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Automatic integration of airborne EM and borehole data into regional groundwater models

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Introduction and background

Large-scale distributed models are used extensively for groundwater resource management, for example related to water scarcity, well field delineation and ecological assessments. The largest source of uncertainty in distributed hydrological models that include saturated zone flow stems from geologic structural errors (Zhou et al. 2014, Refsgaard et al. 2012). Current geological modelling practise has a number of disadvantages: structures and preferential flow paths, which are important for groundwater flow and solute transport, may be overlooked; different geological models give different hydrological predictions; and structural uncertainty cannot be quantified. We propose a method for automatic generation of structural geological input to regional groundwater models. The method is data-driven thus taking advantage of the information in the large airborne EM data sets.

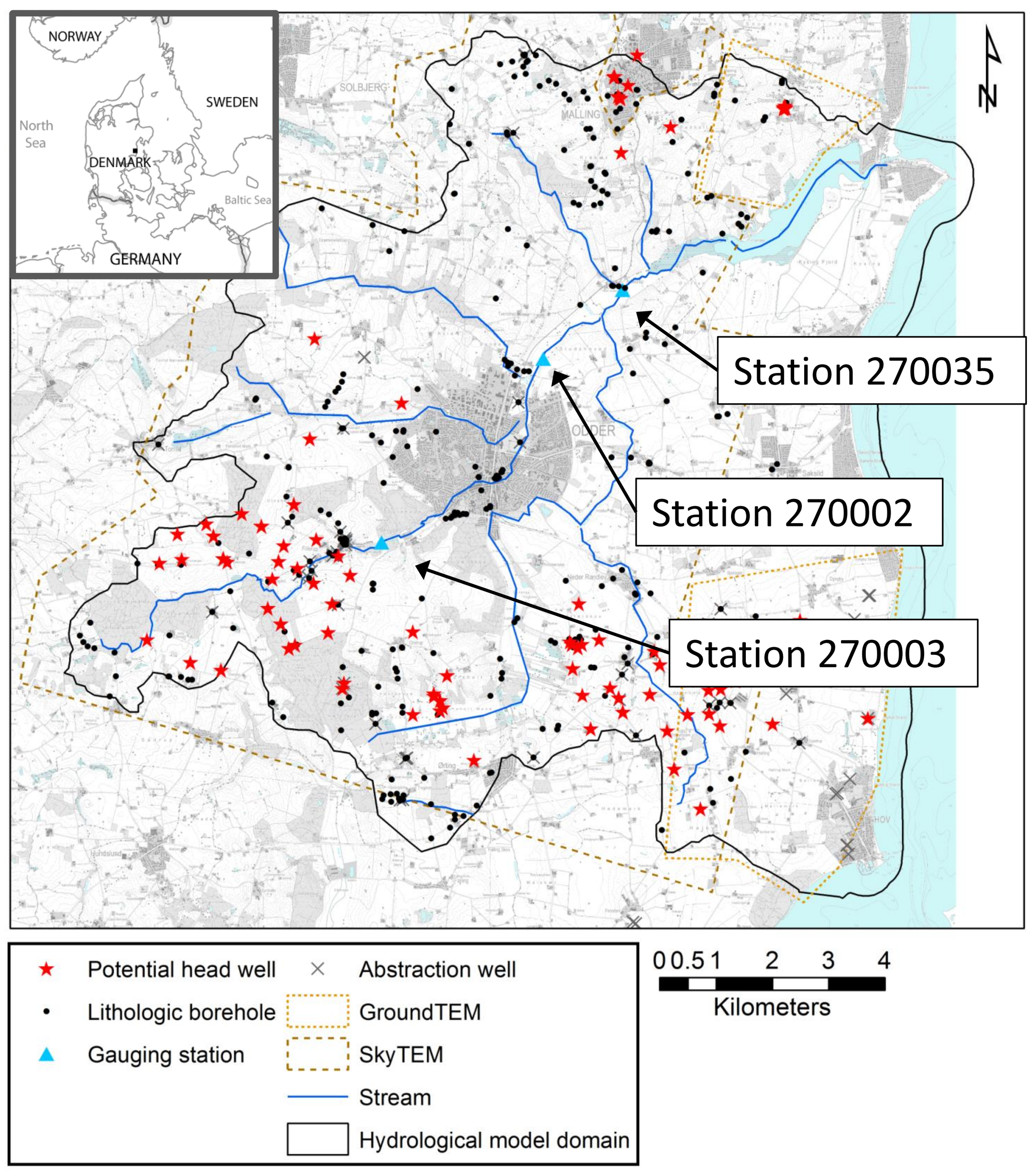
Norsminde case study

Geophysical & lithological data

- Airborne time-domain electro- magnetic (AEM) data collected with SkyTEM[101].
- 106,770 1D geophysical models
- 700 lithological borehole descriptions

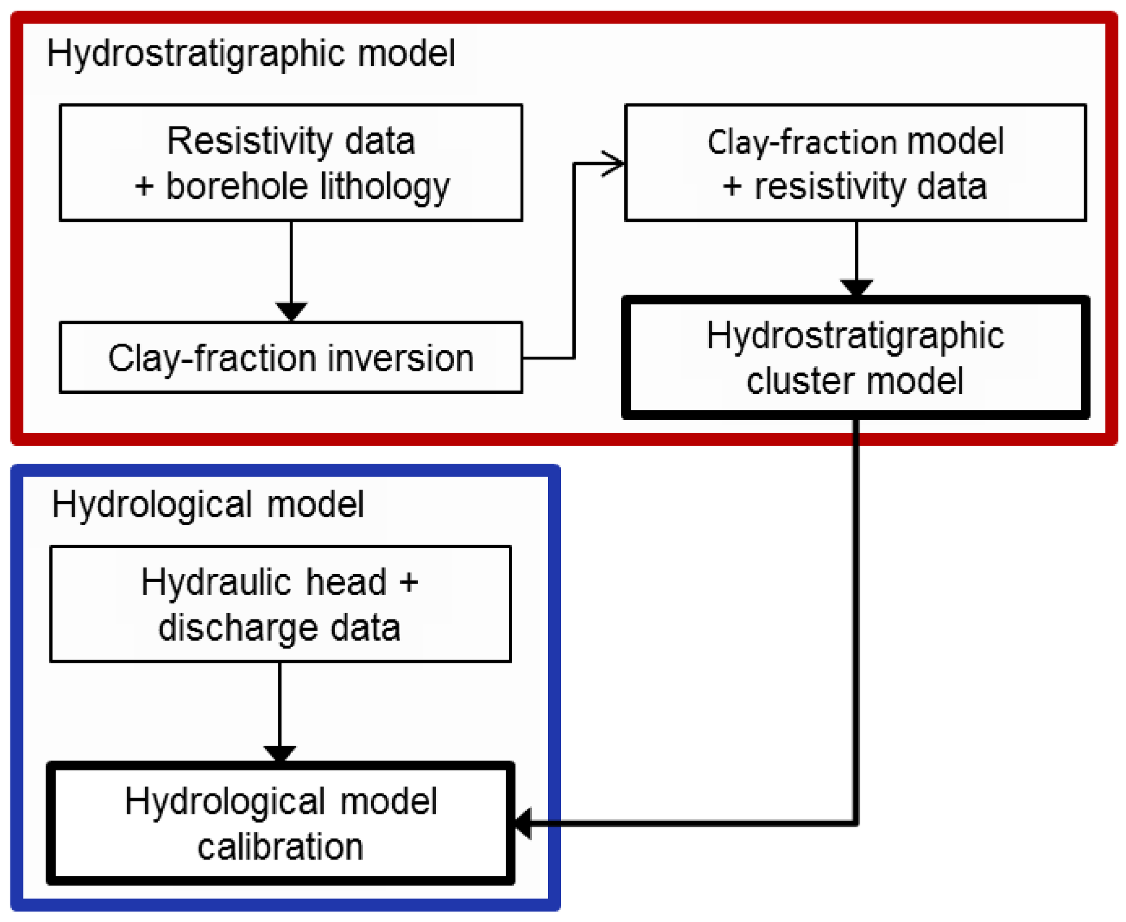
Hydrological data

- Daily stream discharges from 3 gauging stations;
- Groundwater heads at 128 wells, total of 642 measurements.
- Daily precipitation, temperature and ET_0 products and annual pumping rates



