ECOHCC09

Estimating future water resources using probabilistic climate scenarios and weather generators

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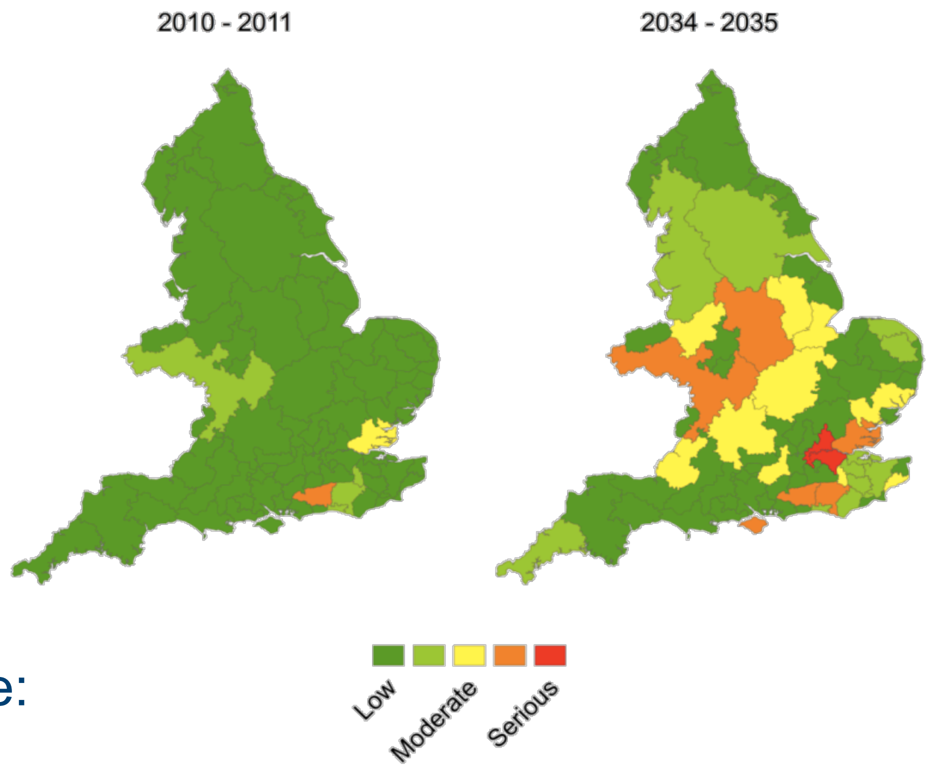
School of Civil Engineering and Geosciences

Motivation

Threat to London water resources

- Thames basin has one of the smallest per capita water resources in the world
- 8 million customers
- Rainfall 700 mm/a
- Evaporation 510 mm/a
- Total abstractions 4500 Ml/day
- 55% of effective rainfall committed
- Projected to become worse in future:
  - Lower rainfall
  - Higher demand
  - Higher evaporation



Anticipated per capita water stress

Overview

1. Probabilistic climate scenarios
2. The Weather Generator
3. London water resource
4. Other applications

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Variability in GCM projections

Projected mean summer precipitation change to 2080s

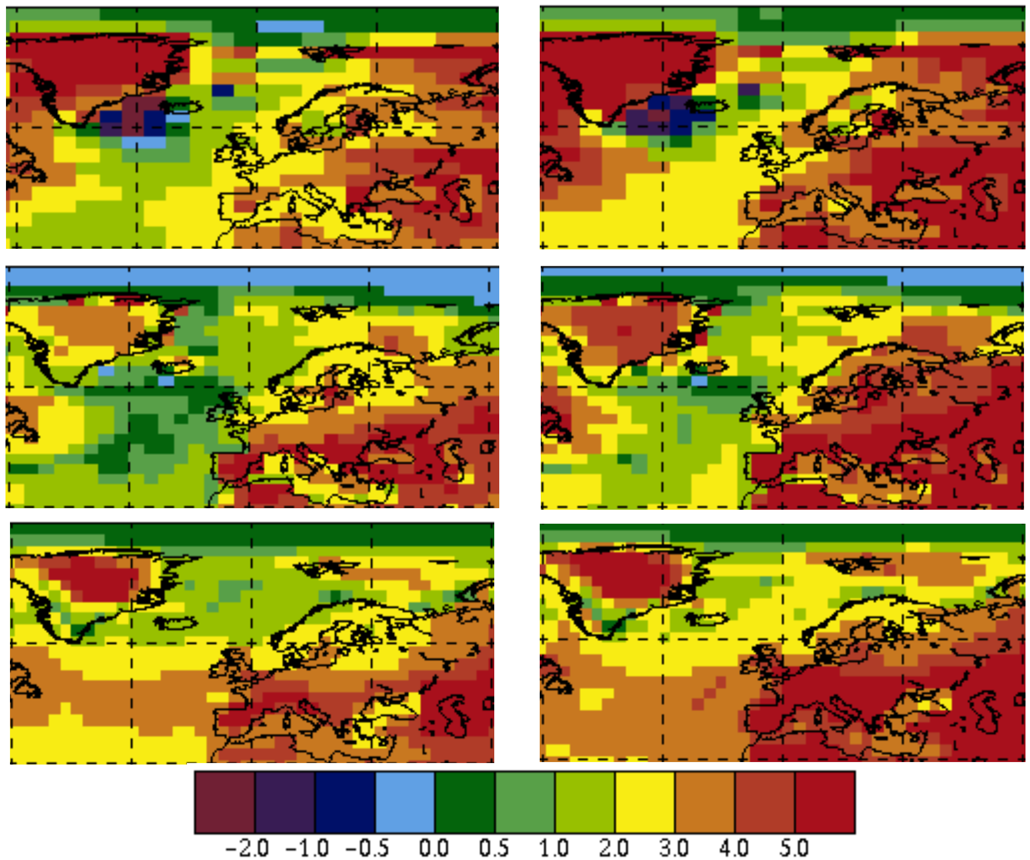
Emissions scenarios: B2 A2

Model:

CSIRO

HadCM3

ECHAM4



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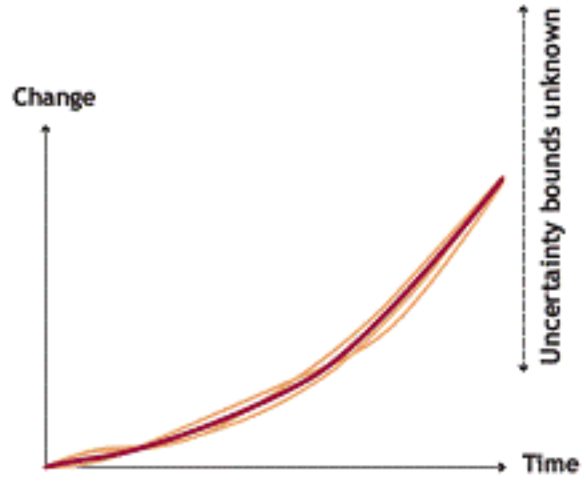
Climate model ensembles

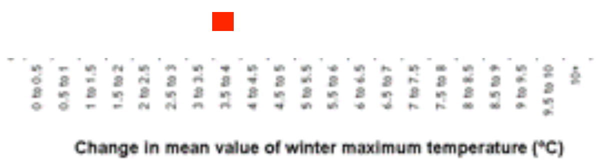
- Ensembles are sets of different climate model runs for same emissions scenario and time slice.
- The range of outputs accounts for uncertainties and errors in the models
- Two types of ensemble: :
  - Hyper – ensemble : different models e.g. HadCM3, Arpege, ECHAM as in PRUDENCE and ENSEMBLES project outputs
  - Perturbed physics ensemble : the same model with different parameters, e.g. climateprediction.net and UKCP09

Probabilistic scenarios

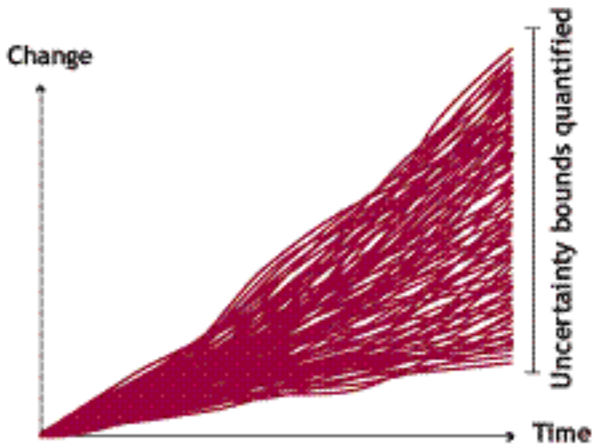
Single model



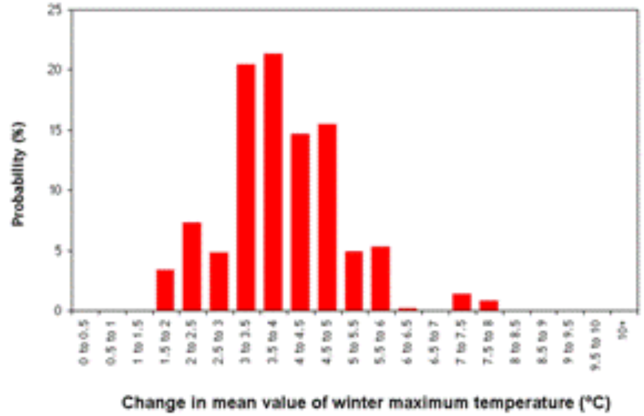
Point estimate



Many models



Distribution



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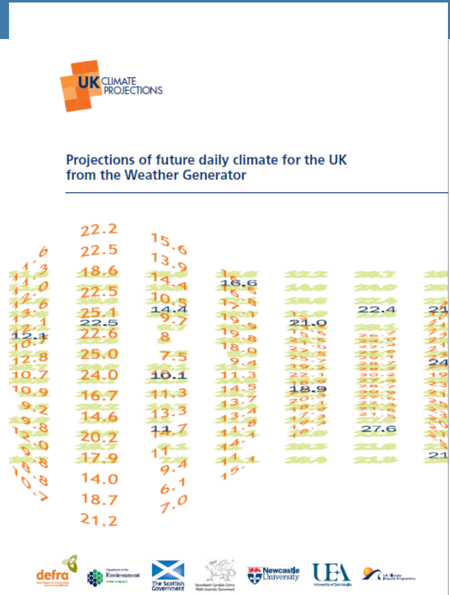
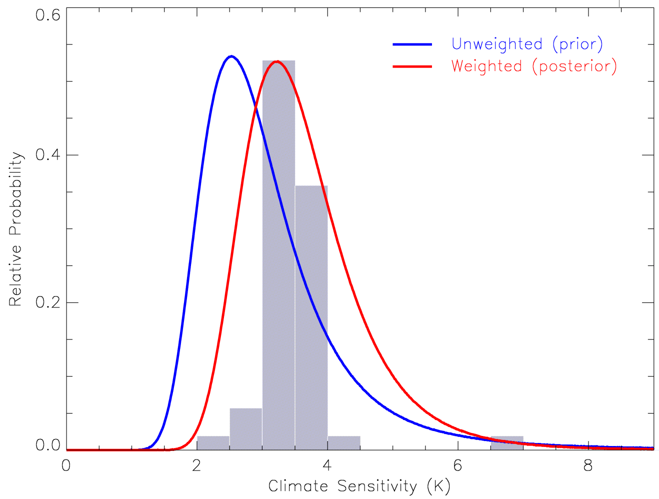
UK CLIMATE PROJECTIONS

- Met Office - Hadley Centre have run a large *Perturbed Physics Ensemble* (PPE) of climate models (GCMS) accounting for uncertainty in parameters. This ensemble is augmented with a range of other GCMs
- These large scale results are downscaled using RCMS to 25km resolution : the outputs are probability distributions (PDs)
- A statistical emulator is used to generate 10,000 vectors of change factors (for multiple variables) for each scenario
- RCM time series not available for full range of scenarios: therefore weather generator used





