Using spatial flux measurements to diagnose model structural errors under data uncertainty

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Project PE0120

Aims of the talk

- Demonstrate how unrealistic conceptualisations and parameterisations of **spatial model units** can interact so as to produce a somewhat realistic looking outlet hydrograph
- Use nested discharge data from “difficult” places
- Account for data uncertainties in model testing

Study catchment & modelling problem

Den Brook catchment (48 ha)

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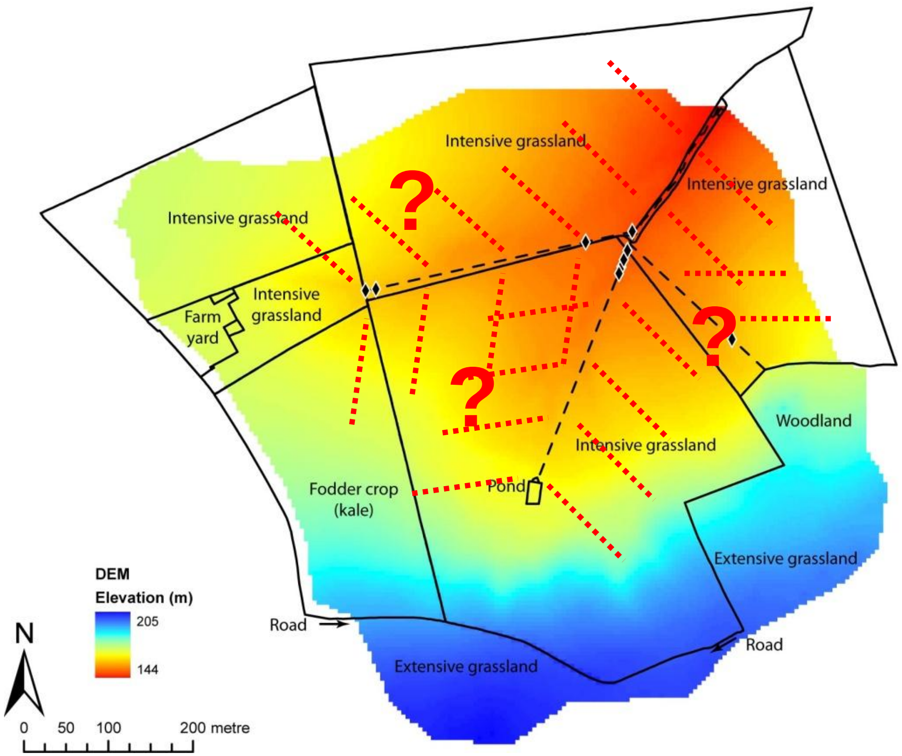
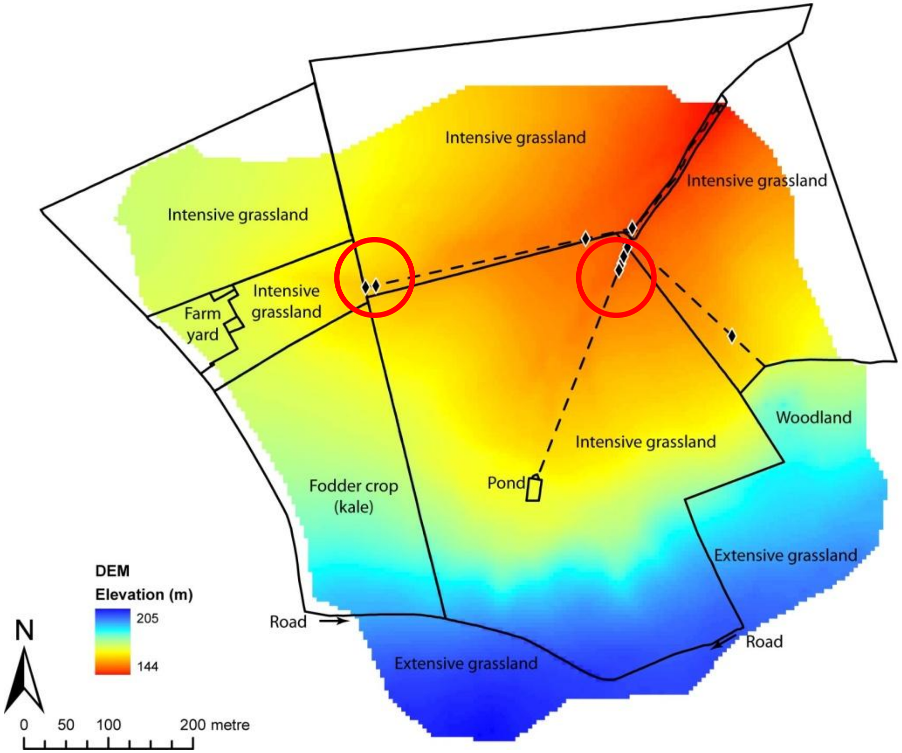


