Impact of rainfall temporal resolution:

urban (storm-) water quality model performance and uncertainty

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Imperial College London 2012

Imperial College London

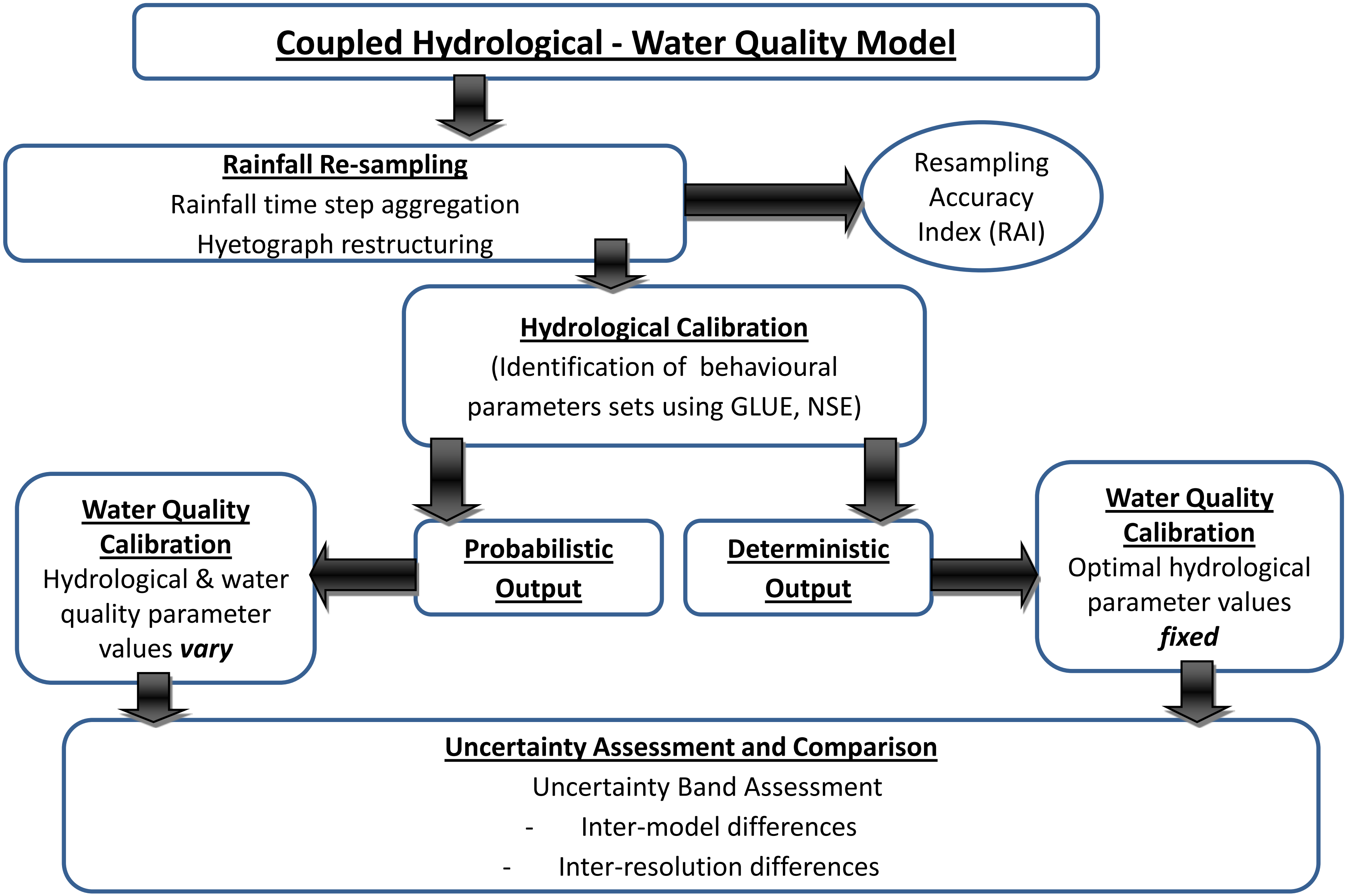
Sediment (Pollutant) Build-up and Wash-off

	Build-up	**Wash-off**
Process	Particulate Deposition & Redistribution	Raindrop impact kinetic energy, shear stress from surface flows
Occurrence	Dry periods	Rainfall events
Sources	Traffic, aerosols, wind, street sweeping	-
Spatial Distribution	Small-scale, site-specific, highly complex distribution	PSD depends on rainfall complexity
Temporal Scale	Days to Months	Minutes to Hours (1^{st} flush phenomenon)

Objectives

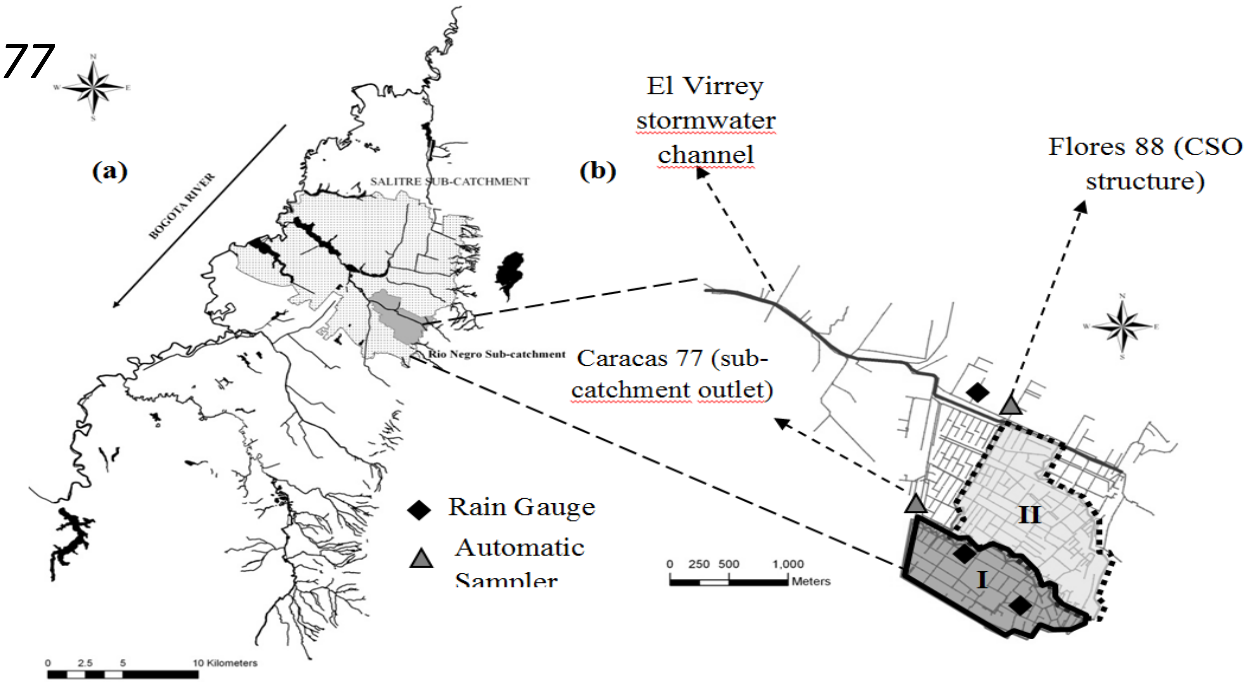
- Impact of varying temporal resolution of input rainfall records on resulting model performance and behaviour
- Model uncertainty sources and how their relative contribution to the overall model output uncertainty
- Effect of rainfall resolution on these relative contributing sources
- Implications for rainfall monitoring (& water quality sampling) regarding model design and application

