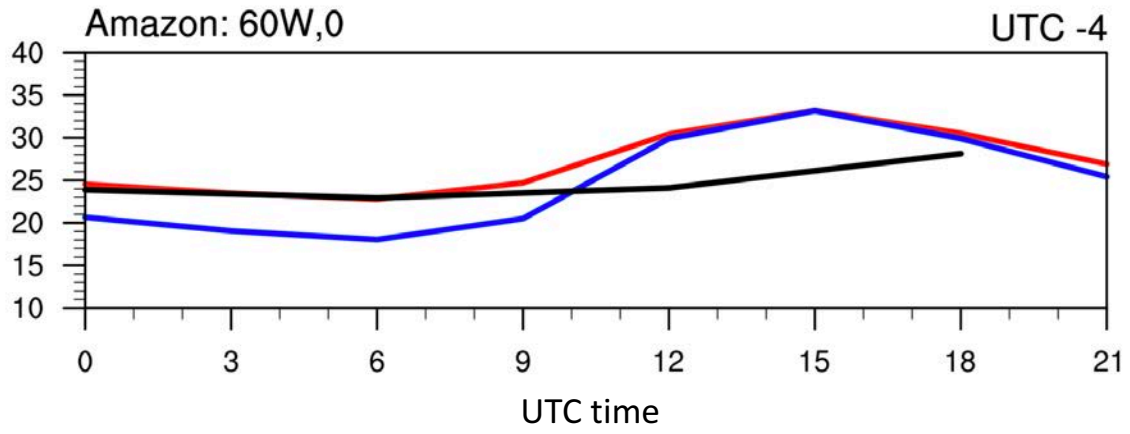
ERAint

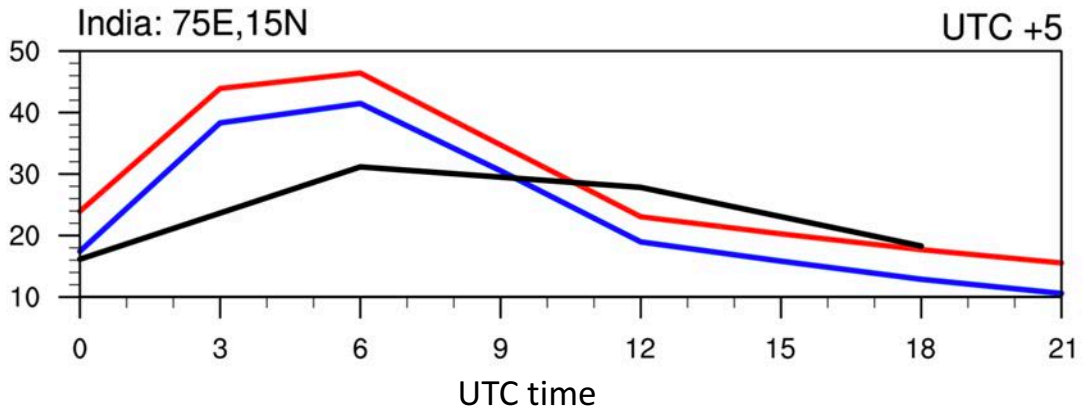
No flux-correction

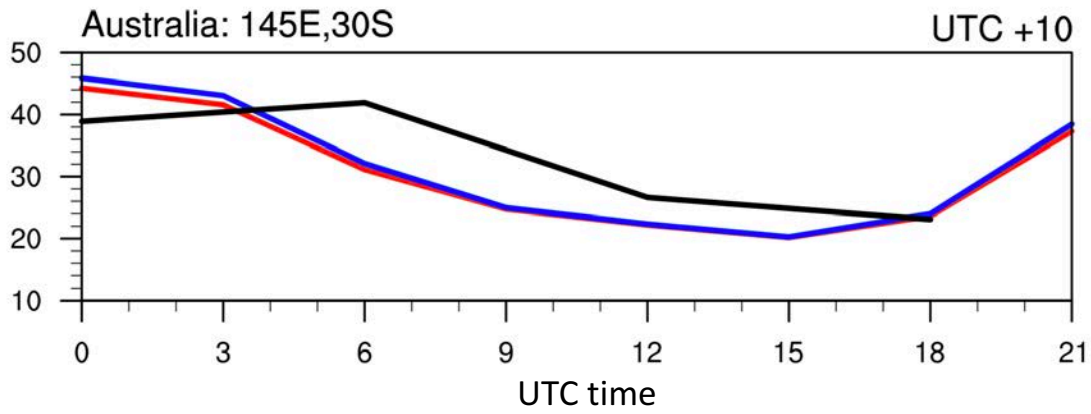
flux-correction

Mean Daily cycle for January

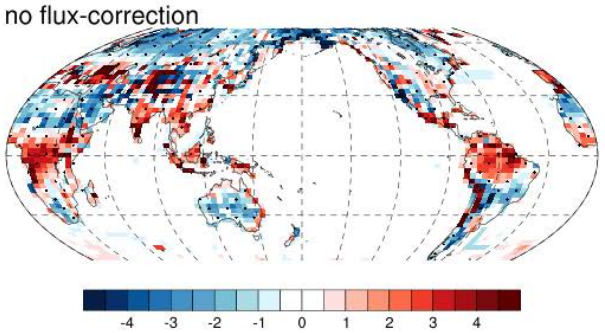




