Reconciling Past and Future Rainfall Trends over East Africa

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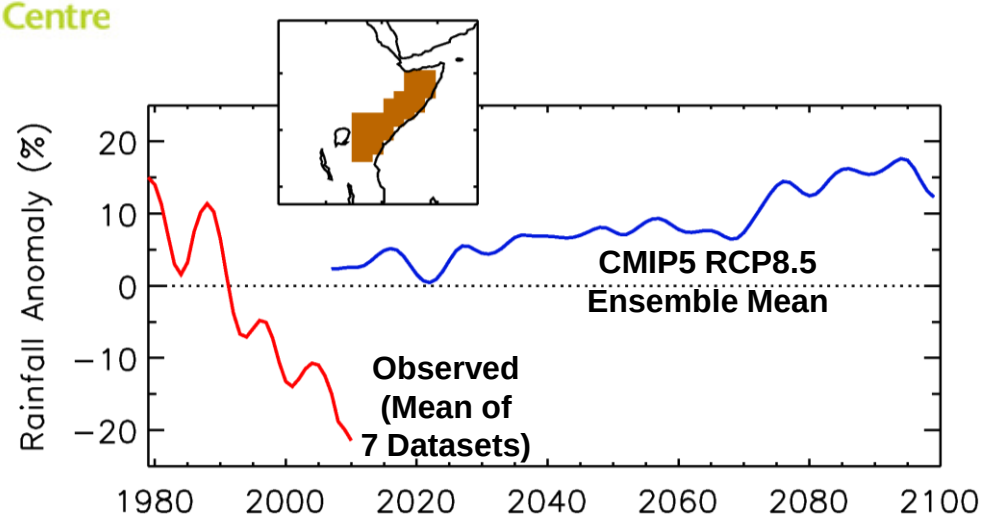
Past and Future Trends: A Contradiction?



Low-pass filtered rainfall (>10yr)
MAM average over
Greater Horn of Africa

Key Questions / Motivation:

- Are the model projections for this region reliable?
- If ‘yes’, when might the drought turn to abundant rainfall (or more flooding)?

Approach:

- List all hypotheses that could explain this contrast between past and future trends
- Briefly investigate the plausibility of each of these hypotheses

Hypotheses to Explain the Contrast Between Past and Future Rainfall Trends

- Past or future trend (or both) result from poor data

  → Hypothesis A:
  Observed trend is due to poor quality data
  (Sufficient evidence to reject this)

  → Hypothesis B:
  Projected trend is due to poor modelling of key processes
  (Large research project, so simple approach is this could result from rejection of all other hypotheses)

- Past or future trend (or both) is/are an artefact of sampling variability

  → Hypothesis C:
  Trend(s) due to natural variability (on interannual or multi-decadal timescales)

- Good physical reasons for a change in the sign of trend

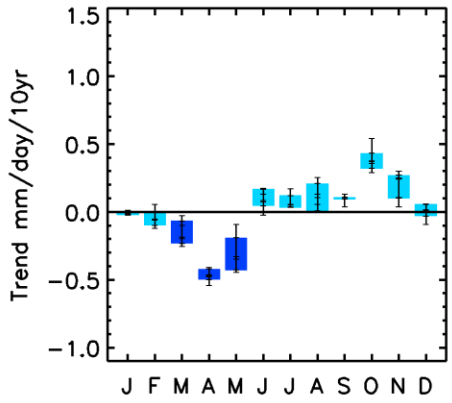
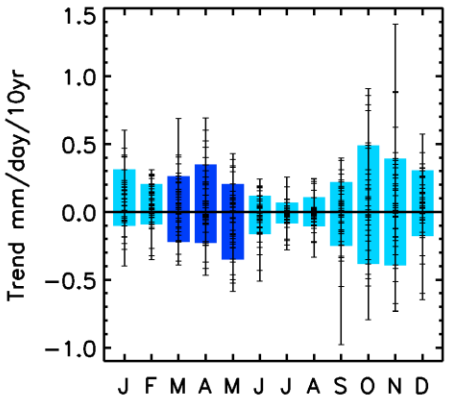
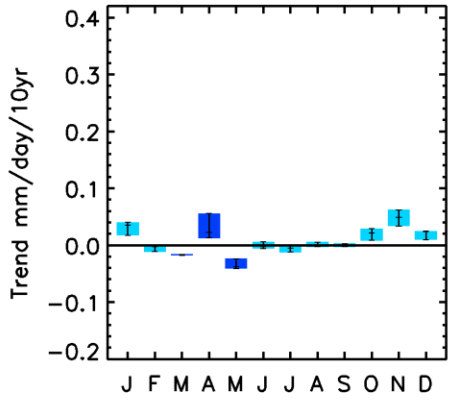
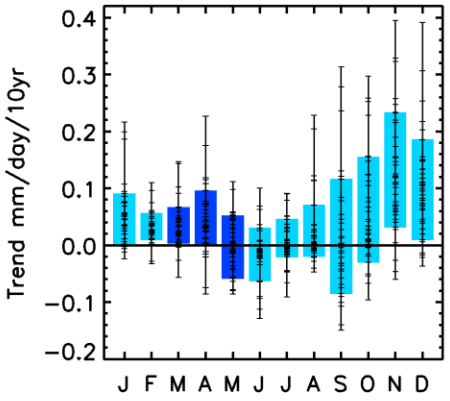
  → Hypotheses D,E:
  Balance between competing forcings is changing, in particular WMGHGs, aerosols (D), and land use (E)