Modelling Framework



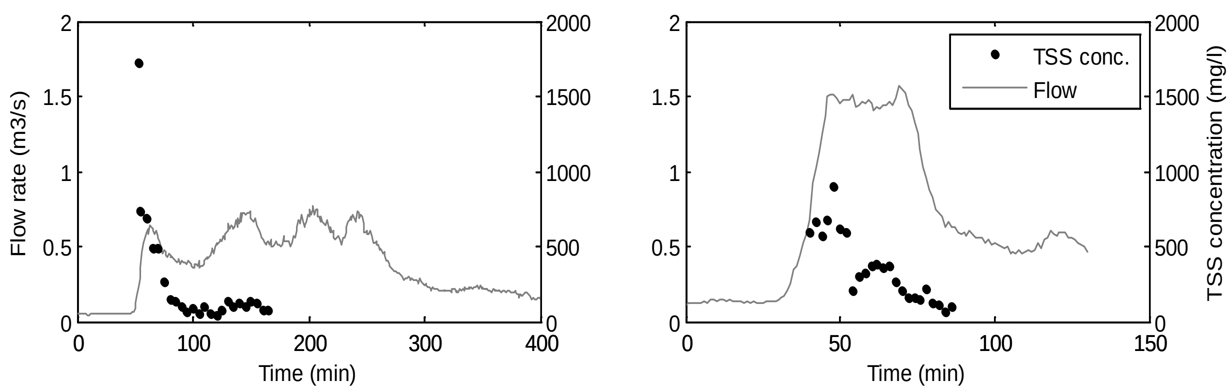
Case Study: El Virrey (Bogota, Colombia)

Sub-catchment Caracas 77



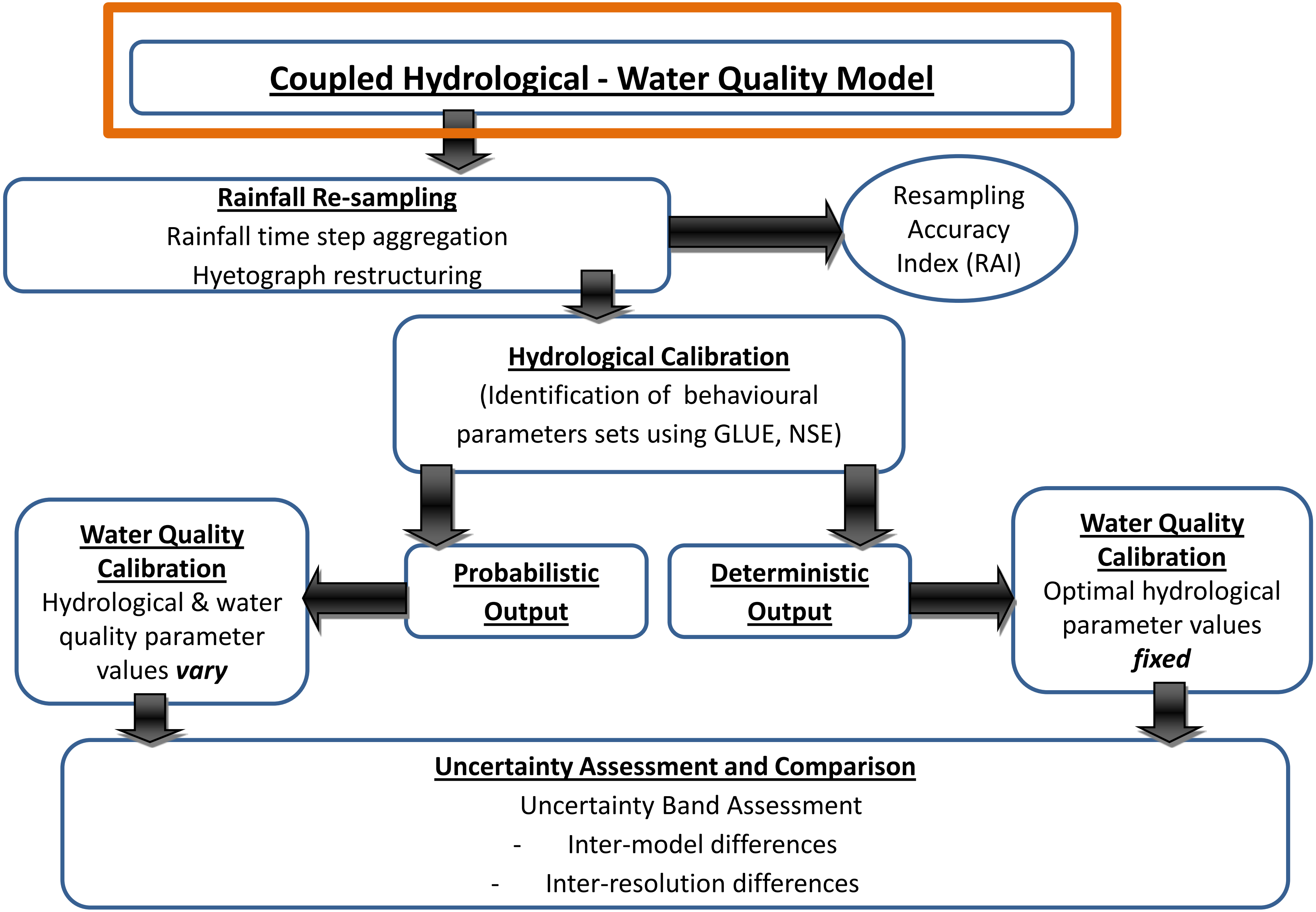
- 85 ha
- Mostly residential
- 60% Impermeable
- Average slope 20%
- ToC 27 min

