Modelling hydrology in JULES: past, present and future

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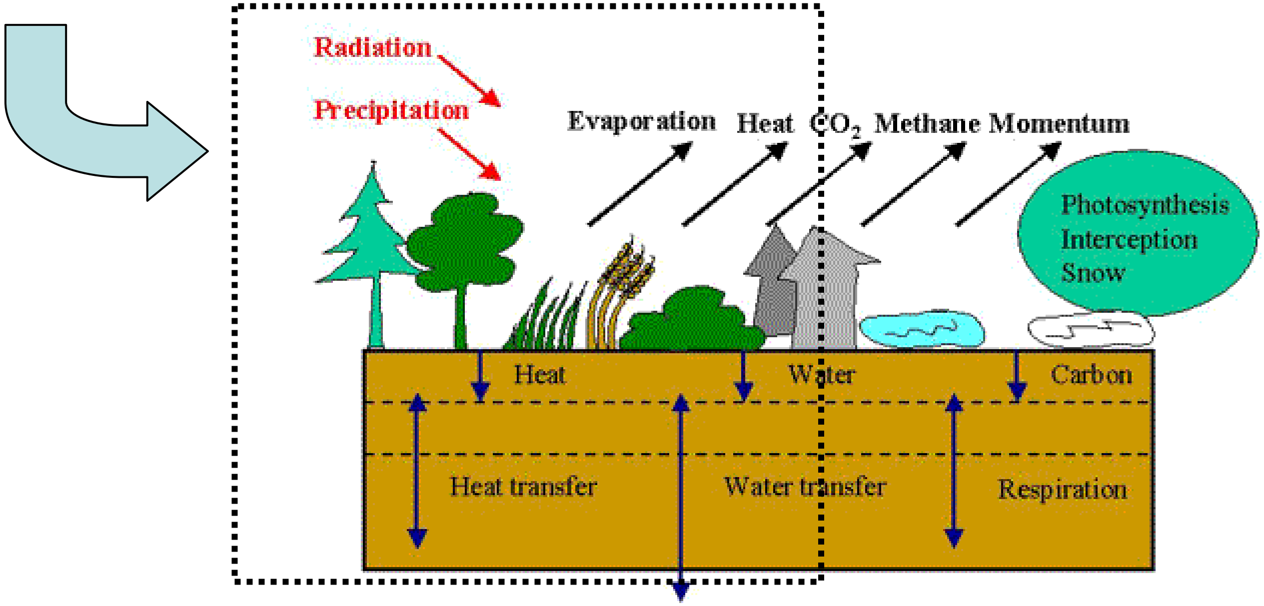
Science expertise: Physical land surface modelling (energy and water), 1-D processes in the soil, representing heterogeneity for water and energy balance modelling, particularly in the Arctic.