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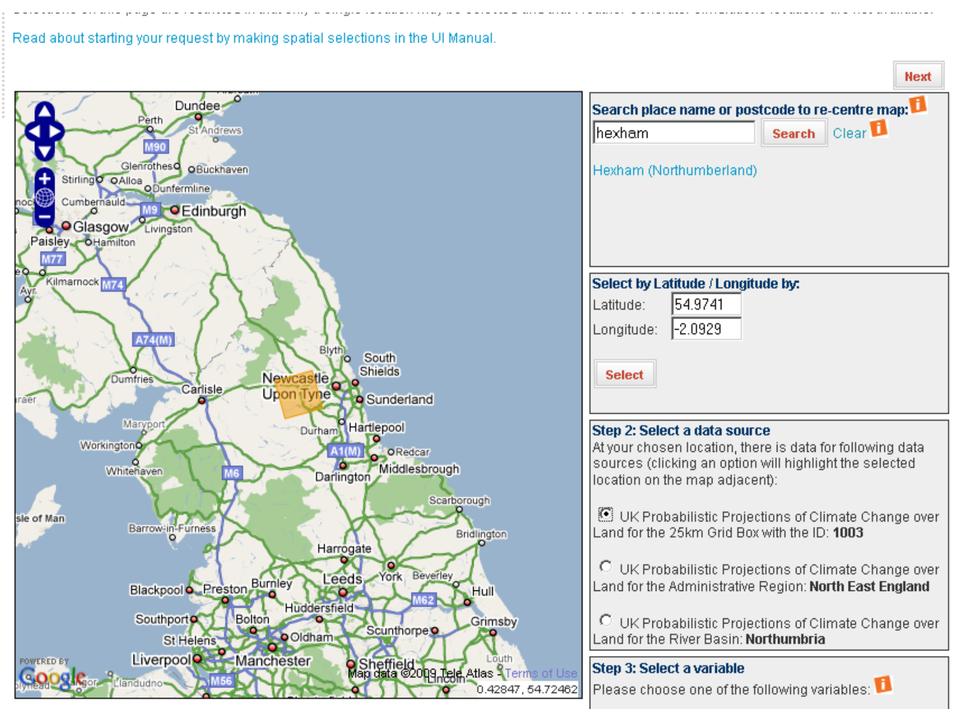
UK Climate Projections 09

- Just launched (June 09)
- Freely available through web
- Extensive user interface



Outputs:

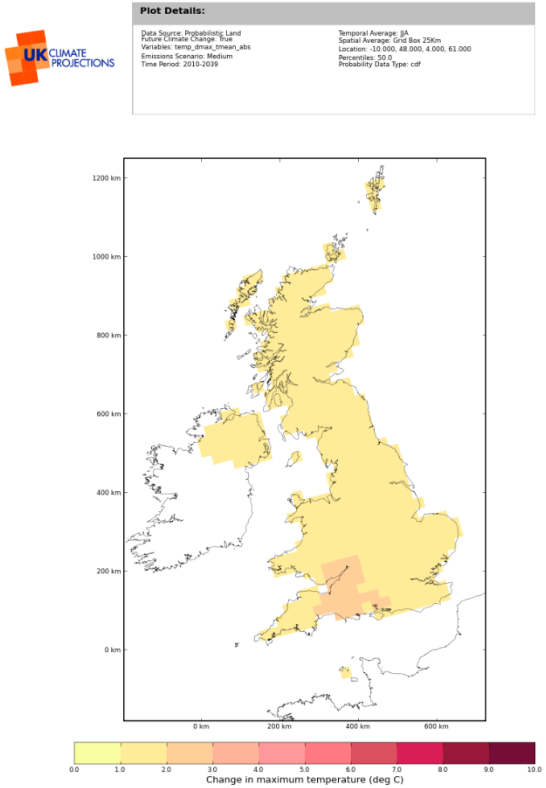
- for 10 year slices in time
- 3 emissions scenarios
- on 25 km grid
- “weather generator” at 5km
- probabilistic

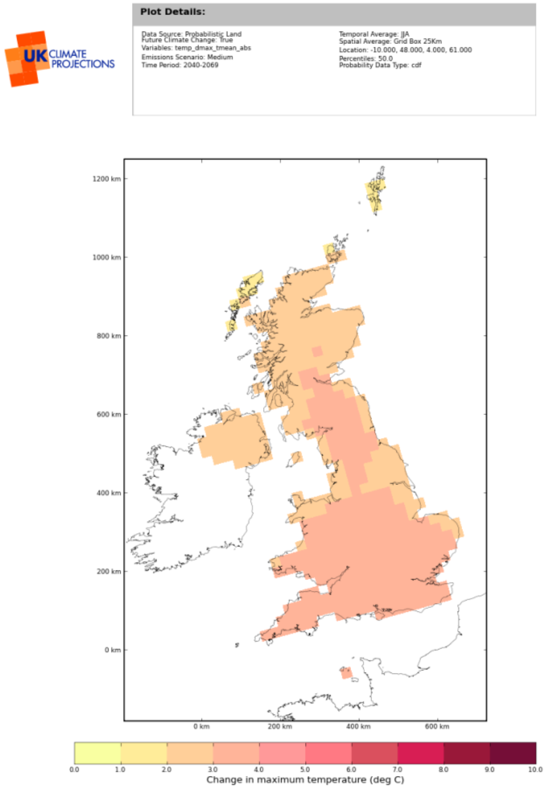
Major advances:

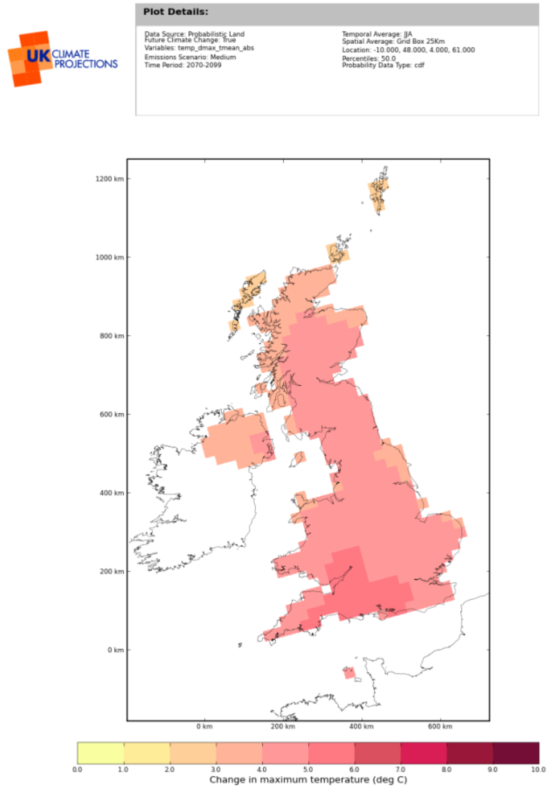
- Can estimate probability of a given change
- Can estimate change for a given probability

UKCP09 - Tmax

Tmax 2020 2050 2080







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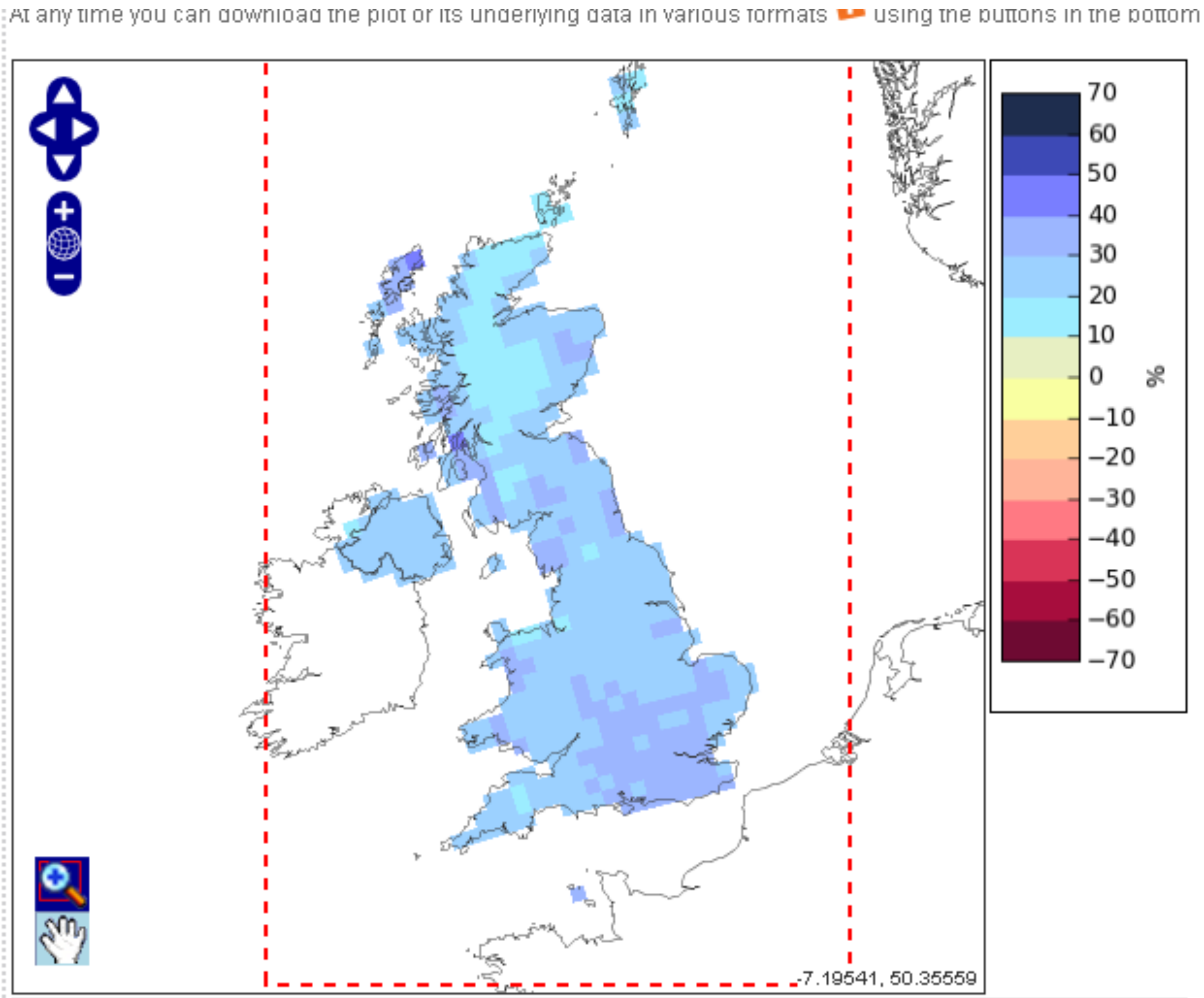
UKCP09 – rainfall

Winter rainfall increasing in N and W of UK

Summer rainfall decreasing everywhere, but especially in South.