- 8 month pilot campaign
- 1 min resolution



-> 21 rainfall events; up to 24 TSS samples / event

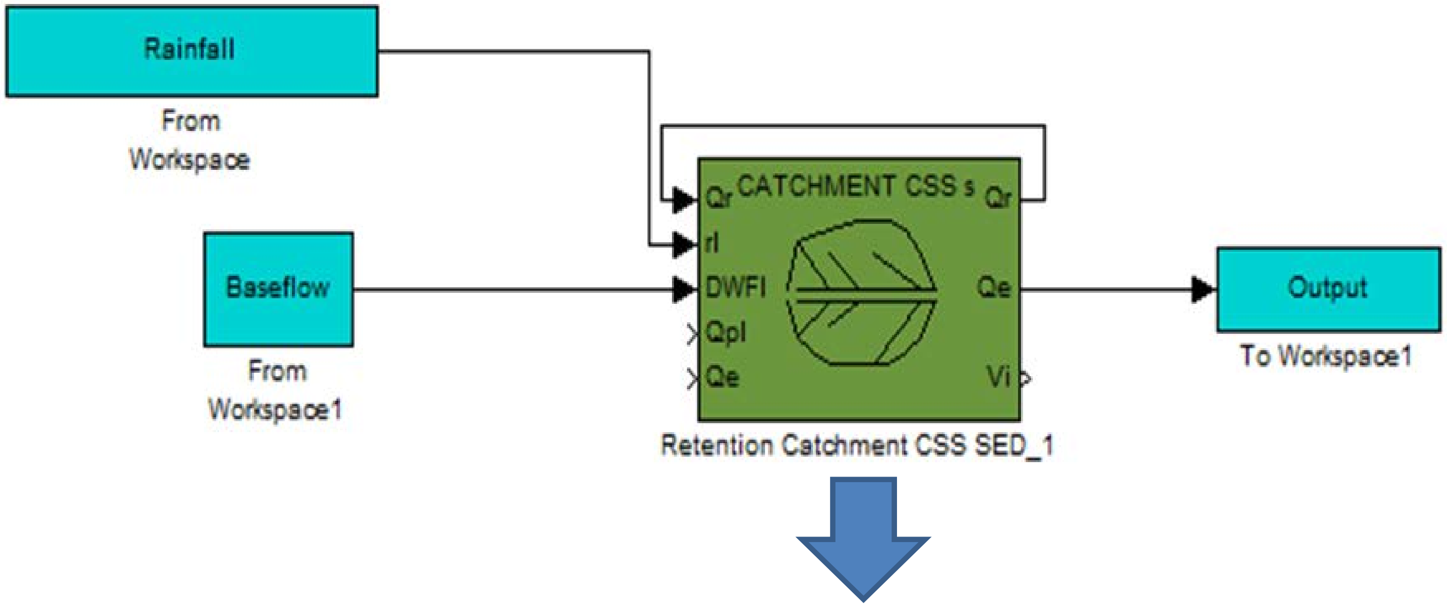
Modelling Framework



Hydrological Modelling – *City Drain*

Achtleitner et al. 2007

Rainfall-Runoff Transformation: *Catchment Loss Model* (3 parameters)



$$h_e = (r_R - h_I).\varphi \geq 0$$

Runoff Routing: *Muskingum routing* (3 parameters)

Water Quality Modelling

Rodriguez et al. 2010

Accumulation Models	Equation
A1 (linear)	$\frac{dM_a(t)}{dt} = D_{accu} \cdot A_i$
A2 (asymptotic)	$\frac{dM_a(t)}{dt} = D_{accu} \cdot A_i - D_{ero} \cdot M_a(t)$
A3	No accumulation (i.e. infinite supply)
Wash-off Models	
W1 (rainfall)	$M_a(t) = K_e \cdot I(t)^w \cdot A_i$
W2 (rainfall / M_a(t))	$\frac{dM_a(t)}{dt} = -W_e \cdot I(t)^w \cdot M_a(t)$
W3 (runoff)	$\frac{dm_c}{dt} = -a_{w1} Q_c(t)^{\alpha_{w1}} . m_c(t)$
W4 (rainfall / M_a(t))	$\frac{dM_a(t)}{dt} = -[C_1 . I(t)^{C_2} - C_3 . I(t)] . M_a(t)$