  → Hypothesis F:
  Non-linear mechanistic response to forcing, or changing balance between competing mechanisms

Or a combination of some of the above

Character of Observed and Modelled (Past and Future) Rainfall Trends

Met Office Hadley Centre

	Observed Trends	CMIP5 RCP8.5 Trends
22-Year Trends	1986-2007 	2010-2031 
88-Year Trends	1920-2007 	2010-2097 

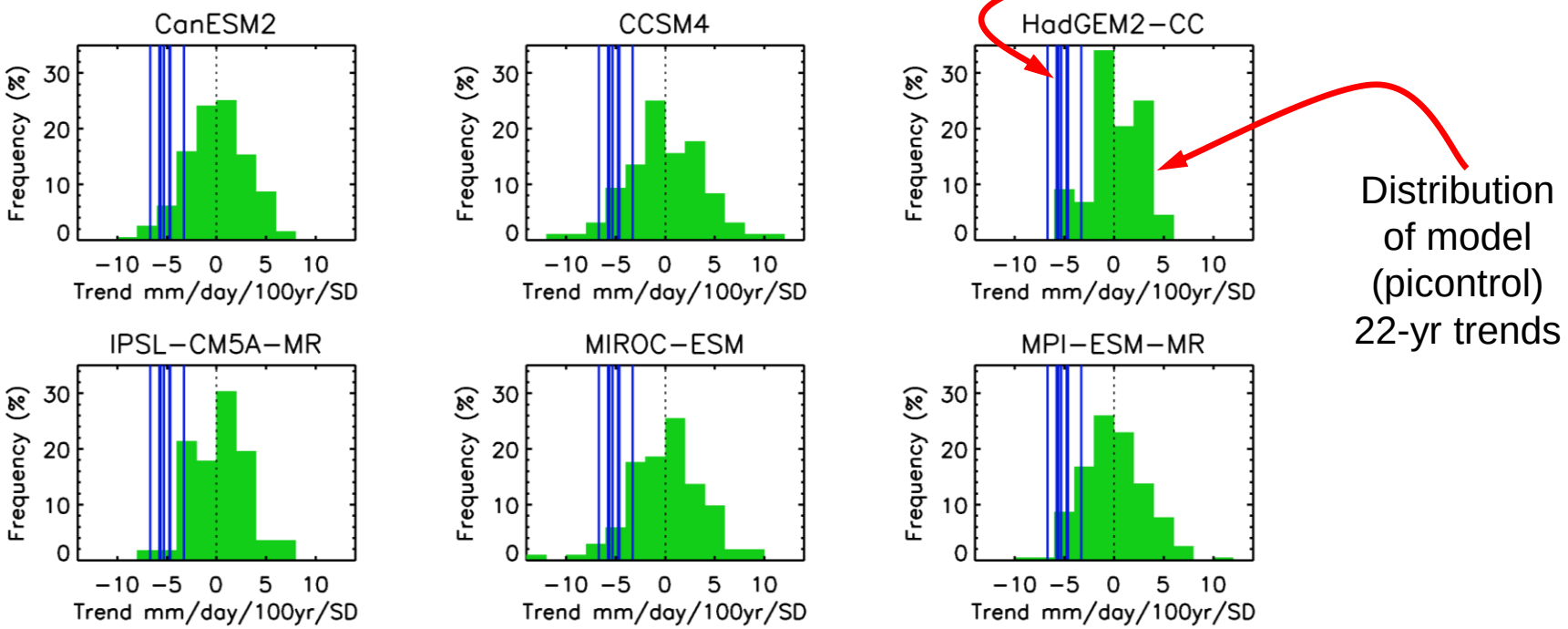
Different timescale of past/future trends implies different mechanisms

