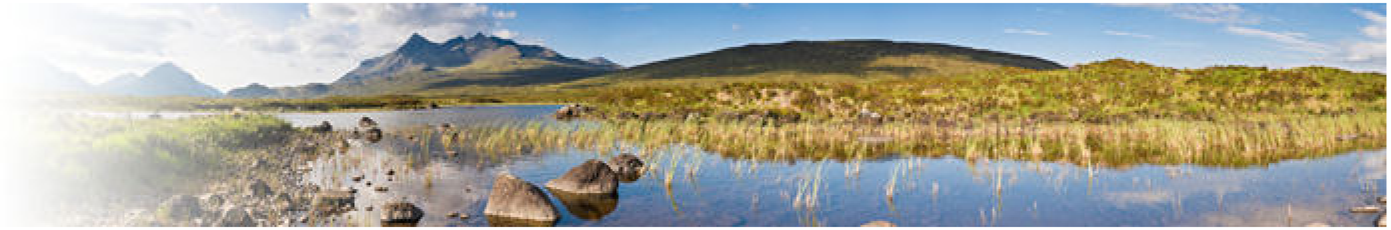
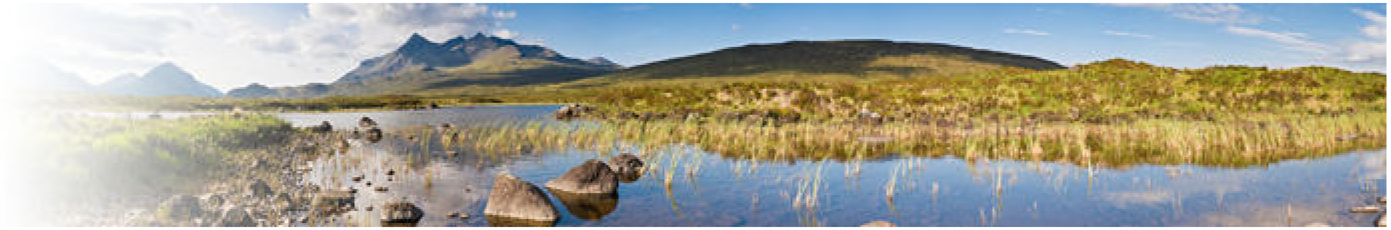


Hydrological extremes and feedbacks in the changing water cycle (HydEF)

Imperial College London
British Geological Survey
University of Reading
University College London

Steering group meeting, 15th February 2012, Imperial College

Changing water cycle



Agenda

11.30-12.45

- *Imperial*: Critical analysis of the JULES land surface model for runoff, recharge and evaporation estimation across scales (~20 mins)
- *Imperial*: Progress on new yield assessment methods and the Isle of Wight water resources adaptation case study (~20 mins)
- *BGS*: The role of groundwater in the changing water cycle for the Thames and Eden catchments: An update of BGS activities (~30 mins)

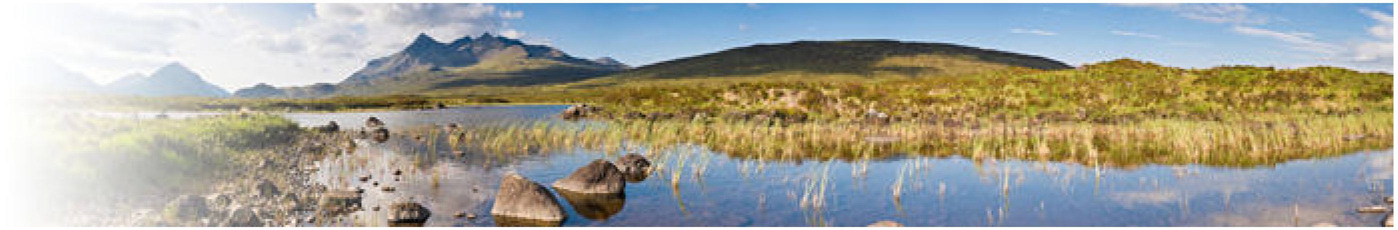
13.30-14.30

- *UCL*: Driving the hydrology: high-resolution weather generation (~30 mins)
- *Reading*: Towards improved simulation of hydrological extremes in response to climate change: linking atmospheric dynamics to winter floods (~30 mins)

14.30-15.00 Overview of other relevant projects

15.00-15.30 Discussion, feedback and agreed actions

Changing water cycle



Hydrological extremes and feedbacks in the changing water cycle (HydEF)

Short introduction

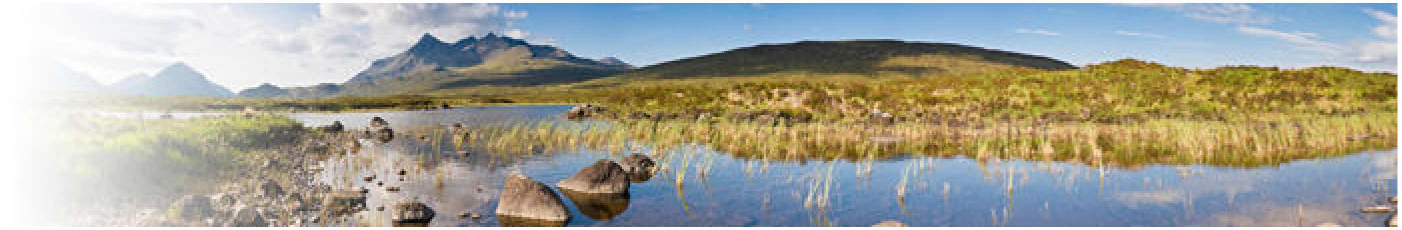
NATURAL ENVIRONMENT RESEARCH COUNCIL

Imperial College London

British Geological Survey NATURAL ENVIRONMENT RESEARCH COUNCIL

UCL

University of Reading

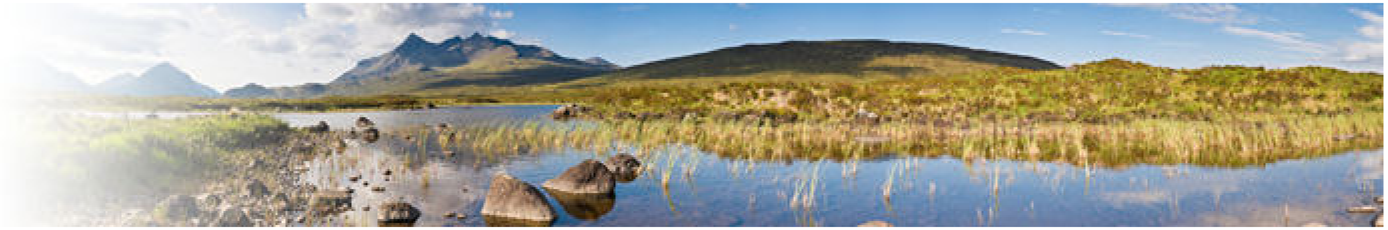


Changing Water Cycle programme – funded projects

Five projects funded in 2010 (~£5M)

Four projects funded in 2011 (~£2.5M)

Current call for third round of projects (~£2.5M)



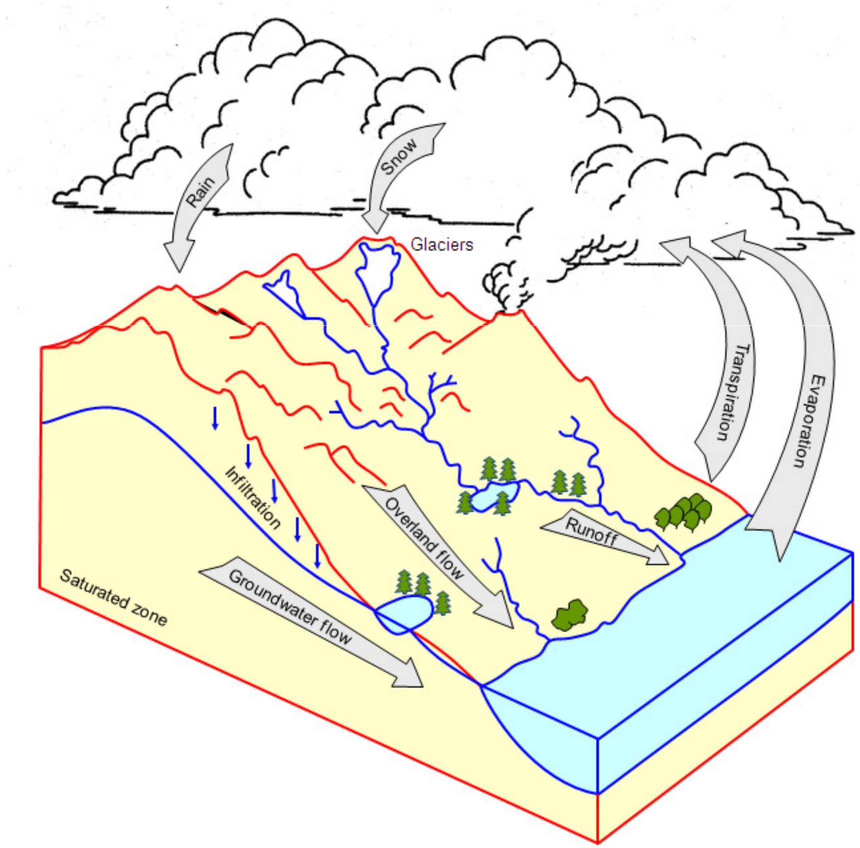
Changing Water Cycle programme - themes

1. Land-ocean-atmosphere interactions
2. Precipitation
3. Detection and attribution
4. Consequences of the changing water cycle

