CORDEX Meeting 2011, Trieste

Climate change signals in Africa from RCMs

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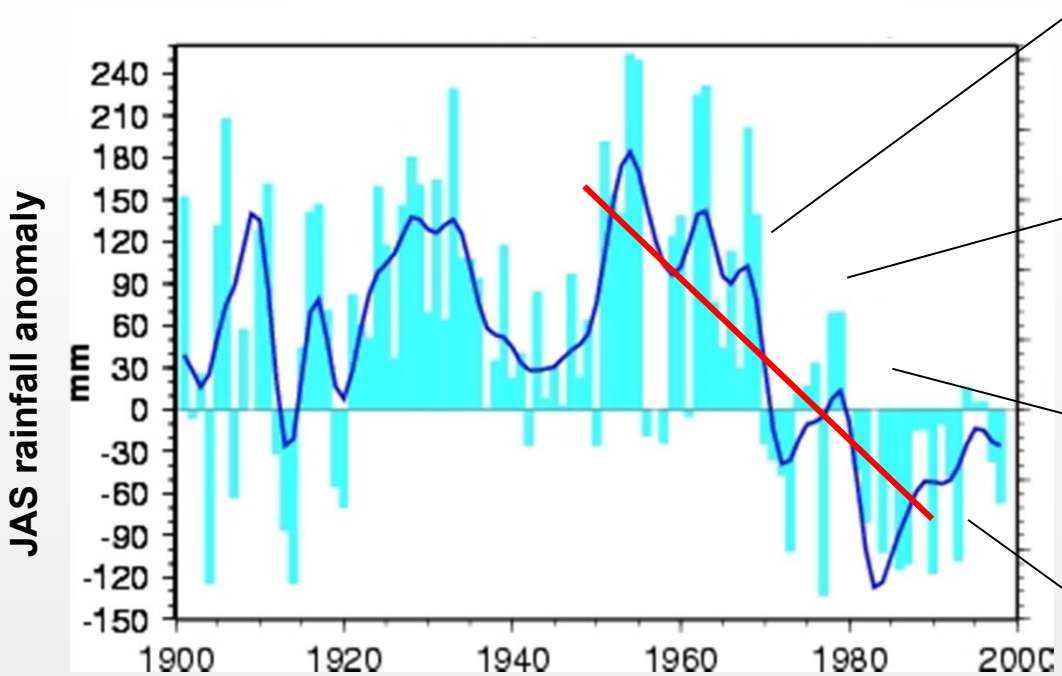
*** with special thanks to colleagues from the AMMA, IMPETUS and ENSEMBLES projects**

Motivation

What has caused the Sahelian drought?



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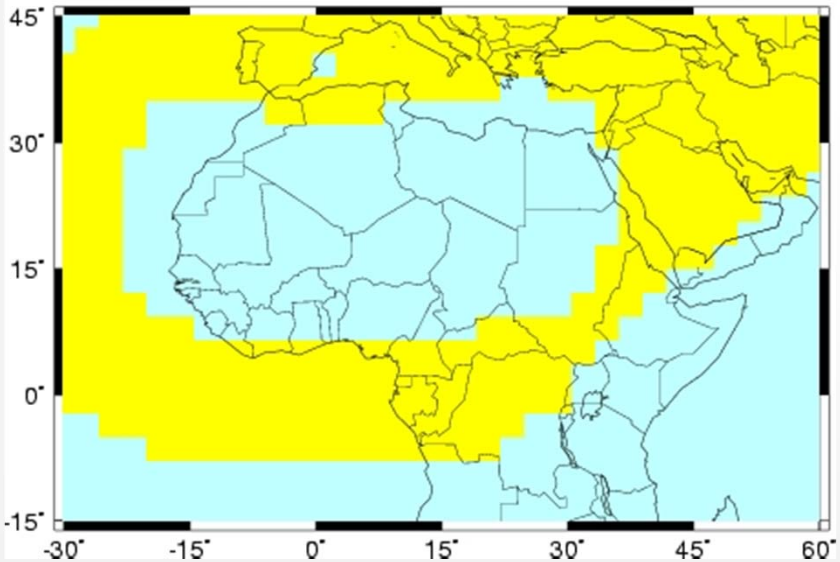
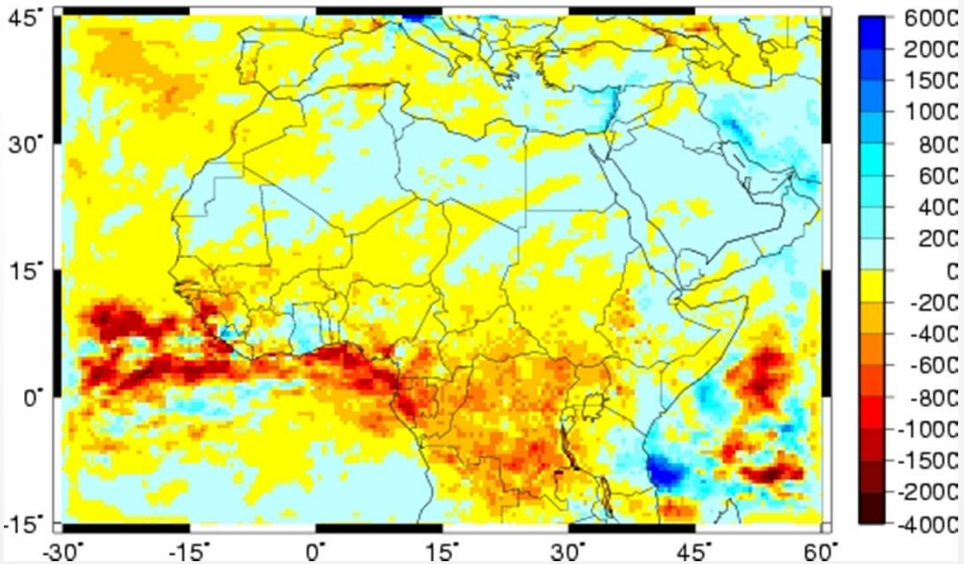
- oceanic forcing
- greenhouse forcing
- feedbacks with land surface / land degradation
- natural variability

Key region for RCMs

GCM (ECHAM4)



RCM (REMO)



precipitation changes under 3 x CO_2

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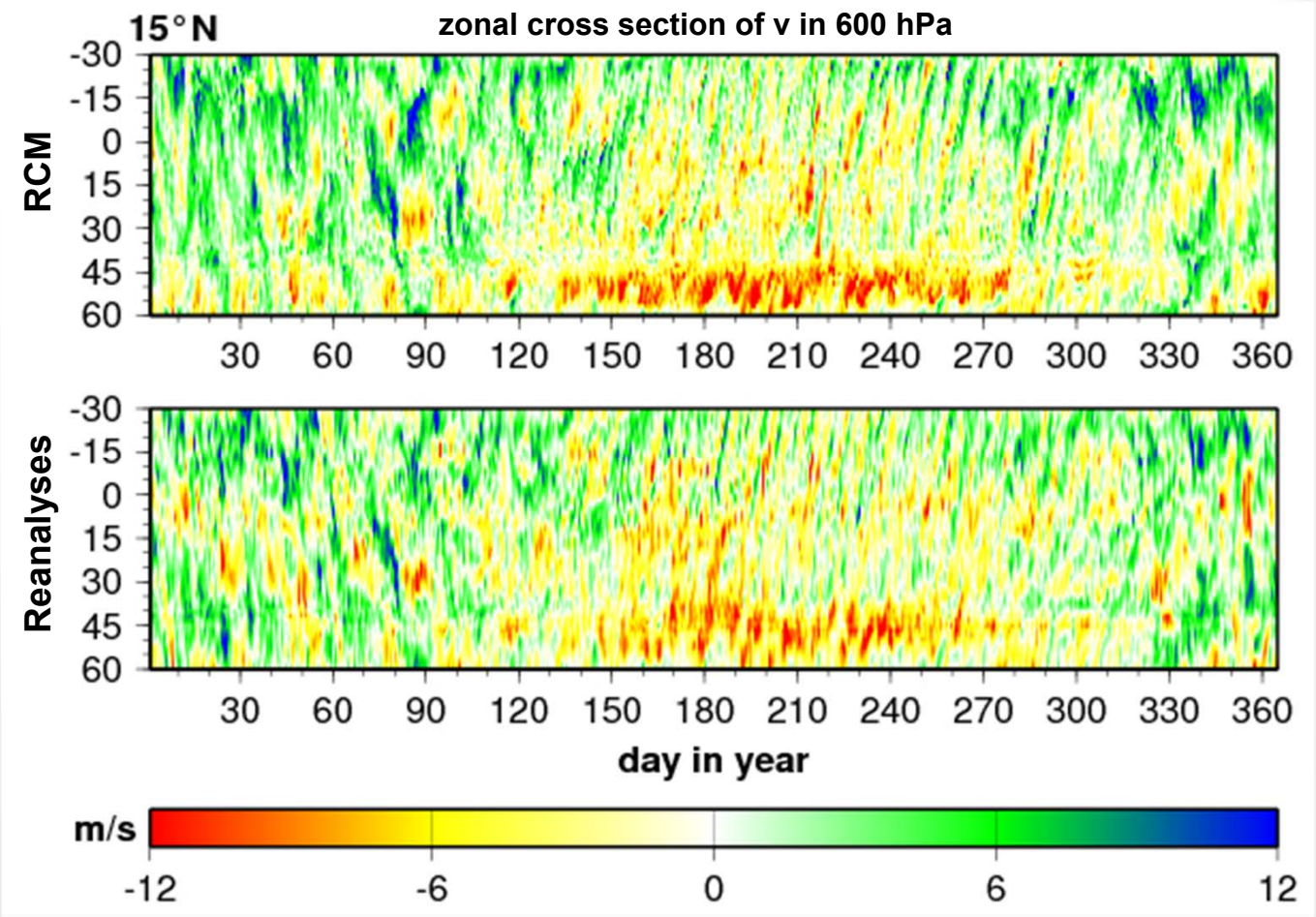
Key region for RCMs

