Met Office Hadley Centre

Convection-permitting climate simulations for South America: a land-surface perspective (with insights from Africa and Europe)

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1) Introduction

Changes in the nature of precipitation in convection-permitting models (CPMs) compared to models with parametrised convection can have implications for land-atmosphere interactions that have not yet been fully investigated. The Met Office has now completed regional climate CPM simulations for Africa (Stratton et al, 2018), Europe (Berthou et al 2020) and South America (Halladay et al, in prep.), which give us an opportunity to explore these land-atmosphere interactions at high resolution in different climates/regions. Aims: (1) introduce the CPM simulations for Climate Science for Services Partnership (CSSP) Brazil and how they add value, (2) show how land surface-atmosphere interactions change with explicit convection, (3) explore sensitivity of CPMs to changes in the land surface scheme.

2) CPM simulations for South America

3 CPM simulations of 10 years (all 4.5km resolution):

-*Hindcast* (1998-2007) ERA Interim → 25km RCM → CPM

-*Present day control* (25km GCM-driven)

-*Future time slice* (25km GCM-driven with RCP8.5 climate ~2100)

Improved timing of diurnal rainfall peak in CPM relative to RCM compared with TRMM observations

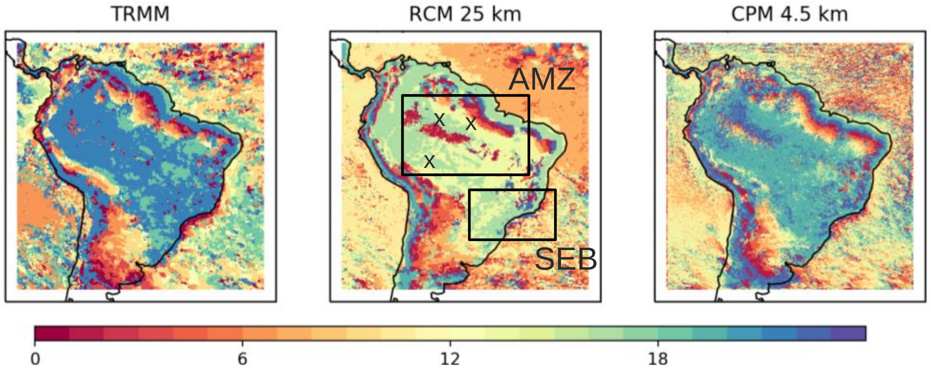

Figure 1. Time of day (UTC) coinciding with peak in diurnal cycle of rainfall (DJF) in TRMM, RCM and CPM hindcast (1998 – 2007). Observation sites are marked with 'x'.

Improved sub-daily precipitation intensity distributions for Amazonia and southeast Brazil in CPM with explicit convection compared to RCM with parametrised convection.

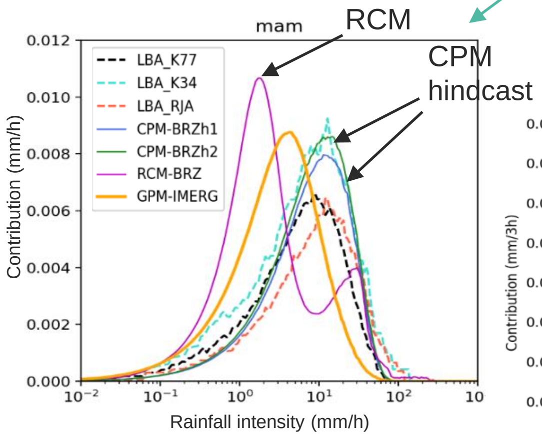

Figure 2. Seasonal distribution (MAM) of hourly rainfall (2001-2005) for **AMZ** region in CPM, RCM and GPM-IMERG and 3 observation sites in AMZ region marked with 'x' in Figure 1.