Method

1) Clay fraction inversion
2) k-means cluster analysis on clay-fraction values and resistivity data
3) Hydrological model calibration with cluster model as hydrostratigraphy



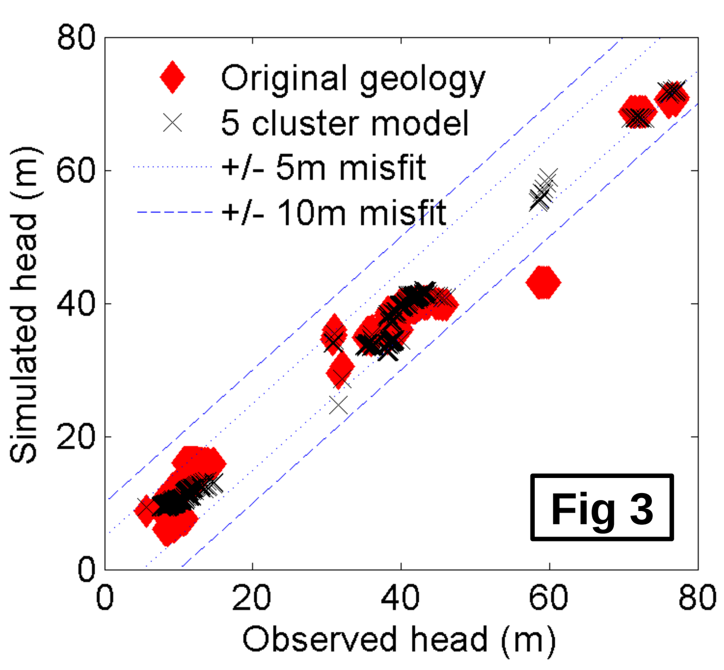
Clay-fraction expresses cumulative drilled depth lithologically described as clay over a given drilling interval. **ACT inversion** uses a spatially variable translation to integrate lithological information from boreholes with geophysical resistivities (Christiansen et al. 2008).

The hydrological model is a distributed, physically based, integrated MIKE-SHE model. **Hydraulic conductivity** of clusters is determined in hydrological calibration.

Benchmarking hydrological performance

with existing geological model (Original model). The table shows performance statistics for the two models.

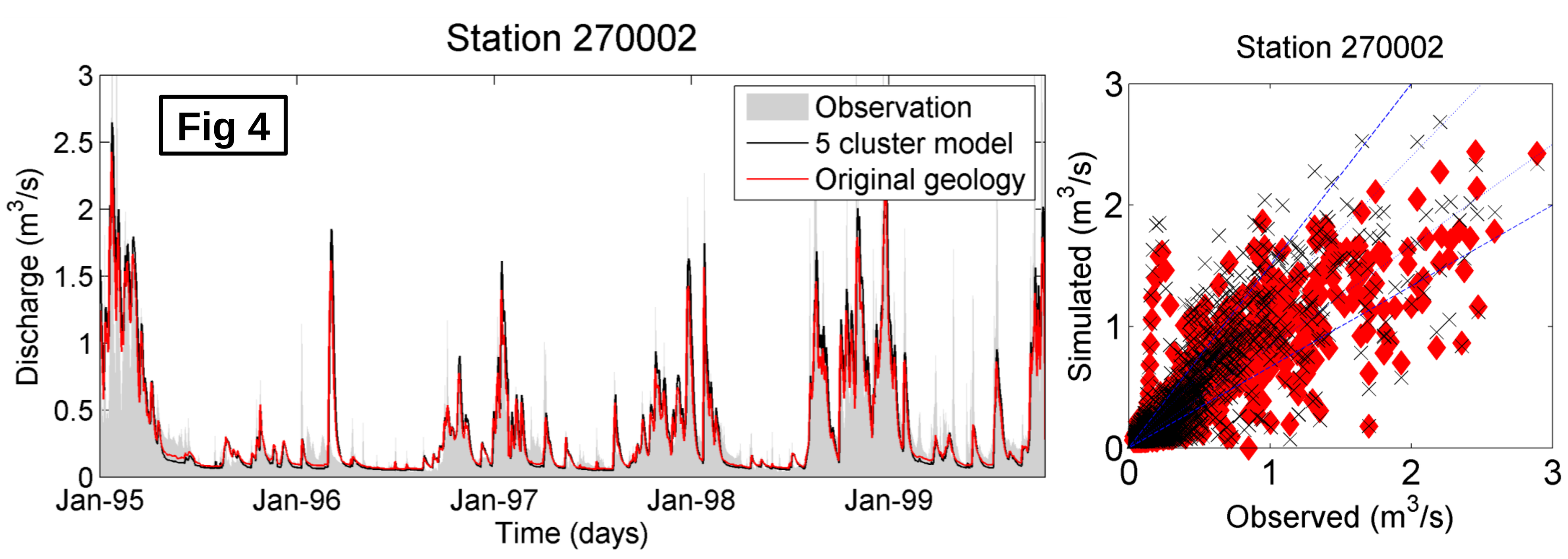
		Original model		5-cluster model	
		RMSE	ME	RMSE	ME
Calibration 2000-2003	Head (m)	**3.27**	**-0.0762**	**2.57**	**0.00310**
	Discharge (m^3/s)	0.267	-0.0259	0.278	-0.0107
Validation 1995-1999	Head (m)	3.24	-0.926	2.19	-1.01
	Discharge (m^3/s)	0.180	-0.0501	0.203	-0.0354