RCM reproduces AEW dynamics



[Paeth et al. 2005]

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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

RCM	Institute	Resolution	20th century	21st century
REMO	MPI	50 km	ERA Interim	ECHAM5-A1B
REGCM3	ICTP	50 km	ERA Interim	ECHAM5-A1B
HIRHAM	DMI	50 km	ERA Interim	ECHAM5-A1B
CCLM	GKSS	50 km	ERA Interim	ECHAM5-A1B
RACMO	KNMI	50 km	ERA Interim	ECHAM5-A1B
RCA	SMHI	50 km	ERA Interim	HadCM3-A1B
HIRHAM	METNO	50 km	ERA Interim	HadCM3-A1B
HadRM3P	Hadley Centre	50 km	ERA Interim	HadCM3-A1B
PROMES	UCLM	50 km	ERA Interim	HadCM3-A1B
REMO	U Würzburg	50 km	ECHAM5-A1B/B1(+LCC), 3x3x	

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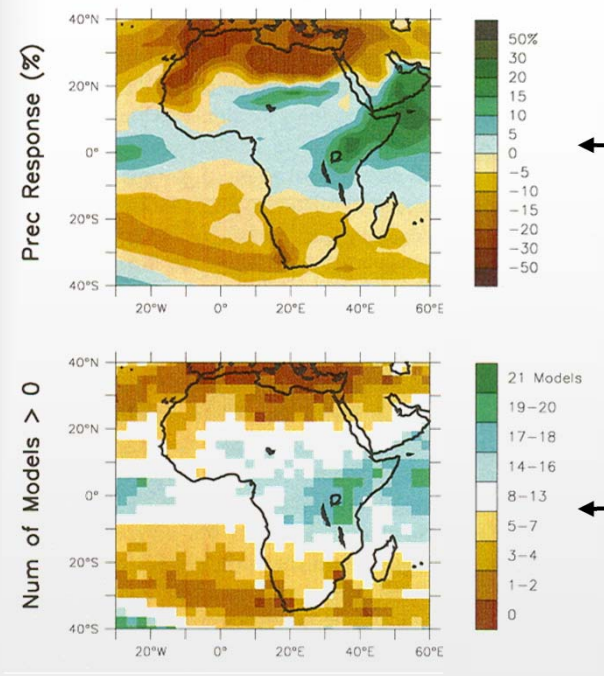
GCM uncertainty

CMIP3 multi-model ensemble

(2080-2099) minus (1980-1999)

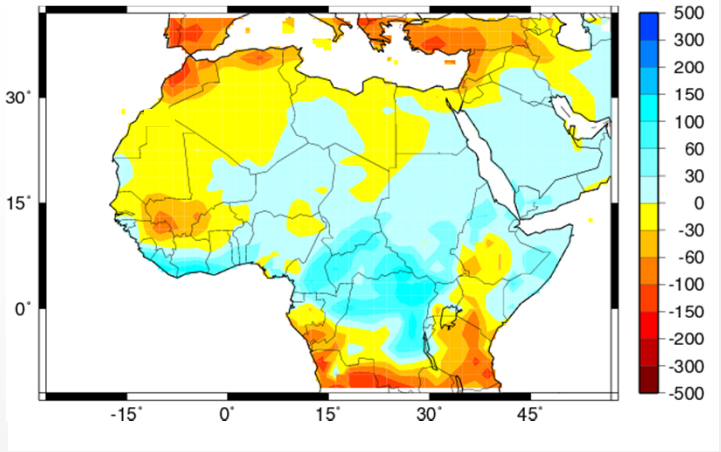


innertropics wetter; Sahel and Sahara drier

large model uncertainty over subsaharan Africa

≈

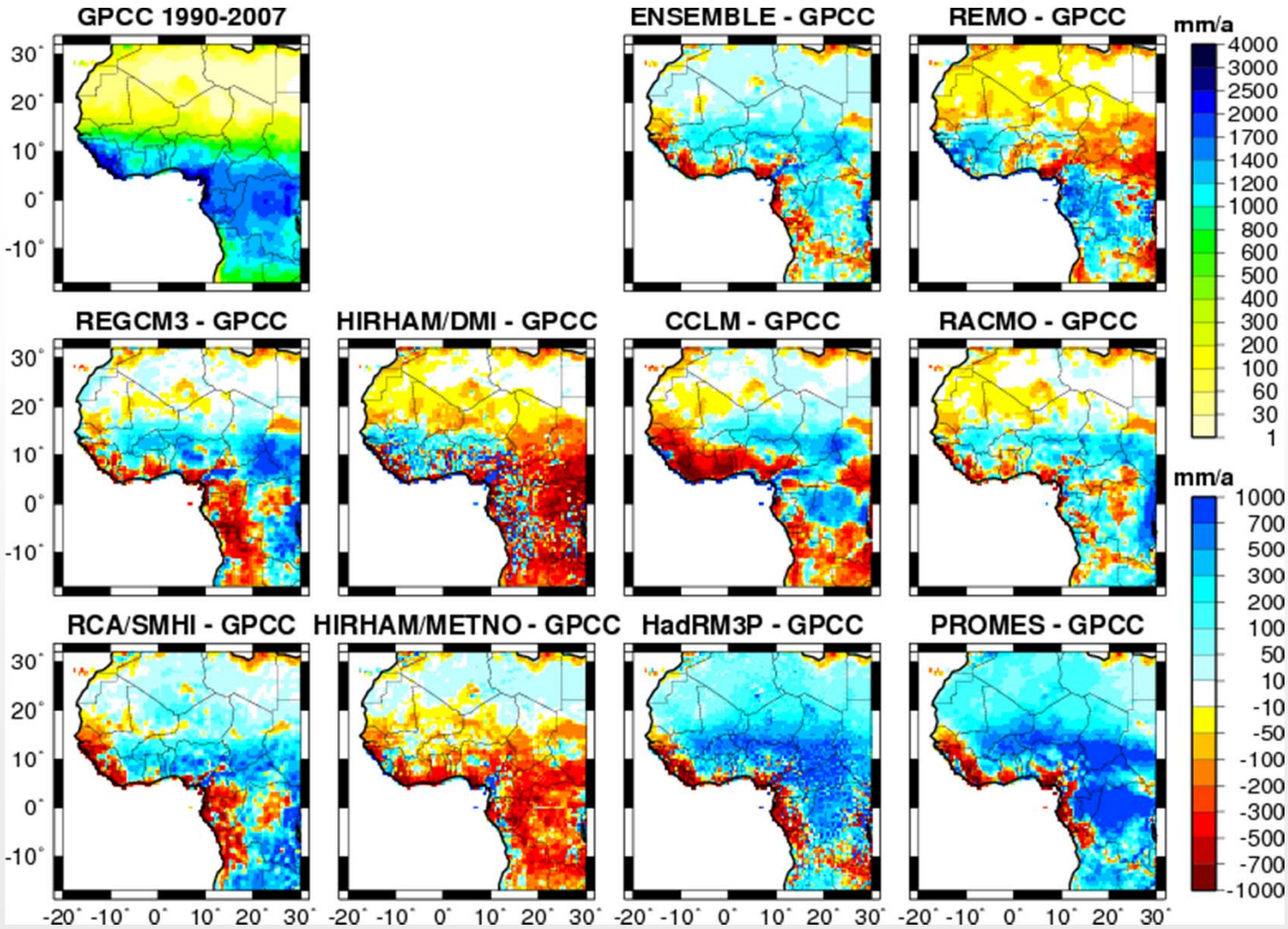
ECHAM5 ensemble



⇒ **ECHAM5 and HadCM3 are consistent with CMIP3 multi-model ensemble mean**

[IPCC 2007]