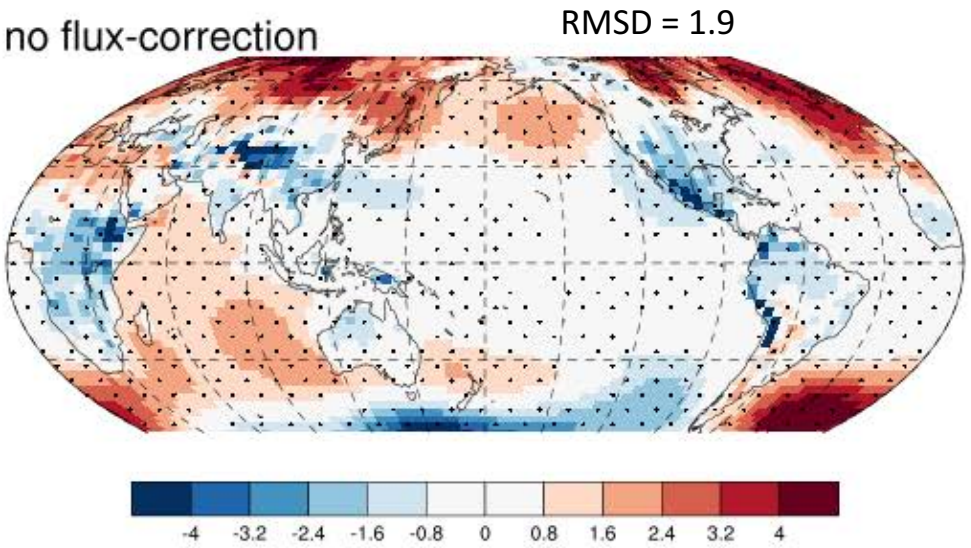


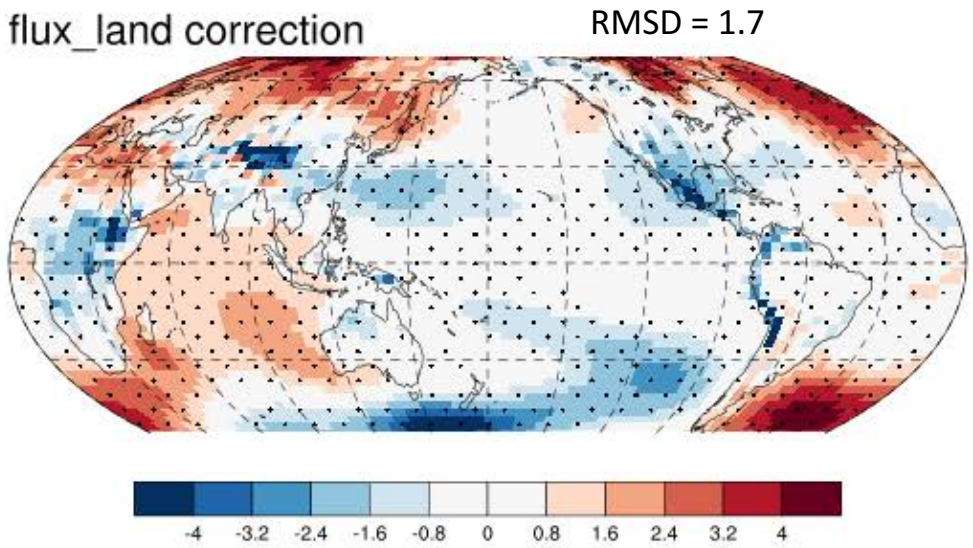


Sea level pressure mean state



Annual mean SLP bias: Model - ERAint

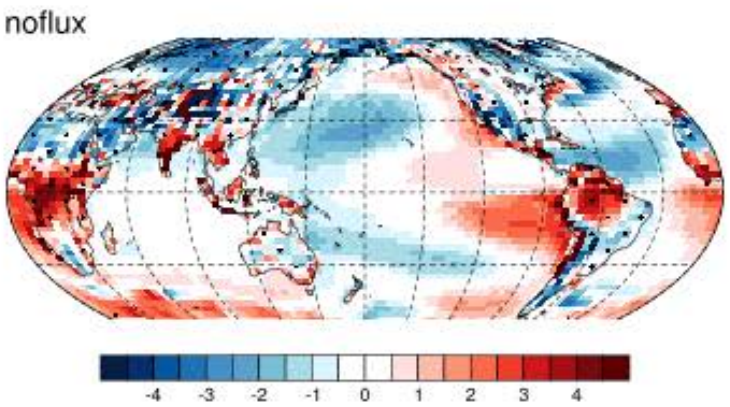


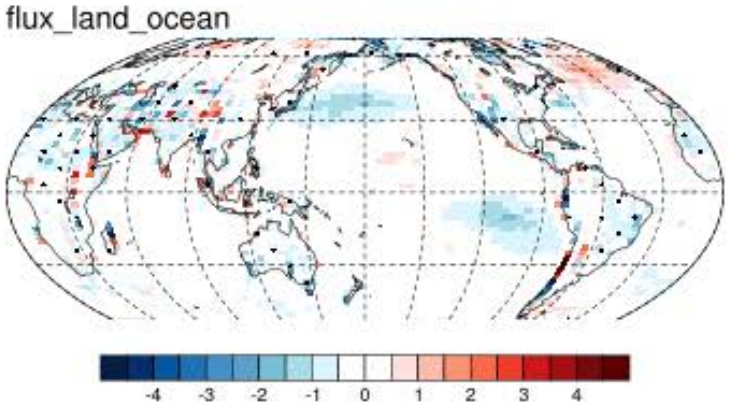


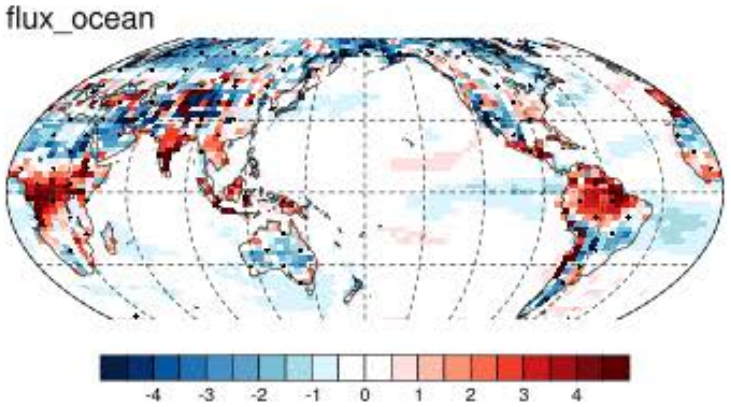