Hydrological extremes and feedbacks in the changing water cycle – **Motivation**

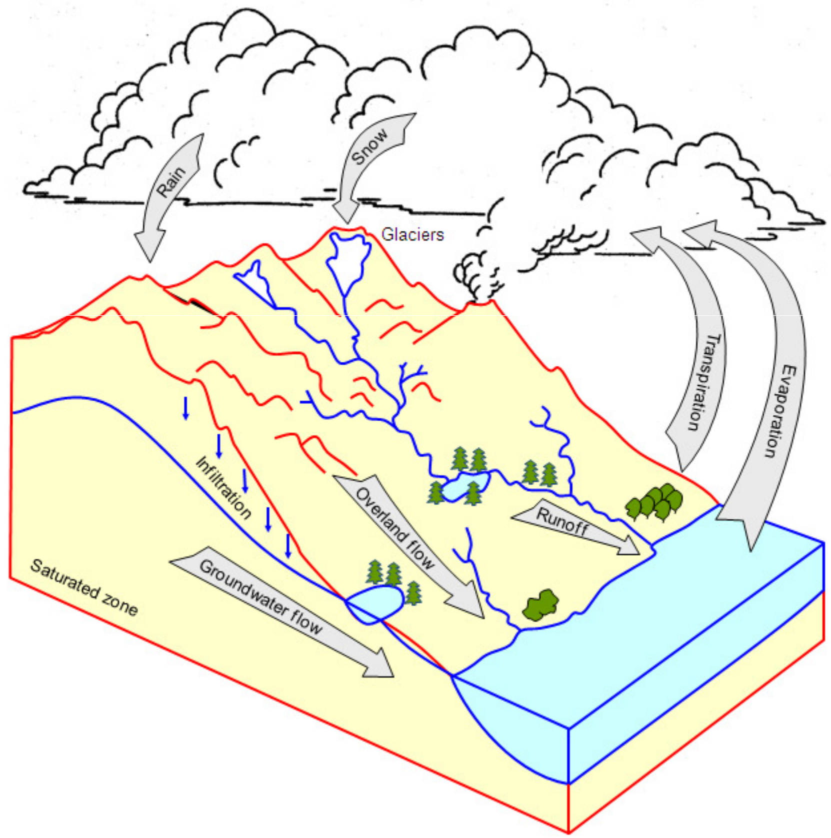
To improve predictions for the next few decades of hydrological storages and fluxes

To understand the consequences of the changing water cycle for water-related natural hazards

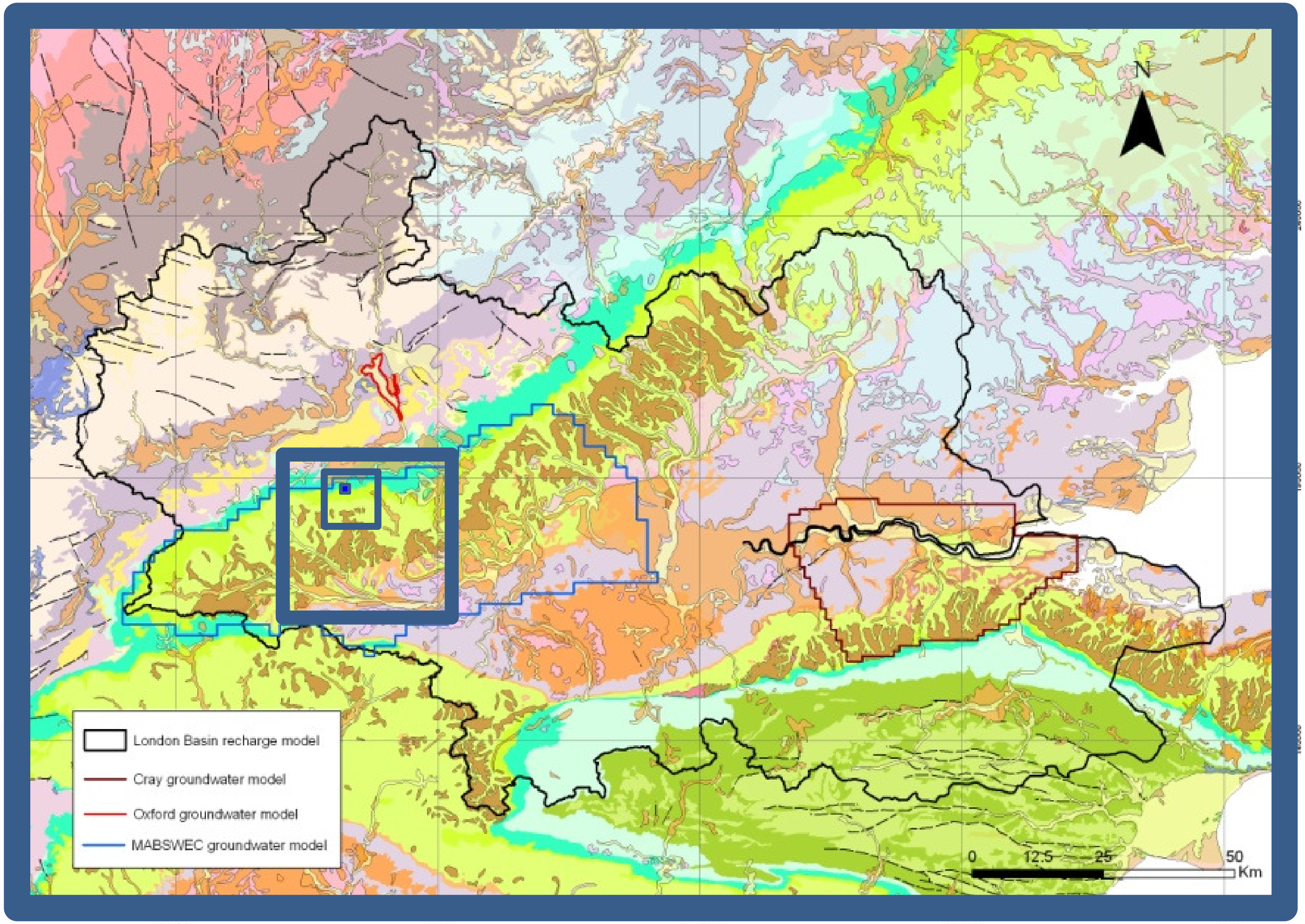


Hydrological extremes and feedbacks in the changing water cycle –
Scientific challenges

- Climate variability and change
- New extremes in hydrology and hydrogeology
- Scaling up hydrology, scaling down climate

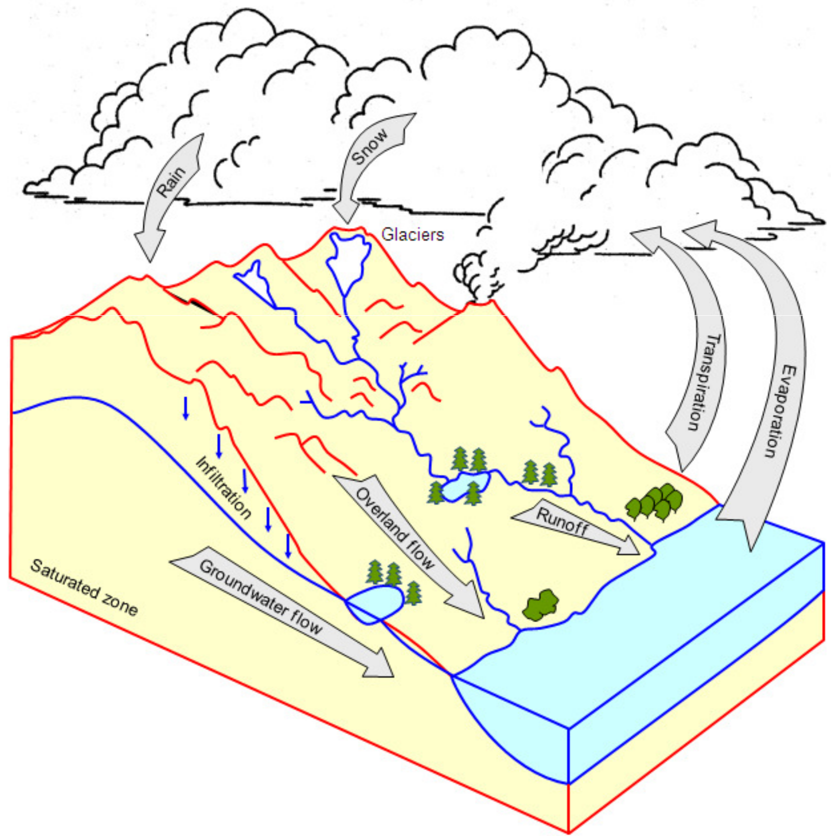


Hydrological extremes and feedbacks
in the changing water cycle –
Scientific challenges