Hypothesis C: Role of Natural Variability

Evidence 1: Significance of Observed MAM Trends wrt Model Control Trend Variability

Examples from 6 Models

(all trends scaled by data's variability)

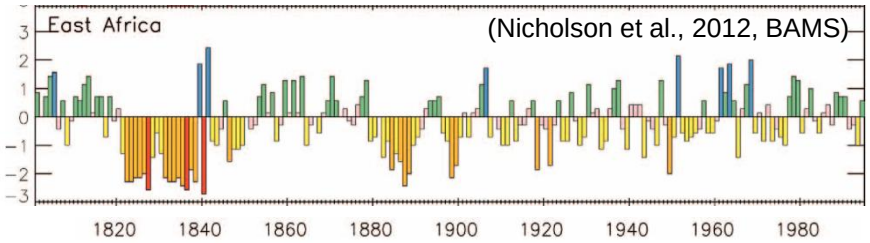


- The recent observed trend is unusual wrt natural variability (except CRU data)
- Statistical significance of the observed trend (at 10% level) is achieved wrt 70-100% of models (39 CMIP5 models) in 6/7 observational datasets

Hypothesis C: Role of Natural Variability

Evidence 2: 19th and 20th Century Precedents for Long Rains Decadal Drought

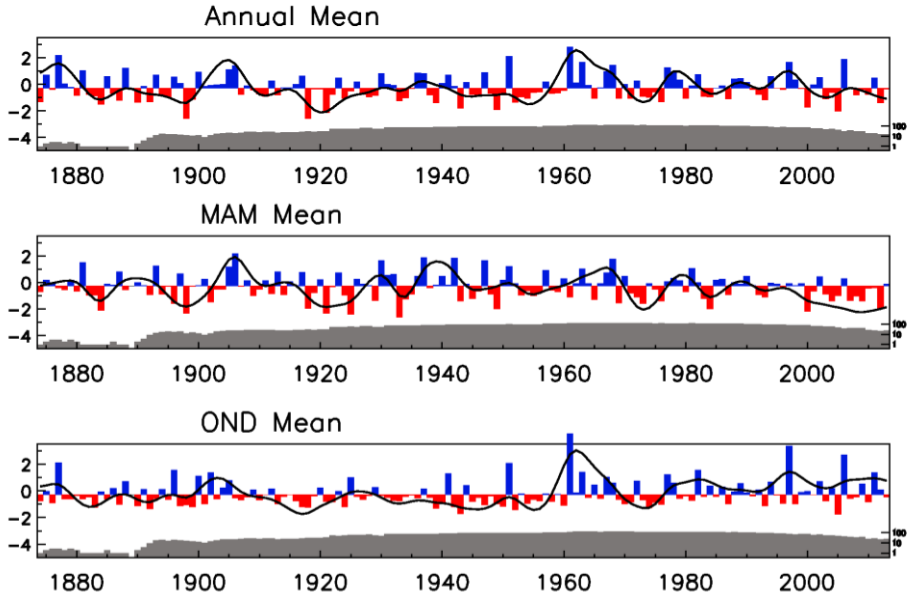
Annual Wetness Index, Based on Lake Levels, Gauge Data, etc.



Key Question:

Are these annual mean decadal droughts due to the Long Rains or Short Rains?

Gauge Data – New Timeseries Reconstruction for East Africa



- 1882-1899 annual mean droughts derive from a mix of Long Rains and Short Rains droughts
- The current Long Rains drought is unprecedented in its persistence and intensity since ~1874
- Further evidence that the current Long Rains drought is either a very unusual natural event, or is due to anthropogenic forcing (CO_2, aerosols, etc.), or a combination of anthropogenic and natural forcing