UM-slab model: surface temperature bias

Running 100 years, analysis the last 50 years as the climatology

Annual mean surface temperature bias: Model - ERAint



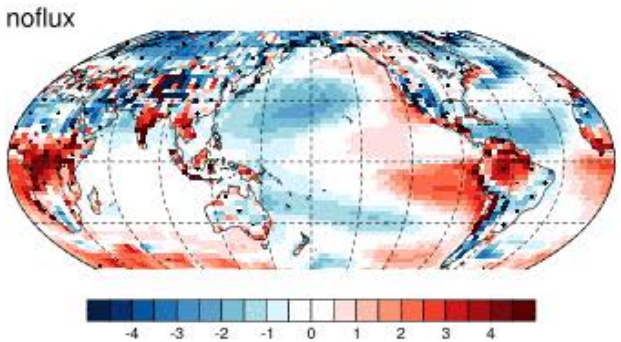


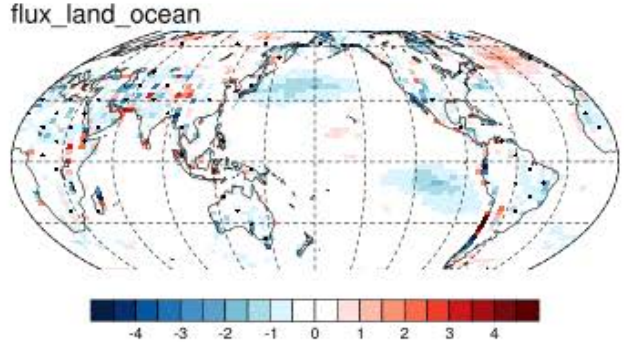