12 tested combinations:
A1-A3 * W1-W4

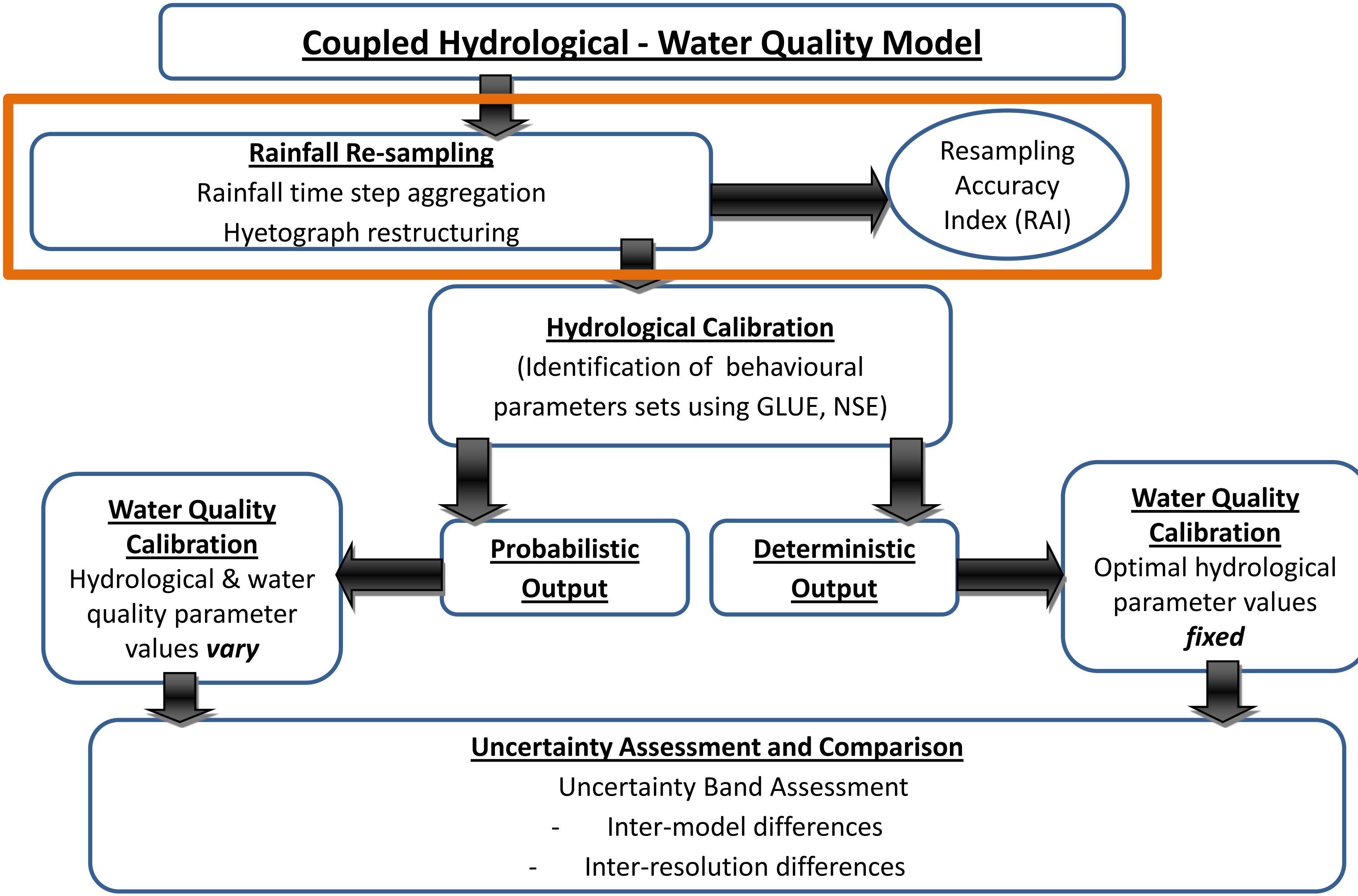
(2-5 parameters)
8-11 total parameters

No. of behavioural models assessed on:
NSE_{flow} >0.7
NSE_{TSS} > 0.0

All models potentially behavioural

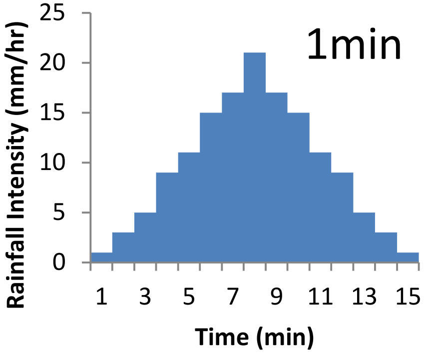
Only A2W2 and A2W4 consistently

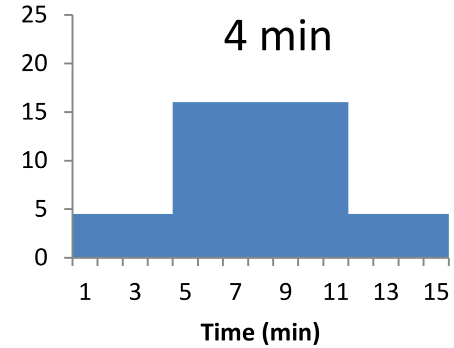
Modelling Framework



Rainfall Re-sampling

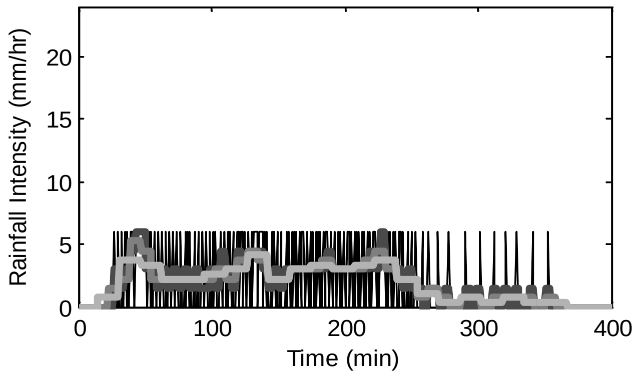
1 min reference
4, 8 & 16 min re-sampled

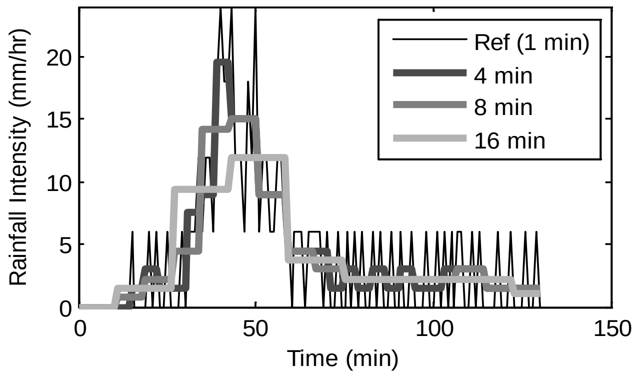




- Rainfalls assessed for 21 events
- Hydrology and water quality modelled for 2 events

May 3





May 8

Rainfall Re-sampling Accuracy Index (RAI)

$$RAI = 1 - \frac{\sigma_e^2}{\sigma_0^2}$$

Freni *et al*. 2010

- σ_e^2 : variance of errors between observed and re-sampled rainfall
- σ_0^2 : variance of the observations