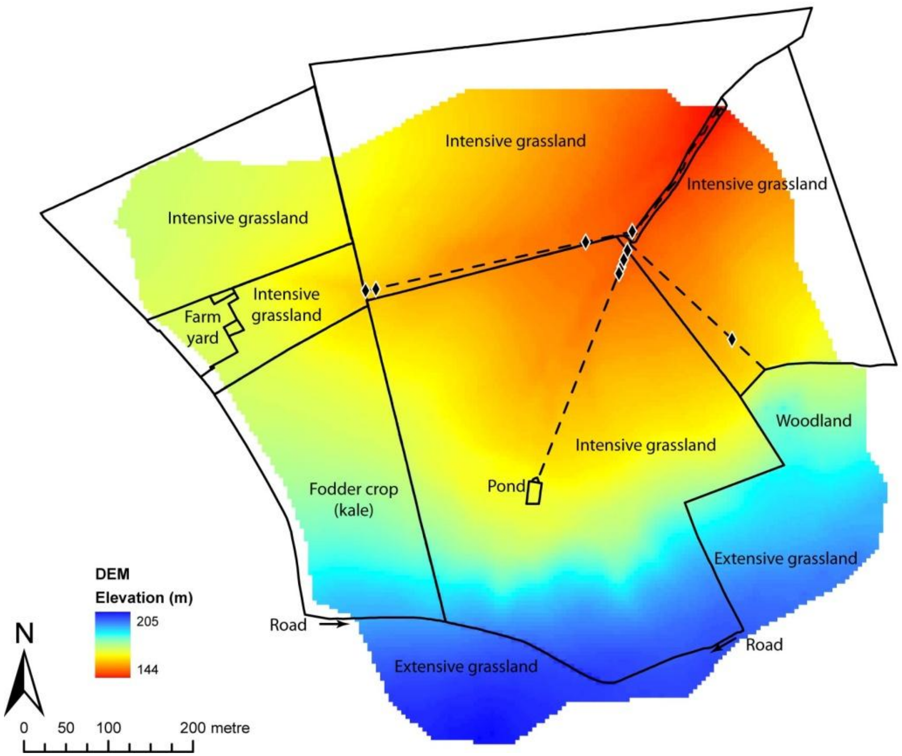
Study catchment & modelling problem

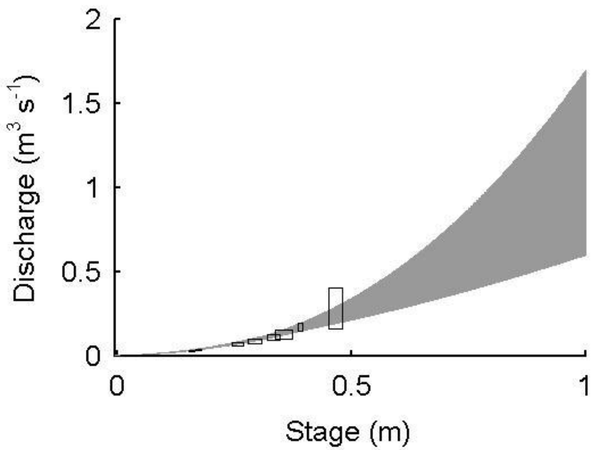
Den Brook catchment (48 ha)



Nested discharge data & uncertainty

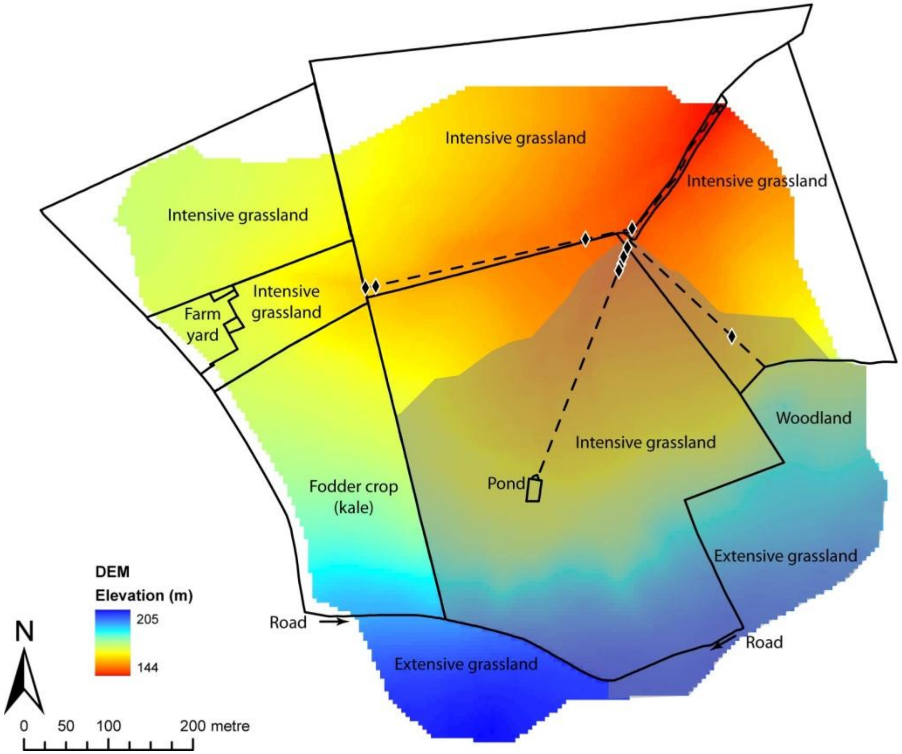
(1) Catchment outlet

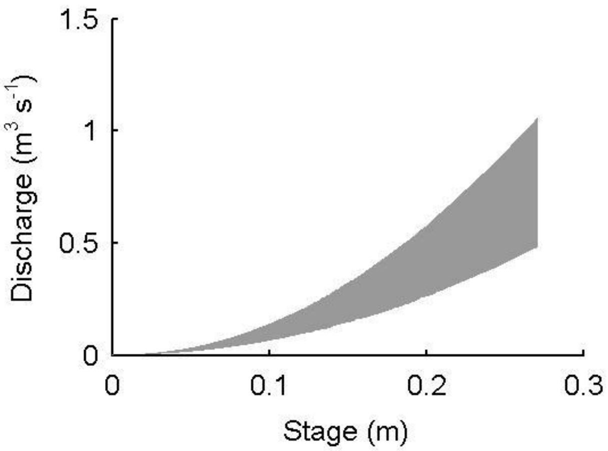




Fuzzy rating curve algorithm (Krueger *et al.* 2010 WRR)