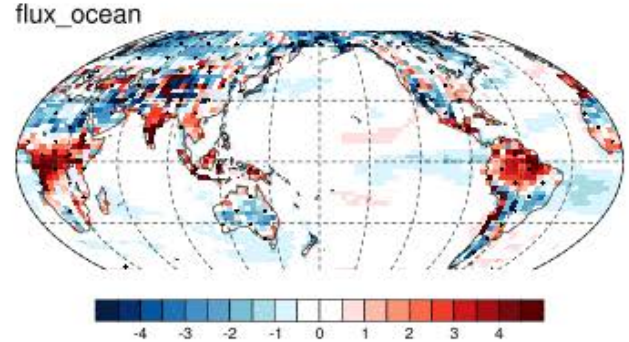
RMSD	No flux	Flux_land_ocean	Flux_ocean
All grid	1.8	0.7 (-61%)	1.4 (-22%)
Land grid	2.6	0.9 (-65%)	2.4 (-7%)

UM-slab model: annual mean SLP and Precipitaion bias

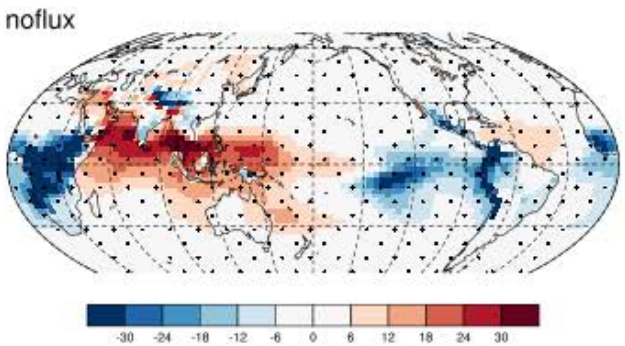
Tsurf bias (K)