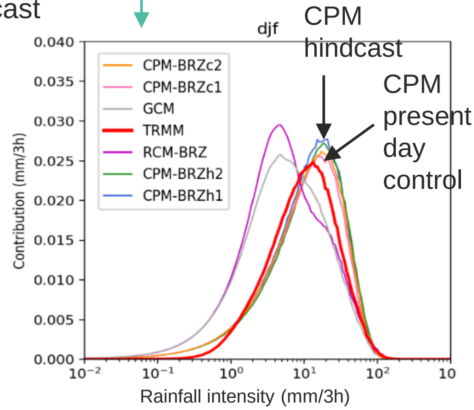

Figure 3. Seasonal distribution (DJF) of 3-hourly precipitation 1998 - 2007 for **SEB**

EUCP European Climate Prediction system
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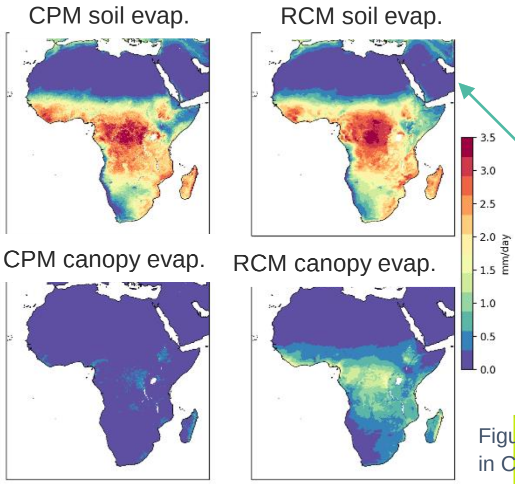
Evapotranspiration (ET) ~ canopy evap. + soil evap.

(includes transpiration and bare soil evap.)

CPM/RCM canopy evap. differences in CP4 Africa have been shown to be caused by the shifts in the rainfall intensity distribution (Folwell et al. 2022).

Less frequent, heavier rainfall in the CPM leads to overflowing of the canopy store whereas frequent light rain in the RCM replenishes the store so that moisture is available for evaporation.



3) Rainfall changes and ET partitioning

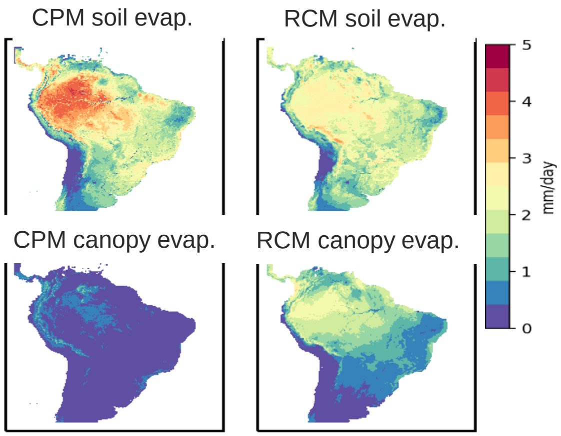


Figure 4. Mean annual soil evaporation and canopy evaporation in CPM and RCM (1998-2007).

South America: increased soil evap. partially compensates for decreased canopy evap.

CP4 Africa: similar soil evap. in CPM and RCM.

Lower canopy evap. in both CPMs -> implications:

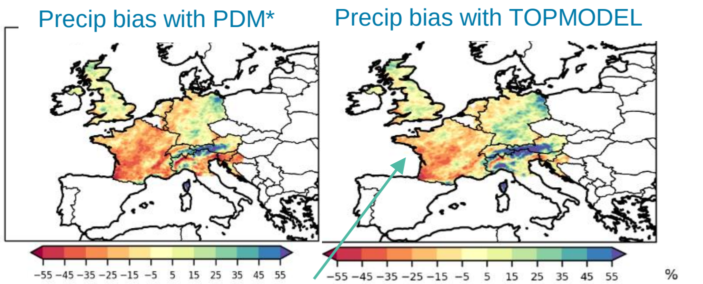
- Changes in surface runoff and surface energy budget
- Increased land-atmosphere coupling as ET more dependent on soil moisture

Figure 5. Mean annual soil evaporation and canopy evaporation in CPM and RCM in CP4 Africa simulations (2004-2006).

4) Effect of runoff scheme on rainfall and temp. biases

2.2 km CPM simulations for Europe have a greater dry precipitation bias in JJA over France and other parts of central Europe (Berthou et al, 2020) than the 12km RCM and a warm bias in the east of the domain.