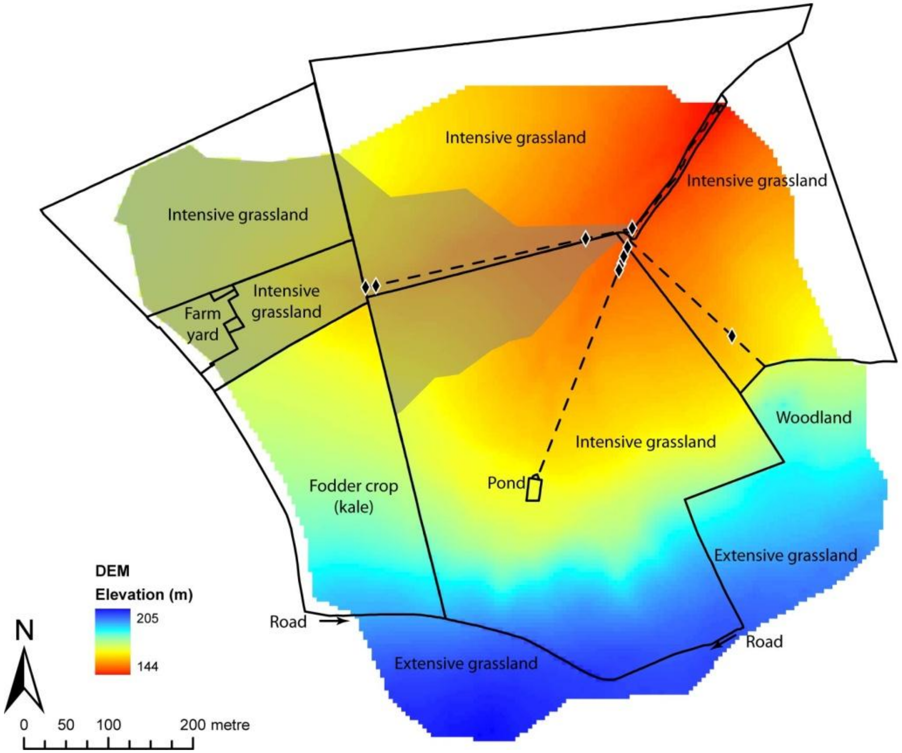
Nested discharge data & uncertainty
(2) Pipe 1

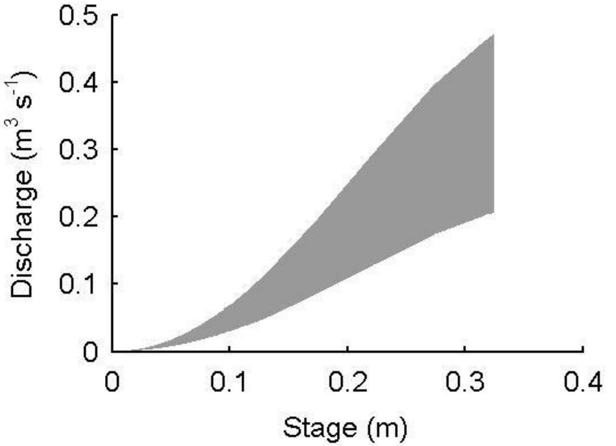




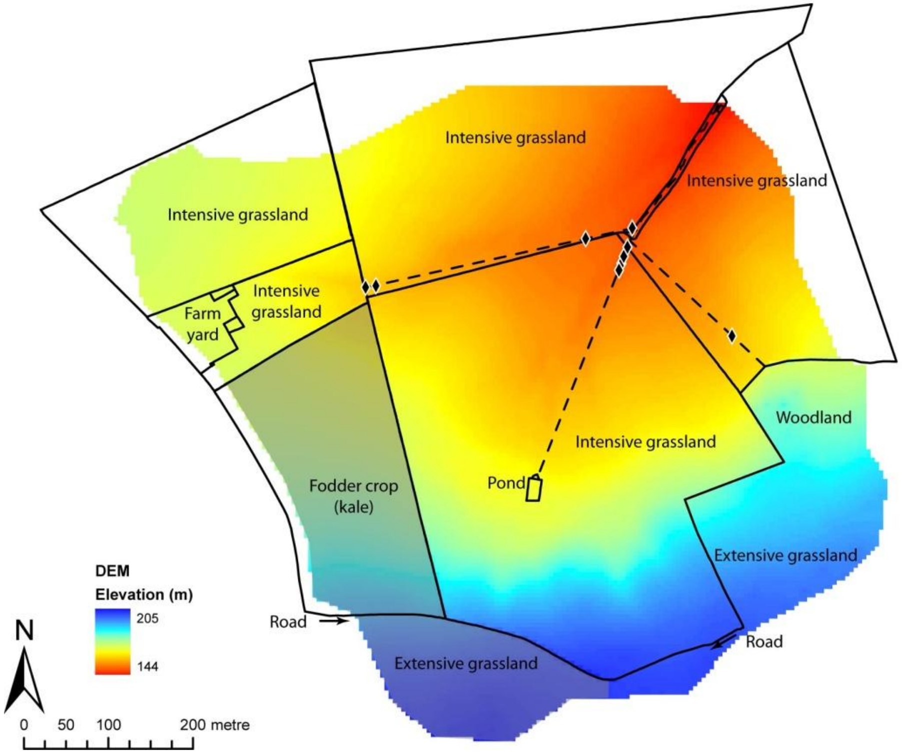
Manning's equation allowing for uncertainty intervals of slope and roughness coefficient

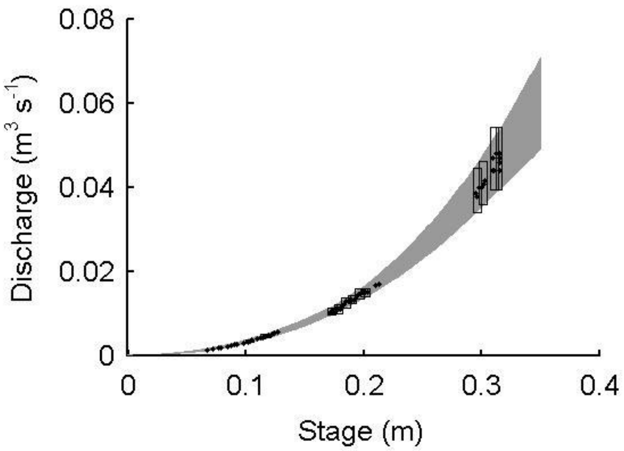
Nested discharge data & uncertainty
(3) Pipe 2





