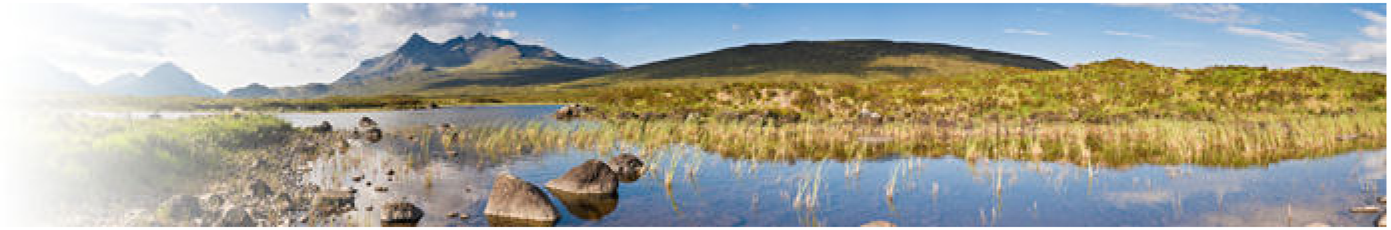

HydEF project

Driving the hydrology: high-resolution weather generation

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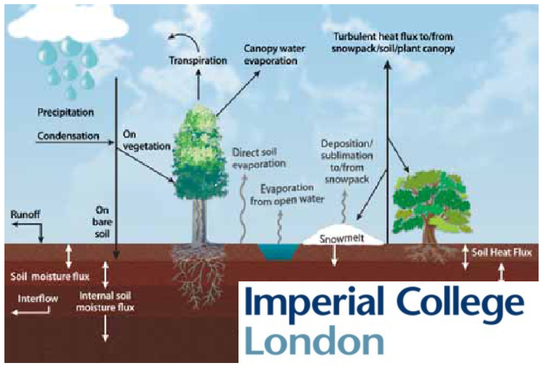
Steering group meeting, 15th February 2012, Imperial College

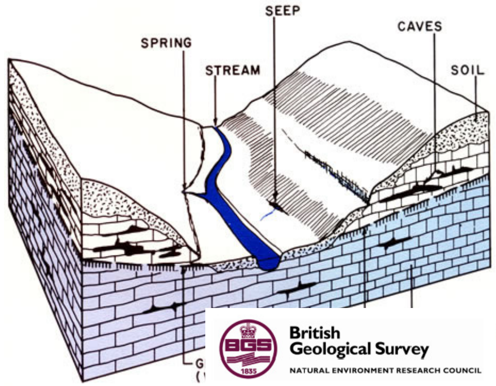
UCL role in the project

Climate (Reading)

Weather (UCL)



Land surface (Imperial)



Subsurface (BGS)

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Objectives

- To provide high-resolution weather inputs (*'weather generator'*), consistent with large-scale atmospheric conditions, for input into hydro(geo)logical models
- Multi-site, multivariate, hourly series required
  - E.g. variables needed by JULES (1km^2 resolution?):

Rainfall rate	*Air pressure*	*Snowfall rate*	*Air temperature*
Wind speed	*Specific humidity*	*Downward short-wave radiation*	*Downward long-wave radiation*

- Impacts of changing climate assessed by generating high-resolution inputs conditioned on large-scale outputs from climate simulators e.g. GCMs

Why not use climate simulator outputs directly?

- Spatial resolution too coarse for many applications despite improvements in regional climate models
- Expensive to obtain multiple runs (~1 month for 100-year simulation) for uncertainty assessment / accurate estimation of extremes etc.
- Reproduction of precipitation still problematic from end-user perspective
- Can't calibrate to reproduce specific features of interest in particular application

Statistical downscaling and weather generation

- Idea: build statistical model for relationship between large-scale circulation and local-scale weather – use to generate high-resolution data conditioned on climate simulator output
- Quick to generate multiple simulations & explore uncertainties
- Can calibrate / tailor to specific applications
- BUT existing generators do not use latest methodological developments and can perform poorly – hence some criticism in literature
  - Don't confuse concept with implementation!

