Influence of vegetation cover on extreme rainfall over southern Africa.
Part 1: Idealised experiments using a global and regional climate model

C. J. R. Williams[1] and D. R. Kniveton[2]

[1]NCAS-Climate / Walker Institute, University of Reading, UK; [2]School of Global Studies, University of Sussex, UK

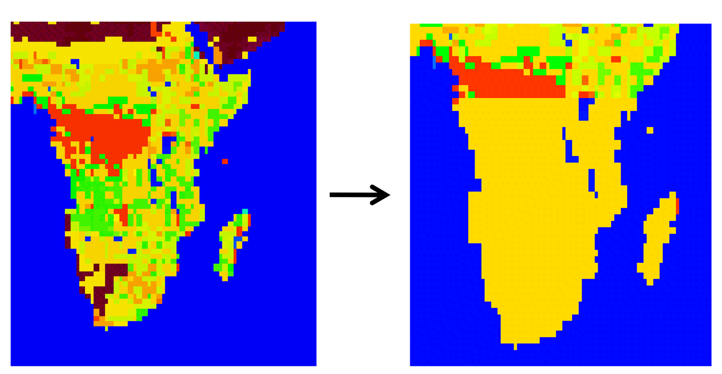
Contact: C.J.R.Williams@reading.ac.uk

1. INTRODUCTION

- To date, the majority of work on regional rainfall variability has focused on sea surface temperature (SST) in various ocean basins, e.g. the Pacific, Indian Ocean and Atlantic – for example, work by the same authors suggests extreme rainfall over southern Africa is associated with regions of both cold and warm SST anomalies throughout the South Atlantic (Williams *et al*. 2007, 2008, 2010)
- However, past research suggests that land surface processes are also critical for rainfall variability (e.g. Charney 1975). Furthermore, there is some suggestion that the positive feedback mechanism between the atmosphere and land surface was responsible for sudden and abrupt climate changes e.g. over the Sahara during the mid-Holocene or, more recently, the Sahel drought and US Dust Bowl
- Despite this, there is currently a lack of understanding of atmosphere-land surface interactions, particularly for environmentally and socio-economically vulnerable regions such as southern Africa
- Thus, the aim of this work is to undertake preliminary, simplistic experiments using a general/global circulation and regional climate model (GCM and RCM, respectively), to test the sensitivity of rainfall to land surface changes

2. MODEL DETAILS AND METHODOLOGY

- The Unified Model (UM) from the UK Met Office Hadley Centre was used, and was run in both regional or global atmosphere-only mode (i.e. forced with prescribed, present-day boundary conditions e.g. CO_2, ozone, SST, etc)
- The main aim of the model experiments was to investigate the simulated response of mean rainfall patterns (at high spatial resolution) to changes in land cover, therefore the primary tool was the RCM. To avoid any potential biases from lateral boundary data, and to simulate large-scale circulation features, a GCM was also used
  - ✓ RCM – We used Providing Regional Climates for Impacts Studies (PRECIS), the standalone version of the regional atmosphere-only component of the UM (HadRM3P). A spatial resolution of 0.5° by 0.5° was used, and the model was run over a limited domain from just above the Equator down to the southern tip of Africa, including Madagascar (hereafter "southern Africa"). At its lateral boundaries, the RCM was forced with reanalysis data from ERA-40
  - ✓ GCM – We used the global atmosphere-only version of the UM, HadAM3. This has been used widely in the scientific literature. It has a spatial resolution of 2.5° by 3.75°, giving a global grid of 96 points in the east-west direction by 73 points in the north-south direction, and 19 vertical levels
- The vegetation types used in the model's land surface scheme were idealised and used to force the model. 3 experiments (of 4 yrs each) were undertaken using different vegetation types across all of southern Africa:
  1) Control: unmodified vegetation file (Con)
  2) Desert: sand-desert + barren land (Des)
  3) Savanna: tropical savanna (Sav)
- Differences in mean rainfall between runs were investigated, as well as any associated large-scale circulation features