Nested discharge data & uncertainty
(4) Fodder field



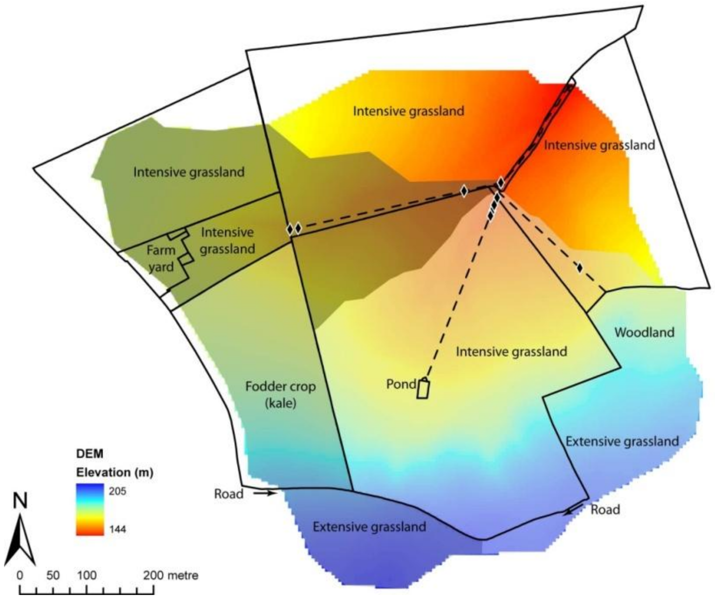


Only overland flow!

Hypotheses to be tested & model setup

(1) Connectivity hypothesis

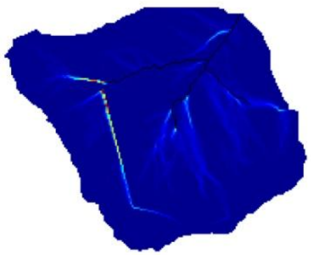
- *Dynamic Topmodel* (Beven & Freer 2001 HP)
- Connectivity defined by surface topography & main artery pipes
- Pipes modelled as stream channel
- Runoff generation controlled by local contributing area & slope (*Topographic Index*)
- Farm yard runoff modelled as Horton overland flow
- Channel routing after Liu *et al.* 2009 JH



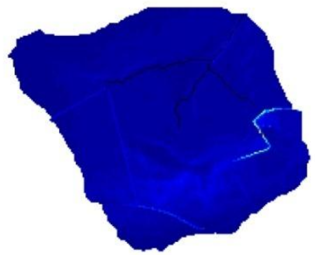
(1) Connectivity hypothesis

Spatially semi-distributed discretisation

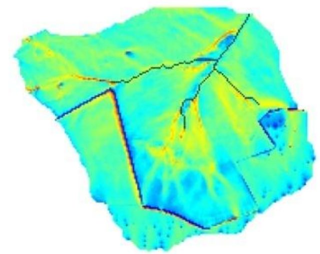
Digital Terrain Analysis



Local
contributing area (*a*)

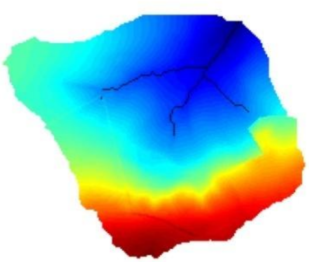


Slope
(tan*β*)

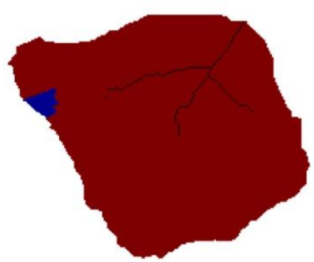


ln(*a*/tan*β*)