RCM uncertainty – 20th century



annual precipitation 1990-2007

[Paeth et al. 2011]

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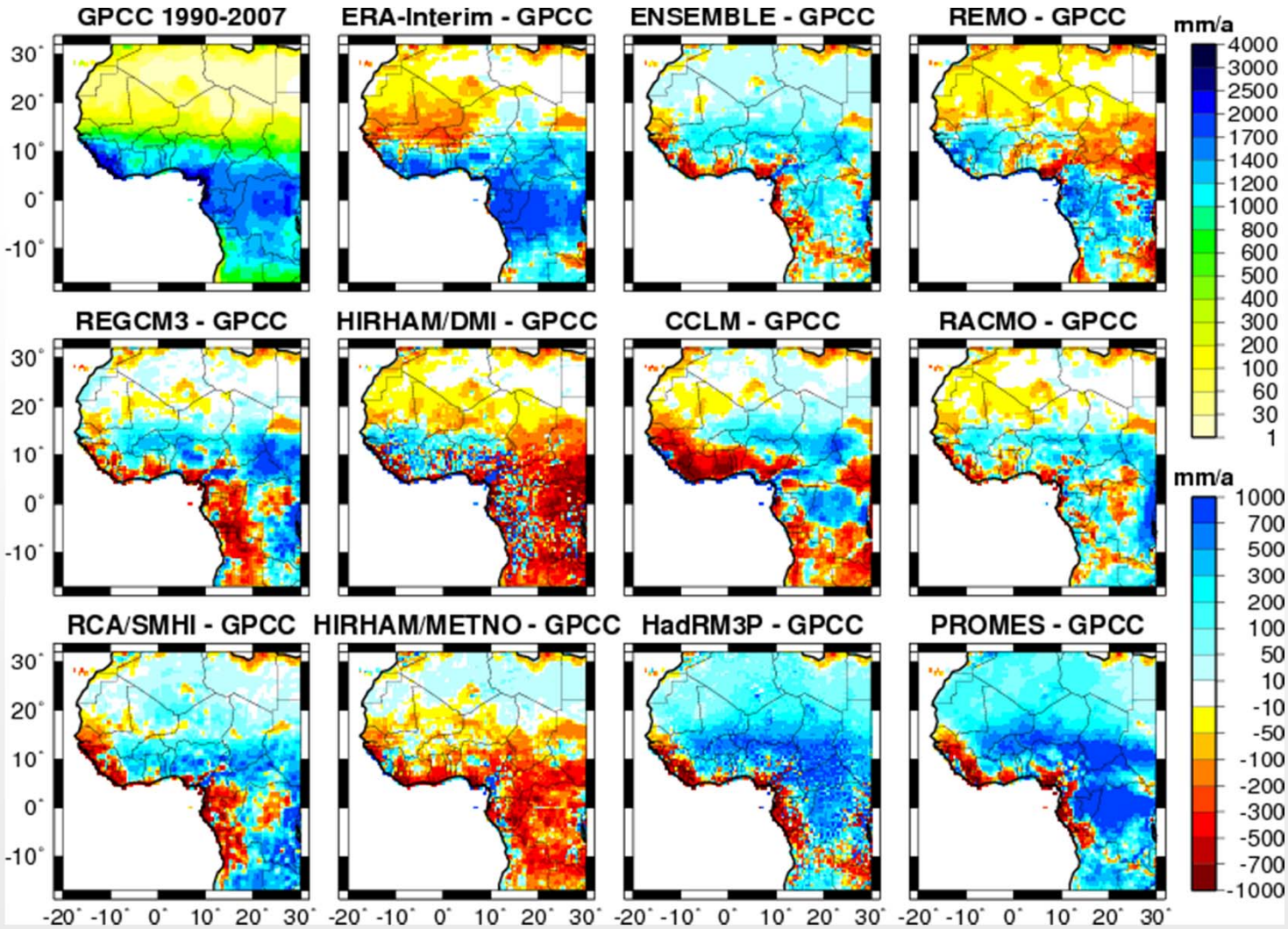
RCM uncertainty – 20th century



annual precipitation 1990-2007

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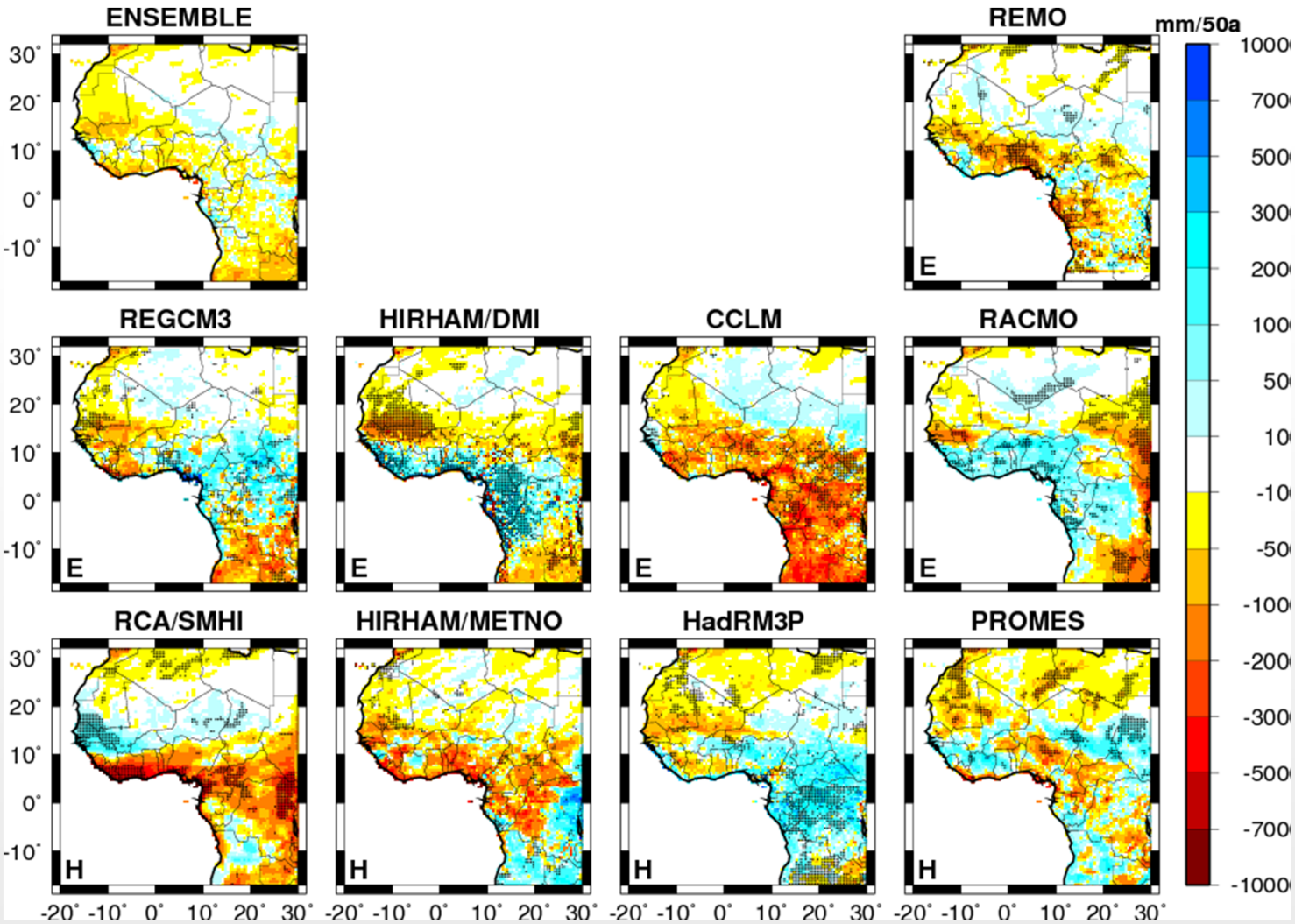
RCM uncertainty – future trends



annual precipitation trend 2001-2050 (5%)