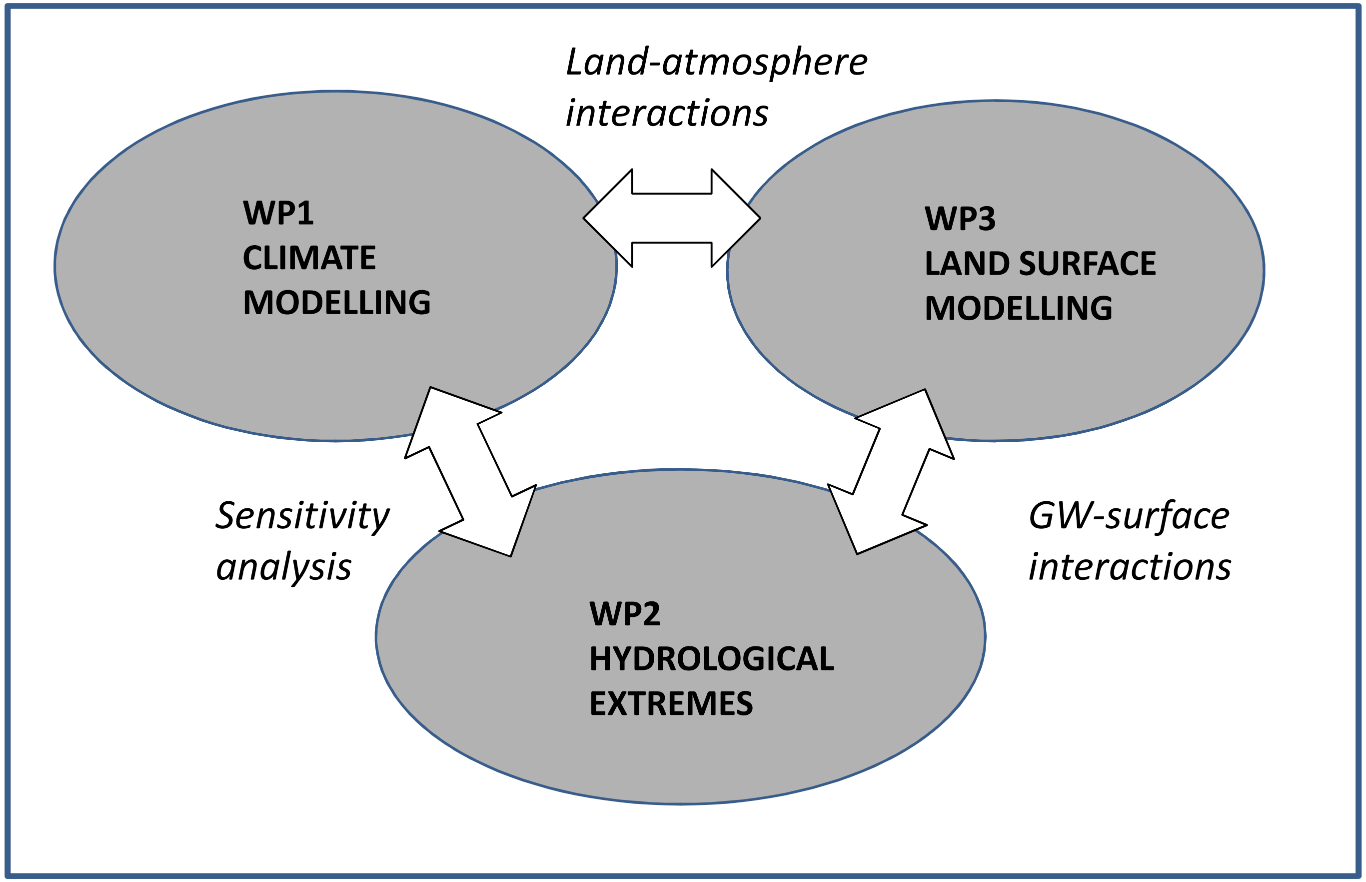


Hydrological extremes and feedbacks in the changing water cycle –
Work packages

1. To improve climate modelling capability for hydrological applications
2. To improve hydrological and hydrogeological models in terms of modelling future extremes...
3. ...and in terms of providing feedbacks to climate models



Hydrological extremes and feedbacks in the changing water cycle –
Work packages



WP1: Climate modelling

A. To identify hydrologically-relevant climate indices and assess the value of current climate models
B. To improve downscaling techniques to exploit new-generation GCMs
C. To produce credible estimates of uncertainty

WP2: Hydrological extremes

A. To incorporate small-scale process understanding into hydrological and hydrogeological models under extremes
B. To develop methods for multi-scale assessment of water resources
C. To develop methods for modelling hydrological non-stationarity

WP3: Land surface models

To evaluate and reduce the feedback errors associated with LSMs:

A. Errors associated with lower boundary conditions
B. Errors associated with GW & horizontal movement of water
C. Errors associated with spatial heterogeneity

Hydrological extremes and feedbacks
in the changing water cycle –
Case studies

- Thames
- Eden
- Isle of Wight

Hydrological extremes and feedbacks in the changing water cycle – **Staff and PhD students**

Imperial College
Neil McIntyre, Adrian Butler, Christian Onof, Howard Wheater, Nataliya Bulygina, Mike Simpson, Christina Bakopoulou, Kirsty Upton (with BGS)

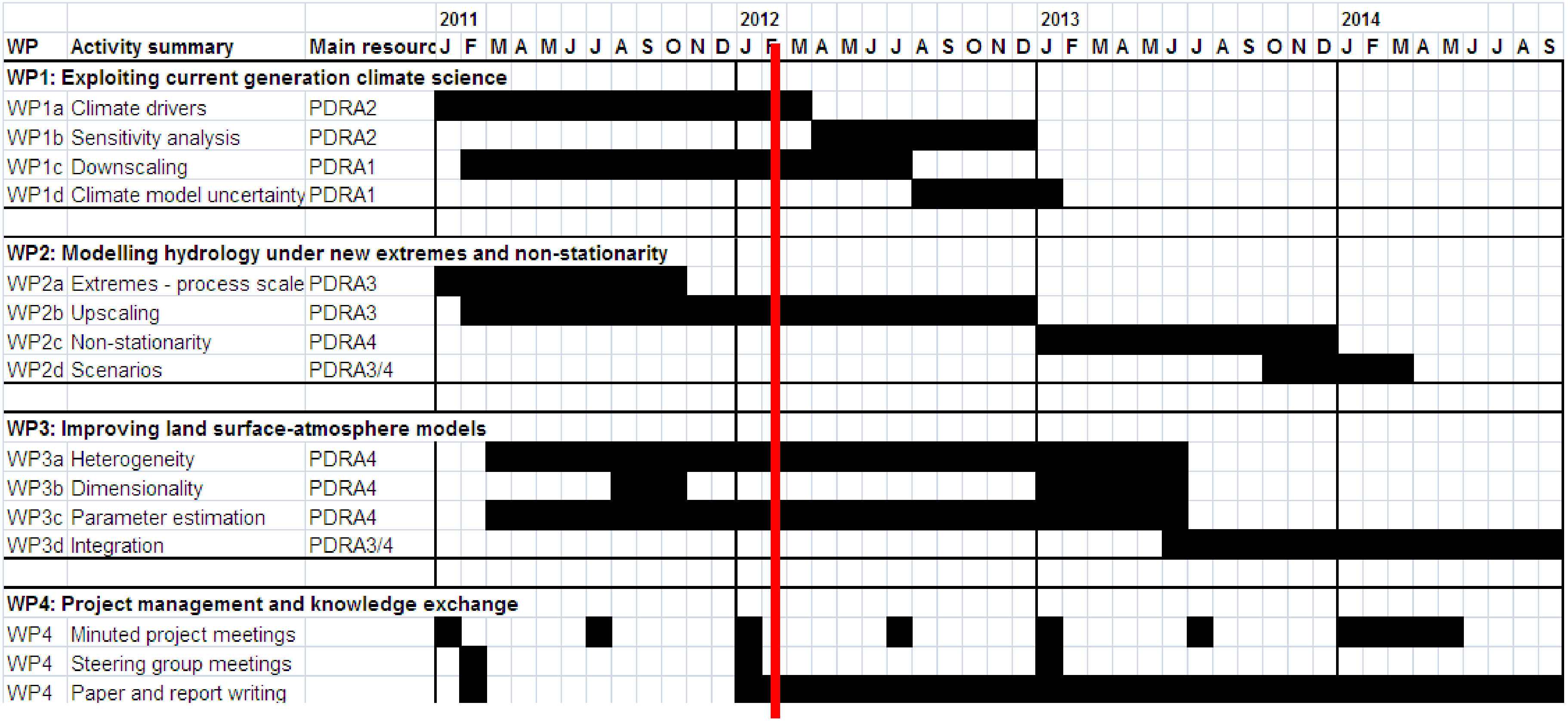
British Geological Survey
Denis Peach, Andrew Hughes, Chris Jackson, David Macdonald, Stephanie Bricker, PDRA

University of Reading
Andrew Wade, Nigel Arnell, Richard Allan, David Brayshaw, David Lavers

University College London
Richard Chandler, Chiara Ambrosino

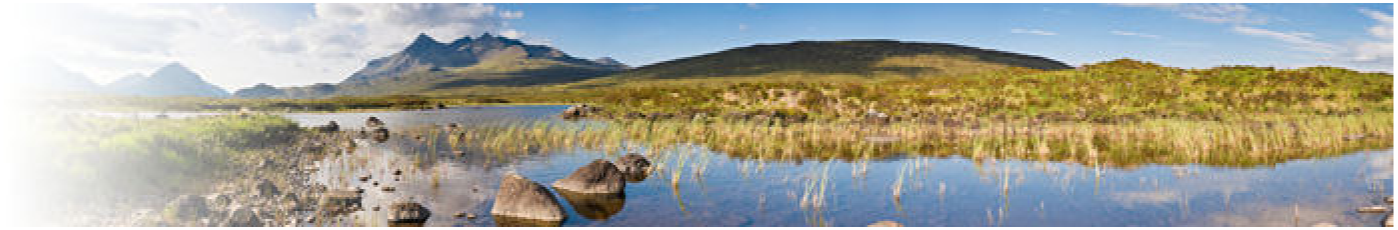
Hydrological extremes and feedbacks in the changing water cycle

Programme



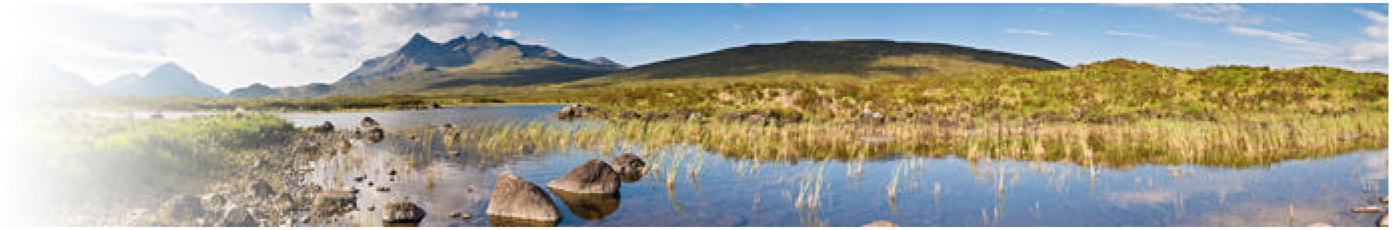
Hydrological extremes and feedbacks in the changing water cycle – **Steering group**

- Grantham Institute for Climate Change
- CEH Wallingford
- Environment Agency
- Thames Water
- Southern Water
- Veolia Water
- CWC Science Management Team



Critical analysis of the JULES land surface model for runoff, recharge and evaporation estimation across scales

