Australian Government

BIOREGIONAL ASSESSMENTS

PROVIDING SCIENTIFIC WATER RESOURCE INFORMATION ASSOCIATED WITH COAL SEAM GAS AND LARGE COAL MINES

Sensitivity analysis as essential tool to gain insight into potential hydrological change due to coal development in Australia

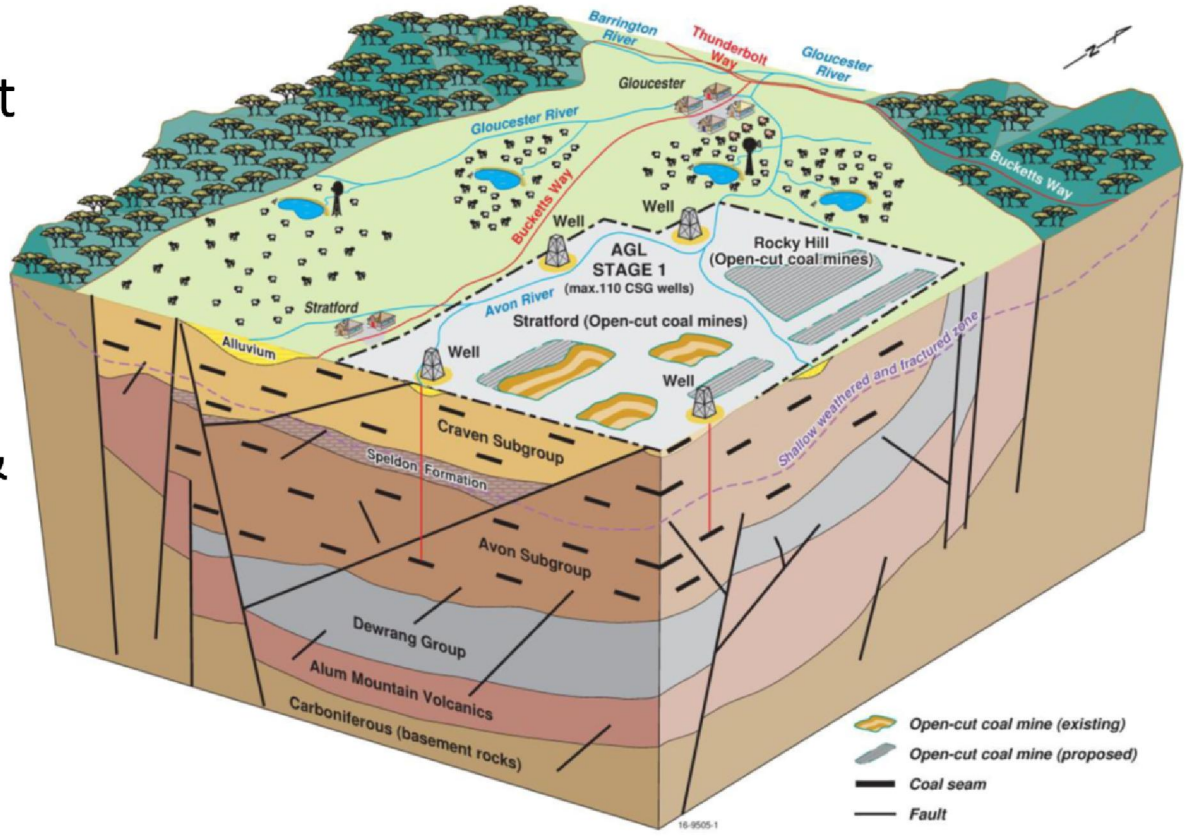
Luk Peeters (+ ~100 researchers)

SAMO2016, La Reunion, 2/12/16

A scientific collaboration between the Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia

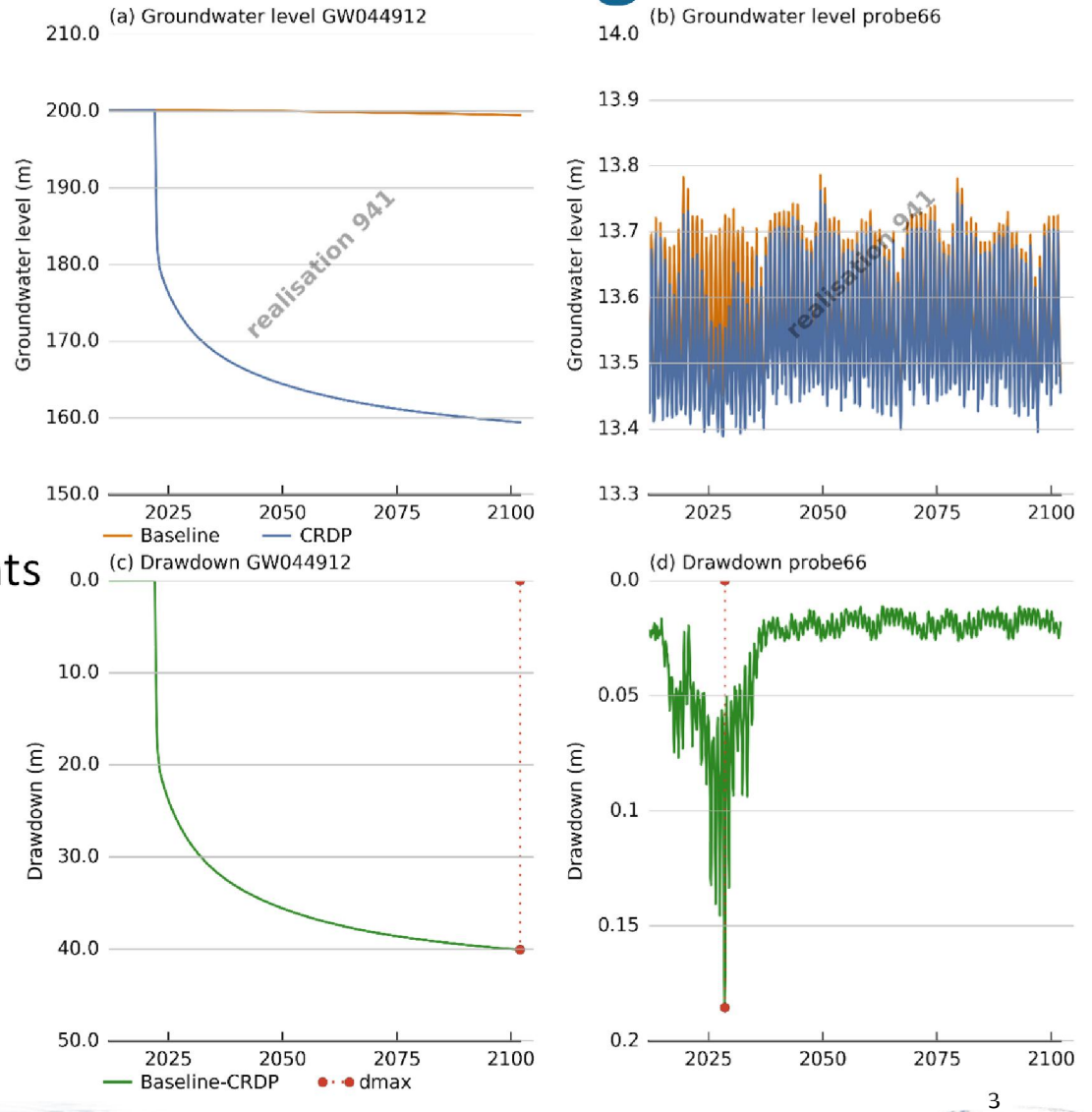
Bioregional Assessments

- risk analysis of impact of coal resource development on water dependent assets
- inform government & general public
- coal mining:
  - GW pumping
  - rainfall interception
- coal seam gas:
  - GW pumping



Groundwater numerical modelling

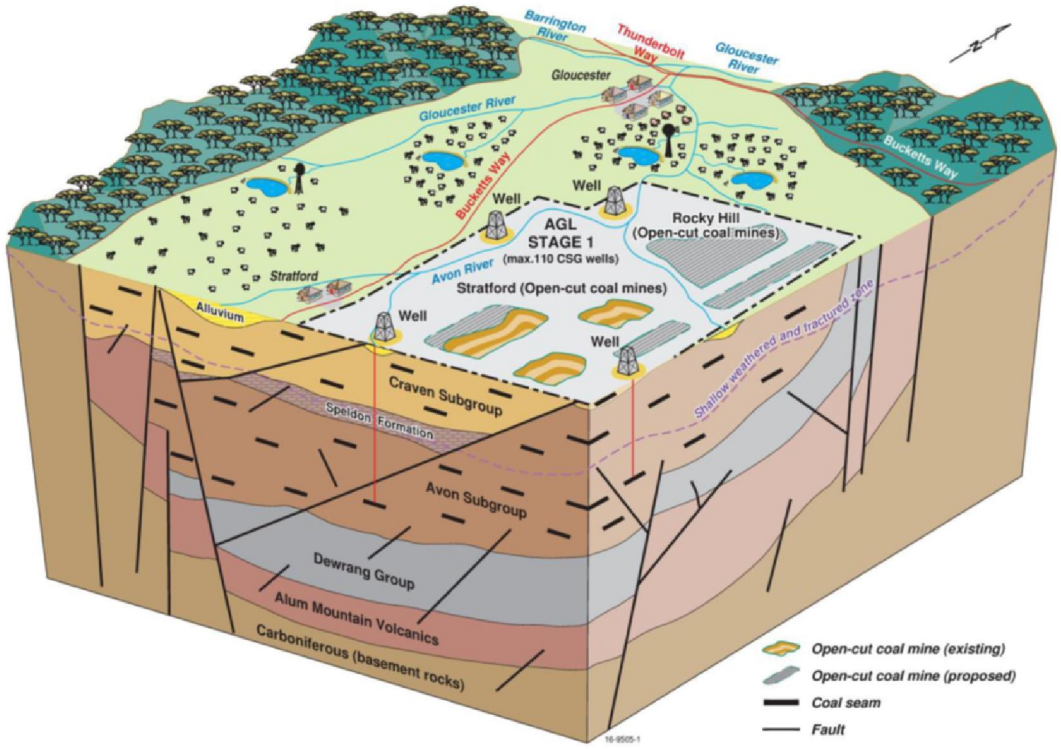
- Scenario
  - Baseline:
    - current and approved developments
  - CRDP
    - Coal Resource Development Pathway
    - Baseline + future developments
- Predictions
  - Baseline – CRDP
  - Hydrological Response Variable
    - maximum drawdown
    - time to maximum drawdown
  - > 1000 prediction locations per region