Developments and opportunities

- Modern developments based on generalized linear models (GLMs) allow generation of realistic daily multisite series at both gauged and ungauged locations
- Probabilistic regression-like framework allowing many different types of distribution (normal, Poisson, gamma, binomial, …) and complex relationships
- Tried and tested for single variables - GLIMCLIM software (www.homepages.ucl.ac.uk/~ucakarc/work/glimclim.html)
- Competitive with other state-of-the-art tools with respect to extremes, interannual variability, persistence etc.
- Flexible framework allows physical understanding to inform model structures (UCL-Reading collaboration)

Challenges for project

- Extend to simultaneous generation of multiple weather variables i.e. multivariate generator
  - Need to preserve inter-variable dependencies
- Provide data at hourly resolution
  - GLMs probably not appropriate here because of strong temporal dependence (correlation) within days
- Provide user-friendly interface for model building, calibration and simulation
  - GLIMCLIM unwieldy – requires manual editing of definition files
- Resource: two person-years, + 3% of PI time

Task list

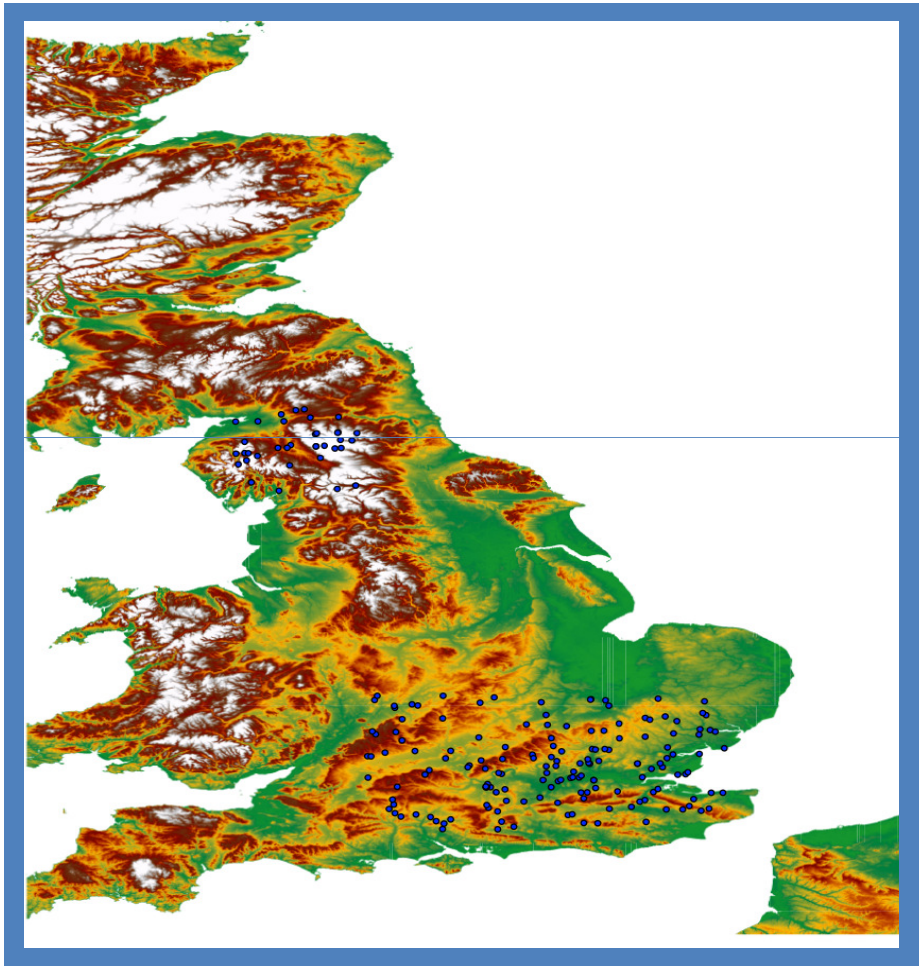
1. Acquire data
2. Identify modelling strategy
3. Extend existing software for model calibration and simulation
4. Develop models for Thames and Eden