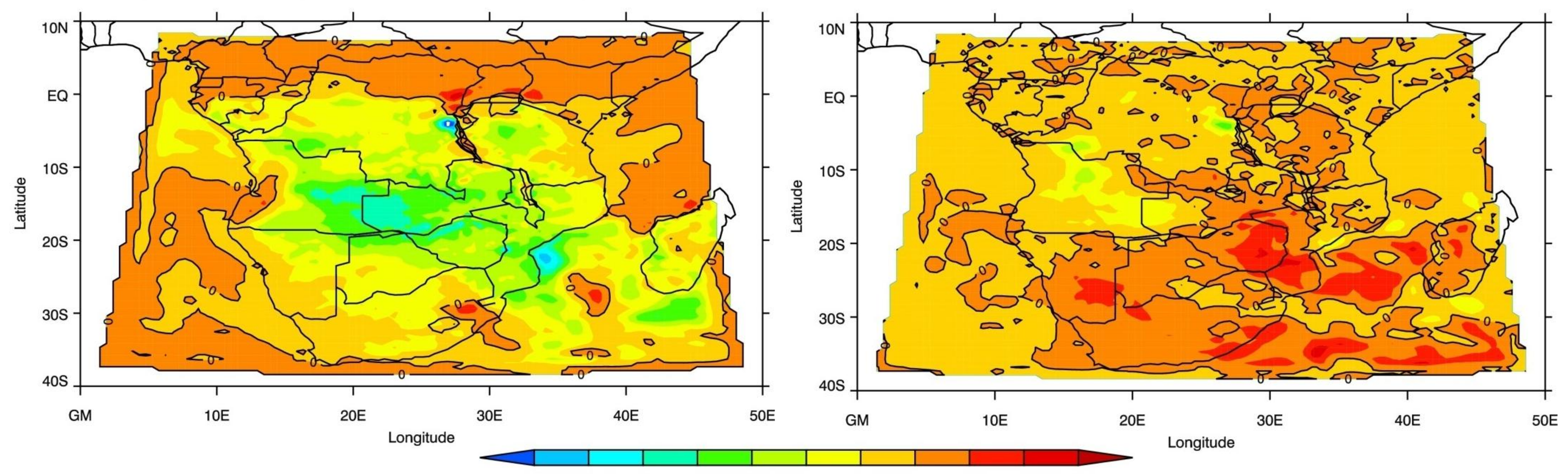
3. RESULTS

- All plots below show daily differences between control run and vegetation runs, for December-February (DJF) 1994-1997
- For the RCM experiments, these are either Des – Con or Sav – Con. For the GCM experiment, all plots are Des – Con

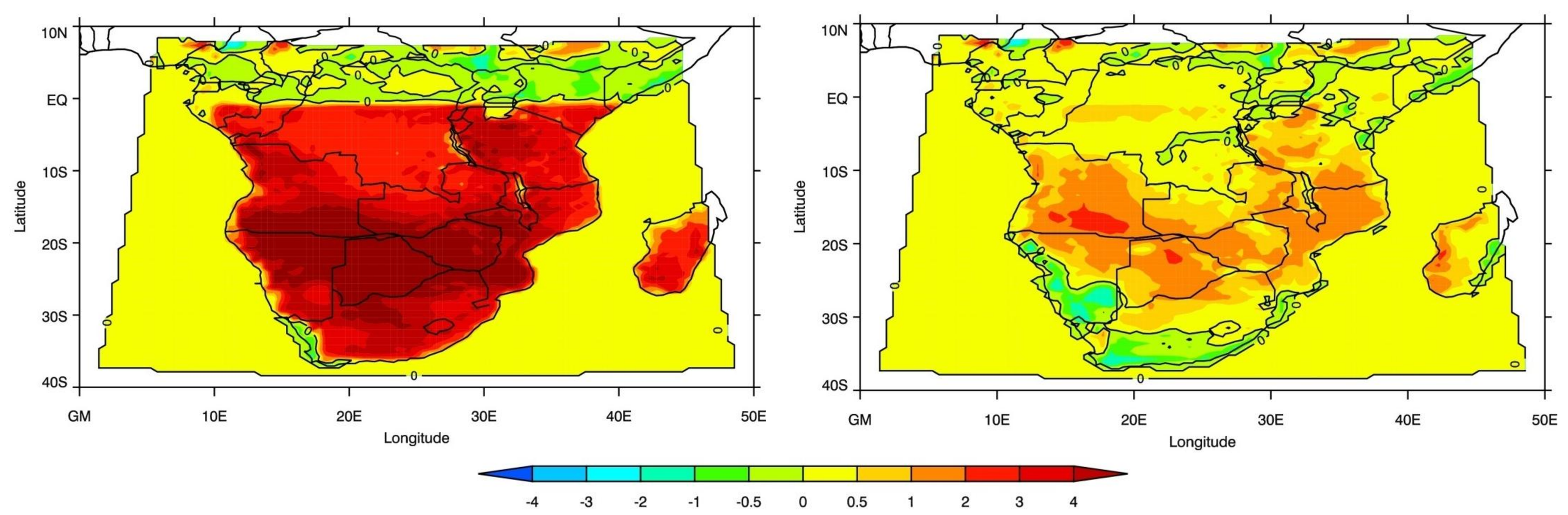
RCM experiments:

Des-Con **Sav-Con**

Surface rainfall rate (mm/day)

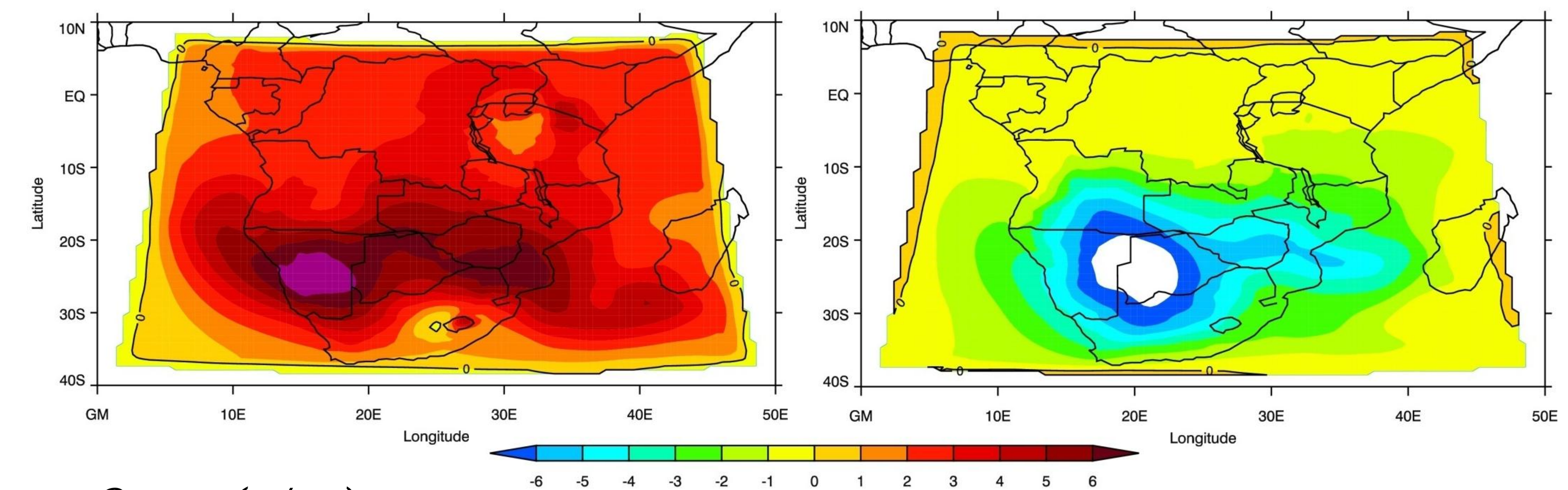


Surface temperature (k)