Groundwater numerical modelling

$$K_h \frac{\delta^2 h}{\delta x^2} + K_h \frac{\delta^2 h}{\delta y^2} + K_v \frac{\delta^2 h}{\delta z^2} = S \frac{\delta h}{\delta t} + R(t) + Q_{riv}(t) + Q_{mine}(t)$$

- Parameterisation
  - spatially and temporally varying fields
  - zonation
  - depth dependence
  - offsets, coefficients & multipliers
- Observations
  - historical
    - groundwater level (measured)
    - river or inter-aquifer fluxes (estimated)
  - future
    - mine water production (estimated)



Quantitative uncertainty analysis

- Design of experiment
  - minimax LHS
- Emulators
  - Gaussian Process
  - 30 fold x-validation
  - hit rates
- ABC MCMC
  - rejection sampling
  - OF acceptance threshold
- Sensitivity analysis

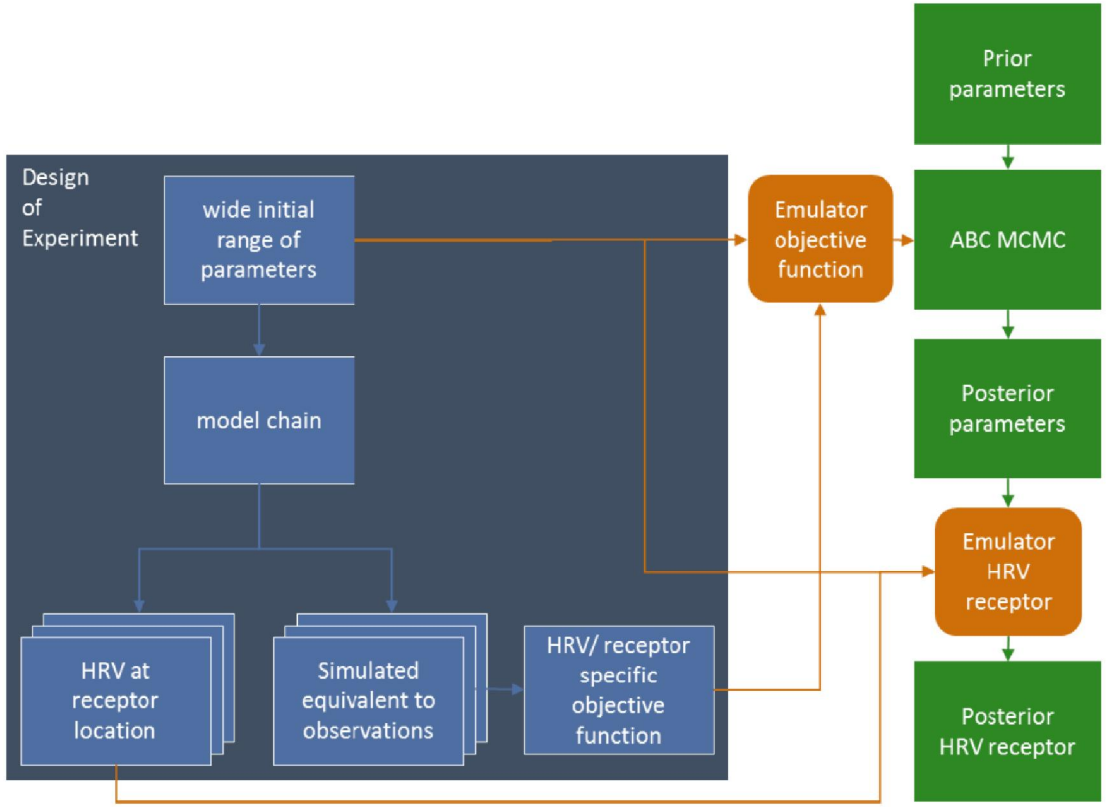


Figure 6 Uncertainty analysis workflow

ABC MCMC= Approximate Bayesian Computating Markov chain Monte Carlo; HRV = hydrological response variable