Changing water cycle

Data (I)

- Hourly data obtained from British Atmospheric Data Centre (BADC), MIDAS Met Office dataset
- Period: January 1950 – February 2011
- Available variables: rainfall, snow, air pressure, air temperature, wind speed, downward SW radiation
- Missing variables: specific humidity and downward LW radiation
  - Can be derived from other variables using standard procedures from literature

Data (II)



Hourly data nominally available

- Thames: 157 stations
- Eden: 35 stations

BUT …

(following months of work to preprocess files and extract data)

Data (III)

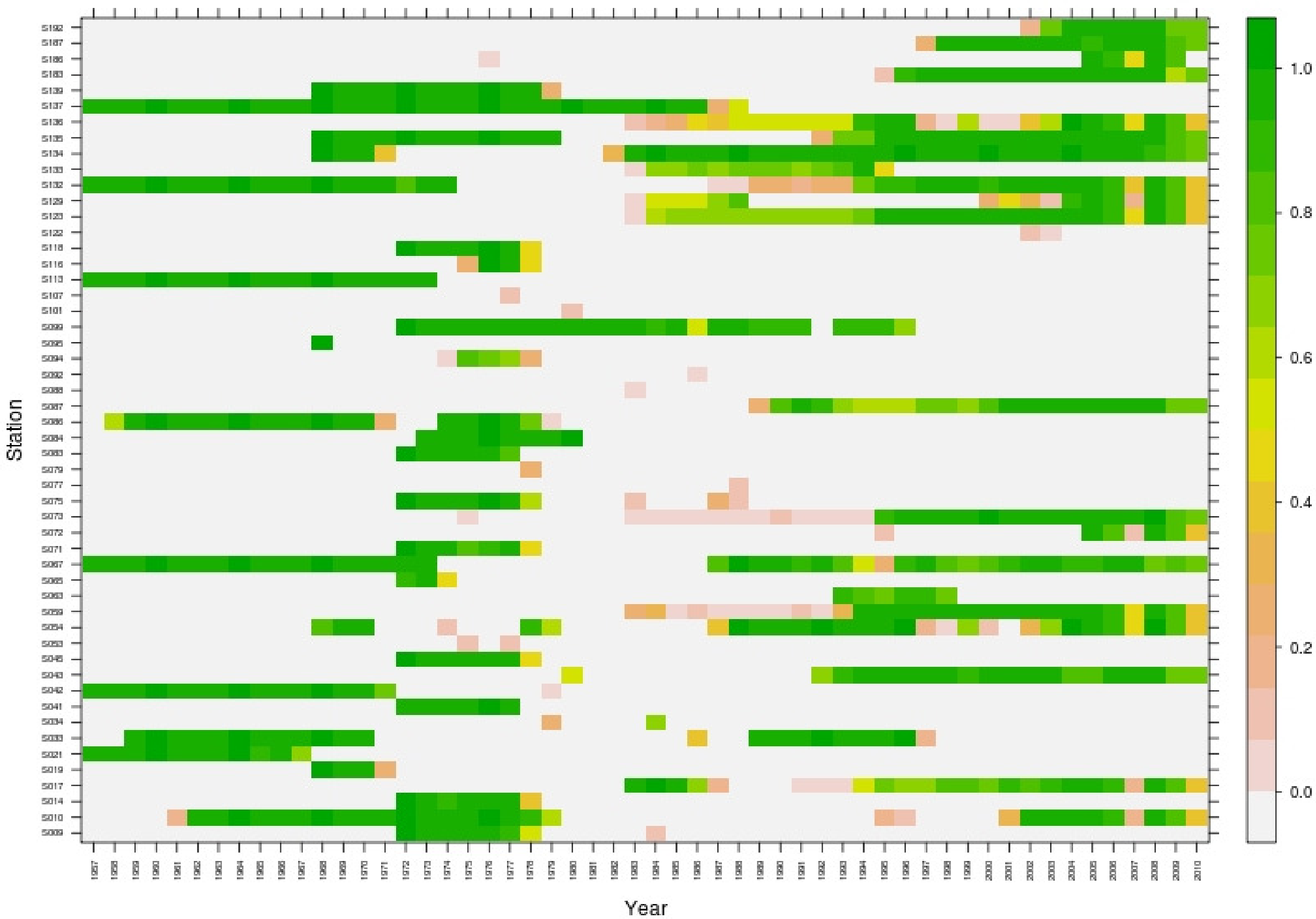
- Not all variables actually available at each station:

	Stations with data	
	Thames (/157)	Eden (/35)
Precipitation	71	16
Pressure	52	7
Temperature	140	28
Wind speed	135	28
Short-wave radiation	22	2

- Short record lengths for some stations / variables
- Additional daily records explored – little additional data available

Data availability example – pressure, Thames catchment

Proportions of available observations - Pressure



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Data availability – implications

- Scarce data for some variables ⇒ potentially large uncertainty in these variables
- Alternative data sources (e.g. gridded data products) neglect this uncertainty – what are implications for hydrological impacts?
- Approach proposed here: use multiple imputation
  - Sample “missing” data from conditional distributions conditioned on all available observations
  - GLIMCLIM provides this already for daily data – can extend as part of weather generator development

Modelling strategy (I)

- Identify "short cuts" so that development is feasible with resource available
- Proposed approach:
  1. Use GLM to generate multisite, multivariate daily series
  2. Disaggregate to hourly using simple representations of diurnal cycle for all variables except precipitation e.g.

     $$Y_{hd} = \overline{Y}_d + \alpha_h + \varepsilon_{hd} \quad \text{or} \quad Y_{hd} = \overline{Y}_d + A_d \alpha_h + \varepsilon_{hd}$$

     where Y_{hd} is value for hour h on day d; $\overline{Y}_d$ and A_d are 24-hourly mean and range for day d (from daily series); and α_h is value of diurnal cycle at hour h
  3. For precipitation, use daily-hourly disaggregation scheme already developed at Imperial College

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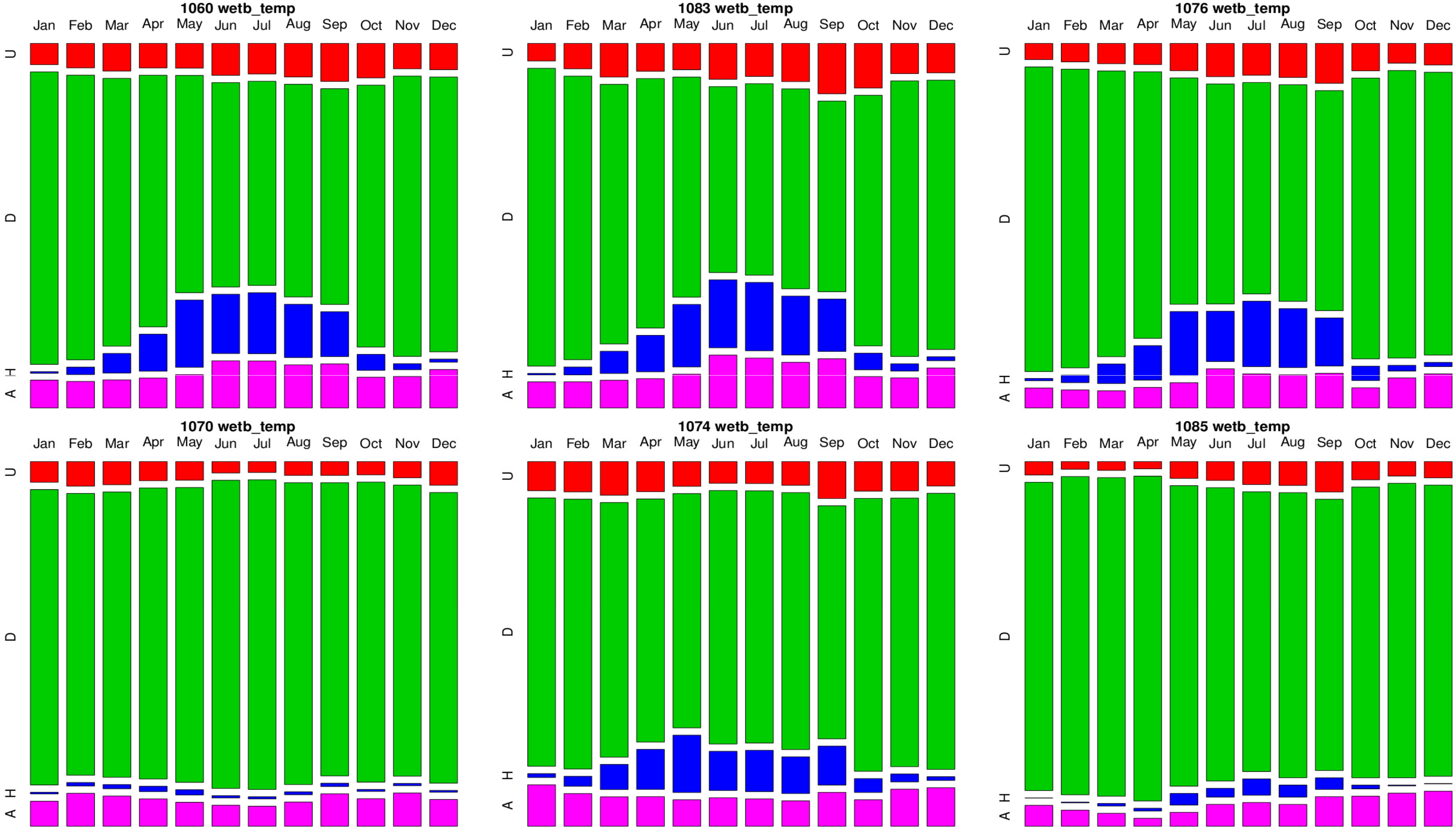
Partitioning of variance for daily-hourly disaggregation