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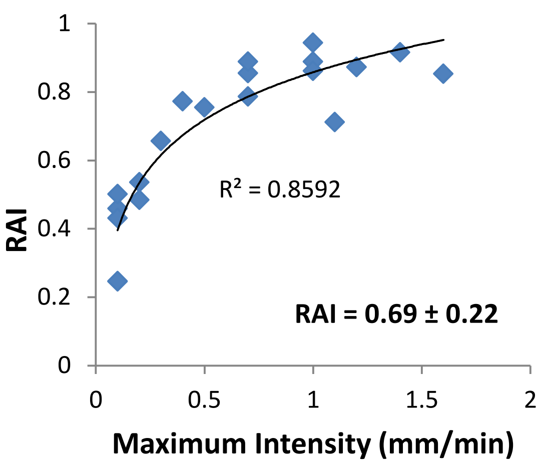
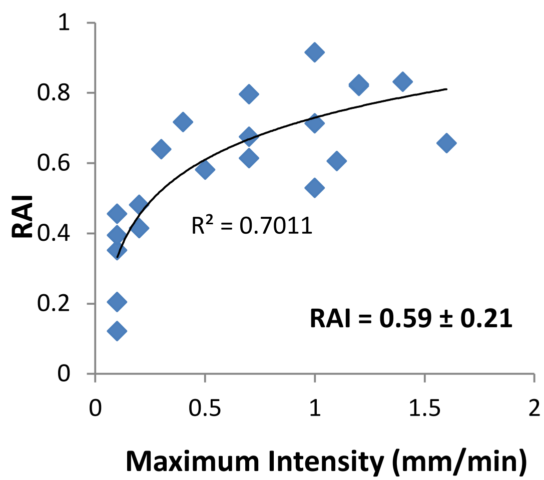
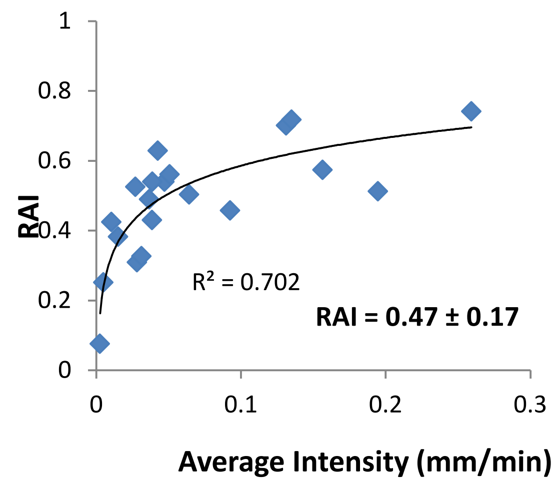
4 min