Qualitative uncertainty analysis

- Formal scoring and systematic discussion
- Assumptions and model choices
- Attributes:
  - Data
  - Resources
  - Technical
  - Effect on Predictions
- Open & transparent
  - justify
  - subjectivity
  - discussion starter

Table 11 Qualitative uncertainty analysis as used for the Gloucester subregion

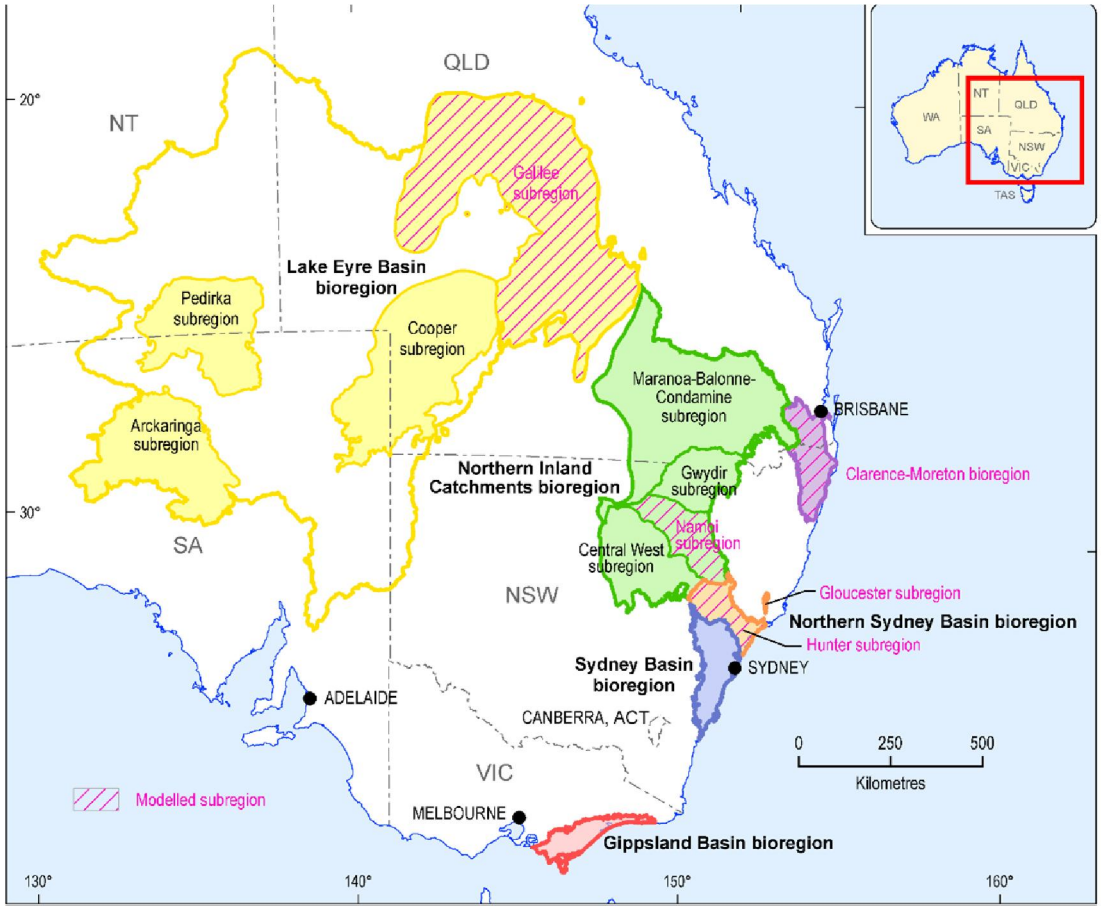
Assumption / model choice	Data	Resources	Technical	Effect on predictions
Hybrid analytic element – MODFLOW model methodology	high	medium	high	low
Principle of superposition	medium	low	low	low
Horizontally spatially uniform hydraulic properties	high	medium	medium	low
Hydraulic properties vary with depth, not with stratigraphy	high	low	low	medium
Stochastic representation of coal seams and faults	high	low	low	low
Random location of CSG wells and assigning pumping interval to random coal seams	high	low	low	low
CSG wells as constant head wells	high	medium	high	medium
Open-cut mines as prescribed pumping rate	high	low	low	high
Specification of prior distributions	high	medium	low	low
River network implemented as drainage boundary	medium	low	low	low
Constrain model with flux estimates rather than head observations	high	low	low	low
Simulation period from 2012 to 2102	low	high	medium	low

CSG = coal seam gas

Peeters L J (2015) Editor's Message: Stand on the shoulders of giants, don't hide behind them *Hydrogeology Journal, 23*, 421-422