Nataliya Bulygina
Christina Bakopoulou
Adrian Butler
Neil McIntyre



Joint UK Land Environment Simulator - JULES

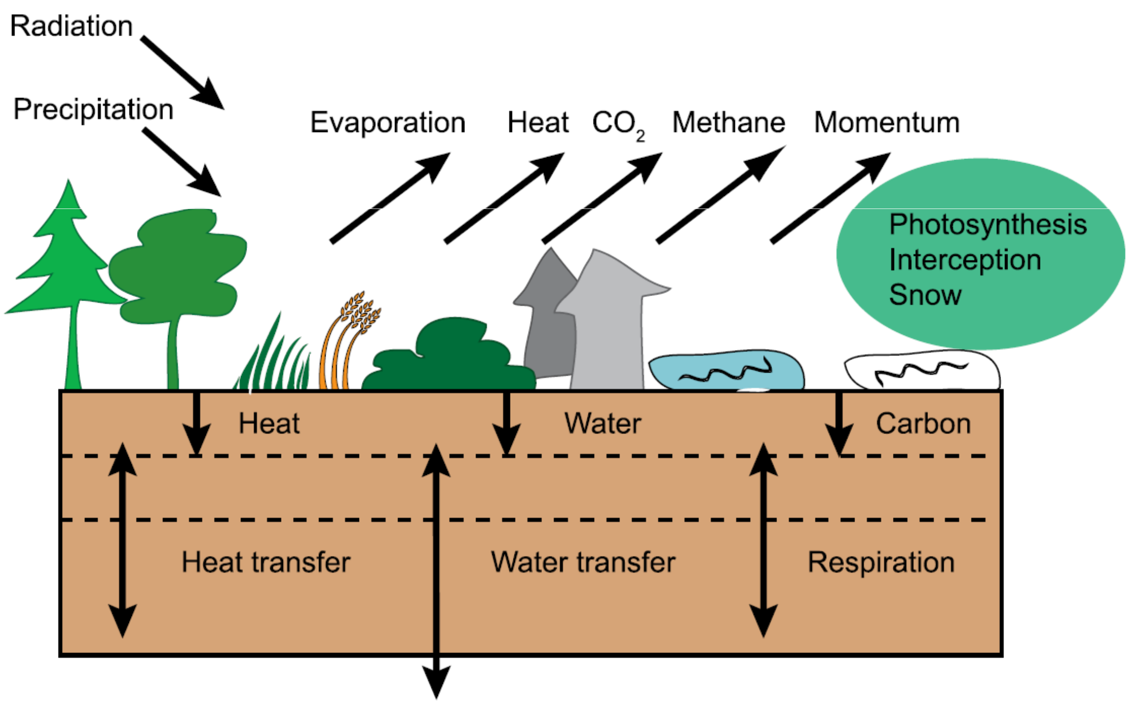
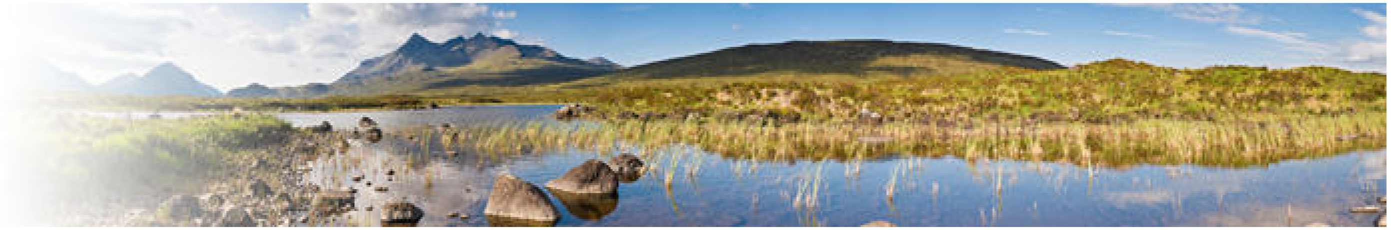


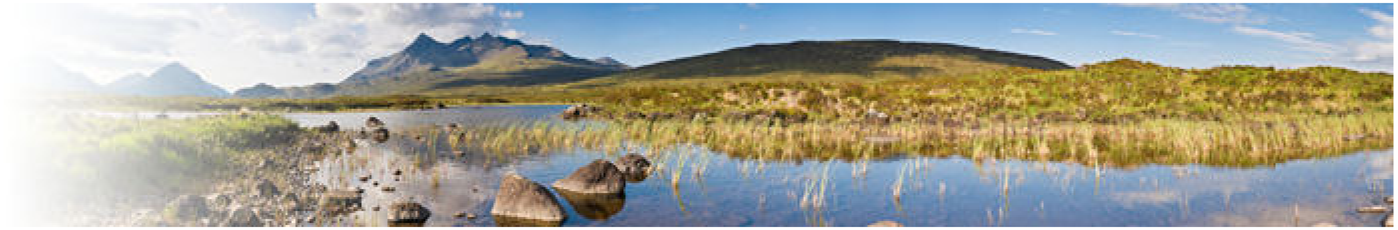
Figure 1. Schematic diagram of the new Land Surface Model, JULES.

http://www.igbp.net/documents/NL_66-3.pdf



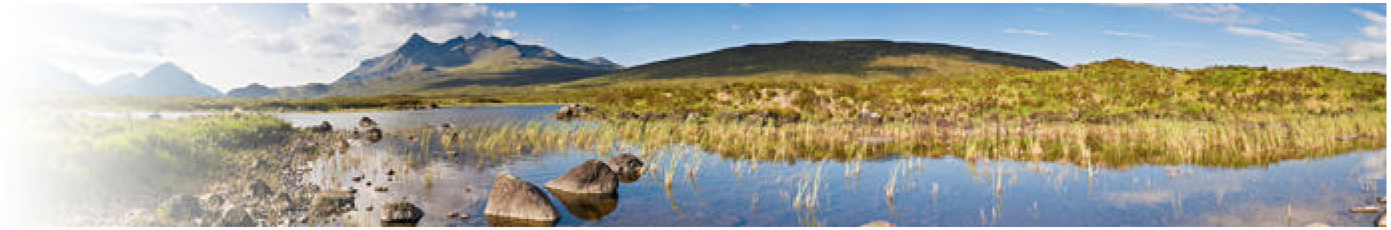
What we like about JULES

- Widely used in UK and always evolving - there is a "JULES community"
- Simulates interactions between hydrology, carbon and energy
- Code is open-source
- Potentially valuable as a groundwater recharge model

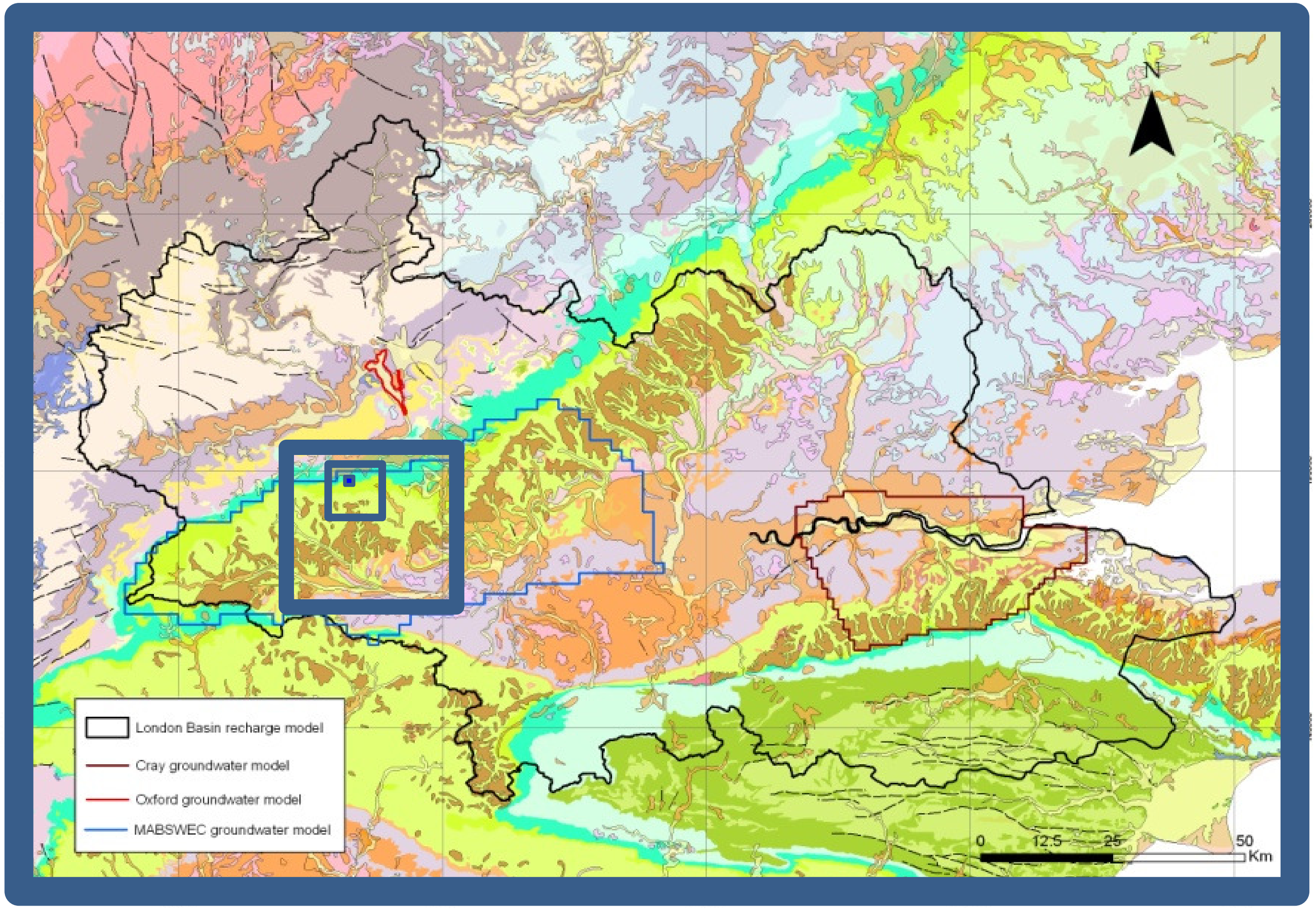


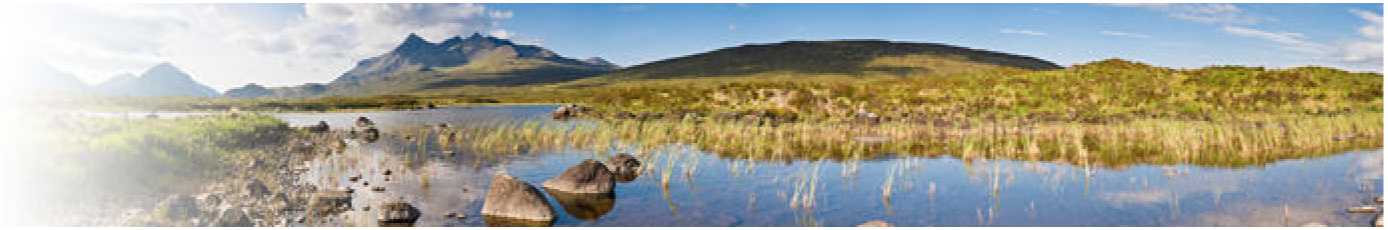
What we don’t like about JULES

- Its application at large grid scales has little scientific logic
- There are ~80 parameters per cell
- It has a fixed ‘free drainage’ lower boundary condition
- Current applications do not include groundwater
- There has been virtually no validation of the model