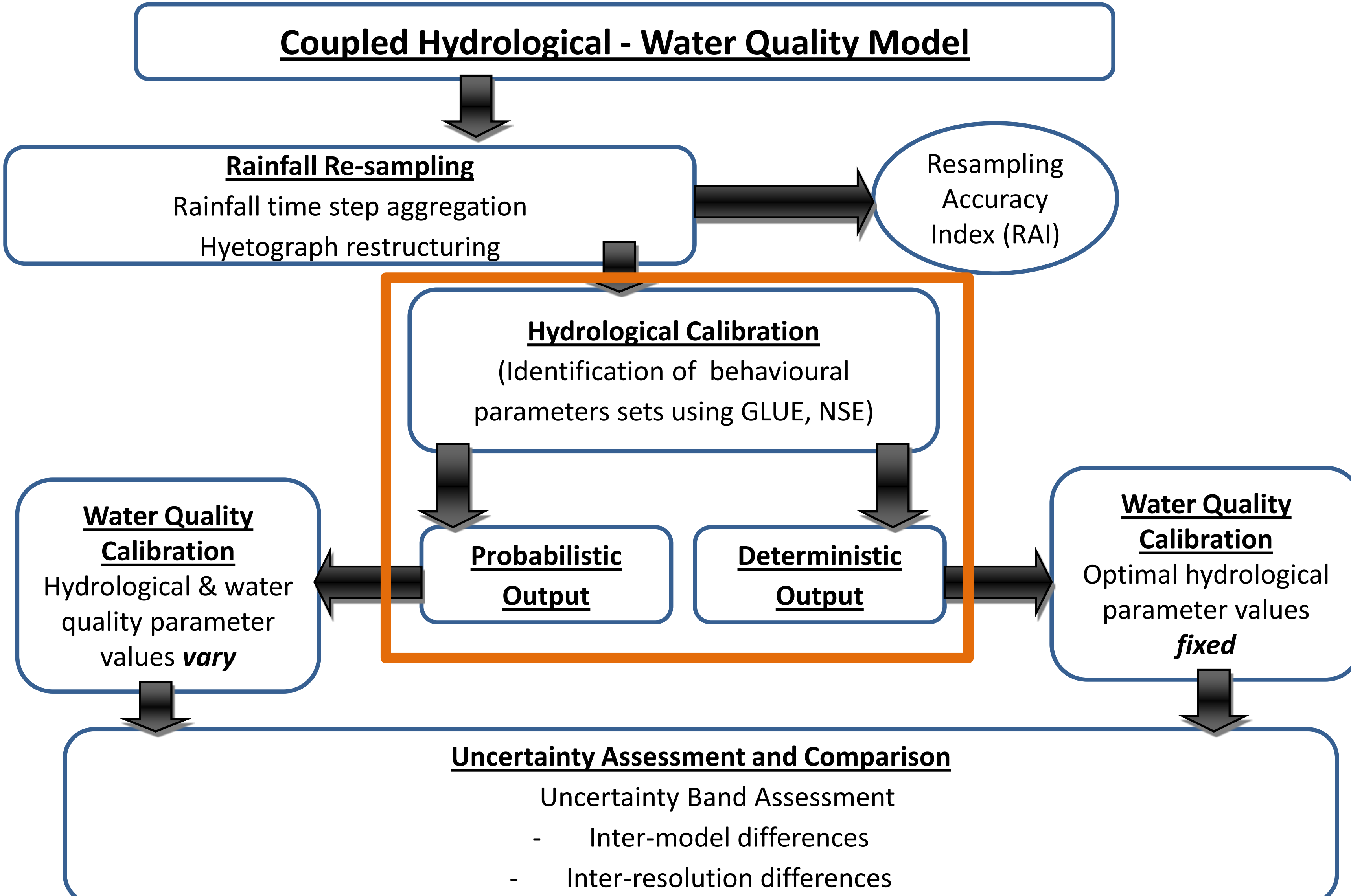
8 min



16 min

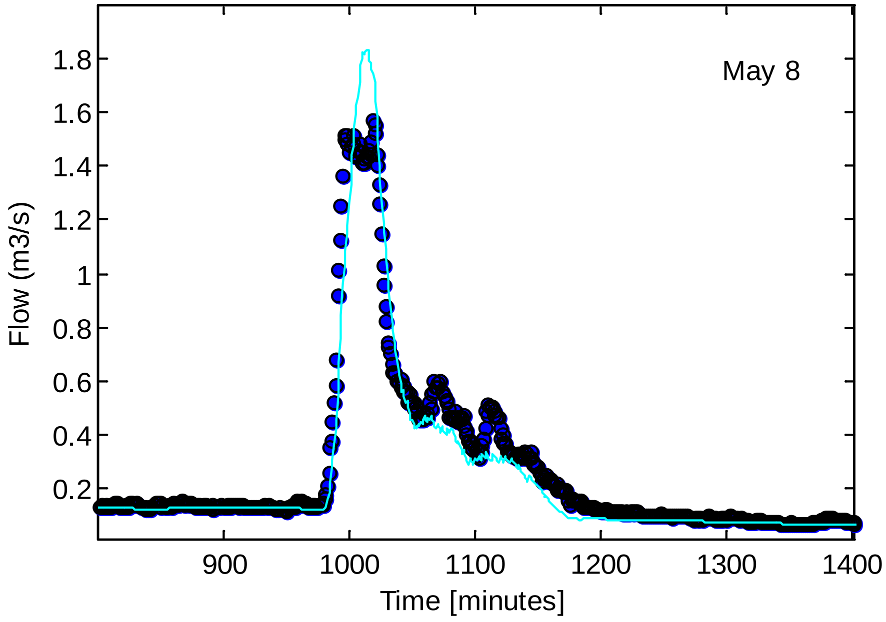


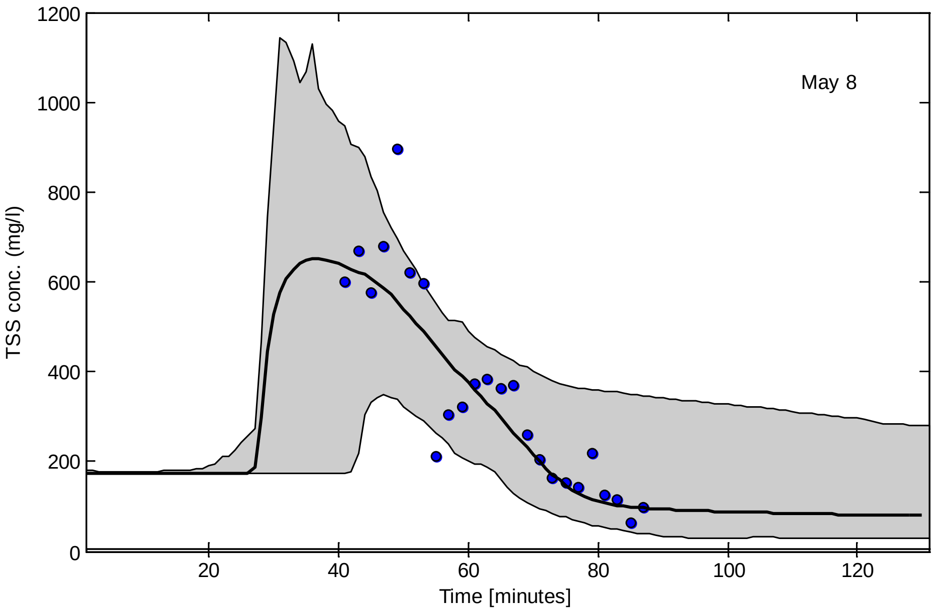
Modelling Framework



Example results hydrograph & pollutograph

Flow and water quality model calibration (May 8)

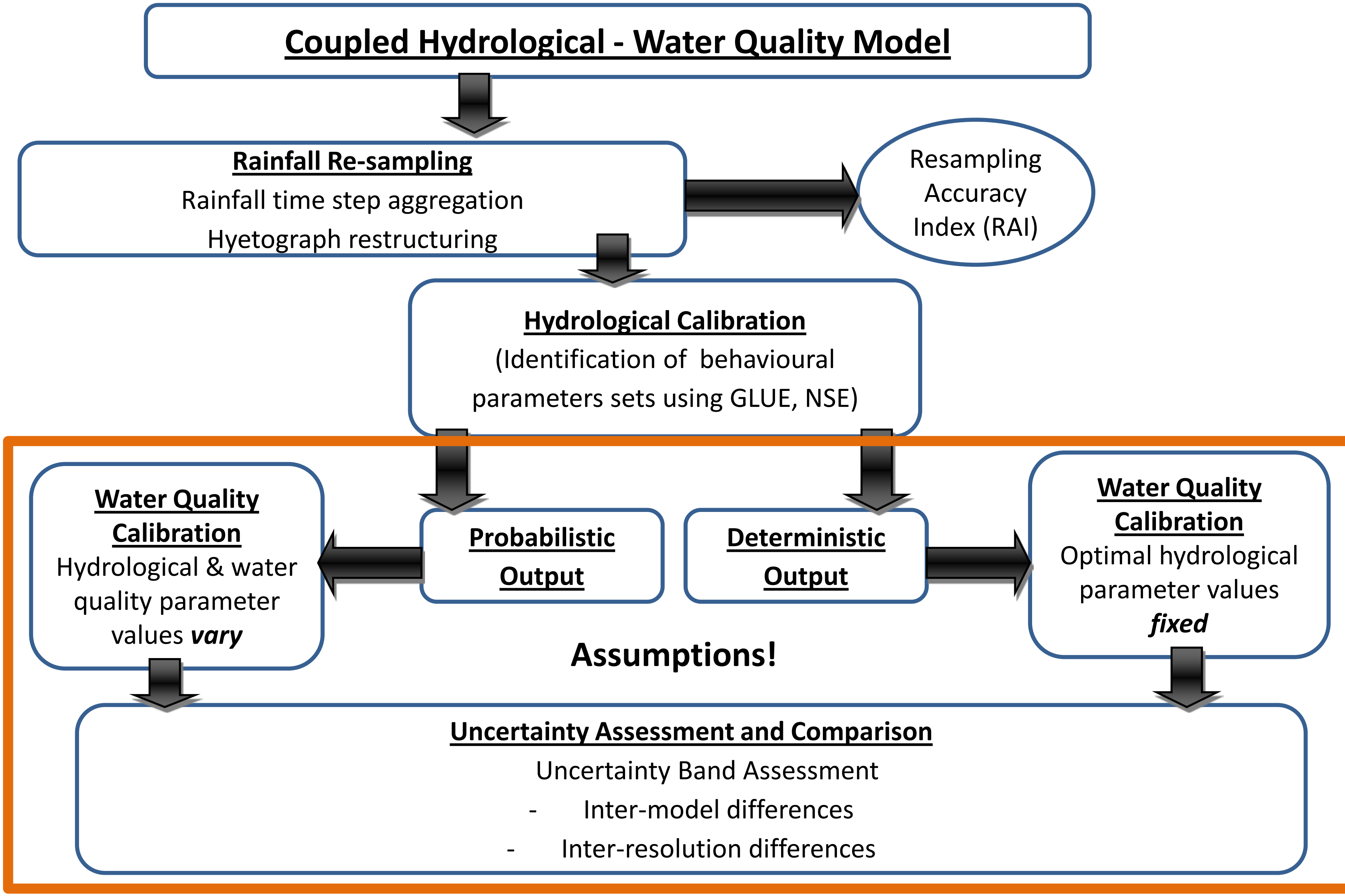




- Deterministic (“fixed”) or probabilistic (“vary”) hydrological sub-model output as basis for a probabilistic water quality sub-model output .