Change in mean winter rainfall
•2080
•50% probability of non-exceedance



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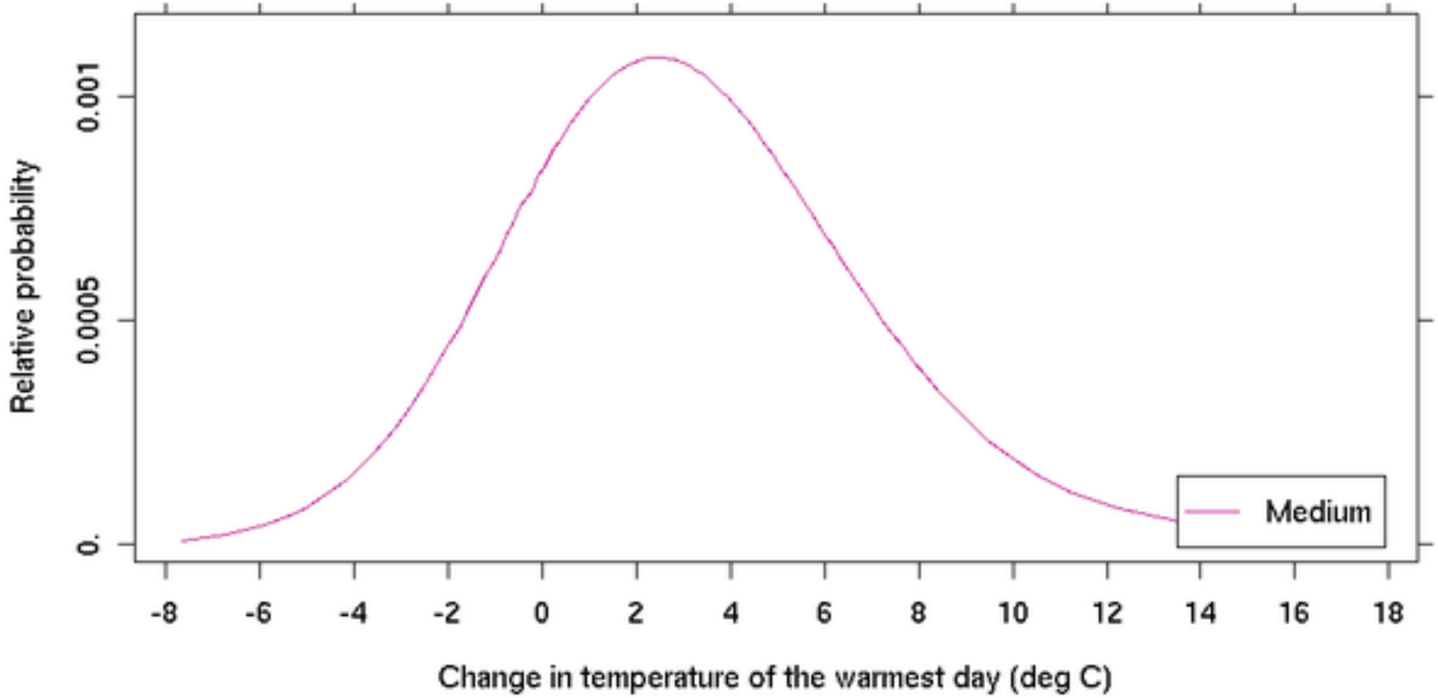
UKCP09 - pdf

Warmest day

UK CLIMATE PROJECTIONS

Plot Details:

Data Source: Probabilistic Land	Temporal Average: JJA
Future Climate Change: True	Spatial Average: Grid Box 25Km
Variables: temp_dmax_t99_abs	Location: Grid Box No. 1003
Emissions Scenario: Medium	Probability Data Type: pdf
Time Period: 2040-2069	



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UKCP09 - cdf

Warmest day

Plot Details:

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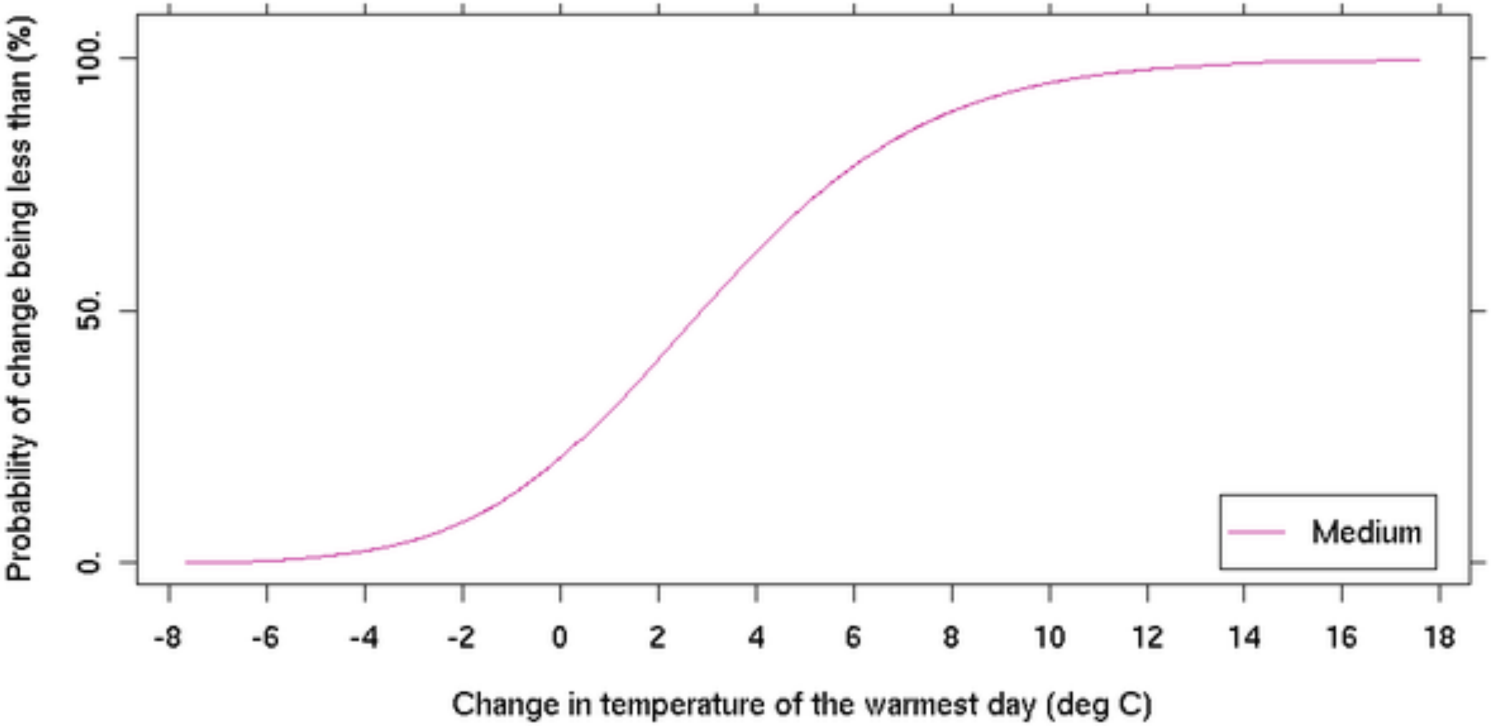

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Overview

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2. The Weather Generator
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The Weather Generator

Because an emulator has been used in UKCP09, time series are not available for all of the scenarios.

A weather generator has therefore been developed to provide these.

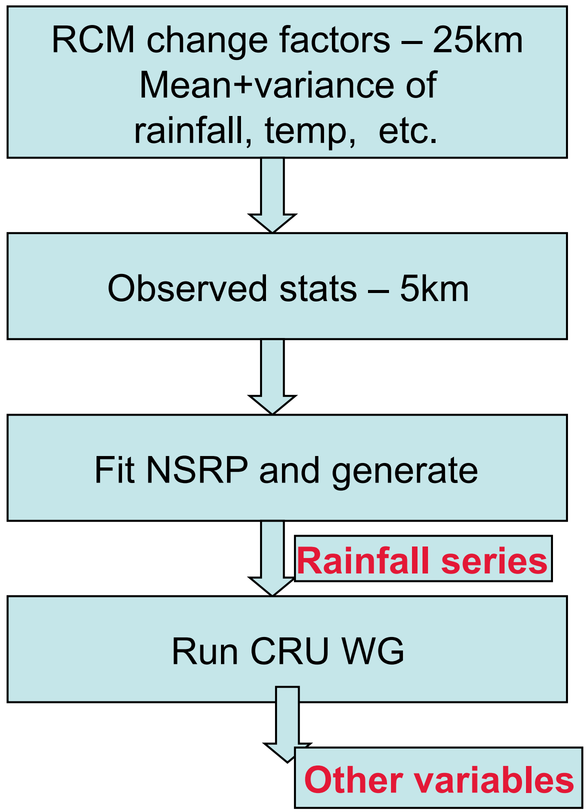
A WG is a statistical model producing synthetic time series of weather variables with realistic properties

A combination of:

- Stochastic rainfall model (NSRP)
- Regression model for other variables

Daily and hourly time resolution, 5km grid coverage of UK, realistic properties of extremes.

WG has been extensively validated against observed data



Weather Generator method

- Generates rainfall, temperature, sunshine, humidity, wind, PET
- Daily and hourly: for sites on 5km grid across UK
- Primary model of rainfall is NSRP
  - Fitted to observed stats, multiplied by climate change factor (now using mean, pdry, variance, skew, autocorrelation for rainfall)
- Autoregressive (AR) model used for inter-variable relationships (IVRs). Fitted for doublets of days in half-months. Anomalies are modelled and transformed back assuming normal distributions .
- *e.g*. for temperature

Dry Periods dd

$T_i = a_1\ T_{i-1} + b_1 + e\ ;\ R_i = a_2\ R_{i-1} + b_2 + e$

Wet Periods ww

$T_i = a_3\ T_{i-1} + b_3 + e\ ;\ R_i = a_4\ R_{i-1} + b_4 + e$

Neyman-Scott model

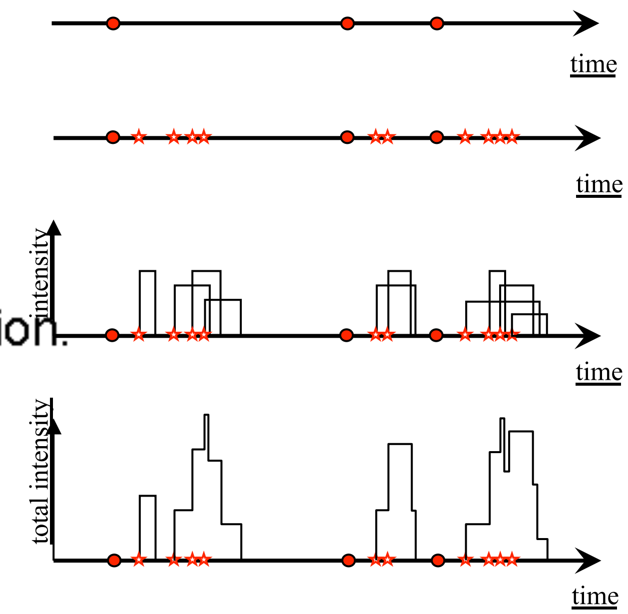
In its simplest form, a single site continuous time model with five parameters:

- λ: the rate of storm arrival (per hour)
- β: the mean waiting time for the raincells after the storm origin
- ν^{-1}: the mean number of raincells per storm
- η^{-1}: the mean cell duration
- ξ^{-1}: the mean cell intensity

λ is described by a simple Poisson process

β, ν^{-1}, and η^{-1} are means of exponential distributions

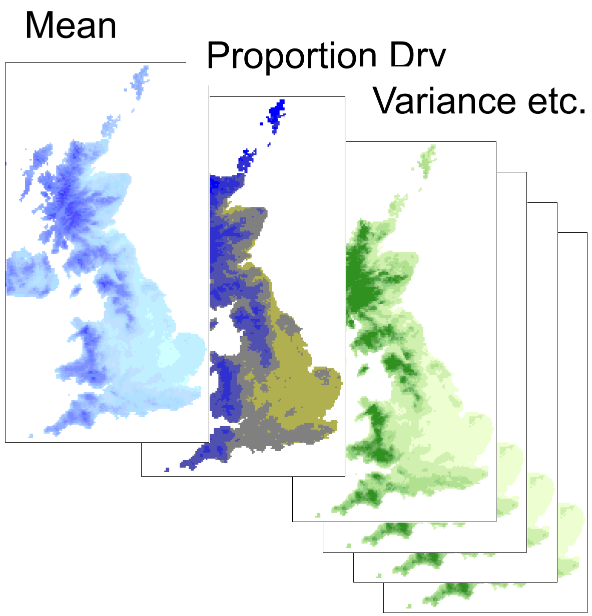
cell intensity has exponential, gamma or other distribution.