Bioregional Assessments

- 6 GW models
- 7 SW models
- runtime
  - 10 minutes to 8 hours
  - 3 runs per model (scenario)
- 150.000 GW & SW model runs (and counting)
- ~ 100 TB storage
- public domain, available (soon)



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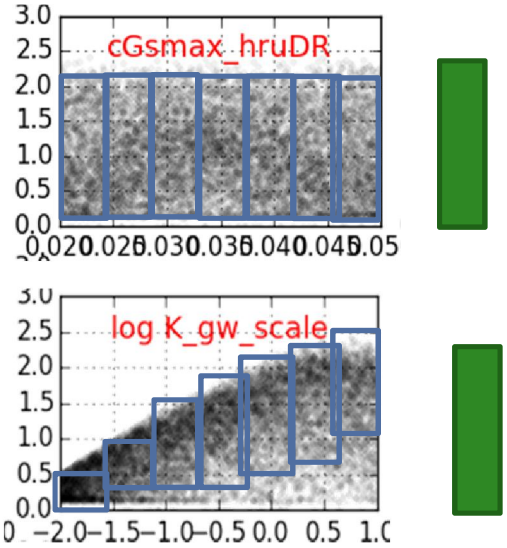
Sensitivity analysis

- Factor prioritisation / Data worth analysis
- Scatter plots
- pdf delta based SI (Plischke et al. 2013)
  - global
  - no prescribed sampling design



$$SI = E(\; \blacksquare - \square \;)$$

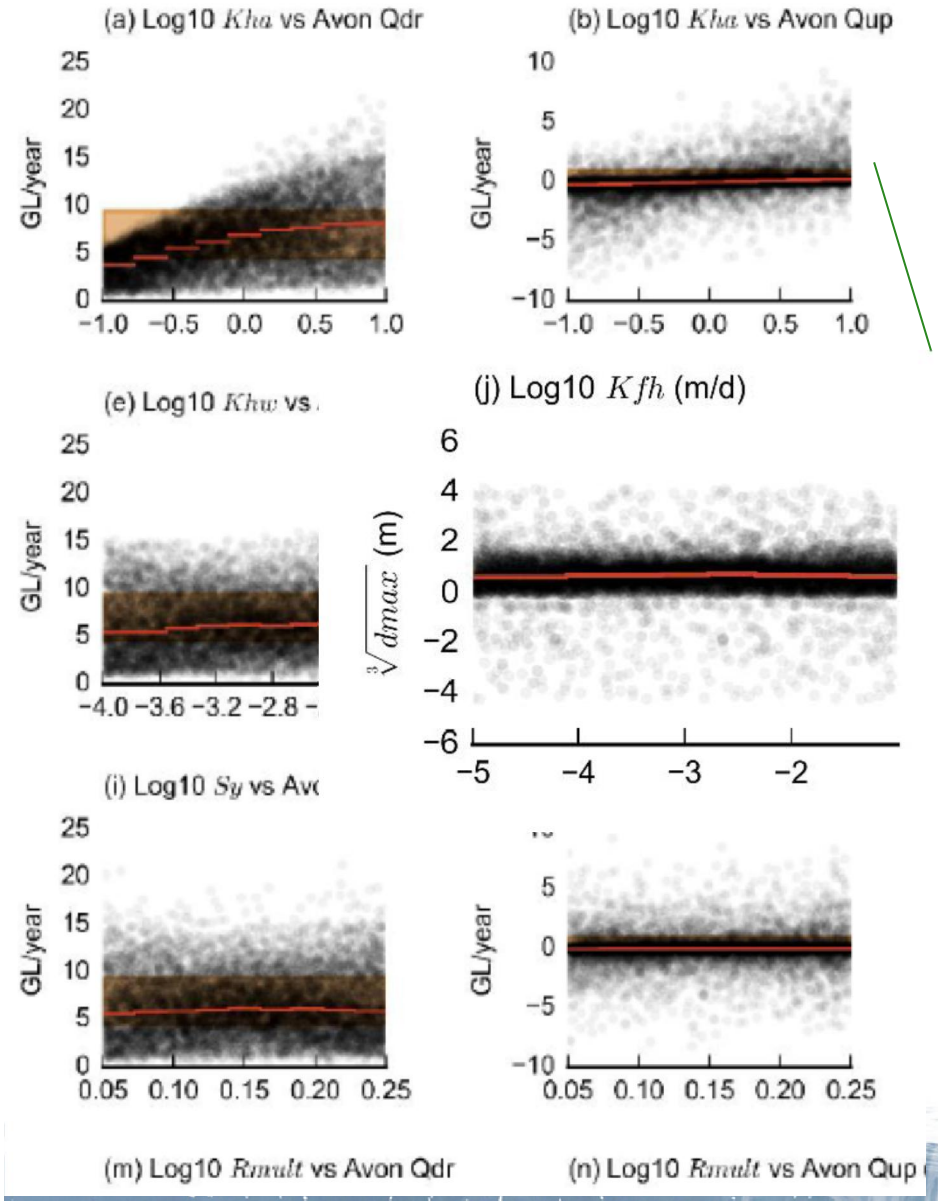
Data: high
Resources: medium
Technical: medium
Predictions: low