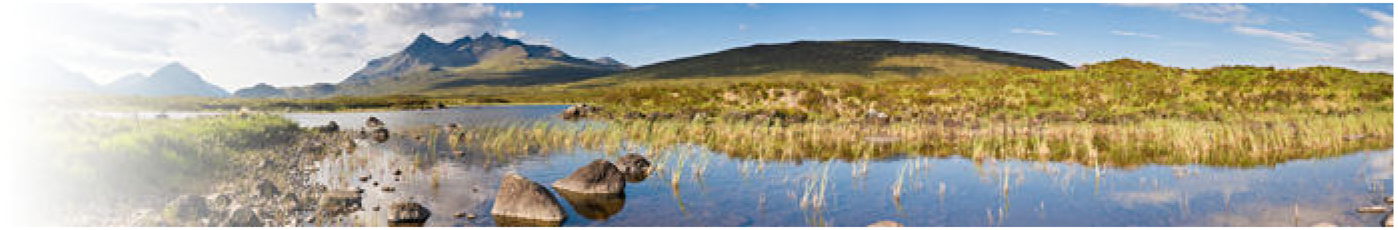
What we don’t like about JULES





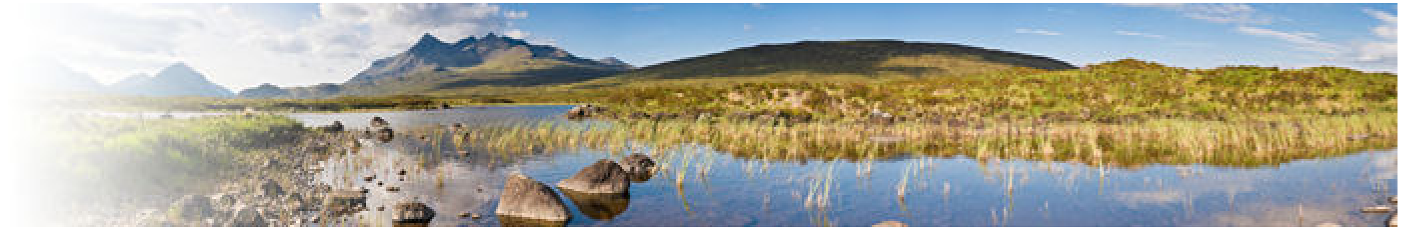
Hypotheses being investigated

- The process equations in JULES are reasonably accurate at very small scales (~0.01m2)
- The equations in JULES remain realistic, or at least useful, at medium to large scales ($100m^2$–$10000km^2$)
- Accuracy of outputs can be significantly improved by better representation of heterogeneity and better parameter estimation techniques.
- There is a tangible benefit in having a suitable representation of groundwater in JULES.



Research strategy outline

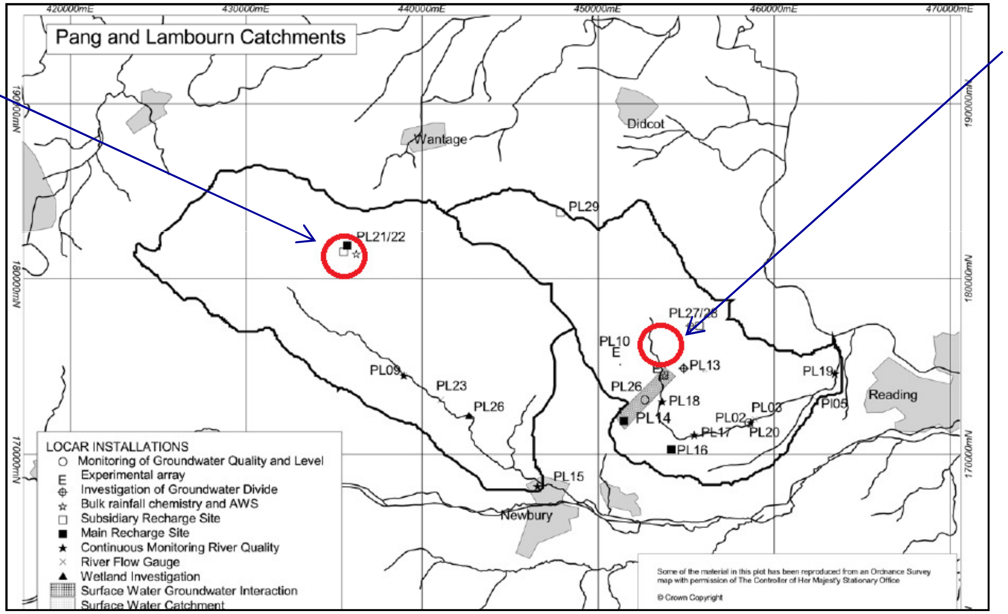
- Case studies of Thames and Eden
- Multi-scale analysis
  - Very small scale (experimental sites)
  - Small scale (hill-slopes and small catchments)
  - Medium scale (Kennet, 1000km2)
  - Large scale (Thames, 10000km2)
- Start by focussing on Kennet and LOCAR sites



JULES - very small scale analysis

Warren Farm

Grassland recharge site, located high on the Lambourn Downs, where livestock are grazed
Located on Upper Chalk – no major drift cover

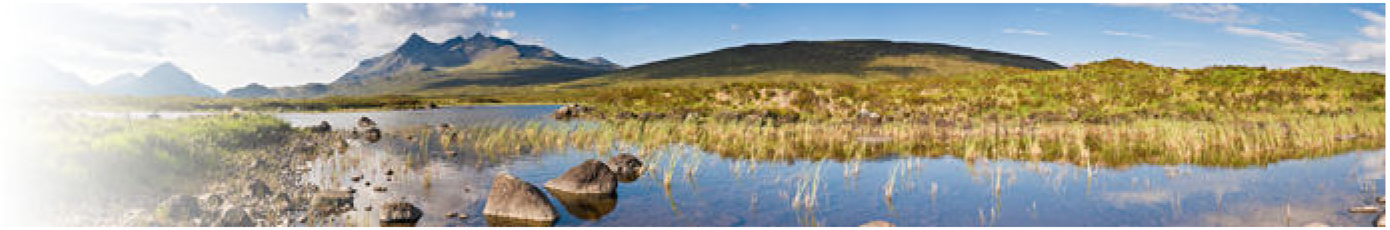


Frilsham Meadow

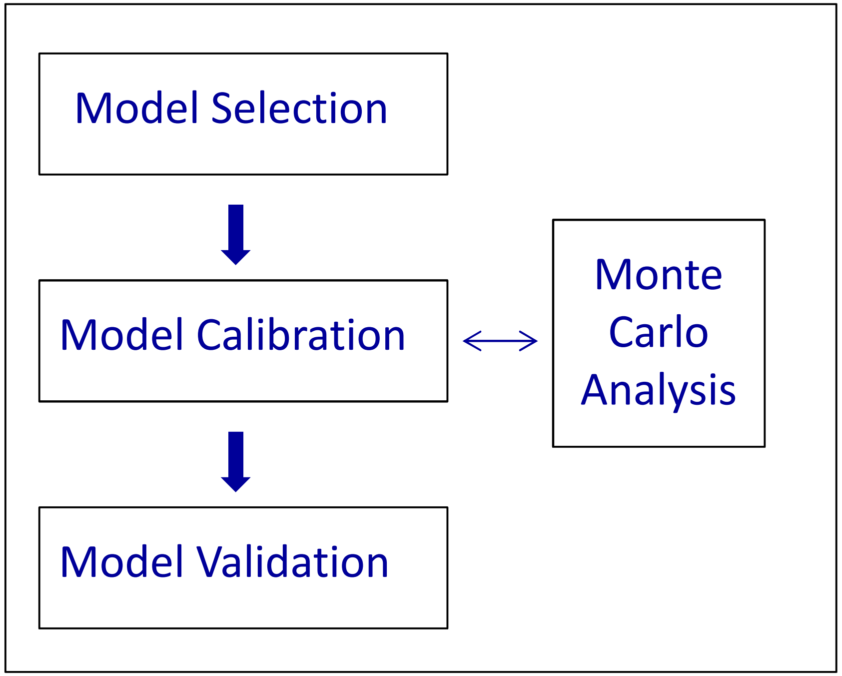
Grassland recharge site, located next to the River pang, in the floodplain
Located on drift deposits, solid formation below is Seaford Chalk

AWS data: 20 October 2002 to 28 December 2008 (hourly)
Soil moisture data – Neutron Probes: 3 January 2003 to 18 December 2008 (fortnightly)

AWS data: 10 October 2002 to 19 December 2008 (hourly)
Soil moisture data – Profile Probes: 23 December 2002 to 1 January 2009 (15 minutes)



JULES - very small scale analysis



Calibration period: 2003 to 2006 (4 years)

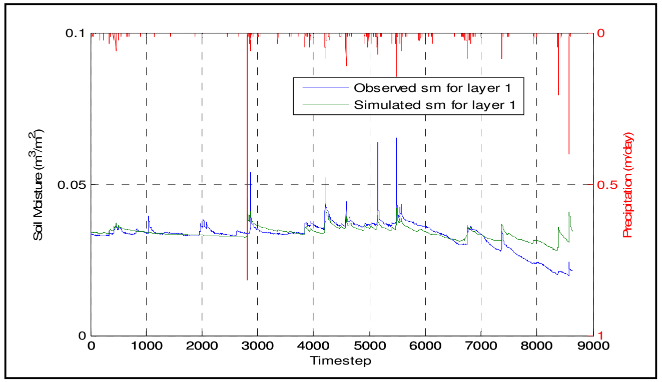
Validation period: 2007 to 2008 (2 years)

b	Exponent in soil hydraulic characteristics
ψ_s	Absolute value of the soil matric suction at saturation
K_s	Saturated hydraulic conductivity
θ_s	Volumetric soil moisture concentration at saturation point
θ_c	Volumetric soil moisture concentration at saturation point
θ_w	Volumetric soil moisture concentration at saturation point
C_s	Dry soil volumetric heat capacity
λ_{dry}	Dry soil thermal conductivity
α	Soil albedo [-]

