Contrôles structuraux à grande échelle des propriétés hydrogéologiques et modélisation des eaux souterraines du bassin de socle de la haute vallée de l'Ouémé (Bénin, Afrique de l'Ouest)

Large-scale structural controls on hydrogeological properties and groundwater modelling in the Upper Ouémé basement basin (Benin, West Africa)

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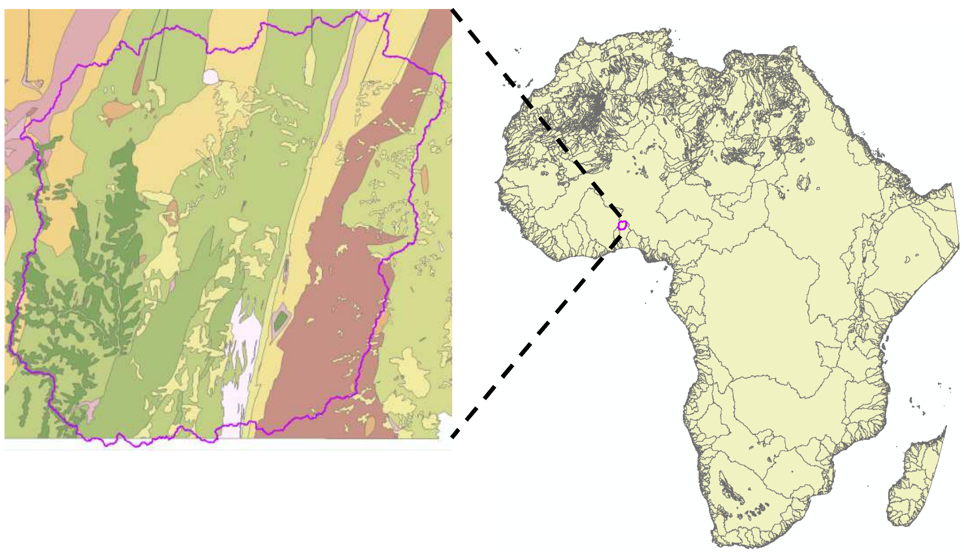
Aquifères de socle : le point sur les concepts et les applications opérationnelles
11-13 juin 2015, Auditorium de l'ICES, la Roche-sur-Yon, France

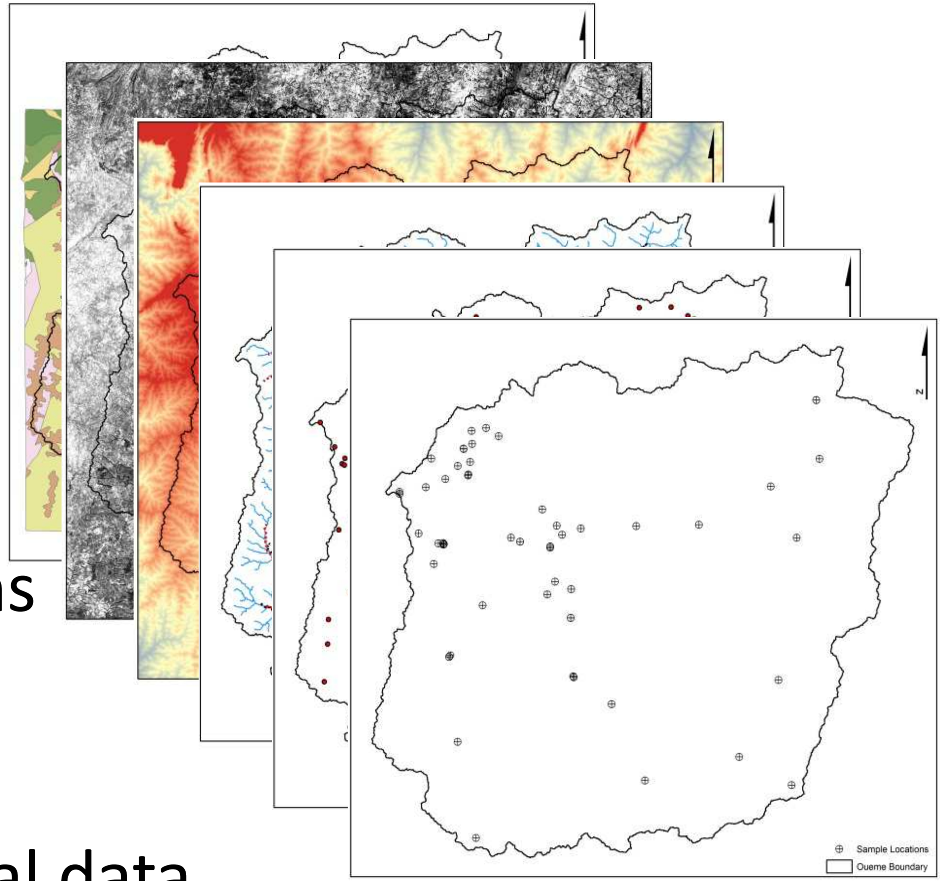
Introduction

- **G**roundwater **R**esources In **B**asement rocks of **A**frica (**GRIBA**) project
- Intial study to obtain field measurements (WP1)
- This work is WP2 – Groundwater modelling
- Approaches to determine regional hydrogeological controls
- Case study
  - Metamorphic Benin: weathering & fractures



Available Data

- Geological maps
- Aerial imagery
- DEM
- Drainage network
- GWL and pumping locations
- Point well/borehole data
  - Lithologs and T, K, S
- Complementary geophysical data
  - ERT and MRS – T (K), Sy and thickness of weathered zone