- NSE_{flow} = 0.93-0.97 across all rainfall resolutions for both events
- Flow sub-model capable of compensating loss of rainfall input information

Modelling Framework



Model Performance & Uncertainty

- Maximum NSE (optimal parameter set)
- No. observations within uncertainty bounds (%)
- Average Relative Interval Length (ARIL)

E.g. Dotto et al. 2012

$$ARIL = \frac{1}{N}\sum_{i=1}^{N} \frac{\mathrm{Limit}_{u,i} - \mathrm{Limit}_{l,i}}{X_{obs,i}}$$

$Limit_{u,i}$ / $Limit_{l,i}$: upper and lower boundary values of the 90% confidence interval

N: number of observations (TSS) X_{obs}: the observed i-th value (TSS in mg/l)

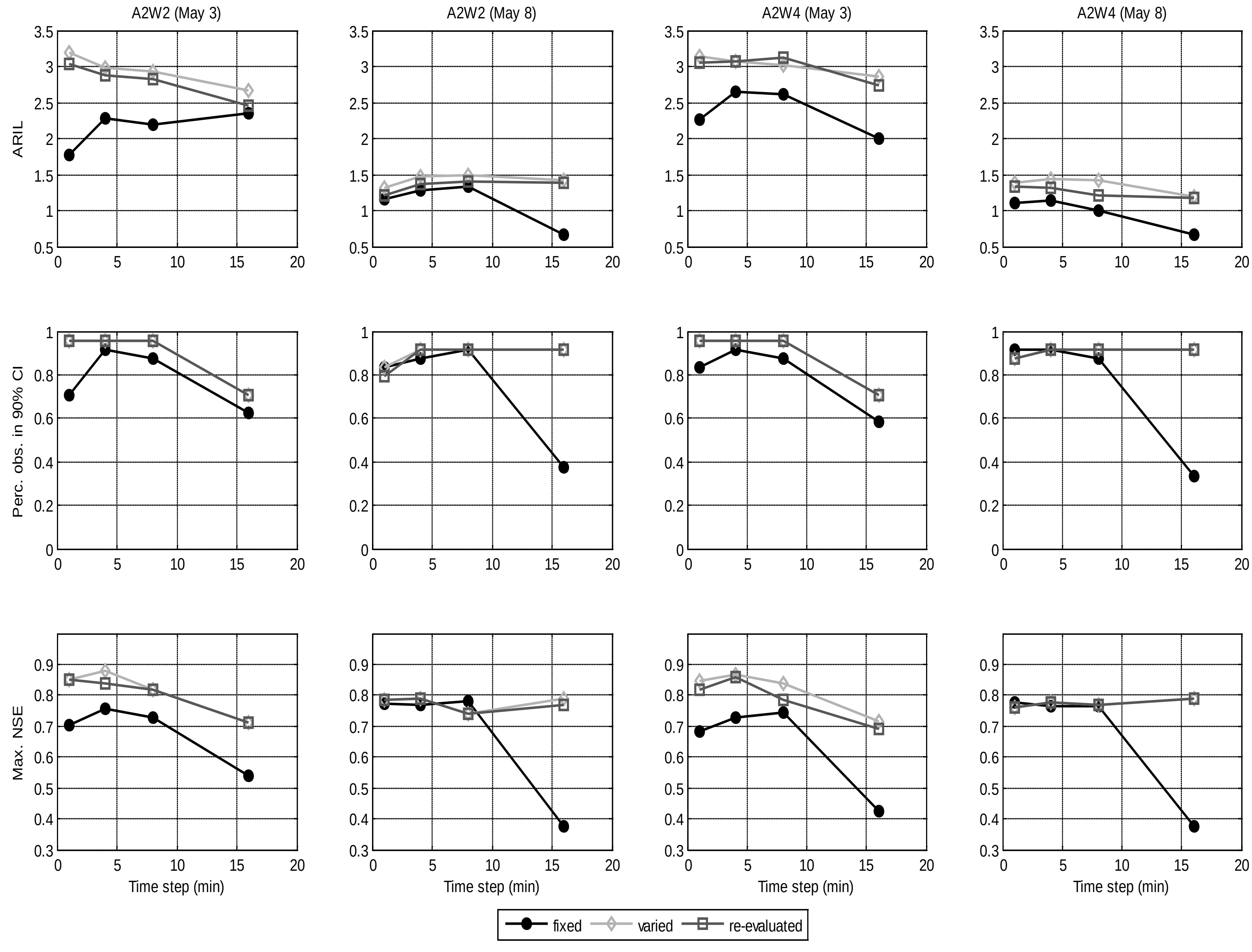
$$\frac{U_{WQ}}{U_{total}} = \frac{ARIL_{fixed}}{ARIL_{vary}} = \frac{\frac{1}{N}\sum_{i=1}^{N} \frac{\mathrm{Limit}_{f:\,u,i} - \mathrm{Limit}_{f:\,l,i}}{X_{obs,i}}}{\frac{1}{N}\sum_{i=1}^{N} \frac{\mathrm{Limit}_{v:\,u,i} - \mathrm{Limit}_{v:\,l,i}}{X_{obs,i}}}$$

$ARIL_{fixed}$ / $ARIL_{vary}$: ratio of ARIL values for “fixed” to “vary”-ing simulations