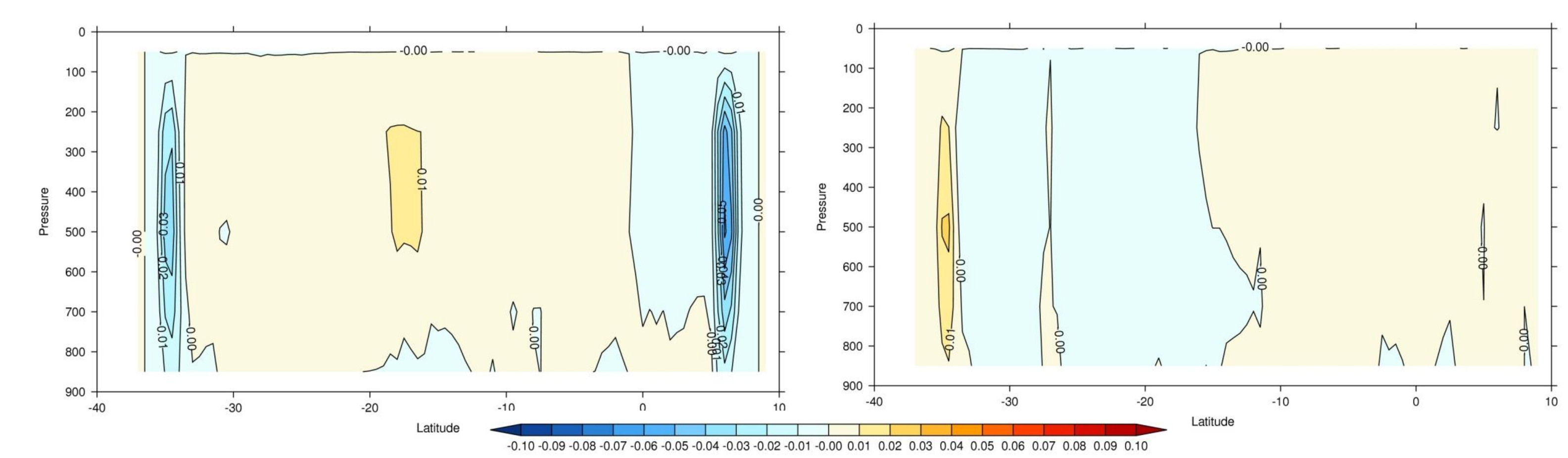


Des-Con **Sav-Con**

850mb geopotential height (m)

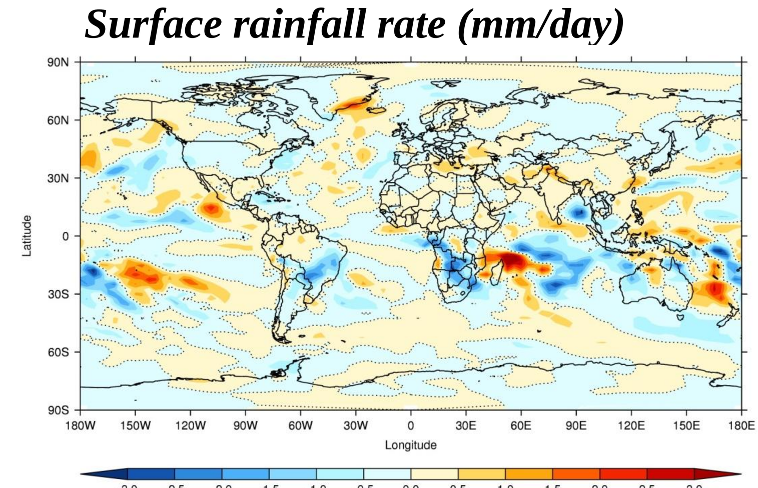


Omega (m/sec)

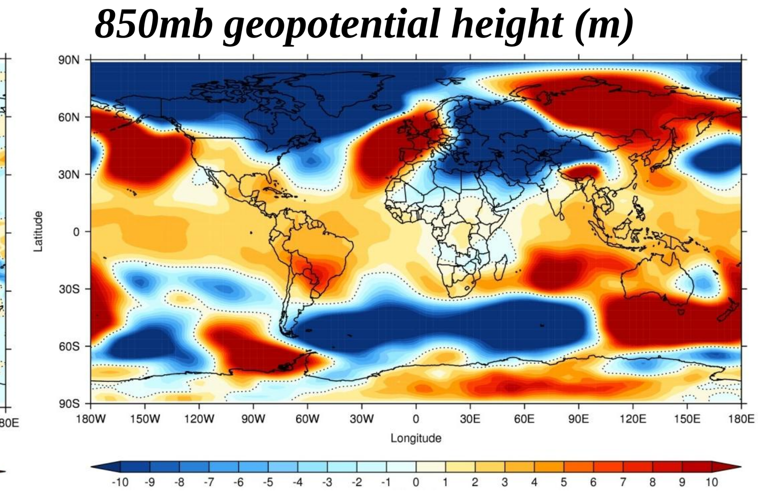


GCM experiment:

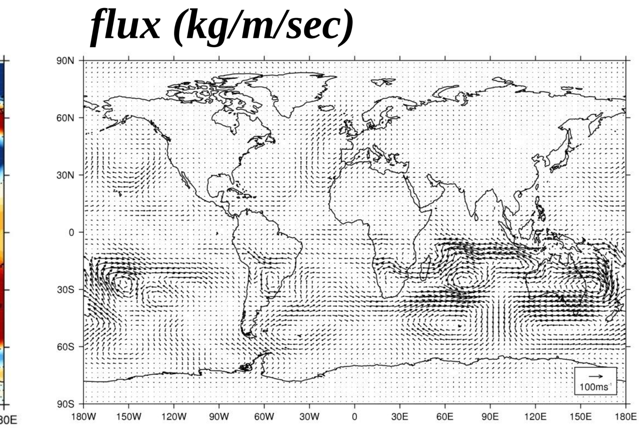
Surface rainfall rate (mm/day)