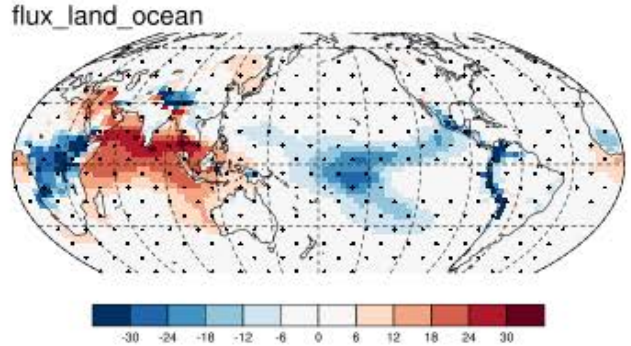


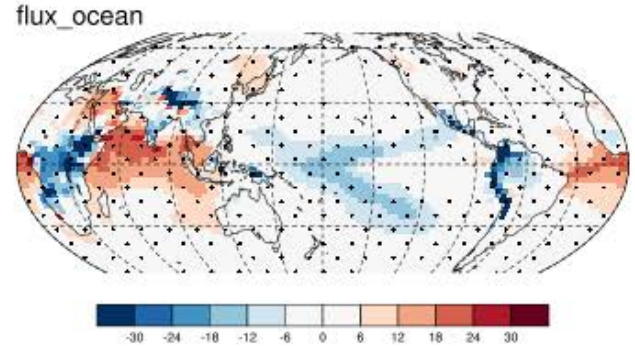




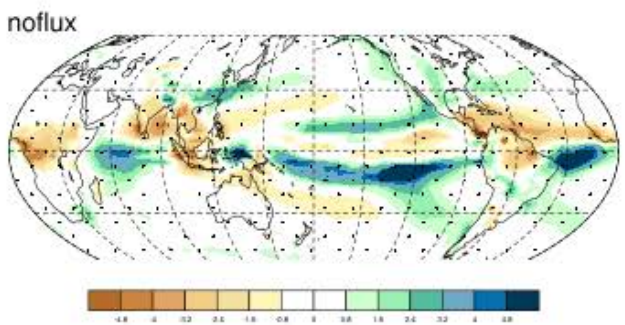
Normalized SLP bias

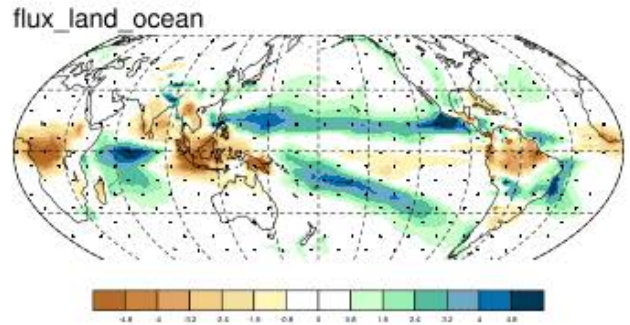


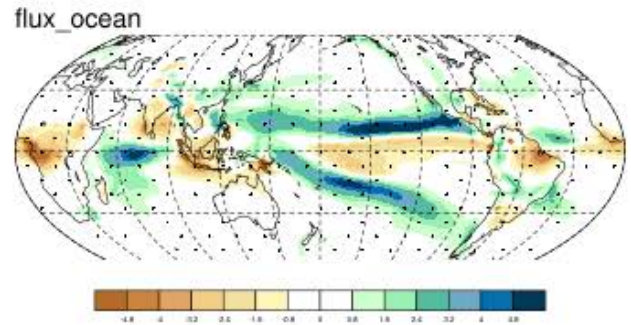




Precipitation bias (mm/day)