Hypothesis D: Role of Aerosols

Aerosol Impact on Recent MAM Rainfall Trends

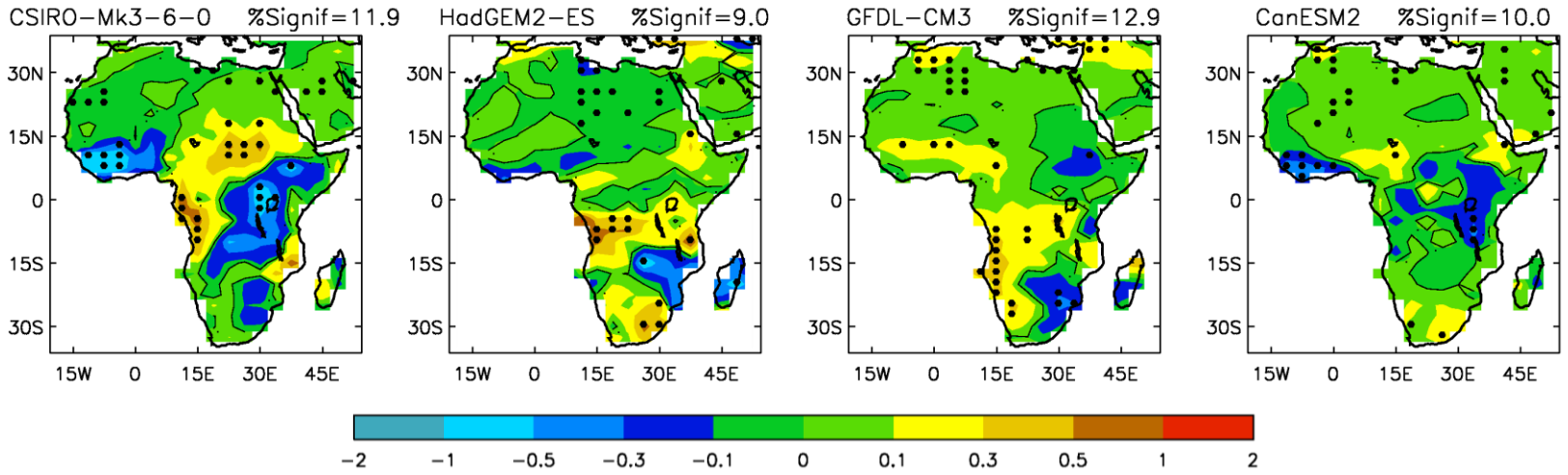
Ensemble Mean 1986-2005 Trends (mm/day/decade)

'Historical' minus 'Historical with Fixed Aerosols'

(Except GFDL: 'Historical Aerosols Only')

Dots show local significance at 10% level

CSIRO-Mk3.6.0 | HadGEM2-ES | GFDL-CM3 | CanESM2



- Impact of aerosols on rainfall trends in this region is probably statistically insignificant
- **But**, we also know:
  - The recent rainfall trend is (at least partly) driven by SSTs (AMIP experiments)
  - Modelled SST-rainfall teleconnections tend to be too weak (Rowell 2013)

Hypothesis D: Role of Aerosols

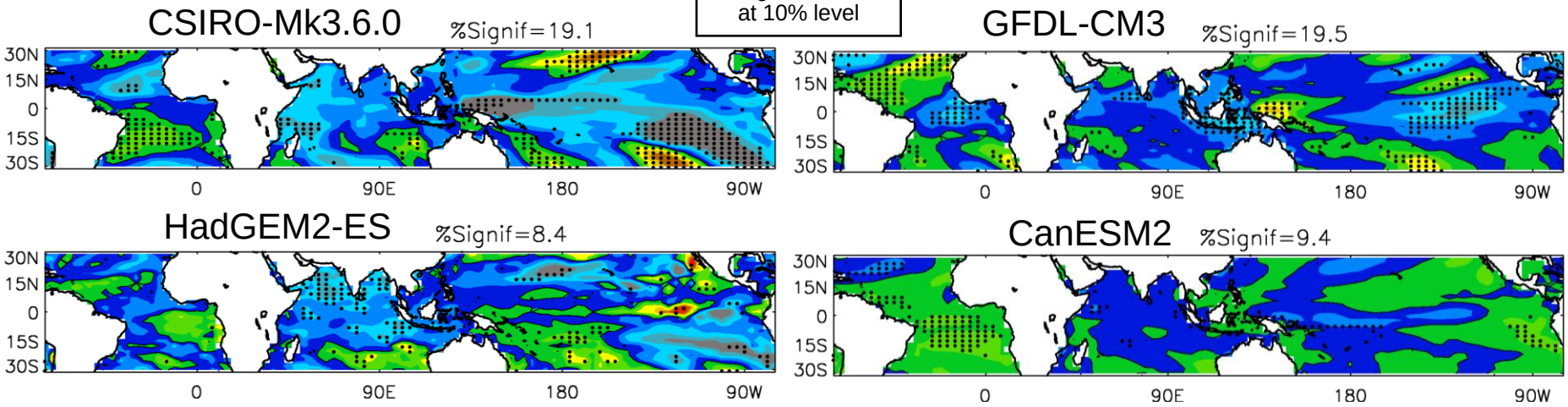
Aerosol Impact on Recent MAM SST Trends

Ensemble Mean 1986-2005 Trends (°C/decade)

'Historical' minus 'Historical with Fixed Aerosols'

(Except GFDL: 'Historical Aerosols Only')