[Paeth et al. 2011]

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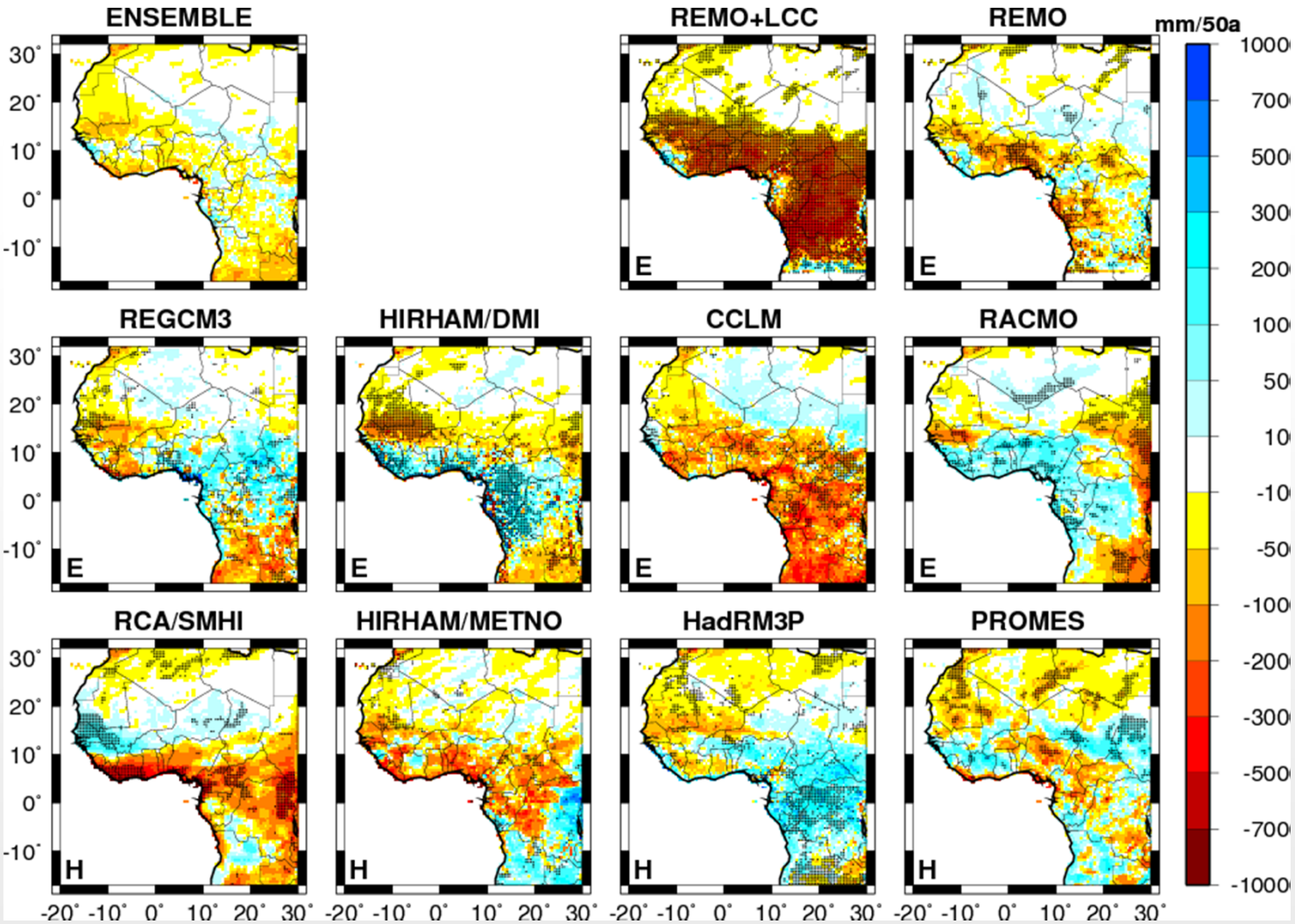
RCM uncertainty – future trends



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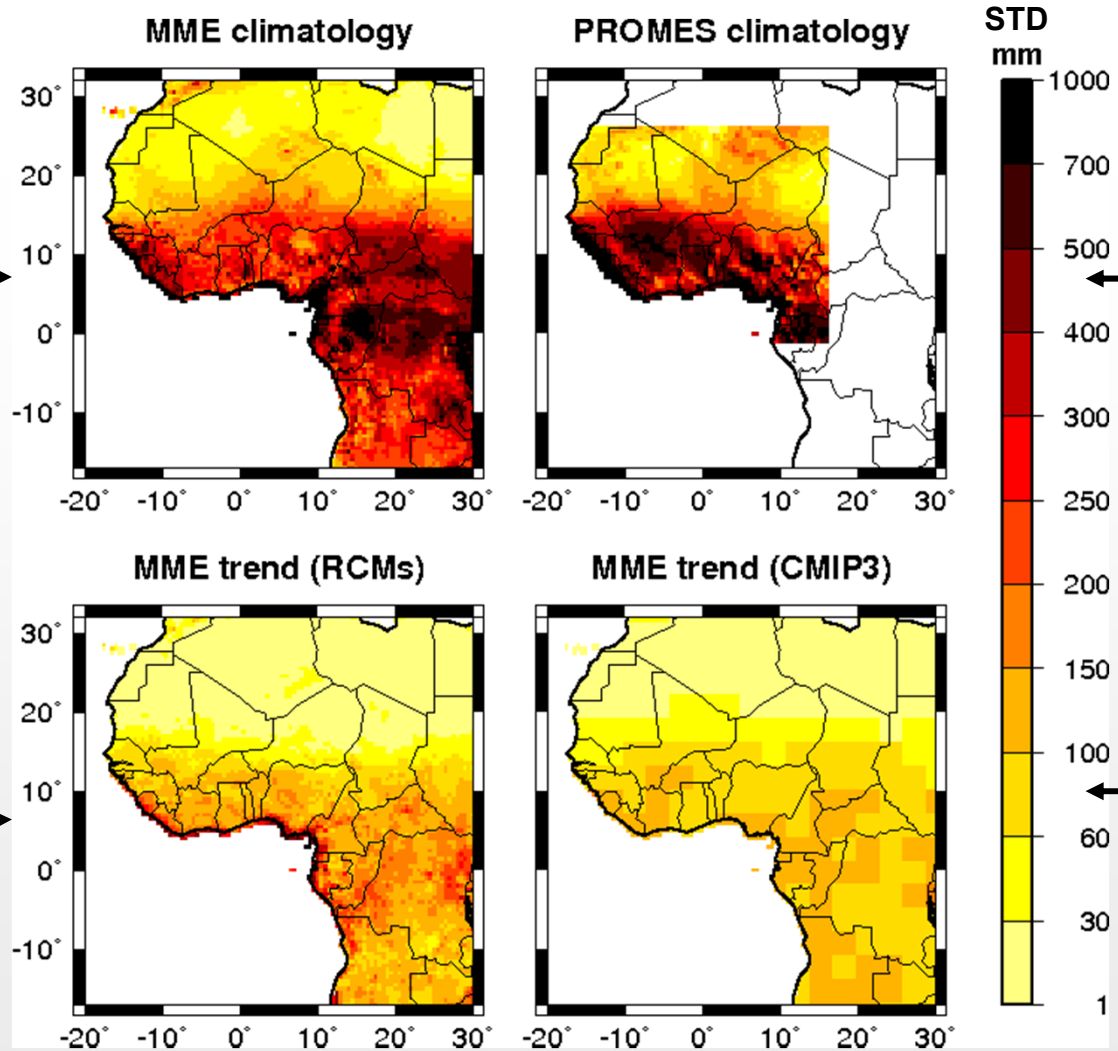
RCM uncertainty – quantatively



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**

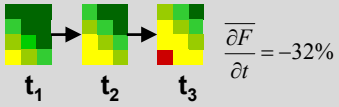
demographic estimates from UN + deforestation from FAO at continental scale