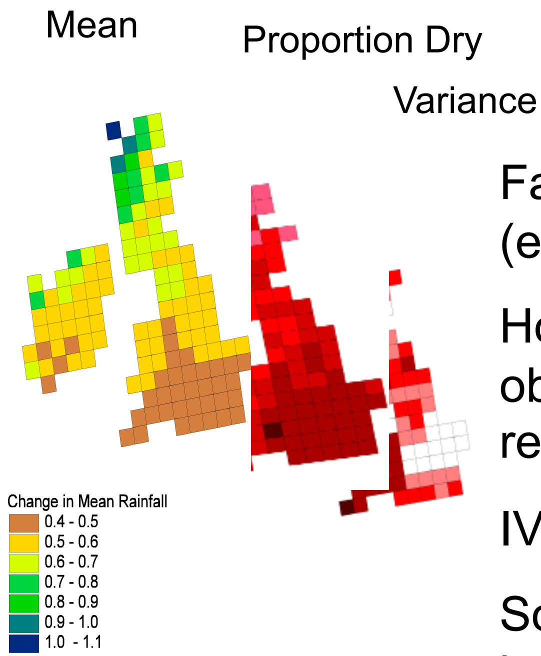
Parameters fitted using an objective function minimizing the differences between observed stats and analytic estimates

Perturbation method

Observed statistics X RCM change factors



X



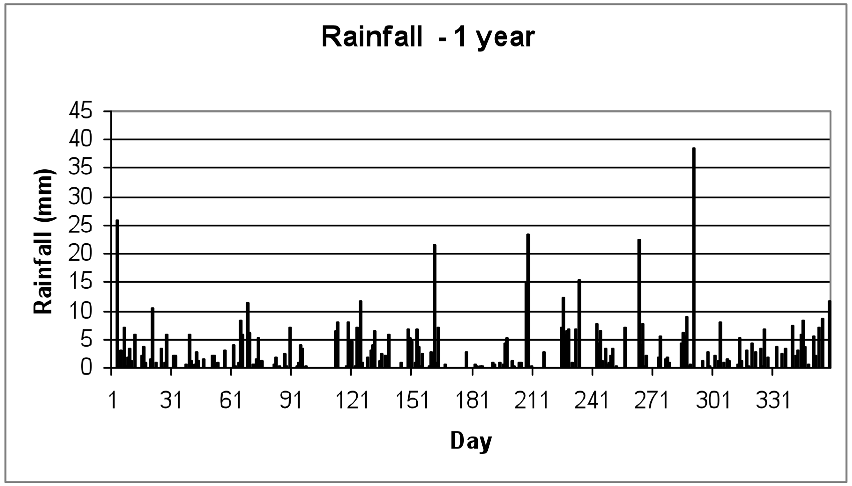
Factors are multiplicative (except for temperature)

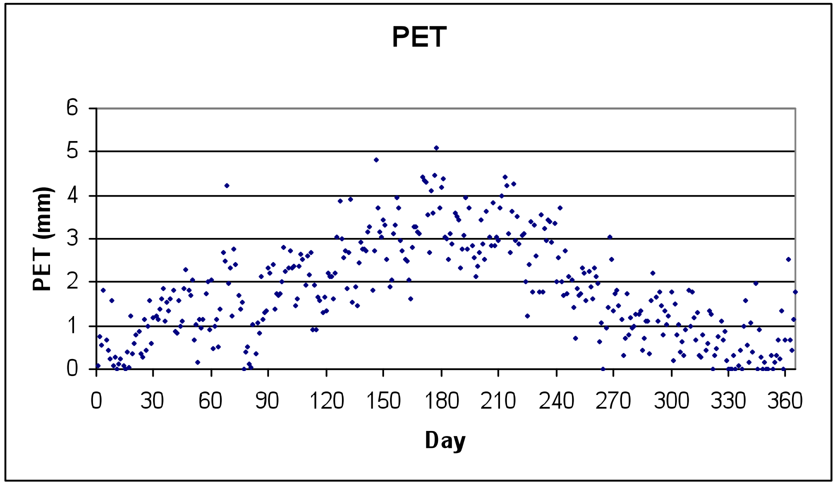
Hourly stats derived using observed regression relations (fixed for future)

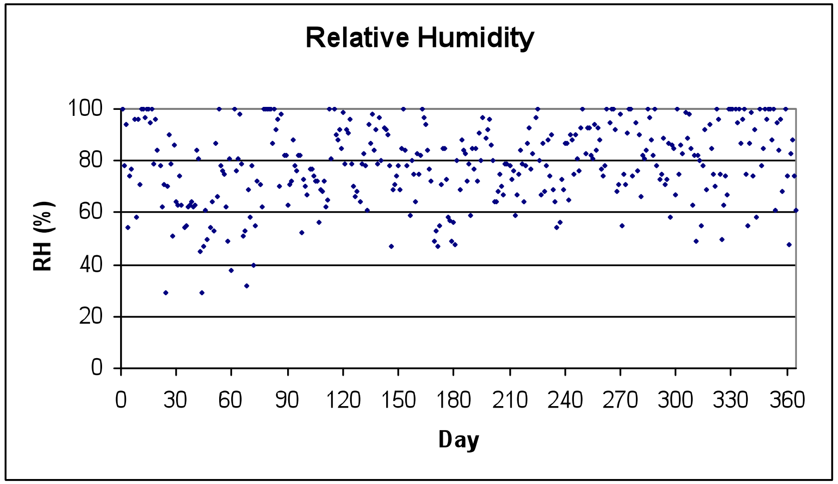
IVRs also fixed for future

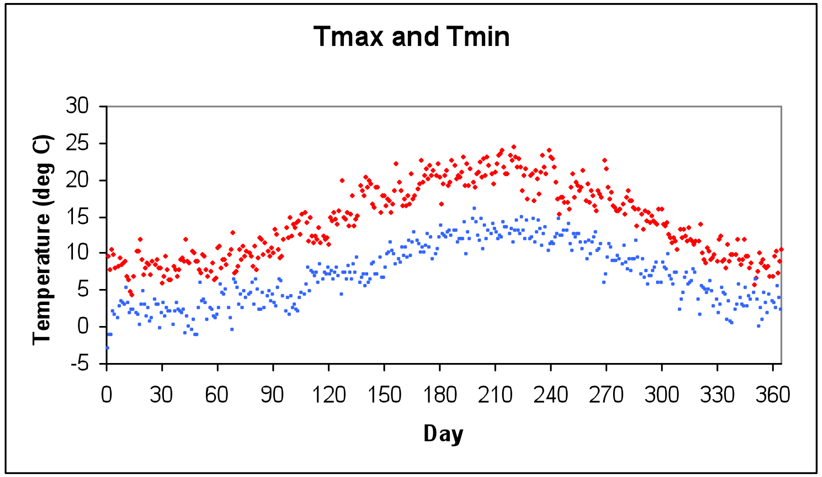
So, no change information included at higher than daily resolution

Outputs









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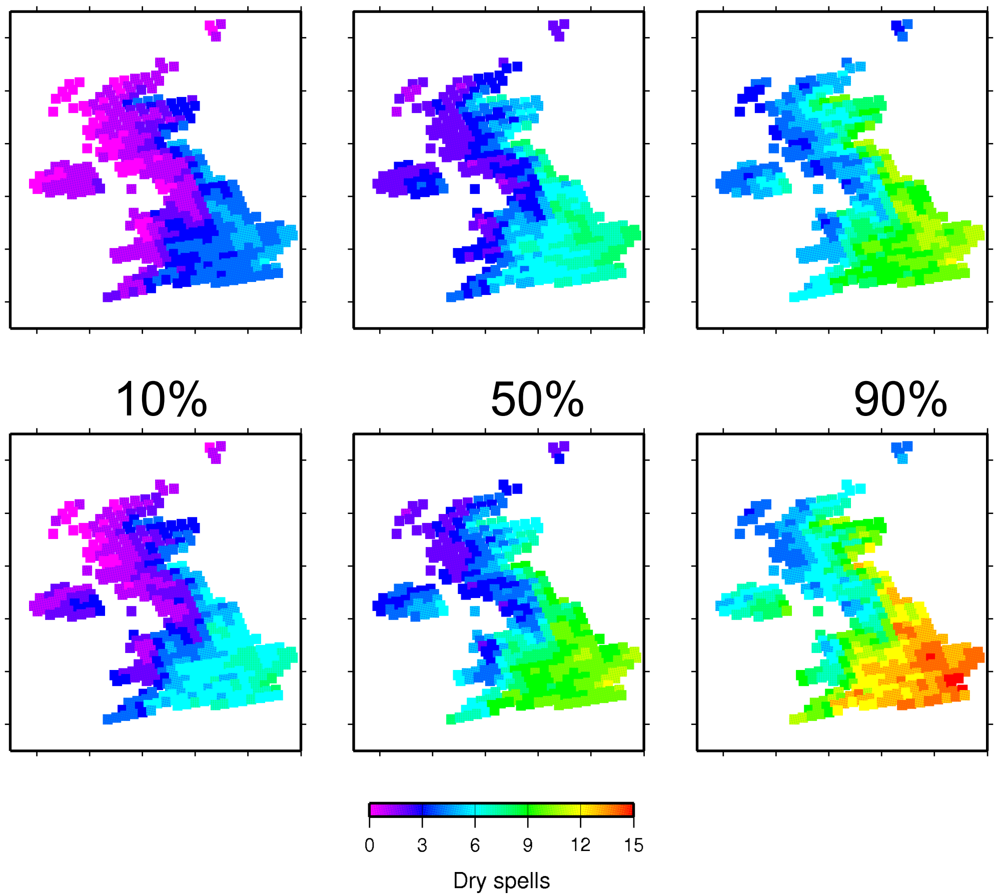
UKCP09 WG outputs



Number of dry spells per year (>10 days)

Control 1961-1990

2080s medium

Simulated by weather generator on 25km grid.
Run on 2600 node Condor grid
1000 change factor variants
30 year simulations

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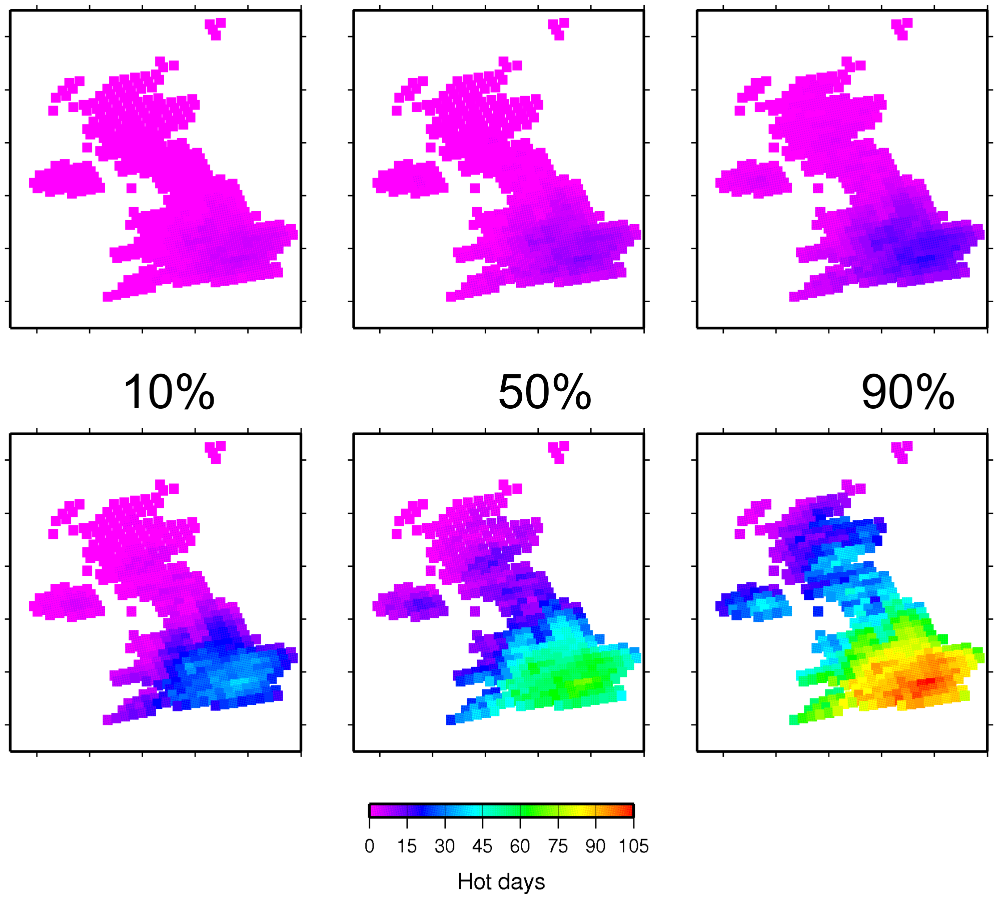
UKCP09 WG outputs



Days above 25 deg C per year

Control 1961-1990

2080s medium

Simulated by weather generator

on 25km grid.