JULES - very small scale analysis

Monte Carlo perturbation of parameter ψ_s

Soil Layer 1 (Grimsbury Wood)



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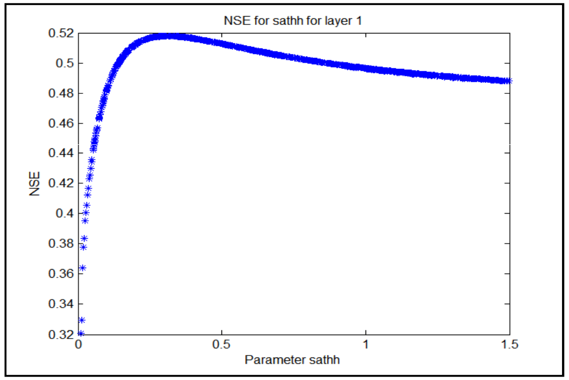
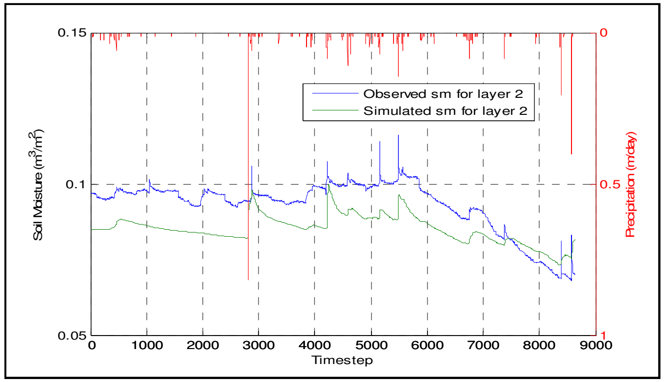


Soil Layer 2 (Grimsbury Wood)



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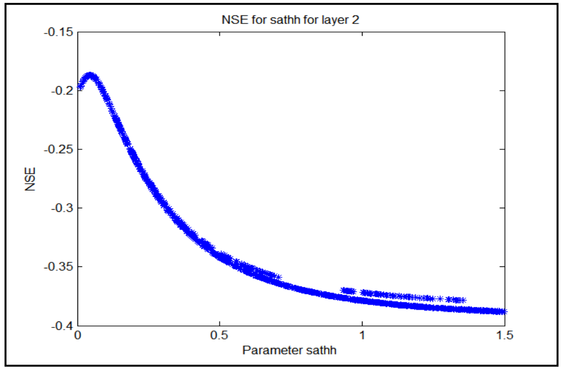
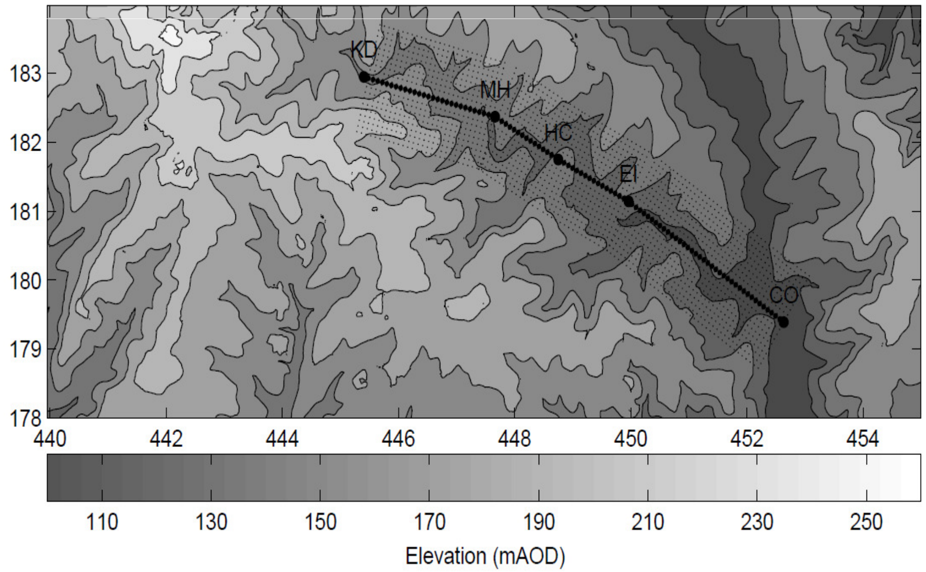


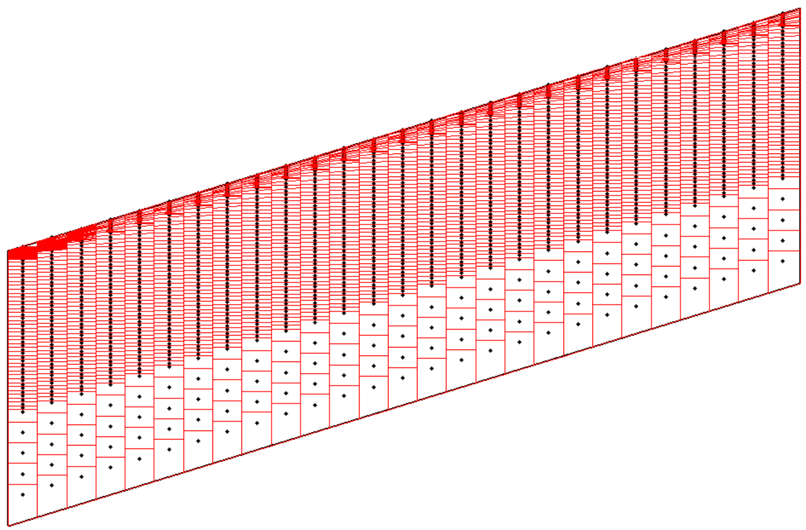
JULES – hillslope analysis

1) 1D Richards' equation-based model (model of Ireson et al, 2009)

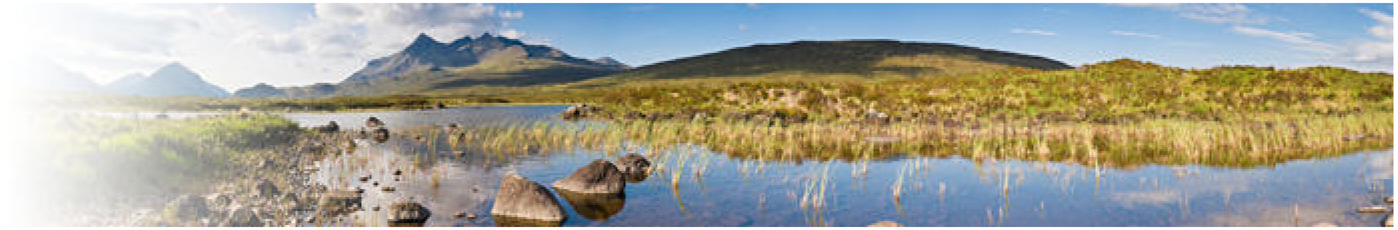
2) 2D Richards' equation-based model for a hillslope



Hillslope topography



Mesh used in the hillslope 2D model

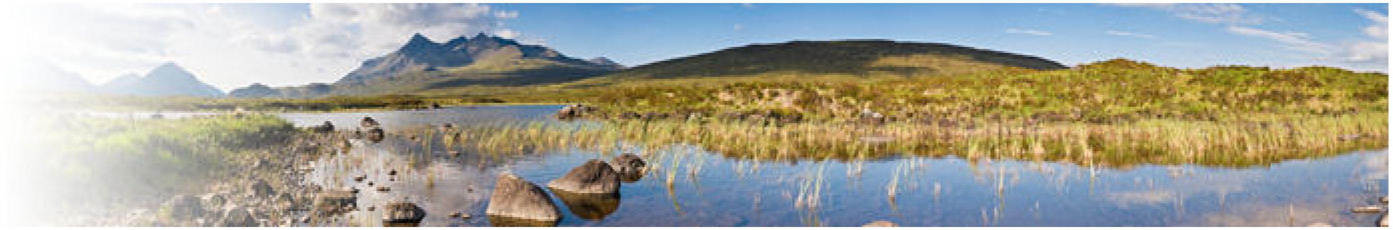


JULES – hillslope analysis

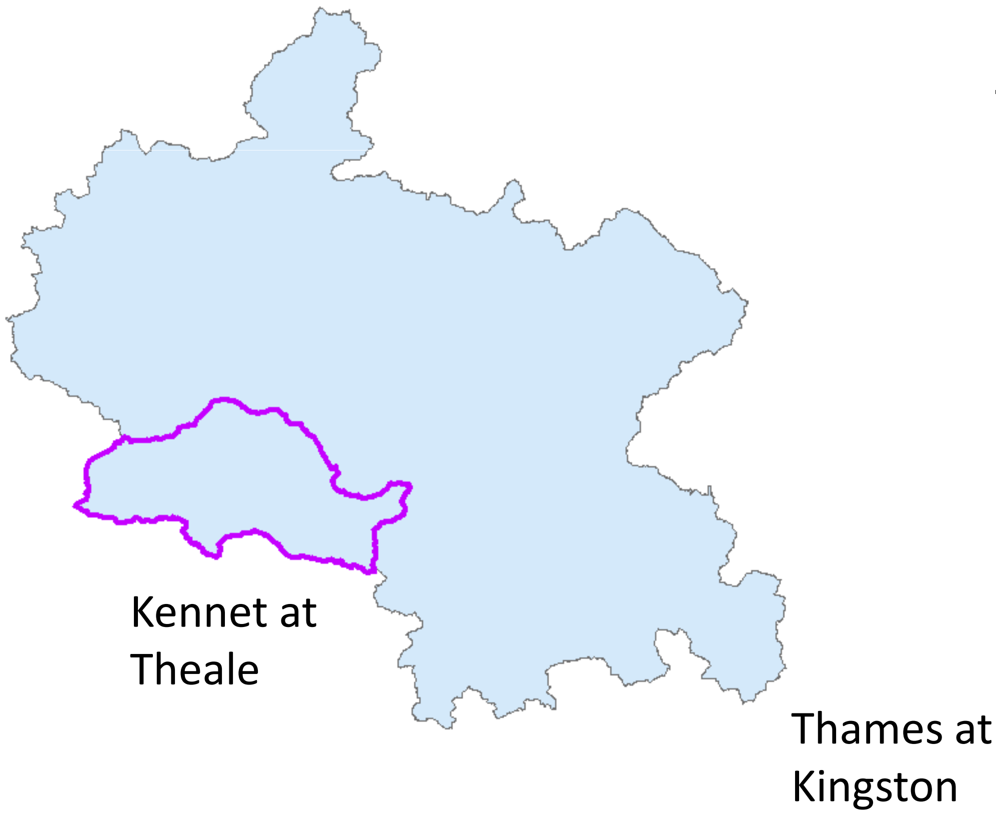
In the context of these tests on Chalk soils:

- The default JULES parameterisation is questionable.
- Simplistic lower boundary leads to inadequate soil moisture variability, but has little effect on evaporation.
- Lateral fluxes in unsaturated zone can safely be neglected.
- Lack of groundwater leads to unrealistic discharge.