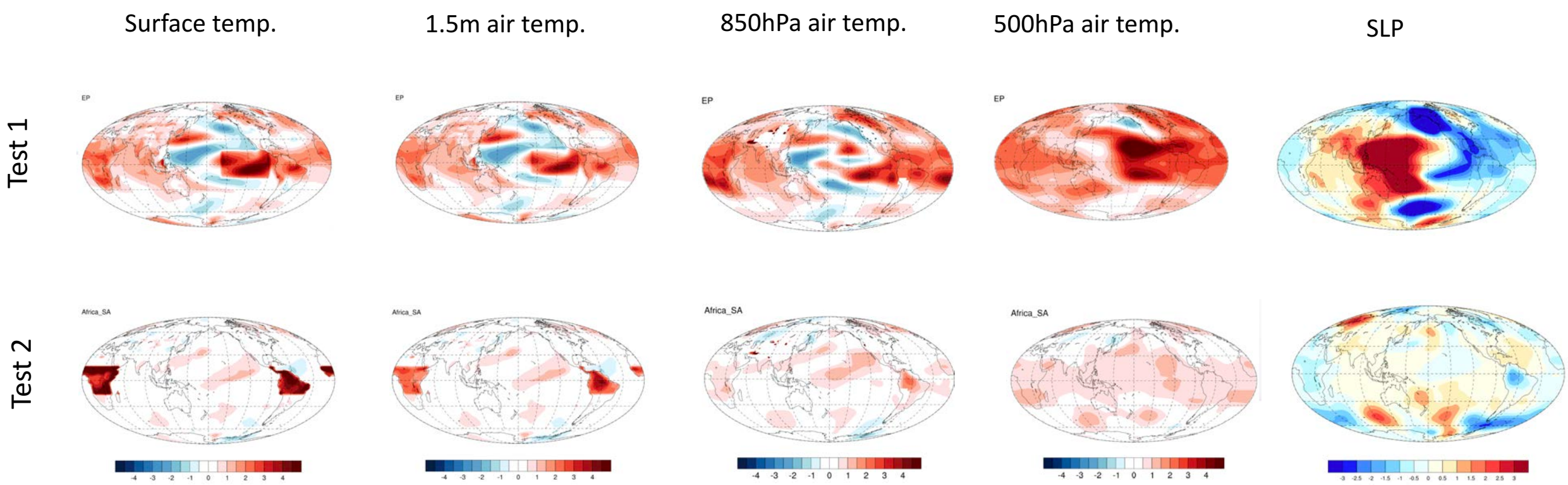






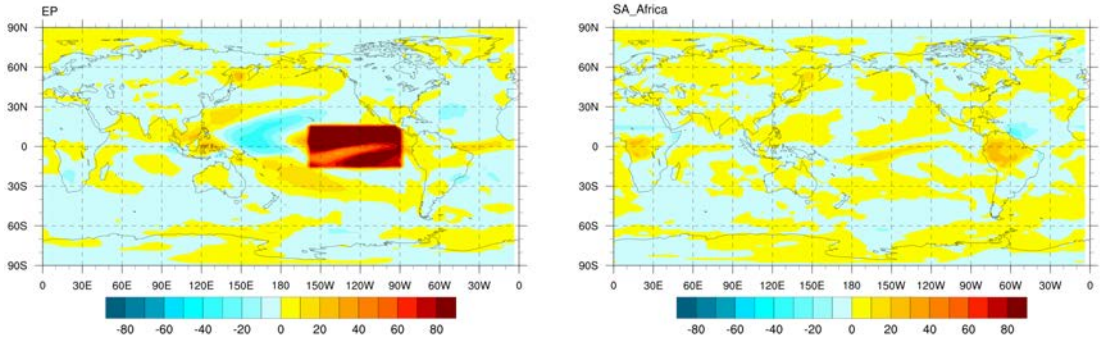
Discussion 1 Different atmosphere responses to the changed land surface temperature and sea surface temperature

Test1: added 100 W/m^2 heat flux in the East Pacific (EP)
Test2: added 100 W/m^2 heat flux in the tropical Africa and South America (Africa_SA)