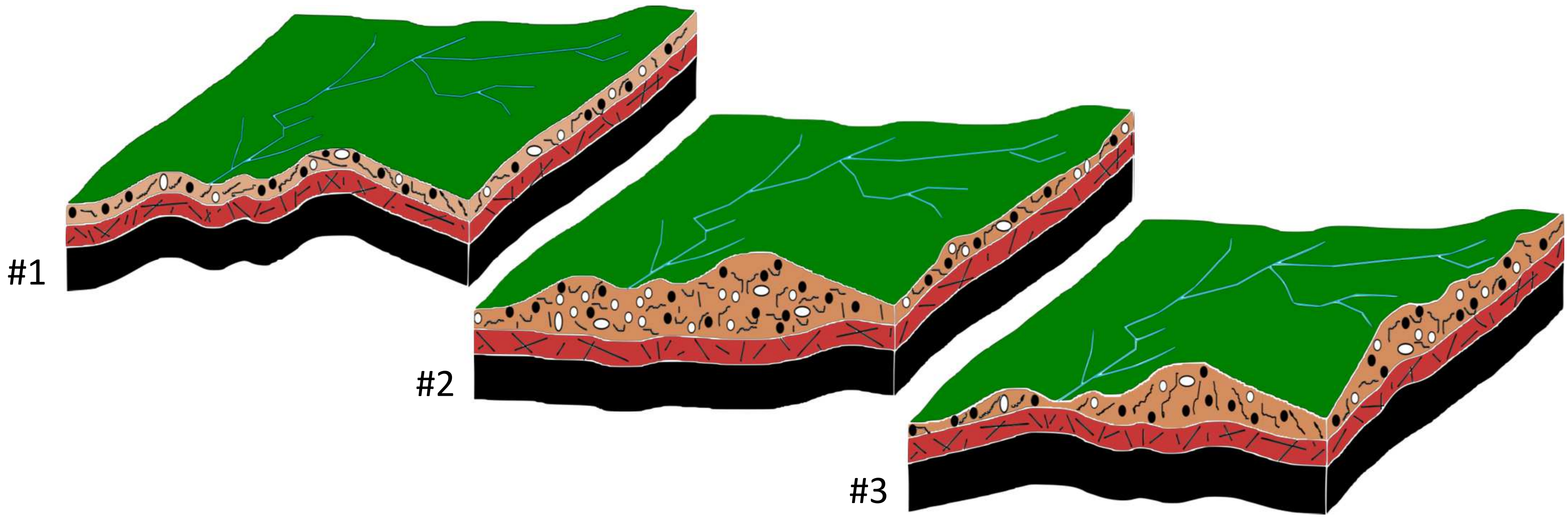


Methodology

1. Model the aquifer structure – conceptual geometry
2. Distribute aquifer properties based on known structure
3. Apply boundary conditions (forcings)
4. Evaluate models results (comparison of observations and multi-model statistical analysis)
5. Calculate aquifer budget

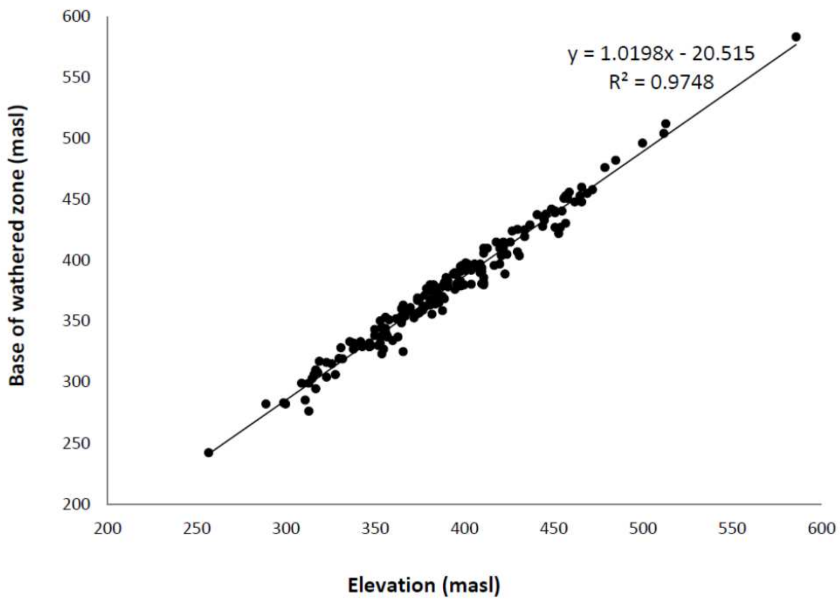
Conceptual Geometries

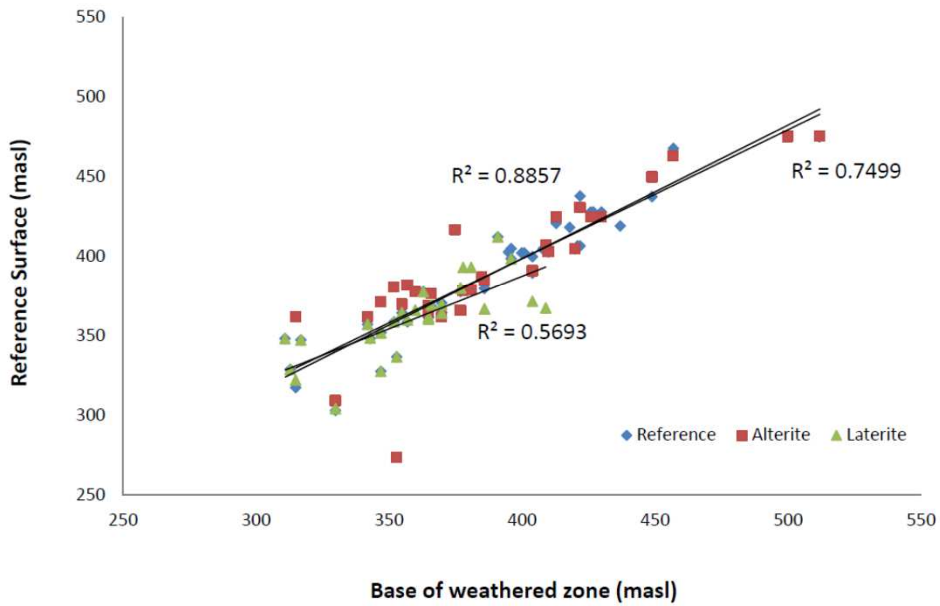
- Three cases -> the weathering profile (3-layers) is computed as a function of:
  1. Topography (El-Fahem 2008)
  2. Palaeo-weathering surface (alterite/laterite remnants)
  3. Simple borehole interpolation (approx. 140 points)



