Flux Correction of the Land Surface Temperature in the UM Model

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What is Flux Correction?

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.

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)
Studies with flux-correction

Uncorrected

Flux-correction

(Manganello et al. 2009)

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 COILA-ODA

(Ding et al. 2015)
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)

\[
T_* = T_S + \frac{1}{A_*} \left[ R_S - H - \lambda E + \frac{C_C}{\Delta t} (T^*_{prev} - T_s) \right]
\]

(UM original code)

\[
T_* = T_{PRES}
\]

(3-hourly data)  \hspace{1cm} (Ackerley and Dommenget 2016)

Is that possible to use a flux correction \((Q\text{flux})\) to adjust the surface temperature instead of holding it to a fixed value?

\[
T_* = T_S + \frac{1}{A} \left[ R_{LW+SW} - H - \lambda E + \frac{C_C}{\Delta t} (T^*_{pre} - T_s) + Q\text{flux} \right]
\]
Estimate the Qflux through Iteration process

Qflux = ‘0’

Iteration 1 (no Qflux)

Iteration 2 (Qflux1)

Iteration X (Qflux X-1)

Tsurf bias = simulated Tsurf – observed Tsurf
Qflux1 = Tsurf bias * HCF (heat capacity factor ~ 50W/m²/K)

Tsurf bias = simulated Tsurf – observed Tsurf (adjust the HCF for each grid)
Qflux2 = Qflux1 + Tsurf bias * HCF

Tsurf bias is generally smaller than 0.5 K

Obtained the monthly mean heat flux correction scheme

Reference data: ERA-interim skin temperature (climatological 1979-2017)
Two long-term runs: with/without heat flux correction
Running 50 years, analysis the last 30 years
Surface temperature mean state

Annual mean surface temperature bias: Model - ERAint

- no flux-correction: RMSD = 2.4
- flux_land correction: RMSD = 0.9

‘JJA – DJF’ surface temperature bias

- no flux-correction
- flux_land correction
Surface temperature seasonal cycle

- **ERAint**
- **No flux-correction**
- **flux-correction**

**Africa: 20E,0**

**Amazon: 60W,0**

**India: 75E,15N**

**Australia: 145E,30S**
Mean Daily cycle for January

- **ERAint**
- **No flux-correction**
- **flux-correction**

**Surfacing temperature daily cycle**
Sea level pressure mean state

Annual mean SLP bias: Model - ERAint

RMSD = 1.9

no flux-correction

RMSD = 1.7

flux_land correction
UM-slab model: surface temperature bias

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

Annual mean surface temperature bias: Model - ERAint

<table>
<thead>
<tr>
<th>RMSD</th>
<th>No flux</th>
<th>Flux_land_ocean</th>
<th>Flux_ocean</th>
</tr>
</thead>
<tbody>
<tr>
<td>All grid</td>
<td>1.8</td>
<td>0.7 (-61%)</td>
<td>1.4 (-22%)</td>
</tr>
<tr>
<td>Land grid</td>
<td>2.6</td>
<td>0.9 (-65%)</td>
<td>2.4 (-7%)</td>
</tr>
</tbody>
</table>
UM-slab model: annual mean SLP and Precipitation 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

<table>
<thead>
<tr>
<th>Change_daily_cycle</th>
<th>Amazon region (17.5S – 5N; 285 -310E)</th>
<th>3hr Input data</th>
<th>-50 W/m² (first half day) +50 W/m² (second half day)</th>
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<tr>
<th>Tsurf daily cycle (mean for January)</th>
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Amazon:

UTC -4

- **Noflux**
- **EXP_daily_cycle**

(~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

Annual mean surface temperature difference

Annual mean Precipitation difference

Significance 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!