→

tropical Africa: demography: +2,7%/a forest: -32% until 2050

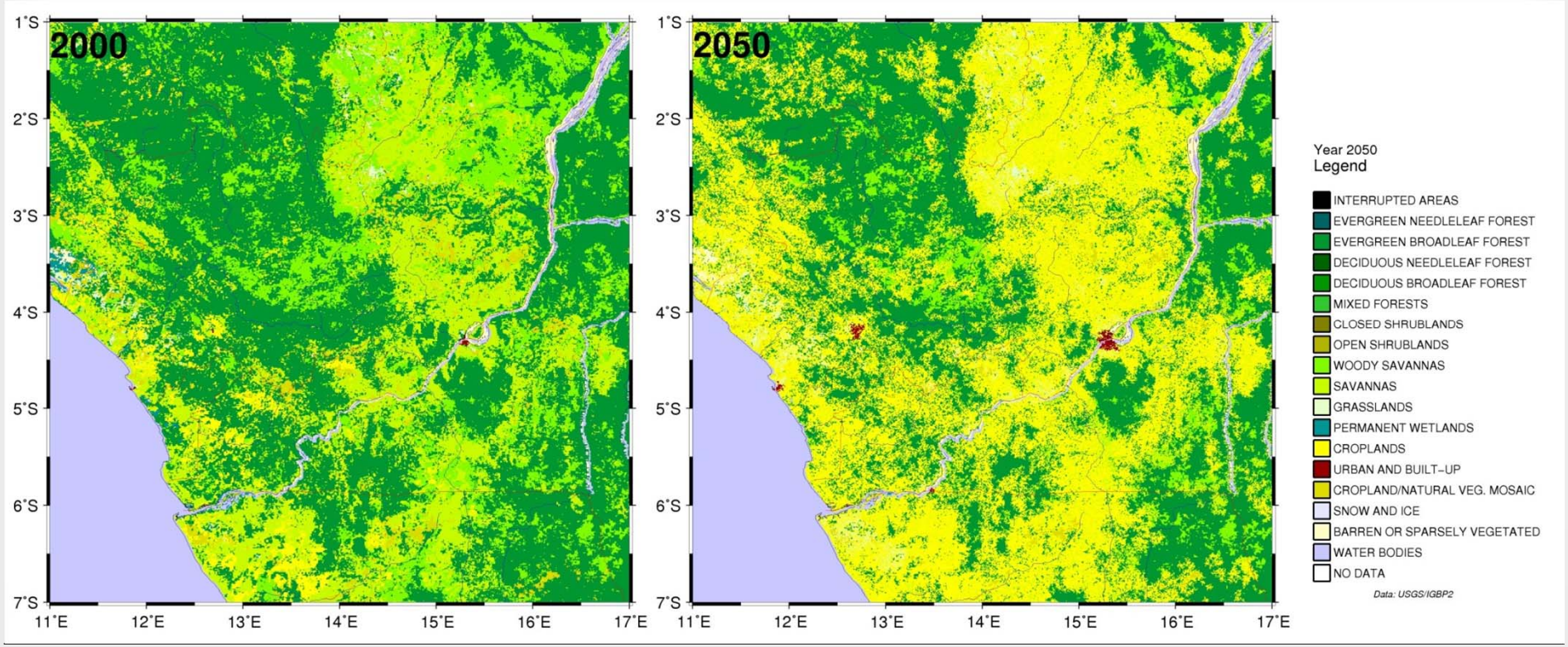
→

stochastic model (USGS 1km x 1km):



→

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



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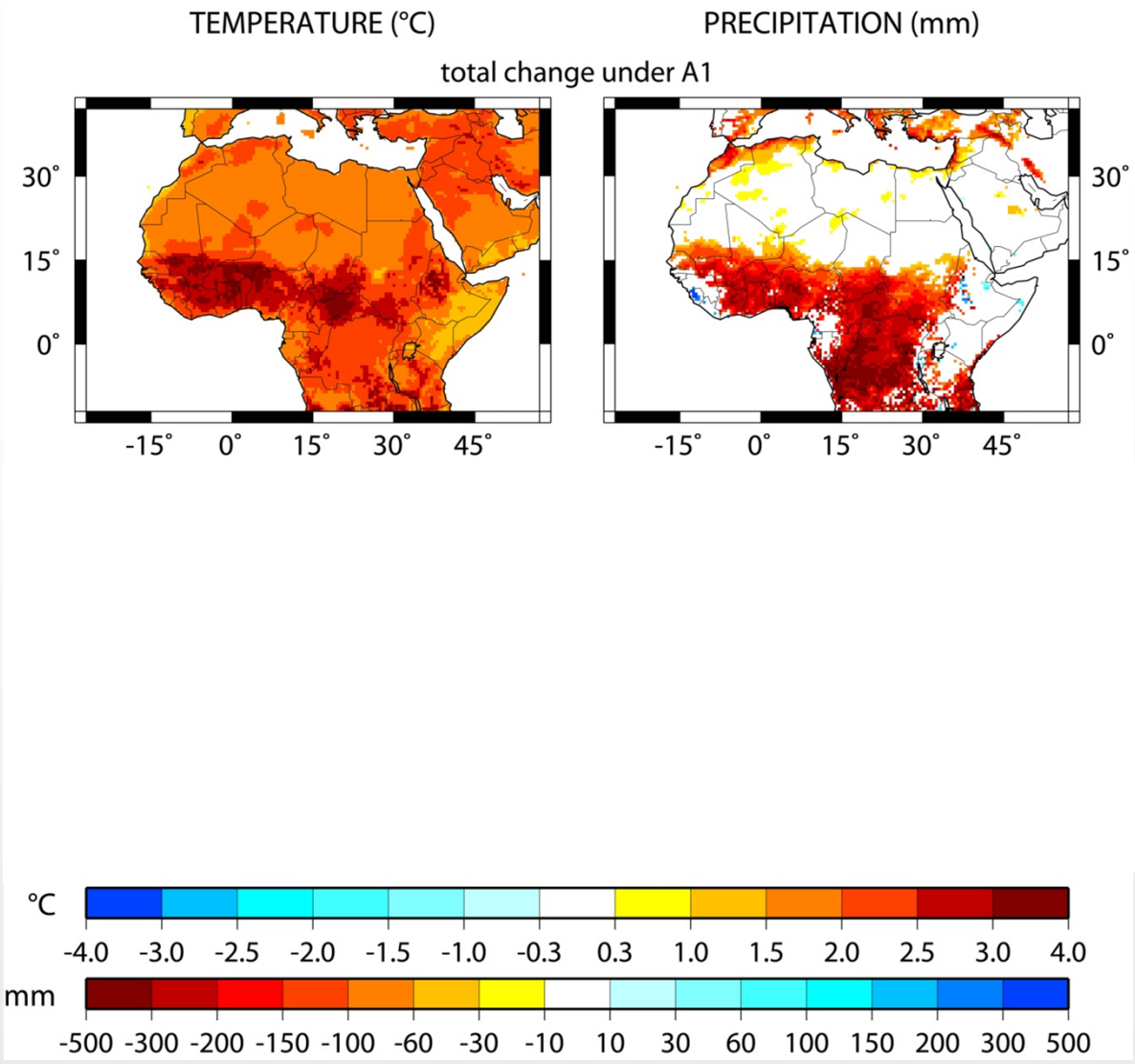
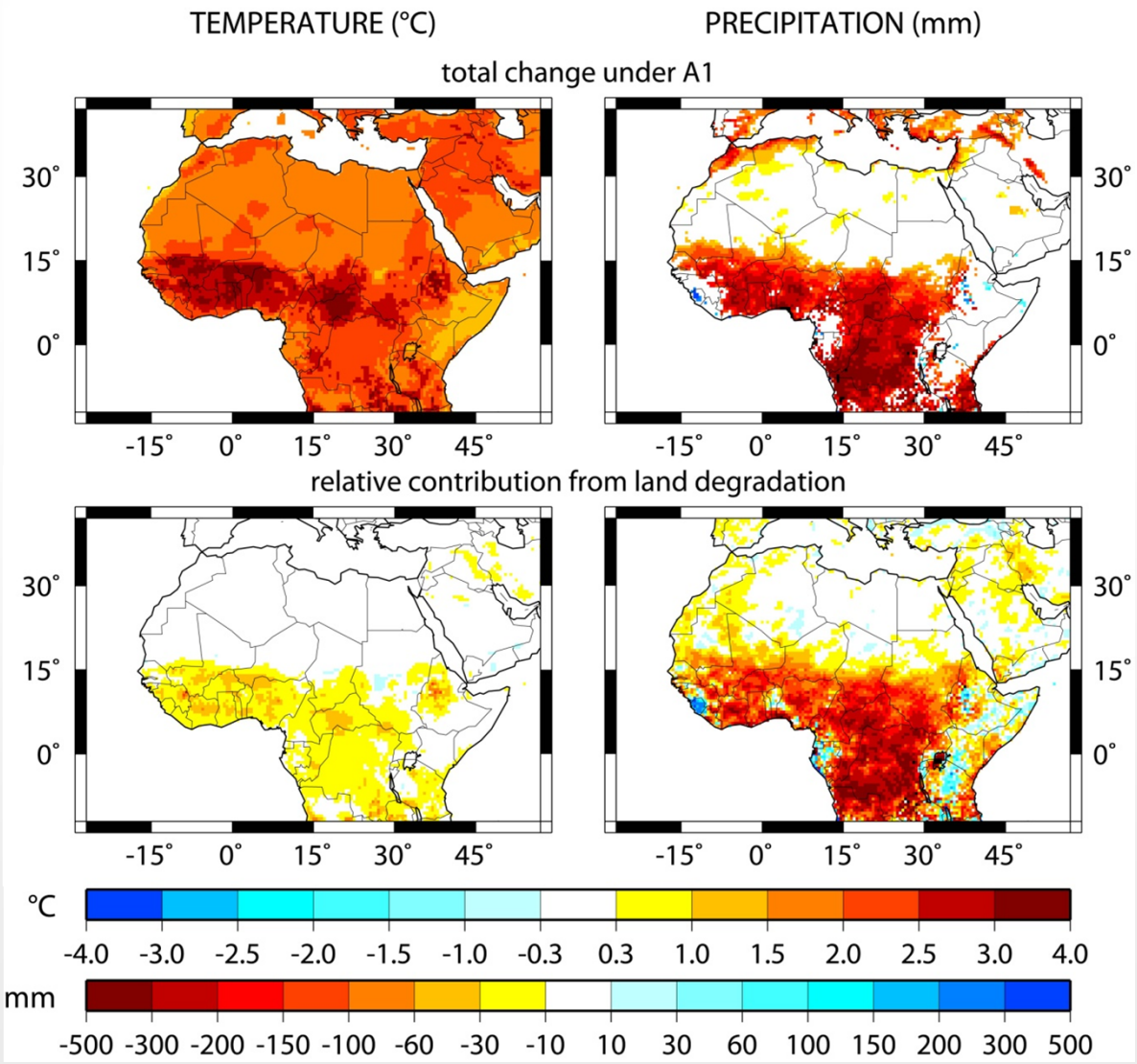
RCM uncertainty – forcing scenario