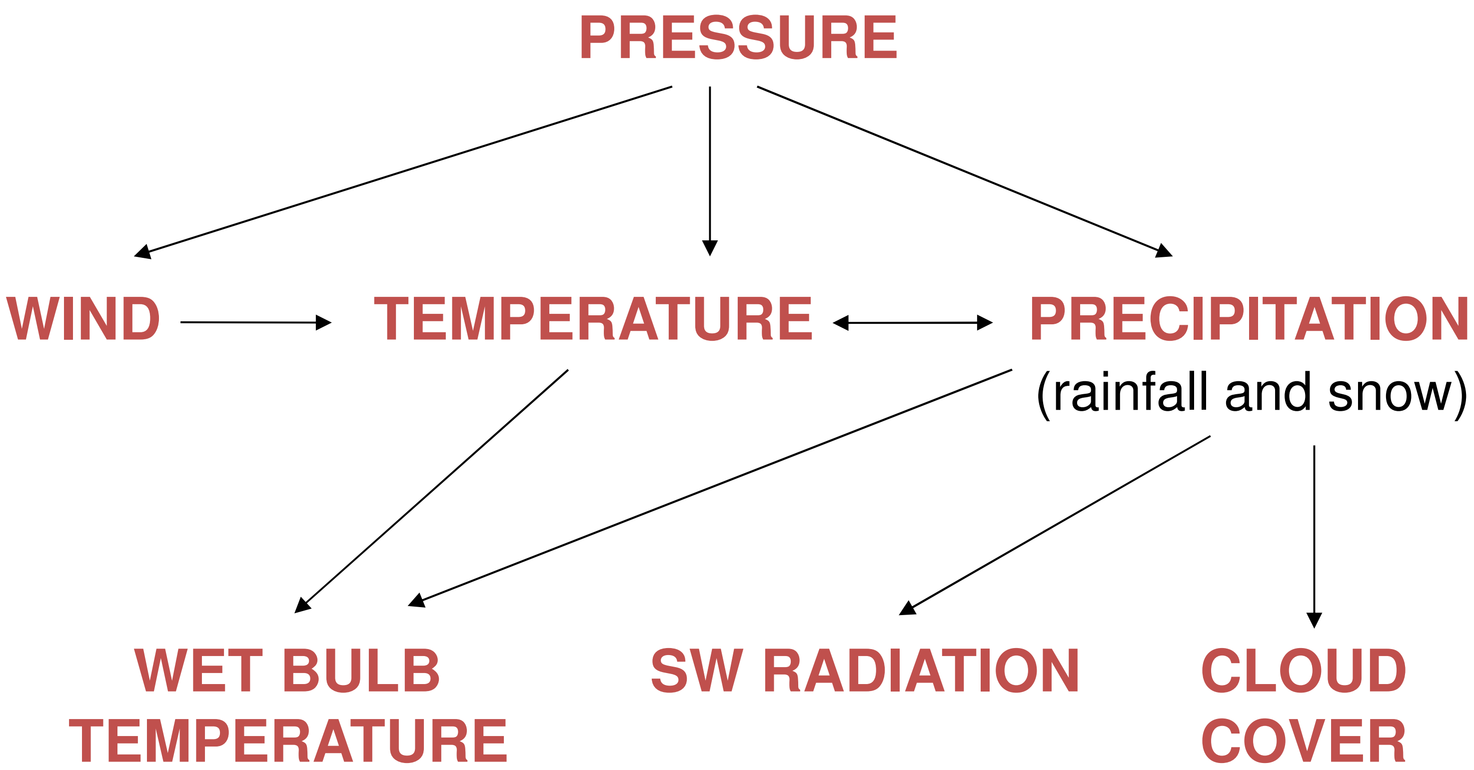


Examples: wet bulb temperature, by month, 6 sites

Modelling strategy (II) – daily weather generator (WG)

- NB all current multivariate WGs start with precipitation and then derive other variables – non-physical
  - Reflects limitations of statistical techniques in early 1980s
- WG here uses modern statistical methods to preserve physical relationships between variables as implemented in numerical weather prediction models (see next slide)
- WG to be driven by indices reflecting results from Reading team to generate "hydrologically interesting weather"

Modelling strategy (III) – daily WG structure

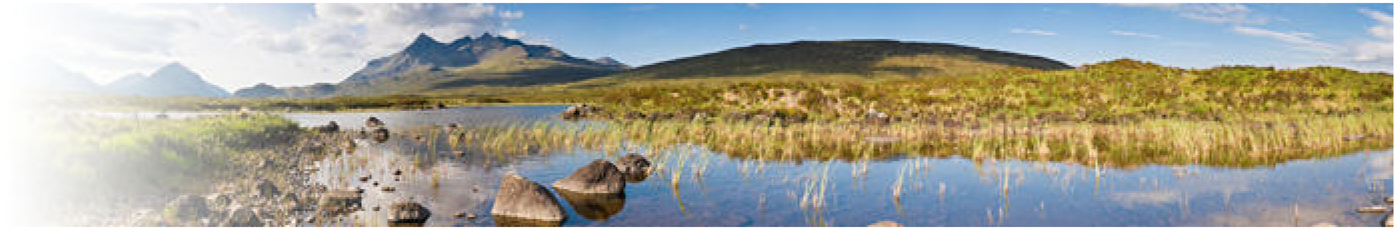


Software development

- GLIMCLIM evolved from code written in Fortran 77 in mid 1990s – substantially expanded since
  - Model structures, site attributes, large-scale climate covariates etc. defined via definition files
  - Manual editing required – tedious and error-prone
  - Results need to be exported to other software for further processing, visualisation etc.
- Currently working on interface to R (www.R-project.org)
  - Freely available
  - Object-oriented programming environment – can write scripts to automate all procedures e.g. updating models
  - Excellent graphical facilities for visualisation etc.

Model development

- Limited progress to date pending software development
- Preliminary results available for daily pressure in Thames catchment
  - GLM with normal distributions
  - Both mean and variance vary through time – need to incorporate joint mean-variance modelling into GLIMCLIM
  - Inter-site residual correlations fairly high so imputation should be fairly precise



Any questions?