Hydrological extremes and feedbacks in the changing water cycle

Contribution from UCL Department of Statistical Science

Christian Onof, impersonating Richard Chandler
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UCL role in the project

- To provide statistical tools that will translate climate projections to space and time scales appropriate for hydro(geo)logical applications
  - Working closely with Reading group to ensure that statistical tools incorporate physical understanding / mechanisms
  - Providing nonstationary precipitation and evaporation scenarios for use by Imperial and BGS in hydro(geo)logical catchment and land surface modelling

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Personnel:
- Richard Chandler (principal investigator)
- Chiara Ambrosino (researcher, 2-year post)

Downscaling — background

- Climate models getting better but precipitation can still be problematic (depending who you listen to!)
- Spatial resolution mostly too coarse for many applications
- Expensive to obtain multiple runs for, e.g., uncertainty assessment / accurate estimation of extremes

Statistical downscaling: a way out?

- Identify variables that:
  - are well reproduced by GCMs / RCMs
  - have physically-based relationship with rainfall (laws of physics unlikely to change in altered climate)

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- Simulate from statistical model conditioned on GCM / RCM output, to generate synthetic rainfall data at fine scale

Precipitation downscaling in this project

- Using generalized linear models (GLMs) with GLIMCLIM software (www.homepages.ucl.ac.uk/~ucakarc/work/glimclim.html)
- Tried and tested methodology
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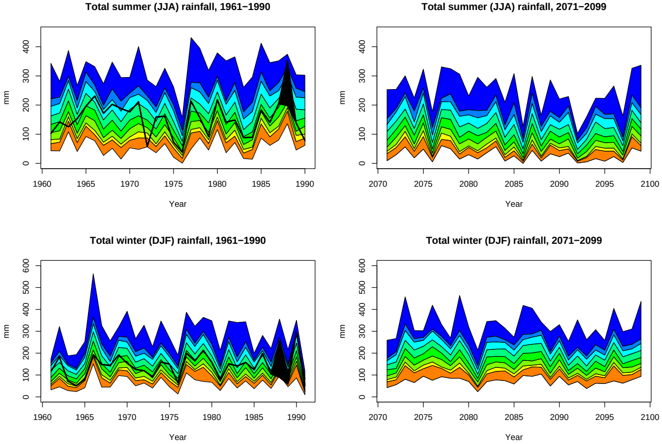
- Provides multisite, nonstationary, non-Gaussian models for daily precipitation time series
- Nonstationarity controlled by dependence on relevant atmospheric drivers
- Can incorporate changing / seasonally-varying relationships — useful if physics suggests driver effects may change in altered climate
- Models are interpretable: drivers linked to means of probability distributions for daily precipitation

Example GLIMCLIM outputs



Distributions of total seasonal rainfall at Heathrow, each from 100 daily GLIMCLIM simulations. Top: JJA, bottom: DJF. Simulations driven by C20 atmospheric sequences (left), HadCM3 outputs 2071–99, A2 scenario (right).

GLIMCLIM: current state

- ☺ Competitive with other advanced downscaling tools with respect to a wide variety of performance measures including extremes, interannual variability, persistence etc.
- ☺ Allows simulation at ungauged locations
- ☺ Allows imputation of missing values conditioned on available observations — hence can quantify uncertainty in historical quantities associated with missing data

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- ☺ Allows imputation of missing values conditioned on available observations — hence can quantify uncertainty in historical quantities associated with missing data
- ☹ Tends to underestimate extreme summer precipitation event intensities
- ☹ Limited options for representing inter-site dependence in precipitation occurrence — designed for catchments up to $\sim$ 2000km^2 but probably inappropriate at larger scales

Precipitation downscaling: deliverables

- Improvements to GLIMCLIM:
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- Produce calibrated and validated models for case study catchments incorporating physical mechanisms identified by Reading team
- Use models to generate multiple spatially consistent 1km^2 gridded precipitation / evaporation scenarios for case study catchments, for input into WP2 and WP3.

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- Proposal: use statistical downscaling to provide calibrated PE generators as well
- Build on previous experience at UCL and Imperial
- GLM approach here as well (but not GLIMCLIM): generate distributions conditional on large-scale atmospheric structure, then sample required sequences
- Need to ensure mutual consistency between generated PE and precipitation sequences (although previous work suggests dependence is typically weak)

Climate simulator uncertainty

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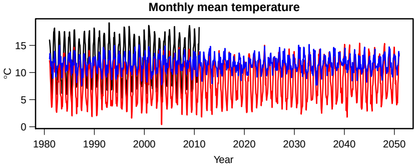
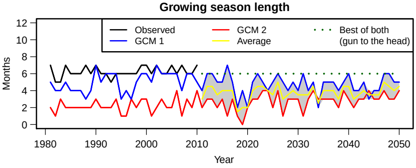
- Choice of climate simulator (i.e. G/RCM etc.) represents significant source of uncertainty in impacts studies
- Prudent management strategies should use information from multiple simulators to acknowledge uncertainty
- Problem: how to combine information to produce something that is relevant to users?
  - Large body of literature on this, but arguably little that is ‘decision-relevant’
  - Useful to have probabilistic projections that recognise limitations of simulators
  - **NB** simple techniques (e.g. weighting different simulators) cannot address all issues

Illustration: why weighting simulators is silly

- Toy example: two GCMs
- Application: length of growing season (monthly temp $\geq 12^\circ$C)

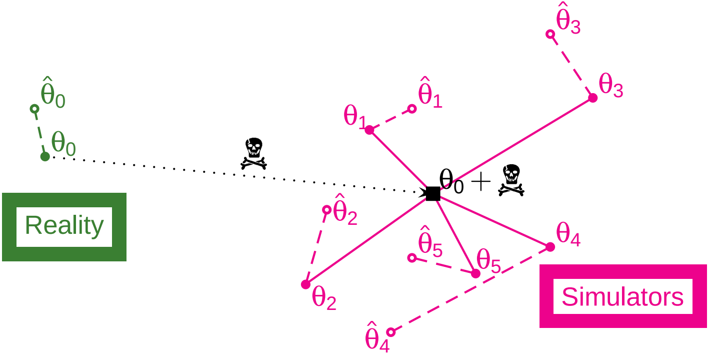




- GCM 1: reasonable mean temp, hopeless seasonality
- GCM 2: vice versa
- Both underestimate growing season length $\Rightarrow$ simulator weighting always underestimates

Approach to simulator uncertainty in this project

- Based on formal representation of how simulators relate to reality:



- Simulators not centred on reality (θ_0) but on reality + ☠
- Aim is to use all available data to learn about reality

Features of uncertainty framework

- Works by using all available information to calibrate a statistical emulator of (relevant aspects of) reality
- Transparent, coherent & logically consistent — assumptions are clear so everybody understands perfectly why they disagree (cf heuristic weighting schemes)
- Automatically compensates for all relevant discrepancies between simulator outputs and reality — ‘reward strengths, discount weaknessess’

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- Automatically compensates for all relevant discrepancies between simulator outputs and reality — 'reward strengths, discount weaknessess'
- 'Poor man's version' developed by cutting some statistical corners — little lost in practice, provides easy and almost instantaneous emulator calibration
- Multiple downscaled precipitation / evaporation scenarios will incorporate uncertainty as represented in this framework

Software

- Software environments used at UCL (both open source and free):
  - R: www.R-project.org
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... and by the way, it's Chiara's birthday today ...