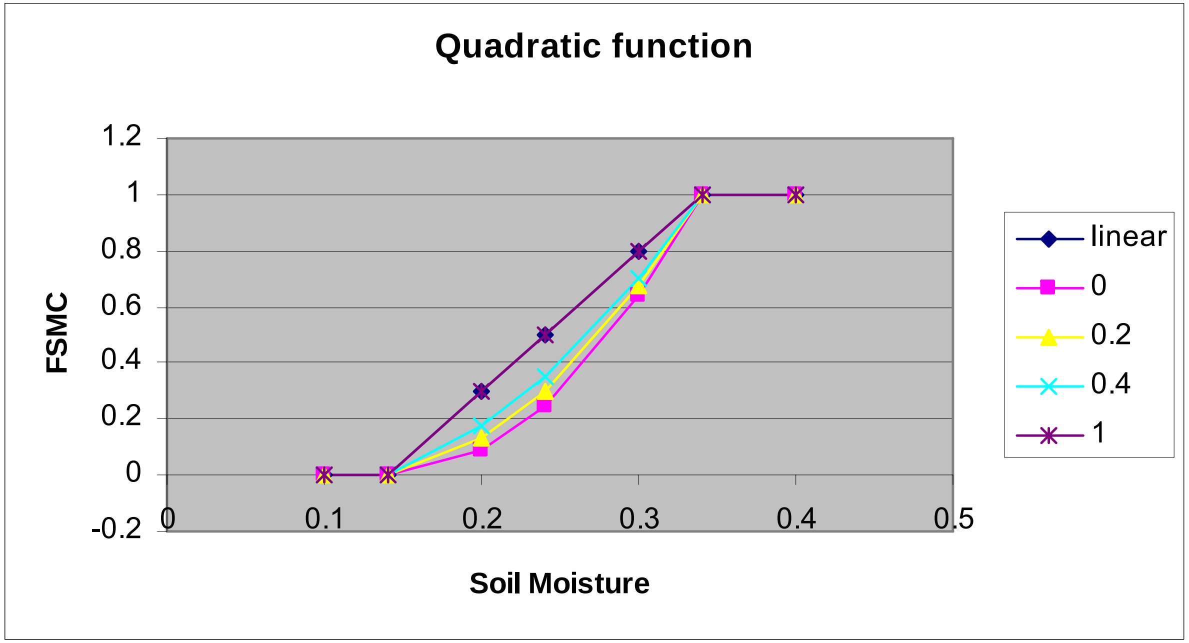


Evaporation Control

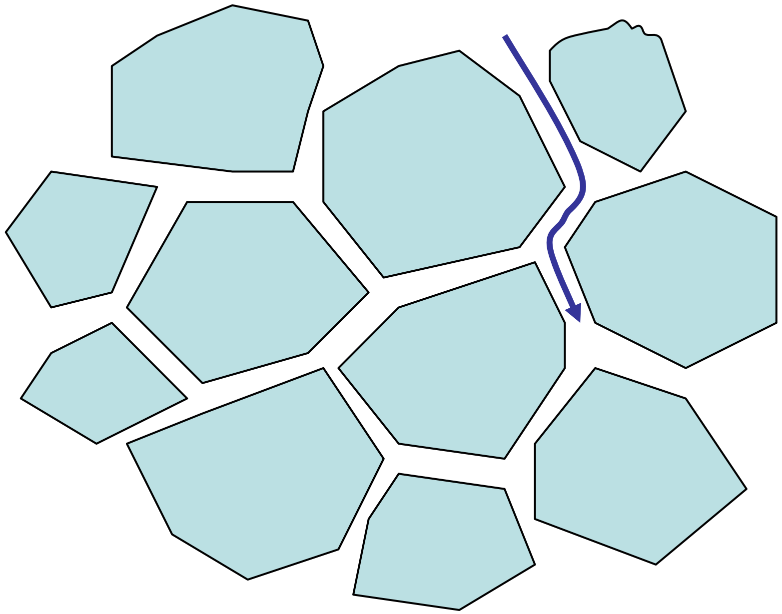
$$\lambda E = PE * FSMC$$

$$FSMC = \frac{(\theta - \theta_w)}{(\theta_c - \theta_w)}$$

New dependency of evaporation on soil moisture trialled

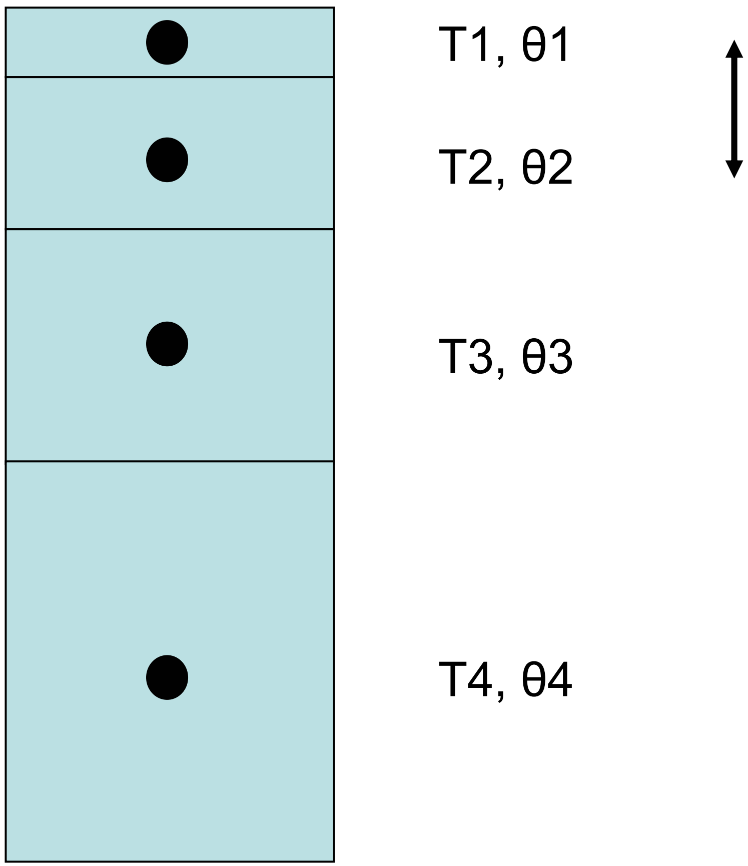


Soil Moisture Processes



- Gravity (drainage)
- Surface tension
- Upward flow
- Evaporation
- Soil Freezing
- Vapour Flow
- Soil swelling/cracking
- Macropores
- Organic soils
- Chalk Soils

Vertical Processes