⇒ prominent warming and drying in sub-Saharan Africa

RCM uncertainty – forcing scenario



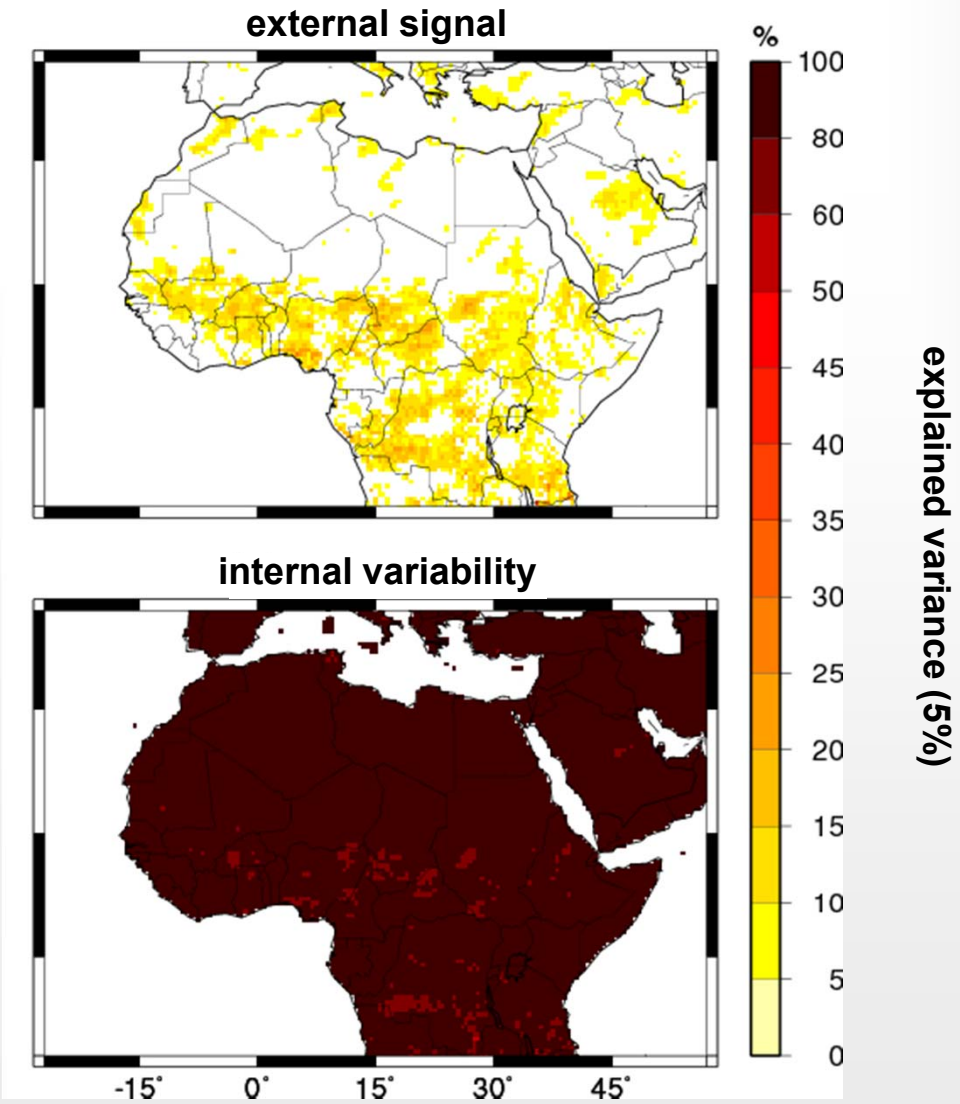
⇒ prominent warming and drying in sub-Saharan Africa

⇒ land degradation is primarily responsible for the drying

RCM uncertainty – temporal noise

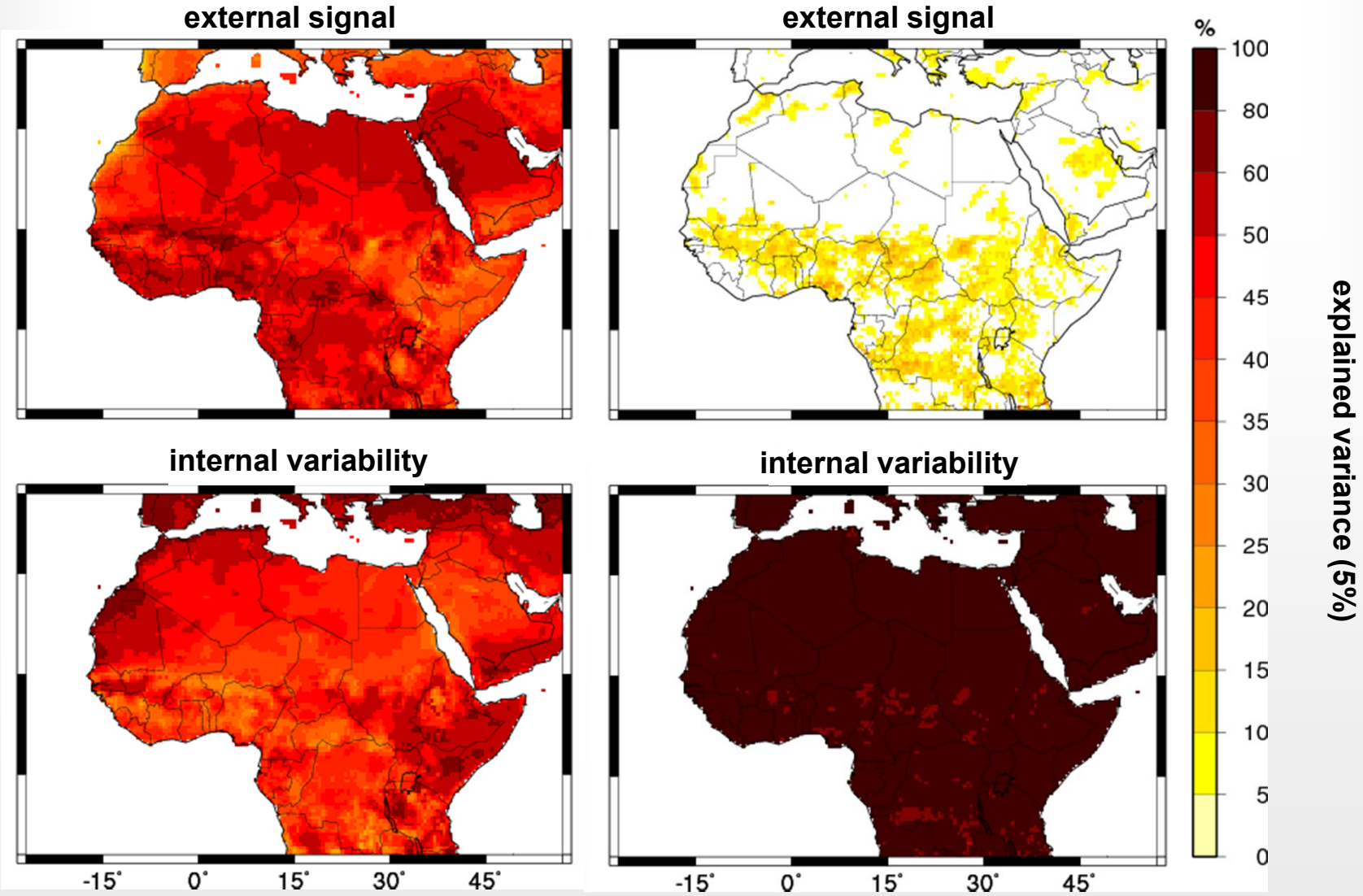
3-member ensemble from REMO (A1B: GHG+LCC):

annual precipitation variability 2001-2050



[Paeth et al. 2009]