Spatial data

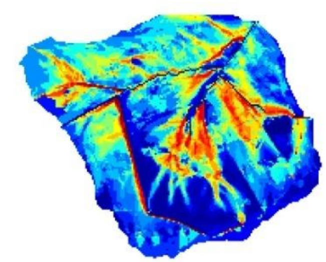


DEM, stream
& main artery pipes



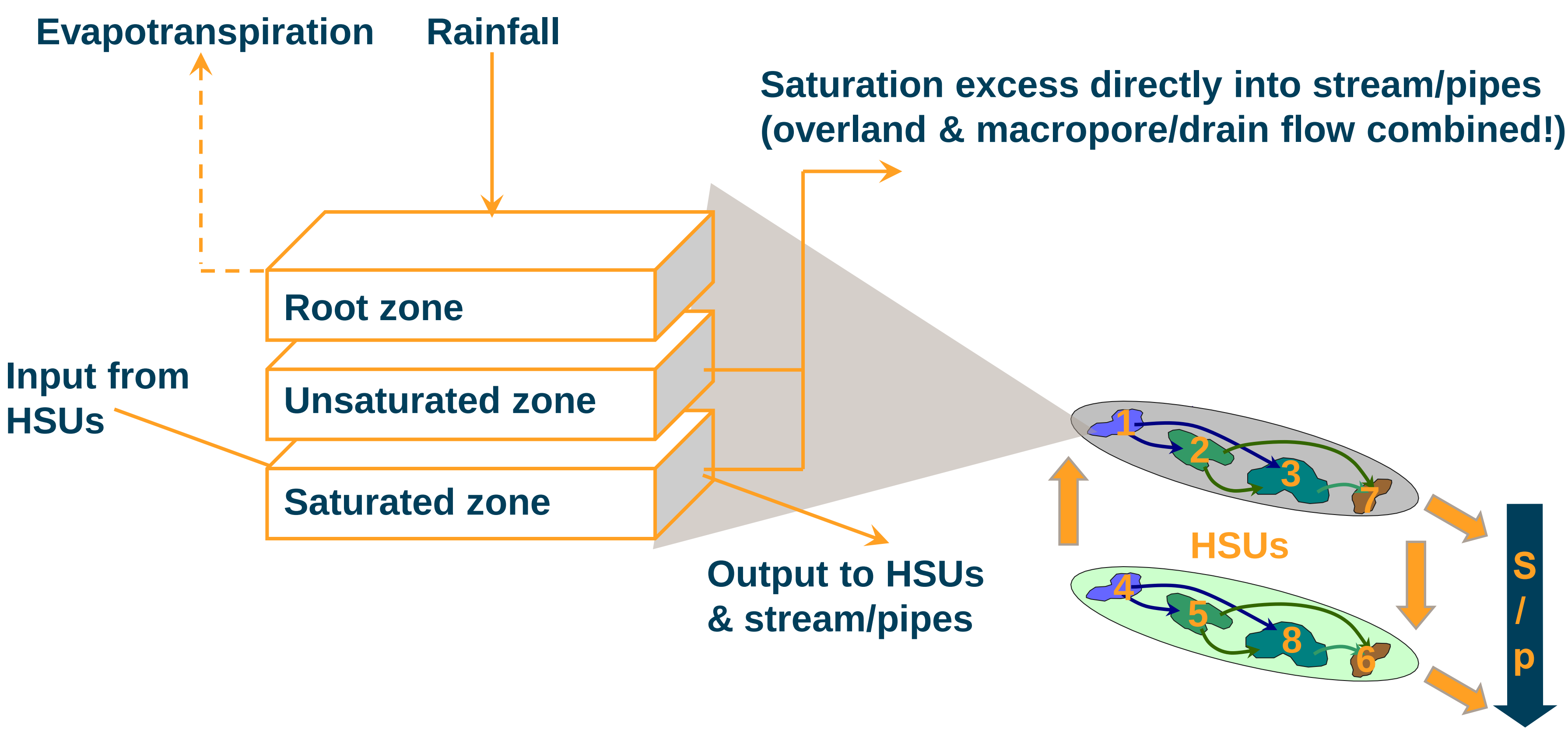
Areas of different
runoff generation

HSUs (201)



Hydrological
Similarity Units

(1) Connectivity hypothesis
Accounting of fluxes per HSU



Timestep: 1 hour

Input: area averaged rainfall & potential evapotranspiration

(no explicit account of uncertainties!)

Hypotheses to be tested & model setup

(2) Parameter sets

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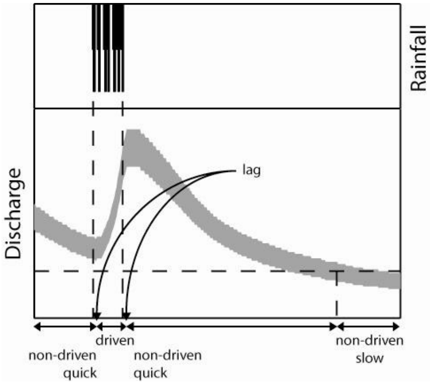
Parameter	Description	Bounds		
SZM (m)	Form of exponential decline of transmissivity with declining saturation	0.001	-	0.4
$\ln T_0$ (m h^{-1})	Effective lateral saturated transmissivity	-9	-	6
SR_{max} (m)	Maximum root zone storage	0.01	-	0.4
SR_{init} (m)	Initial root zone deficit	0	-	0.01
CHV (m h^{-1})	Channel routing velocity	20	-	400
T_d (m h^{-1})	Unsaturated zone percolation time delay per unit saturation deficit	0.001	-	500
S_{max} (m)	Maximum effective saturated zone deficit	0.001	-	1
α (-)	Channel routing fractional retention	0	-	1

10^6 random samples from uniform distribution with bounds

Hypothesis testing using GLUE

Applying "limits of acceptability"

Gauge	Driven	Quick	Slow	Driven, quick & slow	Driven & quick
Outlet				Reject	
Pipe 1			Reject	Reject	Reject
Pipe 2			Reject	Reject	
Fodder field	Reject	Reject	Reject	Reject	Reject
Outlet & pipe 2	Reject		Reject	Reject	Reject

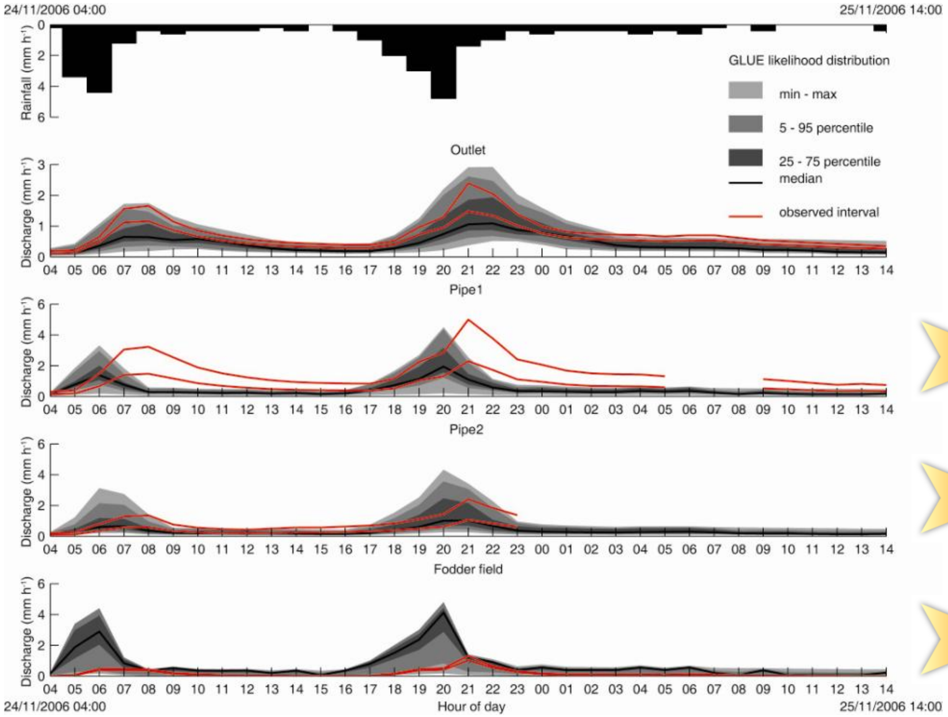


Hydrograph periods: Boyle *et al.* 2000 WRR

Performance measures: Krueger *et al.* 2010 WRR

Model diagnostics

Hypotheses accepted at outlet (driven & quick)