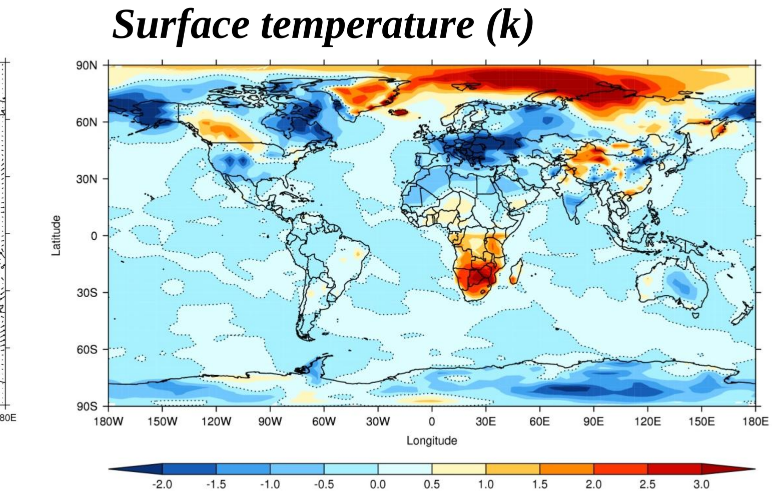
850mb geopotential height (m)



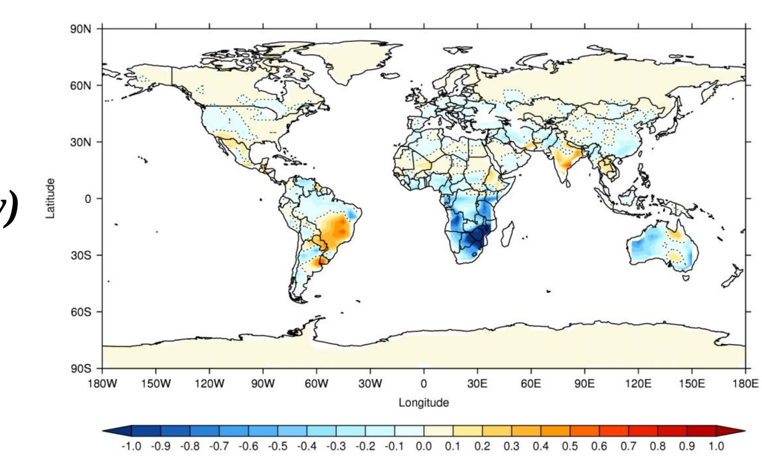
Vertically integrated moisture flux (kg/m/sec)

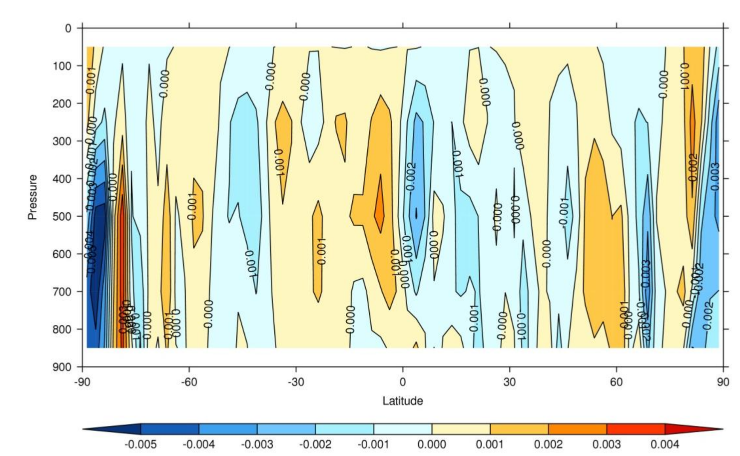


Surface temperature (k)



Surface evaporation rate (mm/day)





Omega (m/sec)

4. CONCLUSIONS

- There is a relatively low understanding of atmosphere-land surface interactions (compared to, for example, the role of SST), especially true for vulnerable regions such as southern Africa
- The RCM and GCM experiment results suggest a decrease in rainfall in the desert run, due to a reduction in available moisture, less evaporation, less vertical uplift and higher near surface pressure. Conversely, an increase in rainfall occurs in the savanna run, due to an increase in available moisture, increase in latent heat and thus surface temperature, increasing vertical uplift and lowering near surface pressure
- Results are only preliminary, forming first stage of wider study into how the atmosphere-land surface feedback influences rainfall extremes over southern Africa in both the past and future

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