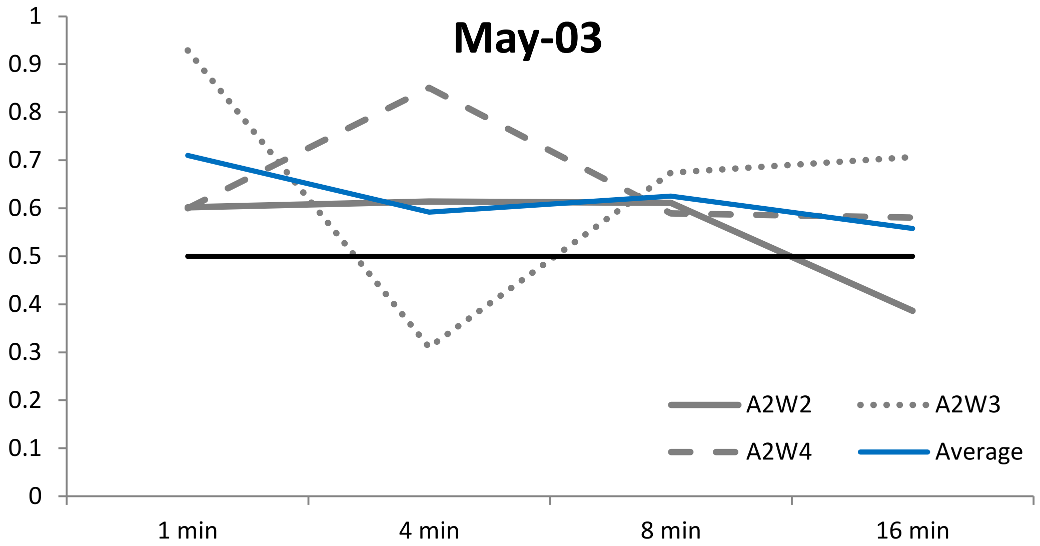
U_{WQ} / U_{total} : ratio of water quality model to total model uncertainty respectively

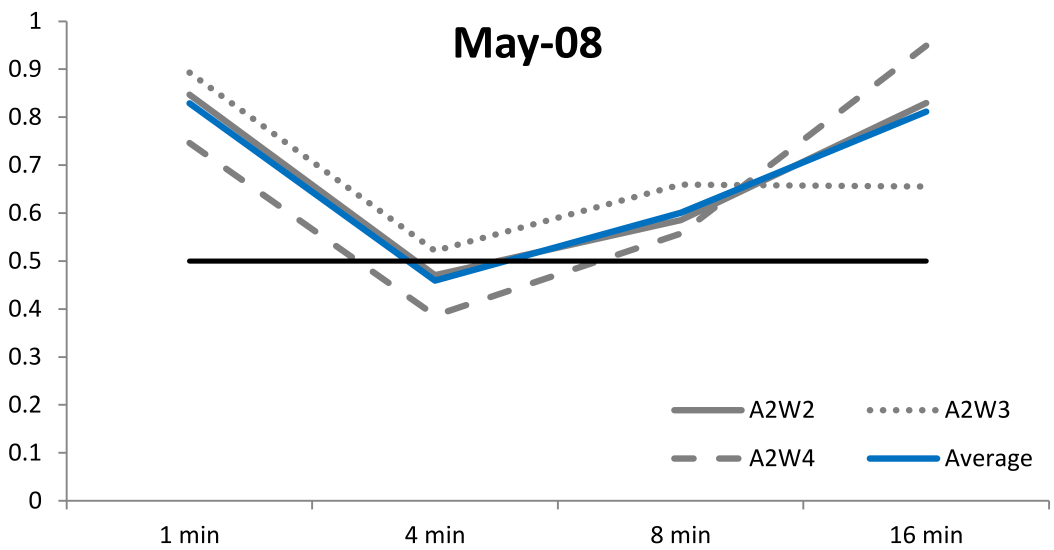
$Limit_f$ / $Limit_v$: Confidence interval limits of “fixed” & “varying” simulations

Model performance & uncertainty results



Uncertainty Contribution

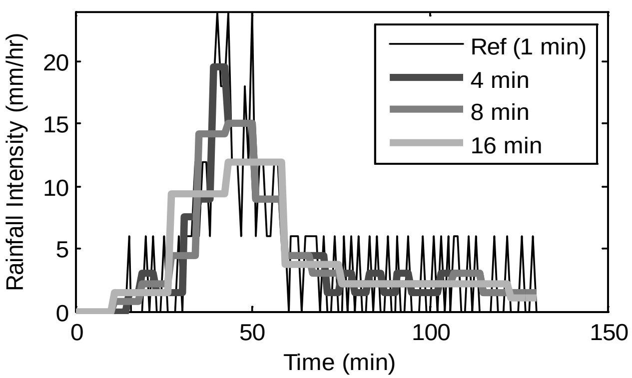




Overall water quality sub-model uncertainty contribution 30-95%

Average: 65%
(May 3 62% / May 8 68%)

Inter-event differences!



Summary

- Input rainfall resolution impact dependent on rainfall event characteristics & complexity

- Flow model insensitive to rainfall resolution

  WQ models: significant inter-model differences

- Very high total model output uncertainties
  - Low parameter identifiability
  - Ratio of WQ: hydrological model uncertainty = 2-4:1
  - Relevance of rainfall resolution difficult to assess

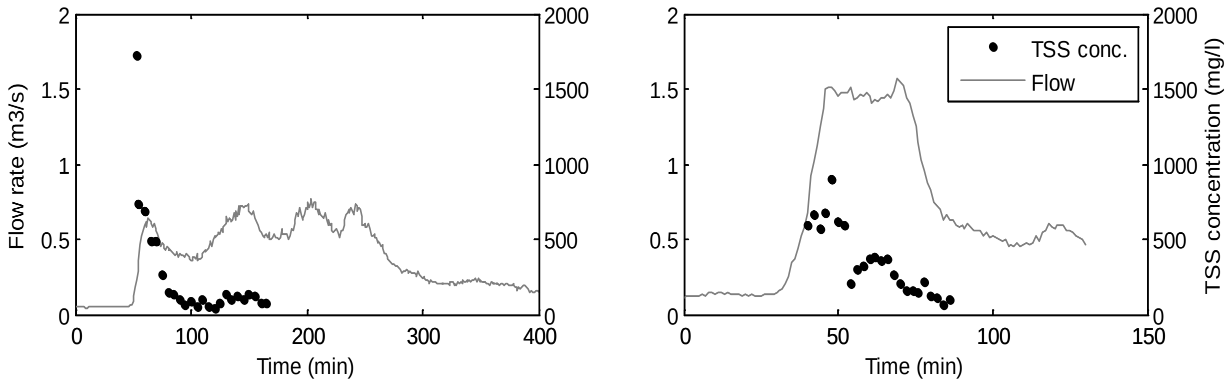
Summary

- Input rainfall resolution impact dependent on rainfall event characteristics & complexity

- Flow model insensitive to rainfall resolution

  WQ models: significant inter-model differences

- Very high total model output uncertainties
  - Low paran
  - Ratio of W
  - Relevance



Implications and Outlook

- More data!
  - TSS obs. scarcity (increasing limb, peak uncertainty)
  - Surrogate parameters instead of TSS?
- More events!
  - different urban catchments & conditions
- Less parameters!
  - Parsimonious model (total 3 parameters)
  - Initial results: similar total output uncertainty
    but better parameters identifiability

Thank you for your attention!

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