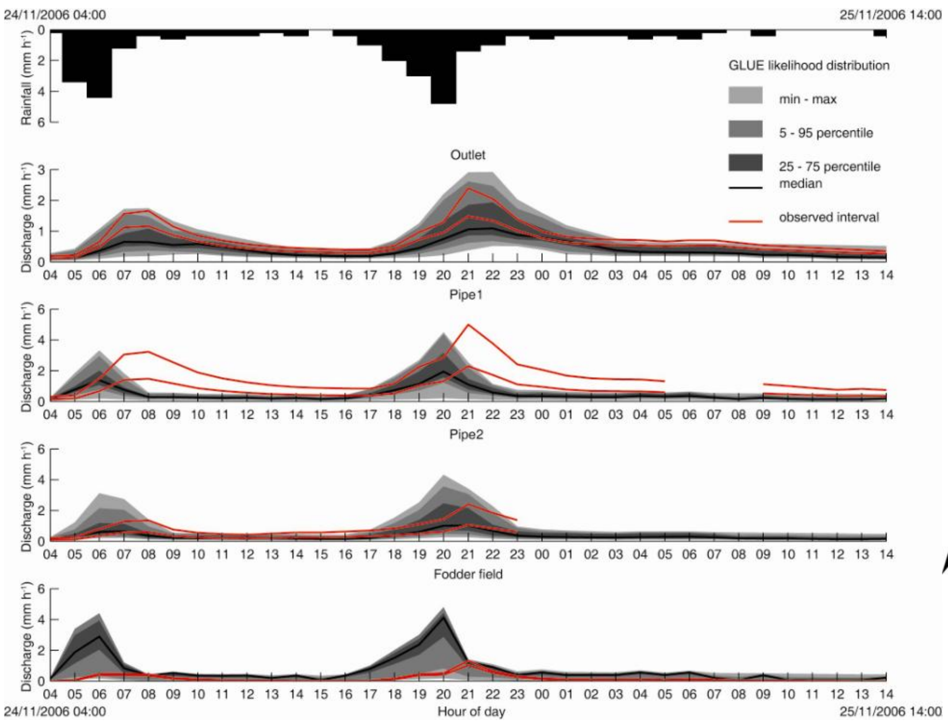


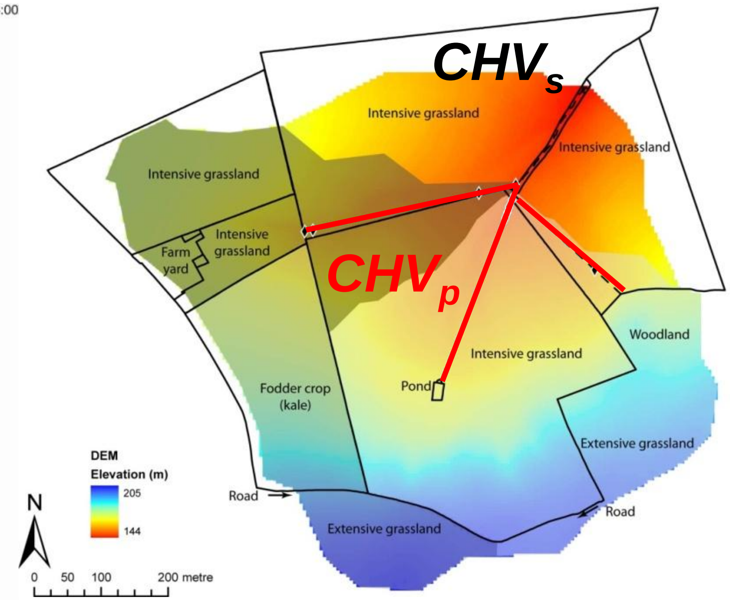
Systematic timing errors & underprediction of high flows, especially at pipe 1

Systematic overprediction, particularly during rising hydrograph

Model diagnostics

Pipe velocity lower than stream velocity?





New hypothesis: introduce separate pipe velocity parameter

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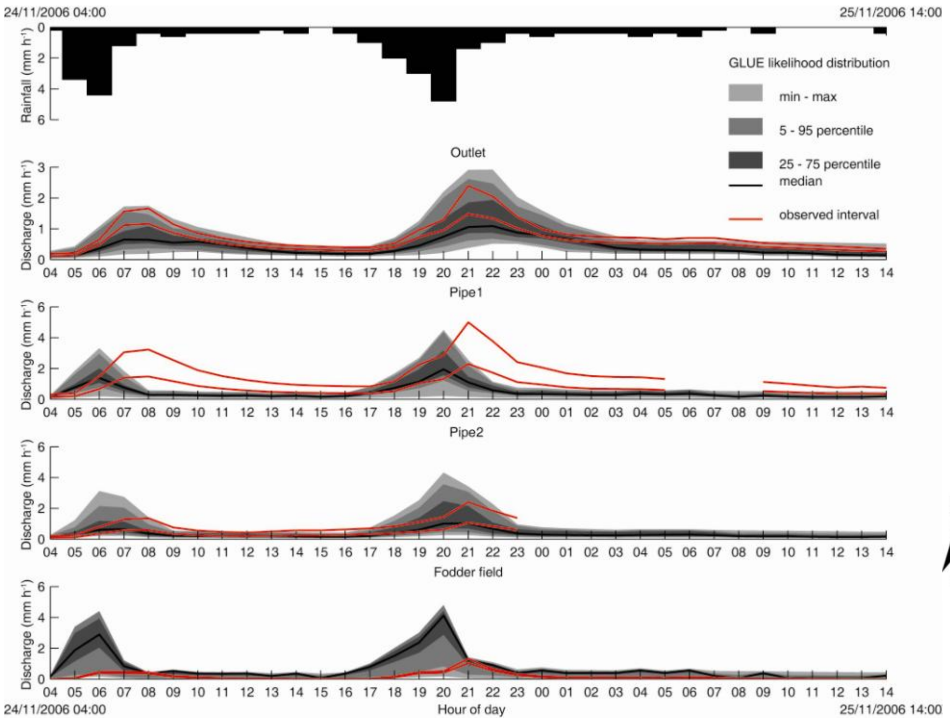
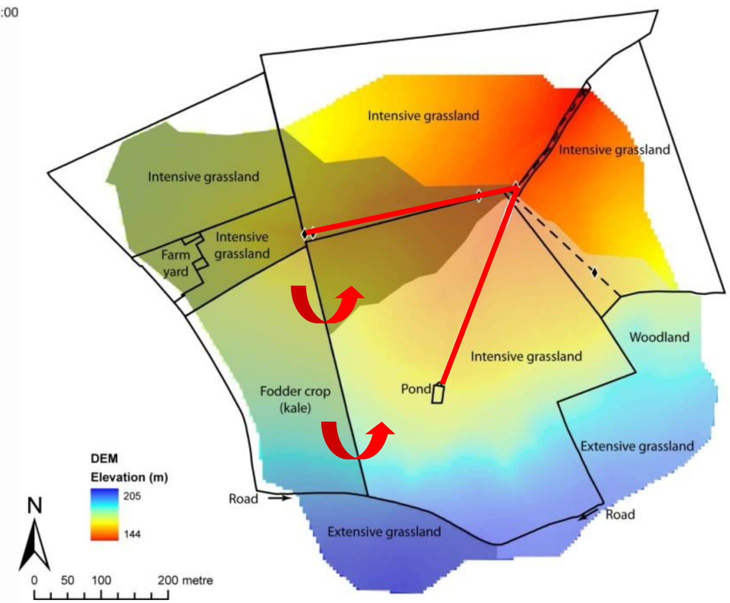
Model diagnostics
Underestimated pipe contributing areas?

