Characterizing dominant hydrological processes under uncertainty: evaluating the interplay between model structure, parameter sampling, error metrics, and data information content

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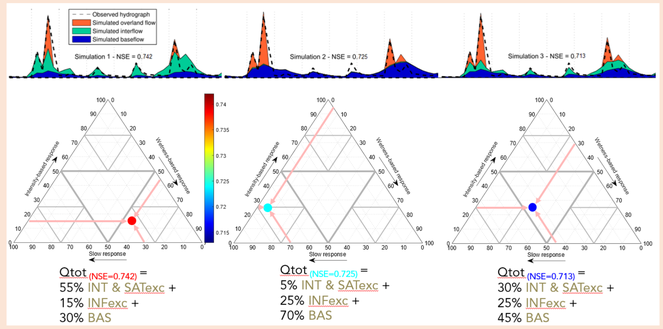
Premise

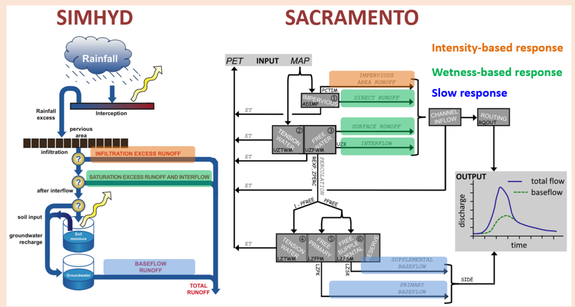
1. A conceptual model is a hypothesis.
2. Multiple Working Hypotheses → Ensemble of plausible models
3. Process-based models require process-based evaluation.

Flux Mapping

Model Response → characterised by mapping the contribution of each model's runoff flux to the total simulated flow, for any acceptable model run. → **flux map**



Models

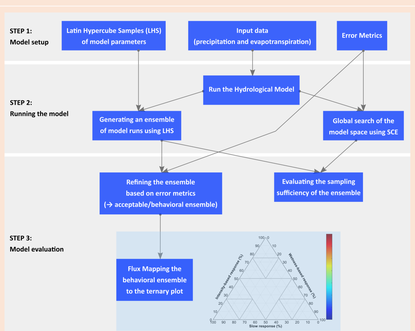


Error Metrics

Three widely used error metrics, all implemented as skill score i.e. benchmarked against the mean observed flow:

- **NSE** (Nash–Sutcliffe efficiency, *Nash & Sutcliffe, 2011*)
- **KGEss** (Kling–Gupta efficiency, *Kling et al., 2012*)
- **WIA** (Willmott's refined index of agreement, *Willmott et al., 2011*)