Validation period 1995-1999

Fig 3 Scatter plot of observed and simulated hydraulic heads. Dotted and dashed blue lines are 5m and 10m misfits.

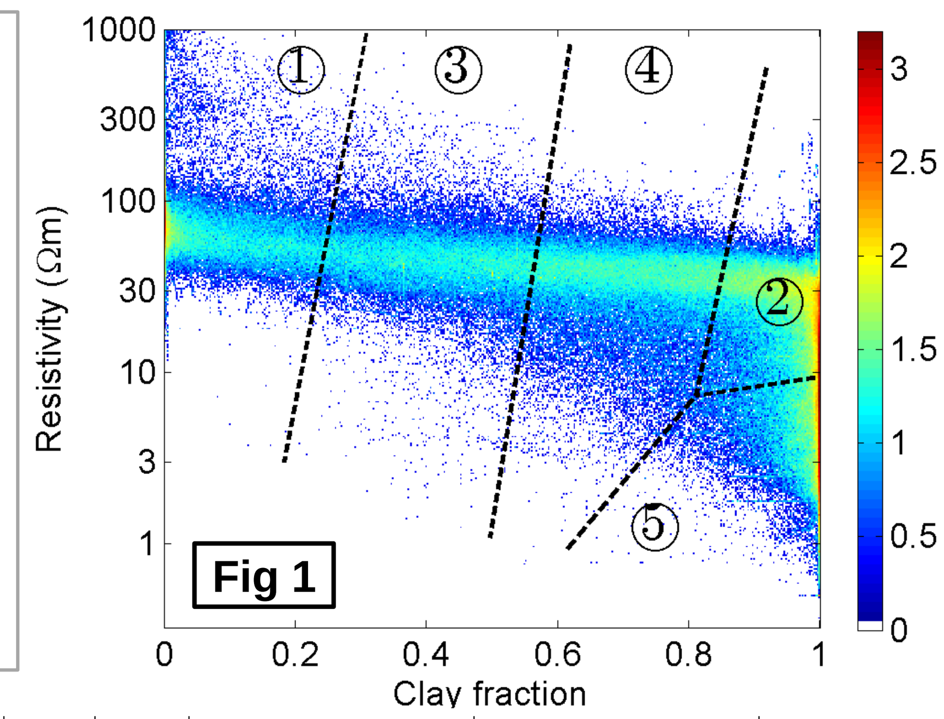
Fig 4 Stream discharges at station 270002. Dotted and dashed lines respectively indicate 20% and 50% misfits.