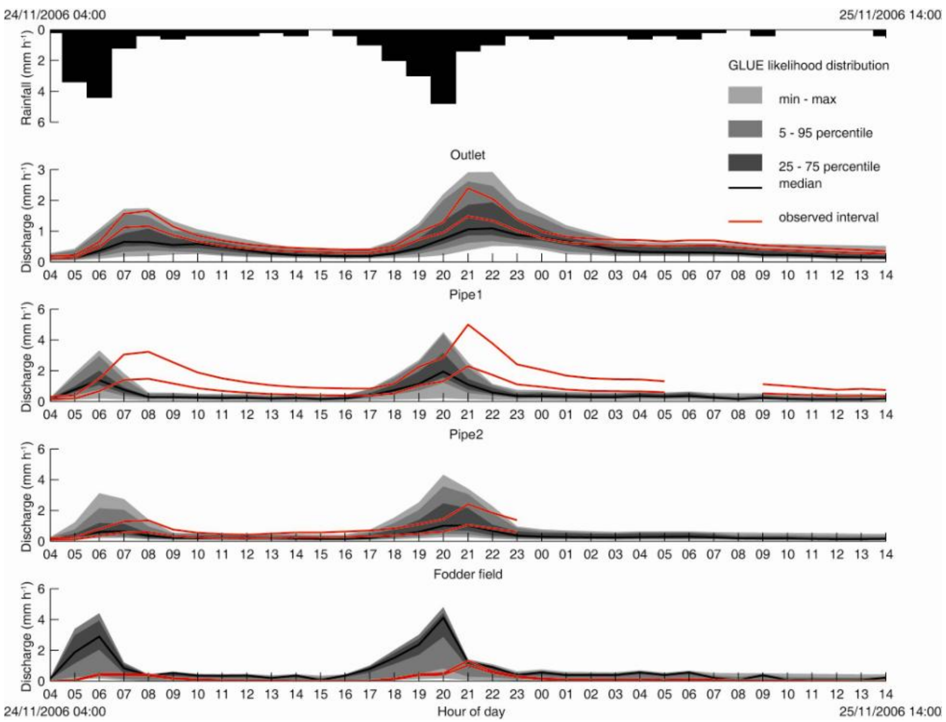


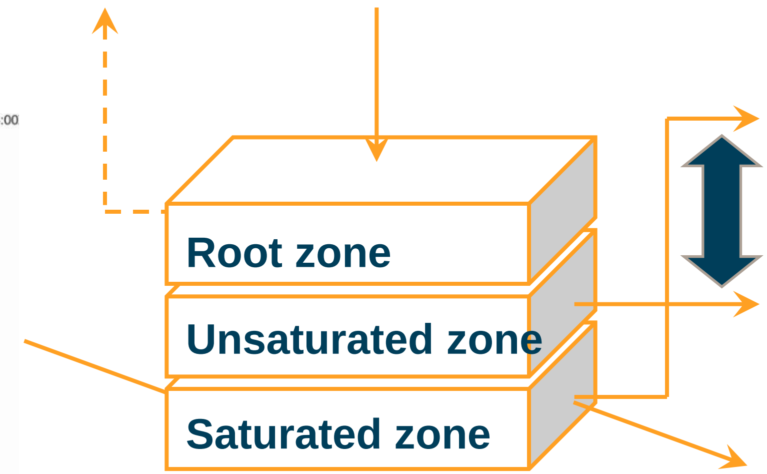


New hypothesis: route fodder field subsurface flow through pipes

Model diagnostics

Saturation excess formulation unrealistic?