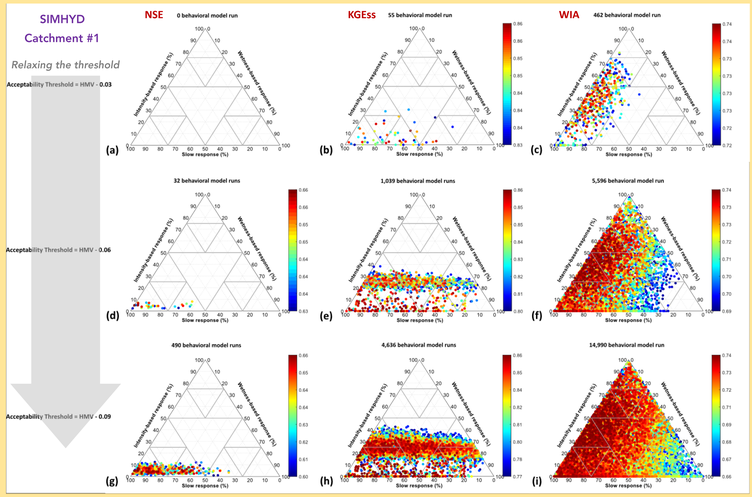
Experiment Design



Results

Example 1– same catchment and different acceptability thresholds

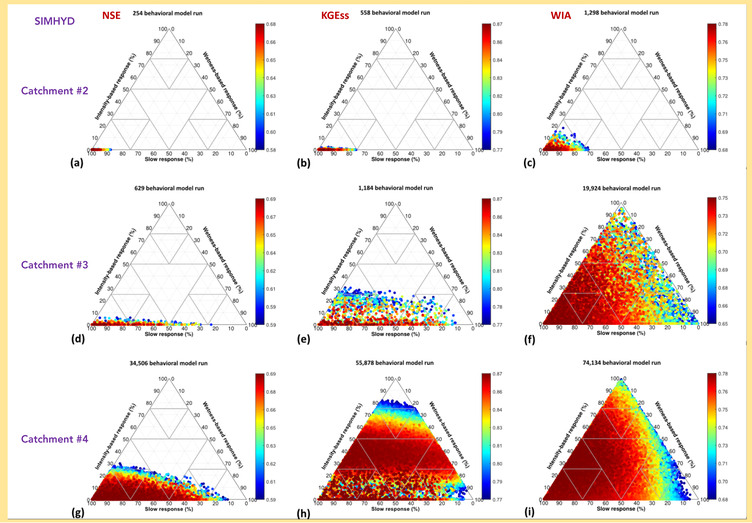
- Relaxing the acceptability threshold based on the distance (of each model run performance) from the highest metric value (HMV)
- Same catchment → information content constant
- 1 million LHS is insufficient using NSE (a), while sufficient for KGEss and WIA (b & c)
- The choice of error metric, other factors constant, can change the flux map (runoff generation hypotheses)



Example 2 – different catchments and same acceptability threshold of (HMV – 0.10)

Model response depends on the choice of error metric:

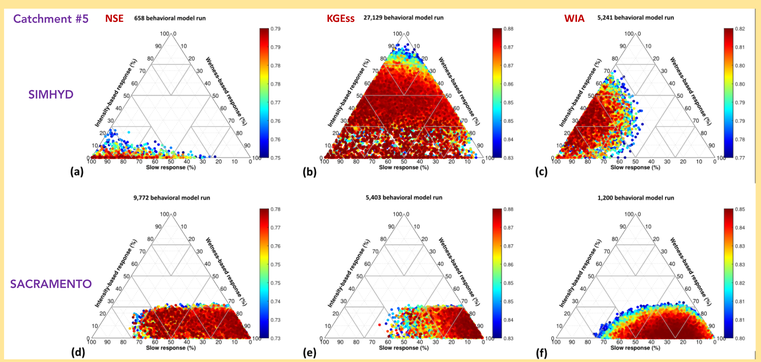
- In catchment 3, KGEss (e) and WIA (f) give rise to different runoff generation dynamics (flux maps), while in catchment 4, KGEss (h) and WIA (i) flux maps are quite similar.
- The choice of error metric can impact how we compare catchments. Comparing the model response of catchments 3 and 4, under KGEss (e and h → different) and WIA (f and i → similar).



Example 3 – same catchment and same acceptability threshold of (HMV – 0.05)

A relatively simpler model (SIMHYD) can give rise to more complex model response:

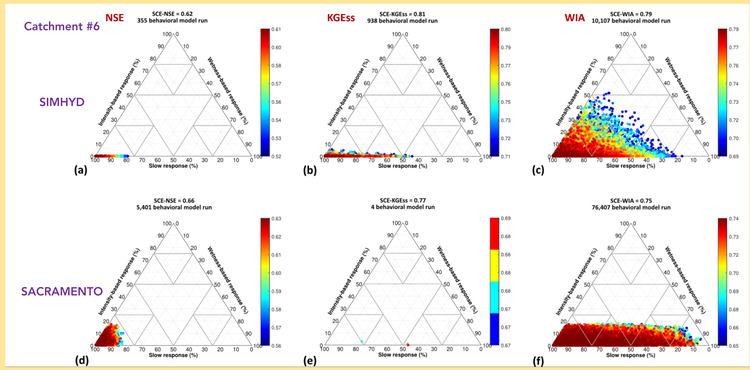
- SIMHYD → the model response is sensitive (remarkably change) for each error metric
- SACRAMENTO → the model response is similar under all three error metrics (insensitive to error metric)



Example 4 – same catchment and same acceptability threshold of (HMV – 0.10)

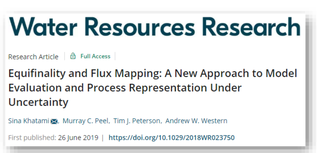
The choice of error metric can change the sufficiency of large parameter sets.

- 1 million LHS of SIMHYD is sufficient under all three error metrics.
- 1.2 million LHS of SACRAMENTO is insufficient for KGEss (e), while sufficient for NSE (d) and WIA (f).



Take-home messages

1. We can evaluate the model response/behaviour based on model's runoff fluxes that amount to the total simulated flow, to characterize how runoff is simulated in the model — the flux mapping method.
2. For a given catchment and model structure and parameterisation, the choice of ***error metric*** can change both the ***sufficiency of parameter samples*** (even as large as 1 M sets) and/or the ***flux map*** (Multiple Working Hypotheses).
3. A simpler model structure (i.e. number of stores and parameters) can produce a more diverse set of hypotheses for catchment response.



Next paper coming soon…

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