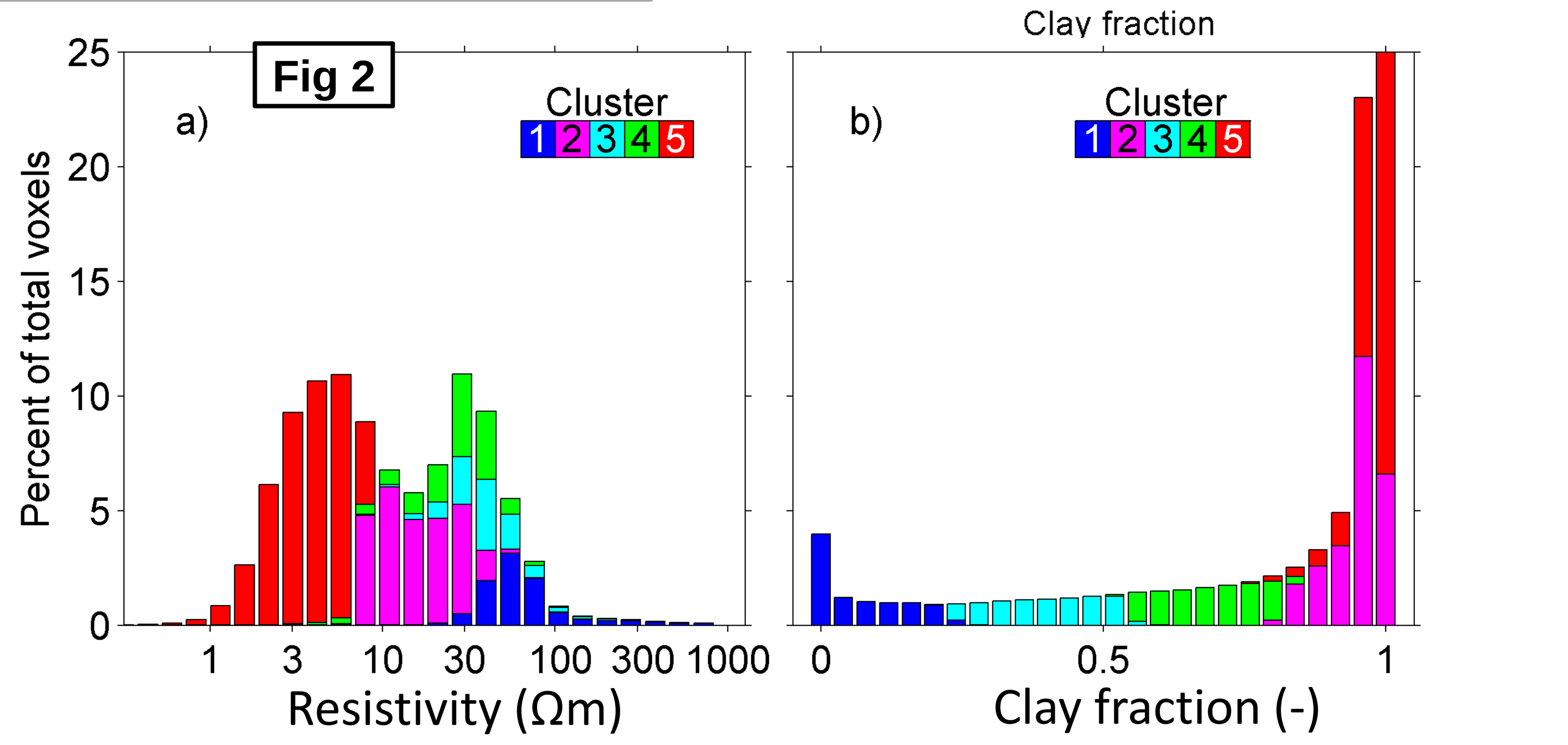


Cluster model

Fig 1 Cluster divisions shown in density cloud of data (density is logarithmic). Data is divided by values rather than data density.

Fig 2 The histograms show how the resistivity and clay fraction values are represented in the clusters. Cluster 1, 2 and 4 are separated in the clay fraction space while overlapping in resistivities.





Conclusions

- From geophysical resistivities and clay fraction values we can divide the subsurface into zones, which can be calibrated with uniform hydrological properties in a hydrological model inversion.
  - Competitive hydrological performance comparable with calibration on original model geology
  - Semi-automatic and data driven
- Prospects for assessment of uncertainty and parsimony in hydrostratigraphic modelling.