Conceptual Geometries

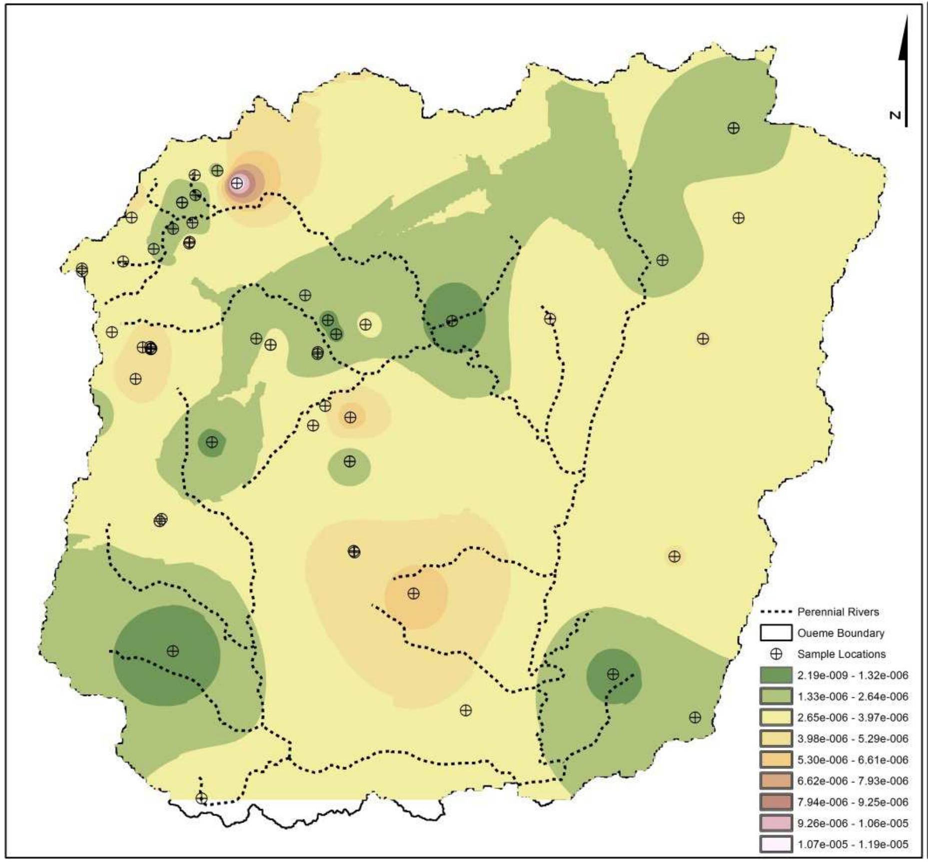
- Strong spatial correlations observed between the base of the weathered zone recorded in boreholes & geophysical soundings and:
  - The ground topography
  - Palaeo-weathering surfaces obtained from mapping laterite remnants