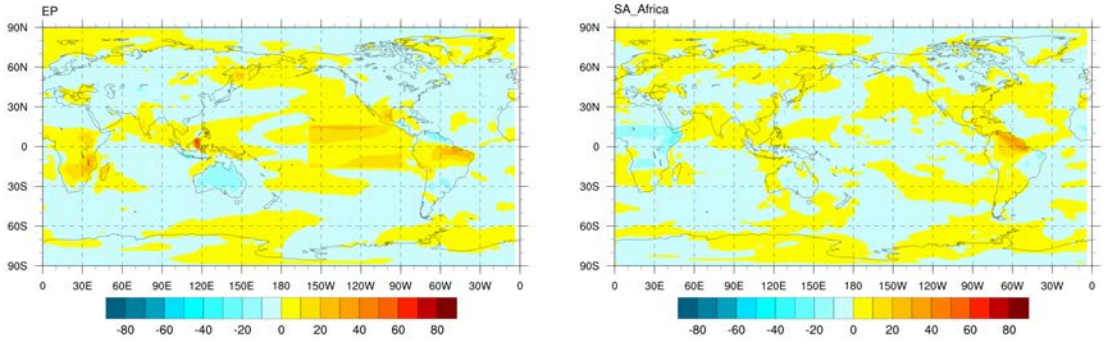


Surface heat flux

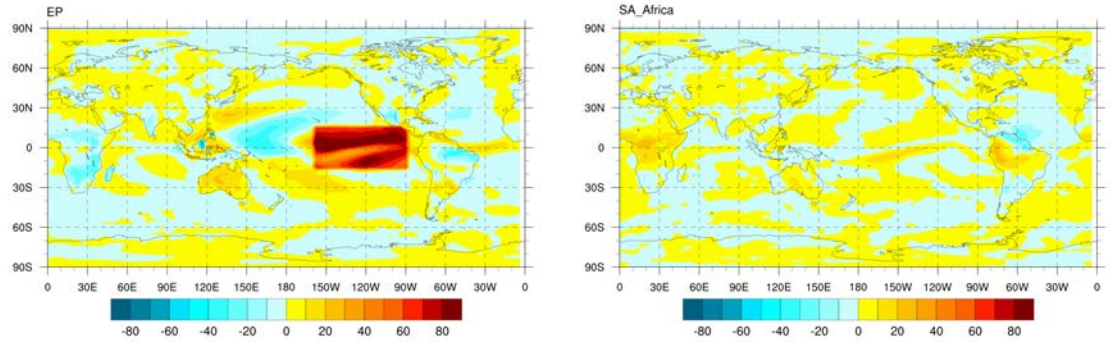
Total upward heat flux



Upward sensible heat flux



Upward latent heat flux

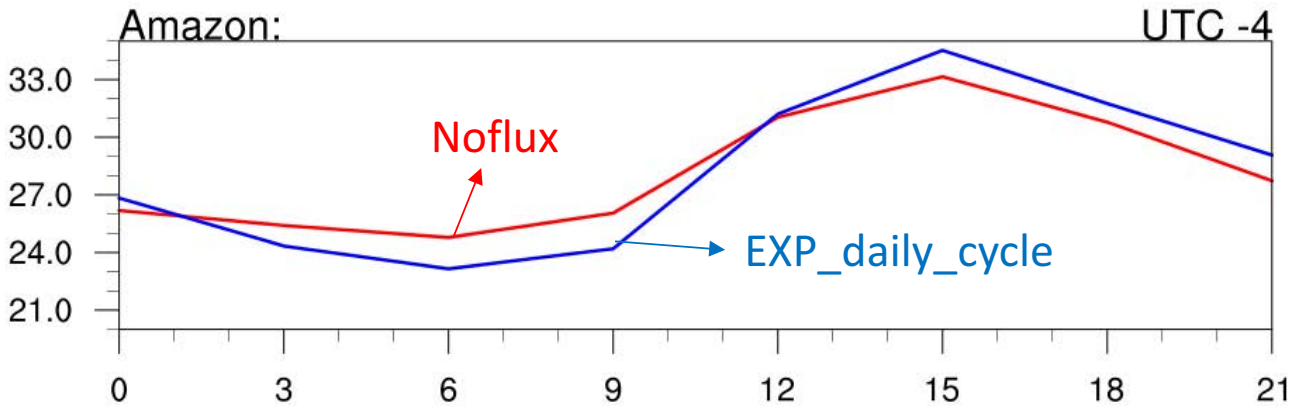


Related to the different moisture conditions over the land/sea surface

Discussion 2 The importance of the daily surface temperature cycle to the annual mean SLP and precipitation

