Climate change signals in Africa from RCMs

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* with special thanks to colleagues from the AMMA, IMPETUS and ENSEMBLES projects
What has caused the Sahelian drought?

- Oceanic forcing
- Greenhouse forcing
- Feedbacks with land surface / land degradation
- Natural variability
Key region for RCMs

precipitation changes under $3 \times \text{CO}_2$
Key region for RCMs

RCM reproduces AEW dynamics

[Paeth et al. 2005]
Open questions in terms of climate change

- What about model uncertainty on behalf of the driving GCM?
- What about model uncertainty on behalf of different RCMs?
- What about internal spatio-temporal variability in RCMs?

⇒ Do RCMs provide more detailed fingerprints or spatial noise?
⇒ Is RCM output reliable for impact research?
# RCM data from AMMA / ENSEMBLES / IMPETUS

<table>
<thead>
<tr>
<th>RCM</th>
<th>Institute</th>
<th>Resolution</th>
<th>20th century</th>
<th>21st century</th>
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<tbody>
<tr>
<td>REMO</td>
<td>MPI</td>
<td>50 km</td>
<td>ERA Interim</td>
<td>ECHAM5-A1B</td>
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<td>SMHI</td>
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<td>HadCM3-A1B</td>
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<td>UCLM</td>
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<tr>
<td>REMO</td>
<td>U Würzburg</td>
<td>50 km</td>
<td>ECHAM5-A1B/B1(+LCC), 3x3x</td>
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</tr>
</tbody>
</table>
GCM uncertainty

CMIP3 multi-model ensemble

ECHAM5 ensemble

\[ \text{ECHAM5 and HadCM3 are consistent with CMIP3 multi-model ensemble mean} \]

[in IPCC 2007]
RCM uncertainty – 20th century

Paeth et al. 2011
RCM uncertainty – 20th century

Paeth et al. 2011
RCM uncertainty – future trends

Paeth et al. 2011
RCM uncertainty – future trends

annual precipitation trend 2001-2050 (5%)

[Paeth et al. 2011]
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RCM uncertainty – quantitatively

9 RCMs, 1990-2007, same forcing

1 RCM, 2003-2005, mixed physics

9 RCMs, 2001-2050, same scenario, different forcings

21 GCMs, 2001-2050, same scenario

[ Paeth et al. 2011 ]
RCM uncertainty – forcing scenario

> exact pattern of future land-use changes can hardly be anticipated: highly fragmented process ⇒ stochastic modelling

demographic estimates from UN + deforestation from FAO at continental scale

tropical Africa: demography: +2.7%/a forest: -32% until 2050

stochastic model (USGS 1km x 1km):

\[ \frac{dF}{dt} = -32\% \]

preprocessor from K. Born adapted to ECHAM4 TFs from S. Hagemann

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RCM uncertainty – forcing scenario

TEMPERATURE (°C)  PRECIPITATION (mm)

total change under A1

⇒ prominent warming and drying in sub-Saharan Africa
RCM uncertainty – forcing scenario

Temperature (°C) and Precipitation (mm) under A1 scenario.

- Prominent warming and drying in sub-Saharan Africa.
- Land degradation is primarily responsible for the drying.
RCM uncertainty – temporal noise

3-member ensemble from REMO (A1B: GHG+LCC):
annual precipitation variability
2001-2050

[ Paeth et al. 2009 ]
RCM uncertainty – temporal noise

- External signal
- Internal variability

explained variance (5%)
RCM uncertainty – spatial noise

3-member ensemble from REMO (A1B: GHG+LCC): annual precipitation

300 km x 300 km resolution

50 km x 50 km resolution

30-year trend patterns from CRU

30-year trend patterns from REMO

[Paeth and Mannig 2011]
RCM uncertainty – spatial noise

3-member ensemble from REMO (A1B: GHG+LCC): annual temperature

300 km x 300 km resolution
50 km x 50 km resolution

40-year trend patterns from CRU

40-year trend patterns from REMO

[ Paeth and Mannig 2011 ]
Bias correction by MOS

1979-2002 rainfall climatology

[ Paeth 2010, Paeth et al. 2011 ]
Bias correction by weather generator

- **REMO rainfall:**
  - correct seasonal cycle
  - underestimated extremes
  - hardly any dry spells

- **Weather Generator:**
  - statistical distribution as observed
  - individual events not in phase with observations

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**Graphs:**
- Original REMO rainfall
- Rainfall from weather generator
- Station time series (Kandi)

**Legend:**
- RCM data
- Station data
- RCM data postprocessed
Summary

- GCM uncertainty is considerable – but GCM signals are not directly translated into RCM signals.
- RCM uncertainty is enormous – but LCCs could lead to more coherent signals.
- Internal spatio-temporal variability in RCMs is high – but allows for statistically significant signal patterns.

⇒ RCMs provide more detailed fingerprints + spatial noise.
⇒ RCM output is reliable for impact research if bias corrected by statistical postprocessing.
Bias correction by weather generator

- Simulated grid-box precipitation (dynamical part)
- Local topography (physical part)
- Random distribution in space (stochastical part)
- Virtual station rainfall (result)

Probability matching:
- Model
- Obs.

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