Figure 6. JJA percent precipitation bias 2000-2004 compared with observations from 4 region-specific data sets (see Berthou et al 2020 for details) for 2.2 km CPM with PDM* (left) 2.2 km CPM with TOPMODEL (right)



Decreased summer warm and dry precip. biases in CPM with more complex runoff scheme

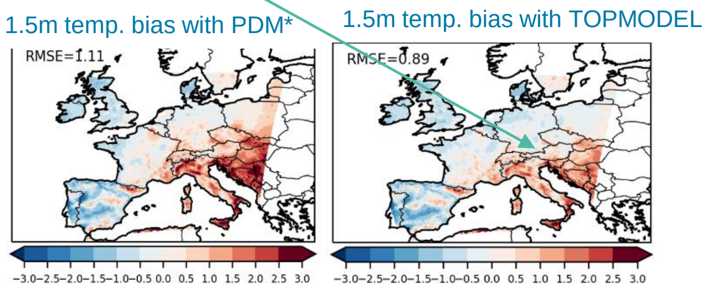


Figure 7. JJA 1.5 m temperature bias (K) 2000-2004 for CPM with PDM (left) and CPM with TOPMODEL (right)

**PDM* (Probability Distributed Model): simple runoff scheme
TOPMODEL: more complex runoff scheme taking into account topography and includes a representation of the water table.

5) Effect of decreased moisture stress threshold in vegetation and increased canopy capacity on precip. and temperature

The latest version of the Met Office Unified Model (RAL3) includes a change to the land surface scheme to delay the onset of moisture stress in vegetation (Harper et al, 2021), i.e. plants can continue to transpire with less soil moisture in the root zone.

Increased precip in some areas

Effect of lower moisture stress threshold

Widespread decreases in temperature

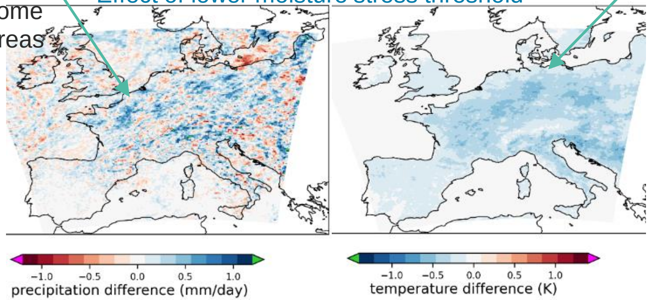


Figure 8. **Difference in JJA precipitation** (left) and **1.5m temperature** (right) (1999-2000) between CPM with **lower moisture stress threshold** values and CPM with default values.

Given the low canopy evaporation in CPMs, we investigated the impact of increasing the canopy storage capacity (currently lower than observed) to maximum observed values (up to 6 times the default values, depending on plant functional type) .

Increased precip in some areas

Effect of maximum canopy capacity

Widespread decreases in temperature

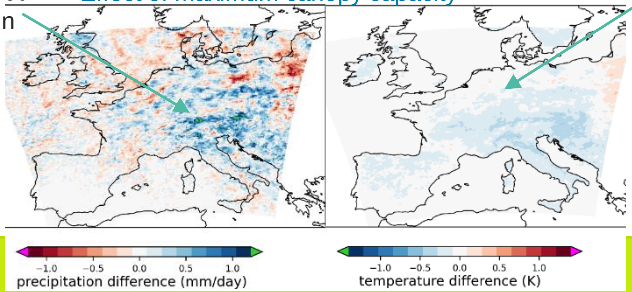


Figure 9. **Difference in JJA precipitation** (left) **1.5m temperature** (right) (1999-2000) between CPM with **maximum canopy capacity** values compared with CPM default values.

6) Conclusions and next steps

- 4.5 km CPM simulations for South America improve the sub-daily precipitation intensity distribution and timing of diurnal peak compared to observations and relative to 25 km RCM simulations with parametrised convection. Future work will involve more detailed assessment of added value and comparison of present-day and future simulations.

- Canopy evaporation is consistently lower in CPM simulations compared to RCM simulations across different modelling domains due to the shift in rainfall intensity distribution. There may be a compensating increase in soil evaporation depending on region. The impact of differences in ET partitioning on surface energy budgets and runoff for different regions requires further investigation.

- Changing the runoff scheme to represent the water table and take into account topography decreases dry and warm biases in 2.2 km simulations for Europe. Further work is needed to assess the impact of a more detailed representation of groundwater.

- Increasing canopy capacity and decreasing the moisture stress threshold for vegetation can and increase rainfall in some areas and decrease temperatures more widely.

References and acknowledgements

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