RCM uncertainty – temporal noise



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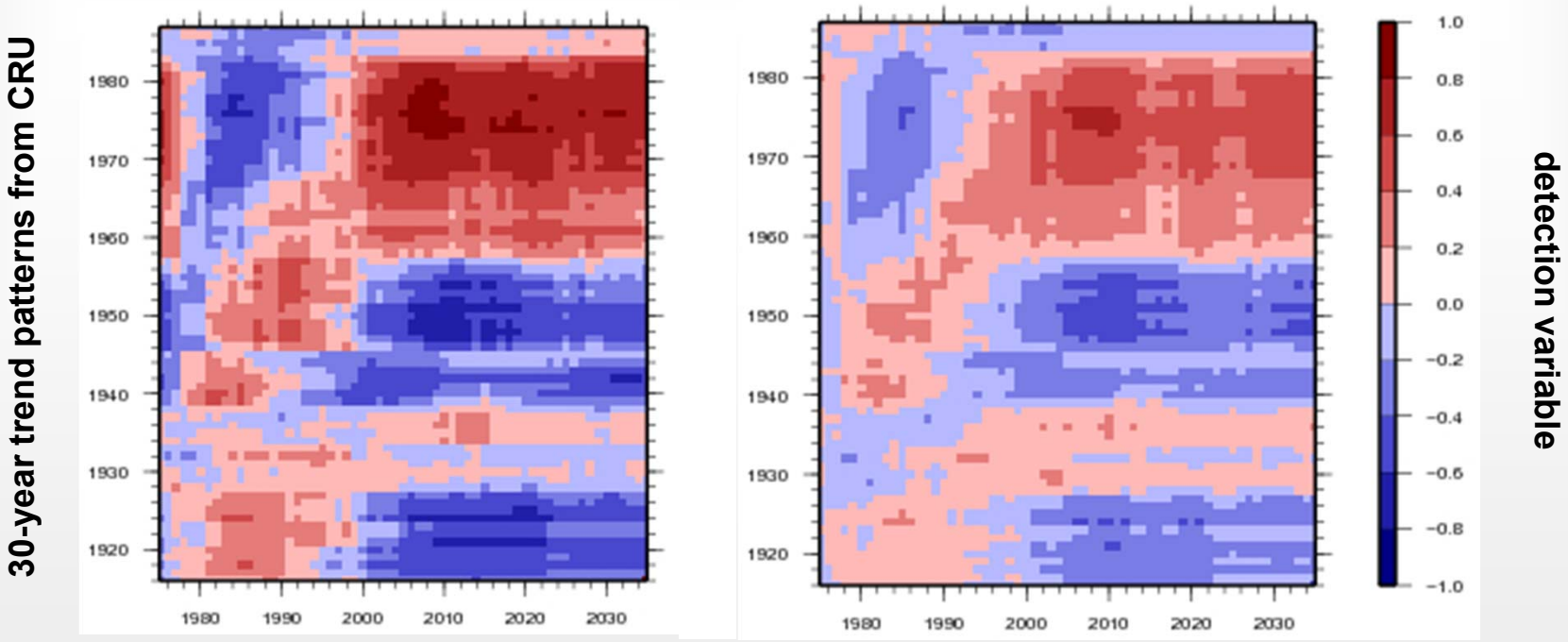
RCM uncertainty – spatial noise

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 REMO

[Paeth and Mannig 2011]

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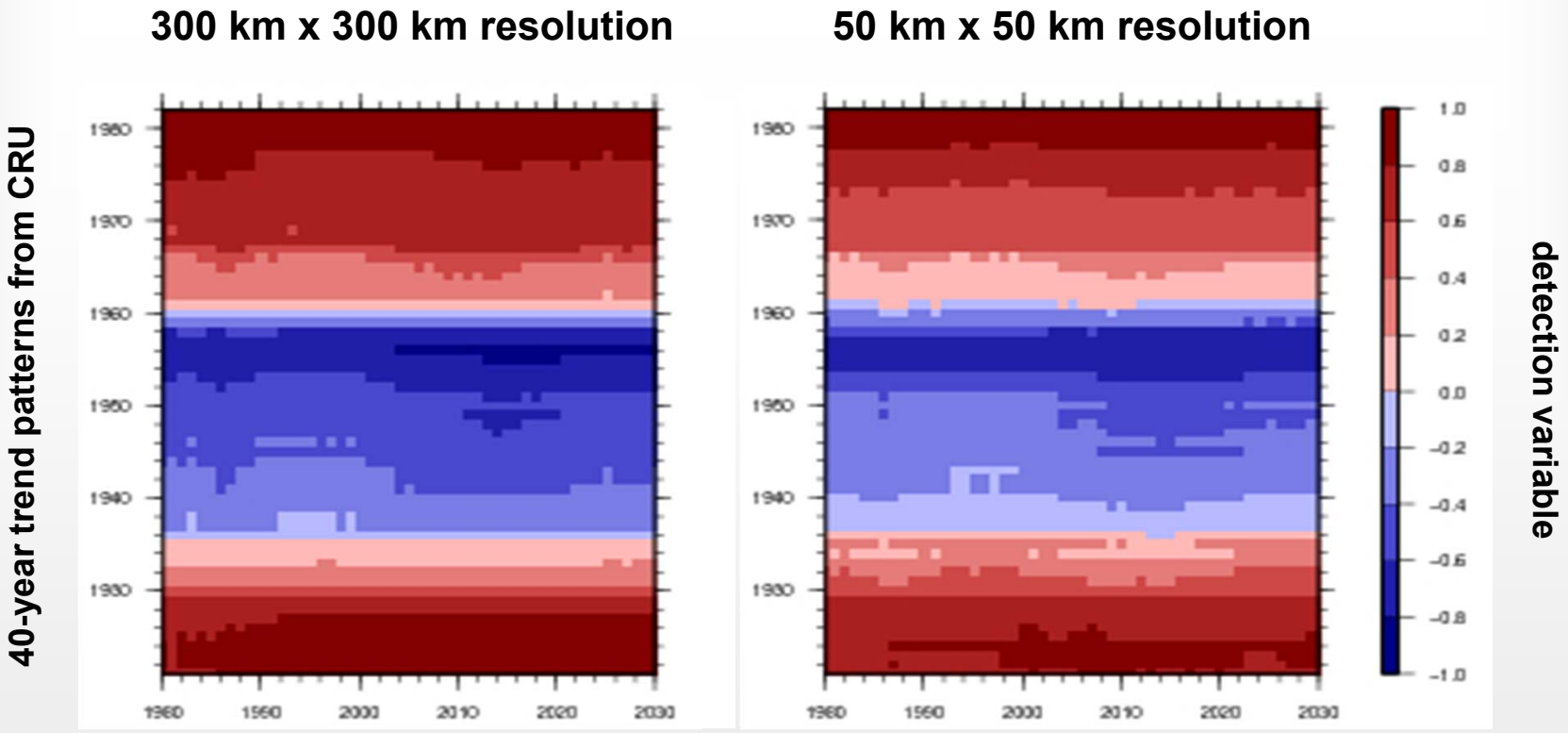
RCM uncertainty – spatial noise

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



[Paeth and Mannig 2011]