Change_daily_cycle	Amazon region (17.5S – 5N; 285 -310E)	3hr Input data	-50 W/m^2 (first half day) +50 W/m^2 (second half day)

Tsurf daily cycle (mean for January)

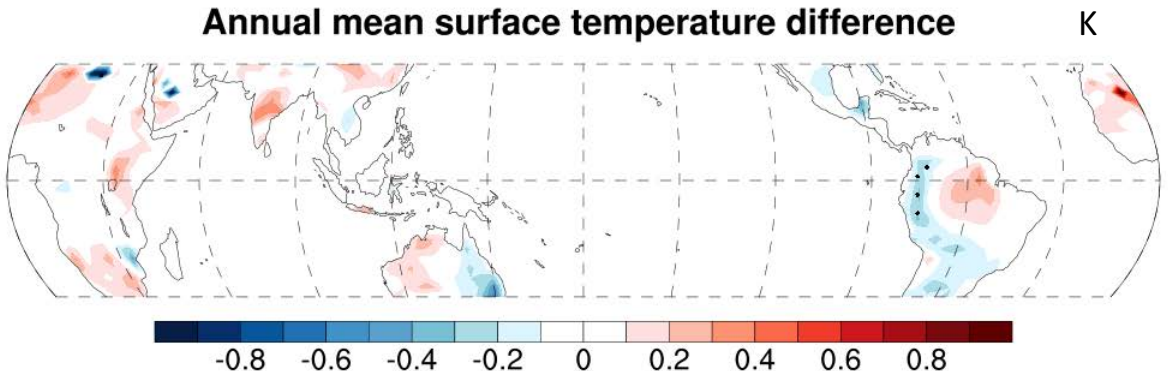


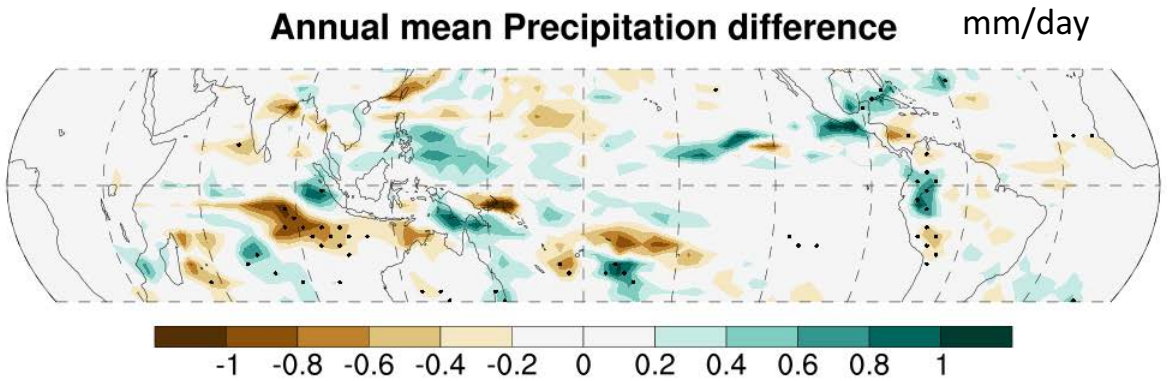
(~1 °C difference)

Results based on 20-yrs average of a 30-yrs simulation

Discussion 2

Mean state difference related to the different daily cycle





Significance t level: 95%

Conclusions

- The land surface temperature can be changed by including a flux-correction scheme in the UM model.

- Correcting the land surface temperature can help to reduce the SLP bias in some areas, however, the corresponding atmospheric responses are much weaker over the land, in comparison with changing the SST.

- Sensitivity experiments suggest the modified land surface temperature has a much weaker impact on the atmosphere due to the dry land air providing much less latent heat flux compared with the ocean surface.

Outlook

- Use a 3-hourly flux-correction, reducing the surface temperature daily cycle bias
- Correcting the low-level air temperature

Thanks!