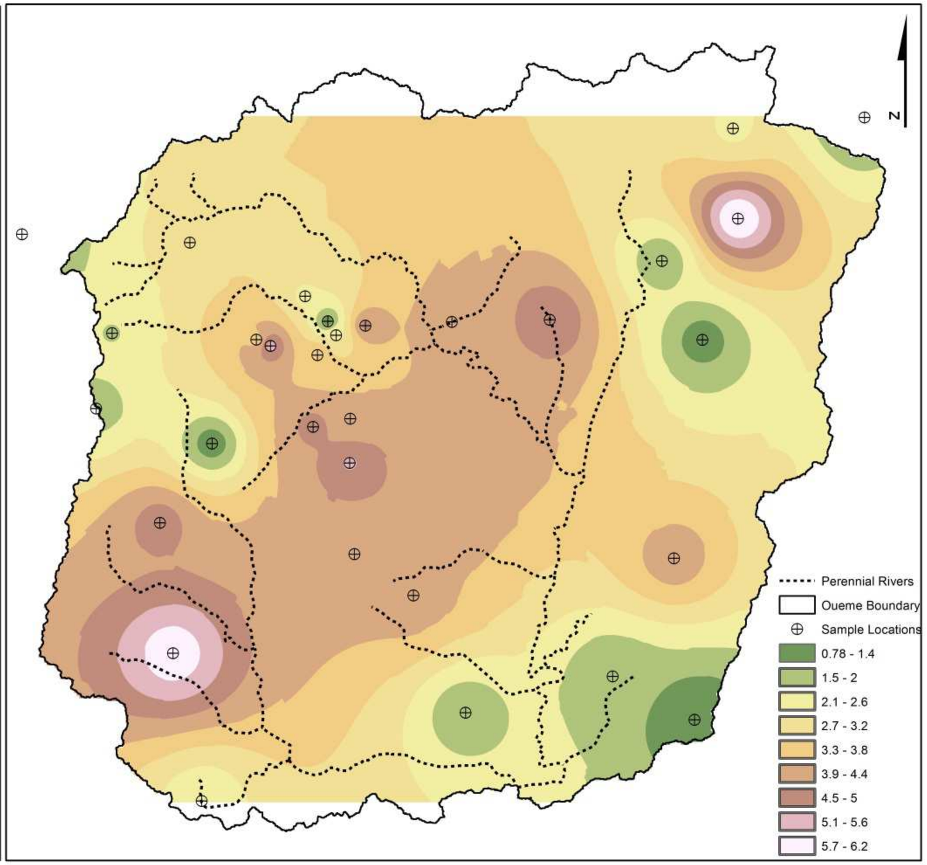




Parameter Distribution Scenario #1

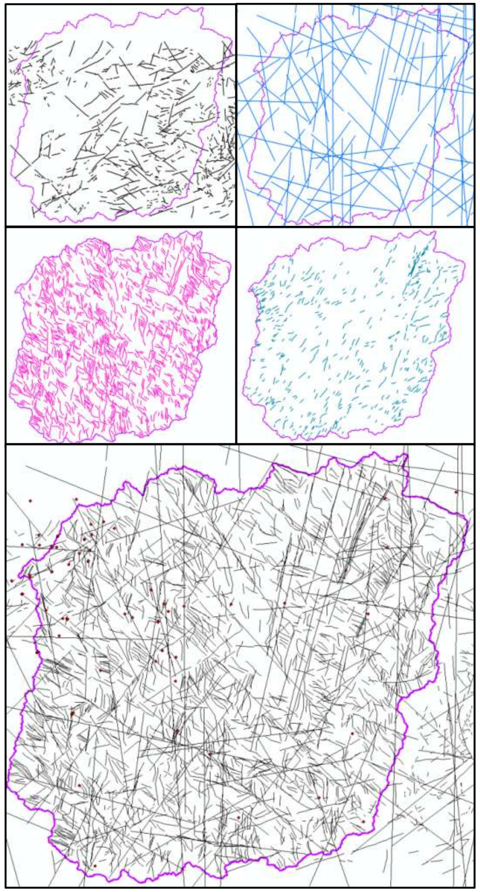
- Interpolated K and Sy

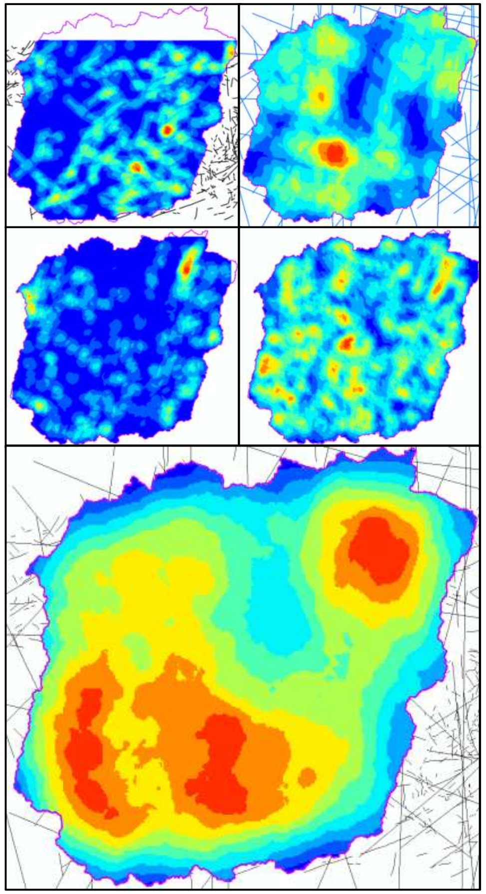


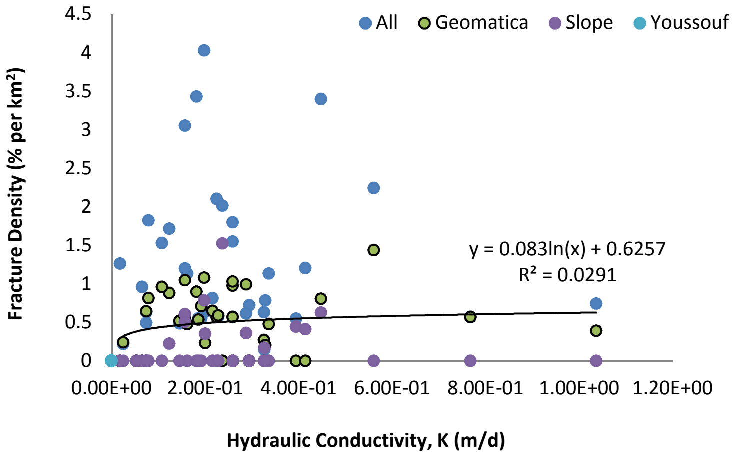


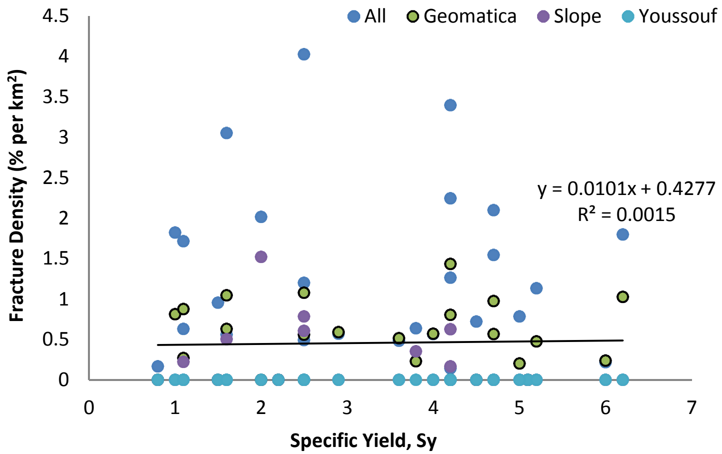
Parameter Distribution Scenario #2

- K and Sy as a function of fracture density



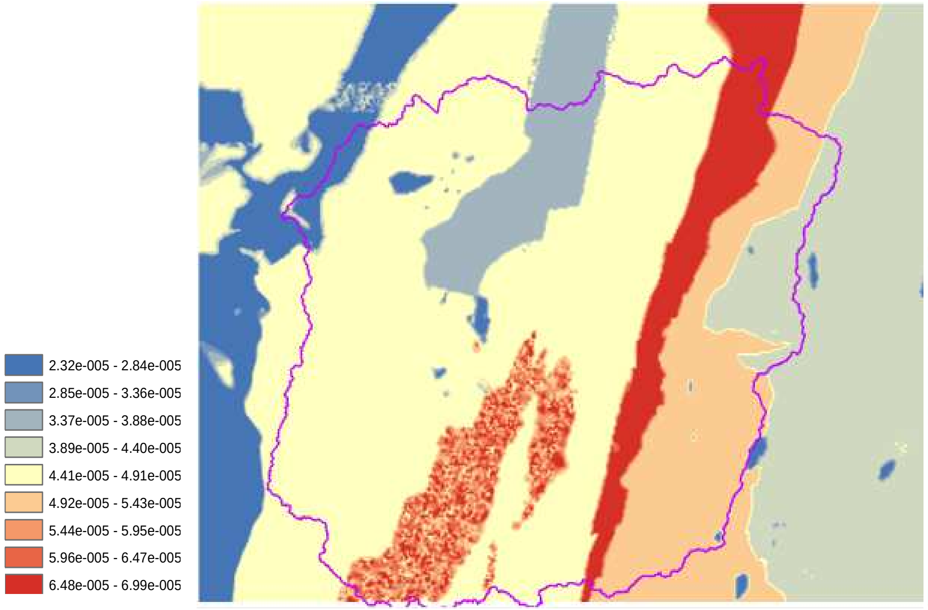


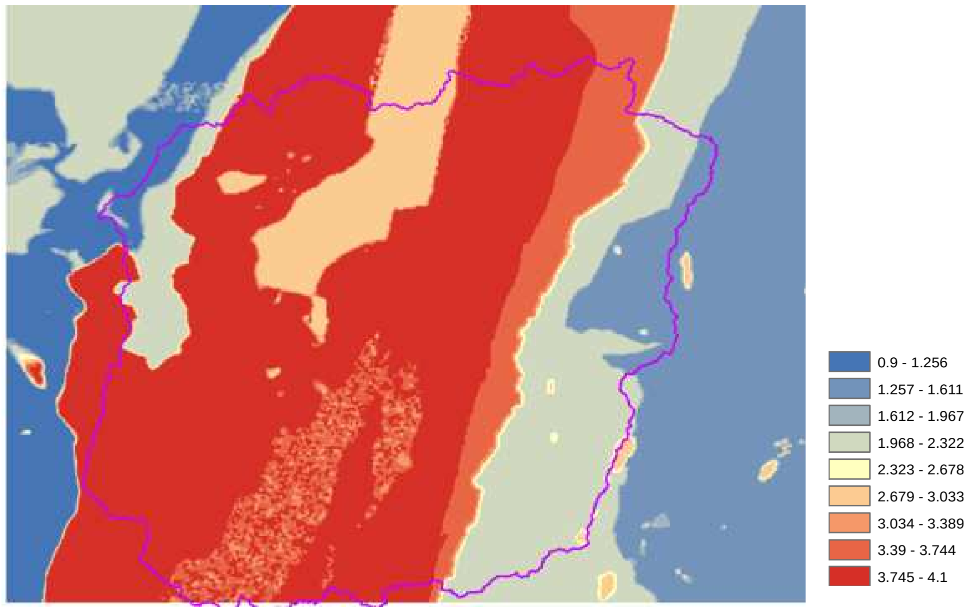




Parameter Distribution Scenario #3