Run on 2600 node Condor grid

1000 change factor variants

30 year simulations

Overview

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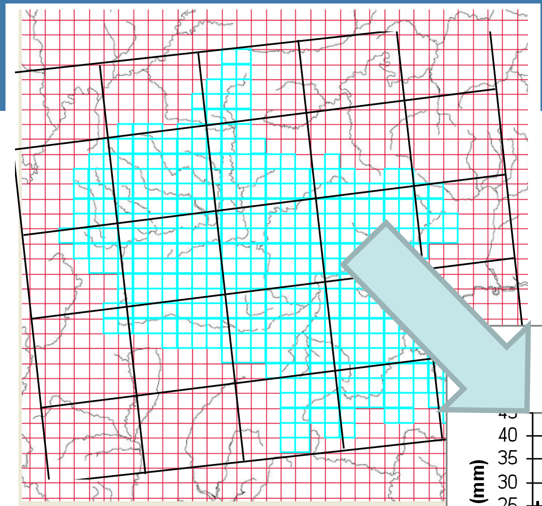
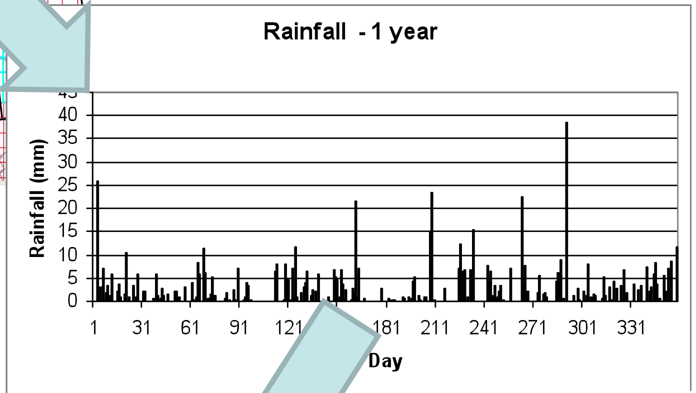
Thames basin UK

- $10{,}000\ km^2$ total
- 10% urban,
- 45% chalk, limestone
- 45% clay
- Max elevation 300m
- 700mm annual rainfall
- Main water supply for London
- We will approximate the main resource by considering flows at Kingston

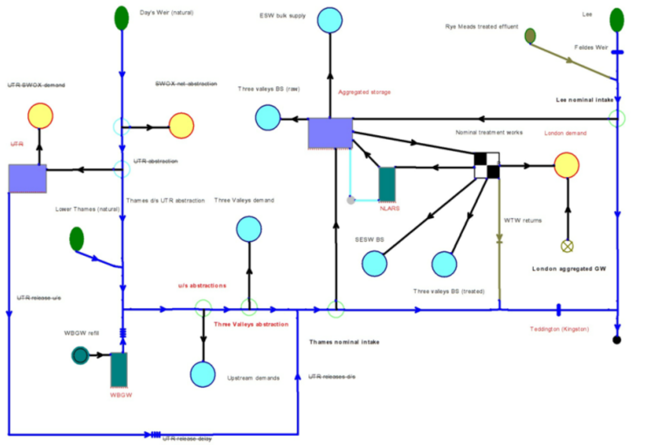


Stochastic weather generator for rainfall for the Thames Catchment



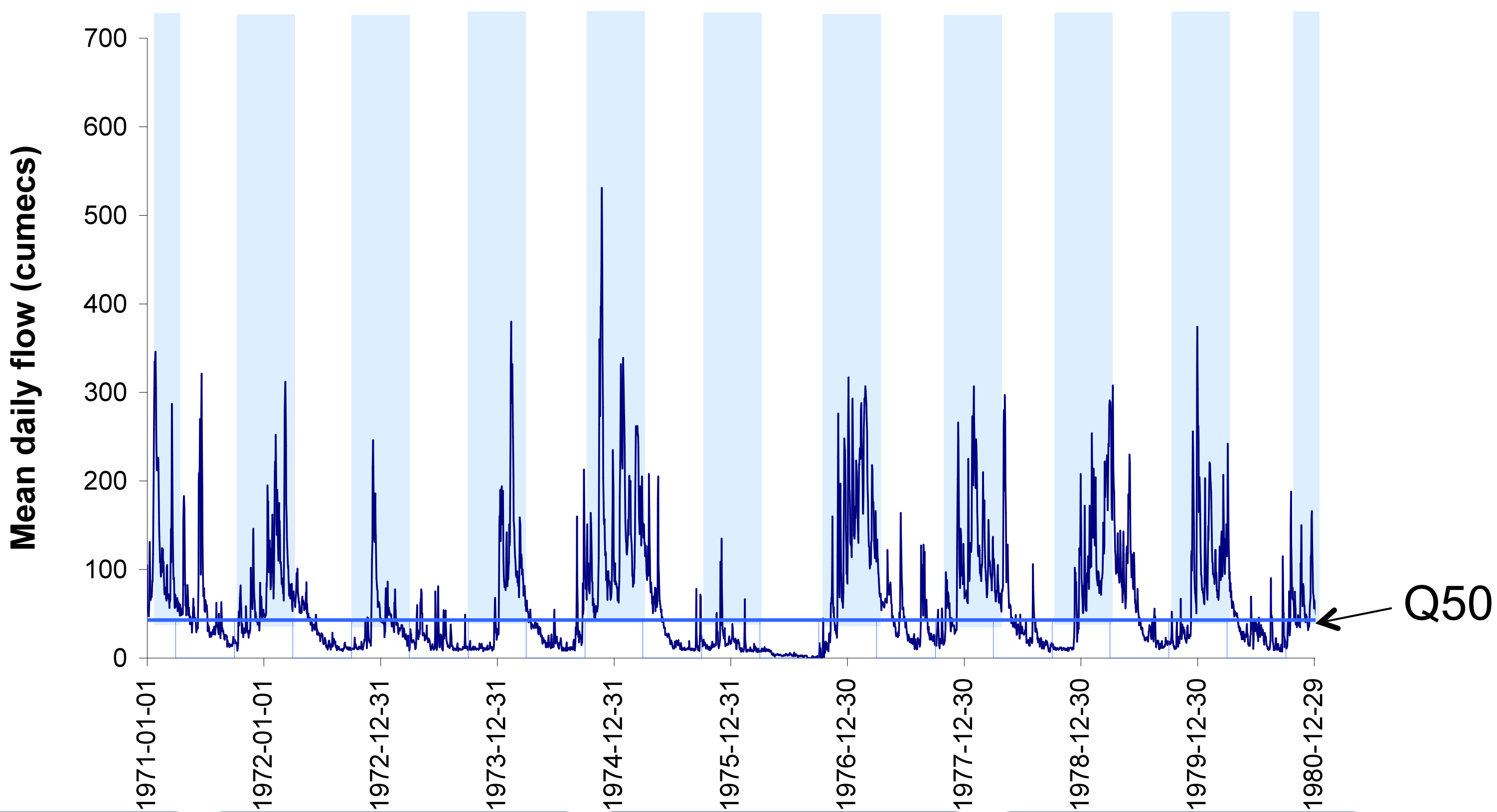
Rainfall-runoff: River Thames and River Lee