Plischke E, Borgonovo E and Smith C L (2013) Global sensitivity measures from given data *European Journal of Operational Research, 226*, 536-550

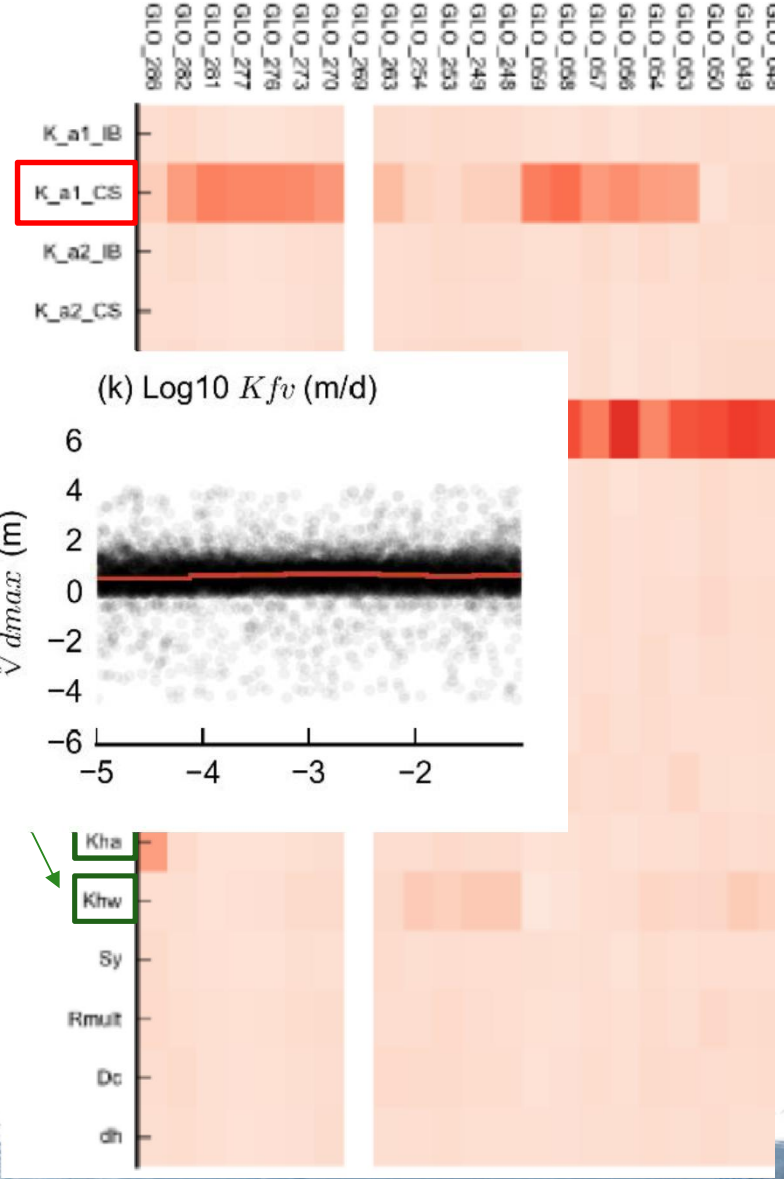
Peeters L J M, Podger G M, Smith T, Pickett T, Bark R H and Cuddy S M (2014) Robust global sensitivity analysis of a river management model to assess nonlinear and interaction effects *Hydrol. Earth Syst. Sci., 18*, 3777-3785 http://www.hydrol-earth-syst-sci.net/18/3777/2014/