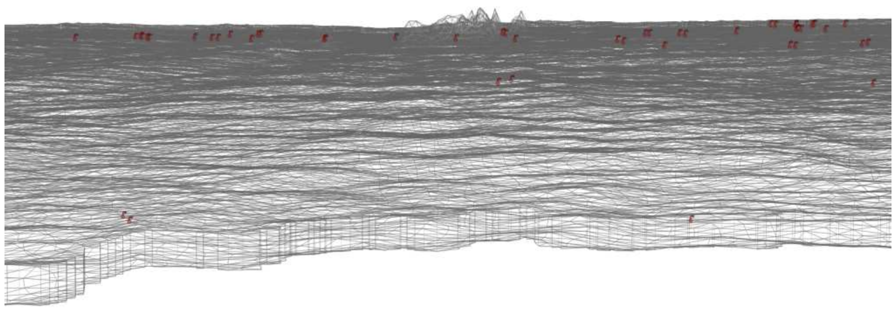
- K and Sy are distributed as function of geology

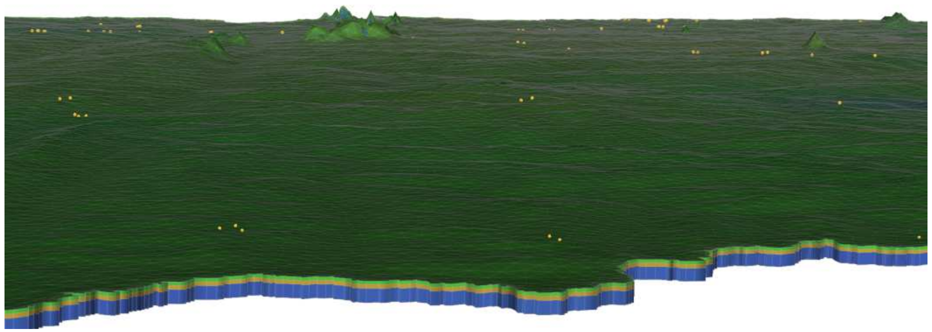




Modelling

- 3 x 3 = 9 conceptual models produced in FEFLOW using transformed DEM points
- No rivers assigned but a free seepage surface (topography)
- High density mesh produced
- Known pumping wells applied
- Monthly recharge distribution from previous studies (GIZ, 2012; and Kotchoni *et al.*, this conference)