Changing water cycle



JULES - medium scale analysis



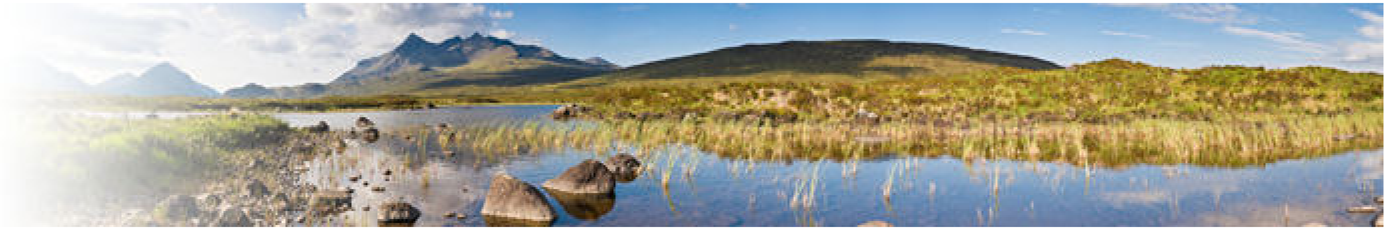
<u>Kennet at Theale</u>

AREA: 1040 km^2

SAAR: 760 mm

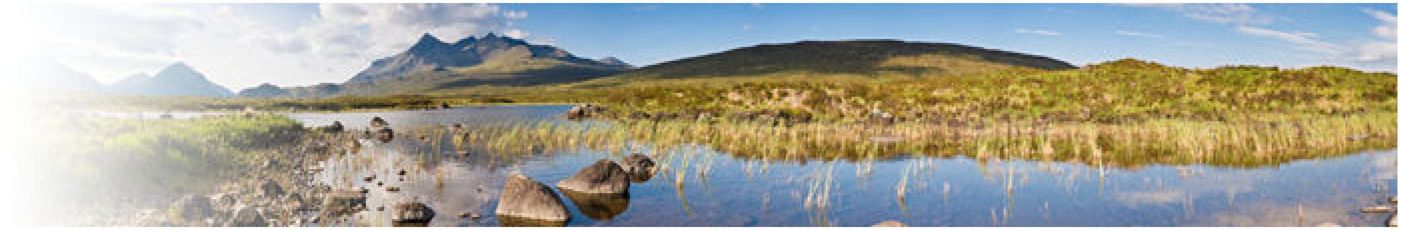
BFIHOST: 0.77

URBEXT: 0.014

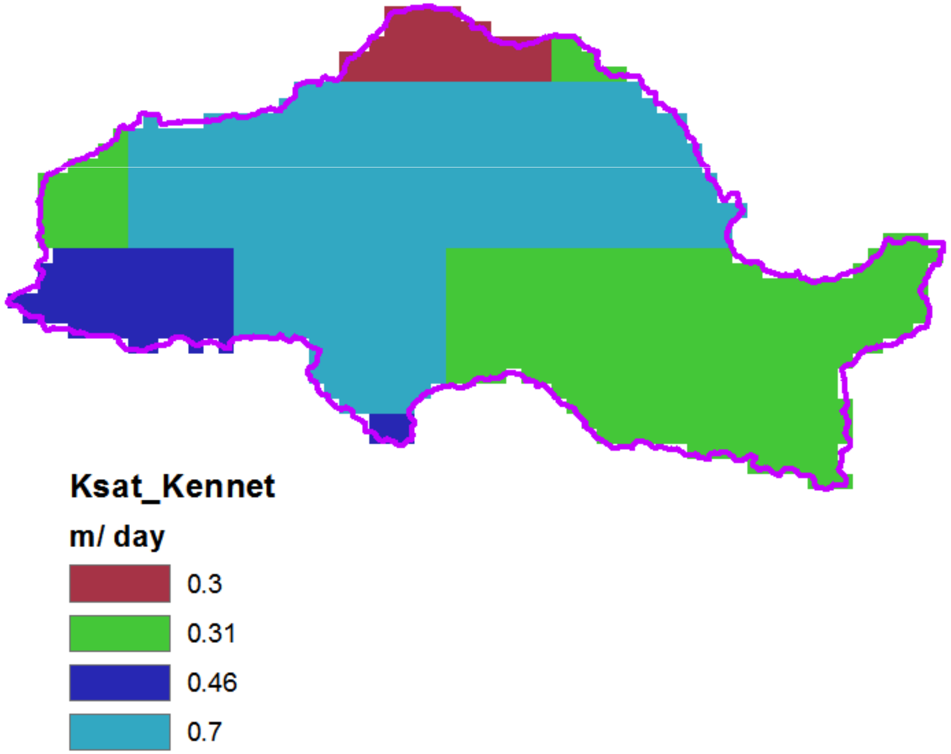


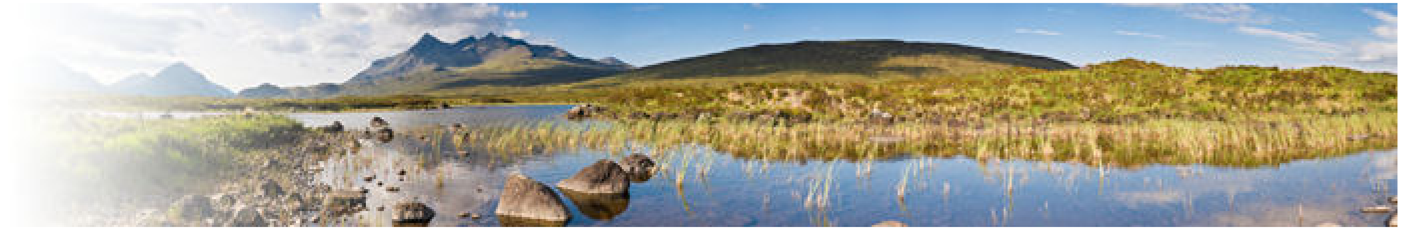
JULES - medium scale analysis

JULES input	Source	Website
1 km grid	50 m resolution raster file	http://edina.ac.uk/digimap
Vegetation cover	50 m IGBP 2007 land cover map	http://webmap.ornl.gov/wcsdown
Soil parameters	0.5 degree IGBP maps	http://cms.ncas.ac.uk/cap_interface
Meteorological	3 hr, 0.5^0 WATCH reanalysis data	http://www.eu-watch.org/data_availability
Flow observations	Daily flow data	http://www.ceh.ac.uk/data/nrfa/data