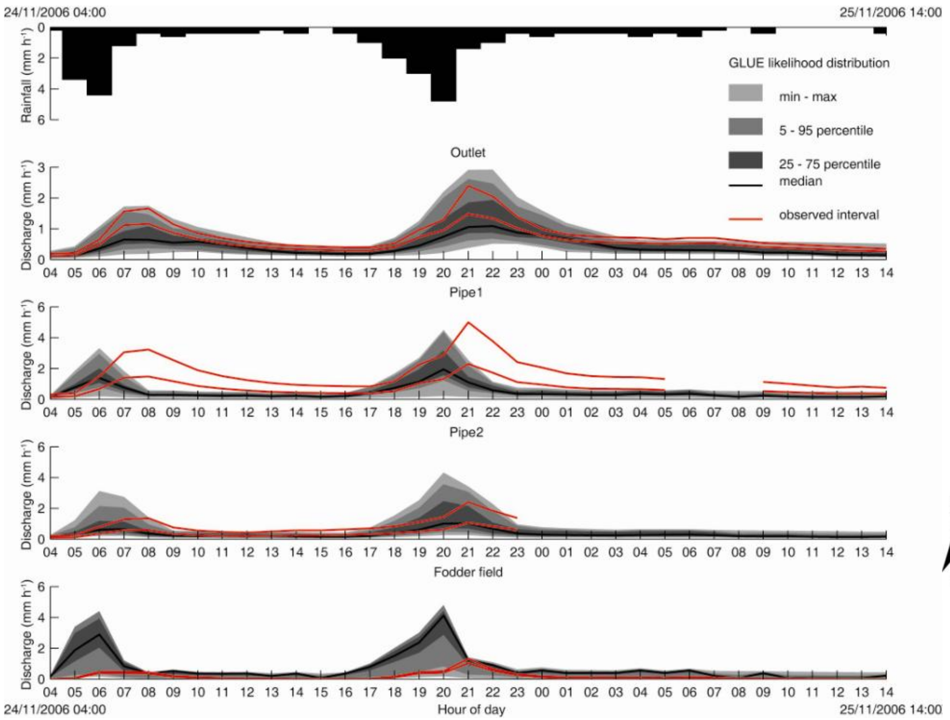


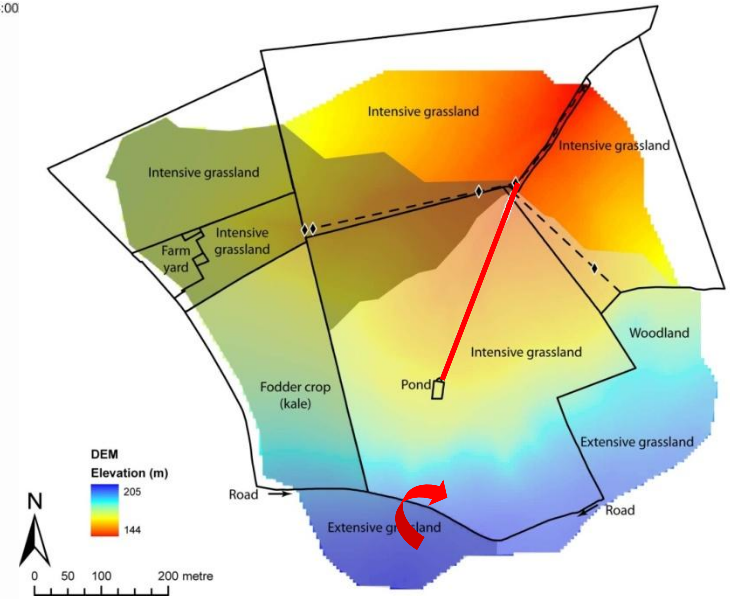
separate overland & macropore/drain flow

New hypothesis: introduce quick subsurface flow component that responds below saturation (macropore & drain flow)

Model diagnostics

Overestimated fodder field contributing area?

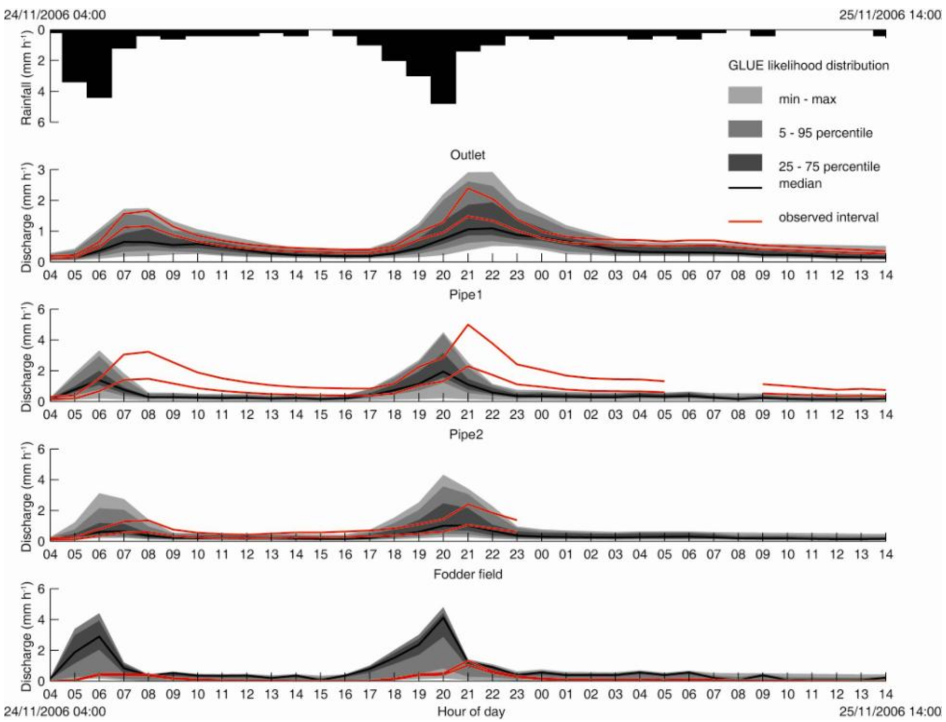


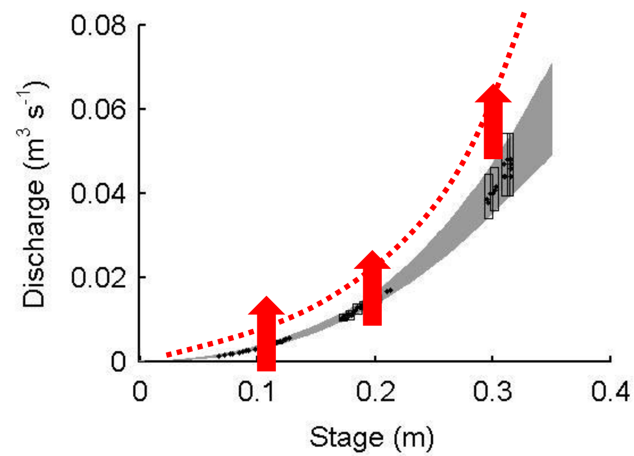


New hypothesis: route southern field through pipe 1

Model diagnostics

Systematic losses around fodder field gauge?





New hypothesis: add bias component

Conclusions

Although all hypotheses were rejected …

- Somewhat realistic looking simulations could be generated for the catchment outlet by internal mechanisms that were proven unrealistic by nested discharge observations
- So if spatial predictions are made using models calibrated at single locations, their spatial realism cannot automatically be assumed
- So we need more spatially nested field experiments to test models
- However, the availability of spatial data creates new challenges in defining catchment connectivity when locations where fluxes can be measured are not where contributing areas can be easily defined
- Geophysical measurements and tracer studies might help separate surface and subsurface contributing areas
- Model development and testing cannot proceed efficiently without close integration with field experimentation