Dots show local significance at 10% level



- Sometimes significant, and uncertain, impact of aerosols on patterns of SST trends
- Aerosol emissions are a potential driver of recent rainfall trends, but modelling needs to be improved

Conclusions and Further Work

Aimed to consider *all* plausible explanations for the contrast between past and future trends

Recent Drying Trend:

- Natural variability may have played a role, but is unlikely to have been the only driver
- Aerosol forcing remains a candidate driver, but modelling of its impact is highly uncertain
- Effects of land-use changes cannot be detected above natural variability
- Non-linearity in the response to CO_2 is < 10% of the contrast between obs and projected trends

Priorities for Further Work to Understand the Recent Drying Trend:

- Improve the modelling of the impact of aerosols on SSTs and SSTs on rainfall
- Improve our understanding of the mechanisms of natural variability over East Africa

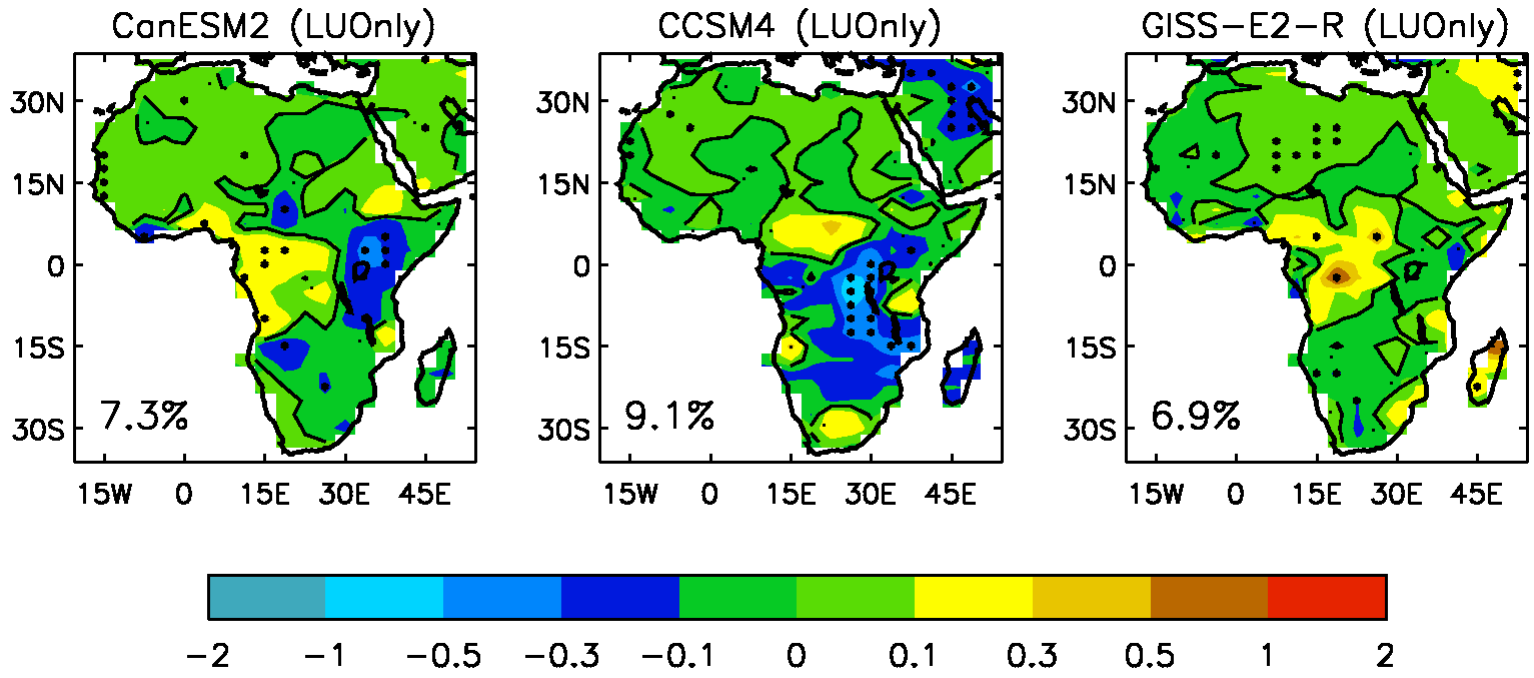
Priorities for Improving Multi-Decadal Predictions of East African Rainfall:

- Properly Assess Hypothesis B – 'Poor Modelling of Future Change':
  Fully understand the models' mechanisms and validate of these against observations

Rowell et al. (2015), *Journal of Climate,* 28, 9768-9788

Spare Slides

Hypothesis E: Role of Changing Land-Use



Hypothesis F: Non-Linear Mechanisms