$$Q = k\left(\frac{\partial \psi}{\partial z} + g\right)$$

$$BrooksandCorey:$$

$$\psi = \psi_s \left(\frac{\theta}{\theta_s}\right)^{-b}$$

$$k = k_s \left(\frac{\theta}{\theta_s}\right)^{2b+3}$$

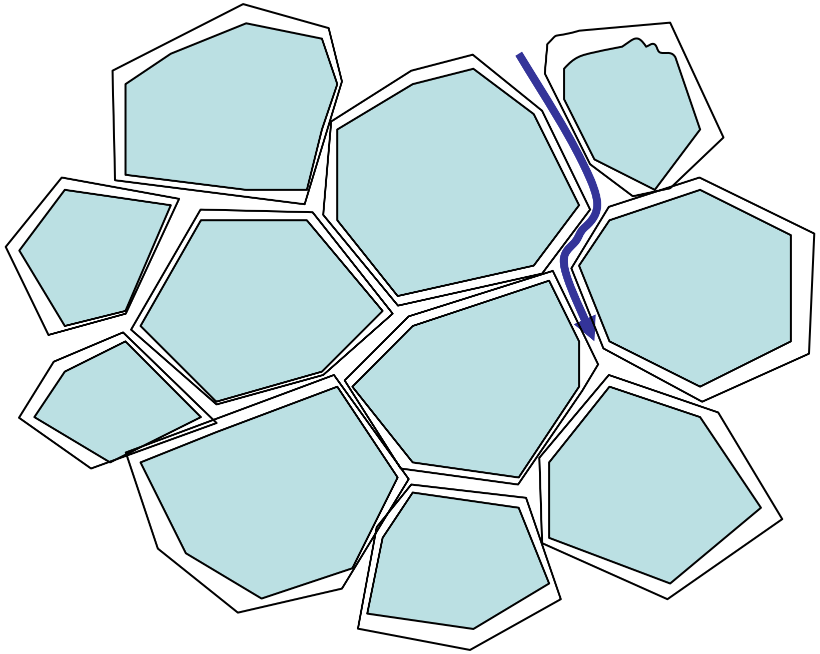
$$vanGenuchten:$$

$$\psi = f(\psi_s, \theta, \theta_s, n)$$

$$k = f(k_s, \theta, \theta_s, n)$$

FAQ: Where is ‘*k*’ calculated?
How to deal with super-saturation?
Solve from bottom-up or top-down?

Frozen Soil Processes



FAQ: Does frozen soil impede water flow or not?