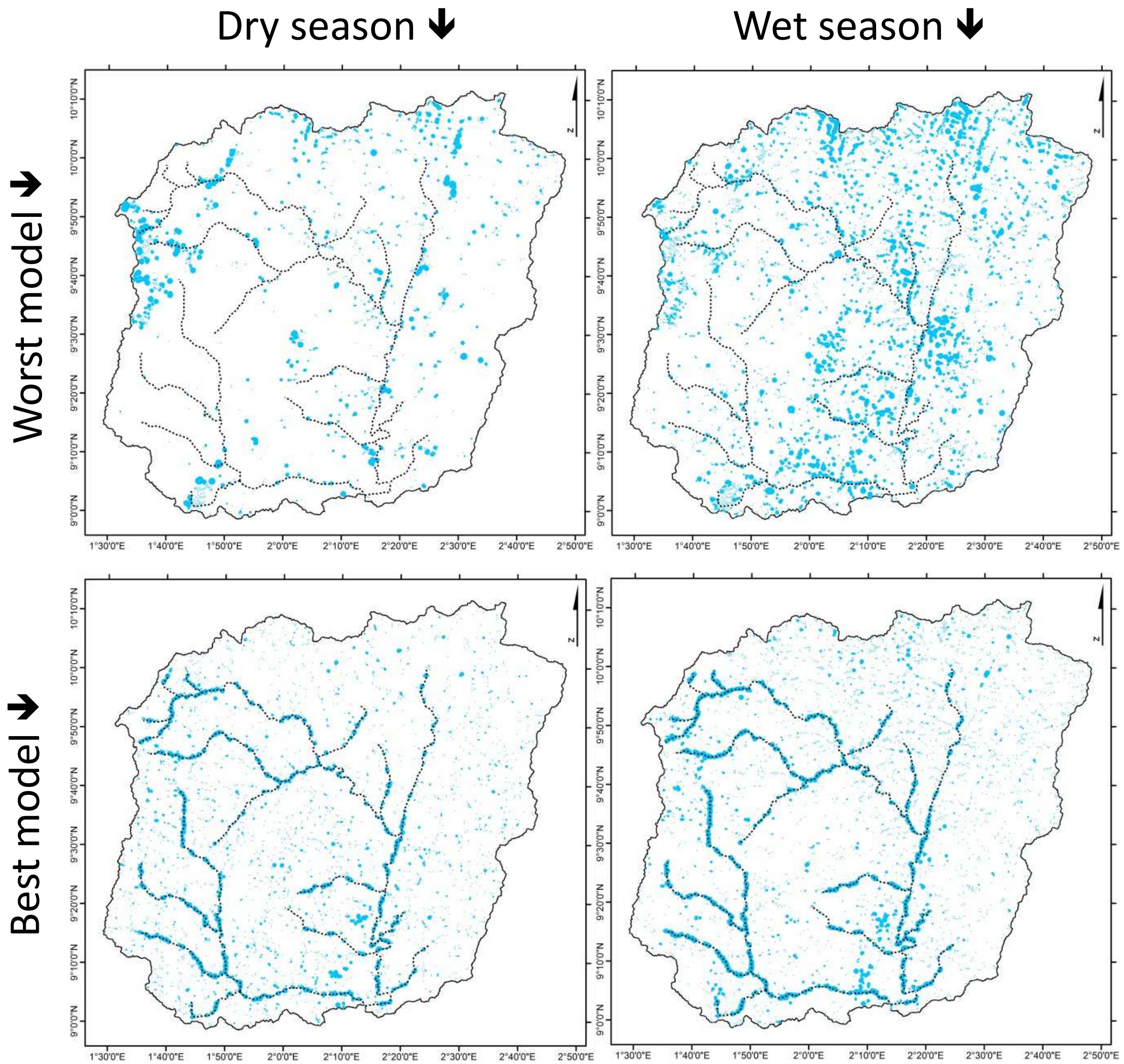




Modelling Analysis

- Lots of variance
- Distinguished by analysing 4 key control datasets:
  - Spatial distribution of discharge
  - Total discharge at basin outlet
  - Spatial piezometry distribution (~140 points)
  - Temporal water table variation (8 boreholes LETS)
- Akaikes Information Criteria (AIC) ranking (multi-model analysis)

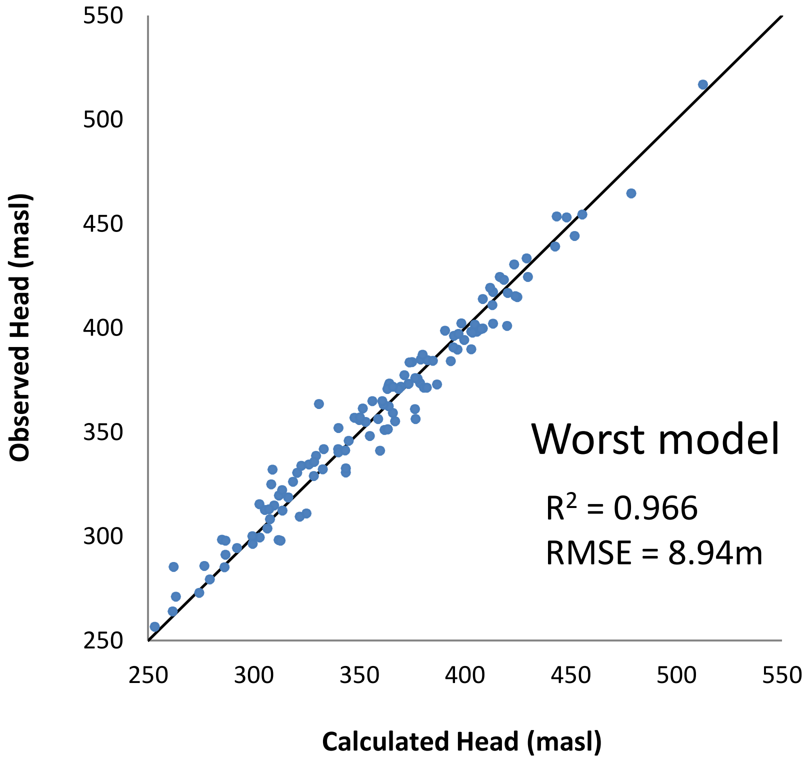
Distribution & Magnitude of Discharge

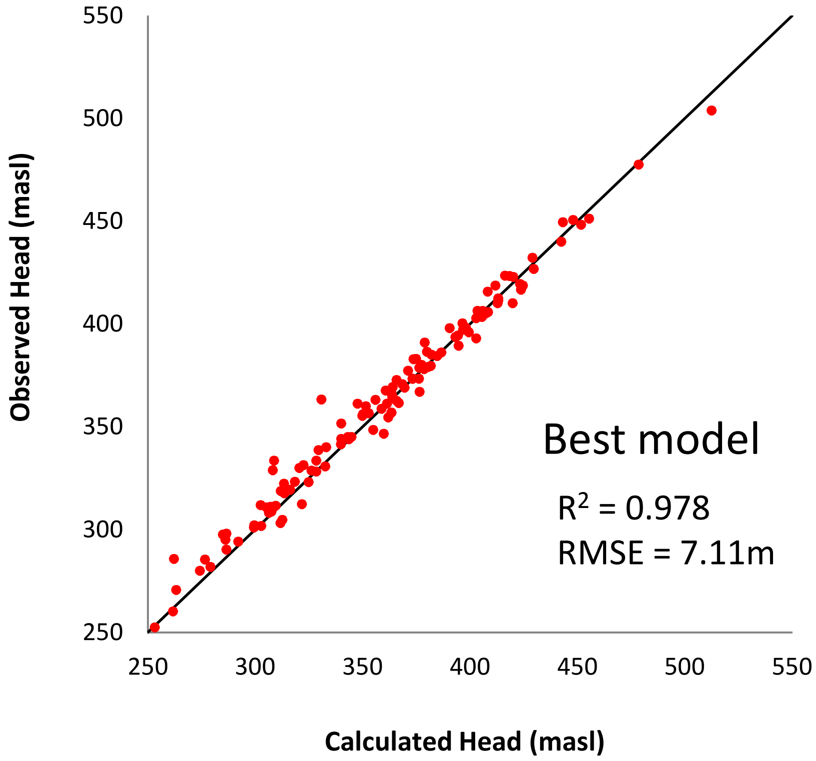


- Some simulations produced highly heterogeneous discharge locations
- Others produced focus along river courses
- Best models (spatial discharge and outlet river flow) are **interpolated weathered zone** *and* **palaeo-surface** *with* **hydro parameters f(fracture density)**

