Remember PUB

- This meeting is important: one of the first in which hydrologists have met to discuss predictive uncertainty
  - for gauged catchments
- For ungauged catchments: PUB goal equivalent to Klemeš 4th validation test
  - how many reports in literature?
- Remember PUB written in terms of methods to reduce uncertainties in predicted response
  - what is best strategy?

Remember PUB

- Remember water quality and good ecological status
  - majority of water framework directive designated water bodies in Europe are ungauged?
- Remember developing countries
  - needs another approach based on remote sensing?
  - and if representation of hydrology on large parts of the world currently poor, what does that imply about climate change predictions?

Uncertainty Estimation: Separation of sources of error

- Behavioural models depend on input realisation (and effective observation errors in evaluations)
- Separation of error sources (to be possible at all) requires strong assumptions that may be difficult to justify
- Thus model structural error will not be easy (and may be impossible) to isolate
- Statistical approach allows implicit or explicit compensation for structural error
- Can only require that models stay consistent with evidence (qualitative and quantitative)
- How to learn about transferability error in space and/or time?

Uncertainty Estimation: Different philosophies

- DBM Inductive approach
- Formal Bayesian approach (likelihood function based on statistical error assumptions)
- Less formal Bayesian approach (subjective likelihoods; multi-criteria evaluations)
- Rejectionist approach (extended GLUE)

Questions for different approaches: DBM inductive approach

- How far does inference depend on measurement errors?
- How can inference on gauged catchments be best used in prior estimation of ungauged catchments?
- Can reasoning about physical parameters of dominant modes of response be used in prediction of impacts of change or site?

Questions for different approaches: Formal Bayes method

- How to define an appropriate error structure/likelihood function for complex error series (may change in model space?)
- How to require that assumptions of likelihood function are checked in reporting applications?
- How to define input errors independently of model?
- How to define likelihoods for complex input errors?
- How to sample posterior efficiently?

Questions for different approaches: Informal Bayes method

- How to define an appropriate likelihood measure(s) for model evaluation?
- How to define input errors independently of model?
- How to define likelihoods for complex input errors?
- How to sample model space efficiently?
- How to report uncertainty estimates (not probabilities of predicting an observation given the model(s))?

Questions for different approaches: Extended GLUE method

- How to define an appropriate effective observation errors/rejection criteria for different variables - especially for commensurability errors
- How to define input errors independently of model and take account of input realisations in producing behavioural models?
- How to sample model space efficiently (including input realisations)?

Comments on Transferability

- Uniqueness of place means that transferability of dynamic responses will be difficult
- How relevant is calibration of models to gauged catchments in ROBUST estimation of dynamic responses of ungauged responses (learn from DBM)?
- Estimating change in marginal parameter distributions may not be sufficient (landscape to model space mapping - drifting of parameter sets through the model space)
- But - prior estimates can be refined as new data become available

Conclusions after 25 years?

- Measurement errors are important and make structural error identification difficult
- Equifinality as multiple working hypotheses - important to retain possibility of rejecting best models if not acceptable
- Modelling (particularly of ungauged catchments) must be set up as a learning process - value of additional measurements needs assessing
- New measurement techniques are needed to make progress with internal/pathway predictions

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