Example 1

Observations



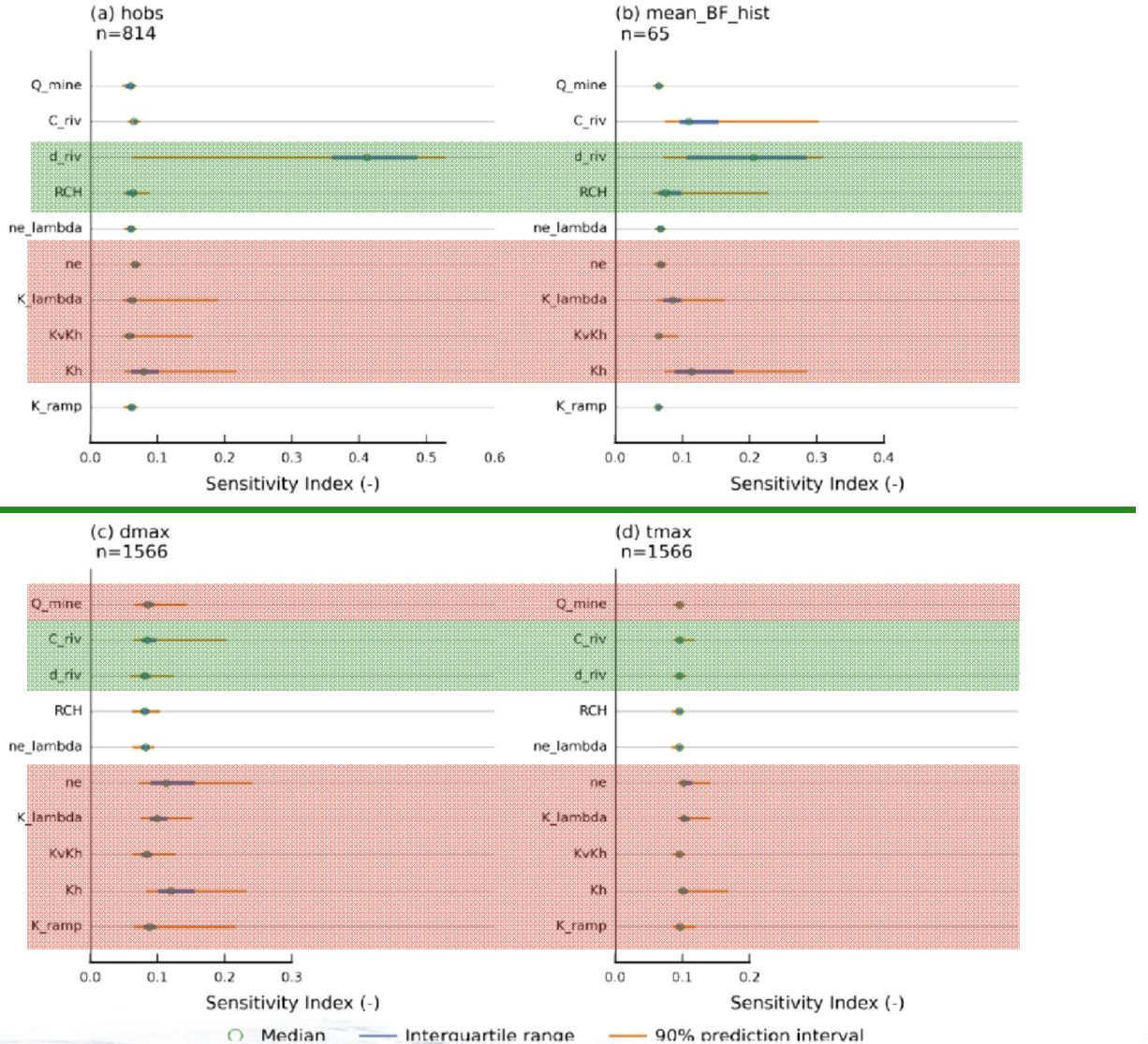
Predictions



Example 2

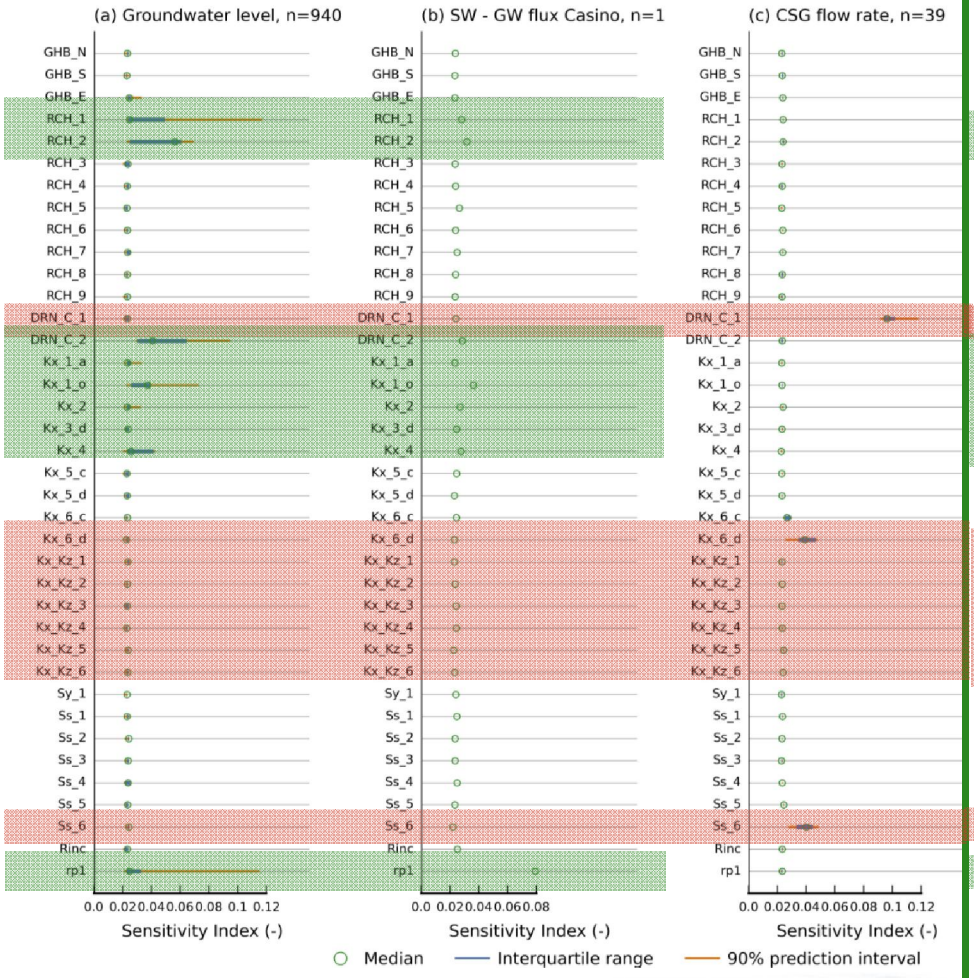
Observations

Predictions

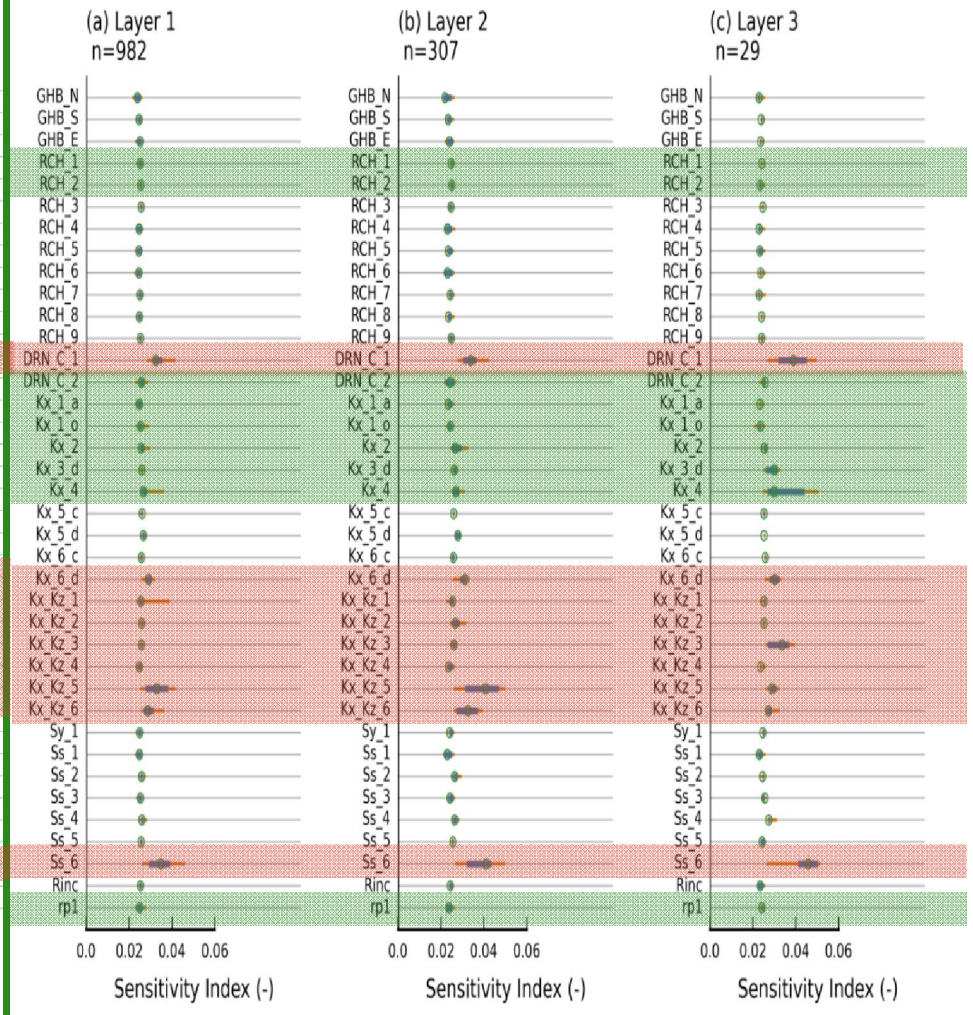


Example 3

Observations



Predictions



Conclusions

- BA GW modelling
  - dmax & tmax
    - Kh, Kv & S of source aquifer, target aquifer and interburden
  - observations (head and flux)
    - SW-GW interactions, recharge
    - do not constrain K & S greatly
    - low hanging fruit:
      - river stage off-set
- Sensitivity & Uncertainty analysis
  - rule in / rule out
  - 1st step in data-worth analysis, guiding further model development
  - further work & opportunities:
    - spatio-temporal variation of SI
    - parameter interaction
    - other SI
    - high-dimensional emulators

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