Spatial Piezometry Distribution

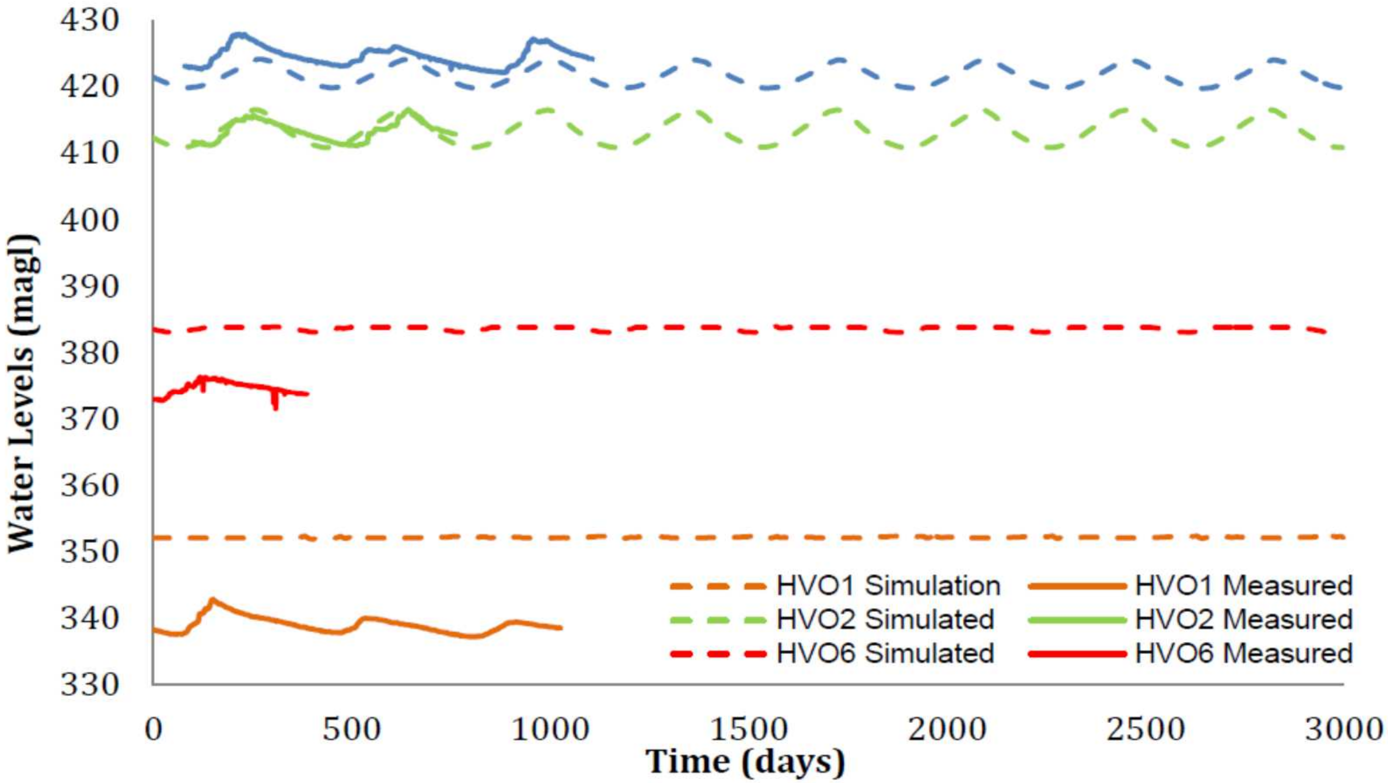
- Analysis of head fit
- Calculation of R^2 and RMSE.





Temporal Water Table Variation

- Head time series are analysed in the same manner as the piezometry statistics
- No one model reproduces all wells appropriately but best model is **interpolated weathered zone** *with* **K,S f(fracture density)**

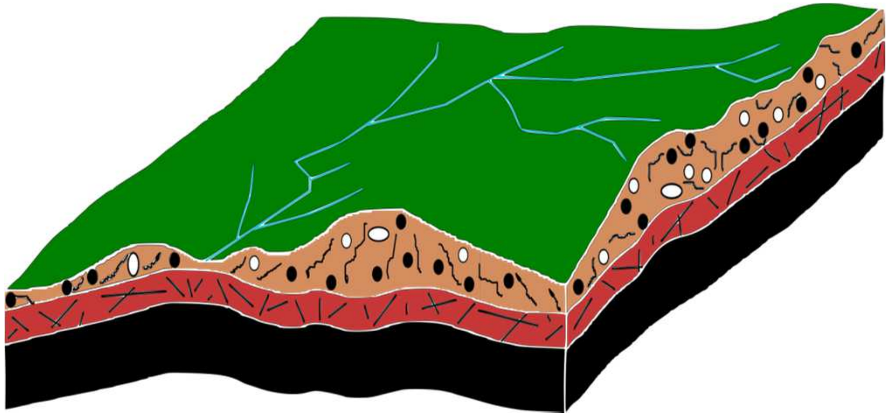


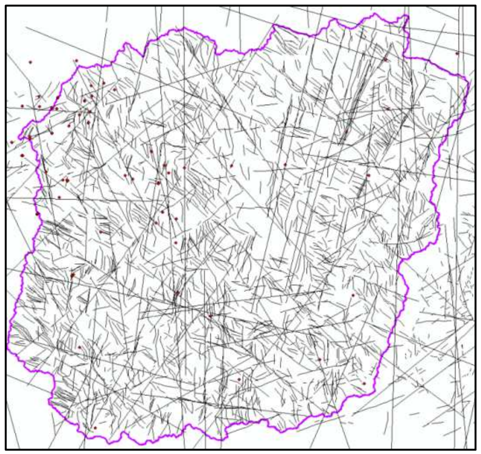
AIC Ranking

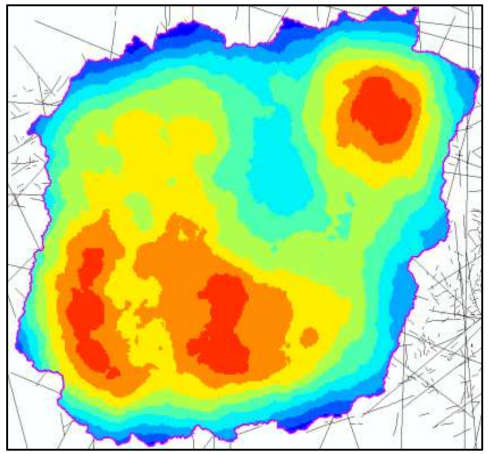
- AIC is a form of multi-model analysis (Ye *et al*., 2008),
- Calculated for spatial and temporal piezometry

$$AIC = n\ln(\hat{\sigma}^2_{ML}) + n\ln(2\pi) + n + \ln|Q^{-1}| + 2p \qquad \hat{\sigma}^2_{ML} = \frac{\sum_{j=1}^{n}(\varepsilon q)_i^2}{n}$$