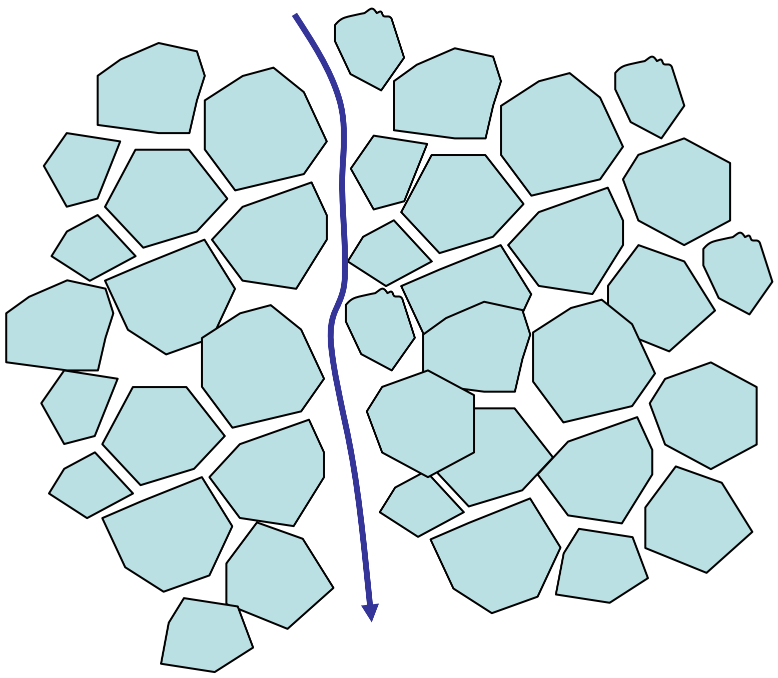
$$\psi = \psi_s \left(\frac{\theta_u}{\theta_s - \theta_f} \right)^{-b} or = \psi_s \left(\frac{\theta_u}{\theta_s} \right)$$

$$k = k_s \left(\frac{\theta_u}{\theta_s} \right)^{2b+3} or = k_s \left(\frac{\theta_u}{\theta_s - \theta_f} \right)$$

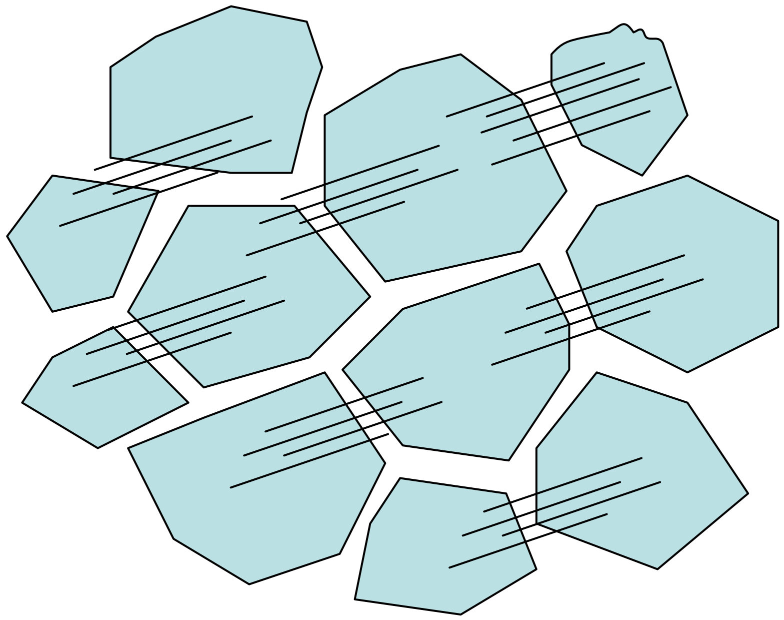
Niu and Yang (2006) suggest spatial heterogeneity allows for infiltration

Unusual Soil Types:

Chalk



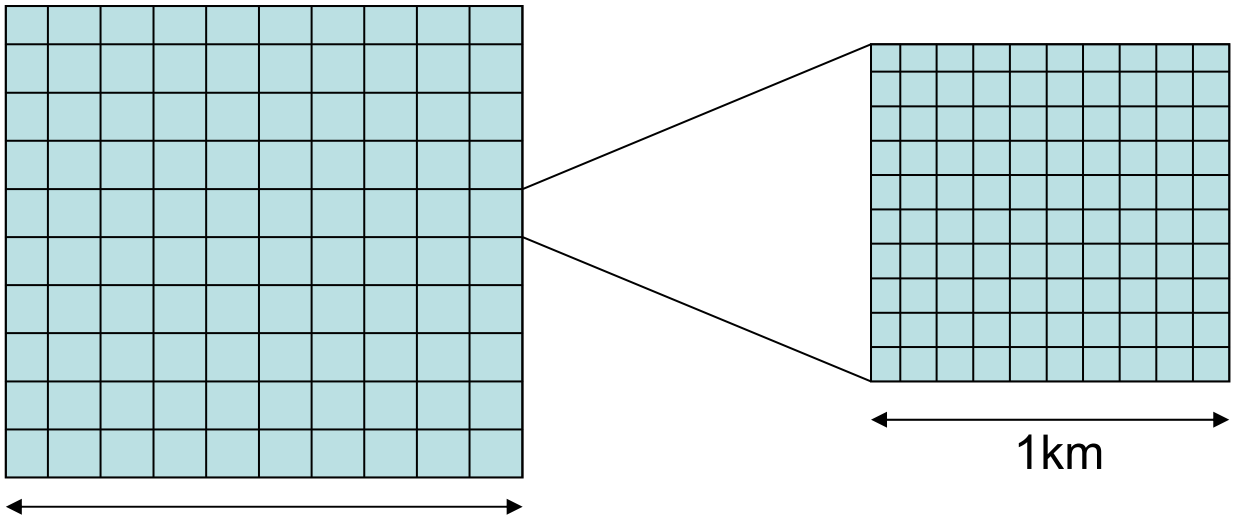
Organic Soils



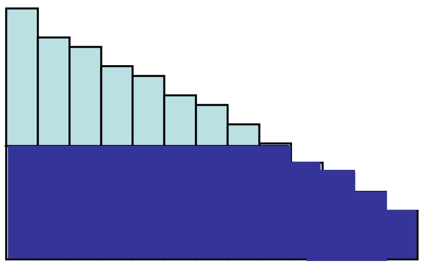
Macro-pore allows fast flow at high soil moistures:
Coded by increasing conductivity above a critical θ

New, depth varying, soil parameters used

Runoff Production and Heterogeneity



Statistical distribution
of soil water (heat & carbon?)
depends on variation
In water-holding capacity
Due to topography and soil types