CATCHMOD - conceptual catchment model



Abstraction availability from the Thames

Daily flow record at Kingston, 1971-1980

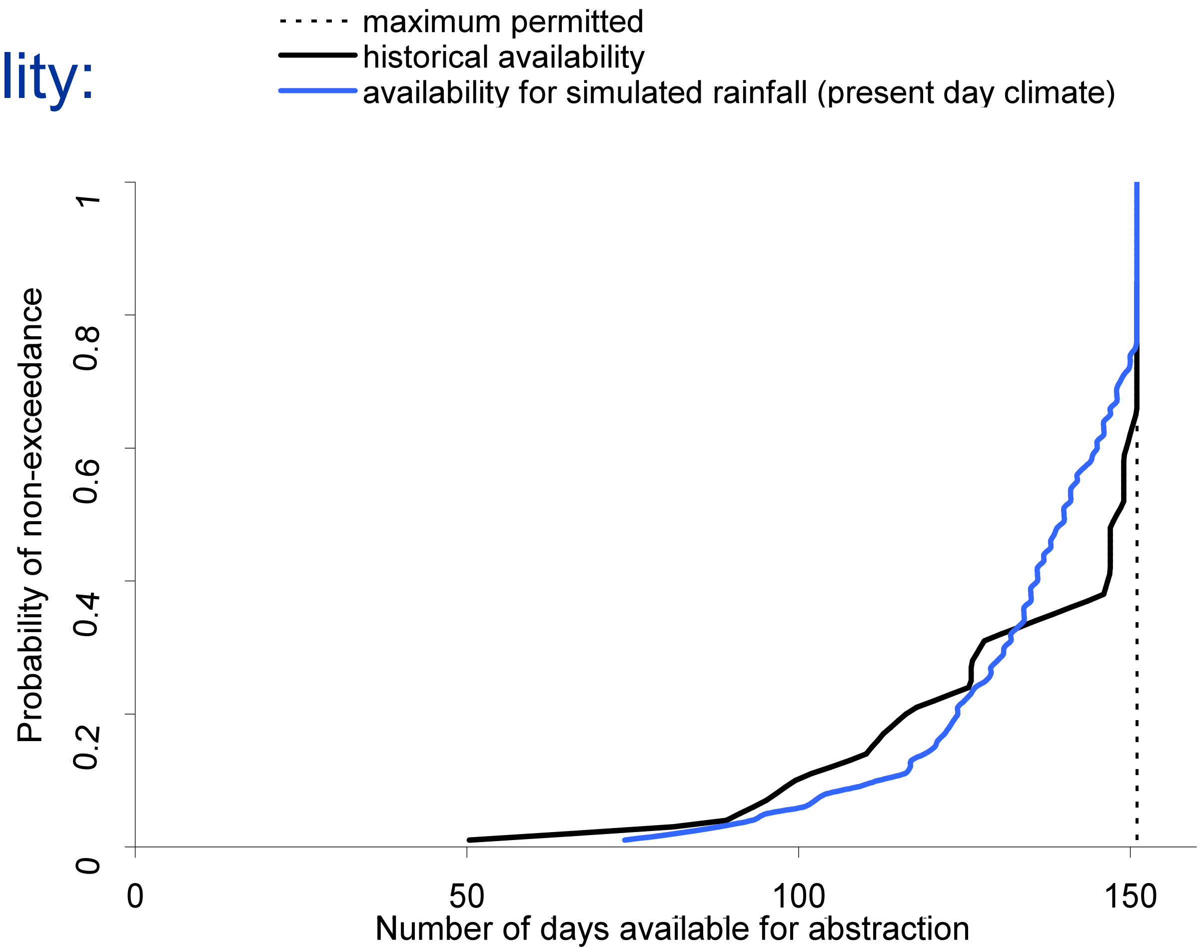


Current abstraction availability

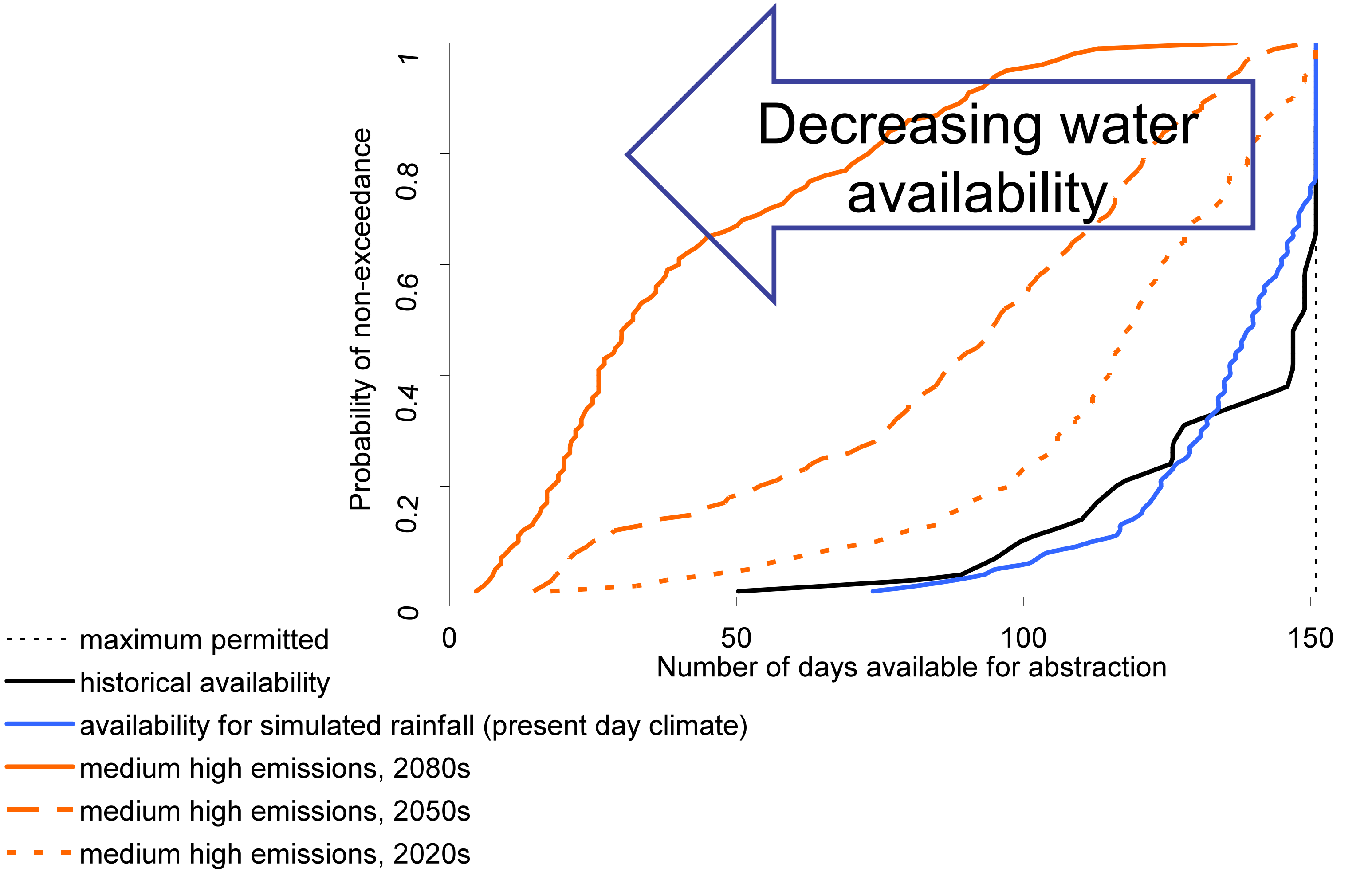
Modelled availability:

1000-year synthetic weather record

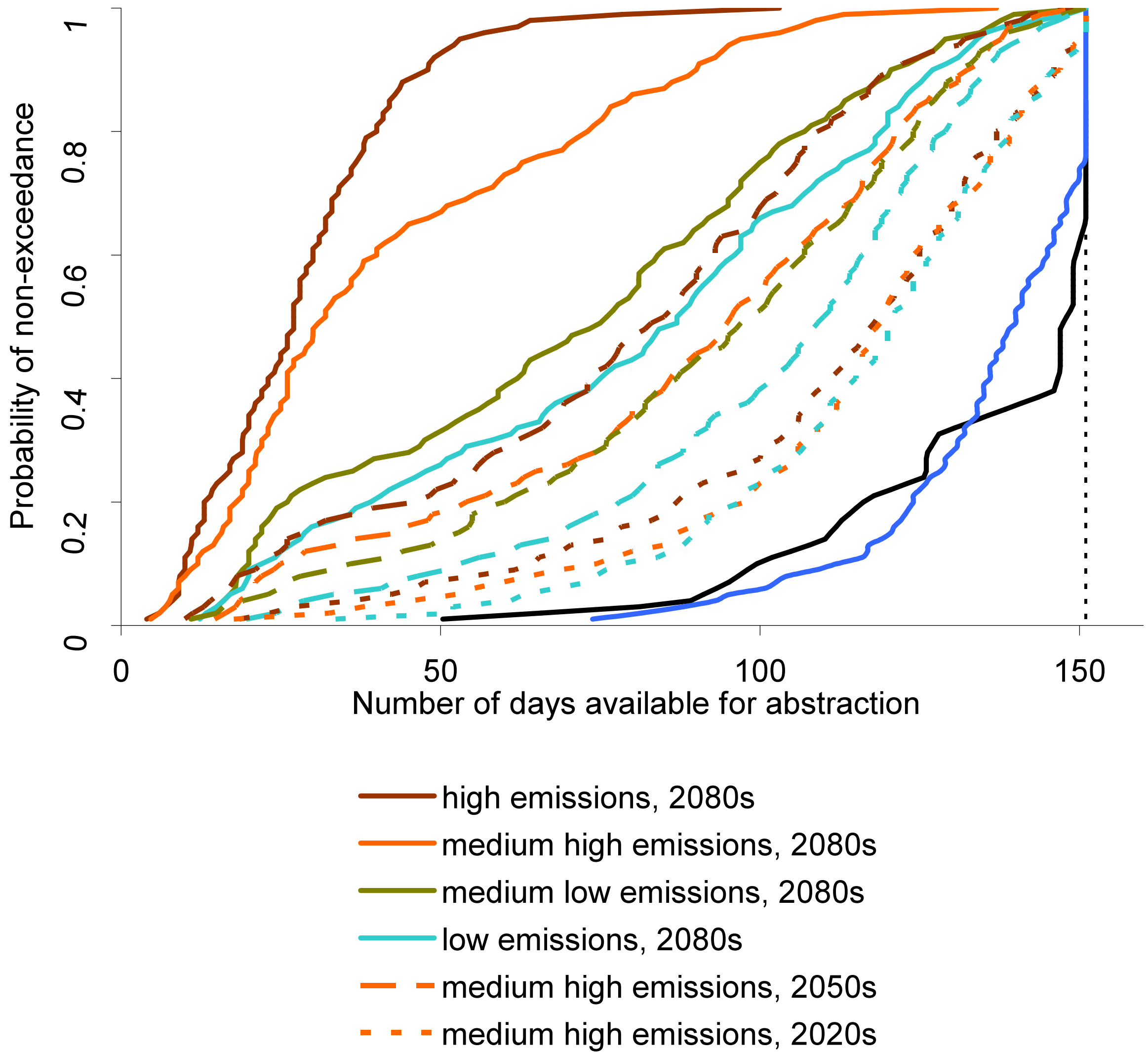
Count availability in each year



Effect of time-frame on projected abstraction availability



Effect of time-frame / emissions scenario on projected abstraction availability



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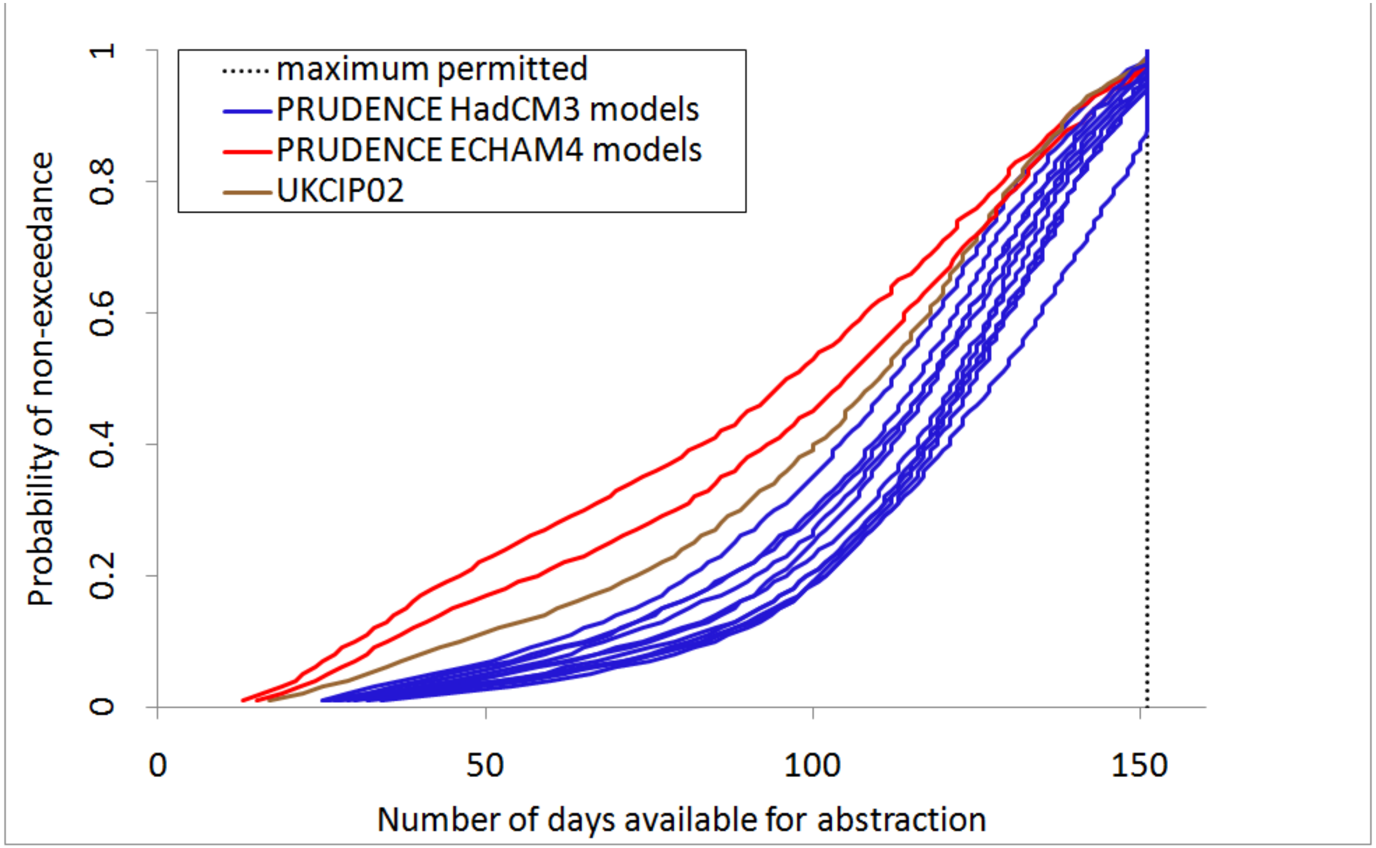
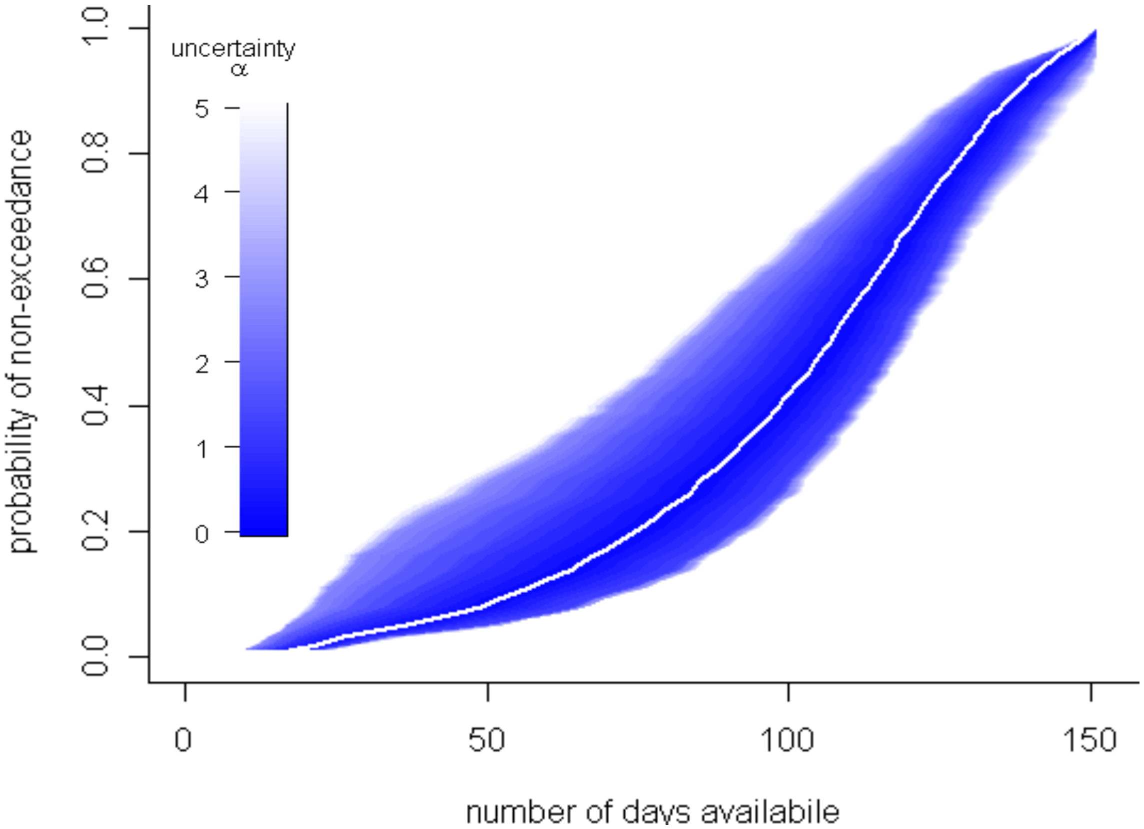
Effect of different climate models on projected availability