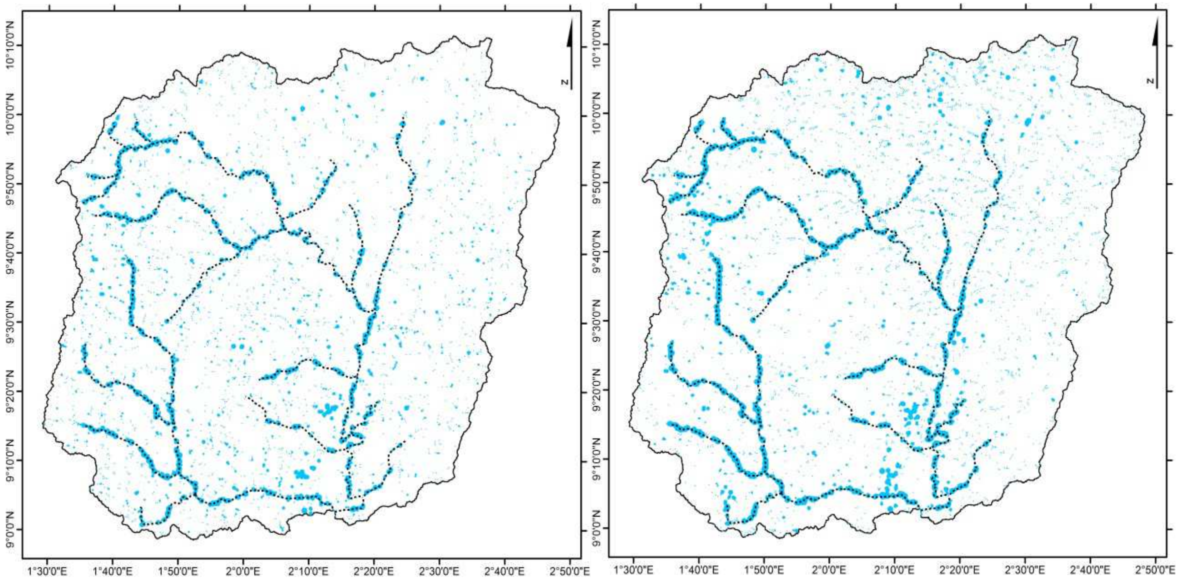
- Overall, **interpolated weathered zone** *and* **palaeo-surface** *with* **parameters f(fracture density)** have almost equally the lowest AIC (best matches)







Aquifer Budget



- **Borehole abstraction negligible** as compared to total groundwater discharge (streams and ET) : **< 0.01%**
- Major part of groundwater discharge (**>80%**) takes place through **evapotranspiration uptake** particularly in valley bottoms
- The remaining **<20%** contributes to **streamflow**

Conclusions

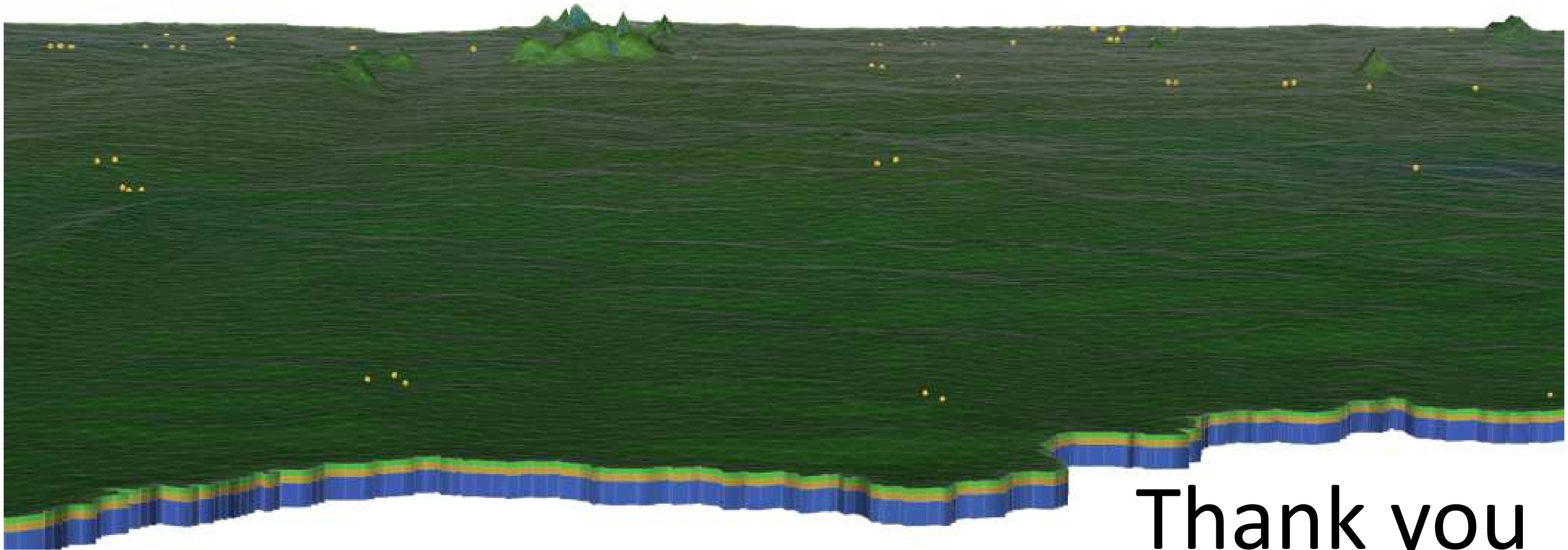
- Regional hydrogeological controls investigated / 3 conceptual geometries tested each with 3 parameter distributions / Transient models evaluated using various control datasets

- Interpolated weathered zone or palaeo-surface with lineament-correlated parameters is the best match overall, despite high discharge

- Generally good performance of structurally constrained models (lineament density), despite poor observed correlation of K,S to structure! Scaling issue?

- Importance of evapotranspiration in valleys

- Needs further testing in light of (i) a new parameter distribution (ie. multi-layer MRS inversion), (ii) combined weathered zone geometry, (iii) direct computation and spatial validation of evapotranspiration uptake, and (iv) future climatic scenarios



Thank you

Merci