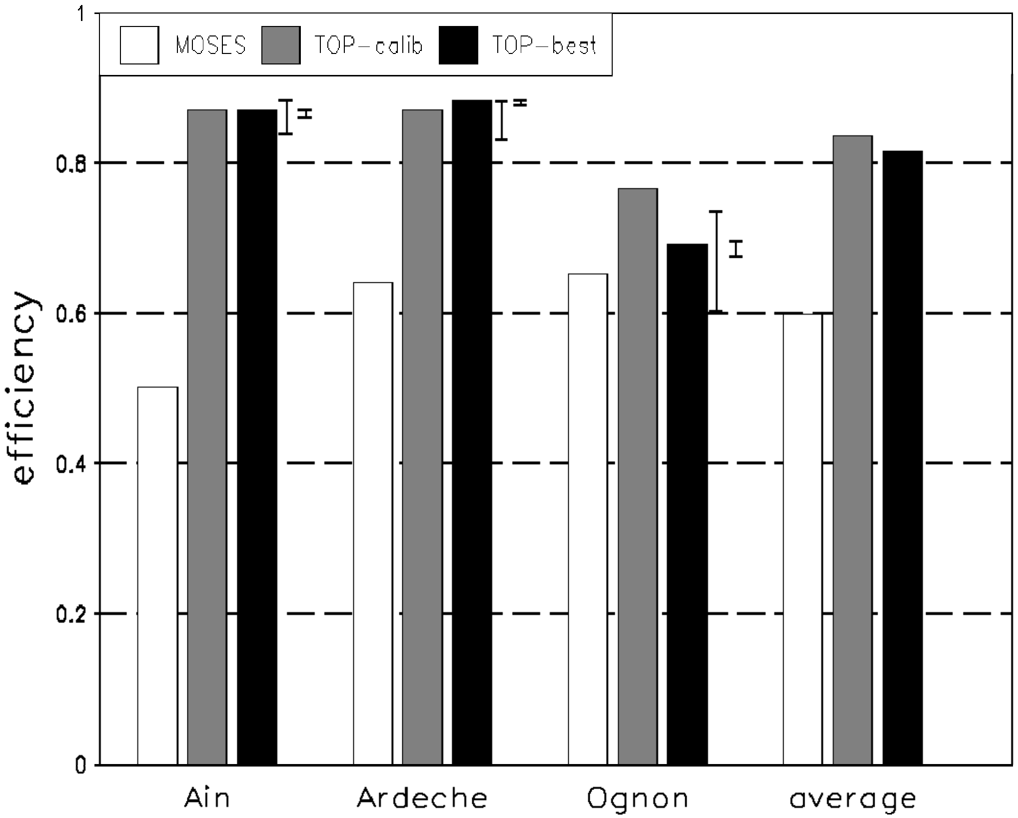


2 methods used:
Topmodel-based
soil moisture distribution

PDM-based soil moisture
distribution

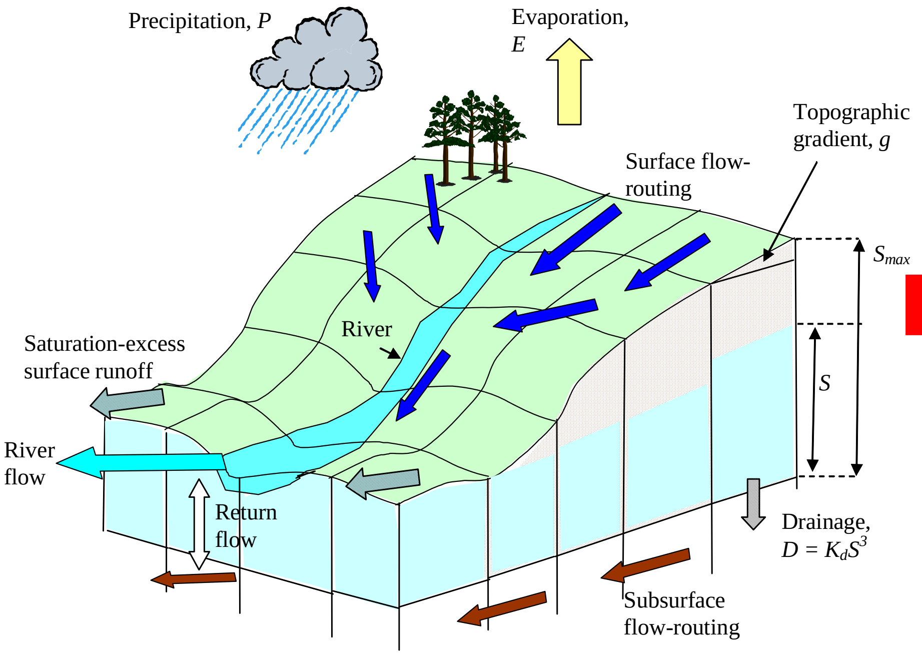
Runoff production method tested

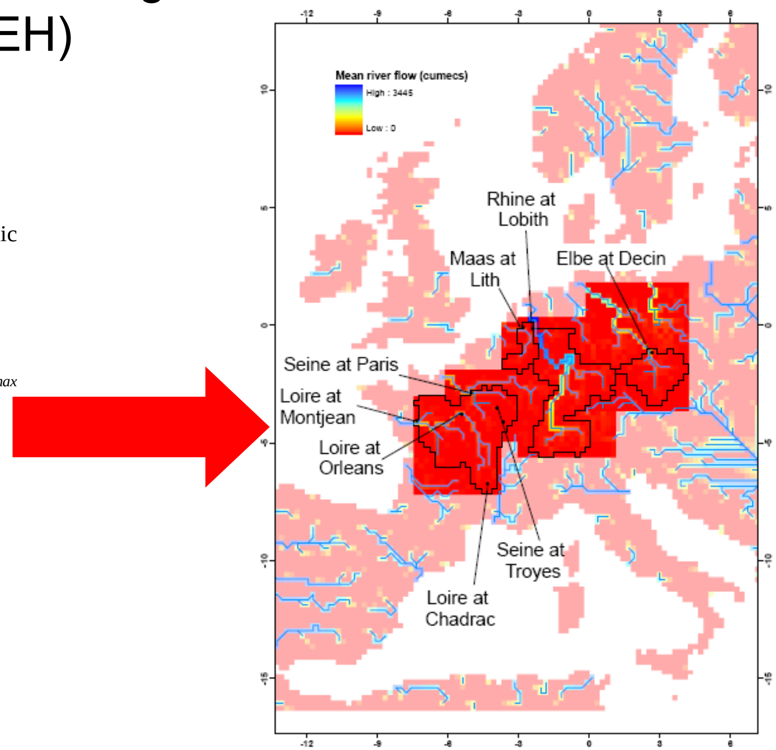
Doug Clark tested both methods (TOPMODEL and PDM) against river data in France.