JULES - medium scale analysis



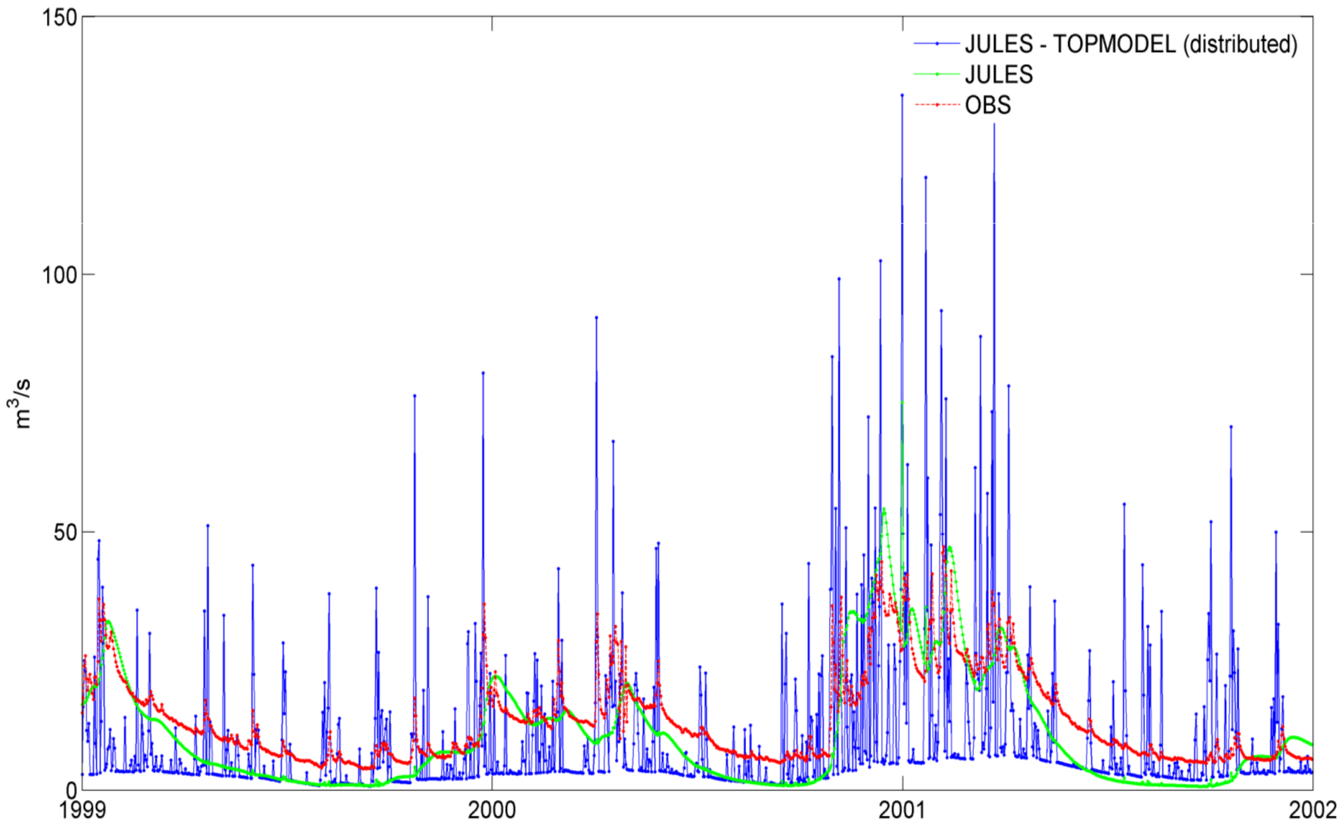


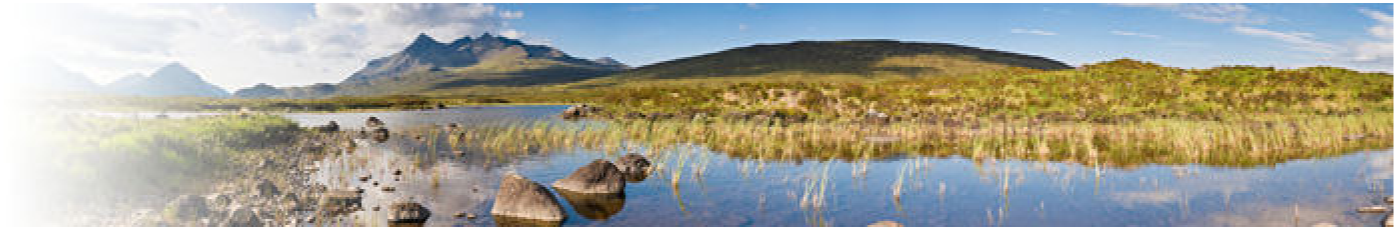
JULES - medium scale analysis

Sensitivity analysis using alternative setups of JULES:

- Standard setup
- Deep soil column
- JULES-PDM
- JULES-TOPMODEL

JULES - medium scale analysis

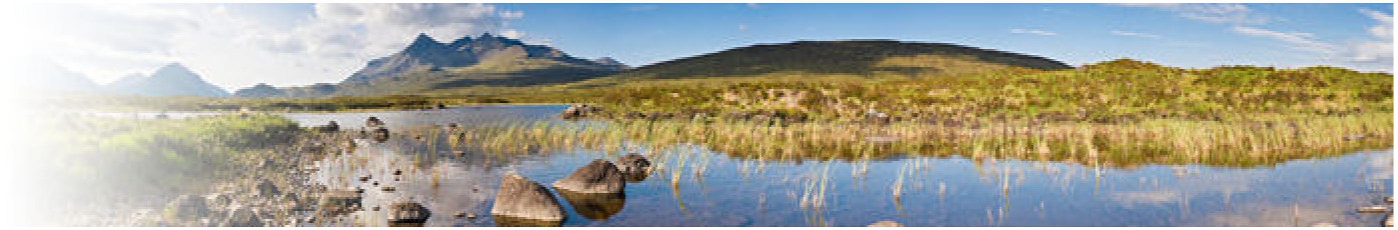




Headline outcomes so far

- Small scale analysis illustrates that JULES has increasing soil moisture errors as depth increases.
- Hill-slope analysis also illustrates problems with internal functioning of JULES, and flow estimates.
- Kennet analysis illustrates significant scale and model structure problems: where reasonable flow outputs are obtained, its not because the model is sensible.
- But no evidence yet that evaporation/energy flux estimates are unreasonable.

Changing water cycle



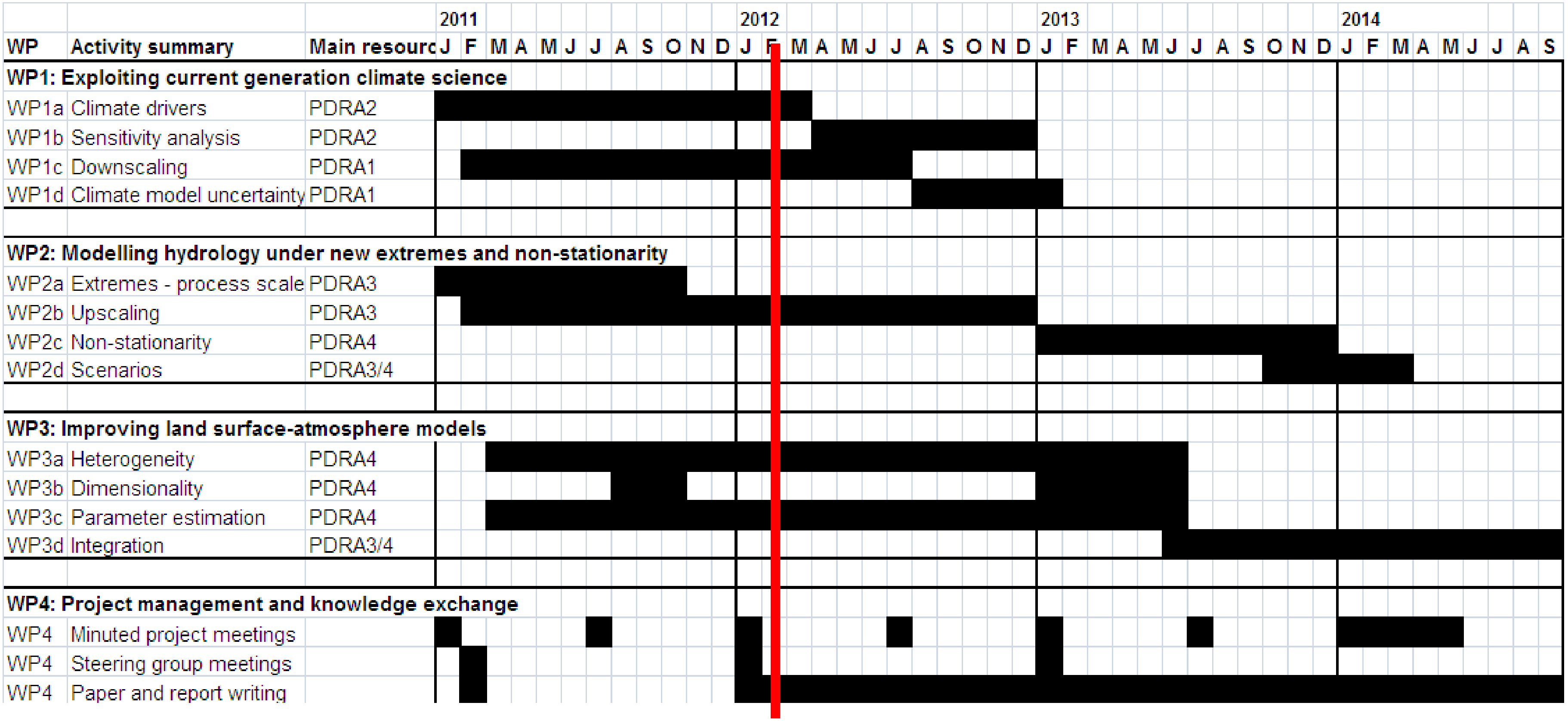
Summary of work plan on WP3

- Very small scale analysis (continuing)
- Hill-slope analysis (shelved)
- Kennet analysis (continuing, to be our focus over next year)
- Thames and Eden catchments (not yet started)

- Link to MABSWEC model and WP2 (started)
- Groundwater-in-JULES working group (continuing)
- Data retrieval (all spatial data sets ready except 1km2 gridded climate data)

Hydrological extremes and feedbacks in the changing water cycle

Programme



Changing Water Cycle Round 1 – other funded projects

Constraining the response of the hydrological cycle, land surface and regional weather to global change
(Oxford, CEH, Exeter)

Hydrological cycle understanding via process-based global detection, attribution and prediction
(Reading, CEH, Southampton, Exeter, Edinburgh, East Anglia)

Soil Water - Climate Feedbacks in Europe in the 21st Century
(CEH, Reading, Leicester)

Using Observational Evidence and Process Understanding to Improve Predictions of Extreme Rainfall Change
(Newcastle, Exeter)

Changing Water Cycle Round 2 (South Asia) – funded projects

Hydrometeorological feedbacks and changes in water storage and fluxes in northern India
(Imperial, BGS, Reading) £0.8M

Mitigating climate change impacts on India agriculture through improved Irrigation water Management
(Heriot-Watt, Cranfield) £0.7M

South Asian Precipitation: a Seamless Assessment - SAPRISE
(Exeter, Reading) £0.9M

Hydrologic and carbon services in the Western Ghats: Response of forests and agro-ecosystems to extreme rainfall events
(Dundee) £0.3M

Hydrometeorological feedbacks and changes in water storage and fluxes in Northern India

Imperial College London

Indian Institute of Science
Bangalore, India

The consortium

UK

Imperial College London
- Wouter Buytaert
- Neil McIntyre
- Brian Hoskins

University of Reading
- Andrew Turner

British Geological Survey
- Chris Jackson
- Andrew McKenzie
- John Bloomfield

India

Indian Institute of Science, Bangalore
- Pradeep Mujumdar
- Muddu Sekhar
- Arindam Chakraborty

Indian Institute of Technology, Kanpur
- Rajiv Sinha

Indian Institute of Technology, Roorkee
- CSP Ojha

UNESCO
- Bhanu Neupane

Imperial PhD projects

1. Tim Foster (Grantham Institute). Hydro-economic modelling of the Isle of Wight for climate impacts assessment
2. Katie Duan (Grantham Institute). Improved downscaling methods for scenarios of rainfall in Southern England for drought risk analysis
3. Tanya Jones (NERC). Scenarios of rainfall and potential evaporation in the Kennet catchment
4. Susana Almeida (Portuguese Government). Improved methods for predicting river flows in poorly gauged areas and under environmental change