Abstraction availability: 2050s, medium-high emissions



Defining uncertainty in prediction



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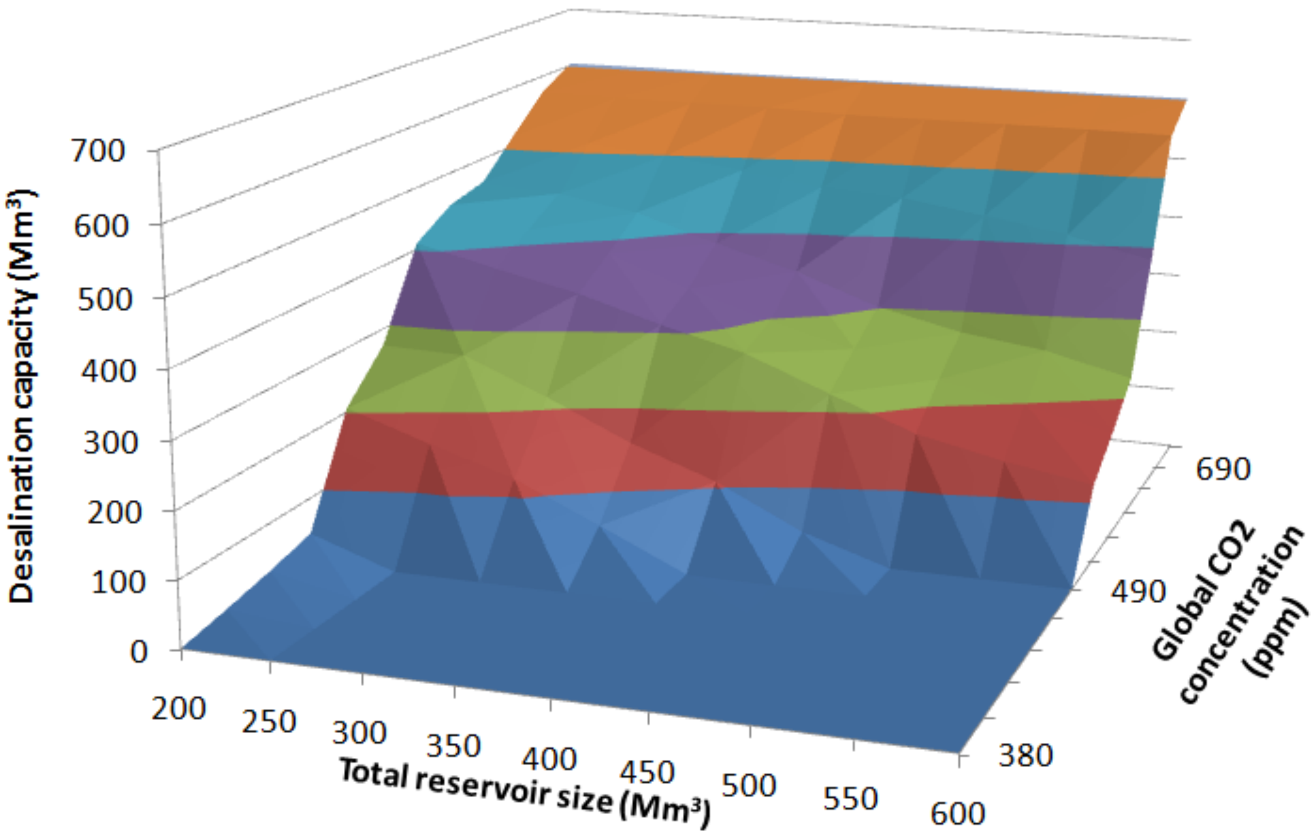
Adaptation strategy

Combination of new reservoirs and desalination plants are planned



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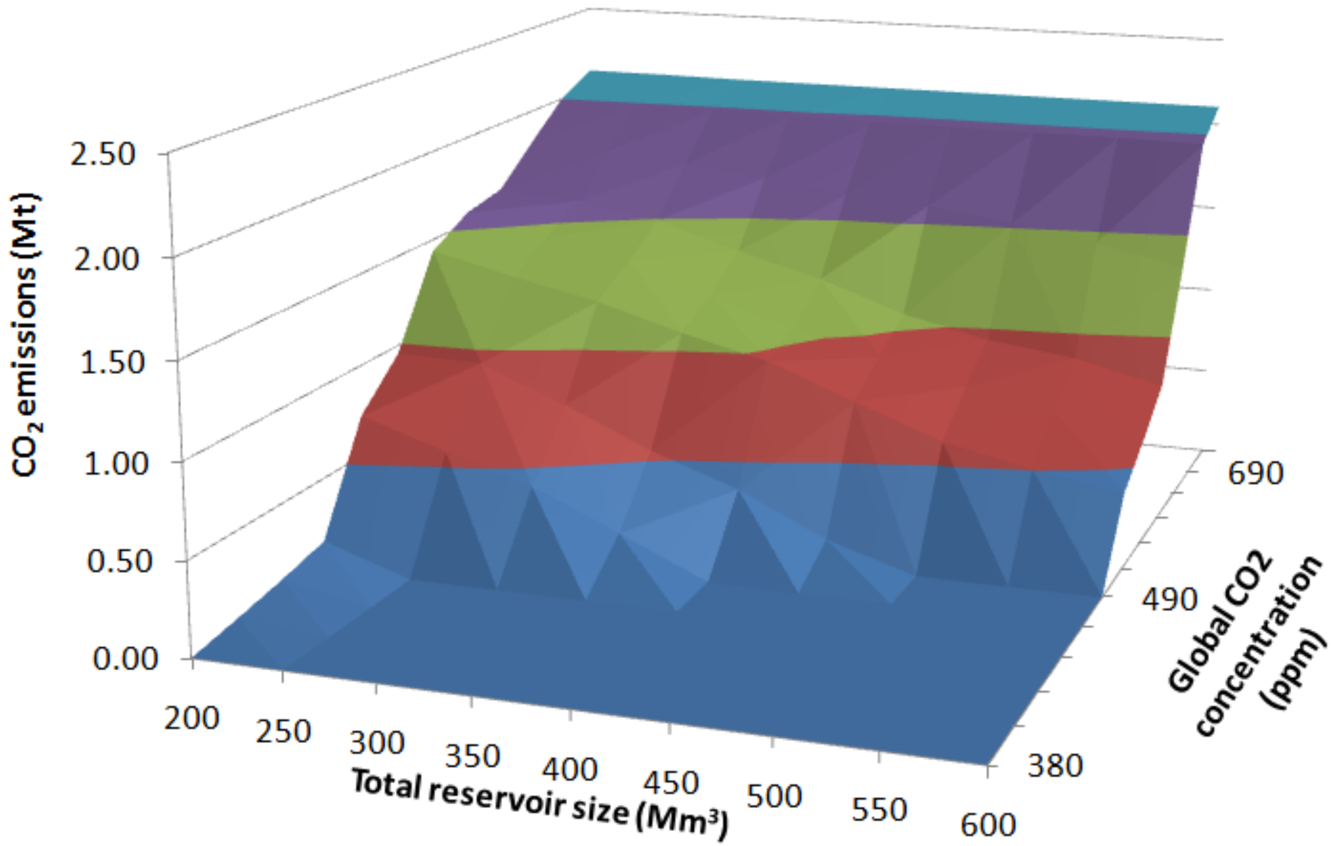
Energy costs of future strategy

Desalination has energy costs however



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Overview

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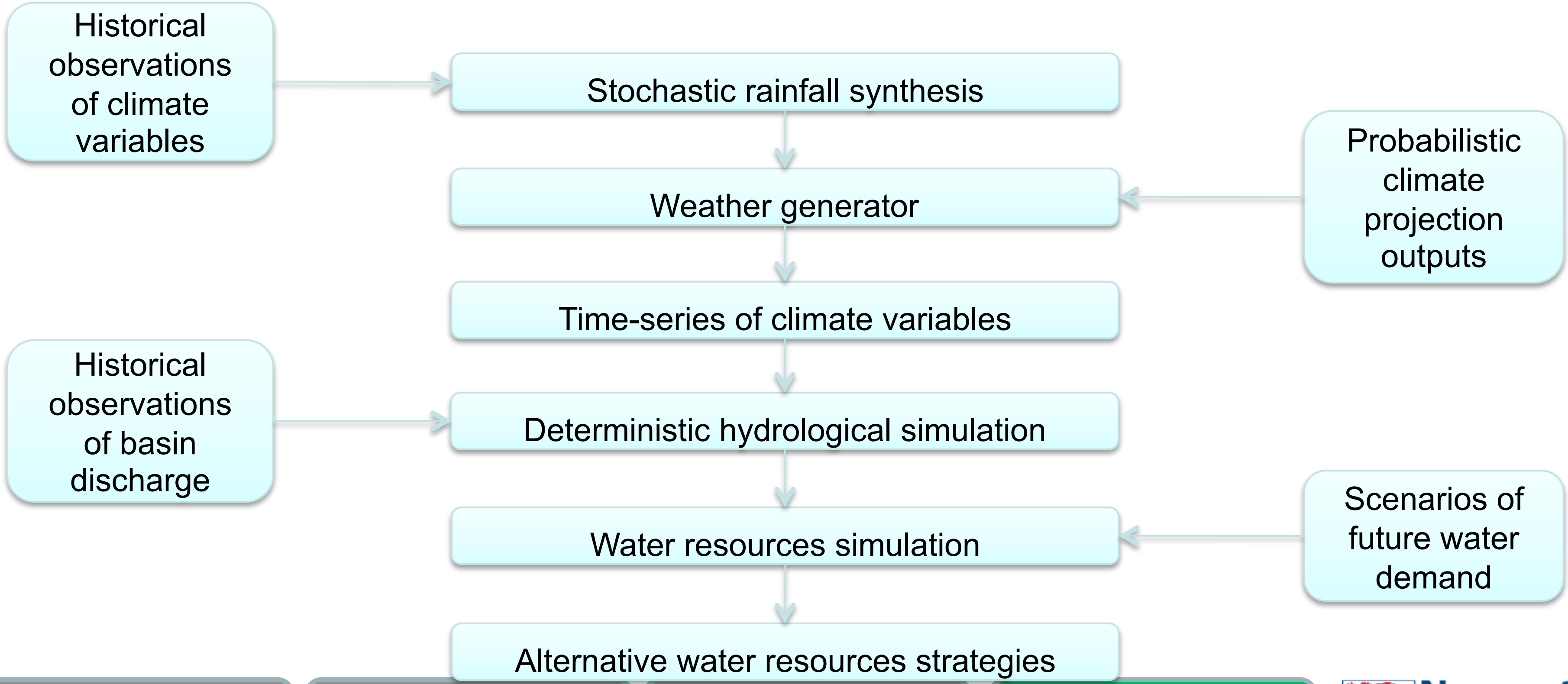
4. Other applications