Runoff Routing

The Grid-to-Grid ("G2G") flow-routing model
Vicky Bell, Simon Dadson (CEH)



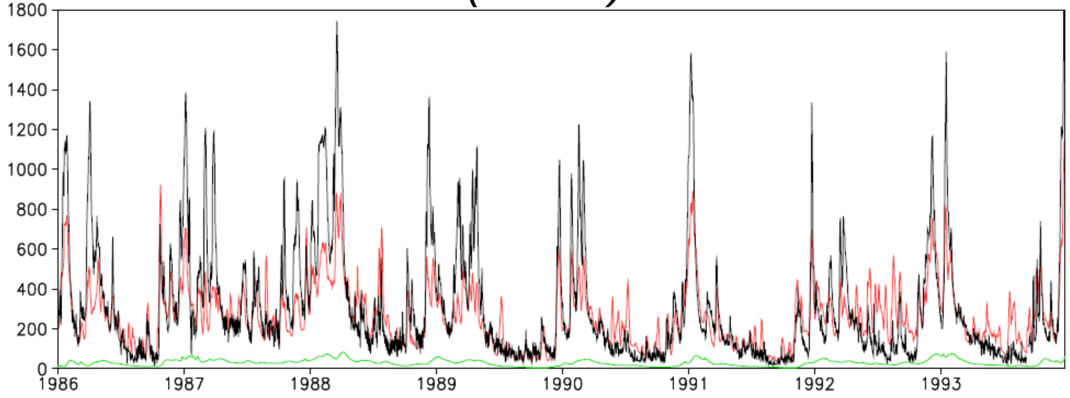


Example: space-time varying river flows over Europe on 25 km grid

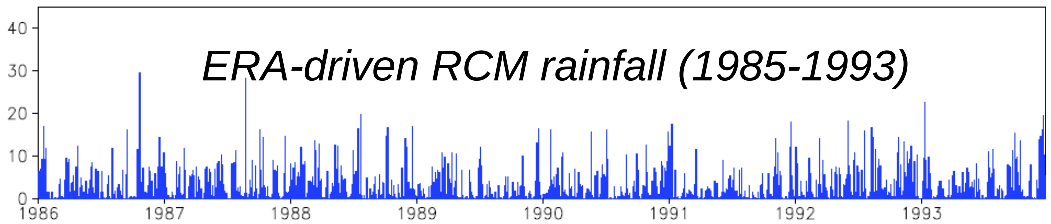
*Bell, V.A., Kay, A.L., Jones, R.G. and Moore, R.J. (2007) Development of a high resolution grid-based river flow model for use with regional climate model output. Hydrology and Earth System Sciences, **11(1)**, 532-549.*