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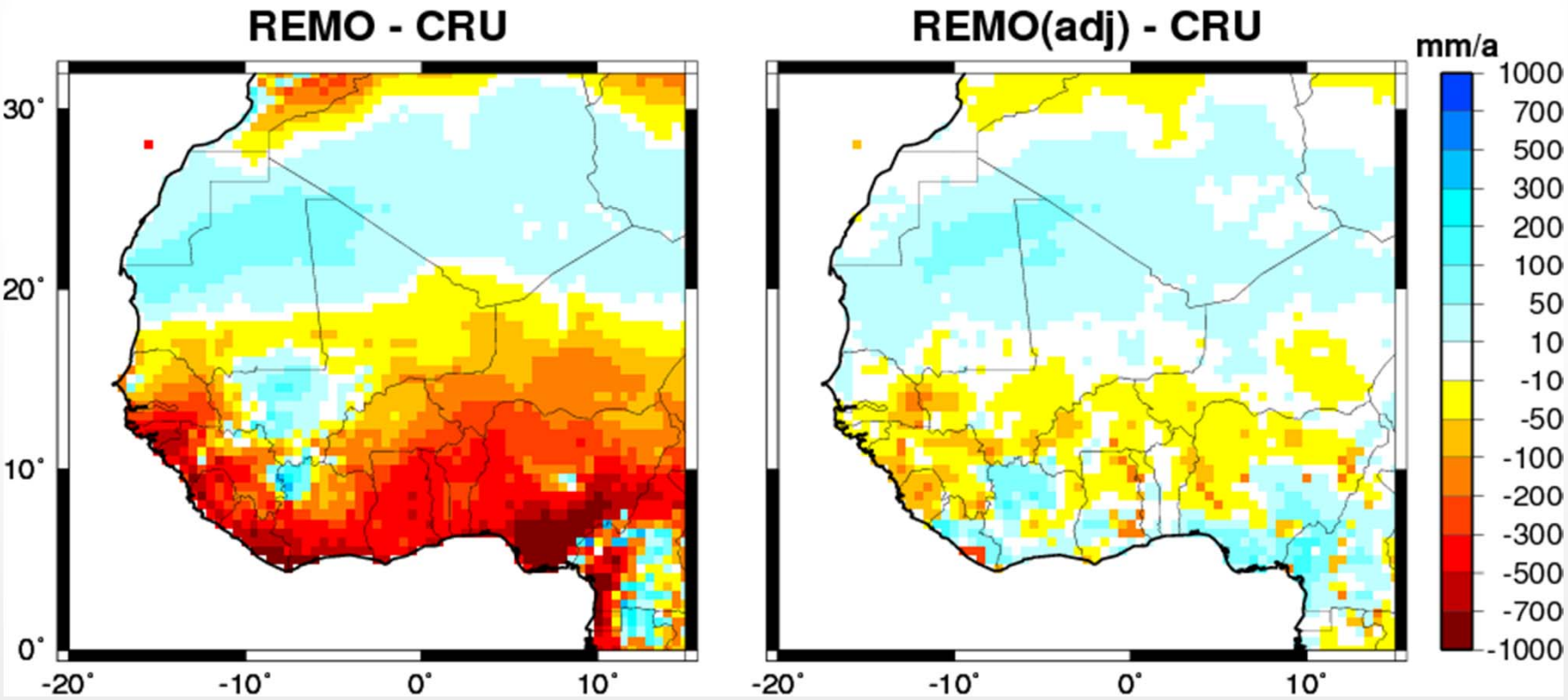
Bias correction by MOS



1979-2002 rainfall climatology

[Paeth 2010, Paeth et al. 2011]

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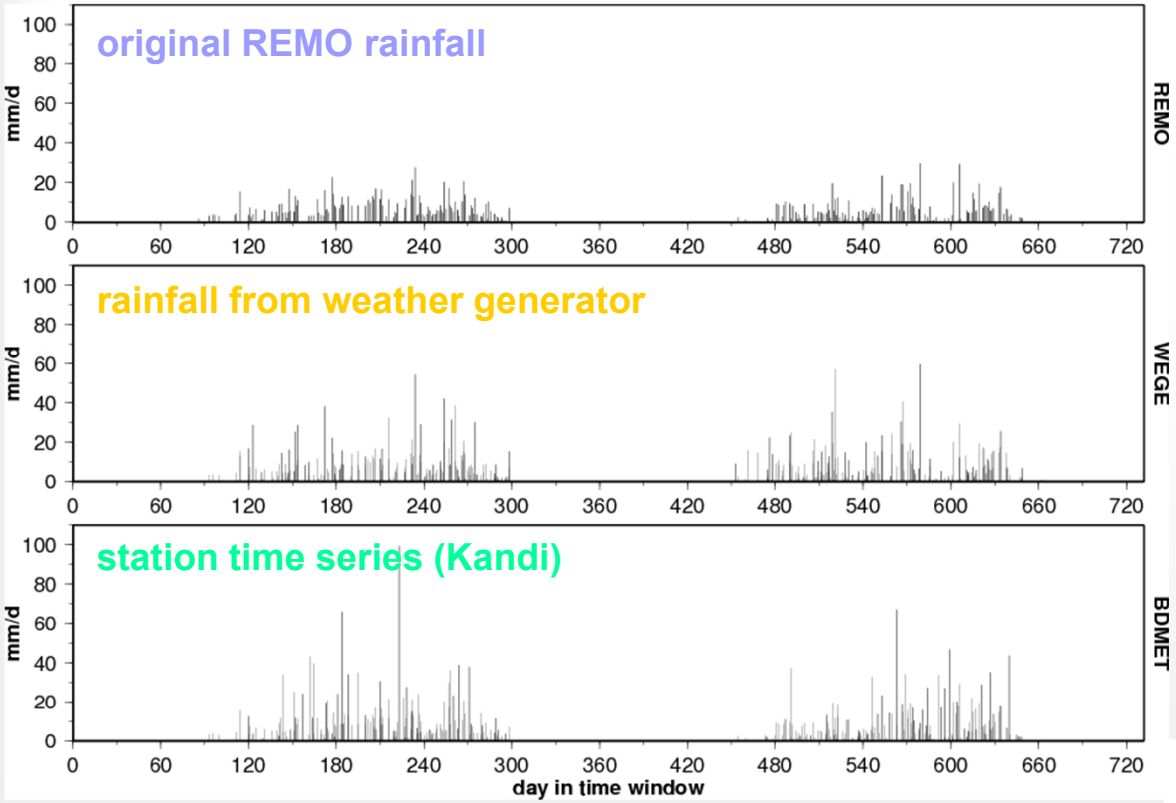
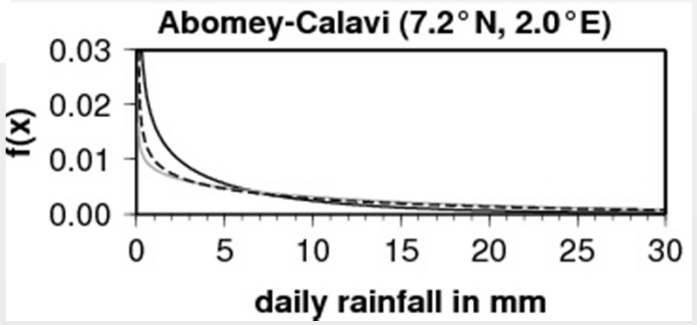
Bias correction by weather generator



- **REMO rainfall:**
  - correct seasonal cycle
  - underestimated extremes
  - hardly any dry spells
- **Weather Generator:**
  - statistical distribution as observed
  - individual events not in phase with observations



RCM data
station data
RCM data postprocessed

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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.**

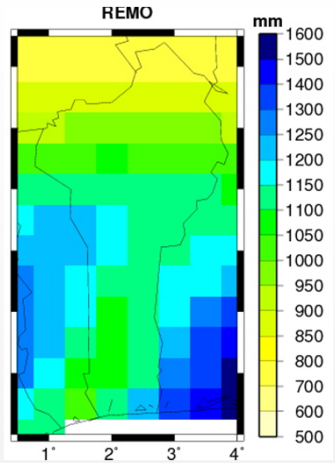
- **Internal spatio-temporal variability in RCMs is high – but allows for statistically significant signal patterns.**

⇒ RCMs provide more detailed fingerprints + spatial noise.

⇒ RCM output is reliable for impact research if bias corrected by statistical postprocessing.

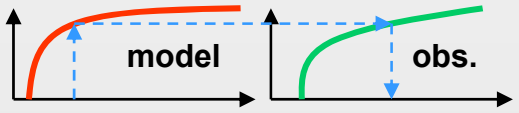
Bias correction by weather generator

simulated grid-box precipitation (dynamical part)



local topography (physical part)

probability matching



virtual station rainfall (result)

random distribution in space (stochastical part)