Other applications – UK water grid

National study: aimed at developing major transfers from north to south to alleviate London resource shortfall

Requires large spatial rainfall model with correct spatial correlation of rainfall and inter-annual variability



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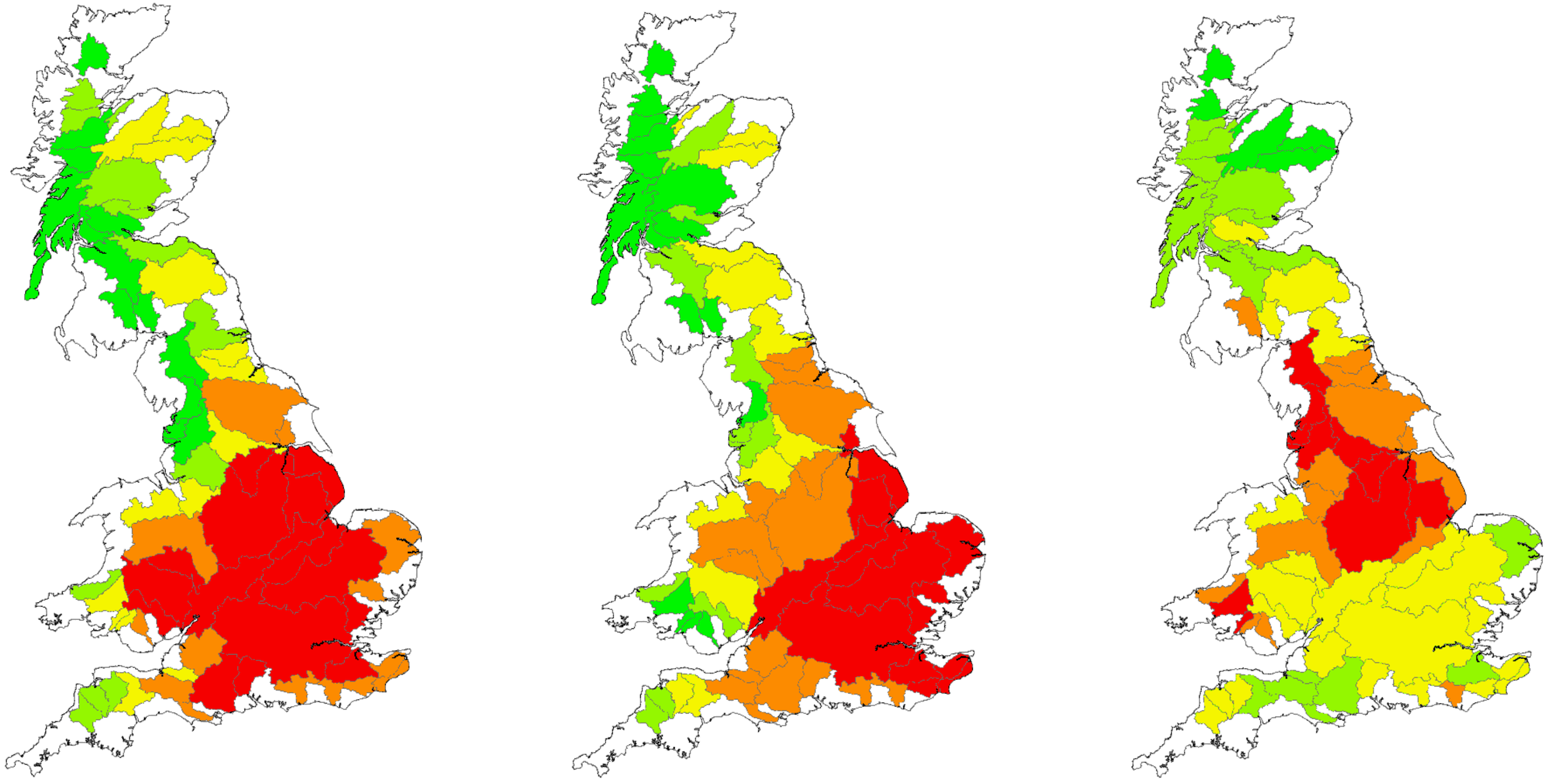
Other applications – UK water grid

- Rainfall model for monthly amounts



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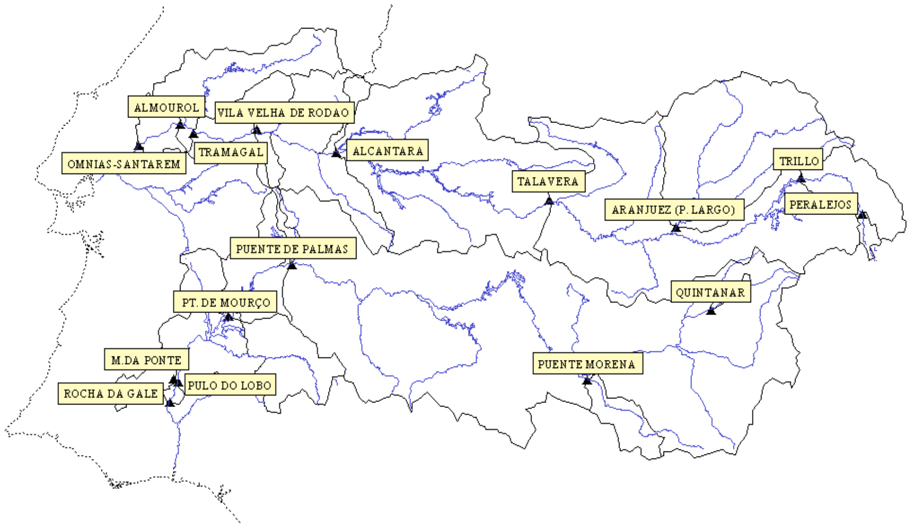
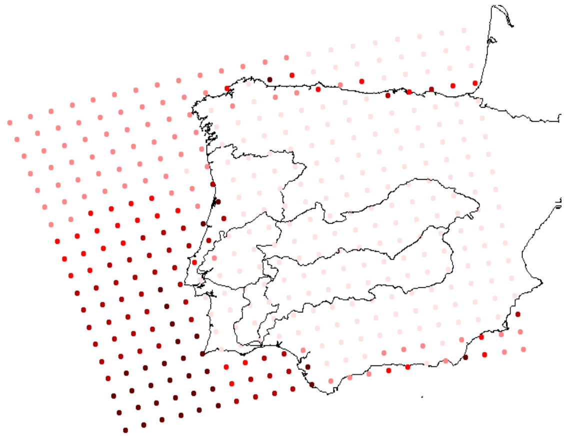
Other applications – Portugal

International resources were studied under EU SWURVE project (2000-2003) (Newcastle University and ICAT) http://www.ncl.ac.uk/swurve

• Hydrological model (UP) was used to estimate impacts of future climate change.

•Inputs were RCM rainfall and rainfall modelled using circulation patterns

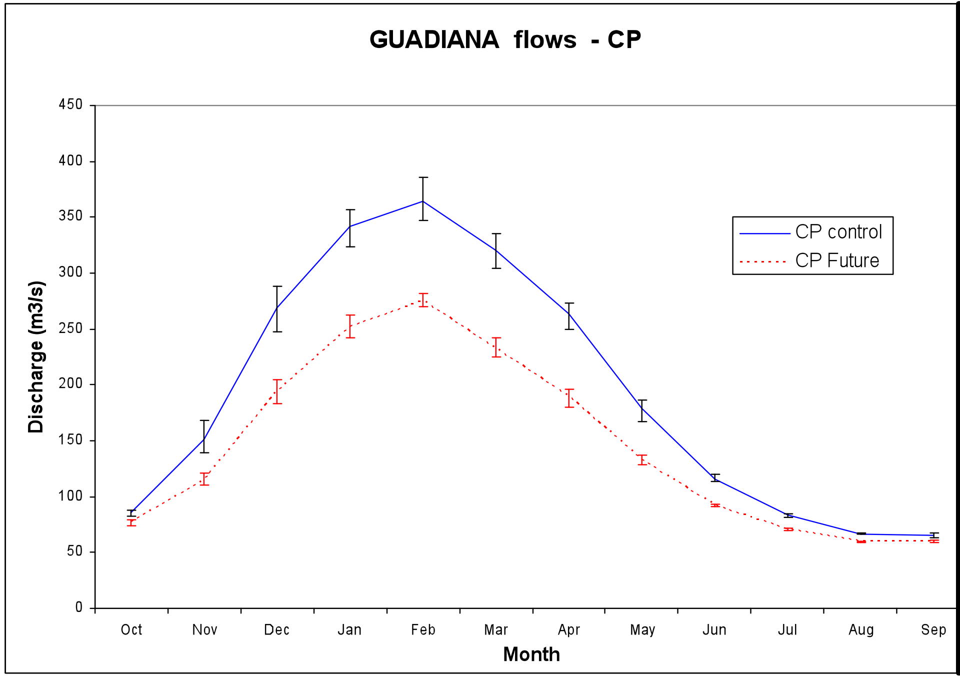


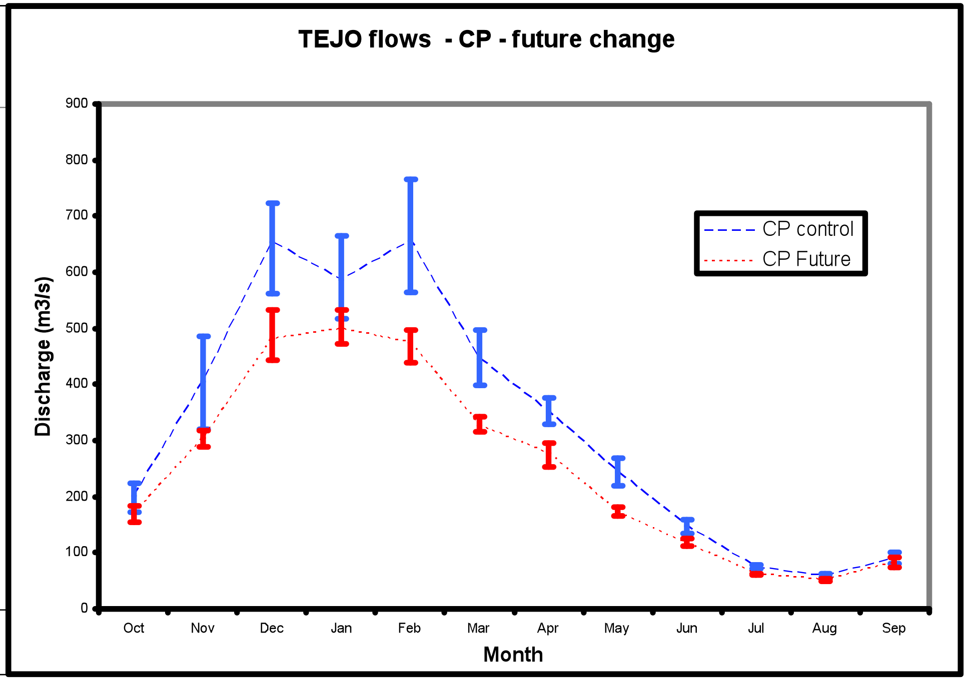


Gauging stations with available data in the Guadiana (southern) and Tejo (northern) basins

Other applications – Portugal

Showed major decreases in flows throughout the years, with severe consequences for future resources





A revised study should use a probabilistic approach with an ensemble of climate models

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Conclusions

- A new era of climate change impact assessments has dawned
- Climate model ensembles can now provide useful (but large!) estimates of uncertainty
- Stochastic models (or weather generators) can be used to provide (multiple) input time series for simulation models (rivers and resources)
- Capabilities are improving for dealing with extremes (floods and droughts) allowing adaptation strategies to be developed

Thank you for your attention!!

Further info on UKCP09 and the weather generator at:

http://ukcp09.defra.gov.uk/