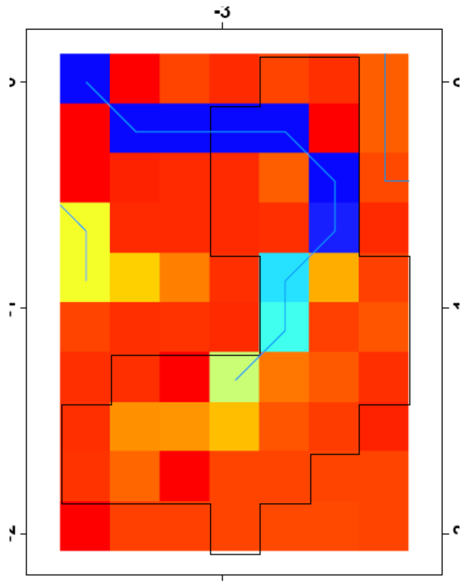
Example in Europe

Flow in the Maas (Meuse) at Lith R^2 = 0.76



Observed flow
Modelled river flow
Modelled sub-surface flow



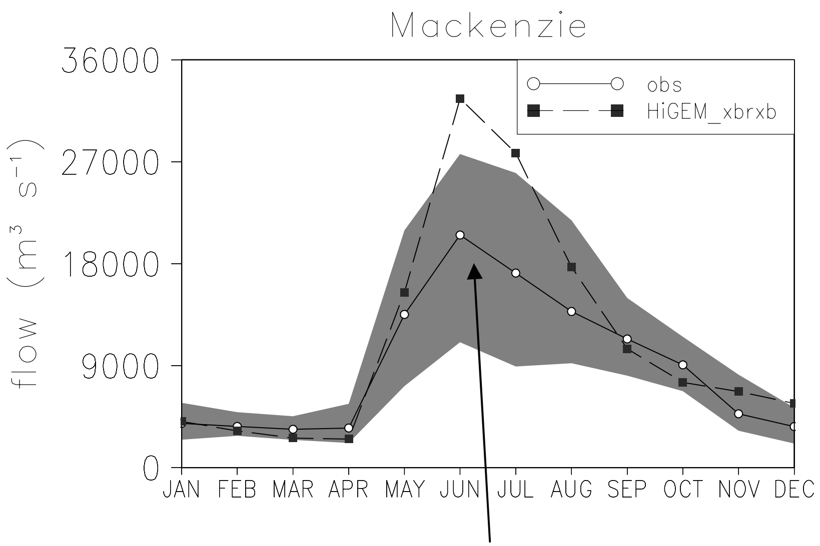


Spatial distribution of flow across the catchment

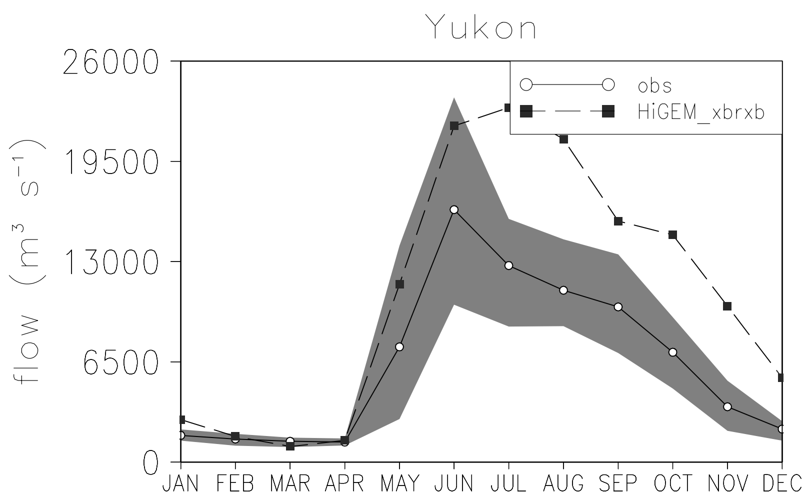
- Good correspondence with observed mean flows and flood peaks
- Work to add sediment transport model is ongoing (with A. Nicholas, T. Quine, M. Kirkby)

Example: Use of river flow to check model at large scale

River flow – represents large area, net effect of several processes. Relatively long records.



Observed climatology (shaded=extremes)



Future developments

- Variations in Soil Depth to change hydrological characteristics
- Links to soil carbon
- Wetlands (how form and where?)
- Links to methane production
- Lateral flow?
- Groundwater
- Irrigation
- Permafrost (link to permafrost model?)
- Integration with the new snow model
- Regional studies: Siberia, Europe, Asia, Amazon
- WATCH project (EU IP): looking at the global water cycle